IMPLEMENTATION OF THE INLAND AVIAN PREDATION MANAGEMENT PLAN, 2016

Final Annual Report

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EXECUTIVE SUMMARY

In 2016, 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 third year of implementation was to reduce the numbers of Caspian terns breeding at colonies on Goose Island 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 on both islands by installing a variety of "passive nest dissuasion" materials prior to the 2016 nesting season, materials that were designed to preclude tern nesting on both islands. In addition, on Crescent Island willows had been planted over extensive areas to preclude tern nesting over the long-term. Ultimately, 4.3 acres, or more than 85% of the upland area of Goose Island and nearby islets, 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; any remaining open areas on Crescent Island had been planted with willows prior to the 2016 nesting season. On both 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.). An effort was also made to prevent nesting by the two species of gulls that nest abundantly on both islands (California gulls [*L. californicus*] and ring-billed gulls [*L. delawarensis*]), on the theory that nesting gulls would attract prospecting Caspian terns and could limit the efficacy of efforts to dissuade Caspian terns from nesting on the two islands. Once Caspian terns and gulls arrived on Goose and Crescent islands to initiate nesting, active nest dissuasion (i.e. human hazing) was used to try to dissuade both Caspian terns and gulls from nesting anywhere on either island.

Both California and ring-billed gulls quickly acclimated to both the passive and active dissuasion employed at Goose Island and, as in 2014 and 2015, gulls initiated nesting and laid eggs despite dissuasion efforts. Once gulls laid eggs, hazing gulls that were attending eggs was precluded due to the risk of causing gull nests to failure. As the area on Goose Island with active gull nests expanded, the opportunities to actively haze Caspian terns that were prospecting for nest sites on Goose Island declined. Nevertheless, between the passive dissuasion deployed on potential Caspian tern nesting habitat and active dissuasion (hazing, including use of a green laser) to deter prospecting terns, nesting by Caspian terns on Goose Island and nearby islets was prevented in 2016. This is the first year since nest dissuasion activities were initiated at Goose Island that efforts were successful in preventing Caspian terns from successfully nesting on Goose Island; in 2014, 159 breeding pairs nested on Northwest Rocks near Goose Island, and in 2015 two breeding pairs of Caspian terns nested on the main island under the passive dissuasion near the site of the former colony. Prior to management (2004-2013), an average of 343 breeding pairs of Caspian terns nested on Goose Island each year.

Despite the use of a combination of passive and active dissuasion on suitable Caspian tern nesting habitat on Goose Island during the 2014-2016 breeding seasons, some Caspian terns have continued to display high fidelity to Potholes Reservoir as a nesting area. 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, which attracts 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, Caspian tern use of Goose Island for roosting and nesting in 2016 was largely limited to areas near the island's shoreline, which gradually were exposed during the nesting season as reservoir levels receded. Active nest dissuasion (hazing), collection of any Caspian tern eggs discovered, and high rates of gull predation on newly-laid Caspian tern eggs were factors in preventing the formation of a Caspian tern colony on Goose Island in 2016. Only six Caspian tern eggs were discovered in five different nests on Goose Island during the 2016 nesting season. Of those six tern eggs, four were collected under permit and two were depredated by gulls soon after they were laid. By comparison, a total of 43 Caspian tern eggs were found on Goose Island and nearby islets in 2015.

Passive and active nest dissuasion techniques were successful in preventing all nesting and roosting by both Caspian terns and gulls on Crescent Island during the 2016 nesting season, as was the case in 2015. The results during the 2015 and 2016 nesting seasons were somewhat unexpected because Caspian terns and gulls had nested consistently on Crescent Island for nearly three decades prior to 2015. 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 as passive dissuasion in much of the suitable Caspian tern nesting habitat on Crescent Island, including the former colony area; similar fencing was not deployed at Goose Island due to shallow rocky soils. Another factor was the successful dissuasion of all gulls from nesting on Crescent Island in both 2015 and 2016; 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 dissuasion techniques at our disposal, whereas at Crescent Island gulls never habituated to the passive and active dissuasion techniques. 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 both 2015 and 2016. Similarly, Caspian terns displaced from Crescent Island relocated to an alternative colony site on the Columbia River, the Blalock Islands in John Day Reservoir (70 river kilometers downriver from Crescent Island), where Caspian terns have nested in small numbers over the last decade. Resightings of Caspian terns that were previously color-banded on Crescent Island confirmed that there was a large influx of terns to the Blalock Islands colony from the colony on Crescent Island in 2015, and many of these same color-banded terns renested at the Blalock Islands colony in 2016.

System-wide action effectiveness monitoring determined that Caspian terns attempted to nest at five different colonies in the Columbia Plateau region in 2016. Four of these occupied colony sites had been used in previous years, and one site was new in 2016. The formerly occupied

sites included the Blalock Islands on the Columbia River (483 breeding pairs in 2016, down from 677 breeding pairs in 2015), Twinning Island in Banks Lake (6 breeding pairs in 2016, down from 64 breeding pairs in 2015), Harper Island in Sprague Lake (3 breeding pairs in 2016, down from 10 breeding pairs in 2015), and an unnamed island in Lenore Lake (39 breeding pairs in 2016, up from 16 breeding pairs in 2015). In 2016, an incipient Caspian tern colony became established on a small, low-lying island in northeastern Potholes Reservoir, where 144 breeding pairs of Caspian terns attempted to nest before the colony was abandoned in early June. As was the case in 2015, the largest Caspian tern colony in the Columbia Plateau region was on the Blalock Islands, where 72% of all the Caspian terns in the region nested during 2016. Compared to the average historical size of the Caspian tern colony on the Blalock Islands during 2005-2014 (58 breeding pairs), the colony was 11 times larger in 2015 and eight times larger in 2016.

The total estimated breeding population of Caspian terns in the Columbia Plateau region during 2016 was 675 breeding pairs at five separate colonies. This represents a 23% 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). Although nest dissuasion actions implemented on Goose and Crescent islands in 2016 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 primarily due to the more than 8-fold increase in the number of Caspian terns nesting in the Blalock Islands in 2016 compared to the pre-management average for that colony. The Blalock Islands colony during 2015-2016 was similar in size to the largest Caspian tern colony recorded anywhere in the Columbia Plateau region since intensive monitoring began in 2000.

Resightings of Caspian terns that were previously color-banded indicated strong site fidelity to the Potholes Reservoir area, despite the third year of efforts to dissuade Caspian terns from nesting at Goose Island and nearby islets. The Blalock Islands experienced a large influx of nesting Caspian terns in 2015, both from the colony on Crescent Island and the colony on Goose Island, but most immigrants came from Crescent Island. Many of the terns that immigrated to the Blalock Islands in 2015 returned to that colony in 2016. Although most Caspian terns dissuaded from Goose and Crescent islands remained in the Columbia Plateau region during the 2015 and 2016 nesting seasons, some terns dispersed to breeding or non-breeding sites along the coasts of Washington and Oregon, as well as to colonies on Corps-constructed islands in interior Oregon and northeastern California. Results from a more robust analysis to estimate inter-annual movement rates and the number of terns that moved among colonies are also included this report.

The goal of the IAPMP is to reduce Caspian tern predation rates (percentage of available fish consumed by terns) on ESA-listed salmonid populations to less than 2% per tern colony per year (USACE 2014). Based on an analysis of former predation rates by Caspian terns nesting in the Columbia Plateau region during 2007-2015 and data on the size of breeding colonies (number of breeding pairs) in 2016, we predicted that predation rate goals would be achieved for many, but not all, tern colonies and salmonid populations in 2016. Predicted predation rates on ESA-

listed salmonid populations were close to zero (≤ 0.2% per ESA-listed population) for Caspian terns nesting at Goose Island due to the near complete abandonment of the colony in 2016. Predicted predation rates on ESA-listed salmonid populations by Caspian terns nesting on Crescent Island were even closer to zero (< 0.1% per ESA-listed population), due to the complete abandonment of the colony in 2016. Because of the large size of the Caspian tern colony at the Blalock Islands in 2016 (483 breeding pairs), however, predicted predation rates were above the 2% threshold for Upper Columbia River steelhead (4.9%; 95% prediction interval [PI] = 3.8 - 6.4%), Snake River steelhead (4.6%; 95% PI = 4.0 - 5.6%), Snake River sockeye salmon (2.6%; 95% PI = 1.6 - 5.0%), and Snake River spring/summer Chinook salmon (2.0%; 95% PI = 1.8 - 2.3%).

There is a lack of sufficient data to estimate former predation rates, or predict current predation rates, on ESA-listed salmonid populations by Caspian terns nesting on (1) Twinning Island in Banks Lake, (2) the small unnamed island in Lenore Lake, and (3) the incipient colony in northeastern Potholes Reservoir. Salmonid PIT tags were recovered, however, from these three nesting sites following the 2016 breeding season and actual (as opposed to predicted) estimates of predation rates are pending further analysis; results will be presented as part of a report to the Grant County Public Utility District and the Priest Rapids Coordinating Committee in January 2017. Actual predation rate estimates based on smolt PIT tag recoveries will also be available for terns that nested on the Blalock Islands in 2016. Due to the small numbers of Caspian terns that were present on Goose Island and the complete abandonment of the Crescent Island tern colony, PIT tag recovery was not conducted at either of these sites and, consequently, predicted predation rates represent the best estimate of predation rates in 2016.

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 2016, the third 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 23%. Based on resightings of banded Caspian terns, most terns that were displaced from colonies on Goose and Crescent islands have remained in the region, and many have attempted to nest at alternative colony sites in the region. Most notable was 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 2015-2016 have consumed sufficient numbers of juvenile salmonids to at least partially compensate for 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. A new tern colony also appeared on a small island in northeastern Potholes Reservoir, but this colony failed before any chicks were fledged due to predators reaching the island as reservoir levels dropped. Based on results during the first three years of implementation of the IAPMP, the goal of the Plan to reduce predation rates on ESA-listed salmonid populations below 2% per tern colony per year

throughout the Columbia Plateau region will not be achieved until alternative tern nesting habitat is reduced from current levels, especially in the Blalock Islands and perhaps at the new colony in Potholes Reservoir.

PROJECT OBJECTIVES

The primary objectives of this study in 2016 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 Goose and Crescent islands; (2) monitor the efficacy of those management components and actions at both the colony- and system-level; (3) measure the inter-colony movements and dispersal of previously color-banded Caspian terns in the context of implemented management actions; (4) model the change in predation rates on juvenile salmonids (*Oncorhynchus* spp.) by Caspian terns in the Columbia Plateau region (*Map 1*) concomitant with management actions implemented as part of the IAPMP; and (5) support the monitoring efforts at Don Edwards National Wildlife Refuge (NWR) by coordinating an aerial photography survey of the Corps-constructed tern islands in the Refuge and processing the photos so that Caspian tern colony size (number of breeding pairs) and nesting area used (m^2) could be calculated.

To address *Objective 1* we sought to (a) dissuade all Caspian terns from nesting using passive measures (i.e. stakes, rope, flagging, propane cannons, and owl decoys on Goose Island and a combination of silt fences, stakes, rope, flagging, and willow *(Salix* spp.) plantings on Crescent Island) prior to the initiation of nesting activities by gulls (*Larus* spp.) 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 Goose and Crescent islands, as necessary; (c) collect any Caspian tern eggs laid on Goose Island 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/Real Time Research and approved by the Corps and Reclamation; and (d) evaluate the effectiveness of willow plantings and Russian olive (*Elaeagnus angustifolia*) management on Crescent Island as a nesting deterrent for Caspian terns.

Action effectiveness monitoring (*Objective 2*) included both colony-level monitoring and system-level monitoring. Colony-level monitoring was conducted in support of the IAPMP at both Goose Island and Crescent Island. Monitoring at both islands was conducted daily by resident field crews throughout the breeding season (i.e., mid-March to late July) in conjunction with management tasks described above. Data collection at each island was conducted according to established protocols (see Roby et al. 2014; Collis et al. 2015; BRNW 2015) 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 (acreage) 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 either island; (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 30 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. Monitoring was by periodic aerial-, ground-, and/or boat-based surveys. High-resolution digital aerial photography was taken at the peak of incubation at colonies to accurately measure the colony area by habitat type, the number of Caspian terns present, and the peak Caspian tern colony size. Additionally, we remotely monitored water levels near the Blalock Islands complex in John Day Reservoir to determine how fluctuations in pool elevation affects the amount of Caspian tern nesting habitat available at that site.

Objective 3 was addressed by systematically resighting previously color-banded Caspian terns during visits to the Goose Island, Crescent Island, and other nesting or roosting sites used by Caspian terns in the Columbia Plateau region during 2016. Using a comprehensive database containing banding and resighting records for Caspian terns dating back to 2005, we assessed (a) colony connectivity among sites in the Columbia Plateau region; (b) emigration rates of banded individuals from colony sites in the Columbia Plateau region to colony sites outside the region; and (c) immigration rates of banded individuals from colony sites outside the Columbia Plateau region to sites in the region. We used this information to assess to what extent Caspian tern management actions implemented as part of the IAPMP (USACE 2014) and the Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006) were successful in relocating Caspian terns to sites outside the Columbia River basin.

The 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 Endangered Species Act (ESA)-listed salmonid population (hereafter ESU/DPS), per Caspian tern colony, per year (USACE 2014). As part of *Objective 4*, we used data on the size of Caspian tern colonies in 2016, coupled with historic predation rate estimates (2007-2015), to predict predation rates by Caspian terns at managed (i.e. Goose and Crescent islands) and un-managed (i.e. Blalock and Twinning islands) tern colonies in 2016. This predictive modeling approach was 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.

Finally, to support on-the-ground efforts conducted by another contractor at the Corps-constructed tern islands at Don Edwards NWR in southern San Francisco Bay, we coordinated and scheduled an aerial photo census of the islands used by nesting Caspian terns (*Objective 5*) so that an accurate measure of peak colony size and colony area could be estimated. Processed photography (i.e., georeferenced, stitched mosaic of individual photos) was provided to the Corps and their contractors for analysis.

METHODS & ANALYSES

PASSIVE NEST DISSUASION

To deter Caspian terns from nesting on Goose Island and the surrounding islets in Potholes Reservoir (hereafter referred to as "Goose Island") and on Crescent Island in the Columbia River during 2016, a network of passive dissuasion was constructed during March 2016, prior to the arrival of breeding Caspian terns and gulls to the islands. Following proven methods developed in the Columbia River Estuary (Collis et al. 2015, BRNW 2015, Roby et al. 2014), and as described in the IAPMP (USACE 2014), we erected a matrix of vertical silt fences, stakes, polypropylene rope, and polyethylene flagging over historical Caspian tern nesting areas and other areas that were potentially suitable Caspian tern nesting habitat on both islands. Extensive planting of native vegetation and woody debris (Crescent Island; completed in February by an independent Corps contractor), owl effigies, and propane canons (Goose Island; provided by BOR) were added in some locations as additional passive nesting deterrents. The passive nest dissuasion materials and configurations differed between islands and are described *below*.

Goose Island

Prior to the installation of new passive nest dissuasion materials on Goose Island in 2016, a thorough inspection of previously installed materials was conducted on 29 February to determine the need for repairs and additional materials. Repairs and installation of new passive dissuasion was initiated on 1 March. As in 2015, concrete pier blocks (Mutual Materials; 12'' x 12'', 63 lbs. each) were placed in a 10' x 10' square grid in areas where additional passive dissuasion was considered necessary. The center of each concrete pier block was drilled out vertically to accommodate a 48-inch length of .5-inch rebar and a 42-inch length of .5-inch PVC pipe that was slipped over the rebar. Twisted polypropylene rope (.25-inch) 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 ("polyethylene flagging;" Mutual Industries; 3 mil) were inserted between the strands of the rope at approximately 3-foot intervals, and allowed to flutter in the wind as a visual and auditory deterrent to prospecting Caspian terns. A second layer of ropes 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. At minimum, a

10 to 15-foot buffer of double layer passive nest dissuasion was installed around the perimeter of all contiguous areas of passive dissuasion (see *Map 2*).

The installation of 4.3 acres of passive dissuasion on Goose Island was completed by 15 March. This was accomplished by first repairing and re-deploying materials (primarily barricade tape) on the 4.1-acre area where passive nest dissuasion was installed in 2015. Additional passive nest dissuasion (0.2 acres) was then installed, primarily along the southern shoreline of Goose Island, where most Caspian tern eggs were laid in 2015. Other areas of new deployment were along the northwest slope, the surrounding rocky islets, and a second layer of passive dissuasion where two nests were established under dissuasion in 2015 (Collis et al. 2015).

Passive dissuasion in 2016 consisted of more than 2,000 pier blocks, rebar stakes, and PVC sections installed on Goose Island to support the rope and flagging matrix covering 4.3 acres, more than 85% of the upland area of Goose Island (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.

Finally, Mylar flagging, propane canons and owl effigies (provided by BOR) were deployed prior to widespread gull nesting to determine their utility as supplemental passive dissuasion techniques on Goose Island. A 10-meter plot of reflective Mylar tape attached to the existing passive dissuasion matrix was installed on 15 April to determine any noticeable effect on gull nesting (in contrast to barricade tape). During late February through 12 April, propane cannons were deployed on Goose Island to deter gulls from landing on the island. The cannons were monitored by field personnel during site preparations and during hazing operations. Cannons were repositioned or intermittently switched off in response to nesting activities by Canada Geese and gulls near the cannon locations. When cannons were deemed to be ineffective they were shut off and removed from the island. Two plastic owl decoys were again mounted on two outlying rocky islets (Northeast Rocks and East Rocks; see *Map 2*) that were used by roosting Caspian terns during the 2015 breeding season.

Crescent Island

Prior to the installation of new passive nest dissuasion materials on Crescent Island in 2016, a thorough inspection of previously installed materials was conducted on 2 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 by independent Corps contractors, there was little potential Caspian tern nesting habitat remaining that required additional passive dissuasion. Installation of replacement flagging and new passive nest dissuasion materials was initiated on 2 March and completed by 15 March. Three additional fence rows were added to the series constructed in 2015. Fence rows were constructed by driving 6-foot fence posts into the ground to depths of at least two feet, spaced six feet apart, with each fence row securely anchored at both ends using angle brackets (Wedge-Loc®). Runs of taught, barbless wire were then secured to the fence posts at ground level, 18 inches AGL, and 36 inches 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 any prospecting Caspian terns that might land on the ground. Additionally, twisted polypropylene rope (0.25-inch) was then attached to the fence posts at approximately 42 inches AGL using clove hitch knots. Ropes were fastened to alternating fence posts diagonally between two adjacent fence rows, and then 4-foot lengths of industrial barricade tape ("polyethylene flagging;" Mutual Industries; 3 mil) were inserted between strands of the rope at 3-foot intervals. Finally, open areas where felled Russian olive trees left pockets of marginal habitat were covered with passive dissuasion consisting of stakes, rope, and flagging. As in 2015, ropes and flagging were deployed in a 10-foot by 10-foot square array using 6-foot steel fence posts driven into the ground, and with diagonal strands of rope and flagging bisecting each square, like the passive dissuasion installed on Goose Island (see *above*).

From late-April through July, we conducted weekly monitoring of Caspian tern and gull presence and of vegetation to evaluate the effectiveness of willow plantings and Russian olive management as nesting deterrents for Caspian terns on Crescent Island. For willows planted in 2016, observers monitored survival, new growth on stems, water stress, insect and beaver damage, and height of secondary competitive vegetation (mostly non-native weeds). Field personnel also monitored tern and gull use of areas were Russian olive was placed on the ground as a visual and/or physical deterrent to nest formation. Finally, observers monitored the beaver exclusion fence that was installed by another contractor around the willow planting areas and repaired any breaches in the fence that were detected.

In total, approximately 2.4 acres were covered in passive dissuasion, consisting of fence rows, rope, and flagging. 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 2016 nesting season (see *Map 3*).

ACTIVE NEST DISSUASION

In accordance with the IAPMP, active nest dissuasion methods were used to supplement passive dissuasion measures to further deter nesting attempts by Caspian terns and gulls on Goose and Crescent islands in 2016 (USACE 2014). Active dissuasion methods were conducted during early March through July, and included: (1) forays into the colony by researchers to haze prospecting birds, (2) waving PVC poles with polyethylene flagging attached to haze prospecting birds, (3) approaching the shoreline of the island by boat to haze prospecting birds along the shore, (4) using a green laser during low light conditions to haze prospecting birds on the ground, and (5) flying a peregrine falcon kite to deter birds on or near the island from landing. A detailed description of active nest dissuasion activities that were used at each island during the 2016 nesting season is provided below. Active hazing targeted both Caspian terns and gulls (i.e. ring-billed gulls [*L. delawarensis*] and California gulls [*L. californicus*) to prevent or delay colony formation. Active gull dissuasion was needed to prevent or delay gull nesting because nesting gulls can attract Caspian terns to nest nearby. In addition, initiation and widespread gull nesting

across the islands would limit or preclude researcher access to the island needed to conduct the management described below (see *Appendix A* for more details).

Goose Island

Active nest dissuasion was conducted at Goose Island by (1) forays into the colony by researchers, (2) waving PVC poles with polyethylene flagging attached, (3) approaching the shoreline of the island by boat, (4) targeted use of a green laser during low light conditions, and (5) flying a peregrine falcon kite on the island (collectively referred to as "active hazing"). Active hazing was performed on Goose Island and the surrounding small rocky islets (see *Map 4*).

On 1 March, an observation blind was installed on the upper part of Goose Island, adjacent to the former Caspian tern colony site (see *Map 4*). The blind was visited once or twice daily to monitor Caspian tern and gull use of the surrounding area that cannot be readily seen from a boat. On 15-16 March, installation of a portable building was completed on Goose Island as a field camp (see *Map 4*) to facilitate overnight stays on the island and allow early morning and late evening hazing of Caspian terns and gulls from potential nesting areas. Regular overnight stays by field personnel were initiated on 5 April shortly after the first Caspian terns were observed flying over Goose Island. Evening hazing to prohibit Caspian terns and gulls from remaining on Goose Island overnight was considered especially important for deterring, or at least delaying, nest initiation.

In accordance with the BMPs (see *Appendix A*) developed and revised during the 2014 – 2015 nesting seasons, the frequency, duration, and methods of active hazing were altered over the course of the breeding season to enhance the efficacy of Caspian tern nest dissuasion and to avoid egg take of non-target species (i.e. gulls and Canada geese). Methods to dissuade prospecting Caspian terns and gulls during 26 February through 15 March included incidental disturbance caused by researchers conducting site visits, installing and monitoring passive dissuasion materials, and intentional (but opportunistic) hazing of prospecting birds when observers walked across the island (hereafter referred to as "walk-throughs"). Beginning on 16 March, regular active human hazing was initiated in response to the first observations of gulls landing on the island. All hazing sessions were recorded to document effort and the response of hazed birds. On 18 March, we initiated the use of a green laser (Agrilaser®; LEM 50) for hazing at dusk to prohibit gulls from remaining on Goose Island overnight. On 4 April, hazing session 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 Caspian terns and gulls. For example, on occasions when Caspian terns showed a greater interest in nesting on Goose Island (i.e. when copulation, nest-scraping, or egg-laying were observed), daytime monitoring and hazing were temporarily increased until nesting behaviors by terns were abated.

During each walk-through, any gull or Canada goose nest observed was recorded and nests that did not contain eggs were destroyed by the observer. The BMPs, which described the procedures for colony monitoring, active hazing, Caspian tern egg collection, and communication/reporting (see *Appendix A*), were followed closely throughout the nesting season. In addition to active human hazing, a peregrine falcon kite was flown by researchers during most hazing sessions from 26 March to 11 April as a supplement to other active dissuasion methods. Similarly, researchers carried and waved 10-foot-long PVC poles with polyethylene flagging during some walk-through hazing sessions.

Beginning on 18 April, due to widespread initiation of gull nests, walk-through hazing and other efforts to curtail gull nesting on Goose Island were discontinued and the primary techniques used to actively dissuade prospecting 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.

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 on 21 May. Locations where Forster's tern nesting affected active hazing efforts for Caspian terns included the South Spit on Goose Island, plus Northwest Rocks, East Rocks, and Northeast Rocks near Goose Island (see *Map 4*). Although hazing of Caspian terns after 21 May was at times curtailed at these sites, Caspian terns were rarely observed in areas occupied by Forster's terns.

