IMPLEMENTATION OF THE INLAND AVIAN PREDATION MANAGEMENT PLAN, 2018

2018 Final Annual Report

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EXECUTIVE SUMMARY

In 2018, the U.S. Army Corps of Engineers - Walla Walla District and the U.S. Bureau of Reclamation (BOR) completed implementation of the Inland Avian Predation Management Plan (IAPMP) to reduce predation by Caspian terns (*Hydroprogne caspia*) on U.S. Endangered Species Act (ESA)-listed salmonid (*Oncorhynchus* spp.) populations from the Columbia River basin (USACE 2014). The primary objective of management in the fifth year of implementation of the plan 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 Columbia Plateau region. 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 prior to the 2018 nesting season, materials that were designed to preclude tern nesting at both locations. In addition, on Crescent Island, willows had been planted over extensive areas of the island to preclude tern nesting over the long-term. On both Goose and Crescent islands, passive dissuasion was placed over all the area 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.). Ultimately, 4.1 acres, or more than 85% of the upland area of Goose Island were covered with passive nest dissuasion materials consisting of stakes, rope, and flagging. On Crescent Island, about 2.4 acres of potential Caspian tern nesting habitat were covered with passive nest dissuasion materials consisting of fences rows of privacy fabric, as well as stakes, rope, flagging, and woody debris in 2018; additionally, all open areas on Crescent Island had been planted with willows and other native vegetation prior to the 2016 nesting season. Finally, an island in northeastern Potholes Reservoir that was used by Caspian terns for nesting in 2016 (0.15 acre) and one additional nearby island where terns were observed prospecting in 2018 (0.10 acre) were covered in passive dissuasion to prevent terns from nesting at those sites. Once Caspian terns arrived to initiate nesting, active nest dissuasion (i.e. human hazing) was used to try 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.

As was the case in 2015-2017, passive and active nest dissuasion techniques were successful in preventing all nesting and roosting by both Caspian terns and gulls in upland areas on Crescent Island during the 2018 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 use of closely-spaced fence rows of privacy fabric and willow plantings as passive nest dissuasion measures in all the suitable Caspian tern nesting habitat; fencing and willow plantings were not deployed at Goose Island due to shallow rocky soils. Another factor was the successful dissuasion of gulls from nesting on Crescent

Island during 2015-2018; 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 likely established a new colony on Badger Island located on the Columbia River just one kilometer upriver from Crescent Island in 2015-2018. 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 2015-2018 and Badger Island in 2017-2018, where Caspian terns have nested in small numbers intermittently over the last decade.

Despite the use of passive and active nest dissuasion techniques on Goose Island and elsewhere in Potholes Reservoir in 2018, some Caspian terns continued to display high fidelity to Potholes Reservoir as a nesting area in 2018, the fifth year of management at this site. This fidelity is likely due to Caspian terns nesting on Goose Island since 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 2015-2017, Caspian tern use of Goose Island for roosting and nesting in 2018 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 (under permit) of any Caspian tern eggs discovered were factors in preventing the formation of a Caspian tern colony in Potholes Reservoir in 2018. This is the third consecutive year that nest dissuasion activities initiated at Goose Island were successful in preventing Caspian terns from successfully 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 2018, egg laying by Caspian terns on Goose Island and elsewhere in Potholes Reservoir occurred between 30 April and 16 July. During this period, a total of 11 Caspian tern eggs were discovered at two different locations in Potholes Reservoir; 10 tern eggs were discovered on Goose Island and one tern egg was discovered on a previously unused island in northern Potholes Reservoir. All 11 tern eggs discovered were collected under permit. By comparison, a total of 20 Caspian tern eggs were found on Goose Island and other islands in northeastern Potholes Reservoir in 2017.

Aerial, ground, and boat-based surveys were conducted in the Columbia Plateau region to determine where Caspian terns displaced from the managed colonies in Potholes Reservoir and at Crescent Island might attempt to re-nest. In 2018, Caspian terns attempted to nest at four extant colony sites in the Columbia Plateau region that are currently unmanaged. All four of these sites have been used for breeding by Caspian terns previously, including the Blalock

Islands complex in John Day Reservoir (313 breeding pairs in 2018; up from the pre-management average [59 breeding pairs] and down from the average during the management period [393 breeding pairs]), Badger Island in McNary Reservoir (8 breeding pairs in 2018; down from the pre-management average [10 breeding pairs] and down from the average during the management period [10 breeding pairs]), Harper Island in Sprague Lake (79 breeding pairs in 2018; up from the pre-management average [8 breeding pairs] and up from the average during the management period [38 breeding pairs]), and an unnamed island in Lenore Lake (91 breeding pairs in 2018; up from the pre-management average [0 breeding pairs] and up from the average during the management period [54 breeding pairs]). The former Caspian tern colony site at Twinning Island in Banks Lake was not active in 2017-2018, with the average colony size during the pre-management and management periods both totaling 27 breeding pairs. As was the case in 2015-2017, the largest Caspian tern colony in the Columbia Plateau region was on the Blalock Islands, where 64% of all the Caspian terns in the region nested during 2018. 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 8-11 times larger during 2015-2018.

The total estimated breeding population of Caspian terns in the Columbia Plateau region during 2018 was 491 breeding pairs at four separate colonies. This represents a 44% decline in the regional breeding population size for Caspian terns compared pre-management average (873 breeding pairs), and a 28% decline when compared to the average during the management period (679 breeding pairs). Although nest dissuasion actions implemented on Goose and Crescent islands in 2018 were effective in preventing all Caspian terns from nesting at these two colonies, formerly the two largest tern colonies in the region, 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, Lenore Lake, and Harper island) when compared to pre-management averages. While smaller in 2018, the average Blalock Islands colony size during 2015-2018 (480 breeding pairs) was similar in size to the largest Caspian tern colonies recorded anywhere in the Columbia Plateau region since intensive monitoring began in 2005.

The overall goal of the IAPMP is to reduce predation on juvenile salmonids in the Columbia Plateau region at Goose and Crescent Islands while implementing adaptive management actions to limit the formation of incipient colonies within the basin, where feasible. The target metric is for a predation rate of less than 2% on any ESA-listed salmonid stock (hereafter ESA/DPS), per colony, per year. Recoveries of smolt PIT tags on Caspian tern colonies in 2018 were used to estimate predation rates and to compare smolt losses prior to and following tern management actions associated with the IAPMP. To ensure adequate 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, we intentionally PIT-tagged and released (n=7,366) steelhead smolts into the tailrace of Rock Island Dam as part of this study in 2018.

Predation rates indicated that the goal of achieving rates of less than 2% were met for most, but not all, Caspian tern colonies and ESA-listed salmonid ESUs/DPSs in 2018. Predation rates were zero or close to zero for terns nesting in Potholes Reservoir (Goose and surrounding islands) and Crescent Island due to the complete (Crescent Island) or nearly complete (Potholes Reservoir) abandonment of these colony sites in 2018. Predation rates per ESU/DPS at unmanaged Caspian tern colonies varies due to colony location as it relates to the availability of juvenile salmonids and alternative prey sources. Predation rates at the unmanaged Lenore Lake tern colony were also less than 2% per ESU/DPS, with the highest rate observed on Upper Columbia River steelhead at 0.8% (95% credible interval [CRI] = 0.4–1.7). Predation rates for the large unmanaged tern colony in the Blalock Islands, however, exceed the 2% threshold for three ESA-listed ESUs/DPSs in 2018; (1) Upper Columbia River steelhead at 2.9% (95% CRI = 1.5–5.2), (2) Snake River steelhead at 2.5% (95% CRI = 1.4–4.5), and (3) Snake River sockeye at 2.0% (95% CRI = 0.4–6.1). Due to a lack of access to the colony site following the nesting season, predation rate estimates were not available for Caspian terns nesting on Harper Island in Sprague Lake in 2018. Based on limited data from years past, Caspian terns nesting on Harper Island forage on juvenile salmonids in lower Snake River but impacts by the colony in 2018 were presumably less than 2% per ESA-listed salmonid population based on the relatively small number of terns (79 breeding pairs) that nested on Harper Island in 2018. Predation rate estimates at the Badger Island tern colony were also not available in 2018, but impacts were presumably close to zero given the small number (8 pairs) and brief (approximately one week) existence of a colony on Badger Island in 2018.

Based on a comparison to historic predation rates by Caspian terns nesting in the Columbia Plateau region during 2007–2017, impacts were amongst the lowest ever recorded in 2018. This was particularly true for predation on Upper Columbia River steelhead, where average pre-management predation rates of 15.7% (95% CRI = 14.1–18.9) by Goose Island terns in Potholes Reservoir were reduced to < 0.1% in 2018. Adaptive management at incipient colony sites in northern Potholes Reservoir also reduced or eliminated predation on Upper Columbia River steelhead from 4.1% (95% CRI = 2.9–6.3) in 2016 to < 0.1% in 2018. Historic predation rates at the unmanaged Lenore Lake tern colony were also low (≤ 1.0% per ESU/DPS), suggesting that at its current size (16 to 91 nesting pairs, per year), the colony poses only a minor threat to Upper Columbia River steelhead survival. Impacts by terns nesting at the unmanaged Blalock Island colony in 2018, however, remained above the 2% minimum goal or threshold for numerous ESUs/DPSs, as was the case during 2015–2017. Due to continued high rates of predation by Blalock Island terns, impacts to some ESA-listed ESUs/DPSs, particularly those originating from Snake River, remain as high or higher than those observed prior to implementation of management actions as part of the IAPMP.

In summary, management aimed at eliminating breeding colonies of Caspian terns on Goose Island in Potholes Reservoir and on Crescent Island in McNary Reservoir, formerly the largest breeding colonies for the species in the Columbia Plateau region, were successful in 2018. Consequently, predation on juvenile salmonids by Caspian terns nesting at these two colony sites was effectively eliminated. Numbers of breeding Caspian terns in the Columbia Plateau region have declined from pre-management levels due to the management of colonies on

Goose and Crescent islands, with the regional population size declining by 44% in 2018, the most appreciable decline since the onset of management in 2014. However, based on opportunistic resightings of banded Caspian terns in previous years, many terns that were displaced from colonies on Goose and Crescent islands have remained in the region, and have attempted to nest at unmanaged colony sites. Most notable has been the post-management increase in the size of the formerly small breeding colony in the Blalock Islands. Caspian terns nesting in the Blalock Islands during 2015-2018 have consumed sufficient numbers of juvenile salmonids to at least partially off-set reductions in smolt consumption due to tern management at Goose and Crescent islands. Nesting habitat for Caspian terns at the Blalock Islands remains heavily dependent on water levels, with tern nesting habitat typically only being available when reservoir levels are below full reservoir levels. Changes in water levels due to weather related events (e.g., high spring flows and/or high wind events) have occurred that limit colony size and productivity at this site. Based on results collected during this five-year study (2014-2018), 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. The adaptive management objective of the IAPMP, to limit predation on ESA-listed salmonid stocks at other colonies in the Columbia Plateau region to less than 2%, will not be realized until the size of the Caspian tern colony at the Blalock Islands is reduced from its current size and there are no further substantive increases in the colony size at other tern colonies in the Columbia Plateau region.

PROJECT OBJECTIVES

The primary objectives of this study in 2018 were to (1) implement components of the Inland Avian Predation Management Plan (IAPMP; USACE 2014), including adaptive management actions, in order to dissuade Caspian terns from nesting on Crescent Island, Goose Island, and elsewhere in Potholes Reservoir and (2) monitor and evaluate the efficacy of those management components and actions at both the colony- and system-level, including measuring changes in (a) Caspian tern nesting distribution and colony size in the Columbia Plateau region (*Map 1*), as well as (b) predation impacts of Caspian terns on ESA-listed juvenile salmonids from the Snake and Columbia rivers.

To address Objective 1 we sought to (a) dissuade all Caspian terns from nesting using passive measures (i.e. stakes, rope, and flagging) at nest sites in Potholes Reservoir and a combination of silt fences, stakes, rope, flagging, woody debris, and willow *(Salix* spp.) plantings on Crescent Island) prior to the initiation of nesting activities by gulls (California gulls [*L. californicus*] and ring-billed gulls [*L. delawarensis*]) and Caspian terns at each island; (b) test the feasibility of planting native grass and shrub seeds in plots on Goose Island to determine the efficacy of seed planting as a long-term sustainable passive nest dissuasion action on that island; (c) use active hazing (i.e. targeted use of human disturbance on land and from skiffs, green lasers, peregrine falcon kites) as an adaptive management technique to prevent Caspian terns and

other birds from nesting at sites in Potholes Reservoir and Crescent Island, as necessary; and (d) collect any Caspian tern eggs laid at sites in Potholes Reservoir or Crescent Island, under permit (i.e. issued by the U.S. Fish and Wildlife Service [USFWS] under the Migratory Bird Treaty Act) and in accordance with Best Management Practices (BMPs; see *Appendix A*) developed by Oregon State University and Real Time Research and approved by the Corps and Reclamation (see Collis et al. 2018).

Action effectiveness monitoring (Objective 2) included both colony-level monitoring and system-level monitoring. Colony-level monitoring was conducted in support of the IAPMP on Crescent Island, Goose Island, and elsewhere in Potholes Reservoir. Data collection at each island was conducted according to established protocols (see Roby et al. 2015a; Collis et al. 2016, 2017, 2018) and included the following colony metrics: (a) temporal and spatial distribution of Caspian terns and gulls roosting or nesting on each island; (b) daily activities (behavior) of Caspian terns and gulls, including any nesting attempts by Caspian terns; (c) seasonal attendance (counts) of roosting and nesting Caspian terns and gulls; (d) types of habitat used by roosting and nesting Caspian terns and gulls; (e) the area (acres) used by roosting and nesting Caspian terns and gulls; (f) formation of any incipient Caspian tern or gull colonies on or in the immediate vicinity of managed sites; (g) peak colony size for Caspian terns and gulls; (h) number of Caspian tern eggs laid and the disposition of those eggs; and (i) Caspian tern nesting success and nesting density, if applicable.

System-level monitoring was conducted in support of both the IAPMP (USACE 2014) and the Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006). System-level monitoring of Caspian tern colonies was carried out to determine the locations of all active historical or incipient Caspian tern breeding colonies in the Columbia Plateau region. At each Caspian tern colony that was larger than 20 breeding pairs, we measured (a) seasonal colony attendance; (b) nesting chronology and behavior; (c) habitat types used for nesting; (d) nesting area occupied; (e) peak colony size (number of breeding pairs); and (f) number of nests initiated and young fledged (i.e. nesting success), if feasible.

The over-all goal of the IAPMP is to reduce predation rates on juvenile salmonids by Caspian terns in the Columbia Plateau region to less than 2% of each ESA-listed ESU/DPS, per colony, per year (USACE 2014). We used recoveries of salmonid passive integrated transponder (PIT) tags to estimate predation rates by Caspian terns at both managed and unmanaged colonies in 2018. Estimated predation rates were then used to evaluate to what extent the overriding predation rate management goals were being met, and where additional or modified management efforts might be implemented in future years to meet those goals. To ensure adequate numbers of PIT-tagged juvenile salmonids were available for predation rate analyses in 2018, we intentionally PIT-tagged run-of-the-river Upper Columbia River steelhead – an ESA-listed population that is particularly susceptible to tern predation – at Rock Island Dam on the middle Columbia River as part of this study.

METHODS & ANALYSES

PASSIVE NEST DISSUASION

To deter Caspian terns from nesting on Crescent Island, Goose Island, and other islands in Potholes Reservoir during 2018, a network of passive dissuasion was constructed beginning in March 2018, prior to the arrival of breeding Caspian terns to the islands. The passive nest dissuasion materials and configurations differed between sites and are described in detail *below*.

Goose Island & Northern Potholes Reservoir

In 2014-2018, a matrix of concrete pier blocks, rebar, PVC pipes, ropes, and flagging were used as the primary passive nest dissuasion method on Goose Island (*Map 2*; Roby et al. 2015a; Collis et al. 2016, 2017, 2018). 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 2018, after inspection of the passive nest dissuasion materials installed on Goose Island in 2014-2016 with Corps and Reclamation staff, we determined the need for repairs and additional materials. Repair of existing materials required installing new rope across the entire dissuasion matrix and new flagging identical to that used in 2014-2017 and as described *above*. Additionally, other passive nest dissuasion materials (e.g., zip ties, PVC pipe) were replaced, as needed. After repairing materials deployed during 2014-2017, we installed new temporary nest dissuasion materials along the shoreline where seasonal inundation requires annual removal, both on Goose Island and on two unnamed islands in northeastern Potholes Reservoir (*Map 3*) used by nesting terns in 2016, and where a single egg was laid in 2018. Except for temporary passive dissuasion installed at locations in northern Potholes Reservoir, where bamboo stakes

were deployed instead of concrete blocks and rebar, we procured and installed materials identical in composition and deployment to those used on Goose Island in 2014-2017 (see *above*), ensuring the structural integrity of all passive nest dissuasion measures. Finally, we had in reserve enough quantities of all 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 other areas of Potholes Reservoir not previously covered by nest dissuasion materials. Any repairs or new construction of passive nest dissuasion materials were carried out without disturbing non-target species, in adherence to established BMPs (see *Appendix A*). Reserve materials were stored on Goose Island in an organized manner, with all excess material and debris removed from the island following the breeding season.

Deployment of passive dissuasion at Goose Island, both repaired components and newly installed, was completed prior to the onset of breeding activities by terns and gulls. 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 material, specifically the barricade tape flagging, was removed from the island following the Caspian tern breeding season.

Crescent Island

In 2015, the first year of implementation of the IAPMP at Crescent Island, fence rows were installed to create a visual barrier for any prospecting Caspian terns that might land on the ground. A series of parallel fence rows spaced 15’ apart were constructed across the former Caspian tern colony site and nearby sparsely vegetated areas, as well as in a second large, sparsely vegetated area in the southern part of the island (*Map 4*). Additional fence rows were constructed along the perimeter of the island where continuous vegetation was not present at the island’s edge, and to bisect other large open areas.

Fence rows were constructed by driving commercial-grade, painted steel, 6’ fence posts into the ground to depths of at least two feet. Along each fence row, fence posts were spaced no more than 6’ apart, and each fence row was securely anchored at both ends using specially designed angle brackets (Wedge-Loc®). Runs of taught, barbless wire were then secured to the fence posts at ground level, at 18” AGL, and at 36” AGL. Commercial grade knitted material (PAK Unlimited Inc.; 90% privacy screen) was then zip tied to the top and bottom wire strands to create a visual barrier for terns that land on the ground. Fence rows were constructed across the entirety of the “Primary Dissuasion Area” and much of the “Secondary Dissuasion Areas” identified in the IAPMP (*Map 4*). Additionally, twisted polypropylene rope (0.25”) was then attached to the fence posts at approximately 42” AGL using clove hitch knots. Ropes were fastened to alternating fence posts diagonally between two adjacent fence rows, and then 4’ lengths of industrial barricade tape (see *above*) were inserted between strands of the rope at approximately 3’ intervals.

Finally, in open areas where Caspian terns were less likely to prospect for nest sites due to the proximity of mature woody vegetation, passive dissuasion consisted of stakes, rope, and flagging or placement of woody debris. Ropes and flagging were deployed in a 10' x 10' square array using 6' steel fence posts driven into the ground, and with diagonal strands of rope and flagging bisecting each square. A double layer of rope and flagging was deployed at or near the high waterline around the island's periphery, where fence rows could not be constructed. Woody debris was collected from downed dead trees and felled Russian olive trees (*Laeagnus angustifolia*; a non-native invasive plant) and was placed primarily on the west side of Crescent Island, where nest prospecting was considered possible but unlikely, and in open areas below the high waterline. In 2016, there was widespread planting of native vegetation, felling of non-native Russian olive trees, and subsequent dispersal of woody debris used as additional passive nest dissuasion on Crescent Island.

In 2018, after inspection of the passive nest dissuasion materials and native vegetation on Crescent Island (see *above*) with Corps staff, existing passive nest dissuasion was repaired. Repair of existing materials required reinstallation of flagging material on all ropes and replacement of other passive nest dissuasion components (e.g., rope, zip ties, fence material), as needed. For all repairs, we procured and installed materials identical in composition and deployment to those used on Crescent Island in 2015-2017 (see *above*), ensuring the structural integrity of all passive nest dissuasion measures. Although final deployment of passive dissuasion was like that of 2015-2017, flagging was not reinstalled in areas of mature willow growth and other dense vegetation. Finally, we reserved sufficient quantities of passive nest dissuasion materials in case any unexpected in-season maintenance was required, and repairs could be accomplished without disturbance to non-target species, in adherence of established BMPs (see *Appendix A*). All reserve materials were stored on Crescent Island in an organized manner, with all excess material and debris removed from the island following the breeding season.

Installation and repair of all passive dissuasion components were completed prior to the historic arrival of terns and gulls at Crescent Island. Once installed, at no time were any passive nest dissuasion materials removed for any reason. However, disposable material, specifically the barricade tape flagging, was removed from the island following the Caspian tern breeding season. In addition, rope and posts were removed following the breeding season (and/or will be prior to the 2019 season).

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 2018 (USACE 2014). Active hazing was done in such a manner as to both prevent Caspian tern nesting and maintain access to the island for walk-throughs for as long as is possible. Finally, all Caspian tern eggs laid on either Crescent Island, Goose Island, or other

islands in Potholes Reservoir, were collected under permit. A detailed description of active nest dissuasion activities used at each site during the 2018 nesting season are provided *below*.

Goose Island & Northern Potholes Reservoir

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 laid at Goose Island or elsewhere in Potholes Reservoir.

In 2014-2017, Caspian terns and gulls were continuously present on the Goose Island throughout the breeding season (Roby et al. 2015a; Collis et al. 2016, 2017, 2018). 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, and that deterring or even delaying gull nesting was unlikely.

In 2018, beginning with the arrival of 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 2018, 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. These seasonal adjustments in hazing activity on Potholes Reservoir were closely coordinated with designated Corps and Reclamation staff, and no reductions in hazing effort were made without their approval.

In March, 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. Also, a portable building was installed on Goose Island as a field camp to allow overnight stays on the island facilitating early

morning and late evening hazing of Caspian terns and gulls from potential nesting areas. Evening hazing to prohibit Caspian terns from remaining on Goose Island overnight was considered especially important for deterring, or at least delaying, nest initiation.

During island walk-throughs during the passive dissuasion deployment period, any gull nests not containing eggs were destroyed. Once widespread establishment of gull nests precluded island walk-throughs on Goose Island, as stipulated in the BMPs (see *Appendix A*), 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 prospecting 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 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 allowed researchers to collect the 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. BMPs were followed for all active hazing and egg collection efforts on Potholes Reservoir, as well as for all necessary communication and reporting of these activities to the COR and other designated POC's (see *Appendix A*). When tern eggs were laid and subsequently collected under permit, we reported each event within 24 hours to representatives from the Corps and Reclamation to ensure compliance with MBTA permit regulations, and to facilitate accurate reporting to the USFWS by the Corps.

Crescent Island

Active nest dissuasion was conducted to disrupt potential nesting attempts by Caspian terns and gulls on Crescent Island 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, and (6) destruction of all gull nests not containing eggs. However, since the implementation of colony management in 2015, no Caspian terns have been observed on Crescent Island. As such, no Caspian terns have been hazed from the island and all hazing efforts have targeted prospecting ring-billed and California gulls to prevent gull colony formation that may attract Caspian terns. Active hazing of Canada geese (*Branta cadadensis*) on Crescent Island was not conducted, as stipulated in the Conditional Use Permit issued to conduct this work on Crescent Island in 2018.

In 2015-2017, Caspian terns and gulls did not nest on Crescent Island and were rarely seen near the island (Collis et al. 2016, 2017, 2018). Based on avian responses to dissuasion in previous years, we anticipated that the active hazing efforts required at Crescent Island would be much less than that at Goose Island and elsewhere in Potholes Reservoir. We monitored Crescent Island weekly to ensure that Caspian terns and gulls did not return to nest in 2018. Beginning with the arrival of gulls on or near Crescent Island, hazing activities were conducted several days each week through July. The duration of island surveys depended on bird activity at the island but was not be less than 1 hour each day. The methods and duration of active hazing sessions were adjusted based on bird numbers and breeding activities observed. These seasonal adjustments in hazing activity on Crescent Island were closely coordinated with the Corps, and no reductions in hazing effort were made without the Corps' approval.

ACTION EFFECTIVENESS MONITORING

Action effectiveness monitoring was conducted both at the colony-level and the system-level (region-wide). Colony-level monitoring was accomplished by resident field crews stationed at Potholes Reservoir and near Crescent Island and was carried out in conjunction with management tasks described *above*. Colony-level monitoring was designed to evaluate the efficacy of nest dissuasion efforts in Potholes Reservoir and Crescent Island 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 Columbia Plateau region 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 the outcome of any nesting attempts (i.e. 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 Columbia Plateau region during 2018. These data were used to evaluate changes in the number and distribution of nesting Caspian terns in the Columbia Plateau region associated with management.

Colony-level Monitoring

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 2018 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, weekly observations were recorded to document use by various avian predators (e.g., raptors) and mammals (i.e. beaver [*Castor canadensis*]) in 2018. Willow observations were largely qualitative and limited to observations of herbivory by beavers. Additionally, in 2018, a feasibility study was conducted to determine if planting native grass and shrub seeds on Goose Island might result in a sustainable, long-term nest dissuasion action at that site. In brief, several test plots were prepared and seeded with native grass and shrub species in November 2017. Beginning in April 2018, supplemental irrigation was installed, and the test plots were monitored weekly from the nearby observation blind. The results from this feasibility study will be provided in a separate report to the funding agency.

We continuously monitored the activities of Caspian terns and other colonial waterbirds (i.e. gulls) on Crescent and Goose islands from mid-March through July using at least two field crew members stationed on or near each 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. 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, in adherence of established BMPs (see *Appendix A*). 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 (*Maps 5-6*). 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 2018 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. 2015a; Collis et al. 2016, 2017, 2018).

High-resolution, vertical, aerial photography was acquired on Goose Island on 16 May 2018. The orthorectified imagery was analyzed to estimate the total area (in acres) covered by passive nest dissuasion materials on each island, and to count nesting gulls and estimate the area (in acres) occupied by nesting gulls on Goose Island.

System-level Monitoring

The geographic scope of the IAPMP includes the 10 “at-risk” sites and other sites within the Columbia Plateau region where Caspian terns displaced from colonies on Goose and Crescent islands may relocate following management (USACE 2014). These colony sites (hereafter referred to as “unmanaged sites”) include islands where Caspian terns have recently nested (i.e. within the last two years), including the Blalock Islands (John Day Reservoir), Badger Island (McNary Reservoir), Twinning Island (Banks Lake), Harper Island (Sprague Lake), and unnamed islands in Lenore Lake and in Potholes Reservoir (*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 (see *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 other islands in Potholes Reservoir in 2018. 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 Columbia Plateau region, where Caspian terns may continue to consume significant percentage of available ESA-listed juvenile salmonids.

Aerial photo surveys

Reconnaissance aerial surveys were 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 the lower Snake River from the mouth of the Clearwater River to the confluence with the Columbia 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 FCRPS (*Map 7*).

The objective of aerial surveys was to identify all active Caspian tern nesting colonies and large roost sites within the region. Three aerial surveys of the Columbia Plateau region were conducted during the 2018 nesting season on the following schedule: (1) on 1-2 May, early in the incubation period, to check for the presence of newly formed colonies; (2) on 30-31 May, late in the incubation period, to determine numbers of breeding pairs, colony area, and habitat types (i.e. bare sand/dirt, cobble, sparsely vegetated) occupied by nesting Caspian terns, as well as to identify late-forming colonies; and (3) on 29-30 June, during the peak fledging period, to assess overall nesting success at active Caspian tern colonies. Aerial surveys followed established methods, including reconnaissance surveys to search for new Caspian tern colonies and photographic surveys of sites where nesting Caspian terns are present. 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 Columbia Plateau region in 2018. 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 the outcome of any nesting attempts (i.e. 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.

Tracking of satellite-tagged Caspian terns

In 2014-2015, Caspian terns that were attempting to nest on Crescent and Goose islands were tagged with satellite transmitters to monitor their movements away from those managed sites (Roby et al. 2015b; Roby et al. 2016; Roby et al. 2017). At the beginning of the 2018 breeding season, there were 14 satellite tags that were still transmitting location information of the tagged terns (D. Lyons, OSU, personal communication). With funding from the Grant County Public Utility District and the Priest Rapids Coordinating Committee (GPUD/PRCC), our research team tracked the movements and overnight roosting locations of these satellite-tagged terns in the Columbia Plateau region during the 2018 breeding season. This information was used along with the reconnaissance aerial surveys to locate incipient Caspian tern colonies at unmanaged sites in the region and assess to what extent managed terns are relocating to nest sites outside the Columbia Plateau region.

