USACE – Walla Walla District

Implementation of the Inland Avian Predation Management Plan

2014 Final Report

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This Final Report has been prepared for the purpose of assessing project accomplishments associated with Contract # W912EF-14-C-0003

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Submitted: September 30, 2014
1st Revision: March 15, 2015
2nd Revision: July 3, 2015
3rd Revision: July 4, 2015

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EXECUTIVE SUMMARY

In 2014, the U.S. Army Corps of Engineers - Walla Walla District and U.S. Bureau of Reclamation began implementation of the Inland Avian Predation Management Plan (IAPMP) as means to reduce predation by Caspian terns on U.S. Endangered Species Act (ESA) listed salmon stocks in the Columbia River basin (USACE 2014). The primary management objective in 2014 was to reduce the size of the Caspian tern colony on Goose Island in Potholes Reservoir to less than 40 breeding pairs. To accomplish this task, extensive passive dissuasion (stakes, ropes, and flagging) was erected in potentially suitable Caspian tern nesting habitat on Goose Island prior to the 2014 nesting season. Ultimately, about 2.4 acres, or over half of the upland area of Goose Island, was covered by passive dissuasion. An effort was also made to prevent any nesting by California and ring-billed gulls on Goose Island, on the theory that nesting gulls would be an attractant for prospecting Caspian terns and could limit abilities to dissuade Caspian terns. Once Caspian terns and gulls arrived on Goose Island to initiate nesting, human hazing was used to actively dissuade both terns and gulls from nesting anywhere on Goose Island. California gulls and, especially, ring-billed gulls quickly adapted and acclimated to the passive and active dissuasion, and initiated nesting (laid eggs) despite our efforts. Once gulls laid eggs, hazing gulls that were attending eggs was precluded due to the risk of gull nest 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 preferred Caspian tern nesting habitat at Goose Island, and active dissuasion (hazing) using a green laser, only three pairs of Caspian terns laid eggs on Goose Island and all three eggs were collected under permit soon after they were laid. Consequently, despite having little effect on the number of gulls nesting on Goose Island, passive dissuasion and active hazing succeeded in preventing any successful nesting by Caspian terns on Goose Island in Potholes Reservoir. However, some Caspian terns that were precluded from nesting on Goose Island were highly motivated to nest in the area, and a small satellite colony of Caspian terns formed on a rocky islet near Goose Island where no Caspian tern nesting activity had previously been recorded. This islet, dubbed “Northwest Rocks,” eventually attracted as many as 156 breeding pairs of Caspian terns, which nested at high density (1.67 nests/m^2) amongst earlier-nesting gulls. The Northwest Rocks had not been considered potential nesting habitat for the Goose Island Caspian tern colony, and as such passive dissuasion and active hazing of Caspian terns attempting to nest on Northwest Rocks were not planned for the 2014 nesting season as part of implementing initial Phase 1 components of the IAPMP. Consequently, managers decided not to attempt to dissuade Caspian terns from nesting on Northwest Rocks in 2014, and the new satellite colony ultimately produced about 46 young Caspian terns.

Caspian terns attempted to nest at four other previously used colony sites in 2014, and perhaps a fifth site where nesting Caspian terns had not previously been recorded.

Extensive aerial and ground searches throughout the region failed to detect any additional Caspian tern nesting activity. The four previously used active colony sites were: (1) Crescent Island in McNary Pool in the Columbia River, (2) the Blalock Islands in John Day Pool in the Columbia River, (3) Twinning Island in Banks Lake, and (4) Harper Island in Sprague Lake. The potential new Caspian tern breeding site was on a small island in Lenore Lake, where a small gull colony exists. Of these five sites, only the colonies at Crescent Island and the Blalock Islands succeeded in raising any young. Crescent Island was the site of by far the largest Caspian tern breeding colony in the Columbia Plateau region during 2014. A total of about 474 breeding pairs of Caspian terns attempted to nest on Crescent Island in 2014, nearly identical to the average colony size during 2000-2013 (461 breeding pairs). Average nesting success at the Crescent Island Caspian tern colony was about 0.33 young raised per breeding pair, slightly below the long-term average (0.52 young raised per breeding pair in 2000-2013). Resighting of banded Caspian terns on the Crescent Island tern colony suggested that much of the increase in colony size at Crescent Island was related to management actions at Goose Island to reduce colony size there, causing some Caspian terns to immigrate to the Crescent Island colony. Despite the increase in the size of the Crescent Island Caspian tern colony in 2014, the overall size of the Caspian tern breeding population in the Columbia Plateau region did not increase, and may have declined slightly from about 773 breeding pairs in 2013 to about 755 breeding pairs in 2014.

Based on average per capita predation rates by Caspian terns nesting at various colonies in the Columbia Plateau region during 2007-2013, predicted predation rates were less than 2% (the goal of the IAPMP) on most, but not all, ESA-listed salmonid populations in 2014. Specifically, predicted predation rates on ESA-listed Upper Columbia River steelhead remained above 2% (7.0%, 95% PI: 4.1-12.4) for Caspian terns nesting at Potholes Reservoir because of the new satellite colony of Caspian terns that formed on Northwest Rocks adjacent to Goose Island. Also, predicted predation rates on ESA-listed Snake River steelhead (5.1%, 95% PI: 2.8-8.8) and Upper Columbia River steelhead (2.8%, 95% PI: 1.2-4.7) by Caspian terns nesting on Crescent Island exceeded 2%. Because of the small size (< 100 pairs) of other Caspian tern breeding colonies in the Columbia Plateau region, including at the Blalock Islands where 45 pairs attempted to nest in 2014, predicted predation rates on ESA-listed salmonid ESUs/DPSs by Caspian terns nesting at other colonies were negligible (< 0.5% per ESU/DPSs).

INTRODUCTION

Avian predation on juvenile anadromous salmonids during out-migration is considered potentially limiting to the recovery of populations from the Columbia River Basin that are listed under the U.S. Endangered Species Act (ESA; Lyons et al. 2011a,b). As part of meeting 2008/2010 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) requirements in regards to Reasonable and Prudent Alternatives (RPAs) 47 and 68 (NOAA 2008, 2010), the U.S. Army Corps of Engineers - Walla Walla District and the U.S. Bureau of Reclamation are in the process of implementing an Inland Avian Predation Management Plan (IAPMP; USACE 2014). This plan outlines steps that will be taken to dissuade Caspian terns (*Hydroprogne caspia*) from nesting on two islands in the Columbia Plateau region where nesting Caspian terns are consuming high numbers of ESA-listed salmonids. The two islands of primary focus are Crescent Island in the Columbia River (just below the confluence with the Snake River) and Goose Island in Potholes Reservoir (near Moses Lake, WA), both of which are anthropogenic — Crescent Island is a dredged material disposal site and Goose Island was formed when the Potholes Reservoir impoundment was created. In order to avoid take of colonial waterbirds protected under the Migratory Bird Treaty Act (MBTA) that are not the subject of this management action, the IAPMP proposed discouraging nesting by two other species of colonial waterbirds that nest in close association with Caspian terns on Crescent and Goose islands: California gulls (*Larus californicus*) and ring-billed gulls (*L. delawarensis*).

The Columbia Plateau region of the Columbia River Basin was monitored throughout the 2014 nesting season to determine the overall success of the IAPMP, as part of implementing Phase 1 actions under the Plan. This included: (1) effectiveness monitoring of Phase 1 Caspian tern nest dissuasion efforts at Goose Island in Potholes Reservoir; (2) evaluating experimental willow stem plantings at Crescent Island for possible implementation as a Caspian tern nest dissuasion method during Phase 2; (3) monitoring at currently active and historical Caspian tern colonies and identification of incipient Caspian tern colonies forming in the region, (4) assessment of changes in numbers and distribution of nesting Caspian terns within the Columbia Plateau region, (5) assessment of inter-colony movements of color-banded Caspian terns, and (6) evaluation of Caspian tern predation rates on PIT-tagged smolts that belong to ESA-listed salmonid populations (as feasible).

The study was funded by the U.S. Army Corps of Engineers – Walla Walla District and the U.S. Bureau of Reclamation. Results from related studies, with funding from the Bonneville Power Administration, the U.S. Army Corps of Engineers – Portland District, and the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee (PRCC), are provided in a separate annual report (BRNW 2015).

STUDY AREA

The Columbia Plateau region is defined as the Columbia River from Bonneville Dam to Chief Joseph Dam, the lower Snake River from the confluence with the Columbia River to the confluence with the Clearwater River, and water bodies off the mid-Columbia and lower Snake rivers that are within tern foraging range (i.e., ~90 km) of the FCRPS (e.g., Potholes Reservoir, Banks Lake, Sprague Lake; Map 1).

SECTION 1: CASPIAN TERN MANAGEMENT ACTIVITIES

1.1. Goose Island, Potholes Reservoir

1.1.1. Passive Nest Dissuasion

Background: To deter Caspian terns from nesting at Goose Island in Potholes Reservoir during 2014, a network of passive dissuasion was constructed in February 2014, prior to the arrival of breeding Caspian terns. Following proven methods established in the Columbia River estuary (BRNW 2014), and as described in the IAPMP (USACE 2014), we erected a matrix of polypropylene rope and polyethylene flagging over historical Caspian tern nesting areas and other areas that were considered to be potentially suitable Caspian tern nesting habitat on Goose Island. The rope and flagging matrix was suspended above the ground using PVC-covered rebar stakes that were supported by concrete pier blocks placed over the surface of the island. The rebar stakes were driven into the substrate through holes in the pier blocks to provide additional stability in the event of high winds.

Methods: All passive dissuasion materials were delivered to Goose Island on 25 February using a helicopter (General Aircraft Services, Pendleton, OR) and boats. The installation of passive dissuasion was initiated on 26 February with concrete pier blocks (Mutual Materials; 12'' x 12'', 63 lbs. each) placed in a 10' x 10' grid. The center of each concrete pier blocks was drilled out vertically to accommodate short sections of ½" rebar and a 42" section of ½" PVC pipe was slipped over the rebar. Twisted polypropylene rope (1/4") was then attached to the PVC at approximately 42" above ground using clove hitch knots and further secured using UV-resistant cable ties. Ropes were fastened to PVC to form a 10' x 10' grid with each grid square also bisected diagonally with a section of rope (see USACE 2014 for grid design). Four-foot-long pieces of industrial barricade tape ("polyethylene flagging;" Mutual Industries; 3 mil) were inserted between strands of the rope at approximately 3-foot intervals, and allowed to flutter in the wind as a visual deterrent to prospecting Caspian terns. A second layer of ropes and flagging was added below the existing layer on portions of the island where Caspian terns were deemed most likely to attempt nesting. This second layer was attached to the PVC approximately 12" above ground level to deter terns and gulls from

landing outside the passive dissuasion and entering suitable nesting habitat by walking under the single layer of rope and flagging.

Initially, 1.4 acres of passive dissuasion (rope and flagging) was installed by 4 March to cover the historical Caspian tern breeding areas on Goose Island and adjacent areas, as well as any additional habitat identified by researchers as suitable Caspian tern nesting habitat. The IAPMP specified reserving some additional passive dissuasion materials, sufficient to cover one additional acre, which could be installed during the 2014 breeding season on Goose Island in the event that Caspian terns attempted to nest on other parts of Goose Island. However, because of limited success in deterring the onset of gull nesting on Goose Island using active dissuasion (human hazing; see Section 1.1.2) and concern over potential take of gull eggs while deploying additional passive dissuasion materials, the action agencies decided to deploy additional passive dissuasion materials prior to the arrival of Caspian terns. One additional acre of passive dissuasion was installed by 22 March to cover Caspian tern habitat that was considered marginal, as well as to delay the onset of gull nesting and facilitate capture efforts for Caspian terns yet to arrive at Goose Island. Areas where two layers of passive dissuasion were installed were completed on 18 April, covering a total of 0.80 acres, or one-third of the entire area on Goose Island that was covered by the rope and flagging dissuasion. Finally, 0.05 acres of passive dissuasion was installed on the far west side of Goose Island later in the nesting season after a Caspian tern nest scrape was found near that area.

In total, 1,158 pier blocks, rebar stakes, and PVC sections were installed to support the rope and flagging matrix that covered a total of 2.39 acres or ca. 51% of the upland area of Goose Island (Map 2). As directed by the action agencies, passive dissuasion materials were installed above the high water line at the time of deployment on the east and west lobes of Goose Island, but not on the rocky islets surrounding the main island. As such, no attempts were made to install passive dissuasion on Northwest Rocks, a small rocky islet to the northwest of Goose Island, where Caspian terns ultimately successfully nested during the 2014 breeding season (see Section 2.1.2).

Once Caspian terns arrived at Goose Island, the former colony area on the western lobe of the island was checked at least twice daily to determine whether Caspian terns were present within the passive dissuasion areas. In addition, the entire island, including areas covered by passive dissuasion materials, was monitored daily, using boat-based surveys, to determine if Caspian terns were prospecting to nest in other areas of Goose Island, both those with passive dissuasion and those without.

Results/Conclusions: In 2014, the installed passive dissuasion materials were successful in preventing Caspian terns from nesting on all areas of historical nesting activity on Goose Island, as well as anywhere else where passive dissuasion materials were installed. These results confirmed that passive visual deterrents (i.e., ropes and flagging suspended above the ground) provide a semi-permanent and targeted means to

prevent Caspian terns from nesting in areas of suitable nesting habitat. The results also demonstrated that the installed passive dissuasion had little deterrent effect on non-target species (i.e., California and ring-billed gulls, and Canada geese), which nested within and immediately adjacent to areas with passive dissuasion. This difference between Caspian terns and other island-nesting species of waterbirds in their susceptibility passive dissuasion techniques should be considered if disturbance to other protected migratory birds is a concern.

At no time during the 2014 nesting season were Caspian terns observed within any of the areas on Goose Island that were covered with passive dissuasion materials. While Caspian terns did show interest in nesting on parts of Goose Island outside the passive dissuasion area (Map 2), prospecting was limited to small areas of marginal nesting habitat on the western lobe where no passive dissuasion was erected. Although Caspian terns were successfully hazed from these areas using active dissuasion techniques (see Section 1.1.2), future management actions should consider the installation of additional passive dissuasion to cover even marginal Caspian tern nesting habitat on Goose Island. In addition, implementing active and passive dissuasion measures on the Northwest Rocks should be considered to deter Caspian terns from nesting there in the future.

While dissuasion measures were ultimately successful at deterring Caspian tern nesting on Goose Island in 2014, results of the passive and active dissuasion employed on Goose Island should consider the use of a new nesting location by Caspian terns, 125 m from the main island, on Northwest Rocks. The successful colonization and raising of young by Caspian terns on Northwest Rocks likely reduced the frequency, duration, and intensity of prospecting for nest sites by Caspian terns on the main island. If additional passive dissuasion is erected on Northwest Rocks prior to the 2015 nesting season, but not on the main Goose Island, Caspian terns may intensify nest prospecting activities on Goose Island compared to that observed in 2014.

While passive dissuasion was effective at preventing Caspian terns from nesting, neither the single-layer nor the double-layer of passive dissuasion was effective at preventing gulls from nesting on Goose Island. California and ring-billed gulls nested throughout areas covered by passive dissuasion. Using counts of mapped gulls and GIS, we determined that the density of individual gulls was higher in areas without passive dissuasion (0.79 gulls/m^2) compared to areas covered in passive dissuasion (0.52 gulls/m^2), and gull densities were nearly identical between areas covered by a single-layer of passive dissuasion (0.52 gulls/m^2) and a double-layer of passive dissuasion (0.53 gulls/m^2). Interestingly, the densities of gulls in passively dissuaded and open areas in 2014 were similar to those observed in those same areas during 2013, when no areas of Goose Island were covered in ropes and flagging; in 2013, an average of 0.50 gulls/m^2 were counted in the area covered by a single-layer of passive dissuasion in 2014, 0.54 gulls/m^2 were counted in the area covered by a double-layer of passive dissuasion in 2014, and 0.67 gulls/m^2 were counted in areas of Goose Island without any passive dissuasion materials (BRNW 2014). Thus, we found very little evidence that the passive

dissuasion installed in 2014 deterred nesting by gulls on Goose Island, or altered gull use of the island.

In the process of selecting and deploying effective and appropriate passive dissuasion materials, researchers tested various types of flagging materials that varied in thickness and construction. While pier blocks, PVC tubing, rebar, and polypropylene rope are all materials that should last many years, the barricade tape (flagging) that was successfully used in 2014 deteriorated over the course of several months and was removed in August 2014 to minimize further deterioration. Action agencies should consider identifying a cost-effective alternative that may not need to be replaced following each year when passive dissuasion is implemented. Based on our experience during the 2014 nesting season, one alternative flagging material was identified that may persist with little deterioration throughout the entire breeding season. This alternative flagging material was the same twisted polypropylene rope that was tied to the PVC throughout the dissuasion matrix. The rope was cut into 4' pieces and the 4' rope lengths were inserted into the rope that was strung between the stakes. The rope was knotted to keep it in place and the hanging ends were untwisted. Installing this material on a large scale would be very labor intensive, but it would likely not have to be replaced annually. A test plot has been left in place to assess whether this alternative flagging material may be suitable for semi-permanent deployment in the future.

By far the most limiting factor associated with the passive dissuasion methods employed on Goose Island remains the use of pier blocks. Due to the sheer weight and number of blocks required to construct a passive dissuasion matrix of this scale, options for delivering, dispersing, or removing these materials (i.e., helicopter delivery and ATV dispersal) are both costly and labor intensive. The action agencies should consider alternative, simplified means to support the rope and flagging matrix in future dissuasion projects. Cost effective and potentially more long-term solutions include using metal posts driven into the ground, where possible, and small holes drilled into the bedrock to accommodate posts, where necessary.

1.1.2. Active Nest Dissuasion

Background: Active nest dissuasion activities were used to supplement passive measures for discouraging Caspian terns from nesting (see Section 1.1.1) on Goose Island in Potholes Reservoir, in accordance with the IAPMP, Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) in 2014 (USACE 2014).

Methods: Active nest dissuasion (hazing) was conducted by (1) forays into the colony by researchers, (2) approaching the shoreline of the island by boat, and (3) use of a green laser during low light conditions (collectively referred to as "active hazing"), all to disrupt nesting attempts by Caspian terns and gulls. Active hazing was restricted to the east and west lobes of the main Goose Island, where potential Caspian tern nesting habitat was most prevalent and where Caspian tern nesting had occurred in previous

years. As directed by the action agencies, researchers conducted no dissuasion of Caspian terns or gulls on the outer rocky islets surrounding Goose Island. Active hazing targeted not just prospecting Caspian terns, but also prospecting gulls with the objective of preventing or delaying the onset of egg-laying by gulls. It was believed that allowing unabated gull nest initiation on Goose Island would not only encourage Caspian terns to nest on Goose Island, but would also limit access by researchers to conduct effective active hazing of prospecting Caspian terns.

An observation blind was constructed on 28 February on the west lobe of Goose Island near the former Caspian tern colony. This blind was visited twice daily to monitor Caspian tern and gull use of the surrounding area. On March 18th a portable building and camp were installed on Goose Island (see Map 2) to allow researchers to stay overnight on the island without disturbing nesting birds. Camping on Goose Island facilitated early morning and late evening hazing that was critical for flushing prospecting Caspian terns from potential nesting areas on the main island. Evening hazing to prohibit Caspian terns from remaining on Goose Island overnight was considered especially important for deterring, or at least delaying, nest initiation.

Active hazing methods used to dissuade prospecting Caspian terns and gull, as well as the frequency of hazing sessions, were adaptively altered over the course of the breeding season. From 26 February through 12 March, forays into the colony by researchers was conducted opportunistically, both through incidental disturbance caused by researchers installing and monitoring passive dissuasion materials (see Section 1.1.1), or by intentionally hazing prospecting birds when observers walked across the island (hereafter referred to as “walk-throughs”). Hazing frequency was increased after 12 March, and daily records of hazing sessions were recorded beginning on 18 March (Table 1). Hazing sessions were conducted from 06:30 to 19:00 during most days, with a 20-min break between the end of one session and the start of the next, and with a 1-2 hour break in the afternoon. During each walk-through, any gull or goose nests observed were recorded and nests that did not contain eggs were scattered by the observer. A best management practices (BMPs) document (Appendix A), drafted on 17 March, was finalized on 4 April to formalize allowable procedures for colony monitoring, active hazing, Caspian tern egg collection, and required reporting. BMPs were initially written to minimize researcher disturbance and avoid unpermitted take of gull nests (egg loss) and were updated to avoid loss of Canada goose eggs as well.

During the period from 1 April through 11 April, active hazing conducted on the former Caspian tern colony site on the west lobe of Goose Island was scaled back in a controlled manner to facilitate Caspian tern capture for satellite tag deployment, research that was funded by the GPUD/PRCC. No Caspian tern eggs were laid on Goose Island during this capture period.

Primary techniques for active dissuasion of prospecting Caspian terns on Goose Island after April 21st were the use of a green laser (LEM 50) during low-light conditions (early

morning and late evening) from a boat, and/or using the boat itself to approach prospecting Caspian terns. The laser allowed the field crew to haze individual Caspian terns that were loafing or prospecting on Goose Island without disturbing gulls that were nesting (attending eggs) nearby. Crew also approached the island with the boat to flush Caspian terns without disturbing nearby nesting gulls. Beginning on 22 April, a combination of boat approaches and/or laser hazing was conducted over three hours in the morning, one hour in the afternoon, and three hours in the evening (weather permitting), with morning and evening hazing sessions beginning and ending at civil twilight (30 min before sunrise and 30 min after sunset, respectively). Additionally, a low scaffolding platform was installed in shallow water adjacent to the south shore of the west lobe of Goose Island on 25 April (Map 2). The platform was accessible from the researcher camp and allowed for laser hazing of a high use area by Caspian terns on the south-facing slope of Goose Island during low light conditions (at dawn and dusk) without the need for a boat. Once the active hazing schedule had been established, there were typically 5 hazing events conducted each day. The first daily hazing event was conducted from the laser platform and targeted the south-facing slope of Goose Island for a minimum of one hour, beginning at civil twilight. The second or subsequent hazing events were conducted from the boat and targeted the entire island, wherever Caspian terns were found roosting or prospecting. The second hazing event was initiated within 1 hour of the end of the first event and lasted for 2 hours. The 3rd and 4th hazing events were conducted in the early afternoon for 1 hour each, depending on the presence of prospecting Caspian terns. The 5th and final hazing event each day was conducted for 3 hours and ended at civil twilight. On 30 June, active hazing events were reduced in number and duration due to much reduced prospecting by Caspian terns on Goose Island. Morning hazing was reduced to 2 hours, beginning at 07:00 from the boat, afternoon hazing was reduced to one 30-min to 60-min event, and evening hazing was reduced to 2 hours, ending at civil twilight. During July, active hazing of Caspian terns was further reduced to 1 hour in the morning and 1 hour in the evening, with no afternoon session. The last day of active Caspian tern hazing on Goose Island was 30 July.

On occasions when Caspian terns showed an increased interest in nesting on the main Goose Island (e.g., when copulations, nest scraping, or egg-laying were observed), daytime hazing and monitoring were temporarily increased and conducted nearly continuously until breeding behaviors abated.

Under permit, a limited number of Caspian tern eggs (not to exceed 200) could be removed from nests initiated on Goose Island, if some Caspian terns laid eggs despite efforts to prevent egg-laying. Take of Caspian tern eggs was intended to enhance the prospects of successfully dissuading nest initiation and colony formation on Goose Island (see *Results/Conclusions* section for the disposition of the collected tern eggs).

Results/Conclusions: Notwithstanding the formation of an active Caspian tern breeding colony on the Northwest Rocks adjacent to Goose Island, active hazing in combination

with passive dissuasion measures were successful in deterring the formation of a breeding colony of Caspian terns on Goose Island in 2014.

For gulls, the response to active hazing during human walk-throughs conducted during daytime was to take flight briefly and then re-land in the same place or within 10 m of the person conducting the active hazing. Early in the season, gulls were most effectively hazed in the evenings. Gulls actively hazed near civil twilight would abandon Goose Island overnight, return to the island at sunrise, and remain on the island throughout the day. An increase in the frequency of active hazing sessions on 18 March to once every 20 min did not appear to reduce the numbers of gulls present on Goose Island, or delay the onset of nesting by gulls. Unlike Caspian terns, gulls habituated to human presence quickly, even when the frequency of active hazing increased. The first gull egg discovered on Goose Island during the 2014 nesting season was found on 9 April on the west lobe of Goose Island, slightly earlier than the first gull egg date reported in 2013 (12 April; BRNW 2014). By 17 April 2014, gull nests containing one or more eggs were so numerous and widely distributed across the east and west lobes of Goose Island that field personnel were unable to conduct active hazing walk-throughs while adhering to the 30-m buffer distance from gull nests with eggs required of active hazers under the BMPs.

Documented loss of gull eggs due to hazing or other researcher activities on Goose Island was limited to one ring-billed gull egg that was recorded as missing after a researcher caused a flush on the east lobe of Goose Island (Map 3) on 19 April. The egg was likely taken by a California gull after the ring-billed gull was flushed from its nest. Additionally, despite increases in numbers of active gull nests containing one or more eggs around this time, all gulls continued leaving the island at night due to evening human hazing activities. Therefore, to avoid possible loss of unattended gull eggs to nest predators overnight, evening hazing using human walk-throughs at civil twilight were discontinued on 21 April.

During the 20 weeks when hazing effort was quantified, average daily effort ranged from 110 min to 488 min, and total hazing time ranged from 360 min to 2,927 min per week (Table 1). The average weekly number of Caspian terns counted by area on Goose Island prior to the first hazing session of the day indicated that the highest area of use during the nest initiation period (mid-April to mid-June) was the south-facing slope of the west lobe (Table 1). From mid-June through July, however, as reservoir levels and nest initiations decreased, Caspian tern use of the south gravel bar, north beach, and northwest mudflat all increased (Map 4). Terns were routinely hazed from all of these areas, except northwest mudflats because this area was mostly used by adult Caspian terns and their young from the breeding colony on adjacent Northwest Rocks (Map 5). Caspian terns landed at the former main colony area on the west lobe only during the 2 weeks when ropes and flagging were removed from the former colony area during late March and early April to facilitate capture of Caspian terns for satellite-tagging, as part of a dispersal study funded by GPUD/PRCC.

During the period of Caspian tern capture (1 - 11 April), as noted in the methods section, hazing was conducted between capture events and no Caspian terns initiated nests anywhere on Goose Island during that period. Table 1 shows the average number of Caspian terns on the former colony area throughout the breeding season before, during, and after the capture period; Caspian terns were only recorded on the former colony area during the 11-day capture period.

Despite active hazing efforts on Goose Island, a total of three Caspian tern eggs were laid in three separate nest scrapes on the south-facing slope of the west lobe of Goose Island during the 2014 nesting season. These Caspian tern eggs were laid on 23 April, 7 June, and 14 June in areas where active hazing was being implemented on a daily basis. All three of these Caspian tern eggs were collected by members of the field crew. In accordance with the federal depredation permit, the collected Caspian tern eggs were offered to R.C. Faucett, Ornithology Collection Manager at the Burke Museum, University of Washington. In addition, a Caspian tern egg was discovered on Northwest Rocks adjacent to the main Goose Island on 23 April. A decision was made by the landowner (Bureau of Reclamation) to allow Caspian terns to continue to nest on that rocky islet, where more Caspian tern eggs were subsequently laid (see Section 2.1 for detailed information on this sub-colony).