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 4 July. On 6 July, active hazing of Caspian terns was reduced to three hazing stints (morning, midday, evening) lasting 3 hrs, 2 hrs, and 2 hrs, respectively. Active hazing sessions were reduced to twice a day on 16 July, with stints lasting about 2 hrs. Hazing sessions were again reduced on July 23 to once per day, lasting about 1.5 hrs. Active hazing of Caspian terns was terminated on 29 July, and the final survey of Goose Island for the season occurred on 8 August.

A limited number of Caspian tern eggs were removed from nests (under permit) on Goose Island in 2016. The collection of Caspian tern eggs laid on Goose Island was intended to enhance the prospects for successfully dissuading Caspian terns from initiating additional nests and forming a breeding colony.

Finally, to monitor water levels at Potholes Reservoir and assess how fluctuations in water level influences seasonal availability of suitable nesting habitat for Caspian terns along the shoreline of Goose Island, a vertical meter stick was installed in the reservoir near the Goose Island camp on 11 April and was monitored daily.

Crescent Island

Active nest dissuasion was conducted to deter nesting attempts by Caspian terns and gulls on Crescent Island by (1) forays into the colony by researchers, (2) waving PVC poles with polyethylene flagging attached, (3) use of a green laser during low light conditions, and (4) flying a peregrine falcon kite on the island, collectively referred to as "active hazing"; see *Map 5*). As on Goose Island, and for the reasons described above, active hazing targeted both prospecting Caspian terns and prospecting ring-billed and California gulls to prevent or delay the onset of egg-laying by these colonial waterbird species. Methods of active hazing were adaptively modified over the course of the breeding season in response to reactions from the birds, and to avoid egg take of non-target species (e.g., Canada geese; see *Appendix A*).

Because camping is not permitted on Crescent Island, a houseboat was transported to and anchored in the cove just offshore of the island (see *Map 5*) on 4 April. The houseboat allowed overnight stays, and facilitated early morning and late evening sessions of active hazing to dissuade nesting by Caspian terns and gulls. Evening hazing to prevent Caspian terns and gulls from remaining on Crescent Island overnight was considered especially important for deterring, or at least delaying, nest initiation. Using the houseboat researchers could be present at or near Crescent Island nearly continuously from 11 April to 1 June.

From 2-15 March, methods to dissuade prospecting Caspian terns and gulls included incidental disturbance caused by researchers while installing passive dissuasion materials (see *Methods & Analysis: Passive Nest Dissuasion*) and intentional, but opportunistic hazing of prospecting Caspian terns and gulls when observers conducted island walk-throughs.

Beginning on 16 March, observers began daily visits to Crescent Island to monitor and haze birds. While at the colony observers conducted walk-throughs and used a PVC pole with flagging attached to (1) haze rafting gulls to move further from the island, (2) dissuade hovering gulls from landing on the island, and/or (3) flush gulls soon after they did land on the island.

During each walk-through, any gull or goose nests observed were recorded and nests that did not contain eggs were destroyed by the observer. 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 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).

Beginning on 11 April, with researchers stationed on the houseboat near Crescent Island, daily monitoring and hazing was initiated that consisted of a hazing session at dawn and another at dusk, with additional day-time hazing sessions done as needed (i.e., when birds were flying or rafting near the island). In addition to walk-throughs and waving a PVC pole, some active dissuasion sessions included the use of a green laser from island locations during low-light conditions. A peregrine falcon kite was used for a brief period when hovering gulls were more prevalent around Crescent Island (15-21 April), and intermittently after that. Beginning on 2

May, in response to the reduction in frequency and intensity of gull activity near the island, active hazing efforts were reduced at Crescent Island to a once daily walk-through of the island and brief additional hazing when needed. These brief stints usually lasted 10-25 minutes, but actual active hazing effort from this date onward was often reported as 0 minutes due to a lack of gulls and Caspian terns at the island.

With authorization from the action agencies, researchers discontinued overnight stays at Crescent Island on 1 June. From 1-12 June observers visited the island twice a day to monitor for the presence of terns and gulls and to inspect the beaver fence for damage. Visits to Crescent Island were further reduced to once per day on 13 June and to every two days on 22 July. The last survey of Crescent Island during the 2016 nesting season was conducted on 27 July.

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 both Goose Island and Crescent Island, and was carried out in conjunction with management tasks described above. Colony-level monitoring was to evaluate the efficacy of nest dissuasion efforts on Goose and Crescent islands in preventing Caspian terns from nesting at these two colony sites (see *below* for more details).

System-level monitoring consisted of periodic, carefully-timed aerial surveys in the Columbia Plateau region 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 by a mobile field crew (separate from the island-based field crews mentioned *above*) at all Caspian tern breeding colonies that were identified 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). System-level monitoring was completed with cost-sharing from the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee (PRCC).

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 2016. These data were used to evaluate changes in size and distribution of nesting Caspian terns in the Columbia Plateau region associated with management.

Finally, to support on-the-ground efforts conducted by another contractor at the Corps-constructed tern islands at Don Edwards NWR in southern San Francisco Bay, we coordinated and scheduled an aerial photography survey of the islands used by nesting Caspian terns so that an accurate measure of peak colony size and colony area can be estimated.

Colony-level Monitoring

Monitoring of Caspian tern nesting attempts at Goose and Crescent islands was necessary to determine the success of passive and active dissuasion of nesting Caspian terns during the 2016 breeding season. With the installation of passive nest dissuasion materials at both sites in addition to newly planted willows on Crescent Island covering most of the potential Caspian tern nesting habitat on both islands, it is anticipated that some Caspian terns might attempt to roost or nest in areas just outside, or perhaps within, the nest dissuasion areas (as was the case on Goose Island in 2015; see Collis et al. 2015). We evaluated the effectiveness of various passive nest dissuasion methods used to prevent tern and gull nesting on Goose and Crescent islands (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 and mammalian species in 2016, including willow growth (e.g., new shoots, buds, leaves), water stress, herbivory, insect damage, and encroachment by other vegetation. Willow observations were largely qualitative, and are summarized *below*.

We continuously (7 days/week) monitored the activities of Caspian terns and other colonial waterbirds (i.e., gulls) on Goose and Crescent islands from mid-March through July using two field crew members stationed on or near each island. Monitoring of nesting and roosting terns and gulls was conducted using ground counts of adults made by observers in a blind located near the edge of the former colony area, by boat, and on foot in areas with potential for minimal disturbance to actively nesting gulls, geese, or other protected migratory birds. Additional counts were made while conducting active hazing efforts to assess action effectiveness of passive and active nest dissuasion measures. Seasonal attendance by adult terns and gulls at each island 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). These ground counts were made by researchers in observation blinds, in boats, or from vantages sufficiently removed as to not disturb actively nesting birds. Data collection methodologies used as part of this study followed established protocols such that the data collected in 2016 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; BRNW 2015). 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 taken of Goose and Crescent islands on 20 May and those georeferenced images were 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 identified in the IAPMP and three 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 13 colony sites (hereafter referred to as "prospective 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 a small unnamed island in Lenore Lake (*Map 1*). Prospective 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 (north Potholes Reservoir), and Goose Island in Banks Lake (Adkins et al. 2014; *Map 1*). Other prospective colony sites that may 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 Columbia River (*Map 1*).

Periodic monitoring was conducted at these prospective colony sites, as well as at newly identified sites, to help evaluate the consequences of management actions implemented on Goose and Crescent islands in 2016. We assessed whether reductions in colony size associated with the nest dissuasion actions at Goose and Crescent islands were off-set by commensurate increases in Caspian tern colony size at prospective and other new sites within the Columbia Plateau region, where Caspian terns may continue to consume significant numbers of ESA-listed salmonids.

Aerial photography surveys – Three aerial surveys were conducted from a fixed-wing aircraft (Cessna 205; Gold Aero Flying Service) to determine the distribution of Caspian terns (both nesting and loafing) 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 Columbia and lower Snake rivers that are within tern foraging range (~90 km) of the FCRPS (*Map 6*). 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, each lasting two days, were conducted during the 2016 nesting season on the following schedule: (1) on 26-27 April, early in the incubation period, to check for the presence of newly formed colonies; (2) on 16-17 May, late in the incubation period, to determine numbers of breeding pairs, colony area, and habitat types occupied by nesting Caspian terns, as well as identify late-forming colonies; and (3) on 27-28 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 were expected to be present. When Caspian terns were observed on the ground on substrate that was potentially 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 digital image inspection revealed a potential Caspian tern breeding colony, ground- or boat-based surveys were conducted to assess the breeding status of Caspian terns using the site.

Geo-referenced high-resolution, vertical aerial photography (2-cm cell size at ground level) was taken by Geoterra (Portland, OR) at Goose and Crescent islands, as well as at alternative colony sites where aerial surveys or field visits indicated that 30 or more breeding pairs of Caspian terns were nesting. The aerial photography survey was flown on 20 May and the alternative sites that were photographed included the Blalock islands complex (Anvil, Long, Middle, Southern, Sand, Rock, and Straight Six islands) in the Columbia River (*Map 1*). The geo-referenced images were analyzed 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 estimate nest density (number of active nests/m^2) of Caspian terns at each site.

Finally, we supported contractors with the United States Geological Survey (USGS), Dixon Field Station in their efforts to accurately estimate the peak colony size and colony area at the Corps-constructed tern islands located in former salt ponds SF2 and A16 of Don Edwards National Wildlife Refuge (DENWR) in southern San Francisco Bay. We coordinated the aerial survey timing with the contractor conducting ground monitoring of the tern colonies and scheduled an aerial photography survey with Geoterra to obtain vertical aerial imagery on 27 May. We georeferenced the images to a ground sample distance (GSD) of 2 cm. The georeferenced imagery was provided to the USGS, Dixon Field Station staff and the USACE, Walla Walla District COR on 6 June.

Land-based surveys – The frequency of ground-based 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 present and the type of bird activity observed at the site. Sizable Caspian tern colonies (> 30 breeding pairs) were visited more often (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). Smaller colonies (< 30 breeding pairs) were visited less frequently (monthly) to determine nesting status, change in colony size, peak colony size, and nesting success, if applicable. If Caspian tern nesting occurred at the site, we estimated the number of breeding pairs and colony productivity (average number of young raised to fledging per breeding pair) using previously described methods (see *Methods & Analysis: Colony-level Monitoring*). Land-based surveys of prospective and new Caspian tern colony sites were conducted with cost sharing from GPUD/PRCC.

INTER-COLONY MOVEMENTS

To help assess the extent to which Caspian tern management actions implemented as part of the IAPMP (USACE 2014) and the Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006) were successful in relocating Caspian terns to sites outside the Columbia River basin, we resighted Caspian terns previously marked with field-readable leg bands during visits to Goose Island, the Blalock Islands, and other nesting and roosting sites used by Caspian terns in the Columbia Plateau region during the 2016 nesting season. Using a comprehensive database containing banding and resighting records for Caspian terns dating back to 2005, we

assessed (a) colony connectivity among sites in the Columbia Plateau region, (b) emigration of banded individuals from sites in the Columbia Plateau region to sites outside the region, and (c) immigration of banded individuals from sites outside the Columbia Plateau region to sites in the region. Caspian tern band resighting efforts in the Columbia Plateau region were conducted with cost sharing from GPUD/PRCC. Furthermore, resighting efforts performed outside the Columbia Plateau region were conducted as part of a related study that was funded by the Bonneville Power Administration.

During 2005-2015, Caspian terns were banded with a federal numbered metal leg-band and two colored plastic leg-bands on one leg, and a colored plastic leg-band engraved with a unique alphanumeric code on the other leg. This compliment of leg bands allowed us to individually identify each banded tern from a distance, such that the banding location (colony) and banding year were known. Banding was conducted at colonies both within the Columbia River basin and outside the basin. In 2016, these previously-banded Caspian terns were resighted at various colony and roost sites in the Columbia Plateau region using binoculars and spotting scopes. Band resighting was conducted up to seven days per week at Goose Island and nearby islets, up to five days/week at the Blalock Islands, and less often at smaller breeding colonies and roosting sites throughout the region. As part of related but separate studies, resighting of previously-banded Caspian terns was also conducted at various sites in the larger Pacific Flyway region during 2016 to evaluate movements of Caspian terns to and from the Columbia Plateau.

Summaries of band resighting data collected at breeding colonies and loafing sites in the Columbia Plateau region during the 2016 field season are presented in this report, along with information on where those individuals were originally banded. The summaries represent dispersal or site fidelity across years, between the time when those terns were banded and when they were observed again in 2016. This report also includes summaries of banded Caspian terns observed at two sites (the Potholes Reservoir area and the Blalock Islands) in 2015, where relatively large numbers of terns were observed, and locations where those terns were observed again in 2016. Those summaries provide information on inter-annual dispersal from, or fidelity to, those two sites.

Multi-state analysis (Hestbeck et al. 1991, Brownie et al. 1993) in Program MARK (White and Burnham 1999) was used to estimate inter-regional movement probabilities of Caspian terns banded as adults during 2005-2016. Movement probabilities were estimated between three regions: (1) the Columbia Plateau region (including the Blalock Islands, Goose Island, and smaller colonies and loafing sites), (2) the Columbia River estuary (including East Sand Island, Rice Island, and loafing sites), and (3) Corps-constructed alternative colony sites (all the Corps-constructed tern islands in southern Oregon and northeastern California). *A priori* models were constructed to evaluate effects of transitions from one region to another and effects of year on movement probabilities. In addition, the following variables were included as covariates to evaluate effects on movement probabilities: number of breeding pairs at source and receiving regions, nesting success (average number of young raised per breeding pair), distance between regions, management implementation (nest dissuasion: yes or no), and drought (yes or no). Models that incorporate location and year effects on resighting probabilities were included in

this analysis, which allowed us to calculate unbiased probabilities of inter-regional movement rates despite resighting efforts that varied among locations and years. Akaike's Information Criterion (AIC) adjusted for small samples (AICc) was used to select the best model (Burnham and Anderson 2002) for estimating inter-regional movements. Based on movement probabilities between 2015 and 2016 from the best model, and the numbers of Caspian terns present at each colony in 2015, numbers of terns that moved between colonies from 2015 to 2016 were estimated.

SMOLT PREDATION RATES

The goal of the IAPMP is to reduce Caspian tern predation rates on ESA-listed salmonid populations (hereafter ESUs/DPSs) to less than 2% per tern colony per year in the Columbia Plateau region (USACE 2014). Presented here are predicted predation rates for Caspian terns nesting at Goose Island, Crescent Island, and the Blalock Islands during 2016. These three colonies were previously identified as posing the greatest risk to the survival of juvenile salmonids out-migrating from the Columbia Plateau region (Lyons et al. 2011a; Lyons et al. 2011b). Estimates of average predation rates from previous years (2007-2015), coupled with information on the size of these Caspian tern colonies (number of breeding pairs) in 2016, were used to predict predation rates by Caspian terns nesting at these colonies in 2016.

A paucity of historical predation rate data from the Caspian tern colonies on (1) Twinning Island (Banks Lake), (2) the unnamed island in Lenore Lake, and (3) the new colony in northeastern Potholes Reservoir prevented an analysis of predicted predation rates at those sites in 2016. Salmonid PIT tags, however, were recovered from these colonies following the 2016 nesting season and thus actual predation rates (as opposed to predicted rates based on measures of colony size alone) are available to regional managers via a draft report submitted to GPUD/PRCC (Roby et al. 2017).

Detailed methods regarding the calculation of predicted predation rates for Caspian terns nesting on Goose, Crescent, and Blalock islands are as follows:

Actual Predation Rates

Estimates of predation rates were based on the methods of Evans et al. (2012) and Hostetter et al. (2015). In brief, the number of PIT-tagged smolts available to Caspian terns were based on the number interrogated (detected alive) passing Lower Monumental Dam (Snake River), Rock Island Dam (mid-Columbia River), or McNary Dam (Columbia River), which ever dam was the nearest upstream dam(s) to each colony with adequate PIT tag interrogation capabilities. PIT-tagged smolts were grouped by ESA-listed ESU/DPS, based on the species, run-type, rearing-type, and river of origin of each PIT-tagged fish (see Evans et al. 2012).

The number of available PIT-tagged smolts consumed by Caspian terns nesting at each of three colonies was modeled dependently as a three-stage probabilistic process: (1) a PIT-tagged smolt was consumed by a Caspian tern (predation probability), (2) the PIT tag was egested on-colony (deposition probability), and (3) the PIT tag was detected by researchers after the

nesting season (detection probability). These events were modeled for each year (2007-2015), each Caspian tern colony (Goose, Crescent, Blalocks), and each ESA-listed salmonid ESU/DPS (Snake River steelhead, Snake River spring/summer Chinook salmon, Snake River fall Chinook salmon, Snake River sockeye salmon, Upper Columbia River steelhead, Upper Columbia River spring Chinook salmon) for which data were available.

We let θ_w represent the probability that a tagged fish is consumed by a Caspian tern in week *w*, ϕ represent the probability that a consumed fish tag is deposited back on the tern's breeding colony, and ψ_w represent the probability that a tag deposited on the tern colony in week *w* remains on the colony and is detected. The number of PIT tags recovered on a Caspian tern colony from a given week can therefore be modeled as a binomial process,

$$k_w \sim Binomial(n_w, \theta_w * \phi * \psi_w),$$

where k_w is the number of smolt PIT tags recovered from the number available during each week (n_w). Detection probability (ψ_w) was estimated directly using surveys of PIT tags known to have been deposited on-colony at specific times (i.e., before, during, and after the breeding season; see Evans et al. 2012). We modeled the change in detection probability over time as a logistic function of week,

$$logit(\psi_w) = \alpha + \beta * w,$$

where α is a logit scale regression intercept and β is the logit-scale estimate of change in detection probability for each week. Based on previous investigations of the tag deposition probability for nesting Caspian terns (BRNW 2015; Hostetter et al. 2015*),* we employed an informative prior (beta [16.20, 6.55]) for ϕ.

We ascribed a hyperdistribution for predation probabilities (θ),

$$logit(\theta_w) \sim Normal\left(\mu_\theta, \tau_\theta^2\right)$$

This enables the sharing of information among weeks, while also allowing predation probabilities (θ_w) among weeks to be unique. Noninformative priors are used in the specification of α, β, μ_θ, and τ_θ^2; $\alpha \sim Normal(0, 0.01)$, β$\sim Normal(0, 0.01)$, *logit*$^{-1}(\mu_\theta) \sim Uniform(0,1)$, and $\tau_\theta^2 \sim Uniform(0,20)$. Note that the Normal distribution is specified here by the mean and precision parameters.

Annual consumption totals for PIT-tagged smolts were defined to be the sum of the estimated number of PIT-tagged smolts consumed during each week:

$$Annual\ Consumption = \sum_w (\theta_w * n_w)$$

This estimate of consumption of PIT-tagged smolts was then divided by the total number of PIT-tagged smolts available during that migration year (based on interrogations of PIT-tagged smolts at dams) to estimate the annual predation probability:

$$Annual\ Predation\ Rate = {\sum_w (\theta_w * n_w)}\Big/{\sum_w (n_w)}$$

All predation probability models were implemented using the software JAGS (Plummer 2003) accessed through R version 3.1.3 (R Core Team 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, as well as 2.5 and 97.5 percentiles, which represent 95% Credibility Intervals (95 CI). Finally, to control for imprecise results that might arise from small sample sizes of interrogated PIT-tagged smolts in any given year, estimates of predation were only calculated for ESUs/DPSs when ≥ 500 PIT-tagged smolts were annually interrogated passing an upstream dam (Evans et al. 2012). Predation probabilities ≤ 0.1% are presented without credibility intervals because the upper bounds of the credibility intervals are not greater than 0.1%.

Colony Size

Methods to estimate the size (number of breeding pairs) of Caspian tern colonies for use in predation rate analyses were the same as those described *above* (see *Methods & Analysis: Action Effectiveness Monitoring*).

Although Caspian terns were unsuccessful in nesting on Goose Island in 2016, five breeding pairs laid eggs on the island, all of which were either collected under permit or depredated by a gull soon after laying. Adult Caspian terns were also routinely observed loafing on Goose Island prior to and following hazing, with an average daily count of 6 adults (equivalent to 3 breeding pairs; range = 1 to 17 adults) observed from 10 April to 28 May, 2016. Given the number of nesting attempts and the daily presence of adult terns on Goose Island, it seems likely that predation rates were greater than zero. Consequently, for estimating predicted predation rates in 2016, Caspian tern colony size on Goose Island was between 3 and 5 breeding pairs in 2016. There were no (zero) Caspian tern nests initiated and no Caspian tern adults observed on Crescent Island during the smolt out-migration period in 2016, so for this colony, zero breeding pairs was the appropriate measure of colony size.

Per Capita Predation Rates

The annual per capita predation probability for each Caspian tern colony and each salmonid ESU/DPS in year, *y*, was calculated by dividing the annual predation probability by the peak colony size from that year:

$$Annual\ Per\ Capita\ Predation\ Rate_y = {\sum_w (\theta_{wy} * n_{wy}) / \sum_w (n_{wy})}\Big/{C_y}$$

where C_y is the peak colony size in year, *y*, as previously defined.

We calculated a per capita predation probability for each colony and each salmonid ESU/DPS in 2016 using the arithmetic average of the annual per capita predation rates in 2007-2015. We built 95% CIs by averaging random samples of per capita predation rates generated from the posterior distributions calculated previously.

Predicted Predation Rates

To estimate predation probabilities in 2016 based on a measure of colony size alone, we used a Markov Chain Monte Carlo process to generate samples from a posterior predictive distribution based on random draws from the posterior distribution of the average annual per capita predation rate. Predicted predation rate estimates for each salmonid ESU/DPS were then generated for (1) the Goose, Crescent, and Blalock islands Caspian tern colonies in 2016 and for (2) various hypothetical Caspian tern colony sizes ranging from 0 to 500 terns at each of these three colony sites.

Key assumptions and caveats that should be considered when using only data on Caspian tern colony size to predict ESU/DPS-specific predation rates include:

- Per capita predation rates do not assume or otherwise rely on a mathematical relationship between annual measures of colony size and predation rates.

- The statistical model used to generate per capita predation rates assumes independence among colony size, smolt abundance, and predation rate.

- Statistical inference of the model should be limited to those colony sizes and smolt abundances observed during 2007-2015; conditions outside of these limits may influence predation probabilities to an unknown degree.

- The prior distribution associated with on-colony tag deposition rates has a large impact on the precision of predation rate credibility intervals. Any unidentified variation in past tag deposition rates or significant deviation in future tag deposition rates may bias predation rate estimates and credibility bounds to an unknown degree.

- The accuracy of Caspian tern colony counts depended on the intensity and frequency of colony monitoring in each year, levels that varied by colony location and year. Similarly, there is no measure of uncertainty associated with estimates of colony size, but presumably some error is associated with these estimates.

- Smolt condition, run-timing, smolt abundance, river discharge, and turbidity have all been linked to variation in predation rates (Hostetter et al. 2012). Thus, changes to

biotic and abiotic conditions in the Snake and Columbia rivers during 2016 may influence Caspian tern predation rates on salmonid smolts.

- Estimates of predation rates presented here are colony-specific; extrapolation to other geographic locations (e.g., Lenore Lake, northeastern Potholes Reservoir, and Twinning Island in Banks Lake) is beyond the scope of the analysis.

RESULTS & DISCUSSION

PASSIVE NEST DISSUASION

Goose Island

In 2016, the installed passive dissuasion was again successful in deterring Caspian terns from establishing a nesting colony on Goose Island with just 6 tern eggs discovered in five tern nests (*Figure 1*). 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 (see *Map 2*). No Caspian terns were observed landing within passive dissuasion in 2016, unlike 2015 when two nests were established under rope and flagging (Collis et al. 2015).