SMOLT PREDATION RATES

The main objectives for collecting and analyzing smolt PIT tag data as part of this study were 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 following tern management actions associated with the IAPMP. 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. In 2018, predation rates at unmanaged Caspian tern colonies included terns nesting on the Blalock Islands in John Day Reservoir and at an unnamed island 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 due to a lack of permission from the land owner to access the site. Scanning during the pre- and post-management periods were also conducted at the Badger Island tern colony in McNary Reservoir and the Twinning Island tern colony in Banks Lakes in years past, but these sites had either a very small number of prospecting terns (8 pairs for one week at Badger Island) or no terns (Twinning Island) during the 2018 nesting season and therefor were not scanned for tags.

PIT-tagging at Rock Island Dam

Rock Island Dam (RIS) is an important location for fish used in this study because it represents the upper-most foraging range for Caspian terns nesting in Potholes Reservoir, WA (Evans et al. 2012; Roby et al. 2015b). Steelhead were selected for tagged because prior research demonstrated that juvenile steelhead were particularly susceptible to Caspian tern predation (Evans et al. 2012; USACE 2014; Roby et al. 2017) and because, in lieu of tagging at RIS, inadequate numbers of steelhead would be available for predation rate analyses (Roby et al. 2017), and because steelhead passing RIS are part of an ESA-listed population; Upper Columbia River steelhead. 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; Collis et al. 2018; Hostetter et al. 2018).

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 2018. Steelhead smolts were anesthetized (tricaine methanesulfonate), PIT-tagged (*Biomark* Model HPT12, 134.2 kHz full-duplex), and released into the tailrace of RIS to resume outmigration. Steelhead smolts were randomly selected for tagging (i.e., tagged regardless of condition, origin, and size) and tagged in concert with, and in proportion to, the run-at-large to ensure that the tagged sample was representative of the steelhead smolt population passing the dam (tagged and untagged fish; see *Results*). In addition to PIT-tagging, data on the size (fork length [mm]) and external condition (disease, body injuries, descaling, and fin damage; see Evans et al. 2014 for details) of each fish were also collected. The target sample size goal was to PIT-tag 7,000 juvenile steelhead. 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 precision (95% credible interval) of approximately ± 2% in cases where predation rates were at or below approximately 8%. This level of precision was specified by the Corps and was based on the highest colony-specific predation rate observed on Upper Columbia River steelhead by terns nesting on the Blalock Islands in 2015 (Roby et al. 2017). Methods to PIT-tag steelhead at RIS in 2018 were identical to those used in years past (2008-2017), allowing for a direct comparison of results from 2018 to those from past years.

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 more detailed description of methods to recover smolt PIT tags from tern colonies and to estimate predation rates based on those recoveries are described below (see also Evans et al. 2012 and Hostetter et al. 2015). Methods to calculate predation rates in 2018 were identical to those used previously, allowing for a direct comparison of results from 2018 to those from previous years.

Availability of PIT-tagged smolts

Availability of smolts for predation rate calculations were based on the methods of Evans et al. (2012). In brief, the number of PIT-tagged smolts available to terns were based on the number interrogated or released at Rock Island Dam (middle Columbia River), Lower Monumental Dam (lower Snake River), or McNary Dam (Columbia River), whichever dam was the nearest upstream dam(s) with adequate PIT tag interrogation capabilities to the tern colony of interest. As described above, the intentional tagging of smolts at Rock Island Dam was necessary to ensure adequate sample sizes of ESA-listed steelhead were available for predation rate estimation. Unlike Rock Island Dam, sufficient numbers of tagged smolts (without an intentional tagging effort by our research team) were likely to be available at Lower Monumental and McNary dams due to the presence of several other tagging studies at or upstream of those dams. PIT-tagged smolts interrogated at each dam were grouped by ESA-listed salmonid population (as defined by NOAA Fisheries) based on the species (Chinook, sockeye, steelhead), run-type (spring, summer, fall), rearing-type (hatchery, wild), and river-of-origin (Upper Columbia River, Snake River) of each PIT-tagged fish detected. Smolt availability to avian predators was limited to fish detected passing each dam during 15 March to 31 July, which reflects the period of overlap in active smolt outmigration and the nesting season of Caspian terns (Adkins et al. 2014; Collis et al. 2018).

Recovery of PIT tags on Caspian tern colonies

Electronic recovery of PIT tags on Caspian tern colonies followed the methods of Evans et al. (2012). In brief, portable pole-mounted antennas (*Biomark*, model HPR) were used to detect PIT tags *in situ* during August - September, after birds dispersed from their breeding colonies. PIT tags were detected by systematically scanning (referred to as a "pass") the entire area occupied by birds during the nesting season, with a minimum of two passes or complete sweeps conducted of the nesting area at each colony. The area occupied by nesting terns on each colony were determined using aerial photographs taken during the nesting season and by visits to the colony during and immediately following the nesting season.

PIT tag detection and deposition probabilities

Not all PIT tags ingested by terns are subsequently deposited on their nesting colony (Hostetter et al. 2015). For instance, a portion of PIT tags implanted in depredated fish are damaged and

rendered unreadable following digestion, are stolen by other bird species (kleptoparasited), or are regurgitated off-colony at loafing, staging, or other areas utilized by birds during the nesting season. Deposition probability (i.e., probability that a tag consumed by a nesting bird will be deposited on its breeding colony) can be estimated by feeding tagged fish to nesting birds and subsequently recovering those tags on the breeding colony. Deposition probabilities for Caspian tern colonies in the Columbia River Basin were directly measured by our research team in years past (see Hostetter et al. 2015). In brief, we fed fish with known tag codes to Caspian terns nesting on multiple colonies, during different times of the day (morning, evening), and throughout the nesting season. The proportion of consumed tags subsequently deposited on-colony were then used to estimate deposition probability and, ultimately, to model predation rates (see *Predation rate calculations* below). The estimated probability of deposition by Caspian terns derived from these studies was 0.71 (95% CRI = 0.51-0.89), which is described using Beta distributions that can readily be incorporated (as prior distributions) in Bayesian analyses (see *Predation rate calculations* below). Use of deposition probabilities collected in years past to correct data collected in 2018 was deemed appropriate because results from previous studies indicate that deposition probabilities do not vary significantly within or between years for Caspian tern colonies (Hostetter et al. 2015).

Not all PIT tags deposited by birds on their breeding colony are subsequently found by researchers after the nesting season (Evans et al. 2012). For instance, some proportion of tags can be blown off the colony during wind storms, washed away during rain storms or flood events, or otherwise damaged or lost during the nesting season. Unlike deposition probabilities, detection probabilities (i.e., the probability of detecting a tag deposited on-colony after the breeding season) often vary significantly within and between nesting seasons (Evans et al. 2012; Hostetter et al. 2015), variation that necessitated a direct measure of detection probabilities for each tern colony included in the study in 2018 (and in each year of study to-date). To measure detection probabilities, PIT tags with known tag codes were intentionally sown (hereafter referred to as “control tags”) on tern colonies in 2018 to quantify detection based on the number of known sown tags recovered following the nesting season at each tern colony included in the study (see *Predation rate calculations* below).

Control tags were sown on tern colonies (1) immediately prior to the nesting season (pre-season) and (2) immediately following the nesting season, but prior to scanning for PIT tags on colony (post-season). Detections (i.e., recoveries) of control tags during scanning efforts after the nesting season were then used to model the probability of detecting tags that were deposited at different times during the nesting season via logistic regression (see *Predation rate calculations* below). A total 100 PIT tags were sown on each tern colony, with equal numbers (n=50) sown during each discrete time-period. Sample sizes of control tags used in 2018 were the same as those used in years past, allowing direct comparisons of independent detection probabilities, with similar precision among years. Control tags sown on tern colonies were the same dimension and type as PIT tags used to mark most juvenile salmonids from the Columbia River Basin (*Biomark* Model HPT12, 134.2 kHz full-duplex).

Predation rate calculations

The methods of Hostetter et al. (2015) were used to calculate predation rates on salmonid populations. Predation rates were modeled independently for each Caspian tern colony and salmonid ESU/DPS. The probability of recovering a PIT tag from a smolt on a tern colony was the product of the three probabilities described above, (1) the probability that an available fish was consumed (θ), (2) the probability that the consumed PIT tag was deposited on-colony (ϕ), and (3) the probability that the deposited PIT tag was detected on-colony (ψ):

$$k_i \sim Binomial(n_i, \theta_i * \phi * \psi_i)$$

where k_i is the number of smolt PIT tags recovered from the number available (n_i) in week *i*. The probable values of these parameters were modeled using a Bayesian approach. The detection efficiency (ψ_i) and predation rate(θ_i) were each modeled as a function of time. The rate, ψ_i, that a deposited tag that was consumed in week *i* is detected is assumed to be a logistic function of week. That is,

$$logit(\psi_i) = \beta_0 + \beta_1 * i$$

where, in most cases, β_0 and $\beta_1$are both derived from non-informative priors (normal [0, 1000]). However, in circumstances where pre-season detection information was unreliable (i.e., Lenore Lake tern colony), supplementary information was used to estimate detection efficiency across time (i.e., using data from similar colonies and years). We modelled detection efficiency, $\boldsymbol{\psi}$, in week *i* of year *y* as

$$logit(\psi_{y,i}) = \beta_{y,0} + \beta_{y,1} * i$$

where $\beta_{y,0}$ and $\beta_{y,1}$ are related among years through a multivariate normal relationship,

$$\begin{bmatrix}\beta_{y,0}\\ \beta_{y,1}\end{bmatrix} \sim normal\left(\begin{bmatrix}\mu_{\beta_0}\\ \mu_{\beta_1}\end{bmatrix}, \begin{bmatrix}\sigma^2_{\beta_0} & \rho\sigma_{\beta_0}\sigma_{\beta_1}\\ \rho\sigma_{\beta_0}\sigma_{\beta_1} & \sigma^2_{\beta_1}\end{bmatrix}\right).$$

Non-informative priors are employed for all hyperparameters (normal [0, 1000] for μ_{β_0} and μ_{β_1}; uniform [-1,1] for ρ; and gamma [0.001, 0.001] for $\sigma^2_{\beta_0}$ and $\sigma^2_{\beta_1}$).

The weekly predation rate, θ_i, is modeled as a random walk process with mean μ_θ and variance σ^2_θ, where:

$$logit(\theta_i) = \mu_\theta + \sum_{w \le i} \varepsilon_w$$

and $\varepsilon_w \sim normal\left(0, \sigma^2_\theta\right) \forall w$. We placed non-informative priors on these two hyperparameters: $\text{logit}^{-1}(\mu_\theta) \sim uniform(0,1)$ and $\sigma^2_\theta \sim normal(0,20)$. This allows each week

(*i*) to have a unique predation rate (θ_i), while still sharing information among weeks to improve precision.

Informative Beta (α, β) priors were used to infer deposition rates (ϕ). The shape parameters for these prior distributions were assumed to be α = 16.20 and β = 6.55 (see also Hostetter et al. 2015).

Annual predation rates were derived as the sum of the estimated number of PIT-tagged smolts consumed each week divided by the total number of PIT-tagged smolts last detected passing the nearest upstream dam with PIT tag interrogation capabilities.

$$\sum_{all\ i} (\theta_i * n_i) \Big/ \sum_{all\ i} (n_i)$$

The derived annual predation rate constitutes the estimated proportion of available PIT-tagged smolts consumed by birds nesting at a colony in each year.

We implemented all predation rate models in a Bayesian framework using the software JAGS accessed through R version 3.1.2 (RCT 2015). We ran three parallel chains for 50,000 iterations each and a burn-in of 5,000 iterations. Chains were thinned by 20 to reduce autocorrelation of successive Markov Chain Monte Carlo samples, resulting in 6,750 saved iterations. Chain convergence was tested using the Gelman-Rubin statistic ($\hat{R}$; Gelman et al. 2004). We report results as posterior medians along with 95% Highest Density Credible Intervals (95% CRI). Predation rates were only calculated for salmonid populations where ≥ 500 PIT-tagged smolts were interrogated passing an upstream dam in each year to avoid spurious results that might arise from very small sample sizes of available PIT-tagged smolts (Evans et al. 2012).

A detailed list of predation rate model assumptions and procedures used to evaluate the validity of those assumptions is provided in Hostetter et al. (2015). Briefly, the model assumed that (A1) PIT tag interrogation/release data obtained from dams were accurate, (A2) PIT-tagged fish passing dams were available to terns nesting downstream, (A3) predation, detection, and deposition were independent variables, and in the case of detection and deposition, were accurately measured in field studies, and (A4) PIT-tagged fish were consumed in a relatively short (one week) period following interrogation/release at dams. These assumptions were validated to the extent possible, or possible violations of the assumption (e.g., predation within a week of interrogation/release) had little influence on estimated predation rates.

RESULTS & DISCUSSION

NEST DISSUASION

Goose Island

Passive nest dissuasion

The installation of 4.1 acres of passive dissuasion on Goose Island was completed on 4 April 2018. This was accomplished by first repairing and re-deploying materials (primarily rope and barricade tape) on much of the area where passive nest dissuasion was installed in 2017. Temporary passive nest dissuasion was then installed, primarily along the southeastern shoreline of Goose Island, where most Caspian tern eggs were laid in 2017, and variable reservoir levels require annual removal of dissuasion components.

Inspections of passive nest dissuasion materials deployed at Goose Island in 2017 determined that most polypropylene rope was too brittle for reuse and required replacement in 2018. As such, all rope deployed from 2014-2017 was replaced prior to the arrival of Caspian terns in 2018. Like in 2017, more than 85% of the upland habitat was ultimately covered by passive dissuasion, with little potential Caspian tern habitat now remaining unaltered above the high-water line.

In total, passive nest dissuasion in 2018 consisted of more than 2,100 pier blocks, rebar stakes, and PVC sections installed on Goose Island to support the rope and flagging matrix covering 4.1 acres (see *Map 2*). Virtually all the previously used and potential Caspian tern nesting habitat that was above the waterline was covered in passive nest dissuasion materials.

Active nest dissuasion

Beginning on 7 March, targeted daily active human hazing was conducted while passive dissuasion installation was underway to delay gull nesting until all infrastructure work could be completed. Once Caspian terns were observed landing on Goose Island (10 April) daily hazing frequency and duration was increased to a minimum of two 3-hour hazing sessions; a morning session that started before dawn an evening session that ended after dark (weather permitting). Morning and evening hazing sessions 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 gulls and Caspian terns.

Despite continued gull hazing effort in 2018, preventing gull nest initiation and the formation of a gull colony on Goose Island was not possible using approved nest dissuasion methods. Since management was first initiated in 2014, our use of these methods to delay gull nest initiation have not been successful. In each of the five years of management, the first gull eggs have been laid between 9 – 16 April (9 April in 2018), preventing any further hazing or disturbance to gulls on Goose Island. The first Caspian tern to land on Goose Island during the 2018 nesting season

was on 10 April, the day after the first gull eggs were discovered and subsequent end to gull hazing. Because widespread gull breeding occurred before Caspian terns were present on Goose Island in significant numbers, and well before the period when Caspian terns initiated nests, efforts to manage gull nesting, while fruitful at Crescent Island, are not likely to produce the desired advantages for Caspian tern management at Goose Island.

Beginning on 9 April, due to gull nests with eggs, walk-through hazing and other efforts to curtail gull nesting on Goose Island were discontinued and all hazing efforts exclusively targeted prospecting Caspian terns. The primary techniques used to actively dissuade Caspian terns until reservoir levels declined in June 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 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 (see *Map 5*).

From 10 April to 23 July, Caspian tern hazing consisted of at least two 3-hour hazing sessions; a morning session that started before dawn an evening session that ended after dark (weather permitting). Morning and evening hazing sessions began and ended at civil twilight (30 min before sunrise and 30 min after sunset, respectively). As prospecting by Caspian terns on Goose Island waned later in the nesting season, active hazing efforts were reduced. On 23 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, and brief evening hazing sessions were continued until 28 July. 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 84 minutes, and the cumulative weekly hazing duration ranged from 29 minutes to 585 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 6 (range: 0 – 43) 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 54 (range: 18 – 142) terns hazed each day through 28 July (*Table 1*).

Colony failures at unmanaged sites in the Blalocks and at Harper Island (see *below*) coincided with the increase in Caspian tern activity on Goose Island during this time. Like in 2015-2017, Caspian tern use of Goose Island in 2018 peaked in late July when 142 terns were hazed during a single session. In addition to the increase in Caspian tern numbers at Goose island associated with colony failures at other colonies in June, 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 Columbia Plateau region), as evident by observations of fledged chicks at Goose Island in July in 2018. 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 and South Spit location with up to 87 terns hazed from the Southeast Main during a single hazing session. By late-July, terns were consistently hazed from a newly exposed shoal between the eastern lobe of Goose Island and East Rock, with up to 138 terns hazed from this location on 27 July (see *Map 5*; *Table 1*).

In summary, hazing efforts were successful in preventing the formation of a Caspian tern colony on Goose Island in 2018. 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 2018; 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*). Caspian terns laid 10 eggs on Goose Island in 2018, but none produced young. All 10 eggs that were laid by Caspian terns on Goose Island were collected under permit issued by the USFWS (*Figure 2* and *Table 2*). By comparison, 43, 6, and 18 eggs were laid on Goose Island during the 2015, 2016 and 2017 breeding seasons, respectively (*Figure 2*). In accordance with the federal depredation permit, 9 intact eggs collected from Caspian tern nests on Goose Island in 2018 were transferred to Dr. Josh Ackerman with the US Geological Survey, Western Ecological Research Center in Dixon, CA, while one damaged egg was buried on site for disposal.

Northern Potholes Reservoir

Passive nest dissuasion

To supplement Caspian tern hazing across Potholes Reservoir in 2018, temporary passive dissuasion (bamboo stakes, rope and flagging) was installed at two locations; the 2016 colony site and a nearby island where a single egg was laid and collected in early-May (*Map 3*). Installation methods for temporary passive dissuasion on sandy islands in northern Potholes Reservoir were consistent across sites and restricted to habitat above the high waterline when installed. In general, dissuasion was like that installed on nearby Goose Island, but used bamboo stakes driven into the ground in lieu of pier blocks. For dissuasion installed early in the season (April), field crew members removed bamboo stakes as they became inundated later in the season (May).

Prior to consistent observations of Caspian terns using northern Potholes Reservoir, virtually all upland habitat at the 2016 colony site was covered in two layers of passive dissuasion totaling 0.15 acre on 20 April 2018. On 4 May, following the collection of a Caspian tern egg, a small low-lying sandy island 2 km SW of the 2016 colony site, was covered in passive dissuasion to prevent further nesting attempts at that site. No additional passive dissuasion was installed in northern Potholes Reservoir until 31 May when receding reservoir levels began exposing new habitat consistently used by prospecting Caspian terns at the 2016 colony site.

In total, 0.30 acres of temporary passive dissuasion was installed at two locations in northern Potholes Reservoir in 2018. All passive dissuasion was removed in July once the chances of egg laying became unlikely and receding water levels created land-bridges to the mainland which provided mammalian predators with easy access to the islands.

Active nest dissuasion

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 2018. Field staff began conducting weekly boat-based surveys of the northern arm of the reservoir in mid-April, once Caspian terns were consistently observed at Potholes Reservoir (*Map 3*). Surveys typically lasted more than four hours and consisted of both observations from a boat and a series of fixed survey point 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 prior to hazing the terns from the site. If tern scrapes or eggs were discovered, eggs were collected under permit and all scrapes were destroyed. The number of complete reservoir surveys varied depending on Caspian tern activity and weather, but at least two complete surveys occurred each week from late April through July. Additionally, beginning on 30 April, the 2016 colony site and islands in the immediate vicinity were visited daily, weather permitting. Although few Caspian terns were observed and subsequently hazed from locations in northern Potholes Reservoir in April and May (*Map 8*), a consistent presence of hazers near the former colony site was thought to be important in deterring nesting attempts in 2018.

In total, Caspian terns were hazed from 26 unique locations in northern Potholes Reservoir, most of which were also used by terns in 2017, with activity peaking late in the breeding season when receding reservoir levels exposed hundreds of small sandy islands (*Map 8*). 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 (*Maps 8-9*). 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 5, 4, 31, 90 in April, May, June, and July, respectively. Although one Caspian tern egg was collected, most terns encountered were found loafing.

Crescent Island

Passive nest dissuasion

Prior to the installation of new passive nest dissuasion materials on Crescent Island in 2018, a thorough inspection of previously installed materials was conducted on 12 March to determine the need for repairs and additional materials. After widespread planting of native vegetation, felling of non-native Russian olive trees, and subsequent dispersal of woody debris was completed in February 2016 by independent Corps contractors, there was little potential Caspian tern nesting habitat remaining that required additional passive dissuasion (*Map 10*). Installation of new passive nest dissuasion materials (mainly flagging) and repair of fences erected to protect the willow plants from herbivory by beavers were initiated on 12 March and completed by 10 April.

In total, approximately 2.4 acres were covered in either mature vegetation or passive dissuasion consisting of fence rows, rope, and flagging in 2018. Virtually all the open and sparsely vegetated upland areas of Crescent Island were eliminated as potential Caspian tern nesting habitat through the deployment of passive nest dissuasion materials, native vegetation, and woody debris prior to the 2018 nesting season (see *Map 4*).

No Caspian terns landed on Crescent Island in 2018, thus willow planting areas and areas where Russian olive were placed on the ground were not used and may have been avoided by Caspian terns. While loafing gulls were intermittently observed and hazed from the shoreline surrounding Crescent Island, no breeding behavior was observed in 2018, and few gulls were generally observed (high count of 33 on 24 April). Although gulls (particularly ring-billed gulls) will use areas with sparse to moderate amounts of low growing vegetation, the combined growth of the willow plantings and secondary vegetation was likely dense enough deter gulls from nesting on Crescent Island.

Active nest dissuasion

Since the implementation of nest dissuasion activities in 2015, no Caspian terns have been observed on Crescent Island. As such, no Caspian terns have been hazed from the island and all hazing efforts have targeted prospecting gulls to prevent a colony from forming that may attract Caspian terns. Beginning on 12 March, observers began visits to Crescent Island to monitor and haze gulls several times per week, as necessary. While at the colony observers conducted walk-throughs to haze any gulls present, although most gulls typically flushed when the boat approached the island.

Throughout the breeding season, field staff visited Crescent Island 2–3 times per week to conduct colony walkthroughs, depending on gull activity and weather conditions. As with Goose Island, the revised BMPs (see *Appendix A*) were followed for colony monitoring, active hazing, Caspian tern egg collection, and all necessary communication/reporting of field activities on Crescent Island. BMPs were written by project personnel and approved by POCs from the Corps and BOR, with the intent of minimizing researcher disturbance and avoiding unpermitted take of non-target nesting species (egg loss; see *Appendix A*).

The installation of passive nest dissuasion materials, in concert with native vegetation and placement of Russian olive cuttings were successful in deterring Caspian terns from establishing a breeding colony on Crescent Island again in 2018. As was the case the previous years, no Caspian terns landed on any portion of the island, and no Caspian tern nests were initiated, or Caspian tern eggs laid, on Crescent Island in 2018. 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 for much of 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, (3) formation of a gull colony on nearby Badger Island, and (4) active hazing activities.

The absence of Caspian terns on Crescent Island, a stable colony for nearly three decades (Adkins et al. 2014), for four consecutive breeding seasons provides considerable support for the effectiveness of passive dissuasion measures used to prevent tern nesting on that island. These findings support the use vegetation and/or vertical fences rows when Caspian tern colony management is considered elsewhere.

In summary, nesting by Caspian terns on Crescent Island was likely prevented in 2018 by dense vegetation and other passive dissuasion erected on the island, as no Caspian terns were observed prospecting near Crescent Island and no subsequent active nest dissuasion was necessary. In addition to the paucity of suitable tern nesting habitat on Crescent Island, the absence of nesting gulls on Crescent Island was also likely a factor that helped prevent the formation of a tern colony on Crescent island, as gulls provide strong social attraction for prospecting Caspian terns. Unlike at Goose Island, where gull nesting could not be prevented using similar passive and active nest dissuasion techniques, no prospecting gulls were observed at Crescent Island in 2018, as nearby Badger Island provided alternative nesting habitat for gulls for the fourth consecutive year.

Caspian tern use of Crescent Island was strongly influenced by placement of passive nest dissuasion materials and native vegetation in 2018. At no time during the 2018 breeding season were Caspian terns observed attempting to land on or near Crescent Island. As was the case in 2015-2017, the abandonment of Crescent Island stands in contrast to continued nesting attempts by Caspian terns at Goose Island. Again, several factors may explain this including: (1) newly planted native vegetation on Crescent Island considerably altered nesting habitat making it unsuitable for both terns and gulls; (2) gulls did not form a colony on Crescent Island, whereas a large gull colony formed on Goose Island, providing social attraction for prospecting Caspian terns to Goose Island; and (3) suitable alternative nesting sites for Caspian terns are closer to Crescent Island (i.e. Blalock islands) than Goose Island.

ACTION EFFECTIVENESS MONITORING

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 2018 (see *above*).

Average weekly attendance by Caspian terns on Goose Island and nearby islets in 2018 was like that observed in 2016-2017, but far lower as compared to the previous two years of management (2014-2015). Weekly attendance since the onset of management (2014-2018) was 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 3*). 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. 2015a). In 2015, only one pair of Caspian terns laid an egg on Northwest Rocks, and no successful nesting by Caspian terns occurred there. The number of breeding pairs of Caspian terns that successfully nested on Goose Island and nearby islets was just two (each on the main island near the former colony area under passive nest dissuasion materials), with each nest producing a single fledgling. In 2016-2018, nest dissuasion activities were successful in preventing Caspian terns from forming a colony on both Goose Island and the surrounding islets (*Figure 3*).

In 2018, 10 Caspian tern eggs were discovered on Goose Island and collected under permit, compared to 18 tern eggs laid on Goose Island the previous year (*Figure 2*). In 2018, Caspian tern eggs were exclusively laid along the shoreline in open or sparsely vegetated habitat that was exposed by receding reservoir levels. In most cases, eggs were laid in areas where passive dissuasion could not be installed in March due to elevated reservoir levels and in-season installation was not possible without disturbing other actively nesting birds. Of the 10 Caspian tern eggs laid on Goose Island, 9 were laid after 1 June when water levels began receding, whereby exposing significant shoreline habitat for prospecting terns.

In 2018, gulls were first observed on Goose Island on 7 March but were likely present prior to the first island visit. Gull numbers increased through April, peaking in May (*Figure 4*). The index of gull colony size on Goose Island in 2018 was ca. 12,000 individuals, within 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 because of Caspian tern management activities on the island and support the conclusion that the combined effects of active and

passive nest dissuasion efforts during the 2014-2018 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 2018. 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 (potentially 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 Goose Island Caspian terns. A third potential factor in the apparent stronger site fidelity of Caspian terns at Goose Island compared to Crescent Island is the type of passive nest dissuasion materials deployed at the two islands, and the ability to alter most suitable nesting habitat. Most potential Caspian tern nesting habitat on Crescent Island was covered with extensive willow plantings and fence rows of privacy fabric erected at 15-foot intervals across the entire island, essentially 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 willow plantings) on that island. Again in 2018, tern activity did not increase at Goose Island until additional shoreline habitat was exposed beginning in late-May. Finally, a fourth potential factor that might explain the strong site fidelity of 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 on the Columbia River that provided ample suitable nesting habitat for ground-nesting colonial waterbirds (e.g., the Blalock Islands and Badger Island; see *below*).

In 2018, nest dissuasion measures were successful in deterring Caspian terns from establishing a nesting colony on Goose Island or elsewhere in northern Potholes Reservoir, with just 10 tern eggs discovered on Goose Island (*Figure 2*). All eggs were laid outside areas of passive dissuasion near or below the high-water line. Caspian terns were not observed landing within passive dissuasion in 2018, unlike 2015 when two nests were established under rope and flagging (Collis et al. 2016).

These results, in addition to findings from 2014-2017, provide considerable evidence that passive nest dissuasion (i.e. ropes and flagging suspended above the ground), when used in concert with human hazing, 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 2014-2017, 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 2018. 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 use 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 (see *Results & Discussion: Active Nest Dissuasion*).

