A Monitoring Strategy for the Western Population of Double-crested Cormorants within the Pacific Flyway

Photo: East Sand Island – Bird Research Northwest

Inquiries about this monitoring strategy may be directed to member States of the Pacific Flyway Council or to the Pacific Flyway Representative, U.S. Fish and Wildlife Service, 911 N.E. 11 Avenue, Portland, Oregon 97232. Information regarding the Pacific Flyway Council and management plans can be found on the internet at PacificFlyway.gov.

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A Monitoring Strategy for the Western Population of Double-crested Cormorants within the Pacific Flyway

Prepared for the

Pacific Flyway Council

by the

Pacific Flyway Nongame Migratory Bird Technical Committee

as directed by the

Double-crested Cormorant Subcommittee

March 26, 2013

Approved by: Thomas J. Ryder ____________ May 10, 2013

Chair, Pacific Flyway Council Date

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Double-crested Cormorant Subcommittee Members
Andrea Hanson, Oregon Department of Fish and Wildlife, Subcommittee Chair
Jim Parrish, Utah Division of Wildlife Resources
Joe Buchanan, Washington Department of Fish and Wildlife

Contract Writer
Josh Dooley

Other Nongame Technical Committee Members
Mary Rabe, Alaska Department of Fish and Game
James Driscoll, Arizona Game and Fish Department
Carie Battistone, California Department of Fish and Game
David Klute, Colorado Division Wildlife and Parks
Rex Sallabanks, Idaho Department of Fish and Game
Lauri Hanauska-Brown, Montana Department of Fish, Wildlife, and Parks
Cris Tomlinson, Nevada Department of Wildlife
Vacant, New Mexico Department of Game and Fish
Susan Patla, Wyoming Game and Fish Department

Other Contributors
Colleen Moulton, Idaho Department of Fish and Game
Martha Wackenhut, Idaho Department of Fish and Game
Mark Otto, U.S. Fish and Wildlife Service
Mike Green, U.S. Fish and Wildlife Service representative
Robert Trost, U.S. Fish and Wildlife Service
Tara Zimmerman, U.S. Fish and Wildlife Service representative

EXECUTIVE SUMMARY

Localized depredation issues within the Pacific Flyway prompted the Pacific Flyway Council to develop a management framework for the Double-crested Cormorant (*Phalacrocorax auritus;* herein cormorant). In July 2012, *A Framework for the Management of Double-crested Cormorant Depredation on Fish Resources in the Pacific Flyway* was approved and adopted by the Pacific Flyway Council (Pacific Flyway Council 2012). The highest priority strategy under the Population Assessment Objective in the Management Framework called for developing and implementing a monitoring strategy for cormorants at the flyway scale to guide and assess management actions.

The goal of the monitoring strategy is to establish a coordinated, long-term monitoring effort to estimate the breeding population size, trend, and distribution of the Western Population of 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 monitoring objective is to have the ability to detect a 5% change/year in the Western Population of cormorants with 80% power ($\beta = 0.20$) and a 10% Type I error rate ($\alpha = 0.10$). A sample of locations was randomly selected using a modified dual-frame sampling approach. Active nests will be counted at these sample locations and will provide an index to estimate the total number of breeding adults in the Western Population. A power analyses was conducted to identify the most cost effective sampling scheme that achieved the monitoring objective. In total, 44 locations will be monitored per monitoring year. Monitoring will begin in 2014 and occur every third year thereafter for at least 10 years (i.e., 2014, 2017, 2020, 2023).

Surveys will consist of a combination of existing monitoring efforts, which are funded by other entities, as well as new locations that will require additional funding. Thirty of the 44 locations selected for monitoring in 2014 are included in existing monitoring efforts. Estimated additional cost to implement the monitoring strategy will be $14,500 per monitoring year to cover additional surveys and enumerate cormorant nests from aerial photographs.

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BACKGROUND

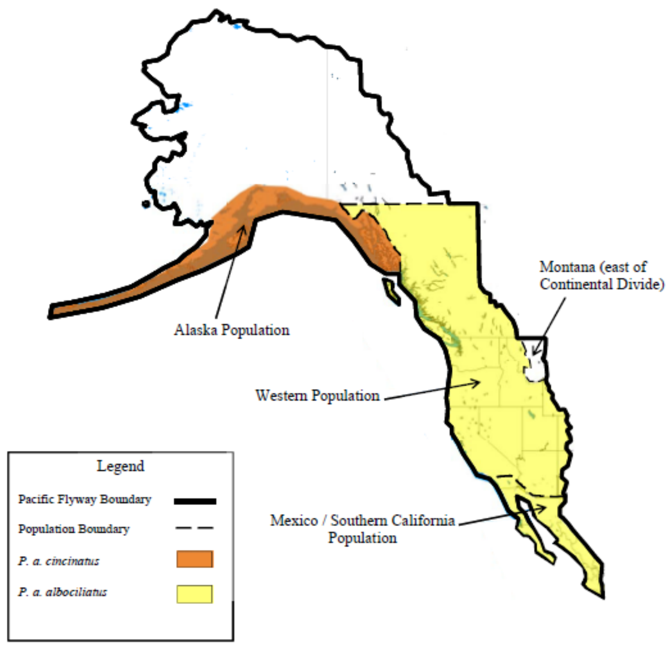
Localized depredation issues within the Pacific Flyway prompted the Pacific Flyway Council to develop a management framework for the Double-crested Cormorant (*Phalacrocorax auritus;* herein cormorant). In July 2012, *A Framework for the Management of Double-crested Cormorant Depredation on Fish Resources in the Pacific Flyway* (herein Management Framework) was approved and adopted by the Pacific Flyway Council (Pacific Flyway Council 2012). The goal of the Management Framework was to maintain cormorants as a natural part of the waterbird biodiversity of the Pacific Flyway, while minimizing negative ecological, economic, and social impacts of cormorant depredation actions. The Management Framework included a synopsis of species' biology and status, and descriptions of resource conflicts, management options, regulatory requirements, and recommended management strategies. The highest priority strategy under the Population Assessment Objective in the Management Framework called for developing and implementing a monitoring strategy for cormorants at the flyway scale to guide and assess management actions.

Currently, no coordinated cormorant monitoring strategy exists for the Pacific Flyway. A status assessment of the cormorant in western North America was completed in 2010, which summarized available data from 1998–2009 (Adkins and Roby 2010). Cormorants have been monitored independently by the U.S. Fish and Wildlife Service (USFWS), State wildlife agencies (States), and other entities as part of various monitoring programs; however, monitoring effort, timing, and techniques have varied.

Scope

Spatial — Since the majority of management concern pertaining to cormorant depredation on fish resources.within the Pacific Flyway involves the Western Population, the monitoring strategy focuses on the Western Population of cormorants. The Pacific Flyway portion of Montana east of the continental divide was included in the monitoring strategy because the delineation of subspecies and population boundaries in that area was unclear (Wires et al. 2001, Mercer 2008; Fig 1). Cormorant monitoring and research conducted in Alaska, northern British Columbia and Yukon Territory, and Mexico will augment this monitoring strategy but will not be emphasized because these areas are outside of the Western Population boundary.

Figure 1. Cormorant subspecies and management populations within the Pacific Flyway.



Temporal—Monitoring will begin in 2014 and occur every third year thereafter for at least 10 years (i.e., 2014, 2017, 2020, 2023). However, there likely will be a need to continue monitoring within the Pacific Flyway beyond this timeframe as long as cormorant depredation issues require management action. Thus, throughout the duration of the monitoring strategy, the Nongame Technical Committee and Pacific Flyway Council, in consultation with the U.S. Fish and Wildlife Service, will evaluate the monitoring strategy's effectiveness, make modifications as needed, and continue monitoring as necessary.

Extent—The monitoring strategy will provide information about the breeding population status, trend, and distribution of the Western Population of cormorants. Monitoring of the breeding population is sufficient to track trends, and breeding population information is commonly used to inform management decisions. The strategy does not include a monitoring component for the non-breeding segment of the population. It is prohibitively costly to monitor non-breeders because a substantially greater survey effort is required. Additionally, non-breeders are difficult to distinguish from breeders using standard monitoring techniques (e.g., aerial surveys).

Not all monitoring needs pertaining to cormorants and depredation issues will be covered by this monitoring strategy. Depredation take permits may require additional monitoring of local cormorant populations, documentation of impacts to fish resources, and measuring the effectiveness of management actions. Guidelines and procedures to address cormorant depredation issues are described in the Impact Reduction Objective in the Management Framework. States and other entities may have research and management priorities that require additional monitoring and data collection beyond what is included in this monitoring strategy. These efforts should be conducted as necessary and coordinated within the Pacific Flyway to the greatest extent possible. Protocols for additional monitoring efforts are not included within this document.

Goal

The goal of this monitoring strategy is to establish a coordinated, long-term, flyway-level monitoring effort to estimate the breeding population size, trend, and distribution of the Western Population of cormorants. This information is fundamental to support development of effective management recommendations, and for guiding and assessing management actions pertaining to cormorant depredation on fish resources.

Monitoring Objective

The monitoring objective is to be able to detect a 5% change/year in the Western Population of cormorants with 80% power ($\beta = 0.20$) and a 10% Type I error rate ($\alpha = 0.10$). The Nongame Technical Committee determined this level of monitoring was appropriate given the conservation status of cormorants, management considerations, and monitoring objectives for species of similar conservation status. It is less stringent than monitoring objectives of species of greater conservation concern than cormorants. Hatch (2002) recommended a similar monitoring standard for seabirds of detecting a 50% decline in 10 years (6.7% change/year) with 90% power ($\beta = 0.10$) and a 5% Type I error rate ($\alpha = 0.05$). Commonly used values of α range from 0.001 to 0.10, and of β range from 0.01 to 0.20 (Gibbs and Ene 2010). The North American Breeding Bird Survey (Sauer 1993, Peterjohn et al. 1995) and Partners in Flight Program (Butcher et al. 1992) monitoring standard is detection of a 50% decline over a 25-year period (2.7% change/year). Monitoring objectives for post-delisted species are typically <3% change/year (USFWS 2003, USFWS 2009).

MONITORING STRATEGY

Definition of Terms

Active Breeding Colony —A breeding colony that contained ≥5 active nests at least 1 time during the past 5 years (2008–2012).

Active Nest —A nest that contains a cormorant egg(s) or fledgling(s) or with at least 1 adult in direct attendance, either incubating or standing directly on a nest.

Breeding Population —The number of cormorants that nest in a given year. The number of breeding adults can be derived by multiplying the number of active nests by 2.

Dual-frame Sampling —A sampling method that involves random sampling from 2 frames: a list frame and an area frame. The list frame includes active breeding colonies as defined above. The area frame includes other possible breeding locations not included within the list frame: 1) historical breeding colonies where 1 year of documented nesting activity has occurred but nesting has not been confirmed in the last 5 years (i.e., before 2008), 2) locations with <5 active nests during the last 5 years (2008–2012), and 3) new breeding colonies that arise during the duration of the monitoring strategy.

Non-breeding Population —The number of cormorants that do not nest in a given year. Fledglings produced during a given should not be included in the non-breeding population.

