IMPLEMENTATION OF THE INLAND AVIAN PREDATION MANAGEMENT PLAN, 2017

2017 Final Annual Report

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EXECUTIVE SUMMARY

In 2017, the U.S. Army Corps of Engineers - Walla Walla District and the U.S. Bureau of Reclamation (BOR) continued 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 populations of salmonids (*Oncorhynchus* spp.) from the Columbia River basin (USACE 2014). The primary objective of management in the fourth year of implementation was to limit the numbers of Caspian terns breeding at colonies in Potholes Reservoir and on Crescent Island in McNary Reservoir to less than 40 breeding pairs each. 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 2017 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, 4.3 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 2016; additionally, all open areas on Crescent Island had been planted with willows and other native vegetation prior to the 2016 nesting season. Finally, the island in northeastern Potholes Reservoir that was used by Caspian terns for nesting in 2016 (0.15 acre) and four nearby islands where terns were observed prospecting in 2017 (0.3 acre) were covered in passive dissuasion to prevent terns from nesting at those sites. An effort was also made to prevent nesting by the two species of gulls (California gulls [*L. californicus*] and ring-billed gulls [*L. delawarensis*]) that have nested at Goose and Crescent islands, on the theory that nesting gulls would attract prospecting Caspian terns and could limit the efficacy of efforts to dissuade Caspian terns from nesting at these managed sites. Once Caspian terns and gulls arrived to initiate nesting, active nest dissuasion (i.e. human hazing) was used to try to dissuade both Caspian terns and gulls from nesting on Goose and Crescent islands, as well as on other islands in the northern portion of Potholes Reservoir.

As was the case in 2015-2016, 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 2017 nesting season, the third year of management at this site. 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 on Crescent Island, including the former colony area; 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 in 2015-2017; 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 established a new colony on Badger Island located on the Columbia River just one kilometer upriver from Crescent Island in 2015-2017. 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 2015-2017 and Badger Island in 2017, 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, some Caspian terns continued to display high fidelity to Potholes Reservoir as a nesting area in 2017, the fourth 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 2015-2016, Caspian tern use of Goose Island for roosting and nesting in 2017 was largely limited to areas near the island's shoreline, areas that became exposed during the nesting season as reservoir levels receded. Despite high fidelity of terns to the area, active nest dissuasion (hazing), collection (under permit) of any Caspian tern eggs discovered, and high rates of gull depredation on newly-laid Caspian tern eggs were factors in preventing the formation of a Caspian tern colony on Goose Island and elsewhere in Potholes Reservoir in 2017. This is the second 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 Northwest Rocks near 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 2017, egg laying by Caspian terns on Goose Island and elsewhere in Potholes Reservoir occurred between 29 April and 7 July. During this period, a total of 20 Caspian tern eggs were discovered at three different locations in Potholes Reservoir; 18 tern eggs were discovered on Goose Island and one tern egg was discovered on two different islands in northern Potholes Reservoir. Of the 20 tern eggs that were discovered, 18 were collected under permit and two were depredated by gulls soon after they were laid. By comparison, a total of 282 Caspian tern eggs were found on Goose Island and an incipient colony in northeastern Potholes Reservoir in 2016; 6 tern eggs were discovered and collected under permit on Goose Island and 276 tern eggs were discovered on an incipient colony in northeastern Potholes Reservoir after the colony was completely abandoned due to predation and disturbance caused by a mink early June. The eggs laid on the incipient colony in northeastern Potholes Reservoir were not collected.

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 2017, Caspian terns attempted to nest at four different unmanaged colony sites in the Columbia Plateau region. Three of these colony sites had been used in previous years, and one site was new in 2017. The formerly occupied colony sites included the Blalock Islands complex in John Day Reservoir (449 breeding pairs in 2017, down from 483 breeding pairs in 2016), Harper Island in Sprague Lake (92 breeding pairs in 2017, up from three breeding pairs in 2016), and Badger Island in McNary Reservoir (41 breeding pairs in 2017, down from 60 breeding pairs in 2012; site not occupied by nesting terns in 2013-2016). The incipient colony site included a new island in Lenore Lake (123 breeding pairs in 2017) located approximately 0.4 km NNE from the former Lenore Lake colony site used by terns in 2014-2016. The former Caspian tern colony sites at Twinning Island in Banks Lake (6 breeding pairs in 2016) and an unnamed island in Lenore Lake (39 breeding pairs in 2016; see *above*) were not active in 2017. As was the case in 2015-2016, 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 2017. 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 2015-2017.

The total estimated breeding population of Caspian terns in the Columbia Plateau region during 2017 was 705 breeding pairs at four separate colonies. This represents a 19% decline in the total number of Caspian terns breeding in the Columbia Plateau region compared to the pre-management average during 2005-2013 (873 breeding pairs), but was a slightly higher (4%) than the regional breeding population size for Caspian terns in 2016 (675 breeding pairs). Although nest dissuasion actions implemented on Goose and Crescent islands in 2017 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 more than 8-fold increase in the number of Caspian terns nesting in the Blalock Islands and increases 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 2017, compared to the pre-management average for those colonies. The Blalock Islands colony during 2015-2017 was similar in size to the largest Caspian tern colonies recorded anywhere in the Columbia Plateau region since intensive monitoring began in 2005.

The over-all goal of the IAPMP is to reduce predation rates (percentage of available fish consumed) on juvenile salmonids by Caspian terns to less than 2% of each Endangered Species Act (ESA)-listed salmonid population (hereafter ESU/DPS), per colony, per year. Recoveries of smolt PIT tags on Caspian tern colonies were used to estimate predation rates and to compare smolt losses prior to and following tern management actions. 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 – were available for predation rate analyses, we intentionally PIT-tagged and released (n= 7,437) steelhead smolts into the tailrace of Rock Island Dam as part of this study in 2017.

Estimated predation rates indicated that the management 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 2017. 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) or nearly complete (Potholes Reservoir) abandonment of these colony sites in 2017. Predation rates at the unmanaged Lenore Lake and Badger Island colonies were also less than 2% per colony and ESU/DPS, with the highest rate observed by Lenore Lake terns on upper Columbia River steelhead at 1.0% (95% credible interval [CRI] = 0.6-2.0). For the third consecutive year, predation rates for the large unmanaged colony in the Blalock Islands exceed the 2% threshold for Snake River and Upper Columbia River steelhead at 3.4% (95% CRI = 2.4-5.1) and 4.2% (95% CRI = 2.7-6.5), respectively. Rates were below the 2% threshold, however, for all other ESA-listed ESUs/DPSs evaluated. Due to lack of access to the colony site following the nesting season, predation rate estimates were not available for terns nesting on Harper Island in Sprague Lake in 2017.

Based on a comparison to historic predation rates by Caspian terns nesting in the Columbia Plateau region during 2007-2016, impacts were amongst the lowest ever recorded at managed colony sites in 2017. 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 were reduced to < 0.1% in 2017. Rates at the unmanaged Lenore Lake and Badger Island colonies were also low (≤ 1.0% per ESU/DPS and colony) in 2017. Impacts by terns nesting at the unmanaged Blalock Island colony, however, remained above the 2% goal for steelhead DPSs in 2017. Due to continued predation by Blalock Island terns, impacts to Snake River steelhead remain as high or higher than those observed prior to management due to the relocation of terns from Crescent Island to the Blalock Islands following implementation of IAPMP in 2015. Adaptive management actions at the Blalock Islands nesting sites may be needed before the over-all goal of reducing predation rates to less 2% per colony, ESU/DPS, and year can be achieved.

In summary, management to eliminate 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, was fully successful in 2017, the fourth year of implementation of the IAPMP. 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 19%. Based on opportunistic resightings of banded Caspian terns in previous years, most terns that were displaced from colonies on Goose and Crescent islands have remained in the region, and many 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 2015-2017 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 in the Blalock Islands is dependent on reservoir level; quality tern nesting habitat is only available when reservoir levels are below full pool. Based on results during the first four years of implementation of the IAPMP, the over-all goal of the Plan to reduce predation rates to less than 2% per tern colony, ESA-listed ESU/DPS, and year will not be fully realized until alternative nesting habitat is further reduced at unmanaged colony sites, especially in the Blalock Islands, the lone tern colony where predation rates exceeded management goals in 2017.

PROJECT OBJECTIVES

The primary objectives of this study in 2017 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 (*Hydroprogne caspia*) 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 (*Oncorhynchus* spp.) 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) 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 (c) 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.

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. 2014; Collis et al. 2015; Collis et al. 2016) 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 2017. Estimated predation rates were then used to evaluate to what extent the overriding 2% predation rate management goal was being met, and where additional or modified management efforts might be implemented in future years to meet that goal. To ensure adequate numbers of PIT-tagged juvenile salmonids were available for predation rate analysis in 2017, 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 2017, a network of passive dissuasion was constructed beginning in March 2017, 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 2014-2016, 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. 2014; Collis et al. 2015; Collis et al. 2016). 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 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 2017, 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 flagging identical to that used in 2014-2016 and as described *above*. Additionally, other passive nest dissuasion materials (e.g., rope, zip ties, PVC pipe) were replaced, as needed. After repairing materials deployed during 2014-2016, we installed new nest dissuasion materials in areas not previously covered (e.g., near the shoreline where Caspian tern eggs were laid in 2016), both on Goose Island and on an unnamed island in northeastern Potholes Reservoir (*Map 3*) used by nesting terns in 2016. A double layer of rope and flagging was installed in all new areas where passive nest dissuasion was deployed in 2017. 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 2014-2016 (see *above*), ensuring the structural integrity of all passive nest dissuasion measures. Finally, we had in reserve sufficient 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 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. A thorough inspection of the nest dissuasion materials placed on Crescent Island in 2015 was conducted in late February – early March. All existing materials were repaired, flagging was reinstalled on all ropes, and three additional fence rows were added to the series constructed in 2015. Finally, open areas where felled Russian olive trees left pockets of marginal habitat were covered with passive dissuasion consisting of stakes, rope, and flagging. The materials and installation methods used in 2016 were the same as those used in 2015 (see *above*) and all repairs and new construction was completed prior to the arrival of birds to the island in 2016.

In 2017, 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 2015-2016 (see *above*), ensuring the structural integrity of all passive nest dissuasion measures. 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.

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 2017 (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 2017 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 2014-2016, Caspian terns and gulls were continuously present on the Goose Island throughout the breeding season (Roby et al. 2014; Collis et al. 2015; Collis et al. 2016). 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 2017, beginning with the arrival of Caspian terns and gulls intent on nesting on Goose Island, hazing activities were conducted daily through July. 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 and other waterbirds off the islands. Efforts were made during this time to prevent Caspian terns and gulls from using Goose Island as an overnight roost. The duration of daily hazing bouts depended on bird activity but were not less than 6 hours each day. Additionally, in 2017, 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. 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.

To facilitate hazing and monitoring, boat landing zones and access routes to potential dissuasion areas were designated prior to nesting by Caspian terns and gulls on Goose Island. Birds were passively and actively hazed from nesting within designated access areas throughout the nesting season or until deemed no longer necessary for successful completion of tern nest dissuasion efforts. 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, any Caspian tern or gull nest observed was recorded and all tern and 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 motorboat 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. 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 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.

Finally, to monitor water levels at Potholes Reservoir and assess how fluctuations in water level influenced seasonal availability of suitable nesting habitat for Caspian terns along the shoreline of Goose Island and other islands in northern Potholes Reservoir, a vertical meter stick was installed in the reservoir near the Goose Island camp and monitored daily.

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 gulls to prevent gull colony formation that may attract Caspian terns. Active hazing targeted prospecting ring-billed and California gulls to prevent or delay the onset of egg-laying by these colonial waterbird species. Active hazing of Canada geese on Crescent Island was not conducted, as stipulated in the Conditional Use Permit issued to conduct this work on Crescent Island in 2017.

In 2015-2016, Caspian terns and gulls did not nest on Crescent Island and were rarely seen near the island beginning in mid-May (Collis et al. 2015; Collis et al. 2016). 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 2017. Beginning with the arrival of gulls on or near Crescent Island, hazing activities were conducted several days each week through July. The duration of hazing bouts 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.

To facilitate hazing and monitoring, a boat landing zone and access routes to potential dissuasion areas was designated prior to the arrival of gulls to Crescent Island. Birds were passively and actively hazed from nesting within designated access areas throughout the nesting season or until deemed no longer necessary for successful completion of the tern nest dissuasion efforts. During each walk-through, any nest observed was recorded and all nests not containing eggs were destroyed.

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 2017. 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 2017 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 2017. Willow observations were largely qualitative and limited to observations of herbivory by beavers.

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 2017 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. 2014; Collis et al. 2015; Collis et al. 2016). These protocols will be summarized in a technical memorandum provided to the funding agency upon completion of this study.

High-resolution, vertical, aerial photography was acquired on Goose Island on 31 May, and on Crescent Island on 18 May. 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), 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), Badger Island (McNary Reservoir), Foundation Island (McNary Reservoir), Cabin Island (Priest Rapids Reservoir), Solstice Island (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 2017. 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 2017 nesting season on the following schedule: (1) on 28-29 April, early in the incubation period, to check for the presence of newly formed colonies; (2) on 22-23 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 28-29 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 delineate habitat areas and 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 2017. Imagery was acquired in mid- to late-May and, and the orthorectified imagery was analyzed in a GIS software application to determine nesting distribution, colony size (number of active nests), and colony area (m^2) used by Caspian terns. Finally, these data were used to calculate nesting density (number of active nests/m^2) of Caspian terns at each site.

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. 2015; Roby et al. 2016; Roby et al. 2017). At the beginning of the 2017 breeding season, there were 30 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 2017 breeding season. This information was used along with the reconnaissance aerial surveys to locate incipient Caspian tern colonies at unmanaged sites in the region. For example, the tracking of satellite-tagged terns assisted us in finding the incipient Caspian tern colony in northeastern Potholes Reservoir before eggs were laid in 2016. Thus, the satellite tag data greatly enhance our ability to find tern colonies in the region and to prevent tern nesting in specific areas where nest dissuasion activities were permitted (i.e. Potholes Reservoir) in 2017.

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 and tern colony. Predation rates at un-managed Caspian tern colonies included terns nesting on the Blalock Islands in John Day Reservoir, Badger Island in the McNary 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 lack of permission from the land owner to access the site following the 2017 nesting season.

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. 2015). 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 finally, steelhead passing RIS are part of an ESA-listed population. The PIT-tagging of steelhead at RIS to evaluate predation impacts by colonial waterbirds was first initiated in 2008, resulting in long-term dataset that has been used to both estimate predation rates and to estimate survival during outmigration (Evans et al. 2012; Evans et al. 2014; Payton et al. 2016; Hostetter et al. 2017).

A detailed description of the sampling methods used to capture, tag, and release steelhead smolts at RIS in 2017 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 2017. 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. 2012; 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 2017 were identical to those used in years past (2008-2016), allowing for a direct comparison of results from 2017 to those of years past.

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).

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. 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 those dams or upstream of those dams in 2017. This was not the case at Rock Island Dam, however. PIT-tagged smolts interrogated at each dam were grouped by ESA-listed salmonid population (as defined by NOAA 2014) 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). In years past, smolt availability for predation rate analyses started on 1 April because very few tagged fish are actively migrating in March (FPC 2017). In 2017, however, due to concerns over elevated total dissolved gas supersaturation associated with higher levels of uncontrolled spill at dams – conditions which can cause gas bubble trauma in juvenile salmonids (see Mesa et al. 2000) – some hatcheries released their fish in March as opposed to April-May and were thus available to predation prior to 1 April 2017.

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 2017 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 2017. To measure detection probabilities, PIT tags with known tag codes were intentionally sown (hereafter referred to as "control tags") on tern colonies to quantify detection based on the number of known sown tags recovered following the nesting season (see *Predation rate calculations* below).

Control tags were sown on tern colonies during discrete time periods, ideally (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). Because two of the tern colonies evaluated in 2017 formed on newly established nesting sites (Lenore Lake and Badger Island), however, it was not possible to sow control tags prior to the nesting season to measure pre-season detection efficiency. Instead, pre-season detection probabilities were inferred for these two colonies based on pre-season detection estimates obtained from other nesting sites with similar habitat and tag densities; factors known to influence detection efficiencies at bird colonies (Evans et al. 2012). For terns nesting on Lenore Lake the estimation of detection efficiency was informed by data observed at the Twinning Island tern colony in Banks Lake during 2009, 2010, and 2015 using a Bayesian hierarchical model (see Predation rate calculations below). Like Lenore Lake Island, nesting habitat on Twinning Island is located several meters above the shoreline on rocky terrain with sage brush and relatively low tag densities (< 500 smolt PIT tags deposited each year; Roby et al. 2017). A similar modelling approach was used for terns at the newly established colony site on Badger Island, where detection efficiency estimates were informed by data from the Badger Island American white pelican nesting site – a site adjacent to the tern nesting site on Badger Island – during 2008, 2009, 2010, and 2017. Like nesting habitat on the Badger tern colony site, nesting habitat on the Badger pelican colony site was located near the shoreline with sandy terrain and medium tag densities (< 1,000 smolt PIT tags deposited per year; Roby et al. 2017).

A total 100 PIT tags were sown on each tern colony, with equal numbers (n=50) sown during each discrete time-period, when possible (see Results). Sample sizes of control tags used in 2017 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 unavailable, supplementary information was used to estimate detection efficiency across time. In these cases, using data from similar colonies and years, we modelled detection efficiency, $\psi_{y,i}$, 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:

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

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 the 2.5 and 97.5 percentiles, which are referred to as 95% 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 data obtained at 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

Access to Goose Island was significantly delayed in 2017, with ice preventing boat access until 14 March. The installation of 4.3 acres of passive dissuasion on Goose Island was completed on 3 April 2017. This was accomplished by first repairing and re-deploying materials (primarily barricade tape) on much of the area where passive nest dissuasion was installed in 2016. However, because of elevated water levels in March, some of the passive dissuasion deployed in 2016 could not be redeployed above water in 2017. Additional passive nest dissuasion was then installed, primarily along the southeastern shoreline of Goose Island, where most Caspian tern eggs were laid in 2016. Other areas of new deployment were along the northwest slope (*Map 2*).

Inspections of passive nest dissuasion materials deployed at Goose Island found virtually no unusable materials. However, we anticipate that some of the twisted polypropylene rope first deployed in 2014 may need replaced prior to the 2018 breeding season if further degradation occurs making rope too brittle to insert new flagging. With more than 85% of the upland habitat now covered by passive dissuasion, little potential Caspian tern habitat now remains unaltered above the high-water line. If permitted, supplemental dissuasion material could be installed in shallow water or below the high-water line to deter prospecting by terns as reservoir levels recede during the summer, eventually exposing suitable nesting habitat by early-June.

In total, passive nest dissuasion in 2017 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 4.3 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

On 14 March, when ice had receded from Potholes Reservoir allowing for safe access to Goose Island by boat, field staff observed ca. 4,200 gulls on the island initiating nests. Beginning on 15 March, targeted daily active human hazing was conducted while passive dissuasion installation was underway to deter gulls from roosting and initiating nesting on the island. All hazing sessions were recorded to document effort and the response of hazed birds. On 19 March the peregrine falcon kite was first deployed to supplement colony walk-throughs, and on 22 March, use of a green laser (Agrilaser®; LEM 50) was initiated for hazing at dusk to prohibit gulls from remaining on Goose Island overnight. Once Caspian terns were observed landing on Goose Island (6 April) daily hazing frequency and duration was increased to three 3-hour walk-through sessions; a morning session that started before dawn, a mid-day or early afternoon session, and 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 decrease as needed in response to intensity of nesting activities by gulls and Caspian terns.