Northern Potholes Reservoir

In 2018, 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 2018. The egg was laid (and collected under permit) on 3 May on a small low-lying sandy island 2 km SW of the 2016 colony site (*Table 2*). While Caspian terns were hazed from 26 islands in northern Potholes Reservoir in 2018, little effort was ultimately required to prevent colony formation, with a maximum of 5 Caspian terns hazed from just five islands during April and May. Relative to 2017, water levels in Potholes Reservoir were generally higher in late-April through May significantly reducing the number of suitable nesting sites in the northern arms of the reservoir.

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 the 2016 colony site and other locations where prospecting terns were observed, (2) consistent hazing efforts at prospecting sites, 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, Caspian terns were found prospecting (i.e., digging nest scrapes and egg laying) at just one location in 2018 (*Map 8*). However, while encouraging, results from 2018 continue to demonstrate Caspian terns have strong fidelity not just to Goose Island, but other locations in Potholes Reservoir.

Crescent Island

As was the case in 2015-2017, 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 2018. This was the fourth consecutive year when no nesting by Caspian terns occurred on Crescent Island, while prior to tern management in the Columbia Plateau region the average colony size for Caspian terns on Crescent Island was 461 breeding pairs (*Figure 5*).

Efforts to dissuade Caspian terns from nesting on Crescent Island were also successful in preventing all gulls from nesting there in 2015-2018. 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 2015-2018.

In summary, nest dissuasion activities were successful in preventing all nesting by both Caspian terns and gulls on Crescent Island in 2015-2018. This was somewhat unexpected because the colonies of Caspian terns and gulls have been present on Crescent Island for close to 3 decades (Ackerman 1994). Several other factors (see *above*) may explain the abandonment of Crescent Island by both nesting gulls and Caspian terns in 2015-2018.

Unmanaged Sites

Caspian terns were confirmed present at 35 different sites during aerial surveys conducted in the Columbia Plateau region during the 2018 nesting season (see *Map 7* and *Table 4*). Most sites (n=27) were loafing sites, with no signs of nesting activity, and most of those (n=26) were located on the Columbia and Snake rivers (*Table 4*).

During aerial surveys in 2018, Caspian terns were confirmed to be present (i.e. loafing or nesting) at 6 of 13 unmanaged colony sites (see *Methods and Analysis: Action Effectiveness Monitoring*). The 6 unmanaged sites where Caspian terns were observed included three sites on the Columbia River (three different islands in the Blalock islands complex, Badger Island, Foundation Island, and Cabin Island) and three sites off the Columbia River (Harper Island in Sprague Lake, the small unnamed island in Lenore Lake, and unnamed islands in northern Potholes Reservoir). Caspian terns were not observed during aerial surveys in 2018 at 7 historic colony/loafing locations, including four sites on the Columbia River (Miller Rocks, Three Mile Canyon Island, Island 18, and Island 20) and three sites off the Columbia River (Solstice Island in northern Potholes Reservoir and Twinning and Goose islands in Banks Lake).

System-wide action effectiveness monitoring confirmed that Caspian terns nested or attempted to nest at four previously used colony sites in 2018; the Blalock Islands, Badger Island, Harper Island in Sprague Lake, and the same unnamed island in Lenore Lake where a colony was established in 2017 (*Map 1*; see *below* for further details on each site). The historic Caspian tern colony site on Twinning Island in Banks Lake was not used for nesting in 2018 (*Figure 6*). As was the case in 2015-2017, the largest Caspian tern colony in the Columbia Plateau region was on the Blalock Islands, representing 64% of the total number of breeding pairs in the region in 2018 (*Map 1*).

Blalock Islands (Columbia River)

The Blalock Islands are located on the Columbia River above John Day Dam near the town of Irrigon, OR, and are managed by the U.S. Fish and Wildlife Service 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.

The Blalock Islands have been the site of multiple breeding colonies of several species of piscivorous waterbird, including Caspian terns, Forster's terns, California gulls, ring-billed gulls, great blue herons (*Ardea herodias*), great egrets (*A. alba*), and black-crowned night-herons

(*Nycticorax nycticorax*). Nesting by Caspian terns on the Blalock Islands was first detected in 2005, when six pairs attempted to nest on Rock Island (Adkins et al. 2014), a low-lying gravel and cobble island. The history of Caspian tern nesting in the Blalock Islands prior to management (2005-2013) is characterized by small colonies (average = 59 breeding pairs; range = 6–136 breeding pairs) that moved frequently among islands (five different islands used for nesting during 2005-2013; see *Map 11*), each experiencing poor nesting success. Nesting attempts by Caspian terns on the Blalock Islands typically failed or nearly failed to raise any young, either due to nest predation by mammalian or avian predators, or due to high water levels in John Day Reservoir during the incubation period that, along with high winds, inundated nesting areas (BRNW 2013, 2014).

In 2015, Caspian terns were first seen in the Blalock Islands on 25 March, when 10 roosting adults were observed on Sand Island (*Figure 7*). The first evidence of nesting by Caspian terns at the Blalock Islands during 2015 was observed on 19 April when 12 attended Caspian tern nests, including three with eggs, were counted on Middle Island (*Figure 7*). In the weeks that followed Caspian tern nests were confirmed on Long Island (26 April) and Southern Island (30 April). As many as ca. 1,300 Caspian terns and 677 attended Caspian tern nests were counted during field visits to the Blalock Islands from 19 April to 15 August (*Figure 8*). Using vertical aerial photography collected on 20 May 2015, during the peak of breeding, a total of 677 pairs of Caspian terns were estimated to have attempted to nest on the three small Blalock Islands, ca. 11-fold increase in colony size as compared to the average colony size during 2005-2013 (*Figure 9*). We estimated that 247 young Caspian terns fledged from the Blalock Islands in 2015 or a productivity of 0.37 young raised per breeding pair, the highest Caspian tern nesting success ever observed at the Blalock Islands. As in previous years, inundation of tern nests due to fluctuations in reservoir level was a factor limiting colony size and nesting success at the Blalock Islands in 2015.

In 2016, Caspian terns were first seen in the Blalock Islands on 23 March (*Figure 7*), when 14 and 2 loafing adults were observed on Sand Island and Long Island, respectively. The first evidence of nesting by Caspian terns at the Blalock Islands during 2016 was observed in mid-April when 22 attended Caspian tern nests and ca. 230 adults were counted on Long and Middle islands (see *Maps 11-12*). The first tern eggs were confirmed in nests on Long and Middle islands on 19 April (*Figure 7*). In the weeks that followed Caspian tern were confirmed nesting in small numbers on three additional islands in the Blalock Island complex (i.e. Southern Island, Rock Island, and Sand Island; see *Maps 11-12*). As many as ca. 1,200 adult Caspian terns were counted at the Blalock Islands on 7 May. Using aerial photography and ground counts during the peak of breeding, a total of 483 pairs of Caspian terns were estimated to have attempted to nest on islands in the Blalock Island complex (*Figure 8*), with the most nesting on Long and Middle islands. This represents a decrease in colony size at the Blalock Island complex as compared to 2015 (677 breeding pairs) and a ca. 8-fold increase in colony size as compared to the average colony size prior to management (2005-2013, 59 breeding pairs; *Figure 9*). We estimated that 207 young Caspian terns fledged from the Blalock Islands in 2016 or a productivity of 0.43 young raised per breeding pair, the highest Caspian tern nesting success ever observed at the Blalock Islands. 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 2016.

In 2017, Caspian terns were first seen on the Blalock Islands on our first visit to the islands on 29 March (*Figure 7*), when 16 loafing adults were observed on Sand Island. The first evidence of nesting by Caspian terns at the Blalock Islands during 2017 was observed in mid-April when 61 attended Caspian tern nests and 310 adults were counted on Long and Middle islands (see *Maps 11-12*). The first tern eggs were confirmed in nests on Long and Middle islands on 29 April (*Figure 7*), although tern eggs were suspected but not confirmed at the Blalock Islands the previous week. In the weeks that followed Caspian terns were confirmed briefly nesting in small numbers on three additional islands in the Blalock Island complex (i.e. Southern Island, Rock Island, and Sand Island; see *Maps 11-12*). As many as ca. 974 adult Caspian terns were counted at the Blalock Islands on 2 May. Using aerial photography and ground counts from 9 May during the peak of breeding, a total of 449 pairs of Caspian terns were estimated to have attempted to nest on islands in the Blalock Island complex, with the most sustained nesting attempts documented on Long, Middle, and Rock islands. However, within 48 hours of the peak colony attendance a period of high wind and elevated reservoir elevations resulted in near complete colony failure in the week that followed. A colony survey on 17 May found all three islands where active nests were present (Middle, Long, and Rock islands) were negatively affected, with all nests lost on Long Island. On Middle and Rock islands, just 50 apparent attended nests remained following the storm. Additional high water and wind events through June caused additional colony failure resulting in Middle Island being the only island where Caspian terns nested throughout the 2017 breeding season. This represents a small decrease in colony size at the Blalock Island complex in 2017 (449 breeding pairs) as compared to 2016 (483 breeding pairs; *Figures 8-9*). We estimated that a maximum of 24 young Caspian terns fledged from the Blalock Islands in 2017 or a productivity of 0.05 young raised per breeding pair, significantly lower than the nesting success observed at the Blalock Islands the previous year (0.43 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 2017.

In 2018, Caspian terns were first seen on the Blalock Islands on 5 April (*Figure 7*), when 65 loafing adults were observed on multiple islands. The first evidence of nesting by Caspian terns at the Blalock Islands was observed on 14 April, when 45 attended nests were counted on Long and Middle islands, with the first eggs confirmed on 21 April (*Figure 7*; also see *Maps 11-12*). As many as ca. 724 adult Caspian terns were counted at the Blalock Islands on 2 May during boat and blind-based surveys and a minimum of 313 pairs of Caspian terns were estimated to have attempted to nest on islands in the Blalock Island complex based on aerial photographs taken on 1 May (*Figure 8*), with sustained nesting attempts documented on just Long and Middle islands in 2018, with colony footprints similar to those documented on Long and Middle islands in previous seasons. However, within one week of this count a period of high wind and elevated reservoir elevations resulted in significant colony failure (*Figure 10*). A colony survey on 11 May, following the first period of inundation, found both Long and Middle Island were negatively affected, with just 108 apparent attended nests remaining (*Figure 10*). Additional high water

and wind events through May caused additional colony failure resulting in Middle Island being the only island where Caspian terns nested throughout the 2018 breeding season (*Figure 10*). This represents a decrease in colony size at the Blalock Island complex in 2018 (313 breeding pairs) as compared to 2017 (449 breeding pairs; *Figure 9*). Similar to 2017, productivity was limited by high water events. After several re-nesting attempts, we estimated that a maximum of 55 young Caspian terns fledged from the Blalock Islands in 2018 or a productivity of 0.18 young raised per breeding pair, higher than the nesting success observed at the Blalock Islands the previous year (0.05 young raised per breeding pair), but lower than estimates from 2015 (0.37) and 2016 (0.43). 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 2018.

Badger Island (Columbia River)

Badger Island, located on the Columbia River upstream of McNary Dam and near the Town of Wallula (WA), is a long, narrow island of about 15 acres owned by the U.S. Fish and Wildlife Service as part of McNary National Wildlife Refuge. Badger Island is the location of the only known nesting colony of American white pelicans in the State of Washington, a species that is listed as threatened by the State. Consequently, the island is closed to both the public and researchers to avoid human disturbance to nesting pelicans that might cause abandonment of the colony. In 2015-2016, gulls that previously nested on Crescent Island prior to management, abandoned that site and established a new colony on Badger Island, located on the Columbia River just one kilometer upriver from Crescent Island. Badger Island was also home to an incipient Caspian tern colony in 2011 and 2012, where 33 and 60 breeding pairs attempted to nest, respectively. Nesting terns did not return to Badger Island in 2013-2016, perhaps due to complete failure of the tern colony in 2011-2012. Colony failure at Badger Island in 2011 and 2012 was attributed to high water levels in mid-June and/or encroachment and trampling of tern nests with eggs by nesting American white pelicans.

In 2017, Caspian terns recolonized Badger Island for the first time since 2012, perhaps due to the lack of nesting habitat for terns on nearby Crescent Island (due to management) and the existence of an established gull colony (2015-2017) on the island. Caspian terns were first seen on Badger Island on 6 May, when 66 adults and 20 attended nests were observed (see *Map 13*). The first tern eggs and tern chicks were confirmed in nests on Badger Island on 10 May and 1 June, respectively. Using aerial photography and ground counts during the peak of breeding, a total of 41 breeding pairs of Caspian terns attempted to nest on island in 2017. We estimated that 4 young Caspian terns fledged from Badger island in 2017 or a productivity of 0.10 young raised per breeding pair; this represents the first documented successful nesting by Caspian terns on Badger Island, however, inundation of tern nests due to high reservoir levels in early June ultimately limited productivity.

In 2018, Caspian terns briefly attempted to nest on Badger Island for a second consecutive year. Caspian terns were first seen on Badger Island on 24 April, when 8 adults and 4 attended nests were observed (see *Map 13*). A total of 8 breeding pairs of Caspian terns attempted to nest on island in 2018, based on boat-based surveys conducted on 30 April. However, by 7 May no

nests remained. As such, no Caspian terns fledged from Badger Island in 2018. Inundation of tern nests due to high reservoir levels, and competition for nesting habitat with American white pelicans ultimately limited colony size and productivity at this site.

Harper Island (Sprague Lake)

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. The island is located about 48 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.

Nesting by Caspian terns on Harper Island in Sprague Lake was first documented in the late 1990s, and Caspian terns have nested sporadically there ever since (Adkins et al. 2014). During 2005-2011, estimates of Caspian tern colony size on Harper Island were generally very small (< 10 breeding pairs), before increasing about 6-fold in 2012, and then declining again to just 8 breeding pair in 2014. The island has also been home to a large California and ring-billed gull colony and a double-crested cormorant colony. No young Caspian terns were apparently fledged from the Harper Island colony during 2012-2014; the cause[s] of colony failure is not known.

In 2015, Caspian terns were first seen on Harper Island on 16 May, when three attended nests were confirmed to be active. A total of 10 breeding pairs of Caspian terns apparently attempted to nest on Harper Island in 2015, like the estimated colony size in 2014 (8 breeding pairs; *Figure 11*). In 2015, egg-laying was not confirmed at the Harper Island Caspian tern colony prior to colony abandonment, which was confirmed on 5 July; the cause(s) of colony failure in 2015 is not known.

In 2016, Caspian terns were first seen on Harper Island in mid-May, when four adult terns and one attended tern nest were counted. A total of three breeding pairs of Caspian terns apparently attempted to nest on Harper Island in 2016, lower than the estimated colony size in 2015 (10 breeding pairs; *Figure 11*). In 2016, egg-laying was not confirmed at the Harper Island Caspian tern colony prior to colony abandonment, which was confirmed in early June; as was the case in previous years, the cause(s) of colony failure in 2016 is not known.

In 2017, Caspian terns were first seen on Harper Island on 10 May, and first observed on colony when 82 adults and 50 attended nests were counted during an aerial survey conducted on 22 May (see *Map 14*). In 2017, Caspian terns colonized a new location on Harper Island ca. 200 meters east of the historic colony location. The new colony formed in rocky upland area which eventually filled in with dense vegetation. The late season colonization of Harper Island by nesting terns coincided with widespread nest failure at Blalock Islands due to rising reservoir levels combined with high winds that flooded the tern colony. A total of 91 breeding pairs of Caspian terns attempted to nest on Harper Island in 2017, by far the largest colony size ever recorded at the island (*Figure 11*). In 2017, tern eggs and chicks were confirmed at the Harper Island Caspian tern colony prior to colony abandonment, which occurred in early June. As was

the case in previous years, the cause(s) of colony failure in 2017 is not known. We estimated that 3 young Caspian terns fledged from Harper Island in 2017 or a productivity of 0.03 young raised per breeding pair.

In 2018, Caspian terns were first seen on Harper Island on 29 April, when 6 adults were observed near the 2017 colony location, a rocky upland location surrounded by dense vegetation that provides only limited visibility to researchers. The first attended nests were confirmed during an aerial survey on 2 May, when 61 adults and 27 attended nests were counted (see *Map 14*). Based on aerial photographs from 31 May, a total of 79 breeding pairs of Caspian terns attempted to nest on Harper Island in 2018. Like in 2017, significant colony failure occurred in June, as just 12 remaining attended nests were observed during the late June aerial survey. As was the case in previous years, the cause(s) of colony failure in 2018 is not known due to access restrictions and limited visibility. We estimated that 4 young Caspian terns fledged from Harper Island in 2018 or a productivity of 0.05 young raised per breeding pair.

Unnamed Island (Lenore Lake)

In 2014, a Caspian tern breeding colony was discovered on a small unnamed island on Lenore Lake (just north of Soap Lake, WA), where two breeding pairs of Caspian terns were detected among nesting gulls (see *Map 15*). This Caspian tern colony was active again in 2015, growing to 16 breeding pairs (see *Map 15*). In 2015, Caspian terns were first observed breeding at Lenore Lake on 18 June, shortly after the Caspian tern colony at Twinning Island (located 23 km away) failed. In addition to Caspian terns, double-crested cormorants and ring-billed gulls also nested on this small island. Six young Caspian terns were fledged from the colony in 2015, while no Caspian terns fledged from the colony the previous year.

In 2016, Caspian terns were first seen on the unnamed island in Lenore Lake in mid-April, when two adult terns were counted (see *Map 15*). Caspian terns were first observed breeding at Lenore Lake in early May, when 22 adult terns and one attended tern nest were counted. A total of 39 breeding pairs of Caspian terns attempted to nest at the colony in 2016, higher than the estimated colony size in 2015 (16 breeding pairs; *Figure 12*). We estimated that 23 young Caspian terns fledged from the small island in Lenore Lake in 2016, or a productivity of 0.59 young raised per breeding pair, while only 6 Caspian terns fledged from the colony the previous year.

In 2017, Caspian terns were first seen on the historic colony site in Lenore Lake in mid-April, when two loafing terns were observed (see *Map 15*). However, high water in April inundated much of the habitat previously used by nesting Caspian terns. The following week a new colony location on an island approximately 0.4 km NNE from the former colony site was detected during an aerial survey on 28 April. During the flight breeding was confirmed when 80 adult terns and 19 attended tern nests were counted. A total of 123 breeding pairs of Caspian terns attempted to nest at this new colony site 2017, by far the largest Caspian tern colony ever documented in Lenore Lake (*Figure 12*). We estimated that 33 young Caspian terns fledged from the new colony site in Lenore Lake in 2017, or a productivity of 0.27 young raised per

breeding pair, lower than the nesting success observed at the historic colony site in Lenore Lake the previous year of 0.59 young per breeding pair.

In 2018, Caspian terns were first seen at Lenore Lake on 19 April, when 2 adults were observed loafing near the 2017 colony location, a rocky upland island approximately 0.4 km NNE from the former colony site used through 2016 (see *Map 15*). Breeding was confirmed the following week, when 6 attended nests were observed on 26 April. Based on aerial photographs from 30 May, a total of 91 breeding pairs of Caspian terns attempted to nest at Lenore Lake 2018. We estimated that 18 young Caspian terns fledged from the new colony site in Lenore Lake in 2018, or a productivity of 0.20 young raised per breeding pair, similar to the nesting success observed at the historic colony site in Lenore Lake 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 2018, Caspian terns also attempted to nest on the low-lying rocky island used by terns in 2014-2016, where up to five nests were established in June. However, the fate of these nests is unknown as the island was mostly vegetated obstructing observations.

Region-wide Nesting Population

In total, an estimated 491 breeding pairs of Caspian terns nested at four different breeding colonies in the Columbia Plateau region during 2018. This represents a 44% decline in the regional breeding population size for Caspian terns compared pre-management average (873 breeding pairs), and a 28% decline when compared to the average during the management period (679 breeding pairs; *Figure 13* and *Table 5*). Although nest dissuasion actions implemented on Goose and Crescent islands in 2018 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 (*Figures 13-14*). This was due to the more than 5-fold increase in the number of Caspian terns nesting in the Blalock Islands and the increase in colony size at three other colony sites (i.e. on an unnamed island in Lenore Lake, on Harper Island in Sprague Lake, and on Badger Island in the mid-Columbia River) in 2018, compared to the pre-management average for those colonies. Although smaller in 2018, the Blalock Islands colony has been similar in size to the largest Caspian tern colonies recorded anywhere in the Columbia Plateau region since intensive monitoring began in 2000.

SMOLT PREDATION RATES

PIT-tagging at Rock Island Dam

A total of 7,366 juvenile steelhead (5,386 hatchery, 1,980 wild) were captured, PIT-tagged, measured (fork-length), condition-scored, and released into the tailrace of Rock Island Dam (RIS) as part of our intentionally sampling effort at RIS in 2018. An additional 145 previously PIT-tagged (i.e., recaptured) juvenile steelhead were also interrogated passing the RIS trap while our crew was not sampling, resulting in a total of 7,511 steelhead available for predation rate analyses in 2018 (see *below*). Numbers of intentionally tagged and previously tagged steelhead

in the 2018 were similar to those available for predation rate analyses in years past (Collis et al. 2018). All (100%) 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 10 April to 15 June 2018. Fish were tagged in concert with, and in proportion to, the run-at-large, with sampling effort and run-timing peaking in early May and again in late-May (*Figure 15*). Mean steelhead fork length was 199 mm (standard deviation [SD] = 28 mm; range = 107 to 320 mm) in 2018. An evaluation of fish condition indicated that most steelhead were in good over-all external condition, with only 11.1% 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 over-all percentage of compromised steelhead in 2018 was near the average value observed in years past (average = 9.6% during 2008-2017; Evans et al. in-prep).

Predation Rate Analysis

Smolt PIT tag recovery

There were no (zero) nesting terns at managed colony sites in 2018 (Goose and surrounding islands in Potholes Reservoir and Crescent Island in McNary Reservoir) and only small numbers of terns attempted to nest and/or were observed loafing/roosting in Potholes Reservoir during the smolt outmigration period (*Figure 1*). As such, PIT tag recovery at managed tern colony sites was unnecessary in 2018 (i.e., there were no colonies to scan). A total of 1,692 PIT tags from 2018 migration year smolts (all species and ESUs/DPSs combined) were recovered on the two unmanaged tern colony sites scanned for PIT tags in 2018 (i.e., Lenore Lake and Blalock Islands; *Table 5*). As noted in the above, terns also established a colony on Harper Island in Sprague Lake in 2018, but we did not scan for PIT tags due to lack of permission from the land owner to access the site after the nesting season.

The total number of smolt PIT tags recovered on Columbia Plateau region tern colonies in 2018 (1,692) was the lowest recorded since scanning efforts associated with the IAPMP plan begun in 2007. Prior to management (2007-2013) an annual average of 11,287 smolt PIT tag (range = 9,209 to 13,640 per year) were recovered from tern colonies and following management (2014-2018) an annual average of 5,659 smolts PIT tag (range = 1,692 to 9,409 per year) were recovered (see *Appendix B* for list of colonies and years where scanned occurred).

PIT tag detection and deposition probabilities

Based on previous studies that empirically measured deposition rates for Caspian tern colonies in the Columbia River Basin, deposition rates were estimated to be 0.71 (95% CI = 0.51–0.89) for all tern colonies included in the study in 2018 (see also Hostetter et al. 2015).

At the Blalock Island tern colony detection efficiency averaged 0.44, with a range during the nesting season from 0.28–0.60 (*Table 7*). There is evidence that detection efficiency at the

Blalock Island tern colony sites has decreased since the colony experienced rapid growth starting in 2015 (*Figure 8*). For instance, prior to 2015, when the colony was relatively small (generally < 100 pairs), annual average detection efficiency estimates ranged from 0.82–0.93. Following increases in colony size starting in 2015, however, annual average detection efficiency has ranged from 0.44–0.72. Recent decreases in detection efficiency are presumably due to higher tag densities, which result in higher rates of tag collision, a phenomenon that renders PIT tags near each other undetectable using electronics. At the Lenore Lake tern colony, detection efficiency averaged 0.58 (range = 0.20–0.96). The lack of vegetation and exposure to high winds (due to the elevated location of the island within the lake) at this site likely caused the low average detection efficiency of tags at Lenore Lake, as tags are likely to be blown off colony. Efforts to measure detection efficiency at the Lenore Lake colony commenced in 2017 (Collis et al. 2018), so a longer time series of data to evaluate trends in detection efficiency at this site were not available.

Availability of PIT-tagged smolts

Numbers of PIT-tagged smolts available for predation rate analyses in 2018 varied by salmonid ESU/DPS and interrogation/release site (Rock Island Dam, Lower Monumental Dam, or McNary Dam). Following the same pattern from years past, numbers of PIT-tagged smolts originating from the Snake River were generally greater than those originating from the Upper Columbia River (*Table 8*). Numbers of available PIT-tagged smolts for all ESUs/DPSs exceeded the 500 fish needed to generate reliable predation rate estimates (see *above* and Evans et al. 2012) in 2018, ranging from 514 Snake River sockeye at Lower Monumental Dam to 19,986 spring/summer Snake River Chinook at Lower Monumental Dam (*Table 8*).

ESU/DPS-specific predation rates

Appendix B provides historic ESU/DPS-specific predation rate estimates for Caspian tern colonies in the Columbia River Plateau region during 2007-2017 for years in which adequate data existed at each colony and year (see also Collis et al. 2018 and Roby et al. 2017). These historic estimates were compared with predation rate estimates from tern colonies included in the study in 2018 (see *below*). The only historic predation rate estimates for terns on Badger Island were from 2017, the only year the colony site was scanned for smolt PIT tags, although incipient colonies briefly attempted to nest in 2011, 2012, and 2018, respectively (BRNW 2013; Collis et al. 2018). Comparable predation rate estimates (those adjusted for detection and deposition probabilities) were also not available for terns nesting on Harper Island in Sprague Lake, although PIT tag scanning and minimum estimates of predation were available in 2012 (see *below*), the only year permission to access the colony site after the nesting season was granted by the land-owner.

Goose Island Caspian terns – The Caspian tern colony site on Goose Island and surrounding islands in Potholes Reservoir were eliminated in 2018, as passive and active dissuasion measures were successful at preventing colony formation (see *above*). Because no terns nested on islands in Potholes Reservoir, PIT tag recovery was not conducted, and predation rates were presumed to be zero or close to zero. This is the fourth 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 the management at Goose Island, a colony of 159 pairs consumed an estimated 2.9% (95% CI = 1.9–5.1; *Appendix B*) 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% CI = 14.1–18.9) during 2007-2013 (*Table 9* and *Appendix B*; see also BRNW 2014).

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 CI = 2.9–6.3) of Upper Columbia River steelhead in 2016 (*Appendix B*), impacts that prompted adaptive management actions at this and surrounding islands in Potholes Reservoir during 2017–2018. Active and passive dissuasion implemented at these sites were successful at preventing Caspian terns from nesting on islands in northern Potholes Reservoir, so PIT tag scanning was not necessary and predation impacts were presumed to be zero or close to zero in both 2017 and 2018.

Crescent Island Caspian terns – For the fourth consecutive year, the Caspian tern colony at Crescent Island was eliminated and predation rates were thus assumed to be zero or close to zero for all ESA-listed salmonid ESUs/DPSs in 2018. 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 2.4% (95% CI = 2.2–2.8) and 3.9% (95% CI = 3.5–4.6) on Upper Columbia and Snake River steelhead, respectively (*Table 9* and *Appendix B*).

Lenore Lake Caspian terns – Caspian tern predation rate estimates at the unnamed island on Lenore Lake were below the 2% threshold for all ESUs/DPSs evaluated in 2018, with the highest rate being 0.8% (95% CI = 0.4–1.7) on Upper Columbia River steelhead (*Table 8*). Rates were at or below 0.1% for all other ESUs/DPSs evaluated in 2018 (*Table 8*). Results in 2018 were very similar to those observed in 2017, with the highest predation rates observed on Upper Columbia River steelhead at 1.0% (95% CI = 0.6-2.0) in 2017 (*Appendix B*).

Historic data for terns nesting on Lenore Lake is available starting in 2015, the first year a colony was observed in the lake. The original colony site was on a different island, located just 0.4 km from the nesting site used in both 2017 and 2018 (*Map 15*). Predation rate estimate in 2015 and 2016 were even lower than those observed in 2017 and 2018 due to the paucity of smolt PIT tags recovered (< 10 PIT tags each year) and the small size of the colony each (< 40 nesting pairs each year; *Appendix B*). Collectively, predation rate results collected from Lenore Lake terns to-date (2015–2018) suggests that predation rates are unlikely to exceed the 2% threshold in the future without a substantial increase in the size of the colony. For instance, based on the average annual per capita (per nesting pair) steelhead predation rate in 2017-2018 (0.000084; Collis et al. 2018 and this study), the colony would have to be greater than 240 nesting pairs to consume more than 2% of the available Upper Columbia River steelhead. Given factors other than colony size (e.g., smolt abundance, run-timing, external condition, and river flows; see Hostetter et al. 2012) are known to influence variation in annual predation rates, however, continued monitoring of smolt impacts by terns nesting on Lenore Lake may be

warranted, particularly if a large colony forms in the future. At its current size (16 to 123 breeding pairs), however, results to-date suggest Lenore Lake Caspian terns pose only a minor threat to ESA-listed Upper Columbia River steelhead smolt survival in the region, and no or little threat to other ESA-listed ESUs/DPSs (see *Appendix B*).