Sampling Approach

Years to Monitor Breeding Colonies—Monitoring will begin in 2014 and occur every third year thereafter for at least 10 years (i.e., 2014, 2017, 2020, 2023). Data collected during other years can augment analyses, but the goal is to conduct a comprehensive, standardized monitoring effort during the years specified. The 3-year monitoring interval was chosen based on the results from the power analysis (see below and Appendix B), an appropriate frequency to update population information as determined by the Nongame Technical Committee, and the average age of cormorant first breeding (average age = 2.74 yr; van der Veen 1973, Hatch and Weseloh 1999). For the power analysis, we evaluated 9 temporal sampling schemes, where monitoring occurred every year, every other year, or every third year for 3, 5, 7, and 9/10 years in duration. The most cost effective temporal sampling scheme (i.e., the fewest number of total sampling units) that achieved the monitoring objective was to monitor every third year for a 10-year duration.

Dual-frame Sampling—To estimate the breeding population, a random sample of locations was selected using a modified dual-frame sampling approach (Haines and Pollock 1998, see above for definition). The number of active nests will be counted at these locations and will provide 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 additional information on population distribution and dynamics.

There are 197 list frame (Appendix A, Table A1) and 224 area frame (Appendix A, Table A2) locations. The list frame was stratified into 4 size classes (>10,000, 10,000–500, 499–100, and 99–5 breeding pairs). Summary statistics of the 4 list frame size classes and area frame are given in Appendix B, Table B1.

Number of Sampling Units— The number of locations to monitor was based on the results of the power analysis (see above and Appendix B). In the power analysis, we evaluated 54 sampling combinations, which varied by the number of locations sampled within the 4 list frame size classes and the area frame, for each of the 9 temporal sampling schemes. The most cost effective sampling scheme (i.e., the fewest number of total sampling units) that achieved the monitoring objective was to monitor 44 locations per monitoring year; 33 from the list frame and 11 from the area frame. The number of locations to monitor within the different list frame size classes is: 100% of the locations within the 2 largest size classes (i.e., >10,000 size class [n=1] and 10,000–500 size class [n=6]), 25% of the 499–100 size class (n=11), and 10% of the 99–5 size class (n=15). Based on available colony information, approximately 17% (33/197) of list frame locations and 5% (11/224) of area frame locations will be monitored in 2014, which constitutes approximately 69% of the Western Population.

Locations to Monitor—The 44 locations to monitor in 2014 are given in Table 1. These locations were randomly selected from all list and area frame locations using the procedures described in

Appendix C. These 44 locations included approximately 69% of the Western Population of cormorants. List frame colonies that are monitored during 2014 should be monitored for the duration of the monitoring strategy, even if no breeding is reported for a given year. For monitoring years after 2014, 5% of area frame locations should be randomly selected from an updated inventory of area frame locations using the weighting scheme described in Appendix C. The weighting scheme increases the probability of selecting the area frame locations most likely to be used by the greatest number of cormorants. If a new breeding colony >500 breeding pairs is documented during the duration of the monitoring strategy, the Nongame Technical Committee will evaluate how it will be incorporated into the monitoring strategy and subsequent analyses.

The proposed sampling scheme provides a minimum number of locations to monitor to achieve the monitoring objective. We recognize that more locations will be monitored under various monitoring efforts and programs. When possible, these data should be included in the database and subsequent analyses. This will ensure a more precise population and trend estimate. Additionally, given available funding and time, monitoring other list and area frame locations that are proximal to selected locations is strongly encouraged. Cormorant selection and use of breeding locations in a given area is dependent upon local environmental conditions (e.g., whether a location has water, levels of disturbance). Monitoring all cormorant breeding locations within a given area (e.g., all breeding colonies on the Salton Sea and adjacent wetlands) will provide a more robust population and trend estimate.

Table 1. Randomly selected locations to monitor during 2014. For monitoring years after 2014, the list frame locations will remain the same but area frame locations will be randomly selected.

Colony	Frame (Size Class)
BRITISH COLUMBIA (n=2)	
Interior	
Creston Valley Wildlife Management Area	List (99-5)
Vancouver Area	
Second Narrows Bridge Power Tower	List (99-5)
CALIFORNIA (n=16)	
Central Coast – Outer Coast North	
South Farallon Islands	List (499-100)
Central Coast – Outer Coast South	
San Lorenzo River Mouth	Area
Central Coast – San Francisco Bay	
Alviso Plant, Pond Nos. A9 & A10	List (499-100)
Bair Island Power Towers (incl. Steinberger Slough)	List (499-100)
Interior	
Laguna de Santa Rosa	Area
Lake Almanor, Almanor Peninsula	List (99-5)
Mullet Island, Salton Sea (So.)	List (10,000-500)
Mystic Lake	Area
North Stone Lake, Stone Lakes NWR	Area
Northern Coast – North Section	
Arcata Bay Sand Islands	List (499-100)

Colony	Frame (Size Class)
Big Lagoon	List (99-5)
Northern Coast – South Section	
Hog Island	List (10,000-500)
Southern Coast	
Anacapa Island - West	List (499-100)
Prince Island	List (99-5)
Santa Barbara Island	List (99-5)
Seal Cove Area	List (99-5)
IDAHO (n=4)	
American Falls Reservoir	List (10,000-500)
Bear Lake NWR	List (99-5)
Blackfoot Reservoir	List (10,000-500)
Palisades Reservoir	Area
MONTANA (n=1)	
East of Continental Divide	
Arod Lake	List (99-5)
NEVADA (n=2)	
Kirch WMA	Area
S-Line Reservoir	List (99-5)
OREGON (n=14)	
Central Coast	
Parrot Rock	List (99-5)
Columbia River	
Smith and Bybee Lakes	Area
Tri-Club Island	Area
Umatilla NWR	Area
Columbia River Estuary	
East Sand Island	List (>10,000)
Miller Sands Navigational Aids	List (499-100)
Rice Island	Area
Interior	
Malheur NWR - Frenchglen Area - Baca Lake	List (99-5)
Rivers End (Lake Abert)	List (99-5)
Northern Coast	
Unnamed Colony (Cape Lookout)	List (499-100)
Southern Coast	
Bolon Island	List (10,000-500)
Hunters Island	List (499-100)
Unnamed Colony (Mack Reef)	List (99-5)
Unnamed Colony (N of Ferry Road Park)	List (499-100)
UTAH (n=1)	
Great Salt Lake	List (99-5)

Colony	Frame (Size Class)
WASHINGTON (n=4)	
Interior	
North Potholes Reservoir	List (10,000-500)
Pend Oreille River - Sandy Shores	Area
San Juan Islands	
Bird Rocks	List (499-100)
Drayton Harbor	List (499-100)

Timing of Breeding Colony Monitoring—The mid- to late incubation period is the most ideal time to survey breeding colonies, since peak counts occur during this time (Steinkamp et al. 2003, USFWS 2008). The timing of egg-laying within the Pacific Flyway varies by latitude, with cormorants breeding in northern latitudes laying eggs later in the year compared to cormorants breeding in southern latitudes. Egg-laying typically begins 2–4 weeks after arrival of adults to breeding sites (Hatch and Weseloh 1999). Suggested monitoring dates for breeding colonies within Pacific Flyway States/Provinces are given in Table 2. These dates provide a tentative guideline but may be subject to change given local or annual environmental and colony conditions. Target monitoring dates for locations selected for monitoring in 2014 are given in Appendix C, Table C1.

Table 2. Suggested monitoring dates for Pacific Flyway States/Provinces based on documented timing of cormorant egg-laying.

State/Province	Time Period	Reference
Southern CA, NM	Jan to mid-Feb	Adkins and Roby 2010
AZ	early Feb to early Mar	Corman 2005
Northern CA, NV, UT, CO	mid-Mar to mid-Jun	Stenzel et al. 1995
B.C.(interior), WA (interior and south coast), OR, ID, MT, WY	mid-Apr to mid-Jun	Campbell et al. 1990; BRNW 2009
B.C. (coast), WA (north coast)	mid-Jun to mid-July	USFWS unpubl., data

MONITORING TECHNIQUES

Overview

Multiple techniques are used to count cormorant nests. Cormorants nest in a variety of habitats, and the most appropriate monitoring technique for a given colony or area will be dictated by habitat characteristics, environmental factors, personnel, and logistical constraints. Air-, water-, and ground-based techniques can be used to monitor cormorants (Steinkamp et al. 2003, USFWS 2008). Monitoring can involve either total counts for smaller colonies, or partial counts for larger colonies (see below). Total counts should be conducted when possible. Conducting multiple counts of a breeding colony during a monitoring year is recommended when possible to better estimate peak abundance and variability. This is strongly recommended for areas where cormorants nest in trees or other vegetation that may hinder detectability. If adults show evidence of breeding in an area (e.g., carrying food, mating or distraction displays) but there is no confirmed active nest or fledglings observed, sites should be revisited at a later date to confirm breeding status of the colony. When monitoring colonies, detection probability and sampling variance should be estimated when possible. This can be achieved in many ways, including the same or different observer(s) recounting the same location or photograph multiple times, conducting trials to estimate detection probability for an observer(s) or area(s) and then applying the correction thereafter, or using double-observer sampling approaches (Nichols et al. 2000, Steinkamp et al. 2003).

Monitoring techniques that reduce the amount of disturbance to the colony are preferred. Individuals should be particularly cautious of disturbance in newly established breeding colonies because cormorants may abandon areas if disturbance levels are too high. It is recommended that adults should not be off the nest >10–30 minutes. Additionally, caution should be exercised when 1) wind chill temperature is <65ºF, 2) it is sunny and air temperature is >80ºF, 3) it is cloudy and air temperature is >90ºF, 4) it is raining or there is a high probability of rain, 5) egg or chick predators are present and appear able to approach exposed nests, and 6) the majority of the colony is in the nest-building or early incubation stage (USFWS 2008).

Aerial Counts

Aerial counts by fixed-winged airplanes or helicopters are commonly used for ground-nesting colonial waterbird species in open habitats, especially for large colonies or colonies that cannot be easily accessed. Flight altitudes between 150–400m above the colony have been recommended. However, altitudes may need to be adjusted to comply with local regulations or if flights cause disturbance to the colony. Photographs or video should be taken during the flight. Direct aerial counts can be highly unreliable and are not recommended. Aerial photographs can either be 1) a single photo of an entire island or nesting colony (usually using a 50mm lens) or 2) overlapping, close-up photos of colonies (using a 200mm or 300mm lens). When enumerating nests from photographs, ≥2 independent counts of the image should be made when possible. If the breeding status of cormorants cannot be determined from aerial photographs, the location should be visited if possible to verify breeding status. At some coastal breeding colonies Pelagic (*Phalacrocorax pelagicus*) and Brandt's (*Phalacrocorax penicillatus*) cormorants may also be present. If differentiation of species is not possible from photographs, the location should be visited to determine the ratio of cormorant species present.

Boat Counts

Boat counts can be used to count nests in colonies proximal to water, especially if ground counts within the colony or aerial flights are not possible. Boat counts may be especially useful in coastal cliff areas, where all or nearly all nests can be viewed from boat level. If anchoring the boat is possible, colony counts can be conducted similar to perimeter counts (see below). If breeding is more dispersed and stretches of coastline are monitored, Trocki et al. (2010) recommended boat speeds of approximately 5 km/h. Boats should be kept at a distance where safe boat operation is feasible and disturbance to the colony is minimal. Photographs or video can also be taken from the boat to later determine nest counts.

Ground Counts

With ground counts, monitoring can occur from 1) the perimeter of the colony or 2) within the colony. If within-colony counts are conducted, efforts should be made to reduce disturbance by minimizing noise, the time spent within the colony, and the proportion of the breeding area disturbed.