Like findings from 2014-2016, gulls quickly habituated to all active hazing techniques in 2017. Initially, once gulls were using the island in large numbers, walk-through hazing was sufficient to flush all gulls from the island. Most settled on the water around the island and rafted in large numbers during the day while researchers were on the island. Within days however, an increase in active hazing was required to clear the birds from the island. By 26 March, human walk thoughts during daylight hours were largely ineffective, only temporarily flushing gulls within 10 meters of the hazers, with hazed birds circling and re-landing near their original position once hazers moved away. As observed in previous years, island walk-throughs were more effective in displacing gulls when conducted during the evening. Initially, gulls hazed near evening civil twilight would abandon Goose Island overnight, return to the island at sunrise, and remain on the island throughout the day, consistent with reports in the literature (Ryder 1993). However, by late-March only a combination of the green laser and peregrine falcon kite deployed at dusk was effective in hazing all gulls from the island. By 6 April no hazing technique (or combination thereof) was effective and all gull hazing was discontinued on 10 April when the first gull eggs were observed.

Despite continued gull hazing effort in 2017, preventing gull nest initiation and the formation of a gull colony on Goose Island was not possible using authorized nest dissuasion methods. Since management was first initiated in 2014, our use of authorized methods to delay gull nest initiation have not been successful and have resulted in no perceptible advantages for preventing the formation of a Caspian tern breeding colony on Goose Island. In each of the first four years of management the first gull eggs have been laid between 9 – 16 April, preventing any further hazing or disturbance to gulls on Goose Island. The first Caspian tern to land on Goose Island during the 2017 nesting season was on 6 April, just four days prior the first gull eggs being laid 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 10 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 effort began exclusively targeting prospecting Caspian terns. The primary techniques used to actively dissuade Caspian terns 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 island beginning in late- May. Locations where Forster's tern nesting affected active hazing efforts for Caspian terns included the South Spit, Northwest Rocks, East Rocks, and Northeast Rocks near Goose Island (see *Map 5*).

From 6 April to 10 July, Caspian tern hazing consisted of three 2 to 3-hour hazing sessions; a morning session that started before dawn, a mid-day or early afternoon session, and 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) and were facilitated by field crew members staying on the island overnight beginning on 29 April. As prospecting by Caspian terns on Goose Island waned later in the nesting season, active hazing efforts were reduced. Overnight use of the camp by researchers was suspended on 9 July. On 10 July, active hazing of Caspian terns was reduced to three hazing stints (morning, midday, evening) lasting 2 hours each, and again reduced to twice a day on 20 July. Active hazing of Caspian terns was terminated on 31 July, and the final survey of Goose Island for the season occurred on 17 August. While most hazing sessions were conducted from a boat, field staff could approach Caspian terns on foot beginning in late-June as lower reservoir levels exposed additional shoreline away from active gull nests.

During the 20 weeks when active hazing efforts at Goose Island were quantified, average daily effort ranged from 59 minutes to 262 minutes, and the cumulative weekly hazing duration ranged from 415 minutes to 1,816 minutes (*Table 1*). 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 14 (range: 0 – 42) Caspian terns hazed from the island each day. However, beginning on 12 June, Caspian terns became more numerous and resumed prospecting behavior with an average of 91 (range: 5 – 180) terns hazed each day through 31 July.

Colony failures at unmanaged sites in the Blalock, Harper, and Badger islands (see *below*) coincided with the substantial increase in Caspian tern activity on Goose Island during this time. Like in 2015 and 2016, Caspian tern use of Goose Island in 2017 peaked during the third week of July when 180 terns were hazed during a single session. In addition to the increase in Caspian tern numbers at Goose island associated with colony failures in June, the July peak in Caspian tern use of Goose Island is consistent with normal post-breeding dispersal from other Plateau colonies. 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 124 terns hazed from the Southeast Main during a single hazing session. Additional locations that had increased and regular use were the Northeast Main and surrounding rocky islets (see *Map 5*; *Table 1*).

In summary, hazing efforts were successful in preventing the formation of a Caspian tern colony on Goose Island in 2017. 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 2017; 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 18 eggs on Goose Island in 2017, but none produced young. Of the 18 eggs that were laid by Caspian terns, 16 were collected under permit issued by the USFWS (*Figure 2*). By comparison, 43 and 6 eggs were laid on Goose Island during the 2015 and 2016 breeding seasons, respectively (*Figure 2*). In accordance with the federal depredation permit, intact eggs collected from Caspian tern nests on Goose Island in 2017 were transferred to Dr. Josh Ackerman with the US Geological Survey, Western Ecological Research Center in Dixon, CA.

Northern Potholes Reservoir

Passive nest dissuasion

To supplement the newly implemented Caspian tern hazing across Potholes Reservoir in 2017, temporary passive dissuasion (bamboo stakes, rope and flagging) was installed at locations of high tern use, including the 2016 colony site (*Map 3*). Installation methods for temporary passive dissuasion at 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 22 April. On 29 April, following the collection of a Caspian tern egg at the site, another small low-lying sandy island 0.25 miles ENE of the 2016 colony site was also covered in passive dissuasion. No additional passive dissuasion was installed in northern Potholes Reservoir until 11 June when receding reservoir levels began exposing new habitat consistently used by prospecting Caspian terns. Between 11-16 June, passive dissuasion was installed on the upland portion of three additional islands where either a Caspian tern egg was collected, or potential nest scrapes were discovered and destroyed.

In total, 0.30 acres of temporary passive dissuasion was installed at five locations in northern Potholes Reservoir in 2017. 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 location in northern Potholes Reservoir, active dissuasion efforts like those employed at Goose Island were expanded to all potential colony sites in Potholes Reservoir in 2017. 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 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 28 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 2017.

In total, Caspian terns were hazed from 41 unique locations in northern Potholes Reservoir 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 three distinct zones: (1) near the 2016 colony site, (2) an area of the northwest arm where dozens of small sandy islands were exposed in June, and (3) an area near the southeast shoreline where several 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 16, 2, 48, 61 in April, May, June, and July, respectively. Although two Caspian tern eggs were collected, and potential nests were destroyed on four occasions at location in northern Potholes Reservoir, most terns encountered were found loafing. Of the 113 times Caspian terns were encountered, 108 (96%) resulted in hazing loafing birds.

Crescent Island

Passive nest dissuasion

Prior to the installation of new passive nest dissuasion materials on Crescent Island in 2017, a thorough inspection of previously installed materials was conducted on 5 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 replacement flagging and new passive nest dissuasion materials was initiated on 6 March and completed by 13 March.

In total, approximately 2.4 acres were covered in passive dissuasion, consisting of fence rows, rope, and flagging in 2017. 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 2017 nesting season (see *Map 4*).

No Caspian terns landed on Crescent Island in 2017, 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, prospecting behavior was limited to a brief time in mid-April that coincided with a high-water event that may have inundated some gull nests on the nearby Badger Island colony. On 17 April, 93 gulls were hazed from Crescent Island and 10 potential nests scrapes were destroyed. Prospecting behavior was limited to the western portion of the island mostly covered in Russian olive debris. 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 13 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 2–5 times per week to conduct colony walkthroughs, depending gull activity and weather conditions. During each walk-through, the number of gulls hazed was counted and any potential gull nest observed was recorded and destroyed. At Crescent Island, 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. 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).

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 2017. 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 2017. While passive nest dissuasion installed elsewhere has provided little deterrent to nesting gulls (e.g., Goose 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) formation of a gull colony on nearby Badger Island, and (3) active hazing activities.

The absence of Caspian terns on Crescent Island, a stable colony for nearly three decades (Adkins et al. 2014), for three 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 of vertical fences and stakes, rope, and flagging when Caspian tern colony management is considered elsewhere. Additionally, an inspection of the dissuasion materials deployed in 2015, specifically the grommet fence material, revealed little to no wear after more than a year of continuous use. Other than the annual replacement of flagging material, we do not anticipate the need for repairs to the dissuasion matrix in the coming years, if it remains in use.

For 11 weeks when active hazing efforts were conducted on Crescent Island, the average duration of daily effort ranged from 5–83 minutes, and total weekly hazing times ranged from 0–581 minutes (*Table 2*). Active hazing efforts were greatly reduced from 2015 due to low numbers of both gulls and Caspian terns that were observed, and because no lasting prospecting or breeding behaviors were observed by gulls at Crescent Island. Gulls were hazed from Crescent Island on 22 days in 2017, with the first gulls being hazed on 9 April. Numbers of gulls observed on the island peaked during mid-June when ca. 200 gulls were hazed from the shoreline.

In summary, nesting by Caspian terns on Crescent Island was prevented in 2017 by the combination of passive and active nest dissuasion techniques implemented on the island. 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, prospecting gulls at Crescent Island never habituated to the combination of passive and active dissuasion techniques that were implemented. Additionally, nearby Badger Island provided alternative nesting habitat for prospecting gulls subject to nest dissuasion measures implemented at Crescent Island.

Caspian tern use of Crescent Island was strongly influenced by placement of passive nest dissuasion materials and native vegetation in 2017. At no time during the 2017 breeding season were Caspian terns observed attempting to land on or near Crescent Island. As was the case in 2015 and 2016, 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 the previous year, Caspian tern use of Goose Island for roosting and nesting 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), collection of Caspian tern eggs that were discovered, and gull depredation on Caspian tern eggs soon after laying were collectively successful in preventing the formation of a Caspian tern colony anywhere on Goose Island or the surrounding small rocky islets in 2017 (see *above*).

Average weekly attendance by Caspian terns on Goose Island and nearby islets was similar in 2016-2017, but far lower as compared to the previous two years of management (2014-2015). Weekly attendance during all four years of management (2014-2017) 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. 2014). 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 2016-2017, nest dissuasion activities were successful in preventing Caspian terns from forming a colony on both Goose Island and the surrounding islets (*Figure 3*).

In 2017, 18 Caspian tern eggs were discovered on Goose Island, of those 16 were collected under permit and two tern eggs were depredated by gulls soon after laying, compared to 6 tern eggs laid on Goose Island the previous year (*Figure 2*). In 2017, Caspian tern eggs were almost exclusively laid along the shoreline in open or sparsely vegetated habitat that was exposed by changing reservoir levels. Just one of the eggs laid was discovered in upland habitat, outside passive dissuasion atop steep rocky terrain on the northwest edge of the island. 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 waterbirds nesting nearby. Of the 18 Caspian tern eggs laid on Goose Island, 15 were laid after 1 June when water levels began receding, whereby exposing significant shoreline habitat for prospecting terns.

In 2017, gulls were first observed on Goose Island on 14 March but were likely present in the weeks prior to the first island visit. Gull numbers increased through April, peaking in mid-May (*Figure 4*). The preliminary index of gull colony size on Goose Island in 2017 was ca. 11,225 individuals, within the range (ca. 11,500–13,000) of gulls counted on the Goose Island during the three years prior to management (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 2014-2017 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 2017. 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. Most potential

Caspian tern nesting habitat on Crescent Island was covered with fence rows of privacy fabric erected at 15-foot intervals and extensive willow plantings across the entire island. This passive dissuasion technique has proven to be highly effective in preventing Caspian terns nesting in the Columbia River Estuary and appears to have been equally effective on Crescent Island. Furthermore, the planting of willows across the entire island prior to the 2016 breeding season essentially eliminated 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. 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 for both Caspian terns and gulls, and Badger Island for gulls; see *below*). Future efforts to prevent gulls and terns from using Goose Island using plantings of various native grasses and shrubs on Goose Island are under consideration, with plantings of test plots planned for the fall/winter of 2017.

In 2017, 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 20 tern eggs discovered at three sites in Potholes Reservoir, with the clear majority (18 eggs) being discovered on Goose Island (*Figure 2*). All eggs were laid outside areas of passive dissuasion either below the high-water line or in steep terrain considered sub-optimal for tern nesting. No Caspian terns were observed landing within passive dissuasion in 2017, unlike 2015 when two nests were established under rope and flagging (Collis et al. 2015).

These results in addition to findings from 2014-2016, 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 2014-2016, gulls nested within both single and double layers of passive nest dissuasion indiscriminately.

In summary, Caspian tern use of Goose Island was again strongly influenced by placement of passive nest dissuasion materials in 2017. No Caspian terns were observed landing in areas of passive dissuasion, and consequently no nests were established. Caspian tern use of Goose Island was largely restricted to exposed beaches along the perimeter of the island at or below the high-water line, where they were easily hazed by researchers using boats (see *Results & Discussion: Active Nest Dissuasion*).

Northern Potholes Reservoir

In 2017, a combination of passive nest dissuasion and targeted hazing 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 two Caspian tern eggs were laid and subsequently collected under permit from locations in northern Potholes Reservoir in 2017 (*Table 3*; *Map 8*). In both cases eggs were laid in on low-lying sandy island, one prior to when it was inundated on 29 April, and the second on 11 June shortly after the island reemerged. While Caspian terns were hazed from more than 40 islands in northern Potholes Reservoir in 2017, little effort was ultimately required to prevent colony formation, with a maximum of 16 Caspian terns hazed from just five islands during April and May. Relative to 2016, 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., nests scrapes, eggs laid) on just five islands (*Map 8*). However, while encouraging, results from 2017 also demonstrate Caspian tern's strong fidelity not just to Goose Island, but other locations in Potholes Reservoir.

Crescent Island

As was the case in 2015-2016, the combination of passive and active nest dissuasion techniques was successful in preventing Caspian terns from landing, roosting, or nesting on suitable nesting habitat on Crescent Island in 2017. This was the third 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 2015-2017. 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 2015-2017.

In summary, nest dissuasion activities were successful in preventing all nesting by both Caspian terns and gulls on Crescent Island in 2015-2017. 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 2015-2017.

Unmanaged Sites

Caspian terns were confirmed present at 20 different sites during aerial surveys conducted in the Columbia Plateau region during the 2017 nesting season (see *Map 7* and *Table 4*). Most sites (n=16) were loafing sites, with no signs of nesting activity, and most of those (n=14) were located on the Columbia and Snake rivers (*Table 4*).

During aerial surveys in 2017, Caspian terns were confirmed to be present (i.e. loafing or nesting) at 7 of 13 unmanaged colony sites (see *Methods and Analysis: Action Effectiveness Monitoring*). The 7 unmanaged sites where Caspian terns were observed included four sites on the Columbia River (Three Mile Canyon Island, Blalock islands complex, Badger 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). The unmanaged sites where Caspian terns were not observed during aerial surveys in 2017 included three sites on the Columbia River (Miller Rocks, Island 18, and Island 20) and three sites off the Columbia River (Solstice Island in Potholes Reservoir and Twinning and Goose islands in Banks Lake).

System-wide action effectiveness monitoring confirmed that Caspian terns nested at three historical colony sites and one new site in 2017. The historical sites included the Blalock Islands and Badger Island on the mid-Columbia River and Harper Island in Sprague Lake (*Map 1*). In 2017, an incipient Caspian tern colony became established on a new island in Lenore Lake, located approximately 0.4 km NNE from the island used by nesting terns in Lenore Lake in 2014-2016 (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 2017 (*Figure 6*). As was the case in 2015-2016, 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 2017 (*Map 1*).

Blalock Islands (mid-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, great egrets, and black-crowned night-herons. 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. 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. 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 649 attended Caspian tern nests were counted during field visits to the Blalock Islands from 19 April to 15 August. 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 7*). 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, 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. 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, 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 7*). 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, 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, 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 (*Figure 8*). 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 (see *Appendix B*) 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). 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.

Badger Island (mid-Columbia River)

Badger Island, located on the mid-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.

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 9*). 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 9*). 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 92 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 9*). 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.

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 10*). 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 10*). 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.

Region-wide Nesting Population

In total, an estimated 705 breeding pairs of Caspian terns nested at four different breeding colonies in the Columbia Plateau region during 2017, slightly higher than the regional breeding population size observed the previous year (675 breeding pairs), but lower than the average number of terns nesting in the region prior to management (873 breeding pairs during 2005-2013; *Figure 11* and *Table 5*). Although nest dissuasion actions implemented on Goose and Crescent islands in 2017 were once again effective in preventing all Caspian terns from nesting at those 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 (*Figures 11-12*). This was due to the more than 8-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 2017, compared to the pre-management average for those colonies. The Blalock Islands colony during 2015-2017 was similar in size to the largest Caspian tern colony 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 7,437 juvenile steelhead (5,777 hatchery, 1,660 wild) were captured, PIT-tagged, measured, condition-scored, and released into the tailrace of Rock Island Dam (RIS) as part of our intentionally sampling effort at RIS in 2017. An additional 207 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 7,644 (7,437 + 207) steelhead available for predation rate analyses in 2017 (see *below*). All PIT-tagged juvenile steelhead 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 13 April to 14 June 2017. Fish were tagged in concert with, and in proportion to, the run-at-large, with sampling effort peaking in early May (*Figure 13*). Mean steelhead fork length was 194 mm (standard deviation [SD] = 27 mm; range = 87 to 310 mm) in 2017. An evaluation of fish condition indicated steelhead were in good over-all external condition, with only 10.4% of steelhead observed with moderate-to-severe body injuries (subcutaneous wounds/scars), disease (fungal or viral infection), severe descaling (> 20% of scales missing), and/or major fin damage (> 50% of fin tissue missing; see also Hostetter et al. 2012). Of those external condition types evaluated, bodies injuries (4.7% of all fish) and severe descaling (4.5% of all fish) were the most prevalent. The over-all condition of fish in 2017 was like that observed in years past at RIS, with the notable exception of 2015, where greater than 25% of steelhead were in compromised condition (Roby et al. 2017).

Predation Rate Analysis

Smolt PIT tag recovery

Due to a complete lack of nesting by terns at managed colony sites in 2017 (Goose and surrounding islands in Potholes Reservoir and Crescent Island in McNary Reservoir), PIT tag recovery was unnecessary (i.e., there were no colonies to scan). A total of 4,464 PIT tags from 2017 migration year smolts (all species and ESUs/DPSs combined) were recovered on three unmanaged tern colonies in 2017 (i.e., Lenore Lake, Badger Island, and Blalock Islands; *Table 6*). As noted in the Methods, we did not scan for PIT tags on the fourth unmanaged tern colony, Harper Island on Sprague Lake, in 2017 due to lack of permission from the land owner to access the site for PIT tag scanning after the nesting season.

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 2017 (see also Hostetter et al. 2015).

Recoveries of PIT tags intentionally sown on tern colonies to measure detection efficiency indicated that detection efficiency varied by colony site (*Table 7*). At the Blalock Island tern colony detection efficiency averaged 0.62, with a range during the nesting season from 0.52-0.72. At the Lenore Lake tern colony, detection efficiency averaged 0.61 (range = 0.41-0.82). At the Badger Island tern colony, detection efficiency averaged 0.79 (range = 0.71-0.91). As described in the Methods, no pre-season tags were sown on the newly established tern nesting sites on Lenore Lake and Badger Island so data from other sites with similar nesting habitat were used to infer pre-season detection efficiency at these two colonies in 2017.

Availability of PIT-tagged smolts

Numbers of PIT-tagged smolts available for predation rate analyses in 2017 varied by salmonid ESU/DPS and interrogation/release site (Rock Island Dam, Lower Monumental Dam, or McNary Dam). In general, numbers of PIT-tagged smolts originating from the Snake River were greater than those originating from the Upper Columbia River (*Table 8*). Numbers of available PIT-tagged smolts for most ESUs/DPSs exceeded the 500 fish needed to generate reliable predation rate estimates (see Evans et al. 2012). The one exception was for Snake River sockeye at Lower Monumental Dam (n= 304) and McNary Dam (n=280; *Table 8*), where an inadequate number of tagged fish were available to generate reliable predation rate estimates.