Harper Island Caspian terns – In 2018, 79 Caspian tern pairs attempted to nest on Harper Island in Sprague Lake but scanning for PIT tags did not occur due to a lack of permission by the land owner to access the site following the nesting season. Similarly, in 2017, 92 pairs of terns attempted to nest on Harper Island, but again, permission was not granted to scan for smolt PIT tags (*Appendix B*). Permission was granted to recover smolt tags on the Harper Island tern colony following the 2012 nesting season, however, and 538 smolt PIT tags were recovered that year (BRNW 2013). Minimum predation rate estimates – those not adjusted for deposition probabilities – indicated that terns consumed less than 1% of available Snake River and Upper Columbia River ESUs/DPSs in 2012, with the highest rates observed on Snake River steelhead (0.5%; BRNW 2013). A correction or adjustment for deposition probability (0.71; see *above* and Hostetter et al. 2015) would increase the estimated minimum predation rate on Snake River steelhead to approximately 0.7%. Low predation rates in 2012 were presumably associated with the relatively small size of the colony that year (30 breeding pairs; BRNW 2013). Given the colony was larger in both 2017 (92 pairs) and 2018 (79 pairs) predation rates, based on these limited data, were potentially at or near the minimum goal of 2%. As such, future monitoring of the colony site maybe warranted, particularly if a substantial increase in colony size occurs and permission to scan for PIT tags can be obtained.

Badger Island Caspian terns – Caspian terns did not successfully establish a colony on Badger Island in 2018, although a small number of birds (8 pairs) briefly (for approximately one week) attempted to nest (see *above*). 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% CI = 0.3–0.8) and 0.4% (95% CRI = 0.2–0.6) on upper Columbia River and Snake River steelhead, respectively (*Appendix B*). 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 on nearby Crescent Island in McNary Reservoir prior to management (*Appendix B*) or at Blalock Islands in John Day Reservoir during the post-management phase (see *below*).

Blalock Island Caspian terns – Predation rates by Caspian terns nesting in the Blalock Islands during 2018 were the highest observed of the two tern colonies evaluated in 2018. In total, 1,598 smolt PIT tags were recovered following the nesting season (*Table 6*) and predation rates were above the 2% threshold for three ESUs/DPS; Upper Columbia River steelhead (2.9%; 95% CI = 1.5–5.2), Snake River steelhead (2.5%; 95% CI = 1.4–4.5%), and Snake River sockeye (2.0%; 95% CI = 0.4–6.1%; *Table 8*). Predation rates for all other ESUs/DPSs ranged from 0.3% (95% CI = 0.1–0.8) for Upper Columbia River spring Chinook to 0.7% (95% CI = 0.4–1.4) for Snake River Fall Chinook (*Table 8*).

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 9*). 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 481 breeding pairs (range = 313 to 677) during 2015–2018 (*Figure 8* and *Appendix B*). Predation rate estimates by Caspian terns nesting on the Blalock Islands during the post-management period were comparable to or higher than those of Caspian terns nesting on Crescent Island during the pre-management period for many of the ESUs/DSPs evaluated, particularly for ESUs/DPSs originating from the Snake River (*Table 9* and *Appendix B*). Consequently, 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 because of management. One notable exception to these offset benefits relates to the consumption of Upper Columbia River steelhead, where cumulative predation rates by all Caspian tern colonies in the region during the pre-management period (annual range = ca. 15 to 25%; *Table 9* and *Appendix B*) were higher than those observed during the post-management period (annual range = ca. 4 to 10%; *Table 9 and Appendix B*), indicating an overall net benefit to Upper Columbia River steelhead due to the implementation of IAPMP. The benefits of the IAPMP to Upper Columbia River steelhead were tied directly to reductions in predation rates by terns nesting in Potholes Reservoir (Goose Island and surrounding islands), colonies that disproportion consumed Upper Columbia River relative to other ESA-listed ESUs/DPSs (*Table 9* and *Appendix B*).

Like results in years past, weekly estimates of steelhead predation rates in 2018 indicated that impacts were generally the highest when smolt availability was the lowest and that late-migrating steelhead were more susceptible to tern predation than early migrating steelhead (*Figure 16*). The relationship between steelhead abundance, steelhead run-timing, and tern predation rates observed in 2018 at Blalock Island tern colony and at other tern colonies in the Columbia River basin is well documented in previously published avian predation studies (Hostetter et al. 2012; Evans et al. 2016; Collis et al. 2018). Hostetter et al. (2012) attributed lower predation rates during periods of greater smolt availability to predator-swamping, the theory that the probability of an individual being consumed decreases as prey density increases (Ims 1990). Tern colonies are also typically at or near peak colony size during May to early-June (Adkins et al. 2014). As such, predation rates on steelhead by Caspian terns nesting on the Blalock Islands in 2018 (and in years past; see Collis et al. 2018) would have likely been even greater than those observed if the colony had not temporary failed in May due to flooding associated higher river levels in John Day Reservoir.

In summary, reductions in tern colony sizes at Goose Island in Potholes Reservoir have greatly reduced Caspian tern predation rates on Upper Columbia River steelhead as part of the IAPMP. For the fourth 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 management 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 through passive and active dissuasion. As such, adaptive management at the Blalock Island nesting sites could benefit ESA-listed populations originating from both Upper Columbia and Snake River ESUs/DPSs, but the greatest net benefit would be to Snake River populations, populations that are yet to receive the full benefits of tern management actions in the region.

MANAGEMENT RECOMMENDATIONS

Based on results collected during this five-year study (2014-2018), 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 over both the short- and long-term.

- Many Caspian terns that formerly nested on Goose Island or Crescent Island continue to show high fidelity to the Columbia Plateau region for nesting, with most terns displaced from the Goose Island and Crescent Island colonies either still attempting to nest in Potholes Reservoir and/or successfully renesting at other unmanaged tern colonies in the region, most notably at the Blalock Islands on the mid-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.

- Currently, predation rates by Caspian terns nesting on the large unmanaged colony in the Blalock Islands exceed the 2% threshold (see *above*) for three ESA-listed ESUs/DPSs; (1) Upper Columbia River steelhead at 2.9% (95% CRI = 1.5–5.2), (2) Snake River steelhead at 2.5% (95% CRI = 1.4–4.5), and (3) Snake River sockeye salmon at 2.0% (95% CRI = 0.4–6.1). Adaptive management by way of colony size reductions at the Blalock Islands tern colony is needed to reduce Caspian tern predation rates on these populations.

- Continued monitoring of unmanaged Caspian tern colonies in the Columbia Plateau region is recommended to confirm that predation rates remain below the 2% target established by the IAPMP and to help identify suitable alternative colony sites for terns displaced from Goose and Crescent islands. Additionally, gaining access to the unmanaged tern colony on Harper Island in Sprague Lake (privately owned) to determine current predation rates on ESA-listed EESUs/DPSs should be considered.

- Management actions implemented at Goose Island in Potholes Reservoir have resulted in a steady decline in the number of Caspian terns attempting to nest at that colony in each year since management was initiated, suggesting that those efforts have been successful in not only preventing tern nesting, but also in reducing the number of Caspian terns that reside in Potholes Reservoir during the smolt outmigration period. If Caspian terns are to be completely or mostly prevented from nesting at Potholes Reservoir during the smolt outmigration period, management to prevent nesting should continue in the short term at or near the level employed during 2014-2018 (see *above*).

- As demonstrated at Crescent Island, passive dissuasion techniques (ropes, flagging, fencing, and revegetation) can be an effective and sustainable means of preventing Caspian terns from nesting. However, at colonies 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. Active hazing aimed at preventing Caspian terns from nesting early in the breeding season, when juvenile salmonids are the most available (April-May), will be necessary to prevent colony formation and minimizing predation impacts.

- Caspian tern predation on ESA-listed juvenile salmonids in the Columbia Plateau region is dynamic, varying significantly across colonies and among years. As is the case with other predator management programs being implemented in the basin (e.g., northern pikeminnow, pinnipeds), some level of monitoring and adaptive management of Caspian terns in the Columbia Plateau region will likely be required in perpetuity.

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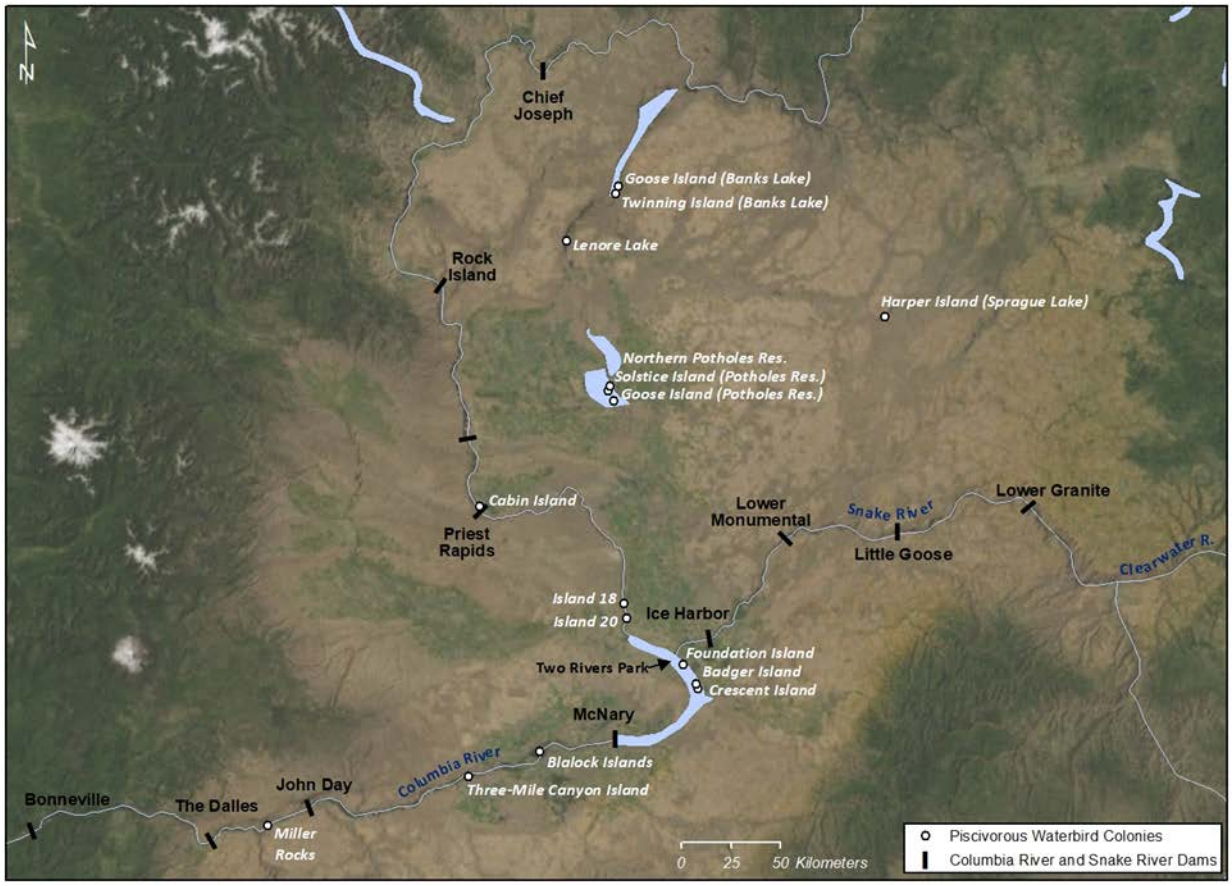
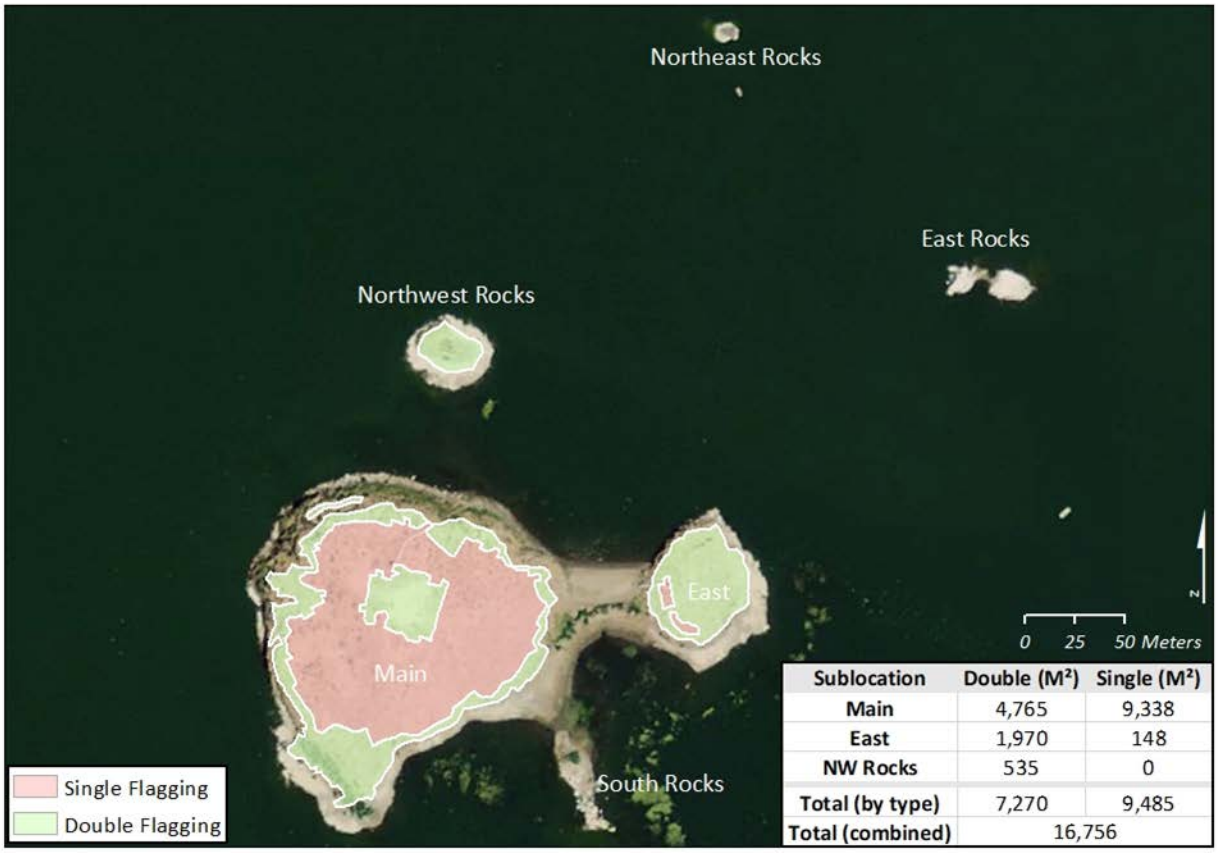
MAPS

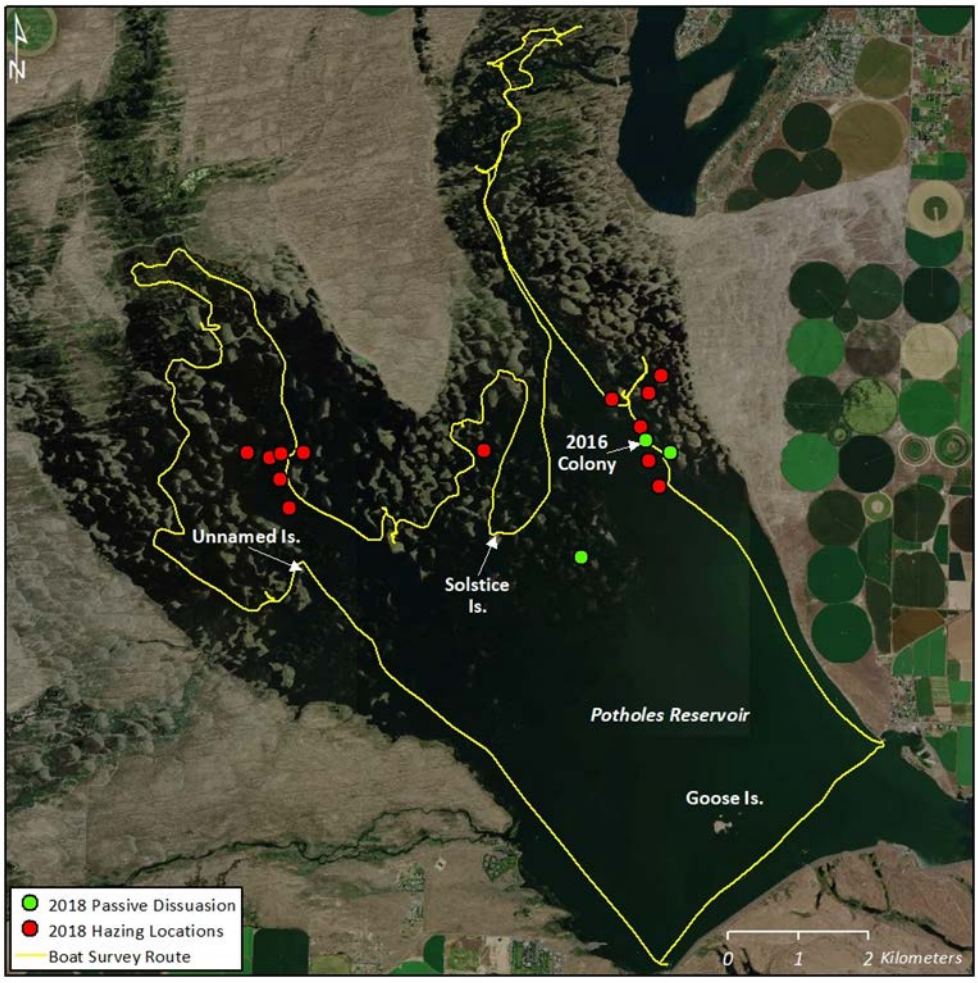


Map 1. Study area in the Columbia Plateau region in 2018.



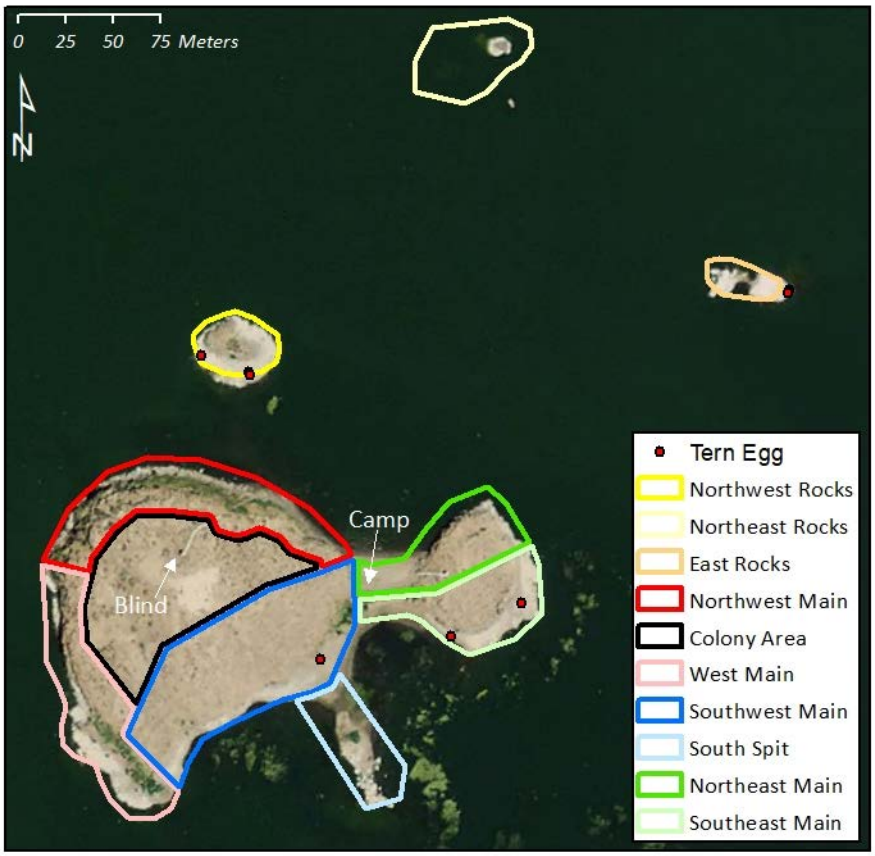
Sublocation	Double (M²)	Single (M²)
Main	4,765	9,338
East	1,970	148
NW Rocks	535	0
Total (by type)	7,270	9,485
Total (combined)	16,756	

Map 2. Distribution of passive nest dissuasion materials on Goose Island and nearby rocky islets, Potholes Reservoir in 2018.

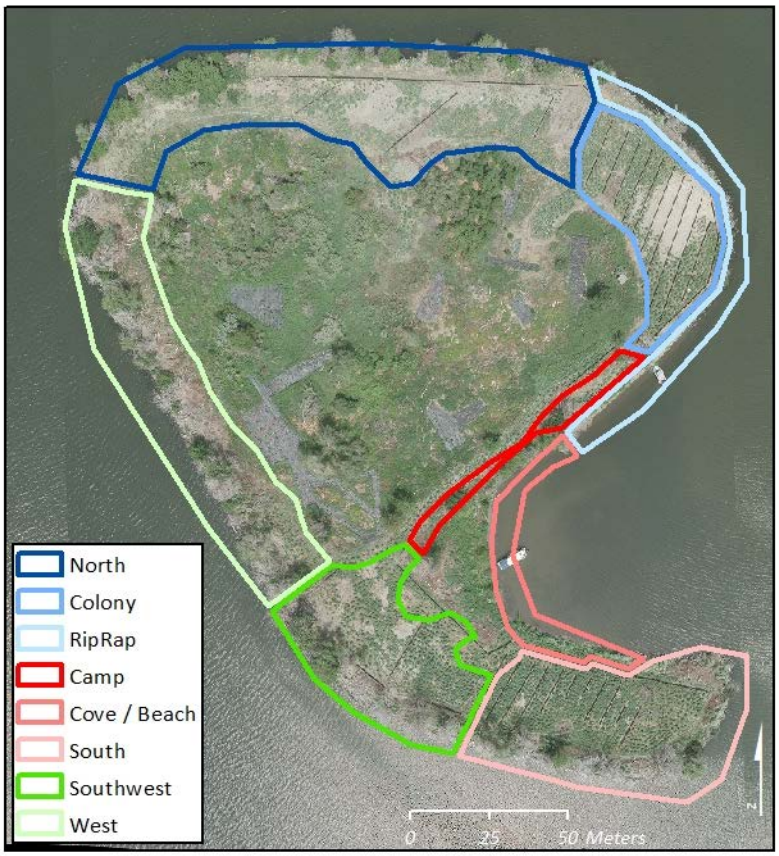


Map 3. Historical Caspian tern colonies, locations where passive dissuasion was installed in 2018 to prevent nesting, tern hazing locations, and approximate boat survey route used when hazing terns in northern Potholes Reservoir.

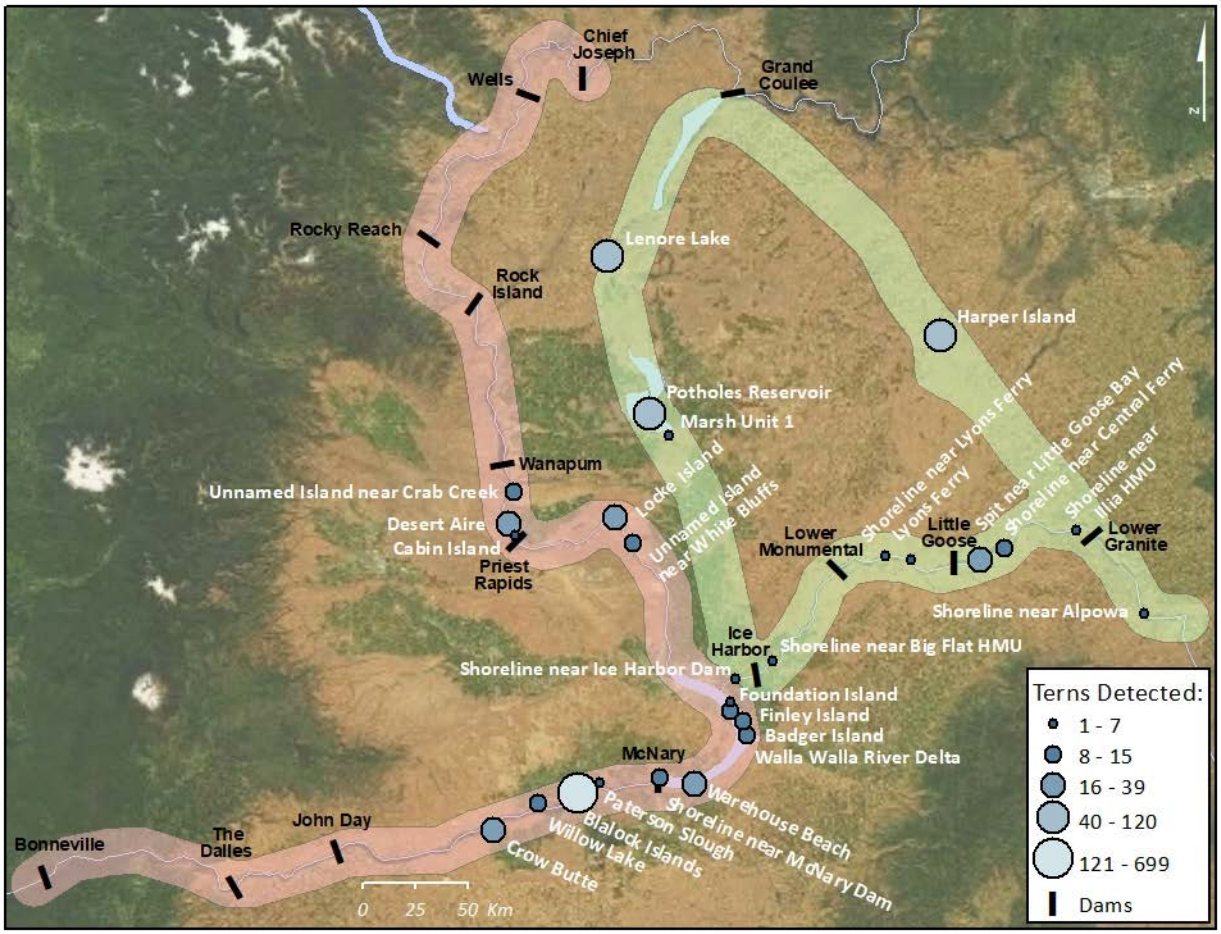
Map 4. Distribution of passive nest dissuasion materials on Crescent Island, Columbia River in 2018.