These results in addition to findings from 2014 and 2015, 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 passive nest dissuasion has little deterrent effect on non-target species (i.e. California gulls, ring-billed gulls, and Canada geese) on Goose Island, which nested in areas covered with passive nest dissuasion. Like in 2014 and 2015, gulls nested within both single and double layers of passive nest dissuasion indiscriminately (see *Map 2* and *Map 7*). Finally, there was little evidence that alternative dissuasion methods tested in 2016 (i.e., Mylar flagging, propane canons and owl effigies) were effective in deterring gulls from nesting on Goose Island. Once deployed, gulls were immediately observed below the reflective Mylar flagging, and actively nesting in areas with Mylar flagging occurred within 24 hours of deployment. Additionally, within the first few weeks of deployment, the Mylar flagging became brittle and started fraying, in contrast the barricade tape deployed across the Island which showed little wear after several months of deployment. Like 2015, the two owl effigies that were used on East Rocks and Northeast Rocks as deterrents were not effective dissuasion tools as both terns and gulls were observed landing near them shortly after deployment.

The arrival of gulls to Goose Island appeared to be delayed using propane canons. During 1 – 15 March, when two propane cannons were in operation, no gulls were observed on Goose Island. However, after the canons were temporarily turned off on 15 March, ca. 3,800 gulls were observed on the island the following day. Although one or both canons were activated and deactivated several times during the overall period of use (25 Feb – 12 April), propane canons were completely ineffective at deterring gull activity on Goose Island after 18 March. During the

second period that the cannons were activated from 16 – 18 March, the gull response to each cannon blast rapidly fell from complete island flushes to flushes of fewer than 5 individuals closest to the canon. Once gull nests with eggs were identified on Goose Island, the propane canons were immediately deactivated. However, as this occurred before Caspian terns were observed roosting on Goose Island, the effect of the canons on Caspian tern nest initiation could not be determined.

Inspections of passive nest dissuasion materials deployed at Goose Island found virtually no wear of materials deployed in 2014 or 2015. However, we anticipate that some of the twisted polypropylene rope first deployed in 2014 may need replaced following the 2017 breeding season if further degradation occurs making rope too brittle to insert new flagging. While more than 85% of the upland habitat was covered by passive dissuasion, additional material should be added to habitat previously deemed not suitable for tern nesting along the northwest slope where three Caspian tern eggs were laid in 2016 (see *Results & Discussion: Active Nest Dissuasion*). If permitted, supplemental dissuasion material could be added below the high-water line prior to seasonal inundation due to spring high-water in Potholes Reservoir so as to deter prospecting by terns as reservoir levels recede later during summer.

In summary, Caspian tern use of Goose Island was again strongly influenced by placement of passive nest dissuasion materials in 2016. 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*).

Crescent Island

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 in 2016. As was the case the previous year, 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 2016. While passive nest dissuasion provided little deterrent to nesting by Canada geese in 2016, the absence of prospecting gulls 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 (see *Results & Discussion: Active Nest Dissuasion*).

The absence of Caspian terns on Crescent Island, a stable colony for nearly three decades (Adkins et al. 2014), for two 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 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.

In summary, Caspian tern use of Crescent Island was strongly influenced by placement of passive nest dissuasion materials and native vegetation in 2016. At no time during the 2016 breeding season were Caspian terns observed attempting to land on or near Crescent Island. As was the case in 2015, 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) the knit privacy screen fences used over much of Crescent Island were a more effective deterrent for nesting Caspian terns than the ropes, stakes, and flagging that were used on Goose Island; (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; (3) suitable alternative nesting sites for Caspian terns are closer to Crescent Island (i.e., Blalock islands) than Goose Island; and (4) newly planted native vegetation on Crescent Island considerably altered nesting habitat making it unsuitable for both terns and gulls.

Willow Plantings and Placement of Russian Olive Cuttings – No Caspian terns landed on Crescent Island in 2016, 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 (*Map 8*). Similarly, gulls landed on Crescent Island on only 6 days during April and may have avoided the areas where willow plantings and Russian olive cuttings were placed. 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 quite dense in some planting areas by mid-May and likely limited availability of potential gull nesting sites on Crescent Island over the remainder of the breeding season (*Map 9*).

Based on mostly qualitative assessments made during the field season (March-July), survival of willow stems planted on Crescent Island in January-February of 2016 was ca. 90%. Lateral stem growth was estimated to have occurred on 85% of planted willow whips, and leaves were estimated to have grown on 90% of willow stems. While growth of stems and presence of leaves on planted willow cuttings were high, water stress was estimated to have affected 5 – 8% of willow whips and was mostly a factor on the former Caspian tern colony area. Additional minor occurrences of water stress were observed in the north, southwest and landing zone areas of the island.

The exclusion fence installed around planting areas appeared to limit beaver damage to the newly planted willows. Evidence of beaver incursions into the willow planting area were detected on two separate occasions resulting in only 18 documented willow stems being eaten. The beaver fence in the cove area of the island had to be repaired or reinforced on several occasions. In March, T-posts were installed to replace the bamboo poles on the water's edge because the bamboo supports were not structurally sufficient to secure the fence across heavy cobble substrate. On six instances throughout the season the fence in the cove area had to be repaired or have supplemental fencing material added to the bottom of the original fence to keep beavers from getting underneath.

Observers reported very few cases of insect herbivory to newly planted willows. On two occasions during May and June, small numbers of willows (12 and 10, respectively) were found with insect herbivory damage to their leaves. In June, blistering that may have been related to disease was discovered on the leaves of 2 willows.

Secondary vegetation coverage began to grow up noticeably beginning at the end of April, with average heights of 10 cm over much of the willow planting areas. By the end of July, non-willow vegetation was covering 85 – 95% of most willow planting areas, with average heights ranging from 75 – 197 cm, depending on the area. Secondary vegetation was less dense in the North and Southwest dissuasion zones, and it was almost non-existent in the former Caspian tern colony area of the island. Despite the growth of secondary vegetation, planted willow cuttings grew to similar or greater heights and were not overtopped by competitive vegetation in the planting areas.

ACTIVE NEST DISSUASION

Goose Island

Active and passive nest dissuasion efforts for Caspian terns on Goose Island were successful in preventing Caspian tern nesting successfully on Goose Island or the surrounding small rocky islets. Five nests were initiated by Caspian terns on Goose Island or the adjacent Northwest Rocks, but none produced young. Of the 6 eggs that were laid by Caspian terns, four were collected under permit issued by the USFWS for this management effort.

In 2016, gull responses to human hazing were like the responses observed in 2014 and 2015. However, initial gull presence on the island appeared to be delayed using propane canons installed by BOR personnel prior to the pre-work site visit conducted on 26 February. During regular site visits during 1 – 15 March, when two propane cannons were in operation, no gulls were observed on Goose Island. However, after the canons were temporarily turned off on 15 March, field crew arrived to find an estimated 3800 gulls on the island on 16 March. Although 1-2 canons were activated and deactivated several times during the overall period of use (26 Feb – 12 April), propane canons were completely ineffective at deterring gull presence and nesting on Goose island by about 18 March. During the second period that the cannons were active from 16 to 18 March, the gull response to each cannon blast fell from complete island flushes to flushes of fewer than five individual gulls with each blast. Thus, nearly complete habituation to the cannons occurred rapidly once gulls presence on the island was initially established.

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 18 March, human walk thoughts during daylight hours were largely ineffective, temporarily flushing gulls that would circle and re-land near their original position within 2-3 minutes when the observer had moved away to continue the walk-through hazing. As observed in the two previous years,

island walk-throughs were more effective in displacing gulls when conducted during the evening. 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). Increasing the daily human hazing intensity sessions to three 3-hour sessions beginning on 4 April did not reduce the numbers of gulls present on the island or delay the onset of gull nesting at Goose Island. As in 2014 and 2015, gulls habituated to human presence quickly, even when the frequency and intensity of active hazing was increased. The first gull egg discovered on Goose Island during 2016 was found on 9 April on the main portion of Goose Island, the same date as 2014 but earlier than the first gull egg discovered in 2015 (14 April; Collis et al. 2015). By 18 April 2016, the same date as in 2015, gull nests containing one or more eggs were so numerous and widely distributed across Goose Island that field personnel were unable to conduct island walk-throughs any longer, for reasons described above (also see *Appendix A*). Therefore, all attempts to haze gulls were discontinued. No documented loss of gull eggs due to hazing occurred during the 2016 breeding season.

After gulls established a regular presence on Goose Island, and prior to wide-spread egg-laying by gulls (26 March – 11 April), we used a peregrine falcon kite during most active hazing sessions on Goose Island. The technique was effective in flushing all gulls from the Island, but with diminished effectiveness over the 2 weeks that the kite was used. During the first week of use, gulls would typically flush to the water about 200-300 meters away from the island, but they were returning to the island within 15 minutes of each hazing session by week's end. During the second week, the gull flushing response to the falcon kite was greater than walk-throughs alone, but gulls only flushed from a 30-meter radius of the kite and only gulls at the island edge were flushed to the water. Like the previous year, once gulls were present on the island in large numbers they began habituating to any combination of hazing techniques within a few days. This was reflected in both the length of time it took for gulls to re-land on the island and the number of gulls that re-landed after each hazing event. Use of the peregrine falcon kite was discontinued on 11 April. Although gulls eventually habituated to the falcon kite, use of the kite proved to be more effective than walk-throughs alone, particularly during initial use at the early stages of the gull breeding season.

During the 20 weeks when active hazing efforts were quantified, average daily effort ranged from 40 minutes to 588 minutes, and the cumulative weekly hazing duration ranged from 40 minutes to 3,154 minutes (*Table 1*). The average number of Caspian terns counted each week, by location on the island, indicated relatively low use of all areas through the first week of June. During this period, a new Caspian tern colony was active in the Northeast portion of Potholes Reservoir, and most locations on Goose Island had no terns counted or hazed in most weeks. Prior to the week of June 6, the East Rocks had the highest weekly average number (15) of terns counted. Immediately following the failure of the Northeast Potholes colony on 5 June, use of Goose Island by Caspian terns increased substantially. The Southwest Main location had the highest use during the remainder of the breeding season (6 June – 31 July) with average weekly counts from 28 to 89 Caspian terns. Additional locations that had increased and regular use were the Northwest Main, Southeast Main, South Spit, West Main, and Northwest Rocks (see *Map 4*; *Table 1*).

During 11 April through 22 May, water levels increased 2 feet, submerging additional shoreline and reducing overall area available for nesting by Caspian terns and gulls at Goose Island. This pattern was reversed during 23 May through 31 July when the reservoir water level measured at Goose Island decreased by about 7.5 feet, exposing large areas of open shoreline habitat around Goose Island and the nearby rocky islets. Caspian terns, many presumed to be failed breeders from the Northeast Potholes colony began utilizing this open habitat, especially on the southeast and southwest shorelines of the main island (see *Map 4*; *Table 1*). On 20 June, as declining reservoir water levels uncovered new open habitat and numbers of prospecting Caspian terns increased in these areas, researchers initiated walk-throughs along the island's southern shoreline to reduce Caspian tern use of that area and to destroy nest scrapes that were being initiated by birds prospecting for nest sites.

Despite active and passive nest dissuasion efforts on Goose Island in 2016, from 24 April to 21 June six Caspian tern eggs were laid during five Caspian tern nest attempts (*Figure 1*). These counts are low relative to the numbers of eggs laid and nests initiated by Caspian terns in 2015. All Caspian tern nesting attempts in 2016 were near the shoreline, three on Northwest Main, one on Southwest Main, and one on Northwest Rocks (see *Map 4*; *Table 1*). Unlike 2015, no Caspian tern nests were initiated under passive dissuasion materials in 2016. Of the six Caspian tern eggs that were confirmed in tern nests on Goose Island, four were collected under permit and two were presumed to be depredated by gulls (*Figure 1*; *Table 2*). All six Caspian tern eggs were collected or depredated by gulls within several days of being laid, thus no Caspian tern chicks were hatched on Goose Island in 2016.

In accordance with the federal depredation permit, eggs collected from Caspian tern nests on Goose Island were offered to R.C. Faucett, Ornithology Collection Manager at the Burke Museum, University of Washington. The eggs will be delivered or shipped to the Burke Museum if they are accepted for deposit to the collection.

In summary, hazing efforts were successful in preventing the formation of a Caspian tern colony on or near Goose Island in 2016. To achieve this objective, however, nearly continuous monitoring and hazing efforts were conducted during much of the Caspian tern breeding season (April – July). Six Caspian tern eggs were laid on or near Goose Island in 2016 but no young were produced at the site, a first at this site since initiation of management in 2014. Restrictions on disturbance of nesting gulls and Canada geese continued to limit the efficacy of active nest dissuasion techniques employed at Goose Island in 2016, but in a limited way due to a significant reduction in Caspian tern presence at the site during the pre-breeding and nest initiation period. It is important to note that the successful prevention of Caspian tern colony formation on Goose Island was almost certainly facilitated by the formation of a new colony in northeastern Potholes Reservoir, which likely served as a release valve for many terns that would otherwise have continued to prospect for nest sites on Goose Island and nearby islets.

In 2016, it became more evident that preventing gull nest initiation and the formation of a gull colony on Goose Island was unlikely to succeed using authorized nest dissuasion methods.

Additionally, our attempts to delay gull nest initiation did not appear to be successful and resulted in no perceptible advantages for preventing the formation of a Caspian tern breeding colony on Goose Island. The first Caspian tern to land on Goose Island during the 2016 nesting season was on 16 April, nearly a week after gull egg-laying was initiated. Because our active hazing methods were not successful at dissuading gulls from nesting until after terns arrived, there is little likelihood that gull dissuasion contributed to tern dissuasion. Also, 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.

Crescent Island

The passive nest dissuasion techniques deployed on Crescent Island, in concert with active hazing, were successful in preventing breeding colony formation by Caspian terns, ring-billed gulls, and California gulls in 2016. No direct active hazing of Caspian terns was required on Crescent Island, as no Caspian terns were observed on Crescent Island at any time in 2016. Only fly-overs by Caspian terns were reported by field personnel at Crescent Island, with a maximum of 11 fly-overs in one day. Additionally, no breeding behaviors or evidence of nesting attempts by gulls were detected on Crescent Island in 2016.

During 7 weeks when active hazing efforts were conducted on Crescent Island, the average duration of daily effort ranged from 5 minutes to 53 minutes, and total weekly hazing times ranged from 5 min to 373 minutes (*Table 3*). Active hazing efforts were greatly reduced from 2015 due to low numbers of both gulls and Caspian terns that were observed, and because no significant prospecting or breeding behaviors were observed by birds at Crescent Island. Gull behaviors that triggered active hazing at Crescent Island were landing on or hovering over the island. The first gulls to land on Crescent Island in 2016 were five California gulls observed perched on a Colony zone fence row on 5 April (*Map 5*). Numbers of gulls observed on the island peaked during 9 –12 April when 280 – 690 gulls were observed rafting around or flying over the island, and 70 gulls were seen loafing on the interior zone of the island. The sharp, but brief, increase in gulls on Crescent Island followed a drop in numbers observed at the nearby Badger Island gull colony, perhaps indicating temporary displacement of birds from that colony.

In response to the spike in gull numbers, observers initiated camping (on a house boat) at the island and 24-hour a day presence. Intensified and adaptive hazing techniques were successful in preventing gulls from landing on Crescent Island for much of the remainder of the season. Gulls were intensely hazed using human walk-throughs, PVC poles with barricade tape, and a Peregrine falcon kite. Beginning on 14 April, no more than 20 gulls were observed on Crescent Island in any week and gulls that did land were seen loafing on shoreline rocks or briefly touching down and then taking flight again. High daily counts of gulls rafting near or hovering over Crescent Island ranged between 10 and 350 during mid-April to mid-June, but gulls observed and counted made only limited attempts to land on the Island. Thus, limited active hazing was conducted (*Table 3*).

In summary, nesting by Caspian terns on Crescent Island was prevented in 2016 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 (see *Results & Discussion: Passive Nest Dissuasion*), 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.

ACTION EFFECTIVENESS MONITORING

Goose Island

Caspian tern use of Goose Island for roosting and nesting was primarily limited to areas at or near the shoreline where passive nest dissuasion had not been deployed. 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 2016 (see *Results & Discussion: Active Nest Dissuasion*).

Average weekly attendance by Caspian terns on Goose Island and nearby islets was generally lower in 2016 compared to the previous two years (*Figure 2*), likely associated with management activities having been implemented at the site for three consecutive breeding seasons and the expansion of passive nest dissuasion efforts in 2016 to include marginal nesting habitat not covered in passive nest dissuasion materials in 2014-2015. In 2014, the first year of implementation for 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, nest dissuasion activities were successful in preventing Caspian terns from forming a colony on both Goose Island and the surrounding islets. In 2016, only 6 Caspian tern eggs were discovered in five nests on Goose Island, of those four tern eggs were collected under permit and two tern eggs were depredated by gulls soon after laying, compared to 43 tern eggs laid on Goose Island the previous year (*Figure 1*). In 2016, Caspian tern eggs were laid in open or sparsely vegetated habitat just above the island's shoreline where passive dissuasion materials were not installed. As was the case the previous year, most of the Caspian tern eggs that were laid in these shoreline areas were not in visible nest scrapes,

and were apparently abandoned immediately after laying.

In 2016, gulls were first observed on Goose Island on March 16 (*Figure 4*), two to three weeks later than the arrival of gulls to the island the previous year. Gull numbers increased until a camp was installed on the island and regular active hazing during dawn and dusk periods commenced (*Figure 4*). This had an effect in reducing the number of gulls on the island until they became habituated to the active hazing beginning in early April and lasting through the remainder of the breeding season (*Figure 4*). The preliminary index of gull colony size on Goose Island in 2016 was ca. 12,500 individuals, a decrease in the number of individual gulls counted on Goose Island from 2016 (ca. 14,800; Collis et al. 2015), but 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 2014a). These index counts indicate an increase in overall gull colony size during the initial years of Caspian tern management, and support the conclusion that the combined effects of active and passive nest dissuasion efforts during the 2014-2016 nesting seasons had little impact on the establishment and size of the Goose Island gull colony.

In summary, nest dissuasion efforts were successful in preventing Caspian terns from forming a colony on Goose Island and nearby islets in 2016. 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 an extended 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. 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 precluded 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 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*). However, changes in pool elevation in Potholes Reservoir can create habitat that is suitable for tern nesting, as was the case in 2016 when a small, low-lying island in northeastern Potholes Reservoir was created and colonized by Caspian terns (see *below*). This was the first recorded nesting by Caspian terns in northern Potholes Reservoir since 2004, when a small colony existed on Solstice Island, but rising pool elevations

in Potholes Reservoir late in the breeding season flooded the colony causing colony failure and abandonment during that year (Adkins et al. 2014).

Crescent Island

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

In summary, nest dissuasion activities were successful in preventing all nesting by both Caspian terns and gulls on Crescent Island in 2015-2016. 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 2015-2016.

Alternative Sites

Caspian terns were confirmed present at 33 different sites during aerial surveys conducted in the Columbia Plateau region during the 2016 nesting season (see *Map 6* and *Table 4*). Most sites (n=28) were loafing sites, with no signs of nesting activity, and most of those (n=19) were located on the Columbia River (*Table 4*). At all but five sites where Caspian terns were observed during aerial surveys, Caspian terns were on substrates that were not suitable for nesting (e.g., exposed rocks, mud flats, or gravel bars subject to periodic inundation; *Table 4*); subsequent air, land, and boat-based surveys suggested that Caspian terns did not attempt to nest at any of these 28 sites.

During aerial surveys in 2016, Caspian terns were confirmed to be present (i.e., loafing or nesting) at 8 of 13 prospective colony sites (see *Methods and Analysis: Action Effectiveness Monitoring*) and one new site where terns or gulls had not previously nested (small low-lying island in northeastern Potholes Reservoir; see *Map 1* and *Table 4*). The 8 prospective sites where Caspian terns were observed included five sites on the Columbia River (Three Mile Canyon Island, Blalock islands complex, Badger Island, Foundation Island, and Cabin Island) and three sites off the Columbia River (Twinning Island in Banks Lake, Harper Island in Sprague Lake, and the small unnamed island in Lenore Lake). The prospective sites where Caspian terns were not observed during aerial surveys in 2016 included three sites on the Columbia River (Miller Rocks, Island 18, and Island 20) and two sites off the Columbia River (Solstice Island in Potholes Reservoir and Goose Island in Banks Lake).

System-wide action effectiveness monitoring confirmed that Caspian terns attempted to nest at four historical colony sites and one new site in 2016. The historical sites included the Blalock Islands on the Columbia River, Twinning Island in Banks Lake, Harper Island in Sprague Lake, and an unnamed island in Lenore Lake. In 2016, an incipient Caspian tern colony became established on a small, low-lying island in northeastern Potholes Reservoir. As was the case in 2015, the largest Caspian tern colony in the Columbia Plateau region was on the Blalock Islands, representing 72% of the total number of breeding pairs in the region in 2016 (see *below* for further details on each site).

Blalock Islands – 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 during 2005-2014 is characterized by small colonies (average = 56 breeding pairs; range = 6–136 breeding pairs) that moved frequently among islands (six different islands used for nesting during 2005-2014; see *Map 10*), 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 2015).

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 6*). 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 (BRNW 2015). 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 *Map 10* and *Map 11*). 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 *Map 10* and *Map 11*). 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 6*). 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 (BRNW 2015). 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 (*Figure 7*).

Twinning Island – At the southern end of Banks Lake, near Coulee City, WA, two volcanic islands with thin topsoil provide nesting habitat for colonial waterbirds. These two sites, Twinning Island and Goose Island, are owned by the U.S. Bureau of Reclamation and managed in cooperation with the Washington Department of Fish and Wildlife.

From 1997 to 2005, Caspian terns nesting at Banks Lake used Goose Island, north of Twinning Island, where colony size ranged from 10 to 40 breeding pairs (Adkins et al. 2014). In 2005, Caspian terns began nesting on Twinning Island (also called Dry Falls Dam Island), which is in Banks Lake just north of Dry Falls Dam. The colony at Twinning Island grew from less than 10 breeding pairs in 2005 to 67 breeding pairs in 2014 (BRNW 2015). Also, there are large mixed species colonies of California and ring-billed gulls on both Goose and Twinning islands, with over 3,000 breeding individuals counted on each island in 2009 (BRNW 2015). Recently, no young Caspian terns have been fledged from the colony at Twinning Island, likely due to human disturbance (the island is situated directly across from a popular boat launch), mammalian predators (the island is approximately 300 meters from the mainland), and competition and nest predation from gulls that also nest on the island (BRNW 2015).

In 2015, Caspian terns were first seen on Twinning Island on 8 April, when one roosting tern was observed. The first evidence of nesting on Twinning Island was confirmed on 1 May when three attended Caspian tern nests were counted on the colony. Based on counts of oblique aerial photos, a total of 64 breeding pairs of Caspian terns attempted to nest on Twinning Island in 2015, like the estimated colony size in 2014 (67 breeding pairs; *Figure 8*; BRNW 2015). In 2015, the first Caspian tern eggs were observed at the Twinning Island colony on 5 May; however, all Caspian tern nesting attempts at the island failed by 10 June (BRNW 2015). The

primary cause of Caspian tern colony failure in 2015 was thought to be a combination of avian and mammalian nest predation.

In 2016, Caspian terns were first seen on Twinning Island in early May, when 10 adult terns and three attended tern nests were counted (see *Map 12*). Based on counts of oblique aerial photos, a total of 6 breeding pairs of Caspian terns attempted to nest on Twinning Island in 2016, lower than the estimated colony size in 2015 (64 breeding pairs; *Figure 8*; BRNW 2015). In 2016, egg laying by terns on Twinning Island was not confirmed prior to the colony being abandoned by nesting terns in late May. The primary cause of Caspian tern colony failure at Twinning Island is thought to be a combination of nest predation (avian and mammalian) and human disturbance.

Harper Island – 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 (BRNW 2015). The island has also been home to a large California and ring-billed gull colony and a double-crested cormorant colony (BRNW 2015). As was the case at Twinning Island in Banks Lake, no young Caspian terns were apparently fledged from the Harper Island colony during 2012-2014; the cause[s] of colony failure is not known (BRNW 2015).

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*; BRNW 2015). 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 on mid-May, when four adult terns and one attended tern nest were counted (see *Map 13*). 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*; BRNW 2015). 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.