ESU/DPS-specific predation rates

Appendix C provides historic ESU/DPS-specific predation rate estimates for Caspian terns nesting in Columbia River Plateau region during 2007-2016 for years in which adequate data existed at each colony and year (see also Collis et al. 2016 and Roby et al. 2017). These historic estimates were compared with predation rate estimates from 2017. There were no historic predation rate estimates for terns on Badger Island in years past because 2017 was the first year the colony site had been scanned for smolt PIT tags, although incipient colonies of 33 and 60 pairs attempted to nest in 2011 and 2012, respectively (BRNW 2013).

Goose Island Caspian terns – The Caspian tern colony site on Goose Island and surrounding islands in Potholes Reservoir were eliminated, as passive and active dissuasion measures were successful at preventing colony formation in 2017. 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 (< 0.1%; *Table 8*). This is the second 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 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 C*) 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 C*; see also Collis et al. 2016).

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 C*), impacts that prompted adaptive management actions at this and surrounding islands in Potholes Reservoir in 2017. Active and passive dissuasion implemented at these sites in 2017 were successful at preventing Caspian terns from nesting on islands in Northeastern Potholes Reservoir, so PIT tag scanning was not necessary and predation impacts were presumed to be zero or close to zero (*Table 8*).

Crescent Island Caspian terns – For the third 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 2017. 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 C*; see also Collis et al. 2016).

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 2017, with the highest rate being 1.0% (95% CI = 0.6-2.0) on upper Columbia River steelhead (*Table 8*). Rates were at or below 0.3% for all other ESUs/DPSs evaluated in 2017 (*Table 8*). Predation rates by Lenore Lake terns in 2017 were informed by temporal detection efficiency trends observed at other colonies, colonies with similar nesting habitat. These inferred pre-season detection efficiency estimates, however, had little influence on predation rate estimates due to the small numbers of smolt PIT tags recovered on the Lenore Lake colony after the nesting season (*Table 6*) and the high post-season detection efficiency estimate observed in 2017 (*Table 7*). For example, even if a pre-season detection efficiency estimates of just 0.27 (the lowest ever recorded on a tern colony; Hostetter et al. 2015) were used instead of 0.41, steelhead predation rate estimates would be only slightly higher at 1.1% (95% CRI = 0.6-1.8).

Historic data for terns nesting on Lenore Lake is limited to data collected in 2015 and 2016, years when birds nested on a different island within Lenore Lake, an island located just 0.4 kilometers from the nesting site used in 2017 (*Map 15*). Predation rate estimate in 2015 and 2016 were even lower than those observed in 2017 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 C*). Collectively, predation rate results collected from Lenore Lake terns to-date (2015-2017) 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 per capita (per nesting pair) steelhead predation rate of 0.000082 (0.01/123) observed in 2017, the colony would have to be greater than 245 nesting pairs to consume more than 2% of the available 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 is warranted and is scheduled as part of the 2018 Work Plan.

Harper Island Caspian terns – As noted in the Methods, 92 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. Permission was granted to recover smolt tags on the Harper Island tern colony following the 2012 nesting season and 538 smolt PIT tags were recovered that year (BRNW 2013). Predation rate estimates indicated that terns consumed less than 1% of available ESUs/DPSs in 2012, with the highest rates observed on Snake River steelhead at 0.5% (95% CI = 0.1-1.0; BRNW 2013). Low predation rates were presumably associated with the relatively small size of the colony in 2012 (30 breeding pairs; BRNW 2013) and may not reflect impacts of a substantially larger number of breeding Caspian terns on Harper Island, as was the case in 2017. If greater than 40 nesting pairs continue to nest on Harper Island in the future, we will again try to gain access to the nesting site following the 2018 breeding season for PIT tag scanning.

Badger Island Caspian terns – Predation rate estimates at the Badger Island tern colony were below the 2% threshold for all ESUs/DPSs evaluated in 2017, with the highest rates being just 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 (*Table 9*). Analogous to estimates by terns nesting on Lenore Lake, Badger Island predation rate estimates were based, in part, on inferred temporal detection efficiency trend estimates derived from a different colony with similar nesting habitat (see *Methods* and *Table 7*). Like Lenore Lake estimates, estimated pre-season detection efficiency values had little influence on predation rate estimates due to the proximity of the predation rate estimate to zero. For instance, using a pre-season detection efficiency estimate of just 0.27 (the lowest recorded on a tern colony to-date; Hostetter et al. 2015), predation rates would be 0.7% (95% CRI = 0.4-1.3) and 0.6% (95% CRI = 0.3-1.0) for upper Columbia River and Snake River steelhead, respectively, still well below 2% threshold.

Blalock Island Caspian terns – Predation rates by Caspian terns nesting in the Blalock Islands during 2017 were the highest observed of any tern colony evaluated in 2017, due in part to the large number of smolt tags recovered after the nesting season (n=3,598; *Table 6*). Predation rates were above the 2% threshold for Upper Columbia River steelhead (4.2%; 95% CI = 2.7-6.5%) and Snake River steelhead (3.4%; 95% CI = 2.4-5.1%) in 2017 (*Table 8*). Predation rates for all other ESU/DPS with adequate sample sizes ranged from 0.6% (95% CI = 0.4-1.1) for Snake River Fall Chinook to 1.2% (95% CI = 0.7-1.8) for Upper Columbia River spring Chinook (*Table 8*).

Weekly estimates of steelhead predation rates indicated that predation rates were generally the highest when smolt availability at McNary Dam was the lowest and that late-migrating steelhead were more susceptible to tern predation than early migrating steelhead (*Figure 14*). The relationship between steelhead abundance, steelhead run-timing, and tern predation rates observed in 2017 at Blalock colony is well documented in previously published avian predation studies (Hostetter et al. 2012; Evans et al. 2016). 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 Blalocks in 2017 would have likely been even greater than those observed if the colony had not temporary failed in May and early June (*Figure 8*; see *above*).

Predation rates on ESA-listed salmonid populations by Caspian terns nesting on the Blalock Islands have been significantly higher since management actions on Crescent Island were implemented in 2015 (*Table 9*). Increases in predation rates have been commensurate with the increase in the size of the Blalock tern colony, with the colony increasing from an average of 59 breeding pairs (range = 6 to 136) during 2007-2014 to average of 536 breeding pairs (range = 449 to 677) during 2015-2017 (*Appendix C*). 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 (*Table 9* and *Appendix C*). Consequently, increases in predation rates on salmonid smolts by Caspian terns nesting on the Blalock Islands has offset some of the benefits achieved by the reduction in the number of Caspian terns nesting on both Crescent and Goose islands since management actions were initiated at both sites in 2015 (see also Roby et al. 2017). 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 C*) were higher than those observed during the post-management period (annual range = ca. 5 to 10%; *Table 9 and Appendix C*), indicating an overall net benefit to Upper Columbia River steelhead due to the implementation of IAPMP.

Adaptive management at nesting sites in northern Potholes Reservoirs in 2017 demonstrated that predation could quickly (in just one year) be eliminated by passive and active dissuasion. This reduction in colony size, in concert with reductions at Goose and Crescent, have greatly reduced predation rates on Upper Columbia River steelhead since implementation of the IAPMP. For the third consecutive year, however, predation rates by Caspian terns nesting on the Blalock Islands exceeded 2% for multiple ESA-listed salmonid ESUs/DPSs, indicating that adaptive management at this colony site will most likely be needed to achieve the over-all management goals of the IAPMP in 2018 and beyond. Adaptive management at the Blalocks will benefit ESA-listed populations originating from both Upper Columbia and Snake River ESUs/DPSs but the greatest net benefit will be to Snake River populations, populations that are yet to receive the full benefits of tern management actions in the region.

LITERATURE CITED

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

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

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

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

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

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

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

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

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

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

FPC (Fish Passage Center) 2017. Fish Passage Center smolt passage index. Available online at www.fpc.org.

Gelman, A., J.B. Carlin, H.S. Stern, and D.B. Rubin. 2004. Bayesian Data Analysis, Second Edition. CRC Press.

Hostetter, N.J., A.F. Evans, D.D. Roby, and K. Collis. 2012. Susceptibility of juvenile steelhead to avian predation: the influence of individual fish characteristics and river conditions. Transactions of the American Fisheries Society 141:1586-1599.

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

Hostetter N.J., B. Gardner, A.F. Evans, B.M. Cramer, Q. Payton, K. Collis, and D.D. Roby. 2017. Wanted dead or alive: a state-space mark-recapture-recovery model incorporating multiple recovery types and state uncertainty. Canadian Journal of Fisheries and Aquatic Sciences. Available at: http://www.nrcresearchpress.com/doi/abs/10.1139/cjfas-2016-0246#.WcxuUWhSzIU

Ims, R.A. 1990. On the adaptive value of reproductive synchrony as a predator swamping strategy. American Naturalist 136:485–498.

Mesa, M. G., L. K. Weiland, and A. G. Maule. 2000. Progression and severity of gas bubble trauma in juvenile salmonids. Transactions of the American Fisheries Society 129:174–185.

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

Payton, Q., A.F. Evans, and B. Cramer. 2016. Effects of biotic and abiotic factors on juvenile steelhead survival in the middle Columbia River, 2008-2015. Final Report to Grant County Public Utility District No. 2 and Blue Leaf Environmental. Available online at: http://www.birdresearchnw.org/Final%20Report_Steelhead%20Survival%20Covariate%20Analysis.pdf.

R Core Team (RCT). 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

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

Roby, D.D, K. Collis, D.E. Lyons, Y. Suzuki, P.J. Loschl, T. Lawes, K. Bixler, A. Peck-Richardson, A. Piggott, O. Bailey, H. McKinnon, A. Lawes, J. Mulligan, S. Toomey, A. Munes, E. Schniedermeyer, A. Wilson, G. Smith, K. Saunders, L. Hanwacker, C. Horton, A.F. Evans, B. Cramer, A. Turecek, Q. Payton, M. Hawbecker, and D. Kuligowski. 2015. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River. 2014 Final Annual Report. Submitted to the Bonneville Power Administration, the U.S. Army Corps of Engineers – Walla Walla District, the U.S Army Corps of Engineers – Portland District, and the Grant County Public Utility District/Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

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

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

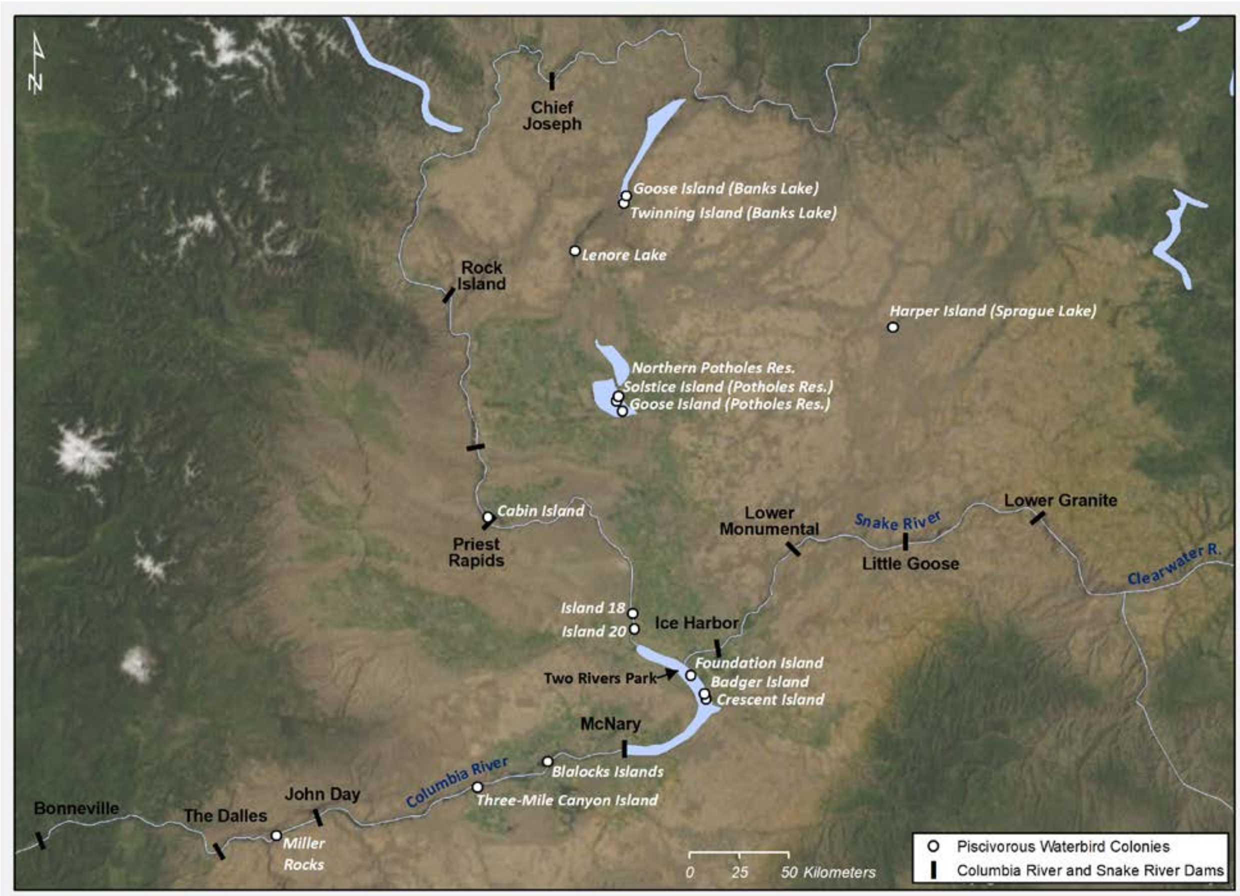
Ryder, J.P. 1993. Ring-billed Gull (Larus delawarensis), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.proxy.library.oregonstate.edu/bna/species/033doi:10.2173/bna.33.

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

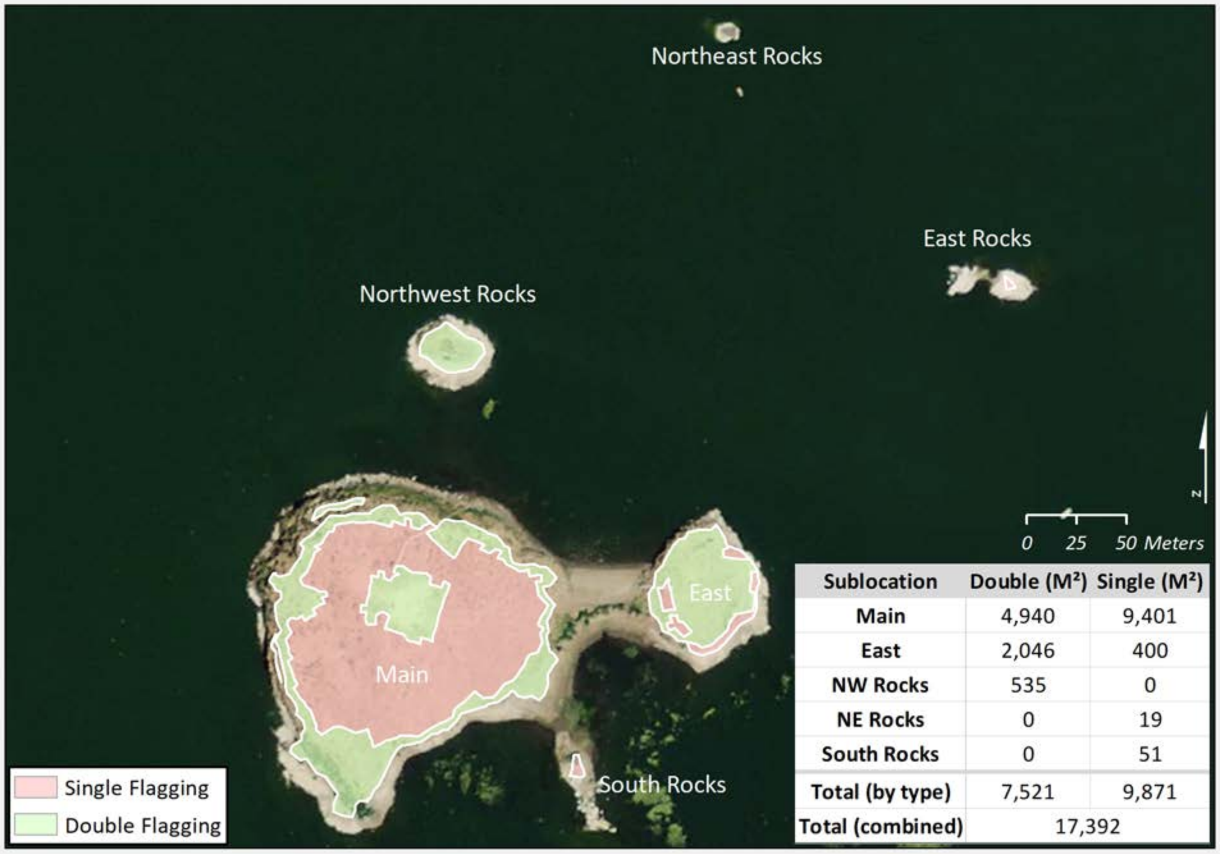
USFWS (U.S. Fish and Wildlife Service). 2005. Caspian tern management to reduce predation of juvenile salmonids in the Columbia River estuary: Final Environmental Impact Statement, January 2005. Migratory Birds and Habitat Program, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2006. Caspian tern management to reduce predation of juvenile salmonids in the Columbia River estuary: Record of Decision, November 2006. Migratory Birds and Habitat Programs, Portland, Oregon.

MAPS

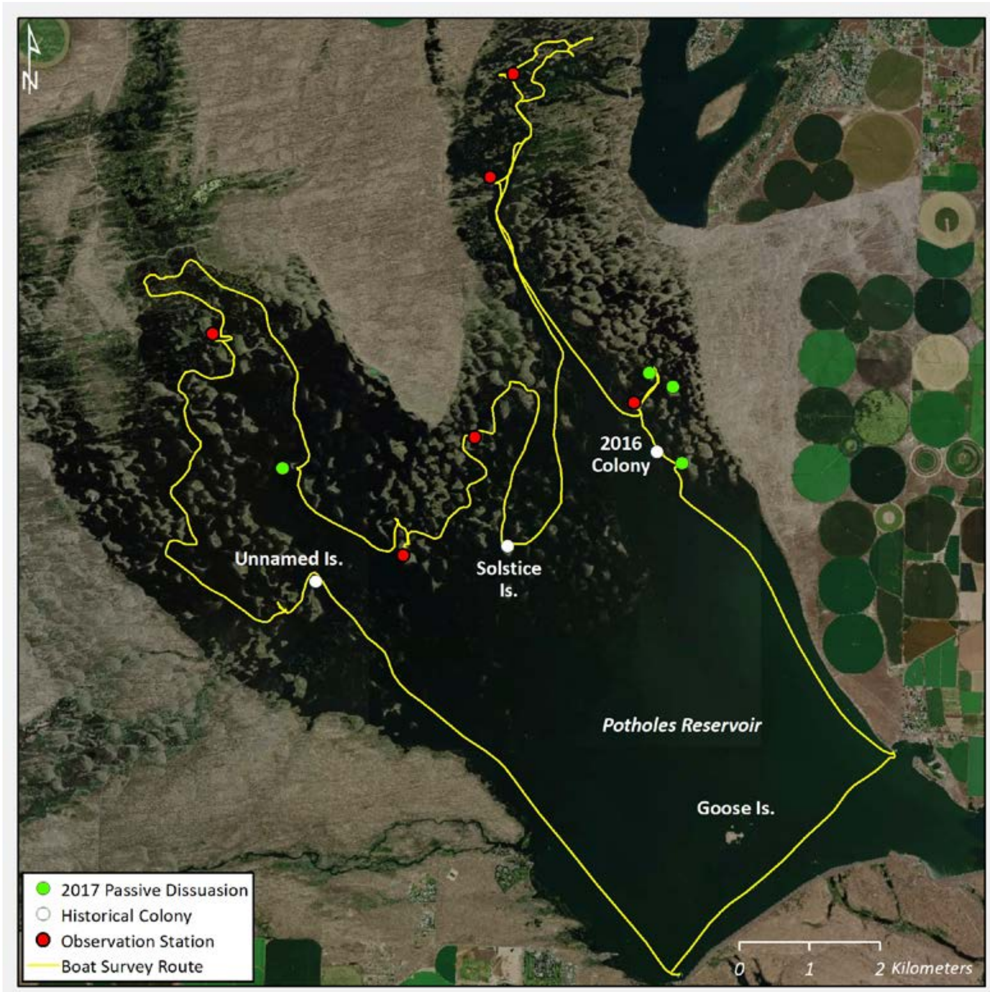


Map 1. Study area in the Columbia Plateau region in 2017.