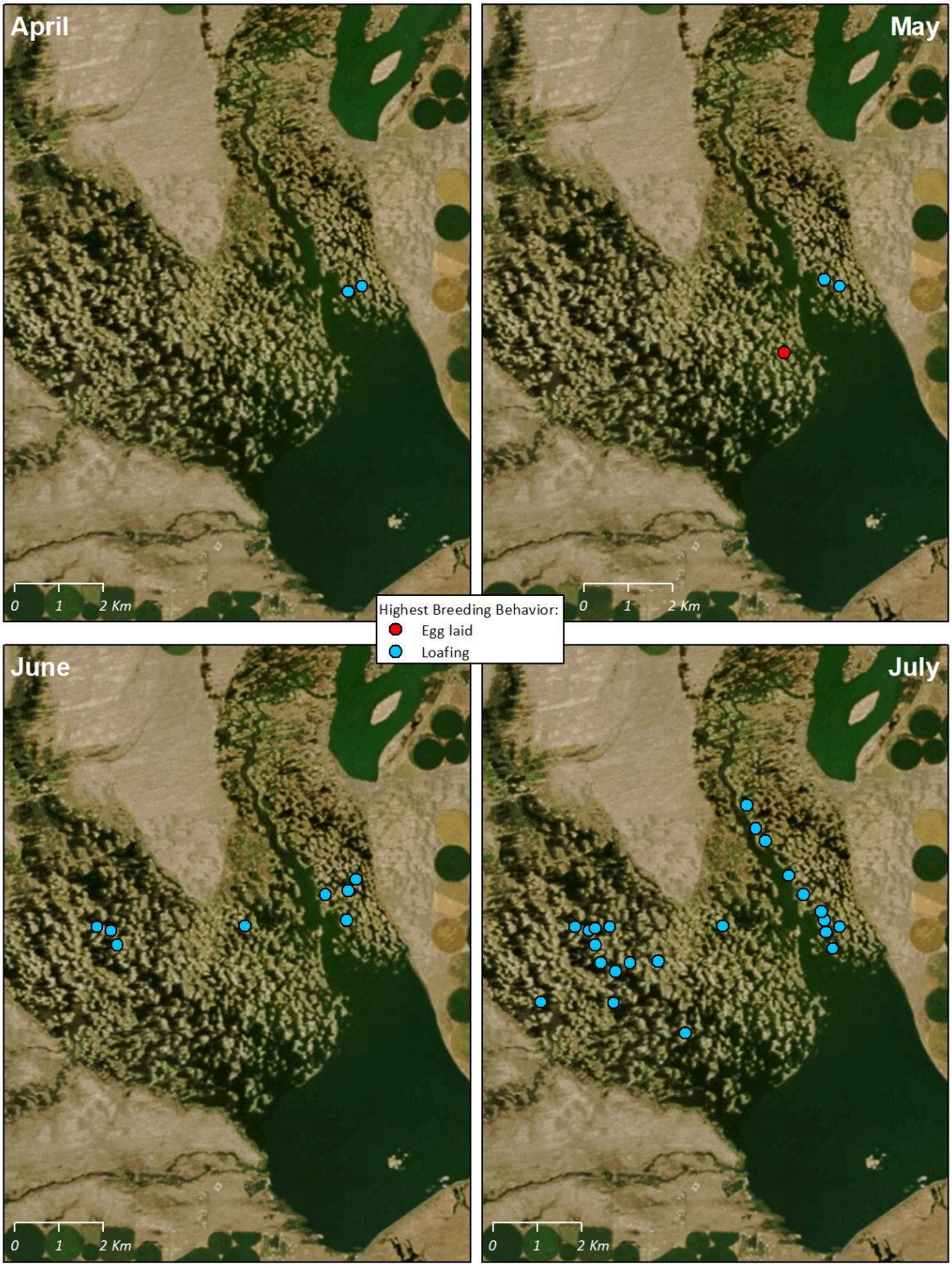
Map 5. Active dissuasion and survey locations on Goose Island and nearby rocky islets, Potholes Reservoir in 2018.



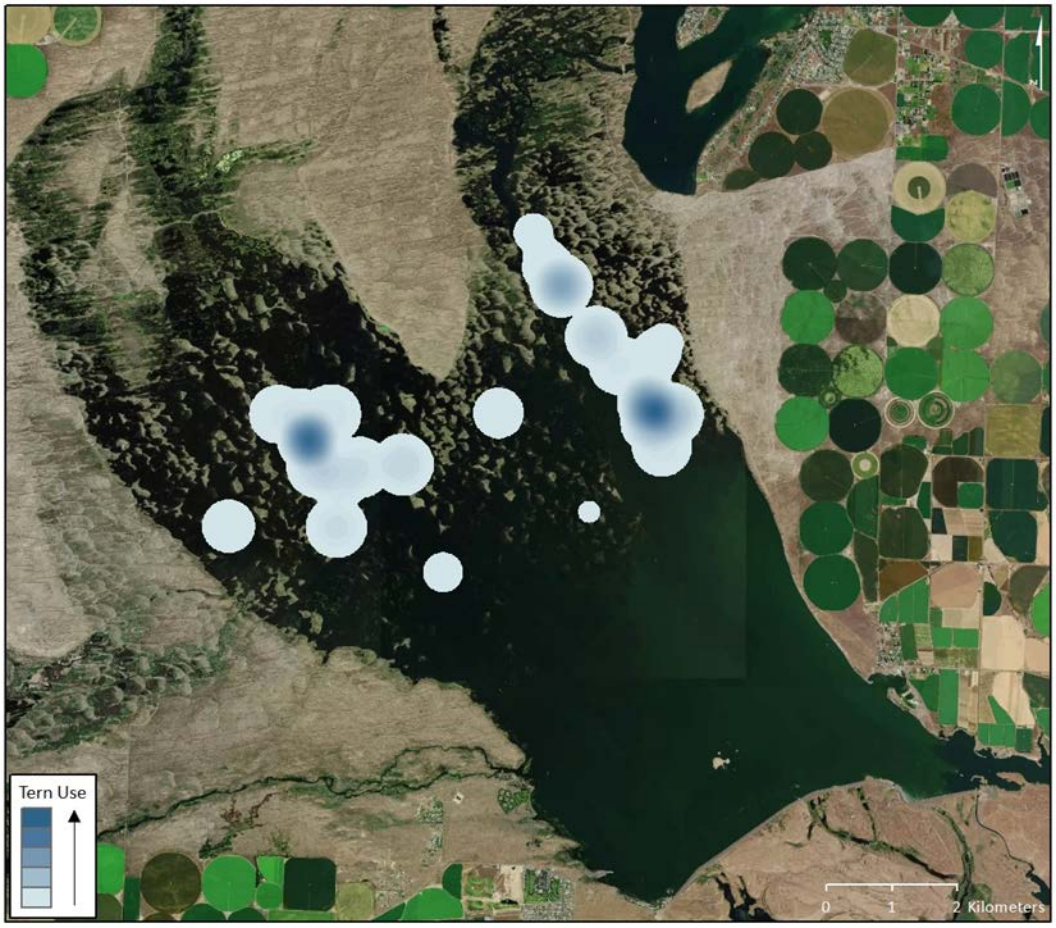
Map 6. Active dissuasion and survey locations on Crescent Island, Columbia River in 2018.



Map 7. Aerial survey flight paths along the Columbia and Snake rivers and at off-river locations within the Columbia Plateau region, including sites where Caspian terns were observed loafing and nesting in 2018.



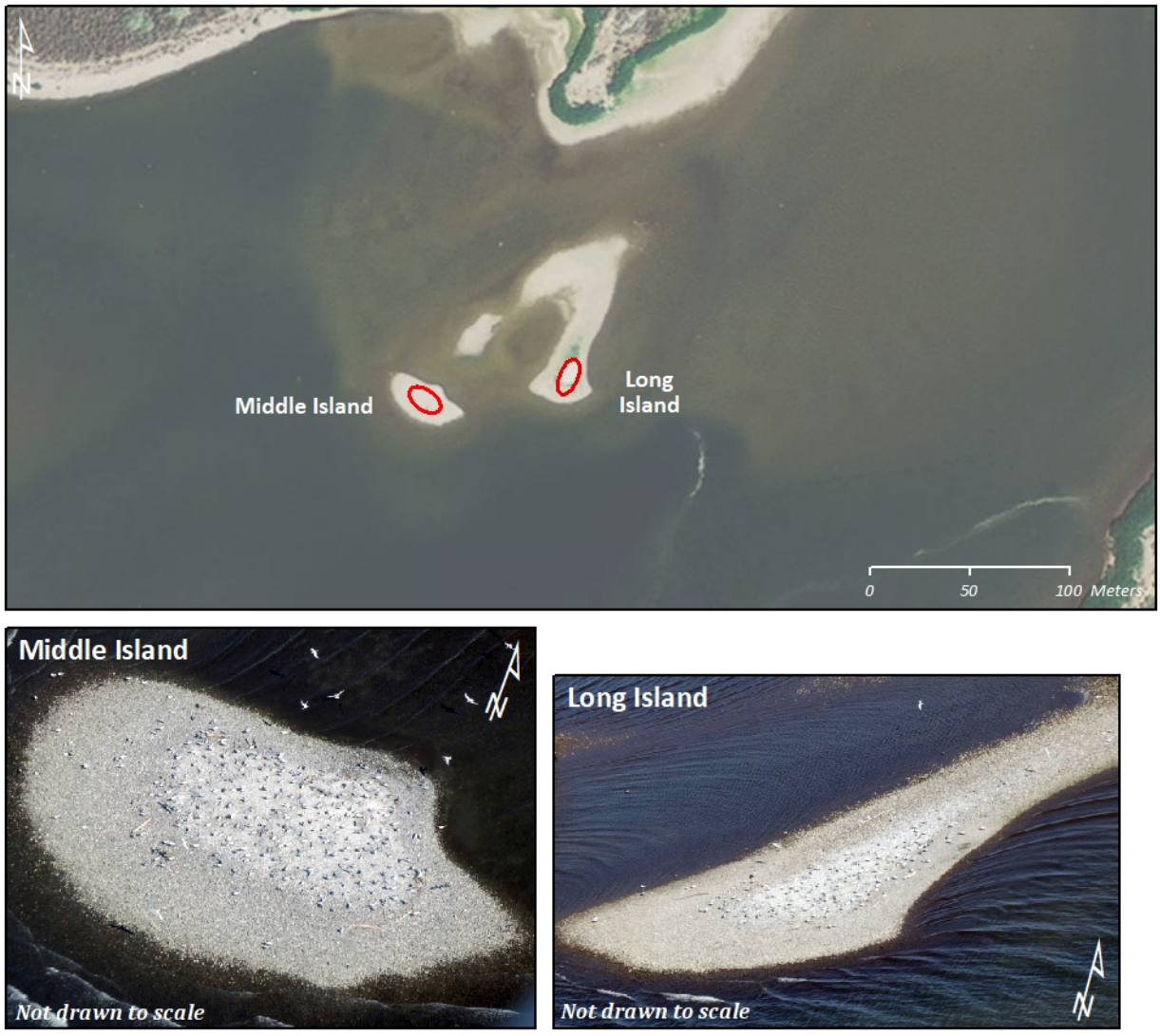
Map 8. Monthly locations where Caspian tern were hazed in northern Potholes Reservoir in 2018 (April – July).



Map 9. Caspian Tern use of northern Potholes Reservoir in 2018.

Map 10. Aerial imagery from June 2015 (top), June 2017 (middle), and June 2018 (bottom) showing the results of vegetation growth that included removal of Russian olive in and around the historical Caspian tern colony (area between fence rows) on Crescent Island.

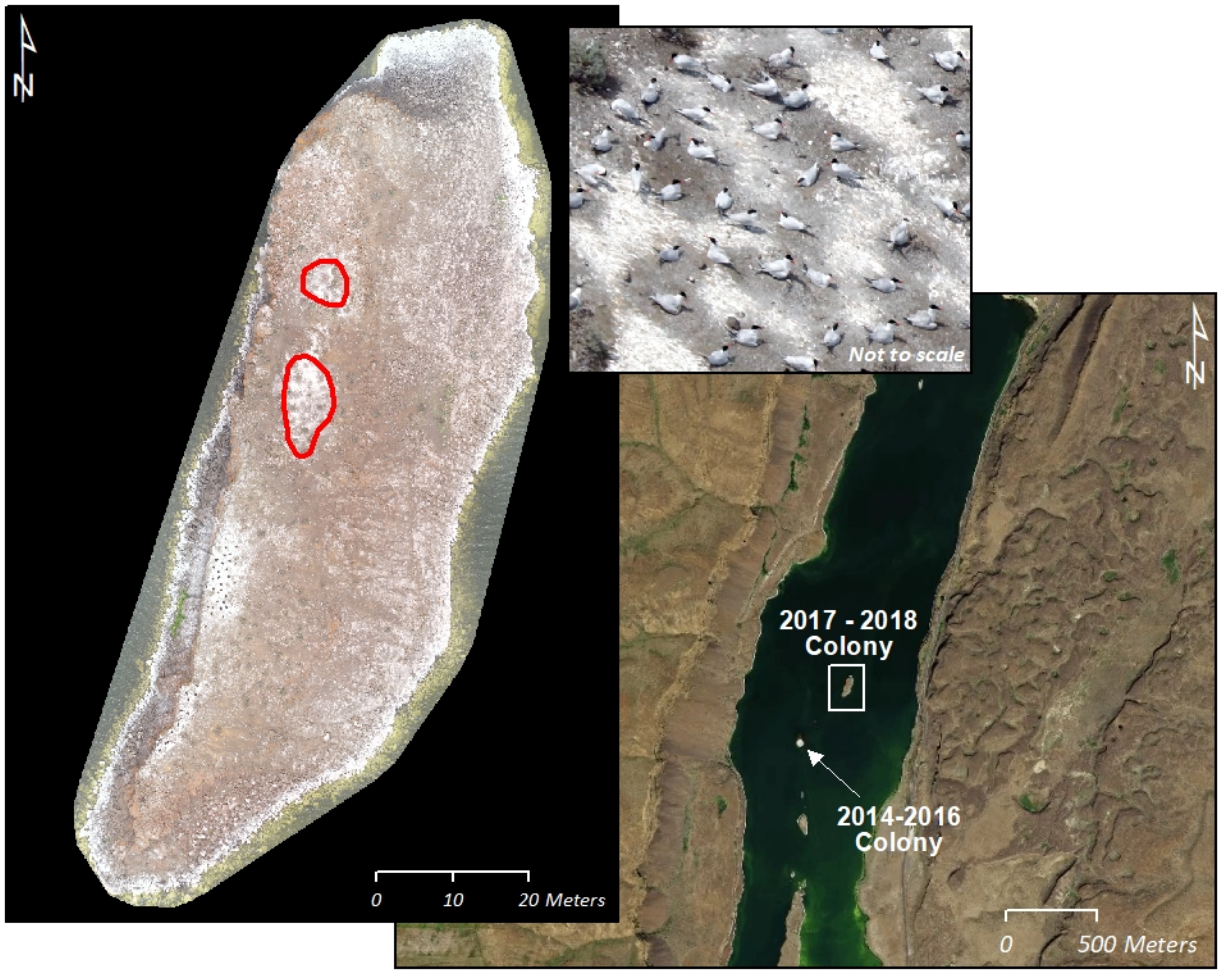
Map 11. Five islands within the Blalock islands complex, Columbia River, where piscivorous waterbirds have historically nested, including Long, Middle, Southern, Sand, and Rock islands. Caspian terns initiated nests on Middle and Long islands in 2018.



Map 12. Distribution of nesting Caspian terns on Middle and Long islands within the Blalock islands complex, Columbia River in 2018.

Map 13. Distribution of nesting Caspian terns on Badger Island, mid-Columbia River in 2018.

Map 14. Approximate distribution of nesting Caspian terns on Harper Island, Sprague Lake in 2018. The approximate colony area is shown on an image acquired on 16 May 2018, approximately two weeks earlier than the estimated peak colony. The 16 May image was not used to enumerate the 2018 colony size.



Map 15. Approximate distribution of nesting Caspian terns on the small unnamed island, Lenore Lake in 2018. The colony area is shown on an image acquired in 2017 and is not the image that was used to enumerate the 2018 colony.

FIGURES

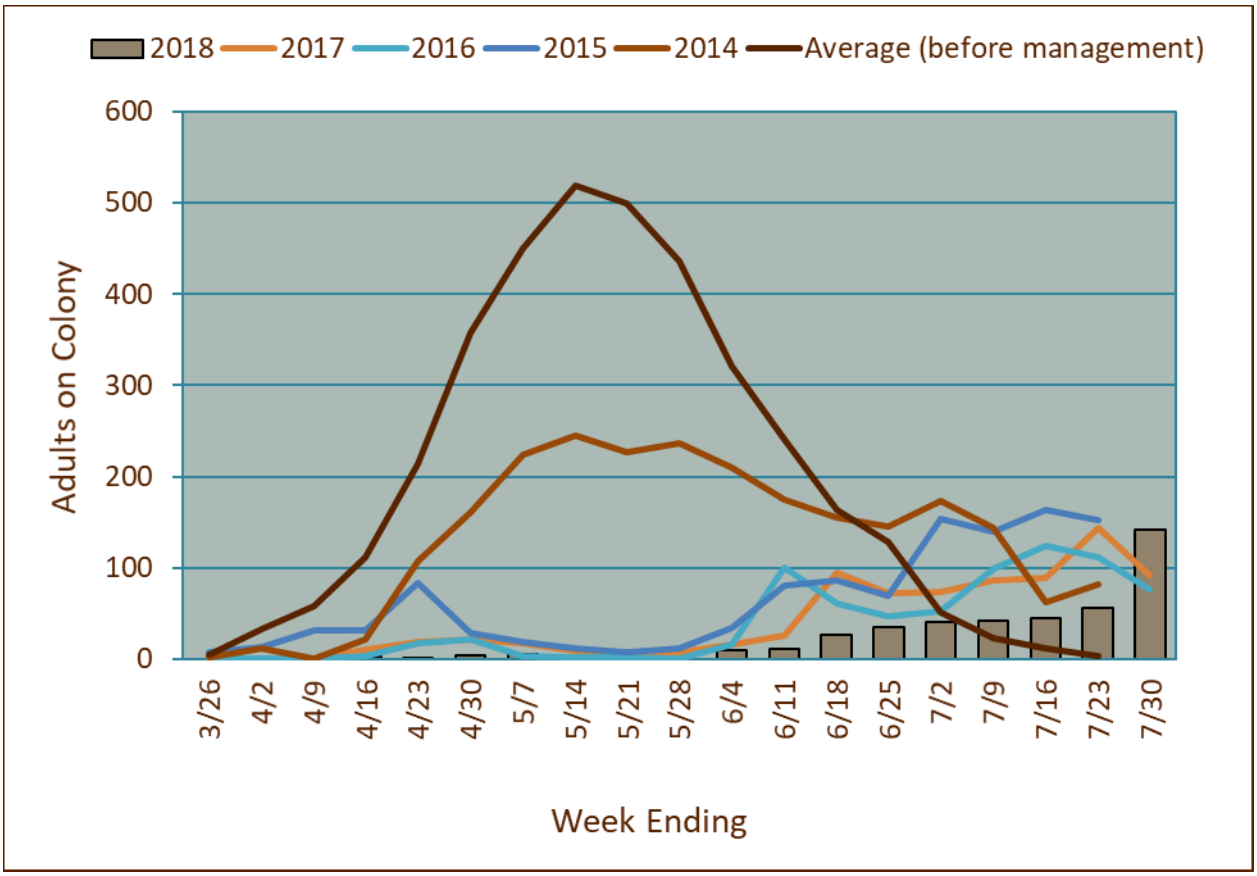


Figure 1. Estimates from the ground of the average number of adult Caspian terns on Goose Island and the surrounding islets in Potholes Reservoir, by week, before (2010-2013) and during (2014-2018) tern management at Goose Island.

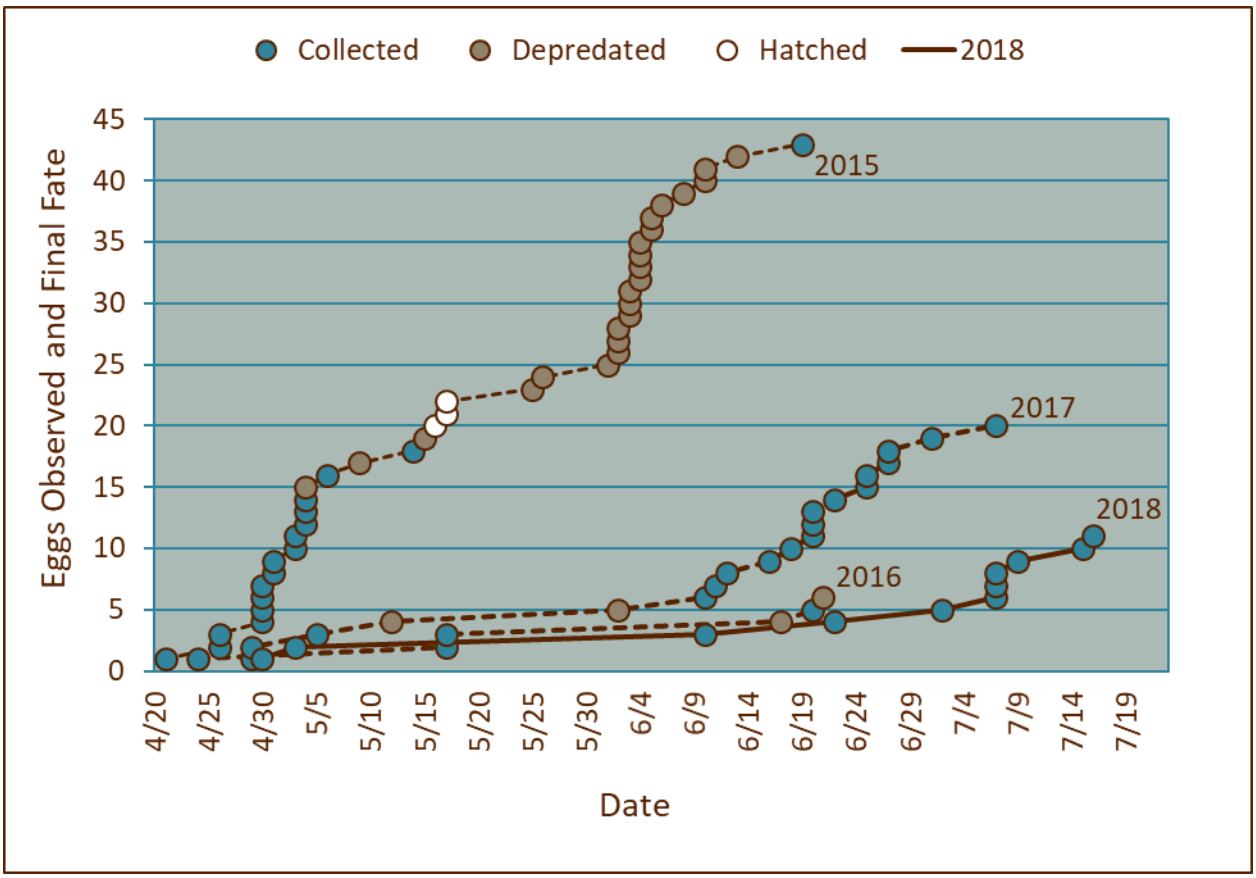


Figure 2. Caspian tern eggs observed on the Goose Island and the surrounding islets in Potholes Reservoir in 2015-2018 and their final fate; collected under permit, depredated by gulls, or hatched.

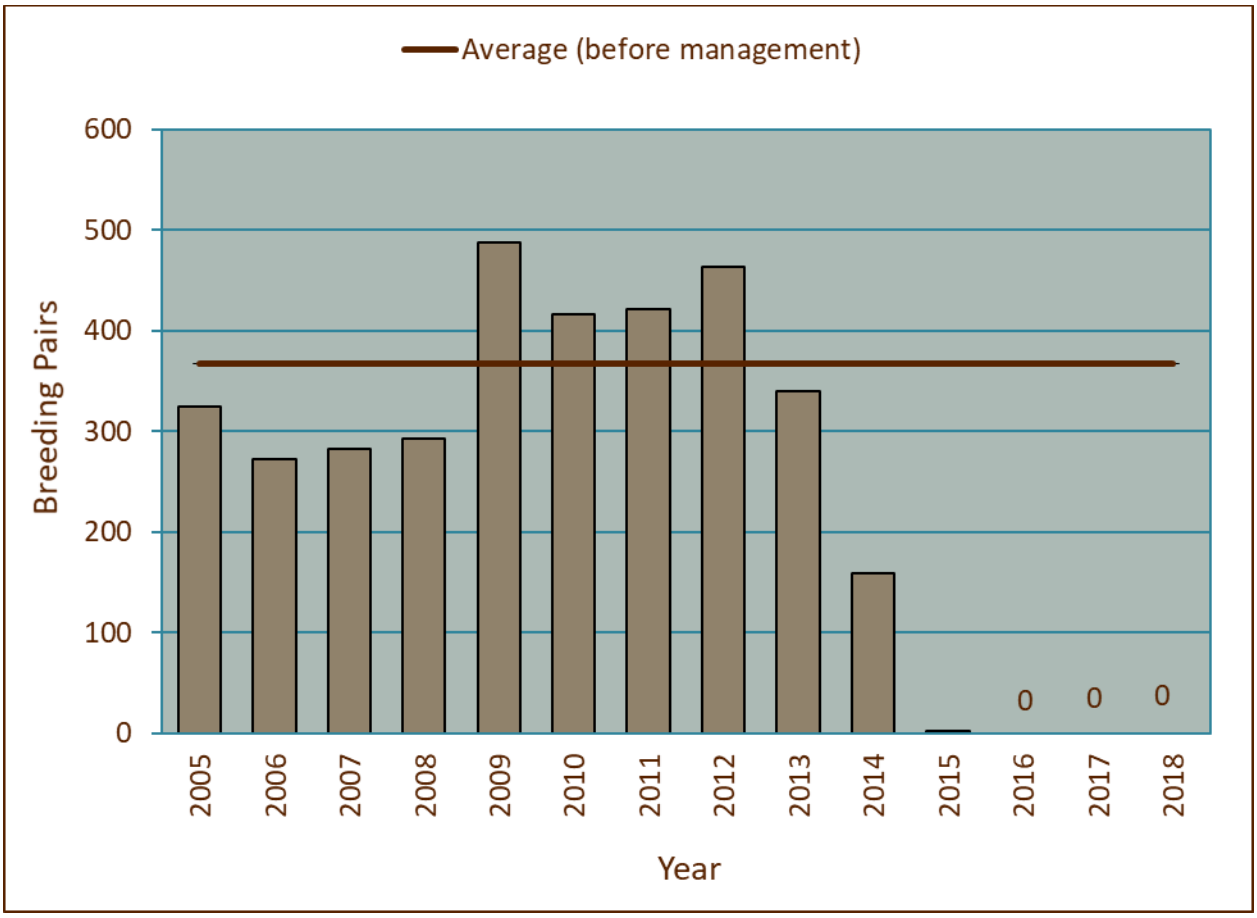


Figure 3. Size of the Caspian tern breeding colony (number of breeding pairs) on Goose Island and the surrounding islets in Potholes Reservoir before (2005-2013) and during (2014-2018) tern management in the region. Also, provided is the average number of breeding pairs of Caspian terns on Goose Island before management (2005-2013).

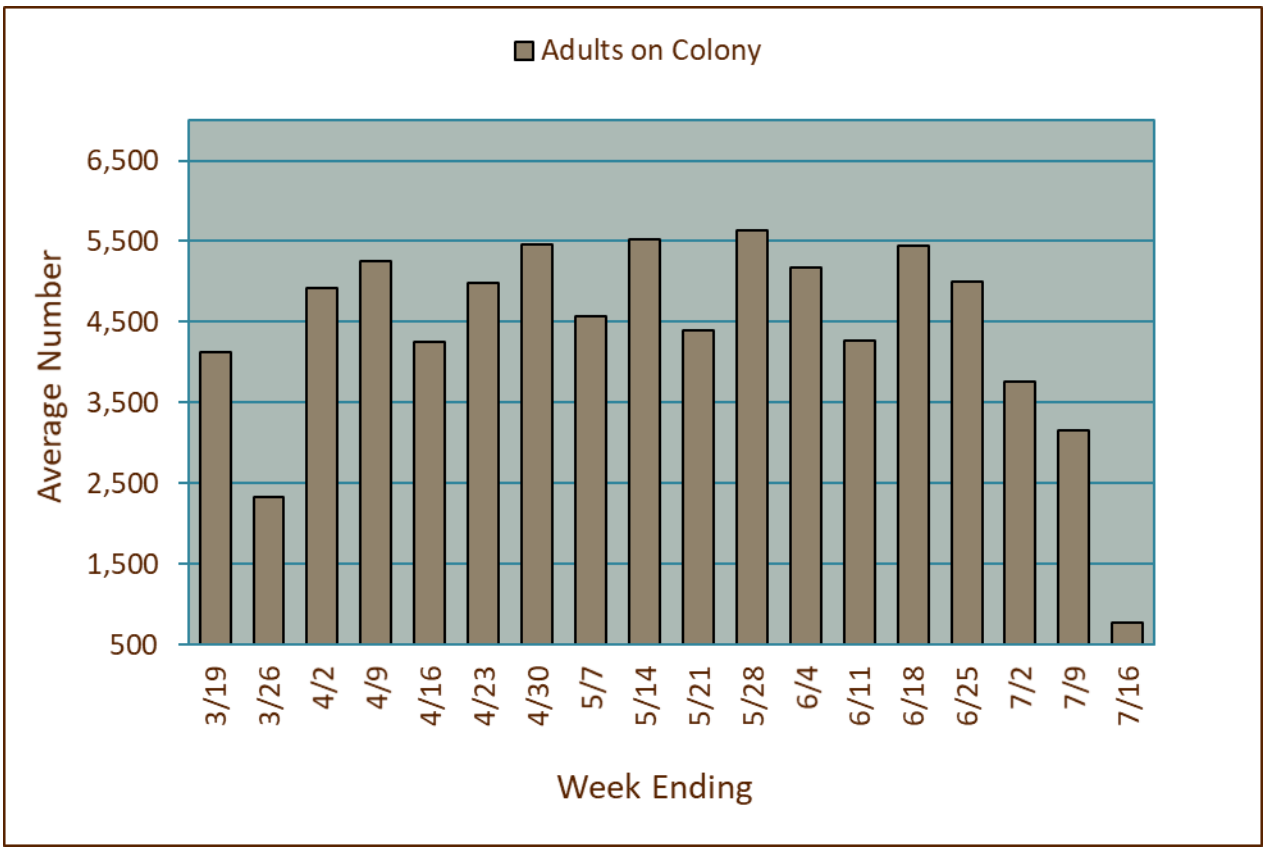


Figure 4. Estimates from the ground of the average numbers of adult gulls and attended gull nests on Goose Island and the surrounding islets in Potholes Reservoir, by week, during the 2018 breeding season.