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. This Caspian tern colony was active again in 2015, growing to 16 breeding pairs (see *Map 14*). 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 14*). 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*; BRNW 2015). 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.

Northeastern Potholes Reservoir – In 2016, an incipient Caspian tern breeding colony was discovered on a small low-lying island in northeastern Potholes Reservoir (see *Map 15*). During low water this island becomes land bridged, providing access to the site by mammalian predators (*Map 16*). Terns were first observed at this site in mid-April, when three loafing terns were counted. Caspian terns were first observed breeding at the site in early May, when 53 adult terns and 7 attended tern nests were counted. A total of 144 breeding pairs of Caspian terns attempted to nest at the colony in 2016. Both egg laying and egg hatching (tern chicks) were confirmed at the site prior to the colony being abandoned by terns in early June, presumably due to predation and disturbance caused by a mink on the small island. This is the first documented nesting by terns in the northern end of Potholes Reservoir since 2004, when a small colony existed on Solstice Island (Adkins et al. 2014).

Region-wide Nesting Population

In total, an estimated 675 breeding pairs of Caspian terns nested at five different breeding colonies in the Columbia Plateau region during 2016, the lowest regional population size observed during 2005-2016 (*Table 5*; *Figure 11*). The estimated total population in 2016 of 675 breeding pairs of Caspian terns nesting in the Columbia Plateau region was lower than the estimated number of terns nesting in the region during 2015 (769 breeding pairs), and lower still than the average number of terns nesting in the region prior to management (873 breeding pairs during 2005-2013; *Figure 11*). Although nest dissuasion actions implemented on Goose and Crescent islands in 2016 were 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 primarily due to the more than 8-fold increase in the number of Caspian terns nesting in the Blalock Islands during 2016 compared to the pre-management average colony size for that site (see *above*). The Blalock Islands colony Caspian tern colony during 2015-2016

was similar in size to the largest Caspian tern colony recorded anywhere in the Columbia Plateau region since intensive monitoring began in 2000.

INTER-COLONY MOVEMENTS

A total of 153 previously color-banded Caspian terns were resighted at Potholes Reservoir, including on Goose Island and nearby islets, in 2016 (*Table 6*). The island in northeastern Potholes Reservoir where a new colony formed in 2016 is within 10 km of Goose Island, and 58 of the 153 color-banded Caspian terns that were resighted at Potholes Reservoir this year were seen at both Goose Island and at the new colony in northeastern Potholes Reservoir. Of the 153 Caspian terns that were resighted in Potholes Reservoir in 2016, 86% were previously banded at Goose Island, 9% were banded at Crescent Island, and 1% were banded each at East Sand Island (Columbia River estuary), the Port of Bellingham (Puget Sound), Malheur Lake (Malheur National Wildlife Refuge), and Brooks Island (San Francisco Bay; see *Map 17*).

A total of 510 previously color-banded Caspian terns were resighted at the active Caspian tern breeding colony and nearby loafing sites in the Blalock Islands during 2016 (see *Map 17*; *Table 7*). The loafing site that was near the town of Irrigon, Oregon and is within 10 km of the Blalock Islands, and 15 of 510 color-banded Caspian terns were resighted both at the Blalock Islands and the loafing site. Of the 510 banded Caspian terns resighted near the Blalock Islands during 2016, 58% were previously banded at Crescent Island, 36% were banded at Goose Island, 2% were banded each at Sheepy Lake (Lower Klamath National Wildlife Refuge, California), East Sand Island, and Malheur Lake, and 1% were banded at Crump Lake (Warner Valley, Oregon; see *Map 17*).

A total of 25 previously color-banded Caspian terns were resighted at a small colony on Lenore Lake. Of these, 64% were banded at Goose Island, 28% were banded at Crescent Island, and 4% were banded each at East Sand Island and Malheur Lake. Only one previously color-banded Caspian tern was resighted at a small colony on Twinning Island (Banks Lake) in 2016 (see *Map 17*), and that individual was banded at Crescent Island.

In McNary Reservoir in the Columbia River, a total of 11 previously color-banded Caspian terns were resighted at non-breeding sites. Two Caspian terns (one banded at Goose Island and the other at Crescent Island) were resighted in the Hanford Reach, two Caspian terns (one banded at Goose Island and the other at Crescent Island) were resighted at the mouth of Snake River, and six Caspian terns (four banded at Crescent Island, one at Goose Island, and one at East Sand Island) were resighted at the mouth of Walla Walla River. One Caspian tern banded at Goose Island was resighted both at Snake River and Walla Walla River Deltas. At Ice Harbor Dam, eight Caspian terns previously color-banded at Crescent Island were resighted. At Priest Rapids Reservoir, 10 Caspian terns (seven banded at Goose Island, two at Crescent Island, one at Malheur Lake) were resighted loafing near Desert Aire. Eight Caspian terns (seven banded at Goose Island and one at Sheepy Lake) were resighted loafing at Cabin Island, also in Priest Rapids Reservoir.

Of a total of 222 color-banded Caspian terns seen in the Potholes Reservoir area during 2015, 171 were resighted again in 2016, either in Potholes Reservoir or elsewhere, some of which were resighted at multiple locations in 2016. Of a total of 245 resighting records of these banded individuals during 2016, 44% were resighted in the Potholes Reservoir, 38% were resighted at the Blalock Islands/Irrigon, 6% were resighted each at Lenore Lake and Priest Rapids Reservoir, 2% were resighted each at Tule Lake NWR (northeastern California) and an active colony in Everett (coastal Washington), 1% were resighted at East Sand Island, and < 1% were resighted each at the Hanford Reach, Ice Harbor Dam, Summer Lake Wildlife Area (Oregon), and Crump Lake (see *Map 17*; *Table 8*).

Of a total of 515 color-banded Caspian terns seen on the Blalock Islands in 2015, 408 were resighted again in 2016, either in the Blalock Islands (including a loafing site in Irrigon) or elsewhere; some of these banded individuals were resighted at multiple locations in 2016. Of a total of 487 resighting records for these birds in 2016, 75% were resighted in the Blalock Islands/Irrigon, 12% were resighted at Potholes Reservoir, 4% were resighted at East Sand Island, 2% were resighted each at Lenore Lake and Everett, 1% were resighted each at Priest Rapids Reservoir, McNary Reservoir, Ice Harbor Dam, and Tule Lake National Wildlife Refuge, and < 1% were resighted at Tongue Point Pier in the Columbia River estuary during 2016 (see *Map 17*; *Table 9*).

In summary, these results suggest that Caspian terns generally exhibited strong site fidelity to the Potholes Reservoir area, despite the third year of efforts to dissuade Caspian terns from nesting at Goose Island. The Blalock Islands experienced a large influx of nesting Caspian terns in 2015, from colonies both on Crescent Island and on Goose Island, but predominantly from Crescent Island. Many of the terns that immigrated to the Blalock Islands in 2015 returned to that colony in 2016. Although most Caspian terns dissuaded from Goose and Crescent islands apparently remained in the Columbia Plateau region, some Caspian terns also dispersed to breeding or non-breeding sites along the coasts of Washington and Oregon, as well as to colonies on Corps-constructed islands in interior Oregon and northeastern California. These results offer some insight into potential locations where Caspian terns from the Columbia Plateau region would recruit back into the breeding population, if further management of Caspian terns in the Columbia Plateau region occurs in the future.

Out of 34 models constructed in 2016, there were four competitive models within two ΔAICc units. Drought, management, and the number of breeding pairs (all in the source region) were each included in all or most of the competing models as having effects on movement. However, only the effect of drought was significant based on evaluation of the 95% confidence limits for the coefficient. Movement probabilities were estimated from the best model, which included an interaction term between transition (from one region to another) and the number of breeding pairs, as well as additive terms of “drought” and “management” for affecting movements.

Movement probabilities from the Columbia Plateau region to the Columbia River estuary for Caspian terns banded as adults ranged from 1.5% to 3.4% per year during 2006-2016, with the

highest probabilities observed in 2015 and 2016. This translates into an estimated movement of a total of 52 Caspian terns from the Columbia Plateau region to the Columbia River estuary in 2016 (*Table 10*). The movement probability in the opposite direction was lower (1.5%) in 2016; however, because of the large size of the source colony at East Sand Island, estimated net movement of adult Caspian terns (the estimated number of terns that moved from one region to another, subtracted from the number of terns that moved in the opposite direction) from the Columbia River estuary to the Columbia Plateau region in 2016 was 137 individuals. Although this number is small, it would partially off-set benefits to salmonids of tern management in the Columbia Plateau region and in the estuary. This is because per bird predation rates on smolts are higher for terns nesting in the Columbia Plateau region compared to those nesting in the estuary, where marine forage fishes (anchovy, smelt, surfperch, etc.) dominate the diet.

Based on the best model selected to estimate inter-regional movements (see *above*), movement probabilities from colonies on the Corps-constructed islands in southern Oregon and northeastern California (SONEC) to the Columbia Plateau region ranged from 3% to 18% during 2009-2015, with the highest movement probability in 2015. The movement probability from the alternative colony sites to the Columbia Plateau remained high (18%) in 2016 (*Table 10*), despite management actions to prevent tern nesting at Crescent Island and Goose Island. The estimated number of adult Caspian terns that moved from the Corps-constructed colony sites in SONEC to the Columbia Plateau region in 2016 was 375 individuals. Insufficient data collection at the SONEC Corps-constructed islands in 2016 made accurate estimation of movement rate from the Columbia Plateau region to the SONEC region impossible; thus, net movement between the two regions is unknown. The drought in the SONEC region during 2014 and 2015 not only made some of the Corps-constructed islands more accessible to terrestrial predators (e.g., raccoons), but also limited foraging habitat and prey availability within commuting distance for Caspian terns nesting on Corps-constructed islands (BRNW 2015a). Another year with high movement rates away from the Corps-constructed islands in the SONEC region in 2016 was presumably due to continued drought in the region. Consecutive seasons (2015 and 2016) of high movement probability from the Corps-constructed colony sites to the Columbia Plateau region might have been partly due to available nesting habitat at the Blalock Islands in John Day Reservoir and the strong fidelity by terns to Goose Island in Potholes Reservoir.

SMOLT PREDATION RATES

Table 11 provides historic data on colony sizes, predation rates, and average per capita predation rates for Caspian terns nesting at Goose Island, Crescent Island, and the Blalock Islands during 2007-2015 (see also BRNW 2015 and BRNW 2016). Results indicate that predation rates were highly variable depending on the Caspian tern colony, the year, and the ESU/DPS of salmonid. In general, predation rates and per capita predation rates were higher on steelhead DPSs compared with salmon ESUs, particularly predation on Upper Columbia River steelhead by Caspian terns nesting on Goose Island and predation on Snake River steelhead by Caspian terns nesting on Crescent Island (*Table 11*). Colony size also varied substantially by

location and year. In the case of Goose and Crescent islands, reductions in colony size were due to management actions in 2014 (Goose Island) and 2015 (Goose and Crescent islands; *Table 11*).

In 2016, for calculating predicted predation rates, Caspian tern colony size at Goose Island was estimated to be between three and five breeding pairs (although no [zero] pairs persisted throughout the nesting season; see *Methods & Analysis: Smolt Predation Rates*); there were zero breeding pairs at Crescent Island; and 483 breeding pairs at the Blalock Islands (*Table 11*). For the third consecutive year, as part of implementation of the IAPMP, the number of Caspian terns nesting on Goose Island was reduced substantially relative to pre-management counts during 2007-2013 (*Table 11*). For the second consecutive year, the Caspian tern colony at Crescent Island was eliminated, a reduction of 349-474 pairs compared to colony size during 2007-2014 (*Table 11*). Conversely, counts of breeding pairs at the Blalock Islands in 2015 (677 pairs) and 2016 (483 pairs) were the highest recorded since the colony site was detected in 2005 (*Table 11 and* Collis et al. 2015).

Based on estimates of Caspian tern colony size in 2016 (three to five pairs, depending on the measure) and the average per capita predation rate during 2007-2015 (*Table 11*), we predict that predation rates by Goose Island Caspian terns was ≤ 0.2% on all ESA-listed ESUs/DPSs in 2016 (*Table 12*). Reductions in predation rates were particularly pronounced in Upper Columbia River steelhead, where average pre-management predation rates were 15.7% (95% CI = 14.1-18.9%) during 2007-2013 (*Table 12* and BRNW 2014a). For both colony size scenarios (three pairs vs. five pairs) and for all ESA-listed salmonid ESUs/DPSs evaluated, predicted Goose Island Caspian tern predation rates were well below the IAPMP target goal of less than 2.0%. This is the second consecutive year that IAPMP predation rate target goals for terns nesting on Goose Island were achieved.

Predicted predation rates by Crescent Island Caspian terns in 2016 were <0.1% for all ESA-listed salmonid ESUs/DPSs because there was no colony (either attempted nests or adults observed on the island) in 2016 (*Table 12*). Like predation impacts by terns on Goose Island, this was the second consecutive year that IAPMP predation rate target goals for terns nesting on Crescent Island were achieved.

Predicted predation rates by Caspian terns nesting in the Blalock Islands during 2016 were the highest of those evaluated herein due the colony's large size (483 breeding pairs). Predicted predation rates were above the 2% threshold for Upper Columbia River steelhead (4.9%; 95% prediction interval [PI] = 3.8-6.4%), Snake River steelhead (4.6%; 95% PI = 4.0-5.6%), Snake River sockeye (2.6%; 95% PI = 1.6-5.0%), and Snake River spring/summer Chinook (2.0%; 95% PI = 1.8-2.3%) in 2016 (*Table 12*).

In summary, predicted predation rates indicate that the IAPMP target goal of achieving predation rates less than 2% on a given ESA-listed salmonid ESU/DPS, per Caspian tern colony, per year were met at both the Crescent Island and Goose Island Caspian tern colonies in 2016. Reduction in the size of the Caspian tern colony on Goose Island in 2016 (estimated at

effectively 3-5 breeding pairs) suggests that predation rates on Upper Columbia River steelhead were substantially reduced compared with pre-management predation rates during 2007-2013 (mean = 15.7%; BRNW 2015) and compared with post-management predation rates in 2014 (ca. 2.9%) and 2015 (ca. 0.5 to 1.5%; Collis et al. 2015). Similarly, a lack of Caspian tern nesting on Crescent Island resulted in predicted predation rates of <0.1% for all ESUs/DPSs in 2016.

Predicted predation rates on ESA-listed salmonid populations by Caspian terns nesting on the Blalock Islands were significantly higher than those observed during the pre-management period of 2007-2014. Increases in predicated predation rates were commensurate with the increase in the size of the tern colony in both 2015 and 2016, with the colony increasing from an average of 59 breeding pairs during 2007-2014 to average of 580 breeding pairs during 2015-2016. Predation rate estimates suggest that salmonid impacts by Caspian terns nesting on the Blalock Islands in 2015 and 2016 were comparable to or higher than those of Caspian terns nesting on Crescent Island or Goose Island during 2007-2014 for most, but not all, of the ESUs/DSPs evaluated. Consequently, the increased predation rates on salmonid smolts by Caspian terns nesting on the Blalock Islands likely offset some of the benefits achieved by the reduction in the number of Caspian terns nesting on Crescent and Goose islands since management actions were initiated (see also Roby et al. 2017). One exception to these offset benefits relates to the consumption of Upper Columbia River steelhead, where cumulative predation rates by all three Caspian tern colonies (Goose Island, Crescent Island, and the Blalock Islands) during the pre-management period (annual range = ca. 15 to 25%) were higher than those observed during the post-management period (annual range = ca. 6 to 10%), indicating an overall net benefit to Upper Columbia River steelhead due to Caspian tern management in the Columbia Plateau region. Preliminary data (based on actual predation rates from PIT tag recoveries) from the newly established tern colony in northeastern Potholes Reservoir, however, indicates that 4.1% (95% CI = 2.9-6.3) of Upper Columbia River steelhead were consumed by Caspian terns – terns that likely prospected or attempted to nest at Goose Island but were successfully dissuaded – consumption that further offset post-management benefits to Upper Columbia River steelhead in 2016 (see Roby et al. 2017).

Due to high inter-annual variation in predation rates and the documented influence of biotic factors (e.g., fish abundance, run-timing, fish condition) and abiotic factors (e.g., river flow, turbidity) on predation probabilities (Hostetter et al. 2012), predicted predation rates presented here may not be indicative of empirically-derived predation rates (those based on actual PIT tag recoveries) in any given year. Predicted predation rates are more likely to accurately reflect actual predation rates when Caspian tern colony sizes, river conditions, and prey abundances are like those observed during 2007-2015. Finally, a precise estimate of the predation rates on salmonid smolts by Caspian terns nesting at Goose Island was not available in 2015 and to lesser degree 2016 because colony size was influenced strongly by both passive and active dissuasion activities. In lieu of a traditional colony size estimate at Goose Island, the number of nesting attempts (39 in 2015 and 5 in 2016) and the average number of adult terns counted on the island (28 in 2015 and 6 in 2016) during the nesting season were used instead. The relationship between attempted nests and the number of adults observed and predation

rates may differ significantly from the impacts of breeding birds, birds that are present on the island throughout the breeding season.

SUMMARY

Management to reduce or 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 2016, the third year of implementation of the IAPMP. Consequently, predation on juvenile salmonids by Caspian terns nesting at these two colony sites was 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 regional population size having declined by 23%.

Based on resightings of banded Caspian terns, most terns that were displaced from breeding colonies on Goose and Crescent islands have remained in the region, and many have attempted to nest at alternative colony sites in the region (see also Roby et al. 2017). Most notable was the dramatic post-management increase in the size of the formerly small breeding colony in the Blalock Islands in John Day Reservoir. Caspian terns nesting in the Blalock Islands during 2015-2016 and at the unnamed island in northeastern Potholes Reservoir in 2016 have consumed sufficient numbers of juvenile salmonids to at least partially compensate for the 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. A new tern colony also appeared on a small island in northeastern Potholes Reservoir, but this colony failed before any chicks were fledged due to predators reaching the island as reservoir levels dropped. Based on results during the first three years of implementation of the IAPMP, the goal of the Plan to reduce predation rates on ESA-listed salmonid populations below 2% per tern colony per year throughout the Columbia Plateau region will not be achieved until alternative tern nesting habitat is reduced substantially from current levels, especially in the Blalock Islands and perhaps at the new colony in Potholes Reservoir. While suitable sites for Caspian tern breeding colonies are clearly limiting in the Columbia Plateau region, the strong fidelity of most Caspian terns that formerly nested at Goose or Crescent islands to the region will likely continue to result in new colony formation and former colony expansion where ever suitable tern nesting habitat persists.

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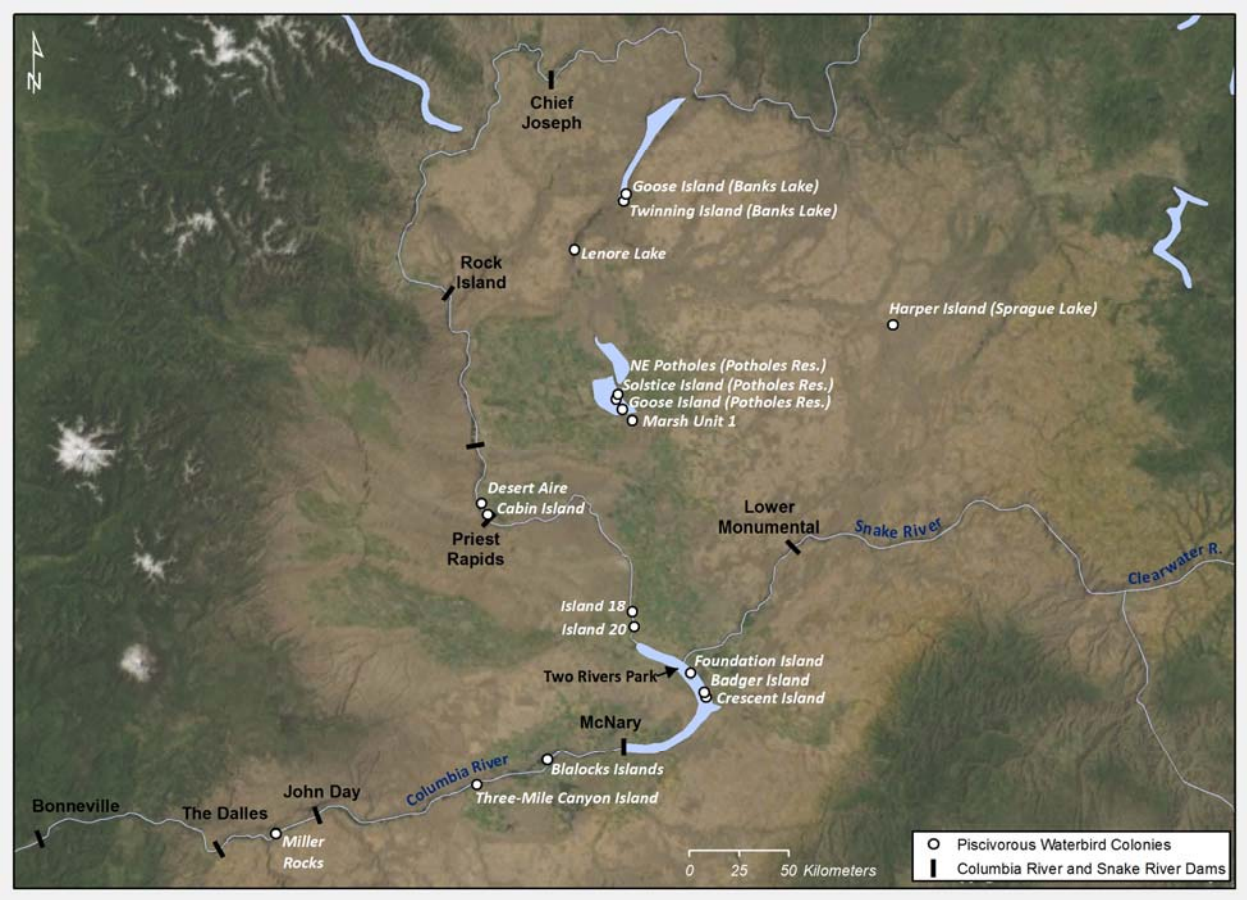
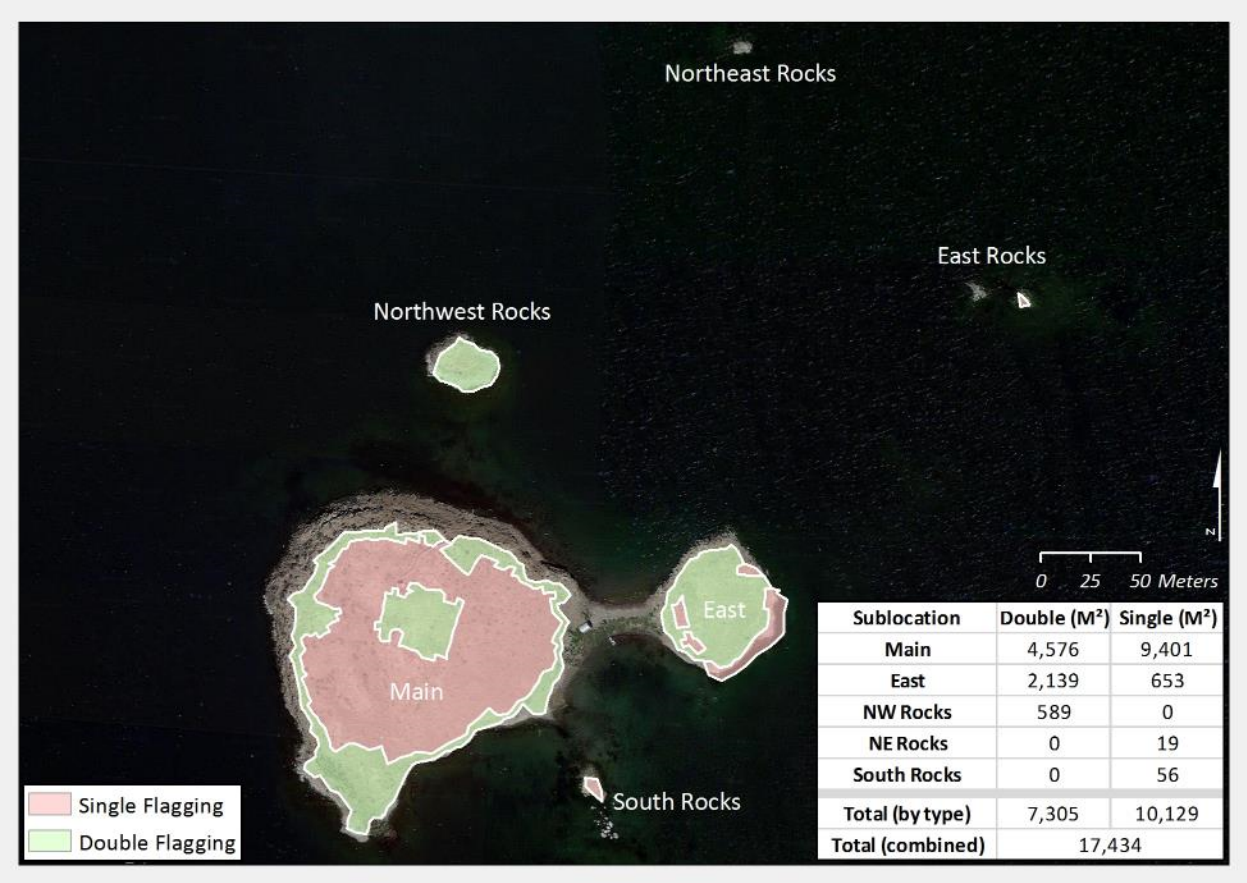
MAPS