Sublocation	Double (M²)	Single (M²)
Main	4,940	9,401
East	2,046	400
NW Rocks	535	0
NE Rocks	0	19
South Rocks	0	51
Total (by type)	7,521	9,871
Total (combined)	17,392	

Map 2. Distribution of passive nest dissuasion materials on Goose Island and nearby rocky islets, Potholes Reservoir in 2017.



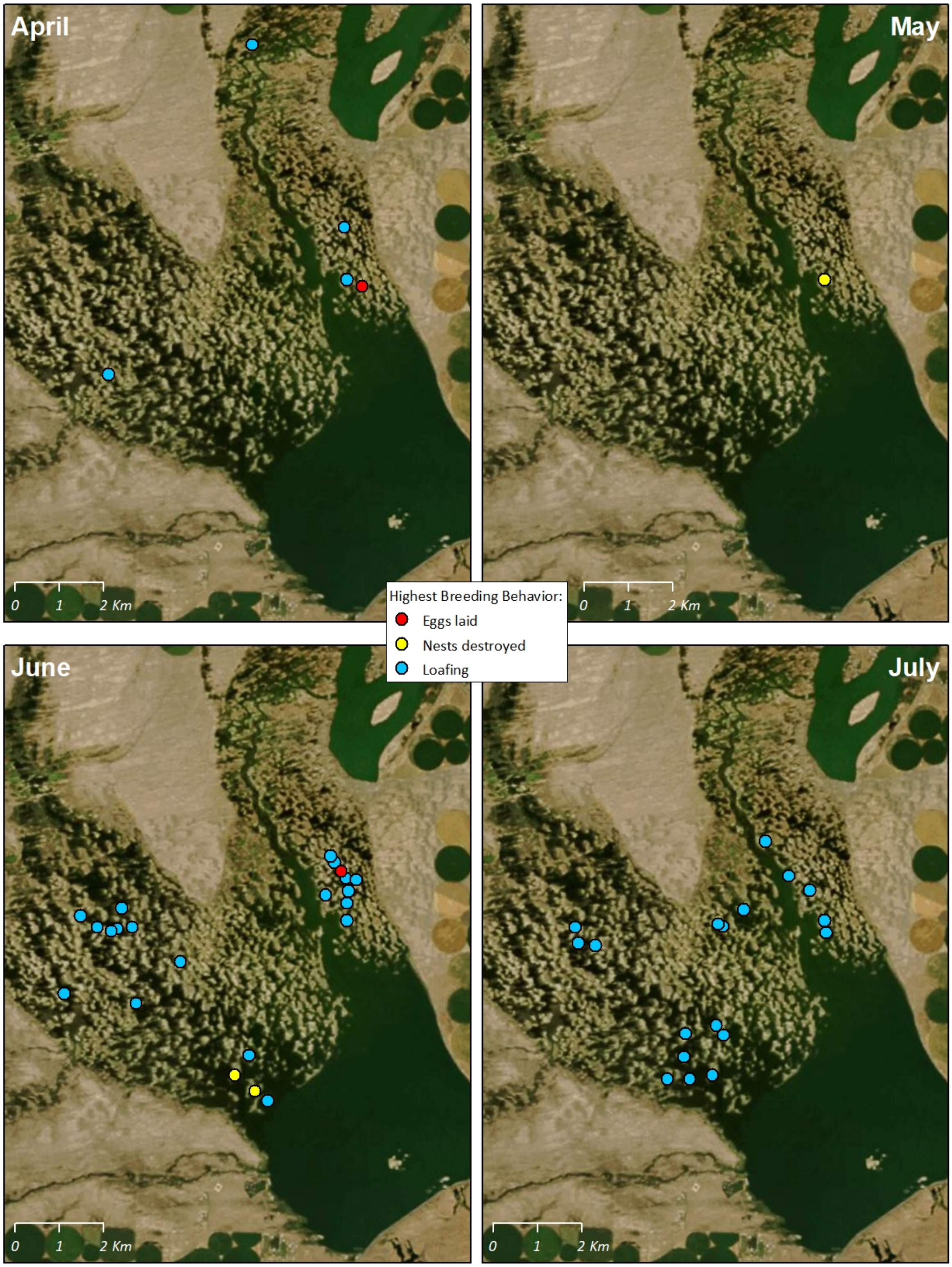
Map 3. Historical Caspian tern colonies, locations where passive dissuasion was installed in 2017 to prevent nesting, and approximate boat survey route used when hazing terns in northern Potholes Reservoir.

Map 4. Distribution of passive nest dissuasion materials on Crescent Island, Columbia River in 2017.

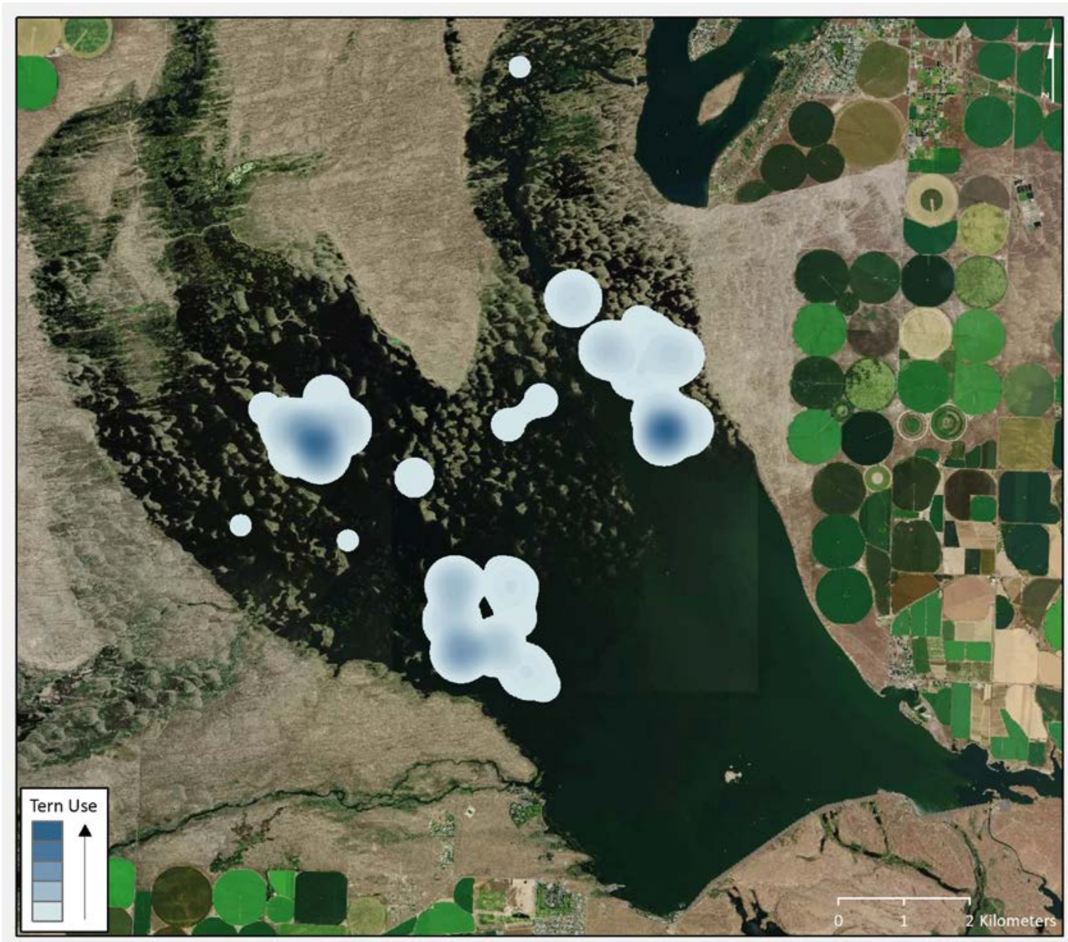
Map 5. Active dissuasion and survey locations on Goose Island and nearby rocky islets, Potholes Reservoir in 2017.

Map 6. Active dissuasion and survey locations on Crescent Island, Columbia River in 2017.

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 2017.



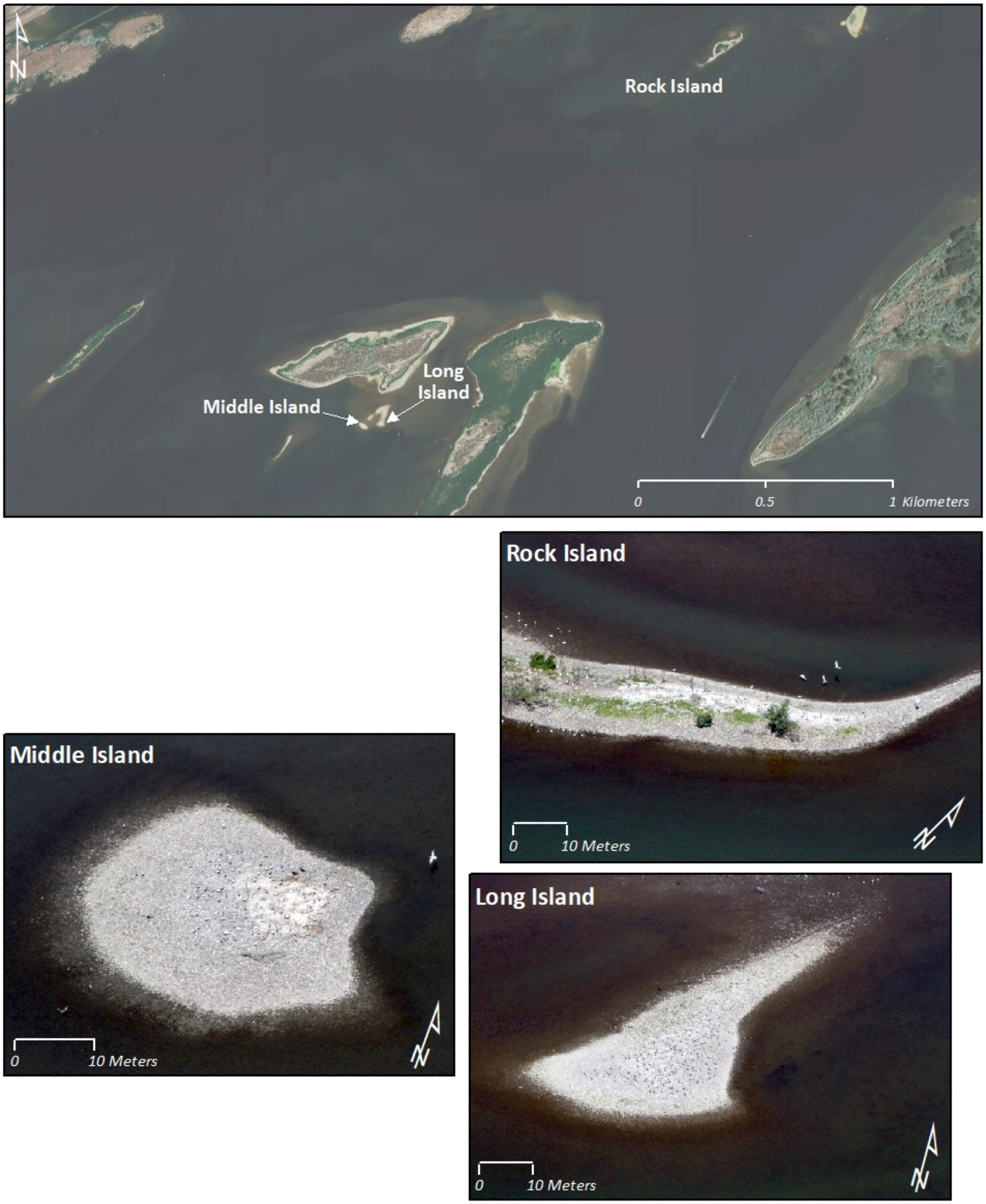
Map 8. Monthly locations where Caspian tern were hazed in northern Potholes Reservoir in 2017 (April – July).



Map 9. Caspian Tern use of northern Potholes Reservoir in 2017.

Map 10. Aerial imagery from June 2015 (top) and June 2017 (bottom) showing the results of vegetation manipulation that included removal of Russian olive and willow planting on and around the of the historical Caspian tern colony area at Crescent Island.

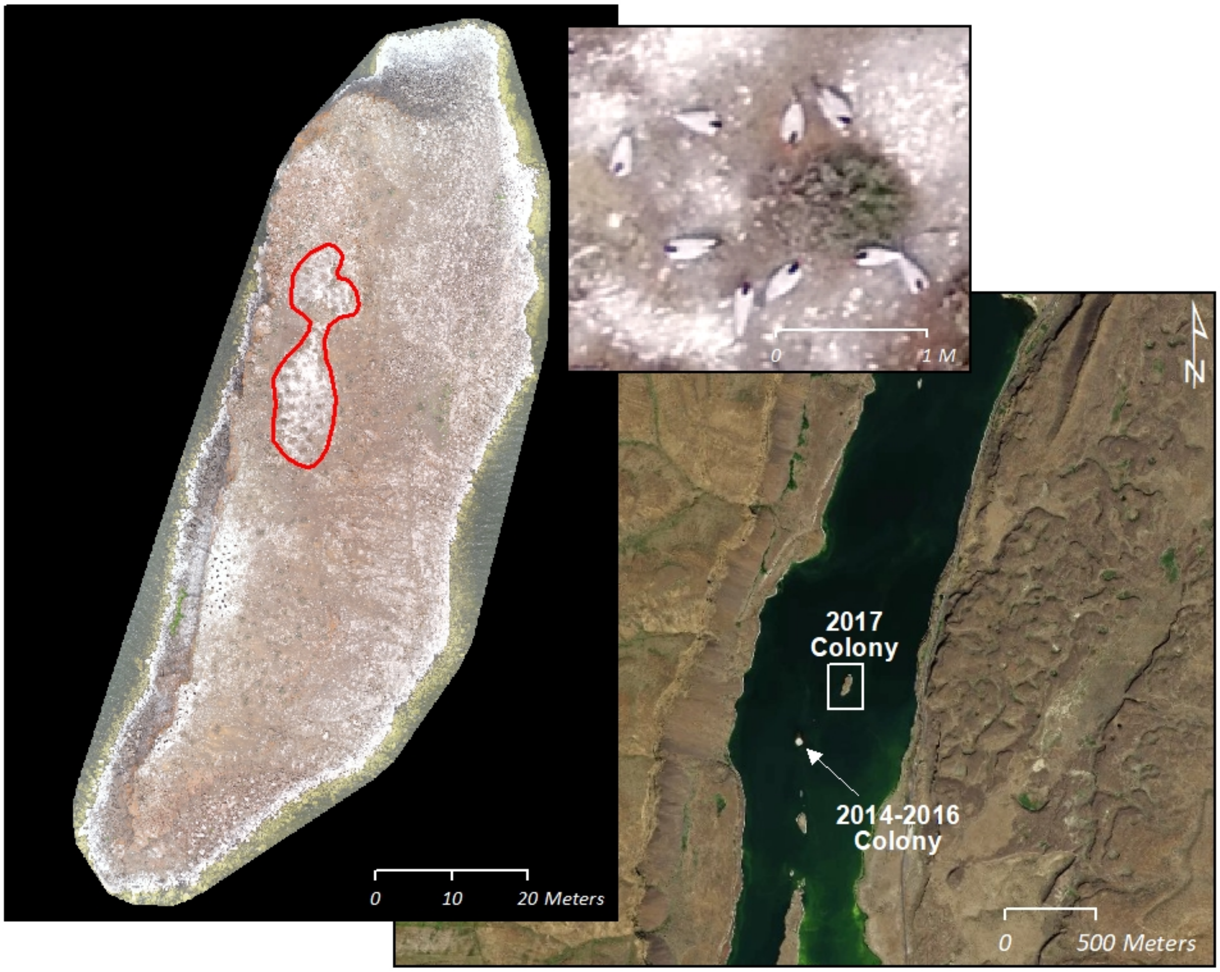
Map 11. Five islands within the Blalock islands complex, Columbia River where piscivorous waterbirds have historically nested, including Long, Middle, Southern, Sand, and Rock islands where Caspian terns initiated nests in 2017.



Map 12. Distribution of nesting Caspian terns on Middle, Long and Rock islands within the Blalock islands complex, Columbia River in 2017.

Map 13. Distribution of nesting Caspian terns on Badger Island, mid-Columbia River in 2017.

Map 14. Distribution of nesting Caspian terns on Harper Island, Sprague Lake in 2017.



Map 15. Distribution of nesting Caspian terns on the small unnamed island, Lenore Lake in 2017.

