AVIAN PREDATION IN THE COLUMBIA PLATEAU REGION: MANAGEMENT, MONITORING, AND EVALUATION

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REAL TIME RESEARCH

Title: Avian Predation in the Columbia Plateau Region: Management, Monitoring, and Evaluation in 2019

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EXECUTIVE SUMMARY

From 2014-2018, the U.S. Army Corps of Engineers – Walla Walla District (Corps) and the Bureau of Reclamation (Reclamation) funded efforts to implement and evaluate the Inland Avian Predation Management Plan (IAPMP). The goal of the management plan was to reduce predation on Endangered Species Act (ESA)-listed juvenile salmonids (*Oncorhynchus* spp.) by Caspian terns (*Hydroprogne caspia*) nesting at colonies in the Columbia Plateau region (CPR), namely Crescent Island on the Columbia River and Goose Island in Potholes Reservoir, the two largest tern colonies in the region. The objectives of the plan were to use passive nest dissuasion techniques (i.e. fencing, stakes, rope, flagging, woody debris, and vegetation plantings) to eliminate tern nesting habitat on both islands and to use active nest dissuasion techniques as an adaptive management tool to insure terns were not able to establish colonies at either site. Concomitant with management implemented as part of the IAPMP, the plan called for monitoring and evaluating the efficacy of those management components and actions at both the colony- and system-level, including measuring changes in Caspian tern nesting distribution and colony sizes in the CPR, as well as tern impacts on ESA-listed juvenile salmonids originating from the Snake and Columbia rivers.

In 2019, the Grant County Public Utility District (GPUD) and the Priest Rapids Coordinating Committee (PRCC) supported continued implementation and monitoring of the IAPMP, so that advances made in reaching the goals of the plan during 2014-2018 were not lost and further reductions in smolt losses to tern predation could be achieved. Additionally, the GPUD and PRCC funded efforts to determine the impacts of unmanaged piscivorous colonial waterbirds (i.e. California gulls [*Larus californicus*], ring-billed gulls [*L. delawarensis*], double-crested cormorants [*Phalacrocorax auratus*], and American white pelicans [*Pelecanus erythrorhynchos*]) on smolt survival and to assess the system-wide, cumulative impacts of avian predation on smolt survival. In total, this study will inform adaptive management actions that could be carried out to maximize the benefits to ESA-listed juvenile salmonids by managing avian predation in the CPR.

The primary objective of the sixth year of implementation of the IAPMP was to limit the numbers of Caspian terns breeding at Goose Island and surrounding islands in Potholes Reservoir, and on Crescent Island in McNary Reservoir, to less than 40 breeding pairs each to reduce predation impacts of terns on ESA-listed juvenile salmonids in the CPR. To accomplish this task, the availability of suitable Caspian tern nesting habitat was nearly eliminated at these sites by installing a variety of passive nest dissuasion materials on Goose Island and elsewhere in Potholes Reservoir, and vegetation growth (planted in 2016) on Crescent Island prior to the 2019 nesting season. On both Goose and Crescent islands, passive nest dissuasion materials and/or vegetation covered all areas where Caspian terns have previously nested, as well as all areas of open, sparsely vegetated habitat that might be used by ground-nesting Caspian terns or gulls (*Larus* spp.). Finally, an island in northeastern Potholes Reservoir that was used by Caspian terns for nesting in 2016, and one additional nearby island where terns were observed

prospecting in 2018, were covered in passive dissuasion to prevent terns from nesting at those sites in 2019. Once Caspian terns arrived to initiate nesting in 2019, active nest dissuasion (i.e. human hazing) was used to dissuade terns from nesting on Goose Island and other islands in Potholes Reservoir. No hazing has been required to prevent Caspian terns from nesting on Crescent Island since the onset of management in 2015.

Despite the use of passive and active nest dissuasion techniques on Goose Island and elsewhere in Potholes Reservoir, some Caspian terns continued to display high fidelity to Potholes Reservoir as a nesting area in 2019, the sixth year of management at this site. This fidelity is likely due to Caspian terns, a relatively long-lived species (i.e. some individuals having of life span of more than 20 years), having first nested on Goose Island in 2004 and the persistence of a large gull colony on the island, both before and after management, which continues to attract prospecting Caspian terns to the site. Another factor that might explain the strong fidelity of Caspian terns to the Potholes Reservoir area is the paucity of alternative Caspian tern colony sites in the vicinity. As was the case in 2015-2018, Caspian tern use of Goose Island for roosting and nesting in 2019 was largely limited to areas near the island's shoreline that became exposed during the nesting season as reservoir levels receded. Despite high fidelity of terns to the area, active nest dissuasion (hazing) and collection of any tern eggs laid (under permit) were factors in preventing the formation of a Caspian tern colony in Potholes Reservoir in 2019. This is the fourth consecutive year that nest dissuasion activities initiated at Goose Island were successful in preventing Caspian terns from nesting there; in 2014, 159 breeding pairs nested on a small rocky islet (i.e. Northwest Rocks) immediately adjacent to Goose Island, and in 2015 two breeding pairs of Caspian terns nested under the passive dissuasion near the former colony location on Goose Island. Prior to management (2005-2013), an average of 367 breeding pairs of Caspian terns nested on Goose Island.

In 2019, egg laying by Caspian terns on Goose Island and elsewhere in Potholes Reservoir occurred between 29 April and 5 July. During this period, a total of 20 Caspian tern eggs were discovered at two different locations in Potholes Reservoir; 19 tern eggs were discovered on Goose Island and the surrounding islets and one tern egg was discovered on the colony site used by terns in 2016 in northern Potholes Reservoir. Eight tern eggs discovered were collected under permit, and the remainder were depredated by gulls prior to collection.

As was the case in 2015-2018, passive nest dissuasion techniques (i.e. revegetation) alone were successful in preventing all nesting and roosting by both Caspian terns and gulls in upland areas on Crescent Island during the 2019 nesting season. Prior to management (2005-2013), an average of 403 breeding pairs of Caspian terns nested on Crescent Island. The complete abandonment of Crescent Island by nesting terns beginning in the first year of management was somewhat unexpected because Caspian terns and gulls had nested consistently on Crescent Island for nearly three decades prior to management. One factor that likely contributed to the absence of nesting Caspian terns on Crescent Island was the successful dissuasion of gulls from nesting on Crescent Island during 2015-2019; gulls are breeding associates of Caspian terns and attract prospecting Caspian terns to nest near their colonies. At Goose Island, gull nesting could not be prevented using the passive and active nest dissuasion

techniques at our disposal, whereas at Crescent Island gulls never habituated to the nest dissuasion techniques implemented there. Instead, gulls abandoned Crescent Island as a nesting site and some, if not most, of these birds established a new colony on Badger Island located on the Columbia River just one kilometer upriver from Crescent Island in 2015-2019. Similarly, many Caspian terns displaced from Crescent Island relocated to unmanaged colony sites on the Columbia River, including the Blalock Islands in John Day Reservoir (70 river kilometers downriver from Crescent Island) in 2015-2019, where Caspian terns have nested in small numbers intermittently over the last decade.

Aerial, ground, and boat-based surveys were conducted in the CPR to determine where Caspian terns displaced from the managed colonies in Potholes Reservoir and at Crescent Island might attempt to re-nest. In 2019, Caspian terns attempted to nest at three extant colony sites in the CPR that are currently unmanaged. All three of these sites have been used for breeding by Caspian terns previously, including the Blalock Islands complex in John Day Reservoir (379 breeding pairs in 2019; up from the pre-management average [59 breeding pairs] and down from the average during the management period [391 breeding pairs]), Harper Island in Sprague Lake (18 breeding pairs in 2019; up from the pre-management average [8 breeding pairs] and down from the average during the management period [35 breeding pairs]), and on North Rock in Lenore Lake (48 breeding pairs in 2019; up from the pre-management average [0 breeding pairs] and down from the average during the management period [52 breeding pairs]). The former Caspian tern colony sites at Twinning Island in Banks Lake and Badger Island on the Columbia River in McNary Reservoir were not active in 2019. As was the case in 2015-2018, the largest Caspian tern colony in the CPR was on the Blalock Islands, where 87% of all the Caspian terns in the region nested during 2019. Compared to the average size of the Caspian tern colony on the Blalock Islands prior to management (2005-2013; 59 breeding pairs), the colony was 5-11 times larger during 2015-2019.

The total estimated breeding population of Caspian terns in the CPR during 2019 was 445 breeding pairs at three separate colonies. This represents a 49% decline in the regional breeding population size for Caspian terns compared to the pre-management average (873 breeding pairs), and a 30% decline when compared to the average during the management period (640 breeding pairs). Although nest dissuasion actions implemented on Goose and Crescent islands in 2019 were effective in preventing all Caspian terns from nesting at these two colonies, it did not result in a commensurate reduction in the total number of Caspian terns breeding in the region. This was due to the continued use and increase in the colony size at unmanaged sites (i.e. Blalock Islands, North Rock, and Harper island) when compared to pre-management averages. While smaller in 2018-2019, the average Blalock Islands colony size during the management period (2015-2019; 391 breeding pairs) was similar in size to the largest Caspian tern colonies recorded anywhere in the CPR since intensive monitoring began in 2000.

A primary goal of the IAPMP is to reduce predation rates (proportion of available fish consumed) on ESA-listed juvenile salmonids by Caspian terns to less than 2% per salmonid population, per colony. Recoveries of smolt passive integrated transponder (PIT) tags on

Caspian tern colonies in 2019 were used to estimate salmonid population-specific (hereafter ESU/DPS) predation rates and to compare predation rates prior to and during tern management actions associated with the IAPMP. To help ensure that ESA-listed Upper Columbia River steelhead – a population that is highly susceptible to tern predation and therefore a suitable population to evaluate the efficacy of management actions – were available for predation rate analyses, 3,784 steelhead smolts were intentionally PIT-tagged and released into the tailrace of Rock Island Dam (RIS) by Chelan County Public Utility District employees in 2019. Numbers of steelhead tagged at RIS in 2019 were less than that of years past but provided a representative sample of the run-at-large for predation analyses in 2019.

Caspian tern predation rate estimates indicated that the goal of achieving rates of less than 2% were met for most, but not all, tern colonies and ESA-listed salmonid ESUs/DPSs in 2019. For the fifth consecutive year, predation rates were zero or close to zero for terns nesting on Goose Island and Crescent Island due to the complete (Crescent Island), or nearly complete (Goose Island and other islands in northern Potholes Reservoir), abandonment of these colony sites. Predation rates at the unmanaged tern colony in Lenore Lake (North Rock) were also less than 2% per ESU/DPS, with the highest rate observed on Upper Columbia River steelhead at 1.0% (95% credible interval [CRI] = 0.6–1.7). Predation rates for the large unmanaged tern colony in the Columbia River on the Blalock Islands, however, exceed the 2% threshold for two ESA-listed ESUs/DPSs, with predation rates of 5.9% (95% CRI = 3.4–10.0) and 3.0% (95% CRI = 1.9–4.7) for Upper Columbia River steelhead and Snake River steelhead, respectively. Predation rate estimates were not available for Caspian terns nesting on Harper Island in Sprague Lake (i.e. we were not granted access to the privately-owned island to recover PIT tags), but just 18 pairs nested on Harper Island in 2019. Based on limited data from years past, Caspian terns nesting on Harper Island are capable of foraging on juvenile salmonids in the lower Snake River, but impacts have been low (< 0.3% for all ESU/DPS), presumably due to the small size of the colony and it's distance from the lower Snake River (> 60 km).

Comparisons of Caspian tern predation rates on juvenile salmonids prior to and during implementation of the IAPMP indicate there have been benefits to Upper Columbia River steelhead, with predation rates by Goose Island and Crescent Island Caspian terns eliminated during implementation of the IAPMP. There is also evidence that Upper Columbia River steelhead smolt survival has increased in the river reach where Goose and Crescent Island terns forage (Rock Island Dam to McNary Dam). Due to continued high rates of predation by Blalock Island terns, however, impacts to some ESA-listed ESUs/DPSs, particularly those originating from the Snake River, remain as high or higher than those observed prior to implementation of management actions as part of the IAPMP. As such, adaptive management actions will likely be necessary to achieve the over-all goals of the IAPMP in the future.

An investigation of predation rates by other piscivorous colonial waterbird species (California and ring-billed gulls [hereafter "gulls"], American white pelicans, and double-crested cormorants) and colonies indicated that several gull colonies posed a risk to smolt survival in 2019. Predation rates by gulls nesting on Island 20, Badger Island, and Miller Rocks Island were amongst the highest of any colony evaluated in 2019, with predation rates on Upper Columbia

River steelhead, Snake River steelhead, and Snake River sockeye greater than 5% of available fish, depending on the colony and ESU/DPS. For instance, predation rate estimates as high as 10.9% (95% CRI = 6.7-17.7) of Upper Columbia River steelhead and 5.9% (95% CRI = 2.6-11.8) of Snake River sockeye were observed by gulls nesting on Badger Island and Miller Rocks Island, respectively. Conversely, predation rate estimates by double-crested cormorants nesting in Lenore Lake were < 0.1% of available fish and minimum estimates of predation of < 0.2% of available fish were observed by American white pelicans nesting on Badger Island, indicating that not all piscivorous colonial waterbird species and colonies posed a risk to smolt survival in the CPR.

To investigate the cumulative effects of avian predation (predation by all colonies combined) on smolts and to determine what proportion of all sources of smolt mortality (1-survival) were due to bird predation, we conducted a mark-recapture-recovery analysis on Upper Columbia River steelhead that were PIT-tagged and released at Rock Island Dam in 2019. We used previously published methods to jointly estimate predation and survival rates during smolt passage through multiple river reaches and we compared results from 2019 to those in years past (2008-2018). Results indicated that avian predation was often the single greatest source of mortality for steelhead during out-migration from Rock Island Dam to Bonneville Dam, with bird predation accounting for more than 50% of all mortality sources in 10 of the last 12 years (2008-2019), including in 2019. Estimated steelhead smolt losses to piscivorous colonial waterbirds were greater than direct losses associated with dam passage, predation from piscivorous fish, mortality from disease, and all other remaining mortality factors combined. Even after passage through the impounded sections of the middle and lower Columbia River upstream of Bonneville Dam, the impact of piscivorous colonial waterbirds on survival of steelhead smolts in the free-flowing section of the Columbia River downstream of Bonneville Dam was substantial, with Caspian terns and double-crested cormorants nesting on East Sand Island annually consuming upwards of 28% of available steelhead smolts in the estuary. Results indicate that although progress has been made to increase steelhead smolt survival by decreasing Caspian tern predation between Rock Island Dam and McNary Dam, avian predation continues to be a dominate source of smolt mortality in the Columbia River basin.

PROJECT OBJECTIVES

The primary objectives of this study in 2019 were to: (1) implement and evaluate the Inland Avian Predation Management Plan (IAPMP; USACE 2014), including adaptive management actions, in order to dissuade Caspian terns (*Hydroprogne caspia*) from nesting on Crescent Island, Goose Island, and elsewhere in Potholes Reservoir to reduce tern predation on Endangered Species Act (ESA)-listed juvenile salmonids (*Oncorhynchus* spp.); (2) investigate the distribution, colony size, and smolt impacts of unmanaged piscivorous colonial waterbirds (i.e. California gulls [*Larus californicus*], ring-billed gulls [*L. delawarensis*], American white pelicans [*Pelecanus erythrorhynchos*]), and double-crested cormorants [Phalacrocorax auratus] to help identify

immerging avian predation issues in the Columbia Plateau region (CPR) that may be of concern to resource managers; and (3) calculate aggregate estimates of avian predation (i.e. consumption by all predator species and colonies combined within a specific river reach) and estimates of reach-specific survival of juvenile salmonids during downstream passage. Collectively, these objectives address several management-relevant questions needed to maximize the benefits to ESA-listed salmonids in managing piscivorous colonial waterbirds, while also maintaining a multiyear avian predation dataset in the Columbia River basin.

METHODS & ANALYSES

INLAND AVIAN PREDATION MANAGEMENT PLAN

This work is part of a comprehensive program to implement avian predation management plans (including adaptive management) and evaluate action effectiveness of those plans. Specifically, as part of Objective 1, we continued work previously funded by the Corps and Reclamation, with additional support from the PRCC, to implement and evaluate the IAPMP (*Map 1*; USACE 2014) in 2019. This work was necessary so that advances made in reaching the goals of the IAPMP during 2014-2018 were not lost and further reductions in smolt losses to tern predation in the region might be achieved. Outlined below are the methods used to implement the IAPMP and to evaluate action effectiveness both at a colony- and system-level.

Implementation

Passive nest dissuasion: In 2014-2019, a matrix of concrete pier blocks, rebar, PVC pipes, ropes, and flagging were used as the primary passive nest dissuasion method to prevent Caspian tern nesting on Goose Island (Roby et al. 2015; Collis et al. 2016, 2017, 2018, 2019). Concrete pier blocks (Mutual Materials; 12'' x 12'', 63 lbs. each) were placed in a 10' x 10' square grid in nearly all open areas on the island. The center of each concrete pier block was drilled out vertically to accommodate a 48" length of 0.5" (outside diameter) rebar and a 42" length of 0.5" (inside diameter) PVC pipe that was slipped over the rebar. Twisted polypropylene rope (0.25") was then attached to the PVC at approximately 42" above ground level (AGL) using clove hitch knots, and the rope was further secured to the pipe using UV-resistant cable ties. Ropes were fastened to the vertical PVC pipes to form a 10' x 10' grid, with each grid square also bisected diagonally with a section of rope. Four-foot-long pieces of industrial barricade tape (Mutual Industries; 3 mil "polyethylene flagging") were inserted between the strands of the rope at approximately 3' intervals and allowed to flutter in the wind as a visual and auditory deterrent to prospecting Caspian terns. A second layer of rope and flagging was added below the initial layer forming a "double layer" in areas where Caspian terns were considered most likely to attempt nesting, and in all new areas of passive dissuasion on the main island. A 10' to 15' buffer of double layer passive nest dissuasion was installed around the perimeter of all contiguous areas of passive dissuasion. Each year, repairs and new construction of passive nest

dissuasion materials were completed prior to the arrival of Caspian terns to the island (mid-March).

In 2019, after inspection of the passive nest dissuasion materials installed on Goose Island in 2014-2018, we determined the need for repairs and additional materials. Repair of existing materials (hereafter referred to as "permanent" passive dissuasion) required installing new flagging identical to that used in 2014-2018 and as described above. Additionally, other passive nest dissuasion materials (e.g., rope, zip ties, PVC pipe) were replaced, as needed. After repairing materials deployed during 2014-2018, we installed new nest dissuasion materials (i.e. bamboos stakes, rope, and flagging; hereafter referred to "temporary" passive dissuasion) in areas not previously covered (e.g., near the shoreline where Caspian tern eggs were laid in previous years), both on Goose Island and on an unnamed island in northeastern Potholes Reservoir (*Map 1*) used by nesting terns in 2016. Finally, we had in reserve enough temporary passive nest dissuasion materials in case any unexpected in-season repairs to existing nest dissuasion materials were required and/or if terns began prospecting in areas not previously covered by nest dissuasion materials.

Deployment of passive dissuasion at Goose Island, both repaired components and newly installed, was completed prior to the onset of breeding activities and during the breeding season in areas used by prospecting terns along the waterline. Elsewhere in Potholes Reservoir, passive dissuasion was installed, as needed, in locations where Caspian terns were observed prospecting in areas with suitable nesting habitat. Once installed, at no time were any upland passive nest dissuasion materials removed. However, disposable materials, specifically the barricade tape flagging, and all temporary nest dissuasion materials were removed from the island following the Caspian tern breeding season.

In 2019, after inspection of the passive nest dissuasion materials and native vegetation on Crescent Island, it was determined that no additional nest dissuasion materials were needed to prevent Caspian terns from nesting on the island. The island had become completely vegetated since planting of native willows in 2016, leaving no open, bare ground, habitat for tern and gull nesting on the island.

Active nest dissuasion: In accordance with the IAPMP, active nest dissuasion methods (also referred to as "active hazing") were used to supplement passive dissuasion measures to further deter nesting attempts by Caspian terns and gulls on Crescent island, Goose Island, and other islands in Potholes Reservoir in 2019 (USACE 2014). Active hazing was conducted in such a manner as to both prevent Caspian tern nesting and maintain access to the island for walk-throughs for as long as was possible.

Active nest dissuasion was conducted on Goose Island and at other islands in Potholes Reservoir to disrupt nesting attempts by Caspian terns and gulls by (1) island walk-throughs, (2) approaching the shoreline of the island by boat, (3) use of a green laser during low light conditions, (4) waving a 10' PVC pole with caution tape tied to each end, (5) flying a peregrine falcon kite on the island, (6) destruction of all Caspian tern and gull nests not containing eggs,

and as a last resort (7) collection of any Caspian tern eggs (under permit) laid at Goose Island or elsewhere in Potholes Reservoir.

In 2014-2018, Caspian terns and gulls were continuously present on the Goose Island throughout the breeding season (Roby et al. 2015; Collis et al. 2016, 2017, 2018, 2019). Based on avian responses to dissuasion in previous years, we anticipated that the need for active hazing efforts at Goose and other islands in Potholes Reservoir would be much greater than that at Crescent Island (no gull nesting in previous years), and that deterring or even delaying gull nesting on Goose Island was unlikely.

In 2019, prior to nest initiation by Caspian terns and gulls, an observation blind and tunnel were installed on the upper part of Goose Island, adjacent to the former Caspian tern colony site. The blind was used to monitor Caspian tern and gull use of the former breeding location and surrounding area, which cannot be readily seen from a boat. Beginning with the arrival of both Caspian terns and gulls intent on nesting on Goose Island, hazing activities were conducted daily through July, weather permitting. These hazing activities were focused primarily during the dawn and dusk periods (starting 30 min before dawn to at least 30 min after dusk), or whenever it was determined to be most effective in keeping Caspian terns off the islands. Efforts were made during this time to prevent Caspian terns from using Goose Island as an overnight roost. As no active hazing measures were found to be effective at delaying gull nesting on Goose Island, only limited attempts to dissuade nesting gulls occurred in March and early April to ensure all passive dissuasion could be installed prior to egg-laying. The duration of daily hazing bouts depended on bird activity but were not less than 6 hours each day when terns were present. Additionally, in 2019, once Caspian terns were observed using sandy islands in northern Potholes Reservoir, human hazing was initiated to deter nesting activity. Beginning in mid-April, at least two complete boat-based surveys of Potholes Reservoir were conducted each week through July, with daily hazing sessions conducted near the 2016 colony location in northern Potholes Reservoir, and other locations of consistent tern use. The methods and duration of active hazing sessions were adjusted based on tern numbers and breeding activities observed on Goose Island and other islands in Potholes Reservoir.

Once widespread establishment of gull nests precluded island walk-throughs on Goose Island (as it would causing nesting failure by gulls which was not allowed under the existing permit issued by the USFWS; see *below*), the primary techniques used to actively dissuade prospecting Caspian terns were the use of a green laser (Agrilaser®; LEM 50) during low-light conditions and boat approaches to the islands edge to flush Caspian terns that were prospecting along the shoreline. During low light conditions, use of green lasers allowed hazing of Caspian terns prospecting at Goose island from a distance, without disturbing gulls attending nests nearby. Once reservoir water levels began to recede in early June, foot access to Goose Island was restored, but limited to the low-lying shoreline as to not disturb nesting gulls on the upland portion of the island. Because no gulls or other waterbirds were identified nesting on islands in northern Potholes Reservoir, island walk-throughs and motorboat approaches were the only hazing techniques used away from Goose Island.

When Caspian tern eggs were laid despite our nest dissuasion efforts, a take permit issued to the Corps and Reclamation by the U.S. Fish and Wildlife Service (USFWS) allowed researchers to collect the tern eggs, as specified in the permit. The collection of Caspian tern eggs laid on Goose Island and elsewhere in Potholes Reservoir was intended to enhance the prospects for successfully dissuading Caspian terns from forming a breeding colony. When tern eggs were laid and subsequently collected under permit, we reported each event within 24 hours to representatives from the GPUD, Corps, and Reclamation to ensure compliance with Migratory Bird Treaty Act permit regulations, and to facilitate accurate reporting to the USFWS by the Corps.

In 2015-2018, Caspian terns and gulls did not nest on Crescent Island and were rarely seen near the island (Collis et al. 2016, 2017, 2018, 2019). Based on avian responses to dissuasion in previous years, we anticipated that the active hazing efforts would not be required to prevent Caspian terns from nesting on Crescent Island. We monitored Crescent Island bi-monthly to ensure that Caspian terns and gulls did not return to nest in 2019.

Action Effectiveness Monitoring

Action effectiveness monitoring was carried out in the CPR at both managed (i.e. Goose island, Crescent Island, and elsewhere in northern Potholes Reservoir) and at unmanaged sites where terns might disperse to renest as a result of management. The colony metrics of primary concern were Caspian tern colony size and predation rates and are described in detail *below*.