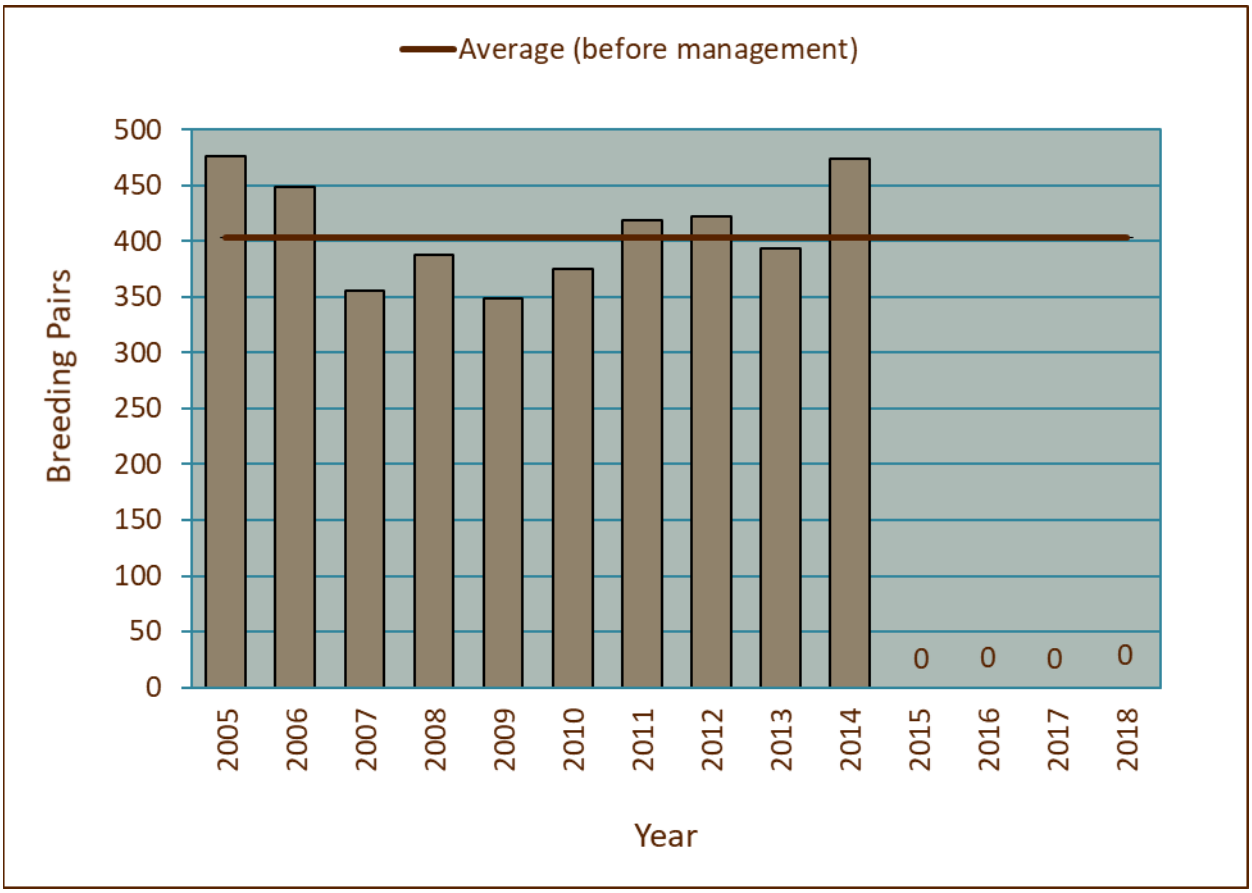


Figure 5. Size of the Caspian tern breeding colony (number of breeding pairs) on Crescent Island in the mid-Columbia River before (2005-2013) and during (2014-2018) tern management in the region. Also, provided is the average number of breeding pairs of Caspian terns on Crescent Island before management (2005-2013).

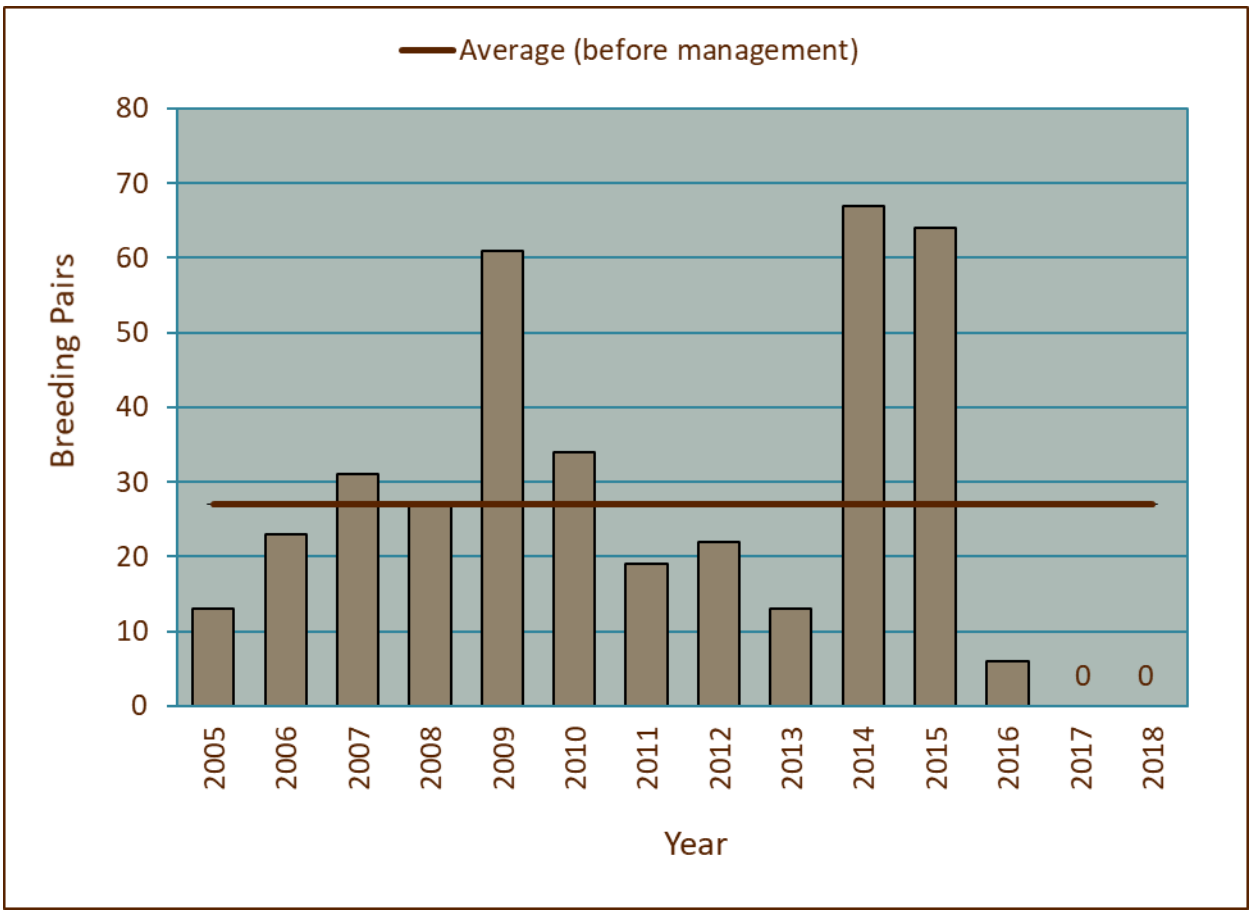


Figure 6. Size of the Caspian tern breeding colony (number of breeding pairs) at Twinning Island in Banks Lake during 2005-2018. Caspian terns did not attempt to nest on Twinning Island in 2017-2018. Also provided is the average number of breeding pairs of Caspian terns on Twinning Island prior to tern management in the Columbia Plateau region (2005-2013).

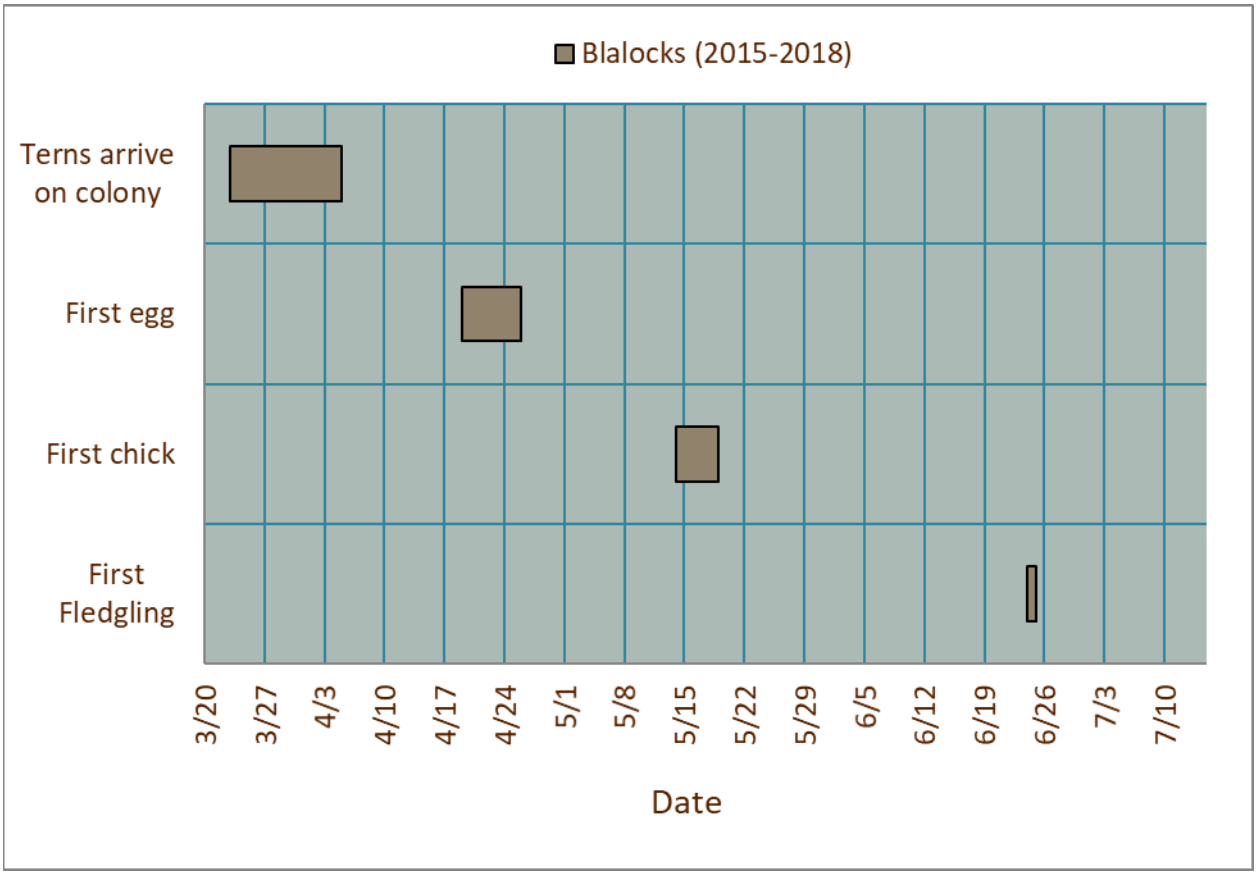


Figure 7. Nesting chronology of Caspian terns at the Blalock Islands in the mid-Columbia River during the 2015-2018 breeding seasons.

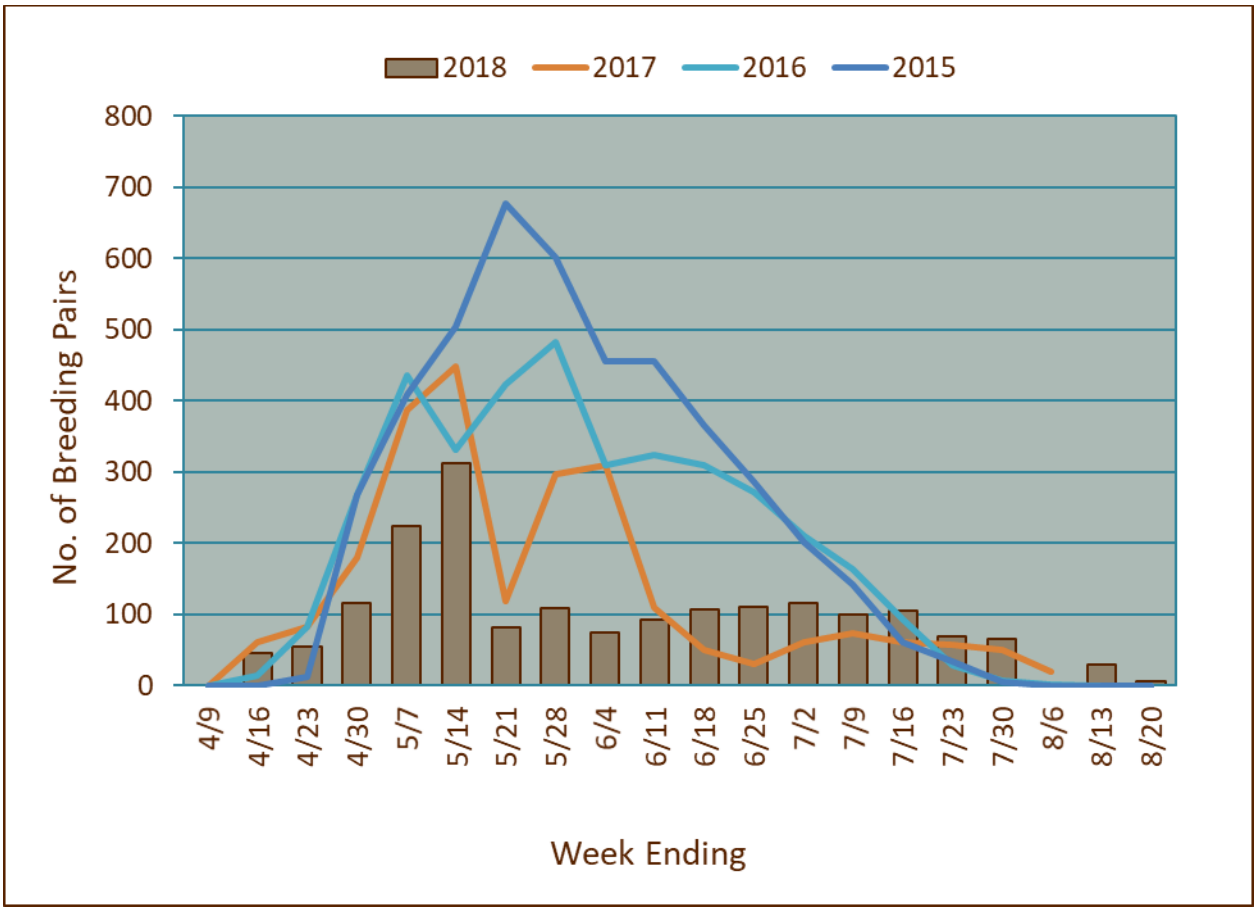


Figure 8. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock Islands in the mid-Columbia River during the 2015-2018 breeding seasons.

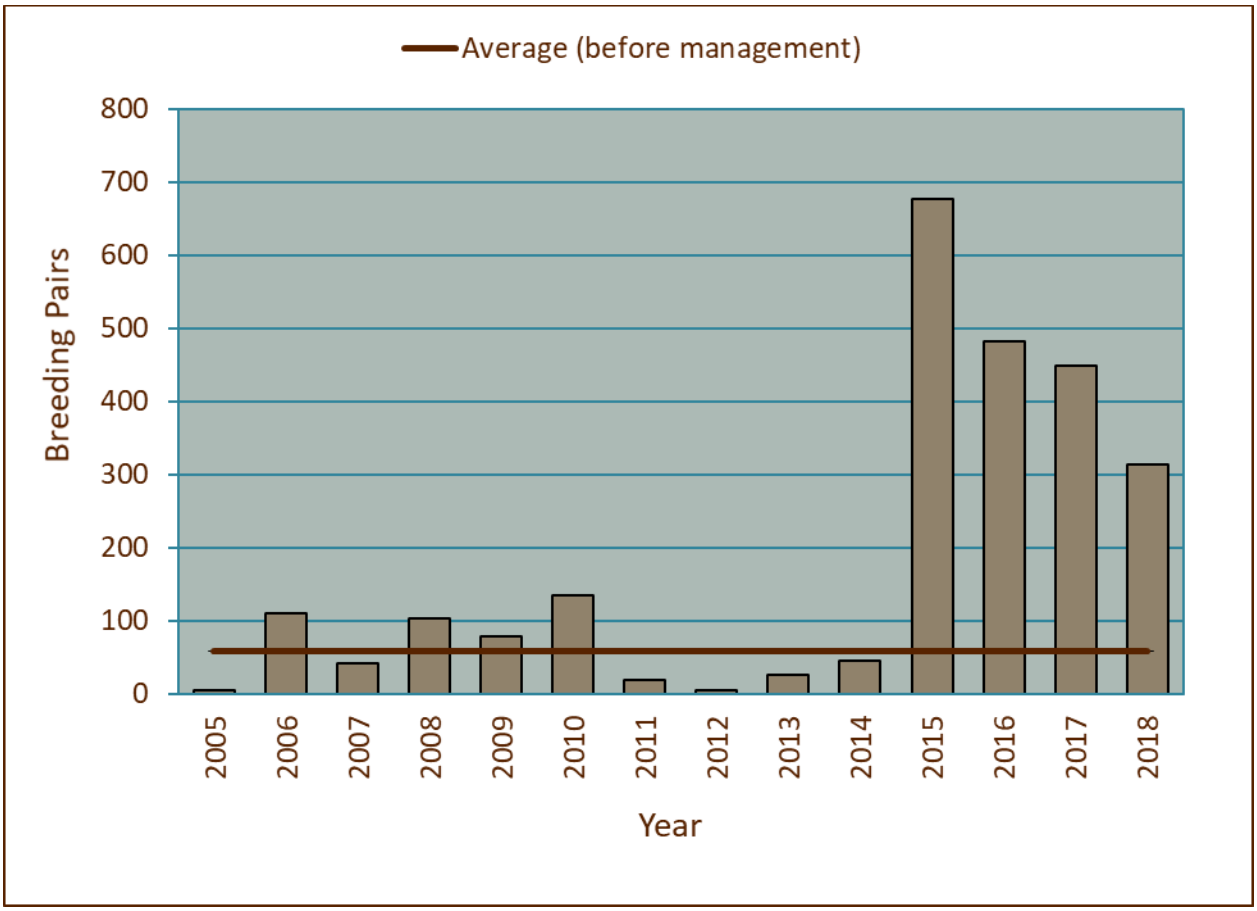


Figure 9. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock Islands in the mid-Columbia River during 2005-2018. Also, provided is the average number of breeding pairs of Caspian terns on the Blalock Islands prior to tern management in the Columbia Plateau region (2005-2013).

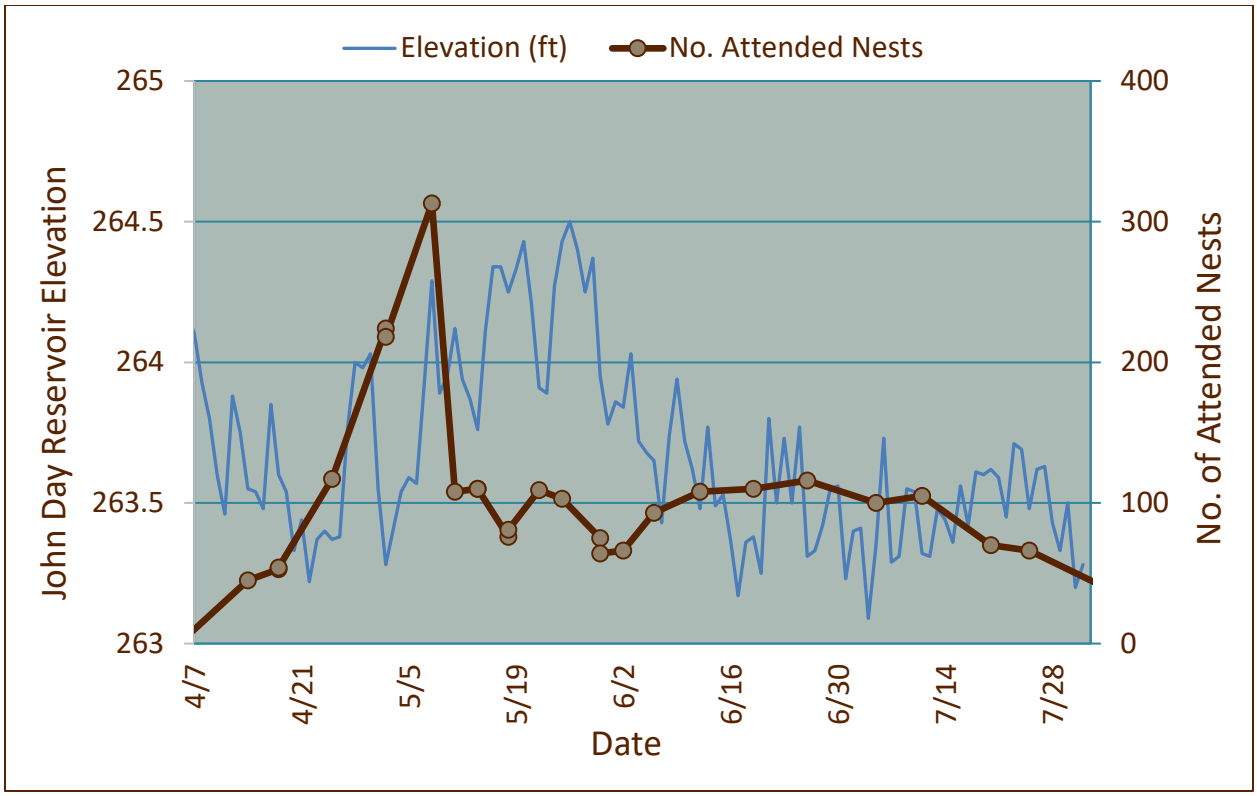


Figure 10. John Day Reservoir elevations as it relates to the availability of Caspian tern nesting habitat at the Blalock Islands in 2018. The water level monitoring system was installed on the west (downstream) side of an irrigation pumping station dock on the north side of the Columbia River, approximately 4.8 km from the Blalock Islands.

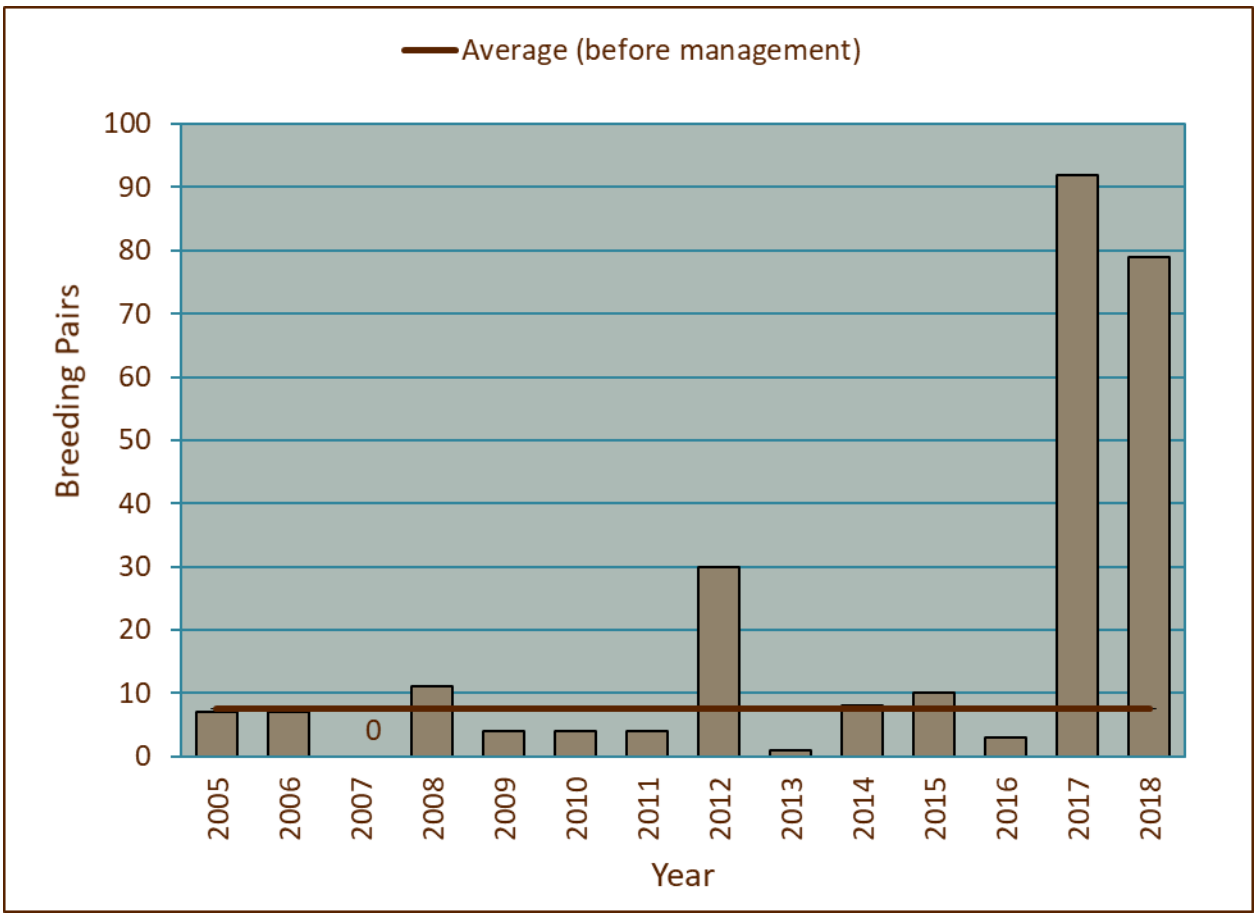


Figure 11. Size of the Caspian tern breeding colony (number of breeding pairs) at Harper Island in Sprague Lake during 2005-2018. Caspian terns did not attempt to nest on Harper Island in 2007. Also, provided is the average number of breeding pairs of Caspian terns on Harper Island prior to tern management in the Columbia Plateau region (2005-2013).