FIGURES

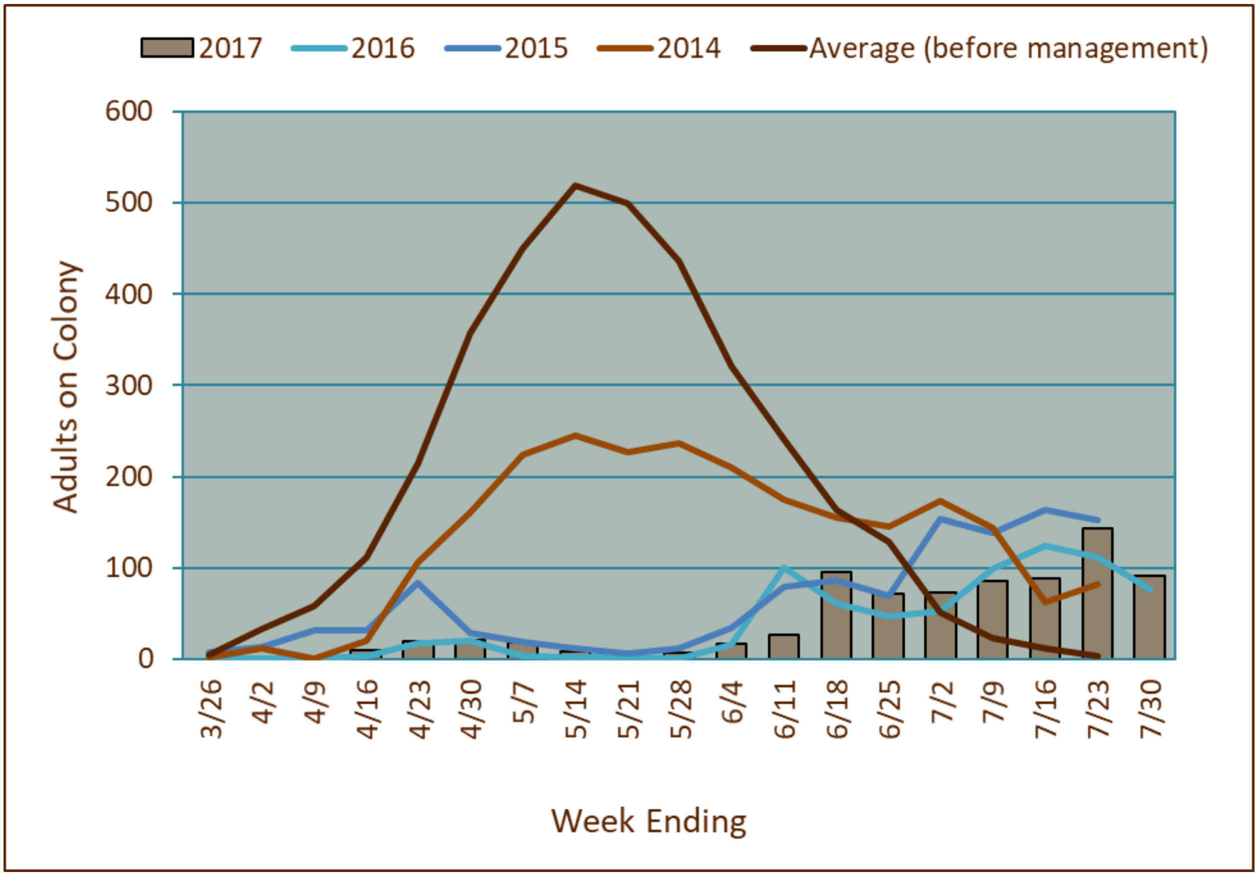


Figure 1. Estimates from the ground of the average number of adult Caspian terns on Goose Island and the surrounding islets in Potholes Reservoir, by week, before (2010-2013) and during (2014-2017) tern management at Goose Island.

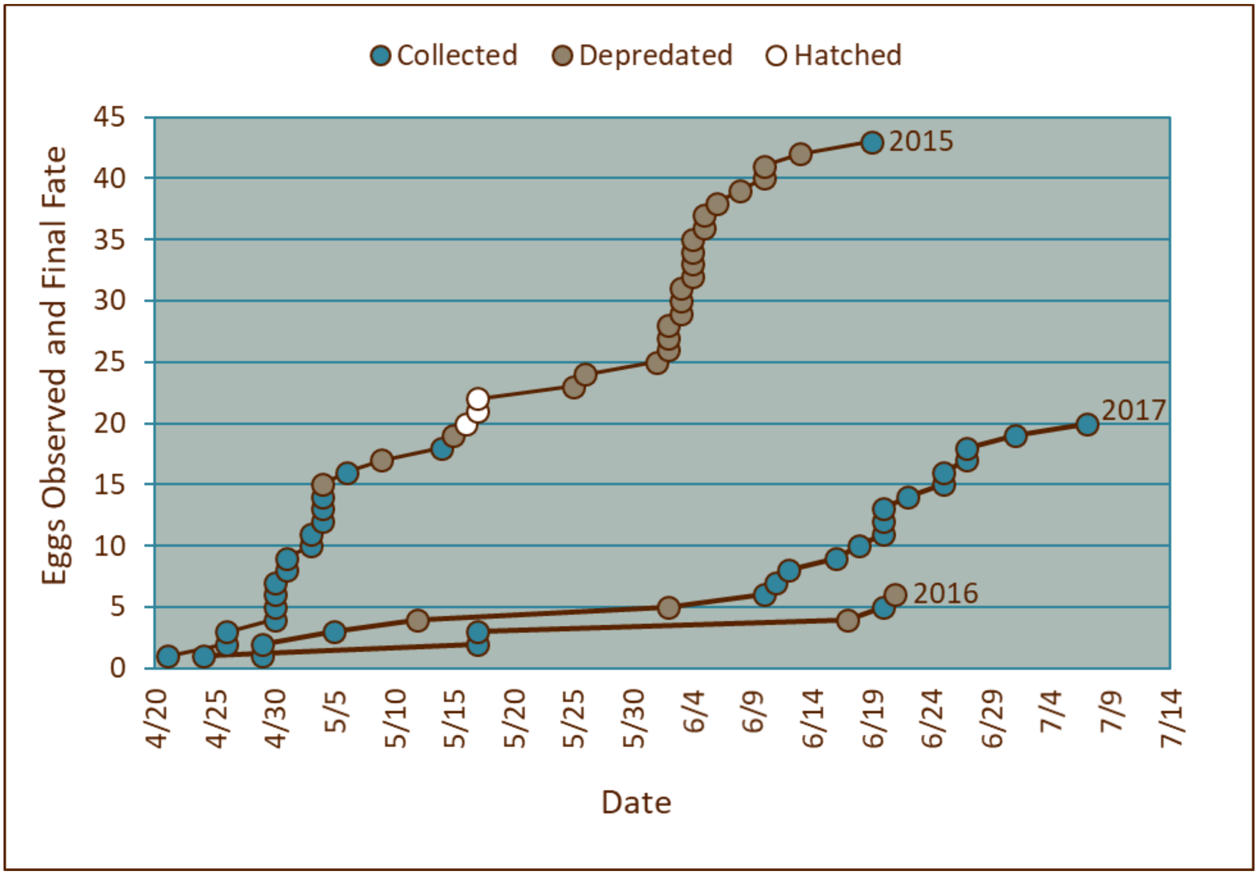


Figure 2. Caspian tern eggs observed on the Goose Island and the surrounding islets in Potholes Reservoir in 2015-2017 and their final fate; collected under permit, depredated by gulls, or hatched.

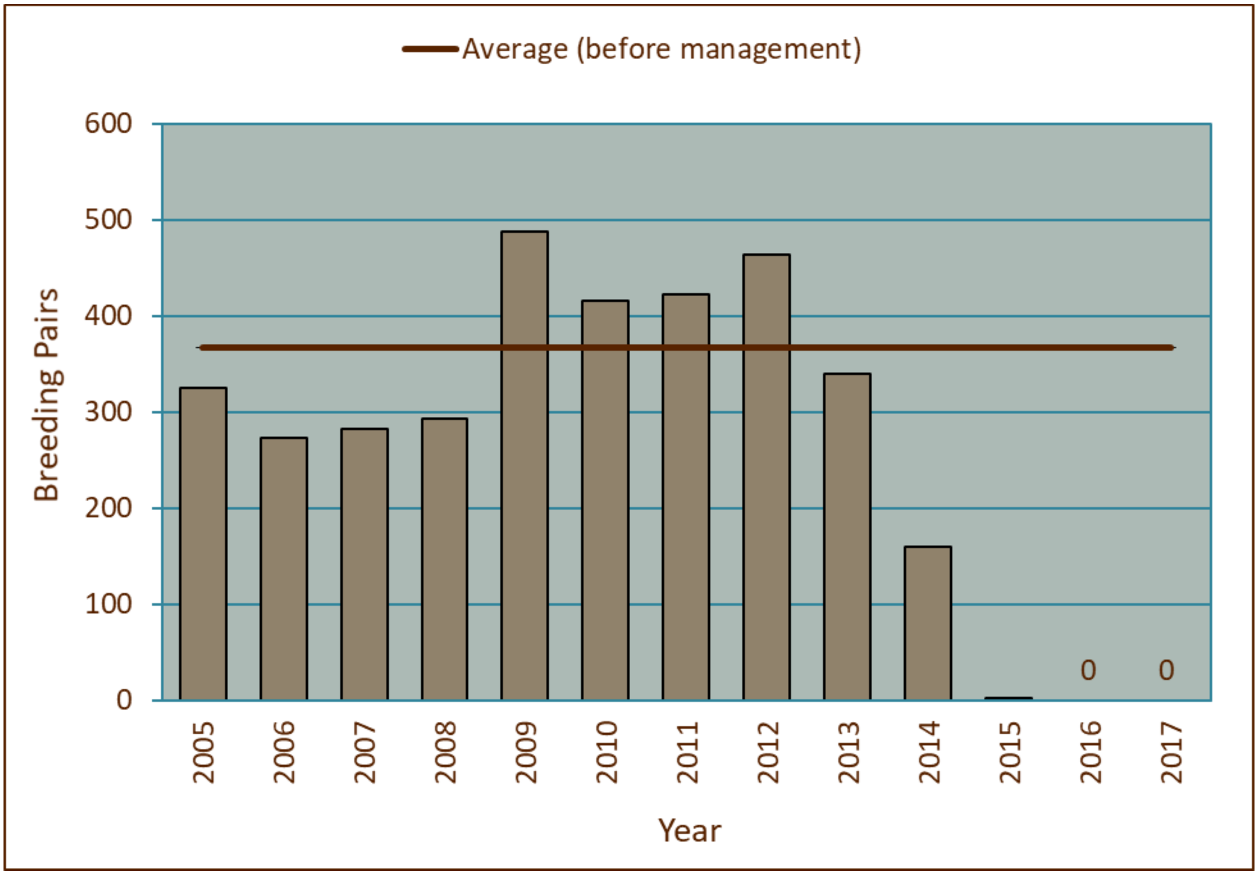


Figure 3. Size of the Caspian tern breeding colony (number of breeding pairs) on Goose Island and the surrounding islets in Potholes Reservoir before (2005-2013) and during (2014-2017) tern management in the region. Also, provided is the average number of breeding pairs of Caspian terns on Goose Island before management (2005-2013).

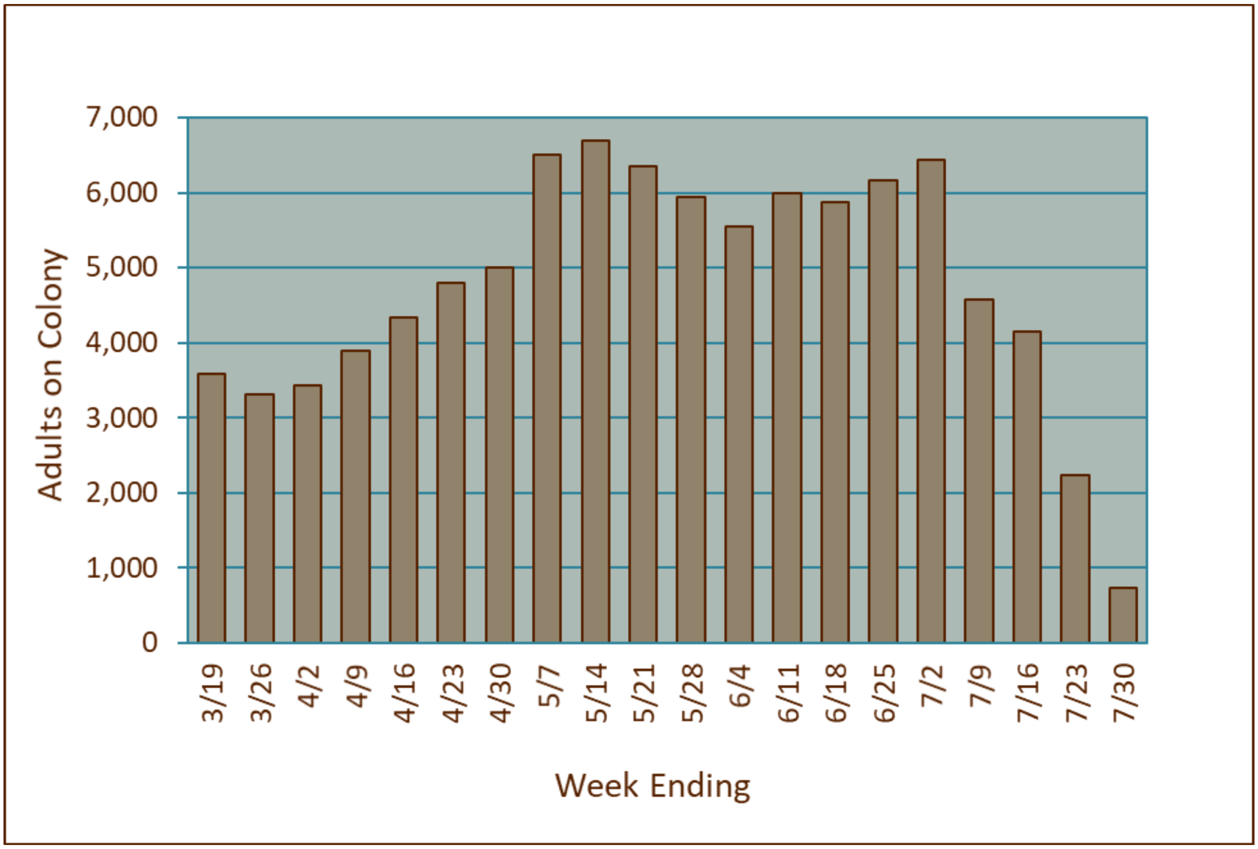


Figure 4. Minimum estimates from the ground of the average numbers of adult gulls on Goose Island and the surrounding islets in Potholes Reservoir, by week, during the 2017 breeding season. These counts should be considered an index of colony attendance, useful only in assessing differences in colony attendance throughout the 2017 breeding season. Counts of gulls from aerial photos are more accurate in estimating colony size, which is also an index (see Report).

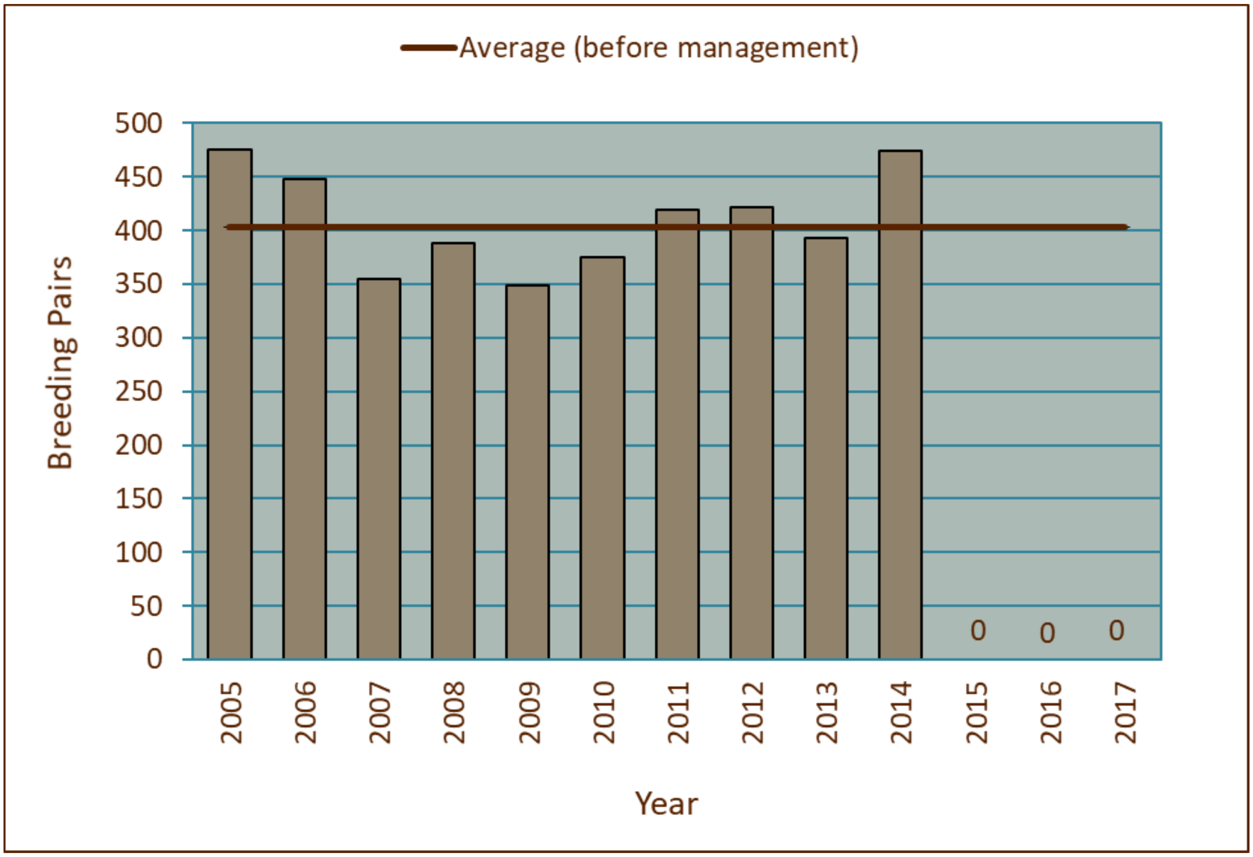


Figure 5. Size of the Caspian tern breeding colony (number of breeding pairs) on Crescent Island in the mid-Columbia River before (2005-2013) and during (2014-2017) tern management in the region. Also, provided is the average number of breeding pairs of Caspian terns on Crescent Island before management (2005-2013).