Colony size: Action effectiveness monitoring was conducted both at the colony-level and the system-level (region-wide). Colony-level monitoring was accomplished by a resident field crew stationed at Potholes Reservoir and was carried out in conjunction with management tasks described *above*. Colony-level monitoring was designed to evaluate the efficacy of nest dissuasion efforts and the need for adaptive management at Goose Island, Crescent Island, and elsewhere in Potholes Reservoir in preventing Caspian terns from nesting at these sites (see *below* for more details).

System-level monitoring consisted of periodic, carefully timed aerial surveys in the CPR to photo document both known and incipient Caspian tern breeding colonies, estimate colony size, and evaluate nesting success at each colony. In addition, periodic ground- and boat-based surveys were carried out at all Caspian tern breeding colonies confirmed during aerial surveys; these ground- or boat-based surveys were intended to accurately assess nesting chronology, colony attendance, and colony size, as well as to determine nesting success.

Additionally, colony size estimates generated as part of the system-level monitoring, along with those generated as part of colony-level monitoring at Goose and Crescent islands, were used to estimate the size of the breeding population of Caspian terns in the CPR during 2019. These data were used to evaluate changes in the number and distribution of nesting Caspian terns in the CPR associated with management.

Monitoring of Caspian tern use of Crescent Island, Goose Island, and other islands in Potholes Reservoir was necessary to determine the success of passive and active dissuasion of nesting Caspian terns during the 2019 breeding season. We evaluated the effectiveness of various passive nest dissuasion methods used to prevent tern and gull nesting at these sites (e.g., recently planted willows, silt fencing, stakes/rope/flagging, and woody debris). To determine factors that may limit the efficacy of recently planted willows and scattered Russian olive debris in deterring nesting Caspian terns on Crescent Island, periodic observations were recorded to document use by various avian predators (e.g., raptors) and mammals (i.e. beaver [*Castor canadensis*]) in 2019. Willow observations were largely qualitative and limited to observations of herbivory by beavers. Additionally, in 2019, a feasibility study was conducted to determine if planting native plants (plugs) in a test plot on Goose Island might result in a sustainable, long-term nest dissuasion action at that site. In brief, a test plot was prepared and planted with plugs of native shrub species in the Fall of 2018. Beginning in April 2019, supplemental irrigation was installed, and the test plot was monitored weekly from the nearby observation blind. The results from this feasibility study have been provided in a memorandum to the funding agency (i.e. Grant County Public Utility District/Priest Rapids Coordinating Committee).

We continuously monitored the activities of Caspian terns and other colonial waterbirds (i.e. gulls) on Goose Island from April through July using at least two field crew members stationed near the island. Additionally, islands suitable for Caspian tern nesting in Potholes Reservoir were surveyed 2-7 days/week, depending on the number of terns and behaviors observed. Crescent Island was monitored bimonthly to determine if active hazing and more frequent monitoring was necessary. Monitoring was conducted from a blind located near the edge of the former colony area (on Goose Island), from a boat, and on foot in areas with potential for minimal disturbance to actively nesting non-target species (see *above*). Daily counts of Caspian terns at these managed sites was differentiated by behavior (i.e. nesting vs. roosting), age (i.e. adult vs. juvenile), and zone. Seasonal attendance by adult terns at each site was estimated based on the average number of adults counted from the ground each week throughout the breeding season. Each island was also closely monitored for the formation of new Caspian tern satellite colonies (i.e. away from the former colony site and in and around areas of passive nest dissuasion). Data collection methodologies used followed established protocols such that the data collected in 2019 could be compared with analogous data collected in previous years and at other colonies (Antolos et al. 2004; Adkins et al. 2014; Roby et al. 2015; Collis et al. 2016, 2017, 2018, 2019).

High-resolution, vertical, aerial photography was acquired on Goose Island on 5 June 2019. The orthorectified imagery was analyzed to estimate the total area (in acres) covered by passive nest dissuasion materials, both permanent and temporary (see *above*), on the island, and to count the number of nesting gulls on Goose Island.

The geographic scope of the IAPMP includes the 10 “at-risk” sites and other sites within the CPR where Caspian terns displaced from colonies on Goose and Crescent islands may relocate following management (USACE 2014). These colony sites (referred to as “unmanaged sites”) include islands where Caspian terns have recently nested, including the Blalock Islands (John

Day Reservoir), Badger Island (McNary Reservoir), Twinning Island (Banks Lake), Harper Island (Sprague Lake), and North Rock/Shoal Island in Lenore Lake (*Map 1*).

Unmanaged colony sites also include sites where Caspian terns have previously, but not recently nested, including Miller Rocks (The Dalles Reservoir), Three Mile Canyon Island (John Day Reservoir), Foundation Island (McNary Reservoir), Cabin Island (Priest Rapids Reservoir), Solstice Island (northern Potholes Reservoir), and Goose Island (Banks Lake; Adkins et al. 2014). Other unmanaged colony sites that have no history of Caspian tern nesting but may be attractive as new colony sites because of the presence of other colonially nesting waterbirds include Island 20 and Island 18 in the Richland Islands complex on the Mid-Columbia River and perhaps other sites on and off the mainstem Columbia and Snake rivers (*Map 1*).

Periodic monitoring was conducted at these unmanaged colony sites to help evaluate the consequences of management actions implemented on Crescent Island, Goose Island, and the other managed islands in Potholes Reservoir in 2019. We assessed whether reductions in colony size associated with the nest dissuasion actions at these sites were compensated by commensurate increases in the occupancy and/or size of Caspian tern breeding colonies at unmanaged sites in the CPR, where Caspian terns may continue to consume significant percentage of available ESA-listed juvenile salmonids.

Aerial photo surveys – A reconnaissance aerial survey was conducted from a manned fixed-wing aircraft to determine the distribution of Caspian terns (both nesting and roosting) along the Columbia River from Bonneville Dam to Chief Joseph Dam, and on lower Snake River from the confluence with the Columbia River to the mouth of the Clearwater River, as well as at sites off the mid-Columbia River and lower Snake River that are within tern foraging range (~90 km) of the Federal Columbia River Power System (FCRPS).

The objective of the aerial survey was to identify all active Caspian tern nesting colonies and large roost sites within the region. The survey was conducted early in the incubation period (3-4 May) to check for the presence of all active Caspian tern colonies in the CPR. When Caspian terns were observed on the ground on substrate that was considered suitable for nesting, oblique aerial photography was taken using a digital SLR camera with an image-stabilizing, zoom lens. When in-flight observations of Caspian terns or post-flight inspection of digital images suggested the presence of a potential Caspian tern breeding colony, ground- or boat-based surveys were conducted to assess the breeding status and other colony metrics at the site (see *below*).

To estimate peak colony size and delineate colony areas, we used an unmanned aircraft system (UAS) to collect high-resolution (~1.6 cm ground sample distance), vertical, aerial photography at all sizeable (> 20 breeding pairs) Caspian tern colonies in the CPR in 2019. Imagery was acquired in mid- to late-May and the orthorectified imagery was analyzed in a GIS software application to determine nesting distribution and colony size (number of active nests with eggs).

Land-based surveys – The frequency of ground- and boat-based surveys of Caspian tern colony sites identified during aerial surveys varied from several times a week to once a month, depending on the number of Caspian terns and behaviors observed at the site. Sizable Caspian tern colonies (> 20 breeding pairs) were visited weekly to determine Caspian tern use of each island (i.e. roosting or nesting), seasonal colony/island attendance, nesting chronology, peak colony size, and nesting success. At the large Caspian tern colony at the Blalock Islands, we installed a temporary blind that facilitated monitoring at that colony and a cellular enabled trail camera to document fluctuations in water level and colony inundation events. Smaller colonies (< 20 breeding pairs) were visited less frequently (no less than monthly) to determine nesting status, change in colony size, peak colony size, and nesting success, if applicable. When Caspian tern colony sites could not be adequately monitored via land or boat, we deployed a UAS to assist in monitoring.

Predation rates: We analyzed smolt PIT tags collected on bird colonies as part of this study to (1) estimate Caspian tern predation rates on ESA-listed salmonid ESUs/DPSs and to (2) assess relative differences in these predation rates prior to and during tern management actions associated with the IAPMP, with a focus on data collected in 2019. Comparisons between current and previous predation rates were made in the context of management initiatives for terns nesting on Goose Island in Potholes Reservoir and Crescent Island in McNary Reservoir and relative to the management goal of achieving predation rates of less than 2% per salmonid ESU/DPS, per colony, per year (USACE 2014). In 2019, predation rates at unmanaged Caspian tern colonies included terns nesting on the Blalock Islands in John Day Reservoir and at North Rock in Lenore Lake. Caspian terns also nested on Harper Island in Sprague Lake, which is located 67 kilometers north of the lower Snake River, a privately-owned island that could not be scanned for PIT tags following the breeding season due to a lack of permission from the landowner to access the site. PIT tag scanning during the pre- and post-management periods were also conducted at other incipient tern colonies in years past (e.g., the Badger Island tern colony in McNary Reservoir and the Twinning Island tern colony in Banks Lakes), but no terns nested at these sites in 2019.

PIT tagging of Upper Columbia River steelhead – Previous research has demonstrated that juvenile steelhead are particularly susceptible to Caspian tern predation (Evans et al. 2012; USACE 2014; Roby et al. 2017; Evans et al. 2019a,b) and to help ensure adequate sample sizes of PIT-tagged steelhead from the Upper Columbia River population were available for predation analyses, steelhead were capture, PIT-tagged, and release at Rock Island Dam (RIS) in 2019 by Chelan County Public Utility District employees. In lieu of tagging at RIS, inadequate numbers of steelhead would be available for predation rate analyses (Roby et al. 2017). The PIT-tagging of steelhead at RIS to evaluate predation impacts by colonial waterbirds was first initiated in 2008, resulting in a long-term dataset that has been used to both estimate predation rates and survival rates (Evans et al. 2012; Evans et al. 2014; Hostetter et al. 2018; Evans et al. 2019a,b).

A detailed description of the sampling methods used to capture, tag, and release steelhead smolts at RIS are presented in Evans et al. (2014). In brief, steelhead were captured, PIT-tagged, and released at the RIS juvenile fish trap throughout the smolt outmigration period of April to

June 2019. Steelhead were randomly selected for tagging (i.e. tagged regardless of condition, origin, and size) and were tagged in concert with, and in proportion to, the run-at-large to ensure that the tagged sample was representative of the steelhead population passing the dam (tagged and untagged fish). The target sample size goal was to PIT-tag approximately 7,000 juvenile steelhead for use in predation analyses. This target sample size was selected because it was consistent with previous steelhead PIT-tagging efforts at RIS (Evans et al. 2014; Roby et al. 2017) and because it was estimated to result in a minimum predation rate precision (95% credible interval) of approximately ± 2%.

Predation rate analysis – Predation rates were derived using the number of PIT tags found on a given Caspian tern colony from the number available passing or interrogated at upstream dams, and then adjusting for the proportion of consumed tags that were deposited by terns on their nesting colony (referred to as "deposition probability") and the proportion subsequently detected by researchers following the nesting season (referred to as "detection probability"). A detailed description of the methods and statistical procedures used to recover smolt PIT tags from bird colonies and to estimate predation rates are provided in Evans et al. (2012) and Hostetter et al. (2015). A list of predation rate model assumptions and procedures used to evaluate the validity of those assumptions are also provided in Hostetter et al. (2015). Methods used to calculate predation rates in 2019 were identical to those used previously, allowing for a direct comparison of results from 2019 to those from previous years.

OTHER PISCIVOROUS COLONIAL WATERBIRDS

Caspian terns are not the only species of avian predator that poses a risk to the survival of ESA-listed salmonids in the CPR. Previous research indicates that other piscivorous colonial waterbirds species (i.e. California and ring-billed gulls, American white pelicans, and double-crested cormorants) also nest in the region and consume a large number and proportion of available salmonid smolts (*Map 1*). For instance, the impact of these other avian predator species on smolts have exceeded 25% and 10% of steelhead and yearling Chinook, respectively, tagged and released below RIS in previous years (Evans et al. 2016; Roby et al. 2017; Evans et al. 2019a,b). These results indicate that concerns over avian predation in the region should not be limited to Caspian terns nesting on Goose and Crescent islands; impacts from Caspian terns nesting at unmanaged colonies (see *above*) and from other colonial waterbird species are comparable to or even greater than those documented for Caspian terns nesting at Goose and Crescent islands (USACE 2014; Evans et al. 2016; Roby et al. 2016; Evans et al. 2019a,b).

As part of Objective 2, we investigated the distribution, colony size, and predation impacts of California gulls, ring-billed gulls, American white pelicans, and double-crested cormorants on smolt survival in the CPR, with a focus on colonies that were known to forage on ESA-listed juvenile salmonids from the mid-Columbia River. These data are important to determine if reductions in colony size and predation impacts of Caspian terns in the CPR associated with management are compensated for by increases in the numbers and smolt impacts of unmanaged piscivorous colonial waterbirds in the region. This objective is key in identifying

immerging avian predation issues in the CPR that may require management attention in the future.

Colony Size

As described *above*, reconnaissance aerial surveys were conducted from a manned fixed-wing aircraft to locate breeding colonies of piscivorous colonial waterbirds along the Columbia River from Bonneville Dam to Chief Joseph Dam, and on the lower Snake River from the confluence with the Columbia River and the mouth of the Clearwater River, as well as at sites off the mid-Columbia River and lower Snake River that are within foraging range of the FCRPS.

When piscivorous colonial waterbirds were observed on the ground on substrate that was considered suitable for nesting, oblique aerial photography was taken using a digital SLR camera with an image-stabilizing, zoom lens. When in-flight observations or post-flight inspection of digital images suggested the presence of a potential breeding colony, carefully timed ground- or boat-based surveys were conducted to assess the breeding status and colony size for colonies that are known to forage on ESA-listed juvenile salmonids from the mid-Columbia River.

To estimate peak colony size, we used an unmanned aircraft system (UAS) to collect high-resolution, vertical, aerial photography at all sizeable (> 20 breeding pairs) colonies in the CPR in 2019. Imagery was acquired in mid-May to mid-June and the orthorectified imagery was analyzed in a GIS software application to count the number of adults on colony as a surrogate for colony size (i.e. number of breeding pairs).

Predation Rates

Another goal of collecting and analyzing smolt PIT tag data as part of this study was to estimate predation rates on juvenile salmonids by other, unmanaged piscivorous colonial waterbird species in 2019. The same methods used to estimate predation rates on smolts by Caspian terns (*see above*) were used to estimate predation rates by California and ring-billed gulls, American white pelicans, and double-crested cormorants in 2019. A detailed description of these methods, including model assumptions and caveats, are provided in Hostetter et al. (2015).

CUMULATIVE PREDATION RATES & SURVIVAL

As part of Objective 3, we evaluate the cumulative effects of avian predation (predation from all piscivorous colonial waterbird species combined) on steelhead smolts tagged and released at RIS in 2019. Results may provide valuable insight regarding the system-wide magnitude of colonial waterbird predation on juvenile steelhead during outmigration from RIS to the Pacific Ocean. Smolts are also subject to numerous other non-avian sources of mortality during outmigration (e.g., hydroelectric dam passage, predation by piscivorous fish, disease, and other

factors) and determining to what degree avian predation limits survival relative to these other sources of mortality may be critical for prioritizing recovery actions for ESA-listed salmonid populations (Evans et al. 2019a,b). To investigate the cumulative effects of colonial waterbird predation and to estimate what proportion of all sources of smolt mortality (1-survival) were due to avian predation, we use the methods of Payton et al. (2019) and Evans et al. (2019a,b). In brief, mark-recapture-recovery data from steelhead that were PIT-tagged and released in the tailrace of RIS were used to jointly estimate mortality and survival (JMS) during outmigration throughout multiple river-reaches. This hierarchal Bayesian modeling approach incorporated both live and dead detections of tagged steelhead in space and time to simultaneously estimate rates of predation and survival (see Evans et al. 2019a,b for detailed methods). Results from 2019 were then compared to results in years past to identify trends and patterns in cumulative predation across colonies and years. Methods used to calculate cumulative predation and survival rates on RIS tagged steelhead in 2019 were identical to those used previously, allowing for a direct comparison of results from 2019 to those from previous years (see Evans et al. 2019a,b).

RESULTS & DISCUSSION

INLAND AVIAN PREDATION MANAGEMENT PLAN

Implementation

Passive nest dissuasion: The installation of over four acres of passive dissuasion on Goose Island was completed on 8 April 2019. This was accomplished by first repairing ropes and re-deploying flagging on the area where the permanent passive nest dissuasion was installed in previous years, covering nearly all upland habitat on Goose Island in 2019. Temporary passive nest dissuasion (bamboo stakes, rope and flagging) was then installed throughout the breeding season, primarily along the shoreline of Goose Island, where most Caspian tern eggs were laid in previous years. A total of 4.98 acres of passive dissuasion (both permanent and temporary) were deployed on Goose Island in 2019 (*Map 2*). Temporary passive nest dissuasion materials were also installed prior to the breeding season on sandy islands in northern Potholes Reservoir where Caspian terns might attempt to nest. After the arrival of terns to northern Potholes Reservoir (late April), additional temporary nest dissuasion materials were deployed in upland areas used by prospecting terns. At the end of the breeding season (late July), temporary passive nest dissuasion materials and all flagging were removed from Goose Island and other sites in northern Potholes Reservoir.

The growth of willows planted in 2016 has eliminated all upland habitat suitable for tern nesting on Crescent Island, hence the placement of additional passive nest dissuasion materials prior to the 2019 breeding season was unnecessary. Following the 2019 breeding season, most of the passive nest dissuasion materials (i.e. stakes, rope, and fencing) and other island infrastructure

(e.g., observation blind) were removed from Crescent Island because it was no longer needed to prevent tern nesting; the remaining materials (i.e. one section of fence) will be removed in the spring, prior to the 2020 breeding season.

Active nest dissuasion: Once Caspian terns were observed landing on Goose Island (11 April), daily active nest dissuasion (i.e. human hazing) commenced to prevent prospecting terns from nesting on the island. A minimum of two 3-hour hazing sessions was conducted each day; a morning session that started before dawn and an evening session that ended after dark (weather permitting). Morning and evening hazing sessions generally began and ended at civil twilight (30 min before sunrise and 30 min after sunset, respectively). Hazing effort was increased or decreased as needed in response to intensity of nesting activities by Caspian terns at the site.

Beginning in early April, due to gull nests with eggs, island walk-through hazing and other efforts that may disturb nesting gulls were discontinued in favor of hazing efforts that targeted prospecting Caspian terns. The primary techniques used to actively dissuade Caspian terns during the remainder of the breeding season were the use of a green laser during low-light conditions and using boat-based approaches to flush prospecting Caspian terns near the shoreline. When working near nesting gulls, boat-based approaches were the most prevalent method used and sometimes included landing the boat, letting observers off on the shoreline, and flushing Caspian terns without disturbing nesting gulls. The use of the green laser in low light conditions allowed hazing of individual Caspian terns that were loafing or prospecting on Goose Island without disturbing nesting gulls that were attending eggs nearby. Additionally, due to the presence of nesting Forster's terns (*Sterna forsteri*) on Goose Island, hazing efforts were more carefully implemented on some parts of the offshore islets beginning in late-May. Locations where Forster's tern nesting restricted active hazing efforts for Caspian terns included the southwest shoreline, South Spit, Northwest Rocks, and East Rocks near Goose Island (*Map 3*).

As prospecting by Caspian terns on Goose Island waned later in the nesting season, active hazing efforts were reduced. In late July, scheduled 3-hour hazing sessions of Caspian terns were discontinued to facilitate the removal of temporary flagging. However, opportunistic hazing bouts were conducted whenever observers were on the island removing flagging and terns were observed. While most hazing sessions were conducted from a boat, field staff could approach Caspian terns on foot beginning in mid-June as lower reservoir levels exposed additional shoreline away from active gull nests.

During the 16 weeks when Caspian terns were present and active hazing efforts at Goose Island were quantified, average daily effort ranged from 4 minutes to 49 minutes, and the cumulative weekly hazing duration ranged from 14 minutes to 343 minutes (*Table 1*). These averages represent the time terns were actively hazed, and do not represent the time spent on island monitoring potential tern activity. The average number of Caspian terns counted each week, by location, indicated relatively low use of all areas through mid-June, with an average of 15 (range: 0 – 54) Caspian terns hazed from the island each day. However, beginning in mid-June,

Caspian terns became more numerous and resumed prospecting behavior with an average of 119 (range: 51 – 159) terns hazed each day through 21 July (*Table 1*).

Like in 2015-2018, Caspian tern use of Goose Island in 2019 peaked in July when 159 terns were hazed during a single session. The July peak in Caspian tern use of Goose Island is consistent with normal post-breeding dispersal of adults and young-of-the-year from other colonies (both within and outside the CPR), as evident by observations of fledged chicks at Goose Island in July in 2019. Furthermore, during the late-season period of elevated Caspian tern activity, lower reservoir levels exposed significant roosting habitat along the southern shoreline of Goose Island. Caspian terns were most commonly hazed from Southeast Main, South Spit, and Southwest Main locations, with up to 80 terns hazed from the Southeast Main during a single hazing session (*Map 3*; *Table 1*).

In summary, hazing efforts were successful in preventing the formation of a Caspian tern colony on Goose Island in 2019. To achieve this objective, however, significant monitoring and hazing efforts were conducted during much of the Caspian tern breeding season (April – July). Restrictions on disturbance to gulls, Forster's terns, and Canada geese attending nests with eggs continued to limit the effectiveness of active nest dissuasion techniques to prevent Caspian tern nesting on Goose Island in 2019. Furthermore, the ineffectiveness of the passive nest dissuasion techniques (i.e. stakes, rope, and flagging) used on Goose Island to prevent gull nesting likely contributed to the strong fidelity that terns have to Goose Island (i.e. the presence of nesting gulls on Goose Island provide strong social attraction for prospecting Caspian terns). Nevertheless, the combination of passive and active nest dissuasion techniques brought about a significant reduction in Caspian tern presence at the site during the pre-breeding and nest initiation period (*Figure 1*) and prevented colony formation at the site (*Figure 2*). Caspian terns laid 19 eggs on Goose Island in 2019, but none produced young. Eight of the eggs that were laid by Caspian terns on Goose Island were collected under permit issued by the USFWS (*Table 2*), while the remainder were depredated by gulls before collection.

To prevent Caspian terns from successfully nesting at locations in northern Potholes Reservoir, active dissuasion efforts like those employed at Goose Island were expanded to all potential colony sites in Potholes Reservoir in 2019. Field staff began conducting weekly boat-based surveys of the northern arm of the reservoir in late-April, once Caspian terns were consistently observed at Potholes Reservoir (*Map 4*). Surveys typically lasted more than four hours and consisted of both observations from a boat and from a series of fixed survey points where field staff could survey a large area from and elevated position. Any Caspian terns that were identified during weekly surveys were hazed either from the boat, or by landing and approaching the birds on foot. Prior to each hazing bout, the location and behavior of the Caspian terns were recorded. If tern scrapes or eggs were discovered, eggs were collected under permit and all nest scrapes were destroyed. The number of complete reservoir surveys conducted each week varied depending on Caspian tern activity and weather.

In total, Caspian terns were hazed from nine unique locations in northern Potholes Reservoir, most of which were also used by terns in previous years, with activity peaking late in the

breeding season when receding reservoir levels exposed hundreds of small sandy islands (*Map 5*). Despite being observed throughout the reservoir, Caspian terns were most commonly hazed from islands in two distinct areas; (1) near the 2016 colony site and (2) an area of the northwest arm where dozens of small sandy islands were exposed in June (*Map 5*). The number of Caspian terns found and subsequently hazed varied throughout the breeding season with the highest number of terns hazed from a single site being 34, 13, 24, 72 in April, May, June, and July, respectively. Although one Caspian tern egg was collected at the site used by terns for nesting in 2016, most terns encountered during these surveys were loafing in northern Potholes Reservoir in 2019.

The existing passive nest dissuasion materials on Crescent island, primarily native willows planted on the island in 2016, were successful in deterring Caspian terns and gulls from establishing breeding colonies on the island again in 2019. As was the case in the previous four years, no Caspian terns or gulls used the island during the 2019 breeding season for loafing or nesting. While passive nest dissuasion installed elsewhere has provided little deterrent to nesting gulls (e.g., Goose Island, East Sand Island), the absence of prospecting gulls on Crescent Island during the breeding season could be the result of several factors including; (1) the newly planted vegetation, (2) use of vertical silt fencing as a nesting deterrent, and (3) the formation of a gull colony on nearby Badger Island. The absence of Caspian terns on Crescent Island, a stable colony for nearly three decades (Adkins et al. 2014), for five consecutive breeding seasons provides considerable support for the effectiveness of passive dissuasion measures used to prevent tern nesting on that island (initially rows of silt fencing and ultimately vegetation). Additionally, the success of passive dissuasion in preventing gulls from nesting on Crescent Island was likely a factor in preventing tern use of the island, since gulls provide strong social attraction for prospecting Caspian terns.