Perimeter Counts—Perimeter counts involve monitoring a colony from set survey points on the periphery of a colony. This method is most practical for cormorant tree-nesting or cliff colonies. The number and location of survey points will depend upon the unique characteristics of each colony. Survey points should be close enough to count individual nests but far enough away so that individuals do not flush. Survey points should be spaced appropriately to count the maximum number of nests without double counting. To avoid double counting nests, a unique and specific segment of the colony should be surveyed from each survey point. Identifying unique landmarks or distinguishing features within the colony can help to delineate the survey area for a particular survey point. Perimeter counts should only be conducted when all nests are visible from the perimeter of the colony.

Within-Colony Total Counts— Within-colony total counts involve counting all nests within the colony boundary. It is generally recommended that within-colony total counts be conducted when there are: 1) <1,000 nests for tree and shrub nesting colonies, 2) <500 nests/observer for ground nesting colonies, or 3) when perimeter counts are not possible (USFWS 2008). If the colony is small (<50 nests) or located along a narrow corridor, a single unmarked transect can be walked and every nest counted. If all nests are not visible from a single transect, the colony should be delineated into strips (i.e., strip transects) using flagging or other markers. Nests are counted within each strip, and the strip totals are combined to provide a colony total. Nests located in trees or shrubs that extend over the strip boundary should be counted only when the base of the supporting tree/shrub is located within the strip, regardless of the actual position of the nest. The width and number of strips will depend upon site-specific characteristics, but should ensure that every nest within the strip can be viewed without double-counting nests within other strips. Total counts on larger colonies can be achieved relatively quickly by having a line of multiple observers walk side-by-side within a strip transect. Each observer uses a clicker and communicates with their neighbor to assure nests are not missed or double-counted.

Within-Colony Partial Counts—Within-colony partial counts are used when the colony is too large or too much time is required to conduct a total count. It is generally recommended that partial nest counts be conducted when there are >1,000 nests for tree and shrub nesting colonies or >500 nests/observer for ground nesting colonies (USFWS 2008). To conduct a partial count, the total area occupied by the colony needs to be determined first by mapping the colony boundary. A proportion of the total area is sampled using transects, quadrants (i.e., squares), or circles. When using sampling circles, GPS points within the colony are first determined. An observer places a pole at that point with an attached piece of string or rope (10–20m typically). The observer then surveys all nests within the area of the circle created by the length of the string or rope. Sampling transects, quadrants, or circles should be randomly placed within the colony, and, if there are known differences in habitat or nest density within the colony, a stratified random sampling approach should be used. The sampled area should encompass 20–40% of the entire colony and sampled areas should not overlap; 40% is preferred under most circumstances. Once the total number of nests is determined for the sampled area, these estimates are extrapolated to the remaining proportion of the colony not sampled to estimate a total colony nest count. Partial counts can also be used for perimeter, boat, and aerial counts, using the same estimation techniques (i.e., surveying a known proportion of the colony, then extrapolating those counts to estimate the entire colony).

IMPLEMENTATION

Responsibilities

The Nongame Technical Committee member of each State will facilitate reporting and sharing of data with the Pacific Flyway Council and USFWS. The data sheet for collecting and reporting data is provided in Appendix D. A centralized database will be housed within the USFWS Division of Migratory Bird Management Region 9 office. The USFWS will manage the database and provide status and other reports concerning data gathered from this monitoring strategy to the Nongame Technical Committee, Pacific Flyway Council, States, and other interested entities. The USFWS Nongame Technical Committee representative will coordinate interactions between the Nongame Technical Committee and the USFWS.

The Nongame Technical Committee will periodically review and revise the monitoring strategy, evaluate its effectiveness, and brief the Pacific Flyway Council. Continued collaboration and dialogue among the Pacific Flyway Council, Nongame Technical Committee, USFWS, States, and other entities will be essential for the successful implementation of this monitoring strategy.

Monitoring Strategy Adjustments

In the event that there is a substantial change to the Western Population of cormorants resulting from management actions or stochastic events during the period covered by the monitoring strategy, there may be a need to modify the monitoring strategy. The percent coefficient of variation and other summary statistics for the power analysis were calculated from current data. In the event that significant management actions (e.g. dissuasion) occur in the future, for example, at East Sand Island, Oregon, the percent coefficient of variation value will increase. Thus, a greater number of monitoring locations may need to be sampled to achieve the stated management objective, and monitoring costs may be greater than those provided above. Also, if selected monitoring locations do not adequately represent new locations used by cormorants, these locations may need to be selected for monitoring.

BUDGET

Cormorants within the Western Population are surveyed by a number of uncoordinated monitoring efforts. This monitoring strategy aims to coordinate existing monitoring efforts and augment them when necessary in order to achieve the monitoring objective. After randomly selecting the 44 monitoring locations, we identified which of the locations are already being monitored under existing programs. We assumed monitoring at State Wildlife Areas, National Wildlife Refuges, and other locations covered by on-going monitoring programs will continue (e.g., USFWS PRIMR database) and thus would not contribute new cost to implement the monitoring strategy. Of the 44 selected monitoring locations, 30 locations are included within existing monitoring programs (Table 3).

We estimated that monitoring the 14 locations not included within existing monitoring programs will cost an additional $7,000 per monitoring year. We estimated that an additional $7,500 per monitoring year will be needed to compile and enumerate aerial photograph data from the USFWS coastal helicopter survey. Therefore, the estimated additional cost to implement the monitoring strategy is $14,500 per monitoring year (i.e., $7,000 + $7,500; Table 3). For each location, a cost estimate was provided by individuals with knowledge of that location. If no information was available, a cost of $500 was used, which was based upon Idaho Department of Fish and Game colonial waterbird monitoring cost estimates. Cost for the USFWS coastal helicopter survey is covered by existing program funding, and altering the flights to photograph the selected cormorant locations should not add to the flight cost. However, photographs taken during these surveys are typically archived but not enumerated.

Estimated cost is based upon the projected 2014 budget (Table 3; also see Appendix C, Table C1 for estimated cost of each monitoring location for 2014). In subsequent monitoring years, the list frame locations will remain the same, but area frame locations will be re-selected. Even though the number of monitoring locations will be approximately the same among monitoring years, costs may differ depending on which locations are selected. Also, if funding support changes for existing monitoring programs, this will influence funding needs for the monitoring strategy. No cost was included for an individual(s) to coordinate monitoring, manage the database, analyze data, and produce reports. It is assumed these duties will be covered in-kind by Nongame Technical Committee, State, and USFWS personnel.

Table 3. Estimated cost to implement the monitoring strategy per monitoring year. See Appendix C, Table C1 for the estimated cost for 2014 monitoring locations.

Breeding Colony Monitoring Not Included in USFWS Coastal Helicopter Survey

State/Province	Total Sampling Units	Sampling Units Included in USFWS Coastal Helicopter Survey (Coastal)	Sampling Units Not Included in USFWS Coastal Helicopter Survey (Non-Coastal)	Non-Coastal Sampling Units Monitored Under Existing Programs	Non-Coastal Sampling Units Not Monitored Under Any Existing Program	Estimated Non-Coastal Monitoring Cost per Monitoring Year	Estimated Non-Coastal Monitoring Cost Covered Under Existing Programs	Estimated New Non-Coastal Monitoring Cost per Monitoring Year
British Columbia	2	0	2	1	1	$1,000	$500	$500
California	16	9	7	2	5	$5,000	$2,500	$2,500
Idaho	4	0	4	1	3	$2,000	$500	$1,500
Montana	1	0	1	1	0	$500	$500	$0
Nevada	2	0	2	1	1	$1,000	$500	$500
Oregon	14	6	8	5	3	$7,500	$6,000	$1,500
Utah	1	0	1	1	0	$2,000	$2,000	$0
Washington	4	0	4	3	1	$3,500	$3,000	$500
Total	*44*	*15*	*29*	*15*	*14*	*$22,500*	*$15,500*	*$7,000*

USFWS Coastal Helicopter Survey

	Item	Estimated Cost per Monitoring Year	Estimated Cost Covered Under Existing Programs	Estimated New Cost per Monitoring Year
USFWS*	Aerial Flights	$45,000	$45,000	$0
USFWS,WA,OR,CA**	Photo enumeration	$7,500	$0	$7,500
Total		*$52,500*	*$45,000*	*$7,500*

	Estimated Cost per Monitoring Year	Estimated Cost Covered Under Existing Programs	Estimated New Cost per Monitoring Year
TOTAL COST PER MONITORING YEAR***	$75,000	$60,500	**$14,500**

*The USFWS Coastal Helicopter Survey covers multiple species.
**Of the $7,500, the exact cost to each entity is to be determined.
***No cost was included for an individual(s) to coordinate monitoring, manage the database, and analyze data/produce reports. It is assumed these duties will be covered in-kind by Nongame Technical Committee, State, and USFWS personnel.

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APPENDICES

APPENDIX A: List and Area Frame Locations

The list frame includes active breeding colonies. Active breeding colonies contained ≥5 active nests at least 1 time during the past 5 years (2008–2012). All known list frame locations are given in Table A1. The area frame includes other possible breeding locations not included within the list frame: 1) historical breeding colonies where 1 year of documented nesting activity has occurred but nesting has not been confirmed in the last 5 years (i.e., before 2008), 2) locations with <5 active nests during the last 5 years (2008–2012), and 3) new breeding colonies that arise during the duration of the monitoring strategy. All known area frame locations are given in Table A2.

Table A1. All known cormorant list frame locations from which the locations to monitor in 2014 were selected.

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
ARIZONA				
Lake Mead, below Hoover Dam	2009	51	36.0096723	-114.74271
Lake Pleasant	2009	18	33.9166667	-112.24167
Roosevelt Lake	2005-2010[e]	175	33.675	-111.14167
San Carlos Lake	2008	50	33.2552392	-110.4383
Scholz Lake	2009	31	35.1916667	-112.01667
Telephone Lake	2009	26	34.2916667	-110.04167
Willow Creek Reservoir	2009	52	34.6083333	-112.45
BRITISH COLUMBIA				
Gulf Islands				
Gabriola Cliffs	2009	43	49.160595	-123.86249
Galiano Island cliffs	2009	47	48.918667	-123.45
Mandarte Island	2009	143	48.633333	-123.283333
Shoal Island (Crofton)	2009	83	48.9	-123.666667
Interior				
Creston Valley Wildlife Management Area	2008	98	49.2	-116.58
Stum Lake	2008	25	52.275	-123.02567
Northern Strait of Georgia				
Mitlenatch Island	2009	20	49.95	-125
Vancouver Area				
Second Narrows Bridge Power Tower	2009	63	49.294776	-123.032421
CALIFORNIA				
Central Coast – Outer Coast North				
Lake Merced - Mesa, North, and South	2011[g]	129	37.719167	-122.490333
South Farallon Islands	2008	334	37.7	-123
Central Coast – Outer Coast South				
Elkhorn Slough	2011[g]	89	36.81115	-121.767822
Morro Bay State Park - Fairbank Point	2011[g]	233	35.351667	-120.845
Morro Rock & Pillar Rock	2008	14	35.352167	-120.868
Pinto Lake	2011[g]	71	36.955489	-121.771631
Schwan Lake	2011[a]	137	36.965273	-121.994564
Shell Beach Rocks	2008	204	35.151	-120.6685
Twitchell Reservoir	2011[g]	30	35.008397	-120.333769
Central Coast – San Francisco Bay				
Alviso A18	2011[g]	22	37.449617	-121.950762
Alviso Plant, Pond Nos. A9 & A10	2011[g]	130	37.452833	-122.006667
Bair Island Power Towers (incl. Steinberger Slough)	2011[g]	136	37.523833	-122.2175

