Bonneville Power Administration, USACE – Portland District, and Grant County PUD/Priest Rapids Coordinating Committee

Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River

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2014 Final Annual Report

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This 2014 Final Annual Report has been prepared for the Bonneville Power Administration, the U.S. Army Corps of Engineers, and the Grant County PUD/Priest Rapids Coordinating Committee.

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EXECUTIVE SUMMARY

The primary objectives of this study in 2014 were to (1) evaluate management initiatives implemented to reduce predation on juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary, including the monitoring of alternative Caspian tern nesting islands built by the Corps outside the Columbia River basin; (2) evaluate management implemented to reduce predation on juvenile salmonids by Caspian terns nesting on Goose Island in Potholes Reservoir by (a) collecting PIT-tags from piscivorous waterbird colonies to estimate smolt predation rates and (b) monitoring Caspian tern dispersal patterns associated with activities to dissuade nesting on the Goose Island colony; (3) monitor and evaluate colony size and juvenile salmon consumption by double-crested cormorants (*Phalacrocorax auritus*) nesting on East Sand Island and other sites in the lower Columbia River estuary; and (4) provide technical assistance to resource managers on the topic of avian predation on ESA-listed juvenile salmonids, as warranted.

The management plan entitled, *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary* was first implemented in 2008 and continued in 2014. As part of this plan, the U.S. Army Corps of Engineers – Portland District (Corps) maintained 1.55 acres of suitable nesting habitat for Caspian terns on East Sand Island in 2014, slightly less than the area of nesting habitat provided during 2012-2013 (1.58 acres), and a 69% reduction in area of tern nesting habitat on East Sand Island compared to what was provided during 2001-2007, prior to implementation of the management plan. In 2014, Caspian terns nested on the East Sand Island colony at an average density of 1.06 nests/m^2, a decrease from the average nesting density recorded in 2013 (1.17 nests/m^2), but still a higher nesting density compared to pre-management (average of 0.55 nests/m^2). Passive nest deterrence measures (stakes, ropes, and flagging) installed by the Corps to dissuade Caspian terns from nesting on the upper beach near the main tern colony and elsewhere on East Sand Island were successful in preventing Caspian terns from forming satellite colonies anywhere on East Sand Island in 2014.

The Caspian tern colony on East Sand Island, the largest for the species in the world, consisted of about 6,270 breeding pairs in 2014. This is a decrease from the estimate of 7,400 pairs in 2013 and the smallest Caspian tern colony size recorded at East Sand Island since the initiation of reductions in tern nesting habitat on the island in 2008, as part of the Caspian Tern Management Plan. This represents a decline of about 41% in the size of the Caspian tern colony on East Sand Island from its peak in 2008 (ca. 10,670 breeding pairs). As was the case in 2013, Caspian terns at this colony were relatively resilient to disturbances by bald eagles (*Haliaeetus leucocephalus*) and associated gull (*Larus* spp.) depredation of tern eggs and chicks, limiting factors that caused the Caspian tern colony to fail or nearly fail during 2010-2012. The Caspian tern colony on East Sand Island produced roughly 1,700 fledglings in 2014 (average of about 0.28 young raised/breeding pair), an increase compared to 2010-2012 when productivity averaged

0 – 0.06 young raised/breeding pair, but still lower than the average during the previous decade (2000-2009).

The average proportion of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island during the 2014 nesting season was 33%, similar to the average observed over the previous eight nesting seasons. The estimated total smolt consumption by Caspian terns nesting at East Sand Island in 2014 was 4.5 million (95% c.i. = 3.9 - 5.1 million), not significantly different from total annual smolt consumption during 2011, 2012, and 2013, but significantly less than pre-management. Predation rates on specific populations of salmonids (ESUs/DPSs) by Caspian terns in 2014 were similar to those observed during 2011-2013, but were generally lower than those observed during the period 2007-2010. Reductions in tern predation rates following the implementation of management coincided with comparable reductions in tern colony size, suggesting that Caspian tern management initiatives to reduce tern nesting habitat on East Sand Island are resulting in lower predation rates on particular ESUs/DPSs of salmonids in the Columbia River estuary. Similar to previous years, Caspian tern predation rates were significantly higher on populations of steelhead (*O. mykiss*) smolts (8.6 – 11.4%, depending on DPS) compared with populations of salmon (0.9 – 1.6%, depending on ESU).

Since 2008, the Corps has constructed nine islands as alternative colony sites for Caspian terns displaced from East Sand Island, six in interior Oregon and three in the Upper Klamath Basin region of northeastern California. Two of these islands were not available for tern nesting in 2014, and one is no longer being monitored for Caspian tern nesting activity. The other six Corps-constructed islands were monitored for Caspian tern nesting activity in 2014, and nesting attempts by Caspian terns were recorded at five of these islands. A combined total of 786 breeding pairs of Caspian terns attempted to nest at Corps-constructed tern islands in 2014, a 27% increase from the average number of breeding pairs that nested on Corp-constructed tern islands in 2008-2013 (618 breeding pairs). Estimated average productivity among the five Corps-constructed islands, however, was somewhat higher in 2014 (0.27 young raised/breeding pair) compared to 2013 (0.18 young raised/breeding pair). The increase in average nesting success by Caspian terns at the Corps-constructed islands from 2013 to 2014 was in large part due to increased predator control efforts at these sites. Regardless, nest predation by mammalian and avian predators, displacement by other colonial waterbird species (i.e., California gulls [*L. californicus*] and American white pelicans [*Pelecanus erythrorhynchos*]), drought, adverse weather conditions, and apparent low availability of preferred forage fish (due to drought) continued to limit Caspian tern colony formation, colony size, and nesting success at the Corps-constructed islands. Nevertheless, a substantial number of Caspian terns that were banded at the colony on East Sand Island in the Columbia River estuary used the Corps-constructed islands as alternative colony sites; a total of 84 Caspian terns banded in the Columbia River estuary were resighted at one or more of the Corps-constructed islands in interior Oregon and northeastern California during the 2014 nesting season. Based on the estimated

movement rate of Caspian terns from East Sand Island to the Corps-constructed islands (3.1%; calculated using Program MARK on mark-resighting data of banded adult Caspian terns), about 461 Caspian terns (3.1% of breeding individuals at the East Sand Island colony in 2013, including both banded and unbanded birds) moved from East Sand Island to the Corps-constructed islands in 2014. This high number of Caspian terns moving from East Sand Island to the Corps-constructed islands in a single year (461 individuals) demonstrates the connectivity of the East Sand Island colony with the colonies that have formed on the Corps-constructed islands in interior Oregon and northeastern California.

To further reduce the impacts of predation by Caspian terns nesting at East Sand Island on survival of salmonid smolts in the Columbia River estuary, more Caspian terns (1,895-3,145 breeding pairs) will need to be relocated to colonies outside the basin based on the size of the colony in 2014 (6,270 breeding pairs) relative to the target colony size for Caspian terns nesting on East Sand Island identified in the management plan (3,125 - 4,375 breeding pairs). This will likely require a further reduction in area of suitable Caspian tern nesting habitat on East Sand Island by at least one third, or down to about 1 acre of nesting habitat.

In 2014, efforts to monitor of the double-crested cormorant colony on East Sand Island in the Columbia River estuary were reduced from previous years, awaiting the completion and release of the *Double-crested Cormorant Management Plan to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*, with management actions scheduled for implementation as early as the spring of 2015. Objectives for monitoring the double-crested cormorant colony on East Sand Island in 2014 were to (1) estimate colony size and (2) estimate stock-specific predation rates on juvenile salmonids. The double-crested cormorant colony on East Sand Island consisted of about 13,600 breeding pairs in 2014, about 26% more than the average number of double-crested cormorants that nested on East Sand Island in 1997-2013 (ca. 10,775 breeding pairs). This one colony includes at least 40% of the breeding population of double-crested cormorants in western North America, and is the largest known breeding colony of the species anywhere. In addition to double-crested cormorants, ca. 1,630 pairs of Brandt's cormorants (*P. penicillatus*) nested in the cormorant colony on East Sand Island in 2014. Brandt's cormorants first nested in this mixed-species colony in 2006, and numbers increased each year through 2012, when 1,680 breeding pairs were counted.

Despite a smaller colony in 2014, recoveries of smolt PIT tags on the East Sand Island cormorant colony in 2014 indicated that ESU/DPS-specific predation rates were up substantially compared with 2013 and were some of the highest recorded since the colony was first scanned for PIT tags in 1999. Predation rates on salmon ESUs were especially high relative to previous years, with an estimated 8.5% (95% c.i. = 6.1 - 13.2%) and 6.1% (95% c.i. = 3.9 - 10.1%) of Snake River spring/summer Chinook (*O. tshawytscha*) and Upper Columbia River spring Chinook, respectively, consumed by cormorants in 2014. Predation on steelhead DPSs ranged from 6.4% (95% c.i. = 3.7 -

10.7%) on Middle Columbia River steelhead to 10.4% (95% c.i. = 7.3 - 16.3%) on Upper Columbia River steelhead. As demonstrated by smolt PIT tag data collected in 2014 and previous years, inter-annual variation in the impact of cormorant predation on survival of salmonid smolts in the Columbia River estuary was poorly explained by differences in colony size alone. Factors that have been linked to high inter-annual variation in cormorant predation (smolt consumption and predation rates) include river discharge into the estuary and ocean conditions (i.e., the North Pacific Gyre Oscillation) as they influence the abundance and availability of alternative prey (marine and estuarine forage fishes).

Native piscivorous colonial waterbirds that nest in the Columbia Plateau region include Caspian terns, double-crested cormorants, American white pelicans, California gulls, and ring-billed gulls (*L. delawarensis*). Of these, Caspian terns have been identified as having the greatest impact on ESA-listed juvenile salmonids in the Columbia Plateau region. The impacts of Caspian tern predation in the Columbia Plateau region on survival of ESA-listed steelhead populations from the Upper Columbia River and Snake River have been especially high. In January 2014, the U.S Army Corps of Engineers – Walla Walla District completed the *Inland Avian Predation Management Plan* (IAPMP). The goal of the IAPMP is to reduce Caspian tern predation rates on ESA-listed Columbia Basin salmonids to less than 2% (per colony and per ESA-listed population) by redistributing Caspian terns from the two largest nesting sites in the Columbia Plateau region (i.e., colonies on Goose Island in Potholes Reservoir and on Crescent Island in the mid-Columbia River) to sites outside the Columbia River Basin. In 2014, the Corps and the Bureau of Reclamation (BOR) implemented Phase I of the IAPMP by reducing nesting habitat on Goose Island and actively discouraging Caspian terns from nesting there.

In 2014, as part of a separately study funded by the U.S. Army Corps of Engineers – Walla Walla District and the U.S. Bureau of Reclamation (see separate report; BRNW 2014b), we monitored Caspian tern nesting activity throughout the Columbia Plateau region to help evaluate the effectiveness of the nest dissuasion actions implemented at Goose Island in dispersing Caspian terns to alternative colony sites outside the basin. These nest dissuasion actions were successful in preventing all but three breeding pairs of Caspian terns from nesting on Goose Island proper in 2014 (340 breeding pairs nested there the previous year). The three breeding pairs that nested on Goose Island each laid a single egg that was collected under permit soon after it was laid. Formation of a Caspian tern breeding colony on Goose Island was prevented in 2014 without causing any apparent disruption of breeding California and ring-billed gulls on the island. Surveys throughout the Columbia Plateau region in 2014 indicated that Caspian terns attempted to nest at four additional sites where they had previously nested and two new sites not previously used by nesting Caspian terns. The four previously used Caspian tern colony sites that were also active in 2014 were: Crescent Island on the mid-Columbia River (474 breeding pairs); Twinning Island in Banks Lake (67 breeding pairs); the Blalock Islands on the mid-Columbia River (45 breeding pairs); and Harper Island in Sprague Lake (8 breeding pairs). The new Caspian tern breeding sites were on a small

rocky islet adjacent to Goose Island in Potholes Reservoir (dubbed “Northwest Rocks”; 156 breeding pairs) and amongst a small colony of gulls on a small island in Lenore Lake (2 breeding pairs). Of these seven sites, only the colonies at Crescent Island, the Blalock Islands, and Northwest Rocks succeeded in raising any young.

Recoveries of smolt PIT tags on the colony at Northwest Rocks indicated that Caspian terns nesting there consumed 2.9% (95% c.i. = 1.9 - 5.1%) and 0.3% (95% c.i. = 0.1 - 0.7%) of Upper Columbia River steelhead and yearling Chinook salmon, respectively. Estimated predation rates by Caspian terns nesting at Northwest Rocks in 2014 were the lowest recorded for Caspian terns nesting at Potholes Reservoir to date, and significantly lower than pre-management estimates during 2007-2013. These results indicate that efforts to dissuade Caspian terns from nesting on Goose Island in Potholes Reservoir were successful at reducing smolt consumption by Caspian terns in the Columbia Plateau region in 2014. The reduction in Caspian tern predation rate on steelhead smolts, however, was not below the 2% threshold target established by the IAPMP.

In conjunction with the efforts to dissuade Caspian terns from nesting on Goose Island in 2014, we evaluated the individual responses of 28 Caspian terns that were captured on Goose Island prior to egg-laying and fitted with solar-powered satellite telemetry tags. We observed three types of initial response by tagged Caspian terns to elimination of tern nesting habitat on Goose Island: (1) stay in the area and compete for reduced available nesting habitat (i.e. Northwest Rocks), (2) move to one of several nearby colonies (70 – 125 km away) and attempt to nest there, returning to the Goose Island area if nesting fails, and (3) nomadic wandering throughout the region, without a sustained association with any colony. Tern foraging activity was reduced in areas of the mid-Columbia River where terns have previously had substantial impacts on Upper Columbia River steelhead (i.e. the Wanapum and Priest Rapids pools). Displaced terns did not leave the larger Columbia Plateau region at an appreciable rate during the primary smolt outmigration period, however. Consequently, some predation may have been shifted to other locations and/or other Columbia Basin salmonid populations. Additional IAPMP actions to be implemented in 2015, including an expansion of nest dissuasion from Goose Island to the nearby adjacent islets, initiation of nest dissuasion at Crescent Island, and enhancement of nesting habitat for Caspian terns in San Francisco Bay, appear poised to address several of the factors limiting the displacement of terns from the Columbia Plateau. Marginal nesting habitat at Banks Lake, Sprague Lake, or in the Blalock Islands in the Columbia River (John Day Pool) may be a continued draw for displaced Caspian terns, however. The inability of tagged terns to nest successfully anywhere away from the rocky islet adjacent to Goose Island in 2014 suggests that the long-term goal of reducing tern predation on Columbia Basin salmonids by encouraging fidelity to nest sites outside the Columbia Basin will likely require a sustained, multi-year effort.

The largest Caspian tern breeding colony in the Columbia Plateau region during 2014 was on Crescent Island in the mid-Columbia River. A total of about 474 breeding pairs of Caspian terns attempted to nest on Crescent Island in 2014, a 21% increase in colony size compared to 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, about 100 km away. Despite increases in colony size at both Crescent Island and other Caspian tern colonies in the Columbia Plateau region in 2014, the overall size of the Caspian tern breeding population in the region did not increase, and apparently declined slightly in 2014 (758 breeding pairs) compared to 2013 (773 breeding pairs).

Predation rates on steelhead populations by Caspian terns nesting on Crescent Island were higher in 2014 compared to previous years (2007-2013). In 2014, predation rates on Upper Columbia River steelhead (3.4%; 95% c.i. = 2.5 - 4.9%) and Snake River steelhead (4.7%; 95% c.i. = 3.7 - 6.9%) and were the first and second highest predation rates recorded since 2007, respectively. Impacts on survival of salmonid smolts, both steelhead and salmon, from Caspian terns nesting on Twinning Island and the Blalock Islands in 2014 were lower than for Caspian terns nesting on Crescent Island, due in part to the much larger size of the Crescent Island tern colony (474 pairs), compared with the Caspian tern colonies on Twinning Island (66 pairs) or the Blalock Islands (45 pairs). Over-all (all Caspian tern colonies combined) predation rate estimates indicate that actions to dissuade Caspian terns from nesting in Potholes Reservoir in 2014 resulted in lower impacts on upper Columbia River ESUs/DPSs compared to previous years, suggesting that management actions in 2014 benefited fish survival, particular survival of Upper Columbia River steelhead.

INTRODUCTION

A Columbia Basin-wide assessment of avian predation on juvenile salmonids (*Oncorhynchus* spp.) indicates that the most significant impacts to smolt survival occur in the Columbia River estuary (BRNW 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013a, 2014a). Caspian terns (*Hydroprogne caspia*) and double-crested cormorants (*Phalacrocorax auritus*) nesting at colonies on East Sand Island in the Columbia River estuary together consumed 6 million to 25 million salmonid smolts annually during 2003 – 2013, based on the sum of the best estimates of total smolt consumption by birds nesting at these two colonies in each year. The magnitude of avian predation in the Columbia River estuary represents about 5-20% of all juvenile salmonids that reach the estuary during out-migration (BRNW 2014a). Estimated smolt losses to piscivorous colonial waterbirds that nest in the Columbia River estuary are more than an order of magnitude greater than those observed elsewhere in the Columbia River basin (Lyons et al. 2011a, Lyons et al. 2011b, BRNW 2014a). Additionally, when compared to the impact of avian predation in the Columbia Plateau region, avian predation in the Columbia River estuary affects juvenile salmonids belonging to every evolutionarily significant unit (ESU) or distinct population segment (DPS; hereafter referred to as ESU) from throughout the Basin that have survived freshwater migration to the ocean, and presumably have a higher probability of returning as adults. For these reasons, management of the colonies of Caspian terns and double-crested cormorants on East Sand Island has the greatest potential to benefit salmonid ESUs from throughout the Columbia River basin that are listed under the U.S. Endangered Species Act (ESA), compared to potential benefits of managing other colonies of piscivorous waterbirds. The Caspian tern colonies on Goose Island (Potholes Reservoir) and Crescent Island (mid-Columbia River), the double-crested cormorant colony on Foundation Island (mid-Columbia River), and the California gull (*Larus californicus*) colonies on Miller Rocks and Crescent Island (mid-Columbia River) may be exceptions to this rule; management of these relatively small colonies on or near the mid-Columbia River may benefit certain salmonid ESUs, in particular steelhead (*O. mykiss*; Lyons et al. 2011a, Lyons et al. 2011b, Evans et al. 2012, Hostetter et al. 2015).

Regional fish and wildlife managers called for management action in 1999 to reduce losses of juvenile salmonids to Caspian terns nesting in the Columbia River estuary. A management plan first implemented in 1999 sought to relocate the Caspian tern colony on Rice Island, the largest of its kind in the world, to a restored colony site on East Sand Island, 21 km closer to the ocean, where it was hoped terns would consume significantly fewer juvenile salmonids. Over 94% of the nesting Caspian terns shifted from Rice Island to East Sand Island in 2000, where juvenile salmonids comprised 47% of tern prey items, compared to 90% of prey items at Rice Island (Roby et al. 2002). During 2001–2013, all Caspian terns nesting in the Columbia River estuary used East Sand Island, with the exception of three nesting pairs that laid a total of four eggs on Rice Island in 2011 (BRNW 2014a). During 2001-2013, estimated consumption of juvenile salmonids by Caspian terns nesting on East Sand Island averaged 5.1 million smolts per year (SD = 0.9

million, n = 13 years), a ca. 59% reduction in annual consumption of salmonid smolts compared to when the Caspian tern colony was on Rice Island (12.4 million smolts consumed in 1998; Roby et al. 2003).

Further management of Caspian terns to reduce losses of juvenile salmonids in the Columbia River estuary is currently in progress; the Records of Decision (RODs) for *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*, signed in November 2006, stipulated the redistribution of approximately 60% of the East Sand Island tern colony to alternative colony sites outside the Columbia Basin in Oregon and California (USFWS 2005, 2006). This management action is intended to further reduce smolt losses to Caspian terns in the estuary by about 60%, while still maintaining the long-term viability of the Pacific Coast population of Caspian terns. By the end of the 2013 nesting season, the U.S. Army Corps of Engineers – Portland District had constructed nine islands, six in interior Oregon and three in northeastern California, as alternative nesting habitat for Caspian terns nesting on East Sand Island. Concurrent with island construction, the Corps has been gradually reducing the area of suitable nesting habitat for Caspian terns on East Sand Island from 5 acres in 2008 to 1.58 acres in 2013, and hazing Caspian terns that attempt to establish new nesting colonies elsewhere in the Columbia River estuary.

The numbers of double-crested cormorants nesting on East Sand Island in the Columbia River estuary have increased dramatically in the last two decades; this growth in colony size appears to have been largely at the expense of other colonies in the region, especially along the coast of Washington and British Columbia (Adkins et al. 2014a). During the period 1997-2013 the cormorant colony on East Sand Island increased nearly three-fold to ca. 14,900 breeding pairs, the largest known breeding colony for the species in western North America. Although juvenile salmonids represented ca. 18% of the diet for cormorants (% biomass) compared to ca. 35% of the diet for terns (% prey items) nesting on East Sand Island in 2010-2012, estimated smolt consumption by cormorants was about four times greater than that of Caspian terns during this same time period (i.e., ca. 20 million vs. ca. 5 million smolts consumed by cormorants and terns, respectively; BRNW 2013a). The large numbers of smolts consumed by the double-crested cormorants nesting at the East Sand Island colony are due to both the larger size of the cormorant colony (number of breeding pairs) and the greater per bird food requirements of double-crested cormorants relative to Caspian terns. The double-crested cormorant colony on East Sand Island has experienced high nesting success (average of 1.8 young raised/breeding pair per year during 1997-2012; BRNW 2013a), perhaps contributing to increases in colony size and the current level of impact of the cormorant colony on smolt survival. Resource management agencies have decided that management of the large colony of double-crested cormorants on East Sand Island in order to reduce losses of ESA-listed juvenile salmonids in the Columbia River estuary is warranted.

Breeding colonies of piscivorous colonial waterbirds are not limited to the Columbia River estuary, but are distributed throughout the Columbia River basin. Work to systematically evaluate predation on salmonids by colonial nesting waterbirds in the interior Columbia Basin, hereafter referred to as the Columbia Plateau region, began in 1997 (Collis et al. 2002). The initial focus of this investigation was Caspian tern colonies at Crescent Island (Rkm 510), near the confluence of the Columbia and Snake rivers (Antolos et al. 2005), and in Potholes Reservoir near Othello, WA (Antolos et al. 2004; Maranto et al. 2010). In 2004, comprehensive research was initiated to identify waterbird nesting colonies within the Columbia Plateau region that had the greatest impact on survival of anadromous salmonids from the Columbia and Snake rivers, and to evaluate those impacts over a broad range of environmental conditions and management regimes (Roby 2011, Lyons et al. 2011b). Over 100,000 piscivorous colonial waterbirds, representing five different species nesting at 18 different colonies, were documented nesting in the Columbia Plateau region during 2004-2009 (Adkins et al. 2014b).

Of the piscivorous colonial waterbirds that nest in the Columbia Plateau region, Caspian terns have garnered the most attention from resource managers with regard to their impacts on ESA-listed juvenile salmonids. Based on a study conducted during 2007-2010, per capita predation rates on juvenile salmonids were found to be much higher for Caspian terns nesting at inland colonies as compared to Caspian terns nesting on East Sand Island in the Columbia River estuary (Evans et al. 2012). The two largest Caspian tern colonies in the Columbia Plateau region are located on Goose Island in Potholes Reservoir, WA, with an average colony size of 404 breeding pairs during 2008-2013, and on Crescent Island in the McNary Reservoir, with an average colony size of 391 breeding pairs during 2008-2013 (BRNW 2014a). Despite each of these inland Caspian tern colonies being less than one-tenth the size of the tern and cormorant colonies on East Sand Island, ESU-specific predation rates on ESA-listed juvenile salmonids were comparable to, if not higher than, those for Caspian terns and double-crested cormorants nesting in the estuary (Evans et al. 2012). For example, predation rates on ESA-listed Upper Columbia River steelhead by Caspian terns nesting on Goose Island during 2007-2010 averaged 10.6% (range = 7.5 – 15.7%) compared to an average of 3.1% (range = 1.7 – 3.5%) and 10.7% (range = 9.8 – 14.0%) for double-crested cormorants and Caspian terns nesting on East Sand Island, respectively (Evans et al. 2012). Since then, estimates of predation on Upper Columbia River steelhead by Caspian terns nesting on Goose Island have exceeded 20% of available fish (BRNW 2014a). This result was surprising given the relatively small size of the Goose Island Caspian tern colony and its distance from the migration corridor (mid-Columbia River) used by Upper Columbia River steelhead (at least 35 km). Lyons et al. (2011b) estimated that the annual population growth rate (λ) of Upper Columbia River steelhead would be increased by 4.2% for hatchery-raised smolts and 3.2% for wild smolts, if predation by Caspian terns nesting at the Goose Island colony was eliminated and compensatory mortality did not occur.

Predation by Caspian terns nesting at Goose Island in Potholes Reservoir is of particular concern to Grant County Public Utility District No. 2, because previous research indicates that Caspian terns from this colony disproportionately forage for smolts within the Wanapum and Priest Rapids projects, facilities owned and operated by the Grant County PUD. As a result of predation by Goose Island Caspian terns, survival standards for steelhead established under the 2004 Biological Opinion were not being met. Comparisons between total steelhead mortality in the Wanapum-Priest Rapids Project and mortality caused by predation from Goose Island Caspian terns indicated that between 37% and 85% of all steelhead mortality in the Project during 2008-2010 was attributable to predation by Caspian terns from the Goose Island colony (Evans et al. 2013).

In January 2014, the U.S Army Corps of Engineers – Walla Walla District completed the *Inland Avian Predation Management Plan* (IAPMP; USACE 2014). The goal of the IAPMP is to reduce Caspian tern predation rates on ESA-listed Columbia Basin salmonids to less than 2% per colony and per ESA-listed population. The management approach is to redistribute Caspian terns from nesting sites in the Columbia Plateau region (i.e., colonies on Goose Island and Crescent Island) to multiple dispersed colony sites within the breeding range of the population, but outside the Columbia River basin (USACE 2014). In 2014, the Corps and the Bureau of Reclamation (BOR) began implementation of Phase I of the IAPMP (USACE 2014) by reducing nesting habitat and actively discouraging Caspian terns from nesting on Goose Island in Potholes Reservoir.

The primary objectives of this study in 2014 were to (1) evaluate management initiatives implemented to reduce predation on juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary, including the monitoring of alternative Caspian tern nesting islands built by the Corps outside the Columbia River basin; (2) evaluate management implemented to reduce predation on juvenile salmonids by Caspian terns nesting on Goose Island in Potholes Reservoir by (a) collecting PIT-tags from piscivorous waterbird colonies to estimate smolt predation rates and (b) monitoring Caspian tern dispersal patterns associated with activities to dissuade nesting on the Goose Island colony; (3) monitor and evaluate colony size and juvenile salmon consumption by double-crested cormorants (*Phalacrocorax auritus*) nesting on East Sand Island and other sites in the lower Columbia River estuary; and (4) provide technical assistance to resource managers on the topic of avian predation on ESA-listed juvenile salmonids, as warranted.

STUDY AREA

The primary focus of our research and monitoring efforts in 2014 were at (1) the Caspian tern and double-crested cormorant colonies on East Sand Island in the Columbia River estuary (Map 1), (2) the Caspian tern colony on Goose Island in Potholes

Reservoir and other Caspian tern colonies in the Columbia Plateau region (Map 1), and (3) six Corps-constructed islands for nesting Caspian terns in southeastern Oregon (i.e., Crump Lake in the Warner Valley, East Link impoundment in Summer Lake Wildlife Area, Gold Dike impoundment in Summer Lake Wildlife Area, and Malheur Lake in Malheur National Wildlife Refuge) and northeastern California (i.e., Sheepy Lake in Lower Klamath National Wildlife Refuge, and Tule Lake Sump 1B in Tule Lake National Wildlife Refuge; Map 2).

Additionally, this report provides information on nesting Brandt's cormorants (*P. penicillatus*) and pelagic cormorants (*P. pelagicus*) in the Columbia River estuary, roosting California brown pelicans (*Pelecanus occidentalis californicus*) on East Sand Island, and various gull colonies in the Columbia River estuary, in the Columbia Plateau region, and at Corps-constructed tern islands in southeastern Oregon and northeastern California; Maps 1 and 2).

SECTION 1: CASPIAN TERNS

Beginning in 2008, the U.S. Army Corps of Engineers – Portland District implemented management described in the January 2005 Final Environmental Impact Statement (FEIS) and November 2006 Records of Decision (RODs) for *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary* (USFWS 2005, 2006). This management plan, which was developed jointly by the U.S. Fish and Wildlife Service (USFWS; lead), the USACE, and NOAA Fisheries, sought to redistribute the majority of Caspian terns nesting at the colony on East Sand Island in the Columbia River estuary to alternative colony sites (artificial islands) in interior Oregon and in the San Francisco Bay area by 2015 (Map 2). The goal of the plan is to reduce Caspian tern predation on out-migrating juvenile salmonids (salmon and steelhead) in the Columbia River estuary, and thereby enhance recovery of salmonid stocks from throughout the Columbia River basin, without negatively affecting the Pacific Coast population of Caspian terns. Thirteen of 20 evolutionarily significant units (ESUs) of Columbia Basin salmonids are currently listed as either threatened or endangered under the U.S. Endangered Species Act.

The Caspian Tern Management Plan in the Columbia River estuary called for the creation of approximately 7 – 8 acres of new or restored Caspian tern nesting habitat (islands) and to actively attract Caspian terns to nest at these sites. As alternative tern nesting habitat is created or restored outside the Columbia Basin, the available nesting habitat for Caspian terns on East Sand Island would be reduced from its initial size (approximately 6 – 6.5 acres in 2001-2007) to 1.0 – 1.5 acres.

The specific objectives of the Plan are to reduce the size of the East Sand Island Caspian tern colony to 3,125 – 4,375 breeding pairs by limiting the availability of suitable nesting habitat, while providing new nesting habitat for Caspian terns at alternative colony sites

outside the Columbia River estuary. These objectives were identified as the preferred alternative in the Final Environmental Impact Statement (EIS) released in early 2005 (USFWS 2005). Caspian terns displaced by habitat reduction on East Sand Island are expected to relocate to alternative colony sites including the nine Corps-constructed tern islands in interior Oregon and northeastern California (i.e., Fern Ridge Reservoir, Crump Lake, Summer Lake Wildlife Area [3 separate islands], Tule Lake NWR, Lower Klamath NWR [2 separate islands], and Malheur NWR). Plans to build additional tern colony sites in the southern portion of San Francisco Bay at Don Edwards National Wildlife Refuge were completed prior to the 2015 breeding season.

As part of a separate avian predation management plan, the U.S. Army Corps of Engineers - Walla Walla District and the U.S. Bureau of Reclamation began implementing the *Inland Avian Predation Management Plan* (IAPMP; USACE 2014) in 2014. This plan outlines steps that will be taken to dissuade Caspian terns from nesting on two islands in the Columbia Plateau region (Inland Basin) where nesting Caspian terns are consuming ESA-listed salmonids. The two islands that are the focus of the IAPMP are Goose Island in Potholes Reservoir (near Moses Lake, WA) and Crescent Island in the mid-Columbia River (just below the confluence with the Snake River). Both of these islands are anthropogenic — Goose Island was formed when the Potholes Reservoir impoundment was created and Crescent Island is a dredged material disposal site in the mid-Columbia River.

1.1. Columbia River Estuary

1.1.1. Implementation of Management Plan in the Columbia River Estuary

As part of the plan entitled *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*, the USACE – Portland District prepared 1.55 acres of suitable bare-sand nesting habitat for Caspian terns on East Sand Island in 2014 (Map 3). Dense, well-established European beach grass (*Ammophila arenaria*) along the northern edge of the managed colony area was not successfully removed by the disking and harrowing in 2014. This resulted in a 0.3-acre reduction in area of nesting habitat compared to the 1.58 acres of habitat prepared the previous year. As was the case in 2013, the colony area was not sprayed with pre-emergent herbicide in the spring of 2014. The area of Caspian tern nesting habitat prepared on East Sand Island in 2014 represented a 74 – 76% reduction from what had been provided prior to implementation of the management plan in 2008 (6 – 6.5 acres in 2001-2007).