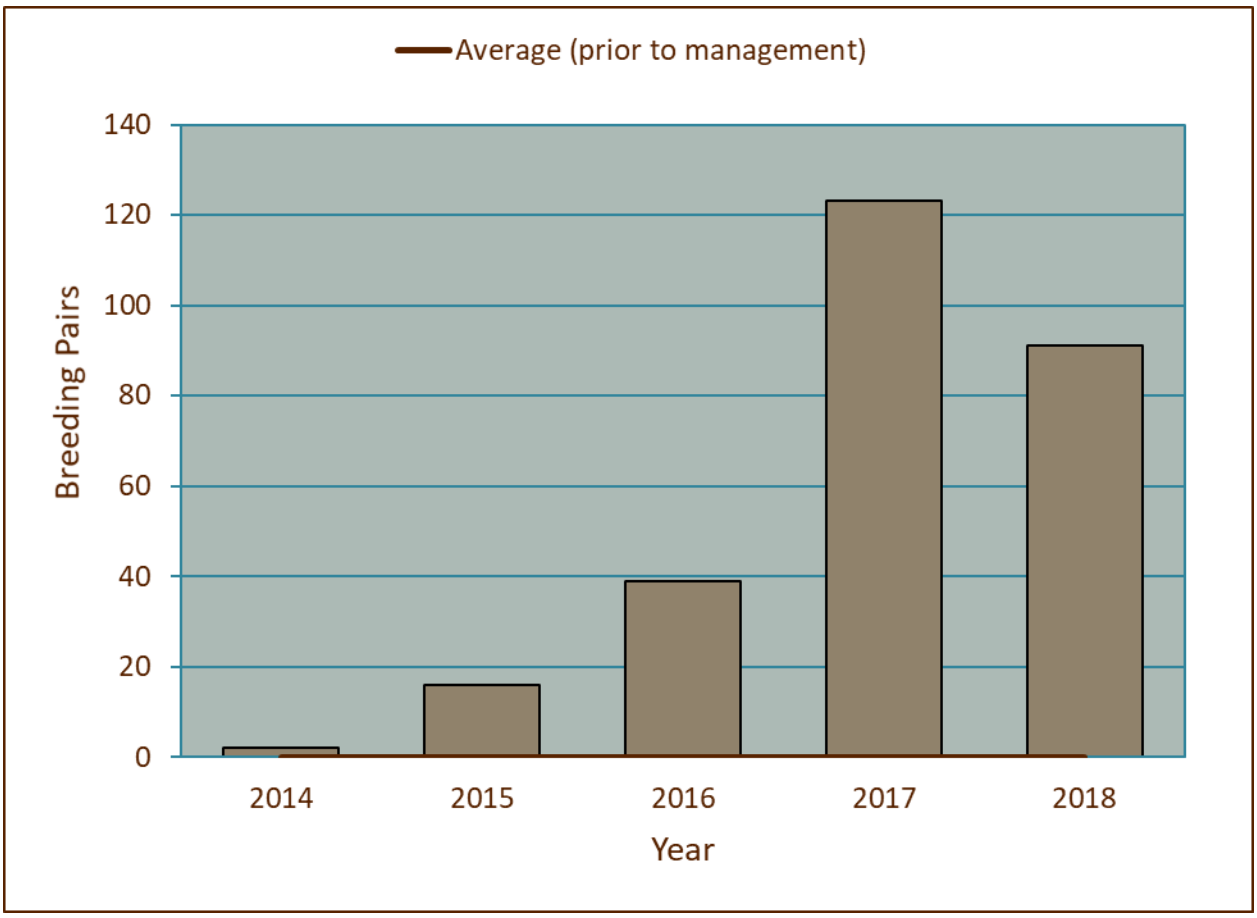


Figure 12. Size of the Caspian tern breeding colony (number of breeding pairs) at small unnamed islands in Lenore Lake during 2014-2018. In 2017-2018, terns moved to a new island in Lenore Lake located approximately 0.4 km northeast from the island used by nesting terns in 2014-2016. Caspian terns did not nest in Lenore Lake prior to tern management in the Columbia Plateau region (2005-2013).

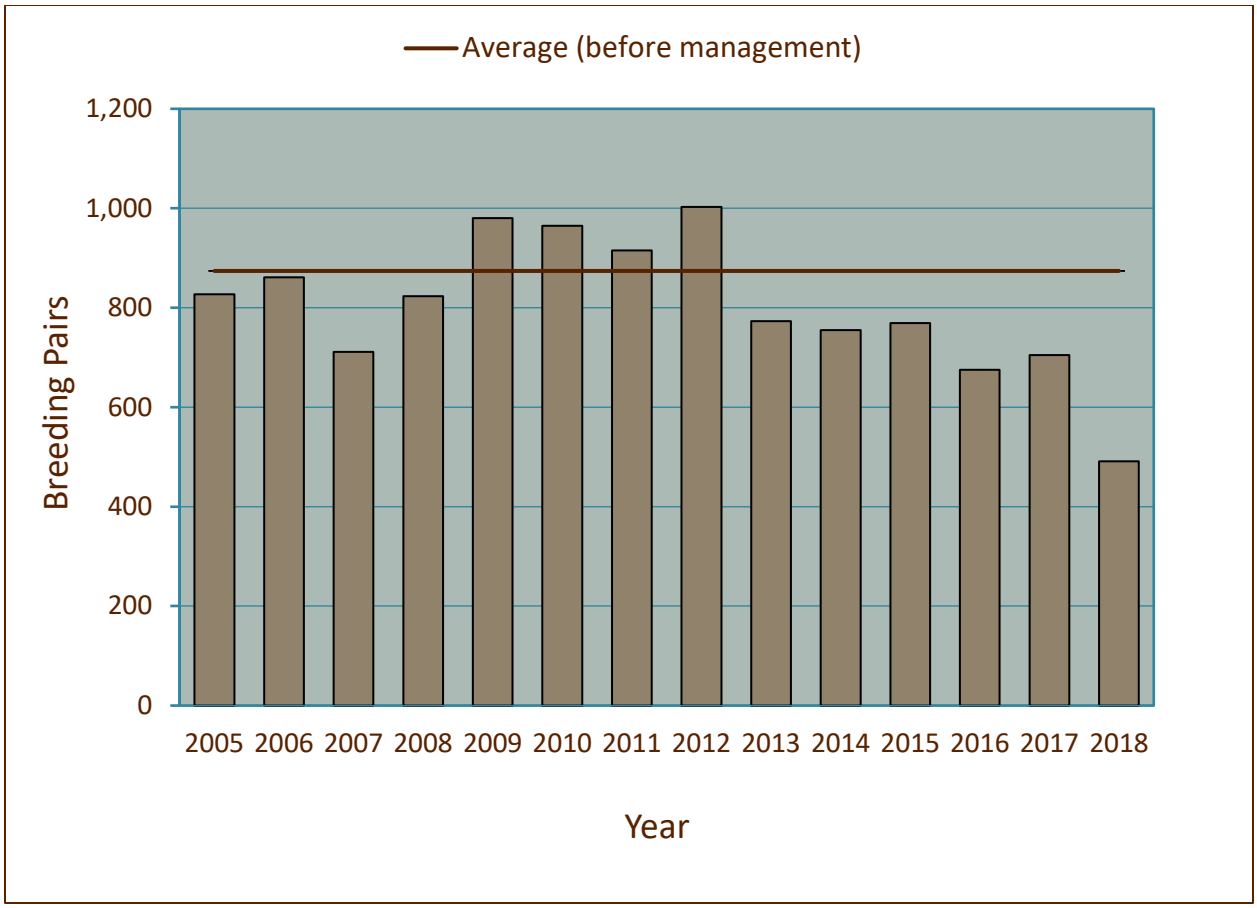


Figure 13. Total numbers of Caspian tern breeding pairs at all known colonies in the Columbia Plateau region during 2005-2018. Also, provided is the average number of breeding pairs of Caspian terns prior to tern management in the Columbia Plateau region (2005-2013).

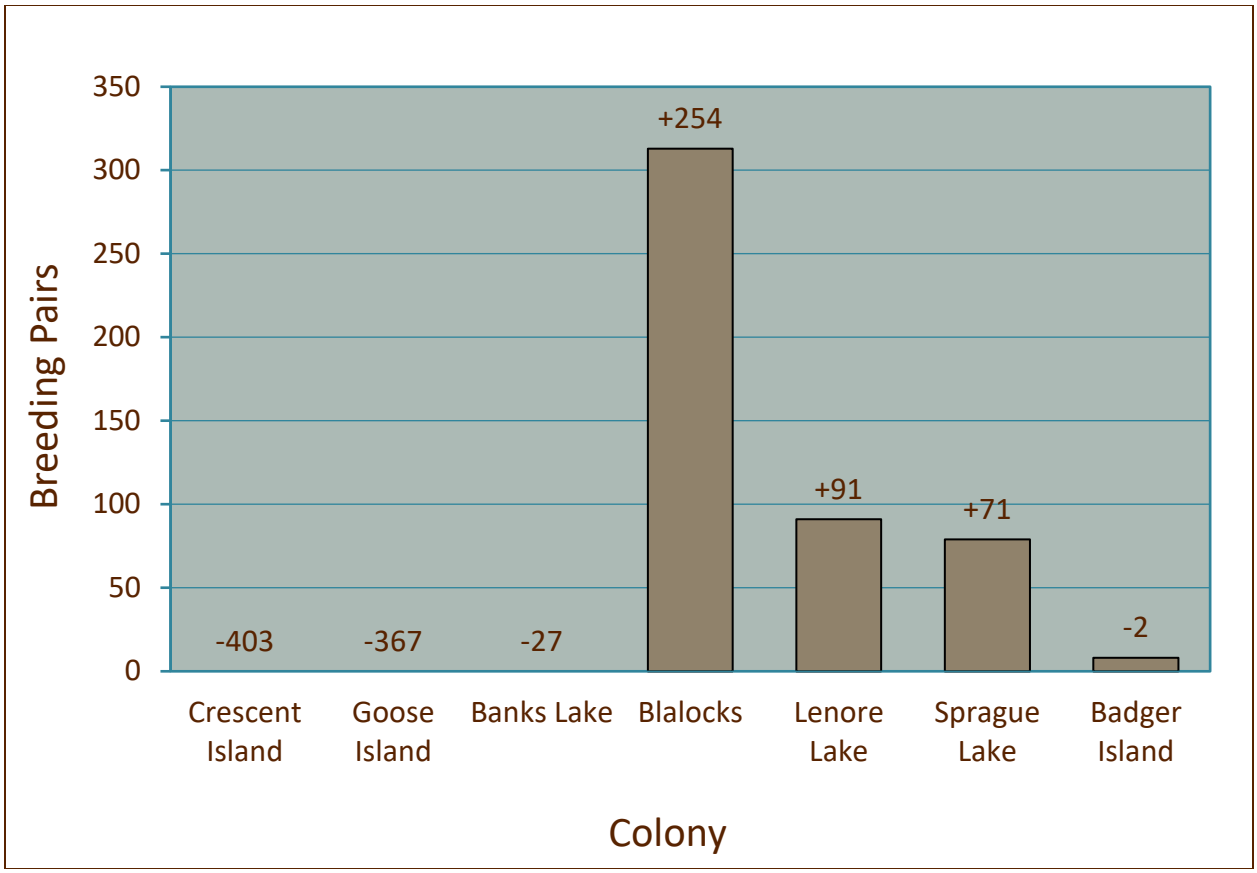


Figure 14. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the Columbia Plateau region during the 2018 breeding season. Numbers over each bar indicate the change in colony size in 2018 compared to the average colony size prior to tern management in the Columbia Plateau region (2005-2013).

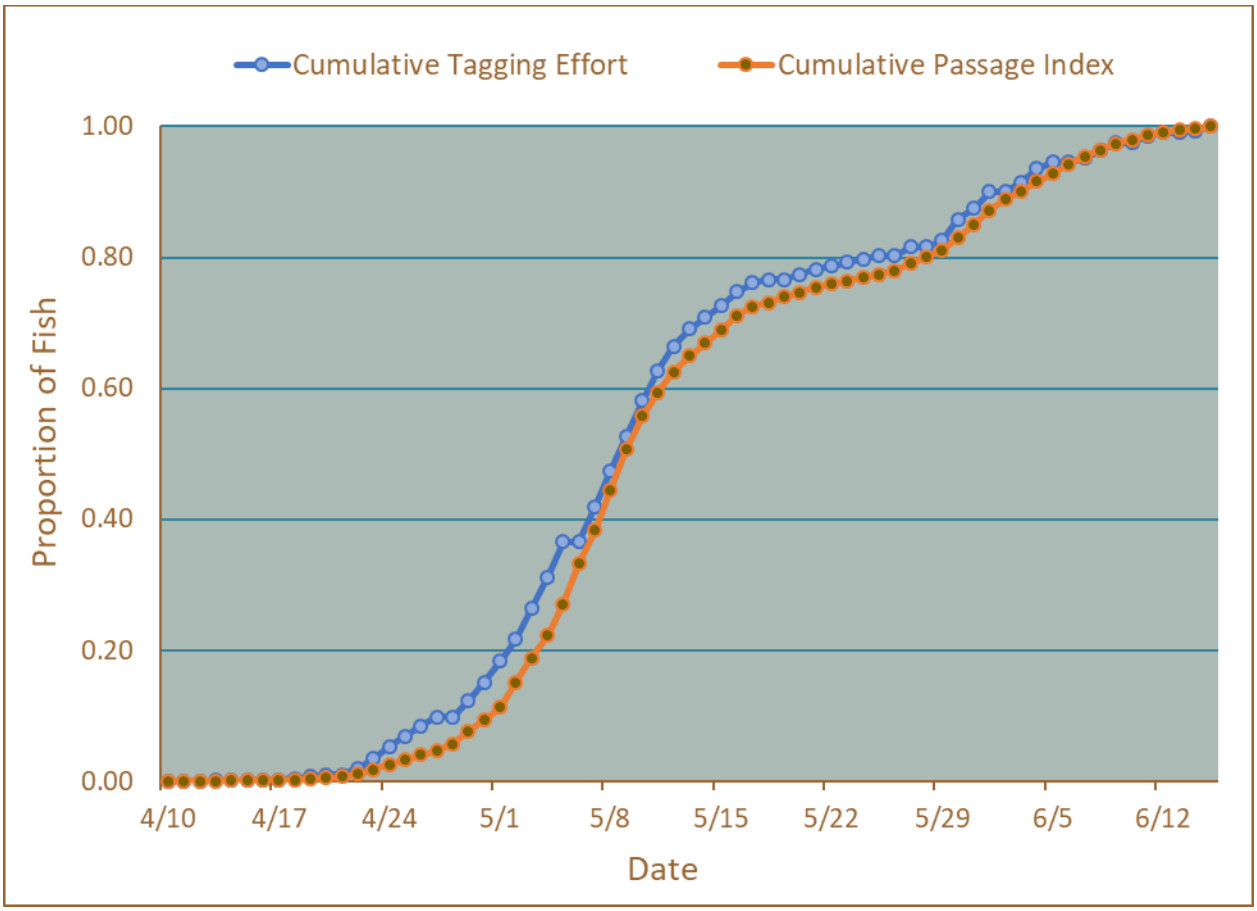


Figure 15. Proportion of steelhead PIT-tagged at the Rock Island Dam (RIS) fish trap relative to the Passage Index (tagged and untagged) in 2018. Passage index data were obtained from the Fish Passage Center (FPC 2018).

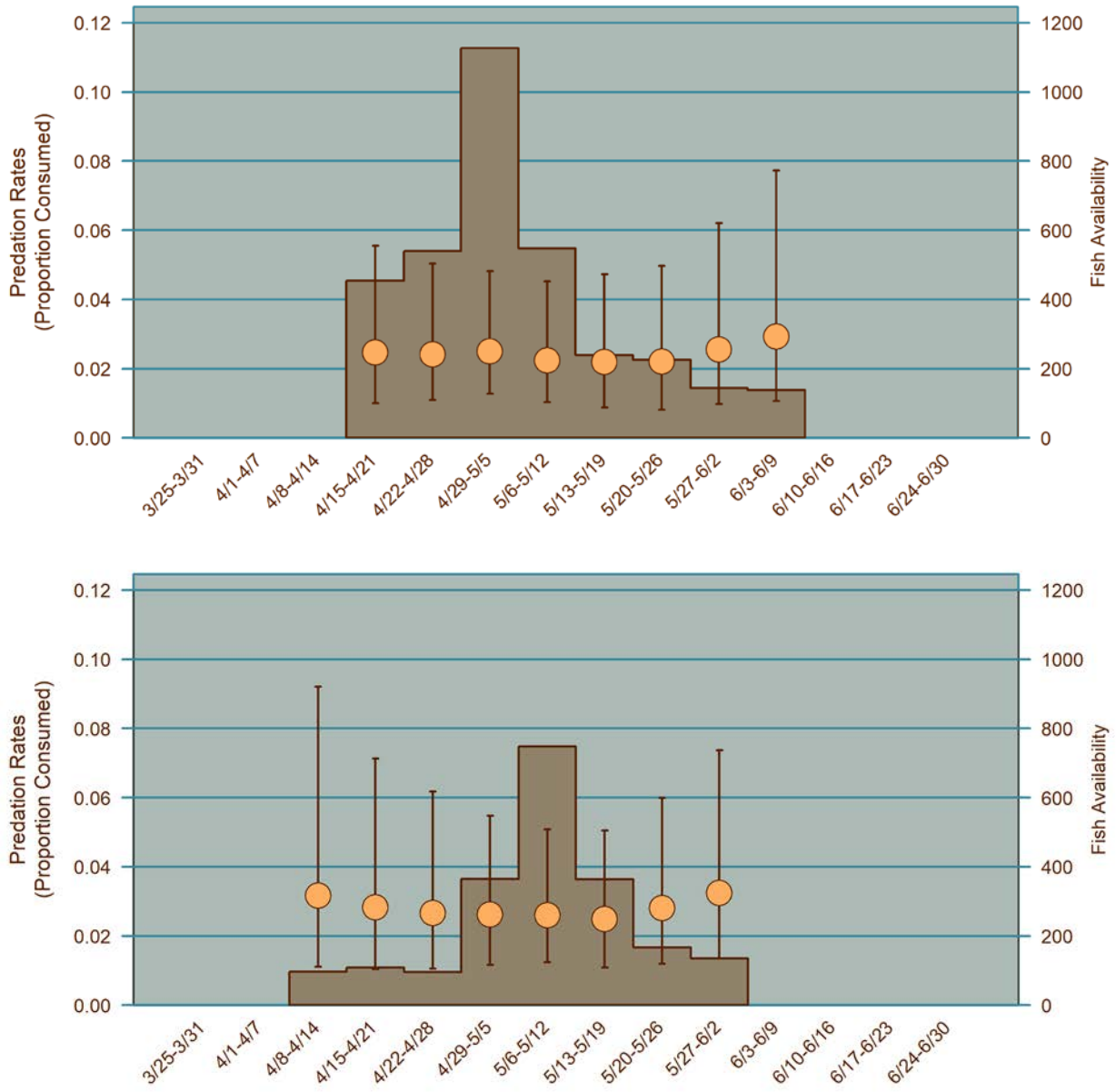


Figure 16. Estimated weekly predation rates (95% credible intervals) on upper Columbia River (top) and Snake River (bottom) steelhead by Caspian terns nesting on the Blalock Islands in John Day Reservoir in 2018. Fish availability was based on number of tagged fish interrogated/released at McNary Dam.

TABLES

Table 1. Weekly estimates of duration (minutes) and average number of Caspian terns hazed during active nest dissuasion activities at locations on Goose Island in 2018. Map 5 indicates 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
3/19-3/25	0	0	0	0	0	0	0	0	0	0	0	0
3/26-4/1	0	0	0	0	0	0	0	0	0	0	0	0
4/2-4/8	0	0	0	0	0	0	0	0	0	0	0	0
4/9-4/15	29	4	0	0	0	0	0	0	0	0	0	0
4/16-4/22	78	11	0	0	0	4	0	0	0	4	0	0
4/23-4/29	16	2	0	0	0	7	0	0	0	4	1	0
4/30-5/6	34	5	0	0	3	12	0	0	0	3	2	9
5/7-5/13	75	11	0	0	0	6	0	0	0	2	0	2
5/14-5/20	55	8	0	0	0	11	0	0	0	0	0	0
5/21-5/27	34	5	0	2	0	2	0	0	0	27	0	1
5/28-6/3	154	22	0	12	2	4	12	0	0	8	0	5
6/4-6/10	438	63	0	12	12	8	11	0	0	2	0	12
6/11-6/17	445	64	0	22	43	23	37	0	0	2	0	32
6/18-6/24	540	77	0	30	10	27	23	0	0	1	0	54
6/25-7/1	505	72	0	0	53	38	55	0	0	2	0	27
7/2-7/8	585	84	0	0	51	34	30	0	0	2	0	63
7/9-7/15	530	76	0	0	50	48	0	0	0	1	0	59
7/16-7/22	560	80	0	55	87	41	0	56	0	0	0	48
7/23-7/29	160	23	3	138	32	12	0	0	0	0	7	48

Table 2. Caspian tern eggs collected under permit on Goose Island and elsewhere in Potholes Reservoir in 2018.

Egg #	Date	Time	Location	Nest Location	Nest Location LAT	Nest Location LONG
1	4/30/2018	9:10	Goose Island	East Shoreline	46.985733	-119.308483
2	5/3/2018	10:30	North Potholes	North Potholes Island	47.01944344	-119.338159
3	6/10/2018	17:20	Goose Island	Southern Shoreline	46.9854334	-119.3098667
4	6/22/2018	11:38	Goose Island	Northwest Rocks	46.98685	-119.310833
5	7/2/2018	18:24	Goose Island	Northwest Rocks	46.98679	-119.31043
6	7/7/2018	7:25	Goose Island	East Rocks	46.987307	-119.306451
7	7/7/2018	7:25	Goose Island	Southeast Shoreline	46.987307	-119.306451
8	7/7/2018	7:48	Goose Island	Northwest Rocks	46.986778	-119.310417
9	7/9/2018	17:48	Goose Island	Southeast Shoreline	46.98556	-119.308965
10	7/15/2018	18:40	Goose Island	Southeast Shoreline	46.9868	-119.31029
11	7/16/2018	18:44	Goose Island	Southeast Shoreline	46.98558	-119.30894

Table 3. Sizes of mixed California and ring-billed gull breeding colonies (peak numbers of individuals counted) at managed sites during the 2018 breeding season, as compared to previous years.

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

Table 4. Summary of sites where Caspian terns were detected during aerial surveys in 2018 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.

Columbia Plateau (off the Columbia River)							
Survey Date	Site Name	Prospective Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
1-May	Lenore Lake - North Rock	Yes	55	28	Rock	Nests	47.482942, -119.520572
30-May	Lenore Lake - North Rock	Yes	120	91	Rock	Nests	47.482942, -119.520572
29-Jun	Lenore Lake - North Rock	Yes	70	27	Rock	Chicks	47.482942, -119.520572
29-Jun	Lenore Lake - Shoal Island	Yes	16	4	Rock/Gravel	Nests	47.47993, -119.523890
1-May	Potholes Res. - Unnamed Island	Yes	1	0	Sand	Loafing	47.019408, -119.338233
29-June	Potholes Res. - Unnamed Islands	Yes	79	0	Sand	Loafing	Multiple Locations
29-June	Potholes Reservoir - Goose Island	Yes	21	0	Sand/Rock	Loafing	46.98522, -119.309662
1-May	Marsh Unit 1	No	2	0	Mudflat	Loafing	46.955375, -119.257124
2-May	Sprague Lake - Harper Island	Yes	61	27	Rock/Dirt	Nests	47.248105, -118.085808
31-May	Sprague Lake - Harper Island	Yes	114	77	Rock/Dirt	Nests	47.248105, -118.085808
30-Jun	Sprague Lake - Harper Island	Yes	29	12	Rock/Dirt	Chicks	47.248105, -118.085808

Mid-Columbia River							
Survey Date	Site Name	Prospective Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
1-May	Willow Lake	No	12	0	Mudflat	Loafing	45.786430, -120.010173
30-May	Willow Lake	No	29	0	Mudflat	Loafing	45.786430, -120.010173
29-Jun	Willow Lake	No	6	0	Mudflat	Loafing	45.786430, -120.010173
1-May	Crow Butte	No	4	0	Mudflat	Loafing	45.865355, -119.816827
29-Jun	Crow Butte	No	15	0	Mudflat	Loafing	45.865355, -119.816827
1-May	Blalock Islands - Straight Six	No	5	0	Gravel	Loafing	45.897767, -119.660903
1-May	Blalock Islands - Rock Island	Yes	7	0	Gravel	Loafing	45.909611, -119.628697
29-Jun	Blalock Islands - Rock Island	Yes	3	0	Gravel	Loafing	45.909611, -119.628697
1-May	Blalock Islands - Sand Island	Yes	31	0	Sand	Loafing	45.897132, -119.636768

29-Jun	Blalock Islands - Sand Island	Yes	17	0	Sand	Loafing	45.897132, -119.636768
1-May	Blalock Islands - Southern Island	Yes	10	0	Gravel	Loafing	45.894784, -119.650418
30-May	Blalock Islands - Southern Island	Yes	1	0	Gravel	Loafing	45.894784, -119.650418
1-May	Blalock Islands - Middle Island	Yes	382	187	Gravel	Nests	45.895385, -119.646652
30-May	Blalock Islands - Middle Island	Yes	166	61	Gravel	Nests	45.895385, -119.646652
29-Jun	Blalock Islands - Middle Island	Yes	320	114	Gravel	Chicks	45.895385, -119.646652
1-May	Blalock Islands - Long Island	Yes	264	142	Gravel	Nests	45.895579, -119.645708
30-May	Blalock Islands - Long Island	Yes	41	0	Gravel	Loafing	45.895579, -119.645708
29-Jun	Blalock Islands - Long Island	Yes	11	0	Gravel	Loafing	45.895579, -119.645708
29-Jun	Blalock Islands - Anvil Island	No	3	0	Gravel	Loafing	45.897141, -119.651377
29-Jun	Paterson Slough	No	4	0	Mudflat	Loafing	45.926629, -119.556653
29-Jun	Shoreline near McNary Dam	No	14	0	Rock/Water	Loafing	45.944252 -119.294329
1-May	Warehouse Beach	No	21	0	Rock	Loafing	45.922529, -119.148930
30-May	Warehouse Beach	No	34	0	Rock	Loafing	45.922529, -119.148930
29-Jun	Warehouse Beach	No	9	0	Rock	Loafing	45.922529, -119.148930
1-May	Walla Walla River Delta	No	3	0	Mudflat	Loafing	46.070111, -118.920233
30-May	Walla Walla River Delta	No	2	0	Mudflat	Loafing	46.070111, -118.920233
29-Jun	Walla Walla River Delta	No	13	0	Mudflat	Loafing	46.070111, -118.920233
1-May	Badger Island	Yes	10	6	Sand	Nests	46.111447, -118.938092
29-Jun	Badger Island	Yes	6	0	Sand	Loafing	46.111447, -118.938092
29-Jun	Finley Island	No	8	0	Gravel	Loafing	46.142094, -118.992950
1-May	Foundation Island	No	2	0	Water	Loafing	46.169757, -118.994637
30-May	Foundation Island	No	1	0	Gravel	Loafing	46.169757, -118.994637
1-May	Unnamed Island near White Bluffs	No	15	0	Gravel	Loafing	46.640407, -119.411098
1-May	Locke Island	No	39	0	Gravel/Water	Loafing	46.714503, -119.487256
30-May	Cabin Island	No	2	0	Mudflat	Loafing	46.663022, -119.921049
1-May	Desert Aire	No	35	0	Mudflat	Loafing	46.695965, -119.943906
30-May	Desert Aire	No	1	0	Mudflat	Loafing	46.695965, -119.943906
1-May	Unnamed Island near Crab Creek	No	9	0	Rock	Loafing	46.791244, -119.926587

Snake River							
Survey Date	Site Name	Prospective Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
30-Jun	Shoreline near Ice Harbor Dam	No	7	0	Rock/Water	Loafing	46.236635, -118.967927
31-May	Shoreline near Big Flat HMU	No	1	0	Mudflat	Loafing	46.291942, -118.809356
30-Jun	Shoreline near Big Flat HMU	No	6	0	Mudflat	Loafing	46.291942, -118.809356
1-May	Lyons Ferry, WA	No	2	0	Log Boom	Loafing	46.592198, -118.217112
31-May	Shoreline near Lyons Ferry, WA	No	3	0	Mudflat	Loafing	46.603874, -118.323976
2-May	Spit near Little Goose Bay	No	26	0	Gravel/Water	Loafing	46.590583, -117.914259
31-May	Spit near Little Goose Bay	No	8	0	Gravel/Water	Loafing	46.590583, -117.914259
30-Jun	Spit near Little Goose Bay	No	1	0	Gravel/Water	Loafing	46.590583, -117.914259
2-May	Shoreline near Central Ferry, WA	No	11	0	Rock/Water	Loafing	46.626385, -117.810177
31-May	Shoreline near Central Ferry, WA	No	6	0	Rock/Water	Loafing	46.626385, -117.810177
2-May	Shoreline near Illia HMU	No	5	0	Sand/Water	Loafing	46.678799, -117.505528
31-May	Shoreline near Illia HMU	No	2	0	Sand/Water	Loafing	46.678799, -117.505528
30-Jun	Shoreline near Illia HMU	No	4	0	Gravel	Loafing	46.678799, -117.505528
30-Jun	Shoreline near Alpowa, WA	No	1	0	Gravel	Loafing	46.431981, -117.210979

Table 5. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) at unmanaged colonies in the Columbia Plateau region during the 2018 breeding season, as compared to previous years. None of the listed colonies were active prior to 2005.