In summary, the pattern of use by Caspian terns of various areas of Goose Island was influenced by placement of passive dissuasion materials, stage of the nesting season, and the implementation distribution of active hazing activities. Caspian terns were never observed roosting or prospecting within areas where passive dissuasion (ropes and flagging) had been installed. During the egg-laying period (mid- April to mid-June), Caspian terns used the south-facing slope of the west lobe of Goose Island more than any other part of the main Goose Island, and three Caspian tern eggs were laid in three separate nests scrapes in that area. The prospective Caspian tern nesting habitat on the south-facing slope that was of most interest to prospecting terns was outside the areas where passive dissuasion materials were deployed. But this area was also relatively low on the slope, and researchers were able to carefully enter the gull colony to collect the Caspian tern eggs without causing gull nests to fail, and were also able to haze other prospecting Caspian terns using the boat and laser, thereby preventing a Caspian tern colony from forming on the main island.

When evaluating the results from this study, it is important to remember that some Caspian terns successfully dissuaded from nesting on Goose Island in 2014 were allowed to nest on Northwest Rocks, a rocky islet just offshore of Goose Island. The outcome of efforts to dissuade Caspian terns from nesting on the main Goose Island described here could have been different if Caspian terns had not been allowed to nest on Northwest Rocks (i.e., Caspian terns may have displayed greater nest site fidelity to Goose Island proper, making nest dissuasion activities more difficult).

1.2. Crescent Island, Columbia River

1.2.1. Experimental Passive Nest Dissuasion

Background: A test planting of native willows was installed at Crescent Island prior to the 2014 nesting season to determine if willow cuttings can be planted with a high probability of long-term survival. Results from the test planting will inform adaptive management efforts and actions taken as part of the IAPMP (USACE 2014). If deemed feasible, willow plantings may be used to reduce or eliminate nesting habitat for Caspian terns currently breeding on Crescent Island.

Methods: A riparian ecologist, Chris Hoag, provided expert guidance on local sourcing of willows, planting methods, and evaluation of planting success. On 27-28 January 2014, field visits were made to examine the test planting site on Crescent Island and one potential willow source was identified by USACE at McKay Creek National Wildlife Refuge south of Pendleton, Oregon. BRNW field personnel identified an additional potential source of willows belonging to the local eco-type at Two Rivers Park, considerably closer to Crescent Island. At Crescent Island, McKay Creek Refuge, and Two Rivers Park, three willow species were identified (coyote willow [*Salix exigua*], yellow willow [*S. lutea*], and whiplash willow [*S. lucida*]), with coyote willow (the target species identified for planting) being most common at all sites. Because coyote willow was relatively abundant close to Crescent Island and the willows growing at Two Rivers Park more vigorous, willows from McKay Creek NWR were not utilized for the test planting on Crescent Island. Instead, willows cuttings for the test planting were collected from Two Rivers Park on 13 and 15 February 2014 and from Crescent Island on 20 February 2014. Willow cuttings from both locations were either treated by soaking in water or were left unsoaked prior to planting (Hoag 2014).

On 27 January, we evaluated single-person-operated and a two-person-operated handheld gas power augers, plus manual post-hole diggers for excavating holes for test plantings at Crescent Island. We estimated that the water table depth at the planting site was at 5.5 to 6 feet below the surface (Hoag 2014). Based on the test excavations, willow planting depth was fixed at 6 feet and planting holes were drilled with a 9 horse power Groundhog towable hydraulic earthdrill (model HD99) fitted with a 6-inch auger and a 4-foot extension (Hoag 2014).

During 20-22 February, willow cuttings were processed for planting, planting holes were drilled, and 75 willow plantings were installed in a test plot approximately 110 feet northwest of the 2013 Caspian tern colony location on Crescent Island (Hoag 2014). Willow source, soaking treatment, and number of cuttings were varied among plantings to generate five planting groups for comparison: (1) Two Rivers Park, single cuttings, soaked in water; (2) Two Rivers Park, single cuttings, not soaked; (3) Two Rivers Park, five cuttings, soaked in water; (4) Two Rivers Park, five cuttings, not soaked; and (5)

Crescent Island, five cuttings, soaked in water. Holes for individual plantings were drilled 3-4 feet apart in 5 columns (numbered 1-5) and 15 rows (lettered A-O, running downslope from the island edge; Hoag 2014, Map 6). Each of the five treatments for comparison were assigned randomly to five holes in the upper (rows 1-5), middle (rows 6-10), and lower (rows 11-15) thirds of the test plot, such that each treatment was used in 15 planting holes across the entire test plot. Standing water was confirmed in each planting hole prior to placing willow cuttings in each planting hole. Holes were then filled with soil while watering to settle the soil, willow stems were clipped 8 inches above the ground, and the tops were spray painted (Hoag 2014). An exclusion fence constructed from 14-gauge welded wire with 2 x 4-inch holes was installed around the willow plot to protect willows from browsing by mammals, particularly beaver.

Conditions at the willow test plot and growth of willow plantings was evaluated from a distance while Caspian terns, gulls, and other species were breeding on Crescent Island. During the avian nesting season, photographs were taken during aerial surveys and field personnel used a spotting scope to photograph the test plot weekly from an observation blind located 50 m away.

After the breeding season, on 26 August, the willow test plot was visited and data were collected to evaluate condition of cuttings at each planting. For each planted cutting that was located, we recorded (1) if the cutting sprouted a new shoot or not, (2) if any sprouted shoots remained alive or not, and (3) the apparent vigor of the planted cutting. Vigor of each planted cutting was recorded as: 0 = no growth or no live stems; 1 = one or a few live stems of low height, plant appears to be in poor condition (e.g., yellow/brown leaves, insect damage); 2 = one or multiple live stems of moderate height; 3 = multiple stems with one or more being relatively tall. For each planting hole, we recorded: (1) length of the tallest shoot, (2) diameter 4 inches above the willow cutting of the tallest shoot, and (3) the highest vigor score for the cuttings placed in the planting hole. For 30 planting holes that received just a single cutting, all data were for one cutting. For each planting hole, we also recorded the presence or absence and height of two non-native invasive plants (*Kochia scoparia* and *Atriplex rosea*) that were prevalent throughout the test plot.

Results/Conclusions: Vegetation growth within the willow test plot was abundant during the 2014 avian breeding season (Map 6) and consisted of three primary species. In addition to growth of the planted willow cuttings, two non-native annual herb species (*Kochia scoparia* and *Atriplex rosea*) grew in profusion throughout the test plot. Vegetative matter from both non-native plant species was present in the growth space of all 75 willow plantings, where *Kochia* and *Atriplex* grew to mean heights of 169 cm and 125 cm, respectively. By comparison, the mean length of the tallest sprouted shoot from planted willow cuttings that grew was 148 cm.

Water table measures were made on 27 January and were 5.5 – 6.0 feet below the surface, as indicated by approximately 15-30 inches of measured in the bottom of 6-foot

deep planting holes dug for willow plantings. In the intervening 3-4 week period, there was an increase in the level of McNary Pool and a commensurate decline in the depth of the water table at the willow test plot.

Overall, performance of the individual willow cuttings was fair. For the 255 cuttings that were planted in late February, 233 (91%) were confirmed to have sprouted and 216 (85%) were alive in late August. Vigor scores indicated that 55% of cuttings were growing and appeared healthy (vigor = 2 or 3), while 45% of cuttings were described as in decline or dead (vigor = 1 or 0, respectively).

Overall performance of the willow plantings was better when multiple stems were planted per planting hole. For the 75 planted holes, 72 (96%) had one or more sprouted cuttings and 68 (91%) had at least one live cutting. Based on data from the individual planted cutting with the most vigorous growth in each planting hole, vigor scores indicated that 63 (84%) planting holes contained cuttings that appeared healthy (vigor = 2 or 3), while 16% of planting holes contained cuttings that were declining or dead (vigor = 1 or 0, respectively). Average willow leader length was 184 cm when data were restricted to just those cuttings with the highest vigor score in each planting hole.

As expected, success in producing a healthy, growing willow in a planting hole was increased by using multiple stems per planting hole. Proportions of willow planting holes with sprouted cuttings and with live cuttings was 100% for all three planting treatments that utilized 5 cuttings per planting hole, whereas both of the single cutting treatments included at least one cutting that did not sprout and at least three cuttings that were not alive in late August (Table 2). In addition, vigor scores for 44 of 45 plantings (98%) with five cuttings indicated presence of cuttings that appeared healthy (vigor = 2 or 3) and only one planting hole contained five cuttings that were all scored as declining or dead. In comparison, 63% of the single stem treatments were scored as healthy. In addition, plantings with single cuttings had lower mean leader lengths (163 and 171 cm) and smaller stem diameters (7.9, 8.6, and 8.9 mm) in comparison to estimates from the five cutting treatments (leader lengths: 177, 200, and 209 cm; stem diameters: 7.9, 9.5, 9.6 mm; Table 2).

For most variables recorded, willow plantings with soaked treatments did not appear to perform better than the paired treatments that used cutting that were not soaked. For both the single and multiple stem treatments, point estimates of mean leader length for soaked cuttings were longer (Table 2). However, sprouting, survival, average leader diameter, and vigor scores were similar or slightly skewed towards better performance in the unsoaked treatments. The willow cuttings that were collected from Crescent Island were soaked and had a 100% survival rate, but mean leader length and diameter were low in comparison to both of the 5-cutting plantings sourced at Two Rivers Park. It should be noted that performance of Crescent Island sourced willows was likely affected by the low vigor and size of the collected cuttings and the shorter soaking time (Hoag 2014).

In general, the success for willow plantings was evaluated based on the growth and survival of at least one willow cutting per planting hole. Based on the planting conditions on Crescent Island, Chris Hoag predicted a first year survival rate of 65% for willows at the level of the planting hole. As such, our confirmation of live willows in late August of the first growing season in 73 – 100% of the planting holes represents unexpectedly good results. The factor that most influenced success rate per willow planting hole was the use of multiple cuttings per planting hole.

Treatments with multiple cuttings per planting hole were advised by Chris Hoag on the premise that the most expensive part of planting a cutting is digging the hole. By increasing the number of cuttings in a planting hole, we increased the probability that at least one cutting would grow and survive. In addition, using multiple cuttings will sometimes deter destruction of a planting because beaver will selectively harvest stems to keep a stand from dying out (C. Hoag, pers. comm.). Thus, at a large scale, where fencing protection or complete protection against beaver damage may not be feasible, plantings with multiple cuttings would provide an additional hedge against total loss of willows at individual planting holes.

Excavating planting holes was extremely labor intensive. In order to excavate holes deep enough to reach water when McNary Pool was at a relatively low level in late January, we needed to use larger equipment than was initially anticipated (handheld and small power equipment); instead, we used a wheeled hydraulic earthdrill. A Waterjet Stinger was not suitable due to large cobbles that were present in the planting substrate. While the earthdrill allowed excavation to a depth of 6 feet, an auger with an extension was needed and extraction of soil from the lower portion of the planting hole required considerable additional physical labor by the drilling crew. Therefore, for implementation of willow planting on a larger scale at Crescent Island, we recommend use of skid steer machine (fitted with a 3-6 inch diameter auger) that could be transported to the island on a landing craft or a small barge.

Fresh beaver sign was observed at several locations on Crescent Island in February and gnawing damage to local willows was evident. The exclusion fence installed around the willow test plot appeared to be effective for protecting the willows from beaver or other large gnawing mammals. Fencing should be a major consideration for willow plantings at a larger scale. Often, vegetation projects like these are planted in a phased approach so that fencing can be smaller and moved every few years to a new planting location. However, the feasibility of using smaller, staged plantings would require consideration of objectives and other methods being employed to limit Caspian tern nesting habitat on Crescent Island.

The willow test plot was not covered and California gulls were allowed to access the test plot area. This was by design because excluding gulls from a larger willow plot would likely be unfeasible. Gulls were observed in the willow test plot throughout the growing

season, and at least 10 pairs nested inside the exclusion fence. Field observers confirmed that gulls occasionally picked at vegetation growing in the test plot area, but there was no indication that this behavior limited the growth or survival of willows, *Kochia,* or *Atriplex*.

Our evaluation at the end of the first growing season indicated that increasing the number of willow cuttings per planting hole increased the proportion of holes with live willows. In fact, every treatment that included 5 willow cuttings per planting hole experienced 100% survival at the level of the planting hole. We also noted that leader lengths and diameters were largest for the cuttings collected from Two Rivers Park. We attribute this primarily to the quality of the source plants. Crescent Island source plants were scarce, and the size and vigor of cuttings likely contributed to reduced leader growth for the Crescent Island planting treatment. Nevertheless, all 15 plantings of Crescent Island cuttings included live willows in late August. We saw no differences based on soaking treatment and this is probably because the river water levels were high when the willows were planted, which was before they started sprouting. While actual pool levels were not recorded, it was clear that pool level was relatively high when willow cuttings were planted, and the cuttings in all holes were planted in at least 15 inches of standing water, which may have mitigated the effect of lack of soaking for some treatments.

Although there was abundant growth of *Kochia* and *Atriplex* in the willow test plot, these species are not typically significant competitors with most willow species (C. Hoag, pers. comm.). Tree willows develop a crown and often shade and eliminate nearby weeds, but *Salix exigua* is a shrub that commonly grows only to heights of about 6-8 feet, under good conditions. Thus *S. exigua* is less capable of shading out invasive weeds. Interestingly, the *Kochia* and *Atriplex* plants that grew in the willow test plot were considerably larger than plants of the same species growing nearby, but outside the test plot. While we removed the non-native vegetation to access the willow plantings for data collection, it is not clear how these potential competitors might have affected long-term willow growth and survival if left in place. Both species are annuals, so continued growth during the second growing season for planted willows should not be factor. However, new plants could sprout from the seed produced this season and the shear density of live or dead plant material could play a role in subsequent willow growth. For example, with such dense vegetative cover, voles (if present) could become a problem. Dense cover around the base of willows provides habitat for voles and they can easily girdle smaller diameter willow stems. Although voles were not noted on Crescent Island, they could be on other islands. Because both *Kochia* and *Atriplex* are annual tumble weeds, they could be blown away by the wind if the willows and/or the exclusion fencing does not trap dead plants in place. Additional research would be needed to determine how *Kochia* and *Atriplex* may affect the growth and survival of willows planted on Crescent Island.

We speculate that the combination of loosening the substrate by drilling holes and watering the holes with a large water pump that also wetted a large area around the willow plot, both inside and outside the exclosure fence, created suitable conditions for the weeds to germinate and grow, particularly at each planting hole. Vigorous growth of *Kochia* and *Atriplex* at the planting holes compared to the surrounding area, which was also watered, suggests that drilling out and refilling the planting holes allowed for germination and release for these non-native species. Further research would be needed to prove this hypothesis and to come up with a procedure that would reduce the number of non-target species that become established in willow planting holes, if deemed necessary to improve willow growth.

Insect damage from an unidentified species was noted on several willows, but did not appear to be a significant limiting factor for growth and survival. The willow leaf beetle (*Plagiodera versicolora*) is commonly found on *Salix exigua* and will eat the leaves and some of the smaller stems, but none were observed on the Crescent Island willows. For 10 cuttings, the field crew observed evidence of insect damage that apparently caused swelling and scarring on some willow stems, but no insect damage to willow leaves was apparent.

SECTION 2: CASPIAN TERN COLONY MONITORING

2.1. Goose Island, Potholes Reservoir

Background: Although efforts were implemented to dissuade both Caspian terns and gulls from nesting on Goose Island in 2014 as part of Phase 1 of the IAPMP (see Section 1.1), colony monitoring was necessary to determine to what extent those efforts affected the number of birds nesting and roosting on the island throughout the 2014 breeding season.

Methods: We monitored the daily activities of Caspian terns and other colonial waterbirds (e.g., gulls) on Goose Island and nearby rocky islets from mid-March through July to assess pertinent colony information, including nesting habitat use, total area occupied by nesting birds, nesting density, colony attendance, colony size, and nesting success. Monitoring of colony attendance by Caspian terns on Goose Island was conducted using early morning ground counts made by observers from fixed or temporary blinds at the edge of each sub-colony, by boat, and on foot in areas with potential for minimal disturbance to other nesting birds. Colony attendance was estimated based on the average number of adult Caspian terns counted on colony each week throughout the breeding season. Additional counts were made throughout the day while conducting active hazing efforts to assess action effectiveness of passive and active nest dissuasion measures. This daily monitoring was conducted in conjunction with efforts described under Section 1.1 by two 2-person field crews (one 2-person field crew was funded by GPUD/PRCC).

Estimates of Caspian tern colony size and nesting success on Goose Island and nearby rocky islets were based on counts of active nests (i.e., adult terns in incubating posture on the colony) and fledging-age terns (i.e., black-capped chicks on or near the colony), respectively. Caspian tern colony size, measured as the number of active nests or breeding pairs, was based on the maximum number of incubating terns counted on the colony, which is observed late in the incubation period (late May). Colony size was estimated from counts of attended nests that were visible in oblique aerial photography taken on 19 May, and verified using ground counts conducted during the same time period. Nesting success was estimated from ground counts of the maximum number of fledging-aged terns counted on the colony at the onset of the fledging period (late June – early July). These ground counts were made by researchers from observation blinds or vantages at the periphery of the tern colony. No precise measures of variance for our estimates of colony size and nesting success for terns at colonies in the Columbia Plateau region are available, but due to the relatively small number of birds counted, are likely to be within 1% of the actual values. High-resolution, vertical aerial photography was taken of Goose Island and nearby islets on May 20th, and those ortho-rectified images were analyzed to estimate the nesting area (acres) and nesting density (nests/m^2) for Caspian terns at the site. For more details on colony monitoring methodologies see BRNW 2015.

High-resolution, vertical aerial photography (mentioned above) was also used to count individual gulls for an index of peak size of the mixed California and ring-billed gull on Goose Island and the surrounding islets. During the breeding season, and also late in the incubation period, field personnel used printed oblique photography to map breeding areas for each species of gull. These mapped breeding areas were then used as a basis for species identification during counting of the aerial images.

Results/Conclusions: In 2014, the passive nest dissuasion efforts on Goose Island (see Section 1.1.1) were successful in preventing Caspian terns from nesting in those areas of the island where they had nested in previous years, specifically at the main colony on the western lobe of the island and at the satellite colony on the eastern lobe of the island (Map 2). This resulted in Caspian terns dispersing to areas on Goose Island and nearby rocky islets where no passive nest dissuasion materials had been erected. Active nest dissuasion methods (hazing; see Section 1.1.2) were mostly successful in dispersing Caspian terns from areas of Goose Island without passive nest dissuasion materials, and limiting the number of Caspian terns that landed on Goose Island (weekly average = 8.6 adult terns on the island from late March through July) and the area of Goose Island used by Caspian terns prospecting for nest sites on Goose Island (< 0.001 acres on the south-facing slope of the western lobe of the island). As directed by the U.S. Bureau of Reclamation, no dissuasion efforts (passive or active) for Caspian terns were implemented on the rocky islets near Goose Island. When a colony of Caspian terns formed on nearby Northwest Rocks, just offshore of Goose Island (Map 5), it was not hazed, and the site was subsequently used by nesting terns throughout the 2014

breeding season. Average weekly attendance by Caspian terns on Goose Island and nearby islets was far lower in 2014 compared to previous years, until mid-June (Figure 1). For the remainder of the breeding season (mid-June through July), weekly attendance by Caspian terns was higher in 2014 compared to previous years. This pattern of attendance was likely associated with a delay in the onset of nesting by Caspian terns at Goose Island in 2014, caused by nest dissuasion activities initiated in 2014 (Figure 1). We estimated that a total of 159 breeding pairs of Caspian terns attempted to nest on Goose Island and the surrounding islets in 2014, 53% less than the estimated colony size on Goose Island in 2013 (340 breeding pairs; Figure 2; BRNW 2014). Only three breeding pairs attempted to nest on Goose Island in 2014; the remainder (156 breeding pairs) nested on a nearby islet (i.e., dubbed "Northwest Rocks"), suggesting that nest dissuasion was successful in areas where it was used (i.e., on the main Goose Island). The reduction in available nesting habitat for Caspian terns at Goose Island and the nearby islets resulted in terns nesting at the highest densities ever observed in the Columbia Plateau region (BRNW 2012, 2013, 2014). The colony area used by nesting terns on Northwest Rocks in 2014 was 93.2 m^2, resulting in a nesting density for terns of 1.67 nests/m^2. During 2011-2013, Caspian tern nesting density at Goose Island ranged from 0.88 – 1.07 nests/m^2, while at the Crescent Island tern nesting density ranged from 1.04 – 1.18 nests/m^2 (BRNW 2012, 2013, 2014).

We estimated that 46 young fledged from the Caspian tern colony that formed in 2014 on Northwest Rocks, compared to 130 young fledged from the colony on Goose Island in 2013 (BRNW 2014). All nesting attempts by Caspian terns on the south-facing slope of the western lobe of Goose Island in 2014 were unsuccessful. Overall, an average of 0.29 young were raised per breeding pair on Goose Island and nearby islets in 2014, down from 0.38 young raised per breeding pair in 2013 (Figure 3; BRNW 2014). Factors limiting colony size and nesting success on Northwest Rocks in 2014 included, but may not have been limited to, (1) the availability of suitable nesting habitat (mostly due to the small size of the islet and fluctuating reservoir levels), (2) competition with gulls for nest sites, and (3) human disturbance, primarily from recreational boaters. These three limiting factors all appeared to have a greater effect on Caspian tern colony size and nesting success at Northwest Rocks compared to previous Caspian tern nesting areas on the western and eastern lobes of Goose Island.

The index of gull colony size on Goose Island in 2014 was ca. 14,300 individuals (ca. 9,600 ring-billed gulls, ca. 4,600 California gulls, and ca. 100 gulls of undetermined species). This compares with an index of ca. 12,800 individuals (ca. 9,800 ring-billed gulls and ca. 3,000 California gulls) in 2013 (BRNW 2014), ca. 12,000 individuals (ca. 8,300 ring-billed gulls and ca. 3,700 California gulls) in 2012 (BRNW 2013), ca. 11,440 individuals (ca. 8,900 ring-billed gulls and ca. 2,500 California gulls) in 2011 (BRNW 2012), and ca. 13,000 individuals (ca. 10,500 ring-billed gulls and ca. 2,500 California gulls) in 2009 (BRNW 2010, Adkins et al. 2014). These index counts suggest a modest increase in overall gull colony size in recent years, and support the conclusion that the

combined effects of active and passive nest dissuasion efforts in 2014 had little impact on the establishment and size of the Goose Island gull colony in 2014.

2.2. Crescent Island, Mid-Columbia River

Background: Although no efforts were made to dissuade Caspian terns from nesting on Crescent Island as part of Phase 1 of the IAPMP, colony monitoring at Crescent Island was necessary to evaluate the efficacy of nest dissuasion activities at the Goose Island colony. Previous research using banded Caspian terns indicated that there is a high degree of connectivity between the Caspian tern colonies on Goose Island and Crescent Island. An expected outcome of dissuading nesting by Caspian terns on Goose Island would be that some portion of the displaced terns from Goose Island would relocate to Crescent Island, and this was the primary motivation for the monitoring the Crescent Island Caspian tern colony in 2014.

Methods: We periodically (2-3 days/week) monitored the activities of Caspian terns and other colonial waterbirds (e.g., gulls) on Crescent Island from mid-March through July. Monitoring of nesting birds on Crescent Island was conducted using early morning ground counts made by observers in a blind near the edge of the existing colony (Map 7), by boat, and on foot in areas with potential for minimal disturbance to nesting birds. The island was also closely monitored for the formation of new Caspian tern satellite colonies (i.e., away from the main colony site) and, once detected, the incipient nest sites were periodically checked to determine the number of tern nests initiated and the ultimate fate of all Caspian tern nesting attempts. The frequency of visitation to the Crescent Island tern colony by the 2-person field crew was sufficient to determine weekly colony attendance, peak colony size, colony productivity (nesting success), and factors limiting colony size and productivity (see Section 2.1 for a more detailed description of colony monitoring methods). High resolution, vertical, aerial photography was taken of Crescent Island on 20 May and those ortho-rectified images were analyzed to estimate the area (acres) used by nesting Caspian terns at Crescent Island. (For more details on colony monitoring methodologies see BRNW 2015)

High-resolution, vertical aerial photography of Crescent Island (mentioned above) was also used to count individual gulls to obtain an index of peak colony size of the mixed California and ring-billed gull colony. During the breeding season, including late in the incubation period, field personnel used printed oblique photos and mapped breeding areas for each species. These mapped breeding areas were then used as a basis for gull species identification during counting on the aerial images.

Results/Conclusions: Caspian tern attendance at the breeding colony on Crescent Island in 2014 was similar to the average during 2000-2013 (BRNW 2014), although attendance was slightly higher than average from mid-May through mid-June (Figure 4). A total of 474 breeding pairs of Caspian terns attempted to nest on Crescent Island in 2014, nearly identical to the average colony size during 2000-2013 (461 breeding pairs; Figure 5;

BRNW 2014). In 2014, the colony area used by nesting Caspian terns on Crescent Island was 438.3 m^2 (Map 8), resulting in a nesting density of 1.07 nests m^2, within the range of nesting densities observed at the Crescent Island tern colony the previous three years (1.04 – 1.18 nests/m^2; BRNW 2012, 2013, 2104).

Similar to what has been observed on Crescent Island in recent years (BRNW 2014), a satellite Caspian tern colony formed on the upper cove beach on Crescent Island in mid-May, with up to 17 adult Caspian terns and 4 attended nest scrapes counted (Map 9). Although eggs were laid in nest scrapes at this satellite colony and as many as 3 chicks were hatched from those eggs, all nesting attempts at this incipient satellite colony failed by mid-June, possibly due to nest inundation from fluctuations in river levels, loss of nest contents to predatory gulls, or nest abandonment due to other unknown causes.

We estimated that 155 young Caspian terns fledged from the Crescent Island tern colony in 2014, or an average of 0.33 young raised per breeding pair. Nesting success at the Crescent Island Caspian tern colony in 2014 was at or below the 14-year average (0.52 young raised per breeding pair) for the 7th consecutive year (Figure 6; BRNW 2014), possibly due to low availability of juvenile salmonids as prey late in the chick-rearing period (Lyons et al. 2011a).

The index of gull colony size on Crescent Island in 2014 was ca. 6,400 individuals (ca. 5,600 California gulls and ca. 800 ring-billed gulls). This compares with an index of ca. 5,700 individuals (ca. 5,550 California gulls and ca. 150 ring-billed gulls) in 2013 (BRNW 2014), ca. 7,200 individuals (ca. 7,100 California gulls and ca. 100 ring-billed gulls) in 2012 (BRNW 2013), ca. 8,000 California gulls and 0 ring-billed gulls in 2011 (BRNW 2012), and ca. 8,600 California gulls and 0 ring-billed gulls in 2009 (BRNW 2010, Adkins et al. 2014). These data on gull index counts suggest a modest decrease in overall gull colony size in recent. Increased numbers of breeding ring-billed gulls on Crescent Island and a decline in total numbers of gulls nesting on Crescent Island may be associated with vegetation succession and encroachment in recent years in areas of Crescent Island that were formerly unvegetated.