Under separate contracts with the Corps and as stipulated in the Caspian Tern Management Plan, the Corps endeavored to prevent Caspian terns from nesting outside the core colony area (1.55 acres) on East Sand Island and elsewhere in the Columbia River estuary. This work was conducted by other contractors and the results were provided to the Corps in separate reports and are not provided here.

1.1.2. Nesting Distribution, Colony Size, and Productivity

Methods: The number of Caspian terns breeding on East Sand Island in the Columbia River estuary was estimated using low-altitude, high-resolution, vertical aerial photography of the colony taken near the end of the incubation period (28 May). The average of 3 direct counts of all adult terns on the colony in aerial photography, corrected using ground counts of the ratio of incubating to non-incubating terns on 12 different plots within the colony area, was used to estimate the number of breeding pairs on the colony at the time of the photography. Confidence intervals for the number of breeding pairs were calculated using a Monte Carlo simulation procedure to incorporate the variance in the multiple counts from the aerial photography and the variance in the ratios of incubating to non-incubating adult terns among the 12 plots. Estimates of breeding pairs were calculated one thousand times using random draws from the sample distributions of numbers of terns on-colony and the ratio of incubating to non-incubating adult terns on plots. Standard error and confidence interval for number of breeding pairs were derived from the resulting distribution.

Nesting success (average number of young raised per breeding pair) at the East Sand Island tern colony was estimated using aerial photography taken of the colony just prior to the fledging period (14 July). The average of 3 direct counts of all terns (adults and juveniles) on the colony in aerial photography, corrected using ground counts of the ratio of fledglings to adults on 12 different plots within the colony area, was used to estimate the number of fledglings on the colony at the time of the photography. To estimate nesting success, the total number of fledglings counted on-colony was divided by the number of breeding pairs estimated during late incubation (see above). Confidence intervals for nesting success were calculated using a Monte Carlo simulation procedure to incorporate the variance in the multiple counts from the aerial photography and the variance in the ratios of fledglings to adults on the plots. Monte Carlo calculations were performed using Visual Basic within Microsoft Excel (Microsoft Corp., Redmond, WA); 1000 iterations were performed and 95% bootstrap percentile limits were used for confidence intervals.

A custom application developed in ArcGIS was used to count adults and fledglings on the aerial photography taken to estimate colony size and nesting success at the East Sand Island Caspian tern colony.

Periodic boat-based and aerial surveys of the dredged material disposal islands in the upper estuary (i.e., Rice Island, Miller Sands Spit, and Pillar Rock Sands; Map 1) were conducted during the breeding season in order to detect signs of any nesting attempts by Caspian terns.

Results and Discussion: We estimate that 6,269 breeding pairs of Caspian terns (95% c.i. = 5,858 – 6,680 breeding pairs) were nesting on East Sand Island at the peak of nesting activity (late May – early June) in 2014 (Figure 1). Unlike what was observed in previous

years, there was no sustained effort by Caspian terns to nest at satellite colonies located near the high tide line on the beaches to the north, east, and south of the main colony at East Sand Island in 2014. This was likely due to nest dissuasion efforts implemented there (see Section 1.1.1), along with inundation of those sites during high high tide events and intense nest predation by glaucous-winged/western gulls. The best estimate of the size of the Caspian tern colony on East Sand Island in 2014 (6,269 breeding pairs) was substantially smaller than the average colony size prior to management (2000-2007: 9,079 breeding pairs; Figure 2 and Table 1). This is the smallest colony size estimate recorded at East Sand Island since the reduction in tern nesting habitat was implemented on the island in 2008. This represents about a 41% decline in Caspian tern colony size on East Sand Island from peak colony size in 2008 (ca. 10,670 breeding pairs), but still larger than the target colony size specified in the Caspian Tern Management Plan for the Columbia River Estuary (3,125 – 4,375 breeding pairs; USFWS 2005, 2006).

The overall decline in colony size at the East Sand Island tern colony during 2008-2014 can be attributed to the planned reductions in area of tern nesting habitat on East Sand Island as part of the Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006; see above). During 2008-2012, the amount of nesting habitat prepared for terns on East Sand Island had been incrementally reduced in each year, from approximately 5 acres in 2008 to 1.58 acres in 2012 and 2013. In 2014, the amount of nesting habitat prepared for Caspian terns on East Sand Island was reduced slightly (1.55 acres) from what was prepared the previous two years. In response to the gradual decline in available nesting habitat for Caspian terns on East Sand Island, there has been a general increase in nesting density, from 0.72 nests/m^2 in 2008 to 1.06 nests/m^2 in 2014 (Figure 3 and Table 1), now well above the nesting densities used to establish the colony size and colony area targets in the Caspian Tern Management Plan for the Columbia River Estuary (0.55 – 0.78 nests/m^2; USFWS 2005, 2006). Based on the Caspian tern nesting densities observed at East Sand Island in recent years, the area of Caspian tern nesting habitat provided on East Sand Island will likely need to be reduced to 1 acre or less to realize the goal of reducing the size of the East Sand Island tern colony to 3,125 – 4,375 breeding pairs, as prescribed in the Caspian Tern Management Plan (USFWS 2005, 2006).

Using the 14 July aerial photography of the Caspian tern colony, we estimate that ca. 1,700 fledglings were produced at the colony on East Sand Island. No tern chicks were observed at any satellite colonies on East Sand Island in 2014. This corresponds to an average nesting success of 0.28 young raised per breeding pair (95% c.i. = 0.06 – 0.49 fledglings/breeding pair). Compared to Caspian tern nesting success at East Sand Island in previous years and at other Caspian tern colonies in the region, this is considered poor productivity, but higher than the average productivity observed at this colony during the previous four years (0.08 fledglings/breeding pair; Figure 4). Nesting success at the East Sand Island Caspian tern colony peaked in 2001 and has trended downward since then (Figure 4). At least two factors have contributed to the decline in productivity

of the Caspian tern colony at East Sand Island: (1) ocean conditions and/or high river flows as they influence the availability of marine forage fishes in the estuary and (2) predation on tern eggs and chicks by gulls, especially during tern colony disturbance events caused by bald eagles (*Haliaeetus leucocephalus*; Collar 2013).

Collar (2013) showed that there was a strong inverse relationship between river discharge and Caspian tern nesting success at East Sand Island. Higher river discharge was also associated with lower abundance and biomass of marine forage fishes, especially northern anchovy and clupeids (herring and sardines), in the community of forage fishes within the estuary (Weitcamp et al., in review). Furthermore, the proportion of clupeids in the diet of Caspian terns nesting at East Sand was negatively correlated with river discharge (Collar 2013). Collar (2013) also found that Caspian tern productivity was negatively correlated with Bald Eagle disturbance and kleptoparasitism rates of Caspian terns by gulls. This study showed that gull predation, especially in the presence of eagle disturbance, was a major limiting factor colony-wide on Caspian tern nesting success.

As was the case prior to 2013, Caspian terns were observed prospecting for nest sites at dredged material disposal sites on Rice Island in the upper Columbia River estuary during 2014. Active and passive measures used by the Corps' contractor to dissuade Caspian terns from nesting on Rice Island were successful. Caspian terns did not attempt to nest at any other dredged material disposal site or other sites (e.g., Tongue Point piers) in the upper estuary during 2014.

1.1.3. Diet Composition and Salmonid Consumption

Methods: Caspian terns transport single whole fish in their bills to their mates (courtship meals) and to their young (chick meals) at the breeding colony. Consequently, taxonomic composition of the diet can be determined by direct observation of adults as they return to the colony with fish (i.e., bill load observations). Observation blinds were set up at the periphery of the tern colony on East Sand Island so that prey items could be identified with the aid of binoculars and spotting scopes. The target sample size was 350 bill load identifications per week. Bill load observations at the East Sand Island tern colony were conducted twice each day, at high tide and at low tide, to control for potential tidal and time of day effects on diet composition. Prey items were identified to the taxonomic level of family. We were confident in our ability to distinguish salmonids from non-salmonids and to distinguish among most non-salmonid taxa based on direct observations from blinds, but we did not attempt to distinguish the various salmonid species. The taxonomic composition of Caspian tern diets (percent of identifiable prey items) was calculated for each 2-week period throughout the nesting season. The diet composition of terns over the entire breeding season was based on the average of the percentages for the 2-week periods.

To assess the relative proportion of the various salmonid species in tern diets, we collected fish near the East Sand Island tern colony from Caspian terns returning to the colony with whole fish carried in their bills (referred to hereafter as "collected bill loads"). We employed a non-lethal sampling technique developed in 2011 that utilizes hazing shells to startle terns into dropping their fish; collection of a total of 273 bill load fish was conducted from 20 April to 26 July 2014. No lethal sampling of Caspian terns to determine diet composition was conducted during 2012-2014. Salmonid bill loads were identified as either Chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), steelhead, or unknown based on analyses of morphometrics, diagnostic bones, and molecular genetics[1].

Estimates of total annual smolt consumption by Caspian terns nesting at the East Sand Island colony were calculated using a bioenergetics modeling approach (see Roby et al. [2003] for a detailed description of model structure and input variables). We used a Monte Carlo simulation procedure to calculate reliable 95% confidence intervals for estimates of smolt consumption by Caspian terns.

Results and Discussion: Of the bill load fish identified at the East Sand Island Caspian tern colony during the 2014 nesting season (n = 5,559 bill loads), on average 33% were juvenile salmonids. This proportion was similar to the annual average proportion of salmonids in the diet during the previous eight years (Figure 5). As in previous years, marine forage fishes (i.e., anchovies [Engraulidae], surf perch [Embiotocidae], smelt [Osmeridae], and herring [Clupeidae]) were most prevalent in the tern diet, together averaging 61% of all identified bill loads in the diet of terns nesting on East Sand Island in 2014 (Figures 6 and 7). In 2014, the peak in the proportion of salmonids in the diet of Caspian terns nesting on East Sand Island occurred in mid-May, a week later than the average timing of the peak in salmonids in the tern diet during the previous 14 years (Figure 8). The proportion of salmonids in the tern diet during the 2014 nesting season was higher than average nearly throughout the month of May (Figure 8).

Genetic stock identification of salmonid bill load fish collected from East Sand Island Caspian terns during 2011-14 indicated that terns consumed smolts from many of the uniquely identifiable stocks from across the Columbia Basin. For Chinook salmon, the most common genetic stocks of origin for smolts depredated by terns during April and May were the Middle Columbia River, Upper Columbia River, and Snake River spring run stocks (combined 48 of 87, or 55%; Figure 9, Table 2). During June and July, most depredated Chinook salmon smolts (42 of 65, or 65%) originated from the lower

[1] Genetic analyses were conducted by NOAA Fisheries (POC: David Kuligowski) at the Manchester Field Station genetics laboratory. Species identifications were carried out by amplifying (PCR) the mitochondrial DNA fragment COIII/ND3 as outlined in Purcell et al. (2004). Following species identification, samples were genotyped using species-specific standardized sets of microsatellite DNA markers (Seeb et al. 2007, Blankenship et al. 2011). Stock origins of individual salmon and steelhead were estimated using standard genetic assignment methods (Van Doornik et al. 2007).

Columbia River (Spring Creek Group fall run, West Cascades Tributary fall run, and the introduced Rogue River fall run). The remaining Chinook salmon in tern diets during this period was dominated by smolts belonging to the Snake River fall run and Upper Columbia River summer/fall run stocks (each 16% of all Chinook identified, approaching that of the individual lower Columbia River stocks). Depredated steelhead trout originated from six stocks, with steelhead from the Snake River consisting of almost half of the identified samples (61 of 130 samples, or 47%; Figure 10, Table 3). Genetic stock identification was performed for 51 coho salmon smolts collected from terns. Just over half of identified coho salmon originated from the Columbia River stock (27 of 51 samples, or 53%; Figure 10, Table 4). Unlike previous years, a majority of coho salmon samples in 2014 were from the Oregon coast ESU (19 of 31, or 61%).

Our best estimate of total smolt consumption by Caspian terns nesting on East Sand Island in 2014 was 4.5 million smolts (95% c.i. = 3.9 – 5.1 million smolts), below the average for the previous 14 years (Figure 11). From 2000 to 2014, the average number of smolts consumed by Caspian terns nesting on East Sand Island was 5.2 million smolts per year. This is less than half the annual consumption of juvenile salmonids by Caspian terns nesting in the Columbia River estuary prior to 2000, when the breeding colony was located on Rice Island in the upper Columbia River estuary. Further reductions in smolt consumption by Caspian terns in the Columbia River estuary will be realized once the management goals associated with reductions colony size and colony area on East Sand Island and elsewhere in the estuary are met.

Of the juvenile salmonids consumed by East Sand Island Caspian terns in 2014, we estimate that 1.7 million or 38% were coho salmon (95% c.i. = 1.5 – 2.0 million smolts), 1.0 million or 22% were sub-yearling Chinook salmon (95% c.i. = 0.8 – 1.1 million smolts), 0.9 million or 20% were steelhead (95% c.i. = 0.7 – 1.0 million smolts), 0.9 million or 20% were yearling Chinook salmon (95% c.i. = 0.7 – 1.0 million smolts), and 0.02 million or < 1% were sockeye salmon (95% c.i. = 0.00 – 0.04 million smolts; Figure 12).

1.1.4. Predation Rates on Salmonids Based on Smolt PIT Tag Recoveries

Passive integrated transponder (PIT) tags are placed in juvenile salmonids and other fishes to study their behavior and survival following release. PIT tags provide specific information on each individual fish, including the species, rearing-type (hatchery, wild), migration timing, and size of each fish. A portion of these PIT-tagged fish are consumed by avian predators, and a portion of the ingested tags is subsequently deposited (regurgitated or defecated) on the bird's nesting colony. For more than a decade, recoveries of PIT tags on bird colonies have been used to estimate predation rates (percentage of available fish consumed) and to compare the relative susceptibility of different fish species and fish populations to avian predators in the Columbia River Basin (Collis et al. 2001; Ryan et al. 2003; Antolos et al. 2005; Maranto et al. 2010; Evans et al. 2012; Hostetter et al. 2012; Sebring et al. 2013; Hostetter et al. 2015).

The main objectives for collecting data on PIT tags deposited on bird colonies as part of this study were to (1) determine colony-specific predation rates on particular populations of salmonids (distinct population segments [hereafter DPSs] or evolutionarily significant units [hereafter ESUs]), (2) assess differences in predation rates on smolt populations based on the bird species and bird colony location, and (3) evaluate whether avian predation rates in 2014 were similar to those reported in previous years and, if not, whether predation rates were trending up or down. Comparisons between current and previous predation rates were made in the context of management initiatives for Caspian terns nesting on East Sand Island (on-going) as a means of evaluating the efficacy of those initiatives in reducing predation on ESA-listed populations of salmonids.

Methods: A description of the methods used to calculate predation rates from PIT tags recovered on bird colonies in the Columbia River Basin is provided below and can also be found in Hostetter et al. (2015). In general, predation rates are derived using the proportion of PIT tags found on a given bird colony from the population of PIT-tagged fish available, and then adjusting by the rate that a consumed PIT tag was subsequently deposited on the bird colony and then subsequently detected by researchers following the nesting season (Figure 13).

Availability of PIT-tagged Fish – Each year more than one million anadromous salmonid smolts are PIT-tagged and released in the Columbia River Basin (FPC 2014). Portions of these PIT-tagged fish are subsequently detected passing hydroelectric dams during out-migration. Following the definitions in Evans et al. (2012), we considered a PIT-tagged juvenile salmonid to be available to avian predators nesting at a particular colony if it was detected at the nearest upstream hydroelectric dam with adequate smolt interrogation capabilities. Smolt availability to avian predators was limited to April-July for birds nesting at inland colonies (those upstream of Bonneville Dam) and March-August for birds nesting at estuary colonies, which reflect the periods of overlap in active smolt out-migration and avian nesting (Evans et al. 2012; Adkins et al. 2014b). PIT-tagged fish were grouped by salmonid population, representing a unique combination of species (Chinook salmon, sockeye salmon, coho salmon, or steelhead trout), run-type (spring, summer, fall, or winter), and river-of-origin (Columbia, Snake, or Willamette). The designation of ESUs/DPSs follows that of NOAA (2014), which can include both wild and hatchery-reared fish, depending on the ESU/DPS. Detection data were retrieved from the regional salmonid PIT Tag Information System (PTAGIS) database maintained by the Pacific States Marine Fisheries Commission (www.ptagis.org; PTAGIS 2014).

Smolt availability to Caspian terns nesting on East Sand Island in the Columbia River estuary was based on interrogations of PIT-tagged fish passing Bonneville Dam (Rkm 234 on the lower Columbia River) and Sullivan Dam (Rkm 203 on the lower Willamette

River), the two nearest upstream dams with adequate smolt interrogation capabilities (Map 1).

PIT Tag Recovery – Electronic recovery of PIT tags on bird colonies followed the methods of Evans et al. (2012) and Zamon et al. (2013). Portable antennas were used to detect PIT tags *in situ* during August through November, after birds dispersed from their breeding colonies. Colony areas were scanned using either a mobile flat-plate detection system (Figure 14) or a portable handheld detection system (Figure 14), depending on the size (surface area) and substrate type (sand, rock, or woody debris) of the colony site. PIT tags were detected by systematically scanning the entire area occupied by birds during the nesting season (referred to as a "pass"), with a minimum of two passes or complete sweeps conducted of the nesting area at each colony. The area scanned by researchers was determined based on aerial photography of the colony site and visits to the colony during the nesting season.

In addition to electronic detection of PIT tags using antennas, PIT tags were also physically removed from some bird colonies with magnets attached to a towable trailer or hand-cart (Figure 14). The physical removal of PIT tags reduces tag collision, a phenomena that renders PIT tags in close proximity to each other undetectable by electronic scanners. The physical removal of PIT tags (and subsequent hand scanning of each tag to acquire its unique code) increases tag detections at colonies where tag densities are high (BRNW 2008; see Results). Physical recovery of PIT tags at the East Sand Island tern colony was attempted on a trial basis in 2014 to address concerns that tag collision is reducing detection efficiency at this colony (see PIT Tag Detection Efficiency below). For instance, prior to 2011 average detection efficiency at the East Sand Island tern colony was > 85%, but detection efficiency has recently dropped to < 70% (Hostetter et al. 2015), presumably due to (1) the large number of PIT tags accumulating on the colony during each nesting season, (2) an increase in Caspian tern nesting density on the East Sand Island colony (BRNW 2014a), and/or (3) PIT tags are remaining on tern colony longer due to rows of silt fencing that have been erected adjacent to the colony area in recent years to reduce colony area.

PIT Tag Detection Efficiency – Not all PIT tags deposited by birds on their nesting colony are subsequently found by researchers after the nesting season. PIT tags can be blown off the colony during wind storms, washed away during high tides, rain storms, or other flooding events, or otherwise damaged or lost during the course of the nesting season (Evans et al. 2012). Furthermore, the detection methods used to recovery PIT tags on bird colonies are not 100% efficient, with some proportion of detectable tags missed by researchers during the scanning process. To address these factors, PIT tags with known tag codes were intentionally sown on the colony (hereafter referred to as "control tags") throughout the nesting season at each bird colony to quantity PIT tag detection efficiency. The sowing of control tags was conducted during one to four discrete periods during the birds' nesting season: (1) prior to arrival of birds (March to April), (2) during the egg incubation period (April to May), (3) during the chick-rearing period (May to

June), and (4) immediately following the fledging of young (July to September). These periods were selected because they encompassed the time periods when juvenile salmonids were out-migrating and therefore available as prey to nesting birds. The total number of control PIT tags sown varied by colony, with sample sizes ranging from 50 to 400 PIT tags per colony (see Results). The number of discrete time periods when control tags were sown also varied by colony, depending on access to the colony during the nesting season (see Results). During each release, control tags were haphazardly sown throughout the entire area occupied by nesting birds during the nesting season.

PIT Tag Deposition Rates – Not all smolt PIT tags that are ingested by birds are subsequently deposited on their nesting colony (Hostetter et al. 2015). A portion of PIT tags implanted in depredated fish are stolen by other predators (kleptoparasitized), damaged and rendered unreadable during digestion, or are excreted off-colony at loafing, staging, or other areas utilized by birds during the nesting season. Methods and results from studies aimed at quantifying PIT tag deposition rates for nesting Caspian terns and double-crested cormorants were conducted during 2004-2013 and result from these studies were used to infer deposition rates in 2014 (see Results). A detailed description of methods and results from these deposition experiments are presented in Hostetter et al. (2015). Briefly, trout implanted with a PIT tag of known code were fed to nesting birds during discrete periods of the day (morning, evening) and throughout the nesting season (April to June), with the number of ingested PIT tags subsequently found by researchers on the colony at the end of the nesting season (August – September) used to estimate deposition rates by avian species and colony.

Predation Rates – Predation rates were modeled independently for each bird colony and each salmonid ESU/DPS. The probability of recovering a PIT tag from a smolt on a particular colony was the product of the three rates described above, (1) the probability that the fish was consumed (θ), (2) the PIT tag deposited on-colony (μ_ϕ), and (3) the PIT tag detected on-colony (ψ):

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

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

$$\psi_i = \beta_0 + \beta_1 * i$$

where β_0 and $\beta_1$are both derived from non-informative priors (normal [0, 1000]).

Weekly predation rate, θ_i, is modeled as a random walk process with mean μ_θ and variance σ_θ^2, where:

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

and $\varepsilon_w \sim normal\left(0,\ \sigma_\theta^2\right) \forall\, w$. We place non-informative priors on these two hyperparameters: ilogit(μ_θ) $\sim uniform(0,1)$ and $\sigma_\theta^2 \sim uniform(0,20)$. This allows each week (*i*) to have a unique predation rate (θ_i), while still sharing information among weeks (*i*) to improve precision.

Informative Beta (α, β) priors were used to infer deposition rates (ϕ) for each bird species and colony (see Results). The shape parameters for these prior distributions was assumed to be α = 16.20 and β = 6.55 for tern colonies and α = 15.98 and β = 15.29 for cormorant colonies (Hostetter et al. 2015).

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

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

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

We implemented all predation rate models in a Bayesian framework using the software JAGS (Plummer 2003) accessed through R version 3.1.2 (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 along with the 2.5 and 97.5 percentiles, which are referred to as 95% Credible Intervals (95% c.i.). Predation rates were only calculated for salmonid ESUs/DPSs where ≥ 500 PIT-tagged salmonids were interrogated passing an upstream dam in a given year to avoid imprecise results that might arise from small annual sample sizes of available PIT-tagged smolts (Evans et al. 2012).

Results from this predation rate modeling procedure were based on the following assumptions:

A1. Information from PTAGIS on release and interrogation of PIT-tagged salmonids were complete and accurate.

A2. PIT-tagged smolts last detected passing the nearest upstream dam were available to birds nesting downstream.

A3. The predation, deposition, and subsequent detection efficiency for PIT-tagged smolts are all independent.

A4. The detection efficiency for control PIT tags sown on-colony were equal to those for PIT tags deposited by birds on-colony.

A5. The deposition rates for PIT tags that were measured by studies in previous years (see Hostetter et al. 2015 and Results) were equal to those of smolt PIT tags consumed by birds during the current study year.

A6. PIT tags from consumed fish were egested by avian predators within a short time period (within one week) of the PIT-tagged fish being detected passing an upstream dam.

A7. PIT-tagged fish were representative of non-tagged fish belonging to the same ESU/DPS and passing the same detection site (dam).

To help meet the first assumption (A1), irregular entries in PTAGIS were either verified by the respective coordinator of the PIT-tagging effort or eliminated from the analysis. Detections of PIT-tagged salmonids at dams upstream of bird colonies were deemed the most appropriate measure of fish availability given the downstream movement of smolts, the ability to standardize data across sites, and the ability to define unique groups of salmonids by a known location and passage date (Assumption A2). Assumption A2 assumes all PIT-tagged fish last detected passing a dam were alive and available to predators downstream. If large numbers of fish halted their out-migration or died immediately following passage and prior to reaching the foraging range of the bird colony, however, predation rates would be biased low. The fate of each PIT tag implanted in a smolt is assumed to be independent (A3). Lack of independence among PIT-tagged fish could potentially bias predation rates and overinflate credibility intervals. Detection efficiency estimates (A4) were generally high (average ca. 70%, depending on colony; see Results), suggesting that any possible violations of assumption A4 would have little effect on estimates of predation rates at most colonies. Deposition rate data collected during 2004-2013 (when multiple estimates of deposition rates were measured for each species of avian predator) showed no evidence of inter- or intra-annual trends in deposition rates (Assumption A5).

Assumption A6 relates to the use of the last date of live fish detection as a proxy for the date a PIT tag was deposited on a bird colony. This assumption needs to be only roughly true because detection efficiency did not change dramatically on a daily or weekly basis (see Results). Assumption A7 relates to inference regarding the susceptibility to consumption of a PIT-tagged fish as it relates to that of all fish (tagged and untagged) from the same stock. There are few empirical data to support or refute assumption A7, except that the run-timing and abundance of PIT-tagged fish is often in agreement with the run-timing and abundance of untagged fish passing dams in the Columbia River Basin. For some stocks (Upper Columbia River steelhead and Upper Columbia River spring Chinook salmon), fish were intentionally PIT-tagged in concert with the run

passing a dam to ensure that a representative sample of fish was available for estimates of predation rate (see Section 1.2.3 below). These and other important assumptions, caveats, and discussion points are presented in more detail in Evans et al. (2012), Lyons et al. (2014a), and Hostetter et al. (2015).

Results and Discussion: Following the nesting season, PIT tags from 13,059 smolts (Chinook salmon, coho salmon, sockeye salmon, and steelhead combined) in the 2014 migration year were recovered on the East Sand Island Caspian tern colony (Table 5). Due to large colony area (1.55 acres; Map 3) and number of PIT tags present, 14 passes of the entire colony area were completed as part of PIT tag recovery efforts in 2014 (Figure 15). Passes were conducted from 16 September to 6 October, 2014. Trial efforts to physically remove PIT tags using a magnet towed behind an ATV were promising, with > 11,000 functional PIT tags removed during a single complete pass of the colony. This single colony pass with the magnet resulted in a higher proportion of newly detected tags (ca. 24%) when compared to the four preceding and two succeeding electronic passes, which all resulted in ca. 10% newly detected tags per pass (Figure 15). Many of these removed PIT tags were from previous migration years (> 75% of all removed tags were from migration years before 2014, with some dating as far back as the 2000 migration year). This result indicates that PIT tags are gradually accumulating on the colony, that some PIT tags have remained on-colony since its inception in 2000, and that the large number of accumulated PIT tags likely contributes to significant collision effects. Of the PIT tags from the 2014 migration year detected on-colony (n = 13,059), only approximately 17% were subsequently physically recovered using magnets and removed. Results from this PIT tag removal trial suggest that future efforts to physically remove PIT tags would likely improve on-colony detection efficiency by minimizing tag collision, as well as recover a significant number of PIT tags that were previously undetected, despite substantial efforts to electronically detect the tags (i.e., > 10 passes). Future management actions directed at the East Sand Island Caspian tern colony (i.e., further restriction of colony area) would likely result in increased on-colony PIT tag collision, and may require the physical removal of larger quantities of PIT tags to ensure the precision of future estimates of predation rates derived from PIT tag detection efforts.

Recoveries of control PIT tags sown on the East Sand Island tern colony (n = 300) indicated that detection efficiency ranged from 40% to 82% for PIT tags deposited on-colony between 1 March and 31 August, 2014 (Table 6). Based on previous studies that empirically measured deposition rates for Caspian terns (see Hostetter et al. 2015), deposition rates for East Sand Island Caspian terns were estimated to be 71% (95% c.i. = 51 - 89%; Table 7).

Estimated predation rates indicated that steelhead were the species of salmonid smolt most susceptible to predation by Caspian terns nesting on East Sand Island in 2014, with predation rates ranging from 8.6% (95% c.i. = 6.7 - 12.5%) on Snake River steelhead to 11.4% (95% c.i. = 8.5 - 16.8%) on Upper Columbia River steelhead (Table 8). By

comparison, predation rates on Chinook and sockeye salmon ESUs were significantly lower than those on steelhead DPSs, ranging from just 0.9% (95% c.i. = 0.5 - 1.7%) on Middle Columbia River spring Chinook to 1.6% (95% c.i. = 0.8 - 3.0%) on Snake River sockeye (Table 8). These results indicate that susceptibility to predation by East Sand Island Caspian terns was similar amongst ESUs of salmon, but that DPSs of steelhead were disproportionally consumed relative to their availability in the Columbia River estuary during 2014, as indicated by the numbers of PIT-tagged smolts interrogated while passing Bonneville Dam. These differences in smolt susceptibility are consistent with those reported in previous years, with Caspian tern predation rates on steelhead populations often 10 times greater than those on salmon in the Columbia River estuary (see Appendix B, Table B1 for East Sand Island Caspian tern predation rates in previous years).

There was no significant difference in Caspian tern predation rates on fish based on rearing type, with approximately equal – albeit variable – predation rates observed on hatchery and wild fish (Table 9). Evans et al. (2011) also found no significant difference in the relative susceptibility of hatchery and wild fish to predation by East Sand Island Caspian terns during 2004-2009. Differences in tern predation rates on hatchery and wild fish, however, have been consistently reported at other Caspian tern colonies in the region (Table 9; Hostetter et al. 2012; BRNW 2014a).

A temporal analysis of weekly predation rates on Upper Columbia River steelhead and Snake River steelhead, the two salmonid populations with highest observed Caspian tern predation rates (Table 8), indicated that predation rates varied significantly during the smolt out-migration period (Figure 16). Predation rates on both of these steelhead DPSs were significantly greater during the last few weeks of the run, with as much as 20% of the available smolts consumed in June compared with 5 to 10% in April (Figure 16). There was some evidence that predation rates on Snake River steelhead were lowest during the peak of the out-migration in May (Figure 16), a trend observed at other Caspian tern colonies in 2014 (Figure 17). Numerous factors may be responsible for differences in steelhead susceptibility to Caspian tern predation during the nesting season, including difference in run-timing between hatchery-reared and wild smolts (Hostetter et al. 2012), differences in the availability of alternative prey in the estuary (Lyons et al. 2014a), and changes in flow regimes during the smolt out-migration period (Hostetter et al. 2012, Lyons et al. 2014a). See also Section 1.2.3 and 2.1.2 for additional details regarding extrinsic and intrinsic factors that influence smolt susceptibility to bird predation.

In relation to management efforts to reduce the size of the East Sand Island Caspian tern colony, thereby reducing consumption of salmonids, predation rates on smolts by East Sand Island Caspian terns in 2014 were similar to those observed during 2011-2013, but were generally lower than predation rates during the previous 4-year period of 2007-2010 (Appendix B). For example, average annual predation rates on Snake River steelhead during 2007-2010 were 16.3% (range = 14.2 - 22.6%), but were only 10.9%

(range = 8.6 - 12.7%) during 2011-2014 (Appendix B, Table B1). Similar reductions in Caspian tern predation rates following the initiation of management actions on East Sand Island have been observed in other steelhead and salmon DPSs/ESUs (Appendix B, Table B1). Reductions in Caspian tern predation rates during 2011-2014 coincided with proportional reductions in colony size at East Sand Island (Figure 2), relative to 2007-2010. This suggests that Caspian tern management initiatives to reduce nesting habitat on East Sand Island are resulting in lower predation rates on salmonid ESUs/DPSs. Reductions in Caspian tern predation rates on juvenile salmonids in the Columbia River estuary have not, however, reached management targets because Caspian terns have increased their nesting density on East Sand Island in response to reduced area of nesting habitat (Figure 3). Further reductions in Caspian tern predation rates and attainment of management targets are likely if the area of Caspian tern nesting habitat on East Sand Island is further reduced.