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
Dumbarton Bridge Power Towers	2011[g]	51	37.505846	-122.120919
Knight Island	2008	37	38.136	-122.293
Lake Merritt	2011[g]	87	37.803667	-122.252667
Moffett B2	2011[g]	12	37.438887	-122.047873
Moffett Power Towers - A2W	2011[g]	15	37.444585	-122.065958
N. San Pablo Bay Radar Target	2008	15	38.100667	-122.323333
Richmond-San Rafael Bridge	2009	169	37.9335	-122.421
Russ Island	2011[g]	33	38.176167	-122.3195
San Francisco-Oakland Bay Bridge	2009	83	37.818333	-122.3385
Spoonbill - Chipps Island	2011[g]	25	38.054704	-121.893365
Wheeler Island	2011[g]	80	38.078616	-121.965866
Interior				
American River, Mississippi Bar	2011[g]	37	38.647966	-121.194767
Anaheim Lakes	2012[g]	168	33.865373	-117.848006
Arroyo del Valle, Shadow Cliffs Park	2011[g]	23	37.66523	-121.832357
Butt Valley Reservoir	2009	11	40.1383333	-121.17167
Butte Sink, nr. confluence Butte Creek and Angel Slough	2011[g]	100	39.341916	-121.895239
Chiles Creek	2011[g]	10	38.491074	-122.349374
Clear Lake NWR	2011[a]	95	41.8885	-121.13717
Clear Lake, Upper Rodman Slough	2011[g]	53	39.136618	-122.902113
Costerisan Farms Lake	2012[g]	10	35.233411	-118.982597
Cut off Slough - Bohannon	2011[g]	158	38.182671	-121.956513
Delta Pond	2011[g]	27	38.446717	-122.834409
Eastside Canal 1	2012[g]	16	37.274575	-120.745822
Eucalyptus Island	2011[g]	27	37.858918	-121.575494
Gray Lodge 1	2011[g]	19	39.315266	-121.861933
Howard Slough, at Butte Creek	2011[g]	5	39.399351	-121.88961
Kern County Water Agency	2012[g]	10	35.397428	-119.037098
Lake Almanor, Almanor Peninsula	2011[g]	15	40.264147	-121.157137
Lake Shastina	2009	41	41.5181667	-122.38833
Leaky Acres	2012[g]	5	36.79123	-119.735155
Legg Lake	2012[g]	30	34.034747	-118.061953
Llanco Seco Rancho (Sac. River E)	2011[g]	33	39.5761667	-121.98883
Meiss Lake, Butte Valley WA	2011[a]	35	41.8535	-122.05717
Milburn Unit, San Joaquin River Eco. Res.	2012[g]	80	36.8521667	-119.87067
Mullet Is., Salton Sea (So.)	2012[g]	6,594	33.225175	-115.608611
Ramer Lake, Imperial WA	2012[g]	203	33.0731667	-115.507
San Joaquin River, RM 121 (SE of Hills Ferry)	2012[g]	20	37.334845	-120.950857
San Joaquin River, SLNWR_1	2012[g]	10	37.269576	-120.830095
San Joaquin River, Sycamore Island	2012[g]	6	36.851978	-119.826987
San Joaquin River, Turner Island	2012[g]	60	37.154865	-120.742627
San Luis NWR	2009	14	37.126393	-120.58761
San Luis NWR_5 (WB-3)	2012[g]	5	37.251626	-120.814912
Sepulveda Dam Recreational Area - Sepulveda Basin	2012[g]	12	34.175462	-118.472483
Sheepy Lake, Lower Klamath NWR	2011[a]	55	41.9683333	-121.78833
South Wilbur Flood Area, Tulare Lake Drainage	2012[g]	90	35.874771	-119.656986
Northern Coast – North Section				
Arcata Bay Sand Islands	2008	103	40.840381	-124.124112
Big Lagoon	2008	42	41.168135	-124.113886
Castle Rock	2008	35	41.756167	-124.25
False Klamath Rock	2008	48	41.59	-124.106
Little River Rock	2008	100	41.034667	-124.119333
Old Arcata Wharf	2008	51	40.8405	-124.105333
Prince Island	2008	220	41.950797	-124.214572
Radar Station Rocks	2008	57	41.555	-124.1
Sea Gull Rock	2008	13	41.086833	-124.151167
Sugarloaf Island	2008	69	40.436333	-124.406833
Teal Island	2008	485	40.6911	-124.224
Trinidad Bay Rocks	2008	5	41.05	-124.133333

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
White Rock (DN)	2008	6	41.509333	-124.084333
Northern Coast – South Section				
Hog Island	2011[g]	548	38.1915	-122.9345
Mendocino - Big River 2	2011[g]	12	39.301767	-123.768947
Russian Gulch	2008	50	38.466667	-123.156
Russian River Rocks	2008	25	38.452333	-123.139
Shell-Wright Beach Rocks	2008	30	38.416667	-123.1
Southern Coast				
Anacapa Island - Middle	2008	47	34.00454	-119.393078
Anacapa Island - West	2008	335	34.006833	-119.419833
Goleta Beach Co. Park and Slough	2012[g]	37	34.418388	-119.82826
Huntington Central Park	2012[g]	10	33.698006	-118.009719
Marina del Rey (Basin A, Bora Bora Way, Coast Guard)	2012[g]	24	33.97217	-118.455591
Prince Island	2008	98	34.054833	-120.333333
Santa Barbara Island	2008	89	33.472833	-119.033833
Seal Cove Area	2008	73	32.901667	-118.526333
Sierra Pablo Area	2008	16	33.94295	-120.028425
South San Diego Bay Saltworks	2012[g]	55	32.606099	-117.098982
Summerland	2012[g]	84	34.421166	-119.611
Sutil Island	2008	51	33.475	-119.041667
COLORADO				
Fruitgrowers Reservoir	2009	41	38.828613	-107.9519
IDAHO				
American Falls Reservoir	2009	500	43.00066	-112.60085
Bear Lake NWR	2009	58	42.188552	-111.31998
Blackfoot Reservoir	2009	634	42.898034	-111.61359
Boise River - Lemp Lane	2009	20	43.7266286	-116.851248
Boise River - Wagner 2	2009	50	43.6992738	-116.747034
Borderline, East Fork Owyhee River	2009[c]	40	42.088288	-116.135948
Gosling Island, Snake River Sector - Deer Flat NWR	2009	25	44.12	-117.05
Gull Island - Minidoka NWR	2009	61	42.662828	-113.45054
Island Park Reservoir	2009	136	44.405801	-111.54254
Mud Lake WMA	2009	26	43.877617	-112.37937
Payette River - Letha	2009	16	43.907952	-116.64736
Pelican Island - Minidoka NWR	2009	87	42.662514	-113.45439
MONTANA				
East of Continental Divide				
Arod Lake	2009-2011[b]	17	47.996	-112.015
Canyon Ferry WMA	2009-2011[b]	356	46.39329	-111.48426
Freezout WMA	2009-2011[b]	138	47.67903	-112.04038
Red Rock Lakes NWR	2009[b]	225	44.63749	-111.8406
West of Continental Divide				
Ninepipes NWR	2010-2011[b]	110	47.4317	-114.1171
Pablo Reservior	2010-2011[b]	8	47.6291	-114.15645
Warm Springs Ponds WMA	2010-2011[b]	12	46.14264	-112.78429
NEVADA				
Anaho Island	2012[c]	400	39.954578	-119.512669
Lahontan Reservoir	2010[c]	25	39.352883	-119.131039
Ruby Lake NWR	2010[c]	50	40.199855	-115.461639
S-Line Reservoir	2012[c]	12	39.488642	-118.726336
Virginia Lake	2010[c]	25	39.500539	-119.80665
Wildhorse Reservoir	2009	200	41.662397	-115.804507
Wilson Reservoir	2009	100	41.67663	-116.334426

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
OREGON				
Central Coast				
Blast Rock	2009	12	44.136111	-124.128333
Heceta Head	2012[i]	12	44.138544	-124.129108
Parrot Rock	2009	19	44.135278	-124.128611
Columbia River Estuary				
Astoria-Megler Bridge	2011[a]	60	46.200333	-123.8525
East Sand Island	2011[a]	13,045	46.262019	-123.980382
Miller Sands Navigational Aids	2009	162	46.253333	-123.658
Miller Sands Spit	2011[a]	248	46.244651	-123.682977
Other Upper Estuary Navigational Aids	2009	73	46.256993	-123.501669
Interior				
Burns Gravel Ponds	2011[g]	5	43.58543	-119.00838
Carlon Ranch	2011[g]	7	43.5029	-118.94336
Crane Prairie Reservoir	2011[g]	39	43.8116667	-121.78833
Dog Lake	2011[g]	15	42.08427	-120.70401
Drews Reservoir	2011[g]	15	42.171287	-120.66331
Howard Prairie Lake	2011[g]	8	42.2643	-122.44498
Hyatt Reservoir	2011[g]	26	42.18602	-122.45537
Malheur Lake	2011[g]	140	43.330591	-118.78816
Malheur NWR - Frenchglen Area - Baca Lake	2011[g]	10	42.91184	-118.85517
Malheur NWR (Sodhouse Ranch)	2011[a]	140	43.263857	-118.84297
Pelican Lake, Pelican Island	2011[a]	38	42.2032	-119.88223
Rivers End (Lake Abert)	2011[g]	11	42.51	-120.26833
Snake River Unnamed Island	2009	27	43.8417083	-117.00853
Snake River Unnamed Island	2009	63	44.241948	-117.04232
Swan Lake	2011[a]	8	42.323774	-121.60807
Upper Klamath Lake NWR	2011[a]	250	42.509639	-122.03903
Yonna Valley - Alkali Lake	2011[g]	5	42.26236	-121.48675
Northern Coast				
Haystack Rock	2009	75	45.211667	-123.986944
Three Arch Rocks - Finley Rock (East)	2009	417	45.464044	-123.987936
Three Arch Rocks - Middle Rock (Middle)	2009	22	45.461816	-123.990339
Unnamed Colony (Cape Lookout)	2009	128	45.3375	-123.992778
Unnamed Colony (Oswald West)	2009	95	45.742333	-123.959667
Southern Coast				
Bolon Island	2009	763	43.707	-124.1015
Castle Rock	2009	15	42.856389	-124.5475
Chiefs Island (Gregory Point)	2009	88	43.34	-124.374444
Coos Bay - Coos River (Chandler Bridge)	2011[g]	40	43.36664	-124.15363
Gull Rock	2009	27	42.850333	-124.5545
Hunters Island	2009	222	42.313889	-124.425833
Qochyax (Squaw) Island	2009	26	43.337778	-124.377778
Redfish Rocks (East Central)	2009	6	42.692666	-124.470667
Sisters Rocks Island (South)	2009	49	42.590556	-124.408611
Sunset Bay	2011[g]	28	43.32964	-124.38062
Table Rock	2009	125	43.1175	-124.435833
Unnamed Colony	2009	56	43.441944	-124.216944
Unnamed Colony (Mack Reef)	2009	14	42.245278	-124.410278
Unnamed Colony (Mack Reef)	2009	24	42.248056	-124.412222
Unnamed Colony (N of Ferry Road Park)	2011[g]	183	43.42352	-124.22498
Whaleshead Cove (East Rock)	2009	17	42.139722	-124.361111
UTAH				
Great Salt Lake	2009	82	41.013066	-112.563377
Mona Reservoir	2009	13	39.867588	-111.866252
Ouray NWR	2009	76	40.153687	-109.609274