2.3. Other Prospective Colony Sites in the Columbia Plateau Region

Background: The geographic scope of the IAPMP includes sites within the inland Columbia River Basin where Caspian terns displaced from Goose and Crescent islands might relocate (USACE 2014). These prospective colony sites include islands where Caspian terns have recently nested (i.e., within the last two years), including the Blalock Islands, Badger Island, Twinning Island, and Harper Island, or historically nested, including Miller Rocks, Three Mile Canyon Island, Cabin Island, and Solstice Island. Other prospective colony sites 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, such as Foundation Island, Island 20, and Island 18; Map 1). Periodic colony monitoring was conducted at these prospective colony sites to help evaluate the

efficacy of management actions implemented on Goose Island in 2014, and specifically to assess whether reduction in colony size associated with Caspian tern nest dissuasion at Goose Island are offset by commensurate increases in colony size at other sites within the Columbia Plateau region where Caspian terns may continue to consume significant numbers of ESA-listed salmonids.

Methods: The frequency of colony monitoring at each of the prospective colony sites varied from once a week to once a month, depending on location and the amount and type of Caspian tern activity observed at the site. Boat-based and/or aerial surveys were conducted at each site throughout the breeding season to determine Caspian tern presence/absence, nesting status, and the outcome of any nesting attempts. If Caspian tern nesting occurred at the site, we estimated colony size (number of breeding pairs) and nesting success (average number of young raised per breeding pair) using previously described methods (see Section 2.1).

2.3.1. Miller Rocks, Columbia River

Miller Rocks on the Columbia River above The Dalles Dam near the town of Biggs, OR is a cluster of small basalt islets just upstream of Miller Island, the much larger main island in the group.

Currently, there is a large California gull colony (ca. 4,800 breeding pairs in 2013) and a smaller ring-billed gull colony (ca. 50 breeding pairs in 2013) on Miller Rocks (BRNW 2014). Caspian terns attempted to nest on Miller Rocks in 2001, when 17 breeding pairs of Caspian terns attempted to nest but failed to fledge any young. Caspian terns have not been detected attempting to nest on Miller Rocks in any year since 2001 (BRNW 2014).

Results/Conclusions: Miller Rocks was visited by boat six times and surveyed by air three times during the 2014 breeding season (April-July). Caspian terns were not observed at Miller Rocks during any of these surveys. As was the case in previous years (BRNW 2014), California and ring-billed gulls successfully nested on Miller Rocks in 2014.

2.3.2. Three Mile Canyon Island, Columbia River

Three Mile Canyon Island is on the Columbia River above John Day Dam near the town of Boardman, OR, and is owned and managed by the U.S. Army Corps of Engineers. Three Mile Canyon Island is a 17-acre island that was created by the John Day Dam impoundment.

Historically, this island was the site of a breeding colony of Caspian terns and a much larger breeding colony of gulls (both California and ring-billed; BRNW 2014, Adkins et al. 2014). The island was abandoned as a nesting site by Caspian terns in 2002 and by gulls in 2012. Caspian terns have not nested on Three Mile Canyon Island since 2002,

presumably because of the presence of mammalian predators on the island (BRNW 2014, Adkins et al. 2014).

Results/Conclusions: As was the case in 2013 (BRNW 2014), no piscivorous waterbirds were detected attempting to nest on Three Mile Canyon Island during the 2014 breeding season (April-July).

2.3.3. Blalock Islands, Columbia River

The Blalock Islands complex is on the Columbia River above John Day Dam near the town of Irrigon, OR, and is owned and managed by the U.S. Fish and Wildlife Service as part of the Umatilla National Wildlife Refuge. The island complex consists of numerous low-lying gravel islands and mudflats that were created by the John Day Dam impoundment.

The Blalock Islands are currently the site of several breeding colonies of a number of piscivorous waterbird species, 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 (BRNW 2014, Adkins et al. 2014). The Rock Island Caspian tern colony peaked at 104 breeding pairs in 2008 and fell to 79 breeding pairs in 2009 before Caspian terns abandoned the island as a nesting site and moved to Anvil Island (another island in the Blalock Islands) in 2010 (BRNW 2014, Adkins et al. 2014). The Caspian tern colony size on Anvil Island declined from its peak size in 2010 (136 breeding pairs) to just 6 breeding pairs in 2012 (BRNW 2914). In 2013, nesting Caspian terns relocated to a small unnamed island in the Blalock Islands, located between Anvil and Sand islands, where 26 breeding pairs were counted (BRNW 2014). This new colony only produced 3 fledgling terns in 2013, or an average of 0.12 young raised per breeding pair in 2013. This was the eighth consecutive year that Caspian terns nesting on islands in the Blalock Island complex 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 Pool during the incubation period (BRNW 2014).

Results/Conclusions: The Blalock Islands were visited by boat about once a week and surveyed by air four times during the 2014 breeding season (April-July). Caspian terns were first seen in the Blalock Islands on 8 April, when 13 roosting terns were counted. The first evidence of nesting by Caspian terns was observed on 13 May when a total of 17 attended Caspian tern nests were counted on three different islands (Long, Middle, and Sand islands; Maps 10-12). A total of 45 breeding pairs of Caspian terns attempted to nest on these 3 islands in the Blalock Islands during 2014, 73% greater than the estimated colony size in 2013 (26 breeding pairs; Figure 7; BRNW 2014). This year was the first year that Caspian terns were observed to nest on multiple islands within the Blalock Island complex, instead of gravitating to a single nesting site.

We estimated that 15 young Caspian terns fledged from the Blalock Islands in 2014, compared to just 3 Caspian terns fledged from this colony in 2013 (BRNW 2014). Tern nesting success in 2014 (0.33 young raised per breeding pair) was the highest ever observed at the Blalock Islands, although the total number of nesting Caspian terns was lower than in previous years (BRNW 2014). Fluctuating John Day Pool levels associated with spring run-off and hydroelectric dam operations will likely continue to be a factor limiting colony size and nesting success at these low-lying islands in the future.

2.3.4. Badger Island, Columbia River

Badger Island, located on the Columbia River upstream of McNary Dam and near the town of Wallula, WA, is a long, narrow island of about 15 acres owned and managed by the U.S. Fish and Wildlife Service as part of McNary National Wildlife Refuge.

Badger Island is the location of the only known nesting colony of American white pelicans in the State of Washington, a species that is listed as endangered by the State. Badger Island was also home to a small Caspian tern colony in 2011 and 2012, when 33 and 60 breeding pairs attempted to nest, respectively (BRNW 2012, BRNW 2013). Nesting Caspian terns did not return to Badger Island in 2013, perhaps due to the failure all nesting attempts during the previous two years (BRNW 2014). Failure of the Caspian tern colony at Badger Island in 2011 and 2012 was attributed to high water levels in mid-June and/or encroachment and trampling by American white pelicans that were nesting nearby (BRNW 2012, BRNW 2013).

Results/Conclusions: Badger Island was visited by boat about once a week and surveyed from the air three times during the 2014 breeding season (April-July). Caspian terns were periodically seen roosting on Badger Island (ca. 20 terns were counted on two occasions), but no Caspian tern nesting was detected on Badger Island in 2014. As was the case in previous years (BRNW 2014), a sizable American white pelican colony was observed on Badger Island in 2014 and they were once again successful in fledging young from the site.

2.3.5. Foundation Island, Columbia River

Foundation Island is located on the Columbia River upstream of McNary Dam near the town of Burbank, WA, and is owned and managed by the U.S. Fish and Wildlife Service as part of McNary National Wildlife Refuge. It is a long and very narrow wooded island of about 5 acres that is just below the confluence of the Snake and Columbia rivers.

Foundation Island is the site of the largest double-crested cormorant colony on the mid-Columbia River. Although both the upstream and downstream ends of the island are commonly used by roosting Caspian terns, Caspian terns have not yet been detected attempting to nest on the island.

Results/Conclusions: Foundation Island was visited by boat about once a week and was surveyed from the air three times during the 2014 breeding season (April-July). Caspian terns were periodically seen roosting on Foundation Island, on both the upstream and downstream ends, but no Caspian tern nesting attempts were detected on Foundation Island in 2014. As was the case in previous years, a sizable double-crested cormorant colony was observed on Foundation Island in 2014 and they were once again successful in fledging young from the site.

2.3.6. Island 20, Columbia River

Island 20 (also called Fencepost Island) is on the Columbia River upstream of McNary Dam near the city of Richland, WA, and is owned and managed by the U.S. Fish and Wildlife Service as part of McNary National Wildlife Refuge.

Island 20 is currently the home to the largest gull colony on the mid-Columbia River, a mixed colony of ring-billed and California gulls consisting of well over 10,000 breeding pairs. To date, nesting by Caspian terns has not been documented on this island.

Results/Conclusions: Island 20 was visited by boat once and surveyed from the air three times during the 2014 breeding season (April-July). Caspian terns were not observed at Island 20 during any of these surveys. As was the case in previous years (BRNW 2014), California and ring-billed gulls successfully nested on Island 20 in 2014.

2.3.7. Island 18, Columbia River

Island 18 is located on the Columbia River upstream of McNary Dam near the city of Richland, WA, and is part of McNary National Wildlife Refuge.

Island 18 was home to a large California/ring-billed gull breeding colony (over 6,000 breeding pairs when last surveyed in 1998; Collis et al. 2002) that was abandoned in 2008, apparently due to a combination of coyote and human disturbance. Gulls have not attempted to resume nesting on Island 18 since the colony failed in 2008. As with Island 20, which is nearby, Caspian tern nesting has not been documented on this island (BRNW 2014).

Results/Conclusions: As was the case in 2013 (BRNW 2014), no gulls were detected nesting on Island 18 during the 2014 breeding season (April-July), and there was no evidence that Caspian terns had attempted to nest there either.

2.3.8. Cabin Island, Columbia River

Cabin Island is located on the Columbia River above Priest Rapids Dam and is owned and managed by the Washington Department of Fish and Wildlife.

Caspian terns were documented to be nesting on Cabin Island in 1975, but in no other year since (BRNW 2014). Cabin Island was the site of a large ring-billed gull colony until the late 1990s, when USDA-Wildlife Services dispersed the colony by oiling eggs and disturbing nesting birds.

Results/Conclusions: Cabin Island was observed from land five times and surveyed from the air three times during the 2014 breeding season (April-July). Caspian terns were regularly seen roosting on Cabin Island (generally < 20 adults), but no nesting by Caspian terns or other colonial waterbirds (e.g., gulls) was detected on Cabin Island in 2014.

2.3.9. Solstice Island, Potholes Reservoir

Solstice Island is a 4-acre sand dune island located at the northern end of Potholes Reservoir, near the City of Moses Lake, WA. The site is owned by the U.S. Bureau of Reclamation and managed in cooperation with the Washington Department of Fish and Wildlife.

Nesting by Caspian terns at Potholes Reservoir dates back to the early 1980s, with Caspian terns using several different small, low-lying sandy islands in the reservoir, including Solstice Island, where Caspian terns nested during 2000-2004 (BRNW 2014, Adkins et al. 2014). In 2004, the Solstice Island colony apparently failed due to flooding, causing the colony to relocate to Goose Island, where Caspian terns have been nesting ever since. In recent years, Solstice Island has become mostly vegetated, making it unsuitable for nesting by gulls, as well as by Caspian terns (BRNW 2014, Adkins et al. 2014).

Results/Conclusions: As was the case in 2013 (BRNW 2014), no piscivorous colonial waterbirds were observed nesting on Solstice Island during the 2014 breeding season (April-July). A large number of other potentially suitable nesting islands exist in Potholes Reservoir, depending on water levels, but no other Caspian tern breeding colonies were detected in 2014 other than on or adjacent to Goose Island.

2.3.10. Twinning Island, Banks Lake

At the southern end of Banks Lake, near Coulee City, WA, two volcanic islands with thin topsoil provide nesting areas for colonial waterbirds. These two sites, Goose Island and Twinning 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 (BRNW 2014, Adkins et al. 2014). In 2005, Caspian terns began nesting on Twinning Island (also called Dry Falls Dam Island), which is located in Banks Lake just north of Dry Falls Dam. The colony at Twinning Island grew from less than 10 breeding pairs in 2005 to 61 breeding

pairs in 2009, before declining to 13 breeding pairs in 2013 (BRNW 2014). Currently, there are large mixed species colonies of California and ring-billed gulls on both islands, with over 3,000 breeding individuals counted on each island in recent years (BRNW 2014). 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) and perhaps encroachment by nesting gulls (BRNW 2014).

Results/Conclusions: Twinning Island was visited by boat 11 times and surveyed from the air three times during the 2014 breeding season (April-July). Caspian terns were first seen on Twinning Island on 15 April, when 7 roosting terns were counted. The first evidence of nesting by Caspian terns on Twinning Island was observed on 7 May when a total of 3 attended Caspian tern nests were counted on the colony (Map 13). As many as 100 Caspian terns and 67 attended Caspian tern nests were counted in five subsequent visits to Twinning Island between 21 May and 18 June. During a visit to the colony on 22 June, all the previously attended Caspian tern nests had been abandoned and only roosting Caspian terns were observed on Twinning Island during subsequent visits. A total of 67 breeding pairs of Caspian terns nested on Twinning Island in 2014, larger than the estimated colony size in 2013 (13 breeding pairs; Figure 8; BRNW 2014), possibly associated with the nest dissuasion activities on Goose Island. This is the largest Caspian tern colony recorded at Twinning Island since monitoring began in 2006 (Figure 8; BRNW 2014).

In 2014, egg-laying by Caspian terns on Twinning Island was not confirmed prior to colony abandonment; the cause[s] of Caspian tern colony failure in 2014 is not known.

2.3.11. Harper Island, Sprague Lake

Harper Island is a privately-owned island in Sprague Lake and is located near the southwestern end of the lake. Sprague Lake is between the towns of Ritzville and Sprague in east-central Washington, and 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 size and covered by upland shrub habitat 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 (BRNW 2914, Adkins et al. 2014). During 2005-2010, estimates of Caspian tern colony size on Harper Island were generally small (< 10 breeding pairs), before increasing about 6-fold in 2012, and then declining again to just one breeding pair in 2013 (BRNW 2014). The island is also home to a small double-crested cormorant colony (174 breeding pairs in 2013; BRNW 2014) and a large California/ring-billed gull colony (over 6,000 breeding pairs when last surveyed in 2009; BRNW 2010). As was the case at Twinning Island in Banks Lake, no young Caspian terns were apparently fledged from the Harper Island colony in 2012 and 2013; the cause[s] of colony failure is not known (BRNW 2013, BRNW 2014).

Results/Conclusions: Harper Island was visited by boat eight times and surveyed from the air three times during the 2014 breeding season (April-July). Caspian terns were first seen on Harper Island on 7 May, when 2 roosting terns were counted. The first evidence of nesting by Caspian terns on Harper Island was observed on 17 June, when a total of eight attended Caspian tern nests were counted on the colony (Map 14). As many as 82 Caspian terns were counted at the colony during visits to the island between 7 May and 24 June. During a visit to the colony on 29 June, all the previous attended Caspian tern nests were abandoned. A total of eight breeding pairs of Caspian terns apparently attempted to nest on Harper Island in 2014, compared to only one breeding pair the previous year (Figure 9; BRNW 2014). Egg-laying was not confirmed at the Harper Island Caspian tern colony prior to colony abandonment; the cause[s] of colony failure in 2014 is not known.

SECTION 3: REGIONAL MONITORING OF CASPIAN TERN NUMBERS

3.1. Aerial Surveys

Background: The success of the IAPMP hinges on the extent to which dissuasion of nesting by Caspian terns at Goose and Crescent islands results in Caspian terns relocating to sites where they eat fewer ESA-listed Columbia Basin salmonids. Aerial surveys were conducted to help determine where Caspian terns displaced from Goose Island might relocate within the Columbia Plateau region, where they might continue to negatively affect salmonid survival. These surveys were used to locate new Caspian tern colonies, as well as to check on the status and size of extant Caspian tern colonies in the region.

Methods: Periodic aerial surveys were conducted from a fixed wing aircraft (Cessna 205) to determine the distribution of Caspian tern breeding colonies along the Columbia River from Bonneville Dam to Chief Joseph Dam and on the lower Snake River from the mouth of the Clearwater River to the confluence with the Columbia River, as well as at sites off the mid-Columbia and lower Snake rivers that are within tern foraging range (~90 km) of the FCRPS (see Map 15). The prospective colony sites identified in the IAPMP (i.e., Miller Rocks Island, Three Mile Canyon Island, Blalock Islands, Badger Island, Foundation Island, Island 18, Island 20, and Cabin Island on the Columbia River; Solstice Island in Potholes Reservoir; Twinning Island in Banks Lake; and Harper Island in Sprague Lake) were checked for the presence of Caspian terns during each aerial survey. Objectives of aerial surveys were to identify all Caspian tern nesting colonies and estimate breeding colony size and nesting success. Three aerial surveys of the Columbia Plateau region, each lasting two days, were conducted during the 2014 nesting season on the following schedule: (1) on 24-25 April during the early incubation period to check for presence of newly formed colonies; (2) on 18-19 May during the late incubation period to quantify numbers of breeding pairs, colony area, and habitat types occupied by nesting adults; and (3) on 24-25 June during the peak

fledging period to assess overall nesting success. Aerial surveys followed established methods, including reconnaissance surveys to search for new Caspian tern colonies and photographic surveys of sites where Caspian terns were present. When Caspian terns were observed on the ground on substrates that were potentially suitable for nesting, 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. Seat space for one management agency representative was provided on each survey flight.

Results/Conclusions: Caspian terns were confirmed to be present at 26 sites during aerial surveys conducted in the Columbia Plateau region or from inspection of aerial survey photography collected in 2014. The majority of Caspian terns observed during aerial surveys were loafing birds that were not located on upland areas of potential nesting habitat. Instead, at most sites where Caspian terns were observed, the birds were on substrates that were not suitable for nesting (e.g., exposed rocks, mud flats, or gravel bars subject to inundation (Table 3).

From aerial survey data, Caspian terns could be confirmed at five of the 10 prospective colony site islands listed in the IAPMP (Table 3). The five prospective colony sites where Caspian terns were observed were Badger Island, the Blalock Islands (several islands), Cabin Island, Foundation Island, and Twinning Island. Prospective colony sites where Caspian terns were not observed during aerial surveys were Three Mile Canyon Island, the Richland Islands (Islands 18 and 20), Miller Rocks, and Solstice Island.

Regionally, most sites where Caspian tern presence was confirmed and all sites where breeding was confirmed from aerial surveys were located on the mid-Columbia River (16 sites) or in the Columbia Plateau region (6 sites). During 2014 aerial surveys, Caspian terns were only detected at four sites on the Snake River, and no nesting activity was detected.

Breeding by Caspian terns was detectable during aerial surveys and on oblique aerial photography taken at five historical breeding sites, including two prospective colony sites: the Blalock Islands (on Long, Middle, and Sand islands), Crescent Island (on the main colony and one new satellite colony), Goose Island (on Northwest Rocks), Harper Island, and Twinning Island. For the Caspian tern nesting colonies located at historical breeding sites, boat-based monitoring was the primary method of monitoring during the breeding season. There was one potential new Caspian tern colony site located at Lenore Lake that was identified through inspection of aerial photography after the aerial survey. Images from the aerial survey of the Lenore Lake gull colony on 25 April indicated that five Caspian terns were present on the gull colony, including two Caspian terns that were apparently attending nest scrapes.

Ground- or boat-based surveys were conducted following aerial surveys at five sites to document potential Caspian tern nesting activities at possible new colony sites, but no breeding colonies were confirmed during these follow-up surveys. Five surveys of Cabin Island and the Desert Aire section of the Columbia River were conducted from the mainland during the period 28 May to 14 July. A maximum of 19 Caspian terns were observed at Cabin Island on 28 May, but only loafing and foraging Caspian terns were observed during follow-up surveys.

At Desert Aire, north of Cabin Island, a maximum of 56 Caspian terns were observed on 28 May on a partially vegetated mudflat in the river. Aside from one observed copulation, Caspian terns observed during follow-up surveys at Desert Aire were only loafing or foraging. Boat and land-based access to Island A in the Hanford Reach was limited, but the site was eventually surveyed on 6 June from the top of a bluff over-looking the Columbia River in Saddle Mountain National Wildlife Refuge. Deer were observed on Island A, but no Caspian terns were present during the 6 June survey.

Although five Caspian terns and two apparently attended Caspian tern nests were visible in aerial photography taken on 25 April of the Lenore Lake gull colony, no signs of breeding Caspian terns were observed during subsequent aerial surveys or during five follow-up visits to the site from 30 April to 18 June. A maximum of eight Caspian terns were counted on the gull colony at Lenore Lake during 12 June, but all Caspian terns observed during four mainland- and one boat-based follow-up surveys at Lenore Lake were just loafing, not nesting.

Large numbers of Caspian terns observed near exposed mudflats in Wanapum Reservoir opposite Crescent Bar (near Trinidad, WA) led to five mainland-based follow-up surveys. A maximum of 31 Caspian terns were observed during the survey on 30 April, but only loafing and foraging Caspian terns were observed during follow-up surveys.

3.2. Nesting Distribution

Background: To help evaluate the efficacy of nest dissuasion activities on Goose Island in Potholes Reservoir, we compared the total number and distribution of nesting Caspian terns within the Columbia Plateau region in 2014 (post-management at Goose Island) with results from previous years (pre-management). Specifically, we sought to answer the question of whether management actions in 2014 resulted in a reduction in the total number of Caspian terns nesting in the Columbia Plateau region.

Methods: The region-wide evaluation of the nesting distribution of Caspian terns in the Columbia Plateau region was conducted using the methods described above (see Sections 2 and 3.1).

Results/Conclusions: We identified a total of six active Caspian tern breeding colonies in the Columbia Plateau region during 2014 (Figure 10); a total of approximately 755 breeding pairs of Caspian terns nested at these six colonies (Figure 11 and Table 4). All of the Caspian tern colonies that were active in the region during 2013 were active again in 2014 (BRNW 2014). In addition, a new Caspian tern breeding colony may have briefly become established on a gull colony on a small island in Lenore Lake (just north of Soap Lake, WA) in 2014, where two breeding pairs were detected in aerial photography. While the number of Caspian terns nesting on Goose Island and nearby rocky islets declined 52% in 2014 relative to 2013 (BRNW 2014), there was a commensurate increase in the size of all the other extant colonies in the region (see Section 2; BRNW 2014). All together, the total number of Caspian terns nesting at sites other than Goose Island increased from 433 breeding pairs in 2013 to 596 breeding pairs in 2014, a 38% increase (BRNW 2014). The total number of Caspian terns nesting in the Columbia Plateau region in 2014 (755 breeding pairs) was similar to the number nesting in the region the previous year (773 breeding pairs), but still lower than the numbers observed in all previous years since monitoring commenced in 1997, with the exception of 2007 (711 breeding pairs; Figure 11 and Table 4; BRNW 2014). These results suggest that although the nest dissuasion implemented on Goose Island in 2014 was effective in reducing the number of Caspian terns nesting at that location, it did not result in a significant reduction in the total number of Caspian terns breeding in the region.

3.3. Inter-colony Movements

Background: Color-banding Caspian terns and subsequent band resighting efforts are designed to assess inter-colony movements of Caspian terns in order to determine how tern management efforts within the Columbia River basin and elsewhere affect the distribution, numbers, and smolt predation rates of Caspian terns in the Columbia Plateau region.

Methods: In 2014, adult Caspian terns and Caspian tern chicks near fledging age were banded at the Goose Island and Crescent Island tern colonies, respectively, as part of broader study efforts with financial support from GPUD/PRCC. Adult Caspian terns were captured at Goose Island in Potholes Reservoir using a compressed air net launcher on the former main colony area. Caspian tern chicks were captured for banding by herding flightless young into holding pens located at the periphery of the colony at Crescent Island. 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 bands allows us to individually identify each banded tern from a distance, such that the banding location (colony) and banding year are known. Tern chicks that were too small to be color-banded were banded with a federal numbered metal leg-band only.

Terns that were banded with alphanumeric colored leg-bands in previous years (2006-2013; BRNW 2014) and adult terns banded at the beginning of the breeding season in

2014 were resighted using binoculars and spotting scopes during 2-4 days per week at Crescent Island and 3-7 days per week at Goose Island throughout the 2014 breeding season. Band resighting was also conducted at other breeding colonies and non-breeding sites in the Pacific Northwest during 2014 to evaluate movements of Caspian terns from the Crescent Island or Goose Island colonies.

Results/Conclusions: At the Crescent Island Caspian tern colony in 2014, 147 tern chicks near fledging age were color-banded; 5 smaller tern chicks were only banded with metal leg-bands. At the Goose Island Caspian tern colony in 2014, 38 adult terns were color-banded.

In 2014, a total of 313 previously color-banded Caspian terns were resighted at the Crescent Island colony (Table 5). Of these, 74% were banded at Crescent Island, 22% were banded at Goose Island, and 3% were banded at East Sand Island. One Caspian tern banded at the Port of Bellingham on the Washington coast and another banded at the Crump Lake colony in interior Oregon were also resighted at the Crescent Island colony in 2014.

In 2014, a total of 294 previously color-banded Caspian terns were resighted at the Goose Island colony (either at the former colony area on the main island or at nearby Northwest Rocks, where Caspian tern nesting occurred in 2014) in Potholes Reservoir (Table 6). Of these, 79% were banded at Goose Island, 13% were banded at Crescent Island, 4% were banded at East Sand Island, 2% were banded at the Port of Bellingham (WA), and 1% were banded at Brooks Island in San Francisco Bay, CA. One Caspian tern banded at Crump Lake, OR, and another banded at Sheepy Lake in Lower Klamath National Wildlife Refuge, CA, were also resighted at Goose Island in 2014.

At the Blalock Islands in the mid-Columbia River, a total of 25 color-banded Caspian terns were resighted in 2014 (Table 7). Of those, 52% were banded at Crescent Island, 40% were banded at Goose Island, and 8% were banded at East Sand Island. Resighting of color-banded terns was attempted at Twinning Island in Banks Lake and at Harper Island in Sprague Lake, where small numbers of Caspian terns attempted to nest in 2014. The water around Twinning Island was rough during surveys, however, and resighting of possible banded terns on the island was not feasible. Harper Island is a private island where landing is prohibited, so there was no vantage from which to conduct resightings of color-banded Caspian terns.

A total of 208 color-banded Caspian terns that were seen on Crescent Island in 2013 were resighted in 2014, either at Crescent Island or elsewhere; 29 of the 208 resighted color-banded terns were resighted at two different locations in 2014. Of a total of 237 resighting data points (including multiple locations for the 29 terns that visited more than one location), 83% were resighted back on Crescent Island, 5% were resighted on East Sand Island, 4% were resighted at Goose Island or nearby Northwest Rocks, 3% were resighted at the Blalock Islands, 3% were resighted at Tule Lake in Tule Lake

National Wildlife Refuge (CA), 2% were resighted at Malheur Lake in Malheur National Wildlife Refuge (OR), and 1 was resighted at Sheepy Lake in Lower Klamath National Wildlife Refuge (CA) during 2014 (Table 8).

A total of 198 color-banded Caspian terns that were seen at Goose Island in 2013 were resighted in 2014, either at Goose Island or elsewhere. Of the 198 resighted terns, 52 were resighted at two different locations in 2014 and 10 were resighted at three different locations in 2014. Of a total of 270 resighting data points (including multiple locations for the 62 terns that visited more than one location), 58% were resighted at Goose Island or nearby Northwest Rocks, 21% were resighted at Crescent Island, 7% were resighted at Malheur Lake, 5% were resighted at East Sand Island, 4% were resighted at Tule Lake, 3% were resighted at the Blalock Islands, 1% were resighted at Sheepy Lake, and 1% were resighted at East Link impoundment in Summer Lake Wildlife Area (Table 9). Although Caspian terns did not nest at Flat Lake in the Ancient Lakes area of central Washington in 2014, one color-banded Caspian tern from Goose Island was resighted there. Also, one color-banded tern from Goose Island was resighted at Tongue Point in the Columbia River estuary near Astoria, Oregon during the 2014 nesting season (Table 9).