Adequate sample sizes of PIT-tagged smolts (≥ 500 PIT-tagged smolts per ESU/DPS) were not available for all salmonid populations originating entirely above Bonneville or Sullivan dams in 2014. For example, there were < 500 known-origin sockeye salmon, Chinook salmon, or winter-run steelhead smolts that were PIT-tagged and released within the geographic range of the Lake Wenatchee, Okanogan River, Deschutes River, or Upper Willamette River ESUs in 2014. Sample sizes for these same ESUs/DPSs were inadequate for estimation of predation rates in previous years (BRNW 2014a). In addition to upriver ESUs/DPSs, predation rates by East Sand Island Caspian terns on PIT-tagged smolts originating from Lower Columbia River ESUs/DPSs (e.g., ESA-listed Lower Columbia River Chinook salmon, coho salmon, and steelhead) could not be estimated due to the paucity of in-stream PIT tag detectors below Bonneville Dam and insufficient sample sizes of PIT-tagged fish released below Bonneville and Sullivan dams (Lyons et al. 2014b). As such, the impacts of predation by East Sand Island Caspian terns on Lower Columbia River ESUs/DPSs are largely unknown at the population-level (Lyons et al. 2014b). Although not directly comparable, predation rates by East Sand Island terns on groups of hatchery-reared subyearling Chinook salmon, PIT-tagged and released into tributaries downstream of Bonneville Dam, were roughly 2 to 3 times higher than those last detected passing Bonneville Dam (Sebring et al. 2013).

Finally, PIT tag-derived predation rates presented here apply only to the in-river component of each ESU/DPS passing Bonneville Dam, and not the portion of each population transported around the Federal Columbia River Power System. Data directly comparing predation rates on in-river and transported groups of PIT-tagged Snake River smolts, however, are generally lacking (Zamon et al. 2013; Lyons et al. 2014b), or are antiquated because adjustments for on-colony PIT tag detection efficiencies and deposition rates were not available (Ryan et al. 2003). In the few cases where comparisons have been made, differences in tern predation rates between in-river and transported fish were generally small (< 2% difference in predation rates), with no consistent trend by year or salmonid species (Ryan et al. 2003; Zamon et al. 2013; Lyons et al. 2014b). A more robust (multi-year) and updated (adjusted for detection

efficiencies and deposition rates) analysis, however, may be needed to adequately quantify potential differences in predation rates between in-river and transported smolts from the Snake River basin. Because transportation of smolts is largely or completely limited to smolts originating from the Snake River (FPC 2014), this is not an area of potential study for other salmonid ESUs/DPSs in the Columbia River basin.

1.2. Columbia Plateau Region

1.2.1. Implementation of Management Plan at Goose Island - Potholes Reservoir

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 no apparent effect on the number of gulls nesting on Goose Island, passive dissuasion and active hazing succeeded in preventing nesting by Caspian terns on Goose Island in Potholes Reservoir during the 2014 nesting season.

See BRNW 2014b for additional details regarding the implementation of the IAPMP in 2014.

1.2.2. Nesting Distribution, Colony Size, and Productivity

Methods: Given the relatively small number of Caspian terns nesting at colonies in the Columbia Plateau region as compared to the East Sand Island tern colony, estimates of colony size and nesting success at these smaller colonies 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 were taken of the Columbia Plateau tern colonies, and those ortho-rectified images were analyzed to estimate the area (acres) used by nesting Caspian terns at each site.

Periodic boat-based and aerial surveys of sites that formerly supported Caspian tern breeding colonies in the Columbia Plateau region (i.e., Three Mile Canyon Island, the Blalock Islands, Miller Rocks, Cabin Island, Sprague Lake, Banks Lake; Map 1) were conducted during the breeding season to determine whether these colony sites were active. We also flew aerial surveys of the lower and middle Columbia River from Bonneville Dam to Grand Coulee Dam, the lower Snake River from its mouth to the confluence with the Clearwater River, and the Potholes Reservoir area searching for new or incipient Caspian tern breeding colonies. See BRNW 2014b for additional details regarding Caspian tern colony monitoring in the Columbia Plateau region.

Results and Discussion: 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 no detectable 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. Some Caspian terns that were precluded from nesting on Goose Island were, however, 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 (Figures 18 and 19). This islet, dubbed "Northwest Rocks," eventually attracted as many as 156 breeding pairs of Caspian terns, which nested at a high density amongst earlier-nesting gulls (Figure 19; see BRNW

2014b for further discussion of nesting densities). 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 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, or an average of 0.28 fledglings per breeding pair (Figure 20).

Caspian terns attempted to nest at four other previously used colony sites in the Columbia Plateau region during 2014, and perhaps a fifth site where nesting by Caspian terns had not been previously 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 (Figure 21), (2) the Blalock Islands in John Day Pool in the Columbia River (Figure 22), (3) Twinning Island in Banks Lake (Figure 23), and (4) Harper Island in Sprague Lake (Figure 24; also see Figure 25). The potential new Caspian tern breeding site was on a small island in Lenore Lake, where a small gull colony existed (Figure 25). 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 (Figure 21). A total of about 474 breeding pairs of Caspian terns attempted to nest on Crescent Island in 2014, a 21% increase in colony size compared to 2013 (Figures 21). 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 (Figure 26). 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 colony and other Caspian tern colonies in the Columbia Plateau region in 2014, the overall size of the Caspian tern breeding population in the Columbia Plateau region declined slightly from about 773 breeding pairs in 2013 to about 758 breeding pairs in 2014 (Figure 27). For more details on the nesting distribution, colony size, and productivity of Caspian terns in the Columbia Plateau region in 2014, see BRNW 2014b.

1.2.3. Predation on Salmonids Based on Smolt PIT Tag Recoveries

As part of Phase I of the Inland Avian Predation Management Plan (IAPMP), Caspian terns were dissuaded from nesting on Goose Island in Potholes Reservoir, WA during 2014 (see Section 1.1.2 and BRNW 2014b for details). The over-all goal of the IAPMP was to reduce predation rates by Caspian terns nesting on Goose Island on salmonid ESUs/DPSs to < 2% per ESA-listed population (USACE 2014). Although efforts to reduce the size of the Goose Island Caspian tern colony were successful, a satellite colony of 156 nesting pairs formed on Northwest Rocks, a small islet directly adjacent to Goose

Island proper in 2014 (BRNW 2014b). Predation rates presented here are based on PIT tags recovered from the Northwest Rocks colony, along with PIT tags recovered on the three largest unmanaged Caspian tern colonies in the Columbia Plateau Region in 2014: (1) Twinning Island in Banks Lake Reservoir, WA, (2) Crescent Island in McNary Reservoir, WA, and (3) Blalock Islands in John Day Reservoir, WA (Map 1).

Finally, PIT tag-derived predation rates presented here apply only to the in-river component of each ESU/DPS passing Lower Monumental Dam (for Snake River ESUs/DPSs) or Rock Island Dam (for Upper Columbia River ESUs/DPSs), and not the portion of each population transported around the Federal Columbia River Power System.

Northwest Rocks (Potholes Reservoir) Caspian terns –

Methods: The methods for calculating predation rates on smolts based on PIT tag recoveries at the Northwest Rocks Caspian tern colony are the same as those described in Section 1.1.4, except that smolt availability was based on PIT-tagged smolts last detected passing Lower Monumental Dam (for Snake River ESUs/DPSs) or Rock Island Dam (for Upper Columbia River ESUs/DPSs). Also, because the emergence of the satellite colony on Northwest Rocks was not anticipated, control PIT tags to quantify detection efficiency were only sown during the post-season (n = 50). Rates for pre-season detection were inferred from an average of pre-season detection efficiency from Goose Island proper in previous years (Table 6). This adds an additional assumption to our estimates that pre-season detection efficiency from prior years on Goose Island are an unbiased estimate of pre-season detection efficiency at the new Northwest Rocks colony.

Rock Island Dam (RIS) is a particularly important tagging location because it represents the upper most foraging range on the Columbia River for Caspian terns nesting in Potholes Reservoir (BRNW 2014a), and the beginning of the smolt migration corridor for ESA-listed Upper Columbia River steelhead and spring Chinook salmon. Due to the limited number of previously PIT-tagged smolts annually interrogated/recaptured passing RIS, we PIT-tagged steelhead and yearling Chinook smolts at the dam to supplement numbers of ESA-listed fish available for analyses of predation. Steelhead and yearling Chinook smolts were captured, PIT-tagged, and released into the RIS tailrace to resume out-migration (see Results). Smolts were randomly-selected for tagging at the dam and were tagged in concert with, and in proportion to, the run passing RIS. In addition to PIT-tagging, fish were measured (mm, fork length), weighed (g), and condition-scored (descaling, body injuries, fin damage, and external disease symptoms; see Hostetter et al. 2011) prior to release in order to gather information on the influence of fish size and condition on predation rates.

Results and Discussion: A total of 7,757 steelhead smolts (5,796 hatchery, 1,961 wild) and 5,446 yearling Chinook salmon smolts (5,072 hatchery, 374 wild) were PIT-tagged

and released at RIS from 12 April to 13 June 2014. Only 969 previously PIT-tagged steelhead and 380 previously PIT-tagged Chinook salmon were recaptured at the RIS trap, indicating that in the absence of our tagging project, inadequate numbers of fish would have been available for analyses on avian predation rates in 2014. All of the steelhead smolts PIT-tagged at RIS as part this study were ESA-listed Upper Columbia River steelhead. Not all of the yearling Chinook salmon smolts PIT-tagged at RIS, however, were from the ESA-listed spring-run because non-listed summer-run hatchery Chinook are also released as yearlings into the middle Columbia River. Based on unique markings (a combination of fin clips and coded wire tags), a minimum of 641 of the yearling Chinook smolts PIT-tagged at RIS were known ESA-listed spring-run Chinook, while the remaining fish were a mixture of ESA-listed spring-run and non-listed summer-run Chinook salmon.

Fish sampling and smolt passage at RIS peaked in May, with 80% of all steelhead sampled between 7 and 27 May (Figure 17) and 80% of all yearling Chinook sampled between 24 April and 26 May (Figure 17). Mean fork lengths were 191 mm (standard deviation [SD] = 66 mm) and 144 mm (SD = 23 mm) for juvenile steelhead and yearling Chinook, respectively. Condition sampling indicated that 6.5% and 3.5% of steelhead and yearling Chinook, respectively, had moderate-to-severe external signs of damage and disease (defined as open body wounds, > 20% descaling, fungal or viral infections, and/or > 50% fin damage; see Hostetter et al. 2011). The incidence of external damage in 2014 was lower than that observed at RIS during the 2013 out-migration, when 10.6% and 4.9% of steelhead and yearling Chinook, respectively, were damaged (BRNW 2014a).

Following the nesting season, a total of 874 PIT tags from smolts tagged in the 2014 migration year (Chinook salmon, coho salmon, sockeye salmon, and steelhead combined) were recovered on the Caspian tern colony at Northwest Rocks (Table 5). Results estimate that detection efficiency ranged from 23% to 98% for tags deposited between 1 April and 31 July, 2014 (Table 6). Based on previous studies that empirically measured deposition rates for Caspian terns (see Hostetter et al. 2015), deposition rates for Northwest Rocks Caspian terns were estimated to be 71% (95% c.i. = 51 - 89%; Table 7).

Of the 7,757 steelhead smolts tagged and released into the tailrace of RIS, an estimated 2.9% (95% c.i. = 1.9 - 5.1) were consumed by Caspian tern nesting on Northwest Rocks in Potholes Reservoir in 2014 (Table 10). The estimated predation rate by Caspian terns nesting at Northwest Rocks in 2014 was the lowest recorded to date for a Caspian tern colony in Potholes Reservoir, and significantly lower than pre-management estimates ranging from 11.1% to 22.6% for the Goose Island colony during 2007-2013 (Figure 17 and Appendix B, Table B2). Our results provide evidence that efforts to dissuade Caspian terns from nesting on Goose Island in 2014 were successful in reducing smolt consumption on Upper Columbia River steelhead, with a reduction of roughly 80% relative to pre-management predation rates. The reduced predation rate in 2014,

however, was not below the target threshold predation rate of 2% established by the IAPMP (USACE 2014).

Similar to the predation rate on steelhead, there was evidence that the predation rate on yearling Chinook salmon was also significantly reduced in 2014, with only 0.3% (95% c.i. = 0.1 - 0.7%) of the 5,446 PIT-tagged yearling Chinook salmon smolts consumed by terns nesting at Northwest Rocks. Of these 5,446 Chinook salmon, 641 were confirmed ESA-listed spring-run Chinook salmon, of which an estimated 0.5% (95% c.i. = 0.1 - 2.2%) were consumed by Caspian tern nesting on Northwest Rocks in 2014 (Table 10). There was no statistically significant difference in Caspian tern predation rates on confirmed spring-run Chinook smolts and unknown-run yearling Chinook smolts, which is not surprising given that some of the unknown-run (spring, summer) Chinook smolts were spring-run Chinook, but could not be positively identified as such during sampling at RIS. Prior to Caspian tern management efforts at Potholes Reservoir in 2014, annual predation rates on spring Chinook salmon ranged from 0.6% to 5.5% during 2009-2013 (Appendix B, Table B2), indicating efforts to reduce predation rates by reducing the size of Goose Island Caspian tern colony were partially successful in 2014.

In addition to predation rates on steelhead and yearling Chinook salmon, predation rates on PIT-tagged subyearling Chinook, coho, and sockeye salmon by Northwest Rocks Caspian terns were also estimated in 2014. These species and age-classes of salmonids are not part of ESA-listed populations from the Upper Columbia River, nor were they PIT-tagged in a manner as to be representative of the run passing RIS, but sufficient sample sizes of PIT-tagged fish (≥ 500 PIT-tagged smolts per population) were available to generate estimates of predation rates. Results indicate that Northwest Rocks Caspian terns consumed about 1.0% of coho salmon (95% c.i. = 0.4 - 2.4%; n = 1,115 tagged fish), < 0.1% of subyearling Chinook salmon (n = 3,129 tagged fish), and < 0.1% of sockeye salmon (n = 3,068 tagged fish). Similar to predation rates on yearling Chinook and steelhead smolts, results from 2014 indicated that Caspian tern predation rates on these other species and age-classes were substantially reduced compared to previous years (see BRNW 2014a), suggesting efforts to dissuade Caspian terns from nesting on Goose Island provided survival enhancements for all populations of anadromous juvenile salmonids out-migrating through the middle Columbia River. Predation rates on these other species of salmonids, in addition to those on yearling Chinook salmon and steelhead, indicate that, relative to their abundance, predation rates by Northwest Rocks Caspian terns were highest on steelhead, were similar on yearling Chinook and coho salmon, and were lowest on subyearling Chinook and sockeye salmon. Differences in average fork length between smolts of these various species and age-classes exist, with steelhead the largest, followed by yearling Chinook, coho, sockeye, and subyearling Chinook salmon (FPC 2014). Estimated predation rates, coupled with average species-specific fork lengths, suggest that size selectivity may be a factor in the higher Caspian tern predation rates on steelhead compared to salmon (see below for additional details), a hypothesis supported by published studies conducted at other Caspian tern colonies in the region (Collis et al. 2001, Ryan et al. 2003, Hostetter et at. 2012).

Data collected to date suggest that there is a positive relationship between Caspian tern predation rates on Upper Columbia River steelhead and the number of Caspian terns breeding at Potholes Reservoir, with predation rates generally higher in years when colony size was greater (Figure 28). This correlation was particularly evident in 2014, when the lowest predation rate recorded to date corresponded with the smallest colony size recorded to date (Figure 28). In an effort to define this correlation at other Caspian tern colonies in the region, the Corps' Walla Walla District calculated per capita (per nesting pair) predation rates based on data collected from the three largest Caspian tern colonies in the Columbia Plateau region (Goose Island, Crescent Island, and the Blalock Islands colonies) during 2007-2013 (BRNW 2014b). The goal was to use per capita predation rates from previous years, coupled with information on the size of each Caspian tern colony in 2014, to predict ESU-specific predation rates based on measures of colony size alone (BRNW 2014b). Data on actual or observed predation rates from this study and other studies (Lyons et al. 2014a), however, indicate that colony size alone is not always a good predictor of predation rates on salmonids. For instance, at Crescent Island, there has been no clear positive correlation between predation rates on Upper Columbia River steelhead and colony size to date (Figure 28). This is not meant to imply that a dramatically smaller Crescent Island tern colony wouldn't result in lower average predation rates, but rather that variability in predation rates, coupled with a relatively stable Caspian tern colony size at Crescent Island to date, makes it difficult to predict predation rates based on measures of colony size alone. Factors other than colony size that have been documented to influence predation rates include salmonid smolt abundance, smolt run-timing, smolt condition, river flows, and river turbidity (Hostetter et al. 2012). Results presented here and elsewhere (Lyons et al. 2014a) suggest that predicted predation rates based on colony size alone, especially those derived from colonies that have remained relatively stable in size during the course of study, should be interpreted cautiously (see BRNW 2014b for a more detailed discussion of predicted per capita predation rates).

A growing body of scientific evidence suggests that behavioral and physical traits associated with hatchery-rearing enhances the susceptibility of salmonid smolts to predation (Olla and Davis 1989, Fritts et al. 2007, Hostetter et al. 2012). For instance, predation rates by Caspian terns nesting at Goose Island in Potholes Reservoir during 2013 were significantly higher for hatchery-reared steelhead smolts (17.2%; 95% c.i. = 14.5 - 20.5%; BRNW 2014a) compared to wild steelhead smolts (8.5%; 95% c.i. = 6.0 - 11.4%; BRNW 2014a). Differences in predation rates between hatchery-reared (3.4%; 95% c.i. = 2.2 - 5.8%) and wild (2.4%; 95% c.i. = 1.3 - 4.5%) steelhead by Northwest Rocks Caspian terns were also observed in 2014, albeit rates on both rearing-types were greatly reduced relative to previous years. Similar differences in susceptibility to avian predation based on rear-type were observed at other bird colonies in 2014 (Table 5). This trend was not universal, however, with predation rates on wild fish sometimes as high, or higher, than those on hatchery-reared fish, depending on the salmonid ESU/DPS and bird colony (Table 9).

Within populations of Pacific anadromous salmonids, higher susceptibility to avian predation has been attributed to differences in abundance, rearing, condition, size, and environmental conditions (Collis et al. 2001, Schreck et al. 2006, Kennedy et al. 2007, Evans et al. 2012, Hostetter et al. 2012). In this study, predation rates by Caspian terns nesting on both Northwest Rocks and East Sand Island varied throughout the smolt run, with predation rates often higher when smolt abundance was lower (Figure 16 and 17). Similar temporal trends in steelhead susceptibility to predation by Caspian terns were observed in previous years (BRNW 2013a). In addition to smolt abundance and rearing-type, intrinsic smolt characteristics, such as fork length and external condition, have also been linked to differences in susceptibility to avian predation. For example, predation rates by Caspian terns were highest on steelhead with fork lengths of 17 - 24 cm, and lower on steelhead that were longer (> 24 cm fork length) or shorter (< 15 cm fork length; BRNW 2014a and Hostetter et al. 2012). Wild steelhead smolts are often shorter than their hatchery-reared counterparts, which may account for in part the lower Caspian tern predation rates on wild steelhead smolts compared to their hatchery-reared counterparts (Table 9). Caspian terns have also been shown to disproportionately consume steelhead in degraded physical condition (Hostetter et al. 2012; BRNW 2013). External condition of out-migrating smolts has previously been used as an indicator of health and linked to internal fish condition (Connon et al. 2012), survival during out-migration (Hostetter et al. 2011), susceptibility to avian predation (Hostetter et al. 2012), and adult returns (Evans et al. 2014). Data from this study in previous years have provided evidence that smolts exhibiting increased levels of body damage and disease symptoms suffer significantly higher avian predation rates compared to smolts without these external anomalies; damaged or diseased fish were 1.5 - 3.0 times more likely to be consumed by birds compared to undamaged or apparently healthy fish, depending on the type of external symptoms and the breeding colony from which the avian predator originated (Hostetter et al. 2012, BRNW 2014a). In 2014, the small number and percentage of PIT tags from steelhead and yearling Chinook salmon recovered on Caspian tern colonies in the Columbia Plateau region would not permit a detailed and statistically robust analysis of size- and condition-dependent mortality.

Ultimately, the probability of an individual smolt surviving the juvenile life stage is determined by a complex set of interacting factors, including individual fish characteristics and environmental conditions (Skalski 1998, Muir et al. 2001, Zabel et al. 2005, Hostetter et al. 2011). Non-lethal external examination was, however, able to identify several individual fish characteristics and environmental factors that were correlated with increased susceptibility to avian predation in 2014 and in previous years (Hostetter et al. 2012; BRNW 2013a; BRNW 2014a). Differences in avian predation rates as a function of smolt rearing-type, fork length, condition, and run-timing indicated that a representative sample of PIT-tagged smolts (i.e., not culled by fork length, condition, rearing-type, or run-timing) is best for estimating the impact of avian predation at the level of the salmonid ESU/DPS.

Twinning Island Caspian terns –

Methods: The methods for calculating predation rates based on PIT tag recoveries at the Twinning Island Caspian tern colony on Banks Lake are the same as those described in Section 1.1.4, except that smolt availability was based on interrogations of PIT-tagged smolts last detected passing Lower Monumental Dam (for Snake River ESUs/DPSs) (Map 1) or Rock Island Dam (for Upper Columbia River ESUs/DPSs). As was the case with the Northwest Rocks Caspian tern colony, control PIT tags were sown only during the post-season (n = 50) to estimate detection efficiency. Detection efficiencies from previous years were used to infer detection efficiency throughout the 2014 nesting season (Table 6). This adds an additional assumption to our model, namely that detection efficiency trends from previous years can be used to inform detection efficiency in the current year for this colony.

Results and Discussion: Following the nesting season, only 131 PIT tags from salmonid smolts tagged in the 2014 migration year (Chinook salmon, coho salmon, sockeye salmon, and steelhead combined) were recovered on the Twinning Island Caspian tern colony (Table 5). Recoveries of control PIT tags sown on the Twinning Island colony, in concert with detection efficiency measured in previous years, indicated that detection efficiency ranged from 21% to 94% for PIT tags deposited between 1 April and 31 August, 2014 (Table 6). Based on previous studies that empirically measured deposition rates for Caspian terns (see Hostetter et al. 2015), deposition rates were estimated to be 71% (95% c.i. = 51 - 89%; Table 7).

Predation rates indicate that impacts to survival of juvenile salmonids from Caspian terns nesting on Twinning Island were low for most salmonid populations (≤ 0.5% per ESU/DPS); the one exception was the Upper Columbia River steelhead DPS, where an estimated 1.2% (95% c.i. = 0.3 - 6.4%) were consumed in 2014. The wide credible interval surrounding this estimate of predation rate was due to variation in inferred pre-season detection efficiency at this colony. It should also be noted that the tailrace of Rock Island Dam is roughly 70 km southwest of Twinning Island, with the closest reach of the middle Columbia River upstream of Rock Island Dam, roughly 50 km west of Twinning Island. Consequently, predation rates by Twinning Island Caspian terns that are based on smolt availability below Rock Island Dam may be underestimates to an unknown extent.

There is evidence that the predation rate on Upper Columbia River steelhead by Twinning Island Caspian terns was higher in 2014 (1.2%) compared with previous years (average of just 0.1% during 2009-2010 and 2012; BRNW 2013a). This finding should be interpreted cautiously, however, due to uncertainty regarding where Caspian terns that nest on Banks Lake forage for smolts on the Columbia River and because of the wide credible interval associated with the 2014 estimate of predation rate.

Crescent Island Caspian terns –

Methods: The methods for calculating predation rates based on PIT tag recoveries at the Crescent Island Caspian tern colony are similar to those described in Section 1.1.4, except that smolt availability was based on interrogations of PIT-tagged smolts last detected passing Lower Monumental Dam (for Snake River ESUs/DPSs) or Rock Island Dam (for Upper Columbia River ESUs/DPSs). In addition to electronic recovery of PIT tags, PIT tags were also physically recovered and removed from the Crescent Island colony using magnetic hand-carts (Figure 14) to reduce tag collision (BRNW 2009; see Section 1.1.4).

Results and Discussion: Following the nesting season, a total of 7,270 PIT tags from smolts tagged during the 2014 migration year (Chinook salmon, coho salmon, sockeye salmon, and steelhead combined) were recovered on the Crescent Island Caspian tern colony (Table 6). Control PIT tags sown on the Crescent Island tern colony (n = 200) indicated that detection efficiency ranged from 67% to 95% for PIT tags deposited between 1 April and 31 July (Table 7). Based on previous studies that empirically measured deposition rates for Caspian terns (see Hostetter et al. 2015), deposition rates for Crescent Island Caspian terns were estimated to be 71% (95% c.i. = 51-89%; Table 7).

Predation rates by Crescent Island Caspian terns were highest for Snake River steelhead (4.7%; 95% c.i. = 3.7 - 6.9%) and Upper Columbia River steelhead (3.4%; 95% c.i. = 2.5 - 4.9%; Table 10). Predation rates on salmon ESUs were < 1.0% for all populations evaluated in 2014 (Table 10). Predation rates on steelhead DPSs in 2014 were generally higher than those observed in previous years; predation rates on Upper Columbia River steelhead were the highest recorded since 2007 and predation rates on Snake River steelhead were the second highest recorded since 2007 (Appendix B, Table B3). Differences in predation rates by Crescent Island Caspian terns on hatchery-reared and wild steelhead were small and non-significant (Table 10); however, the point estimate of the predation rate on wild Snake River steelhead (5.8%; 95% c.i. = 4.5 - 8.6%) was higher than that on hatchery-reared Snake River steelhead (4.4%; 95% c.i. = 3.4 - 6.5%), which has not generally been the case at the Caspian tern colony on Crescent Island or other Caspian tern colonies in previous years (BRNW 2014a).

The higher predation rates on steelhead populations by Crescent Island Caspian terns are commensurate with the larger colony size in 2014, with an estimated 474 breeding pairs using the colony in 2014 (Figure 25). Evidence from resightings of banded Caspian terns and tracking of satellite-tagged Caspian terns (see Appendix A for details) indicates that some of this increase was a result of management of the Goose Island Caspian tern colony to dissuade terns from nesting there in 2014, and the displaced terns relocating to Crescent Island. Higher Caspian tern predation rates on steelhead, particularly Upper Columbia River steelhead, by terns nesting at Crescent Island may have partially offset the benefits achieved by the reduced predation rate on Upper Columbia River steelhead by Goose Island-Northwest Rocks Caspian terns in 2014. Over-all predation rates on

Upper Columbia River steelhead by Caspian terns nesting at colonies in the Columbia Plateau region during 2014 were lower compared to previous years (Appendix B, Tables B2 and B3), suggesting that management actions in 2014 were a net benefit for survival of Upper Columbia River steelhead smolts. In 2015, management plans will be implemented to dissuade Caspian terns from nesting on both Crescent and Goose islands (USACE 2014). Collecting data on predation rates will again be paramount in determining the efficacy of these management actions for reducing predation rates to < 2% per ESUs/DPSs per colony, the target set by the IAPMP.

Predation rates by Crescent Island Caspian terns on smolts originating from rivers downstream of Lower Monumental Dam and Rock Island Dam (the two dams used to determine fish availability for predation rate estimates), but upstream of McNary Dam (i.e. within the foraging range of Caspian terns nesting at Crescent Island) on the middle Columbia River are not included here, but are likely lower because only a fraction of smolts originating from these ESUs/DPSs are susceptible to predation by Crescent Island terns (i.e., large numbers of smolts from Middle Columbia River ESUs/DPSs enter the river downstream of McNary Dam and thus have a low susceptibility to predation by Caspian terns nesting at Crescent Island; Lyons et al. 2011b). It is also important to note that portions of the smolt populations from Snake River ESUs/DPSs are captured at dams on the lower Snake River, loaded on barges for downstream transportation, and released below Bonneville Dam. These transported smolts are not exposed to predation by Crescent Island Caspian terns or any other avian predators in McNary, John Day, The Dalles, and Bonneville reservoirs. This means that the impact on each Snake River ESU/DPS from avian predation in McNary Reservoir is less than indicated by the predation rate on the in-river migrating portion of the population. Transportation rates of smolts from Snake River ESUs/DPSs vary considerably among years and salmonid species, with between roughly 20% and 60% of available Snake River smolts collected for transportation during 2007-2012 (FPC 2014). An estimate of transportation rates for smolts from Snake River ESUs/DPSs in 2014 is not yet available, but because some portion of each ESU/DPS was transported in 2014 the overall predation rates by Crescent Island Caspian terns on salmonid populations from the Snake River is less than those presented in Table 10. Because smolts originating from the Upper Columbia River are not collected for transportation until McNary Dam, however, the estimated predation rates on in-river migrants apply to all available fish belonging to Upper Columbia River ESUs/DPSs (i.e., no correction for transportation rate is required).

Blalock Islands Caspian terns –

Methods: The methods for calculating predation rates based on PIT tag recoveries at the Caspian tern colony in the Blalock Islands, John Day Reservoir are similar to those described in Section 1.1.4, except that smolt availability was based on interrogations of PIT-tagged smolts last detected passing McNary Dam (for both Snake River and Upper Columbia River ESUs/DPSs). Additionally, control PIT tags to calculate detection efficiency were only sown during the post-season (n = 50), with detection efficiency

from previous years used to infer pre-season detection efficiency in 2014 (see description above for Twinning Island Caspian terns). This adds an additional assumption to our model that detection efficiency trends from previous years can be used to inform detection efficiency during the current year at the Blalock Islands colony.

Results and Discussion: Following the nesting season, a total of 1,130 PIT tags from smolts tagged during the 2014 migration year (Chinook salmon, coho salmon, sockeye salmon, and steelhead combined) were recovered on the Blalock Islands Caspian tern colony (Table 5). Recoveries of control PIT tags sown on the Blalock Islands colony, in concert with detection efficiencies calculated in previous years, indicated that detection efficiency ranged from 84% to 86% for PIT tags deposited between 1 April and 31 August, 2014 (Table 6). Based on previous studies that empirically measured deposition rates for Caspian terns (see Hostetter et al. 2015), deposition rates were estimated to be 71% (95% c.i. = 51 - 89%; Table 7).

Similar to predation rates by Goose Island, Twinning Island, and Crescent Island Caspian terns, predation rates by Blalock Islands terns were highest on steelhead populations, with estimated predation rates of 0.6% (0.3 - 1.2%) and 0.4% (95% c.i. = 0.2 - 0.7%) on Upper Columbia River and Snake River steelhead, respectively (Table 11). Predation rates on salmon ESUs ranged from 0.4% (Snake River sockeye salmon) to 0.1% (Snake River spring/summer Chinook salmon; Table 11). The overall number of smolt PIT tags and consequent estimates of predation rates by Caspian terns nesting on the Blalock Islands were significantly higher in 2014 compared with 2011-2013, but similar to those during 2007-2010 (see BRNW 2014a). Trends in annual predation rates during this period generally follow estimates of Caspian tern colony size in the Blalock Islands. For example, prior to 2011 Caspian tern colony size averaged about 90 nesting pairs, but averaged only 17 nesting pairs during 2011-2013. In 2014, a total of 45 breeding pairs attempted to nest at one of three small islets located in the Blalock Islands complex (Figure 22). Productivity of Caspian terns nesting in the Blalock Islands has also varied dramatically among years, with complete colony failure noted in some years, and the successful fledging of limited numbers of young in others.