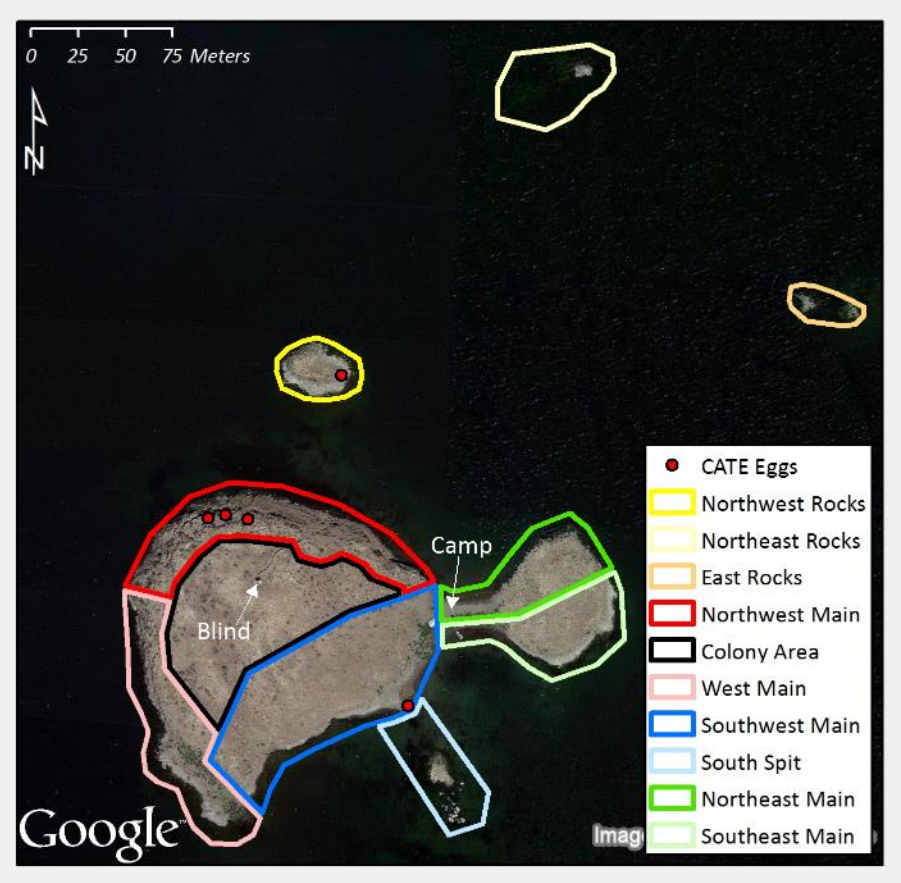
Map 1. Study area in the Columbia Plateau region in 2016.



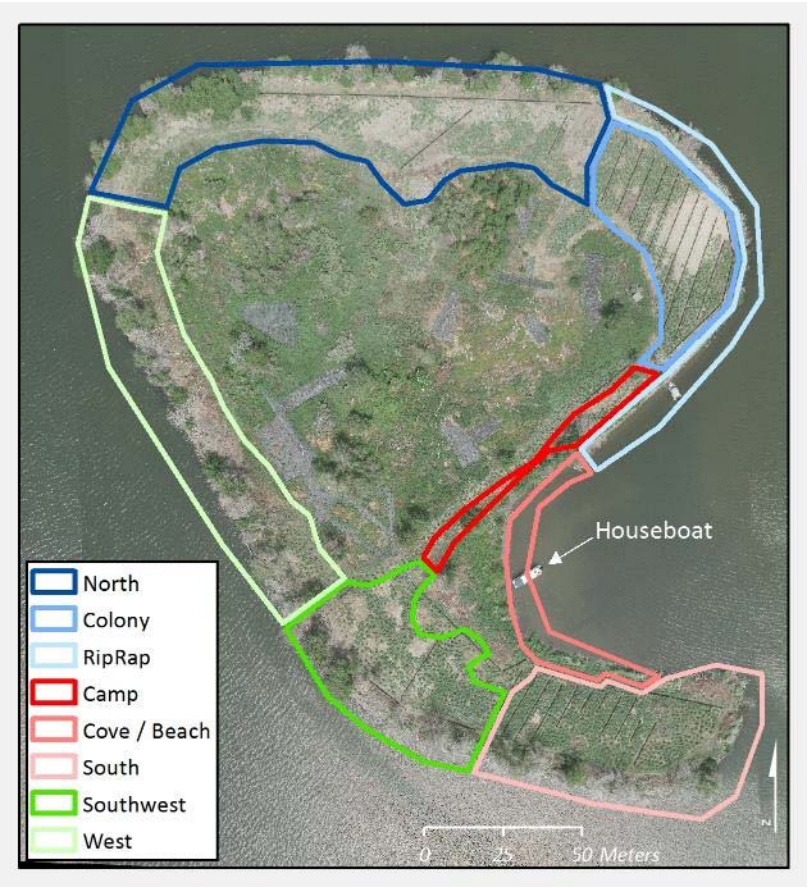
Sublocation	Double (M²)	Single (M²)
Main	4,576	9,401
East	2,139	653
NW Rocks	589	0
NE Rocks	0	19
South Rocks	0	56
Total (by type)	7,305	10,129
Total (combined)	17,434	

Map 2. Distribution of passive nest dissuasion materials on Goose Island and nearby rocky islets, Potholes Reservoir in 2016.

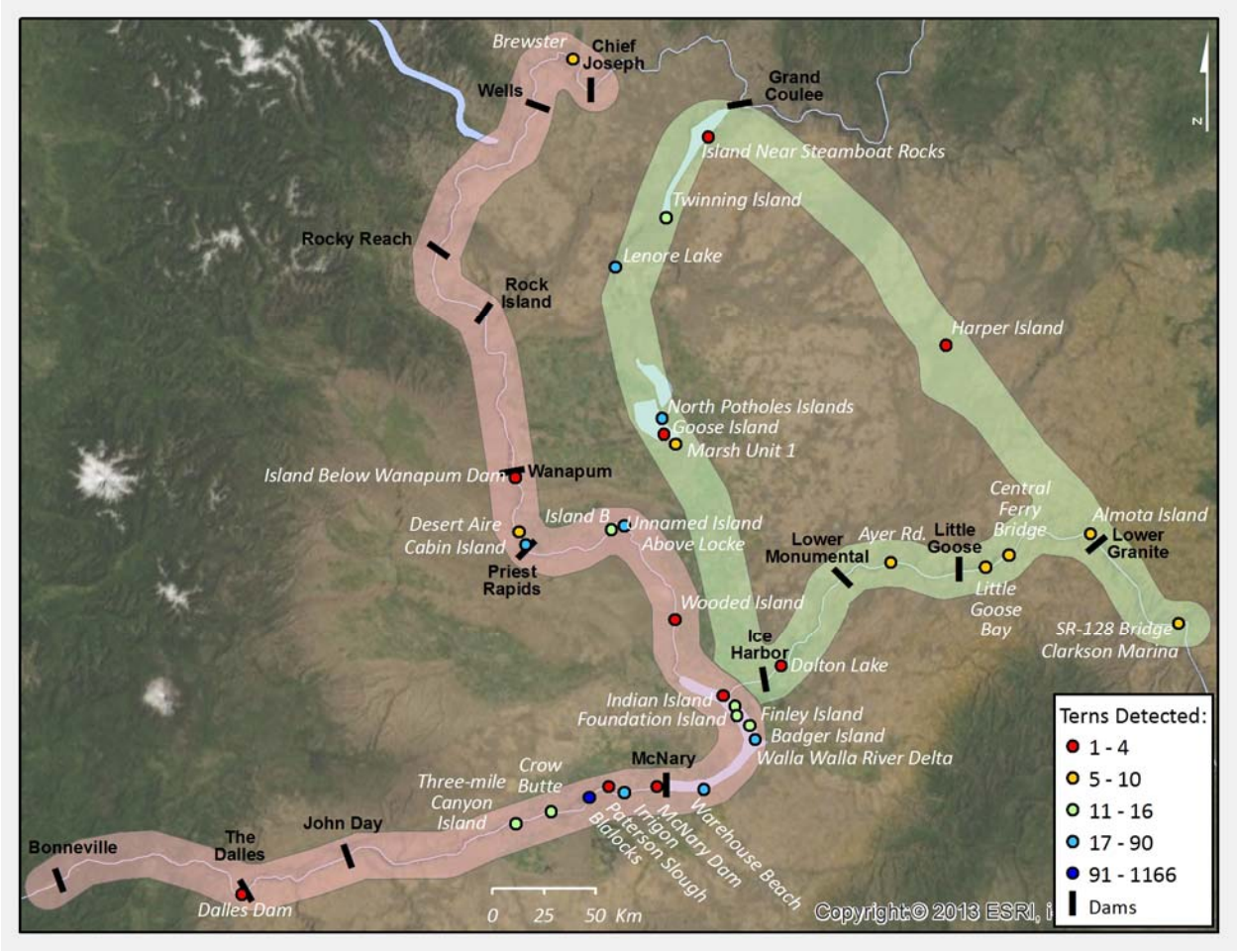
Map 3. Distribution of passive nest dissuasion materials on Crescent Island, Columbia River in 2016.



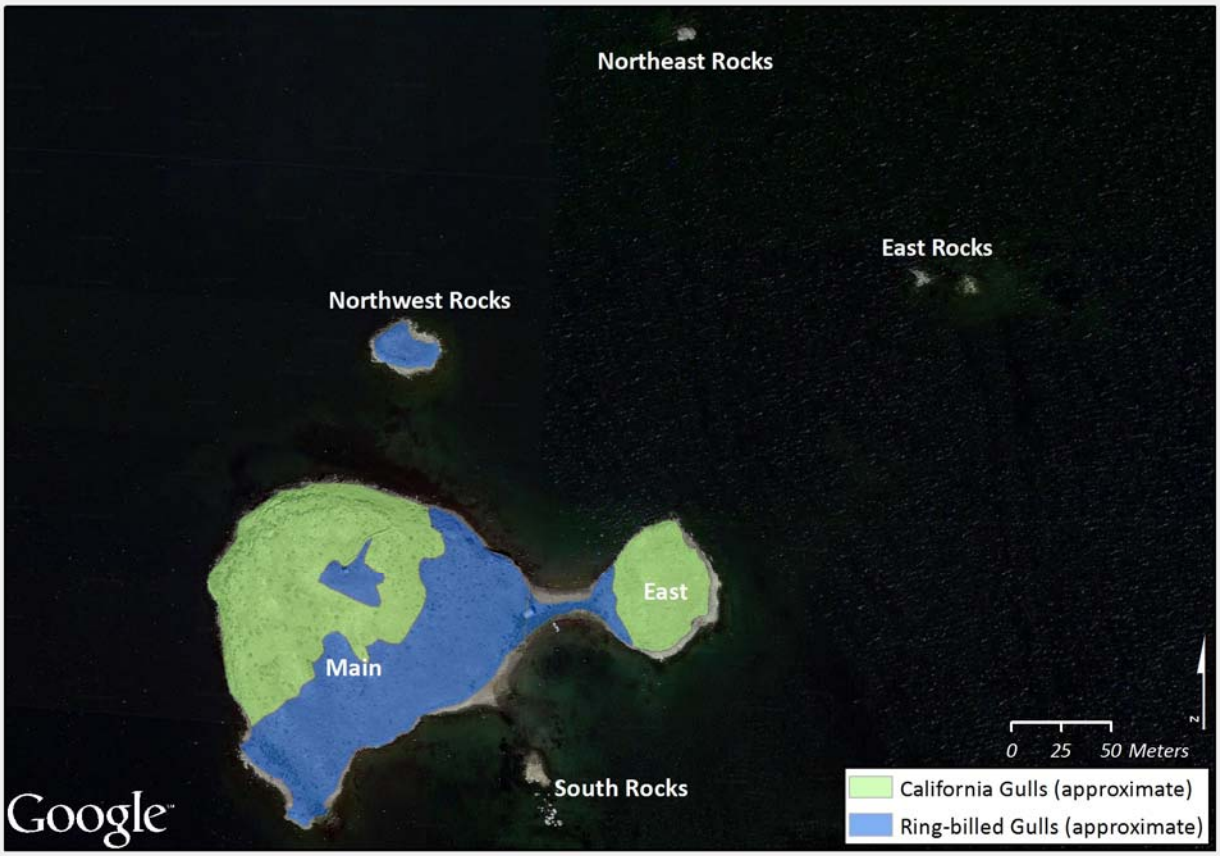
Map 4. Active dissuasion and survey locations on Goose Island and nearby rocky islets, Potholes Reservoir in 2016.



Map 5. Active dissuasion and survey locations on Crescent Island, Columbia River in 2016.



Map 6. 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 2016.

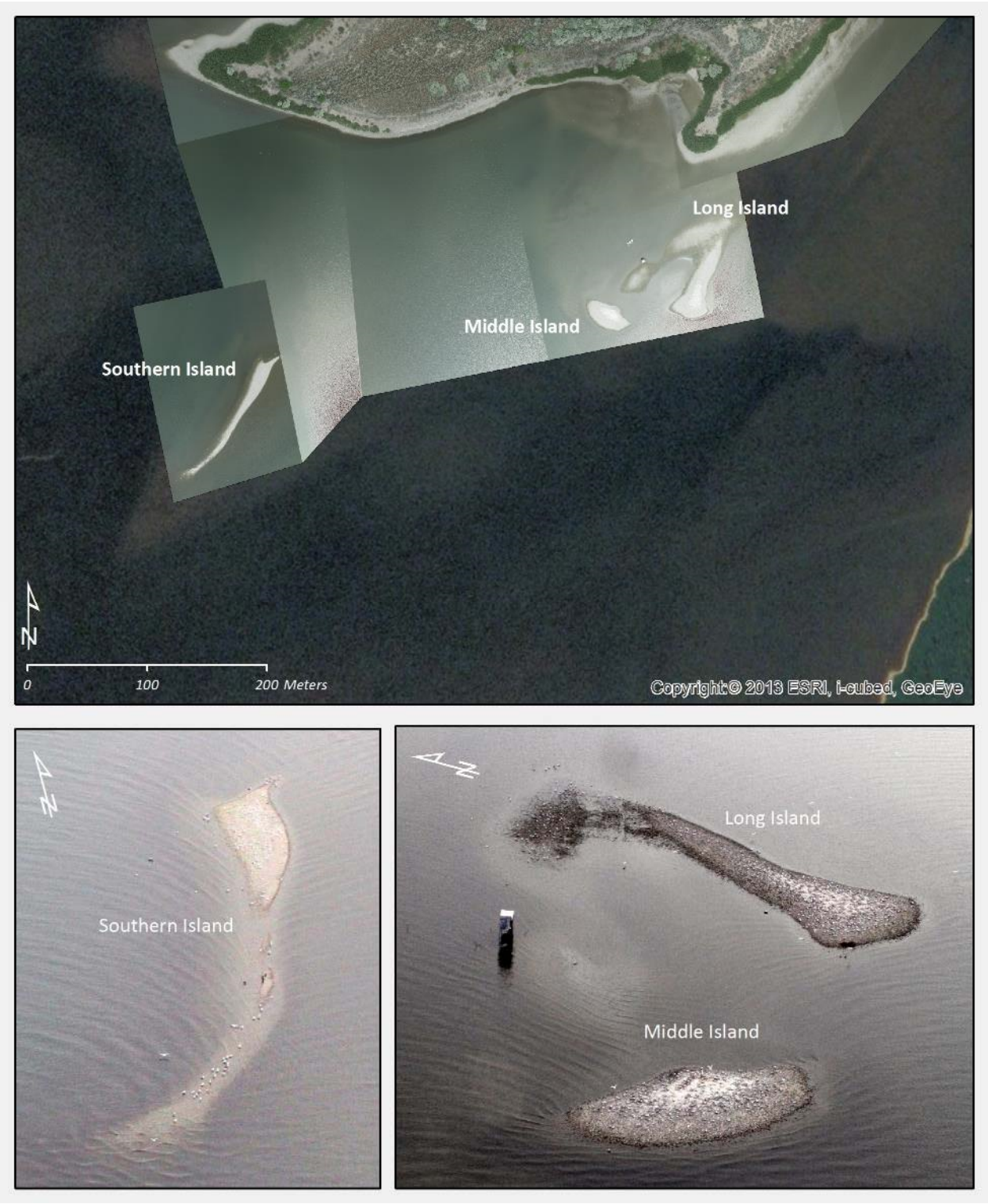


Map 7. Distribution of nesting California gulls and ring-billed gulls on Goose Island and the surrounding islets, Potholes Reservoir in 2016.

Map 8. Aerial imagery from June 2015 (top) and June 2016 (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 9. Seasonal growth of native and non-native vegetation near the former Caspian tern colony on Crescent Island during 31 March (top photo) to 16 July 2016 (bottom photo).

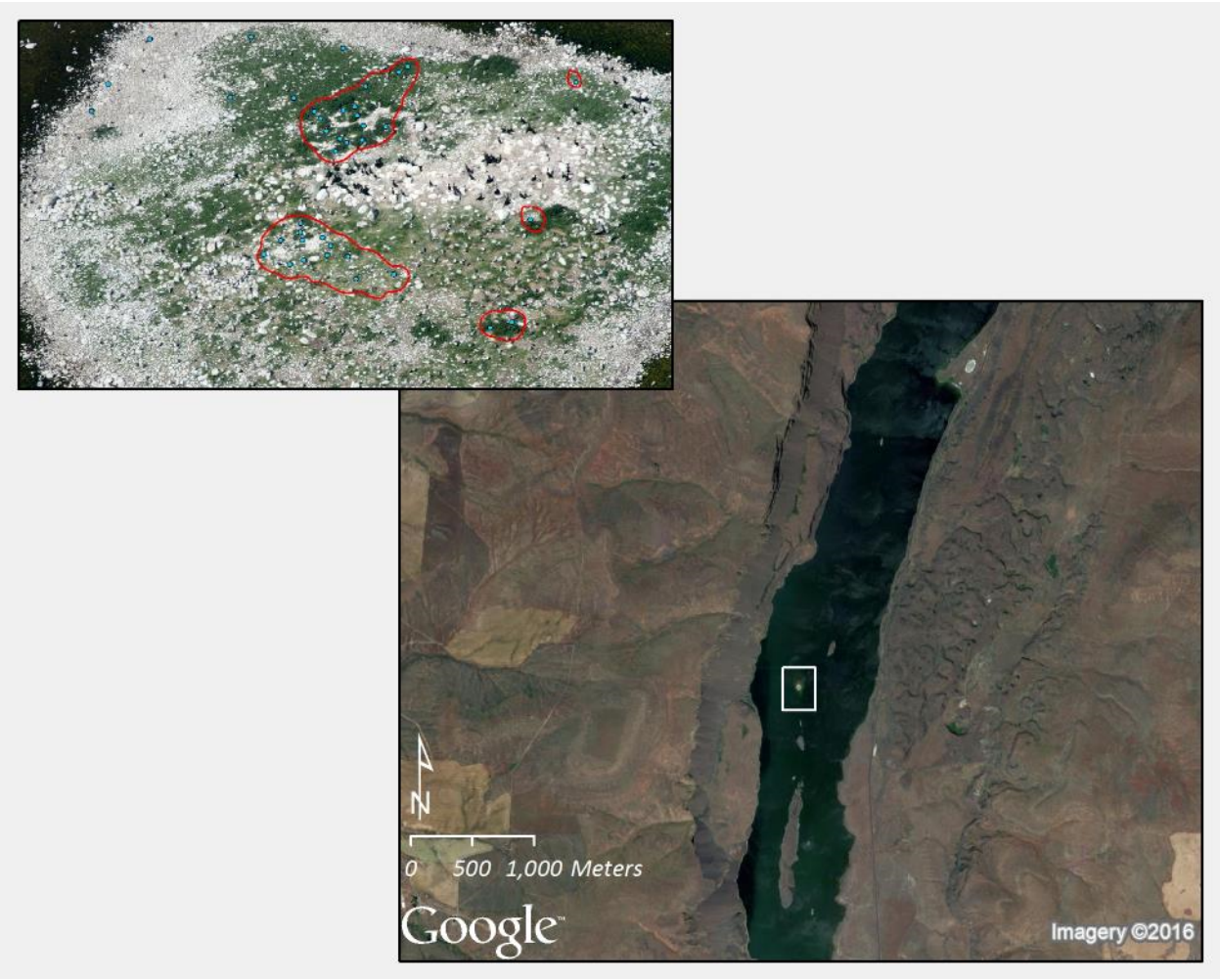
Map 9. Six islands within the Blalock islands complex, Columbia River where piscivorous waterbirds have historically nested, including Long, Middle, Southern, Sand, and Rock islands where Caspian terns initiated nests in 2016.



Map 10. Distribution of nesting Caspian terns on Southern, Middle, and Long islands within the Blalock islands complex, Columbia River in 2016.