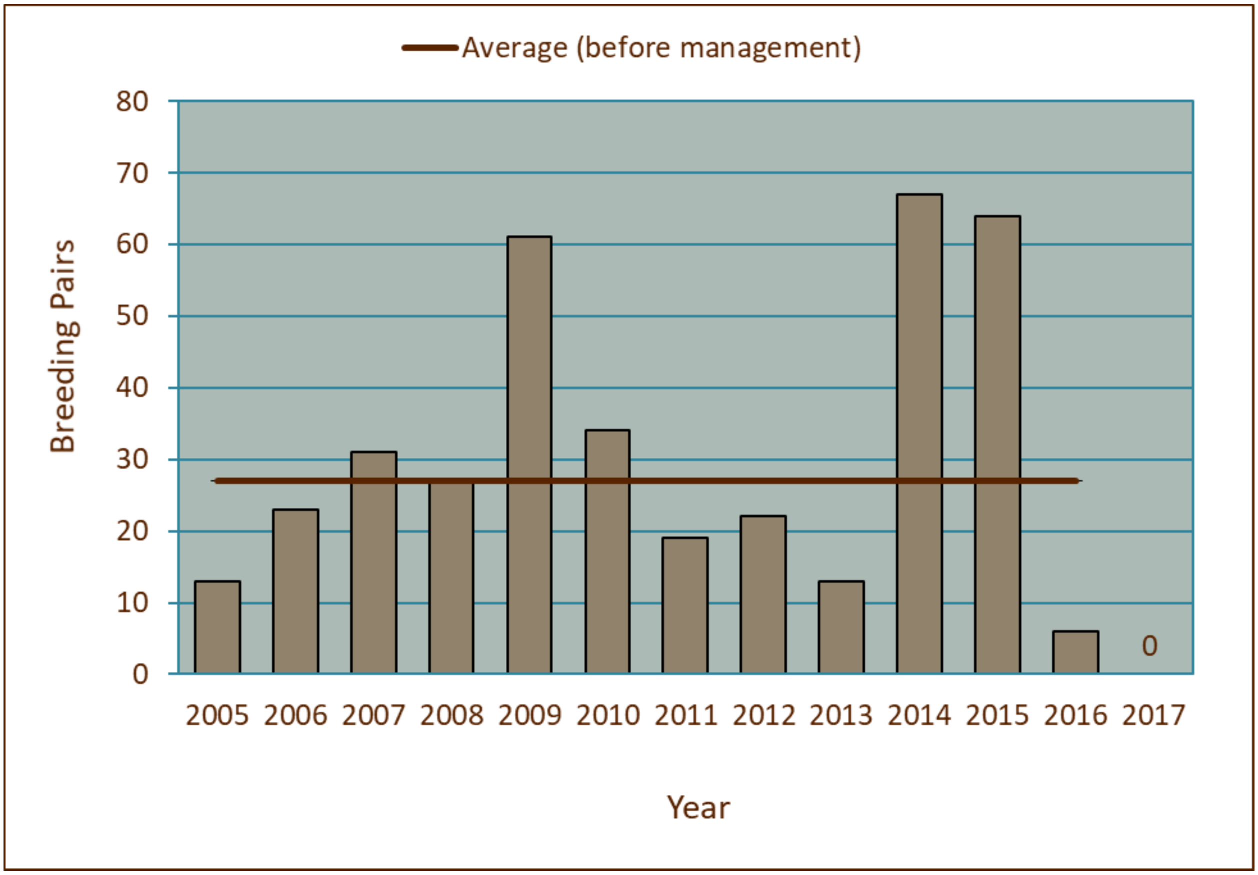


Figure 6. Size of the Caspian tern breeding colony (number of breeding pairs) at Twinning Island in Banks Lake during 2005-2017. Caspian terns did not attempt to nest on Twinning Island in 2017. Also provided is the average number of breeding pairs of Caspian terns on Twinning Island prior to tern management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

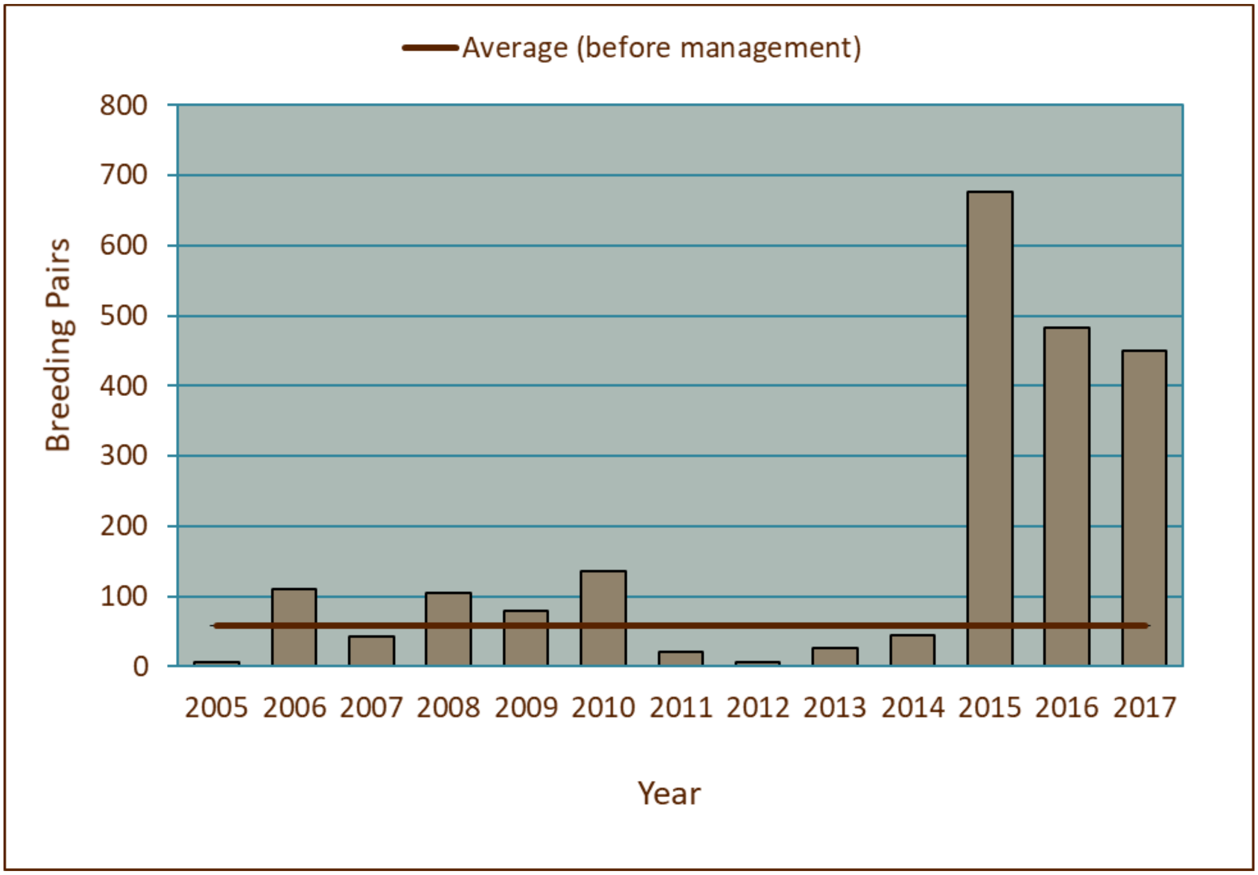


Figure 7. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock Islands in the mid-Columbia River during 2005-2017. Also, provided is the average number of breeding pairs of Caspian terns on the Blalock Islands prior to tern management in the Columbia Plateau region (2005-2013).

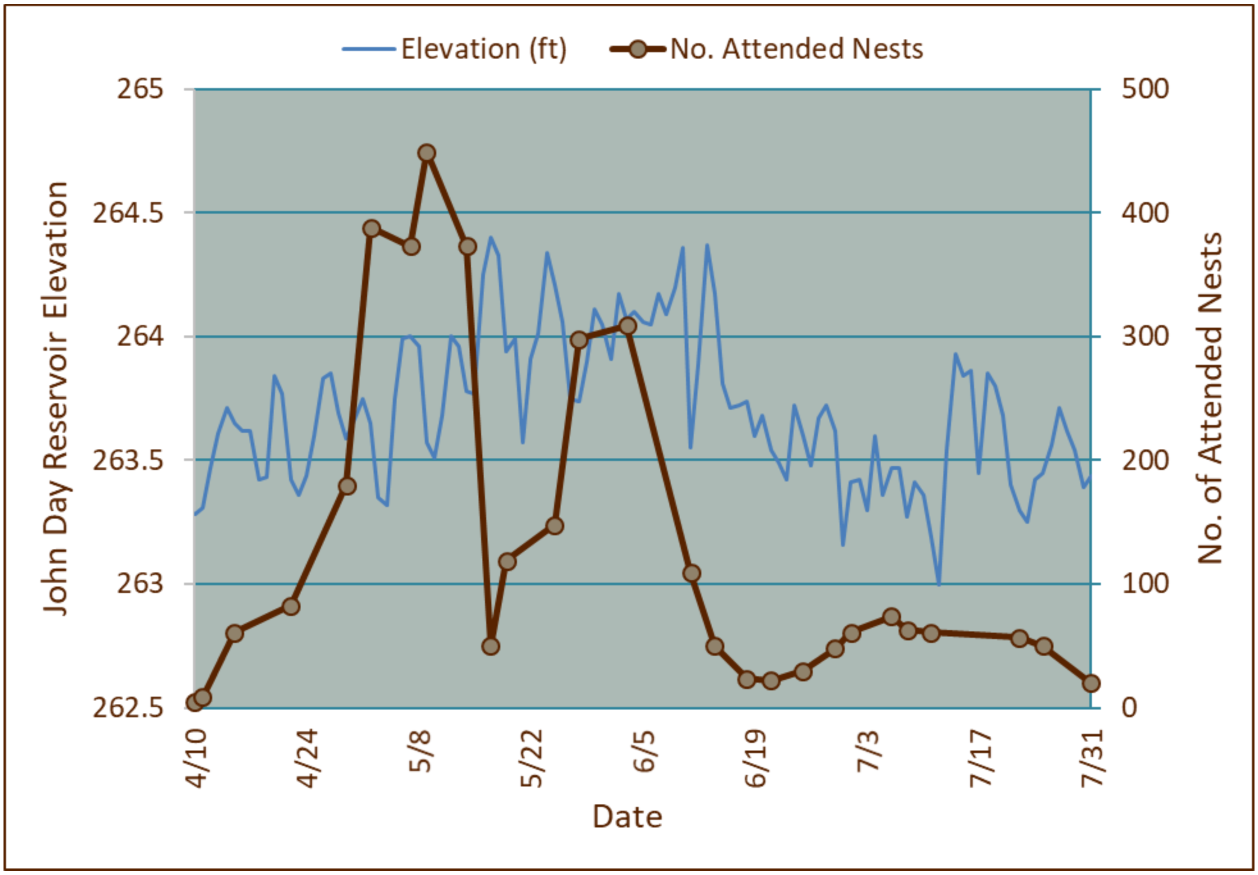


Figure 8. John Day Reservoir elevations as it relates to the availability of Caspian tern nesting habitat at the Blalock Islands in 2017. The water level monitoring system was installed on the west (downstream) side of an irrigation pumping station dock on the north side of the Columbia River, approximately 4.8 km from the Blalock Islands.

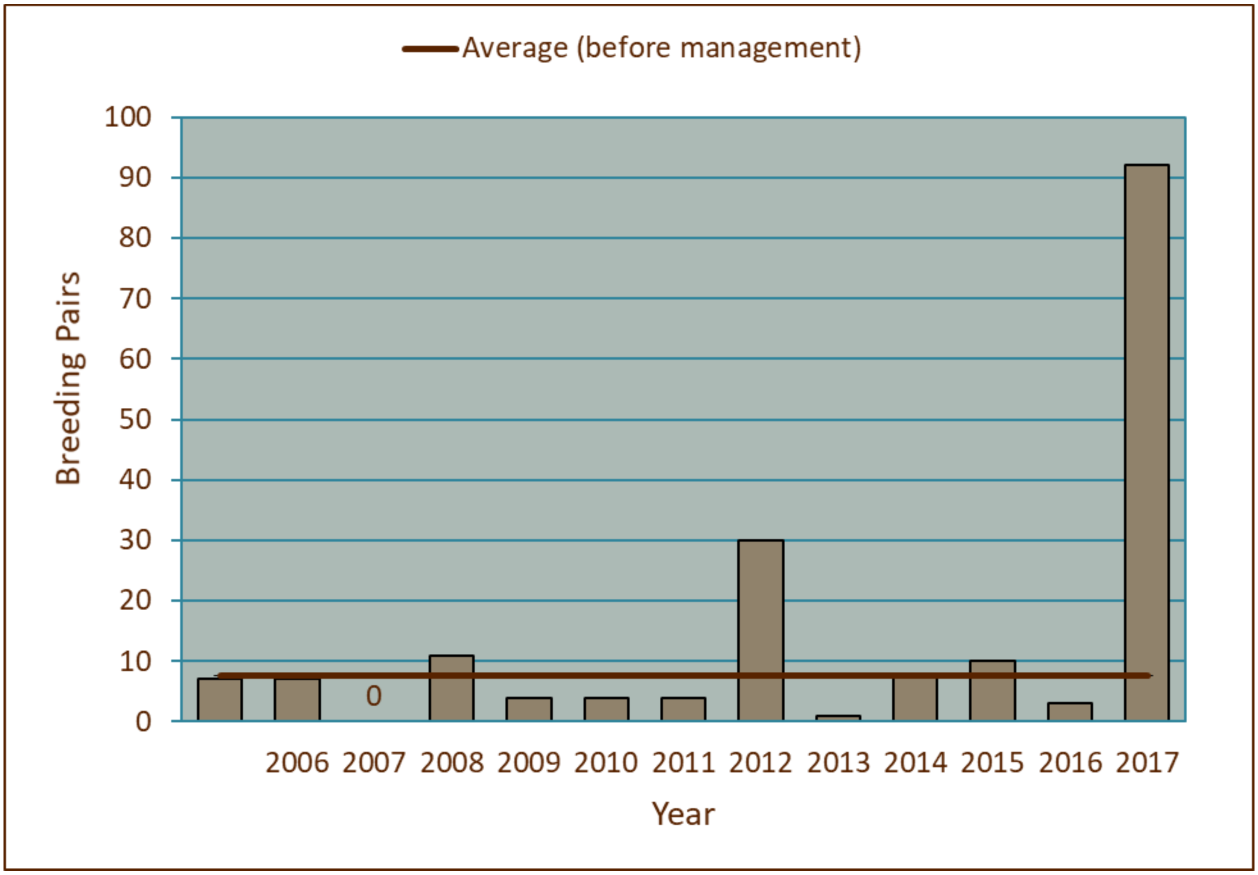


Figure 9. Size of the Caspian tern breeding colony (number of breeding pairs) at Harper Island in Sprague Lake during 2005-2017. Caspian terns did not attempt to nest on Harper Island in 2007. Also, provided is the average number of breeding pairs of Caspian terns on Harper Island prior to tern management in the Columbia Plateau region (2005-2013).

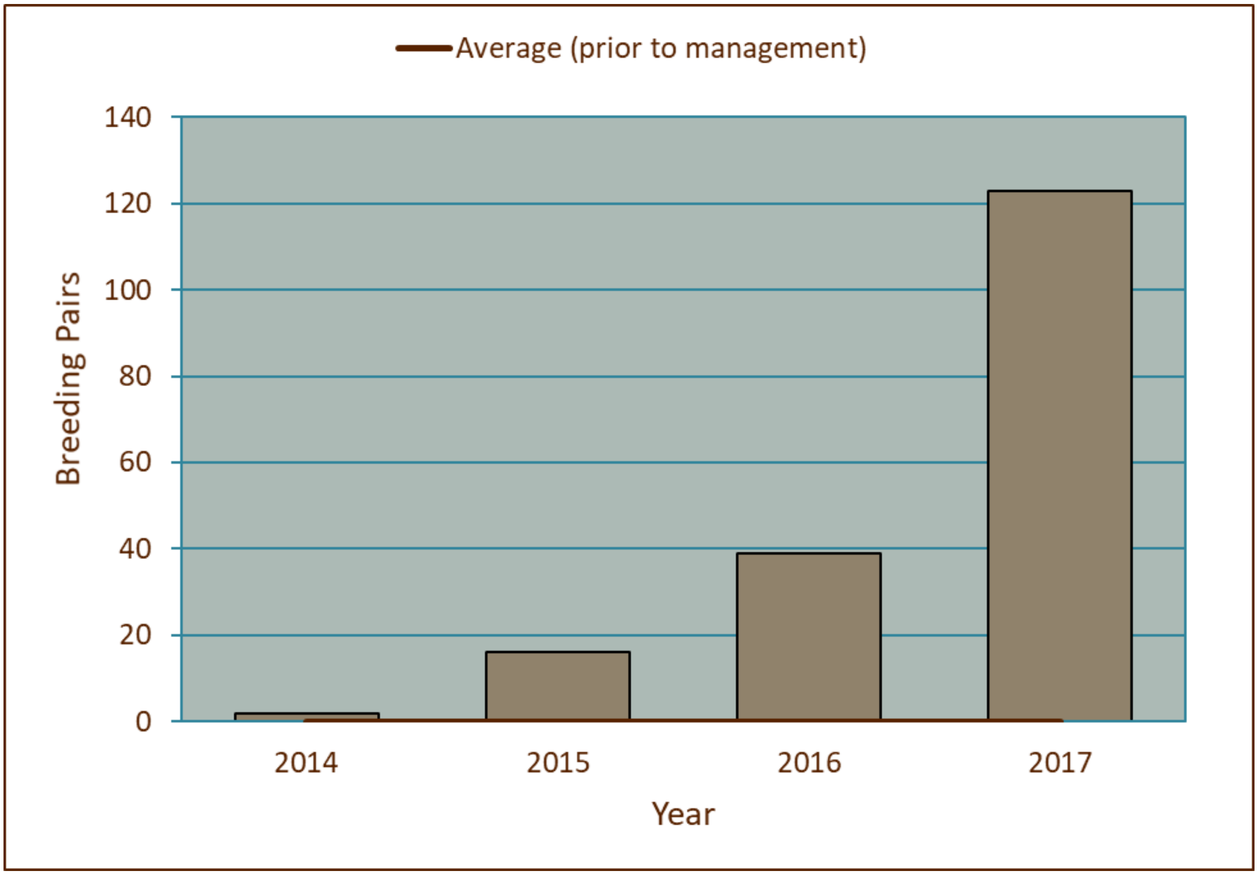


Figure 10. Size of the Caspian tern breeding colony (number of breeding pairs) at small unnamed islands in Lenore Lake during 2014-2017. In 2017, terns moved to a new island in Lenore Lake located approximately 0.4 km northeast from the island used by nesting terns in 2014-2016. Caspian terns did not nest in Lenore Lake prior to tern management in the Columbia Plateau region (2005-2013).

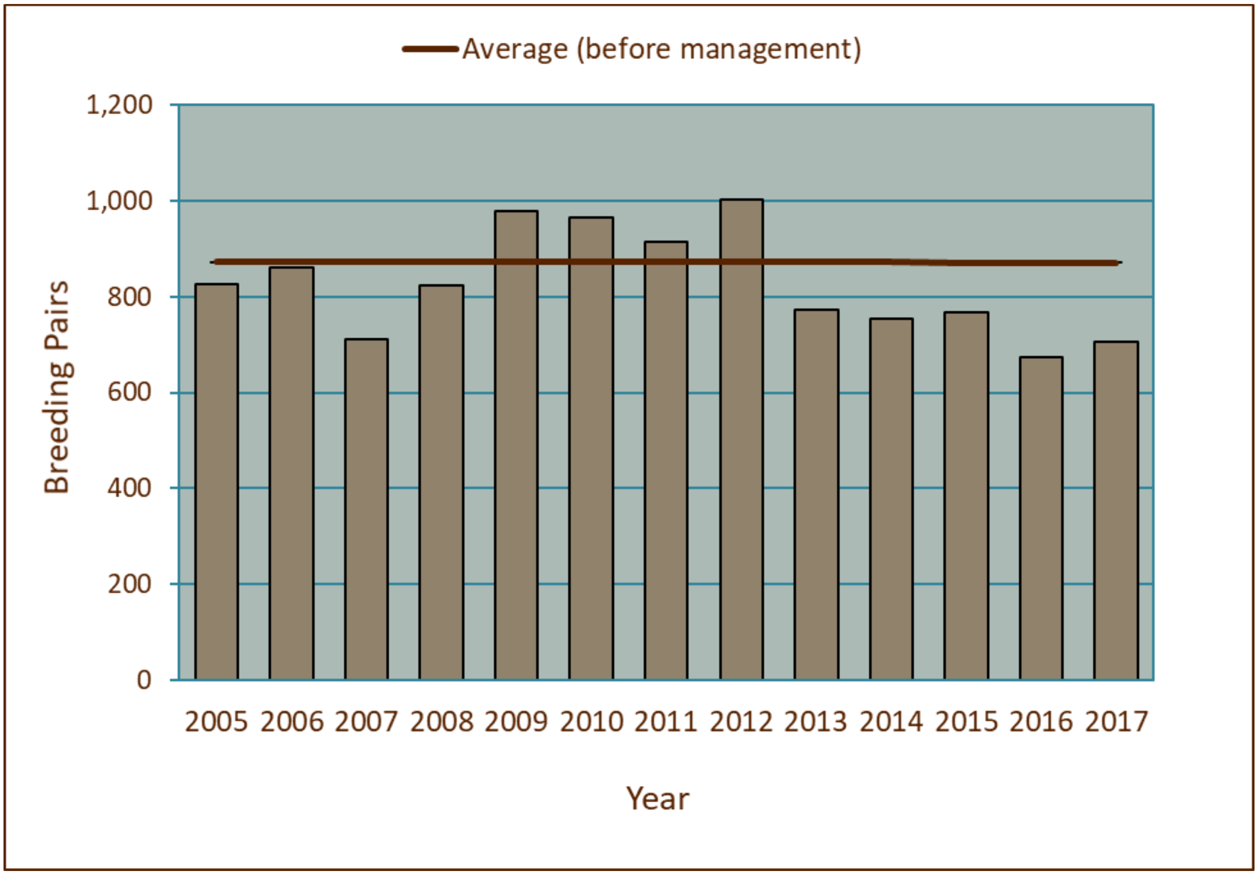


Figure 11. Total numbers of Caspian tern breeding pairs at all known colonies in the Columbia Plateau region during 2005-2017. Also, provided is the average number of breeding pairs of Caspian terns prior to tern management in the Columbia Plateau region (2005-2013).