In 2014, some Caspian terns satellite-tagged at Goose Island in Potholes Reservoir visited the Blalock Islands, confirming connectivity between colonies on Goose Island and on the Blalock Islands (Appendix A). Similar connectivity likely exists between the Caspian tern colony on Crescent Island (which is closer to the Blalock Islands than Goose Island) and the Blalock Islands colony, although no data to confirm this were collected in 2014. Despite the small size of the Caspian tern colony on the Blalock Islands, per capita predation rates on salmonid smolts have been as high or higher than those measured at other Caspian tern colonies in the region (Lyons et al. 2011b, BRNW 2013a). High per capita predation rates, coupled with connectivity to Caspian tern colonies at managed sites (i.e. Goose Island and Crescent Island), means that the predation rates on salmonid ESUs/DPSs by Caspian terns nesting at the Blalock Islands is likely to increase in 2015 (USACE 2014).

1.3. Interior Oregon and Northeastern California

1.3.1. Implementation of Management Plan at Corps-constructed Tern Islands

By the beginning of the 2014 breeding season, the USACE and its state and federal partners had completed construction of nine islands (total of 8.3 acres; Table 12) designed for Caspian tern nesting as part of the Caspian Tern Management Plan (USFWS 2005). Of these nine islands, we monitored six for Caspian tern nesting in 2014. Monitoring was not conducted at the other three sites in 2014 because the island at the Orems Unit impoundment was not completely surrounded by water, the floating island at Dutchy Lake was decommissioned and removed prior to the 2013 breeding season, and Corps-sponsored monitoring of the island in Fern Ridge Reservoir has been terminated because nesting by Caspian terns has not been detected there since the island's construction in 2008.

1.3.2. Nesting Distribution, Colony Size, and Productivity

Methods: We used social attraction techniques (i.e., decoys and audio playback systems; Kress 1983, Kress 2000, Kress and Hall 2002, Roby et al. 2002) to enhance prospects for Caspian terns to nest at each of the six Corps-constructed tern islands that were monitored in 2014, with the exception of the Crump Lake tern island. Placement of Caspian tern decoys (ca. 225) and audio playback systems (n = 2) on each island was timed to coincide with the arrival of the first prospecting Caspian terns at each site (around mid-April). We also installed video monitoring and recording systems at four of the Corps-constructed islands (Gold Dike, East Link, Malheur, and Tule Lake islands) in April to provide additional monitoring coverage throughout the 2014 breeding season.

Our efforts to identify and control nocturnal avian predators (e.g., great horned owls [*Bubo virginianus*]) and mammalian predators (e.g., raccoons [*Procyon lotor*]) at the Corps-constructed tern islands were increased in 2014 compared to previous years. We used regular nighttime colony monitoring in conjunction with on-colony trapping and/or lethal take of confirmed nuisance predators (under permit) to help ensure colony establishment and nesting success by Caspian terns at each site. In 2014, we also increased efforts to selectively remove (i.e., shoot under permit) predatory California gulls and ring-billed gulls to protect Caspian tern eggs and chicks from gull depredation. Finally, as was done during the previous two years, we erected a 50' x 100' net with ¾" mesh above the decoy array and used targeted human hazing at the Sheepy Lake tern island to delay gull nest initiation on part of the island in an effort to reserve some space on the island for Caspian tern nesting.

We used observation blinds situated at the periphery of Caspian tern nesting habitat on each of the four Corps-constructed islands in interior Oregon (i.e. Crump Lake, East Link Impoundment at Summer Lake Wildlife Area, Gold Dike Impoundment at Summer Lake

Wildlife Area, Malheur Lake at Malheur NWR) and in northeastern California (i.e., Sheepy Lake at Lower Klamath NWR, Tule Lake Sump 1B at Tule Lake NWR; Map 2) to monitor for Caspian tern nesting activity. Data on Caspian tern colony attendance, colony size, productivity, and factors limiting colony size and productivity were generally collected 3 days per week at each of the six monitored islands. Measurement uncertainty in colony size and colony productivity was not expressly estimated; however, repeatability of ground-based counts was generally within 5% or less.

The numbers of Caspian tern pairs breeding at colonies on Corps-constructed islands in interior Oregon and northeastern California were estimated from ground counts of incubating adult terns near the end of the incubation period. Nesting success (average number of young raised per breeding pair) at each colony was estimated from ground counts of young at the colony at the beginning of the fledging period.

As part of a related task to identify key foraging areas (see Section 1.3.3), surveys were conducted to detect other nesting attempts by Caspian terns in central, south-central, and southeastern Oregon and northeastern California (Map 2).

Results and Discussion: In total, 7 of the 9 Corps-constructed tern islands (or 7 of the 8.3 acres) were available/suitable for tern nesting in 2014 (Table 12). Caspian terns were observed during the 2014 nesting season at six of the islands that we monitored in interior Oregon and northeastern California (Figure 29); however, Caspian terns only attempted to nest at five of the islands: Crump Lake, East Link, Sheepy Lake, Tule Lake, and Malheur Lake tern islands (Table 13). Caspian terns were observed loafing on the tern island in the Gold Dike Impoundment, but no nesting attempts by Caspian terns were detected at this site.

In 2014, Caspian terns attempted to nest at one of the two tern islands in the Summer Lake Wildlife Area, the island in East Link Impoundment. Although small numbers of Caspian terns (n = 1 – 4 individuals) were observed during daylight hours on the tern island in Gold Dike impoundment early in the 2014 breeding season (late April through mid-June), no Caspian terns initiated nests at that site. At the Summer Lake tern islands, combined colony attendance by Caspian terns peaked at 36 adults on-colony in mid-June and declined thereafter (Figure 30). Twenty-two Caspian tern breeding pairs attempted to nest at the East Link tern island in 2014, similar to the number of breeding pairs that nested there the year before (21 breeding pairs; Figure 31). Nine ring-billed gulls and four California gulls that were observed depredating tern and/or other gull eggs at the East Link tern island were shot under permit during the 2014 nesting season, and the 2014 season marked the second year in a row with successful nesting by Caspian terns at East Link impoundment (0.14 and 0.55 young raised per breeding pair in 2013 and 2014, respectively; Figure 32); no young Caspian terns were fledged from East Link tern island during 2011-2012 (Figure 32).

Caspian terns attempted to nest at the 0.8-acre island at Sheepy Lake in Lower Klamath NWR during 2014. The average weekly colony attendance by Caspian terns at the Sheepy Lake tern island was generally higher throughout the 2014 breeding season than was observed during 2010-2013 (Figure 33). A total of about 520 breeding pairs of Caspian terns attempted to nest at the Sheepy Lake tern island in 2014, the largest colony size observed at this site since it was constructed in early 2010 (Figure 34). Nine California gulls and 4 ring-billed gulls that were observed depredating tern and/or other gull eggs at the Sheepy Lake colony were shot under permit in 2014. Nesting success of Caspian terns at the Sheepy Lake tern island in 2014 (0.07 young raised per breeding pair) was ultimately lower, however, compared to the previous year (0.37 young raised per breeding pair; Figure 35). Drawdown of Sheepy Lake due to drought and water allocation issues resulted in the grounding of the floating island late in the nesting season, which in turn led to nest abandonment by parent Caspian terns and high mortality of the remaining unfledged tern chicks. Caspian terns were not observed loafing or attempting to nest on the Corps-constructed tern island in Orems Unit during the 2014 breeding season, presumably because the Orems Unit impoundment was dry throughout the nesting season.

In 2014, average weekly colony attendance by Caspian terns on the tern island at Sump 1B in Tule Lake NWR was generally higher, especially early and late in the breeding season, compared to colony attendance during 2011-2013 (Figure 36). The Tule Lake Caspian tern colony consisted of 109 breeding pairs in 2014; more breeding pairs than was observed in either 2011 (34 breeding pairs) or 2013 (79 breeding pairs), but lower than the number observed in 2012 (207 breeding pairs; Figure 37). Depredation rates by gulls on Caspian tern eggs and chicks at the Tule Lake tern island were low, necessitating the removal of only one ring-billed gull (under permit) at the colony in in 2014. Nevertheless, other predators were frequently observed causing disturbance and nest failure of Caspian terns at the colony, which necessitated the removal of four raccoons and one great horned owl (under permit) from the island during the 2014 breeding season. Nesting success of Caspian terns at the Tule Lake tern island was nearly as high in 2014 (0.60 young raised per breeding pair) as it was the first year Caspian terns nested at that site (2011; 0.65 young raised per breeding pair; Figure 38); in comparison, all Caspian tern nesting attempts on the Tule Lake tern island failed during 2012-2013 (Figure 38), due to repeated disturbance and nest depredation by raccoons and great horned owls.

Caspian terns nested on the Corps-constructed island at Malheur Lake in Malheur NWR in 2014; however, weekly colony attendance was markedly lower in 2014 compared to 2012-2013 (Figure 39). Colony size was estimated at 134 breeding pairs in 2014, less than one-third the estimated colony size the previous year (530 breeding pairs; Figure 40). Six California gulls and 3 ring-billed gulls that were observed depredating tern and/or other gull eggs at the Malheur Lake tern island were shot under permit in 2014. Average nesting success at the Malheur Lake tern island in 2014 (0.11 young raised per breeding pair) was similar to nesting success in 2013 (0.14 young raised per breeding

pair), but quite a bit lower than was observed in 2012 (0.84 young raised per breeding pair; Figure 41), the first year that Caspian terns nested there. The poor nesting success observed at the Malheur Lake tern island in 2014 was likely caused by low lake levels and poor foraging conditions associated with the regional drought that began in the area during 2012.

By the end of the 2013 breeding season, the Corps-constructed tern island at Crump Lake was nearly land-bridged on all sides due to severe drought conditions in the region. The island became completely land-bridged over winter and remained so throughout the 2014 breeding season. Despite the lack of water surrounding the island, a small number of Caspian terns (ca. 13 individuals) attended the island for two months beginning in late April (Figure 42). One pair of Caspian terns initiated nesting and laid an egg on 1 June 2014; however, this nest failed within several days and the island was completely abandoned by roosting and nesting Caspian terns by late June. This was the first year since island construction at Crump Lake in early 2008 that the island had become completely land-bridged during the breeding period, allowing terrestrial predators easy access to the island. There was also a high level of motorized human activity on the dry lakebed around the island in 2014, which may have caused disturbance to prospecting Caspian terns at the site. Since construction of the Crump Lake tern island in early 2008, both colony size and nesting success of Caspian terns nesting on the island have varied widely (Figures 43 and 44). This variability can be attributed to high rates of nest predation on Caspian tern eggs and chicks by gulls in some years and the effects of worsening drought on foraging conditions for terns and access to the island by terrestrial predators.

During aerial surveys conducted in 2014, one additional Caspian tern nesting site was detected in interior Oregon and northeastern California: at Dorris Reservoir in Modoc National Wildlife Refuge. This site was monitored from the ground on several occasions and nesting by a few pairs of Caspian terns was confirmed in early June; however, the colony site had become land-bridged and was abandoned by late July. No Caspian tern fledglings were apparently raised at this colony site in 2014.

Summary - A combined total of 786 breeding pairs of Caspian terns attempted to nest at Corps-constructed tern islands in 2014, a 27% increase from the average number of breeding pairs that nested on Corp-constructed tern islands in 2008-2013 (618 breeding pairs; Figure 46). In 2014, the largest colony of Caspian terns was observed at Sheepy Lake (Figure 45). Average productivity at Corps-constructed islands in 2014 (0.27 young per breeding pair), was similar to the long-term average (0.30 young per breeding pair during 2008-2013), but nearly twice the average productivity at these same sites in 2013 (0.15 young raised per breeding pair). This increase in productivity in 2014 relative to 2013 can be attributed in part to expanded efforts to control both avian and mammalian predators at each site in 2014 (Table 14), particularly at the Tule Lake and East Link tern islands (Figure 47). However, severe drought in interior Oregon and northeastern California was a major limiting factor in Caspian tern colony size and

nesting success at the Corps-constructed tern islands in 2014. With the exception of the island at Tule Lake NWR, all of the other Corps-constructed tern islands had become land-bridged or nearly so before the end of the 2014 nesting season, and mammalian predators were detected on all monitored islands at least once during the 2014 Caspian tern nesting season. Therefore, despite our predator control efforts, disturbance and predation by terrestrial predators was a limiting factor for Caspian tern nesting success at each of the Corps-constructed islands in 2014.

Disturbance and nest predation caused by avian and mammalian predators may be the most significant proximal factor limiting the size and productivity of Caspian tern colonies in interior Oregon and northeastern California, but low forage fish availability due to drought has also likely been a contributing factor to small colony size and low productivity at some colonies, during some years (e.g., Crump Lake tern island in 2013 and 2014 and Malheur Lake tern island in 2014). In addition to small colony sizes and low productivity, evidence that food availability may be a limiting factor at some of the Corps-constructed islands is illustrated by the high degree of inter-annual variation in diet composition and the presence in the tern diet of non-local fishes (e.g., lamprey [Petromyzontidae] at the Crump Lake tern island and yellow perch at the Malheur Lake tern island). The high variability in diet composition of Caspian terns at several of the Corps-constructed islands suggests there are fluctuations in the prey base and the availability of prey for breeding Caspian terns, while the non-local prey items indicate that some Caspian terns are traveling long distances from the colony to forage.

1.3.3. Diet Composition and Foraging Distribution

Methods: The taxonomic composition of the diet of Caspian terns nesting on the Corps-constructed tern islands at East Link, Sheepy Lake, Tule Lake Sump 1B, and Malheur Lake were determined by direct observation of adults as they returned to the colony with fish (i.e., bill load observations; described above). Bill load fish were identified each week throughout the breeding season at each colony site (see above for further details on the analysis of diet composition data). Bill load fish were identified to the lowest taxonomic grouping possible using visual observation. Visual identifications were verified using voucher specimens, whenever possible. The breakdown in diet composition from identified bill loads is provided below; measurement uncertainty was not estimated. In addition to the visual identification of bill load fish, PIT tags were recovered on selected Caspian tern colonies to estimate tern predation rates on fish species of special concern to resource managers (see Section 1.3.4.).

Periodic aerial, road-based, and boat-based surveys in central, south-central, and southeastern Oregon and northeastern California (Map 2) were conducted during the 2014 nesting season in order to identify key foraging areas for Caspian terns and other piscivorous waterbirds utilizing the Corps-constructed tern islands, particularly as it relates to predation on fish of conservation concern (see Appendix D for further details).

Results and Discussion: A total of 568 Caspian tern bill loads were identified at the East Link Caspian tern colony in Summer Lake Wildlife Area in 2014. As was the case in 2009-2013, the diet composition of Caspian terns nesting at Summer Lake Wildlife Area in 2014 was dominated by cyprinids (primarily tui chub [*Gila bicolor*]; 91% of identifiable prey items; Figure 48). In 2014, rainbow trout comprised 7% of the diet of Caspian terns nesting at the Summer Lake Wildlife Area, compared to an average of 11% during 2009-2013 (Figure 48). Based on fish watch observations, there was one sucker (Catostomidae; 0.2% of identifiable prey items) observed among the identified prey items at the East Link tern colony in 2014. It is unknown whether this sucker was an ESA-listed Warner sucker (*Catostomus warnerensis*) or an unlisted species. Warner suckers are not endemic to the Summer Lake area, although a small number of Warner suckers were intentionally relocated to the area by the Oregon Department of Fish and Wildlife and the U.S. Fish and Wildlife Service several years ago as part of a salvage operation due to drought conditions in the Warner Valley (P. Scheerer, ODFW, pers. comm.).

A total of 657 Caspian tern bill loads were identified at the Sheepy Lake colony in 2014. As was the case in previous years, the diet composition of Caspian terns nesting on the Sheepy Lake tern island in 2014 was dominated by cyprinids (primarily chub and fathead minnows [*Pimephales promelas*]) at 92% of identifiable prey items, followed by centrarchids (primarily Sacramento perch [*Archoplites interruptus*]) at 5% of identifiable prey items (Figure 49). In 2014, the percent of the diet that were cyprinids was higher and the percent of the diet that were centrarchids was lower as compared to the average for the 2010-2013 (Figure 49). No juvenile suckers were detected in the diet of Caspian terns nesting at the Sheepy Lake colony in 2014. One juvenile sucker (< 0.1% of identifiable prey items) was observed among the identifiable prey items at the Sheepy Lake tern colony in 2011. This sucker could not be positively identified as either an ESA-listed Lost River sucker (*Deltistes luxatus*) or an ESA-listed shortnose sucker (*C. brevirostris*). An un-listed species of sucker, the Klamath largescale sucker (*C. snyderi*), is also found within foraging distance of the Sheepy Lake tern island.

A total of 1,941 Caspian tern bill loads were identified at the Tule Lake Sump 1B colony in 2014. In every year of monitoring (2011-2014), the diet composition of Caspian terns nesting on the Tule Lake Sump 1B tern island was dominated by cyprinids (primarily chub and fathead minnows) at 79% of identifiable prey items, followed by centrarchids (primarily Sacramento perch) at 21% of identifiable prey items (Figure 50). Based on fish watch observations, there was one sucker (< 0.1% of identifiable prey items) observed among the identified prey items at the Tule Lake Sump 1B colony in 2014. As was the case at other Caspian tern colonies in interior Oregon and northeastern California, this sucker could not be identified as either an ESA-listed or unlisted sucker species.

A total of 1,558 Caspian tern bill loads were identified at the Malheur Lake colony in 2014. As was in in 2012-2013, the diet composition of Caspian terns nesting on the Malheur Lake new tern island in 2014 was dominated by cyprinids (primarily common

carp [*Cyprinus carpio*]) at 95% of the identifiable prey items (Figure 51). Twenty-five trout (2% of identifiable prey items) were identified among the bill loads at the Malheur Lake new tern island in 2014, up from 0% and 0.5% of the diet in 2012 And 2013, respectively. Based on the size (16 – 25 cm total length) and capture dates (May through early July) of these trout, some were likely rainbow trout stocked in nearby lakes and reservoirs, while others were wild redband trout from the nearby Donner and Blitzen River.

See Appendix D for results from surveys conducted to identify key foraging areas for Caspian terns and other piscivorous waterbirds utilizing the Corps-constructed tern islands.

1.3.4. Predation Rates on Suckers and Salmonids Based on PIT Tag Recoveries

Methods: Similar to anadromous salmonids from the Columbia River Basin, Warner suckers, Lost River suckers, shortnose suckers, and redband trout have been PIT-tagged to evaluate their behavior and survival following release. All ESA-listed sucker species have been PIT-tagged in their respective habitats, as well as the redband trout, a sensitive species, in the Harney Basin.

In 2014 we continued to evaluate the impacts of Caspian terns nesting at Corps-constructed islands located at Crump Lake, Tule Lake, and Sheepy Lake (Map 2) on survival of suckers by recovering sucker PIT tags on these islands after the nesting season. The Corps-constructed island on Malheur Lake was also scanned for PIT tags in 2014, a location where redband trout from the nearby Donner and Blitzen River were PIT-tagged by the Oregon Department of Fish and Wildlife (ODFW). Results from the Malheur Lake redband trout study are not presented here, but are instead summarized and reported by ODFW (POC, Shaun Clements, see also Ramirez 2014). The same methods used to recover PIT tags from bird colonies in the Columbia Basin bird (see Section 1.1.4) were used at Corps-constructed tern islands.

Results and Discussion: The Crump Lake, Tule Lake, and Sheepy Lake tern islands (Map 2) were scanned for sucker PIT tags following each of the nesting seasons when breeding Caspian terns were present during 2008-2014. Only one PIT tag from an ESA-listed sucker has been recovered on a tern colony during this period, a PIT tag recovered following the 2008 nesting season on the Crump Lake tern island. This PIT tag was from a 22-cm Warner sucker that was captured and released by ODFW into Crump Lake in June 2008 (P. Sheerer, ODFW, pers. comm.). In 2013, a PIT tag from a juvenile sucker (species unknown) was found on the Sheepy Lake tern island, but the tag was not found on a part of the island typically used by Caspian terns, but instead along the edge of the island where American white pelicans (*Pelecanus erythrorhynchos*) and double-crested cormorants frequently roosted. In 2014, sucker PIT tag scanning was limited to the Tule Lake tern island because no Caspian terns nested on Crump Lake tern island (see Section

1.1.2) and because researchers could not access the Sheepy Lake tern island after the nesting season due to low water levels, which prevented boat access.

Redband trout PIT tags were detected on the Corps-constructed tern island at Malheur Lake in 2013 (n = 15) and 2014 (n = 53); see Ramirez et al. 2014 for results from 2013. Analogous to the sucker PIT tag found on the Sheepy Lake tern island, redband trout tags found on the Malheur Lake tern island were from in an area occupied by multiple bird species during the nesting season, including Caspian terns, American white pelicans, double-crested cormorants, and several species of gull. As such, the fraction of the PIT tags that were from redband trout depredated by Caspian terns is unknown.

The small number of PIT tags from Warner suckers recovered on the Crump Lake Caspian tern colony (n = 1) and the low percentage of suckers identified in bill load fish (< 0.1%; BNRW 2013) suggests that mortality to Warner suckers from predation by Caspian terns nesting at Crump Lake island has been extremely low since the island was built during the winter of 2007-08. With the exception of the lone PIT tag found at an off-colony, mixed-species loafing area on Sheepy Lake in 2013, no sucker PIT tags have been recovered at the Tule Lake tern island or the Sheepy Lake tern island to date, which also suggests that mortality of shortnose and Lost River suckers due to predation by Caspian terns in the Upper Klamath Basin is extremely rare.

Although no PIT-tagged suckers have been found on Caspian tern colonies in the Upper Klamath Basin, juvenile suckers have occasionally been observed in Caspian tern bill loads (see Section 1.3.3), indicating that Caspian terns do consume suckers, albeit rarely. Because these suckers were juveniles, however, it is not known whether they were ESA-listed suckers or non-listed suckers (i.e. Klamath largescale suckers) because juvenile suckers in this region cannot be identified to the level of species based on morphology (D. Hewitt, USGS, pers. comm.). Similar to juvenile suckers, juvenile trout were also occasionally observed in tern bills at the Corps-constructed tern island in Malheur Lake during 2013 and 2014 (see Section 1.3.3).

1.4. Inter-colony Movements and Dispersal Patterns

In 2014, we continued our efforts to band breeding adult Caspian terns and Caspian tern chicks near fledging age at several nesting colonies as part of on-going demographic studies. The banding efforts are also part of our continuing studies of movement probabilities by adult Caspian terns among breeding colonies. Results presented here track the movements of banded Caspian terns among colonies, either within or between years, to better assess the consequences of various management initiatives implemented as part of the Caspian Tern Management Plan for the Columbia River Estuary.

Columbia River Estuary - Caspian terns that 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 in previous years (2005 – 2013) were resighted on the East Sand Island tern colony by researchers using binoculars and spotting scopes during 5-7 days per week throughout the 2014 breeding season. Numbers of banded Caspian terns resighted with a complete set of color bands, thus identifying banding location and year, are presented in this report.

Multi-state analysis (Hestbeck et al. 1991, Brownie et al. 1993) in program MARK (White and Burnham 1999) was used to estimate inter-colony (or inter-region, in some cases) movement probabilities of Caspian terns banded as adults during 2005-2013. *A priori* models were constructed to evaluate effects of transitions from one colony (or region) to another and effects of year on movement probabilities. Akaike's Information Criterion (AIC) adjusted for small samples (AICc) was used to select the best model (Burnham and Anderson 2002) for estimating inter-colony movements. Based on movement probabilities between 2013 and 2014 from the best model, and the numbers of Caspian terns present at a colony in 2013, numbers of terns that moved between colonies from 2013 to 2014 were estimated.

In 2014, a total of 468 previously color-banded Caspian terns were resighted on East Sand Island. Of the 468 resighted terns, 408 (87%) were banded at East Sand Island (228 as adults and 180 as chicks), 22 (5%) were banded at Crescent Island (10 as adults and 12 as chicks), 19 (4%) were banded at Goose Island (14 as adults and 5 as chicks), 14 (3%) were banded as chicks at the Port of Bellingham, Washington, 2 (< 1%) were banded as chicks at Brooks Island in San Francisco Bay, California, 2 (< 1%) were banded as chicks at Crump Lake tern island in the Warner Valley, Oregon, and 1 (< 1%) was banded as a chick at the Sheepy Lake tern island in Lower Klamath NWR, California. Resightings of banded Caspian terns at the East Sand Island colony indicate that some Caspian terns are moving from both inland and coastal colonies to the East Sand Island colony.

Out of 10 *a priori* models constructed in 2014, a model with transition (from one colony to another) and year effects on inter-colony movement probabilities was selected based on the smallest value of AICc. This model included an interaction term between transition and year effects, which allows movement probabilities to vary over years regardless of trends observed in other transitions. There was little movement (< 0.01%) of Caspian terns banded as adults from East Sand Island to Crescent Island prior to 2010. During 2010-2014, there were limited movements from East Sand Island to Crescent Island, < 1 % in most years, with the exception of a 1.8% movement rate in 2012. Estimated net movement of adult Caspian terns (the estimated number of terns that moved from one colony to another, subtracted from the number of terns that moved in the opposite direction) from East Sand Island to Crescent Island in 2014 was 40 individuals (Table 15). Movement probabilities of Caspian terns banded as adults from the East Sand Island colony to the Goose Island-Potholes colony ranged from < 0.01% to 0.6% during 2010-2014. The estimated net movement of terns from East Sand Island to Goose Island in 2014 was 50 individuals.

Movement probabilities of Caspian terns banded as adults from the East Sand Island colony to alternative colony sites on the Corps-constructed tern islands in interior Oregon and northeastern California (all sites were lumped together and considered as one region in this analysis) ranged from < 0.01% to 5.7% during 2008-2014, with the highest movement probability recorded in 2013 (Table 15). A movement probability of 3.1% in 2014 translates into an estimated movement of 461 terns from East Sand Island to the Corps-constructed islands in 2014.

The substantially higher estimated movement of adult Caspian terns from East Sand Island to the Corps-constructed tern islands, compared to that from East Sand Island to other colonies in 2014, suggests that the on-going implementation of the Caspian Tern Management Plan for the Columbia River Estuary, which is designed to redistribute part of the East Sand Island colony to the alternative colonies in interior Oregon and northeastern California, was effective to some extent.

Columbia Plateau - 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 supported by the Grant County PUD/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. 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 (2005-2013) 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. The methods to estimate inter-colony movement probabilities were the same as those described above.

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 305 previously color-banded Caspian terns were resighted at the Crescent Island colony. Of these, 231 (76%) were banded at Crescent Island (155 as adults and 76 as chicks), 62 (21%) were banded at Goose Island in Potholes Reservoir (44 as adults and 18 as chicks), 10 (3%) were banded at East Sand Island (2 as adults and 8 as chicks), 1 (< 1%) was banded as a chick at the Port of Bellingham, and 1 (< 1%) was banded as a chick at Crump Lake tern island in the Warner Valley, Oregon. In 2014, a total of 259 previously color-banded Caspian terns were resighted at Goose Island in Potholes Reservoir (either at the former colony area on the main island or at nearby

Northwest Rocks, where Caspian tern nesting occurred in 2014). Of these, 198 (76%) were banded at Goose Island (134 as adults and 64 as chicks), 38 (15%) were banded at Crescent Island (8 as adults and 30 as chicks), 12 (5%) were banded as chicks at East Sand Island, 7 (3%) were banded as chicks at the Port of Bellingham, 2 (< 1%) were banded as chicks at Brooks Island in San Francisco Bay, 1 (< 1%) was banded as a chick at Crump Lake tern island, and 1 (< 1%) was banded as a chick at Sheepy Lake tern island in Lower Klamath NWR.

Based on the best model selected to estimate inter-colony movements (see above), movement probabilities of Caspian terns banded as adults from Crescent Island to Goose Island ranged from < 0.01% to 10.5% during 2010-2014, with a movement probability of 2.1% in 2014 (Table 15). Movement probabilities from Goose Island to Crescent Island ranged from < 0.01% to 18.0% during 2011-2014, with the highest movement probability so far seen in 2014. The estimate of net movement between the two colonies was 106 terns from Goose Island to Crescent Island in 2014, apparently due to management efforts to discourage Caspian terns from nesting on Goose Island in 2014.

Although the numbers are small, a few adult Caspian terns present at East Sand Island in the Columbia River estuary in 2013, where management actions to reduce the size of the colony are being implemented, moved to Crescent Island and Goose Island in 2014. Caspian tern movements from East Sand Island to colonies in the Columbia Plateau region could partially off-set benefits to salmonids of tern management in the estuary because per bird impacts on smolt survival are higher for terns nesting in the Columbia Plateau region compared to those nesting in the estuary, where marine forage fishes (anchovy, smelt, surfperch, etc.) tend to dominate the diet.

Interior Oregon and Northeastern California- Caspian terns that were color-banded in previous years (2005-2013) were resighted during 1-3 days per week at the Corps-constructed tern islands on Crump Lake, 2-7 days per week at Summer Lake Wildlife Area (East Link and Gold Dike), 2-6 days per week at Sheepy Lake and Tule Lake Sump 1B, and 3-5 days per week on Malheur Lake throughout the 2014 breeding season.

A total of 16 color-banded Caspian terns were resighted at the Corps-constructed tern island at Crump Lake in 2014; 8 (50%) were banded at Crump Lake (1 as an adult and 7 as chicks), 3 (19%) were banded at the Sheepy Lake tern island (2 as adults and 1 as a chick), 3 (19%) were banded as chicks at Crescent Island, 1 (6%) was banded as an adult at Summer Lake, and 1 (6%) was banded as a chick at East Sand Island.

A total of 12 color-banded Caspian terns were resighted at the Corps-constructed tern islands in East Link and Gold Dike impoundments at Summer Lake Wildlife Area during 2014; 4 (33%) were banded at Sheepy Lake tern island (2 as adults and 2 as chicks), 3 (25%) were banded as chicks at Crescent Island, 3 (25%) were banded at Goose Island (1 as an adult and 2 as chicks), and 2 (17%) were banded as chicks at East Sand Island.

A total of 75 color-banded Caspian terns were resighted at the Corps-constructed tern island at Sheepy Lake in Lower Klamath NWR during 2014; 19 (25%) were banded at East Sand Island (1 as an adult and 18 as chicks), 18 (24%) were banded at the Sheepy Lake tern island (8 as adults and 10 as chicks), 10 (13%) were banded at Crump Lake tern island (3 as adults and 7 as chicks), 9 (12%) were banded as chicks at Crescent Island, 9 (12%) were banded at Goose Island-Potholes (4 as adults and 5 as chicks), 7 (9%) were banded as adults at the Tule Lake tern island, 1 (1%) was banded as an adult at Summer Lake, 1 (1%) was banded as a chick at the Port of Bellingham, and 1 (1%) was banded as a chick at Eden Landing in San Francisco Bay.

A total of 222 color-banded Caspian terns were resighted at the Corps-constructed island at Tule Lake Sump 1B in Tule Lake NWR during 2014; 53 (24%) were banded at East Sand Island (10 as adults and 43 as chicks), 39 (18%) were banded at Goose Island in Potholes Reservoir (12 as adults and 27 as chicks), 38 (17%) were banded at Crescent Island (4 as adults and 34 as chicks), 36 (16%) were banded at Sheepy Lake tern island (9 as adults and 27 as chicks), 25 (11%) were banded at Crump Lake tern island (5 as an adults and 20 as chicks), 14 (6%) were banded as chicks at the Port of Bellingham, 8 (4%) were banded as adults at Tule Lake tern island, 5 (2%) were banded as chicks at Brooks Island in San Francisco Bay, 2 (< 1%) were banded as chicks in the Copper River Delta, Alaska, 1 (< 1%) was banded as a chick at Malheur Lake tern island, and 1 (< 1%) was banded as a chick at Eden Landing, San Francisco Bay.

A total of 142 color-banded Caspian terns were resighted at the Corps-constructed tern island in Malheur Lake during 2014; 45 (32%) were banded at Goose Island in Potholes Reservoir (20 as adults and 25 as chicks), 42 (30%) were banded at Crescent Island (5 as adults, 37 as chicks), 31 (22%) were banded at Crump Lake tern island (10 as adults and 21 as chicks), 9 (6%) were banded as chicks at East Sand Island, 8 (6%) were banded at Sheepy Lake tern island (1 as an adult and 7 as chicks), 3 (2%) were banded as chicks at Malheur Lake tern island, 3 (2%) were banded as adults at Tule Lake tern island, and 1 (< 1%) was banded as a chick at the Port of Bellingham.