	Year													
Colony	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	**2018**
Blalock Is. (Columbia River)	6	110	43	104	79	136	20	6	26	45	677	483	449	**313**
Badger Is. (Columbia River)	0	0	0	0	0	0	33	60	0	0	0	0	41	**8**
Twinning Is. (Banks Lake)	13	23	31	27	61	34	19	22	13	67	64	6	0	**0**
Harper Is. (Sprague Lake)	7	7	0	11	4	4	4	30	1	8	10	3	92	**79**
Unnamed Is. (Lenore Lake)	0	0	0	0	0	0	0	0	0	2	16	39	123	**91**
Unnamed Is. (Potholes Res.)	0	0	0	0	0	0	0	0	0	0	0	144	0	**0**

Table 6. Number of 2018 migration year PIT-tagged juvenile salmonids (all species combined) recovered from Caspian tern colonies in the Columbia Plateau region in 2018.

Nesting Island	Location	PIT Tags Recovered
Unnamed Island	Lenore Lake, WA	94
Blalock Islands	John Day Reservoir	1,598
Total		1,692

Table 7. Average detection efficiency (range = first-to-last week of nesting season) estimates for PIT tags on Caspian tern colonies during the 2018 nesting season. Results were used to adjust for the proportion of PIT-tags deposited by birds on their nesting colony that were subsequently detected by researchers on the colony after the nesting season. Sample sizes of the numbers of sown tags and the number of discrete sowing events (in parentheses) are also provided.

Nesting Island	Location	Sample Size	Detection Probability
Unnamed Island	Lenore Lake	100 (2)	0.58 (0.20 - 0.96)
Blalock Islands	John Day Reservoir	100 (2)	0.44 (0.28 - 0.60)

Table 8. Annual predation rates (95% credible intervals) on PIT-tagged salmonid populations (ESU/DPS) by Caspian terns nesting on Lenore Lake and the Blalock Islands in 2018. The number (N) of PIT-tagged smolts interrogated/released at Rock Island Dam (Upper Columbia River [UCR]) or Lower Monumental Dam (Snake River [SR]) used to estimate predation rates by terns nesting on Lenore Lake are provided. The number (N) of PIT-tagged smolts interrogated/released at McNary Dam used to estimate predation rates by terns nesting on the Blalock Islands are provided. Only salmonid populations with > 500 PIT-tagged smolts available were evaluated.

ESU/DPS	N	Lenore Lake Terns	N	Blalock Island Terns
SR Sockeye	1,443	< 0.1%	514	2.0% (0.4-6.1)
SR Spr/Sum Chinook	19,986	< 0.1%	17,963	0.5% (0.3-0.9)
UCR Spr Chinook	2,090	0.1% (<0.1-0.8)	5,228	0.3% (0.1-0.8)
SR Fall Chinook	8,753	< 0.1%	8,450	0.7% (0.4-1.4)
SR Steelhead	19,632	< 0.1%	3,585	2.5% (1.4-4.5)
UCR Steelhead	7,511	0.8% (0.4-1.7)	2,228	2.9% (1.5-5.2)

Table 9. Average annual pre- and post-management period predation rates by Caspian terns nesting at colonies in the Columbia Plateau region on Snake River (SR) and Upper Columbia River (UCR) salmonid populations (ESU/DPS) during 2007-2018. Management actions were implemented on Goose Island in Potholes Reservoir during 2014-2018, on an unnamed island in northeastern Potholes Reservoir during 2017-2018, and on Crescent Island during 2015-2018. No management actions have been conducted at Caspian tern colonies on Twinning Island (data first available in 2009), Blalock Islands (data first available in 2009), Lenore Lake (data first available in 2015), Badger Island (data available in 2017), and Sprague Lake (data not available [NA]; see Methods). Annual predation rate estimates with 95% credible intervals are provided in Appendix B.

	Managed Colonies								Unmanaged Colonies					
	Goose Is. Potholes R.		North Potholes Is. Potholes R.		Crescent Is. McNary R.		Twinning Is. Banks Lake		Badger Is. McNary R.	Blalock Is. John Day R.		Lenore Lake	Sprague Lake	
ESU/DPS	Pre- 07-13’	Post- 14-18’	Pre- 16’	Post- 17-18’	Pre- 07-14’	Post- 15-18’	Pre- 09-14’	Post- 15-18’	Post- 17’	Pre- 07-14’	Post- 15-18’	Post- 15-18’	Pre- 12’	Post- 17-18’
SR Sockeye	0.1%	< 0.1%	< 0.1%	< 0.1%	1.1%	< 0.1%	< 0.1%	< 0.1%	NA	0.3%	1.5%	< 0.1%	NA	NA
SR Sp/Su Chinook	< 0.1%	< 0.1%	< 0.1%	< 0.1%	0.7%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	0.1%	0.8%	< 0.1%	NA	NA
UCR Spr Chinook	2.5%	< 0.1%	0.1%	< 0.1%	0.5%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	0.6%	< 0.1%	NA	NA
SR Fall Chinook	< 0.1%	< 0.1%	< 0.1%	< 0.1%	0.8%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	0.6%	< 0.1%	NA	NA
SR Steelhead	< 0.1%	< 0.1%	< 0.1%	< 0.1%	3.9%	< 0.1%	< 0.1%	< 0.1%	0.4%	0.6%	4.5%	< 0.1%	NA	NA
UCR Steelhead	15.7%	0.1%	4.1%	< 0.1%	2.4%	< 0.1%	0.3%	0.7%	0.5%	0.6%	4.7%	0.5%	NA	NA

APPENDIX A: BEST MANAGEMENT PRACTICES

The goal of management in Potholes Reservoir and Crescent Island (hereafter referred to collectively as the "managed islands") is to prevent any more than 40 pairs of Caspian terns from nesting on either island. To achieve this goal, the objective in 2018 is to dissuade all Caspian terns from nesting on the two managed islands. Caspian tern nesting is defined as terns laying one or more eggs in a nest scrape.

A strategy the federal management agencies (Corps of Engineers, Bureau of Reclamation, and U.S. Fish and Wildlife Service) have advocated for achieving the above objective is to try to prevent or delay all gulls from nesting on the managed islands. The strategy is based on the supposition that once gulls lay eggs on the managed islands, Caspian terns that subsequently attempt to nest near active gull nests cannot be hazed without causing gull nests to fail, because nests of gulls flushed during tern hazing will be at risk of having their eggs depredated by other gulls. The U.S. Fish and Wildlife Service has stated that, while it is prepared to issue a permit to take a limited number of Caspian tern eggs on the managed islands (< 200 eggs per island), if Caspian terns successfully lay eggs, the agency cannot issue a permit for incidental take of other migratory bird species, including incidental take of gull eggs during tern hazing activities. Therefore, by preventing or delaying gull nesting on the managed islands, the potential for active gull nests (those with eggs) to shield Caspian tern nests from hazing will be reduced. Similarly, Canada geese, herons, and egrets have nested on one or both managed islands in previous years and best management practices (BMPs) have been developed for these species as well.

The difficulty in dissuading all gulls from nesting on the managed islands using passive dissuasion (landscape fabric fences or stakes, ropes, and flagging) and human hazing techniques has been communicated to the federal management agencies. Prior to the waterbird breeding season, large areas of passive dissuasion will be installed on each island at the direction of the management agencies to make the islands less attractive to nesting Caspian terns. Observations on Goose Island in 2014-2017 indicated that, unlike Caspian terns, ring-billed gulls and California gulls were not responsive to passive dissuasion; gulls readily entered areas of passive dissuasion and initiated nests. In addition, gulls tended to acclimate more readily than Caspian terns to repeated human hazing, and quickly returned to their nest sites after flushing due to human hazing.

Crepuscular and nocturnal hazing using bright lights and lasers to enhance the efficacy of passive dissuasion and daytime human hazing have been authorized for use again this season under Reclamation's NEPA Categorical Exclusion for test actions noted above. These techniques showed some promise for delaying the initiation of gull nests on Goose Island in 2014-2017 by causing island abandonment by gulls each night during the early stages of the breeding season (before egg-laying commences). However, once gull nests with eggs are confirmed, crepuscular or night-time hazing that may lead to overnight island abandonment

will be discontinued to avoid egg loss during the nocturnal absence of nesting adults. Weather-permitting, personnel will stay overnight in portable buildings on Goose Island, so they can haze any gulls that attempt to spend the night on the islands during the pre-egg-laying period, and to use bright lights and lasers to dissuade gulls that attempt to return to the island at first light.

The passive dissuasion at islands in Potholes Reservoir (i.e. stakes, ropes, and flagging) and on Crescent Island (i.e. fabric fencing, stakes, ropes, flagging, woody debris, and willow plantings) will be installed to cover essentially all the suitable and marginally suitable Caspian tern nesting habitat on the managed islands, and the area where passive dissuasion has been deployed will be the primary focus of gull hazing. Fixed and portable observation blinds may also be used to dissuade gull nesting using lasers, especially gulls that attempt to nest in any interior areas of either of the islands.

Results of passive and active nest dissuasion at Goose Island in 2014-2017 indicated that even with intensive human hazing, gulls are likely to ultimately establish nests and lay eggs, both within and outside the passive dissuasion areas, but it is unlikely that Caspian terns will be decoyed into areas of passive dissuasion by nesting gulls. Instead, Caspian terns are more likely to initiate nests on marginal habitat that lies outside areas covered by passive dissuasion, mostly near the water's edge as reservoir levels drop. As these areas become available to nesting terns, more passive dissuasion will be deployed in-season to prevent tern use of these areas.

We have developed best management practices (BMPs) for minimizing disturbance during hazing of gulls and Caspian terns to other migratory bird species that nest on the managed islands. Canada geese are known to nest on all managed islands, and great blue herons, black-crowned night-herons, and great egret are known to nest on Crescent Island. Flushing any of these non-target species from their nests has the potential to result in egg loss due to egg predators. Canada geese generally nest on the ground, whereas herons and egrets generally build stick nests in trees and tall shrubs. The areas where herons and egrets have nested previously on Crescent Island are in the densely-vegetated interior of the island; these areas are not used by nesting gulls or Caspian terns and are unsuitable nesting habitat for either gulls or terns. Consequently, these areas of the island will not be hazed to prevent or delay gull nesting and will be avoided to minimize disturbance to non-target nesting herons and egrets.

Using the same techniques described for Caspian terns and gulls, geese, herons, and egrets will be dissuaded from establishing new nests on the portions of the managed islands where gull and tern hazing will be conducted. For any goose, heron, or egret nests with eggs, or nests of other non-target migratory birds that may be discovered during the process of hazing Caspian terns or gulls, practices to reduce the chances of egg loss are described in detail below.

Early in the pre-breeding period, before behaviors associated with imminent egg-laying are widespread (e.g., nest-building, copulation), human hazing of gulls will consist of walk-throughs of the island to flush all gulls that are present. Twice each day, a 2-person crew will conduct a walk-through of each managed island. These walk-throughs will occur early in the day (before

10:00 am) and late in the day (after 3:00 pm), weather permitting. During each walk-through, the locations of any gull aggregations will be mapped on a diagram of the island. Once per week, the locations of gulls by species (ring-billed gulls or California gulls) will be mapped. Any areas where gulls are holding territories or engaged in pre-laying behaviors (i.e. courtship, territorial display, copulation, and nest-building) will also be marked on the map. If possible, the species of gull (California or ring-billed) that is engaged in pre-laying behaviors will be recorded. All gulls on the island will be flushed at least once during each walk-through event, unless gulls are known or suspected of attending eggs.

Prior to each of the early-day walk-throughs, the crew will boat around each managed island and estimate the numbers of all gulls and Caspian terns on the island, as well as the numbers of gulls and Caspian terns roosting on any emergent rocks nearby. Counts will be completed relatively quickly (< 30 min). When large numbers of gulls are present (thousands), it will be acceptable to estimate the number of gulls present by counting in the 100's, and there will be no attempt to distinguish between the two gull species in the numbers of gulls present. Gull counts/estimates will be entered into the waterbird survey PDA application and reported in the weekly report to the Corps and Reclamation. An estimate of the proportion of each gull species on each managed island and how gull numbers were estimated (e.g., counted in 100's) will be included. Counts of Caspian terns observed on each island will be entered into the Caspian tern PDA application and reported in the weekly report to the Corps and Reclamation. If Caspian terns are likely present in areas difficult to survey from the boat, follow-up counts of Caspian terns will be conducted from blinds adjacent to the former colony areas, or other suitable vantage. For extended observations of Caspian terns from a blind, we will include counts upon arrival and before departure, and will include the maximum number of Caspian terns observed in the "notes" section of the tern PDA application. We will update or replace boat-based counts/estimates of gulls and Caspian terns with blind-based counts when blind-based counts are more accurate or complete. In addition to counts of gulls present on the managed islands, we will use the waterbird survey PDA application to record the numbers of Canada geese, herons, and egrets that are observed during waterbird surveys and during hazing activities. For each species, we will record data on the number of individuals, nesting status (if known), and number of eggs for any active goose nests located (clutch size for heron and egret nests will not be determined because they generally nest only in trees or tall shrubs). As for gulls and Caspian terns, we will include counts/estimates of individuals, nesting status, and any observed pre-laying behaviors in the weekly report to the Corps and Reclamation.

Once large numbers of gulls have initiated pre-laying behaviors on the managed islands, island walk-throughs will be increased in frequency to increase the deterrence for gulls and Caspian terns to lay eggs on the islands. At least two morning walk-throughs starting in the hour before dawn and conducted over the subsequent 3-hour period, and two afternoon walk-throughs conducted over a 3-hour period and ending after dark will be conducted; during each walk-through, all gulls and/or Caspian terns will be flushed, except for those gulls known or suspected to be attending eggs. During the period leading up to egg-laying by gulls, colony monitors will stay over-night on the island (with landowner authorization and weather-permitting) so that all gulls can be cleared off the island over-night by hazing after dark, and so

that hazing can be initiated as soon as gulls attempt to return to the island in the pre-dawn hours.

If gulls are suspected of having laid eggs in a nest, either outside or inside the passive dissuasion area, the attending adult gull will be approached slowly and cautiously to induce the gull to stand-up, but not flush from its nest. This may require carefully approaching the gull nest to within a few meters. Once the gull has stood up and if the observer determines that eggs are present, the observer will gradually back away from the nest to avoid flushing the adult gull and exposing the egg(s) to potential predation by other gulls. The number of gull nests with eggs and the number of eggs per nest will be recorded. Each gull egg detected on a managed island will be reported to the field coordinator(s) as soon as practical (during the same day, at the latest) so that they can forward the information to the Corps and Reclamation. If loss of a gull egg due to gull depredation is observed, this will also be reported the same day to field coordinator(s). Potential new gull nests will be checked for eggs only if the nest is more than 15 m from the nearest gull nest already confirmed to contain eggs.

If a Caspian tern nest with eggs is suspected anywhere on a managed island, the verification procedure will depend on the context of the suspected Caspian tern nest. If no active gull nests are verified or suspected within 15 m of the suspected Caspian tern nest, then the tern nest will be approached close enough to cause the tern to flush from the nest scrape. If there are known or suspected gull nests within 15 m of the suspected tern nest, then the approach of the suspected tern nest will be slow and cautious to preclude gulls from flushing from their nests and exposing their eggs to gull predation. If the Caspian tern on the suspected nest is flushed and reveals one or more tern eggs, those eggs will be collected (under permit) and transported whole in egg containers back to the field house. Collected Caspian tern eggs will be stored temporarily in a refrigerator, for eventual transport to research institutions that have interest in receiving the eggs.

If a suspected Caspian tern nest is located within 15 m of a known or suspected gull nest containing eggs, the tern nest will not be approached to verify the presence of tern eggs UNLESS previous experience with the nesting gulls in question indicates that they are unlikely to flush from their nests. If a recently laid Caspian tern egg can be collected without causing nesting gulls to flush and expose their own eggs to gull predation, then it will be collected; if the Caspian tern egg cannot be collected without flushing gulls from nearby nests with eggs, then the tern egg will not be collected. Any Caspian tern eggs that are laid on the managed islands, whether they are collected or not, will be reported to the field coordinator(s) as soon as practical so that they can forward the information to the Corps and Reclamation, and for subsequent reporting to the USFWS. Reporting to the Corps and Reclamation will occur during the same day that any Caspian tern eggs are detected or collected for reporting to the USFWS Migratory Bird office in Portland.

If a Canada goose nest with eggs is suspected anywhere on a managed island, the verification procedure will depend on the context of the suspected goose nest, as for suspected Caspian tern nests. If no active gull nests are verified or suspected within 15 m of the suspected goose

nest, then the goose nest should be inspected to confirm the nest contents. If eggs are confirmed, they should be counted quickly and the goose down lining the nest should be pulled over the eggs to shield them from the view of predators. This should occur very quickly, and researchers should then move away from the nest.

If a heron or egret nest is being built on the managed islands in an area that is suitable for gull or Caspian tern nesting (i.e. sparsely vegetated or unvegetated ground), then these pre-laying herons and egrets will be hazed in the process of hazing pre-laying gulls and terns. If a heron or egret nest is suspected of containing eggs (based on the behavior of parent birds at the nest, the verification procedure will again depend on the context of the suspected nest, as for suspected Caspian tern nests). Field technicians will use professional judgment to decide whether a heron or egret nest suspected of containing eggs is in potential gull or Caspian tern nesting habitat. If the suspected heron or egret nest is in densely-vegetated habitat completely unsuitable for gull or tern nesting habitat, it will be avoided. Because field technicians will likely be unable to see into heron and egret nests in trees or tall shrubs, field personnel should observe suspected heron and egret nests in potential tern or gull nesting habitat from a vantage that does not cause the heron or egret to leave the nest. Herons or egrets that hold tight to well-built stick nests when an observer moves slowly to within 15 m will be considered to contain eggs. Heron and egret nests will be recorded as “active” for nests deemed likely to contain eggs or “inactive” for herons/egrets that appear to be pre-breeding or nest building. Researchers will promptly move away from heron and egret nests that likely contain eggs.

Continued gull or Caspian tern nest dissuasion in any area around a known or suspected active goose, heron, or egret nest (i.e. containing eggs) will be carried out using techniques to minimize the possibility of egg loss by these non-target species. These include (1) a slow, indirect approach to the area where a nest is known to be present, (2) averting eyes to avoid direct eye contact with the attending bird, (3) when possible, traveling along the island perimeter to avoid pressuring the attending bird into a preferred escape route in the direction of water, (4) moving relatively quickly away from the area where a nest with eggs is located (the general 30-m vicinity), and, when the possibility of gull nest initiation (egg-laying) appears low, (5) the frequency of gull dissuasion will be temporarily reduced in areas with newly discovered goose nests with eggs and/or goose nests with recently-laid eggs (as suggested by small, likely incomplete clutches [e.g., < 4 eggs]). If feasible, gull dissuasion near incipient goose nest will be reduced for 4-7 days until the nesting geese further invest in their nesting effort and there is less risk of nest abandonment. Gull dissuasion will be reduced locally in a similar manner around newly discovered heron and egret nests that likely contain eggs to reduce the likelihood of nest abandonment during the early incubation phase. If there is a potential risk of egg predation during any short-term displacement of a goose from a nest (e.g., by common ravens), (6) the goose down lining the nest will be used to cover the eggs to obscure them from view. Other best management practices to minimize nest abandonment and egg loss by migratory bird species other than Caspian terns will be employed as identified.

APPENDIX B: HISTORIC ESU/DPS-SPECIFIC PREDATON RATES

Table A1. Annual colony sizes and predation rates (95% credibility intervals) by Caspian terns on ESA-listed salmonid populations (ESU/DPS) originating from the Snake River (SR) and Upper Columbia River (UCR) during 2007-2018. Colony size is depicted as the number of breeding pairs. NA denotes that sample sizes of available PIT-tagged smolts were too small (< 500) to generate reliable predation rate estimates or that estimates were not calculated due to lack of scanning that year (see Methods). Dashed lines denote that predation rates were presumed to be zero or close to zero due to a lack of nesting terns at that site in that year.

Predation Rates by Goose Island Caspian Terns in Potholes Reservoir, Managed Colony During 2014-2018							
Year	Colony Size	UCR Steelhead	UCR Spr Chinook	SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
2007	282	15.3% (9.8-27.7)	NA	0.1% (0-0.2)	<0.1%	0.3% (0-1.1)	NA
2008	293	11.1% (8.6-16.4)	NA	<0.1%	<0.1%	<0.1%	0.4% (0-1.6)
2009	487	22.6% (17.2-33.7)	5.5% (2.7-10.7)	0.1% (0-0.2)	<0.1%	<0.1%	0.1% (0-0.4)
2010	416	14.6% (11-21.8)	2.0% (0.7-4.4)	<0.1%	<0.1%	<0.1%	0.3% (0-1.4)
2011	422	12.9% (9.6-19.6)	0.6% (0.1-1.9)	<0.1%	<0.1%	<0.1%	<0.1%
2012	463	18.4% (13.5-28.5)	2.6% (1.2-5.4)	0.2% (0.1-0.4)	<0.1%	<0.1%	0.1% (0-0.4)
2013	340	14.8% (11.4-21.6)	2.5% (1.1-5.2)	0.1% (0-0.3)	<0.1%	0.1% (0-0.3)	0.1% (0-0.5)
2014	159	2.9% (1.9-5.1)	0.6% (0.1-2.2)	<0.1%	<0.1%	<0.1%	<0.1%
2015	2	-	-	-	-	-	-
2016	0	-	-	-	-	-	-
2017	0	-	-	-	-	-	-
2018	0	-	-	-	-	-	-

Predation Rates by Caspian Terns on an Unnamed Island in North Potholes Reservoir, Managed Colony During 2017-2018							
Year	Colony Size	UCR Steelhead	UCR Spr Chinook	SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
2016	144	4.1% (2.9-6.3)	0.1% (0-0.3)	<0.1%	<0.1%	<0.1%	<0.1%
2017	0	-	-	-	-	-	-
2018	0	-	-	-	-	-	-

Predation Rates by Crescent Island Caspian Terns in McNary Reservoir, Managed Colony During 2015-2018							
Year	**Colony Size**	**UCR Steelhead**	**UCR Spr Chinook**	**SR Steelhead**	**SR Spr/Sum Chinook**	**SR Fall Chinook**	**SR Sockeye**
2007	355	2.5% (1.7-3.8)	NA	3.9% (3.1-5.6)	0.4% (0.3-0.6)	0.9% (0.4-1.7)	NA
2008	388	2.9% (2.1-4.3)	NA	5.9% (4.7-8.5)	0.9% (0.7-1.3)	1.6% (1.2-2.3)	1.7% (0.6-3.7)
2009	349	2.3% (1.7-3.5)	0.2% (0-1.2)	4.6% (3.7-6.6)	1.5% (1.1-2.2)	1.1% (0.8-1.6)	1.0% (0.5-1.7)
2010	375	1.8% (1.3-2.7)	0.9% (0.3-2.3)	4.0% (3.1-5.9)	0.4% (0.3-0.7)	1.0% (0.7-1.4)	1.5% (0.5-3.5)
2011	419	2.4% (1.8-3.6)	0.5% (0.1-1.2)	2.7% (2.1-4.0)	0.7% (0.5-1.0)	0.5% (0.4-0.8)	0.7% (0.5-1.1)
2012	422	1.2% (0.8-2.0)	0.2% (0-0.8)	2.8% (2.1-4.1)	0.6% (0.4-0.9)	0.5% (0.4-0.8)	1.3% (0.9-2.2)
2013	393	2.9% (2.1-4.3)	0.4% (0.1-1.2)	2.9% (2.2-4.3)	0.5% (0.4-0.8)	0.7% (0.4-1.1)	0.6% (0.2-1.4)
2014	474	3.4% (2.5-4.8)	0.7% (0.2-2.1)	4.7% (3.7-6.9)	0.5% (0.3-0.7)	0.5% (0.3-0.8)	0.7% (0.4-1.3)
2015	0	-	-	-	-	-	-
2016	0	-	-	-	-	-	-
2017	0	-	-	-	-	-	-
2018	0	-	-	-	-	-	-

ESU/DPS-specific Predation Rates by Twinning Island Caspian Terns in Banks Lake, Unmanaged Colony							
Year	**Colony Size**	**UCR Steelhead**	**UCR Spr Chinook**	**SR Steelhead**	**SR Spr/Sum Chinook**	**SR Fall Chinook**	**SR Sockeye**
2009	61	0.1% (0-0.3)	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
2010	34	0.1% (0-0.3)	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
2011	19	-	-	-	-	-	-
2012	22	0.1% (0-0.3)	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
2013	13	-	-	-	-	-	-
2014	67	1.2% (0.3-6.4)	0.5% (0.1-7.9)	<0.1%	<0.1%	<0.1%	<0.1%
2015	64	2.6% (1.8-3.9)	0.2% (0-0.9)	<0.1%	<0.1%	<0.1%	NA
2016	6	0.1% (0-0.3)	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
2017	0	-	-	-	-	-	-
2018	0	-	-	-	-	-	-

Predation Rates by Caspian Terns on an Unnamed Island in Lenore Lake, Unmanaged Colony							
Year	**Colony Size**	**UCR Steelhead**	**UCR Spr Chinook**	**SR Steelhead**	**SR Spr/Sum Chinook**	**SR Fall Chinook**	**SR Sockeye**
2015	16	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	NA
2016	39	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
2017	123	1.0% (0.6-2.0)	0.3% (0.1-0.8)	<0.1%	<0.1%	<0.1%	NA
2018	91	0.8% (0.4-1.7)	0.1% (0-0.8)	<0.1%	<0.1%	<0.1%	<0.1%

Predation Rates by Harper Island Terns in Sprague Lake, Unmanaged Colony							
Year	**Colony Size**	**UCR Steelhead**	**UCR Spr Chinook**	**SR Steelhead**	**SR Spr/Sum Chinook**	**SR Fall Chinook**	**SR Sockeye**
2012	30	NA	NA	NA	NA	NA	NA
2017	92	NA	NA	NA	NA	NA	NA
2018	79	NA	NA	NA	NA	NA	NA

Predation Rates by Badger Island Caspian Terns in McNary Reservoir, Unmanaged Colony							
Year	**Colony Size**	**UCR Steelhead**	**UCR Spr Chinook**	**SR Steelhead**	**SR Spr/Sum Chinook**	**SR Fall Chinook**	**SR Sockeye**
2017	41	0.5% (0.3-0.8)	<0.1%	0.4% (0.2-0.6)	<0.1%	<0.1%	NA
2018	8	-	-	-	-	-	-

Predation Rate by Blalock Island Caspian Terns in John Day Reservoir, Unmanaged Colony							
Year	**Colony Size**	**UCR Steelhead**	**UCR Spr Chinook**	**SR Steelhead**	**SR Spr/Sum Chinook**	**SR Fall Chinook**	**SR Sockeye**
2007	43	1.0% (0.6-1.7)	<0.1%	0.9% (0.6-1.4)	<0.1%	0.1% (0-0.2)	NA
2008	104	0.7% (0.4-1.2)	0.1% (0-0.2)	0.8% (0.6-1.2)	0.1% (0.1-0.2)	<0.1%	NA
2009	79	0.5% (0.3-1.0)	0.2% (0.1-0.5)	0.6% (0.4-0.9)	0.3% (0.2-0.4)	<0.1%	<0.1%
2010	136	0.9% (0.6-1.6)	0.1% (0-0.1)	0.9% (0.7-1.4)	0.1% (0-0.1)	<0.1%	0.2% (0-0.6)
2011	20	0.1% (0-0.3)	<0.1%	0.1% (0.1-0.2)	0.1% (0-0.1)	0.1% (0.1-0.2)	0.3% (0.1-0.8)
2012	6	-	-	-	-	-	-
2013	26	0.2% (0-0.5)	<0.1%	0.1% (0-0.2)	<0.1%	0.1% (0-0.1)	<0.1%
2014	45	0.6% (0.3-1.2)	0.2% (0.1-0.4)	0.4% (0.2-0.7)	0.1% (0.1-0.2)	0.3% (0.2-0.5)	0.4% (0.1-1.1)
2015	677	8.2% (5.9-12.4)	0.9% (0.5-1.5)	8.0% (6.0-11.4)	1.4% (1.1-2.2)	0.4% (0.4-0.8)	1.3% (0.7-2.5)
2016	483	3.1% (2.3-4.6)	0.2% (0.1-0.4)	3.9% (3.9-5.7)	0.3% (0.2-0.5)	0.6% (0.4-1.1)	2.3% 1.2-4.1)
2017	449	4.2% (2.7-6.5)	1.1% (0.7-1.8)	3.4% (2.4-5.1)	0.9% (0.6-1.3)	0.6% (0.4-1.1)	NA
2018	313	2.9% (1.5-5.2)	0.3% (0.1-0.8)	2.5% (1.4-4.5)	0.5% (0.3-0.9)	0.7% (0.4-1.4)	2.0% (0.4-6.1)