The proportion of color-banded Caspian terns resighted at the same colony in 2013 and 2014 was higher at Crescent Island (83%) than at Goose Island (58%), apparently due to the dissuasion of nesting Caspian terns conducted at Goose Island in 2014. Of the 157 Caspian terns resighted at Goose Island in 2013 and 2014, 150 were resighted at Northwest Rocks near Goose Island in 2014. Of those, 54 Caspian terns (36%) were confirmed to be nesting (eggs or chicks visually confirmed) at Northwest Rocks. Of the Caspian terns seen at Goose Island in 2013 and resighted elsewhere in 2014, 33 terns were confirmed breeding in 2014 at colonies other than Goose Island or nearby Northwest Rocks; 26 terns were confirmed breeding at Crescent Island, 3 terns were confirmed breeding at East Sand Island, 2 terns were confirmed breeding at Tule Lake, 1 tern was confirmed breeding at Malheur Lake, and 1 tern was confirmed breeding at Sheepy Lake. In contrast, none of the banded Caspian terns seen at Crescent Island in 2013 and resighted elsewhere in 2014 were confirmed breeding at colonies other than Crescent Island.

These findings from the resighting of color-banded Caspian terns indicate that both Crescent Island and Goose Island continue to host breeding terns from neighboring colonies in the Columbia Plateau region and from more distant colonies throughout the Pacific Northwest. The effect of dissuasion of nesting Caspian terns at Goose Island on the degree of dispersal was apparent; dispersal of Caspian terns from Goose Island to other colonies was much greater than that from Crescent Island to other colonies. Some banded Caspian terns seen at Goose Island in 2013 and resighted in 2014 exhibited strong colony site fidelity, however, and attempted to nest on nearby Northwest Rocks, where nesting habitat was very limited. Resighting of banded Caspian terns identified colonies where terns dissuaded from Goose Island were recruited back into the

breeding population. Those colonies are likely locations for more recruits in the future if dissuasion of nesting Caspian terns continues at Goose Island and nearby rocky islets in the future years. Resighting of color-banded Caspian terns from Crescent Island at six other colonies in 2014 offers some insight into potential locations where terns from the Crescent Island colony would recruit back into the breeding population, if management of the Crescent Island Caspian tern colony occurs in the future.

3.4. Per Capita Predation Rates

Background: The goal of the IAPMP is to reduce Caspian tern predation rates on ESA-listed salmonid populations to less than 2% (USACE 2014). Presented here are estimated per capita (per bird) predation rates for Caspian terns nesting at colonies in the Columbia Plateau region identified as posing the greatest risk to survival of juvenile salmonids outmigrating from the Columbia Plateau region (Lyons et al. 2011a, b). Estimated per capita predation rates, coupled with information on the size of Caspian tern colonies in the Columbia Plateau region during 2014, can be used to predict predation rates in cases where empirical predation rate estimates due to Caspian tern depredation are lacking.

Methods: Per capita predation rate estimates presented here are based on the most recent data available regarding Caspian tern colony size and salmonid predation rates by terns nesting at each colony, data collected during 2007-2013. Data collected during 2007-2010 were previously used by Lyons et al. (2011a, b) to estimate the benefits to ESA-listed salmonid populations (hereafter ESU/DPS) of tern management through reductions in colony size. Data from Lyons et al. (2011a, b) were the impetus for Caspian tern management actions identified in the IAPMP. Because many of the datasets and methods used to calculate predation rates are described elsewhere, only a brief description is provided herein. It is worth noting, however, that methods used to calculate predation impacts presented here are based on a Bayesian analytical approach (Hostetter et al. 2015), which differs some from the frequentist approach used by Bird Research Northwest in years past (Evans et al. 2012; BRNW 2014). A more detailed description of these methods can be found in Appendix B.

Estimates of the peak or maximum Caspian tern colony size were based on the methods of BRNW (2014). Briefly, colony sizes for Caspian terns nesting on Goose Island (Potholes Reservoir), Crescent Island (McNary Reservoir), and the Blalock Islands (John Day Reservoir) were determined based on the largest number of incubating Caspian terns counted near the end of the egg incubation period, which generally occurred in mid- to late May.

The number of PIT-tagged juvenile salmonids consumed by Caspian terns were estimated for each year (2007-2013), each tern colony (Goose Island, Crescent Island, the Blalock Islands), and each ESA-listed salmonid population or ESU/DPS (Snake River steelhead, Snake River spring/summer Chinook, Snake River fall Chinook, Snake River

sockeye, Upper Columbia River steelhead, Upper Columbia River spring Chinook). Estimates of predation rates were based on methods previously developed by Evans et al. (2012), Osterback et al. (2013), and Hostetter et al. (2015). Briefly, predation rates were based on recoveries of PIT tags from juvenile salmonids on tern colonies following the nesting season. The number of PIT tags recovered each year was adjusted for PIT tag detection efficiency and deposition probabilities on-colony (see Appendix B for details). The numbers of PIT-tagged smolts available to Caspian terns nesting at each colony were based on the number interrogated passing Lower Monumental Dam (Snake River), Rock Island Dam (Middle Columbia River), or McNary Dam (Columbia River).

Annual per capita predation rates for each tern colony and each salmonid ESU/DPS were calculated by dividing the annual predation probability by the peak colony attendance from that year (see Appendix B for details).

In order to estimate predation rates on smolts for a tern colony of various sizes, 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 (see Appendix B for details). Predation rate estimates for each tern colony and each salmonid ESU/DPS were then presented for (1) colony sizes observed in 2014 and (2) various hypothetical colony sizes ranging from 20 to 500 breeding Caspian terns, representing the smallest and largest colonies observed during 2007-2013.

Results: Table 10 provides data on peak colony sizes, predation rates, and average per capita predation rates for Caspian terns nesting at Goose Island, Crescent Island, and the Blalock Islands during 2007-2013. Data indicate that predation rates were variable depending on the tern colony, year, and 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 (Table 10). Colony sizes also varied by location and year, although fluctuations in colony size were less dramatic than fluctuations in predation rates.

In 2014, Caspian tern colony size was estimated to be 159 breeding pairs at Goose Island-Potholes (including nearby Northwest Rocks), 474 breeding pairs at Crescent Island, and 45 nesting pairs at the Blalock Islands (Table 11 and Section 2). The number of Caspian terns nesting on Goose Island and the surrounding islets (159 pairs) was down substantially relative to pre-management counts (range = 282-463 pairs) during 2007-2013. Colony size at Crescent Island (474 pairs) in 2014, a location where management did not occur, was higher than during 2007-2013 (range = 349-422 pairs; Table 10). Counts at the Blalock Islands in 2014 (45 pairs) were similar to counts during 2007-2013 (range = 6-136 pairs; Table 10).

Based on 2014 estimates of Caspian tern colony size and per capita predation rates during 2007-2013 (Table 10), we predict that impacts to ESA-listed salmonids by Goose Island Caspian terns were substantially reduced in 2014 (Table 11). This was especially true for Upper Columbia River steelhead, with a predicted predation rate of 7.0% (95% PI = 4.1-12.4%; Table 11), compared with an average predation rate of 15.7% (95% CI = 14.1-18.9%; Table 10) during 2007-2013. Predicted Caspian tern predation rates on Upper Columbia River steelhead in 2014, however, were still above the IAPMP target goal of less than 2% for Caspian terns nesting on or near Goose Island. Predicted predation rates on Upper Columbia River spring Chinook (1.0%. 95% PI = 0.1-2.8%) and ESA-listed salmonid populations from the Snake River (generally < 0.1%) were below the 2% threshold, however (Table 11).

Predicted predation rates by Crescent Island Caspian terns in 2014 were higher for all ESA-listed salmonid populations compared with average predation rates observed during 2007-2013 due to the greater than average number of Caspian terns nesting at Crescent Island in 2014. Predicted predation rates by Crescent Island terns were still below the 2% threshold for most ESA-listed salmonid populations; the exceptions were Upper Columbia River steelhead (predicted predation rate = 2.8%) and Snake River steelhead (predicted predation rate = 5.1%; Table 11). The higher predicted predation rates on Upper Columbia steelhead by Crescent Island Caspian terns slightly offset the benefits achieved by a smaller Caspian tern colony at Goose Island in 2014.

Predicted predation rates by Blalock Islands Caspian terns in 2014 were close to the average impact during 2007-2013 due to an average colony size in the Blalock Islands during 2014 (45 pairs). Predicted predation rates were well below the 2% threshold for all ESA-listed salmonid populations (Table 11). Results suggest that the Blalock Islands tern colony would have to exceed 200 nesting pairs before impacts from tern predation would reach the 2% threshold (Table 11).

Conclusions: A technique to calculate average per capita predation rates with a measure of uncertainty (95% Credibility Intervals) for various colony sizes and locations was development and used to predict predation impacts by Caspian terns nesting on Goose Island, Crescent Island, and the Blalock Islands in 2014. As previously documented by Lyons et al. (2011a, 2011b) and Evans et al. (2012), per capita predation rates varied significantly by year, by colony, and by salmonid ESU/DPS, indicating that the benefits of Caspian tern management will also likely vary.

Predicted predation rates indicate that the IAPMP target goal of achieving predation rates less than 2% on a given ESA-listed population, per Caspian tern colony, was met for many but not all ESA-listed salmonid populations in 2014. Reductions in the size of the Caspian tern colony on Goose Island (including Northwest Rocks) in 2014 suggest that predation rates on Upper Columbia River steelhead were substantially reduced (to ca. 7.0%) compared with average previous predation rates (ca. 15.7%) observed during 2007-2013. Consistent with data presented in the IAPMP, the predicted predation rates

presented here suggest that the Goose Island colony needs to be reduced to 50 pairs or less to achieve the < 2% target goal for predation on upper Columbia River steelhead.

Predicted predation rates on ESA-listed salmonid populations by Caspian terns nesting on Crescent Island and the Blalock Islands were higher (Crescent Island) or similar (Blalock Islands) to those observed during 2007-2013. Increased predation rates on salmonids by Crescent Island Caspian terns may have offset some of the benefits achieved by the reduction in number of Caspian terns nesting on or near Goose Island-Potholes in 2014. Cumulative predicted impacts to Upper Columbia River steelhead, however, were still substantially reduced in 2014 compared with impacts observed during 2007-2013, indicating an overall net benefit to Upper Columbia River steelhead, the most vulnerable ESA-listed species to inland Caspian tern predation, from management of the Caspian tern colony on Goose Island-Potholes (Lyons et al. 2011a, 2011b; Evans et al. 2012).

Due to high inter-annual variation in predation rates and the documented influence of biotic (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 actual predation rates in any given year. Predicted predation rates are more likely to accurately reflect actual predation rates when tern colony sizes, river conditions, and prey abundances are similar to those observed during 2007-2013. Predicted predation rates are also more likely to reflect actual predation rates when colony sizes are small due to reduced uncertainty in predicted estimates of predation rates when colony sizes are small.

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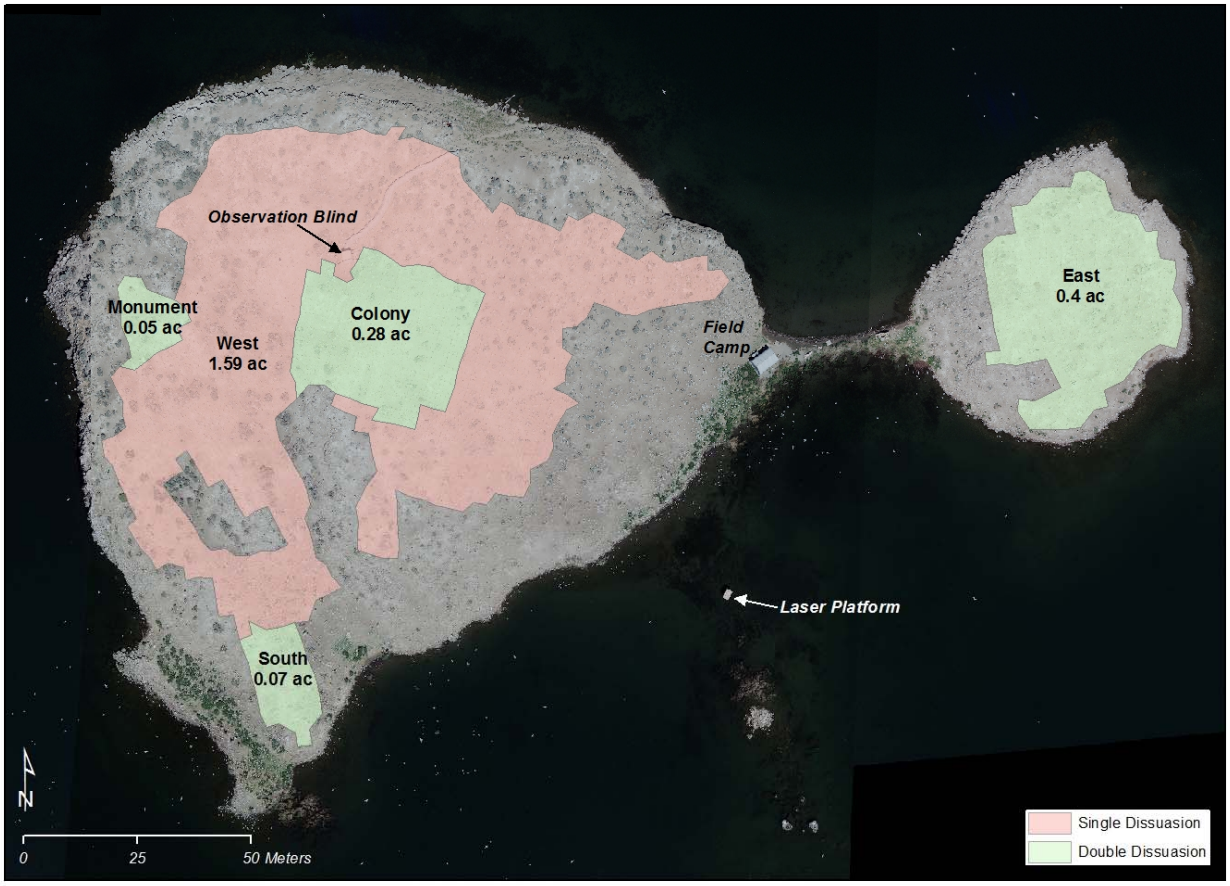
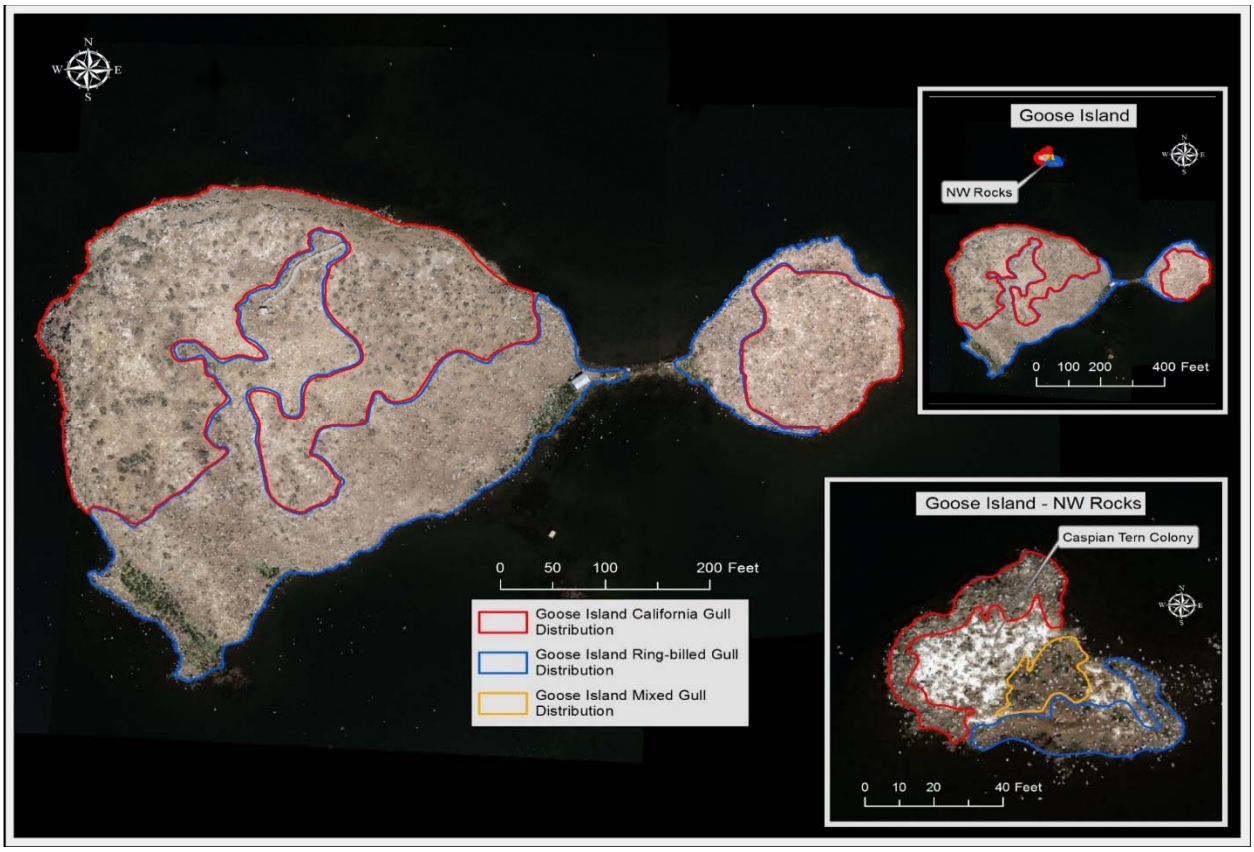
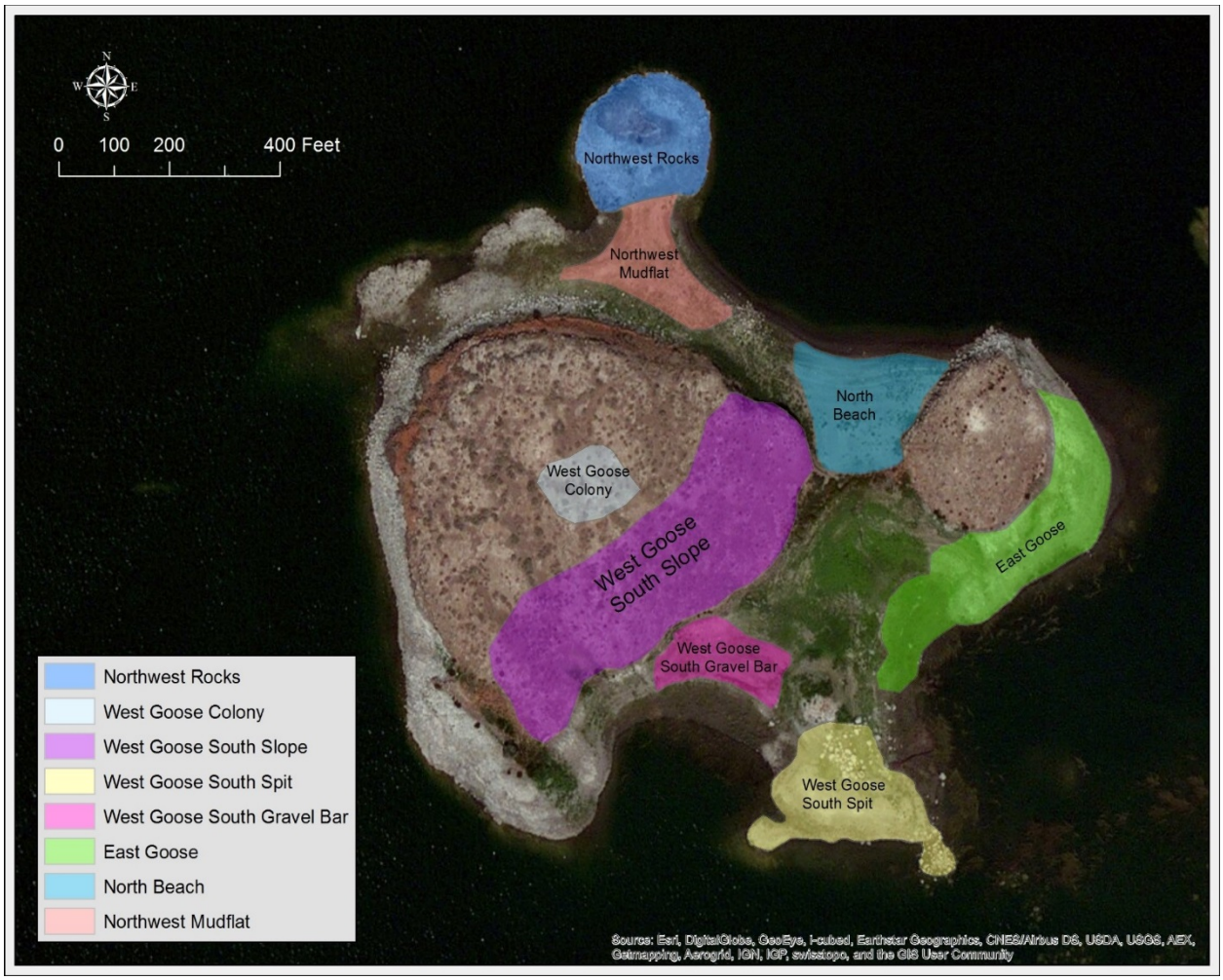
Map 1. Study area in the Inland Basin of the Columbia River in 2014.



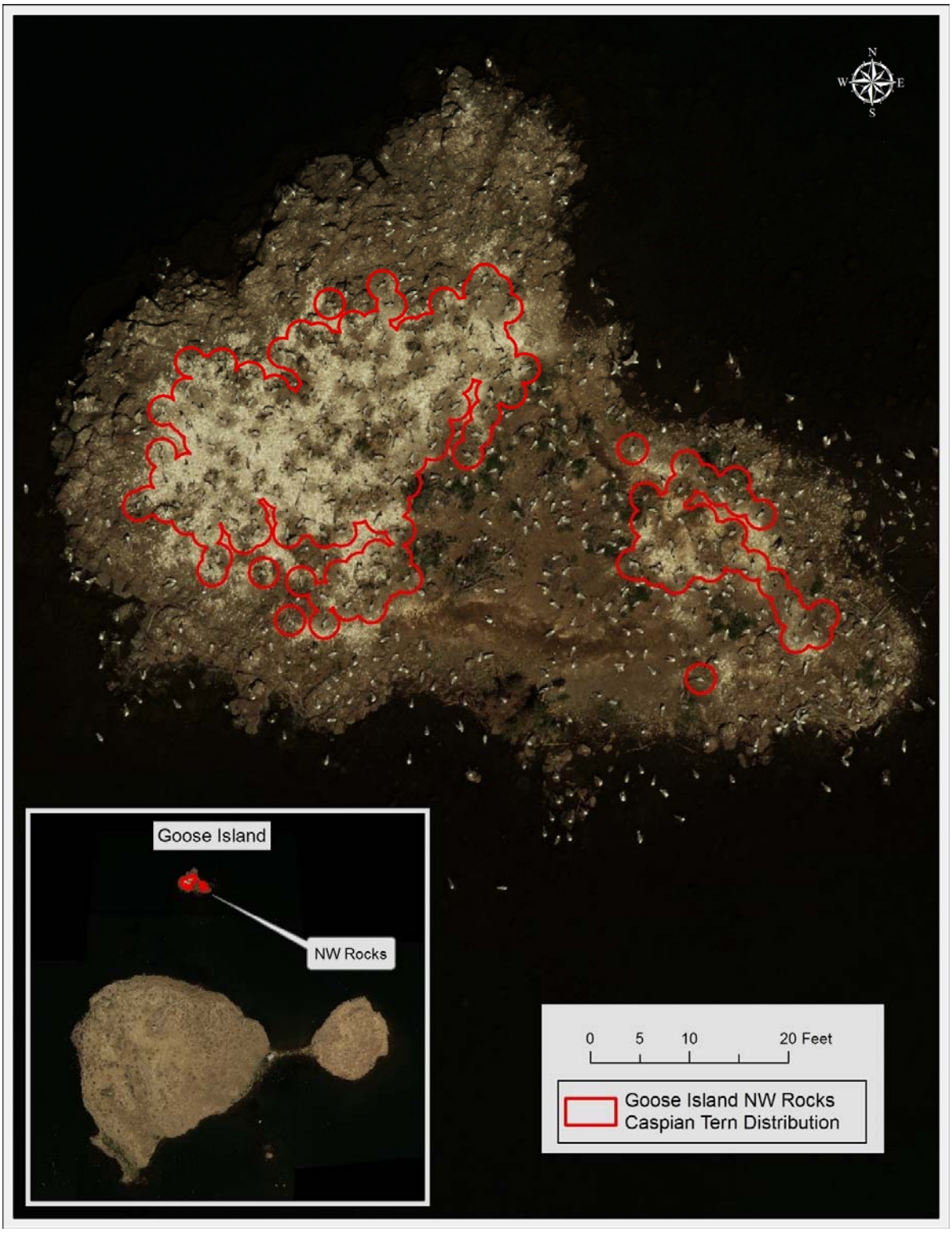
Map 2. Single-layer and double-layer rope dissuasion areas and acreages deployed on Goose Island, Potholes Reservoir in 2014.