Resightings of banded Caspian terns at the recently established colonies on the Corps-constructed islands in interior Oregon and northeastern California Lake continue to reveal inter-colony connectivity, both among and between coastal and interior breeding colonies. Caspian terns banded at East Sand Island were resighted at five different Corps-constructed islands that were built by the Corps as alternative Caspian tern nesting habitat in interior Oregon and northeastern California as part of the Caspian Tern Management Plan for the Columbia River Estuary; all of these recently built tern islands are more than 400 km from the Caspian tern colony on East Sand Island in the Columbia River estuary. Movements of banded Caspian terns among the Corps-constructed alternative nesting islands in interior Oregon and northeastern California were also documented.

Based on the best model selected to estimate inter-colony movements (see above), movement probabilities of Caspian terns banded as adults from alternative colony sites on the Corps-constructed tern islands in interior Oregon and northeastern California to East Sand Island ranged from < 0.01% to 1.6% per year during 2008-2013. The movement probability from the Corps-constructed islands to East Sand Island in 2014 was much higher than in previous years, however, and was estimated at 14.0%. This translates into an estimated movement of a total of 328 Caspian terns from the Corps-constructed islands to East Sand Island (Table 15). Because the estimated movement from East Sand Island to the Corps-constructed islands in 2014 (3.1% of the East Sand Island colony, or 461 terns) was greater than the estimated movement in the opposite direction (14% of the colonies on the Corps-constructed islands, or 328 terns), the net movement of Caspian terns between East Sand Island and the Corps-constructed islands in 2014 was 133 terns moving from East Sand Island to the Corps-constructed islands. Movement probabilities from colonies on the Corps-constructed islands to Crescent Island also increased in 2014, from about 1.8% during 2012-2013 to 6.4% in 2014. Increased movement of terns from colonies on Corps-constructed islands to East Sand Island and Crescent Island in 2014 were apparently due to severe drought in interior Oregon and northeastern California in 2014. The drought not only made some of the Corps-constructed islands more accessible to terrestrial predators (e.g., coyotes, raccoons), but also limited foraging habitat and prey availability within commuting range of Caspian terns nesting on Corps-constructed islands. Movement probabilities from the Corps-constructed tern islands to Goose Island in Potholes Reservoir ranged from 0.6% to 5.6% during 2010-2014, with a movement probability of 2.5% in 2014. Management actions implemented at Goose Island to reduce the size of that Caspian tern colony probably prevented higher movement from the Corps-constructed tern islands to Goose Island in 2014.

SECTION 2: CORMORANTS

2.1. Columbia River Estuary

In 1989, fewer than 100 pairs of double-crested cormorants nested on East Sand Island. Growth in the size of the breeding colony since 1989 has resulted in the East Sand Island colony becoming the largest known colony of double-crested cormorants in western North America (Adkins et al. 2014a). The size of the East Sand Island double-crested cormorant colony grew rapidly from 1997 to 2007, nearly tripling in size (BRNW 2014a). In 2008, however, the colony experienced an unexpected decline (20%) before rebounding to the peak colony size observed in 2013 (BRNW 2014a). The growth of the East Sand Island colony appears to be exceptional among colonies of double-crested cormorants along the coast of the Pacific Northwest, where most colonies are stable or declining. The available data suggest that much of the early growth of the East Sand Island colony was a result of immigration from colonies outside the Columbia River estuary.

Prior to 1999, double-crested cormorants on East Sand Island nested exclusively on the boulder riprap and driftwood at the southwest corner of the island. After 1999 they began nesting on the ground in satellite colonies in the adjacent low-lying habitat. Based on the apparent habitat preferences of nesting double-crested cormorants, there is currently ample unoccupied habitat on East Sand Island, which could support further expansion of the colony in the future (Map 4). Despite availability of habitat to support continued colony expansion, bald eagle disturbance and predation, plus the associated nest predation by glaucous-winged/western gulls, may currently be limiting recruitment to the western North America population of double-crested cormorants and, consequently, the size of the colony on East Sand Island.

In 2014, nest dissuasion feasibility studies that were tested on the East Sand Island double-crested cormorant colony during 2011-2013 were discontinued (BRNW 2014a, 201e3a, and 2013b; see Map 4).

2.1.1. Nesting Distribution and Colony Sizes

Methods: High-resolution, vertical aerial photography of the double-crested cormorant colony on East Sand Island was taken during the late incubation period to estimate the peak size of the colony. Three independent counts of the number of attended cormorant nests visible in aerial photography taken on 28 May were used to estimate the total number of breeding pairs; standard errors from these counts were used to estimate a confidence interval for the estimate of colony size. Starting in 2008, we expanded the use of aerial photography to estimate cormorant colony size across the entire breeding season. High-resolution, aerial photography of the cormorant colony was also taken on 21 May, 28 May, and 5 June. ArcGIS was used to count nests or individual birds on all of the aerial photography of the East Sand Island cormorant colony.

Boat-based and aerial surveys of double-crested cormorants nesting on 12 navigational markers near Miller Sands Spit and Fitzpatrick Island (river km 34 and 50, respectively; Map 5) in the Columbia River estuary were conducted monthly from late-April through June, 2014. Because nesting chronology varied among the different navigational marker groups, the number of cormorant breeding pairs at each marker group was estimated using the greatest number of attended nests observed on each group of markers throughout the season. Any well-maintained nest structure attended by a cormorant adult and/or chick was considered active. To minimize impacts to nesting cormorants (i.e., chicks jumping from nests into the water when disturbed), we did not climb navigational markers and check nests to estimate productivity.

Five boat-based surveys of nesting cormorants on the Astoria-Megler Bridge in the Columbia River estuary were conducted from mid-April to early July, 2014 (Map 5). Our vantage point from a boat enabled us to count the number of attended cormorant nests

on the underside of the bridge; however, visual confirmation of eggs or very small chicks in nests was not possible. Any well-maintained nest structure that was attended by an adult cormorant was considered active, along with any nests that contained visible chicks.

Additionally, three aerial surveys were conducted of the lower Columbia River and estuary from Bonneville Dam to the Astoria-Megler Bridge from mid-May through early-July to monitor for indicators of double-crested cormorant nesting activity in 2014.

Results and Discussion: We estimated that 13,626 breeding pairs (95% c.i. = 13,334 – 13,918 breeding pairs) of double-crested cormorants attempted to nest at the East Sand Island colony in 2014, significant larger than the average colony size observed over the previous 17 years (10,776 breeding pairs during 1997-2013; Figure 52 and Table 16).

In 2014 about 1,630 pairs of Brandt's cormorants nested on East Sand Island (Figure 53), mixed in with nesting double-crested cormorants in the large cormorant colony. This Brandt's cormorant colony is now one of the largest in Oregon and Washington, and the only site in the Columbia River estuary where Brandt's cormorants are known to nest. The Brandt's cormorant colony on East Sand Island started in 2006 when 44 breeding pairs nested within the much larger double-crested cormorant colony, and since then the number of Brandt's cormorant nests has increased steadily. Before 2006, a small breeding colony of Brandt's cormorants existed on the pile dike at the western end of East Sand Island, but the site was abandoned after a storm damaged the pile dike during the winter of 2005-2006. Brandt's cormorants were first documented to nest on this pile dike in 1997, when a few pairs were found nesting there (Couch and Lance 2004). While estimates of Brandt's cormorant nesting success on East Sand Island are not available, Brandt's cormorants are known to have been successful in raising young at the East Sand Island colony in recent years, including 2014.

Nesting cormorants responded to the removal of the dissuasion fences and cessation of hazing of nesting cormorants by reoccupying some nesting habitat that was not used the previous year (Map 4). Of the total number of breeding pairs of cormorants (double-crested and Brandt's cormorants) counted on East Sand Island in 2014, roughly 26.5% nested in areas outside the privacy fences, where cormorants did not nest in 2013. An estimated 2,330 breeding pairs nested west of the western privacy fence, 1,677 breeding pairs nested east of the eastern privacy fence, and 11,090 breeding pairs nested between the two privacy fences (Map 4).

In 2014, a maximum of 318 pairs of double-crested cormorants nested on 11 navigational markers located in the upper Columbia River estuary (Table 17); this total number of active nests is slightly less than the 2013 count (330 breeding pairs on 11 navigational markers). Counts of attended cormorant nests at both groups of navigational markers peaked in late June.

Double-crested cormorants continued nesting near the pelagic cormorant colony on the Astoria-Megler Bridge in 2014. During five boat-based surveys from 22 April to 2 July, a maximum of 333 active double-crested cormorant nests were counted on the Astoria-Megler Bridge (Table 17; this was an increase from 2013, when 231 double-crested cormorant nests were counted on the bridge. Along with nesting double-crested cormorants, at least 82 breeding pairs of pelagic cormorants nested on the Astoria–Megler Bridge in 2014, slightly more than were observed the previous year (77 breeding pairs). This is the only site in the Columbia River estuary where pelagic cormorants are known to nest. Pelagic cormorants have been observed nesting on the underside of the southern portion of the Astoria-Megler Bridge since we began surveying the structure in 1999.

During aerial surveys of the lower Columbia River and estuary, double-crested cormorants were confirmed breeding at two additional sites; on the Lewis and Clark Bridge in Longview, WA (a maximum of 11 attended nests) and on a transmission tower near Troutdale, OR (a maximum of 80 attended nests). These nests were attended throughout the season, but eggs and/or chicks could not be confirmed due to the inaccessible location and obscured view. Double-crested cormorants were not observed nesting at any other location on the lower Columbia River and estuary during these aerial surveys.

2.1.2. Predation Rates on Salmonids Based on Smolt PIT Tag Recoveries

Methods: Methods for calculating predation rates on juvenile salmonids based on smolt PIT tag recoveries at the East Sand Island double-crested cormorant and Brandt's cormorant colonies are the same as those described in Section 1.1.4. To better understand detection efficiency at this colony in 2014, however, three complete passes of nesting habitat (Map 4) were conducted instead of two passes (Zamon et al. 2013). Passes were conducted during 6 October to 17 October, 2014. Aerial images and the distinctly different nesting materials used by the two cormorant species allowed us to distinguish double-crested cormorant nests from Brandt's cormorant nests. Aggregations of more than 20 Brandt's cormorant nests were then spray painted prior to PIT tag recovery, with PIT tag files downloaded from the PIT tag detectors separately for the two species (see Results). Isolated or small groups of Brandt's cormorant nests were not scanned due to their proximity to double-crested cormorant nests in an attempt to avoid cross-over contamination of PIT tags between the two species.

East Sand Island Double-crested Cormorants -

Results and Discussion: Following the nesting season, 22,069 PIT tags from smolts (Chinook salmon, coho salmon, sockeye salmon, and steelhead combined) tagged and released during the 2014 migration year were recovered on the East Sand Island double-crested cormorant colony (Table 5). The number of smolt PIT tags recovered on the double-crested cormorant colony in 2014 was nearly twice the number recovered on

the East Sand Island Caspian tern colony in 2014, and an order of magnitude greater than the number of PIT tags recovered on most of the inland bird colonies that were scanned for PIT tags in 2014 (Table 5).

Control PIT tags sown to measure detection efficiency indicated that detection efficiency ranged from 63% to 84% for PIT tags deposited between 1 March and 31 August (Table 6). Detection efficiency estimates were higher in 2014 compared with 2011-2013 (see BRNW 2012-2014), an increase related in part to conducting three passes of the entire colony, instead of two passes. Other factors that may have contributed to higher detection efficiency in 2014 include use of larger crew (n = 5) and continuous daily scanning until all three passes were completed, with limited weather delays or other interruptions that could have resulted in additional tag loss between passes (e.g., storms, flooding, or other events that could remove or damage tags). Deposition rates for East Sand Island double-crested cormorants were estimated to be 51% (95% c.i. = 34 - 70%; Table 7 and Hostetter et al. 2015).

Predation rates on PIT-tagged smolts last detected passing Bonneville Dam on the Columbia River or Sullivan Dam on the Willamette River (Map 1) ranged from 1.8% (95% c.i. = 0.9 - 3.6%) on Upper Willamette River spring Chinook salmon to 10.4% (95% c.i. = 7.3 - 16.3%) on Upper Columbia River steelhead (Table 8). Predation rates in 2014 were higher than those observed in 2013 for all ESUs/DPSs evaluated (Appendix B, Table B4). Predation rates on some salmon ESUs in 2014 were the highest recorded since the colony was first scanned for PIT tags in 1999 (Appendix B, Table B4 and Lyons et al. 2014a). For example, predation rates by East Sand Island double-crested cormorants on Snake River spring Chinook salmon in 2014 (8.5%; 95% c.i. = 6.1 - 13.2%) were roughly 2 - 10 times higher than those recorded during 1999-2013 (ca. 0.9 - 6.8%; Lyons et al. 2014a and Appendix B, Table B4).

Predation rates by double-crested cormorants nesting on East Sand Island were generally higher on steelhead populations compared with salmon populations (Table 8), although the differences were not as pronounced as those observed for Caspian terns nesting on East Sand Island (Table 8). For example, predation rates on steelhead DPSs by Caspian terns nesting on East Sand Island were 5-10 times greater than those on salmon ESUs. For double-crested cormorants nesting on East Sand Island, differences in predation rates on steelhead vs. salmon populations were smaller and in some cases salmon populations (e.g., predation rate on Snake River spring/summer Chinook salmon = 8.5%) were depredated at higher rates than steelhead populations (e.g., predation rate on Middle Columbia River steelhead = 6.4%; Table 8). These results suggest that, relative to Caspian terns, double-crested cormorants tend to consume juvenile salmonids in relative proportion to their availability on an annual basis (this study; Lyons et al. 2014a).

A temporal analysis of weekly predation rates by East Sand Island double-crested cormorants on Upper Columbia River steelhead and Snake River spring Chinook salmon,

the two salmonid populations with the highest observed predation rates (Table 8), indicated that predation rates vary significantly across the smolt out-migration period of April to June (Figure 54). For both salmonid populations, predation rates increased along with the number of available PIT-tagged smolts passing Bonneville Dam, and the highest predation rates were observed during the peak out-migration period in May. This finding differs from that observed in Caspian tern, where weekly predation rates were highest during the latter part of the run in June (Figure 16). Taken together, results indicate that susceptibility of salmonid ESUs/DPSs to bird predation in the Columbia River estuary varies considerably by week and by species of avian predator (Caspian tern vs. double-crested cormorant).

For those salmonid populations with adequate sample sizes of PIT-tagged smolts (≥ 500 PIT-tagged smolts per rearing-type), there were no significant differences in predation rates on hatchery-reared vs. wild Snake River steelhead or hatchery-reared vs. wild Upper Columbia River spring Chinook salmon (Table 9), a finding that is consistent with previous years (Evans et al. 2011, Lyons et al. 2012, BRNW 2014a). There was, however, evidence that hatchery-reared Snake River (SR) spring/summer Chinook salmon were disproportionately consumed compared with their wild counterparts, with predation rates on hatchery-reared fish (9.3%; 95% c.i. = 6.7 - 14.8) significantly higher than those observed on wild fish (3.8%; 95% c.i. = 2.3 - 6.7) in 2014 (Table 9). One possible explanation for this discrepancy relates to differences in run-timing between hatchery-reared and wild SR spring/summer Chinook salmon in 2014; hatchery-reared smolts were more abundant during May, when predation rates were the highest (Figure 54), while wild smolts were more evenly distributed throughout the run, including late April and early June when predation rates were the lowest (Figure 54).

Estimates of predation rates using PIT-tagged salmonid populations for LCR ESUs/DPSs were not available because a representative sample of PIT-tagged fish by location (geographic boundary, including releases below Bonneville Dam), by origin (hatchery, wild), and by outmigration timing were lacking. An analysis of double-crested cormorant predation rates on LCR ESUs/DPSs conducted by Lyons et al. (2014a), which attempted to account for these data gaps, indicated that an average of 26% and 28% of available LCR Chinook salmon and coho salmon, respectively, were depredated by double-crested cormorants nesting on East Sand Island each year during 2007-2010. Although more research is needed to understand the impact of double-crested cormorant predation on LCR ESUs/DPSs, the limited available data suggest that LCR Chinook salmon and coho salmon may be more susceptible to predation by double-crested cormorants nesting on East Sand Island compared to ESUs originating further upriver (Sebring et al. 2013, Lyons et al. 2014b).

Finally, research conducted by Lyons et al. (2014a) indicated that the size of the East Sand Island cormorant colony (number of nesting pairs) was not always a good predictor of predation rates on juvenile salmonids in any given year. For example, in 2013 the East Sand Island double-crested cormorant colony was the largest ever recorded, yet

predation rates on salmonid ESUs/DPSs were some of the lowest recorded since the early 2000s (Appendix B, Table B4; Lyons et al. 2014a). Factors other than colony size that have been linked to cormorant predation rates include ocean conditions (i.e. the North Pacific Gyre Oscillation), river discharge into the estuary, and the abundance of alternative prey (marine and estuarine forage fishes). All of these factors are believed to directly or indirectly influence the susceptibility of salmonid smolts to cormorant predation in the estuary. Results presented here and those of Lyons et al. (2014a) indicate that predation rates by East Sand Island double-crested cormorant are best evaluated in the context of biotic and abiotic factors and over the course of several consecutive years.

East Sand Island Brandt's Cormorants –

Methods: The methods for calculating predation rates on juvenile salmonids based on smolt PIT tag recoveries at the Brandt's cormorant colony on East Sand Island are the same as those described above for double-crested cormorants, with two exceptions: (1) the Brandt's cormorant colony and the double-crested cormorant colony on East Sand Island were intermixed in 2014; thus, detection efficiency was measured for both colonies using the same groups of sown control tags (Table 6). Also, since there are no data available on PIT tag deposition rates for Brandt's cormorants, values for double-crested cormorants nesting on East Sand Island were applied (Table 7). Although there are some similarities in the foraging behavior, size, and general life history of Brandt's cormorants and double-crested cormorants, it is possible that deposition rates differ between the two species.

Results and Discussion: Following the 2014 nesting season, 927 PIT tags from salmonid smolts (Chinook salmon, coho salmon, sockeye salmon, and steelhead combined) that were PIT-tagged during the 2014 migration year were recovered on the Brandt's cormorant colony at East Sand Island (Table 5). Due to the high degree of intermixing of the nests of the two cormorant species on the East Sand Island colony, recoveries of smolt PIT tags could not in all cases be definitively assigned to either Brandt's cormorants or double-crested cormorants. On East Sand Island several small pockets of Brandt's cormorant nests (< 20) were surrounded by larger, contiguous areas of nesting double-crested cormorants. For this reason, estimates of smolt predation rates by the Brandt's cormorant colony in 2014 and in previous years (BRNW 2014a) may have been over-estimated, and as such, those results should be viewed with caution.

Of the PIT-tagged juvenile salmonids last detected passing Bonneville Dam or Sullivan Dam (Map 1), predation rates by Brandt's cormorants were $\leq$ 0.6% for all ESUs/DPSs evaluated in 2014 (Table 5). In most cases, predation rates by Brandt's cormorants were so low that differences between salmonid species and ESUs/DPSs were not readily discernible, and likely not biologically meaningful. Because some deposition of smolt PIT tags near Brandt's cormorant nests was attributable to double-crested cormorants,

predation rates by Brandt's cormorants are likely less than the estimates reported in Table 8.

Despite increases in the size of the Brandt's cormorant colony on East Sand Island during the last decade (Figure 53), predation rates on smolts by Brandt's cormorants remain among the lowest of all the piscivorous waterbird colonies evaluated since studies of PIT tags on the Brandt's cormorant colony were initiated in 2008 (BRNW 2014a). PIT tag results presented here continue to provide evidence that Brandt's cormorants consume far fewer salmonid smolts per capita than double-crested cormorants or Caspian terns nesting on East Sand Island (BRNW 2014a). Several factors likely account for this difference. First, Brandt's cormorants are a marine seabird that usually forages for prey in the nearshore ocean environment, where non-salmonid prey types (e.g., anchovy, herring, smelt, and others) are more common (Couch and Lance 2004). Consequently, salmonids comprise a smaller proportion of the diet of Brandt's cormorants compared to that of Caspian terns and double-crested cormorants. Second, the nesting chronology of Brandt's cormorants differs slightly from that of Caspian terns and double-crested cormorants in the Columbia River estuary, with colony attendance peaking in late June, compared to mid-May for Caspian terns and early June for double-crested cormorants. This difference in nesting chronology may be important because by late June the peak of the salmonid run has passed, especially for large groups of PIT-tagged steelhead and yearling Chinook salmon smolts (FPC 2014). Finally, relative to double-crested cormorants, Brandt's cormorants are slightly smaller (by body mass) and thus presumably have lower daily food requirements (Ellis and Gabrielsen 2001).

2.2. Columbia Plateau Region

Methods: Quantitative data on the nesting ecology and diet of double-crested cormorants in the Columbia Plateau region were not collected in 2014 (see BRNW 2014a for results from previous years).

Results and Discussion: During aerial surveys for nesting Caspian terns in the Columbia Plateau region during the 2014 breeding season (see Section 1.2.2), we observed nesting double-crested cormorants at four extant colony sites: Foundation Island on the mid-Columbia River, North Potholes Reserve in Potholes Reservoir, Harper Island in Sprague Lake, and at the confluence of the Okanogan and Columbia rivers). We also observed nesting double-crested cormorants at three other colony sites: on Island A in the Hanford Reach, on a small island in Lenore Lake, and on a transmission tower at Rock Island Dam; Map 1).

2.3. Interior Oregon and Northeastern California

Methods: Quantitative data on the nesting ecology and diet of double-crested cormorants in interior Oregon and northeastern California were not collected in 2014 (see BRNW 2014a for results from previous years).

Results and Discussion: During aerial surveys for nesting and foraging Caspian terns in interior Oregon and northeastern California during the 2014 breeding season (see Section 1.3.2), double-crested cormorants were confirmed nesting at nine different locations: Upper Klamath NWR; Sump 1B in Tule Lake NWR; Clear Lake NWR; River's End Ranch near Valley Falls, OR; Gold Dike impoundment at Summer Lake Wildlife Area; Sodhouse Ranch in Malheur NWR; Cole Dike Island in Malheur NWR; Wickiup Reservoir, OR; and Crane Prairie Reservoir, OR (Map 2).

2.4. Inter-colony Movements and Dispersal Patterns

Methods: In 2014, we continued to resight double-crested cormorants banded with field-readable colored leg-bands on East Sand Island during 2008-2013 as part of a longer-term effort to collect data on the demography (survival and recruitment), inter-colony movements, and dispersal patterns of double-crested cormorants nesting at the East Sand Island colony.

Banded double-crested cormorants were resighted from multiple observation blinds on the cormorant colony at East Sand Island. In general, resighting efforts totaled 10-12 hours per week from all blinds combined throughout the 2014 breeding season.

Encounter reports sent by the public were compiled to evaluate movements of banded double-crested cormorants away from East Sand Island. Reports were received through a band reporting website set up by Bird Research Northwest (http://www.brnwbandedbird.org), the U.S. Geological Survey Bird Banding Lab, and by e-mail.

In 2013, 83 double-crested cormorants were captured on the East Sand Island cormorant colony during the pre-laying period and fitted with satellite transmitters. The satellite tags were programmed to collect nighttime roost locations every night or every other night through July 2013, then once a week from August 2013 through March 2014, before switching back to the more frequent cycle in April 2014. During the 2014 nesting season, a portion of these satellite tags continued to transmit data on nighttime roost locations to the ARGOS satellite network, and these data were later delivered electronically by CLS America, Inc.

Results and Discussion: We have banded a total of 1,961 double-crested cormorants (816 adults during 2010-2013 and 1,145 chicks during 2008-2013) with field-readable colored leg-bands at East Sand Island. To date, only a small proportion (ca. 3-4%) of the

total number of nesting double-crested cormorants on East Sand Island have been banded. About 47% (n = 383) of the double-crested cormorants banded as adults at East Sand Island during 2010-2013 were observed at least once on East Sand Island in 2014. A total of 110 double-crested cormorants that were banded as chicks in 2010-2013 were observed at East Sand Island in 2014. Some cormorants banded as chicks in 2013 were observed returning to the East Sand Island colony in 2014. The age of first reproduction for double-crested cormorants, based on chicks banded in previous years and confirmed breeding on East Sand Island in 2014, ranged from 2 to 5 years old.

While a significant effort was expended to resight banded double-crested cormorants on East Sand Island during the 2014 breeding season, resighting efforts at other colonies remained infrequent and opportunistic. Encounters with banded cormorants away from East Sand Island were limited, but have increased in recent years, with most observations occurring between breeding seasons and reported by the public. From January 2014 to date, we have received reports of 46 banded double-crested cormorants observed alive or dead from eight different regions outside the Columbia River estuary: the Salish Sea/Puget Sound region (banded cormorants resighted alive: n = 12; banded cormorants recovered dead: n = 9); western British Columbia (resighted: n = 4; recovered: n = 0); Oregon coast (resighted: n = 2; recovered: n = 1); Western Columbia Basin (resighted: n = 2; recovered: n = 2), Willamette Valley (resighted: n = 1; recovered: n = 1); interior Oregon (recovered: n = 1), California coast (resighted: n = 7; recovered: n = 1); and interior California (resighted: n = 2; recovered: n = 1). Although there were no banded cormorants resighted in the Columbia Plateau region during 2014, one cormorant banded at the East Sand Island colony was resighted near Richland, WA during the post-breeding season in 2012.

Continued banding and resighting efforts will allow us to measure movement rates of double-crested cormorants from East Sand Island to other colonies and roosting sites, and to measure demographic parameters for estimating population trajectories. That is critical information for both predicting and assessing the outcome of various prospective management strategies for double-crested cormorants nesting on East Sand Island.

Seventy-seven percent (23 of 30) of double-crested cormorants with satellite tags that remained functional into April 2014 were tracked back to East Sand Island in 2014. Six of the seven satellite-tagged individuals that were not detected at East Sand Island had tags that stopped transmitting by 21 April or earlier. The one remaining individual was detected in the Columbia River estuary, but not at East Sand Island. Tagged individuals that returned to East Sand Island either remained at the colony (n = 7), or went on to visit locations elsewhere in the Columbia River estuary (n = 15), on the outer Washington Coast (n = 5), the Oregon Coast (n = 1), and the Salish Sea (n = 1). Small sample size and continued satellite tag failures limited further assessments of final nesting locations in most cases.

SECTION 3: GULLS AND PELICANS

3.1. Columbia River Estuary

Methods: Counts of the number of adults on-colony at East Sand Island were conducted for glaucous-winged/western gulls and for ring-billed gulls in 2014 (based on one count of all adults on-colony in aerial photography; see Section 1.1.2 for a description of methods); these counts were used as an index to colony size. Peak numbers of California brown pelicans using East Sand Island as a nighttime roost in 2014 were determined by periodic boat-based surveys (approximately every two weeks) conducted in the evening from mid-May through mid-September. Because three California brown pelican nests containing eggs were discovered on East Sand Island in 2013, an effort was made to monitor for any nesting activity by brown pelicans during the 2014 breeding season.

Results and Discussion: As in previous years, large numbers of both glaucous-winged/western gulls and ring-billed gulls nested on East Sand Island. Also as in previous years, East Sand Island was the site of a large post-breeding, nighttime roost for California brown pelicans.

Gulls − Based on one count of aerial photography taken of East Sand Island on 11 June, we estimate that ca. 3,600 glaucous-winged/western gulls and ca. 2,280 ring-billed gulls were on their respective colonies. This represents a 21% and 15% decline in the index counts of glaucous-winged/western gulls and ring-billed gulls, respectively, on East Sand Island in 2014 compared to 2013. Nesting ring-billed gulls were restricted to a small area at the northeastern tip of the island, while nesting glaucous-winged/western gulls were more evenly distributed across the island, but with a large gap with no nesting gulls in the central, densely-vegetated portion of the island.

In 2014, cormorant nest dissuasion trials that were conducted on the East Sand Island cormorant colony during 2011-2013 were discontinued (BRNW 2014a, 2013a, and 2013b). There were no marked differences in the distribution of glaucous-winged/western gulls on the western end of East Sand Island between 2013, when cormorant nest dissuasion trials were ongoing (see Section 2.1.1), and 2014, when the trials were no longer being conducted (Map 6). In 2014, 1,040 individuals or 28.9% were counted west of the western privacy fence (compared to 1,103 individuals or 24.1% in 2013), 1,970 individuals or 54.8% were counted east of the eastern privacy fence (compared to 2,852 individuals or 62.3% in 2013), and 585 individuals or 16.3% were counted between the fences (compared to 626 individuals or 13.6% in 2013; Map 6).

California Brown Pelicans − East Sand Island is the largest known post-breeding nighttime roost site for California brown pelicans, and the only known night roost for this species in the Columbia River estuary (Wright 2005). In 2014, the first California

brown pelicans were observed roosting on East Sand Island on 20 April. These first pelicans were roosting on a grassy area near the east end of the island, not far from where three pairs of brown pelicans laid eggs in 2013. The weekly counts of California brown pelicans roosting on East Sand Island peaked in late June at about 10,835 individuals (Figure 55), significantly more than the peak count in 2013 (ca. 3,850 individuals), but similar to the peak count in 2012 (ca. 10,600 individuals), and less than the peak count in 2011 (ca. 14,225 individuals; Figure 56).

As was the case in 2009, 2010, 2012, and 2013 we observed some breeding behavior by brown pelicans on East Sand Island (i.e., courtship displays, nest-building, attempted copulations) in 2014. In response to the discovery of brown pelican eggs in 2013, the monitoring of brown pelican breeding behaviors was increased during the 2014 field season. In addition to increased researcher effort, two remote sensing camera traps were positioned to cover the area of failed nesting in 2013, an area where we predicted brown pelicans might attempt to nest again. In 2014, at least 11 breeding pairs of California brown pelicans built and attended nests on East Sand Island near the location where three pairs of pelicans built nests and laid eggs in 2013. Of these 11 nests, 6 could be seen and monitored from our observation blinds adjacent to the Caspian tern colony. Each of these 6 nests was continuously attended by a pair of brown pelicans in breeding adult plumage, all of which retained the red gular pouches characteristic of adults early in the breeding season. Behaviors resembling egg rolling and incubation switches were observed, although the nest contents could not be confirmed due to the distance and obscured view of the nests from our observation blinds. In order to avoid disturbance to potentially nesting brown pelicans, no effort was made to approach the nests and confirm that eggs had been laid in 2014; however, all brown pelican nests on East Sand Island were abandoned by mid-June, indicating that any and all nesting attempts by brown pelicans were ultimately unsuccessful. Peak counts of California brown pelicans roosting on East Sand Island occurred soon after nest abandonment, in late June.

In 2014, all California brown pelicans that nested at colonies in southern California and northeastern Mexico failed, apparently due to a collapse in the food supply (D. Anderson, pers. comm.). This provides some explanation for the much higher numbers of adult brown pelicans that arrived early in the season at East Sand Island, and the unprecedented high incidence of breeding behavior and nest building at the eastern end of East Sand Island during May. The nearest breeding colony of California brown pelicans to East Sand Island is on Anacapa Island in the Channel Islands of southern California, 900 miles to the south.

3.2. Columbia Plateau Region

Few data were collected on American white pelicans, California gulls, and ring-billed gulls nesting in the Columbia Plateau region during 2014 (see BRNW 2014a for results from previous years). During aerial surveys in the Columbia Plateau region for nesting Caspian terns in 2014 (see Section 1.2.2), American white pelicans were confirmed

nesting on Badger Island on the mid-Columbia River, where ca. 2,450 adults were counted on-colony from aerial photography taken on 20 May (Map 1). This is the largest number of American white pelicans counted on the Badger Island colony since monitoring began at the site in 1997 (Figure 57).