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
WASHINGTON				
Eastern Strait of Juan de Fuca				
Smith Island	2009	28	48.318	-122.838667
Minor Island	2012[d]	25	48.324129	-122.819437
Grays Harbor				
Grays Harbor Channel Markers	2011[a]	137	46.9545	-123.9005
Interior				
Foundation Island	2011[a]	318	46.1593333	-118.99117
Lower Turnbull Slough NWR	2012[h]	27	47.42019000	-117.59702100
Mouth of Okanogan River	2011[a]	32	48.0925	-119.70983
North Potholes Reservoir	2011[a]	900	47.0406667	-119.40283
Pend Oreille River - Kent Creek (Greggs Addition)	2011[h]	14	48.23221643	-117.20069299
Pend Oreille River - Usk Bridge	2011[h]	146	48.31984800	-117.28430100
Sprague Lake, Harper Island	2011[a]	107	47.241	-118.08383
Olympic Peninsula Outer Coast				
Little Hogsback Island	2009	71	47.435167	-124.3385
Puget Sound				
Henderson Inlet - Woodard Bay	2012[h]	150	47.131527	-122.844585
San Juan Islands				
Bird Rocks	2012[d]	155	48.485695	-122.76158
Drayton Harbor	2009	142	48.9875	-122.757833
Goose Island (Cattle Pass)	2009	56	48.457787	-122.957016
Hall Island	2011[d]	13	48.434333	-122.906167
Snohomish River Mouth	2009	249	48.022833	-122.217
Viti Rocks	2012[d]	50	48.633333	-122.6195
Williamson Rocks	2010[d]	5	48.449699	-122.706005

*Data come from Adkins and Roby 2010 and Courtot et al. 2012 unless otherwise noted: [a] Oregon State University (OSU) / Bird Research Northwest (BRNW); [b] Montana Department of Fish, Wildlife, and Parks (MFWP); [c] Nevada Department of Wildlife (NDOW); [d] U.S. Fish and Wildlife Service (USFWS); [e] Arizona Department of Fish and Game (ADFG); [f] Shuford et al. 2004; [g] Western Colonial Waterbird Survey data (WCWS); [h] Washington Department of Fish and Game (WDFG); [i] Oregon Department of Fish and Wildlife (ODFW); [j] Idaho Department of Fish and Game (IDFG); [k] Canadian Wildlife Service (CWS)

Table A2. All known cormorant area frame locations from which the locations to monitor in 2014 were selected.

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
ARIZONA				
Painted Rock Dam	1996	5	33.0791667	-113.02083
Painted Rock Road Exit	2001	8	32.9096047	-112.9568
River Reservoir	2006	30	34.0301665	-109.43586
BRITISH COLUMBIA				
<u>Gulf Islands</u>				
Annette Inlet	2009	0	48.821667	-123.388333
Ballingal Islets	2009	0	48.907255	-123.459531
Bare Point	2009	0	48.923333	-123.703
Canoe Islet	2009	0	49.028344	-123.588704
Chain Islets	2009	0	48.419167	-123.266667
Channel Islands	2009	0	48.801167	-123.375333
Charles Island	1977[k]	0	48.900833	-123.433333
Five Fingers Island	2009	0	49.231499	-123.915838
Great Chain Island	2009	0	48.418833	-123.272
Hudson Rocks	2009	0	49.224941	-123.926996
Ladysmith Harbor	2009	0	48.996294	-123.811594
Red Islets	2009	0	48.809333	-123.352
Rose Islets	2009	0	49.00967	-123.643359
Second Sister Islet (Chain Islands)	2009	0	48.838333	-123.453333
<u>Northern Strait of Georgia</u>				
Christie Islet	2009	0	49.49935	-123.301719
Franklin Rock/Merry Island	2000	0	49.466667	-123.916667
McRae Islets	2000	1	49.7395	-124.288833
Pam Rock	2009	4	49.487922	-123.299488
<u>Vancouver Area</u>				
Douglas Island (Queen's Reach)	1987	0	49.221185	-122.781246
Sand Heads	2009	0	49.105333	-123.290333
Westshore Terminal	2009	0	49.018333	-123.155
CALIFORNIA				
<u>Central Coast – Outer Coast North</u>				
Pillar Point	2008	0	37.488333	-122.4925
Point Resistance	2008	0	37.9925	-122.823333
Seal Rocks	2008	0	37.77833	-122.51528
<u>Central Coast – Outer Coast South</u>				
Anderson Canyon Rocks	2008	0	36.151167	-121.658833
Cape San Martin	2008	0	35.886167	-121.459167
Partington Ridge North	2008	0	36.167667	-121.685667
Rockland Landing North	2008	0	36.0095	-121.538333
San Lorenzo River Mouth	2009	4	36.964483	-122.012621
<u>Central Coast – San Francisco Bay</u>				
Donlon Island	2008	0	38.024167	-121.775
N.E. San Pablo Bay Beacon	2008	2	38.0695	-122.286167
San Mateo Bridge & PG&E Towers	2005	78	37.587333	-122.24

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
Interior				
76th Ave	2012[g]	1	33.505008	-116.080053
Alamo River mouth, Salton Sea (So.)	1999	106	33.205	-115.61683
Beaver Lake (Sac. River W)	1999	16	38.888828	-121.812268
Big Sage Reservoir	2009	0	41.5925	-120.6425
Bridgeport Reservoir, Mono Co.	1974	6	38.2903333	-119.22667
Buena Vista Lake, Kern Co.	1912	300	35.2206667	-119.25867
Colusa NWR, T14.4	2011[g]	3	39.153033	-122.031885
Corcoran Irrigation District Ponds	1980	6	36.150074	-119.552639
Cut-off Slough, Solano Co.	1920	40	38.1866667	-122.006
Eagle Lake, Pelican Point	2009	0	40.6266667	-120.74083
Eagle Lake, btw Buck and Little Troxel Pt.	2009	2	40.65946	-120.7148
East Hacienda Ranch, Tulare Lake Drainage	1999	6	N/A	N/A
East Poe Rd., Salton Sea (So.)	1999	13	33.1003333	-115.73383
Goose Lake	2011[g]	1	41.8036667	-120.42017
Hartson Reservoir	1990	50	40.29	-120.37267
Indian Valley Reservoir	2011[g]	3	39.152981	-122.53595
Iron Gate Reservoir - Copco Lake	1980	0	41.9518333	-122.43367
Johnson St., Salton Sea (No.)	1999	2	33.4575	-116.0565
Laguna de Santa Rosa	1999	59	38.3865	-122.80067
Lake Henshaw, San Diego Co.	1932	B	33.2356667	-116.74133
Mallard Rd duck club	2012[g]	1	33.317906	-115.615503
Merced NWR (East Side Bypass)	1999	0	37.1673333	-120.62667
Modoc NWR	1977	16	41.4573333	-120.5195
Mystic Lake	1999	64	33.8751667	-117.07417
New River mouth, Salton Sea (So.)	1999	30	33.1335	-115.69017
NNE Grimes (Sac. River W)	1999	0	39.1063333	-121.903
North Butte Country Club, Butte Sink	1999	65	39.2703333	-121.89117
North Stone Lake, Stone Lakes NWR	1999	154	38.384	-121.486
Pellandini Ranch	1999	29	38.284	-121.367
Petaluma Waste Water Treatment Plant	2011[g]	4	38.2193333	-122.57283
Port of Sacramento	1999	0	38.5583333	-121.55367
Prado Basin near dam	1999	30	33.8895	-117.63833
Reservoir F	1970's	13	41.5711667	-120.87367
Sacramento River, Mile 188 (W of Murphy's Slough)	2011[g]	1	39.666161	-121.982269
San Felipe Lake	1998	11	36.9756667	-121.4561667
San Gabriel River, Pico Rivera	1999	6	33.9838333	-118.07383
San Joaquin River NWR	2009	0	37.626	-121.193
San Joaquin River, River Mile 242.5	2012[g]	1	36.835612	-119.938687
San Luis NWR_8 (FT-1A)	2012[g]	1	37.298358	-120.88755
Santa Ana River Ponds	1999	0	33.8528333	-117.8255
Sutter Bypass West	1999	12	38.837	-121.65467
Sweetwater Reservoir	1999	28	32.7045	-116.97233
Trout Lake	1992	40	41.6845	-122.47233
Tulare Lake	1907	100	36.0675	-119.75217
Tule Lake NWR, Sump 1A	2009	0	41.896743	-121.52973
Tule Lake NWR, Sump 1B	2009	0	41.837	-121.442
Valensin Ranch, Cosumnes R. Reservoir	1999	3	38.3038333	-121.39167
Venice Tip	1999	9	38.0416667	-121.52533
Northern Coast – North Section				
False Cape Rocks	2008	1	40.506333	-124.39
Flint Rock Head	2008	0	41.521833	-124.083333

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
Humboldt Bay Platforms	2008	0	40.717167	-124.234333
Last Chance Rock	2008	0	41.634167	-124.121667
Pilot Rock	2008	0	41.051	-124.1515
Sea Lion Rock	2008	0	41.09	-124.158167
Tolowa Rocks	2008	0	41.7525	-124.233333
Unnamed Small Rocks	2008	0	41.690153	-124.150022
White Rock (HU)	2008	0	41.08655	-124.159044
Northern Coast – South Section				
Dillon Beach Rocks	2008	0	38.271	-122.985167
Gull Rock	2008	0	38.421667	-123.118333
Kibesillah Rock	2008	0	39.574833	-123.775167
Southern Coast				
Cormorant Rock Area	2008	0	33.238833	-119.552833
Hoffman Point Area	2008	0	34.040333	-120.358667
La Jolla (Seal Rock)	2008	0	32.847653	-117.278703
Scorpion Rocks	2008	0	34.042	-119.541167
Shag Rock	2008	0	33.485833	-119.034167
Ship Rock	2008	0	33.457833	-118.487833
IDAHO				
Boise River - Hop Road	2009	0	43.71783	-116.790689
Deer Flat NWR - Gull Island	1993[g]	30	43.51487	-116.60348
Emmett Rookery	2009	0	43.878345	-116.516559
Foreman Reservoir	2009	0	43.024156	-116.3326
Henry's Lake	2009	0	44.639291	-111.40265
Lake Lowell Sector - Deer Flat NWR	2009	0	43.555391	-116.678607
Magic Reservoir	2009	0	43.258535	-114.36619
Mormon Reservoir	2012[j]	0	43.255969	-114.82903
Old Castle Rookery A	2004	13	43.678006	-116.321431
Palisades Reservoir	2009	0	43.262017	-111.12894
Snake River - Gold Isle	1993[g]	15	42.9852208	-116.0700675
Snake River - Unnamed Island	1993[g]	85	43.5751337	-116.8146564
Stork Island	2009	0	42.5	-116.1
MONTANA				
West of Continental Divide				
Lee Metcalf NWR	2009	3	46.56965	-114.07844
NEVADA				
Carson Sink	1987	B	39.815282	-118.76644
Humboldt WMA	2007[c]	500	40.000268	-118.612226
Kirch WMA	1994	40	38.419866	-115.08274
OREGON				
Central Coast				
Sea Lion Caves	2009	0	44.119333	-124.121333
Unnamed Colony	2006	0	44.5925	-124.020556
Yaquina Bay Bridge	2006	2	44.619667	-124.0535
Columbia River				
Columbia River - W Boardman	2011[g]	3	45.8166935	-119.9655565
McGuire Island	2011[g]	1	45.56272	-122.45208