Action Effectiveness Monitoring

Nesting distribution and colony size: Nest dissuasion efforts in 2019 were once again successful in preventing colony formation by Caspian terns on Crescent Island, Goose Island, and elsewhere in Potholes Reservoir. In 2019, Caspian terns nested at three different historic colony locations that are not being managed, including the Blalock Islands on the Columbia River, Harper Island in Sprague Lake, and on North Rock in Lenore Lake (see *below* for more details).

Goose Island – As was the case in previous years, Caspian tern use of Goose Island for roosting and nesting attempts was largely limited to areas near the island's shoreline, which gradually was exposed during the nesting season as reservoir levels receded. Active nest dissuasion (hazing) and collection of Caspian tern eggs were successful in preventing the formation of a Caspian tern colony anywhere on Goose Island or the surrounding small rocky islets in 2019 (see *above*).

Average weekly attendance by Caspian terns on Goose Island and nearby islets in 2019 was lower than was observed the first five years of management in 2014-2018, and appreciably

lower than the pre-management average (*Figure 1*). In 2014, the first year of implementation of the IAPMP at Goose Island, we estimated that a total of 159 breeding pairs of Caspian terns nested on Goose Island and the surrounding islets, which was a sizeable reduction in colony size compared to previous years (*Figure 2*). Of the total number of breeding pairs of Caspian terns on or near Goose Island in 2014, all but three pairs nested on a nearby rocky islet (Northwest Rocks), where nest dissuasion techniques were not implemented (Roby et al. 2015). In 2015, only one pair of Caspian terns laid an egg on Northwest Rocks, and no successful nesting by Caspian terns occurred there. During that same year, the number of breeding pairs of Caspian terns that successfully nested on Goose Island was just two breeding pairs (each on the main island near the former colony area under passive nest dissuasion materials), with each nest producing a single fledgling. In 2016-2019, nest dissuasion activities were successful in preventing Caspian terns from forming a colony on both Goose Island and the surrounding islets (*Figure 2*).

In 2019, 19 Caspian tern eggs were discovered on Goose Island and the surrounding islets. Eight of the tern eggs discovered were collected under permit, and the remainder were depredated by gulls prior to collection (*Table 2*). As was the case in previous years, Caspian tern eggs were exclusively laid along the shoreline in open or sparsely vegetated habitat that was exposed as the reservoir level receded during the 2019 breeding season. In most cases, eggs were laid in areas where passive dissuasion could not be installed in late March – early April due to elevated reservoir levels.

In 2019, gulls were present on the Goose Island (4,000-4,500 loafing birds) during the crew's first visit to the island on 31 March; prior to that date the island was inaccessible by boat due to Potholes Reservoir being frozen over. Gull numbers increased through April, peaking in May. The index of gull colony size on Goose Island in 2019 was ca. 11,100 individuals, near the range (ca. 11,500–13,000) of gulls counted on the Goose Island during the four years prior to management (*Table 3*; Adkins et al. 2014; BRNW 2014). These index counts indicate that the colony size for gulls on Goose Island has not changed appreciably because of Caspian tern management activities on the island and support the conclusion that the combined effects of passive and active nest dissuasion efforts during the 2014-2019 nesting seasons had little impact on the establishment and size of the Goose Island gull colony.

Nest dissuasion efforts and egg collection were successful in preventing Caspian terns from forming a colony on Goose Island and nearby islets in 2019. Despite their inability to form a breeding colony, some Caspian terns continued to show strong site fidelity to Goose Island, perhaps bolstered by the presence of a large gull colony on the island that served to attract prospecting Caspian terns. Another likely factor in the strong site fidelity exhibited by some Caspian terns at Goose Island is a long history of nesting on the island (since 2004; Adkins et al. 2014). However, the Crescent Island Caspian tern colony has been present annually since 1986, suggesting that colony longevity is not the primary explanation for the strong site fidelity exhibited by some Caspian terns to Goose Island. A third potential factor in the apparent stronger site fidelity of Caspian terns to Goose Island as compared to Crescent Island is the type of passive nest dissuasion materials deployed at the two islands. Most potential Caspian tern

nesting habitat on Crescent Island was covered with fence rows of privacy fabric erected at 15-foot intervals across the entire island (initially) and extensive willow plantings (ultimately), eliminating all bare open habitat on Crescent Island, which is preferred by nesting terns. The shallow, rocky soils of Goose Island, and dynamic water levels at Potholes Reservoir, preclude the use of these passive nest dissuasion techniques (i.e. fencing and revegetation) on that island. Finally, a fourth potential factor that might explain the strong site fidelity by some Caspian terns to Goose Island, compared to Crescent Island, is the paucity of alternative colony sites near Goose Island in most years. In contrast, Caspian terns and gulls nesting on Crescent Island have access to numerous islands located nearby that provided ample suitable nesting habitat for ground-nesting colonial waterbirds (e.g., the Blalock Islands and Badger Island both located on the Columbia River; see *Map 1*).

These results, in addition to findings from 2014-2018, provide considerable evidence that passive nest dissuasion (i.e. ropes and flagging suspended above the ground), when used in concert with human hazing and egg collection, provide an effective and targeted means to deter Caspian terns from nesting in areas of suitable habitat. These results also confirmed previous findings that currently employed passive nest dissuasion (i.e. stakes, rope, and flagging) has little deterrent effect on non-target species (i.e. California gulls, ring-billed gulls, and Canada geese) on Goose Island. Like in 2014-2018, gulls nested within both single and double layers of passive nest dissuasion indiscriminately, utilizing virtually all upland habitat.

In summary, Caspian tern use of Goose Island was again strongly influenced by placement of passive nest dissuasion materials in 2019. No Caspian terns were observed landing in areas of passive dissuasion, and consequently no nests were established. Few Caspian terns were hazed from Goose Island until mid-June and tern use of the island was largely restricted to exposed beaches along the perimeter of the island at or below the high-water line, where they were easily hazed by researchers on foot and using boats.

Northern Potholes Reservoir – In 2019, a combination of passive nest dissuasion, targeted hazing, and egg collection was successful in preventing the formation of an incipient Caspian tern colony on islands in northern Potholes Reservoir. In contrast to 2016 when a Caspian tern colony of 144 breeding pairs was sustained from early-May to June, just one Caspian tern egg was laid in northern Potholes Reservoir in 2019. The egg was collected under permit on 4 May on the colony site used by terns in 2016 in northern Potholes Reservoir (*Table 2*). While Caspian terns were hazed from nine islands in northern Potholes Reservoir in 2019, little effort was ultimately required to prevent colony formation.

In summary, Caspian tern use of northern Potholes Reservoir was influenced during the nest initiation period by (1) the placement of temporary passive dissuasion on sites suitable for tern nesting, (2) consistent hazing efforts at sites used by prospecting terns, and (3) high reservoir conditions that limited suitable nesting habitat during April and May. Of the 100s of low-lying sandy islands in northern Potholes Reservoir that became available later in the breeding season, Caspian terns were found prospecting (i.e. digging nest scrapes and egg laying) at just

one location in 2019. While these results are encouraging, some Caspian terns continue to show strong fidelity to Goose Island and other locations in Potholes Reservoir.

Crescent Island – As was the case in 2015-2018, the combination of dense vegetation and other passive nest dissuasion measures were successful in preventing Caspian terns from landing, roosting, or nesting on Crescent Island in 2019. This was the fifth consecutive year when no nesting by Caspian terns occurred on Crescent Island, while prior to tern management in the CPR the average colony size for Caspian terns on Crescent Island was 461 breeding pairs (*Figure 3*).

Efforts to dissuade Caspian terns from nesting on Crescent Island were also successful in preventing all gulls from nesting there in 2015-2019. In 2014, we estimated that ca. 6,400 individual gulls (ca. 5,600 California gulls and ca. 800 ring-billed gulls) nested on Crescent Island, all of which were displaced because of management in 2015-2019.

In summary, nest dissuasion activities were successful in preventing all nesting by both Caspian terns and gulls on Crescent Island in 2015-2019. This was somewhat unexpected because the colonies of Caspian terns and gulls have been present on Crescent Island for close to three decades (Ackerman 1994). Several factors (see *above*) may explain the abandonment of Crescent Island by both nesting gulls and Caspian terns in 2015-2019.

Unmanaged sites – Caspian terns were confirmed present at 13 different sites during the fixed-wing aerial survey conducted in the CPR on 3-4 May in 2019 (*Table 4*). Most sites (n=9) were loafing sites, with no signs of nesting activity, with the remainder (n=4) being active colonies on two different islands in the Blalock Islands complex on the Columbia River, on Harper Island in Sprague Lake, and on North Rock in Lenore Lake (*Table 4*; *Map 1*). The historic Caspian tern colony sites on Badger Island on the Columbia River and Twinning Island in Banks Lake were not used for nesting in 2019. As was the case in 2015-2018, the largest Caspian tern colony in the CPR in 2019 was on the Blalock Islands, representing 87% of the total number of breeding pairs in the region in 2019.

The Blalock Islands are located on the Columbia River above John Day Dam near the town of Irrigon, OR, and are managed by the USFWS as part of Umatilla National Wildlife Refuge. The island group consists of several sizable, permanently vegetated islands, as well as numerous low-lying gravel islands and mudflats that were created by the John Day Dam impoundment. In 2019, Caspian terns were seen on the Blalock Islands during the crew's first visit to the site on 8 April, when ca. 100 adult terns were observed loafing on multiple islands. The first evidence of nesting by Caspian terns at the Blalock Islands was observed on 15 April, when five attended nests were counted on Middle Island, with the first eggs confirmed on 25 April (*Figure 4*). As many as 379 attended Caspian tern nests were counted on Middle and Long islands in the Blalock islands complex in 2019. As was the case in previous years, periods of high wind and elevated reservoir elevations resulted in significant colony failure (i.e. egg loss) in 2019. The colony size estimate of 379 breeding pairs in 2019 represents an increase in colony size at the Blalock Island complex relative to 2018 (313 breeding pairs), but a decline in colony size

compared to the 2015-2017 (*Figure 5*). Like 2017-2018, productivity was limited by high water events. After several re-nesting attempts, we estimated that a maximum of 129 young Caspian terns fledged from the Blalock Islands in 2019 or a productivity of 0.34 young raised per breeding pair, higher than the nesting success observed at the Blalock Islands the previous year (0.18 young raised per breeding pair). As in previous years, inundation of tern nests due to high reservoir levels coupled with high winds was a factor limiting colony size and nesting success at the Blalock Islands in 2019.

Harper Island is a privately-owned island located near the southwestern end of Sprague Lake between the towns of Ritzville and Sprague in east-central Washington and is located about 68 km from the nearest section of the Snake River. Harper Island is a steep-sided, rocky island approximately 10 acres in area and covered by upland shrub habitat, sparse herbaceous vegetation, and bare rock. In 2019, Caspian terns were first seen on Harper Island on 19 April, when 27 loafing adults were observed near the 2018 colony location, a rocky upland location surrounded by dense vegetation that provides only limited visibility to researchers. The first attended nests were confirmed during a survey on 24 April, when 22 adults and 5 attended nests were counted. Based on aerial photographs from 4 May, a total of 18 breeding pairs of Caspian terns attempted to nest on Harper Island in 2019, a decrease in colony size compared to 2018 (79 breeding pairs; *Figure 6*). Like in 2017-2018, significant colony failure occurred in June, as no attended nests were observed during the mid-June aerial survey. As was the case in previous years, the cause of colony failure in 2019 is not known due to access restrictions and limited visibility. We estimated that 10 young Caspian terns fledged from Harper Island in 2019 or a productivity of 0.55 young raised per breeding pair.

Lenore Lake was formed by the Missoula Floods in the lower Coulee just north of Soap Lake, Washington and is managed by the Washington Department of Fish and Wildlife. Lenore Lake is known for its very alkaline waters that only Lahontan cutthroat trout can survive in. Caspian terns first nested in Lenore Lake on Shoal Island (2014-2016) and then moved to North Rock, approximately 0.4 km NNE from the former colony site, in 2017. North Rock is a steep-sided, rocky island approximately one acre in area and is located about 48 km from the nearest section of the Columbia River. In 2019, Caspian terns were first seen at Lenore Lake on 19 April, when 51 adults and 5 attended nests were observed on North Rock. Based on aerial photographs taken on 3 May, a total of 48 breeding pairs of Caspian terns attempted to nest at North Rock in Lenore Lake 2019, down from the colony size estimate in 2018 (91 breeding pairs; *Figure 7*). We estimated that 10 young Caspian terns fledged from North Rock in Lenore Lake in 2019, or a productivity of 0.26 young raised per breeding pair, similar to the nesting success observed at the site the previous year. The cause(s) for limited nesting success at this site are not know due to obstructed colony observations and limited nature of weekly surveys.

In total, an estimated 445 breeding pairs of Caspian terns nested at three different breeding colonies in the CPR during 2019. This represents a 49% decline in the regional breeding population size for Caspian terns compared pre-management average (873 breeding pairs; *Figure 8* and *Table 5*). Although nest dissuasion actions implemented on Goose and Crescent islands in 2019 were once again effective in preventing all Caspian terns from nesting at those

two colonies, it did not result in a commensurate reduction in the total number of Caspian terns breeding in the region. This was due to the increase in the number of Caspian terns nesting in the Blalock Islands, Harper Island, and North Rock in Lenore Lake in 2019 relative to the pre-management average for those colonies (*Figure 9*). While smaller in 2018-2019, the average Blalock Islands colony size during the management period (2015-2019; 391 breeding pairs) was similar in size to the largest Caspian tern colonies recorded anywhere in the CPR since intensive monitoring began in 2000.

Predation rates: A primary goal of the IAPMP is to reduce predation rates (proportion of available fish consumed) on ESA-listed juvenile salmonids by Caspian terns to less than 2% per salmonid population, per colony (USACE 2014). Recoveries of smolt PIT tags on Caspian tern colonies in 2019 were used to estimate salmonid population-specific (hereafter ESU/DPS) predation rates and to compare predation rates prior to and during tern management actions associated with the IAPMP. To help ensure numbers of ESA-listed Upper Columbia River steelhead – a population that is highly susceptible to tern predation and therefore a suitable population to evaluate the efficacy of management actions – were available for predation rate analyses, steelhead smolts were intentionally PIT-tagged and released into the tailrace of Rock Island Dam (RIS) as part of this study in 2019.

PIT tagging of Upper Columbia River steelhead – A total of 3,784 juvenile steelhead (2,629 hatchery, 1,155 wild) were captured, PIT-tagged (*Biomark* model APT12), measured (fork-length), condition-scored, and released into the tailrace of Rock Island Dam (RIS) by Chelan County Public Utility District employees in 2019. An additional 617 previously PIT-tagged (i.e. recaptured) juvenile steelhead were also detected at the RIS trap, resulting in a total of 4,401 steelhead available for potential predation rate analyses (see *below*). The number of steelhead tagged in the 2019 were less than those available for predation analyses in years past (range = 5,893 – 7,756; average 7,128 during 2008-2018; Evans et al. 2019a) but provided a representative sample of the run-at-large juvenile steelhead for predation analyses. All PIT-tagged juvenile steelhead included in the study were part of the ESA-listed Upper Columbia River DPS, as all hatchery and wild steelhead originating from tributaries upstream of Rock Island Dam are part of the ESA-listed population (NOAA 2014).

Steelhead were tagged and released at RIS from 14 April to 8 June 2019. Fish were randomly selected for tagging and were tagged in concert with, and in proportion to, the run at-large (Evans et al. 2014). Mean steelhead fork length was 192 mm (standard deviation [SD] = 24 mm; range = 123 to 287 mm). An evaluation of fish condition indicated that most steelhead were in good over-all external condition, with only 5.3% of steelhead observed with severe body injuries (subcutaneous wounds/scars), disease (fungal or viral infections), severe descaling (> 20% of scales missing), and/or major fin damage (> 50% of fin tissue missing). The most common type of damage was body injuries, followed by severe descaling. The over-all percentage of compromised steelhead in 2019 was lower than that observed in years past (average = 11.1%; range 5.2-27.3% during 2008-2018; Evans et al. 2019b).

PIT tag recovery – A total of nine avian colonies were scanned for smolt PIT tags following the 2019 breeding season, including two Caspian tern colonies, four California and ring-billed gull colonies, one double-crested cormorant colony, and one American white pelican colony (*Table 6*). Scanning was also conducted at three known avian loafing/roosting sites where large numbers of mixed species colonial waterbirds were observed during the smolt out-migration period. From these locations (breeding and loafing combined), a total of 10,361 PIT tags from 2019 migration-year smolts were detected (*Table 6*). The vast majority (> 97%) of tags were recovered from breeding colonies, with the largest number of smolt PIT tags found on the Badger Island gull colony (n=3,823), followed by the Miller Rocks gull colony (n=1,999), the Blalock Islands Caspian tern colony (n = 1,805), and the Island 20 gull colony (n=1,273; *Table 6*). We did not attempt to recover PIT tags from the two managed Caspian tern colonies sites on Goose Island and Crescent Island because no terns were observed nesting at these sites in 2019. We also did not recover PIT tags from the Foundation Island double-crested cormorant colony because a prior study indicated that birds from this colony forage primarily of fish from the Snake River (Evans et al. 2012; see *Map 1*).

PIT tag detection and deposition probabilities – *Table 7* provides results on the probability that a consumed PIT tag was deposited on each colony and subsequently detected by researchers following the breeding season. Deposition probabilities were based on previous studies that empirically measured deposition rates for Caspian terns, double-crested cormorants, and California and ring-billed gulls at their colonies in the Columbia River Basin (see also Hostetter et al. 2015). Detection probabilities were directly measured in 2019 based on the proportion of tags that were intentionally sown at each colony during the breeding season that were subsequently detected by researchers at the colony after the breeding season (see also Hostetter et al. 2015). Detection probabilities were highly variable (range 0.14 – 0.99), depending on colony and when during the nesting season tags were sown (*Table 7*). The lowest detection probabilities were on the Blalock Islands tern colony, a location where detection efficiency has steadily decreased since 2015 due to high rates of PIT tag collision (a phenomena that renders tag codes in close proximity to one another unreadable (see Evans et al. 2019a).

Predation rate analysis – No terns nested on Goose Island or elsewhere in Potholes Reservoir in 2019, so predation rates were presumed to be zero or close to zero (denoted as < 0.1%; *Table 8*). This is the fifth consecutive year that the IAPMP target goal of ESU/DPS-specific predation rates of less than 2% per ESU/DPS were achieved at Goose Island in Potholes Reservoir. In 2014, the first year of management at Goose Island, a colony of 159 pairs consumed an estimated 2.9% (95% CI = 1.9–5.1) of Upper Columbia River steelhead. Predation rates on Upper Columbia River steelhead by Goose Island terns prior to implementation of management actions in 2014 were among the highest of any tern colony in the region, averaging 15.7% (95% CRI = 14.1–18.9) during 2007-2013 (*Table 8*). In 2016, a colony of 144 pairs formed on an unnamed island in northeastern Potholes Reservoir. Recoveries of smolt PIT tags indicated that terns consumed an estimated 4.1% (95 CRI = 2.9–6.3) of Upper Columbia River steelhead in 2016, impacts that prompted adaptive management actions at this and other surrounding islands in Potholes Reservoir during 2017–2019. Since then, active and passive dissuasion techniques implemented

at these sites have been successful at preventing Caspian terns from nesting on islands in northern Potholes Reservoir (see *above*).

For the fifth consecutive year, the Caspian tern colony at Crescent Island was eliminated in 2019 (see *above*) and predation rates were thus assumed to be zero or close to zero. Prior to management actions in 2015, predation rates by Crescent Island terns were highest on steelhead populations, with an average annual predation rate estimate of 2.5% (95% CRI = 2.2–2.9) and 4.5% (95% CRI = 4.2–5.1) on Upper Columbia River steelhead and Snake River steelhead, respectively (*Table 8*). Predation rates on most other ESA-listed ESU/DPS were less than 2% prior to management (*Table 8*).

Caspian tern predation rate estimates at North Rock in Lenore Lake were below the 2% threshold for all ESUs/DPSs evaluated in 2019, with the highest rate being 1.0% (95% CRI = 0.6–1.7) on Upper Columbia River steelhead (*Table 9*). Rates were at or below 0.1% for all other ESUs/DPSs evaluated in 2019 (*Table 9*). Results in 2019 were very similar to those observed in 2017 and 2018, with the highest predation rates observed on Upper Columbia River steelhead. Historic data for terns nesting on islands in Lenore Lake is available starting in 2015, the first year a colony was observed on the lake. Predation rate estimates in 2015 and 2016 were even lower than those observed in 2017-2019 due to the paucity of smolt PIT tags recovered (< 10 PIT tags each year) and the small size of the colony (< 40 nesting pairs) during those years.

In 2019, just 18 Caspian tern pairs attempted to nest on Harper Island in Sprague Lake. Scanning for PIT tags did not occur because the landowner did not grant permission to access the island. In 2017 and 2018, 92 and 78 nesting pairs, respectively, attempted to nest on Harper Island, but again, permission was not granted to scan for smolt PIT tags. Permission was granted to recover smolt PIT tags on the Harper Island tern colony following the 2012 nesting season, when 30 pairs nested at that site (BRNW 2013). Predation rate estimates in 2012 indicated that terns consumed less than 0.3% of available Snake River and Upper Columbia River ESUs/DPSs, with the highest rates observed on Snake River steelhead (0.2%; 95% CRI – 0.1-1.3). Low predation rates in 2012 were presumably associated with the relatively small size of the colony that year and as such, future monitoring of the colony site may be warranted, particularly if a substantial increase in colony size occurs and permission to scan for PIT tags can be obtained.

No Caspian terns nested on Badger Island in 2019 and predation rates were thus assumed to be zero or close to zero. In 2017, a colony of 41 pairs was established and predation rate estimates were below the 2% threshold for all ESUs/DPSs evaluated that year, with the highest rates being 0.5% (95% CRI = 0.3–0.8) and 0.4% (95% CRI = 0.2–0.6) on upper Columbia River steelhead and Snake River steelhead, respectively. Given the location of Badger Island (i.e. in McNary Reservoir), a larger-sized colony at this site could have an appreciable impact on ESA-listed ESUs/DPSs, impacts that could be comparable to those observed at Crescent Island prior to management or at Blalock Islands during the post-management phase (*Tables 10-11*).

Predation rates by Caspian terns nesting in the Blalock Islands were the highest observed of the tern colonies evaluated in 2019. Predation rates were above the 2% threshold for two ESA-listed DPSs; Upper Columbia River steelhead (5.9%; 95% CRI = 3.4–10.0) and Snake River steelhead (3.0%; 95% CRI = 1.9–4.7%; *Table 10*). Predation rates for all other ESUs/DPSs ranged from 0.4% (95% CRI = 0.2–0.8) for Snake River spring/summer Chinook to 1.4% (95% CRI = 0.4–3.7) for Snake River sockeye (*Table 10*).

Predation rates on ESA-listed salmonid populations by Caspian terns nesting on the Blalock Islands have been, on average, significantly higher since management actions on Crescent Island were implemented in 2015 (*Table 11*). Increases in predation rates were commensurate with the over-all increase in the size of the Blalock Island tern colony, with the colony increasing from an average of 57 breeding pairs (range = 6 to 136) during 2007–2014 to average of 460 breeding pairs (range = 313 to 677) during 2015–2019 (*Figure 5*). Predation rate estimates by Caspian terns nesting on the Blalock Islands during the post-management period were comparable to or higher than those of terns nesting on Crescent Island during the pre-management period for most of the ESUs/DSPs evaluated, particularly for ESUs/DPSs originating from the Snake River (*Table 8*). For instance, predation rates on Snake River steelhead by Blalock Island terns increased from an average of 0.5% (95% CRI = 0.4-0.9) prior to management to an average of 3.7% (95% CRI = 3.1-4.6) during implementation of management at Goose and Crescent islands. Consequently, as described by Evans et al. (2019b), increases in predation rates on salmonid smolts by Caspian terns nesting on the Blalock Islands has offset the benefits achieved by the elimination of the Caspian tern colonies on Crescent and Goose islands associated with management.