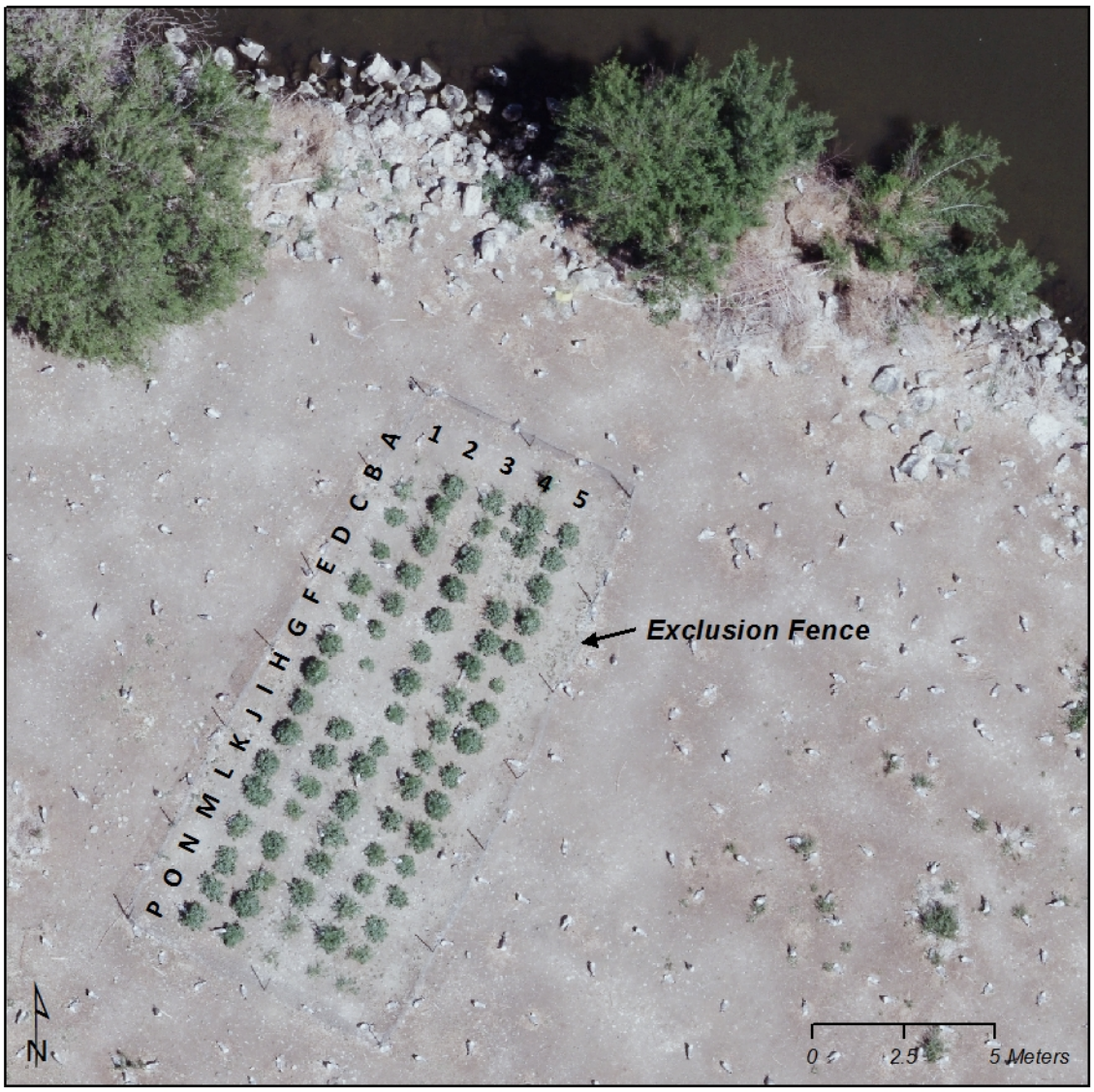
Map 3. Distribution of nesting California and ring-billed gulls on Goose Island and the nearby rocky islets, Potholes Reservoir in 2014.



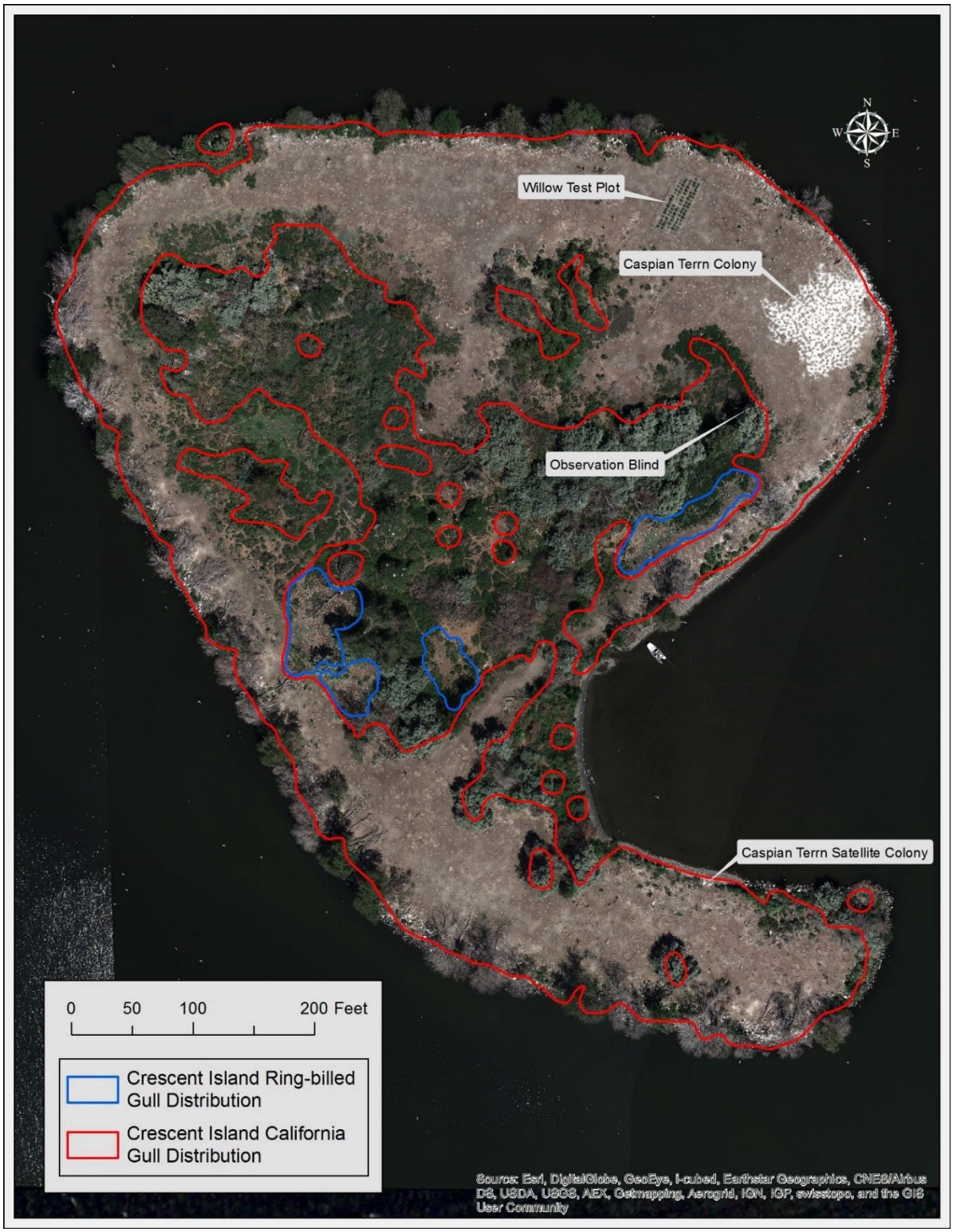
Map 4. Survey areas referenced in report for loafing and nesting Caspian terns on Goose Island and nearby rocky islets, Potholes Reservoir in 2014.



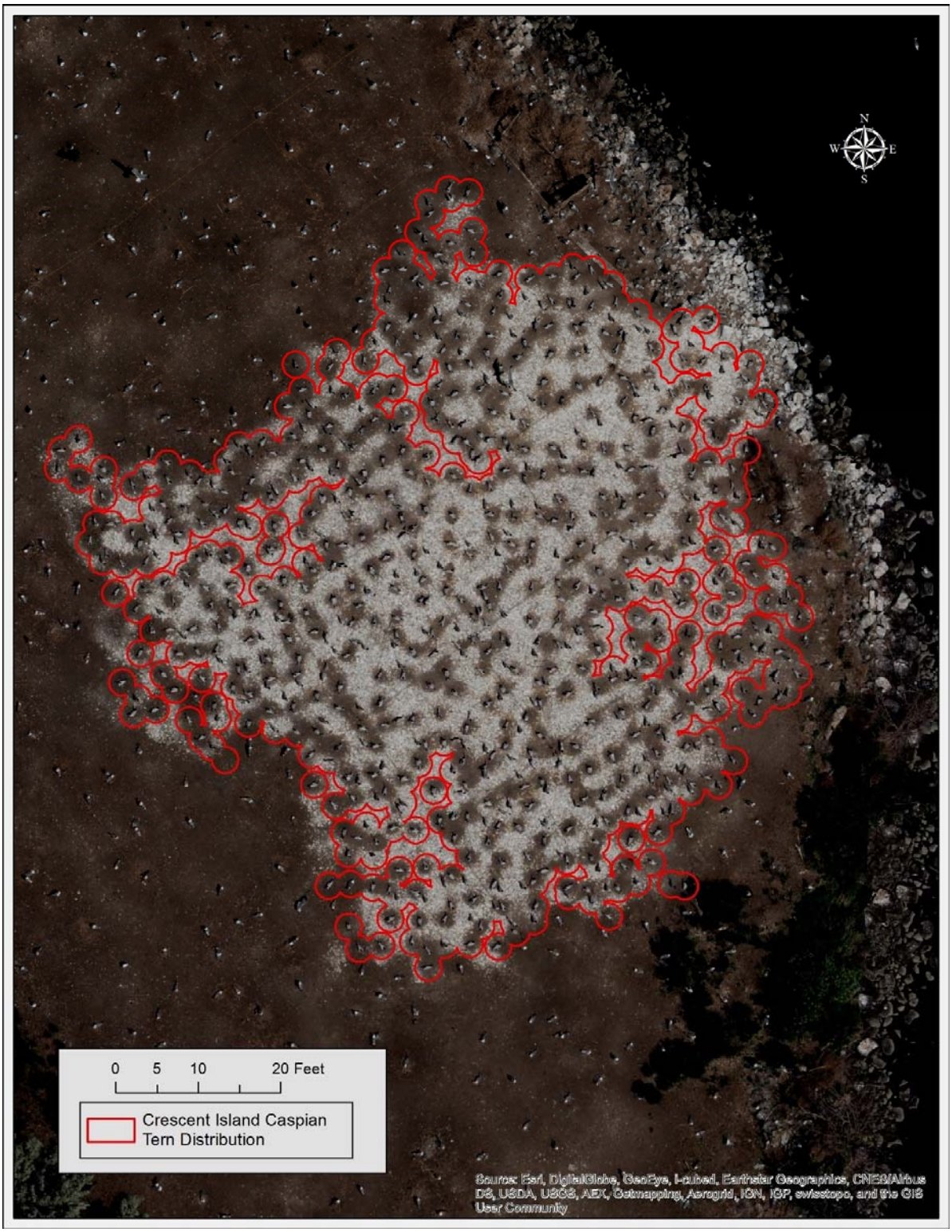
Map 5. Distribution of nesting Caspian terns on Northwest Rocks, an islet 125 m to the north of Goose Island, Potholes Reservoir in 2014.



Map 6. Aerial image of the willow test plot on Crescent Island, mid-Columbia River in 2014. Vegetation growth inside the plot includes planted native willows as well as non-native annuals. Holes for 75 individual plantings were drilled 3-4 feet apart in five columns (numbered 1-5 from east to west) and 15 rows (lettered A-O, running downslope from the island's edge). An exclusion fence was installed around the plot to protect the willows from browsing mammals.



Map 7. Locations of the main and satellite Caspian tern breeding colonies, willow test plot, and researcher observation blind, and the distribution of nesting California and ring-billed gulls on Crescent Island, mid-Columbia River in 2014.

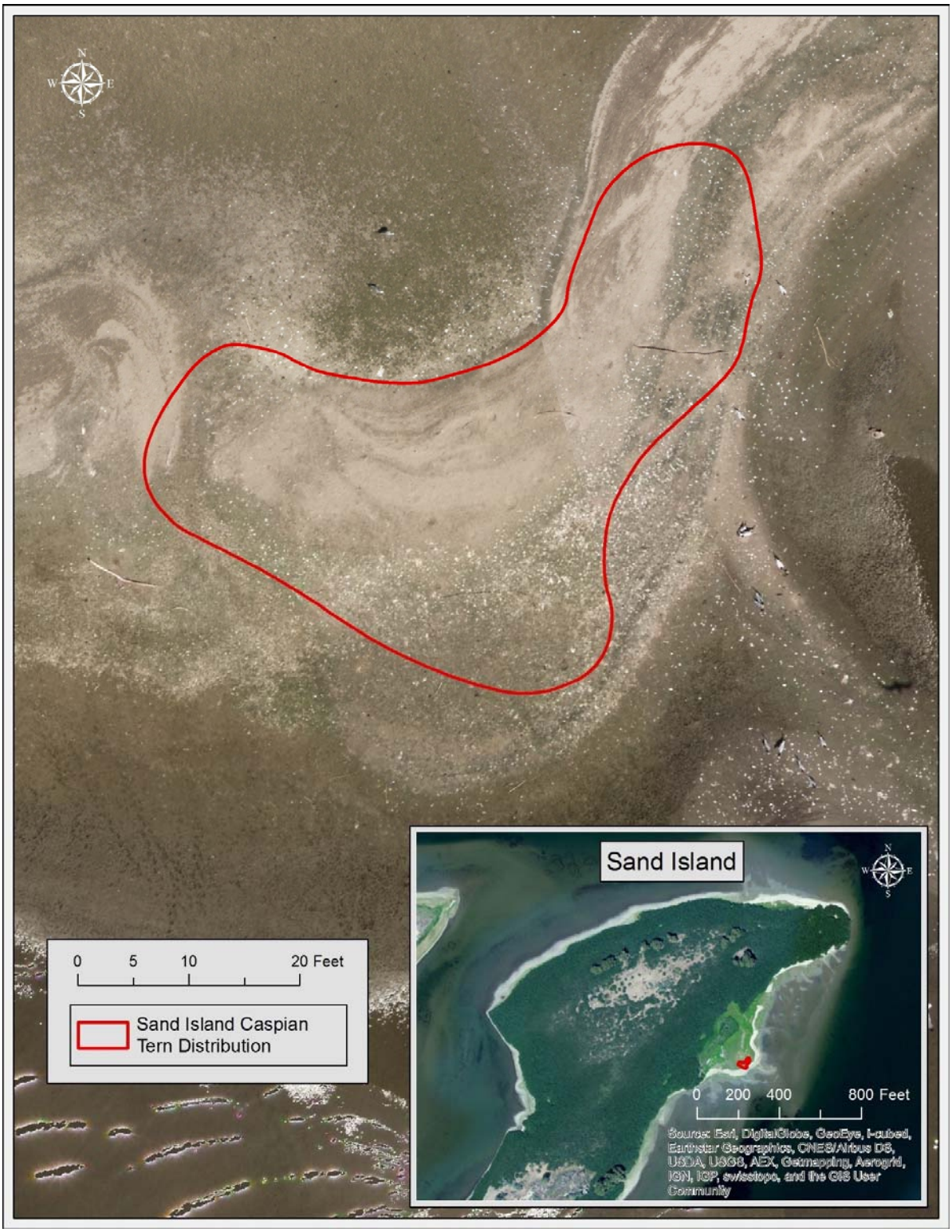


Map 8. Distribution of nesting Caspian terns on Crescent Island, mid-Columbia River in 2014.

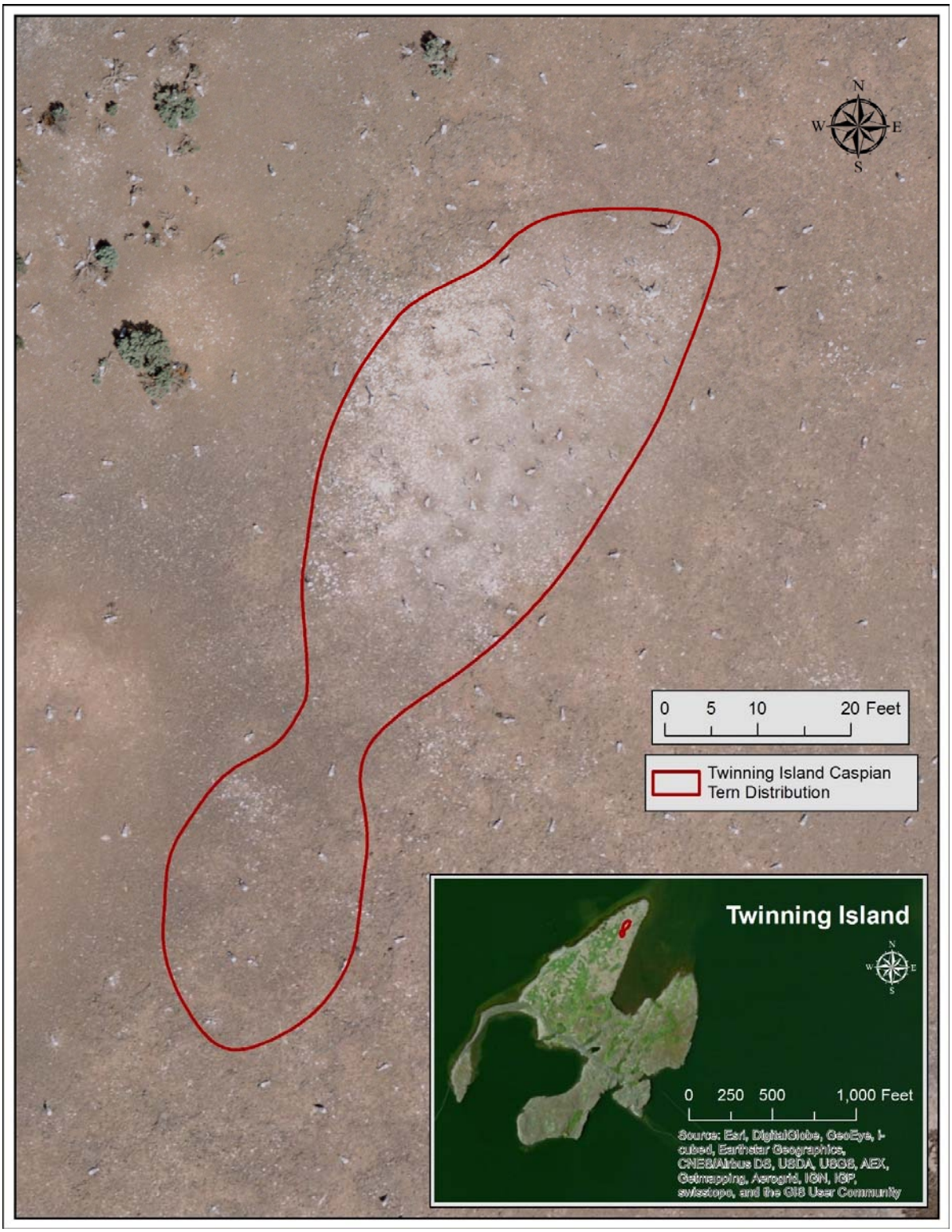
Map 9. Satellite Caspian tern breeding colony located on the north-facing slope just above the rocky shoreline on the southern arm of Crescent Island, mid-Columbia River in 2014.

Map 10. Middle, Long, Sand, and Anvil islands in the Blalock Islands complex, mid-Columbia River in 2014.

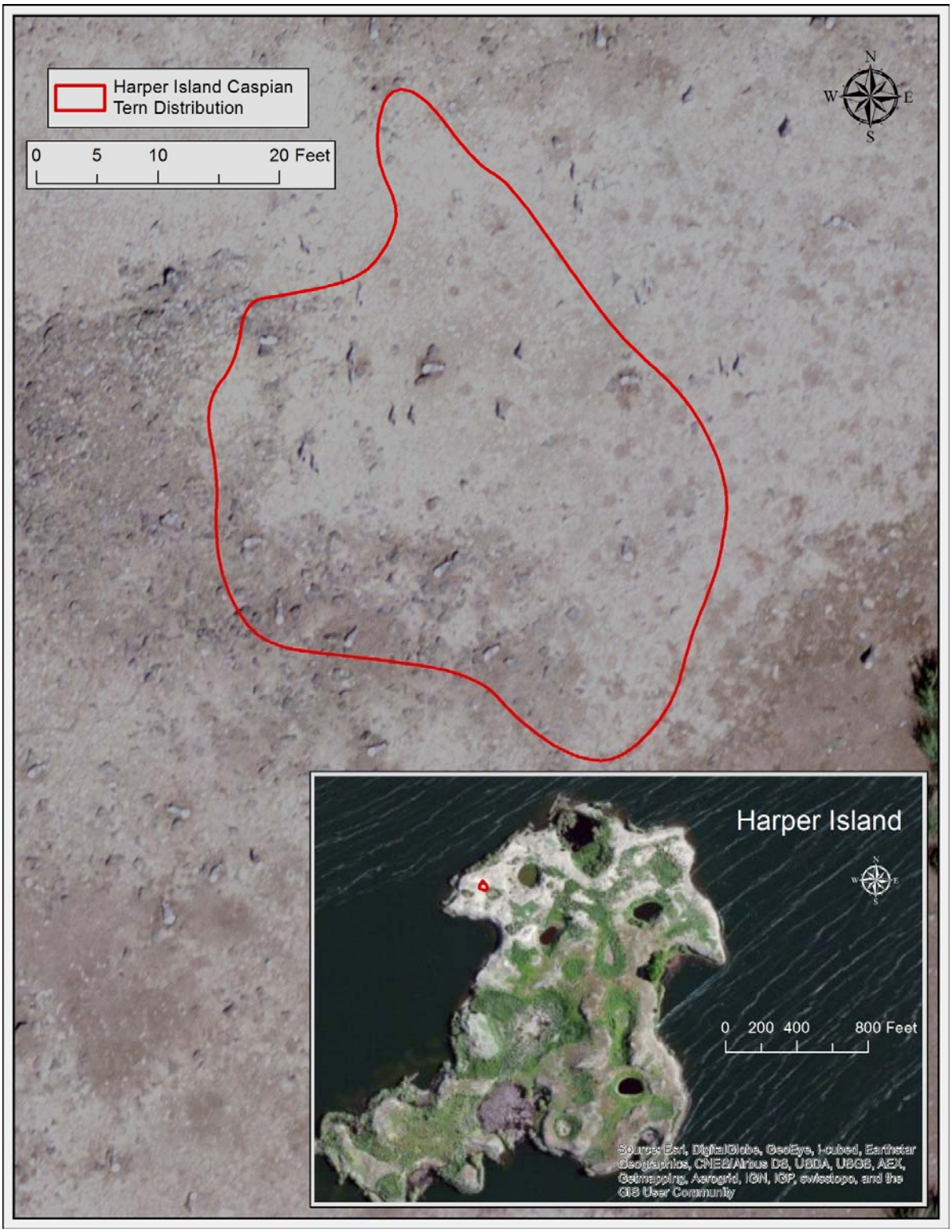
Map 11. Distribution of nesting Caspian terns on Middle and Long islands within the Blalock Islands complex, mid-Columbia River in 2014.



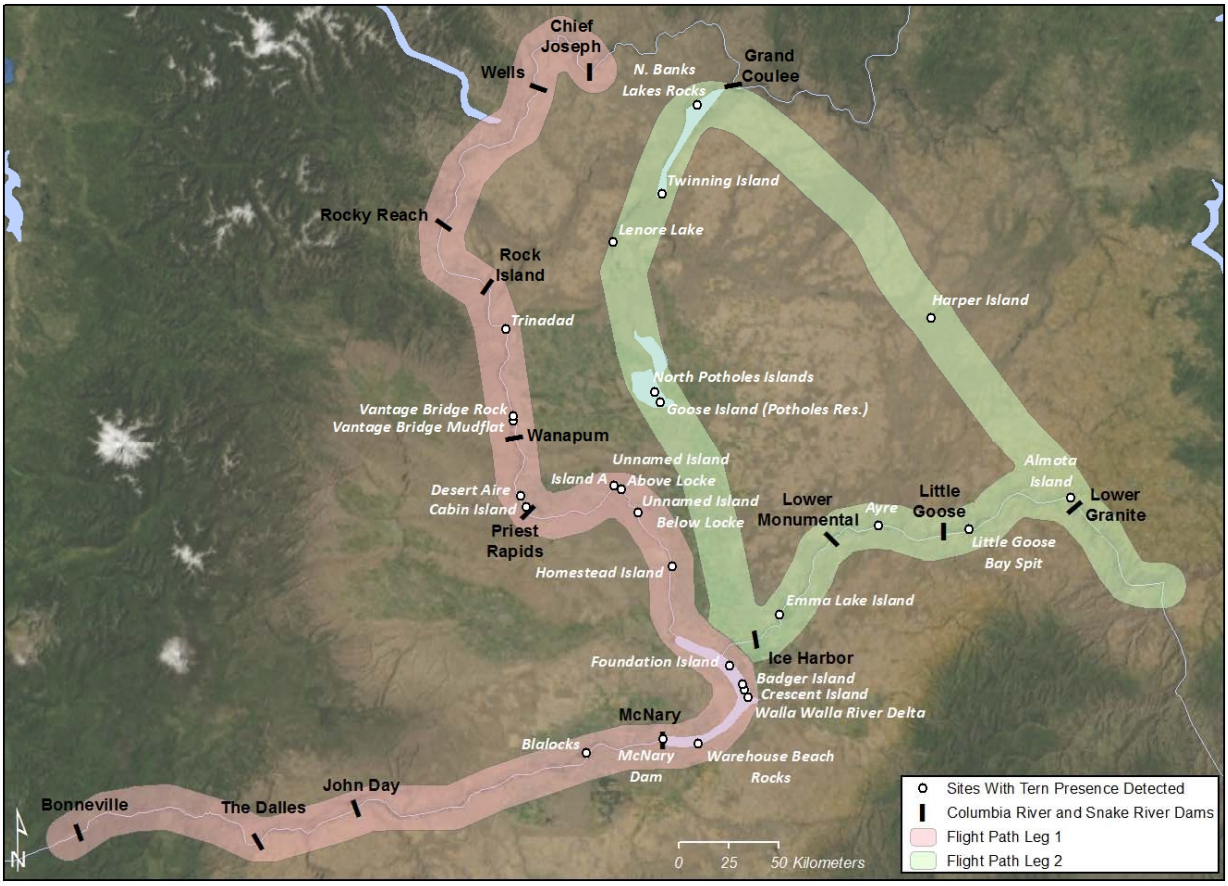
Map 12. Distribution of nesting Caspian terns on Sand Island in the Blalock Islands complex, mid-Columbia River in 2014.



Map 13. Distribution of nesting Caspian terns on Twinning Island, Banks Lake in 2014.



Map 14. Distribution of nesting Caspian terns on Harper Island, Sprague Lake in 2014.



Map 15. Aerial survey flight paths along the Columbia and Snake rivers and at off-river locations within the Inland Basin of the Columbia River, including sites where Caspian terns were observed loafing and nesting in 2014.