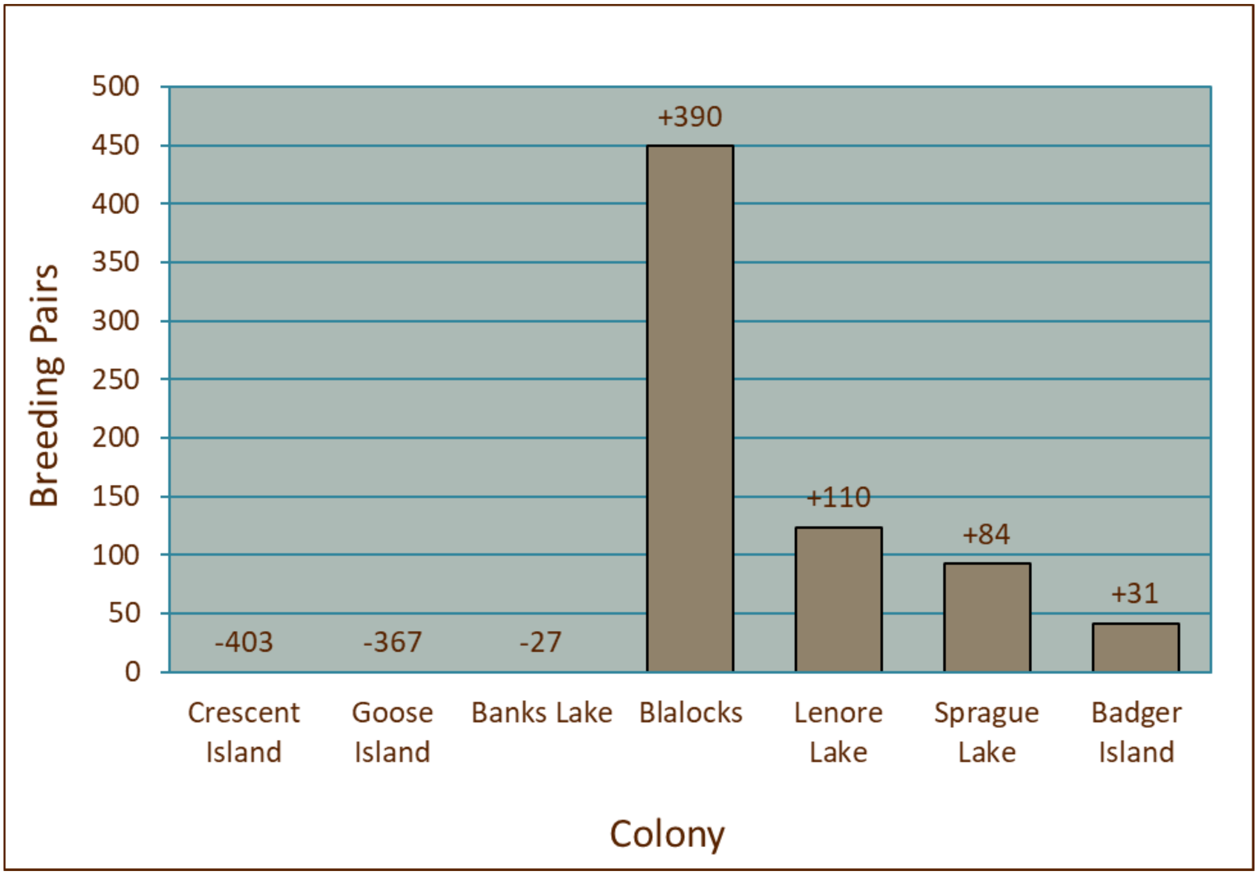


Figure 12. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the Columbia Plateau region during the 2017 breeding season. Numbers over each bar indicate the change in colony size in 2017 compared to the average colony size prior to tern management in the Columbia Plateau region (2005-2013).

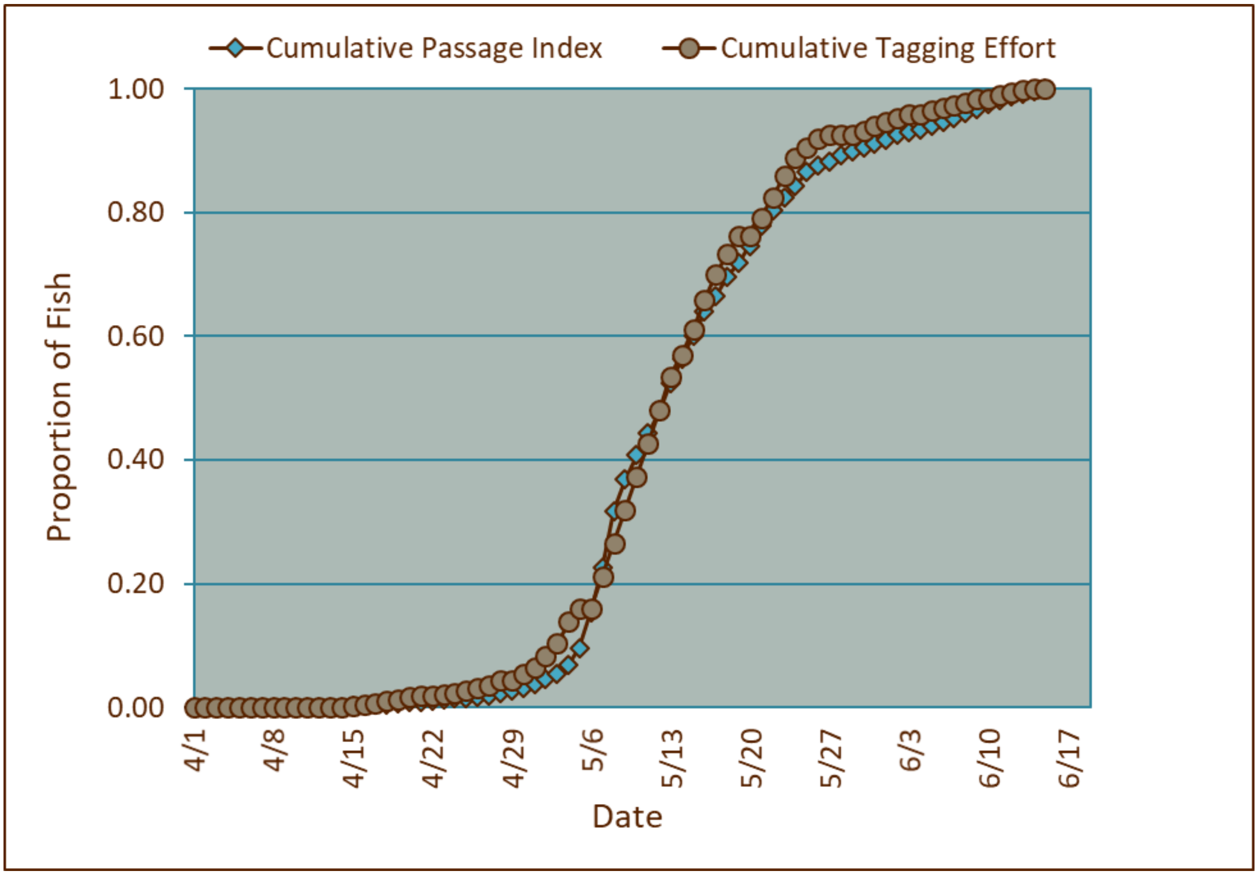
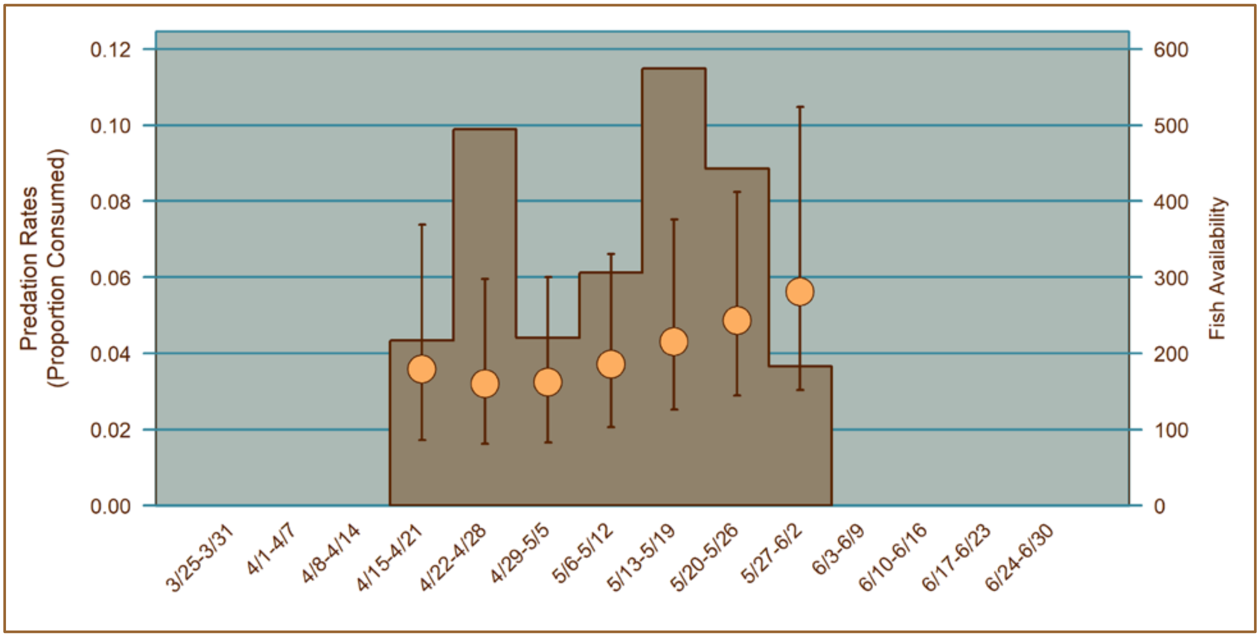


Figure 13. Proportion of steelhead PIT-tagged at the Rock Island Dam (RIS) fish trap relative to the Passage Index (tagging and untagged) in 2017. Passage index data were obtained from FPC (2017).



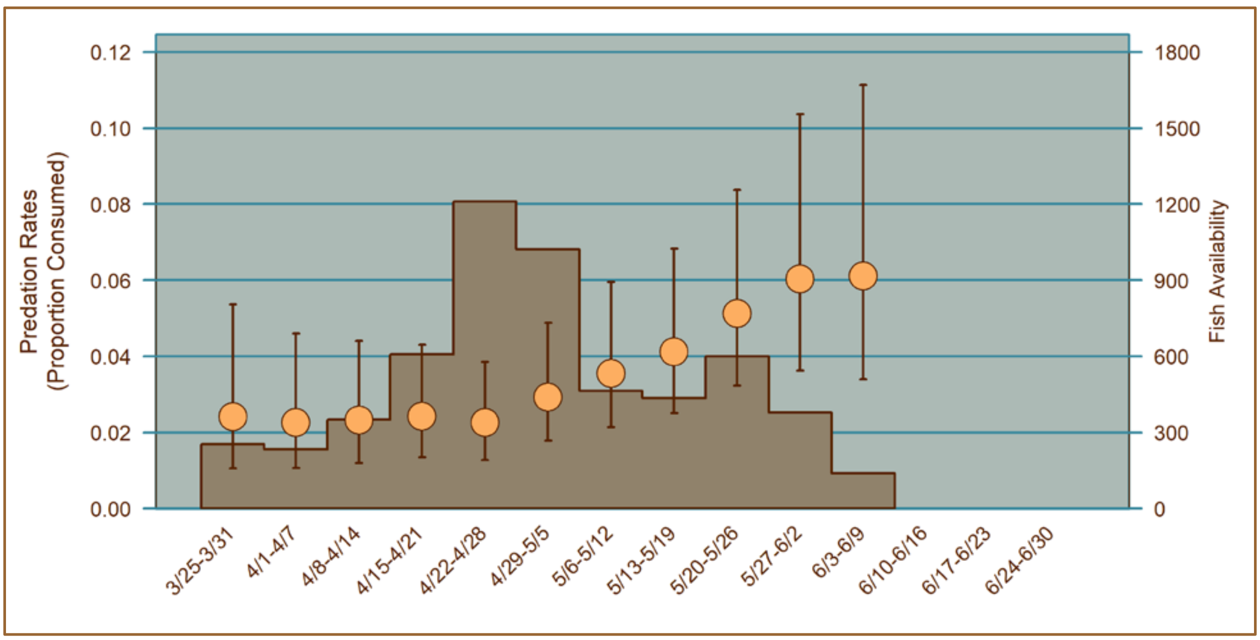


Figure 14. Estimated weekly predation rates (95% credible intervals) on upper Columbia River (top) and Snake River (bottom) steelhead by Caspian terns nesting on the Blalock Islands in John Day Reservoir in 2017. Fish availability is based on detections at McNary Dam.

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 2017. 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
3/13–3/19	1300	260	0	0	0	0	0	0	0	0	0	0
3/20–3/26	1680	240	0	0	0	0	0	0	0	0	0	0
3/27–4/02	1100	183	0	0	0	0	0	0	0	0	0	0
4/03-4/09	805	134	0	0	0	1	0	0	0	5	0	0
4/10-4/16	486	69	0	0	0	9	0	0	0	11	2	6
4/17-4/23	725	104	0	0	14	5	22	0	0	30	8	16
4/24-4/30	415	59	0	0	0	7	0	0	0	35	5	26
5/01-5/07	809	116	0	0	0	26	12	11	0	22	5	3
5/08-5/14	621	89	2	0	0	13	0	4	0	8	2	0
5/15-5/21	855	122	0	4	0	12	0	8	0	6	0	0
5/22-5/28	529	76	0	0	0	9	0	6	0	13	0	0
5/29-6/04	704	101	0	0	28	8	27	4	0	25	0	12
6/05-6/11	870	124	1	0	26	4	42	1	0	24	0	9
6/12-6/18	1609	230	0	16	38	48	82	3	0	36	16	64
6/19-6/25	1562	223	4	7	55	74	63	22	0	28	0	66
6/26-7/02	1816	259	21	8	46	86	49	0	0	9	3	13
7/03-7/09	1547	221	48	7	83	105	44	8	0	10	0	36
7/10-7/16	1836	262	49	0	124	48	30	0	0	7	0	58
7/17-7/23	894	128	39	100	117	105	15	0	0	68	0	44
7/24-7/30	1065	152	83	109	109	40	42	0	0	13	106	40

Table 2. Weekly estimates of cumulative duration (minutes) required to deter gulls from landing on Crescent Island in 2017.

Week	Weekly Hazing Effort (m)	Average Hazing Effort (m/d)
2/27–3/05	0	0
3/06–3/12	0	0
3/13–3/19	0	0
3/20–3/26	0	0
3/27–4/02	0	0
4/03-4/09	35	5
4/10-4/16	248	35
4/17-4/23	581	83
4/24-4/30	261	37
5/01-5/07	0	0
5/08-5/14	145	21
5/15-5/21	60	9
5/22-5/28	0	0
5/29-6/04	55	8
6/05-6/11	107	15
6/12-6/18	149	21
6/19-6/25	40	6
6/26-7/02	0	0
7/03-7/09	0	0
7/10-7/16	30	4
7/17-7/23	0	0
7/24-7/30	0	0

Table 3. Caspian tern eggs collected under permit on Goose Island and elsewhere in Potholes Reservoir in 2017.

Egg #	Date	Time	Location	Nest Location	Nest Location LAT	Nest Location LONG
1	4/29/2017	7:30	Goose Island	NW Rocks	46° 59.211'N	119° 18.626'W
2	4/29/2017	10:27	North Potholes	North Potholes Island	47° 01.996'N	119° 19.329'W
3	5/5/2017	7:50	Goose Island	South Spit	46° 59.105'N	119° 18.576'W
6	6/10/2017	12:45	Goose Island	E Rocks	46° 59.236'N	119° 18.398'W
7	6/11/2017	8:30	North Potholes	North Potholes Island	47° 02.672'N	119° 19.722'W
8	6/12/2017	13:40	Goose Island	SE Main	46° 59.140'N	119° 18.556'W
9	6/16/2017	13:05	Goose Island	E Rocks	46° 59.236'N	119° 18.397'W
10	6/18/2017	5:20	Goose Island	E Rocks	46° 59.235'N	119° 18.399'W
11	6/20/2017	13:33	Goose Island	South Spit	46° 59.113'N	119° 18.574'W
12	6/20/2017	14:30	Goose Island	SW Main	46° 59.119'N	119° 18.600'W
13	6/20/2017	19:10	Goose Island	SW Main	46° 59.119'N	119° 18.599'W
14	6/22/2017	15:00	Goose Island	South Spit	46° 59.111'N	119° 18.573'W
15	6/25/2017	5:45	Goose Island	SW Main	46° 59.117'N	119° 18.598'W
16	6/25/2017	19:44	Goose Island	South Spit	46° 59.110'N	119° 18.571'W
17	6/27/2017	13:20	Goose Island	SW Main	46° 59.119'N	119° 18.596'W
18	6/27/2017	21:10	Goose Island	E Rocks	46° 59.235'N	119° 18.399'W
19	7/1/2017	20:12	Goose Island	South Spit	46° 59.109'N	119° 18.571'W
20	7/7/2017	6:02	Goose Island	SE Main	46° 59.134'N	119° 18.539'W

Table 4. Summary of sites where Caspian terns were detected during aerial surveys in 2017 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
28-Apr	Lenore Lake - North Rock	Yes	71	25	Rock/Gravel	Attended Nests	47.482942 -119.520572
22-May	Lenore Lake - North Rock	Yes	146	77	Rock/Gravel	Attended Nests	47.482942 -119.520572
28-Jun	Lenore Lake - North Rock	Yes	94	24	Rock/Gravel	Rearing Chicks	47.482942 -119.520572
28-Apr	Potholes Reservoir	Yes	6	0	Sand	Loafing	47.033325 -119.321275
28-Jun	Potholes Reservoir	Yes	83	0	Sand	Loafing	47.033325 -119.321275
28-Apr	Marsh Unit #1	No	1	0	Mud/Water	Loafing	47.955181 -119.262114
23-May	Harper Island	Yes	82	49	Dirt/Rock/Gravel	Attended Nests	47.248105 -118.085808
28-Jun	Harper Island	Yes	12	0	Dirt/Rock/Gravel	Rearing Chicks	47.248105 -118.085808
Mid-Columbia River							
Survey Date	Site Name	Prospective Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
22-May	Upper Slough below 3 Mile Canyon Island	No	53	0	Sand	Loafing	45.786019 -120.010972
22-May	3 Mile Canyon Island	No	2	0	Rock	Loafing	45.817867 -119.959383
22-May	Blalock Islands - Straight Six Island	No	3	0	Gravel	Loafing	45.897767 -119.660903