In summary, reductions in tern colony sizes at Goose Island in Potholes Reservoir have reduced Caspian tern predation rates on Upper Columbia River steelhead as part of the IAPMP. For the fifth consecutive year, however, predation rates by Caspian terns nesting on the Blalock Islands exceeded the 2% threshold for multiple ESA-listed salmonid ESUs/DPSs, indicating that adaptive management at this colony site will most likely be needed to achieve the over-all goals of the IAPMP. As demonstrated at the incipient colony site in northern Potholes Reservoir, adaptive management at tern nesting sites can quickly (in just one year) eliminate tern impacts using passive and active nest dissuasion techniques. As such, adaptive management at the Blalock Island nesting sites could benefit ESA-listed populations originating from both Upper Columbia River and Snake River ESUs/DPSs, but the greatest net benefit would be to Snake River populations, populations that have yet to receive the full benefits of the Caspian tern management actions in the CPR.

OTHER PISCIVOROUS COLONIAL WATERBIRDS

Colony Size

Surveys conducted in the CPR in 2019 confirmed that gulls nested at five previously used colony sites in 2019; Miller Rocks, Blalock Islands, Badger Island, and Island 20 on the

Columbia River and Goose Island in Pothole Reservoir (*Map 1*). The largest gull colony was on Goose Island in Potholes Reservoir (11,090 adults on colony), followed by islands on the Columbia River at Island 20 (9,284 adults on colony), Miller Rocks (3,223 adults on colony), Badger Island (2,824 adults on colony), and two islands in the Blalock Islands complex (Anvil Island [2,358 adults on colony] and Straight Six Island [274 adults on colony]; *Figure 10*). Gulls also nested at Twinning Island in Banks Lake (approximately 1,200 adults on colony) and Harper Island (approximately 1,215 adults on colony, but PIT recovery at these gull colonies was not conducted given the lack of evidence that gulls from these colonies prey on juvenile salmonids from the Columbia and Snake rivers). It should be noted that the colony size estimate for gulls on Badger Island is likely biased low given that the survey was conducted after the peak in breeding.

Predation Rates

Of the predator species evaluated, the largest numbers of smolt PIT tags were recovered on non-tern piscivorous waterbird colonies in 2019 (*Table 6*). The large number of smolt PIT tags recovered, coupled with low on-colony PIT tag deposition probabilities (*Table 7*), resulted in high estimates of predation by several California and ring-billed gull colonies in 2019 (*Tables 4-5*). For instance, predation rates by gulls nesting at several colonies were equal to or greater than those of Caspian terns nesting on the Blalock Islands in 2019, with predation rates in excess of 5% of available fish for several ESA-listed ESUs/DPSs (*Tables 9-10*). Unlike Caspian terns, however, gulls are known to consume dead or moribund fish and to kleptoparasitize (steal fish from) other piscivorous waterbirds, such as Caspian terns. Consequently, smolt PIT tag recoveries on gull colonies may be more indicative of consumption rates, rather than predation rates *per se* (Roby et al. 2016). Based on the large number of good condition steelhead that were consumed by gulls, however, smolt consumption by gulls may be primarily on healthy or uncompromised fish (see also Evans et al. 2016), but research to address this critical uncertainty is currently lacking in the published literature (Evans et al. 2019a).

Island 20 gulls: Consumption rates of salmonid smolts by gulls nesting on Island 20 were less than 1.0% for most ESUs/DSPs evaluated in 2019, with the notable exception of predation on Snake River steelhead and Upper Columbia River steelhead, where an estimated 2.8% (95% CRI = 1.9–4.2%) and 7.4% (95% CRI = 4.8–11.7%) of available fish were consumed, respectively (*Table 9*). Estimates from 2019 were similar to those observed in 2015, where gulls consumed an estimate 3.6% and 7.9% of Snake River steelhead and Upper Columbia River steelhead, respectively (Roby et al. 2016). In most other years, however, predation rates on steelhead DPSs were less than 2% of available fish or less than 1.0% of available salmon ESUs (A. Evans, unpublished data). Increased rates of consumption by Island 20 gulls in 2015 and 2019 may be associated with increases in colony size and/or due to environmental conditions (e.g., low flows) that increase smolt exposure times to gull predation during out-migration (Roby et al. 2016; Payton et al. 2016).

Badger Island gulls: Similar to Island 20 gulls, consumption rates by gulls nesting on Badger Island on juvenile salmonids were highly variable, ranging from 1.2% (95% CRI = 0.6–2.1) of

Snake River spring/summer Chinook salmon to 10.9% (95% CRI = 6.7–17.7) of Upper Columbia River steelhead (*Table 9*), the highest ESU/DPS-specific predation rate observed by any colony in the Columbia Plateau region in 2019 (*Tables 9-10*). Predation rates by Badger Island gulls were also high on Snake River steelhead, Upper Columbia River spring Chinook salmon, and Snake River sockeye salmon, with an estimated 5.6% (95% CRI = 3.9–8.4), 3.6% (95% CRI = 1.1–8.8), and 3.1% (95% CRI = 0.9–8.3) of available fish consumed, respectively (*Table 9*). Predation rates by Badger Island gulls in 2019 were consistently higher than those observed in years past. It should be noted that small samples sizes of some available ESUs/DPSs (e.g., SR sockeye and UCR steelhead) resulted in imprecise estimates of predation relative to past years. Furthermore, since the gull colony became established on Badger Island in 2015, there has been more over-lap in areas where American white pelicans and gulls nest on Badger Island. As such, it's likely that some of the tags recovered on gull nesting areas were deposited by pelicans but were erroneously attributed to gull consumption. Pelican predation rate estimates, however, prior to 2015 – when only pelicans nesting on Badger Island – indicated that pelicans consume a very small percentage of available steelhead, particularly Upper Columbia River steelhead (Evans et al. 2014).

Blalock Island gulls: Since at least 2012, there have been two separate gull colonies present within the Blalock Islands complex in John Day Reservoir, one on Anvil Island (Rkm 440) and one on Straight Six Island (Rkm 439). Of the two gull colonies in the Blalock Islands complex, smolt consumption rates have been significantly higher for gulls nesting on Anvil Island as compared to gulls nesting on Straight Six Island (see also Roby et al. 2016). Differences in relative predation rates are attributed to difference in the size of the colonies (with substantially more gulls on Anvil Island) and difference in species composition (Anvil Island was dominated by nesting California gulls and Straight Six Island was dominated by nesting ring-billed gulls, the former are known to consume a higher proportion of juvenile salmonids; Collis et al. 2002). Also, data from Hostetter et al. (2015) indicated that per capita (per bird) consumption of juvenile salmonids was greater for gull colonies dominated by California gulls as compared to those dominated by ring-billed gulls. This difference in smolt consumption rates between the gull species is likely due to differences in body size and energy requirements (Winkler 1996), as well as the proportion of the diet that consists of fish (Collis et al. 2002), both of which are greater for California gulls compared with ring-billed gulls.

For the purpose of this and other predation rate studies (Evans et al. 2019a,b), we have combined estimates of gulls nesting on Anvil and Straight Six islands (collectively referred to as "Blalock Islands gulls"; see also Evans et al. 2019a). Results of both colonies combined indicate that predation rates were less than 2% for all ESA-listed ESUs/DPSs evaluated in 2019 (*Table 10*). Predation rates were highest on Snake River steelhead (1.6%; 95% CRI = 0.8–2.8), followed closely by Upper Columbia River steelhead (1.5%; 95% CRI = 0.4–3,8), and Snake River sockeye (1.4%; 95% CRI = 0.3–4.2; *Table 10*). Predation rate estimates by Blalock Island gulls in 2019 were similar to, but slightly lower than, those observed in years past. Similar to predation by Island 20 gulls and Badger Island gulls, predation impacts on Upper Columbia River steelhead were often higher than other ESUs/DPSs.

Miller Rocks Island gulls: Consumption rates by gulls nesting at Miller Rocks Island were some the highest of any gull colony evaluated in 2019, with rates in excess of 5% observed in Upper Columbia River steelhead (6.5%; 95% CRI = 3.4–11.8), Snake River sockeye (5.9%; 95% CRI = 2.6–11.8), and Snake River steelhead (5.1%; 95% CRI = 3.2–8.1; *Table 11*). Unlike many other gull colonies evaluated in the region, predation rates were also elevated in SR Fall Chinook salmon (3.2%; 95% CRI = 1.7–5.8). Predation rates by Miller Rocks Island gulls in 2019 were similar to, but slightly lower than, those observed in years past. For instance, in 2015, predation rates of 13.2%, 9.7%, and 7.4% were observed in Upper Columbia River steelhead, Snake River steelhead, and Snake River sockeye, respectively, the highest rates observed to-date. Miller Rocks Island is in close proximity to John Day and The Dalles dams (18 Rkm and 23 Rkm, respectively), and Evans et al. (2016) observed that gulls disproportionately consumed smolts near dams and hypothesized that smolts may be more vulnerable near dams as a result of (1) increased smolt travel times or delayed migration in the forebay of dams, (2) smolt morbidity or mortality associated with dam passage, or (3) smolts being temporarily stunned or disoriented by hydraulic conditions in the tailrace of dams. Gull consumption of smolts, however, is not limited to foraging near dams, with gulls consuming substantial numbers of good-condition smolts from open reservoirs and free-flowing sections of the river as well (see Evans et al. 2016 for a detailed discussion).

Lenore Lake double-crested cormorants: Despite an estimated colony size of 112 breeding pairs, only one smolt PIT tag was recovered from the Lenore Lake double-crested cormorant colony following the breeding season in 2019 (*Table 6*). In 2018, when an estimated 111 breeding pairs were present, no PIT tags were recovered. Results provide evidence the Lenore Lake cormorants pose little or no threat to out-migrating juvenile salmonids and unlike Caspian terns breeding on islands in Lenore Lake (see *above*), cormorants apparently do not commute to the middle Columbia River to forage on juvenile salmonids during the breeding season.

Badger Island American white pelicans: Minimum smolt predation rate estimates for Badger Island pelicans in 2019 were less than 0.2% for all ESUs/DPSs evaluated (*Table 11*). Estimates in 2019 were similar to, but slightly lower than, those of years past, with minimum estimates upwards of 0.5% observed in Snake River steelhead in 2010. No deposition rate data for American white pelicans nesting on Badger Island, however, currently exist, so even after an adjustment for detection efficiency (*Table 7*), estimated predation rates represent minimum estimates of predation. Additionally, since the gull colony formed on Badger Island in 2015, the pelican colony has overlapped, spatially, with the gull colony (see also Badger Island gulls *above*). As such, predation rate estimates reported herein are derived from a subset of PIT tags deposited by nesting white pelicans on Badger Island. Based on other studies, there is also some evidence that predation rates on smolts originating for other river systems (e.g., Yakima River) or other salmonid stocks (e.g., Upriver Bright Fall Chinook) may differ from those of smolts originating from the upper Columbia and Snake rivers. For example, during 2010-2014 minimum predation rates (those corrected for detection but not deposition probabilities) on Yakima River sub-yearling Chinook salmon last detected at Prosser Dam on the Yakima River ranged from 2.2% (95% CRI = 1.6–3.0%) to 6.5% (95% CRI = 5.2–8.0%) and estimates in excess

of 10% of wild Upriver Bright Chinook salmon have also recently been observed (A. Evans, unpublished data).

Finally, unlike Caspian terns, double-crested cormorants, and California and ring-billed gulls, American white pelicans are capable of consuming adult salmonids, with PIT tags implanted in adult sockeye salmon, adult steelhead (both pre- and post-spawned), and jack Chinook salmon recovered on the Badger Island pelican colony. Adult salmonids ranging in size from 425 mm fork length to 675 mm fork length were consumed by Badger Island pelicans (Roby et al. 2017).

In summary, estimates of consumption rates of juvenile salmonids by gulls nesting at certain colonies in the Columbia Plateau region were substantial in 2019, as they were in many other years since predation rates estimates were adjusted to account for on-colony PIT detection and deposition probabilities (see Hostetter et al. 2015). Further research is needed to better understand the mechanisms that influence fish susceptibility to consumption by gulls, specifically whether gulls are disproportionately consuming weak or compromised smolts, especially near dams. Regardless of the reasons, smolt consumption rates associated with certain gull colonies were comparable to and often higher than those associated with Caspian tern colonies, and have continued to be some of the highest consumption rates associated with any piscivorous waterbird colony in the Columbia Plateau region since multi-predator species studies were initiated.

Minimum estimates of predation by American white pelicans nesting at the Badger Island colony were low, indicating that pelicans nesting at this colony posed little risk to ESA-listed PIT-tagged smolts migrating through the mainstem Columbia River. Additional research is needed, however, to quantify PIT tag deposition probabilities in American white pelicans and to evaluate impacts on specific stocks (e.g., Upriver Bright Fall Chinook), stocks that maybe more susceptibility to pelican predation.

CUMULATIVE PREDATION RATES & SURVIVAL

A multiple year (2008-2019) investigation of the cumulative effects of predation (predation by all colonies combined) on Upper Columbia River steelhead tagged and released into the tailrace of Rock Island Dam (see PIT-tagging at Rock Island Dam *above*) indicated that predation rates were highly variable depending on the predator species, river-reach, and year. Of the colonies capable of foraging between Rock Island Dam and McNary Dam, the highest predation rates were those of Caspian terns prior to implementation of the IAPMP management plan in 2014, with estimates as high as 26% (95% CRI = 19.0–35.0) of available fish in some years (*Figure 11* and Evans et al. 2019a,b). After implementation of management actions at Goose Island, tern predation rates in this river reach significantly decreased, with the lowest estimate to-date observed in 2019 at just 2.1% (95% CRI = 0.1–4.3%; *Figure 11*). Steelhead survival through this river reach has also increased during implementation of IAPMP, with a large percentage of steelhead surviving passage to McNary Dam (see also Evans et al. 2019b). In 2019, an estimated 75.9% (95 CRI = 57.9–84.6) of steelhead survived passage from Rock Island Dam to McNary

Dam, the highest annual estimate observed since research began in 2008 (*Figure 11*). There was some evidence that gull predation rates have increased since implementation of the management plan, especially in 2015 and 2019. However, not all gull colonies were scanned for PIT tags prior to 2014 (resulting in minimum estimates of predation in those years) and rates in 2014, 2017, and 2018 were similar to those observed prior to implementation of the IAPMP during 2008-2013 (see also Evans et al. 2019b).

Of those birds capable of foraging on steelhead between McNary and Bonneville dams, predation by gull colonies was consistently the highest, with annual estimates ranging from 5.6% (95% CRI = 3.3–9.5) to 25.7% (95% CRI = 17.9–35.9; *Figure 11*). Of those gull colonies evaluated, predation rates by gulls nesting on Miller Rocks Island were consistently the highest. Of the Caspian tern colonies foraging in this river reach, predation rates were the highest and the most variable by terns nesting on the Blalock Islands, with annual estimates ranging from less than 1.0% to 12.2% (95% CRI = 7.6–23.9; *Figure 11*). Estimates of predation by Blalock Island terns significantly increased during 2015-2019, a period that coincided with the elimination of the Crescent Island tern colony as part of the IAPMP (*Figure 11*). Increases in predation rates were also commensurate with decreases in steelhead survival in this river reach (see also Evans et al. 2019b for a detailed discussion).

Of the colonies foraging between Bonneville Dam and the Pacific Ocean, predation rate estimates on Upper Columbia River steelhead smolts were the highest by Caspian terns nesting on East Sand Island, with annual estimates ranging from 7.4% (95% CRI = 5.3–11.1) to 23.2% (95% CRI = 17.7–34.7; *Figure 11*). Predation on steelhead smolts by double-crested cormorants on East Sand Island were generally lower than those for terns, but were substantial in years when cormorants were present on-colony throughout the smolt out-migration period, with estimates ranging from 3.5% (95% CRI = 2.0–6.4) to 10.8% (95% CRI = 7.1–17.6; *Figure 11*) during 2008-2015. Due to several *en masse* dispersal events away from the East Sand Island cormorant colony during the peak nesting and smolt out-migration periods in 2016-2019, predation rates on Upper Columbia River steelhead smolts should be considered minimum estimates (Evans et al. 2019b). During these colony dispersal events, most double-crested cormorants remained in the Columbia River estuary, with the majority nesting on the Astoria-Megler Bridge, where they presumably continued to consume steelhead, but consumed PIT tags from smolts were not being recovered.

Cumulative predation rate estimates on Upper Columbia River steelhead during smolt passage from Rock Island Dam to the Pacific Ocean were substantial, ranging from 31.5% (95% CRI = 26.6–37.6) to 53.2% (95% CRI = 42.9–63.6; *Figure 11*). Of the piscivorous colonial waterbird species evaluated, predation rate estimates on steelhead smolts were often the highest for Caspian tern colonies, particularly prior to implementation of management actions. Predation by gull colonies was also substantial, but gull consumption could not be fully evaluated across all study years and river reaches due to a lack of PIT tag recoveries from the Island 20 and Blalock Islands gull colonies during 2008-2012. The estimated cumulative impact of double-crested cormorants from the two colonies included in the study (Foundation Island and East Sand Island) on Upper Columbia River steelhead smolts was consistently less than that of the

tern and gull colonies included in the study. Analogous to several gull colonies, however, estimates of predation rates by cormorants nesting on Foundation Island in McNary Reservoir were not available in all study years, including 2019, so in those years cumulative predation rates by cormorants were minimum estimates.

Finally, comparisons of total steelhead smolt mortality (1-survival) to predation by colonial waterbirds indicated that predation by colonial waterbirds was the one of the greatest, and in many years the single greatest, direct sources of steelhead mortality during out-migration to Bonneville Dam, with predation from the colonies included in this study accounting for an estimated 42% (95% CRI = 30–56%) to 70% (95% CRI = 53–87%) of all Upper Columbia River steelhead smolt mortality during 2008-2019. As such, results indicate that the direct impact of colonial waterbird predation on steelhead smolts were greater than the direct impact of all other mortality sources combined in most study years. A more detailed discussion of these results, including a statistical analysis of the strength and magnitude of the relationship between predation rates and survival rates, is provided in Evans et al. (2019b).

MANAGEMENT RECOMMENDATIONS

Based on results collected during this six-year study (2014-2019), the IAPMP objective of preventing Caspian terns from nesting on Goose and Crescent islands, thereby reducing predation rates by terns nesting at these two sites on ESA-listed salmonid stocks to less than 2%, has been achieved. Despite this, there remain several critical uncertainties associated with the efficacy and long-term sustainability of these management actions in reducing the impacts of avian predation on smolt survival to levels outlined in the management plan (USACE 2014). The following is a list of management recommendations with the aim of meeting these management objectives, as well as to identify new emerging avian predation issues worthy of management consideration both in the short- and long-term.

- Caspian terns that formerly nested on Goose and Crescent islands continue to show high fidelity to the CPR for nesting. Many terns displaced from the Goose Island are still attempting to nest at Goose Island and elsewhere in Potholes Reservoir, while many terns displaced from Crescent Island have relocated to nest at other unmanaged tern colonies in the region, most notably at the Blalock Islands on the Columbia River. A system-wide, adaptive management approach is needed to prevent Caspian terns that formerly nested on Goose and Crescent islands from remaining in the region where they continue to significantly impact the survival of ESA-listed salmonid smolts.

- As demonstrated at Crescent Island, the passive dissuasion technique of revegetation is an effective and sustainable means for preventing Caspian terns and gulls from nesting at that site without the need for active hazing. Passive dissuasion techniques (i.e. stakes, rope, and flagging) along with active hazing targeted at prospecting terns are effective in

preventing terns from nesting at Goose Island but does not deter gulls from nesting underneath the nest dissuasion arrays. It is likely that the greater fidelity shown by terns to Goose Island relative to Crescent Island is due to the presence of a gull colony on Goose Island. Nesting gulls provide a strong social attraction for nesting Caspian terns, as they nest communally at most colony sites in the Pacific Flyway. Efforts to effectively and sustainably prevent nesting by Caspian terns on Goose Island would be greatly enhanced by the elimination of the gull colony at that site.

- Feasibility studies to use vegetation as the passive nest dissuasion method on Goose Island have been unsuccessful. In the previous two years (2018-2019), we have been unable to establish vegetation in irrigated test plots from seed or plugs. It is believed that the substrate, primarily rock with little topsoil, is unsuitable for large scale revegetation of Goose Island. Other passive nest dissuasion methods that are more sustainable (e.g., placement of large woody debris), as compared to ropes, stakes, and flagging, may have promise to prevent tern nesting on Goose Island but have yet to be tested at that site.

- Little potential breeding habitat along the shoreline of Goose Island exists when Potholes Reservoir nears peak elevation (ca. 1044'), which typically occurs in early May. In recent years tern activity has been limited by high water and passive dissuasion until water levels begin to recede. Additionally, few potential breeding locations remain exposed in northern Potholes Reservoir at peak elevation. Based on these data, if it were possible to keep reservoir levels are near peak elevation until early June when the majority of juvenile salmonids have out-migrated through the mid-Columbia River, this would likely reduce the numbers of terns utilizing Potholes Reservoir during the peak of the smolt outmigration.

- At colony sites where passive dissuasion is less effective or where options to install passive dissuasion are limited (e.g., Goose Island in Potholes Reservoir), some level of active hazing will likely be required each year to prevent tern nesting. Active hazing aimed at preventing Caspian terns from nesting early in the breeding season, when juvenile salmonid availability is highest (April-May), will be necessary to prevent colony formation and minimizing predation impacts.

- Although predation on juvenile salmonids by Caspian terns at managed colonies have been mostly eliminated, predation rates by Caspian terns nesting on the large unmanaged colony in the Blalock Islands continues to exceed the 2% threshold (see *above*) for several ESA-listed ESUs/DPSs. Average annual predation rates on Upper Columbia River steelhead, Snake River steelhead, and Snake River sockeye by Blalock Island terns is similar to or greater than those observed on the Crescent Island tern colony prior to implementation of IAPMP. Adaptive management by way of colony size reductions at the Blalock Islands tern colony is needed to reduce Caspian tern predation rates to levels specified in the IAPMP.

- Continued monitoring of unmanaged Caspian tern colonies in the CPR is recommended to identify those colony sites where predation rates remain high (i.e. above the 2% target established by the IAPMP) and to help identify colony sites in the CPR where predation impacts are minimal (i.e. places where management might be implemented to encourage tern nesting).

- An investigation of the cumulative effects of avian predation indicates that predation by several unmanaged gull colonies, primarily California gulls, are a dominate source of Upper Columbia River steelhead mortality during outmigration to Bonneville Dam. Research to better understand factors that influence smolt susceptibility to gull predation are needed, and management actions at specific gull colonies in the CPR should be considered.

- System-wide, cumulative studies of avian predation provide the most comprehensive and management-relevant data to evaluate the over-all effects of avian predation on smolt survival, as well as to best evaluate the true efficacy of management actions. Continuing these types of studies in the future will ensure accurate information is available for adaptive management decisions in both the short- and long-term.

- PIT tag deposition rates for American white pelicans remains a critical uncertainty resulting in minimum predation rate estimates for the large colony located on Badger Island in the McNary Pool. Further study is needed to determine the on-colony deposition rates of consumed PIT tags by American white pelicans so that the smolt predation rates for pelicans are comparable to those of other piscivorous colonial waterbirds (i.e. Caspian terns, California gulls, ring-billed gulls, and double-crested cormorants) included in this study.

- Historically predation rates for the double-crested cormorant colony located in McNary Pool often exceeded or were comparable to those of larger Caspian tern and gull colonies, particularly for Snake River ESU/DPSs. Efforts to measure current predation impacts by cormorants nesting at this colony should be incorporated into future system-wide avian predation studies.

- Irrespective of the need for additional avian predation management in CRP, accounting for factors that limit smolt survival to the degree observed in this and other studies may be paramount in interpreting the results and measuring the efficacy of other, non-avian salmonid management actions. Conversely, by not considering avian predation when evaluating the efficacy of non-avian management actions, the benefits of such actions would likely be confounded or otherwise masked due to unaccounted-for fluctuations in avian predation.

LITERATURE CITED

Ackerman, S.M. 1994. American white pelicans nest successfully at Crescent Island, Washington. Washington Birds 3:49-50.

Adkins, J.Y., D.E. Lyons, P.J. Loschl, D.D. Roby, K. Collis, A.F. Evans, and N.J. Hostetter. 2014. Demographics of piscivorous colonial waterbirds and management implications for ESA-listed salmonids on the Columbia Plateau. Northwest Science 88:344-359.

Antolos, M., D.D. Roby, and K. Collis. 2004. Breeding ecology of Caspian terns at colonies on the Columbia Plateau. Northwest Science 78:303-312.

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

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

Collis, K., D.D. Roby, D.P. Craig, S. Adamany, J. Adkins, and D.E. Lyons. 2002. Colony size and diet composition of piscivorous waterbirds on the lower Columbia River: Implications for losses of juvenile salmonids to avian predation. Transactions of the American Fisheries Society 131:537-550.

Collis, K., D.D. Roby, P.J. Loschl, Y. Suzuki, A. Munes, J. Mulligan, E. Schniedermeyer, A.F. Evans, B. Cramer, A. Turecek, and Q. Payton. 2016. Implementation of the Inland Avian Predation Management Plan. 2015 Final Annual Report. Submitted to the U.S. Army Corps of Engineers – Walla Walla District and the U.S. Bureau of Reclamation. Available on-line at www.birdresearchnw.org.