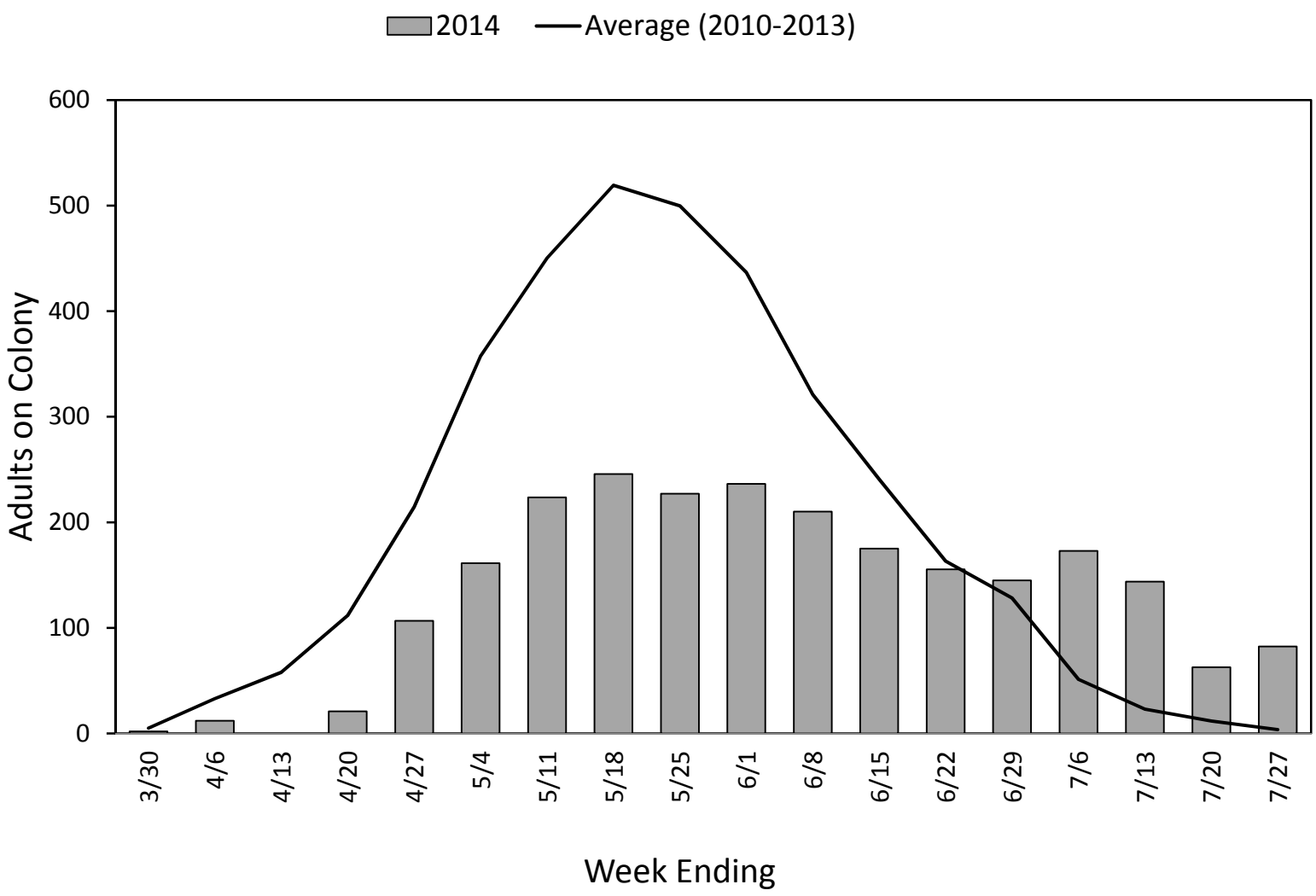


Figure 1. Estimates from the ground of the numbers of adult Caspian terns on the Goose Island breeding colonies (Northwest Rocks and the south-facing slope of Goose Island) in Potholes Reservoir, by week, during the 2014 breeding season.

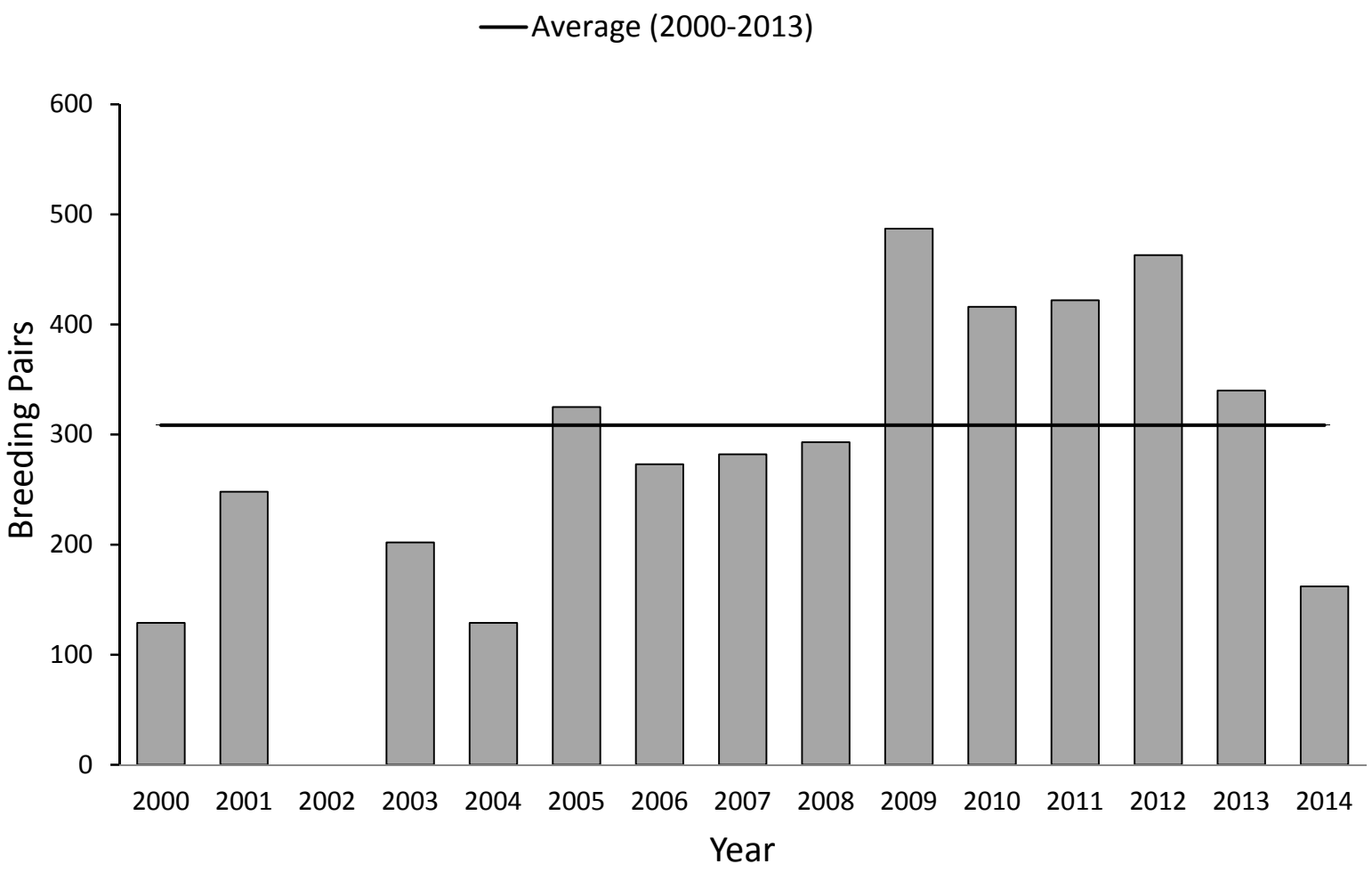


Figure 2. Size of the Caspian tern breeding colonies (number of breeding pairs) at Potholes Reservoir during 2000-2014. The colony was located on Solstice Island during 2000-2004, on Goose Island during 2004-2013, and mostly on Northwest Rocks just offshore of Goose Island in 2014. Colony size in 2002 was not determined.

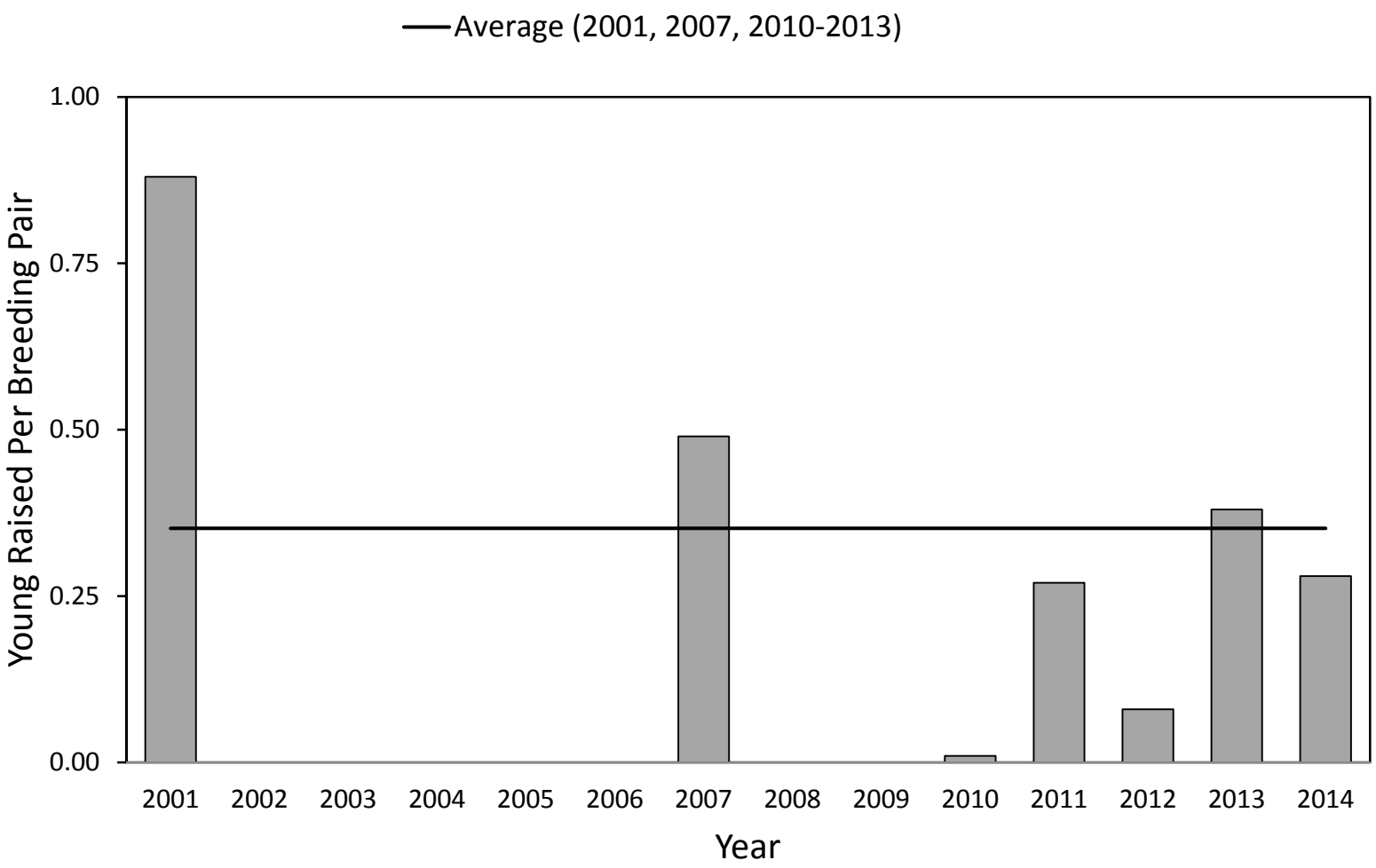


Figure 3. Caspian tern nesting success (average number of young raised per breeding pair) at breeding colonies on Potholes Reservoir during 2001-2014. The colony was located on Solstice Island during 2000-2004, on Goose Island during 2004-2013, and mostly on Northwest Rocks just offshore of Goose Island in 2014. Nesting success during 2002-2006 and 2008-2009 was not determined.

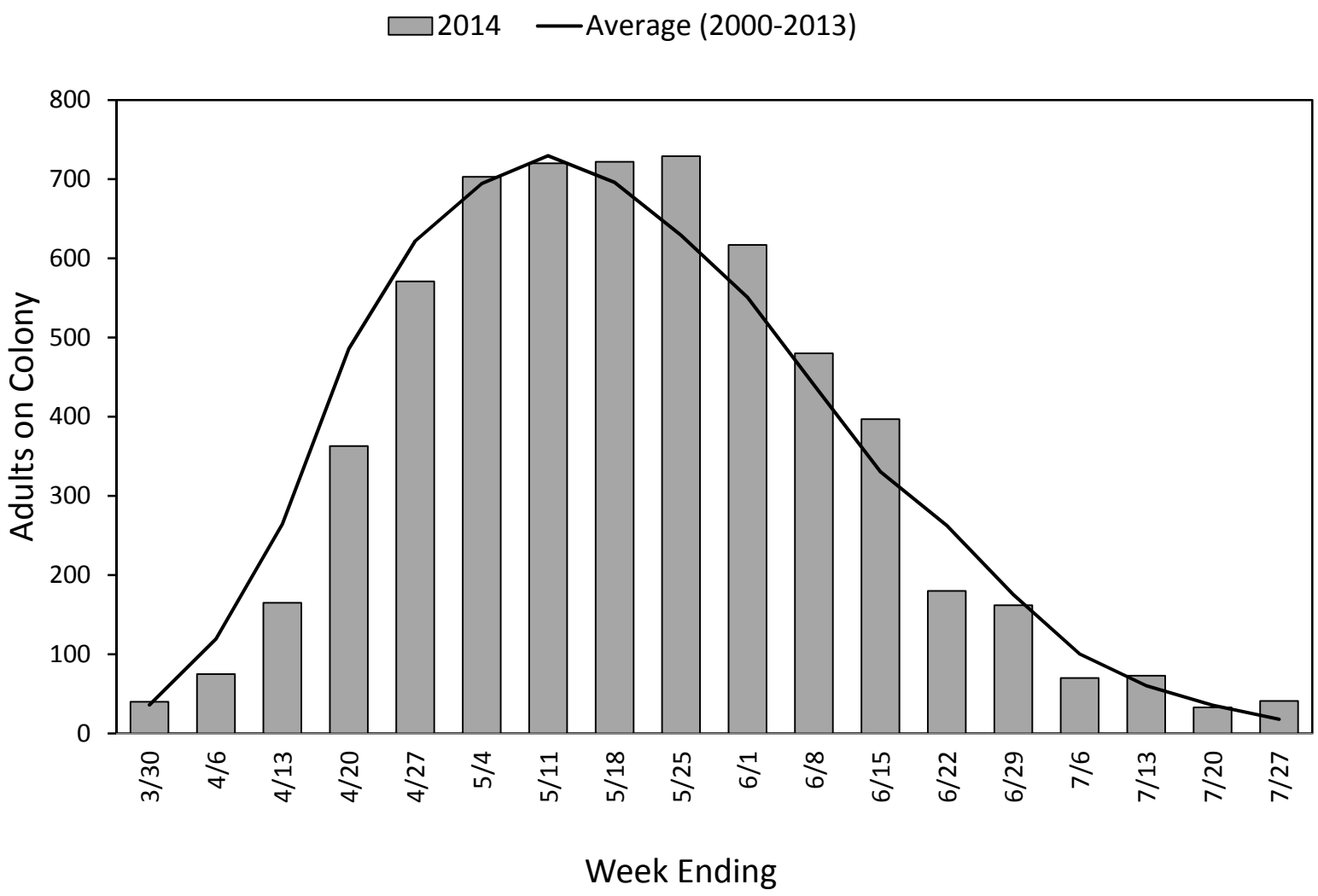


Figure 4. Estimates from the ground of the number of adult Caspian terns on the Crescent Island breeding colony in the mid-Columbia River, by week, during the 2014 breeding season.

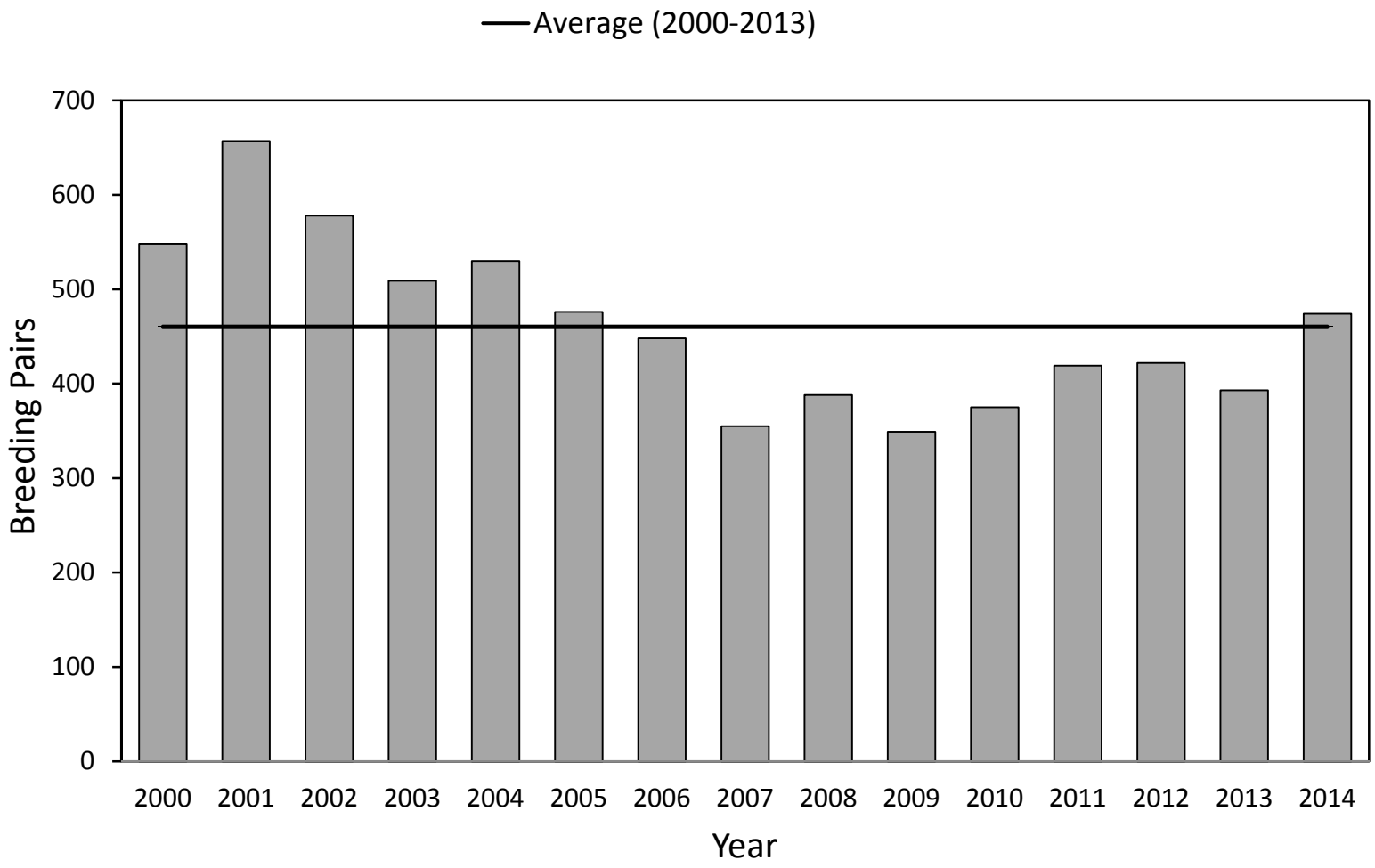


Figure 5. Size of the Caspian tern breeding colony (number of breeding pairs) on Crescent Island in the mid-Columbia River during 2000-2014.

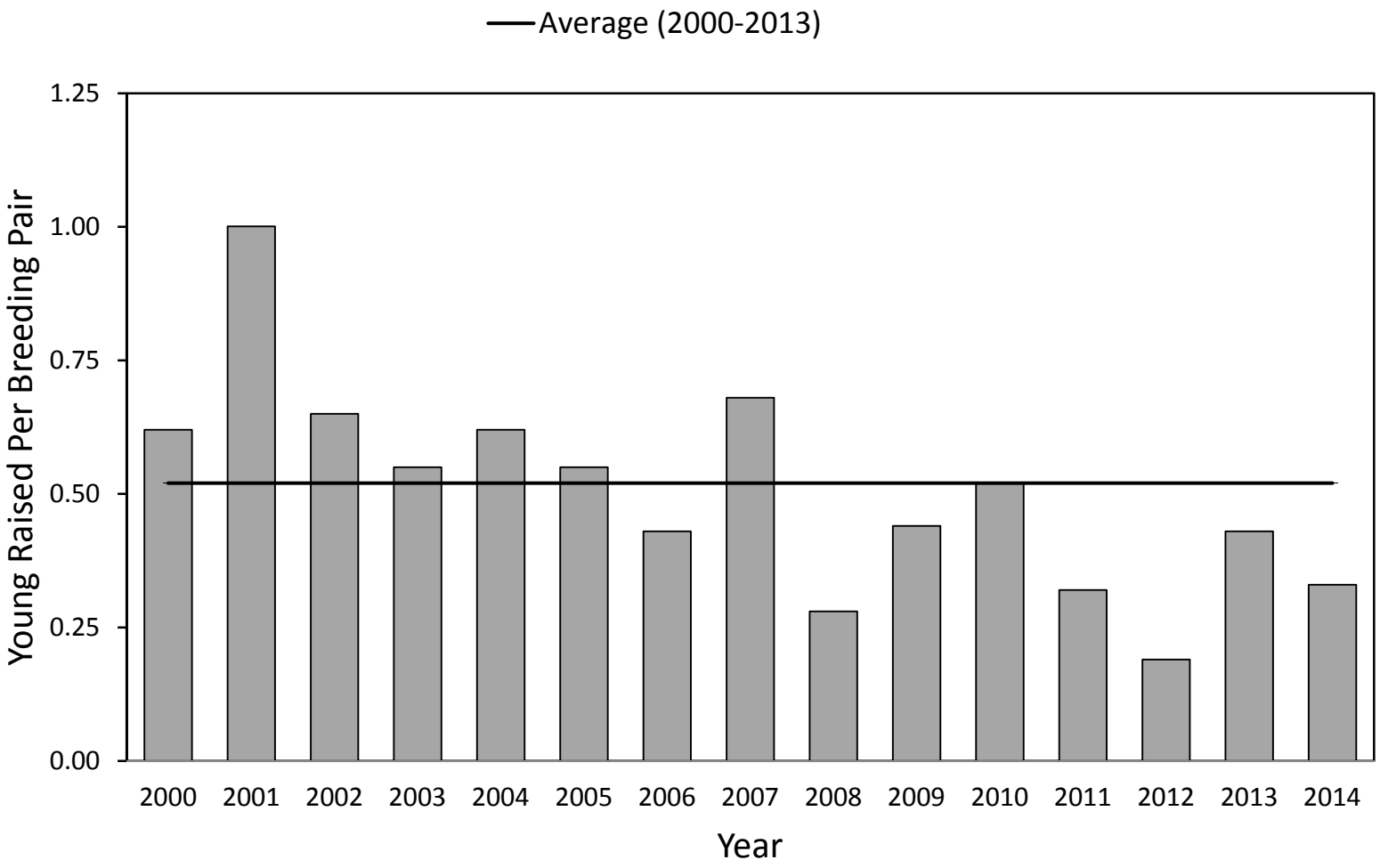


Figure 6. Nesting success of Caspian terns (average number of young raised per breeding pair) at the breeding colony on Crescent Island in the mid-Columbia River during 2000-2014.

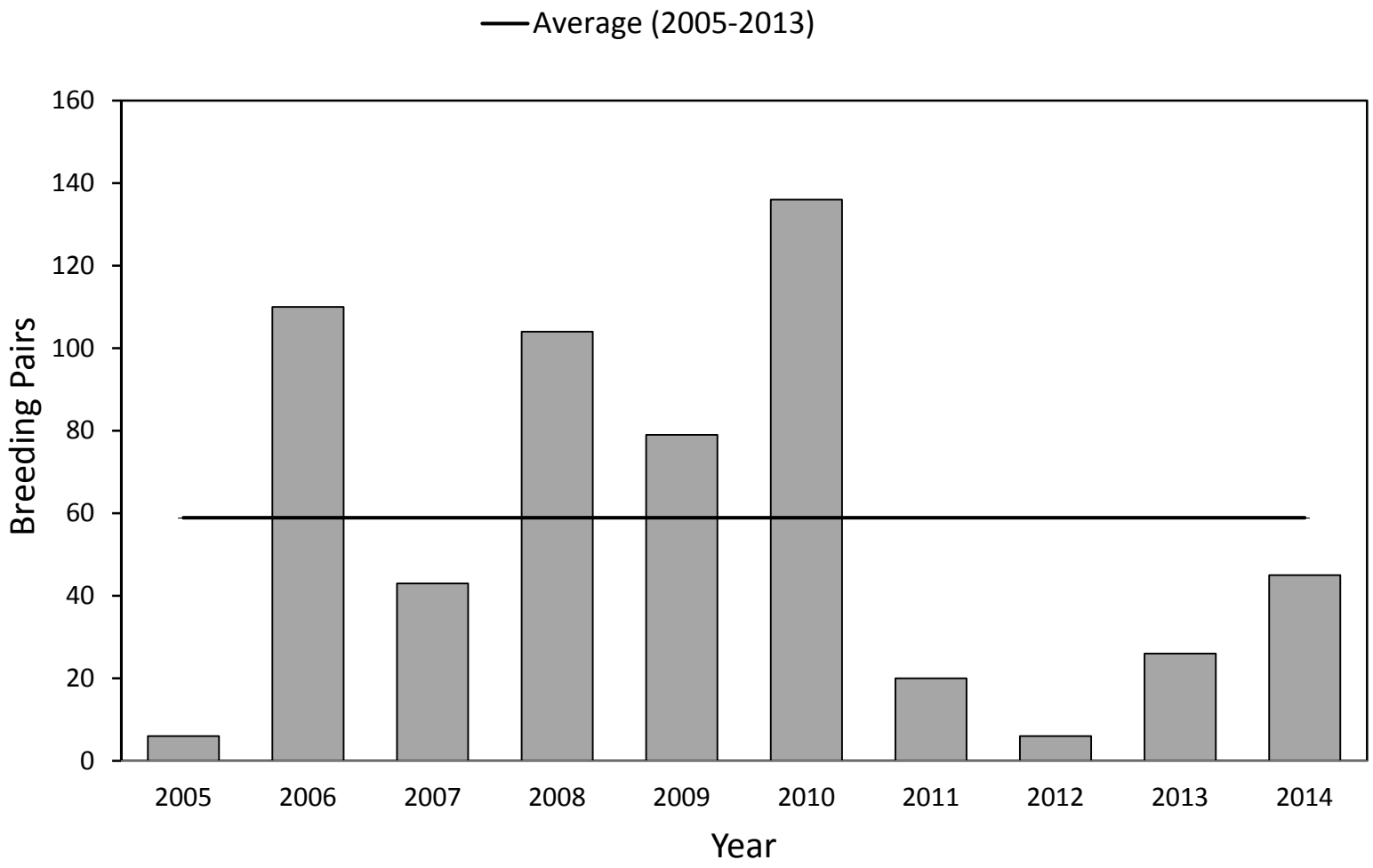


Figure 7. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock Islands in the mid-Columbia River during 2005-2014.