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
Smith and Bybee Lakes	2011[g]	1	45.62286	-122.74613
Tri-Club Island	2011[g]	1	45.593925	-122.554389
Umatilla NWR	2011[g]	1	45.8943258	-119.605172
Columbia River Estuary				
Desdemona Sands Pilings	2009	0	46.206167	-123.8725
Rice Island	2009	0	46.258333	-123.758333
Trestle Bay	2009	0	46.218667	-123.987833
Interior				
Anderson Lake	2009	0	42.502744	-119.81705
Chewaucan Marshes	2011[g]	1	42.57083	-120.38611
Cow Lakes - Jordan Caves	2011[g]	3	43.07472	-117.34972
Crump Lake, Tern Island	2011[g]	1	42.2838333	-119.83967
Gerber Reservoir	2009	0	42.205018	-121.10474
Hart Lake	2011[g]	1	42.438	-119.861
Historic Lower Klamath Lake	2011[g]	1	42.0762155	-121.8022878
Klamath River Bridge	2011[g]	2	42.17368	-121.79766
Ladd Marsh WMA	2011[g]	2	45.26905	-117.95113
Lawen	2011[g]	1	43.4062932	-118.8539029
Lost River - Nuss Lake	2011[g]	1	42.14511	-121.64452
Malheur NWR - Derrick Lake	2011[g]	3	43.3030149	-119.30629
Prineville	2011[g]	1	44.309592	-120.870333
Round Lake	2011[g]	1	42.18722	-121.91813
Sprague River Valley - Devil Lake	2011[g]	1	42.31643	-120.95994
Sprague River Valley _ Unnamed Lake	2011[g]	1	42.45039	-121.03678
Spring Lake	2011[g]	2	42.094306	-121.748306
Summer Lake, WMA	2011[g]	4	42.9708267	-120.7692459
Tingley Lake	2011[g]	4	42.11847	-121.77787
Twentymile Slough	2011[g]	3	42.1398	-119.83772
Upper Klamath Lake - Link River Outlet	2011[g]	2	42.23802	-121.80673
Warm Springs Reservoir	2011[g]	4	43.63881	-118.2566
Willamette River - W Coburg	2011[g]	1	44.14576	-123.12719
Willow Valley Reservoir	2011[g]	1	42.00929	-121.11615
Northern Coast				
Bird Rocks - North	2009	0	45.905667	-123.97
Three Arch Rocks - Shag Rock (West)	2009	0	45.460681	-123.992778
Unnamed Colony (Unnamed Rock)	2009	0	45.345556	-123.990278
Southern Coast				
Chetco River	2011[g]	2	42.04504	-124.26991
Coos Bay - Jordan Cove	2011[g]	3	43.43402	-124.24412
Elephant Rock	2009	0	43.112778	-124.438056
Middle Coquille Point Rock	2009	0	43.114444	-124.438889
Munsel Lake	2011[g]	1	44.00718	-124.08738
North Crook Point Rock	2009	0	42.256667	-124.413611
Rainbow Island	2006	0	42.085	-124.337222
Siuslaw River Trees	2009	0	43.965	-124.095833
Tenmile Lakes (Rocky Point)	2012[i]	B	43.566226	-124.1428896
Unnamed Colony	2009	0	43.692222	-124.1675
Unnamed Colony	2006	0	42.171389	-124.365278
Unnamed Colony (Mack Reef)	2009	0	42.235833	-124.413889
Unnamed Colony (Unnamed Rock)	2009	1	42.2575	-124.415556
Whaleshead Cove (West Rock)	2009	0	42.138611	-124.362778

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
UTAH				
Fish Springs NWR, Mallard Pond	2009	2	39.853488	-113.377559
Green River	2009	4	N/A	N/A
Pelican Lake	2009	0	40.194151	-109.67996
WASHINGTON				
Eastern Strait of Juan de Fuca				
Point No Point	2009	0	47.909167	-122.521667
Protection Island	2009	0	48.123333	-122.925
Grays Harbor				
Goose Island	2009	0	46.973333	-124.068333
Unnamed Sand Island	2009	0	46.9575	-124.054167
Interior				
Coffeepot Lake	2012[h]	B	47.49000700	-118.56927300
Crescent Island	2011[a]	0	46.095079	-118.931221
Goat Island	2009	0	46.2353333	-119.19283
Hanford Reach	2009	0	46.6548333	-119.41667
Lions Ferry Railroad Trestle	2009	0	46.5893333	-118.22383
Miller Rocks	2011[a]	1	45.657	-120.87183
Pend Oreille River - Kelly Island	2011[g]	0	48.19314213	-117.03933918
Pend Oreille River - near Willy-O Lake	2011[g]	0	48.21545236	-117.06383773
Pend Oreille River - Sandy Shores	2011[h]	3	48.22931754	-117.11376802
Rock Lake	2012[h]	B	47.14594800	-117.71509800
Twin Lakes	2012[h]	B	47.52935800	-118.50858100
Vancouver Lake	1936	4	45.673	-122.7175
Olympic Peninsula Outer Coast				
Abbey Island	2009	0	47.709667	-124.418333
Alexander Island	2009	0	47.792	-124.502667
Bodelteh Islands	2009	0	48.172	-124.755
Carroll Island	2009	1	48.003333	-124.719333
Dahdayla	2009	0	47.934667	-124.666833
Dahodaalah	2009	0	47.950833	-124.668833
Destruction Island	2009	0	47.674548	-124.485533
Father and Son	2009	0	48.222667	-124.706833
Ghost Rock	2009	0	47.853667	-124.5675
Gunsight Rock	2009	0	47.904833	-124.650333
Half Round Rocks	2009	0	47.827778	-124.537222
Hoh Head Mainland	2009	0	47.768667	-124.471667
Jagged Islands	2009	0	47.991333	-124.69
Middle Rock	2009	0	47.742333	-124.442333
No Name 061	2009	0	48.369333	-124.725333
North Rock	2009	0	47.75	-124.471667
Point Grenville Islands	2009	0	47.3	-124.274167
Point of the Arches	2009	0	48.241944	-124.707778
Quillayute Needles NWR	2009	0	47.822318	-124.511925
Rounded Island	2009	0	47.825833	-124.552167
Seal Rock	2009	0	48.3575	-124.541667
Split Rock	2009	0	47.404833	-124.357667
Tunnel Islands	2009	0	47.458333	-124.34
White Rock	2009	0	48.134167	-124.733333
Willoughby Rock	2009	0	47.407	-124.352833

Colony	Year of the Most Recent Survey	Number of Nests (Breeding Pairs)	Latitude	Longitude
San Juan Islands				
Bare Island	2009	0	48.724667	-123.007833
Castle Island	2009	0	48.42	-122.818833
Colville Islands	2009	0	48.415278	-122.821389
Flattop Island	2009	0	48.641833	-123.075333
Gull Rock	2009	0	48.650667	-123.086333
Little Sister Island	2009	0	48.687167	-122.755
Puffin Island	2009	0	48.740333	-122.818667
Secar Rock	2005[d]	9	48.437714	-122.906548
Waldron Island	2009	0	48.700833	-123.024667
White Rock	2009	0	48.667333	-123.069

*Data come from Adkins and Roby 2010 and Courtot et al. 2012 unless otherwise noted: [a] Oregon State University (OSU) / Bird Research Northwest (BRNW); [b] Montana Department of Fish, Wildlife, and Parks (MFWP); [c] Nevada Department of Wildlife (NDOW); [d] U.S. Fish and Wildlife Service (USFWS); [e] Arizona Department of Fish and Game (ADFG); [f] Shuford et al. 2004; [g] Western Colonial Waterbird Survey data (WCWS); [h] Washington Department of Fish and Game (WDFG); [i] Oregon Department of Fish and Wildlife (ODFW); [j] Idaho Department of Fish and Game (IDFG); [k] Canadian Wildlife Service (CWS)
**B = breeding known but not assessed.

APPENDIX B: Sampling Approach

Dual-Frame Sampling—To estimate the breeding population, a sample of locations was randomly selected using a modified dual-frame sampling approach (Haines and Pollock 1998). The number of active nests will be counted at these locations during the mid- to late incubation period and will provide an index to estimate the number of breeding adults. Dual-frame sampling involves random sampling from 2 frames: a list frame and an area frame. The list frame includes active breeding colonies. Active breeding colonies contained ≥5 active nests at least 1 time during the past 5 years (2008–2012). The area frame includes other possible breeding locations not included within the list frame: 1) historical breeding colonies where 1 year of documented nesting activity has occurred but nesting has not been confirmed in the last 5 years (i.e., before 2008), 2) locations with <5 active nests during the last 5 years (2008–2012), and 3) new breeding colonies that arise during the duration of the monitoring strategy.

Summary Statistics and Description of the Western Population—There are 197 list frame (Appendix A, Table A1) and 224 area frame (Appendix A, Table A2) locations. The list frame was stratified into 4 size classes (>10,000, 10,000–500, 499–100, and 99–5 breeding pairs) based on suspected differences in colony dynamics. We used available cormorant colony data to calculate the mean number of breeding pairs and the number of colonies within the 4 list frame size classes and the area frame (i.e., strata). For each list frame size class, we calculated the average percent coefficient of variation of the number of breeding pairs using colonies that had ≥3 years of count data (n=33). We obtained multiple year colony data for the following areas: Columbia River and Estuary, Oregon and Washington (Roby et al. 2012); Oregon coast (Naughton et al. 2007); Salton Sea and Klamath Basin, California (Shuford 2010); and San Francisco Bay area, California (PRBO 2003). Summary statistics of the 4 list frame size classes and area frame are provided in Table B1.

The cormorant breeding colony on East Sand Island, Oregon comprises approximately 40% of the Western Population. In 2011, there were 13,045 breeding pairs on East Sand Island (Roby et al. 2012). Only 6 colonies had >500 breeding pairs (Table B1). The percent coefficient of variation of the number of breeding pairs was inversely related to colony size, ranging from 15% for the largest size class, which contains the single colony at East Sand Island, Oregon, to 92% for the smallest size class (i.e., 99–5 breeding pairs; Table B1).

The percent coefficient of variation and other summary statistics used in the power analysis (see below) were calculated using past count data. Recommended sample sizes and monitoring locations may need to be adjusted in the future if management actions cause substantial changes to the Western Population. If management actions cause the percent coefficient of variation values to increase, a greater number of sampling units will be needed to achieve the desired management objective. Thus, monitoring costs will be greater than those presented in this document.

Power Analysis—We conducted a power analysis using Program R (R Development Core Team 2008) to identify the most cost effective sampling scheme (i.e., fewest number of total sampling units) that achieved the monitoring objective. The monitoring objective is to have the ability to detect a 5% change/year in the Western Population of cormorants with 80% power ($\beta = 0.20$) and a 10% Type I error rate ($\alpha = 0.10$). Sampling schemes varied by the number of locations sampled within the 4 list frame size classes and area frame and the frequency and duration of monitoring years. We examined 9 temporal sampling schemes, where monitoring occurred every year, every other year, or every third year for 3, 5, 7, and 9/10 years in duration. For each temporal sampling scheme, 54 different combinations of sampling units were constructed (see Table B1 for sampling combination input values). In total, there were 486 different sampling schemes (9 x 54 = 486). To ensure that each stratum will have a representative sample, we chose 5% of the total number of locations within a list frame size class and the area frame as the lowest threshold (i.e., minimum number of sampling units) to sample.