During these same aerial surveys in the Columbia Plateau region, California gulls and/or ring-billed gulls were confirmed nesting at five islands on the Columbia River: Miller Rocks, "Anvil Island" and Straight Six Island in the Blalock Islands group, Crescent Island, and Island 20). California and or ring-billed gulls were also confirmed nesting on five islands off the Columbia River, but within foraging range of the river: Goose Island in Potholes Reservoir, Twinning Island and Goose Island in Banks Lake, Harper Island in Sprague Lake, and a small unnamed island in Lenore Lake; Figure 58; Map 1).

There were no efforts to calculate ESU/DPS-specific salmonid predation rates based on smolt PIT tags recovered from gull and white pelican colonies in 2014. Cumulative impacts of avian predation on survival of steelhead and yearling Chinook salmon smolts PIT-tagged at Rock Island Dam (as part of this study; see Section 1.1.4), including predation by California and ring-billed gull colonies and an American white pelican colony in the Columbia River Plateau, are presented in Appendix C.

3.3. Interior Oregon and Northeastern California

Few data were collected on American white pelicans, California gulls, and ring-billed gulls in interior Oregon and northeastern California in 2014 (see BRNW 2014a for results from previous years). During aerial surveys in interior Oregon and northeastern California for nesting and foraging Caspian terns in 2014 (see Section 1.3.2), American white pelicans were confirmed nesting at three different locations: Upper Klamath NWR; Clear Lake NWR; and Cole Dike Island in Malheur NWR (Map 2). Nesting success of American white pelicans at these sites was not confirmed in 2014.

Gulls were confirmed nesting at all six of the Corps-constructed tern islands that were monitored in interior Oregon and northeastern California in 2014. The Sheepy Lake tern island in Lower Klamath NWR, CA, had a peak count of ca. 3,930 California and ring-billed gulls. The Crump Lake tern island in the Warner Valley, OR, had a peak count of ca. 2,670 California and ring-billed gulls. The East Link tern island in Summer Lake Wildlife Area, OR, had a peak count of ca. 1,800 California and ring-billed gulls. The Gold Dike tern island in Summer Lake Wildlife Area, OR, had a peak count of 28 ring-billed gulls. The Malheur Lake tern island at Malheur NWR, OR, had a peak count of ca. 250 California and ring-billed gulls. The Tule Lake tern island in Sump 1B at Tule Lake NWR, CA, had a peak count of ca. 175 ring-billed gulls. In addition, gull breeding colonies were noted at two additional sites during aerial surveys: at Clear Lake NWR, CA, and on Dorris Reservoir in Modoc NWR, CA (Map 2). Gulls were successful in rearing at least some young on three of the six Corps-constructed tern islands: Sheepy Lake, East Link, and

Malheur Lake. Nesting success at the other two gull colonies in interior Oregon and northeastern California (i.e., Clear Lake NWR and Dorris Reservoir) was not confirmed.

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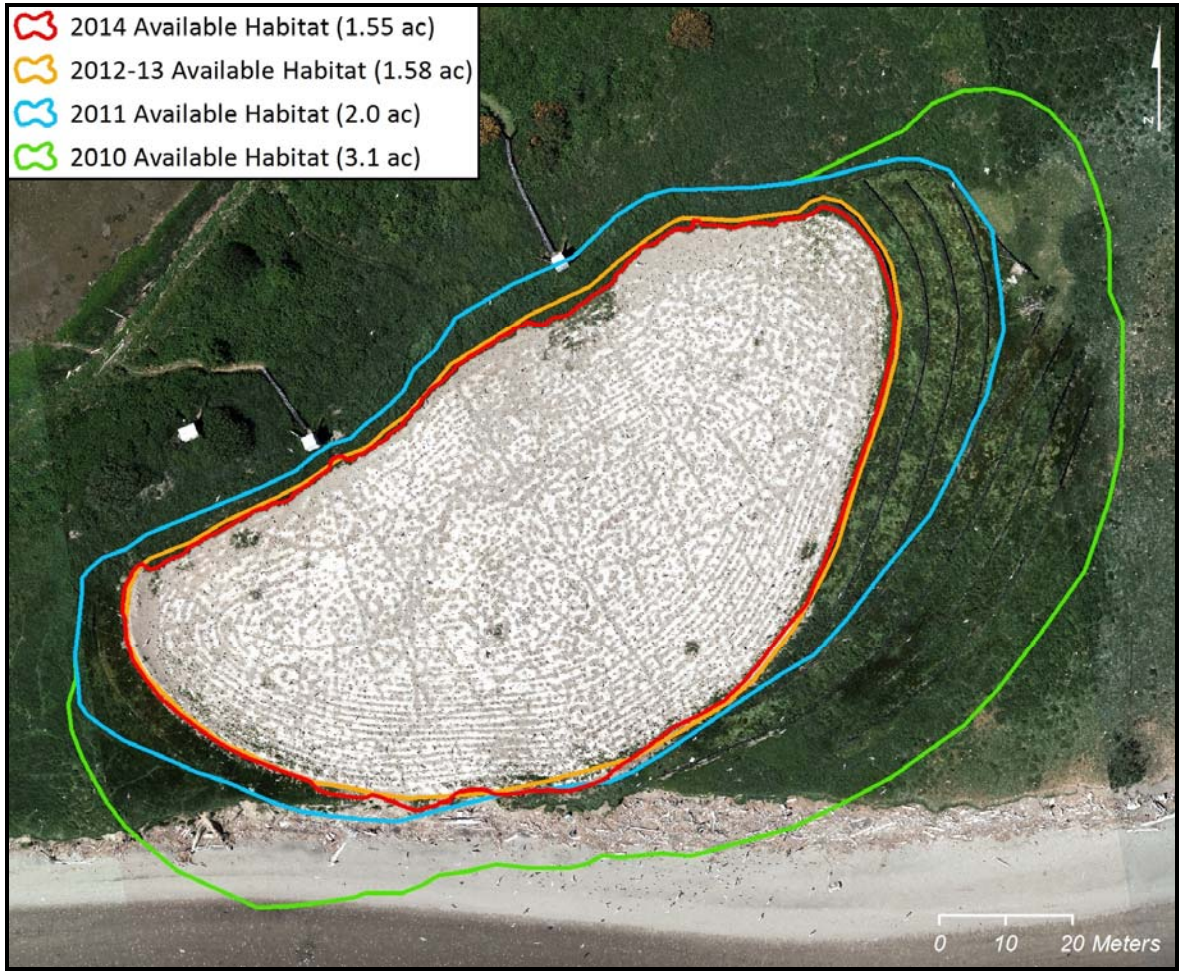
	Funding Contribution by Agency				
	BPA	USACE Portland District	USACE Walla Walla District	BOR	GPUD/PRCC
Caspian Terns					
1.1. Columbia River Estuary					
1.1.1. Implementation of Management Plan in Columbia River Estuary		x			
1.1.2. Nesting Distribution, Colony Size, and Productivity	x				
1.1.3. Diet Composition and Salmonid Consumption	x				
1.1.4. Salmonid Impacts Based on PIT Tag Recoveries	x	x			
1.2. Columbia Plateau Region					
1.2.1. Implementation of Management Plan at Goose Island				x	
1.2.2. Nesting Distribution, Colony Size, and Productivity			x	x	x
1.2.3. Salmonid Impacts Based on PIT Tag Recoveries			x	x	x
1.3. Interior OR and Northeastern CA					
1.3.1. Implementation of Management Plan Outside Columbia Basin		x			
1.3.2. Nesting Distribution, Colony Size, and Productivity		x			
1.3.3. Diet Composition and Foraging Distribution		x			
1.3.4. Sucker and Salmonid Impacts Based on PIT Tag Recoveries		x			
1.4. Inter-colony Movements and Dispersal Patterns	x	x	x	x	x

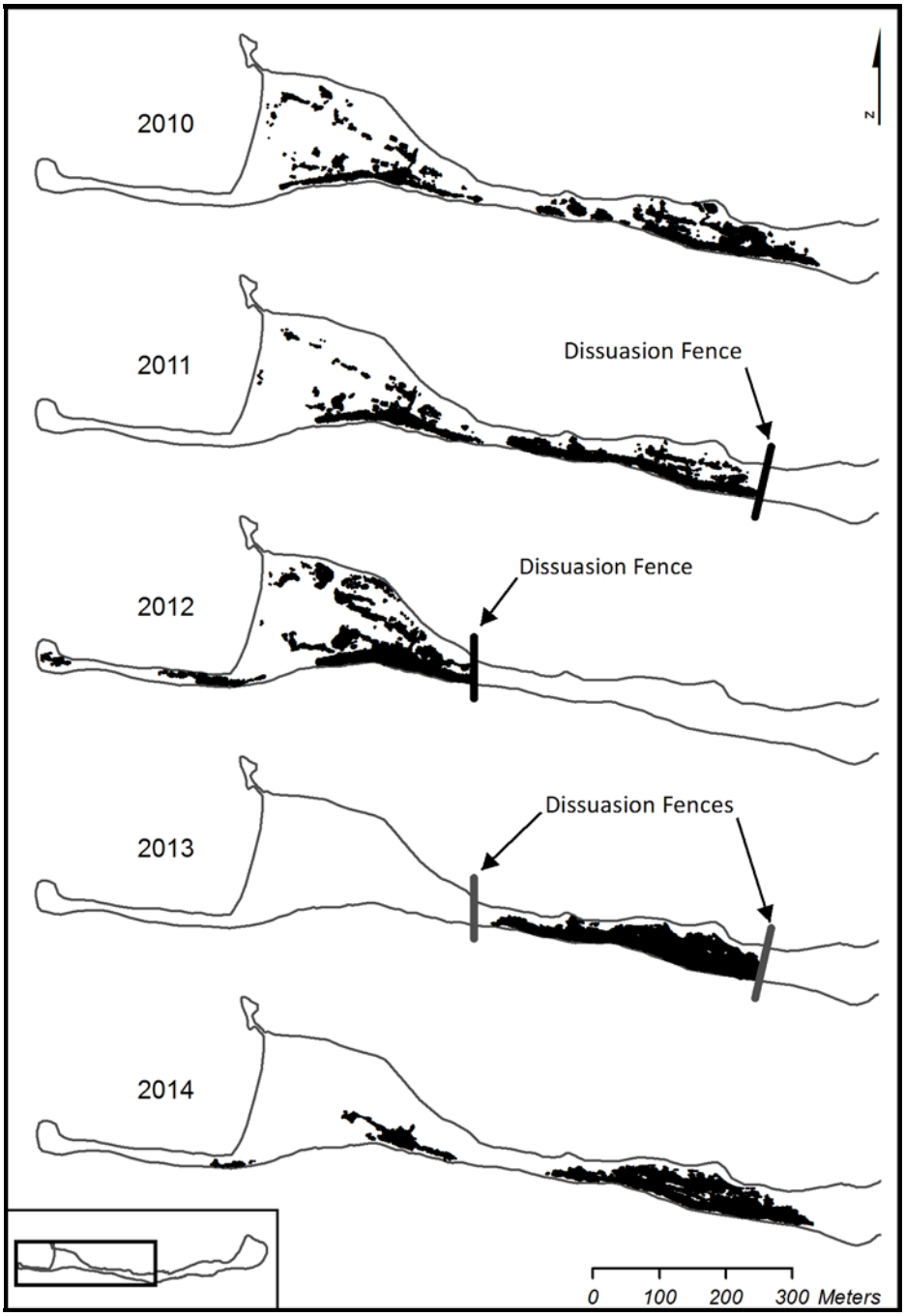
	Funding Contribution by Agency				
	BPA	USACE Portland District	USACE Walla Walla District	BOR	GPUD/PRCC
Cormorants					
2.1. Columbia River Estuary					
2.1.1. Nesting Distribution and Colony Sizes		x			
2.1.2. Salmonid Impacts Based on PIT Tag Recoveries		x			
2.2. Columbia River Plateau Region					x
2.3. Interior OR and Northeastern CA		x			
2.4. Inter-colony Movements and Dispersal Patterns		x			
Gulls and Pelicans					
3.1. Columbia River Estuary	x	x			
3.2. Columbia Plateau					x
3.3. Interior OR and Northeastern CA		x			

Map 1. Study area in the Columbia River basin showing the locations of active and former breeding colonies of piscivorous colonial waterbirds mentioned in this report.

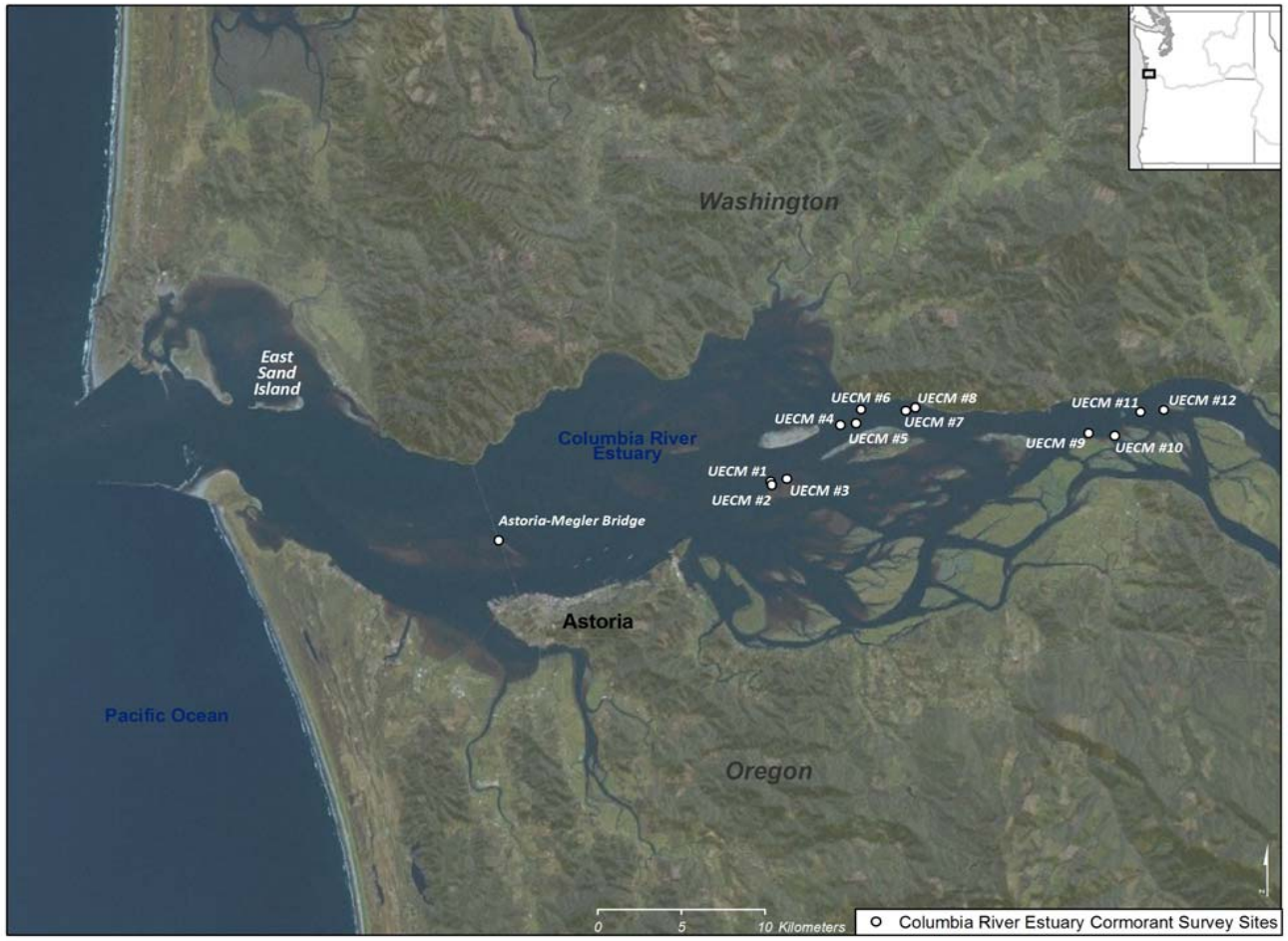
Map 2. East Sand Island and out of basin sites mentioned in this report.



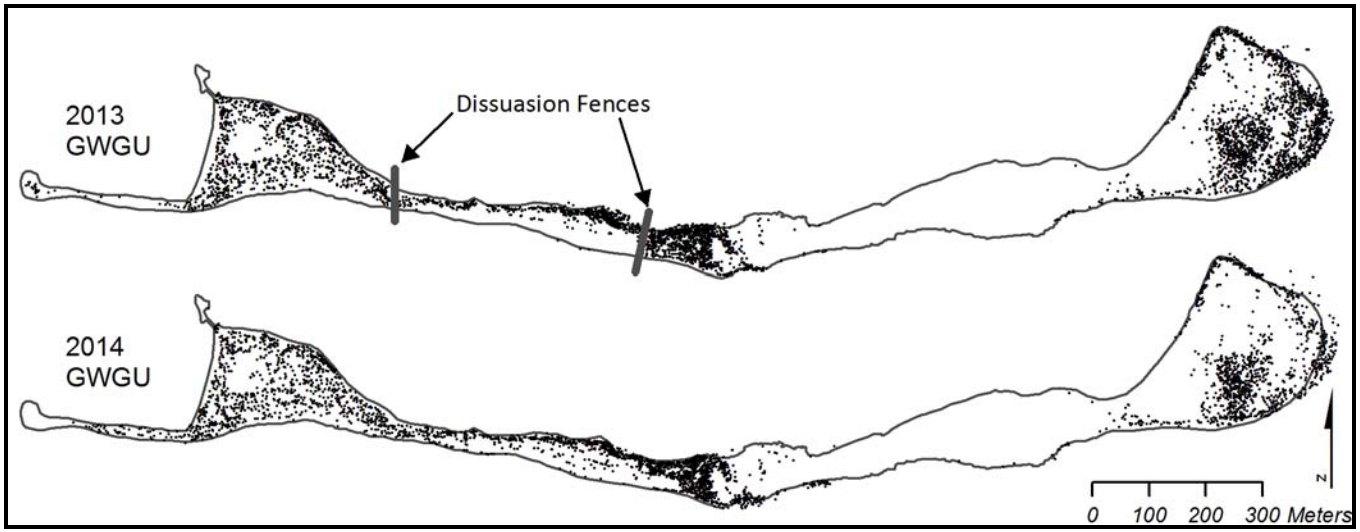
Map 3. Nesting habitat prepared for Caspian terns on the eastern end of East Sand Island in the Columbia River estuary during 2010-2014. Silt fencing was erected in 2010-2011 on a portion of the nesting habitat used by terns to further reduce the amount of nesting habitat made available to Caspian terns during 2012-2014 (see text for details).



Map 4. Distribution of double-crested and Brandt's cormorant nests (shown in black) on western East Sand Island in the Columbia River estuary during the 2010-2014 breeding seasons. Nesting distributions are shown prior to cormorant nest dissuasion trials (2010), during nest dissuasion trials (2011-2013), and after nest dissuasion trials (2014) (see BRNW 2014a, BRNW 2013a, BRNW 2013b).



Map 5. Survey sites for nesting double-crested cormorants in the Columbia River estuary in 2014, which include East Sand Island, the Astoria-Megler Bridge, and 12 navigation/channel markers located in the upper Columbia River estuary (UECM).



Map 6. Distribution of glaucous-winged/western gulls (GWGU) on East Sand Island in the Columbia River estuary based on high-resolution, vertical aerial photography taken at the peak of the incubation period during the 2013 and 2014 breeding seasons. The distribution of gulls in 2013 was concurrent with cormorant nest dissuasion trials that prevented all cormorant nesting except between the two dissuasion fences, and the distribution of gulls in 2014 was during a year when no cormorant nest dissuasion trials were conducted (see BRNW 2014a, BRNW 2013a, BRNW 2013b).

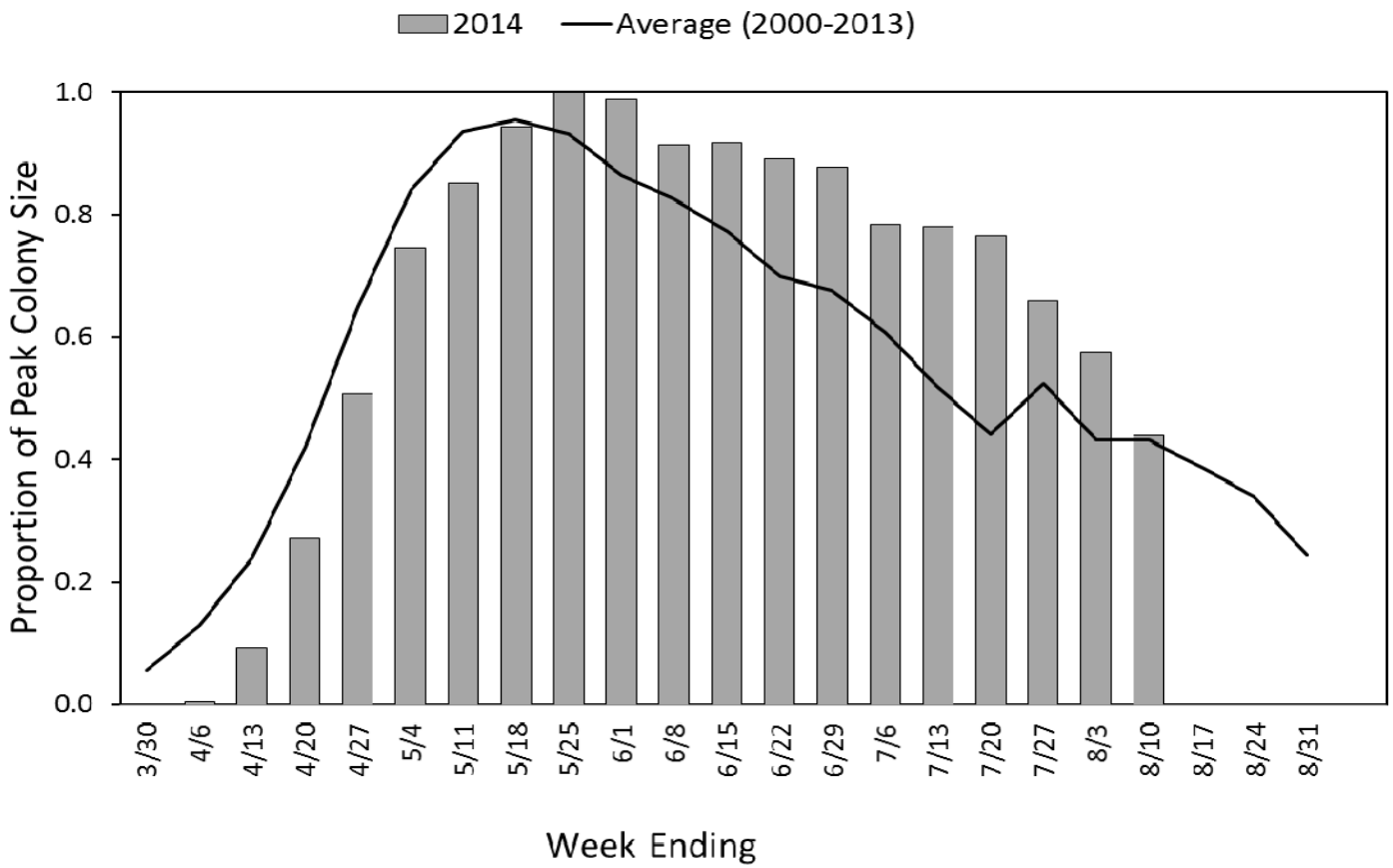


Figure 1. Weekly estimates from the ground of the number of adult Caspian terns on the East Sand Island colony during the 2014 breeding season, normalized to peak colony attendance during the week ending May 25 as determined from counts of aerial photography of the colony taken during that week (late in the incubation period).

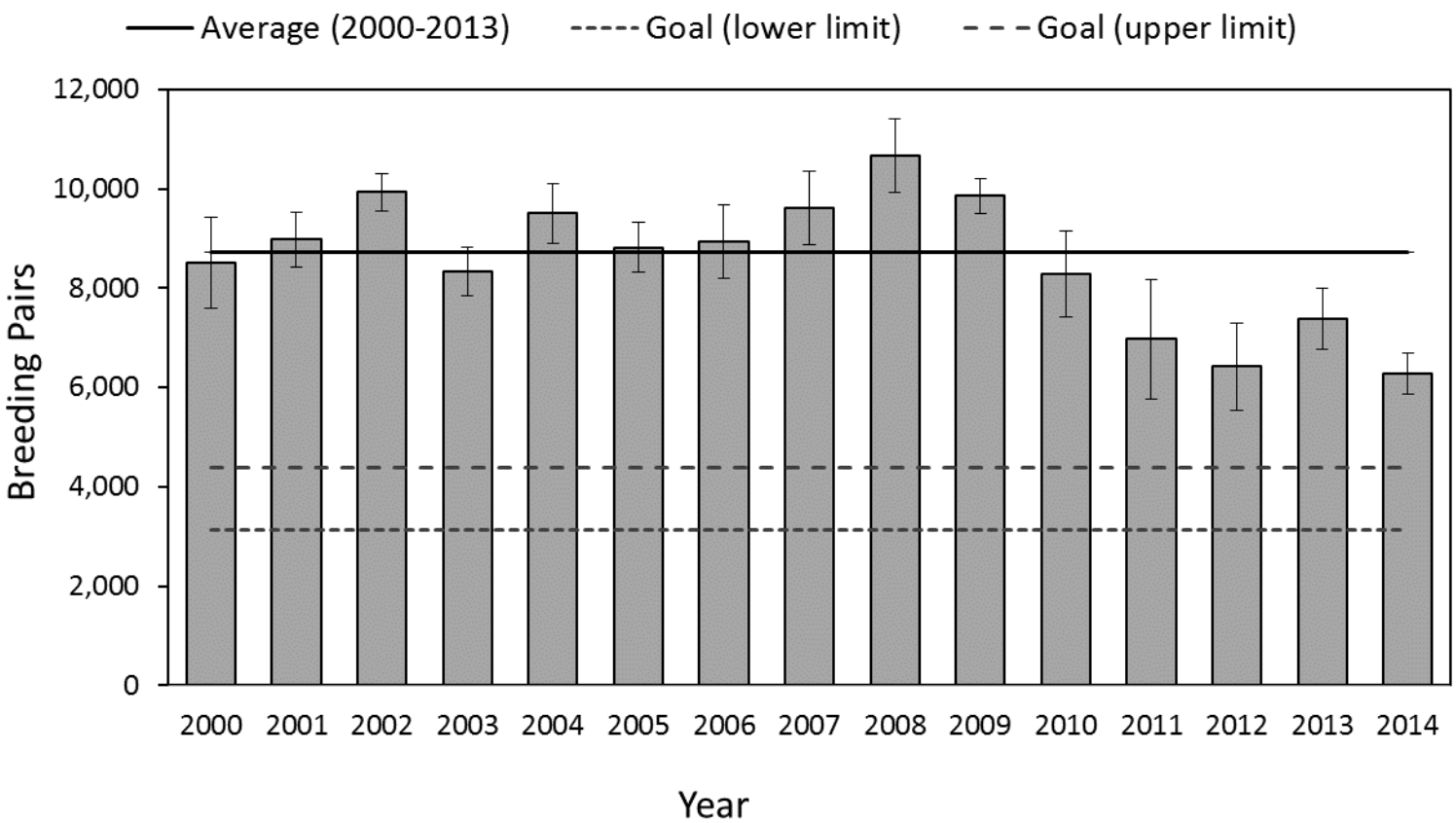


Figure 2. Caspian tern colony size (number of breeding pairs) on East Sand Island in the Columbia River estuary during 2000-2014. The error bars represent 95% confidence intervals for the estimate of the number of breeding pairs. The upper and lower management target (goal) for colony size for Caspian terns on East Sand Island is also provided for comparison.

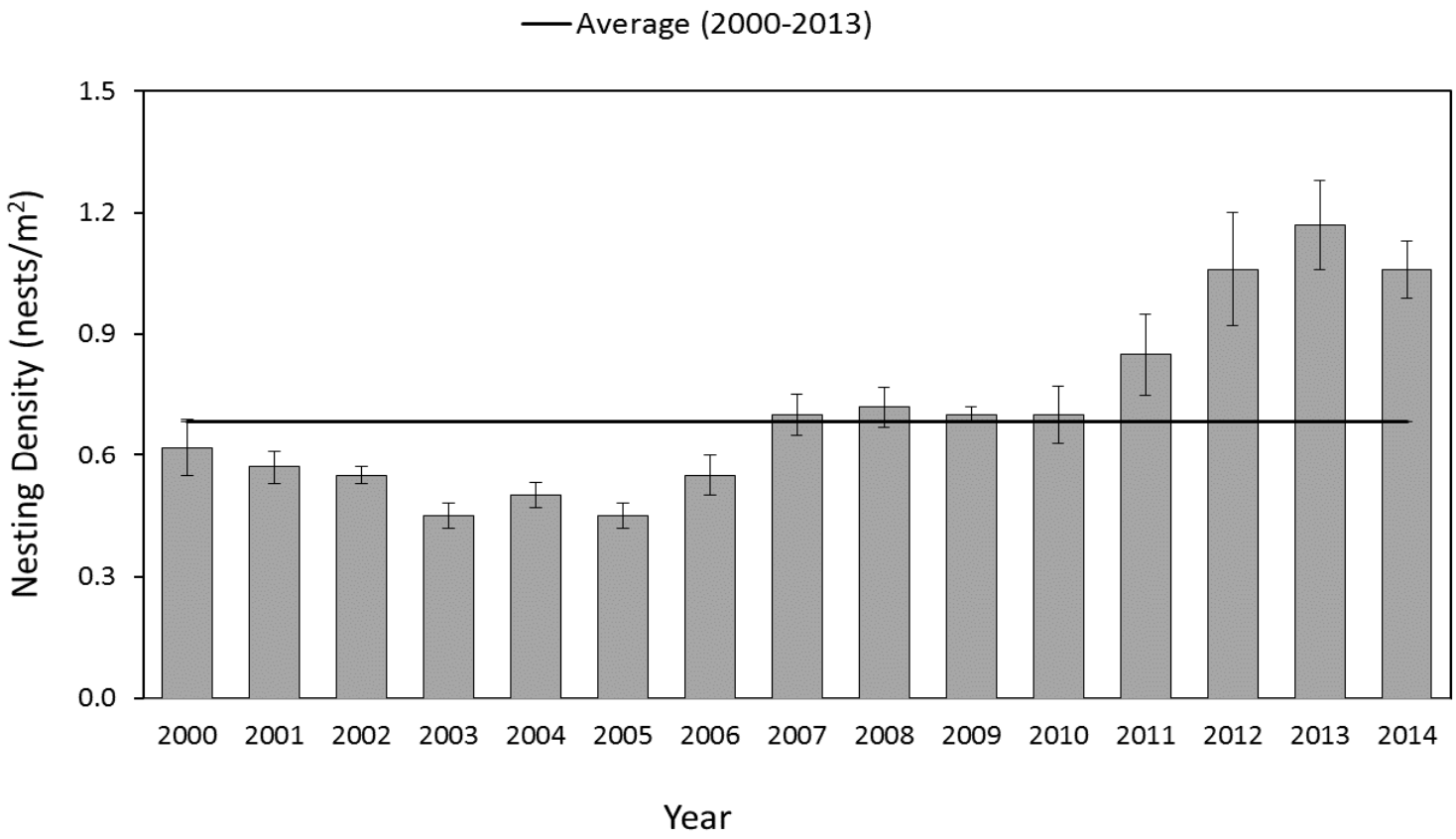


Figure 3. Caspian tern nesting density at the breeding colony on East Sand Island, Columbia River estuary during 2000-2014. The error bars represent 95% confidence intervals for the estimate of nesting density (confidence interval not available for 2011 and based on confidence interval for 2012).