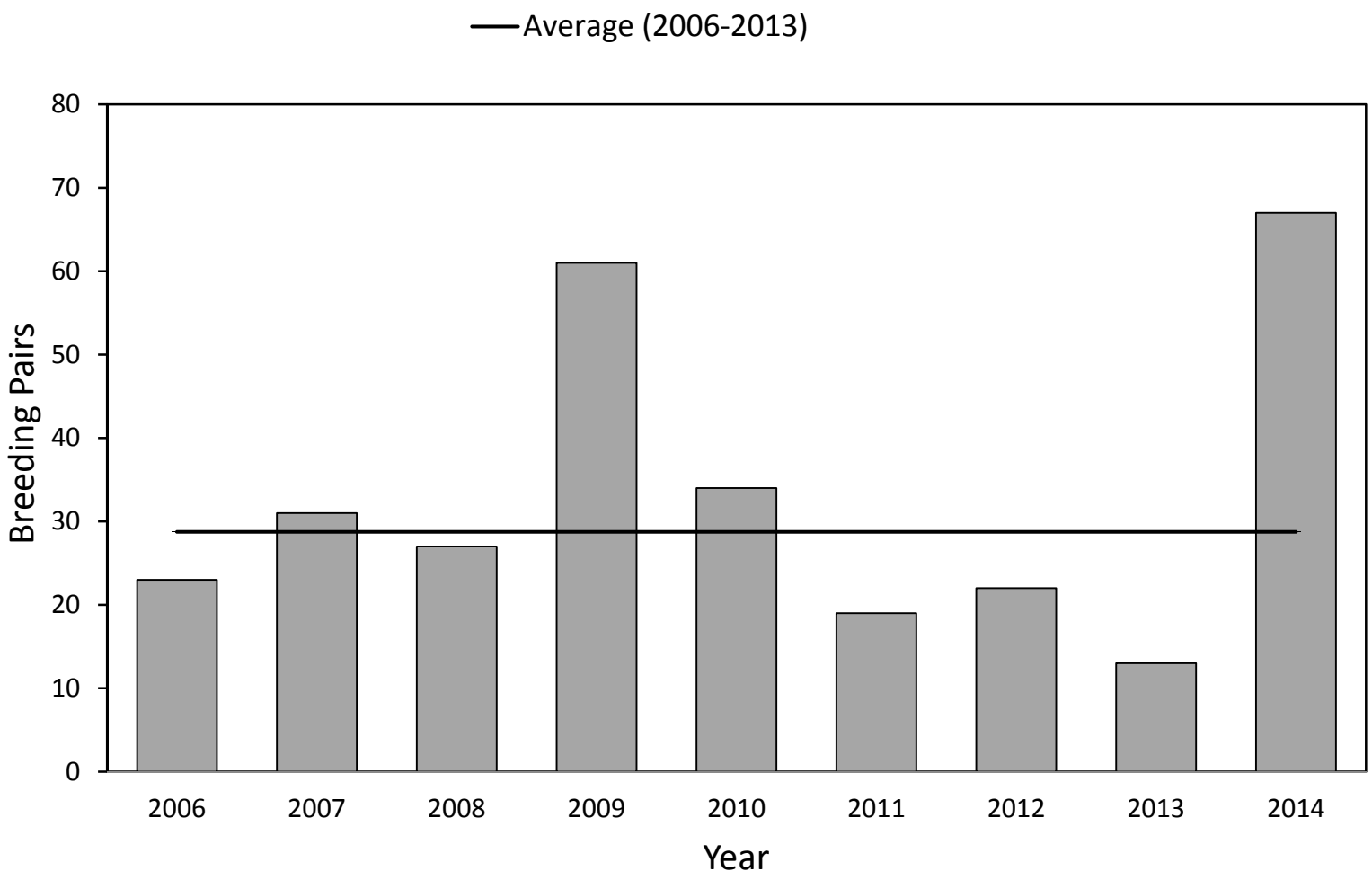


Figure 8. Size of the Caspian tern breeding colony (number of breeding pairs) at Twinning Island in Banks Lake during 2006-2014. In 2005, Caspian terns nested on two islands in Banks Lake (Twinning and Goose islands), and colony size was estimated to be less than 10 breeding pairs at each site.

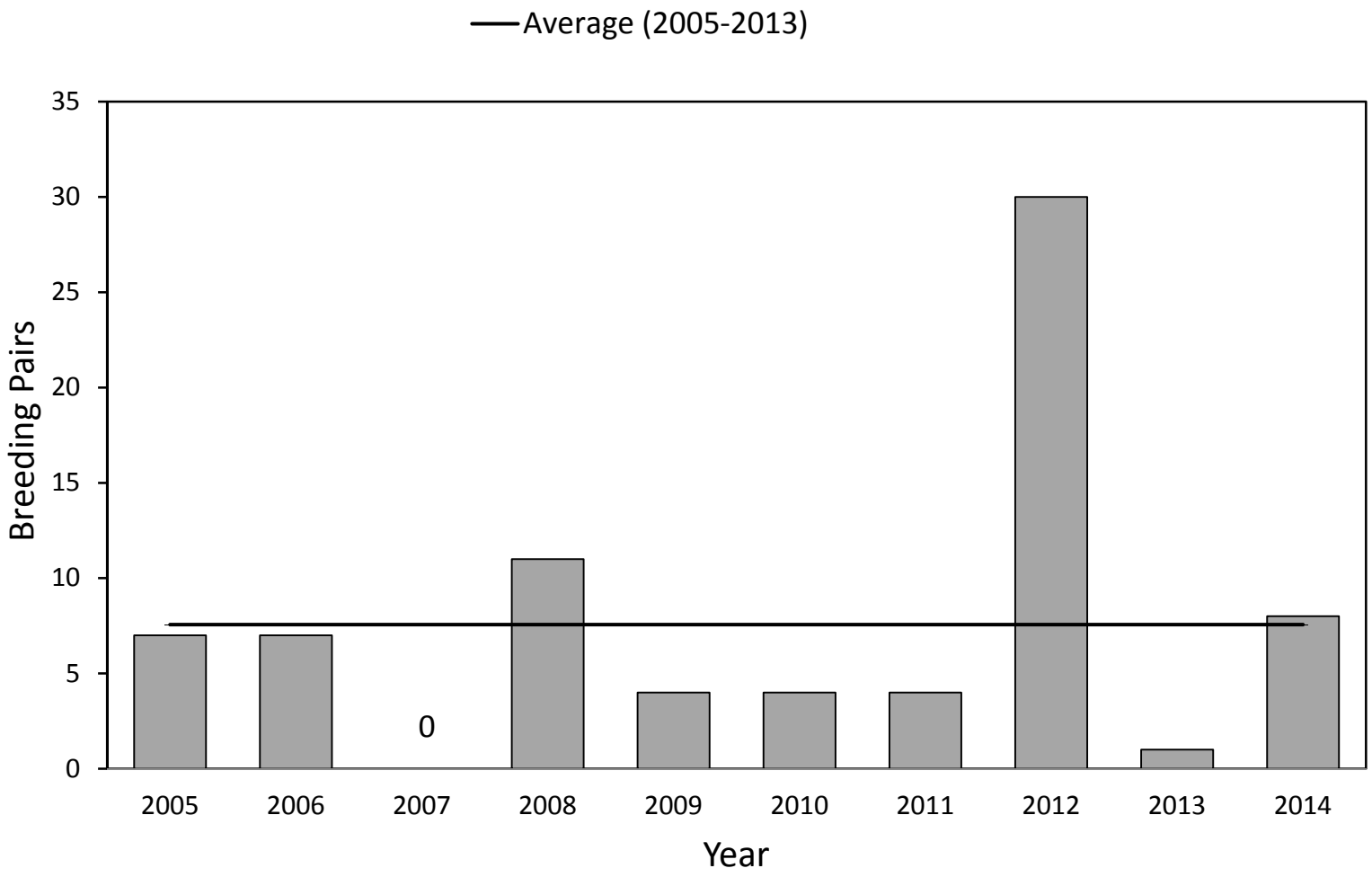


Figure 9. Size of the Caspian tern breeding colony (number of breeding pairs) at Harper Island in Sprague Lake during 2005-2014. Caspian terns did not attempt to nest on Harper Island in 2007.

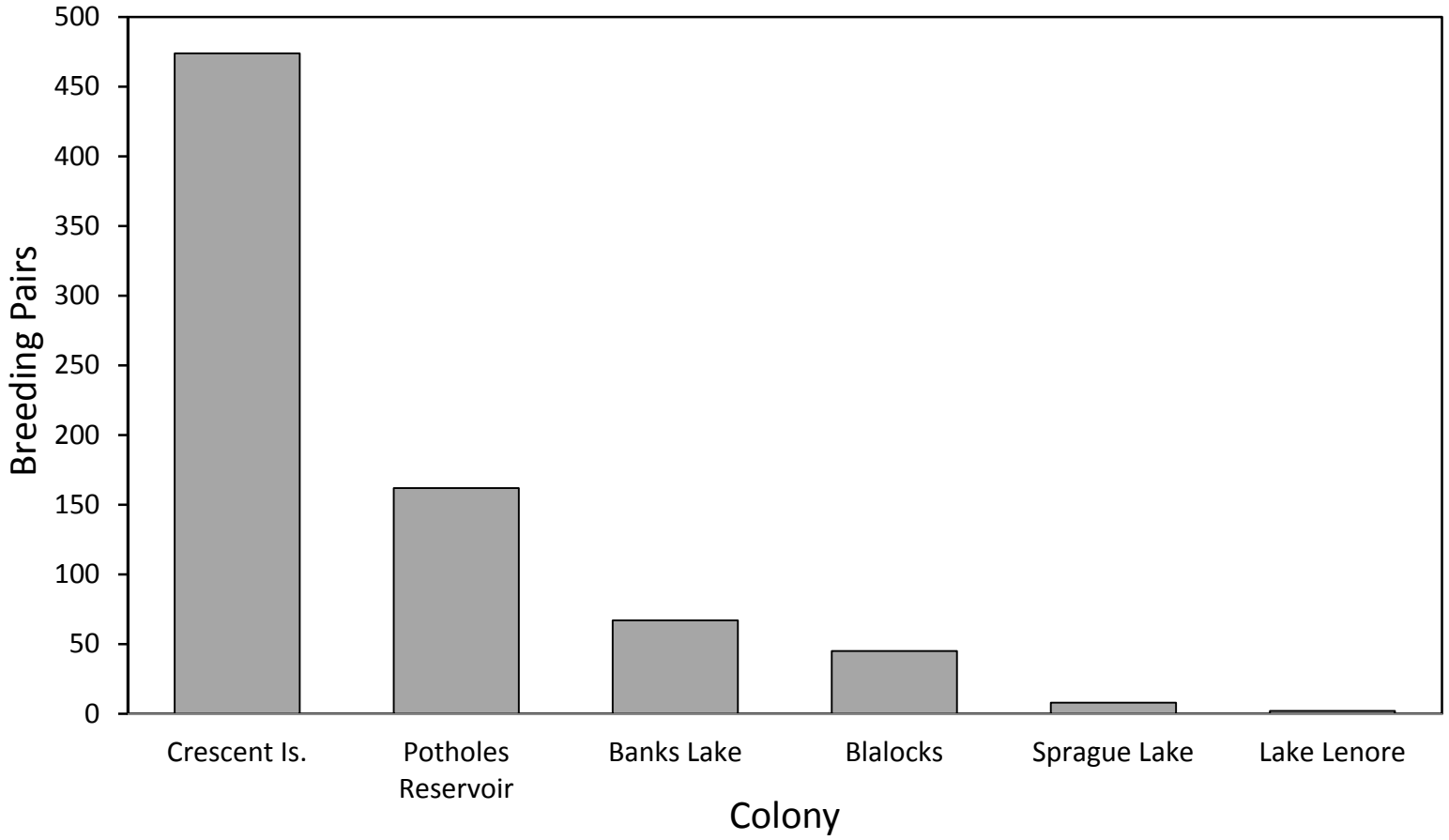


Figure 10. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the inland Columbia River Basin during the 2014 breeding season.

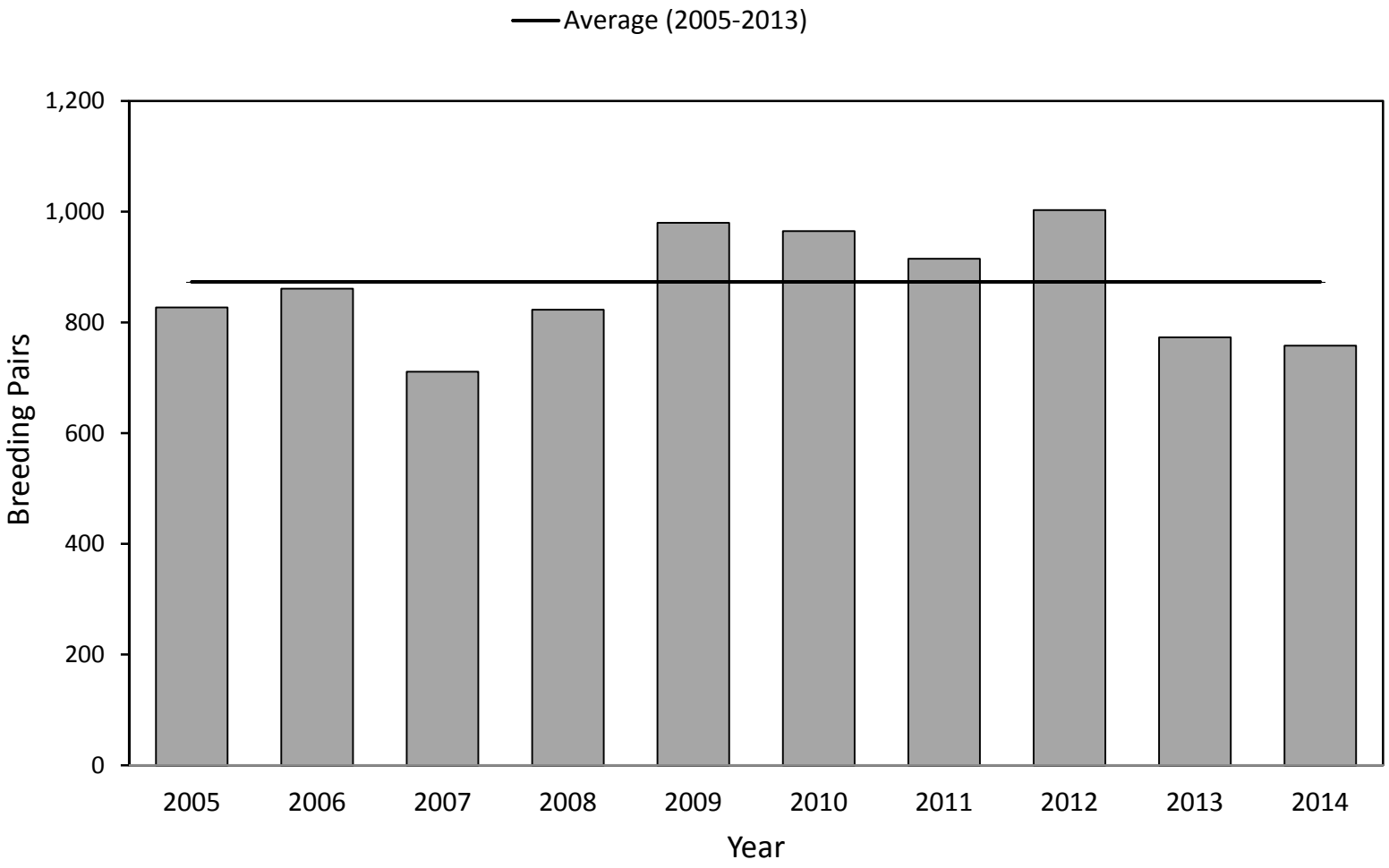


Figure 11. Total numbers of Caspian tern breeding pairs nesting at all known colonies in the inland Columbia River Basin during 2005-2014.

Table 1. Weekly estimates of the time spent (in minutes) and number of Caspian terns hazed during active nest dissuasion activities at various locations on Goose Island, Potholes Reservoir in 2014. Map 4 indicates the locations where daily counts of Caspian terns were conducted prior to the first morning hazing event.

			Average Daily Count of Caspian Terns by Location							
Dates	Active Dissuasion (Total Minutes)	Active Dissuasion (Average Minutes per Day)	West Goose South Spit	West Goose South Slope	West Goose South Gravel Bar	West Goose Colony	North Beach	Northwest Mudflat	East Goose	Goose Island Totals
3/17–3/23	550	110	0	0	0	0	0	0	0	0
3/24–3/30	937	187	0	0	0	0	0	0	0	0
3/31–4/06	724	121	1	0	0	8	0	0	0	9
4/07–4/13	1448	207	9	0	0	12	0	0	0	21
4/14–4/20	2927	488	1	10	0	0	0	0	0	11
4/21–4/27	2517	360	15	26	0	0	0	0	0	41
4/28–5/04	2226	318	0	0	3	0	0	0	0	3
5/05–5/11	2585	369	0	1	2	0	0	0	0	3
5/12–5/18	2684	383	0	26	0	0	0	0	0	26
5/19–5/25	2804	401	0	16	0	0	0	0	0	16
5/26–6/01	2771	396	0	42	0	0	0	0	0	42
6/02–6/08	2858	408	0	21	0	0	0	0	0	21
6/09–6/15	2880	411	0	11	2	0	0	0	0	14
6/16–6/22	2573	368	0	2	32	0	3	0	0	37
6/23–6/29	2633	376	0	0	63	0	0	0	0	63
6/30–7/06	1555	259	0	0	25	0	8	0	0	33
7/07–7/13	1490	248	0	0	17	0	13	49	0	79
7/14–7/20	1185	198	0	0	13	0	14	32	3	62
7/21–7/27	360	360	0	0	21	0	30	19	0	71
7/28–8/03	620	310	0	0	5	0	34	0	0	39

Table 2. Results of test plantings of native willows in an experimental plot on Crescent Island in McNary Pool, Columbia River in 2014. See section 1.2.1 of the text for a detailed description of the five treatments and the criteria used for quantifying the success of each treatment.

	Treatment				
	Two Rivers single cutting soaked	Two Rivers single cutting not soaked	Crescent Island five cuttings soaked	Two Rivers five cuttings not soaked	Two Rivers five cuttings soaked
Number of plantings	15	15	15	15	15
Number of cuttings per planting	1	1	5	5	5
Proportion with ≥ 1 sprouted cutting	0.87	0.93	1.00	1.00	1.00
Proportion with ≥ 1 live leader	0.73	0.80	1.00	1.00	1.00
Proportion w/ Kochia in growth space	1.00	1.00	1.00	1.00	1.00
Proportion w/ Atriplex in growth space	1.00	1.00	1.00	1.00	1.00
Average length (cm) of tallest leader	171	163	177	199.80	208.53
Average diam (mm) of tallest leader	8.6	8.9	7.9	9.6	9.5
# of cuttings with vigor = 3	7	8	12	11	12
# of cuttings with vigor = 2	2	2	3	3	3
# of cuttings with vigor = 1	2	2	0	1	0
# of cuttings with vigor = 0	4	3	0	0	0

Note: Summary statistics and the counts above are for each set of 15 planting holes and provide results after one growing season at the planting hole level for the five planting treatments.

Table 3. Summary of sites where Caspian terns were detected during aerial surveys in 2014 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	"At Risk" Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/Longitude
5/19	Goose Island-E Rocks	No	4	NA	Rock	Loafing	46°59'14.39"N 119°18'25.81"W
4/26	Goose Island-Northwest Rocks	No	37	9	Upland	Attended Nests	46°59'12.88"N 119°18'38.05"W
5/19	Goose Island-Northwest Rocks	No	232	159	Upland	Attended Nests	46°59'12.88"N 119°18'38.05"W
6/24	Goose Island-Northwest Rocks	No	>100	NA	Upland	Nestlings	46°59'12.88"N 119°18'38.05"W
5/19	Harper Island	No	36	4	Upland	Attended Nests	47°14'48.56"N 118° 5'5.26"W
6/24	Harper Island	No	22	NA	Upland	Loafing	47°14'48.56"N 118° 5'5.26"W
4/25	Lenore Lake	No	5	2	Upland	Nesting	47°28’47.43”N 119°31’26.16”W
6/24	Lenore Lake	No	24	NA	Rock	Loafing	47°28’47.43”N 119°31’26.16”W
4/26	NE Potholes	No	4	NA	Sand	Loafing	47° 3'4.79"N 119°20'3.87"W
6/24	North Banks Lake Rocks	No	2	NA	Rock	Loafing	47°53'41.29"N 119° 8'32.46"W
4/25	Twinning Island	Yes	8	NA	Rock	Loafing	47°37'30.81"N 119°18'9.36"W
5/18	Twinning Island	Yes	105	67	Upland	Attended Nests	47°37'30.81"N 119°18'9.36"W
6/24	Twinning Island	Yes	42	4	Rock/Upland	Attended Nests	47°37'30.81"N 119°18'9.36"W

Mid-Columbia River							
Survey Date	Site Name	"At Risk" Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/Longitude
5/18	Badger Island	Yes	*	NA	Gravel Bar	Loafing	46° 6'12.50"N 118°56'7.43"W
5/18	Blalock Islands-Anvil Island	Yes	2	NA	Gravel Bar	Loafing	45°53'48.91"N 119°38'42.11"W
4/25	Blalock Islands-Long Island	Yes	13	NA	Gravel Bar	Loafing	45°53'43.89"N 119°38'44.60"W
5/18	Blalock Islands-Long Island	Yes	13	8	Gravel Bar	Attended Nests	45°53'43.89"N 119°38'44.60"W
6/24	Blalock Islands-Long Island	Yes	10	5	Gravel Bar	Attended Nests	45°53'43.89"N 119°38'44.60"W
4/25	Blalock Islands-Middle Island	Yes	7	NA	Gravel Bar	Loafing	45°53'43.27"N 119°38'48.06"W
5/18	Blalock Islands-Middle Island	Yes	67	30	Gravel Bar	Attended Nests	45°53'43.27"N 119°38'48.06"W
6/24	Blalock Islands-Middle Island	Yes	63	32	Gravel Bar	Nestlings	45°53'43.27"N 119°38'48.06"W
4/25	Blalock Islands-Sand Island	Yes	69	**	Sand	Loafing	45°53'50.12"N 119°38'12.25"W
5/18	Blalock Islands-Sand Island	Yes	76	9	Sand	Attended Nests	45°53'50.12"N 119°38'12.25"W
4/25	Blalock Islands-Southern Island	Yes	14	NA	Gravel Bar	Loafing	45°53'41.32"N 119°39'1.39"W
4/25	Cabin Island	Yes	15	NA	Gravel Bar	Loafing	46°39'26.24"N 119°54'51.91"W
5/18	Cabin Island	Yes	24	NA	Gravel Bar	Loafing	46°39'26.24"N 119°54'51.91"W
6/24	Cabin Island	Yes	11	NA	Gravel Bar	Loafing	46°39'26.24"N 119°54'51.91"W
4/25	Crescent Island-Main	No	100s	NA	Upland	Nesting	46° 5'37.22"N 118°55'47.68"W

Mid-Columbia River (continued)							
Survey Date	Site Name	"At Risk" Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/Longitude
5/18	Crescent Island-Main	No	708	NA	Upland	Nestlings	46° 5'37.22"N 118°55'47.68"W
6/24	Crescent Island-Main	No	100s	NA	Upland	Fledglings	46° 5'37.22"N 118°55'47.68"W
5/18	Crescent Island-Satellite	No	7	3	Upland	Attended Nests	46° 5'32.62"N 118°55'48.66"W
4/25	Desert Aire	No	25	NA	Mudflat	Loafing	46°41'45.17"N 119°56'38.20"W
4/25	Foundation Island	Yes	6	NA	Gravel Bar	Loafing	46°10'18.79"N 119° 0'15.09"W
5/18	Foundation Island	Yes	8	NA	Gravel Bar	Loafing	46°10'18.79"N 119° 0'15.09"W
6/24	Homestead Island	No	1	NA	Gravel Bar	Loafing	46°28'6.31"N 119°15'27.94"W
5/18	Island A	No	31	NA	Gravel Bar	Loafing	46°43'34.47"N 119°31'16.17"W
5/18	McNary Dam Forebay	No	3	NA	Rock	Loafing	45°56'39.41"N 119°17'38.74"W
4/25	Trinadad	No	57	NA	Mudflat	Loafing	47°12'39.44"N 120° 0'30.69"W
4/25	Unnamed Island above Locke Is.	No	43	NA	Gravel Bar	Loafing	46°42'52.18"N 119°29'14.12"W
5/18	Unnamed Island below Locke Is.	No	27	NA	Gravel Bar	Loafing	46°38'32.67"N 119°24'41.98"W
5/18	Vantage Bridge Mudflat	No	42	NA	Mudflat	Loafing	46°55'44.78"N 119°58'37.64"W
6/24	Vantage Bridge Rock	No	32	NA	Rock	Loafing	46°56'34.67"N 119°58'36.62"W
5/18	Walla Walla River Delta	No	83	NA	Mudflat	Loafing	46° 4'11.96"N 118°54'55.80"W

Mid-Columbia River (continued)							
Survey Date	Site Name	"At Risk" Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/Longitude
6/24	Walla Walla River Delta	No	13	NA	Mudflat	Loafing	46° 4'11.96"N 118°54'55.80"W
4/25	Warehouse Beach Rocks	No	44	NA	Rock	Loafing	45°55'21.21"N 119° 8'21.23"W
5/18	Warehouse Beach Rocks	No	34	NA	Rock	Loafing	45°55'21.21"N 119° 8'21.23"W
6/24	Warehouse Beach Rocks	No	3	NA	Rock	Loafing	45°55'21.21"N 119° 8'21.23"W

Snake River							
Survey Date	Site Name	"At Risk" Site	Adult Count	Attended Nest Count	Substrate	Breeding Activity	Latitude/Longitude
5/19	Almota Island	No	2	NA	Gravel Bar	Loafing	46°41'24.07"N 117°27'21.76"W
6/25	Ayre	No	31	NA	Rocks	Loafing	46°36'14.00"N 118°19'27.07"W
4/26	Emma Lake Island	No	13	NA	Gravel Bar	Loafing	46°19'36.66"N 118°46'15.47"W
5/19	Little Goose Bay Spit	No	10	NA	Gravel Bar	Loafing	46°35'25.61"N 117°54'51.36"W

* No count, Caspian terns flushed from Island before count could be completed.

** No attended nests, but nest scrapes were evident on aerial photography.

Table 4. Colony size (number of breeding pairs) for Caspian terns nesting at sites in the Columbia Plateau region in 2000-2014.

	Columbia Plateau Caspian Tern Colonies									
Year	Potholes Reservoir Solstice Is./Goose Is.	Mid-Columbia River Crescent Is.	Mid-Columbia River Miller Rocks	Mid-Columbia River Three Mile Canyon Is.	Mid-Columbia River Blaylock Island Complex	Mid-Columbia River Badger Is.	Banks Lake Twinning Is./Goose Is.	Sprague Lake Harper Is.	Lenore Lake Unnamed island	**TOT**
2000	129	548	0	275	nd	0	10	20	0	**982**
2001	248	657	17	2	nd	0	23	20	0	**967**
2002	250	578	0	0	nd	0	nd	nd	0	**828**
2003	202	509	0	0	nd	0	21	nd	0	**732**
2004	129	530	0	0	0	0	nd	nd	0	**659**
2005	325	476	0	0	6	0	13	7	0	**827**
2006	273	448	0	0	110	0	23	7	0	**861**
2007	282	355	0	0	43	0	31	0	0	**711**
2008	293	388	0	0	104	0	27	11	0	**823**
2009	487	349	0	0	79	0	61	4	0	**980**
2010	416	375	0	0	136	0	34	4	0	**965**
2011	422	419	0	0	20	33	19	4	0	**917**
2012	463	422	0	0	6	60	22	30	0	**1003**
2013	340	393	0	0	26	0	13	1	0	**773**
2014	159	474	0	0	45	0	67	8	2	**755**

Table 5. Numbers of banded Caspian terns resighted at Crescent Island in 2014 and the colony locations where they were originally marked with uniquely engraved alphanumeric color bands during 2006-2014. Chicks banded at Crescent Island in 2014 and resighted later in the same year are not included.

Colony where banded	Banded as adults	Banded as chicks	Total
Crescent Island	155	76	231
Goose Island	52	18	70
East Sand Island	2	8	10
Port of Bellingham	0	1	1
Crump Lake	0	1	1
Total	209	104	313

Table 6. Numbers of color-banded Caspian terns resighted at Goose Island in 2014. Terns were banded in 2006-2014 with color bands engraved with unique alphanumeric codes. Resighting was conducted at former colony area of Goose Island and at Northwest Rocks near Goose Island.