Collis, K., D.D. Roby, P.J. Loschl, Y. Suzuki, K. Kelly, E. Schniedermeyer, A.F. Evans, B. Cramer, A. Turecek, and Q. Payton. 2017. Implementation of the Inland Avian Predation Management Plan. 2016 Final Annual Report. Submitted to the U.S. Army Corps of Engineers – Walla Walla District and the U.S. Bureau of Reclamation. Available on-line at www.birdresearchnw.org.

Collis, K., A.F. Evans, B. Cramer, A. Turecek, Q. Payton, K. Kelly, F. Stetler, S. Fitzmaurice, and P.J. Loschl. 2018. Implementation of the Inland Avian Predation Management Plan. 2017 Final Annual Report. Submitted to the U.S. Army Corps of Engineers – Walla Walla District and the U.S. Bureau of Reclamation. Available on-line at www.birdresearchnw.org.

Collis, K., A.F. Evans, B. Cramer, A. Turecek, Q. Payton, R. Bhatt, T. Kaufman, A. Gibson, and T. Lawes. 2019. Implementation of the Inland Avian Predation Management Plan. 2018 Final Annual Report. Submitted to the U.S. Army Corps of Engineers – Walla Walla District and the U.S. Bureau of Reclamation. Available on-line at www.birdresearchnw.org.

Evans, A.F., N.J. Hostetter, D.D. Roby, K. Collis, D.E. Lyons, B.P. Sandford, R.D. Ledgerwood, and S. Sebring. 2012. Systemwide evaluation of avian predation on juvenile salmonids from the Columbia River based on recoveries of passive integrated transponder tags. Transactions of American Fisheries Society, 141:975-989.

Evans, A.F., N.J. Hostetter, K. Collis, D.D. Roby, and F.J. Loge. 2014. Relationship between juvenile fish condition and survival to adulthood in steelhead. Transactions of the American Fisheries Society 143:899-909.

Evans, A.F., Q. Payton, A. Turecek, B.M. Cramer, K. Collis, D.D. Roby, P.J. Loschl, L. Sullivan, J. Skalski, M. Weiland, and C. Dotson. 2016. Avian predation on juvenile salmonids: Spatial and temporal analysis based on acoustic and Passive Integrated Transponder tags. Transactions of the American Fisheries Society 145:860-877.

Evans, A.F., Q. Payton, B.M. Cramer, K. Collis, N.J. Hostetter, D.D. Roby, and C. Dotson. 2019a. Cumulative effects of avian predation on Upper Columbia River Steelhead. Transactions of the American Fisheries Society 148:896-913.

Evans, A., Q. Payton, B. Cramer, K. Collis, N. Hostetter, and D. Roby. 2019b. System-wide effects of avian predation on the survival of Upper Columbia River steelhead: Implications for predator management. Final Report submitted to Grant County Public Utility District No. 2 and the Priest Rapids Coordinating Committee. Available on-line: www.birdresearchnw.org.

Hostetter, N.J., A.F. Evans, B.M. Cramer, K. Collis, D.E. Lyons, and D.D. Roby. 2015. Quantifying avian predation on fish populations: Integrating predator-specific deposition probabilities in tag–recovery studies. Transactions of the American Fisheries Society 144:410-422.

Hostetter N.J., B. Gardner, A.F. Evans, B.M. Cramer, Q. Payton, K. Collis, and D.D. Roby. 2018. Wanted dead or alive: a state-space mark-recapture-recovery model incorporating multiple recovery types and state uncertainty. Canadian Journal of Fisheries and Aquatic Sciences 75:1117-1127.

NOAA (National Oceanic and Atmospheric Administration). 2014. Updated status of federally listed ESUs of West Coast salmon and steelhead. Available at on-line at http://www.nwr.noaa.gov/Publications/Biological-Status-Reviews/Salmon.cfm.

Payton, Q., A.F. Evans, and B. Cramer. 2016. Effects of biotic and abiotic factors on juvenile steelhead survival in the Middle Columbia River, 2008-2015. Final Report submitted to the Grant County Public Utility District and the Priest Rapids Coordinating Committee.

Payton, Q., N.J. Hostetter, and A.F. Evans. 2019. Jointly estimating survival and mortality: Integrating recapture and recovery data from complex multiple predator systems. Environmental and Ecological Statistics 26:107-125.

Roby, D.D, K. Collis, P.J. Loschl, J. Tennyson, Y. Suzuki, A. Munes, S. Toomey, A.F. Evans, B. Cramer, A. Turecek, and Q. Payton. 2015. Implementation of the Inland Avian Predation Management Plan. 2014 Final Annual Report. Submitted to the U.S. Army Corps of Engineers – Walla Walla District and the U.S. Bureau of Reclamation. Available on-line at www.birdresearchnw.org.

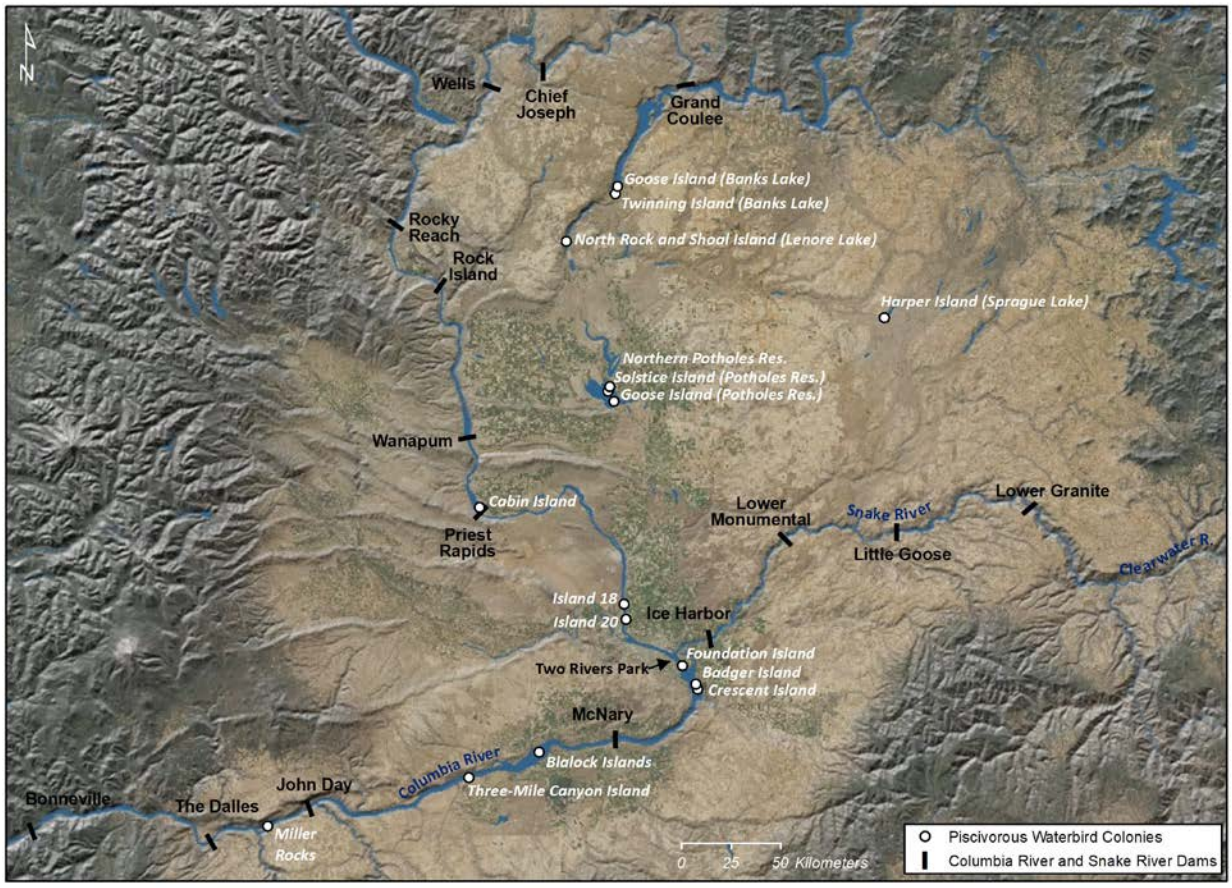
Roby, D.D, K. Collis, D.E. Lyons, T. Lawes, Y. Suzuki, P.J. Loschl, K. Bixler, E. Hanwacker, J. Mulligan, E. Schniedermeyer, A.F. Evans, B. Cramer, A. Turecek, Q. Payton, and M. Hawbecker. 2016. Evaluation of Foraging Behavior, Dispersal, and Predation on ESA-listed Salmonids by Caspian Terns Displaced from Managed Colonies in the Columbia Plateau Region. 2015 Final Annual Report. Submitted to the Grant County Public Utility District and the Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

Roby, D.D, K. Collis, D.E. Lyons, T. Lawes, Y. Suzuki, P.J. Loschl, K. Bixler, K. Kelly, E. Schniedermeyer, A.F. Evans, B. Cramer, J. Morella, A. Turecek, Q. Payton, and M. Hawbecker. 2017. Evaluation of Foraging Behavior, Dispersal, and Predation on ESA-listed Salmonids by Caspian Terns Displaced from Managed Colonies in the Columbia Plateau Region. 2016 Final Annual Report. Submitted to the Grant County Public Utility District and the Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

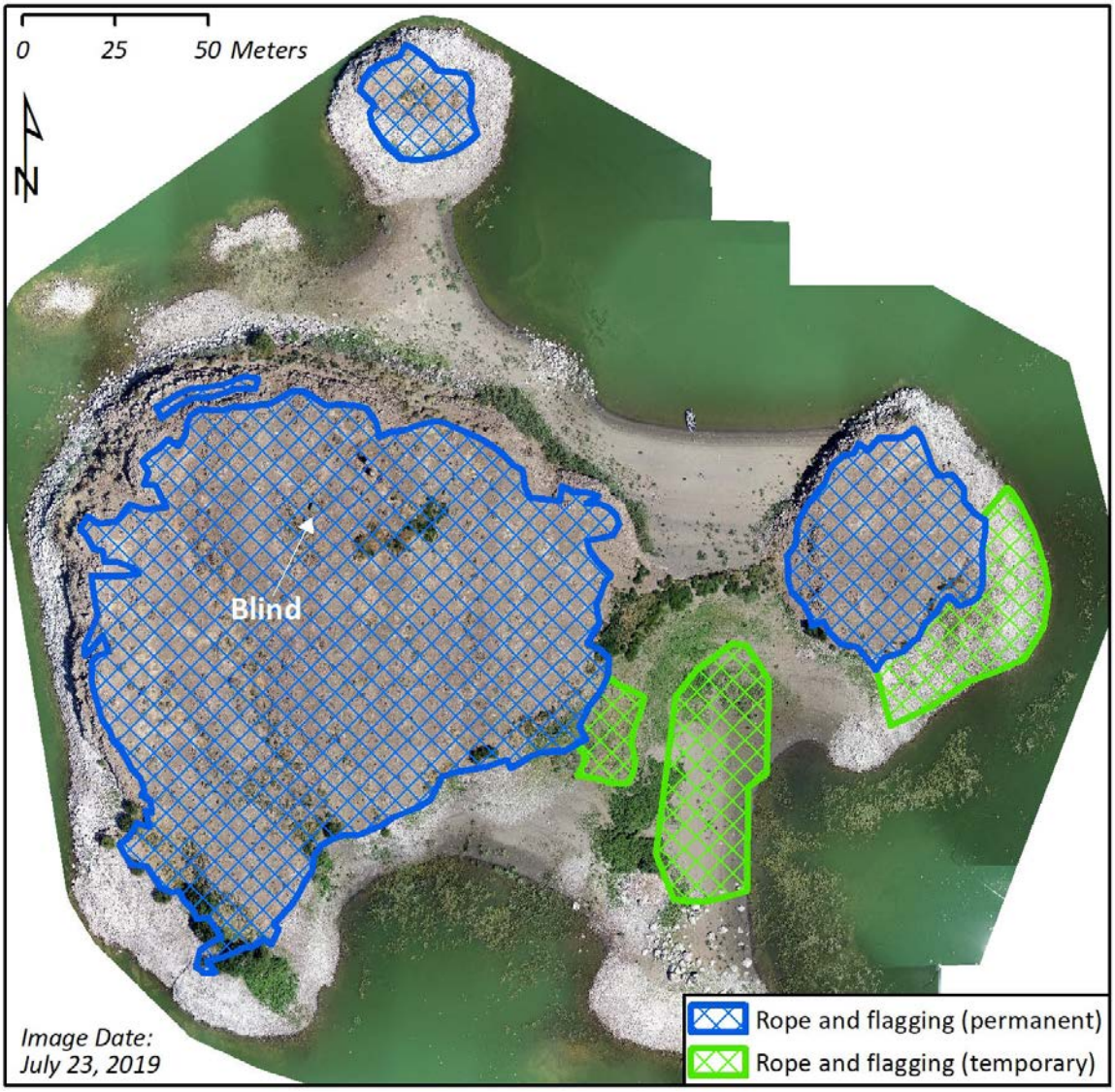
USACE (U.S. Army Corps of Engineers). 2014. Inland Avian Predation Management Plan Environmental Assessment. U.S. Army Corps of Engineers, Walla Walla District, Northwestern Division. January 2014. Available online at http://www.nww.usace.army.mil/Missions/Projects/InlandAvianPredationManagementPlan.aspx.

Winkler, D.W. 1996. California gull (*Larus californicus*), version 2.0. *In* The Birds of North America. *Edited by* A. Poole. Cornell Lab of Ornithology, Ithaca, New York.

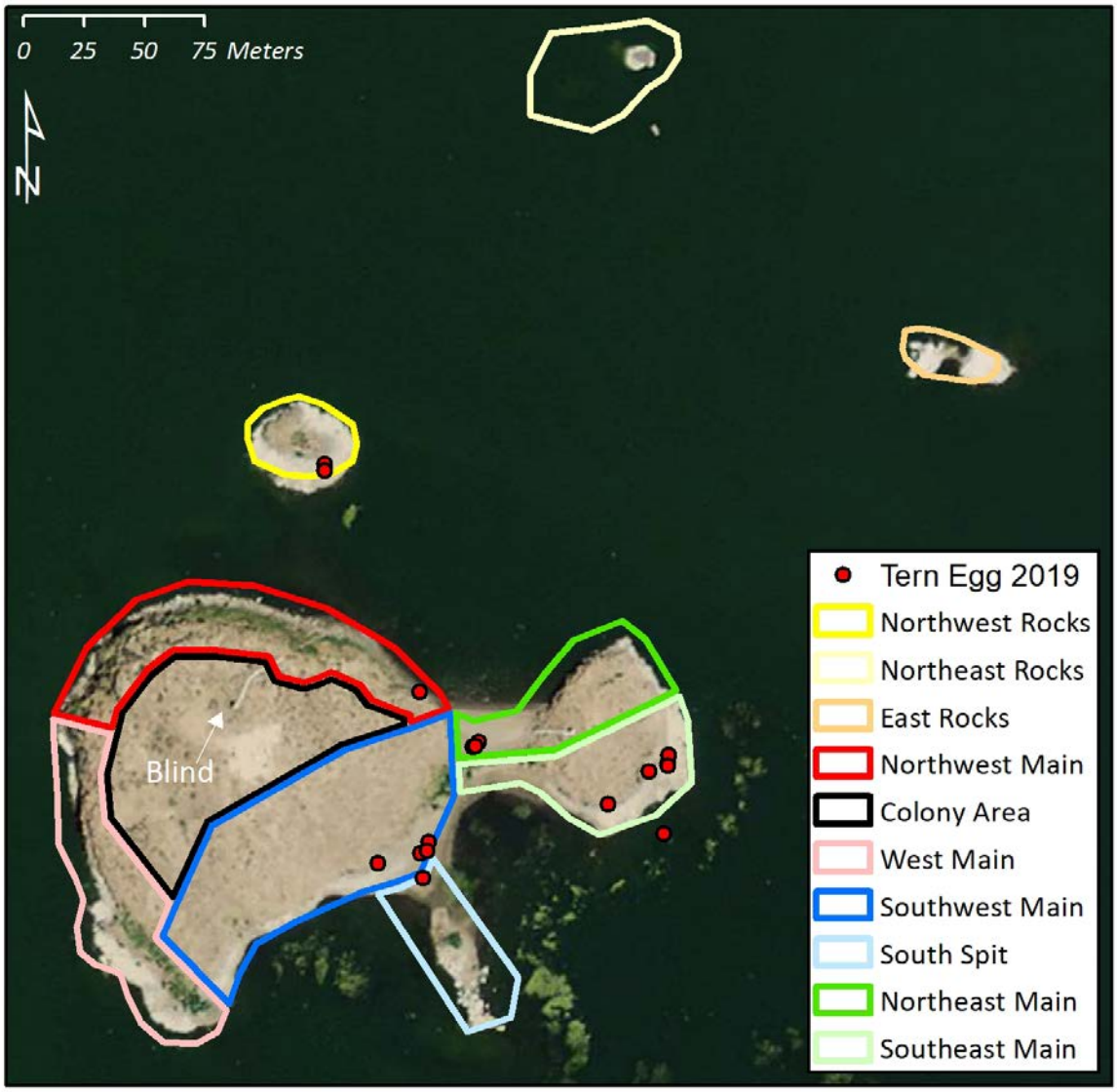
MAPS



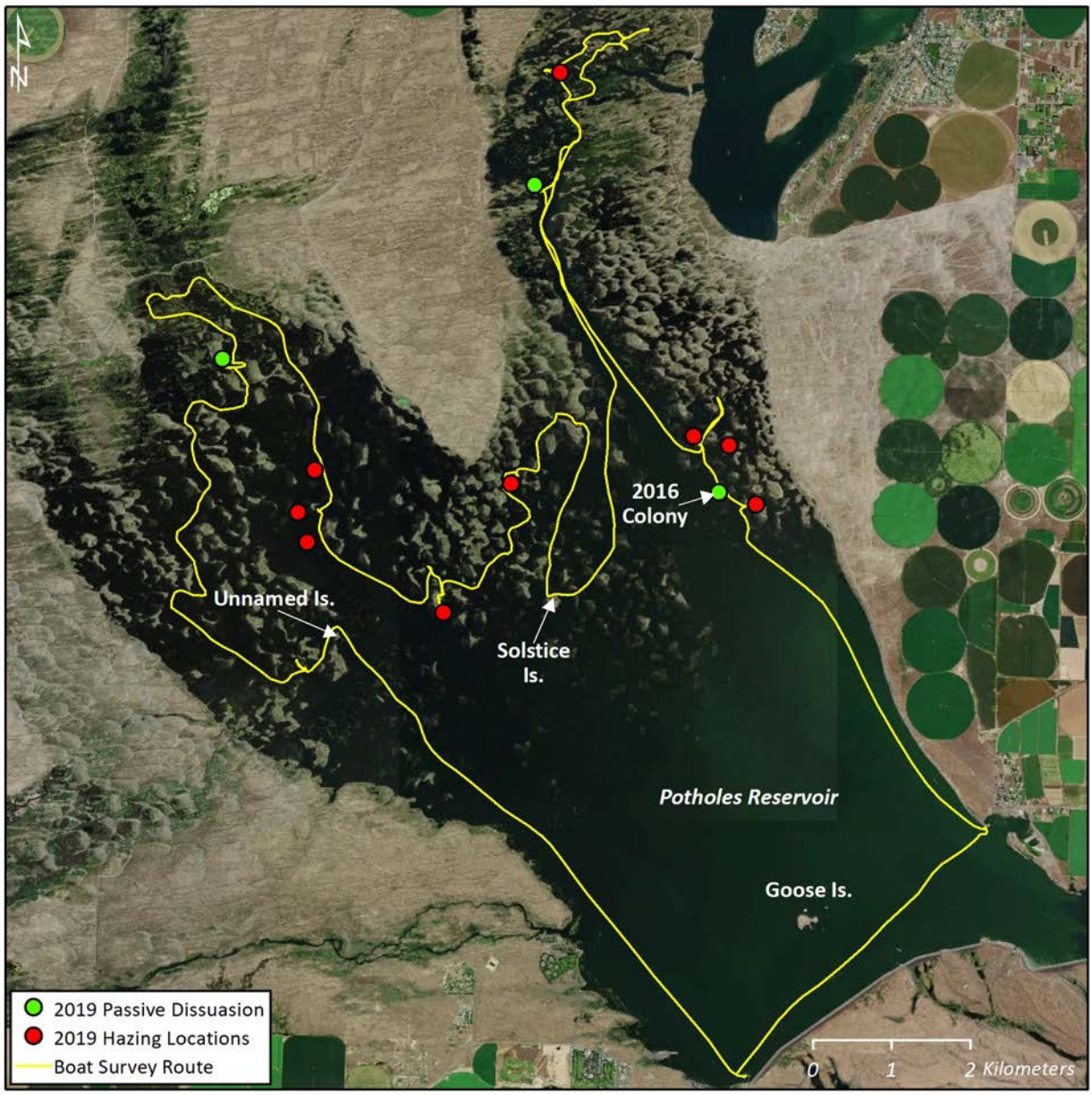
Map 1. Study area in the Columbia Plateau region in 2019.



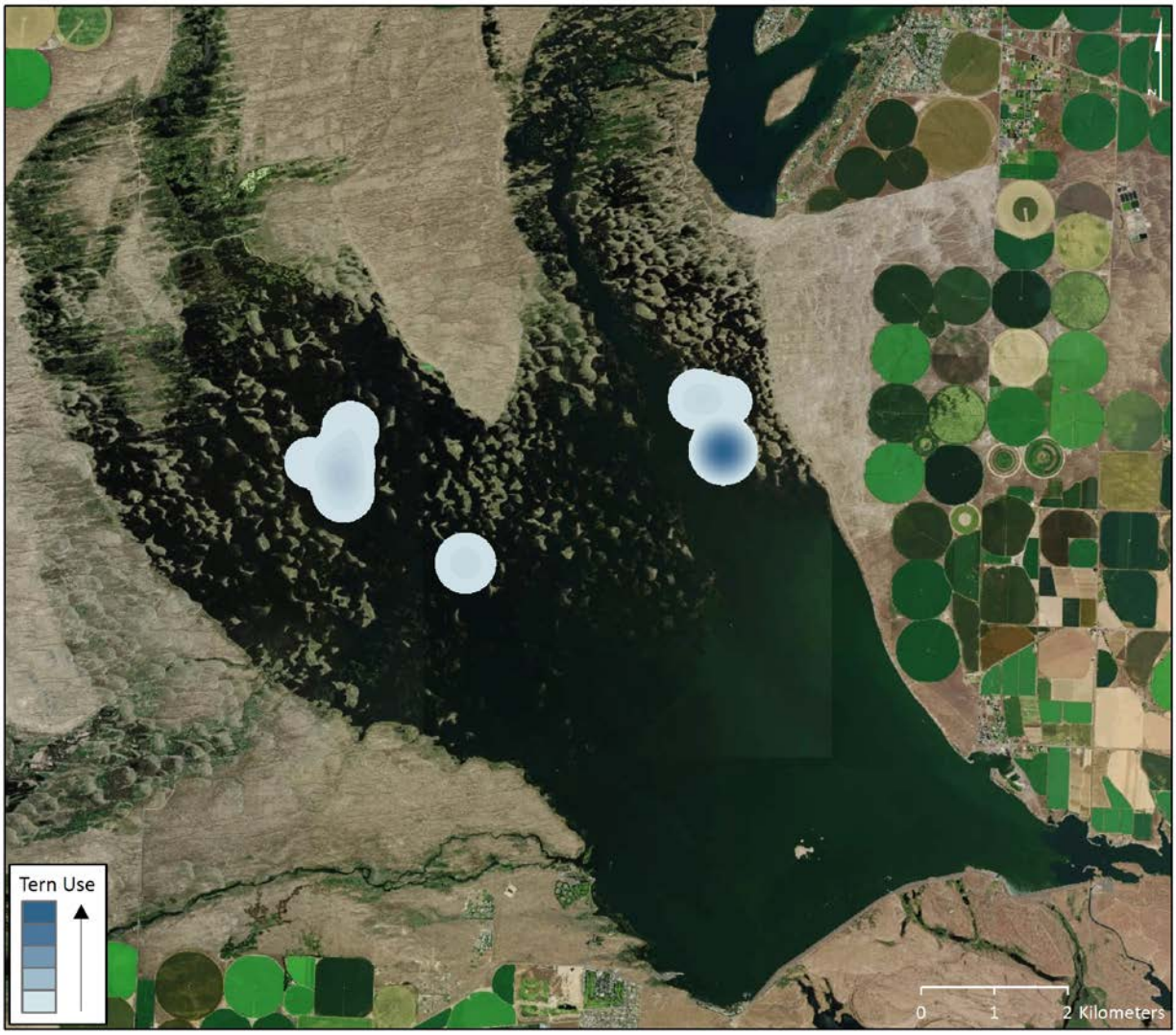
Map 2. Passive nest dissuasion arrays installed on Goose Island in 2019. Permanent nest dissuasion consisted of concrete blocks, stakes, rope, and flagging and was assembled prior to the breeding season. Temporary nest dissuasion (i.e. bamboo stakes put directly in the ground, rope, and flagging) was installed prior to and during the breeding season as the reservoir levels receded exposing shoreline habitat for prospecting terns. Photo was taken in late July, after reservoir levels had dropped from what was observed at the onset of the breeding season (April).