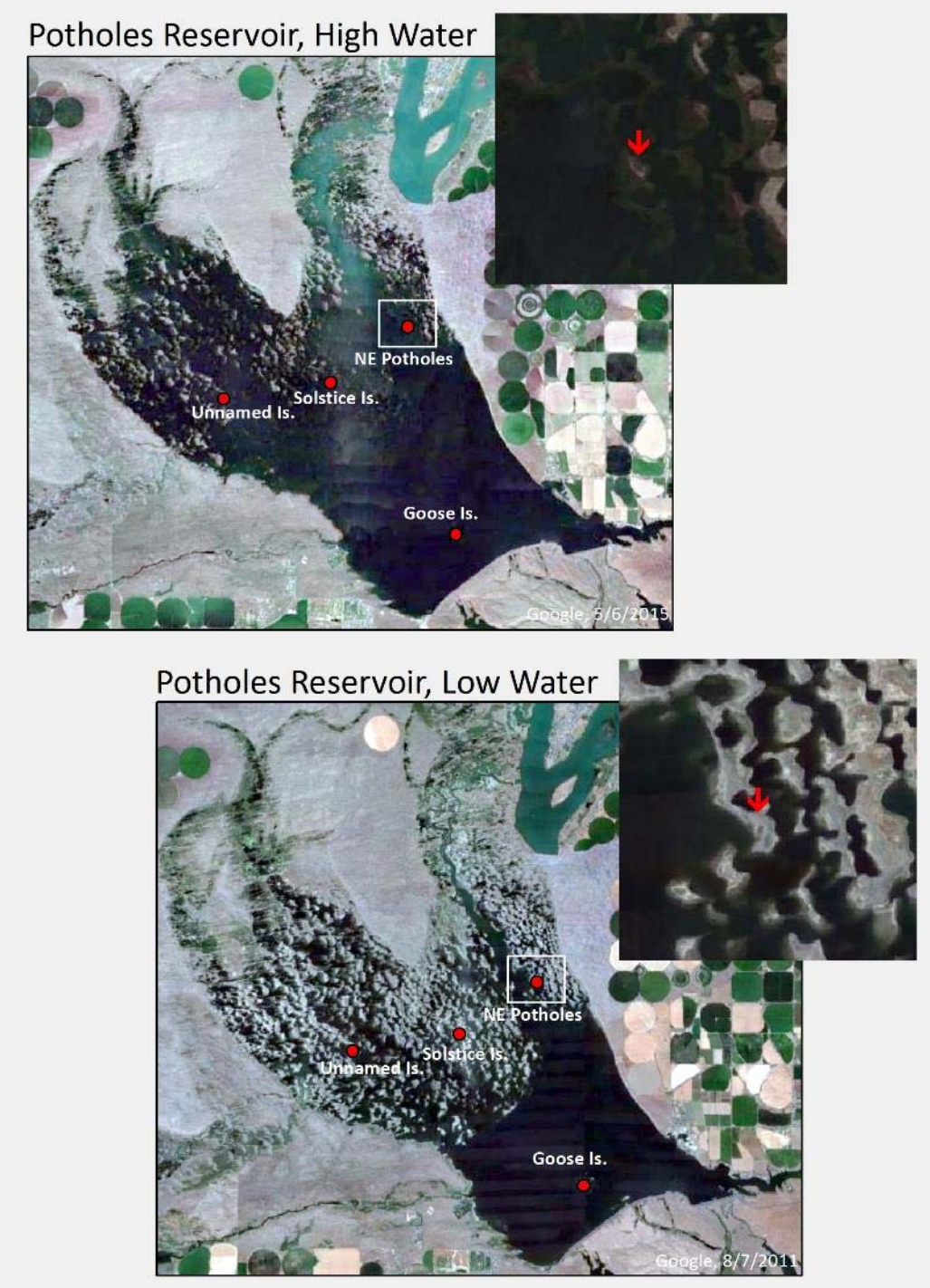
Map 11. Distribution of nesting Caspian terns on Twinning Island, Banks Lake in 2016.

Map 12. Distribution of nesting Caspian terns on Harper Island, Sprague Lake in 2016.



Map 13. Distribution of nesting Caspian terns on the small unnamed island, Lenore Lake in 2016.

Map 15. Distribution of nesting Caspian terns on the small unnamed island in northeastern Potholes Reservoir in 2016.



Map 16. Changing reservoir elevations as it affects the availability of Caspian tern nesting habitat in Potholes Reservoir.

Map 17. Locations where color-banded Caspian terns were resighted in 2016 and colonies where those terns were originally banded during 2005-2015.

FIGURES

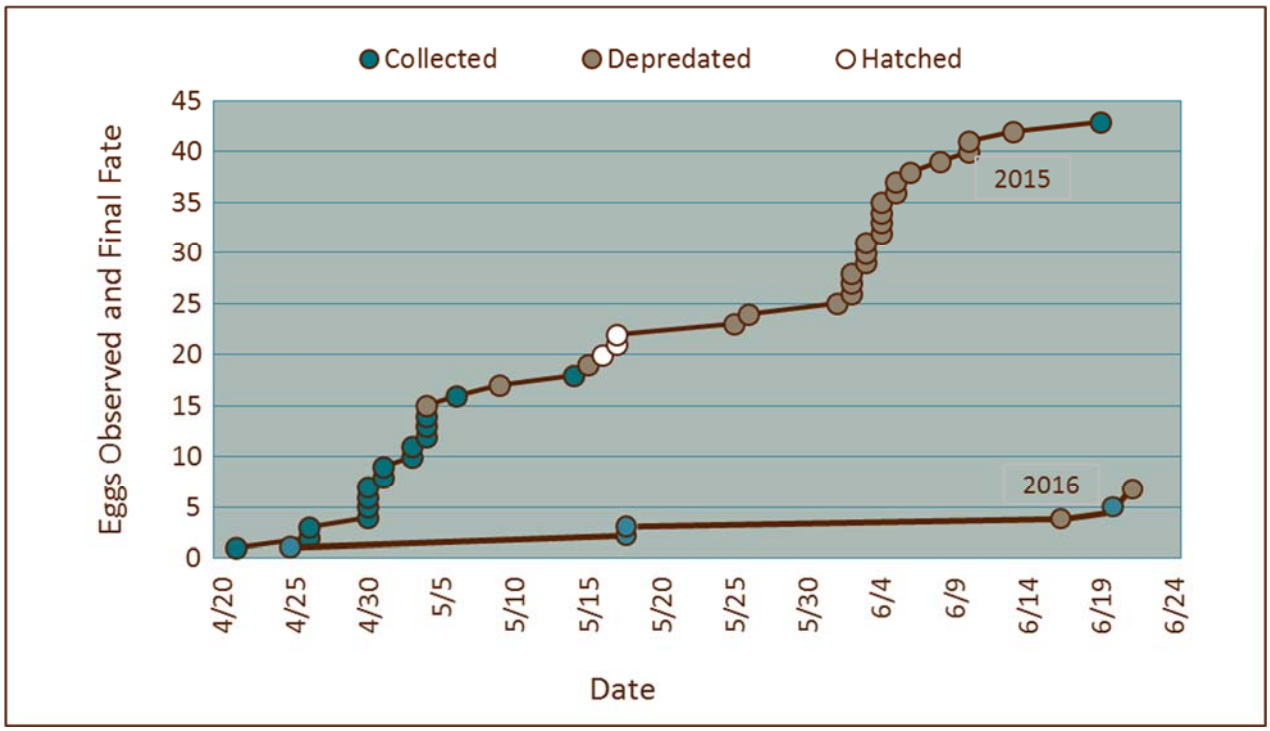


Figure 1. Caspian tern eggs observed on the Goose Island colony in 2015-2016 and their final fate; collected under permit, depredated by gulls, or hatched.

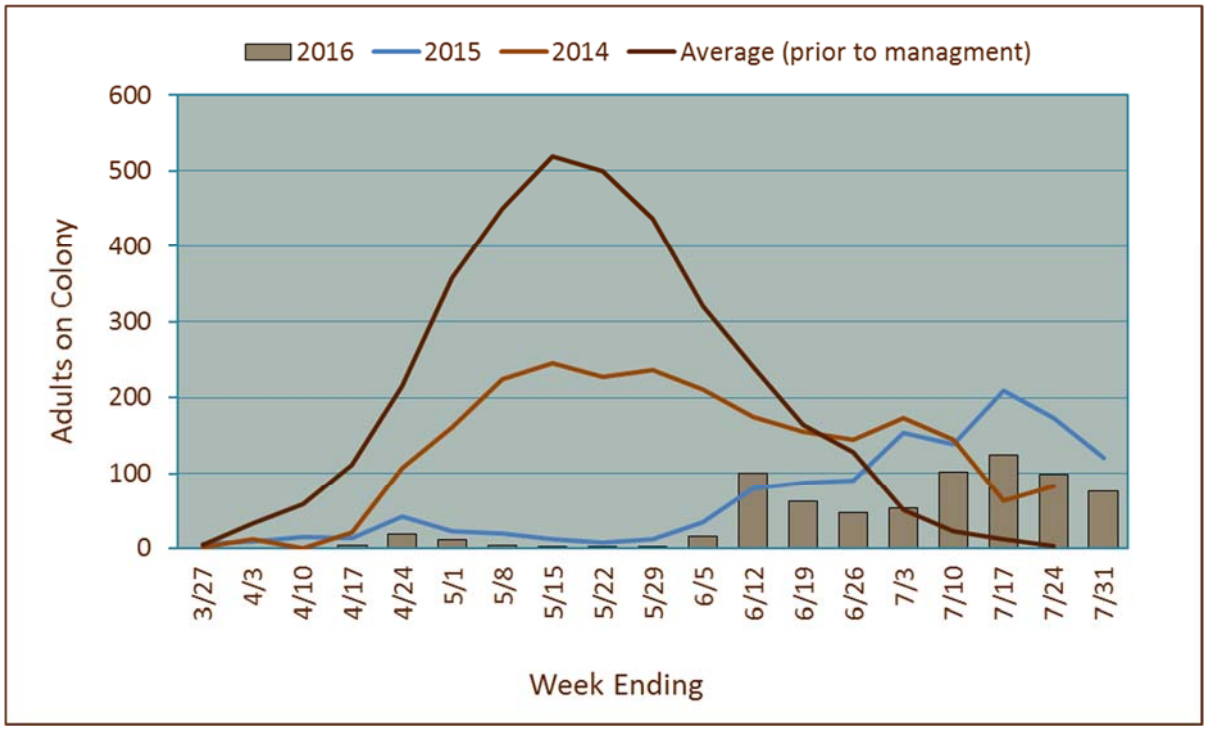


Figure 2. Estimates from the ground of the numbers of adult Caspian terns on Goose Island and the surrounding islets (Potholes Reservoir), by week, during 2014-2016 and prior to tern management in the Columbia Plateau region (2000-2013).

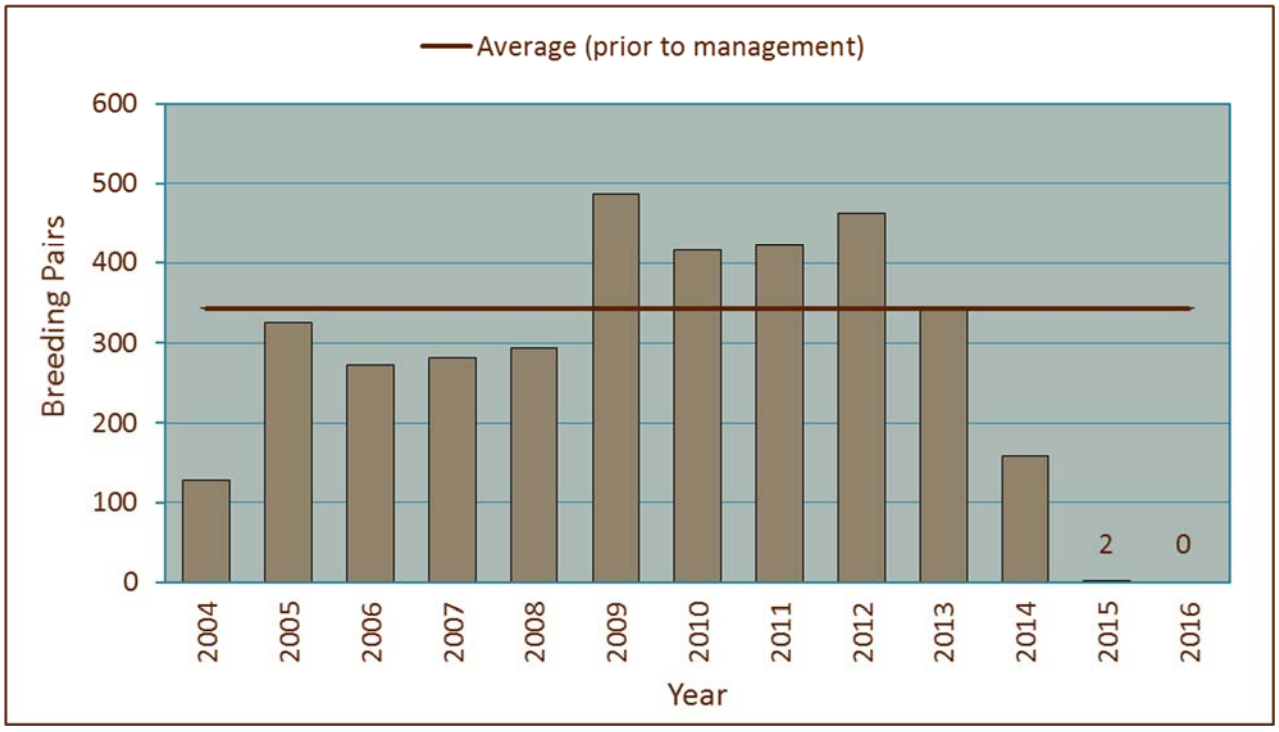


Figure 3. Size of the Caspian tern breeding colonies (number of breeding pairs) at Goose Island and the surrounding islets in Potholes Reservoir during 2004-2016. Also, provided is the average number of breeding pairs of Caspian terns on Goose Island prior to tern management on the Columbia Plateau (2004-2013).

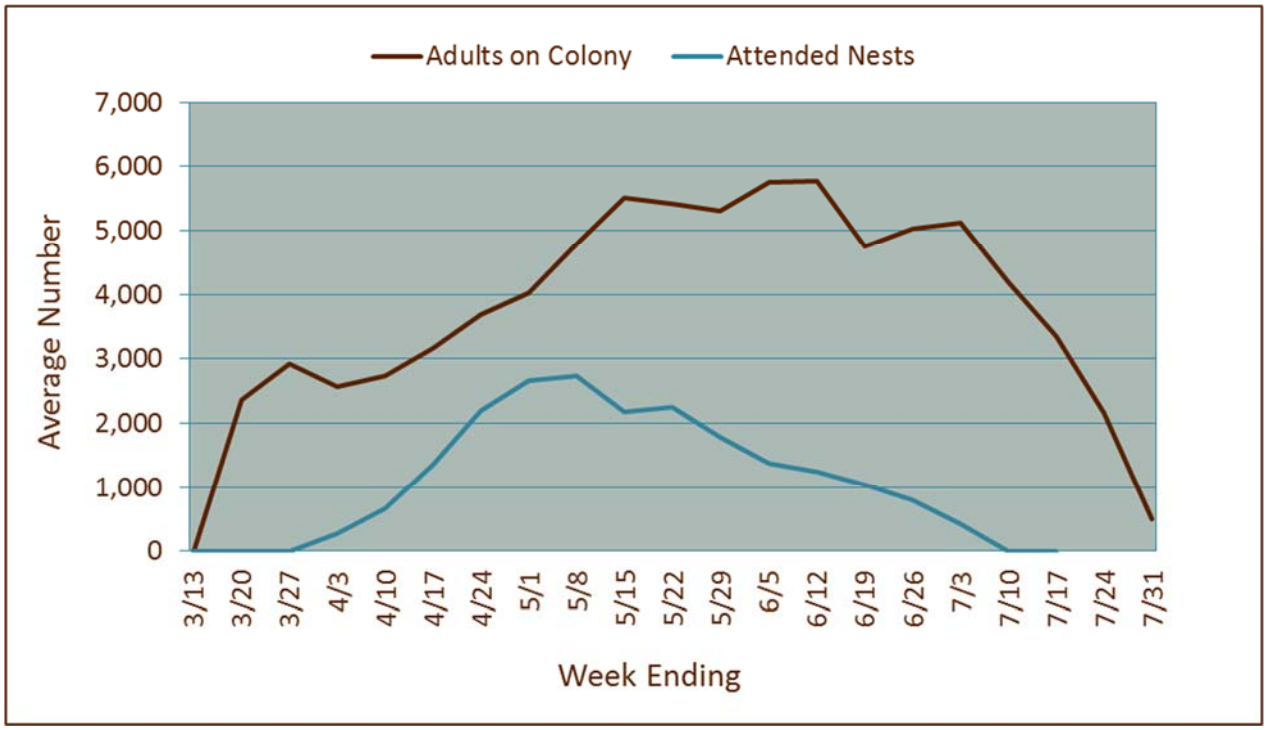


Figure 4. Estimates from the ground of the numbers of adult gulls and attended gull nests on Goose Island and the surrounding islets (Potholes Reservoir), by week, during the 2016 breeding season.

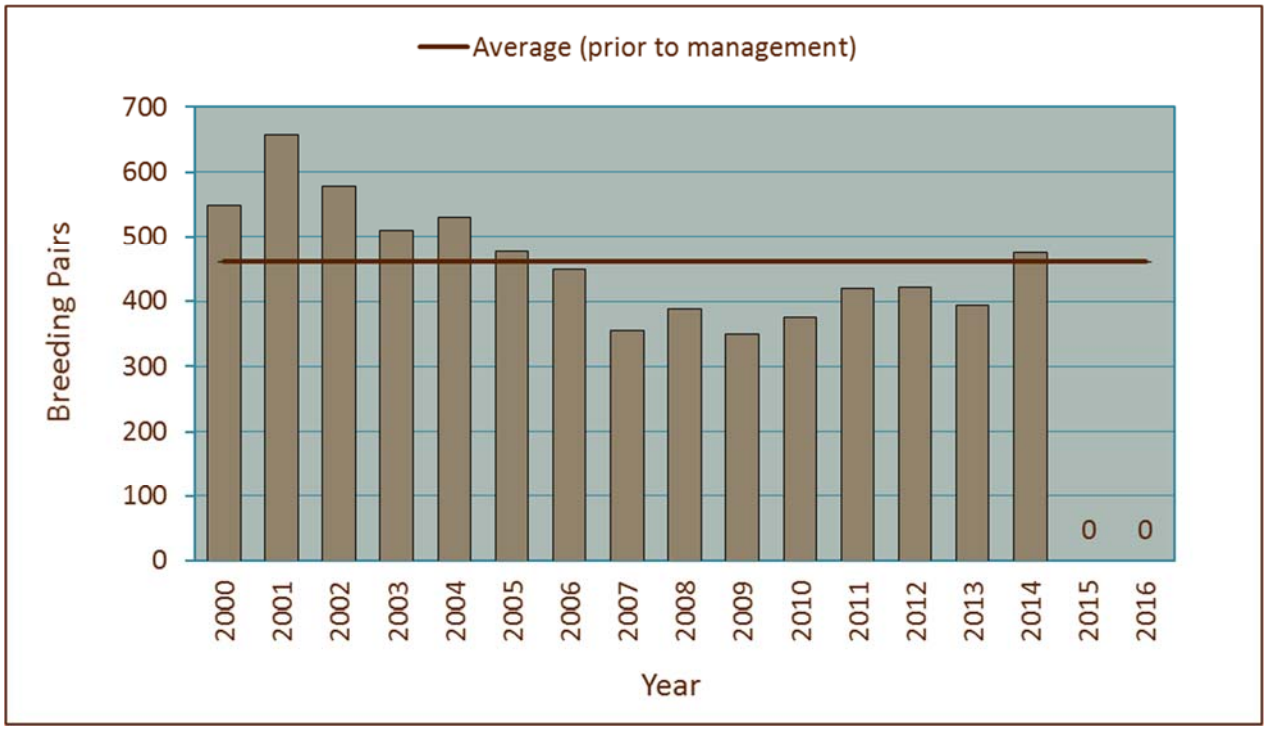


Figure 5. Size of the Caspian tern breeding colony (number of breeding pairs) on Crescent Island in the Columbia River during 2000-2016. Also, provided is the average number of breeding pairs of Caspian terns on Crescent Island prior to tern management in the Columbia Plateau region (2000-2013).

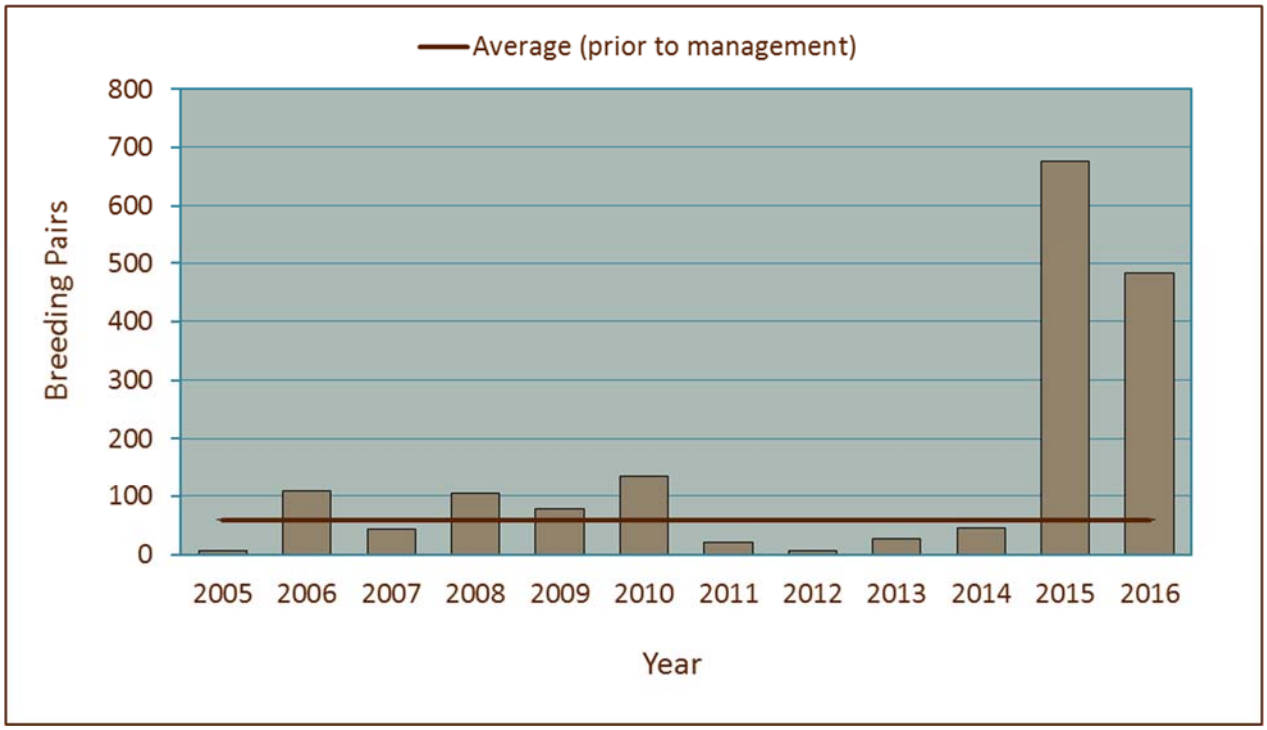


Figure 6. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock Islands in the Columbia River during 2005-2016. Also, provided is the average number of breeding pairs of Caspian terns on the Blalock Islands prior to tern management in the Columbia Plateau region (2005-2013).

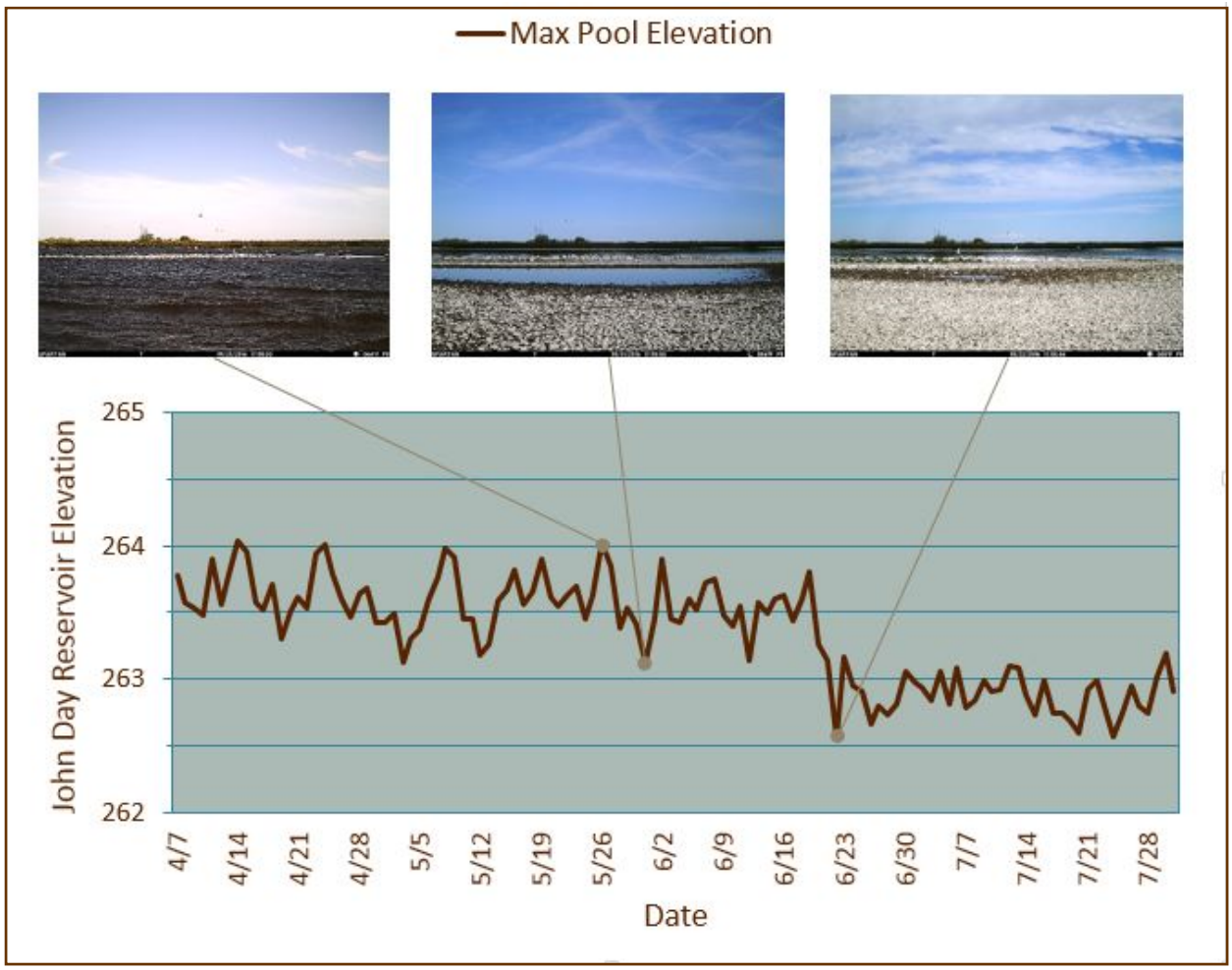


Figure 7. John Day Reservoir elevations as it relates to the availability of Caspian tern nesting habitat at the Blalock Islands in 2016. The water level monitoring system was installed on the west (downstream) side of an irrigation pumping station dock on the north side of the Columbia River, approximately 4.8 km from the Blalock Islands.