Colony where banded	Banded as adults	Banded as chicks	Total
Goose Island	169	64	233
Crescent Island	8	30	38
East Sand Island	0	12	12
Port of Bellingham	0	7	7
Brooks Island	0	2	2
Crump Lake	0	1	1
Sheepy Lake	0	1	1
Total	177	117	294

Table 7. Numbers of color-banded Caspian terns resighted at the Blalock Islands in 2014. Terns were banded in 2006-2014 with color bands engraved with unique alphanumeric codes.

Colony where banded	Banded as adults	Banded as chicks	Total
Crescent Island	6	7	13
Goose Island	7	3	10
East Sand Island	0	2	2
Total	13	12	25

Table 8. Numbers of color-banded Caspian terns seen at Crescent Island in 2013 and resighted in 2014 at Crescent Island or other colony locations. Terns were banded in 2006-2013 with color bands engraved with unique alphanumeric codes. A total of 208 banded terns were seen at Crescent Island in 2013 and resighted in 2014 at Crescent Island or elsewhere; 29 of them were resighted at two different colonies in 2014.

Colony where resighted in 2014	Banded as adults	Banded as chicks	Total
Crescent Island	153	44	197
East Sand Island	11	1	12
Goose Island	9	0	9
Blalock Islands	6	1	7
Tule Lake	3	3	6
Malheur Lake	4	1	5
Sheepy Lake	0	1	1
Total	186	51	237

Table 9. Numbers of color-banded Caspian terns seen at Goose Island in 2013 and resighted in 2014 at Goose Island or elsewhere. Terns were banded in 2006-2013 with color bands engraved with unique alphanumeric codes. A total of 198 terns were seen at Goose Island in 2013 and resighted in 2014 at Goose Island or elsewhere; 62 of them were resighted at more than one colony in 2014.

Colony where resighted in 2014	Banded as adults	Banded as chicks	Total
Goose Island	125	32	157
Crescent Island	40	18	58
Malheur Lake	14	4	18
East Sand Island	8	6	14
Tule Lake	8	2	10
Blalock Islands	5	2	7
Sheepy Lake	2	1	3
Summer Lake (East Link)	0	1	1
Flat Lake (Ancient Lakes)*	1	0	1
Tongue Point*	0	1	1
Total	203	67	270

* Non-breeding site in 2014.

Table 10. Colony sizes and estimated 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 2007-2013. NA denotes colonies that were not scanned for PIT tags in a given 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)
Average		15.7% (14.1-18.9)	2.5% (1.7-3.6)	<0.1%	<0.1%	<0.1%	0.1% (0-0.2)
Average Per Capita		0.044% (0.038-0.054)	0.006% (0.004-0.009)	<0.001%	<0.001%	<0.001%	0.001% (0-0.001)

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)	0.7% (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)
Average		2.3% (2.0-2.7)	0.5% (0.3-0.8)	3.8% (3.4-4.6)	0.7% (0.6-0.9)	0.9% (0.8-1.0)	1.1% (0.7-1.2)
Average Per Capita		0.006% (0.005-0.007)	0.001% (0.001-0.002)	0.011% (0.01-0.013)	0.002% (0.001-0.002)	0.003% (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)
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%
Average		0.6% (0.4-0.8)	<0.1%	0.6% (0.5-0.7)	0.1% (0.1-0.2)	<0.1%	0.3% (0.1-0.4)
Average Per Capita		0.010% (0.007-0.013)	0.001% (0.001-0.003)	0.009% (0.007-0.011)	0.002% (0.002-0.003)	0.002% (0.002-0.003)	0.006% (0.003-0.013)

Table 11. Predicted annual predation rates (95% Prediction Intervals) for different Caspian tern colony sizes. Predicted predation rates are based on average per capita predation rates during 2007-2013 (see Table 1). Predicted predation rates are shown for salmonid populations (ESU/DPS) originating from the Snake River (SR) and Upper Columbia River (UCR). Highlighted predation rates are based on actual Caspian tern colony counts in 2014. Starred colony sizes indicate entries exceeding the empirical range, resulting in considerable uncertainty in the associated predicted predation rate.

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
20	0.9% (0.5-1.6)	0.1% (0-0.3)	<0.1%	<0.1%	<0.1%	<0.1%
40	1.8% (1-3.1)	0.3% (0-0.7)	<0.1%	<0.1%	<0.1%	<0.1%
60	2.7% (1.5-4.7)	0.4% (0-1)	<0.1%	<0.1%	<0.1%	<0.1%
80	3.5% (2.1-6.2)	0.5% (0.1-1.4)	<0.1%	<0.1%	0.0% (0-0.2)	<0.1%
100	4.4% (2.6-7.8)	0.6% (0.1-1.7)	<0.1%	<0.1%	0.0% (0-0.2)	<0.1%
150	6.6% (3.9-11.7)	1.0% (0.1-2.6)	<0.1%	<0.1%	0.0% (0-0.3)	0.1% (0-0.2)
159	*7.0% (4.1-12.4)*	*1.0% (0.1-2.8)*	*<0.1%*	*<0.1%*	*0.0% (0-0.3)*	*0.1% (0-0.2)*
200	8.9% (5.1-15.6)	1.3% (0.1-3.4)	0.0% (0-0.2)	<0.1%	0.0% (0-0.4)	0.1% (0-0.3)
250	11.1% (6.4-19.5)	1.6% (0.2-4.3)	0.1% (0-0.2)	<0.1%	0.1% (0-0.5)	0.1% (0-0.3)
300	13.3% (7.7-23.4)	1.9% (0.2-5.2)	0.1% (0-0.2)	<0.1%	0.1% (0-0.6)	0.2% (0-0.4)
350	15.5% (9-27.3)	2.3% (0.2-6)	0.1% (0-0.3)	<0.1%	0.1% (0-0.7)	0.2% (0-0.5)
400	17.7% (10.3-31.2)	2.6% (0.3-6.9)	0.1% (0-0.3)	<0.1%	0.1% (0-0.8)	0.2% (0-0.5)
450	19.9% (11.6-35.1)	2.9% (0.3-7.7)	0.1% (0-0.4)	<0.1%	0.1% (0-0.9)	0.3% (0-0.6)
500	22.1% (12.9-39)	3.2% (0.3-8.6)	0.1% (0-0.4)	<0.1%	0.1% (0-1)	0.3% (0-0.7)

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
20	0.1% (0.1-0.2)	<0.1%	0.2% (0.1-0.4)	<0.1%	<0.1%	0.1% (0-0.2)
40	0.2% (0.1-0.4)	0.1% (0-0.2)	0.4% (0.2-0.7)	0.1% (0-0.2)	0.1% (0-0.2)	0.1% (0-0.3)
60	0.4% (0.2-0.6)	0.1% (0-0.3)	0.7% (0.3-1.1)	0.1% (0-0.3)	0.2% (0.1-0.3)	0.2% (0.1-0.5)
80	0.5% (0.2-0.8)	0.1% (0-0.3)	0.9% (0.4-1.5)	0.2% (0.1-0.4)	0.2% (0.1-0.4)	0.2% (0.1-0.6)
100	0.6% (0.3-1)	0.1% (0-0.4)	1.1% (0.5-1.9)	0.2% (0.1-0.5)	0.3% (0.1-0.5)	0.3% (0.1-0.8)
150	0.9% (0.4-1.5)	0.2% (0-0.7)	1.6% (0.8-2.8)	0.3% (0.1-0.8)	0.4% (0.2-0.8)	0.5% (0.1-1.2)
200	1.2% (0.5-2)	0.3% (0-0.9)	2.2% (1.1-3.7)	0.4% (0.2-1)	0.5% (0.2-1)	0.6% (0.2-1.5)
250	1.5% (0.6-2.5)	0.3% (0-1.1)	2.7% (1.4-4.7)	0.5% (0.2-1.3)	0.6% (0.3-1.3)	0.8% (0.2-1.9)
300	1.8% (0.8-3)	0.4% (0-1.3)	3.3% (1.6-5.6)	0.6% (0.2-1.5)	0.8% (0.3-1.5)	0.9% (0.3-2.3)
350	2.1% (0.9-3.5)	0.4% (0-1.5)	3.8% (1.9-6.5)	0.7% (0.3-1.8)	0.9% (0.4-1.8)	1.1% (0.3-2.7)
400	2.4% (1.0-4.0)	0.5% (0-1.7)	4.3% (2.2-7.5)	0.8% (0.3-2.1)	1.0% (0.4-2)	1.2% (0.4-3.1)
450	2.7% (1.1-4.5)	0.6% (0-2.0)	4.9% (2.5-8.4)	0.9% (0.4-2.3)	1.1% (0.5-2.3)	1.4% (0.4-3.5)
474	*2.8% (1.2-4.7)*	*0.6% (0-2.0)*	*5.1% (2.6-8.8)*	*1.0% (0.4-2.4)*	*1.2% (0.5-2.4)*	*1.4% (0.4-3.6)*
500	3.0% (1.3-5.0)	0.6% (0-2.2)	5.4% (2.7-9.3)	1.0% (0.4-2.6)	1.3% (0.5-2.5)	1.5% (0.5-3.8)

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

Colony Size	UCR Steelhead	UCR Spring Chinook	SR Steelhead	SR Spr/Sum Chinook	SR Fall Chinook	SR Sockeye
20	0.2% (0-0.6)	<0.1%	0.2% (0-0.5)	<0.1%	0.0% (0-0.2)	0.1% (0-0.6)
40	0.4% (0.1-1.2)	0.1% (0-0.2)	0.4% (0.1-1.0)	0.1% (0-0.2)	0.1% (0-0.3)	0.2% (0-1.2)
45	*0.4% (0.1-1.4)*	*0.1% (0-0.3)*	*0.4% (0.1-1.2)*	*0.1% (0-0.2)*	*0.1% (0-0.3)*	*0.3% (0-1.4)*
60	0.6% (0.1-1.9)	0.1% (0-0.3)	0.5% (0.1-1.6)	0.1% (0-0.3)	0.1% (0-0.5)	0.4% (0-1.8)
80	0.8% (0.2-2.5)	0.1% (0-0.5)	0.7% (0.2-2.1)	0.2% (0-0.4)	0.2% (0-0.6)	0.5% (0-2.5)
100	1.0% (0.2-3.1)	0.1% (0-0.6)	0.9% (0.2-2.6)	0.2% (0-0.5)	0.2% (0-0.8)	0.6% (0-3.1)
150	1.4% (0.3-4.7)	0.2% (0-0.9)	1.3% (0.4-3.9)	0.3% (0-0.7)	0.3% (0-1.1)	0.9% (0-4.6)
200*	1.9% (0.4-6.2)	0.3% (0-1.2)	1.8% (0.5-5.2)	0.4% (0-1)	0.4% (0-1.5)	1.2% (0-6.1)
250*	2.4% (0.5-7.8)	0.4% (0-1.5)	2.2% (0.6-6.5)	0.5% (0-1.2)	0.5% (0.1-1.9)	1.5% (0-7.7)
300*	2.9% (0.6-9.3)	0.4% (0-1.7)	2.7% (0.7-7.8)	0.6% (0-1.5)	0.6% (0.1-2.3)	1.8% (0-9.2)
350*	3.4% (0.7-10.9)	0.5% (0-2.0)	3.1% (0.8-9)	0.7% (0-1.7)	0.7% (0.1-2.6)	2.1% (0-10.7)
400*	3.8% (0.8-12.4)	0.6% (0-2.3)	3.6% (1-10.3)	0.8% (0-2)	0.9% (0.1-3)	2.4% (0-12.3)
450*	4.3% (0.9-14)	0.6% (0-2.6)	4.0% (1.1-11.6)	0.9% (0-2.2)	1.0% (0.1-3.4)	2.7% (0-13.8)
500*	4.8% (1.0-15.5)	0.7% (0-2.9)	4.5% (1.2-12.9)	1.0% (0-2.5)	1.1% (0.1-3.8)	3.0% (0-15.3)

Appendix A: Goose Island Best Management Practices
2014 Nesting Season

The goal of management on Goose Island, Potholes Reservoir is to prevent more than 40 pairs of Caspian terns from nesting on Goose Island.

In order to achieve this goal, the objective in 2014 is to dissuade all Caspian terns from nesting on Goose Island. Caspian tern nesting is defined as terns laying one or more eggs in a nest scrape.

The strategy that 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 all gulls from nesting on Goose Island. This strategy is based on the supposition that if gulls start to nest on Goose Island (lay eggs), then any Caspian terns that subsequently attempt to nest near active gull nests can not be hazed without causing gull nests to fail (nests of gulls that are flushed during tern hazing would be at high 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 Goose Island (< 200 eggs) as a fallback in the event that Caspian terns successfully lay eggs, it can not issue a permit for incidental take of other migratory bird species, including incidental take of gull eggs during tern hazing activities. Therefore, by preventing any gulls from nesting on Goose Island, the prospect of active gull nests (those with eggs) shielding Caspian tern nests from hazing would be precluded. Similarly, small numbers of Canada geese have bred on Goose Island in past years, and several goose nests were located in late March 2014. Therefore, best management practices (BMPs) have been developed for Canada geese as well.

The difficulty in dissuading all gulls from nesting on Goose Island using passive dissuasion (stakes, ropes, and flagging) and human hazing techniques alone has been communicated to the federal management agencies. The large area of passive dissuasion on Goose Island that has been installed at the direction of the management agencies (2.25 acres pre-season; up to an additional 0.25 acres in-season) is in part an effort to make most of Goose Island less attractive to nesting gulls, as well as nesting terns. Recent observations on Goose Island have indicated that ring-billed gulls are less responsive to passive dissuasion compared to Caspian terns. In addition, gulls tend to acclimate more readily than terns to repeated human hazing.

The Bureau of Reclamation (owner of Goose Island) has considered additional management approaches to precluding gull nesting on Goose Island, such as the use of dogs, pyrotechnics, propane cannons, trained falcons, etc. However, none of these management techniques were evaluated and described in the Corps' Environmental Assessment (EA), and therefore cannot be used during this season. Nocturnal hazing using bright lights and lasers to enhance the efficacy of passive dissuasion and daytime

human hazing has been authorized for use this season. Nocturnal and crepuscular human hazing using lights and lasers seems to hold some promise for delaying gulls in initiating nests on Goose Island. Weather-permitting, personnel will stay overnight in the portable building on Goose Island so that they can haze any gulls that attempt to spend the night on Goose Island, and use bright lights and the laser to dissuade gulls that attempt to return to the island at first light.

The passive dissuasion (stakes, ropes, and flagging) covers essentially all of the suitable and marginally suitable Caspian tern nesting habitat on Goose Island, and the area where passive dissuasion has been deployed should be the primary focus of gull hazing. The "doughnut hole" of no dissuasion on top of the island (where Caspian terns will be captured for satellite-tagging) should be the focus of intense gull hazing, especially at night, to prevent gulls from laying eggs in this area before Caspian terns are captured and tagged. The observation blind can be used to laser any gulls that attempt to nest in the doughnut hole. Even if Caspian terns are present in the doughnut hole, the laser can potentially be used to scare off individual gulls without scaring off the terns.

Even if gulls are successful in establishing nests and laying eggs around the edge of the island outside the passive dissuasion area, it is unlikely that significant numbers of Caspian terns would nest close to these gulls. Gulls that establish nests inside the passive dissuasion, however, may attract Caspian terns to nest nearby, and thereby decoy terns into the passive dissuasion.

Because several Canada goose nests with eggs were discovered on Goose Island during late March 2014, we have developed best management practices (BMPs) for reducing researcher disturbance that could lead to take of goose eggs. First, using the same techniques described for terns and gulls, Canada geese will be dissuaded from establishing new nests on Goose Island. For any existing or newly established goose nests with eggs that may be discovered, practices to reduce the chances of nest loss are detailed below.

Dissuasion Protocol

Early in the pre-breeding period, before widespread pre-egg-laying behaviors are observed, human hazing of gulls should consist of walk-throughs of the island to flush any and all gulls that are present. Twice each day, a 2-person crew should conduct a walk-through of the entire area of Goose Island. These walk-throughs should 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 gull aggregations should be mapped on a diagram of the island. Once per week, map the locations of gulls by species (ring-billed gulls or California gulls). Any areas where gulls are holding territories or engaged in pre-laying behaviors (courtship, territorial display, copulation, nest-building) should also be marked on the map. If possible, the species of gull (California or ring-billed) that is engaged in pre-laying behaviors should be recorded. All gulls on the island should 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 should boat around Goose Island and count all gulls and terns on the island, as well as the numbers of gulls and terns roosting on emergent rocks near the Goose Island shoreline. Counts should be completed relatively quickly ($\lesssim$ 20 min). It is acceptable to count gulls in 100's and there is no need to distinguish between gull species. Gull counts should be entered into the waterbird survey application and reported in the weekly report to the Corps and Reclamation. Include an estimate of the proportion of each gull species and how gull numbers were estimated (e.g., "counted in 100's"). Tern counts should be entered into the tern application and reported in the weekly report to the Corps and Reclamation. If terns are likely present in areas difficult to survey from the boat, follow-up tern counts should be conducted from the blind adjacent to the former colony, or other suitable vantage. For extended observations of terns from the blind, include counts upon arrival and before departure, and include the maximum number of terns observed in the "notes" section of the tern app. Update or replace boat-based counts of gulls in the waterbird survey and tern applications with blind-based counts when blind-based counts are more accurate or complete. In addition to counts of piscivorous waterbirds, use the waterbird survey application to record the number of Canada geese that are observed during waterbird surveys and during hazing activities. Record data on the number of individual geese, nesting status (if known), and number of eggs for any active goose nests located. As for gulls and terns, include goose counts, nesting status, and any observed pre-breeding behaviors in the weekly report to the Corps and Reclamation.

Once large numbers of gulls have initiated pre-laying behaviors on Goose Island, island walk-throughs should be increased in frequency in an effort to increase the deterrence for gulls and terns to lay eggs on the island. At least two morning walk-throughs starting in the pre-dawn hour and conducted over a 3-hour period, and two afternoon walk-throughs conducted over a 3-hour period and ending after dusk should be conducted, when all gulls and/or terns are flushed each time, with the exception of those gulls known or suspected to be attending eggs. During this period leading up to egg-laying by gulls, colony monitors should stay over-night on the island (weather-permitting) so that all gulls can be cleared off the island over-night by hazing after dark, and 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 should be approached slowly and cautiously in order 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 the observer determines that eggs are present, the observer should gradually back off from the nest in order 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 should be recorded. The first gull eggs detected on Goose Island, as well

as the first gull eggs to be laid in areas of Goose Island where gull eggs have not previously been detected, should be reported to Pete Loschl and/or Dan Roby as soon as practical (same day at minimum) so that they can forward the information to the Corps and Reclamation. If loss of gull eggs due to gull depredation is observed, this should also be reported the same day to Pete Loschl or Dan Roby. Check potential gull nests for eggs only if the potential nest is more than 30 m from the nearest gull nest confirmed to contain eggs.

If a Caspian tern nest with eggs is suspected anywhere on Goose Island, the verification procedure would depend on the context of the suspected tern nest. If no active gull nests are verified or suspected within 15 m of the suspected tern nest, then the tern nest should be approached close enough to cause the tern to flush from the nest scrape. If there are known or suspected gull nests within 25 m of the suspected tern nest, then the approach of the suspected tern nest should be slow and cautious so as to preclude gulls from flushing from their nests and exposing their eggs to gull predation. If the tern on the suspected nest is flushed and reveals one or more tern eggs, those eggs should be collected (under permit) and transported whole in egg containers back to the field house. Collected tern eggs can be stored temporarily in a refrigerator, for eventual transport back to OSU 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 should 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 as a result of an observer approaching the suspected tern's nest. If a recently laid tern egg can be collected without causing nesting gulls to flush and expose their own eggs to gull predation, then it should be collected; if the tern egg can't be collected without flushing gulls from nearby nests with eggs, than the tern egg should not be collected. Any Caspian tern eggs that are laid on Goose Island, whether they are collected or not, should 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 shall occur the same day any 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 Goose Island, the verification procedure would depend on the context of the suspected goose nest, as for suspected tern nests. If no active gull nests are verified or suspected in the vicinity 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.

Continued gull nest dissuasion in any area around an active or suspected goose nest should be carried out using techniques to minimize the possibility of goose nest loss.

These include (1) a slow, indirect approach to the area where a goose nest is known to be present, (2) averting eyes to avoid direct eye contact with the attending goose, (3) when possible, traveling along the water line below the goose nest to avoid pressuring the attending goose into the preferred escape route in the direction of the water, and (4) moving relatively quickly through the area where a goose nest is located (the general 25-m vicinity). When the possibility of gull nest initiation 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, possibly incomplete clutches [e.g., < 4 eggs]). If feasible, gull dissuasion near the incipient goose nest will be reduced for 4-7 days until geese further invest in their nesting effort and there is less risk of nest abandonment. 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 goose nest loss will be employed as identified.

If there are known or suspected gull nests with eggs within 25 m of the suspected goose nest, then the goose nests should not be approached and monitoring of goose nesting activity should be done from a distance to avoid flushing nesting gulls and the geese at this location, or goose nest monitoring should be terminated if subsequent gull dissuasion is distant enough so as to be unlikely to displace the attending geese.

Appendix B: Per Capita Predation Rate Calculations

Methods to calculate predation rate estimates presented herein are based on a Bayesian analytical approach (Hostetter et al. 2015), which differs some from the Frequentist (e.g., bootstrapping) approach used by Bird Research Northwest in years past (Evans et al. 2012; BRNW 2014). The Bootstrap method is straightforward and easy to interpret, making it a great method when complete datasets are available for analysis. This means datasets with direct measures of PIT tag deposition rates (specific to each colony and year), direct measures of detection efficiency rates (specific to each colony and year), and where PIT tags are found on-colony throughout the smolt out-migration season. Unfortunately, these complete datasets were not always available during 2007-2013 and may not be available in the future. For example, we expect that the estimation of deposition rates on bird colonies in the future will continue to be based on data collected from past studies. We also expect management actions to alter the abundance and distribution of various bird colonies within the region, changes that could alter deposition rates and result in a higher prevalence of migration weeks without any recovered PIT tags (i.e., no direct evidence of predation). A Bayesian approach can more appropriately handle these sparse datasets and offers a more flexible approach to incorporation of uncertainty with respect to deposition rates (Hostetter et al. 2015).

Despite some differences in the mechanics of each model (Bayesian, Bootstrap), both approaches use the same datasets of fish availability (PIT-tagged smolts interrogated passing dams), PIT tag detection efficiency, and PIT tag deposition (see below). The result of using the same input parameters is that the point estimates calculated by the Bayesian method are often very similar, if not identical, to those generated via bootstrapping. This means that Fisheries Managers that focus on average annual predation impacts will see little difference between Bayesian and bootstrap generated estimates. Nonetheless, we see a decided difference in the widths of their associated uncertainty intervals (i.e., confidence intervals for the bootstrap model, credibility intervals for the Bayesian model). This implies that the choice of using a Bayesian or a Frequentist (Bootstrapping) method for the estimation of annual avian predation rates is largely a question of how we address and quantify areas of uncertainty. The choice of which model to use at this point may be considered largely academic but we believe that the flexibility of the Bayesian model will prove to be of more practical value in the future.

The following is a detailed description of Bayesian methods used to calculate per capita predation rate estimates, those presented in Section 3.4, Table 9, and Table 10 of the main Report.

Colony Counts – Counts were conducted from observation blinds, boat-surveys, and aerial-surveys to determine the maximum or peak number of nesting pairs of Caspian terns at Goose Island (Potholes Reservoir), Crescent Island (McNary Reservoir), and the Blalock Islands complex (John Day Reservoir). Peak colony sizes were determined based on the highest number of incubating terns counted near the end of the egg incubation period, which generally occurred

in mid- to late May. Details regarding survey techniques and the counting of aerial photography can be found in BRNW (2014).

Predation Rates – Predation rate estimates were based on methods previously developed by Evans et al. (2012), Osterback et al. (2013), and Hostetter et al. (2015). The recovery of a PIT tag on a bird colony is the result of a three-stage probabilistic process that must be modeled dependently. First, a PIT-tagged smolt must be consumed by a bird, then the bird must transport the PIT tag back to the colony and egest it on the colony, and finally the tag must remain on the colony and be detected by researchers after the nesting season. To calculate predation rates, these events are modeled for each year, tern colony, and salmonid population (hereafter ESU/DPS). The uncertainty associated with each event is modeled on a weekly basis for precision and then aggregated over the breeding/migration season. However, for many years we lack empirical measurements of PIT tag deposition rates (see BRNW 2014), and results for probabilities of predation and deposition are statistically unidentifiable. To address these gaps in data on PIT tag deposition rates, we employed Bayesian methods to incorporate our prior knowledge of deposition rates to the analysis, while properly accounting for uncertainty.

We let θ_w represent the probability that a tagged fish is consumed by a tern in week *w*, ϕ represent the probability that a consumed fish tag is deposited back on the tern 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 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 (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 for each week. Based on the previous investigation of the tag deposition probability for Caspian terns (BRNW 2014; Hostetter et al. *in-review),* we employed an informative prior (beta[16.20, 6.55]) for ϕ.

We ascribed a hyperdistribution for predation probabilities ($\boldsymbol{\theta}$),

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

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; $\alpha \sim Normal(0, 0.01)$, $\beta \sim Normal(0, 0.01)$, $logit^{-1}(\mu_\theta)$ ~

$Uniform(0,1)$ and $\tau_\theta^2 \sim Uniform(0,20)$. Note that the Normal distribution is specified here by the mean and precision parameters.

Annual smolt consumption totals were defined to be the sum of the estimated number of PIT-tagged smolts consumed each week,

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

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

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

All predation probability models were implemented using the software JAGS (Plummer 2003) accessed through R version 3.0.1 (R Core Team 2014). 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 (95CRI). Finally, to control for imprecise results that might arise from small sample sizes of interrogated PIT-tagged smolts, estimates of predation were only calculated for ESUs/DPSs when ≥ 500 PIT-tagged salmonids were interrogated passing an upstream dam in a given year (Evans et al. 2012). Predation probabilities ≤ 0.1% are presented without credibility intervals because the upper bounds of credibility intervals are not greater than 0.1%.

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

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

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

We calculated a per capita predation rate for each colony and each salmonid ESU/DPS using the arithmetic average of the annual per capita predation rates. We built 95% Credibility Intervals by averaging random samples of per capita predation rates generated from the posterior distributions calculated previously.

Predicted Per Capita Predation Rates – In order to estimate predation rates of a colony of various sizes, 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. Predation rate estimates for each tern colony and each salmonid ESU/DPS are then presented for (1) tern colony sizes observed in 2014 and (2) various hypothetical colony sizes ranging from 20 to 500 terns, a range that represent the smallest and largest Caspian tern colonies observed in the study area during 2007-2013.

Key assumptions and caveats that should be considered when using data on Caspian tern colony size to predict salmonid 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, fish abundance, and predation rates.
- Statistical inference of the model should be limited to colony sizes and fish abundance observed during 2007-2013; 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 tern colony counts depended on the intensity and frequency of tern 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.
- Fish condition, run-timing, fish abundance, river discharge, and turbidity have all been linked to variation in predation rates on smolts (Hostetter et al. 2012). Thus, changes to biotic and abiotic conditions in the Snake and Columbia rivers during 2014 and beyond may influence Caspian tern predation rates on salmonid smolts.
- Estimates of predation rates presented here are colony-specific and area (reservoir)-specific; extrapolation to other geographic locations is beyond the scope of the analysis.

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