Map 3. Active dissuasion and survey locations on Goose Island and nearby rocky islets, Potholes Reservoir in 2019. Red dots are locations where Caspian tern eggs were laid and either depredated by gulls or collected under permit from the USFWS.



Map 4. Historical Caspian tern colonies, locations where passive dissuasion was installed in 2019 to prevent nesting, tern hazing locations, and approximate boat survey route used when hazing terns in northern Potholes Reservoir.



Map 5. Caspian Tern use of northern Potholes Reservoir in 2019.

FIGURES

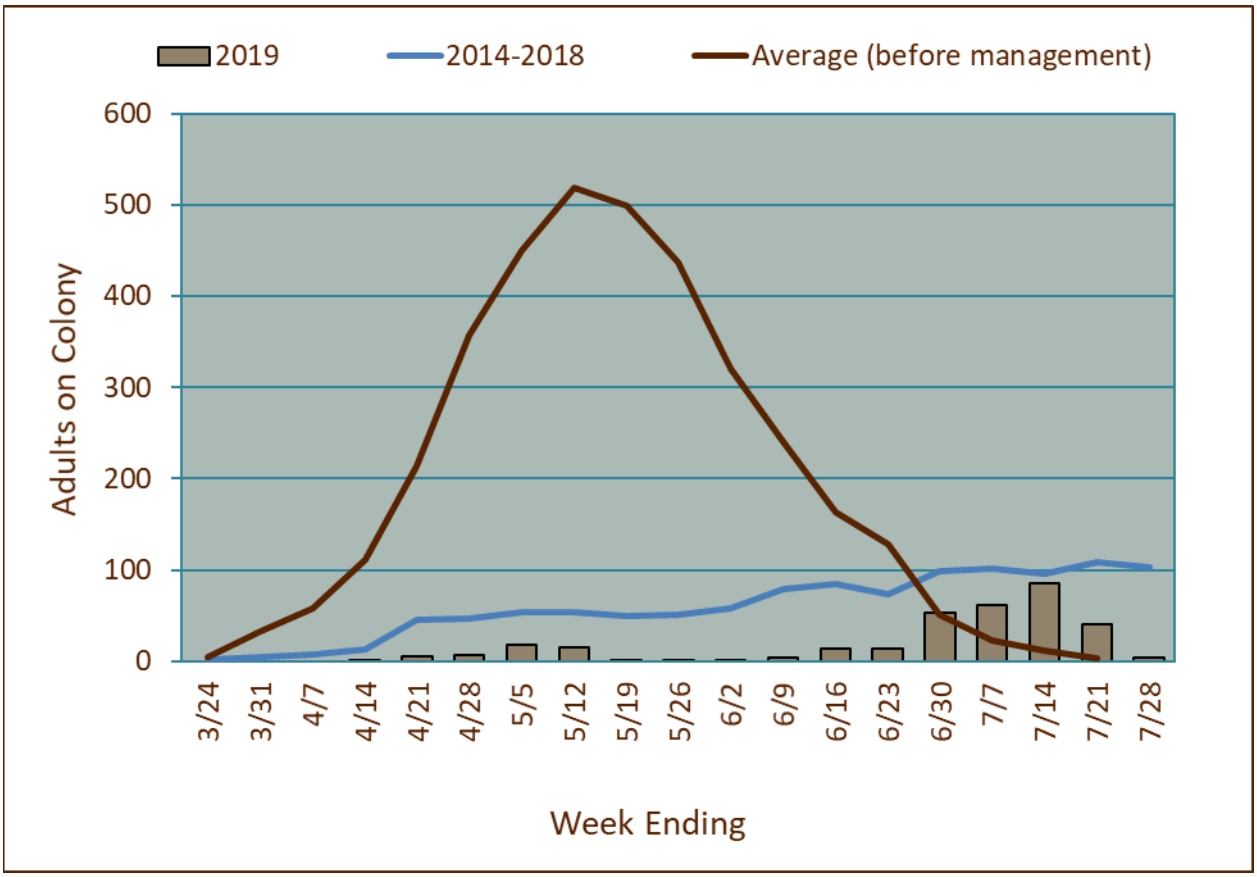


Figure 1. Estimates from the ground of the average number of adult Caspian terns on Goose Island and the surrounding islets in Potholes Reservoir, by week, before (2010-2013) and during (2014-2018, 2019) tern management at Goose Island.

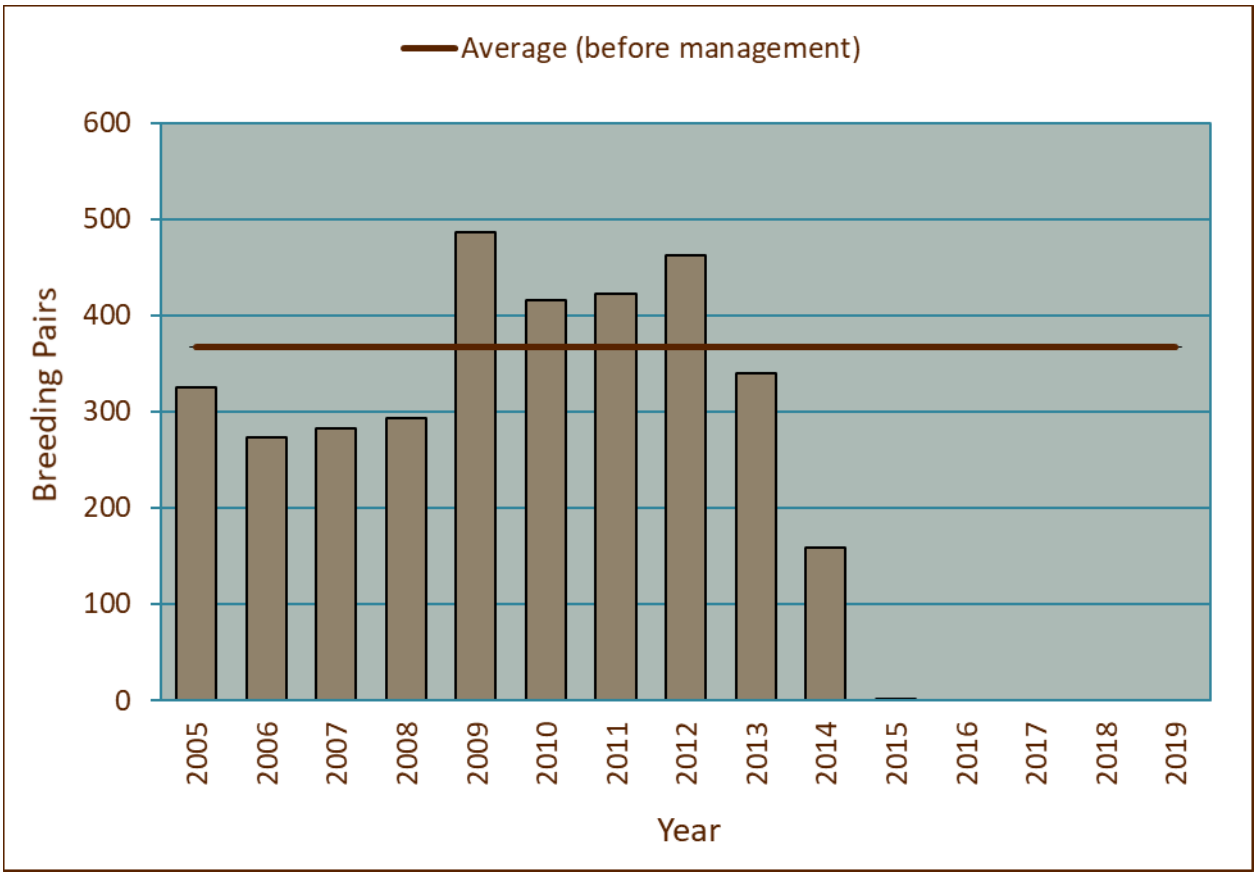


Figure 2. Size of the Caspian tern breeding colony (number of breeding pairs) on Goose Island and the surrounding islets in Potholes Reservoir before (2005-2013) and during (2014-2019) tern management in the region. Caspian terns did not nest on Goose Island and the surrounding islets in 2016-2019. Also, provided is the average number of breeding pairs of Caspian terns on Goose Island before management (2005-2013).

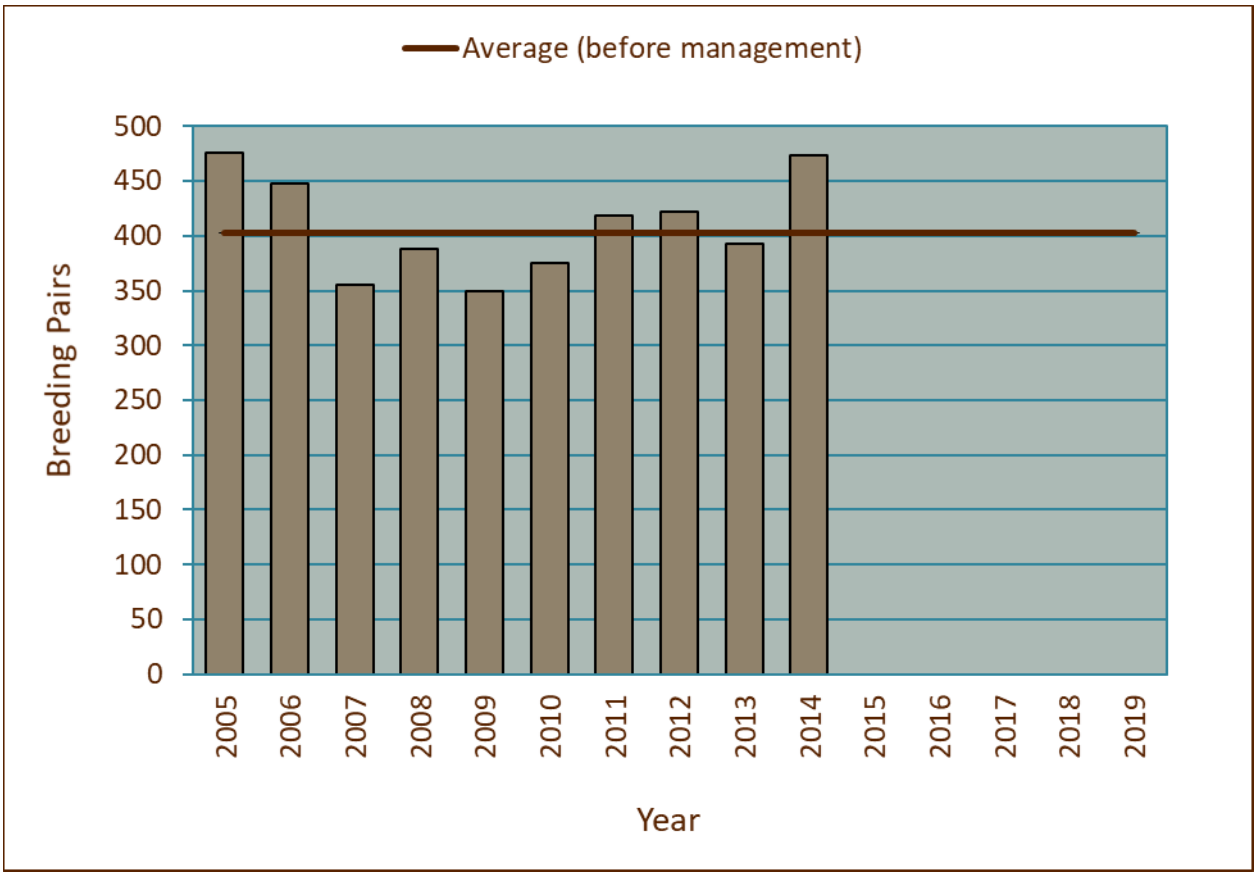


Figure 3. Size of the Caspian tern breeding colony (number of breeding pairs) on Crescent Island in the mid-Columbia River before (2005-2013) and during (2014-2019) tern management in the region. Caspian terns did not nest on Crescent Island in 2015-2019. Also, provided is the average number of breeding pairs of Caspian terns on Crescent Island before management (2005-2013).

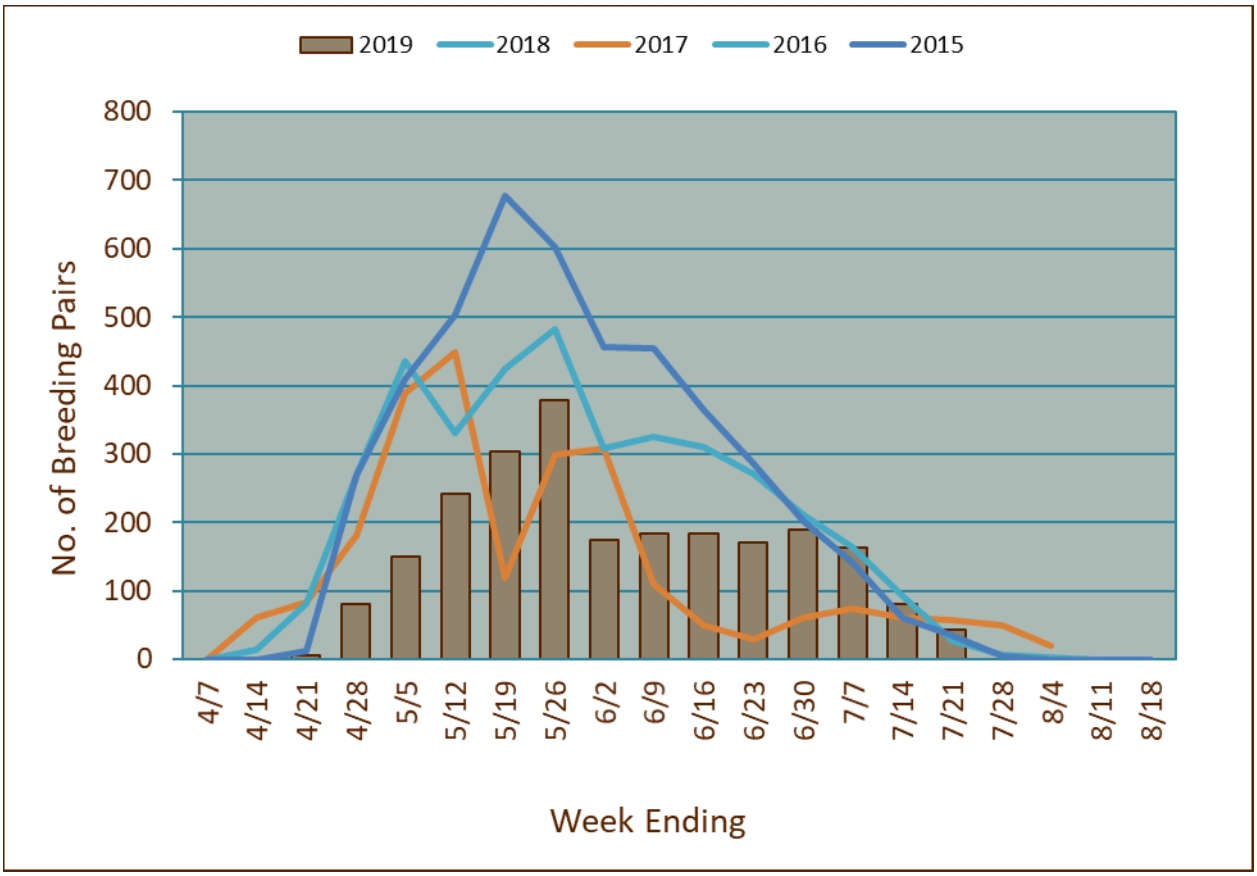


Figure 4. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock Islands in the mid-Columbia River during the 2015-2019 breeding seasons.

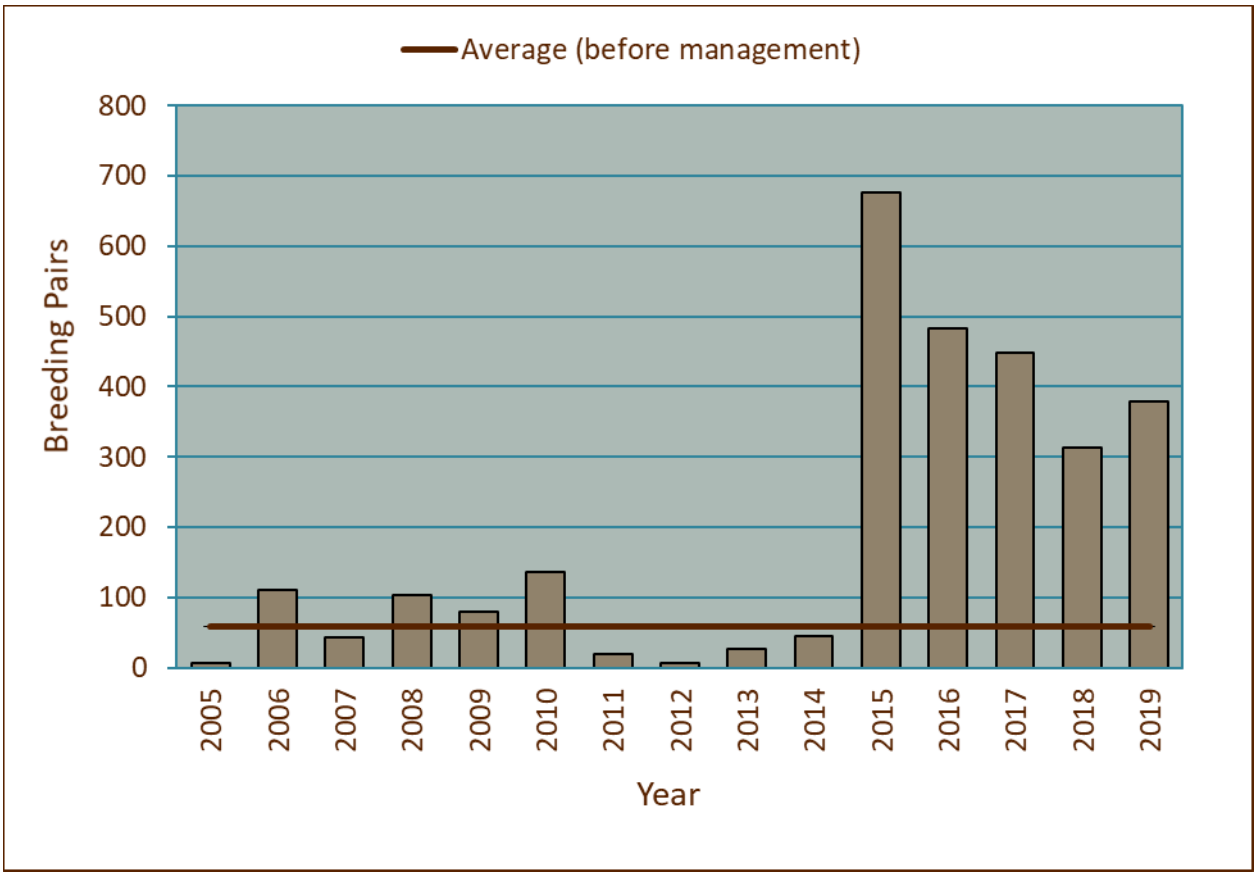


Figure 5. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock Islands in the mid-Columbia River during 2005-2019. Also, provided is the average number of breeding pairs of Caspian terns on the Blalock Islands prior to tern management in the Columbia Plateau region (2005-2013).

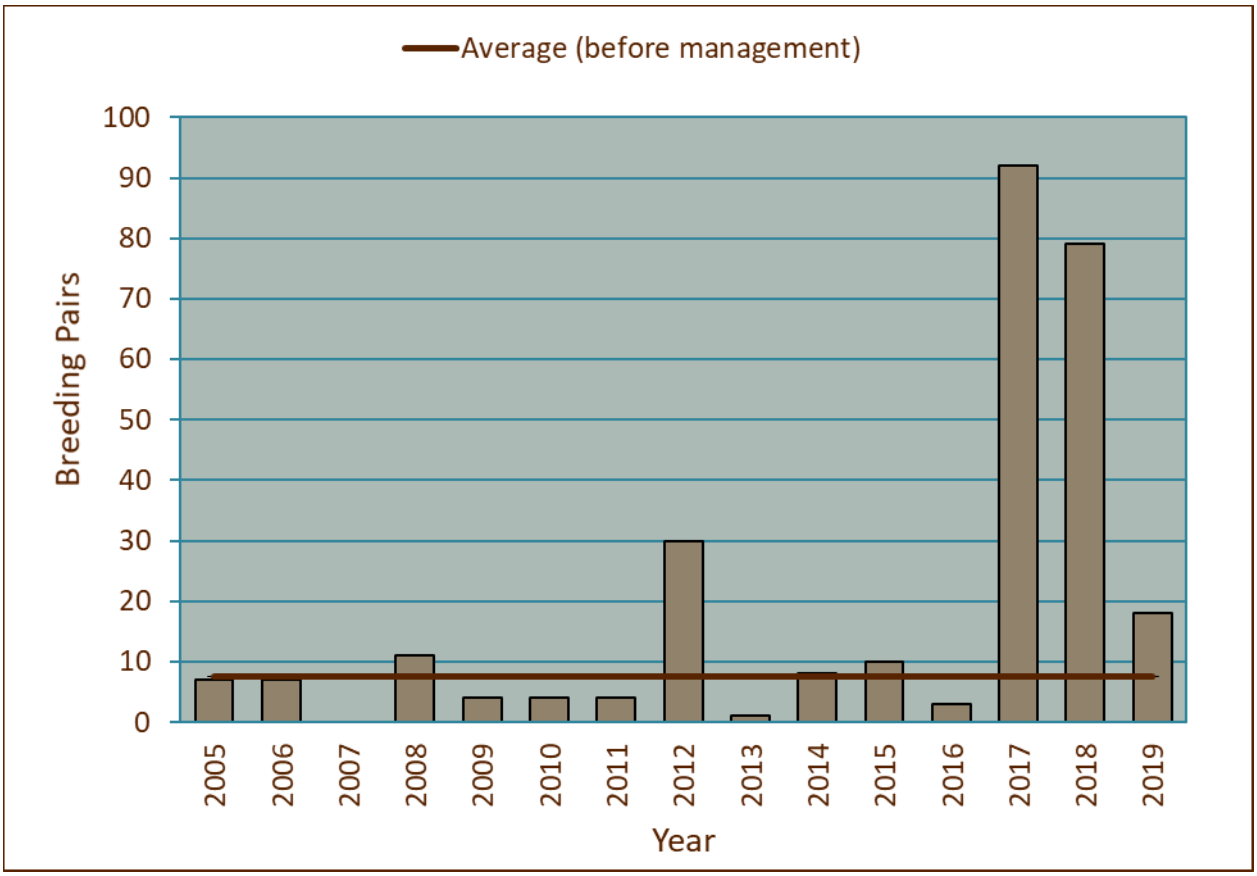


Figure 6. Size of the Caspian tern breeding colony (number of breeding pairs) at Harper Island in Sprague Lake during 2005-2019. Caspian terns did not attempt to nest on Harper Island in 2007. Also, provided is the average number of breeding pairs of Caspian terns on Harper Island prior to tern management in the Columbia Plateau region (2005-2013).