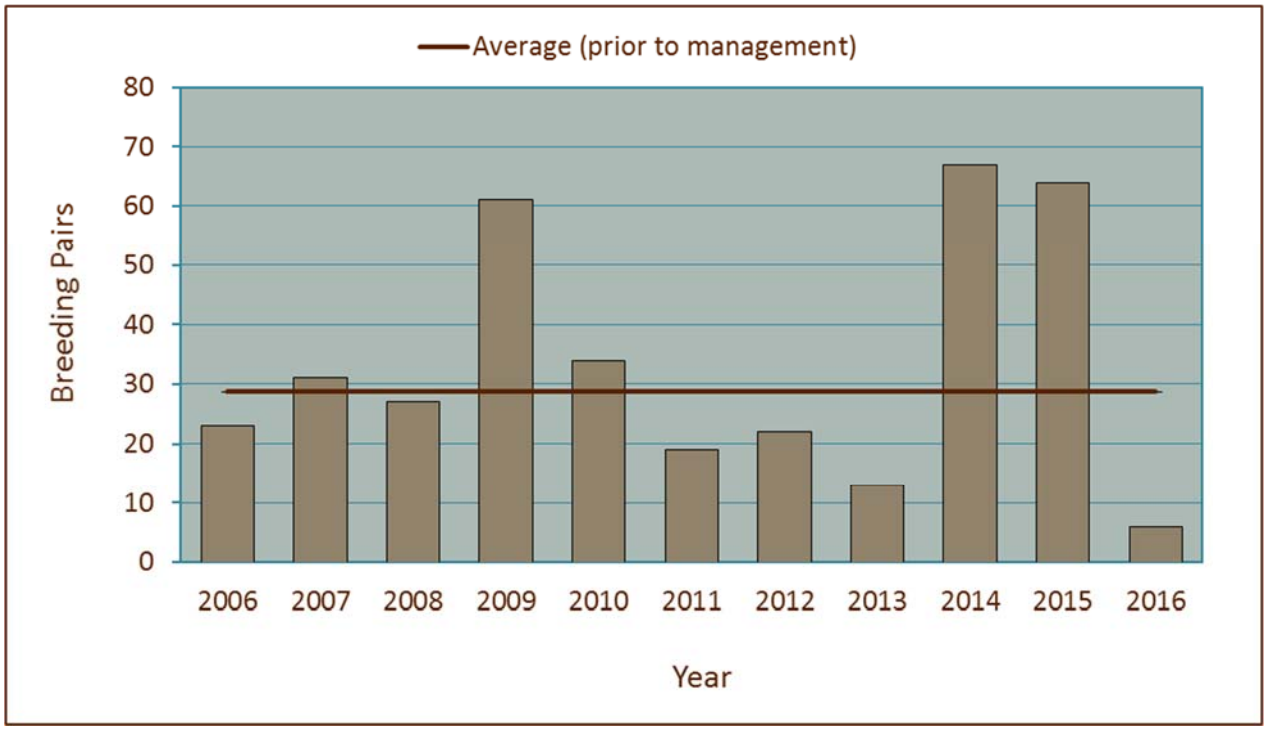


Figure 8. Size of the Caspian tern breeding colony (number of breeding pairs) at Twinning Island in Banks Lake during 2006-2016. Also provided is the average number of breeding pairs of Caspian terns on Twinning Island prior to tern management in the Columbia Plateau region (2006-2013).

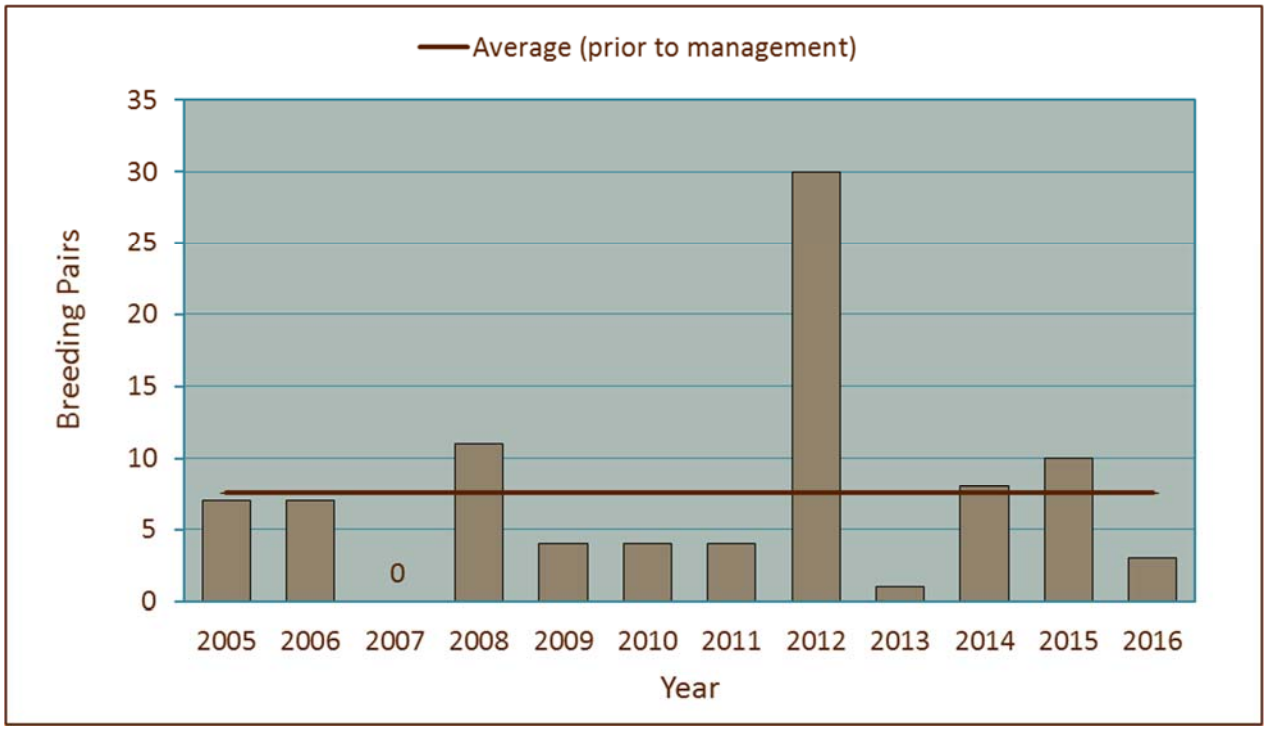


Figure 9. Size of the Caspian tern breeding colony (number of breeding pairs) at Harper Island in Sprague Lake during 2005-2016. Caspian terns did not attempt to nest on Harper Island in 2007. Also, provided is the average number of breeding pairs of Caspian terns on Harper Island prior to tern management in the Columbia Plateau region (2005-2013).

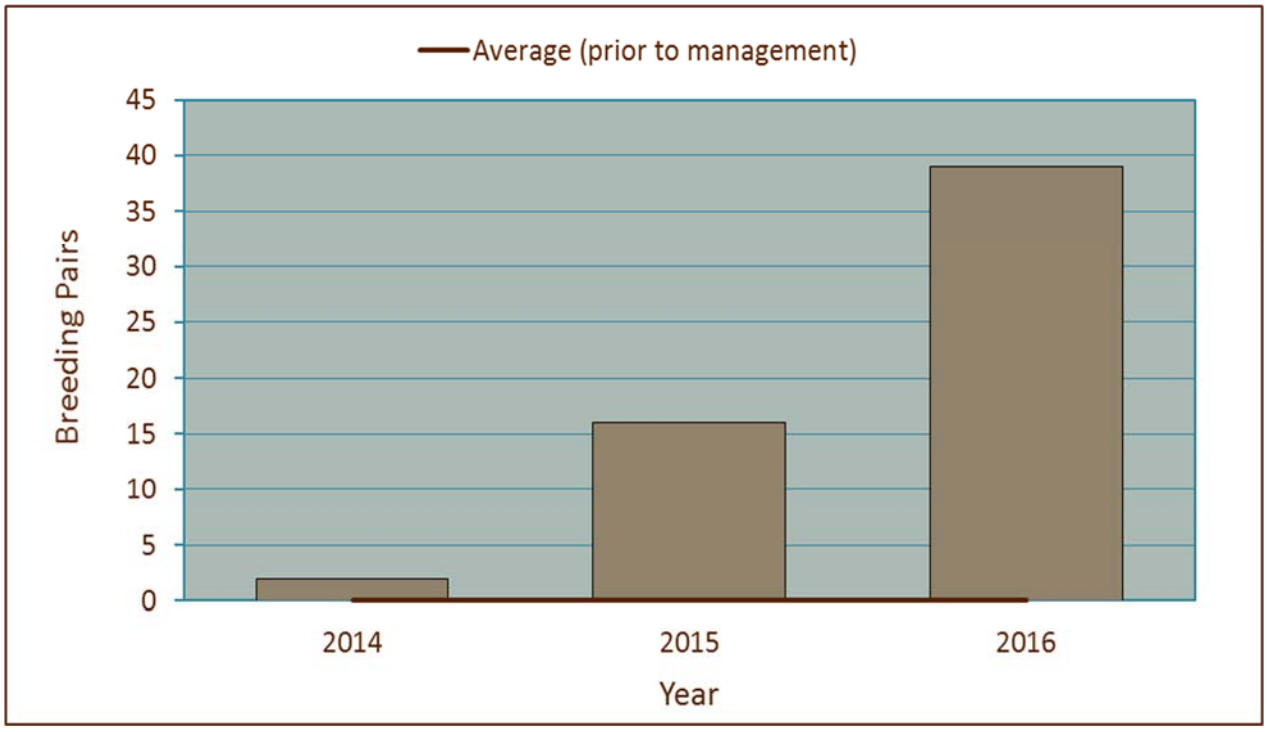


Figure 10. Size of the Caspian tern breeding colony (number of breeding pairs) at a small unnamed island in Lenore Lake during 2014-2016. Caspian terns did not nest in Lenore Lake prior to tern management in the Columbia Plateau region (<2014).

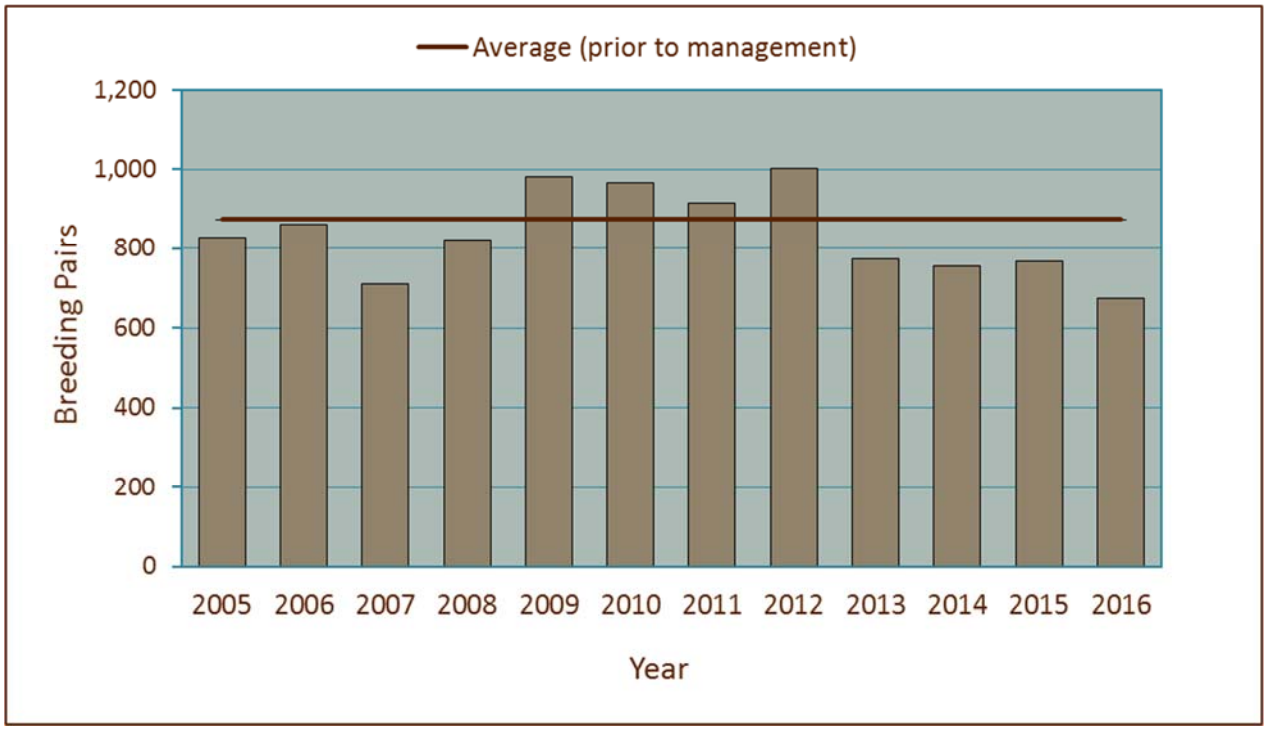


Figure 11. Total numbers of Caspian tern breeding pairs at all known colonies in the Columbia Plateau region during 2005-2016. Also, provided is the average number of breeding pairs of Caspian terns prior to tern management in the Columbia Plateau region (2005-2013).

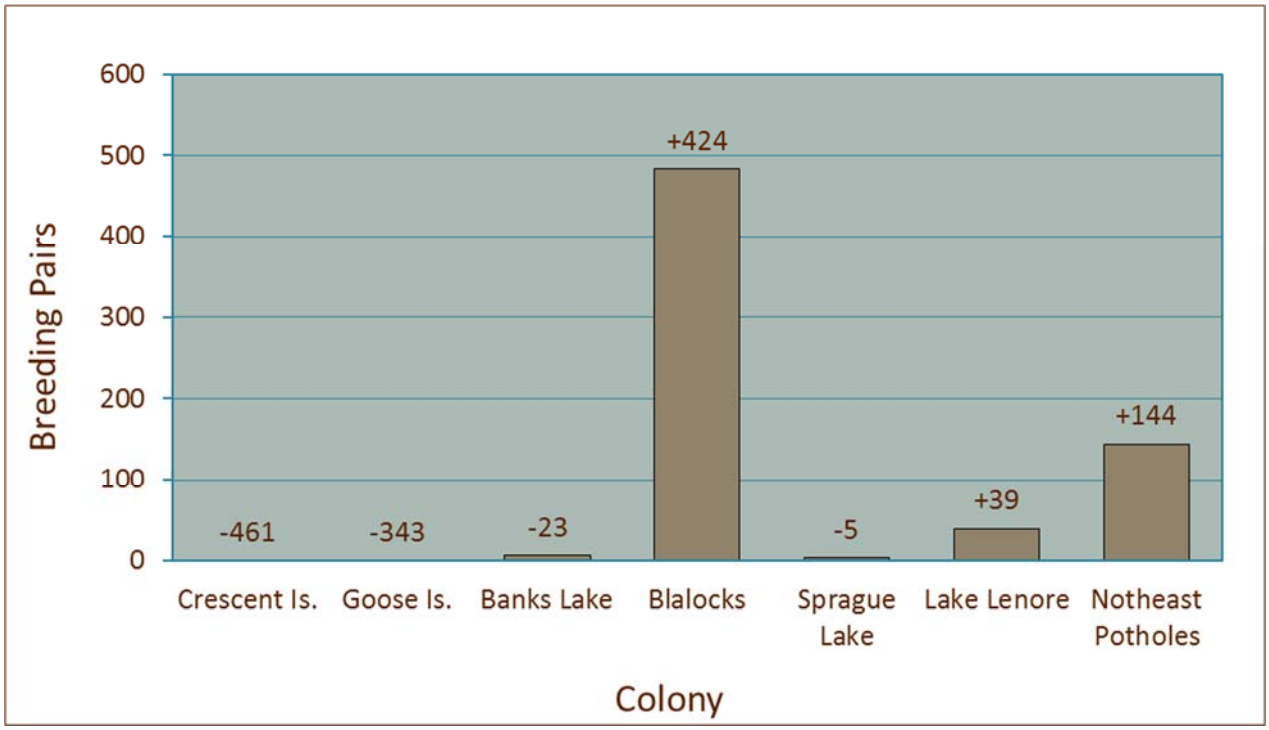


Figure 12. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the Columbia Plateau region during the 2016 breeding season. Numbers over each bar indicate the change in colony size in 2016 compared to the average colony size prior to tern management in the Columbia Plateau region (<2014).

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 2016. Map 4 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
3/07-3/13	0	0	0	0	0	0	0	0	0	0	0	0
3/14-3/20	40	40	0	0	0	0	0	0	0	0	0	0
3/21-3/27	588	84	0	0	0	0	0	0	0	0	0	0
3/28-4/03	864	123	0	0	0	0	0	0	0	0	0	0
4/04-4/10	3154	451	0	0	0	0	0	0	0	0	0	0
4/11-4/17	1526	218	0	0	0	0	0	2	0	0	0	0
4/18-4/24	1653	236	0	0	0	9	5	8	0	14	0	7
4/25-5/01	1117	160	0	0	0	8	0	1	0	10	0	2
5/02-5/08	935	134	0	0	0	2	0	0	0	1	0	0
5/09-5/15	934	133	0	0	0	1	0	0	0	0	0	0
5/16-5/22	982	140	0	0	0	0	0	0	0	1	0	0
5/23-5/29	691	99	0	0	0	0	0	0	0	0	0	0
5/30-6/05	897	128	0	0	2	1	0	1	0	15	0	6
6/06-6/12	1754	251	22	1	35	2	61	2	0	7	0	18
6/13-6/19	1328	190	21	0	30	1	31	3	0	0	0	3
6/20-6/26	1490	213	7	0	25	0	28	4	0	0	0	6
6/27-7/03	1509	216	2	0	28	2	35	9	0	0	0	36
7/04-7/10	1483	212	12	0	25	15	80	9	0	0	0	62
7/11-7/17	2221	317	17	0	37	33	89	0	0	0	0	24
7/18-7/24	1018	145	24	7	44	17	50	0	0	0	0	18
7/25-7/31	584	117	12	0	51	9	28	0	0	0	0	3
3/07-3/13	0	0	0	0	0	0	0	0	0	0	0	0

Table 2. Caspian tern eggs collected under permit on Goose Island in 2016.

NestID	Egg #	Date	Time	Country	State	Waterbody	Location	Nest Location
1	1	4/24/2016		USA	WA	Potholes Reservoir	Goose Island	NW Rocks
2	2	5/17/2016		USA	WA	Potholes Reservoir	Goose Island	NW Main
2	3	5/17/2016		USA	WA	Potholes Reservoir	Goose Island	NW Main
4	4	6/20/2016		USA	WA	Potholes Reservoir	Goose Island	NW Main

Table 3. Weekly estimates of cumulative duration (minutes) required to deter gulls from landing on Crescent Island in 2016.