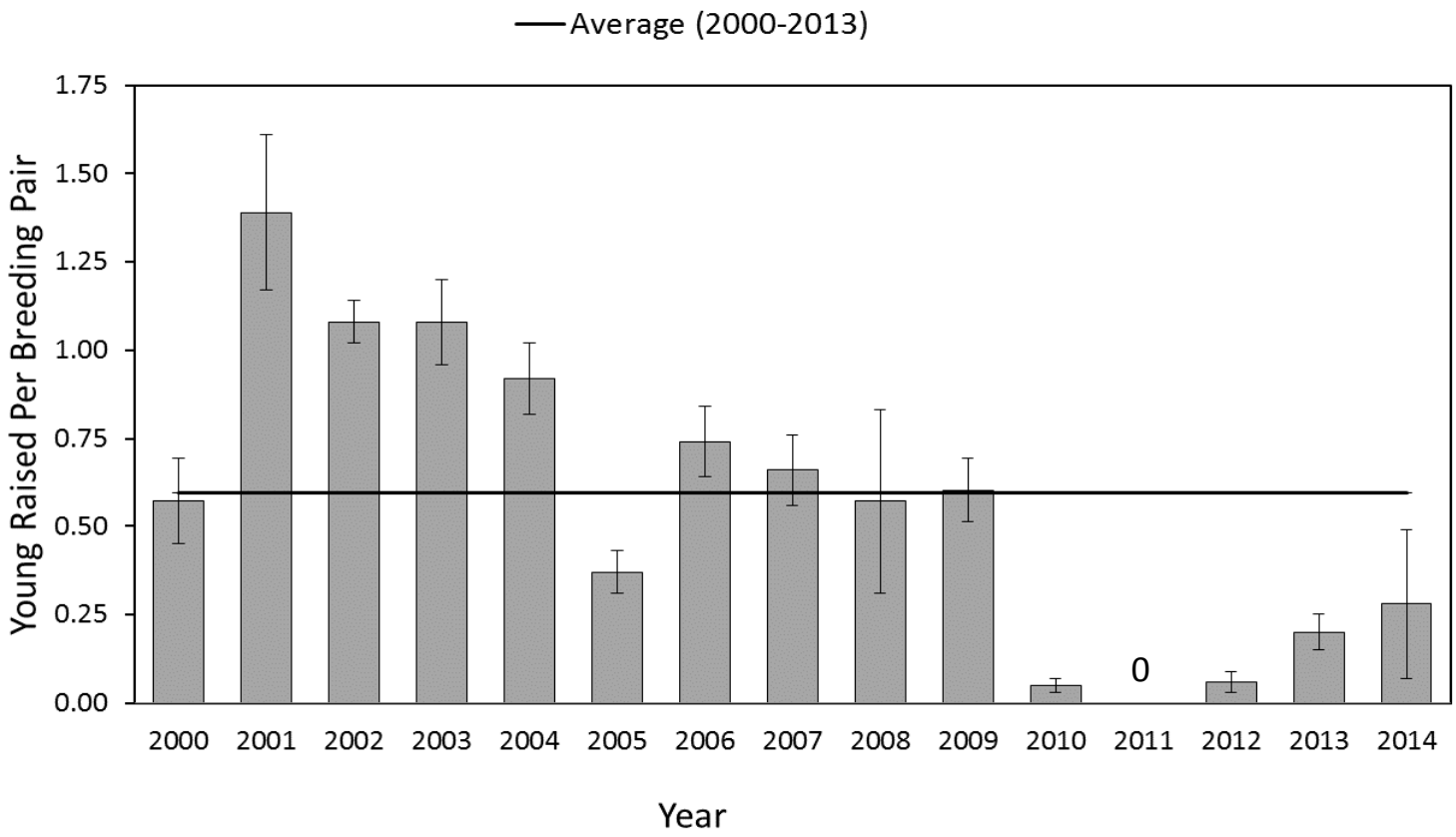


Figure 4. Caspian tern nesting success (average number of young raised per breeding pair) at the breeding colony on East Sand Island in the Columbia River estuary during 2000-2014. The error bars represent 95% confidence intervals. No young were raised at the East Sand Island breeding colony in 2011.

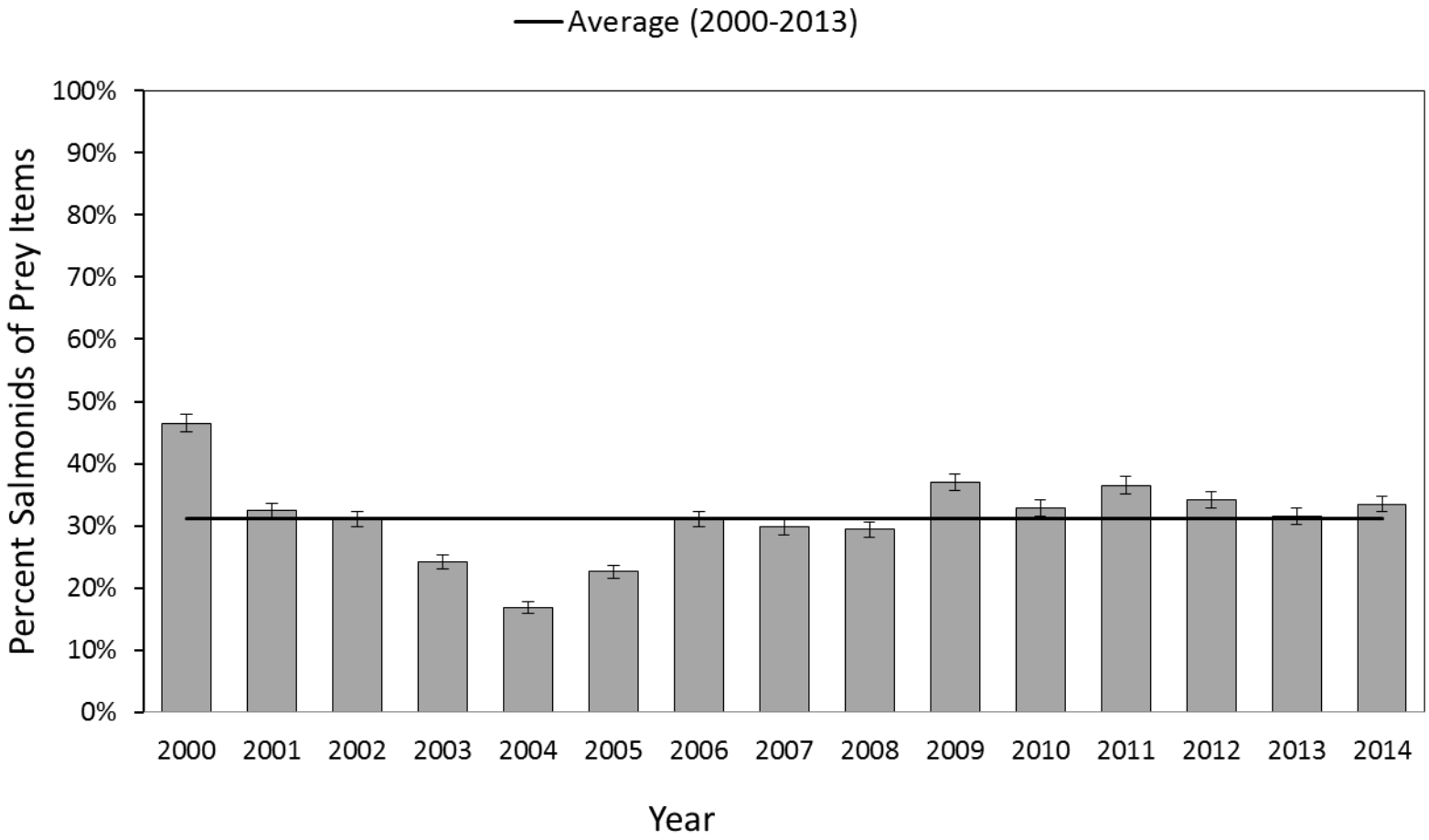


Figure 5. Average annual proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2014 breeding seasons. Each annual value represents the average of the proportions during the 2-week periods encompassing the entire nesting season. The error bars represent 95% confidence intervals.

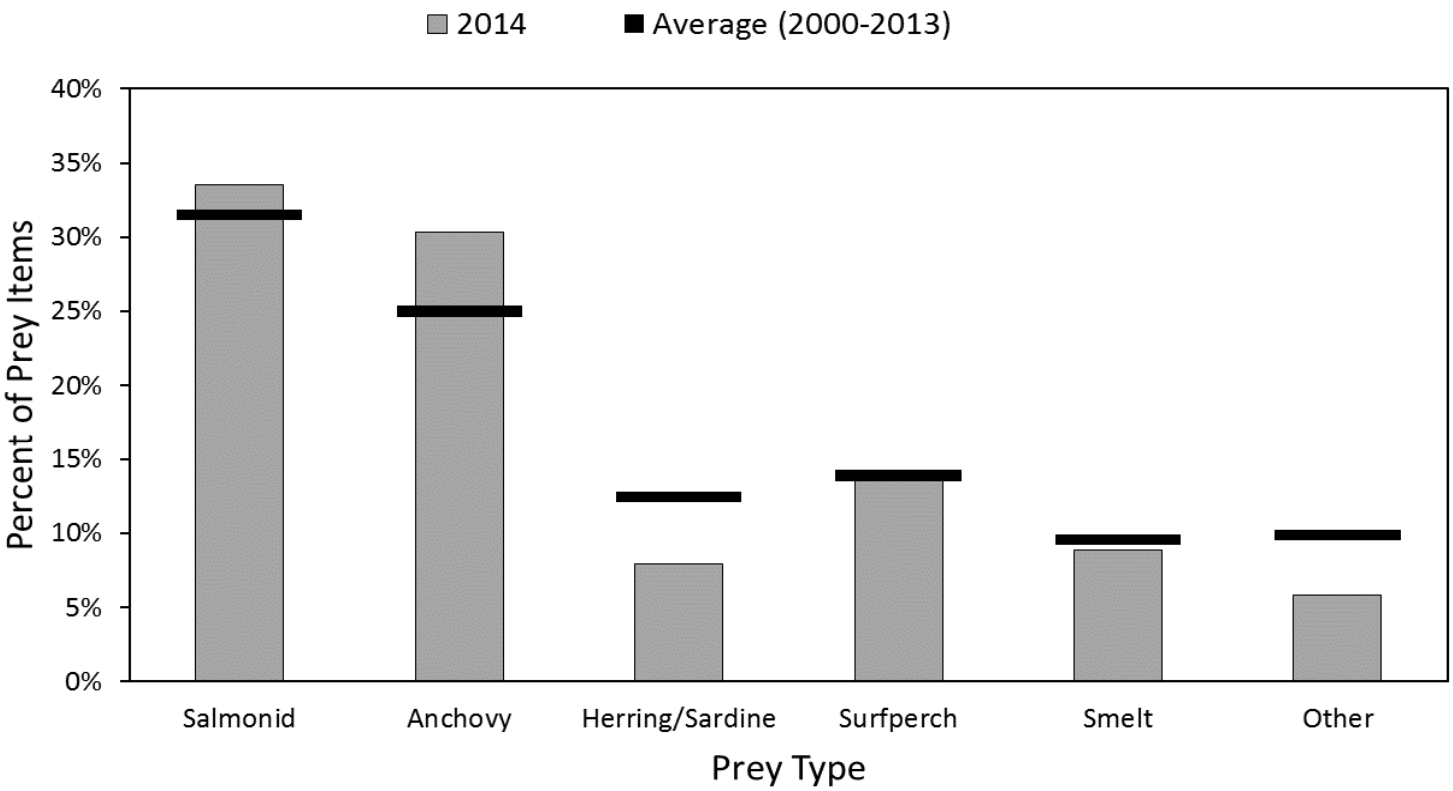


Figure 6. Diet composition (percent of identified prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2014 breeding season. Diet composition was based on fish visually identified on-colony in Caspian tern bill-loads.

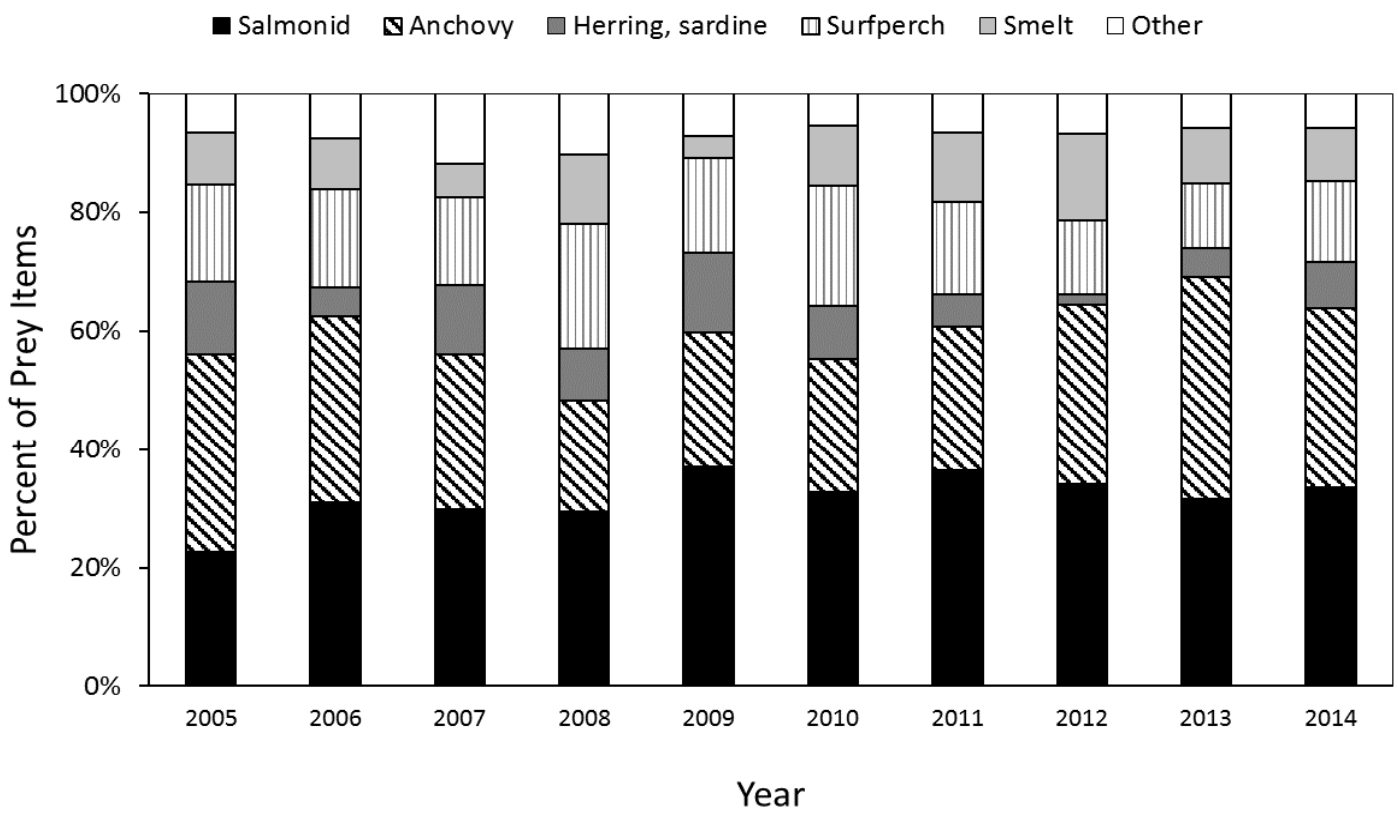


Figure 7. Annual diet composition (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2005-2014 breeding seasons. Diet composition was based on fish visually identified on-colony in Caspian tern bill-loads.

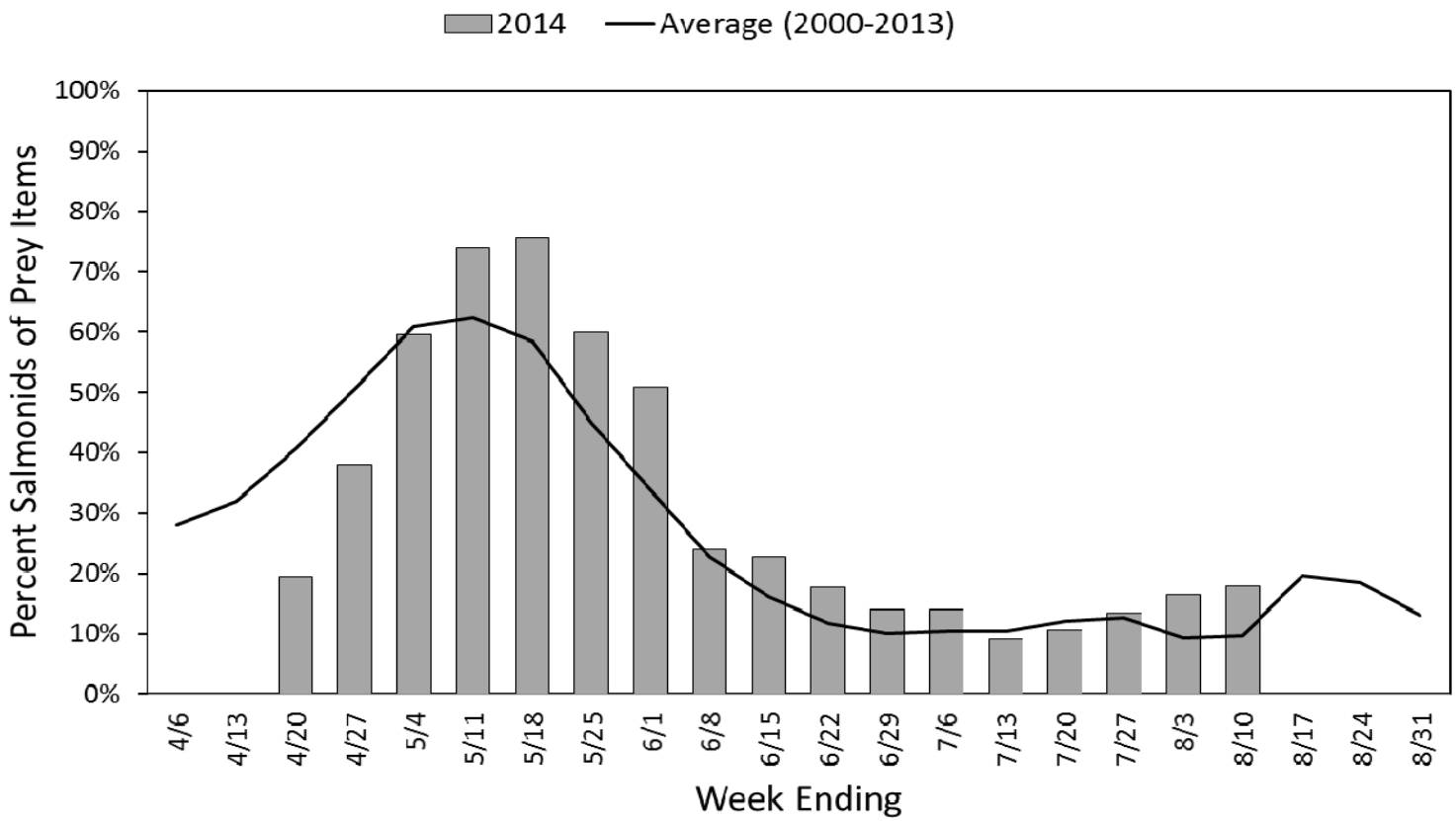
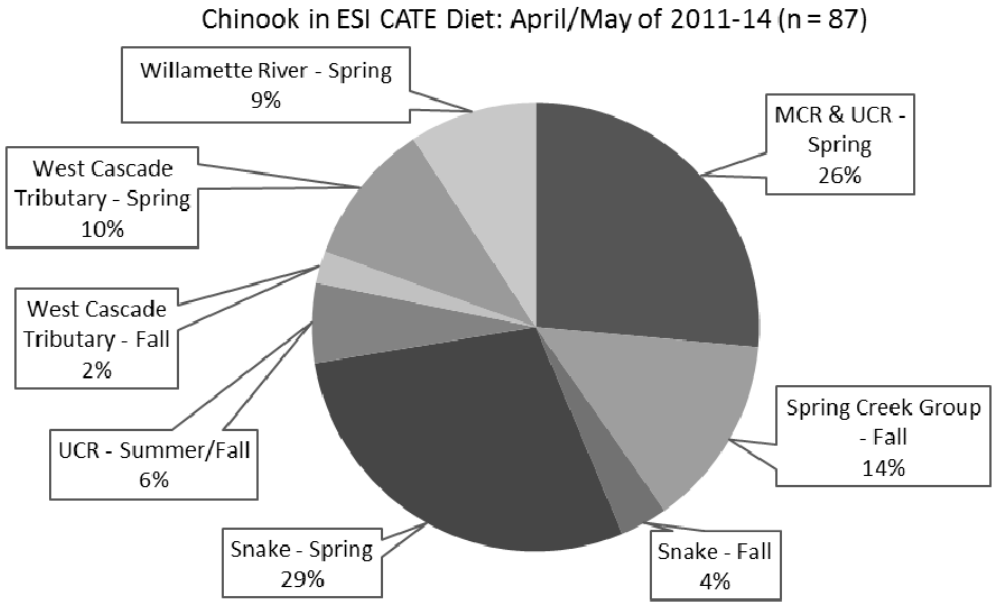


Figure 8. Proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary, by week during the 2014 breeding season.



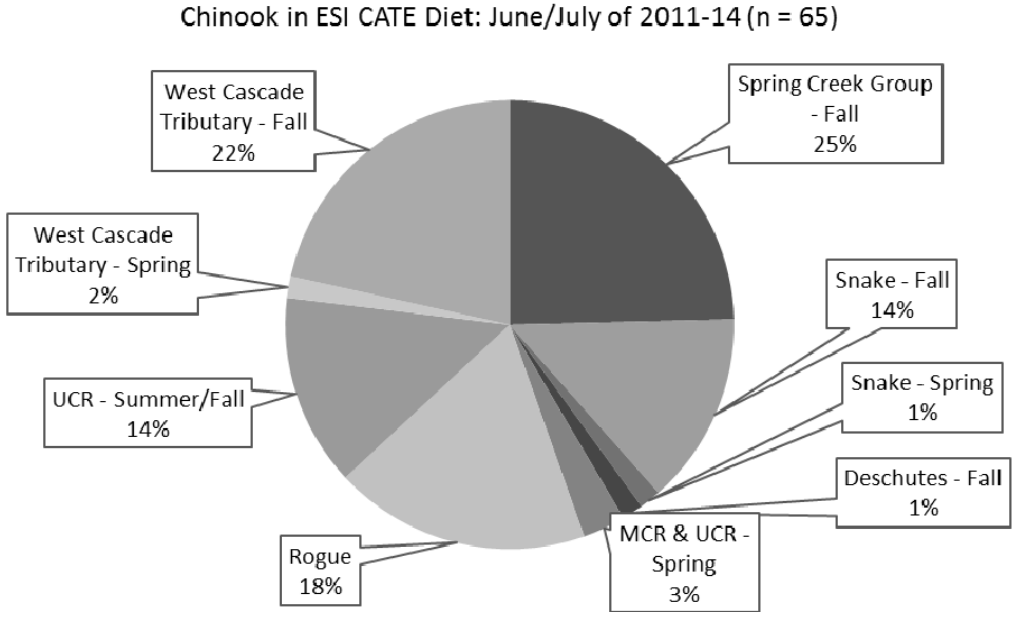
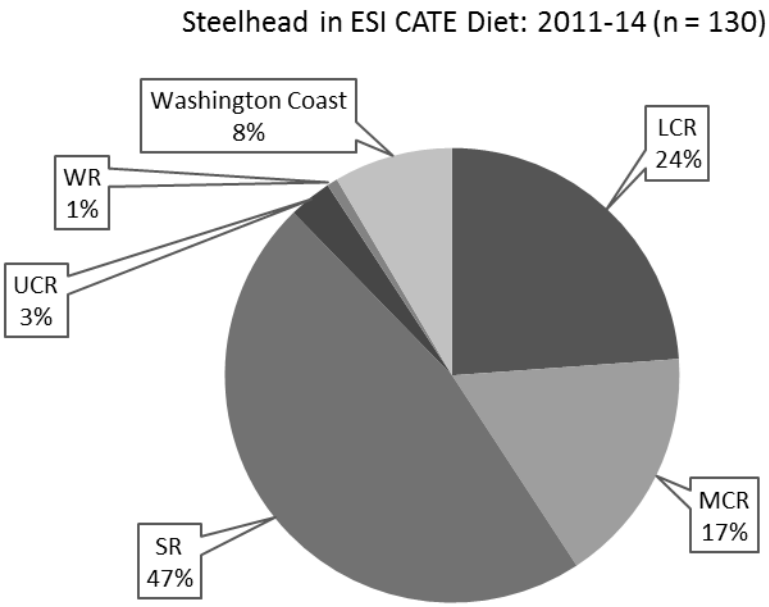


Figure 9. Genetic stock of origin for Chinook salmon in the diet of Caspian terns (CATE) nesting at East Sand Island (ESI) in the Columbia River estuary. Genetic stock identification of salmonids was performed by D. Kuligowski, NOAA Fisheries, on bill-load fish obtained from Caspian terns returning to the East Sand Island colony during the 2011-2014 breeding seasons. The Rogue River fall run stock was introduced to the lower Columbia River as part of a select area fishery enhancement project (North et al. 2006).



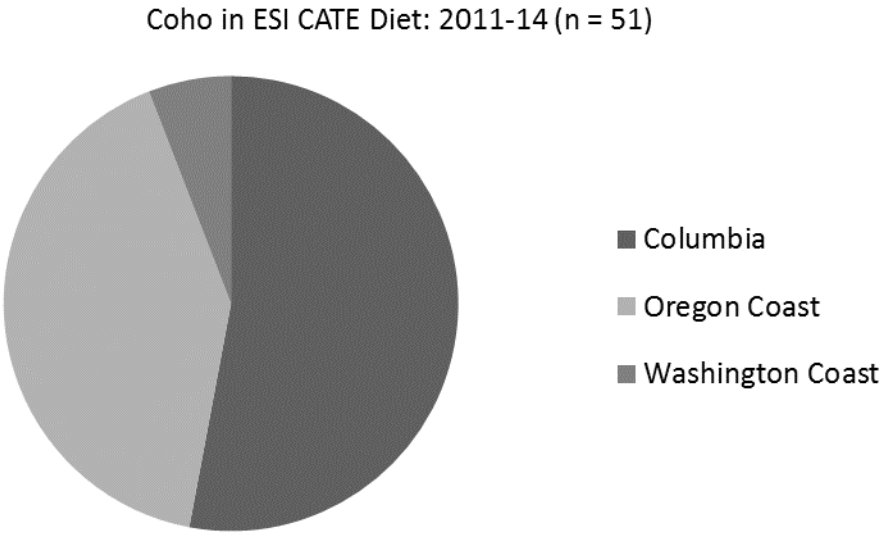


Figure 10. Genetic stock of origin for steelhead trout and coho salmon in the diet of Caspian terns (CATE) nesting on East Sand Island (ESI) in the Columbia River estuary. Genetic stock identification of salmonids was performed by D. Kuligowski, NOAA Fisheries, on bill-load fish obtained from Caspian terns returning to the East Sand Island colony during the 2011-2014 breeding seasons.

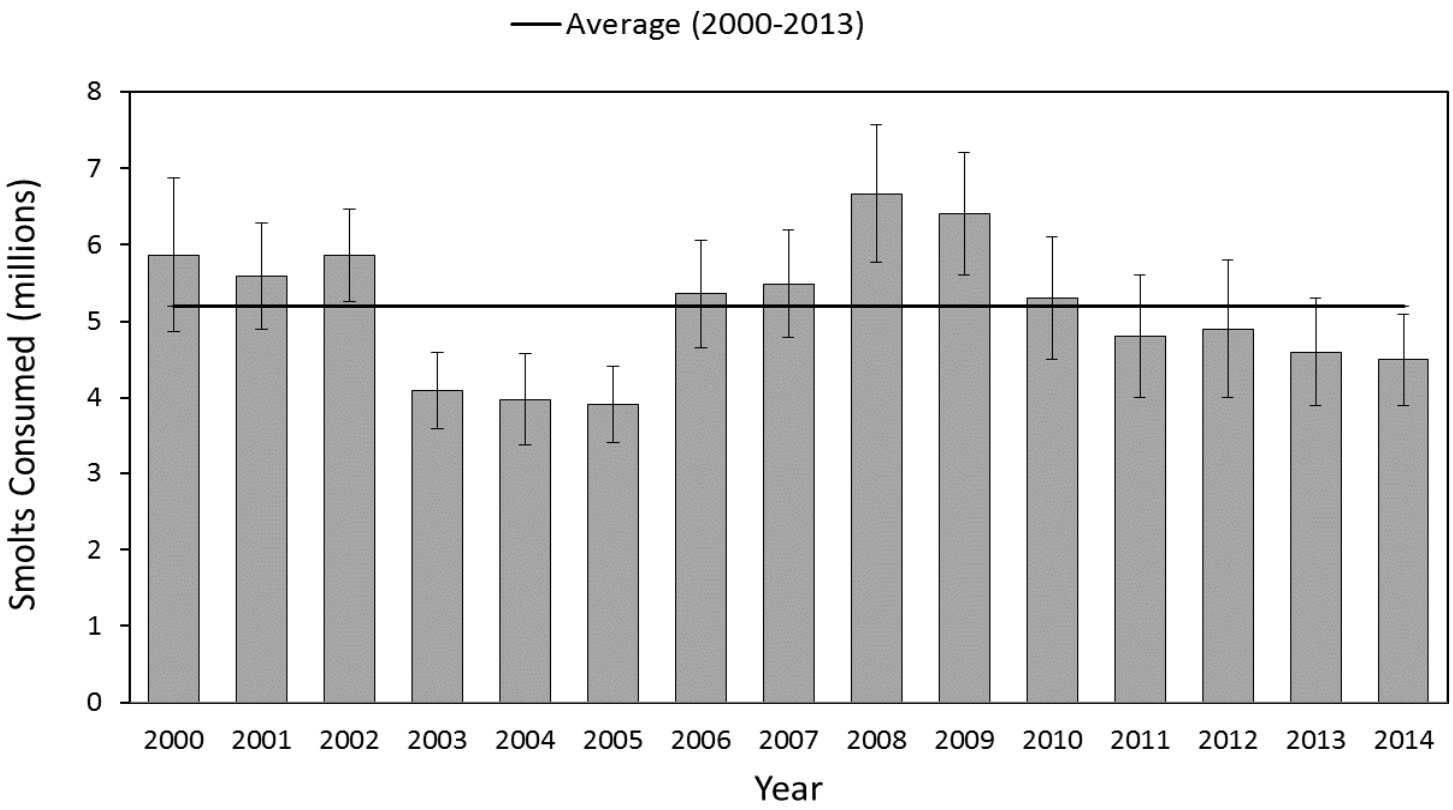


Figure 11. Estimated total annual consumption of juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2014 breeding seasons. Estimates are based on fish identified in tern bill-loads on-colony and bioenergetics calculations. Error bars represent 95% confidence intervals for the number of smolts consumed.