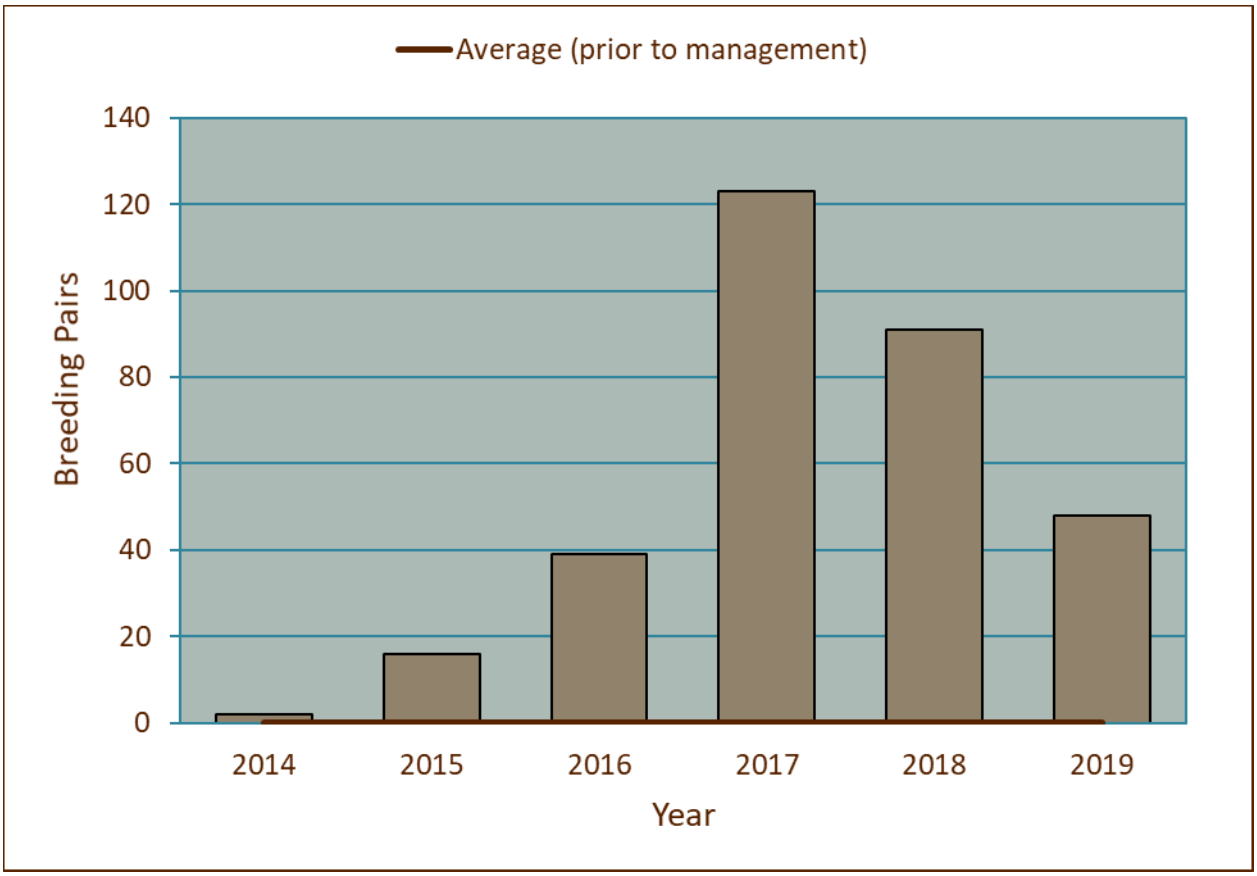


Figure 7. Size of the Caspian tern breeding colony (number of breeding pairs) at small islands in Lenore Lake during 2014-2019 (Shoal Island) and 2017-2019 (North Rock). Caspian terns did not nest on islands in Lenore Lake prior to tern management in the Columbia Plateau region (before 2014).

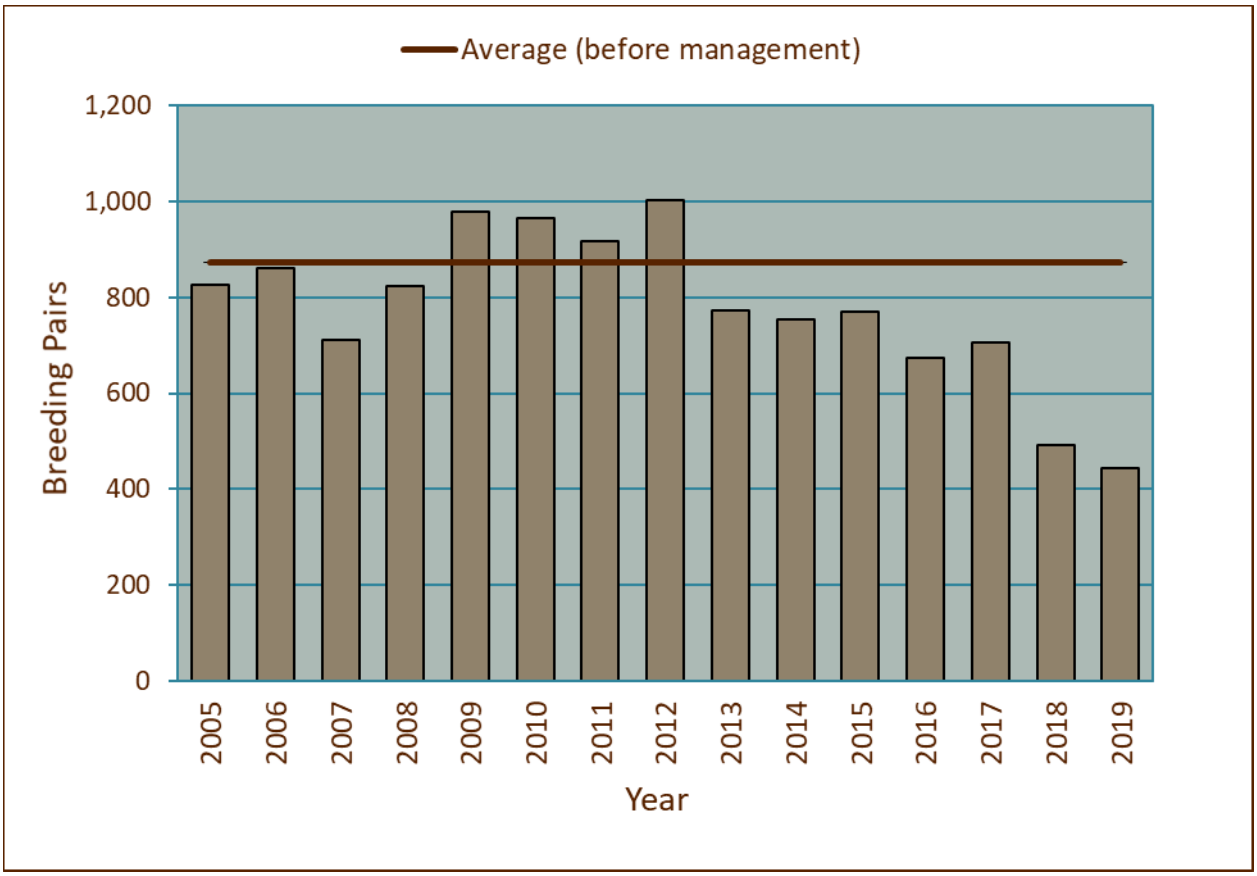


Figure 8. Total numbers of Caspian tern breeding pairs at all known colonies in the Columbia Plateau region during 2005-2019. Also, provided is the average number of breeding pairs of Caspian terns prior to tern management in the Columbia Plateau region (2005-2013).

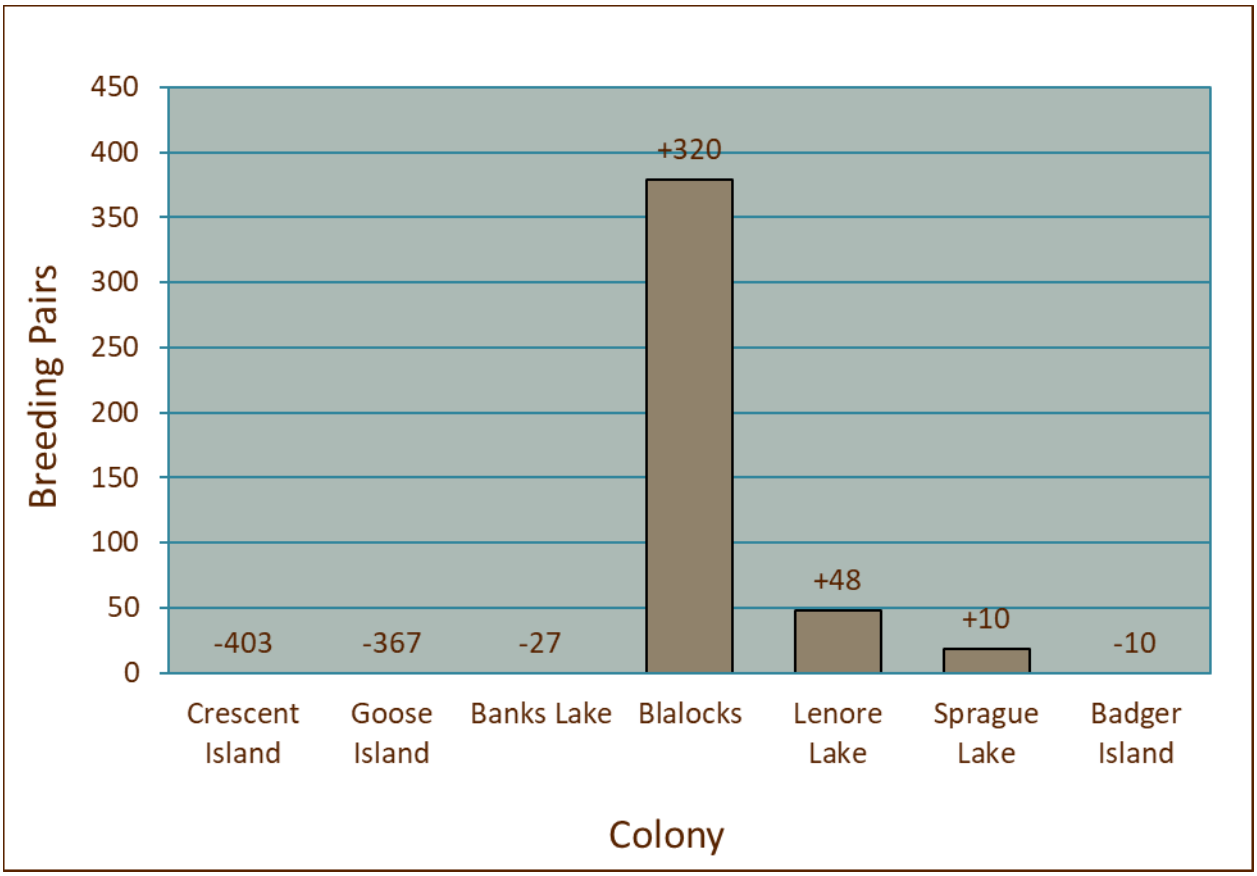


Figure 9. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the Columbia Plateau region during the 2019 breeding season. Numbers over each bar indicate the change in colony size in 2019 compared to the average colony size prior to tern management in the Columbia Plateau region (2005-2013).

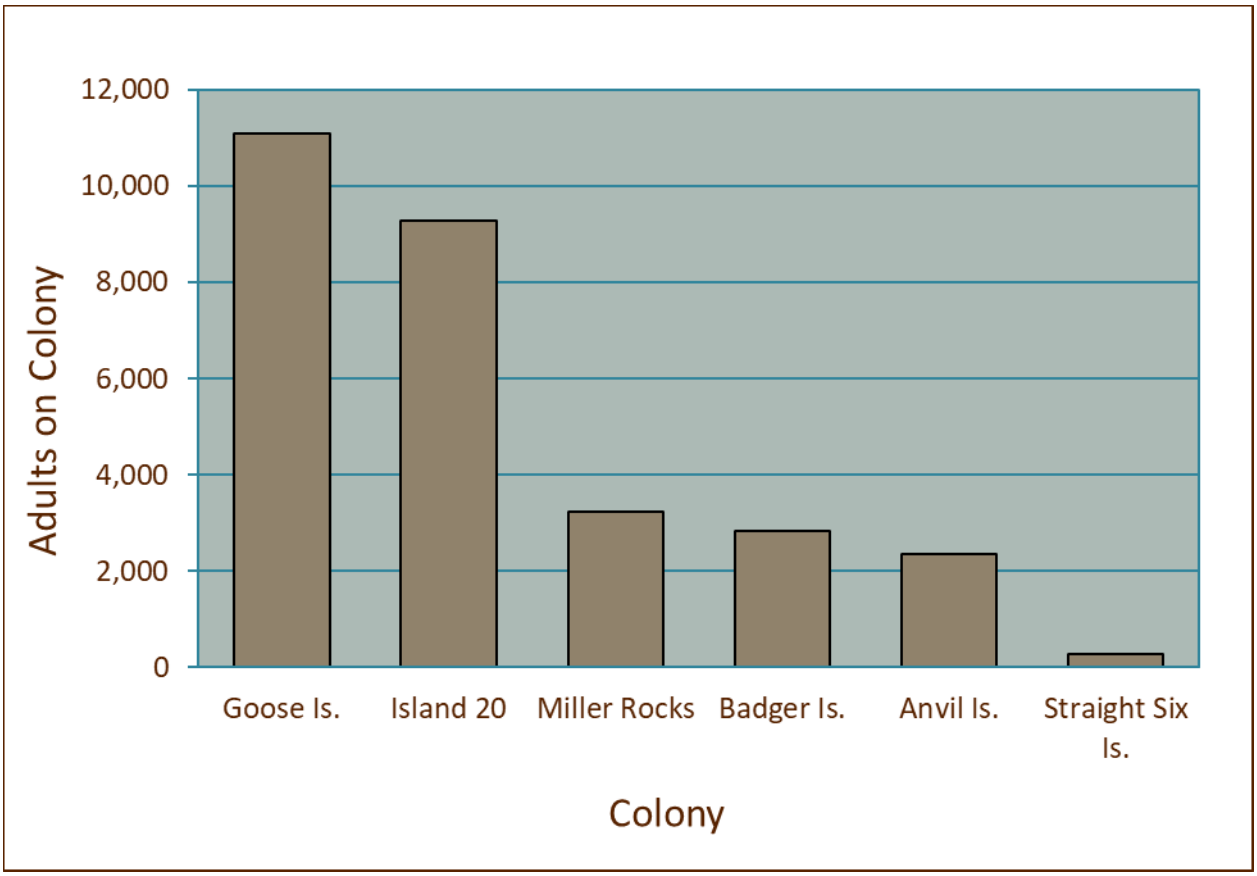


Figure 10. Sizes of gull breeding colonies (adults on colony) in the Columbia Plateau region during the 2019 breeding season. It should be noted that the colony size estimate for gulls on Badger Island is likely biased low given the survey was conducted after the peak in breeding.

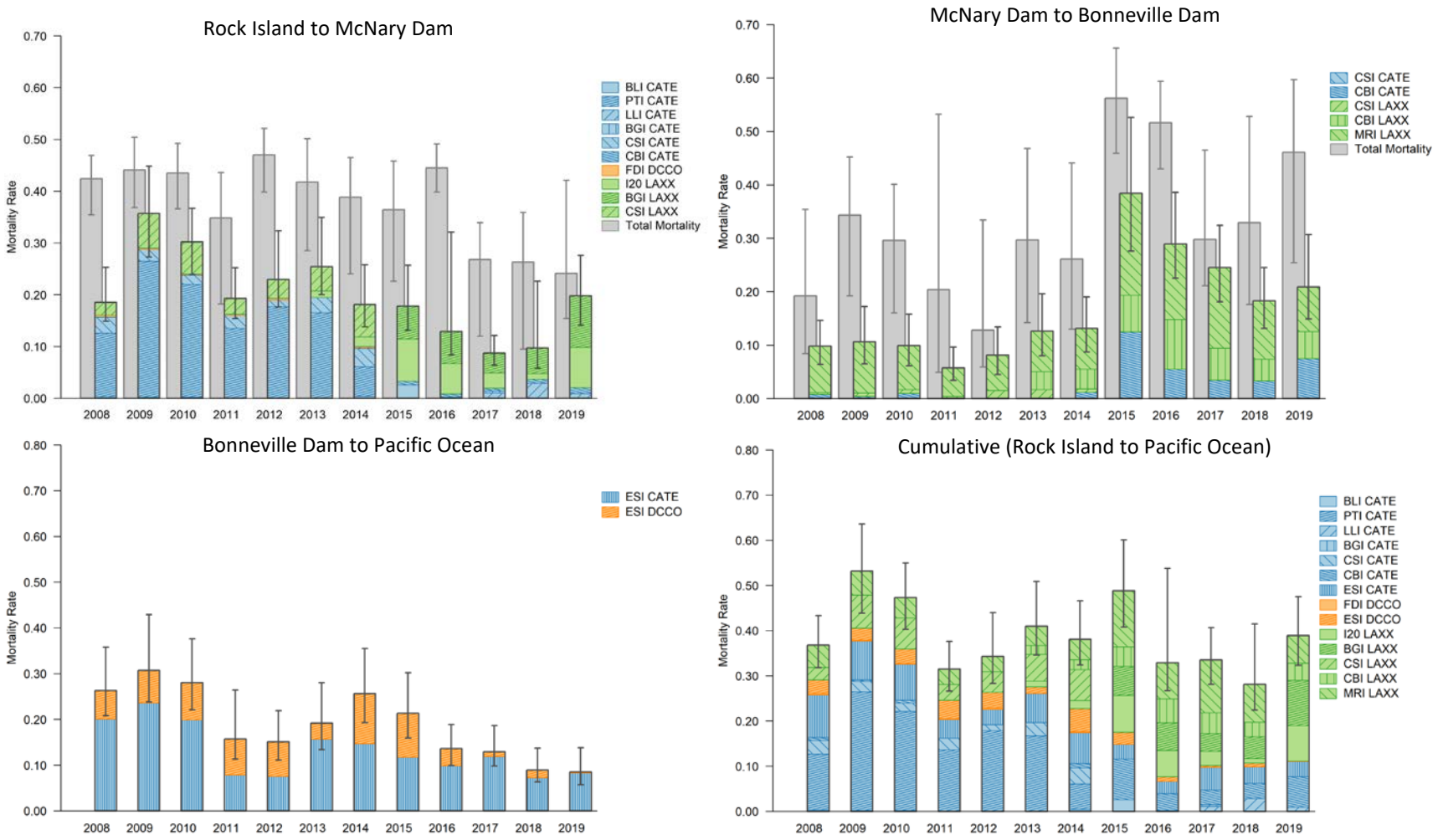


Figure 11. Estimated total mortality (grey bars) and mortality due to colonial waterbird predation (colored bars) on steelhead smolts during passage from Rock Island Dam to McNary Dam, McNary Dam to Bonneville Dam, Bonneville Dam to the Pacific Ocean. Colony locations include Banks Lake Island (BLI), Potholes Reservoir (PTI), Lenore Lake Island (LLI), Island 20 (I20), Foundation Island (FDI), Badger Island (BGI), Crescent Island (CSI), central Blalock Islands (CBI), Miller Rocks Island (MRI), and East Sand Island (ESI). Avian species include Caspian terns (CATE), double-crested cormorants (DCCO), and California and ring-billed gulls (LAXX). Error bars represent 95% credible intervals for total mortality and avian predation. Data from 2008-2018 is from Evans et al. (2019a)

TABLES

Table 1. Weekly and daily estimates of duration of active hazing (minutes) and average number of Caspian terns hazed by location on Goose Island in 2019. Map 2 identifies the locations where daily counts of Caspian terns were conducted.

Week	Weekly Hazing Effort (m)	Average Hazing Effort (m/d)	Northwest Main	Northeast Main	Southeast Main	South Spit	Southwest Main	West Main	Colony	East Rocks	Northeast Rocks	Northwest Rocks
3/31-4/7	0	0	0	0	0	0	0	0	0	0	0	0
4/8-4/14	0	0	0	0	0	0	0	0	0	0	0	0
4/15-4/21	14	4	0	0	0	0	0	0	0	4	0	0
4/22-4/28	55	14	0	2	6	0	0	0	0	8	0	0
4/29-5/5	133	22	0	2	18	0	0	0	0	5	0	0
5/6-5/12	343	49	23	10	8	0	0	1	0	12	0	0
5/13-5/19	20	10	0	0	0	0	0	0	0	7	0	2
5/20-5/26	46	15	0	2	0	0	0	0	0	0	0	0
5/27-6/02	180	30	0	0	0	1	0	0	0	3	0	0
6/3-6/9	80	16	0	0	7	3	0	0	0	3	0	0
6/10-6/16	209	35	0	0	19	10	0	0	0	10	0	4
6/17-6/23	133	27	0	0	7	8	28	0	0	3	0	5
6/24-6/30	267	38	0	1	2	30	65	0	0	0	0	33
7/1-7/7	128	26	0	0	19	45	77	0	0	0	0	18
7/8-7/14	159	28	6	0	67	30	47	0	0	0	0	0
7/15-7/21	43	14	0	0	80	7	15	0	0	0	0	0

Table 2. Caspian tern eggs discovered and either depredated or collected under permit on Goose Island and elsewhere in Potholes Reservoir in 2019. Map 2 identifies the locations where Caspian tern eggs were discovered in 2019.

Egg #	Date	Time	Location	Nest Location	Egg Fate	Nest Location LAT	Nest Location LONG
1	4/29/2019	9:12	Goose Island	North Beach	Depredated	46.98581	-119.309509
2	5/3/2019	18:12	Goose Island	SE Main	Collected	46.985752	-119.308478
3	5/4/2019	10:38	North Potholes	2016 Colony	Collected	47.03451	-119.3268
4	5/5/2019	19:01	Goose Island	SE Main	Collected	46.985783	-119.308472
5	5/6/2019	18:50	Goose Island	SE Main	Depredated	46.985783	-119.308472
6	5/7/2019	8:55	Goose Island	SE Main	Depredated	46.98549	-119.308485
7	5/7/2019	8:55	Goose Island	SE Main	Depredated	46.985744	-119.308477
8	5/9/2019	14:35	Goose Island	NW Main	Depredated	46.985991	-119.309834
9	5/10/2019	18:05	Goose Island	N. Beach	Depredated	46.9857911	-119.3095399
10	5/10/2019	18:05	Goose Island	N. Beach	Depredated	46.9857945	-119.3095232
11	6/12/2019	18:02	Goose Island	SE Main	Depredated	46.9855937	-119.3087956
12	6/16/2019	17:57	Goose Island	SE Main	Collected	46.985719	-119.308579
13	6/18/2019	9:10	Goose Island	S. Beach	Collected	46.985392	-119.309807
14	6/18/2019	9:10	Goose Island	S. Beach	Collected	46.9853	-119.309788
15	6/18/2019	12:48	Goose Island	S. Beach	Collected	46.985433	-119.309763
16	6/21/2019	18:51	Goose Island	S. Beach	Collected	46.9854	-119.30977
17	6/28/2019	9:12	Goose Island	NW Rocks	Depredated	46.986826	-119.310387
18	6/28/2019	9:12	Goose Island	NW Rocks	Depredated	46.986801	-119.31039
19	7/1/2019	19:24	Goose Island	SW Main	Depredated	46.9854	-119.30977
20	7/5/2019	10:30	Goose Island	SW Main	Depredated	46.9853499	-119.3100365

Table 3. Sizes of mixed California and ring-billed gull breeding colonies (peak numbers of individuals counted) at managed sites in the Columbia Plateau region prior to (2008-2013) and during (2014-2019) management.

	Year											
Colony	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Goose Is. (Potholes Res.)	NA	13,021	NA	11,392	12,005	12,790	14,334	14,808	13,273	11,225	11,994	11,090
Crescent Is. (Columbia River)	8,567	8,575	8,108	7,108	7,187	5,707	6,404	0	0	0	0	0

Table 4. Summary of sites where Caspian terns were detected during the fixed-wing aerial survey on 3-4 May in 2019. The survey was conducted along the Columbia and Snake rivers and on the Columbia River Plateau within tern foraging range (~90 km) of the Federal Columbia River Power System. Caspian terns were not observed on Goose Island in Potholes Reservoir or Crescent Island in the mid-Columbia River during this survey.

Survey Date	Site Name	Prospective Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
Columbia Plateau (off the Columbia River)							
3-May	Lenore Lake - North Rock	Yes	76	38	Rock	Nesting	47.482942, -119.520572
3-May	Lenore Lake - Shoal Island	Yes	2	0	Rock/Gravel	Loafing	47.47993, -119.523890
3-May	Potholes Res. - 2016 Colony Site	Yes	9	0	Sand	Loafing	47.034447, -119.327110
4-May	Sprague Lake - Harper Island	Yes	34	18	Rock/Dirt	Nesting	47.248105, -118.085808
Mid-Columbia River							
3-May	Willow Lake	No	40	0	Mudflat, sand	Loafing	45.786430, -120.010173
3-May	Blalock Islands - Sand Island	Yes	12	0	Sand	Loafing	45.897132, -119.636768
3-May	Blalock Islands - Middle Island	Yes	367	226	Gravel	Nesting	45.895385, -119.646652
3-May	Blalock Islands - Long Island	Yes	226	96	Gravel	Nesting	45.895579, -119.645708
3-May	Shoreline near McNary Dam	No	29	0	Rock/Water	Loafing	45.944252 -119.294329
3-May	Walla Walla River Delta	No	17	0	Mudflat	Loafing	46.070111, -118.920233
3-May	Locke Island DWN stream Tip	Yes	144	0	Gravel/Water	Loafing	46.714503, -119.487256
Snake River							
4-May	Shoreline near Ice Harbor Dam	No	1	0	Rock/Water	Loafing	46.236635, -118.967927
4-May	Shoreline near New York Island	No	1	0	Mudflat	Loafing	46.291942, -118.809356

Table 5. Sizes of Caspian tern breeding colonies (number of breeding pairs) at both managed and unmanaged colonies in the Columbia Plateau region prior to (2005-2013) and during (2014-2019) management.