Week	Weekly Hazing Effort (m)	Average Hazing Effort (m/d)
3/07-3/13	0	0
3/14-3/20	0	0
3/21-3/27	0	0
3/28-4/03	0	0
4/04-4/10	0	0
4/11-4/17	304	43
4/18-4/24	353	50
4/25-5/01	373	53
5/02-5/08	80	11
5/09-5/15	35	9
5/16-5/22	30	8
5/23-5/29	5	5
5/30-6/05	0	0
6/06-6/12	0	0
6/13-6/19	0	0
6/20-6/26	0	0
6/27-7/03	0	0
7/04-7/10	0	0
7/11-7/17	0	0
7/18-7/24	0	0

Table 4. Summary of sites where Caspian terns were detected during aerial surveys in 2016 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	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
26-Apr	Island Near Steamboat Rocks Park (Banks Lake)	1	0	Sand	Loafing	47.860321° -119.119763°
16-May	Twinning Island	13	6	Rock/Sand	Attended Nests	47.625189° -119.302795°
26-Apr	Lenore Lake	3	0	Gravel/Rock	Loafing	47.479995 -119.523975
16-May	Lenore Lake	35	20	Gravel/Rock	Attended Nests	47.479995 -119.523975
27-Jun	Lenore Lake	48	39	Gravel/Rock	Nestlings	47.479995 -119.523975
26-Apr	North Potholes CATE colony	8	0	Sand	Loafing	47.034306° -119.326967°
16-May	North Potholes CATE colony	90	49	Sand	Attended Nests	47.034306° -119.326967°
27-Jun	North Potholes CATE colony	26	0	Sand	Loafing	47.034306° -119.326967°
26-Apr	North Potholes Islands	5	0	Sand/Shrub	Loafing	47.033181° -119.322094°
27-Jun	North Potholes Islands	56	0	Sand	Loafing	47.028956° -119.391703°
26-Apr	Marsh Unit 1	8	0	Sand/Mud	Loafing	46.954728 -119.261882
16-May	Marsh Unit 1	2	0	Sand/Mud	Loafing	46.954728

						-119.261882
17-May	Harper Island	4	3	Gravel/Rock/Sand	Loafing	47.248105 -118.085808

Columbia River

Survey Date	Site Name	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
16-May	The Dalles Dam	1	0	Rock	Loafing	45.604737° -121.149531°
27-Jun	Three-mile Canyon Island	14	0	Rock/Gravel	Loafing	45.817758° -119.958306°
26-Apr	Crow Butte (Upstream Tip)	2	0	Sand	Loafing	45.854923 -119.803397
27-Jun	Crow Butte (Upstream Tip)	15	0	Sand	Loafing	45.854923 -119.803397
26-Apr	Blalock Islands - Long Island	350	122	Gravel	Attended Nests	45.895579 -119.645708
16-May	Blalock Islands - Long Island	629	248	Gravel	Attended Nests	45.895579 -119.645708
27-Jun	Blalock Islands - Long Island	286	185	Gravel	Nestlings	45.895579 -119.645708
26-Apr	Blalock Islands - Middle Island	250	101	Gravel	Attended Nests	45.895385 -119.646652
16-May	Blalock Islands - Middle Island	395	165	Gravel	Attended Nests	45.895385 -119.646652
27-Jun	Blalock Islands - Middle Island	141	62	Gravel	Nestlings	45.895385

						-119.646652
26-Apr	Blalock Islands - Southern Island	9	0	Gravel	Attended Nests	45.894784 -119.650418
16-May	Blalock Islands - Southern Island	50	2	Gravel	Attended Nests	45.894784 -119.650418
26-Apr	Blalock Islands - Sand Island (Beach)	75	5	Sand	Attended Nests	45.897201° -119.636753°
16-May	Blalock Islands - Sand Island (Beach)	62	0	Sand	Loafing	45.897201° -119.636753°
16-May	Blalock Islands - Sand Island (Downstream Tip)	30	0	Sand	Loafing	45.889850° -119.644458°
26-Apr	Blalock Islands - Rock Island	80	6	Gravel	Attended Nests	45.909593° -119.628208°
16-May	Blalock Islands - Rock Island	14	0	Gravel	Loafing	45.909593° -119.628208°
26-Apr	Paterson Slough (Gravel Island)	2	0	Gravel	Loafing	45.929542 -119.552578
26-Apr	Irrigon	43	0	Sand/Rock	Loafing	45.912185° -119.486833°
16-May	Irrigon	19	0	Sand/Rock	Loafing	45.911972° -119.485757°
27-Jun	Rocks below McNary Dam	4	0	Rock	Loafing	45.911972° -119.485757°
26-Apr	Warehouse Beach	17	0	Rock	Loafing	45.922336° -119.149756°
16-May	Warehouse Beach	39	0	Rock	Loafing	45.922552 -119.139231
27-Jun	Warehouse Beach	5	0	Rock	Loafing	45.922552 -119.139231
26-Apr	Walla Walla River Delta	47	0	Mud	Loafing	46.070197 -118.915324

16-May	Walla Walla River Delta	35	0	Mud	Loafing	46.070197 -118.915324
27-Jun	Walla Walla River Delta	58	0	Mud	Loafing	46.070197 -118.915324
16-May	Badger Island (Upstream Tip)	14	0	Gravel	Loafing	46.113546° -118.940861°
26-Apr	Finley Downstream	14	0	Gravel	Loafing	46.142094° -118.992930°
27-Jun	Finley Downstream	1	0	Gravel	Loafing	46.142094° -118.992930°
26-Apr	Finley Upstream	2	0	Gravel	Loafing	46.144038° -118.993622°
27-Jun	Finley Upstream	5	0	Gravel	Loafing	46.144038° -118.993622°
27-Jun	Foundation Island (Downstream Tip)	2	0	Gravel	Loafing	46.163842 -118.994773
16-May	Foundation Island (Upstream Tip)	11	0	Gravel	Loafing	46.171934 -119.004152
27-Jun	Indian Island	1	0	Sand	Loafing	46.203036° -119.056235°
27-Jun	Wooded Island	1	0	Gravel	Loafing	46.432561° -119.266223°
26-Apr	Unnamed Island below Locke Island	11	0	Gravel	Loafing	46.640530° -119.411294°
16-May	Unnamed Island below Locke Island	4	0	Gravel	Loafing	46.631242° -119.411757°
27-Jun	Unnamed Island below Locke Island	7	0	Gravel	Loafing	46.631242° -119.411757°
26-Apr	Unnamed Island above Locke Island	67	0	Gravel	Loafing	46.7138 -119.486494
16-May	Unnamed Island above Locke Island	39	0	Gravel	Loafing	46.7138

						-119.486494
16-May	Island B	14	0	Gravel	Loafing	46.702048° -119.541793°
26-Apr	Cabin Island	37	0	Gravel	Loafing	46.657398° -119.914439°
27-Jun	Desert Aire	8	0	Gravel	Loafing	46.695709° -119.944071°
16-May	Shoreline Rocks below Wanapum Dam	1	0	Rock	Loafing	46.838878° -119.951987°
27-Jun	Near Shore of Brewster	5	0	Gravel	Loafing	48.085915° -119.708883°

Snake River

Survey Date	Site Name	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/ Longitude
27-Apr	Shoreline Rocks near Dalton Lake	2	0	Rock	Loafing	46.293021° -118.802726°
17-May	Nearshore rocks near Ayer Rd.	10	0	Gravel	Loafing	46.603984° -118.323875°
27-Apr	Spit across from Little Goose Bay	6	0	Gravel	Loafing	46.590612° -117.914652°
17-May	Spit across from Little Goose Bay	3	0	Gravel	Loafing	46.590612° -117.914652°
17-May	Rocks below Central Ferry Bridge	1	0	Rock	Loafing	46.626401° -117.811577°
28-Jun	Rocks below Central Ferry Bridge	7	0	Rock	Loafing	46.627678°

						-117.814335°
27-Apr	Almota Island	5	0	Gravel	Loafing	46.688905 -117.455804
27-Apr	Clarkson Marina	5	0	Shallow Water	Loafing	46.421723° -117.073748°
28-Jun	Submerged concrete slab below SR-128 Bridge (Clarkston)	2	0	Concrete	Loafing	46.424049° -117.069408°

Table 5. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the Columbia Plateau region during the 2016 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
Blalock Is. (Columbia River)	6	110	43	104	79	136	20	6	26	45	677	483
Twinning Is. (Banks Lake)	0	23	31	27	61	34	19	22	13	67	64	6
Harper Is. (Sprague Lake)	7	7	0	11	4	4	4	30	1	8	10	3
Unnamed Is. (Lenore Lake)	0	0	0	0	0	0	0	0	0	2	16	39
Unnamed Is. (Potholes Res.)	0	0	0	0	0	0	0	0	0	0	0	144

Table 6. Numbers of banded Caspian terns resighted in Potholes Reservoir in 2016 and the colony locations where they were originally marked with uniquely engraved alphanumeric color bands during 2005-2015. Potholes Reservoir includes Goose Island and small islands in north Potholes.

Colony where banded	Banded as adults	Banded as chicks	Total
Goose Island	75	57	132
Crescent Island	4	10	14
East Sand Island	0	2	2
Malheur Lake	0	2	2
Bellingham	0	2	2
Brooks Island	0	1	1
Total	**79**	**74**	**153**

Table 7. Numbers of banded Caspian terns resighted at Blalock Islands area in 2016 and the colony locations where they were originally marked with uniquely engraved alphanumeric color bands during 2005-2015. Blalock Islands area includes loafing site in Irrigon.

Colony where banded	Banded as adults	Banded as chicks	Total
Crescent Island	126	170	296
Goose Island	103	81	184
Sheepy Lake	0	10	10
East Sand Island	0	9	9
Malheur Lake	0	8	8
Crump Lake	1	2	3
Total	**230**	**280**	**510**

Table 8. Numbers of banded Caspian terns seen in Potholes Reservoir area in 2015 and resighted in 2016 at breeding or non-breeding sites. Terns were banded in 2005-2015 with color bands engraved with unique alphanumeric codes. A total of 171 banded terns were seen in Potholes Reservoir area in 2015 and resighted in 2016 again in Potholes Reservoir or elsewhere; some of them were resighted at multiple locations in 2016.

Location where resighted in 2016	Banded as adults	Banded as chicks	Total
Potholes Reservoir*	63	45	108
Blalock Islands area**	64	29	93
Lenore Lake	12	3	15
Priest Rapids***	8	6	14
Tule Lake	2	2	4
Everett (Coastal Washington)	2	3	5
East Sand Island	1	1	2
Hanford Reach	1	0	1
Ice Harbor Dam	0	1	1
Summer Lake	0	1	1
Crump Lake	0	1	1
Total	**153**	**92**	**245**

* Potholes Reservoir includes Goose Island and islands in North Potholes Reservoir.
** Blalock Islands area includes Blalock Islands and a loafing site in Irrigon.
*** Priest Rapids includes Desert Aire and Cabin Island.

Table 9. Numbers of banded Caspian terns seen at Blalock Islands in 2015 and resighted in 2016 at breeding or non-breeding sites. Terns were banded in 2005-2015 with color bands engraved with unique alphanumeric codes. A total of 408 banded terns were seen at Blalock Islands in 2015 and resighted in 2016 again at Blalock Islands or elsewhere; some of them were resighted at multiple locations in 2016.

Location resighted in 2016	Banded as adults	Banded as chicks	Total
Blalock Islands area*	185	182	367
Potholes Reservoir**	43	16	59
East Sand Island	12	9	21
Lenore Lake	8	1	9
Everett (Coastal Washington)	2	6	8
Priest Rapids***	4	2	6
McNary Pool****	4	2	6
Ice Harbor Dam	5	0	5
Tule Lake	1	4	5
Tongue Point Pier (Columbia River estuary)	1	0	1
Total	**265**	**222**	**487**

* Potholes Reservoir includes Goose Island and islands in North Potholes Reservoir.
** Blalock Islands area includes Blalock Islands and a loafing site in Irrigon.
*** Priest Rapids includes Desert Aire and Cabin Island.
**** McNary Pool includes Hanford Reach, Snake River Delta, and mouth of Walla Walla Delta.

Table 10. Inter-regional movement probabilities of Caspian terns between 2015 and 2016. Data used in movement probability estimates were from terns banded as adults during 2005-2015 and re-sighted during 2006-2016. The numbers of individuals that moved between 2015 and 2016 were estimated from movement probabilities between those years multiplied by estimated numbers of adult terns present at source regions in 2015.

Source region	Receiving region	Movement probabilities (%)	Estimated number of individuals that moved
Columbia Plateau region	Columbia River estuary	3.4	52
Columbia River estuary	Columbia Plateau region	1.5	189
Corps-constructed islands	Columbia Plateau region	17.7	375
Corps-constructed islands	Columbia River estuary	11.0	233

Table 11. Colony sizes and annual 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 2007-2015 (data from BRNW 2015-2016). Colony size is depicted as the number of breeding pairs. NA denotes colonies that were not scanned for PIT tags in each year or where sample sizes of PIT-tagged smolts interrogated passing dams were too small (< 500) to generate reliable predation rate estimates.

ESU/DPS-specific Predation Rates by Goose Island Caspian Terns in Potholes Reservoir

Year	Colony Size	UCR Steelhead	UCR Spring 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% (0-0.1)	<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[1]	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -
Average		**14.3% (12.7-16.3)**	**2.1% (1.4-2.9)**	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**
Average Per Capita		**0.039% (0.034-0.045)**	**0.004% (0.003-0.007)**	**<0.001%**	**<0.001%**	**<0.001%**	**<0.001%**

ESU/DPS-specific Predation Rates by Crescent Isalnd Caspian Terns in McNary Reservoir

Year	Colony Size	UCR Steelhead	UCR Spring 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	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -
Average		**2.4% (2.2-2.8)**	**0.5% (0.3-0.8)**	**3.9% (3.5-4.6)**	**0.7% (0.6-0.8)**	**0.8% (0.7-1.0)**	**1.1% (0.7-1.3)**
Average Per Capita		**0.006% (0.005-0.008)**	**0.001% (0.001-0.002)**	**0.011% (0.009-0.013)**	**0.002% (0.001-0.002)**	**0.002% (0.002-0.003)**	**0.003% (0.002-0.004)**

ESU/DPS-specific Predation Rate by Blalock Island Caspian Terns in John Day Reservoir

Year	Colony Size	UCR Steelhead	UCR Spring 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%	0.3% (0-2.0)
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	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -
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)
Average		**1.0% (0.8-1.3)**	**0.1% (0.1-0.2)**	**1.0% (0.9-1.3)**	**0.2% (0.2-0.3)**	**0.1% (0.1-0.2)**	**0.4% (0.3-0.6)**
Average Per Capita		**0.010% (0.008-0.013)**	**0.003% (0.002-0.004)**	**0.010% (0.008-0.012)**	**0.004% (0.004-0.005)**	**0.003% (0.003-0.004)**	**0.005% (0.003-0.010)**

[1] Number of breeding pairs that presisted throughout the nesting season; a total of 39 nesting attempts were thwarted by researchers and an average 17 adult terns were observed on Goose Island during the 2015 smolt run (see BRNW 2016).

Table 12. Predicted annual predation rates (95% Prediction Intervals) for different Caspian tern colony sizes. Predicted predation rates were based on average per capita predation rates during 2007-2015 (see Table 11). Colony size is depicted as the number of breeding pairs. Predicted predation rates are shown for ESA-listed salmonid populations (ESU/DPS) originating from the Snake River (SR) and Upper Columbia River (UCR). Highlighted (grey rows) predation rates are based on actual Caspian tern colony counts in 2016. All other estimates are for hypothetical colony sizes.

	ESU/DPS-specific Predation Rates by Goose Island Caspian Terns in Potholes Reservoir					
Colony Size	UCR Steelhead	UCR Spring Chinook	SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
3 [1]	**0.1% (0.1-0.2)**	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**
5 [2]	**0.2% (0.2-0.3)**	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**
20	0.8% (0.7-0.9)	0.1% (0.1-0.1)	<0.1%	<0.1%	<0.1%	<0.1%
40	1.6% (1.4-1.8)	0.2% (0.1-0.3)	<0.1%	<0.1%	<0.1%	<0.1%
60	2.3% (2.0-2.7)	0.3% (0.2-0.4)	<0.1%	<0.1%	<0.1%	<0.1%
80	3.1% (2.7-3.6)	0.4% (0.2-0.6)	<0.1%	<0.1%	<0.1%	<0.1%
100	3.9% (3.4-4.5)	0.4% (0.3-0.7)	<0.1%	<0.1%	<0.1%	<0.1%
150	5.9% (5.1-6.8)	0.7% (0.4-1.1)	<0.1%	<0.1%	<0.1%	<0.1%
200	7.8% (6.8-9.1)	0.9% (0.5-1.4)	<0.1%	<0.1%	<0.1%	<0.1%
250	9.8% (8.5-11.3)	1.1% (0.7-1.8)	<0.1%	<0.1%	<0.1%	<0.1%
300	11.7% (10.2-13.6)	1.3% (0.8-2.1)	<0.1%	<0.1%	<0.1%	0.1% (0-0.2)
350	13.7% (11.9-15.9)	1.6% (0.9-2.5)	<0.1%	<0.1%	<0.1%	0.1% (0-0.2)
400	15.6% (13.6-18.1)	1.8% (1.1-2.8)	<0.1%	<0.1%	<0.1%	0.1% (0-0.2)
450	17.6% (15.3-20.4)	2.0% (1.2-3.1)	<0.1%	<0.1%	<0.1%	0.1% (0-0.2)
500	19.5% (17.0-22.7)	2.2% (1.3-3.5)	<0.1%	<0.1%	<0.1%	0.1% (0-0.3)

	ESU/DPS-specific Predation Rates by Crescent Island Caspian Terns in McNary Reservoir					
Colony Size	UCR Steelhead	UCR Spring Chinook	SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
0	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**	**<0.1%**
20	0.1% (0.1-0.2)	<0.1%	0.2% (0.2-0.3)	<0.1%	<0.1%	<0.1%
40	0.3% (0.2-0.3)	<0.1%	0.4% (0.4-0.5)	<0.1%	<0.1%	0.1% (0.1-0.2)
60	0.4% (0.3-0.5)	0.1% (0-0.2)	0.6% (0.5-0.8)	<0.1%	0.1% (0.1-0.2)	0.2% (0.1-0.2)
80	0.5% (0.4-0.6)	0.1% (0.1-0.2)	0.9% (0.7-1)	0.1% (0.1-0.2)	0.2% (0.2-0.3)	0.2% (0.2-0.3)
100	0.6% (0.5-0.8)	0.2% (0.1-0.3)	1.1% (0.9-1.3)	0.2% (0.1-0.2)	0.2% (0.2-0.3)	0.3% (0.2-0.4)
150	1.0% (0.8-1.2)	0.2% (0.1-0.4)	1.6% (1.4-1.9)	0.2% (0.2-0.3)	0.4% (0.3-0.5)	0.4% (0.3-0.6)
200	1.3% (1.1-1.6)	0.3% (0.1-0.6)	2.2% (1.8-2.6)	0.3% (0.3-0.4)	0.5% (0.4-0.6)	0.6% (0.4-0.8)
250	1.6% (1.4-1.9)	0.4% (0.2-0.7)	2.7% (2.3-3.2)	0.4% (0.3-0.5)	0.6% (0.5-0.8)	0.7% (0.5-1)
300	1.9% (1.6-2.3)	0.5% (0.2-0.9)	3.2% (2.7-3.9)	0.5% (0.4-0.6)	0.7% (0.6-0.9)	0.8% (0.6-1.2)
350	2.3% (1.9-2.7)	0.5% (0.2-1.0)	3.8% (3.2-4.5)	0.6% (0.5-0.7)	0.9% (0.7-1.1)	1.0% (0.7-1.4)
400	2.6% (2.2-3.1)	0.6% (0.3-1.2)	4.3% (3.6-5.2)	0.6% (0.5-0.8)	1.0% (0.8-1.2)	1.1% (0.8-1.6)
450	2.9% (2.5-3.5)	0.7% (0.3-1.3)	4.8% (4.1-5.8)	0.7% (0.6-0.9)	1.1% (0.9-1.4)	1.3% (0.9-1.8)
500	3.2% (2.7-3.9)	0.8% (0.3-1.5)	5.4% (4.5-6.5)	0.8% (0.7-1.0)	1.2% (1-1.6)	1.4% (1.0-2.0)

[1] Average daily number of adult terns observed during the smolt outmigration period (see Methods)

[2] Number of nests intiated (see Methods)

Table 12. Continued…

Colony Size	ESU/DPS-specific Predation Rate by Blalock Island Caspian Terns in John Day Reservoir					
	UCR Steelhead	UCR Spring Chinook	SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
20	0.2% (0.2-0.3)	0.1% (0.1-0.1)	0.2% (0.2-0.2)	0.1% (0.1-0.1)	0.1% (0.1-0.1)	0.1% (0.1-0.2)
40	0.4% (0.3-0.5)	0.1% (0.1-0.2)	0.4% (0.3-0.5)	0.2% (0.2-0.2)	0.1% (0.1-0.2)	0.2% (0.1-0.4)
60	0.6% (0.5-0.8)	0.2% (0.2-0.2)	0.6% (0.5-0.7)	0.3% (0.2-0.3)	0.2% (0.2-0.3)	0.3% (0.2-0.6)
80	0.8% (0.6-1.1)	0.2% (0.2-0.3)	0.8% (0.7-0.9)	0.3% (0.3-0.4)	0.3% (0.2-0.4)	0.4% (0.3-0.8)
100	1.0% (0.8-1.3)	0.3% (0.2-0.4)	1.0% (0.8-1.2)	0.4% (0.4-0.5)	0.3% (0.3-0.4)	0.5% (0.3-1.0)
150	1.5% (1.2-2.0)	0.5% (0.4-0.6)	1.4% (1.2-1.7)	0.6% (0.6-0.7)	0.5% (0.4-0.7)	0.8% (0.5-1.6)
200	2.0% (1.6-2.7)	0.6% (0.5-0.8)	1.9% (1.7-2.3)	0.8% (0.7-0.9)	0.7% (0.6-0.9)	1.1% (0.7-2.1)
250	2.5% (2.0-3.3)	0.7% (0.6-1.0)	2.4% (2.1-2.9)	1.0% (0.9-1.2)	0.9% (0.7-1.1)	1.3% (0.8-2.6)
300	3.1% (2.3-4.0)	0.9% (0.7-1.1)	2.9% (2.5-3.5)	1.2% (1.1-1.4)	1.0% (0.8-1.3)	1.6% (1.0-3.1)
350	3.6% (2.7-4.7)	1.0% (0.9-1.3)	3.4% (2.9-4.0)	1.4% (1.3-1.6)	1.2% (1.0-1.5)	1.8% (1.1-3.6)
400	4.1% (3.1-5.3)	1.2% (1.0-1.5)	3.8% (3.3-4.6)	1.6% (1.5-1.9)	1.4% (1.1-1.7)	2.1% (1.3-4.1)
483	***4.9% (3.8-6.4)***	***1.4% (1.2-1.8)***	***4.6% (4.0-5.6)***	***2.0% (1.8-2.3)***	***1.6% (1.4-2.1)***	***2.6% (1.6-5.0)***
500	5.1% (3.9-6.7)	1.5% (1.2-1.9)	4.8% (4.1-5.8)	2.1% (1.8-2.3)	1.7% (1.4-2.2)	2.6% (1.6-5.2)

APPENDIX A: BEST MANAGEMENT PRACTICES

The goal of management on Goose Island 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 2016 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 2014-2015 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.

The Bureau of Reclamation (owner of Goose Island) is planning to test additional management actions for precluding gulls and terns from nesting on Goose Island in 2016 and 2017, including propane cannons, water cannons, predator decoys, bird distress call systems, and windsocks. These test actions are limited in use and until gulls begin laying eggs on the island and will be managed directly by Reclamation. 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 2014-2015 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 the managed islands 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 (stakes, ropes, and flagging at both islands and fabric fencing on Crescent Island) will be installed to cover essentially all of 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 2014-2015 indicated that even with intensive human hazing, gulls are likely to ultimately establish nests and lay eggs on the managed islands, 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 so more passive dissuasion is being added to Goose Island for a total of ca. 3.5 acres of rope and flagging as a well as double roping to the perimeter of the dissuaded areas.

We have also developed best management practices (BMPs) for minimizing disturbance during hazing of gulls and Caspian terns to other migratory bird species that nest on the two managed islands. Canada geese are known to nest on both 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 Pete Loschl and/or Dan Roby 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 Pete Loschl or Dan Roby. 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 can be stored temporarily in a refrigerator, for eventual transport to Oregon State University for further analyses.

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 because of an observer approaching the suspected tern nest. 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 either of the managed islands, whether they are collected, will be reported to Pete Loschl and/or Dan Roby 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 either of 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 one or more 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 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 7 April 2016. 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 at approximately 3 pm on 7 April 2016.

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. The pumping station is operated by Sandpiper Farms, of Paterson, WA. Sandpiper Farms generously granted RTR permission to access the site to deploy the system, and to return to the site multiple times throughout the project to conduct system inspection and maintenance. *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/). The CDMALink Data Collection Platform (DCP) and the CS451 are powered by a 5 Watt solar panel with a sealed lead acid battery backup power supply. Water level readings are transmitted by the DCP via a wireless cellular network.

Installation Methods – Water level elevations are reported 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 (*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. 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 (*Figure 3*).

Figure 3. Water level data collection platform with RAIL point marked.

The Corps had previously established a temporary benchmark (TBM) above the project area, 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 to measure vertical differences from each point to the TCP.

Results – The OPUS processing of the GNSS data collected on TCP provided horizontal and vertical positions relative to the North American Datum of 1983 NA2011 (Epoch 2010.000) datum (NAD 83(2011)) with an estimated uncertainty of 0.013 m (0.04 ft) over 3.5 hours of observations. The ellipsoid height 1988 (NAVD 88) 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 were applied:

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

Table 1 summarizes the elevation of each of the control points for each datum described above.

Table 1. 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) was established on an arbitrary datum (station datum) and 11 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 79.612 m (261.19 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 261.19 ft to adjust to NAVD 88 (or 257.85 for NGVD 29)

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). The recorded water level 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 was delivered to the Corps in csv format weekly. Each weekly data delivery consisted of water level measurements for a seven-day period, starting at 00:00:00 (UTC) Sunday morning and ending at 23:55:00 (UTC) the following Saturday night. Data fields included: *Date* (mm/dd/yyyy), *UTC* (time in UTC), *Ft_88* (elevation in ft NAVD 88), and *Ft_29* (elevation in ft NGVD 29). *Figure 5* shows a sample weekly data file.

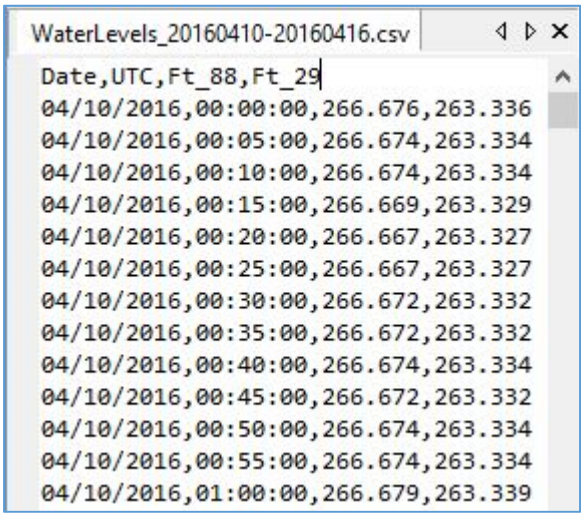


Figure 5. Sample weekly water level data.