Simulations were based upon route regression procedures in Program Monitor (Gibbs and Ene 2010). For each simulation, a deterministic linear trend was calculated for each list frame size class given the initial mean colony size, the years monitoring occurred, and the specified percent change per year (i.e., trend). The trend values tested were 1%, 5%, 10%, and 15%. Random data sets for the 4 list frame size class and the area frame were generated from a random normal distribution using the deterministic trend means of each time period and the calculated percent coefficient of variation of each stratum (Table B1). A constant percent coefficient of variation was used so that variance was proportional to the deterministic trend mean over time. Data sets were constrained so that negative values were truncated at 0. The number of data sets generated for each list frame size class and the area frame equaled the number of colonies sampled per monitoring year within each stratum. Data sets were then combined to create the overall, or metapopulation, dataset. The slope of the metapopulation dataset was calculated using a linear model. The confidence interval of the metapopulation slope was calculated using a 10% Type I error rate ($\alpha = 0.10$). A positive trend was detected if the confidence intervals of the metapopulation slope were both greater than zero. Power was calculated as the proportion of iterations ($i = 2{,}500$) that the metapopulation trend was detected.

Results from Power Analysis—The power to detect trend increased as the number of colonies sampled per year, number of years, duration of years, and trend values increased (Table B2 and B3; Fig. B1). Monitoring >9 years in duration will most likely be necessary to ensure detection of a 5% trend with approximately 80% power (Table B3; Fig. B1). Shorter durations may be sufficient if trends values are greater than 5%. There was little loss in power by sampling every third year as compared to every other year. Power estimates to detect a 5% trend were slightly higher when monitoring every year compared to every third year (0.90 vs. 0.80), but the total number of units sampled was much greater (396 vs. 176; Table B3; Fig. B1). The 10 most cost effective sampling schemes that achieved the monitoring objective are given in Table B2. For these sampling schemes, we also estimated the percent coefficient of variation of the breeding pair estimate using the stratified dual-frame estimator (see below).

Monitoring Recommendation from Power Analysis—The most cost effective sampling scheme that will achieve the monitoring objective is to monitor every third year for a 10-year duration. Forty-four locations should be monitored per monitoring year; 33 from the list frame and 11 from the area frame. The number of locations within each list frame size class to monitor per monitoring year is: 100% of the locations within the 2 largest size classes (>10,000 size class [n=1] and 10,000–500 size class [n=6]), 25% of the 499–100 size class (n=11), and 10% of the 99–5 size class (n=15).

Estimating the Breeding Population— To estimate the total number of breeding pairs and the percent coefficient of variation of breeding pair estimate of the top 10 sampling schemes, we used the stratified dual-frame estimator similarly described in Haines and Pollock (1998). In the future, collected data from this monitoring strategy can be analyzed using this approach. The estimator is:

$$\hat{Z}_T = \sum_{s=1}^{n}(N_{L(s)} \times \bar{z}_{L(s)}) + (N_A \times \bar{z}_A)$$

where:

s = strata, from 1 to n.
$\hat{Z}_T$ = total number of breeding pairs
N_L = total number of sampling units in the list frame
$\bar{z}_L$ = sample mean number of breeding pairs in the list frame
N_A = total number of sampling units in the area frame
$\bar{z}_A$ = sample mean number of breeding pairs in the area frame

The variance estimator is:

$$\widehat{Var}\left(\hat{Z}_T\right) = \sum_{s=1}^{n}\left(N_{L(s)}^2 \times \frac{s_{\bar{z}_{L(s)}}^2}{n_{L(s)}}\right) + \left(N_A^2 \times \frac{s_{\bar{z}_A}^2}{n_A}\right)$$

$s_{\bar{z}_L}^2$ = sample variance of the number of breeding pairs in the list frame
n_L = number of units sampled from the list frame
$s_{\bar{z}_A}^2$ = sample variance of the number of breeding pairs in the area frame
n_A = number of units sampled from the area frame

For future monitoring years, the total number of sampling units in the 4 list frame size classes and area frame will have to be estimated. Colonies selected from the original list frame will be monitored for the duration of the monitoring strategy. The probability of a colony within a given list frame size class changing to another size class or becoming inactive during time (t) to (t+1) can be estimated using a multi-state model or the raw proportion data. Likewise, the probability of an area frame location becoming active or changing size classes can be estimated during time (t) to (t+1). These 2 probabilities can be combined to estimate the total number of colonies in each list frame size class and the area frame for a given monitoring year.

Table B1. Summary statistics and input values for the power analysis for the 4 list frame size classes and area frame.

	Colony Size (Breeding Pairs)	Mean Colony Size (Breeding Pairs)	# of Colonies in Size Class	Total Count (Breeding Pairs)	% of Total Population	# of Sampling Units Used in Power Analysis[c]	% of Sampling Units Used in Power Analysis	% CV Used in Power Analysis
List Frame[a]								
	>10,000	13,045	1	13,045	35%	1	100%	15%
	10,000-500	1,657	6	9,939	27%	3,6	50%,100%	47%
	499-100	194	45	8,746	24%	11,23,34	25%,50%,75%	55%
	99-5	36	145	5,244	14%	15,44,73	10%,30%,50%	92%
TOTAL			197	36,974	100%			
Area Frame[b]								
		10	224	N/A	N/A	11,22,34	5%,10%,15%	92%[d]

[a] The list frame includes active breeding colonies. Active breeding colonies contained ≥5 active nests at least 1 time during the past 5 years (2008–2012).

[b] The area frame includes other possible breeding locations not included within the list frame: 1) historical breeding colonies where 1 year of documented nesting activity has occurred but nesting has not been confirmed in the last 5 years (i.e., before 2008), 2) locations with <5 active nests during the last 5 years (2008–2012), and 3) new breeding colonies that arise during the duration of the monitoring strategy

[c] For the power analysis, all possible combinations of sampling units (n=54) were used for each temporal sampling scheme (n=9).

[d] % CV was not available for the area frame. The % CV value of the smallest list frame size class (92%) was used in the power analysis.

Table B2. The 10 most cost effective sampling schemes (i.e., fewest number of total sampling units) that achieved the monitoring objective of detecting a 5% change/year with 80% power. The recommended sampling scheme is highlighted. In total, 486 sampling schemes were constructed. Shown also is the percent coefficient of variation (% CV) of the total annual breeding pair estimate using the stratified dual-frame estimator.

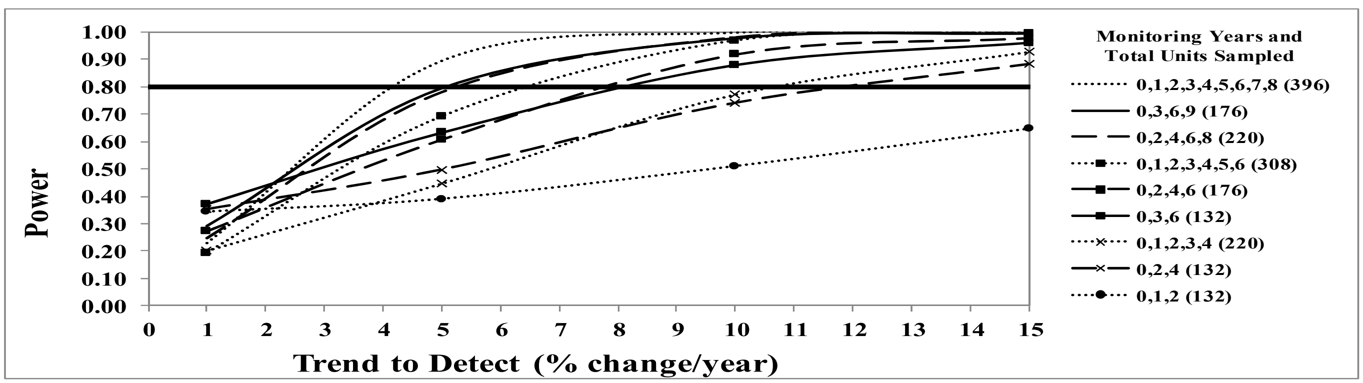
	Number of Units Sampled in Each List Frame Size Class									
Monitoring Years	>10,000	9,999-500	499-100	99-5	List Frame Units Sampled per Year	Area Frame Units Sampled per Year	Total Units Sampled per Year	Total Units Sampled All Monitoring Years	Power to detect 5% trend	% CV of the Breeding Pair Population Estimate
0,3,6,9	1	6	11	15	33	11	44	176	0.80	8.77%
0,3,6,9	1	3	23	15	42	11	53	212	0.81	9.31%
0,3,6,9	1	6	11	15	33	22	55	220	0.81	8.69%
0,3,6,9	1	6	23	15	45	11	56	224	0.83	8.38%
0,3,6,9	1	3	23	15	42	22	64	256	0.82	9.24%
0,3,6,9	1	3	34	15	53	11	64	256	0.86	9.18%
0,3,6,9	1	6	23	15	45	22	67	268	0.84	8.30%
0,3,6,9	1	6	11	15	33	34	67	268	0.80	8.67%
0,3,6,9	1	6	34	15	56	11	67	268	0.88	8.23%
0,2,4,6,8	1	6	23	15	45	11	56	280	0.83	8.38%

Table B3. Power to detect trend (i.e., % change/year) for various temporal sampling schemes. Temporal sampling schemes include monitoring every year, every other year, and every third year for 3, 5, 7, and 9/10 years in duration. Highlighted is the recommended sampling scheme, which is the most cost effective sampling scheme (i.e., fewest number of total sampling units) that achieved the monitoring objective of detecting a 5% change/year with 80% power.

	Number of Units Sampled in Each Size Class Per Monitoring Year							Power to Detect Trend (% change/year)			
Monitoring Years	>10,000 (100%)	9,999-500 (100%)	499-100 (25%)	99-5 (10%)	Area (5%)	Number of Monitoring Years	Total Units Sampled Over Monitoring Program (44 units/monitoring year)	1%	5%	10%	15%
0,1,2	1	6	11	15	11	3	132	0.34	0.39	0.51	0.65
0,1,2,3,4	1	6	11	15	11	5	220	0.20	0.45	0.77	0.93
0,1,2,3,4,5,6	1	6	11	15	11	7	308	0.20	0.69	0.97	1.00
0,1,2,3,4,5,6,7,8	1	6	11	15	11	9	396	0.23	0.90	1.00	1.00
0,2,4	1	6	11	15	11	3	132	0.35	0.50	0.74	0.88
0,2,4,6	1	6	11	15	11	4	176	0.27	0.61	0.92	0.98
0,2,4,6,8	1	6	11	15	11	5	220	0.25	0.78	0.98	1.00
0,3,6	1	6	11	15	11	3	132	0.37	0.63	0.88	0.96
0,3,6,9	1	6	11	15	11	4	176	0.29	0.80	0.98	1.00

*For the power analyses, 54 sampling combinations (i.e., the number of units sampled per monitoring year) were constructed for each of the 9 temporal sampling schemes. Only the most cost effective sampling combination (i.e., fewest number of total sampling units) that achieved the monitoring objective was shown.

Figure B1. Power to detect trend (i.e., % change/year) for various temporal sampling schemes. Temporal sampling schemes include monitoring every year (dotted line), every other year (dashed line), and every third year (solid line) for 3 (●), 5 (x), 7 (■), and 9/10 (no mark) years in duration. The solid line with no marks is the recommended sampling scheme, which is the most cost effective sampling scheme (i.e., fewest number of total sampling units) that achieved the monitoring objective of detecting a 5% change/year with 80% power. The solid horizontal line denotes 80% power.