28-Apr	Blalock Islands - Long Island	Yes	313	115	Gravel	Attended Nests	45.895579 -119.645708
22-May	Blalock Islands - Long Island	Yes	258	56	Gravel	Attended Nests	45.895579 -119.645708
28-Jun	Blalock Islands - Long Island	Yes	29	0	Gravel	Loafing	45.895579 -119.645708
28-Apr	Blalock Islands - Middle Island	Yes	253	99	Gravel	Attended Nests	45.895385 -119.646652
22-May	Blalock Islands - Middle Island	Yes	163	54	Gravel	Attended Nests	45.895385 -119.646652
28-Jun	Blalock Islands - Middle Island	Yes	223	61	Gravel	Rearing Chicks	45.895385 -119.646652
28-Apr	Blalock Islands - Southern Island	Yes	7	0	Gravel	Loafing	45.894784 -119.650418
22-May	Blalock Islands - Southern Island	Yes	3	0	Gravel	Loafing	45.894784 -119.650418
28-Apr	Blalock Islands - Sand Island	Yes	231	30	Sand	Attended Nests	45.897132 -119.636768
22-May	Blalock Islands - Sand Island	Yes	11	0	Sand	Loafing	45.897132 -119.636768
28-Apr	Blalock Islands - Rock Island	Yes	83	35	Rock	Attended Nests	45.909611 -119.628697
22-May	Blalock Islands - Rock Island	Yes	184	51	Rock	Attended Nests	45.909611 -119.628697
22-May	Warehouse Beach	No	19	0	Rock	Loafing	45.922552 -119.139231
28-Jun	Warehouse Beach	No	48	0	Rock	Loafing	45.922552 -119.139231
28-Apr	Walla Walla River Delta	No	52	0	Mudflat	Loafing	46.070111 -118.920233
28-Jun	Walla Walla River Delta	No	31	0	Mudflat	Loafing	46.070111

							-118.920233
28-Apr	Badger Island	Yes	65	8	Sand	Attended Nests	46.111447 -118.938092
22-May	Badger Island	Yes	131	38	Sand	Attended Nests	46.111447 -118.938092
28-Jun	Badger Island	Yes	77	1	Sand	Rearing Chicks	46.111447 -118.938092
28-Apr	Finley Downstream	Yes	22	0	Gravel	Loafing	46.14185 -118.992689
22-May	Finley Downstream	Yes	15	0	Gravel	Loafing	46.14185 -118.992689
28-Jun	Finley Downstream	Yes	2	0	Gravel	Loafing	46.14185 -118.992689
28-Jun	Transmission Island; north of Richland, WA	No	6	0	Mudflat	Loafing	46.45636 -119.258725
28-Apr	Gravel island Below Locke Island	No	67	0	Gravel	Loafing	46.7138 -119.486494
22-May	Island A	No	3	0	Gravel	Loafing	46.723811 -119.526278
28-Apr	Cabin Island	No	10	0	Gravel	Loafing	46.657333 -119.914475
22-May	Cabin Island	No	8	0	Gravel	Loafing	46.657333 -119.914475
28-Jun	Cabin Island	No	57	0	Gravel	Loafing	46.657333 -119.914475
28-Apr	Mouth of the Okanogan River	No	1	0	Gravel Bar	Loafing	48.098636 -119.720208
28-Jun	Mouth of the Okanogan River	No	1	0	Gravel Bar	Loafing	48.098636 -119.720208

Snake River							
Survey Date	Site Name	Prospective Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
23-May	Spit across from Little Goose Bay	No	24	0	Gravel/Water	Loafing	46.590592 -117.912711
29-Jun	Southern shoreline near Lyons Ferry, WA	No	6	0	Rocks	Loafing	46.604027 -118.324026
29-Jun	Southern shoreline near Almota, WA	No	4	0	Gravel	Loafing	46.689086 -117.494373
23-May	Almota Island	No	5	0	Gravel	Loafing	46.690217 -117.456038

Table 5. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the Columbia Plateau region during the 2017 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
Blalock Is. (Columbia River)	6	110	43	104	79	136	20	6	26	45	677	483	449
Badger Is. (Columbia River)	0	0	0	0	0	0	33	60	0	0	0	0	41
Twinning Is. (Banks Lake)	0	23	31	27	61	34	19	22	13	67	64	6	0
Harper Is. (Sprague Lake)	7	7	0	11	4	4	4	30	1	8	10	3	92
Unnamed Is. (Lenore Lake)	0	0	0	0	0	0	0	0	0	2	16	39	123
Unnamed Is. (Potholes Res.)	0	0	0	0	0	0	0	0	0	0	0	144	0

Table 6. Number of 2017 migration year PIT-tagged juvenile salmonids (all species combined) recovered from Caspian tern colonies in the Columbia Plateau region in 2017. River kilometer (Rkm) is the distance from nesting island to the Pacific Ocean for colonies located on the mainstem Columbia River.

Nesting Island	Location (Rkm)	PIT Tags Recovered
Unnamed Island	Lenore Lake, WA (Off-river)	199
Badger Island	McNary Reservoir, WA (512)	667
Blalock Islands	John Day Reservoir (441-439)	3,598
Total		4,464

Table 7. Average detection efficiency (range = first-to-last week of nesting season) estimates for PIT tags sown on Caspian tern colonies during the 2017 nesting season. Results were used to estimate the proportion of PIT-tags deposited by birds on their nesting colony that were subsequently detected by researchers on the colony following the nesting season. Sample sizes of the numbers of sown tags and the number of discrete sowing events (in parentheses) are provided.

Nesting Site	Location (Rkm)	Sample Size	Detection Probability
Unnamed Island	Lenore Lake (Off-river)	100 (2)	0.61 (0.41[1] - 0.82)
Badger Island	McNary Reservoir (512)	100 (2)	0.79 (0.71[1] - 0.91)
Blalock Islands	John Day Reservoir (441-439)	100 (2)	0.62 (0.52 - 0.72)

[1] Trends in pre-season detection efficiency at the Lenore Lake and Badger Island tern colonies were inferred from data collected at other bird colonies with similar nesting habitat and tag densities (see Methods).

Table 8. Annual predation rates (95% Credible Interval) on PIT-tagged salmonid populations (ESU/DPS) by Caspian terns nesting on Lenore Lake, Badger Island, and the Blalock Islands in 2017. 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 and Badger Island 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	Badger Island Terns	N	Blalock Island Terns
SR Sockeye	304	NA	NA	280	NA
SR Spr/Sum Chinook	27,977	< 0.1%	< 0.1%	17,215	0.9% (0.6-1.3)
UCR Spr Chinook	2,681	0.3% (0.1-0.8)	< 0.1%	6,517	1.1% (0.7-1.8)
SR Fall Chinook	9,769	< 0.1%	< 0.1%	9,230	0.6% (0.4-1.1)
SR Steelhead	24,247	< 0.1%	0.4% (0.2-0.6)	5,795	3.4% (2.4-5.1)
UCR Steelhead	7,644	1.0% (0.6-2.0)	0.5% (0.3-0.8)	2,536	4.2% (2.7-6.5)

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 2007-2017. Management actions were implement on Goose Island in Potholes Reservoir during 2014-2016, on an unnamed island in northeastern Potholes Reservoir in 2017, and on Crescent Island during 2015-2017. No management actions have been conducted at Caspian tern colonies on Twinning Island (data first available in 2009), Blalock Islands, Lenore Lake (data first available in 2015), and Badger Island (data first available in 2017). Annual predation rate estimates with 95% credible intervals are provided in Appendix C.

ESU/DPS	Goose Is. Potholes Res.		North Potholes Is. Potholes Res.		Crescent Is. McNary Res.		Twinning Is. Banks Lake		Badger Is. McNary Res.	Blalock Is. John Day Res.		Lenore Lake
	Pre- 07-13’	Post- 14-17’	Pre- 16’	Post- 17’	Pre- 07-14	Post- 15-17’	Pre- 09-14’	Post- 15-17’	Post- 17’	Pre- 07-14’	Post- 15-17’	Post- 15-17’
SR Sockeye	0.1%	< 0.1%	< 0.1%	< 0.1%	1.1%	< 0.1%	< 0.1%	< 0.1%	NA	0.3%	3.9%	< 0.1%
SR Sp/Su Chinook	< 0.1%	< 0.1%	< 0.1%	< 0.1%	0.7%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	0.1%	0.9%	< 0.1%
UCR Spr Chinook	2.5%	0.1%	0.1%	< 0.1%	0.5%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	0.8%	< 0.1%
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%
SR Steelhead	< 0.1%	< 0.1%	< 0.1%	< 0.1%	3.9%	< 0.1%	< 0.1%	< 0.1%	0.4%	0.6%	5.2%	< 0.1%
UCR Steelhead	15.7%	0.7%	4.1%	< 0.1%	2.4%	< 0.1%	0.3%	0.9%	0.5%	0.6%	5.3%	0.3%

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 2017 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 2014-2016 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 2014-2016 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 pre-egg-laying, 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 2014-2016 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: BLALOCK ISLANDS WATER LEVEL MONITORING

Overview – A water level and wind monitoring system was installed near the Blalock Islands to help assess how fluctuations in pool level affects the amount of available Caspian tern nesting habitat at the Blalock Islands. The water level gauge (WLG) was installed on 29 March 2017. The installation process consisted of a site survey to reference the system to a vertical datum, calibration of the pressure sensor, and configuration of the autonomous power and telemetry systems. The WLG began collecting water level elevations and wind measurements at approximately 2 pm on 29 March 2017.

The water level monitoring system was installed in the same location as in 2016, 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. The pumping station is operated by Sandpiper Farms, of Paterson, WA. Sandpiper Farms generously granted RTR permission to locate the water level monitoring system once again in 2017.

Figure 1 shows the location of the water level monitoring system.

Figure 1. Water Level monitoring station location.

System Components – Water level measurements are acquired with a Campbell Scientific CS451 Water-Level Recording Sensor (https://www.campbellsci.com/cs451), which is a vented, submersible pressure sensor that is designed for extended-duration deployment in riverine and lake settings. Measurements acquired by the CS451 are recorded by a Sutron CDMALink 2-Way Logging Transmitter (http://www.sutron.com/product/cdmalink/). Wind measurements are acquired with a Lufft WS200-UMB ultrasonic wind sensor (https://www.lufft.com/products/wind-sensors-anemometers-289/ws200-umb-smart-weather-sensor-2323/). The CDMALink Data Collection Platform (DCP), the CS451, and the WS200 are all powered by a 5-Watt solar panel with a sealed lead acid battery backup power supply. Water level and wind readings are transmitted by the DCP via a wireless cellular network.

Installation Methods – Water level elevations are referenced to the North American Vertical Datum of 1988 (NAVD 88). This was achieved by establishing a temporary control point referenced to NAVD88, and in turn referencing the water level gauge (WLG) to the temporary control point. The temporary control point (TCP) is a PK Nail set in the concrete pad adjacent to the WLG during the 2016 gauge installation (*Figure 2*).

Figure 2. Temporary control point (TCP) establishment.

The TCP was occupied with a dual frequency Global Navigation Satellite System (GNSS) receiver for a period of 3.5 hours. GNSS data was collected for TCP in 2017 to provide a check on the horizontal and vertical position from original installation in 2106. Position data recorded by the GNSS receiver was then submitted to the Online User's Positioning Service (OPUS) for position processing. To facilitate measure-downs to the water surface to reference water surface measurements to the TCP, a secondary point referred to as RAIL was established on the hand rail above the WLG in 2016. *Figure 3* shows the water level data collection platform with the integrated wind sensor.

Figure 3. Water level data collection platform with wind sensor.

The Corps had previously established a temporary benchmark (TBM) above the project area in 2016, adjacent to a substation fence. The TMB is a rail road spike driven horizontally into a wooden power pole. The TMB was not suitable for GNSS observations but was referenced vertically during the installation as described below. The project layout is shown in *Figure 4.*

Figure 4. Water level gauge (WLG), RAIL point, temporary control point (TCP) and USACE temporary benchmark (TBM).

To tie together these points, a 3rd Order optical level loop was conducted during the 2016 installation to measure vertical differences from each point to the TCP.

Results – The OPUS processing of the GNSS data collected on TCP in 2017 provided horizontal and vertical positions relative to the North American Datum of 1983 2011 (Epoch 2010.000) (NAD 83(2011)) with an estimated uncertainty of 0.016 m (0.05 ft) over 3.5 hours of observations. Differences between the original installation in 2016 and the current installation are show below in *Table 1*.

Table 1. Verification of temporary control points.

Point	Description	NAD83 (2011) (m)		
		2016	2017	Difference
TG-1	PK Nail	63.235	63.192	-0.043
Rail	Top of handrail	64.224	64.201	-0.023
TBM	Railroad spike	68.535	68.536	0.001

The temporary control point values from 2016 were held for the new installation because no significant difference was observed. The ellipsoid height of TG-1 on NAD83(2011) from 2016 was converted to NAVD88 using the GEOID12B model. National Geodetic Vertical Datum of 1929 (NGVD 29) elevations were then determined using the VERTCON94 model. To establish the elevations of TBM and RAIL, the elevation differences relative to TCP that were derived via the optical level loop in 2016 were applied:

TCP to RAIL = +0.989 m (+3.245 ft)
TCP to TBM = +5.300 m (+17.388 ft)

Table 2 summarizes the elevation of each of the control points for each datum described above.

Table 2. Summary of elevation for each control point by datum.

Control Point	Description	NAVD 88 (ft)	NGVD 29 (ft)	NAD 83(2011) (m)
TCP	PK Nail set in N corner of concrete pad	279.12	275.78	63.235
RAIL	Top of hand rail NW of gauge	282.36	279.02	64.224
TBM	Rail road spike extending horizontally from pole	296.51	293.17	68.535

The water level gauge (WLG) mounted in the same location as in 2016 on an arbitrary datum (station datum). Manual water level observations relative to RAIL were used to determine the vertical offset to NAVD 88. The average difference between the manual water level observations and the gauge was determined to be 79.660 m (261.35 ft), with a standard deviation of 0.007 m (0.02 ft).

Water level elevations are reported to the Corps relative to both NAVD 88 and NGVD 29 datums. It should be noted that the WLG measures water level in Pounds Per Square Inch Gage (PSIG) on the station datum. The conversion from raw gauge data in PSIG to stage in feet above NAVD 88 is as follows:

- Multiply by 2.31 to convert PSIG to Feet
- Add 261.35 ft to adjust to NAVD 88

To verify conversions, two TRK edge of water shots were taken. This allows GNSS-derived water elevation to be compared to the gauge as an independent check. *Table 3* shows a comparison of gauge- and RTK-derived water elevations.

Table 3. RTK Water Level Verification

Time	NAVD88 (ft)		
	Gauge	RTK	Difference
19:55	267.49	267.48	-0.01
20:10	267.47	267.40	-0.07

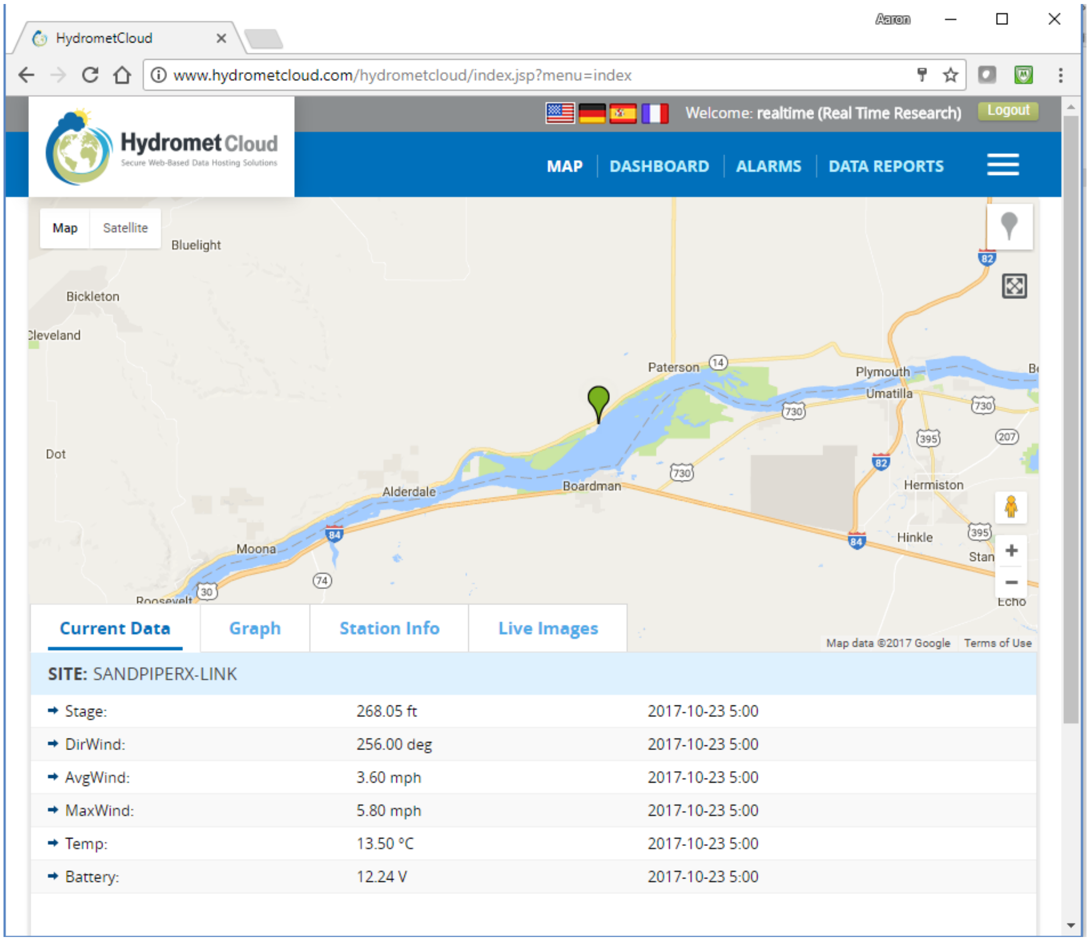
The wind sensor records 4 wind parameters. Each parameter is logged every 5 minutes on the even intervals (concurrent with the water level measurement).:

- Average wind speed (meters per second)
- Maximum wind speed (meters per second)
- Average wind direction (degrees True)
- Compass (degrees)

Data – Water level elevation is observed and recorded on a five-minute cycle. Each recorded value is the water level averaged over one minute, sampled in 5 second intervals. Water levels are recorded in PSIG with time recorded in Coordinated Universal Time (UTC). Wind measurements are recorded on the same five-minute cycle, concurrently with the water level elevation observations. The recorded water level and wind data is transmitted to a data server via cellular network once per hour. Upon receipt by the server the water level elevations are converted from PSIG to Feet NAVD 88 and Feet NGVD 29.

Data is available in real-time via the web-based portal:

http://www.hydrometcloud.com/hydrometcloud/



A final water level and wind dataset will be delivered to the Corps in csv format upon completion of data collection.

APPENDIX C: HISTORIC ESU/DPS-SPECIFIC PREDATON RATES

Table C1: 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 2007-2017. 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. 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 As of 2014							
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	-	-	-	-	-	-

Predation Rates by Caspian Terns on an Unnamed Island in North Potholes Reservoir, Managed Colony As of 2017							
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	-	-	-	-	-	-

Predation Rates by Crescent Island Caspian Terns in McNary Reservoir, Managed Colony As of 2015							
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	-	-	-	-	-	-

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	-	-	-	-	-	-

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	0.7% (0.4-1.2)	0.1% (0-0.5)	<0.1%	<0.1%	<0.1%	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

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