	Year														
Colony	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Goose Is. (Potholes Res)	325	273	282	293	487	416	422	463	340	159	2	0	0	0	0
Crescent Is. (Columbia River)	476	448	355	388	349	375	419	422	393	474	0	0	0	0	0
Blalock Is. (Columbia River)	6	110	43	104	79	136	20	6	26	45	677	483	449	313	379
Badger Is. (Columbia River)	0	0	0	0	0	0	33	60	0	0	0	0	41	8	0
Twinning Is. (Banks Lake)	13	23	31	27	61	34	19	22	13	67	64	6	0	0	0
Harper Is. (Sprague Lake)	7	7	0	11	4	4	4	30	1	8	10	3	92	79	18
Shoal Is. (Lenore Lake)	0	0	0	0	0	0	0	0	0	2	16	39	0	0	0
North Rock (Lenore Lake)	0	0	0	0	0	0	0	0	0	0	0	0	123	91	48
Unnamed Is. (Potholes Res.)	0	0	0	0	0	0	0	0	0	0	0	144	0	0	0
Total	**827**	**861**	**711**	**823**	**980**	**965**	**917**	**1003**	**773**	**755**	**769**	**675**	**705**	**491**	**445**

Table 6. Number of 2019 migration year PIT-tagged juvenile salmonids (Chinook, sockeye, coho, and steelhead combined) recovered on bird colonies and loafing locations in the Columbia Plateau region in 2019. Piscivorous colonial waterbird species include Caspian terns (CATE), California and ring-billed gulls (LAXX), double-crested cormorants (DCCO), and American white pelican (AWPE). Mixed colonies represent a combination of these species. Numbers of recovered PIT tags were not adjusted to account for tag loss due to PIT detection and deposition probabilities (see Table 7) on each colony and thus represent minimum numbers of consumed fish by birds at each site.

Location	Rkm	Bird Species	Area Use	No. Recovered
Lenore Lake	Off-river	CATE	Breeding	270
		DCCO	Breeding	1
		Mix	Loafing	30
Hanford Island	592	Mix	Breeding	100
Island 20	549	LAXX	Breeding	1,273
Badger Island	512	LAXX [1]	Breeding	3,823
		AWPE	Breeding	95
Blalocks	441-439	CATE	Breeding	1,805
		LAXX	Breeding	718
		Mixed	Loafing	226
Preacher Island	345	Mixed	Loafing	21
Miller Rocks	331	LAXX	Breeding	1,999
Total				**10,361**

[1] *AWPE also likely deposited some tags, but the area was numerically dominated by breeding gulls*

Table 7. Detection efficiency (range during nesting season) and deposition (95% credible interval) estimates (depicted as a proportion) for smolt PIT tags on bird colonies during the 2019 breeding season. Results were used to estimate predation rates (see Tables 8-9) based on the number of tags recovered on bird colonies following the breeding season (see Table 6). Piscivorous colonial waterbird species include Caspian terns (CATE), California and ring-billed gulls (LAXX), double-crested cormorants (DCCO), and American white pelican (AWPE).

Location	Rkm	Bird Species	Detection (Range)	Deposition (95% CRI) [1]
Lenore Lake	Off-river	CATE	0.54 - 0.96	0.71 (0.51-0.89)
Island 20	549	LAXX	0.62 - 0.99	0.15 (0.11-0.21)
Badger Island	512	AWPE	0.44 - 0.60	NA
		LAXX	0.22 - 0.64	0.15 (0.11-0.21)
Blalock Islands	441-439	CATE	0.14 - 0.68	0.71 (0.51-0.89)
		LAXX	0.88 - 0.96	0.15 (0.11-0.21)
Miller Rocks	331	LAXX	0.83 - 0.84	0.15 (0.11-0.21)

[1] *Deposition estimates are those of Hostetter et al. (2015)*

Table 8. Average annual predation rates (95% credible intervals) by Caspian terns at managed colonies prior to (Pre) and following/during (Post) implementation of management actions to reduce colony size as part of the IAPMP. ESA-listed salmonid populations (ESU/DPS) from the Snake River (SR) and Upper Columbia River (UCR) with runs of spring (Sp), summer (Su), and fall (Fall) fish were evaluated. Time periods are denoted as the average of all years within a time period or data from the last three years of the management period (2017-2019). NC denotes that no colony (NC) existed during that period.

ESU/DPS	Goose Is.			North Potholes Is.			Crescent Is.		
	Pre 2007-2013	Post 2014-2019	Last 3-years 2017-2019	Pre 2007-2013	Post 2016 [1]	Last 3-years 2017-2019	Pre 2007-2014	Post 2015-2019	Last 3-years 2017-2019
SR Sockeye	< 0.1%	< 0.1%	< 0.1%	NC	< 0.1%	< 0.1%	1.5% (1.2-2.0)	< 0.1%	< 0.1%
SR Sp/Su Chinook	< 0.1%	< 0.1%	< 0.1%	NC	< 0.1%	< 0.1%	0.8% (0.7-1.0)	< 0.1%	< 0.1%
UCR Sp Chinook	2.5% (1.7-3.6)	< 0.1%	< 0.1%	NC	0.1% (0.1-0.3)	< 0.1%	0.5% (0.3-0.9)	< 0.1%	< 0.1%
SR Fall Chinook	< 0.1%	< 0.1%	< 0.1%	NC	< 0.1%	< 0.1%	1.0% (0.9-1.2)	< 0.1%	< 0.1%
SR Steelhead	< 0.1%	< 0.1%	< 0.1%	NC	< 0.1%	< 0.1%	4.5% (4.1-5.1)	< 0.1%	< 0.1%
UCR Steelhead	15.7% (14.1-18.9)	< 0.1%	< 0.1%	NC	4.1% (2.9-6.3)	< 0.1%	2.5% (2.2-2.9)	< 0.1%	< 0.1%

[1] *Colony formed in 2016 and was then actively managed during 2017-2019*

Table 9. Estimated predation rates (95% credible interval) on PIT-tagged salmonid populations by unmanaged Caspian terns (CATE) and double-crested cormorants (DCC0) nesting on islands on Lenore Lake, California and ring-billed gulls (LAXX) nesting on Island 20, gulls and America white pelicans (AWPE) nesting on Badger Island in 2019. The number (n) of PIT-tagged smolts interrogated/released at Lower Monumental Dam or Rock Island Dam are provided. Only salmonid populations (Snake River [SR], Upper Columbia River [UCR]) with > 500 PIT-tagged smolts available were evaluated.

ESU/DPS	N	Lenore Lk. CATE	Lenore Lk. DCCO	Island 20 LAXX	Badger Is. LAXX [1]	Badger Is. AWPE [2]
SR Sockeye	1,675	0.1% (0.1-0.3)	< 0.1%	0.2% (<0.1-1.5)	3.1% (0.9-8.3)	0.1% (<0.1-0.4)
SR Sp/Su Chinook	18,757	< 0.1%	< 0.1%	0.2% (0.1-0.4)	1.2% (0.6-2.1)	< 0.1%
UCR Sp Chinook	1,885	< 0.1%	< 0.1%	0.2% (0.1-1.5)	3.6% (1.1-8.8)	< 0.1%
SR Fall Chinook	7,501	< 0.1%	< 0.1%	0.2% (0.1-0.7)	1.9% (0.8-3.8)	< 0.1%
SR Steelhead	28,813	< 0.1%	< 0.1%	2.8% (1.9-4.2)	5.6% (3.9-8.4)	0.1% (<0.1-0.2)
UCR Steelhead	4,401	1.0% (0.6-1.7)	< 0.1%	7.4% (4.8-11.7)	10.9% (6.7-17.7)	< 0.1%

[1] Tags deposited by pelicans were likely included in the estimate (see Table 6 for details)

[2] No correction for deposition, rate is thus a minimum estimate of predation

Table 10. Estimated predation rates (95% credible interval) on ESA-listed (ESU/DPS) PIT-tagged salmonids by unmanaged Caspian terns (CATE) nesting at the Blalock Islands, California and ring-billed gulls (LAXX) nesting at the Blalock Islands, and gulls nesting at Miller Rocks Island. The number (n) of PIT-tagged smolts interrogated at McNary Dam are also provided. Only salmonid populations (Snake River [SR], Upper Columbia River [UCR]) with > 500 PIT-tagged smolts available were evaluated.

ESU/DPS	N	Blalock Is. CATE	Blalock Is. LAXX	Miller Rocks Is. LAXX
SR Sockeye	1,167	1.4% (0.4-3.7)	1.4% (0.3-4.2)	5.9% (2.6-11.8)
SR Spr/Sum Chinook	11,225	0.4% (0.2-0.8)	0.2% (0.1-0.5)	0.9% (0.5-1.7)
UCR Spr Chinook	2,838	0.9% (0.2-2.1)	0.3% (0.1-1.2)	2.4% (1.1-4.9)
SR Fall Chinook	3,395	1.3% (0.6-2.5)	0.3% (0.1-1.1)	3.2% (1.7-5.8)
SR Steelhead	5,878	3.0% (1.9-4.7)	1.6% (0.8-2.8)	5.1% (3.2-8.1)
UCR Steelhead	1,671	5.9% (3.4-10.0)	1.5% (0.4-3.8)	6.5% (3.4-11.8)

Table 11. Average annual predation rates (95% credible intervals) by Caspian terns nesting at unmanaged colonies prior to (Pre) and following/during (Post) implementation of management actions to reduce colony sizes at Goose and Crescent Islands. ESA-listed salmonid populations (ESU/DPS) from the Snake River (SR) and Upper Columbia River (UCR) with runs of spring (Sp), summer (Su), and fall (Fall) fish were evaluated. Time periods represent the average of all years with data during each time period or data from the last three years of the management period (2017-2019). Not all colonies were active in all years or where scanned for smolt PIT tags in all years. NA denotes that predation estimates were not available. NC denotes that no colony existed during that period.

ESU/DPS	Twinning Is.			Badger Island			Blalock Is.		
	Pre 2007-2013	Post 2014-2019	Last 3-years 2017-2019	Pre 2007-2013	Post 2014-2019	Last 3-years 2017-2019	Pre 2007-2013	Post 2014-2019	Last 3-years 2017-2019
SR Sockeye	0.2% (0-0.6)	0.2% (0-0.6)	NC	NA	NA	NA	0.2% (0.1-0.4)	1.6% (1-2.5)	1.8% (0.7-4)
SR Sp/Su Chinook	< 0.1%	< 0.1%	NC	NA	< 0.1%	< 0.1%	0.1% (0.1-0.2)	0.7% (0.5-0.9)	0.6% (0.4-0.9)
UCR Spr Chinook	0.2% (0-0.6)	0.2% (0-0.7)	NC	NA	< 0.1%	< 0.1%	< 0.1%	0.6% (0.5-0.9)	0.8% (0.5-1.3)
SR Fall Chinook	< 0.1%	< 0.1%	NC	NA	< 0.1%	< 0.1%	< 0.1%	0.7% (0.6-1.1)	0.9% (0.6-1.4)
SR Steelhead	< 0.1%	< 0.1%	NC	NA	0.4% (0.2-0.6)	0.4% (0.2-0.6)	0.5% (0.4-0.9)	3.7% (3.1-4.6)	3.1% (2.4-4.1)
UCR Steelhead	0.3% (0.2-0.5)	1.1% (0.8-1.6)	NC	NA	0.5% (0.3-0.8)	0.5% (0.3-0.8)	0.5% (0.3-0.7)	4.3% (3.6-5.6)	4.5% (3.4-6.1)

ESU/DPS	Lenore Lake Is.			Sprague Lake Is.		
	Pre 2007-2013	Post 2014-2019	Last 3-years 2017-2019	Pre 2007-2013	Post 2014-2019	Last 3-years 2017-2019
SR Sockeye	NC	0.3% (0-1.6)	0.2% (0-2.2)	< 0.1%	NA	NA
SR Sp/Su Chinook	NC	< 0.1%	< 0.1%	< 0.1%	NA	NA
UCR Spr Chinook	NC	< 0.1%	< 0.1%	< 0.1%	NA	NA
SR Fall Chinook	NC	< 0.1%	< 0.1%	< 0.1%	NA	NA
SR Steelhead	NC	< 0.1%	< 0.1%	0.2% (0.1-1.3)	NA	NA
UCR Steelhead	NC	0.7% (0.5-1.1)	0.9% (0.6-1.4)	< 0.1%	NA	NA

APPENDIX: AERIAL SURVEY RESULTS

Appendix Table 1. Results from fixed-wing aerial survey conducted on 3-4 May of piscivorous colonial waterbirds in the Columbia Plateau region in 2019. Bird species are Caspian terns (CATE), double-crested cormorants (DCCO), gull species (LAXX), American white pelicans (AWPE), great egrets (GREG), and great blue herons (GBHE). n/a means that there were no birds present at the site and n/c means that birds were present at the site, but counts are unavailable.

Date	Time	Location	Species	Count	Activity	Habitat
3 May	0736	Troutdale Towers	DCCO	n/c	Nesting	Towers
3 May	7:51	Bonneville Dam	n/a	n/a	n/a	n/a
3 May	8:11	The Dalles TDA	n/a	n/a	n/a	n/a
3 May	8:15	Is. DWNS Little Memaloose	LAXX	100	Loafing	Rock
3 May	8:17	Little Memaloose	n/a	n/a	n/a	n/a
3 May	8:19	Browne Is.	n/a	n/a	n/a	n/a
3 May	8:21	Little Miller Island	n/a	n/a	n/a	n/a
3 May	8:22	Miller Is.	LAXX	10,000	Nesting	Rock/Sand
3 May	8:26	Rufus	AWPE	4	Loafing	Gravel Bar
3 May	8:27	Gravel Bar DWNS JDA	AWPE	30	Loafing	Gravel
3 May	8:28	JDA	n/a	n/a	n/a	n/a
3 May	8:46	Willow Lake	CATE	40	Loafing	Veg/Cobble
3 May	8:46	Willow Lake	AWPE	1	Loafing	Veg/Cobble
3 May	8:48	Is. DWNS Three Mile Canyon	n/a	n/a	n/a	n/a
3 May	8:50	Three Mile Canyon	n/a	n/a	n/a	n/a
3 May	8:54	Crow Butte	n/a	n/a	n/a	n/a
3 May	8:59	Straight Six Is.	AWPE	3	Loafing	Veg/Cobble
3 May	8:59	Straight Six Is.	LAXX	200	Nesting	Veg/Cobble
3 May	9:01	Anvil Is.	LAXX	1200	Nesting	Veg/Cobble
3 May	9:03	Southern Is.	LAXX	40	Loafing	Rock/Cobble
3 May	9:04	Long Is.	CATE	200	Nesting	Gravel
3 May	9:04	Middle Is.	CATE	300	Nesting	Gravel
3 May	9:06	Little Blalock Is.	n/a	n/a	n/a	n/a
3 May	9:07	Rock Is.	LAXX	4	Loafing	Gravel
3 May	9:08	Big Blalock Is.	AWPE	3	Loafing	Gravel
3 May	9:09	Basketball Is.	n/a	n/a	n/a	n/a

Date	Time	Location	Species	Count	Activity	Habitat
3 May	9:11	Long Walk Is.	n/a	n/a	n/a	n/a
3 May	9:12	Sand Is.	GREG	22	Nesting	Trees
3 May	9:12	Sand Is.	CATE	6	Loafing	Gravel
3 May	9:12	Sand Is.	AWPE	10	Loafing	Gravel
3 May	9:12	Sand Is.	LAXX	12	Loafing	Gravel
3 May	9:17	Paterson Slough	AWPE	20	Loafing	Gravel
3 May	9:19	Gravel Bar below MCN	AWPE	48	Loafing	Gravel
3 May	9:23	Gravel Bar below MCN	AWPE	16	Loafing	Gravel
3 May	9:24	Gravel Bar below MCN	AWPE	26	Loafing	Rock
3 May	9:25	MCN	n/a	n/a	n/a	n/a
3 May	9:26	Shoreline MCN	AWPE	30	Loafing	Rock
3 May	9:26	Shoreline MCN	CATE	12	Loafing	Rock
3 May	9:26	Shoreline MCN	LAXX	70	Loafing	Rock
3 May	9:30	Warehouse Beach	LAXX	n/c	Loafing	Rock
3 May	9:31	Hat Rock	n/a	n/a	n/a	n/a
3 May	9:38	Walla Walla River Delta	CATE	18	Loafing	Bare Sand
3 May	9:38	Walla Walla River Delta	AWPE	1	Loafing	Bare Sand
3 May	9:40	Crescent Is.	LAXX	3	Loafing	Cobble
3 May	9:41	Badger Is.	AWPE	n/c	Nesting	Veg/Cobble/Sand
3 May	9:41	Badger Is.	LAXX	n/c	Nesting	Veg/Cobble/Sand
3 May	9:47	Finley Is.	LAXX	10	Loafing	Gravel
3 May	9:48	Foundation Is.	DCCO	n/c	Nesting	Trees
3 May	9:48	Foundation Is.	AWPE	5	Loafing	Gravel
3 May	9:53	Indian Is.	AWPE	1	Loafing	Gravel
3 May	9:54	Indian Is.	LAXX	30	Loafing	Gravel
3 May	9:56	Is. near Blue Bridge Pasco	n/a	n/a	n/a	n/a
3 May	9:58	Bordane Is.	AWPE	3	Loafing	Gravel
3 May	9:59	Yakima River Delta	n/a	n/a	n/a	n/a
3 May	9:59	Bateman Island	n/a	n/a	n/a	n/a
3 May	10:03	Nelson Is.	LAXX	50	Loafing	Gravel
3 May	10:04	Island 20	LAXX	n/c	Nesting	Gravel
3 May	10:04	Island 20	GREG	n/c	Nesting	Gravel
3 May	10:04	Island 20	AWPE	n/c	Loafing	Gravel

Date	Time	Location	Species	Count	Activity	Habitat
3 May	10:06	Island 19	n/a	n/a	n/a	n/a
3 May	10:07	Island 18	n/a	n/a	n/a	n/a
3 May	10:08	Johnson Is.	LAXX	1	Loafing	Gravel
3 May	10:09	Wooded Is.	GREG	9	Loafing	Gravel
3 May	10:11	Homestead Is.	AWPE	1	Loafing	Gravel
3 May	10:14	Savage Is.	n/a	n/a	n/a	n/a
3 May	10:17	Transmission Is.	GREG	1	Loafing	Gravel
3 May	10:19	Is. White Bluffs	GREG	9	Loafing	Gravel
3 May	10:19	Is. White Bluffs	LAXX	5	Loafing	Gravel
3 May	10:22	Rookery below Barbe Is.	GREG	35	Nesting	Trees
3 May	10:23	Barbe Is.	n/a	n/a	n/a	n/a
3 May	10:23	Locke Is.	AWPE	1	Loafing	Gravel
3 May	10:24	Is. DNWS Locke Is.	DCCO	3	Loafing	Gravel
3 May	10:24	Is. DNWS Locke Is.	CATE	40	Loafing	Gravel
3 May	10:25	Island A	AWPE	4	Loafing	Gravel
3 May	10:25	Island A	DCCO	75	Nesting	Trees
3 May	10:25	Island A	DCCO	40	Nesting	Trees
3 May	10:25	Island B	n/a	n/a	n/a	n/a
3 May	10:27	Gravel Is.	n/a	n/a	n/a	n/a
3 May	10:31	N. Shore Near Reactors	GREG	3	Loafing	Gravel
3 May	10:35	DCCO Roost Tree	n/a	n/a	n/a	n/a
3 May	10:36	Is. Below PRD	LAXX	4	Loafing	Gravel
3 May	10:39	Goose Is.	GBHE	8	Nesting	Trees
3 May	10:42	Desert Aire	n/a	n/a	n/a	n/a
3 May	10:47	Train Bridge DSO WAN	AWPE	3	Loafing	Cobble
3 May	1:04	Wailing Canyon	n/a	n/a	n/a	n/a
3 May	11:07	Rock Island RIS	DCCO	20	Nesting	Transmission lines
3 May	11:07	Rock Island RIS	DCCO	14	Nesting	Rock
3 May	11:09	Is. UPS RIS	DCCO	12	Loafing	Rock
3 May	12:36	Jameson Lake	n/a	n/a	n/a	n/a
3 May	12:40	Lenore	DCCO	110	Nesting	Rock
3 May	12:40	Lenore	CATE	40	Nesting	Rock
3 May	12:40	Lenore	LAXX	1200	Nesting	Rock

Date	Time	Location	Species	Count	Activity	Habitat
3 May	12:40	North Rock - Lenore	LAXX	300	Loafing	Gravel/Rock
3 May	12:40	Shoal Island - Lenore	LAXX	300	Nesting	Gravel/Rock
3 May	12:40	Shoal Island - Lenore	CATE	2	Loafing	Gravel/Rock
3 May	13:00	Crab Creek	DCCO	200	Nesting	Trees
3 May	13:00	Crab Creek	AWPE	8	Loafing	Marsh
3 May	13:15	Potholes	GREG	100	Nesting	Trees
3 May	13:31	Npot West NW6	DCCO	2	Loafing	Trees
3 May	13:35	2016 Colony Site - Potholes	LAXX	70	Loafing	Gravel
3 May	13:35	2016 Colony Site - Potholes	CATE	2	Loafing	Gravel
3 May	14:01	Scootney Reservoir	AWPE	2	Loafing	Rocks
4 May	7:29	Strawberry Is.	AWPE	50	Loafing	Gravel
4 May	7:32	Goose Lake ICE Harbor	AWPE	60	Loafing	Gravel
4 May	7:32	ICH Tailrace	AWPE	5	Loafing	Gravel
4 May	7:34	South Bank ICH	AWPE	20	Loafing	Gravel
4 May	7:34	South Bank ICH	DCCO	4	Loafing	Gravel
4 May	7:36	Dalton Lake	AWPE	25	Loafing	Gravel
4 May	7:38	Dalton Lake	GBHE	9	Nesting	Trees
4 May	7:39	Triangle Is.	AWPE	22	Loafing	Gravel
4 May	7:40	WPT 05/31/18	AWPE	10	Loafing	Gravel
4 May	7:47	East Bank	AWPE	15	Loafing	Gravel
4 May	7:50	Windust Park	n/a	n/a	n/a	n/a
4 May	7:51	LMN Tailrace	AWPE	5	Loafing	Gravel
4 May	7:51	LMN Tailrace	DCCO	2	Loafing	Gravel
4 May	7:53	LMN Forebay	AWPE	3	Loafing	Woody Debris
4 May	7:54	LMN Forebay	DCCO	3	Loafing	Channel Marker
4 May	7:58	South Bank LMN	CATE	1	In Air	in Air
4 May	7:58	South Bank LMN	AWPE	11	Loafing	Gravel
4 May	7:58	South Bank LMN	LAXX	20	Loafing	Gravel
4 May	8:02	Lyons Ferry	LAXX	20	Loafing	Wake Break
4 May	8:07	Mouth of Tucannon	LAXX	10	Loafing	Gravel
4 May	8:07	Mouth of Tucannon	AWPE	30	Loafing	Gravel
4 May	8:12	N. Bank below LGR	AWPE	40	Loafing	Gravel
4 May	8:17	N. Bank Below NY Island	AWPE	30	Loafing	Woody Debris

Date	Time	Location	Species	Count	Activity	Habitat
4 May	8:17	New York Is.	n/a	n/a	n/a	n/a
4 May	8:23	East Bank NYI	AWPE	20	Loafing	Gravel
4 May	8:23	East Bank NYI	LAXX	10	Loafing	Gravel
4 May	8:23	East Bank NYI	CATE	2	Loafing	Gravel
4 May	8:36	Almota Is.	AWPE	75	Loafing	Gravel
4 May	8:36	Almota Is.	LAXX	20	Loafing	Gravel
4 May	8:45	Granite Island	AWPE	35	Loafing	Gravel
4 May	8:52	Chief Timothy Park	GBHE	1	Nesting	Trees
4 May	8:52	Chief Timothy Park	AWPE	120	Loafing	Gravel
4 May	9:25	Harper Is. - Sprague Lake	DCCO	n/c	Nesting	Rock/Sand
4 May	9:25	Harper Is. - Sprague Lake	CATE	n/c	Nesting	Rock/Sand
4 May	9:25	Harper Is. - Sprague Lake	LAXX	n/c	Nesting	Rock/Sand
4 May	9:25	Harper Is. - Sprague Lake	GBHE	n/c	Nesting	Trees