*For the power analyses, 54 sampling combinations (i.e., the number of units sampled per monitoring year) were constructed for each of the 9 temporal sampling schemes. Only the most cost effective sampling combination (i.e., fewest number of total sampling units) that achieved the monitoring objective was shown.

APPENDIX C: Monitoring Locations

Forty-four monitoring locations (i.e., 33 from the list frame and 11 from the area frame) were randomly selected from all list and area frame locations that were available for sampling. Locations that were unavailable to sample due to inaccessibility were excluded before selection (n=1). The number of locations selected in each list frame size class and the area frame was determined from the power analysis. All locations within the 2 largest list frame size classes were selected (>10,000 size class [n=1] and 10,000–500 size class [n=6]). For the 2 smallest list frame size classes, each location was assigned a random number between 0 and 1. The locations with the greatest assigned random number were selected in the amount determined for each size class (499–100 size class [n=11] and 99–5 size class [n=15]). To concentrate sampling effort on the locations with the highest potential cormorant use, area frame locations were assigned the following weights: 6 = breeding colonies before 2008 with >25 breeding pairs; 3 = breeding colonies after 2008 with 1–4 breeding pairs; 1 = all other locations (i.e., <25 breeding pairs before 2008 and 0 breeding pairs after 2008). The number of times a location was included on the area frame list from which locations were selected equaled its weight. Random numbers were then assigned for each entry. The 11 unique area frame locations with the greatest assigned random number were selected.

List frame colonies that are monitored during 2014 will be monitored for the duration of the monitoring strategy, even if no breeding is reported for a given year. For monitoring years after 2014, 5% of area frame locations will be randomly selected from an updated inventory of area frame locations using the weighting scheme described above. If a new breeding colony >500 breeding pairs is documented during the duration of the monitoring strategy, the Nongame Technical Committee will evaluate how it will be incorporated into the monitoring strategy and subsequent analyses.

The locations selected for monitoring in 2014 and survey and budgetary information for each location are given in Table C1. After randomly selecting the 44 monitoring locations, we identified which locations will be monitored under existing programs. We assumed monitoring at State Wildlife Areas, National Wildlife Refuges, and other locations covered by on-going monitoring programs will continue and thus would not contribute new cost to implement the monitoring strategy. Of the 44 selected monitoring locations, 30 locations will be included within existing monitoring programs (Table C1). We estimated that monitoring the 14 locations not included within existing monitoring programs will cost an additional $7,000 per monitoring year. For each location, survey methodology and monitoring cost were provided by individuals with knowledge of that location. If no information was available, a cost of $500 was used, which was based upon Idaho Department of Fish and Game colonial waterbird monitoring cost estimates. Cost associated with the 15 locations that will be surveyed during the USFWS coastal helicopter survey were considered collectively. We estimated that an additional $7,500 per monitoring year will be needed to compile and enumerate aerial photograph data from the USFWS coastal helicopter survey.

Table C1. Survey information and estimated cost of randomly selected monitoring locations for 2014. For monitoring years after 2014, the list frame locations will remain the same but area frame locations will be randomly selected.

Colony	Frame (Size Class)	Recommended Survey Technique G=ground B=boat A=aerial	Time of Year	Lead Organization(s)	Description	Estimated Cost per Monitoring Year	Estimated Cost Covered Under Existing Programs	Estimated New Additional Cost per Monitoring Year
BRITISH COLUMBIA (n=2)								
Interior								
Creston Valley Wildlife Management Area	List (99-5)	G	Late May	CVWMA	Included in on-going avian monitoring efforts on CVWMA	$500	$500	$0
Vancouver Area								
Second Narrows Bridge Power Tower	List (99-5)	G	Late May	CWS	New monitoring	$500	$0	$500
CALIFORNIA (n=16)								
Central Coast – Outer Coast North								
South Farallon Islands	List (499-100)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Central Coast – Outer Coast South								
San Lorenzo River Mouth	Area	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Central Coast – San Francisco Bay								
Alviso Plant, Pond Nos. A9 & A10	List (499-100)	G, B	Late May to early Jun	CDFG, PRBO	New monitoring	$500	$0	$500
Bair Island Power Towers (Steinberger Slough)	List (499-100)	G, B	Late May to early Jun	CDFG, PRBO	New monitoring	$500	$0	$500
Interior								
Laguna de Santa Rosa	Area	G	Late May to early Jun	CDFG, PRBO	New monitoring	$500	$0	$500
Lake Almanor, Almanor Peninsula	List (99-5)	B	Late May to early Jun	CDFG, PRBO	New monitoring	$500	$0	$500
Mullet Island, Salton Sea (So.)	List (10,000-500)	A	Late Jan to early Feb	CDFG, PRBO	Included in on-going avian monitoring efforts on Salton Sea	$2,000	$2,000	$0
Mystic Lake	Area	G	Late Jan to early Feb	CDFG, PRBO	New monitoring	$500	$0	$500
North Stone Lake, Stone Lakes NWR	Area	G	May	USFWS	Included in on-going avian monitoring efforts on Stone Lakes NWR	$500	$500	$0
Northern Coast – North Section								
Arcata Bay Sand Islands	List (499-100)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Big Lagoon	List (99-5)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Northern Coast – South Section								
Hog Island	List (10,000-500)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Southern Coast								
Anacapa Island - West	List (499-100)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Prince Island	List (99-5)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*

Colony	Frame (Size Class)	Recommended Survey Technique G=ground B=boat A=aerial	Time of Year	Lead Organization(s)	Description	Estimated Cost per Monitoring Year	Estimated Cost Covered Under Existing Programs	Estimated New Additional Cost per Monitoring Year
Santa Barbara Island	List (99-5)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Seal Cove Area	List (99-5)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
IDAHO (n=4)								
American Falls Reservoir	List (10,000-500)	A	early Jun	IDFG	New monitoring	$500	$0	$500
Bear Lake NWR	List (99-5)	G	early Jun	IDFG	New monitoring	$500	$0	$500
Blackfoot Reservoir	List (10,000-500)	G	early Jun	IDFG	Included in on-going colonial waterbird monitoring efforts	$500	$500	$0
Palisades Reservoir	Area	G	early Jun	IDFG	New monitoring	$500	$0	$500
MONTANA (n=1)								
East of Continental Divide								
Arod Lake	List (99-5)	G	early Jun	MFWP	Included in on-going colonial waterbird monitoring efforts	$500	$500	$0
NEVADA (n=2)								
Kirch WMA	Area	G	May	NDOW	Included in on-going avian monitoring efforts on Kirch WMA	$500	$500	$0
S-Line Reservoir	List (99-5)	G	May	NDOW	New monitoring	$500	$0	$500
OREGON (n=14)								
Central Coast								
Parrot Rock	List (99-5)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Columbia River								
Smith and Bybee Lakes	Area	B	Late May to early Jun	ODFW	New monitoring	$500	$0	$500
Tri-Club Island	Area	B	Late May to early Jun	ODFW	New monitoring	$500	$0	$500
Umatilla NWR	Area	G	Late May to early Jun	USFWS	Included in on-going avian monitoring efforts on Umatilla NWR	$500	$500	$0
Columbia River Estuary								
East Sand Island	List (>10,000)	A	early May	OSU / USACE	Included in on-going Cormorant monitoring efforts on the Columbia River Estuary	$3,000	$3,000	$0
Miller Sands Navigational Aids	List (499-100)	A	early May	OSU / USACE	Included in on-going Cormorant monitoring efforts on the Columbia River Estuary	$1,000	$1,000	$0
Rice Island	Area	A	early May	OSU / USACE	Included in on-going Cormorant monitoring efforts on the Columbia River Estuary	$1,000	$1,000	$0
Interior								
Malheur NWR - Frenchglen Area - Baca Lake	List (99-5)	G	Late May to early Jun	USFWS	Included in on-going avian monitoring efforts on Malheur NWR	$500	$500	$0
Rivers End (Lake Abert)	List (99-5)	G	Late May to early Jun	ODFW	New monitoring	$500	$0	$500
Northern Coast								
Unnamed Colony (Cape Lookout)	List (499-100)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Southern Coast								

Colony	Frame (Size Class)	Recommended Survey Technique G=ground B=boat A=aerial	Time of Year	Lead Organization(s)	Description	Estimated Cost per Monitoring Year	Estimated Cost Covered Under Existing Programs	Estimated New Additional Cost per Monitoring Year
Bolon Island	List (10,000-500)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Hunters Island	List (499-100)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Unnamed Colony (Mack Reef)	List (99-5)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
Unnamed Colony (N of Ferry Road Park)	List (499-100)	A	Late May to early Jun	USFWS	Included in USFWS annual coastal helicopter survey	*	*	*
UTAH (n=1)								
Great Salt Lake	List (99-5)	A	May	UDWR	Included in on-going colonial waterbird efforts on Great Salt Lake	$2,000	$2,000	$0
WASHINGTON (n=4)								
Interior								
North Potholes Reservoir	List (10,000-500)	B	early May	OSU / USACE	Included in on-going Cormorant monitoring efforts on the Columbia River	$2,000	$2,000	$0
Pend Oreille River - Sandy Shores	Area	B	Jun	WDFW	Included in on-going monitoring efforts for Box Canyon Hydroelectic Dam	$500	$500	$0
San Juan Islands								
Bird Rocks	List (499-100)	B	Mid-Jun to mid-Jul	USFWS	Included in USFWS annual boat surveys for San Juan Island NWR	$500	$500	$0
Drayton Harbor	List (499-100)	B	Mid-Jun to mid-Jul	WDFW	New monitoring	$500	$0	$500
					TOTAL	**$22,500**	**$15,500**	**$7,000**

*Cost associated with the 15 locations that will be surveyed during the USFWS coastal helicopter surveys were considered collectively. An estimated $7,500 per monitoring year will be needed to enumerate and compile aerial photograph data from this survey.

APPENDIX D: Data Sheet

PACIFIC FLYWAY DCCO MONITORING PROGRAM DATASHEET
BREEDING COLONY ACTIVE NEST COUNT

RECORD # (DO NOT FILL-IN): 2014 DCCO DS#___________

General Information

Lead observer name ____________ Lead observer contact phone # ____________

State ____ County ____ Latitude (Decimal; e.g. 49.492667) ____ Longitude (Decimal; e.g. -123.916667) ____

Colony Name or Location Name ____________ General Directions to colony or location; e.g. 2 mi W of Salem ____________

Survey Information

Survey Method (check 1)

☐ Perimeter ☐ Boat ☐ Other:__________

☐ Ground ☐ Aerial

Survey Method (check 1)

☐ Full (complete) survey ☐ Partial survey

If partial survey, what technique was used

☐ Strip Transects ☐ Circles

☐ Quadrants ☐ Other __________________

# of total observers ____ Est. total time in colony ____

*Colony Classification Codes:

NoB = Non-breeder (no active nest, egg, or fledgling)
Bn = Breeder; active nest confirmed
Be = Breeder; active egg confirmed
Bf = Breeder; active fledgling confirmed

Count Information

Sample #	Observer initials	Date (mm-dd-yy)	Time (0000-2400)	*Colony Classification	% of colony sampled	# of nests in sampled area	Total colony nest count	Nest Count Std. Deviation
1								
2								
3								
4								
5								
6								
7								

AVERAGE TOTAL COLONY NEST COUNT ____

Comments