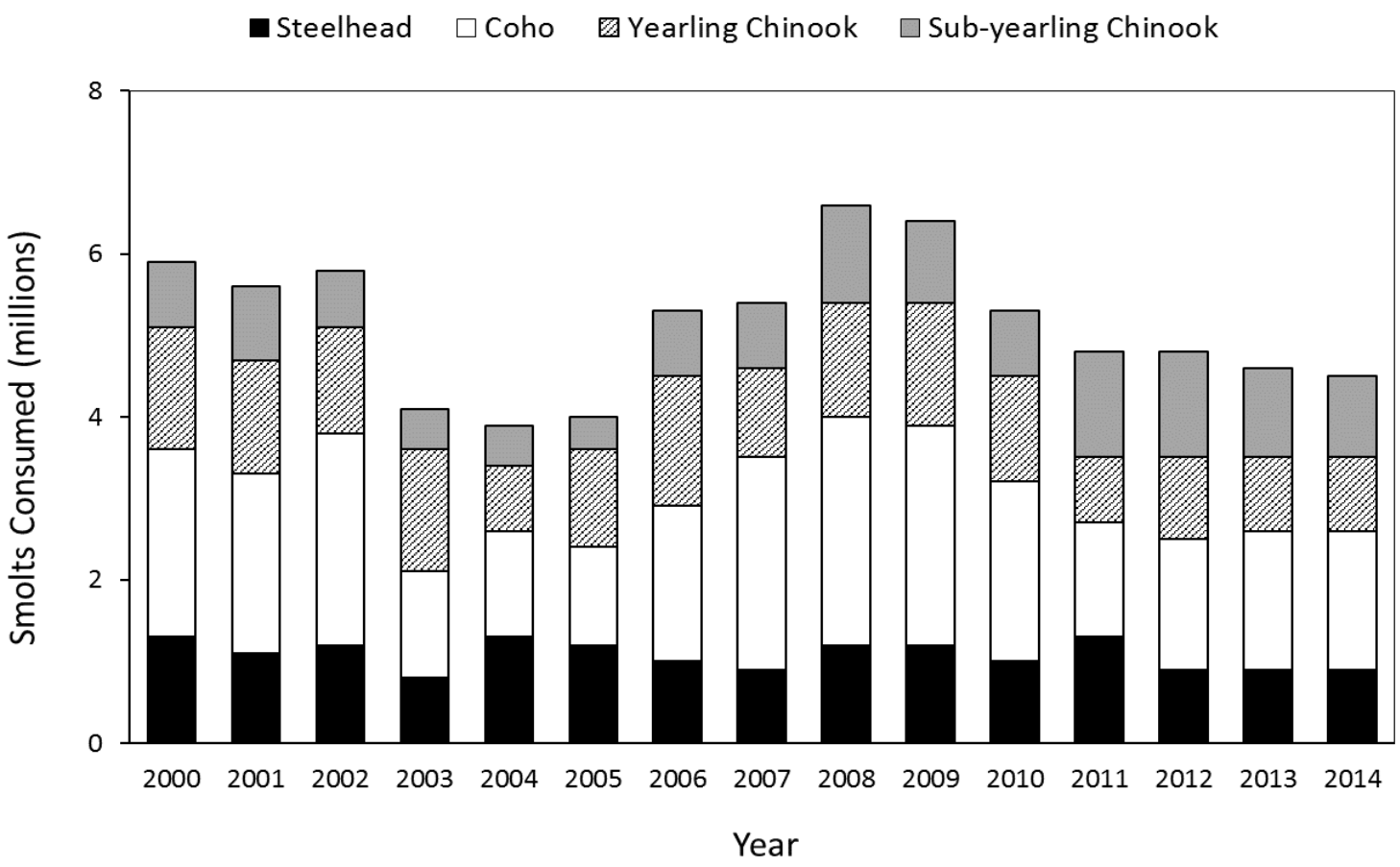


Figure 12. Estimated total annual consumption of four species/run types of juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2014 breeding seasons. Estimates are based on fish collected from tern bill-loads near the colony and bioenergetics calculations.

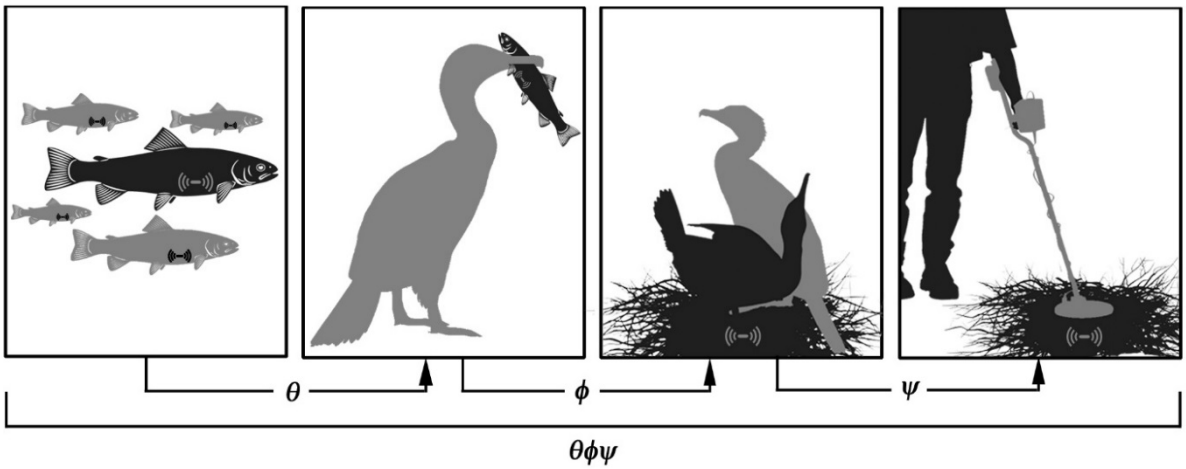


Figure 13. Conceptual model of the tag-recovery process in studies of avian predation. The probability of recovering an implanted fish tag on a bird colony is the product of three probabilities: a tagged fish was consumed (predation rate, θ), a consumed tag was deposited on the nesting colony (deposition rate, ϕ), and a deposited tag was detected by researchers (detection efficiency, ψ). Diagram from Hostetter et al. (2015).

Figure 14. PIT tag scanning equipment used on fish-eating bird colonies to recover smolt PIT tags following the 2014 breeding season. Electronic scanning equipment included a pole-mounted antenna (upper left) and an eight-coil, flat-plat antenna attached to an ATV (upper right). Equipment to physically remove PIT tags (lower middle) using magnets included a hand-cart (lower left) or trailer hooked to an ATV (lower right).

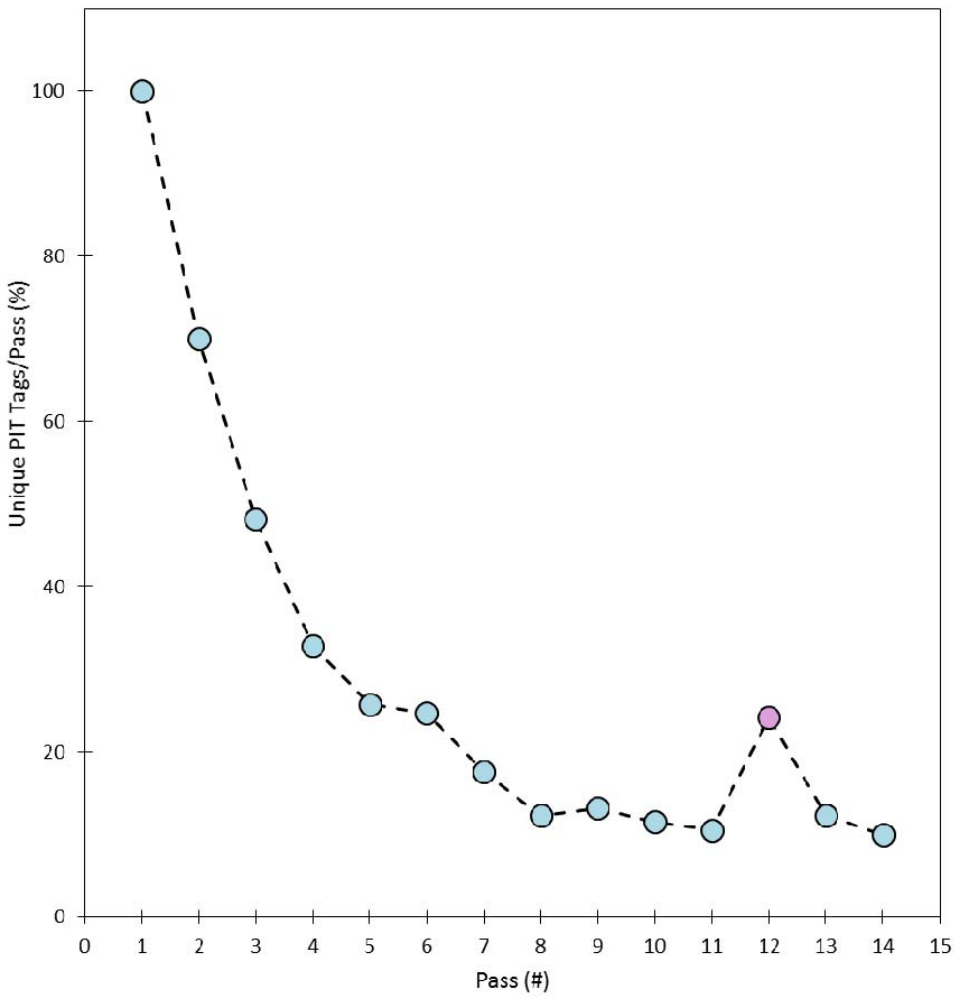


Figure 15. Numbers of unique (not previously detected) PIT tags detected during electronic passes (blue dots) and a physical removal pass (pink dot) of the Caspian tern colony on East Sand Island. Electronic passes were conducted with a flat-plate antenna and the physical pass used a magnet towed behind an ATV to collect and remove PIT tags from the surface of the colony (see Methods and Figure 14).

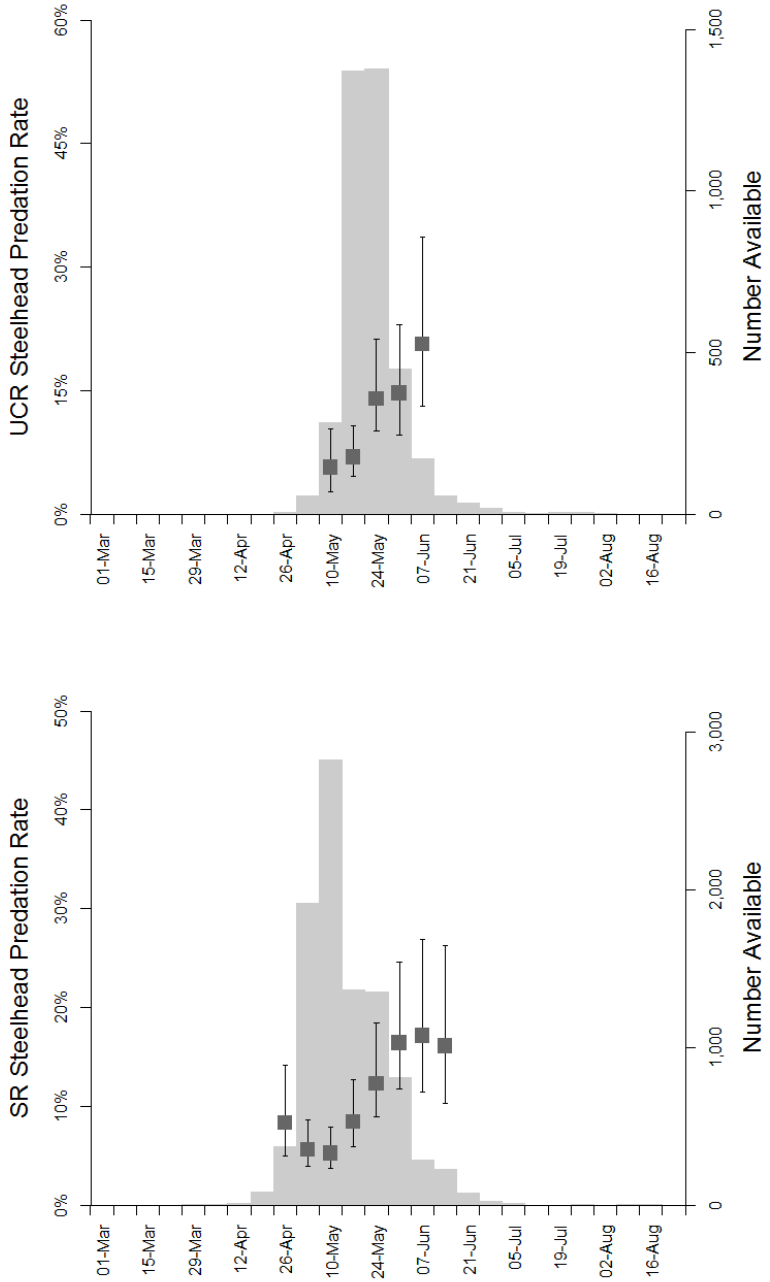


Figure 16. Weekly predation rates (squares with error bars) on PIT-tagged Upper Columbia River (UCR) steelhead and Snake River (SR) steelhead detected passing Bonneville Dam (number available; gray bars) by Caspian terns nesting on East Sand Island during 2014. Error bars represent 95% credible intervals for steelhead predation rates.

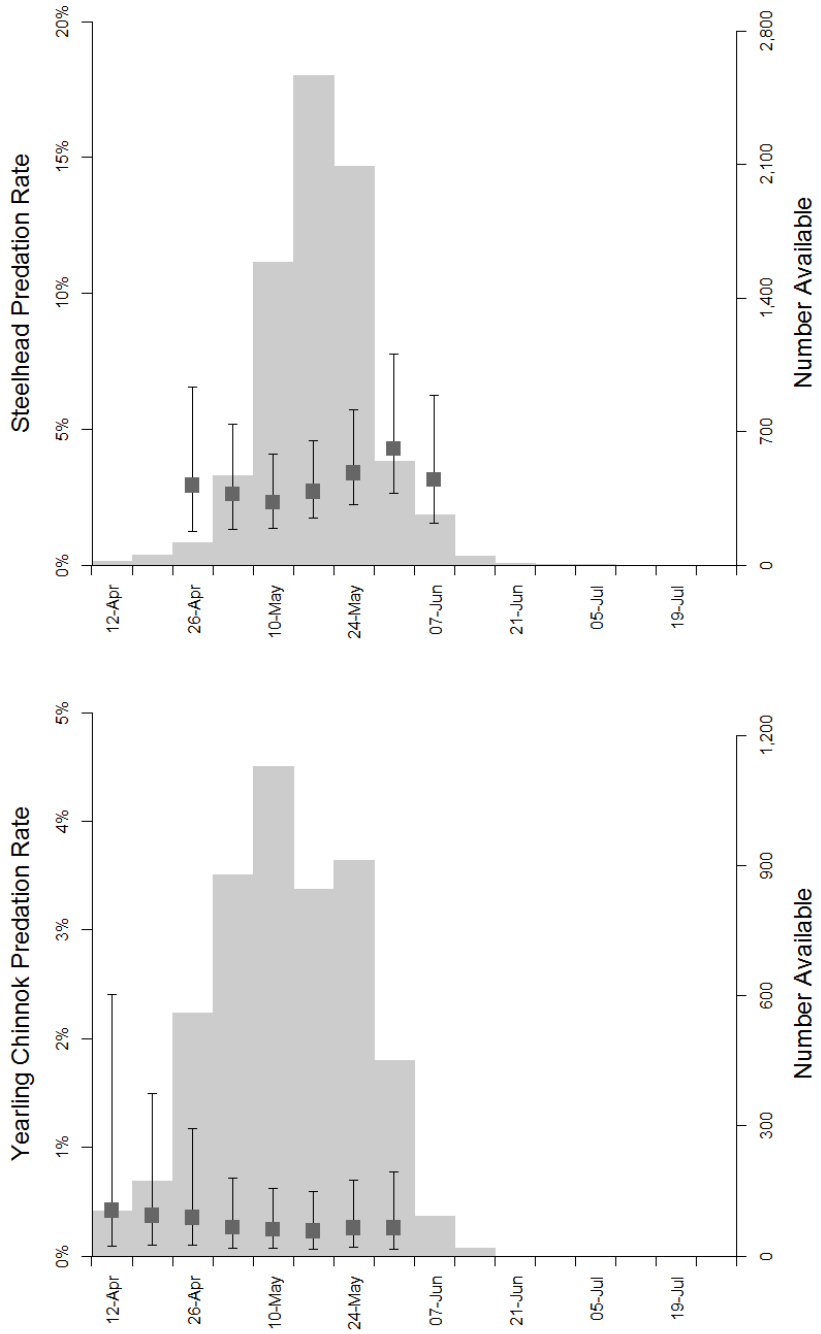


Figure 17. Weekly predation rates (squares with error bars) on steelhead and yearling Chinook salmon PIT-tagged at Rock Island Dam (number available; gray bars) by Caspian terns nesting on Northwest Rocks in Potholes Reservoir during 2014. Error bars represent 95% credible intervals for predation rates on steelhead and yearling Chinook salmon.

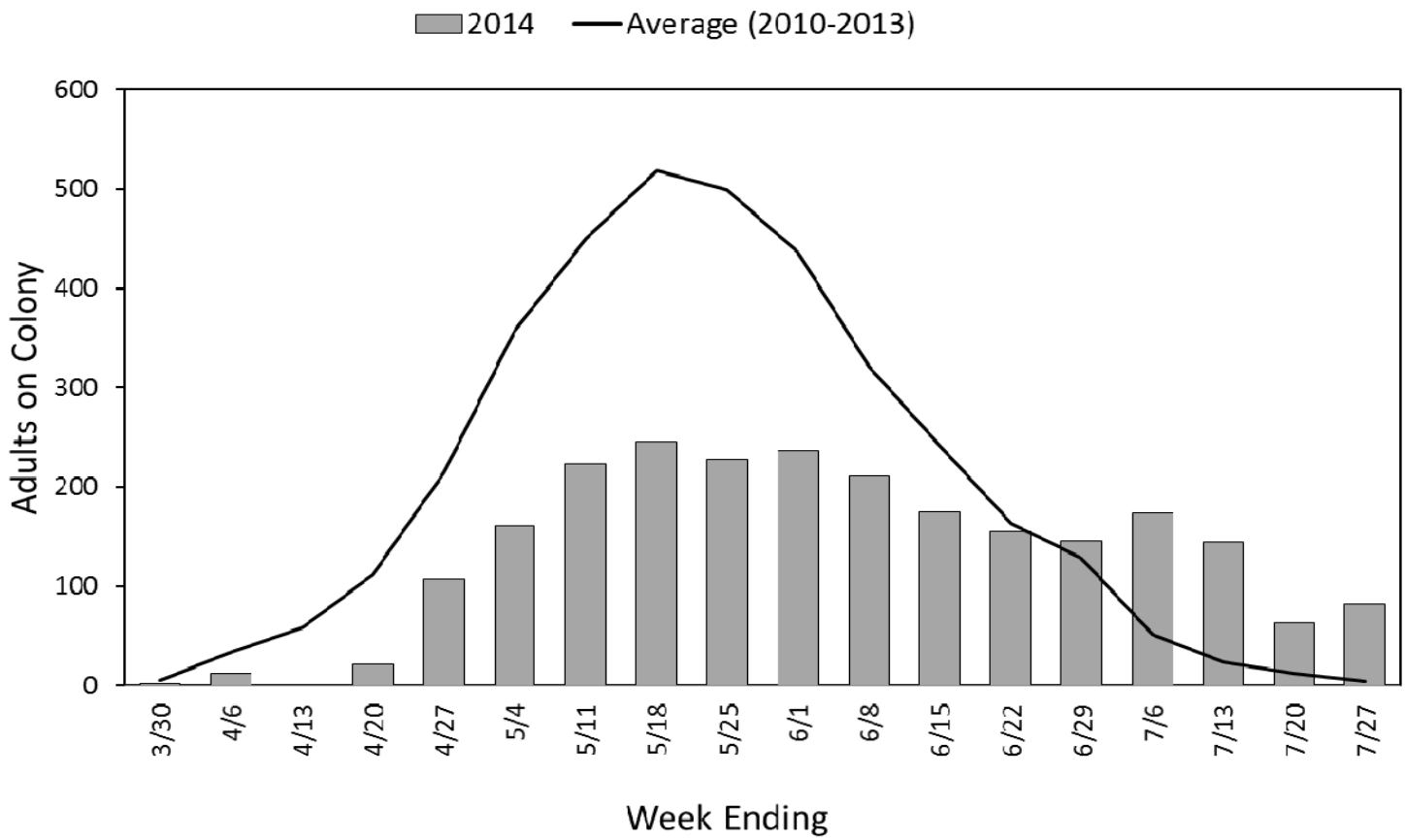


Figure 18. Estimates from the ground of the number of adult Caspian terns at the breeding colony on Goose Island and Northwest Rocks in Potholes Reservoir, by week, during the 2014 breeding season.

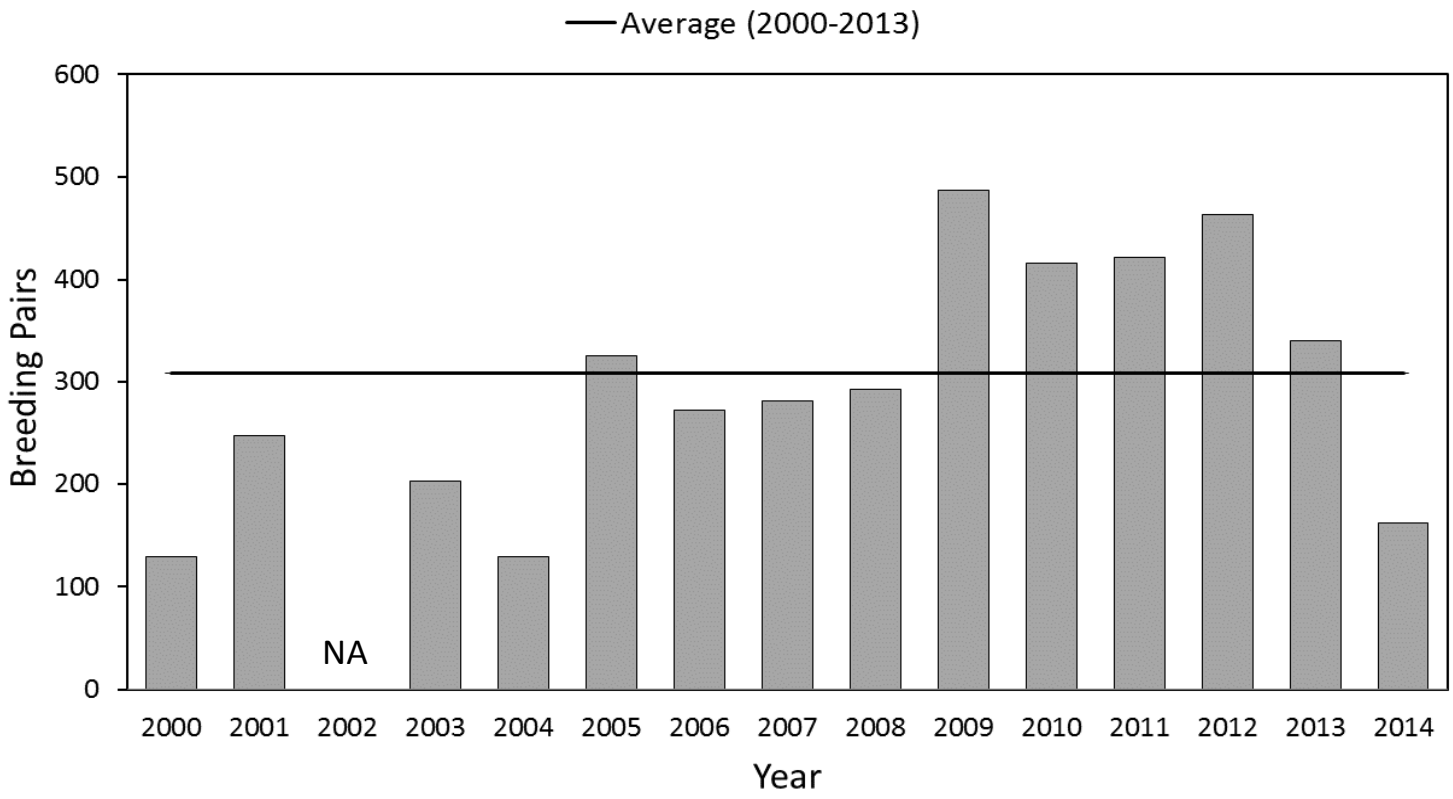


Figure 19. Size of the Caspian tern breeding colony (number of breeding pairs) at Potholes Reservoir during 2000-2014. The colony was located on Solstice Island during 2000-2004, on Goose Island during 2004-2013, and on Northwest Rocks in 2014. Colony size in 2002 is not known.

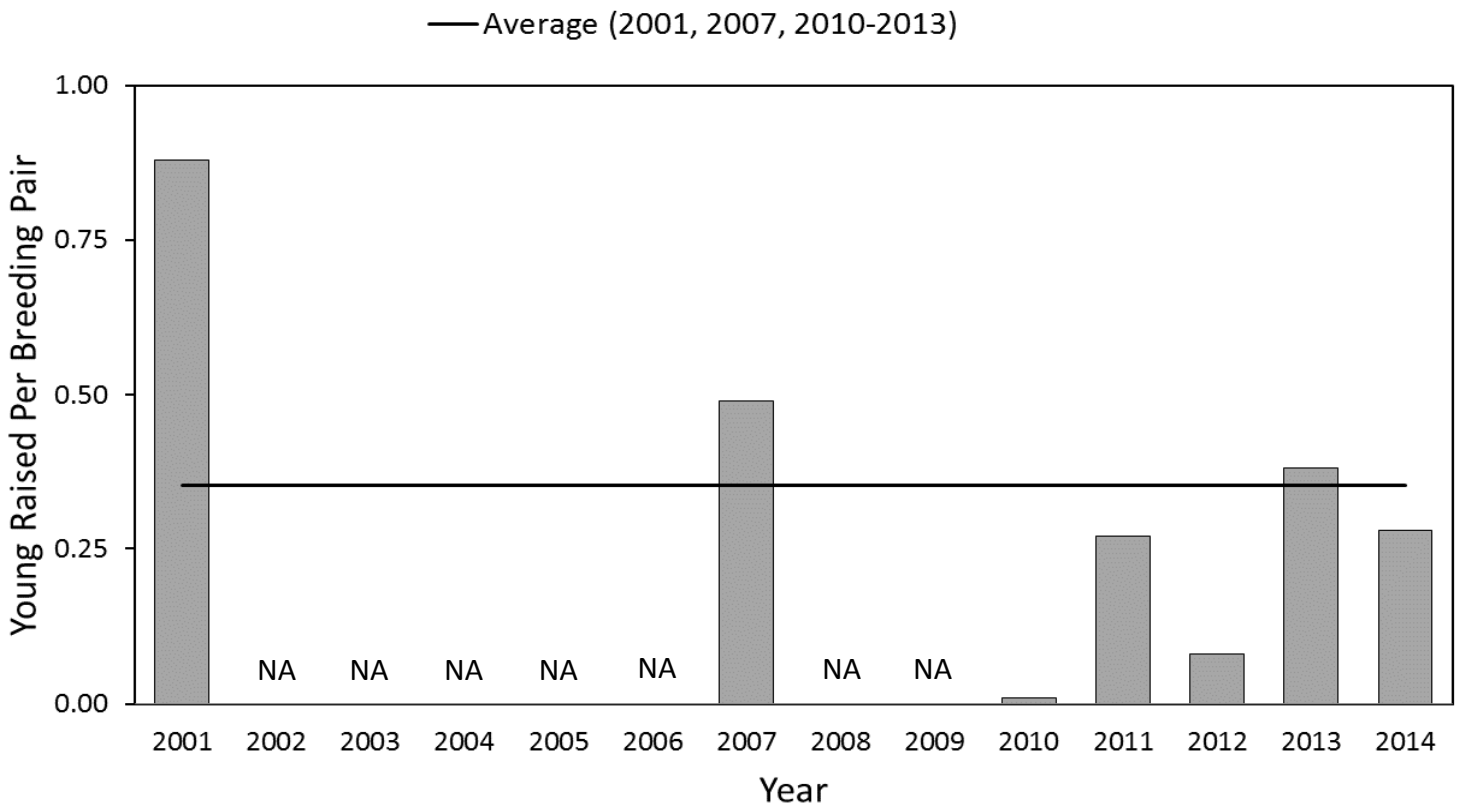


Figure 20. Caspian tern nesting success (average number of young raised per breeding pair) at the breeding colony at Potholes Reservoir during 2001-2014. The colony was on Solstice Island during 2001-2004, on Goose Island during 2004-2013, and on Northwest Rocks in 2014. Nesting success during 2002-2006 and during 2008-2009 is not known.

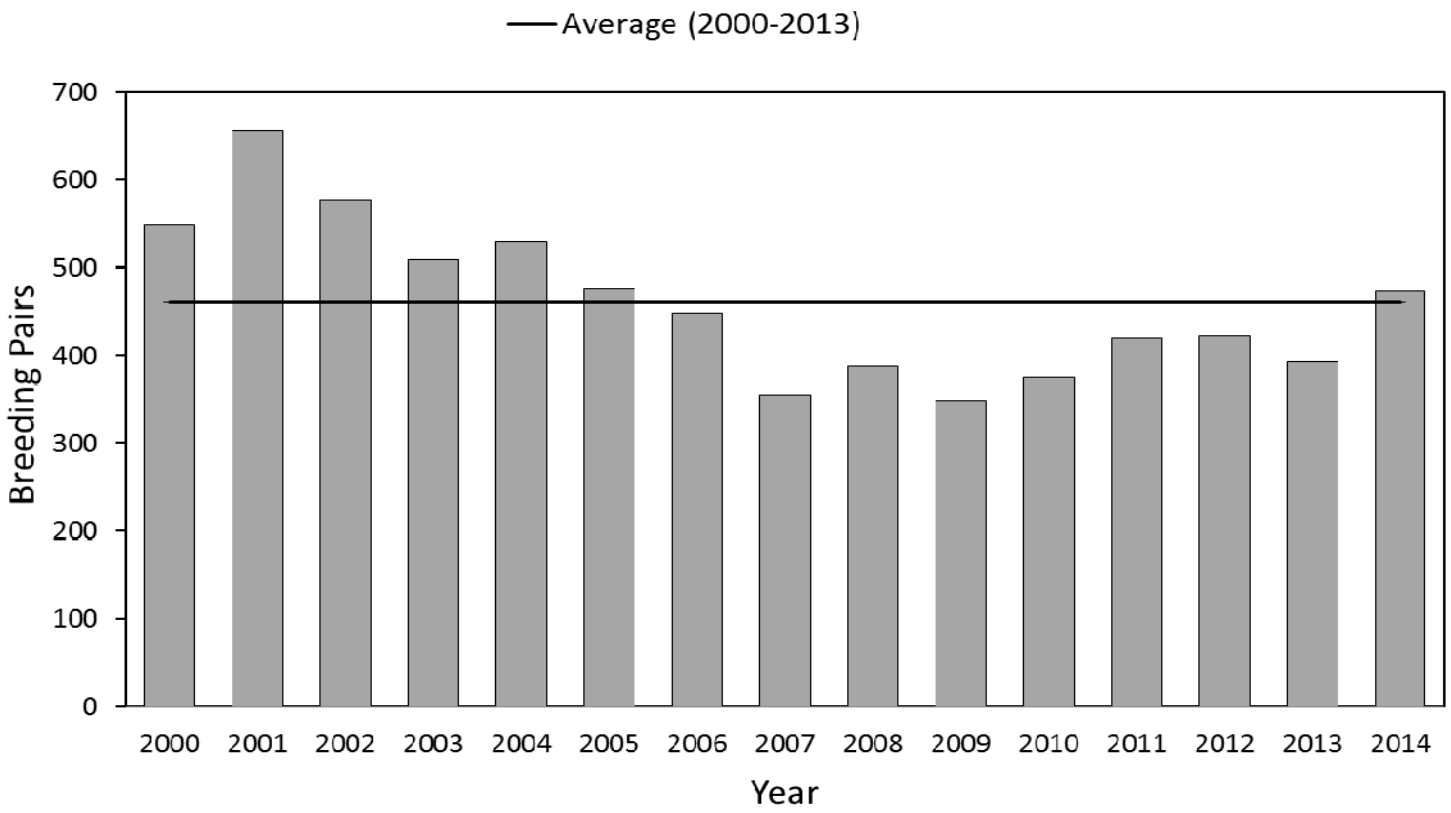


Figure 21. Size of the Caspian tern breeding colony (number of breeding pairs) on Crescent Island in the mid-Columbia River during 2000-2014.

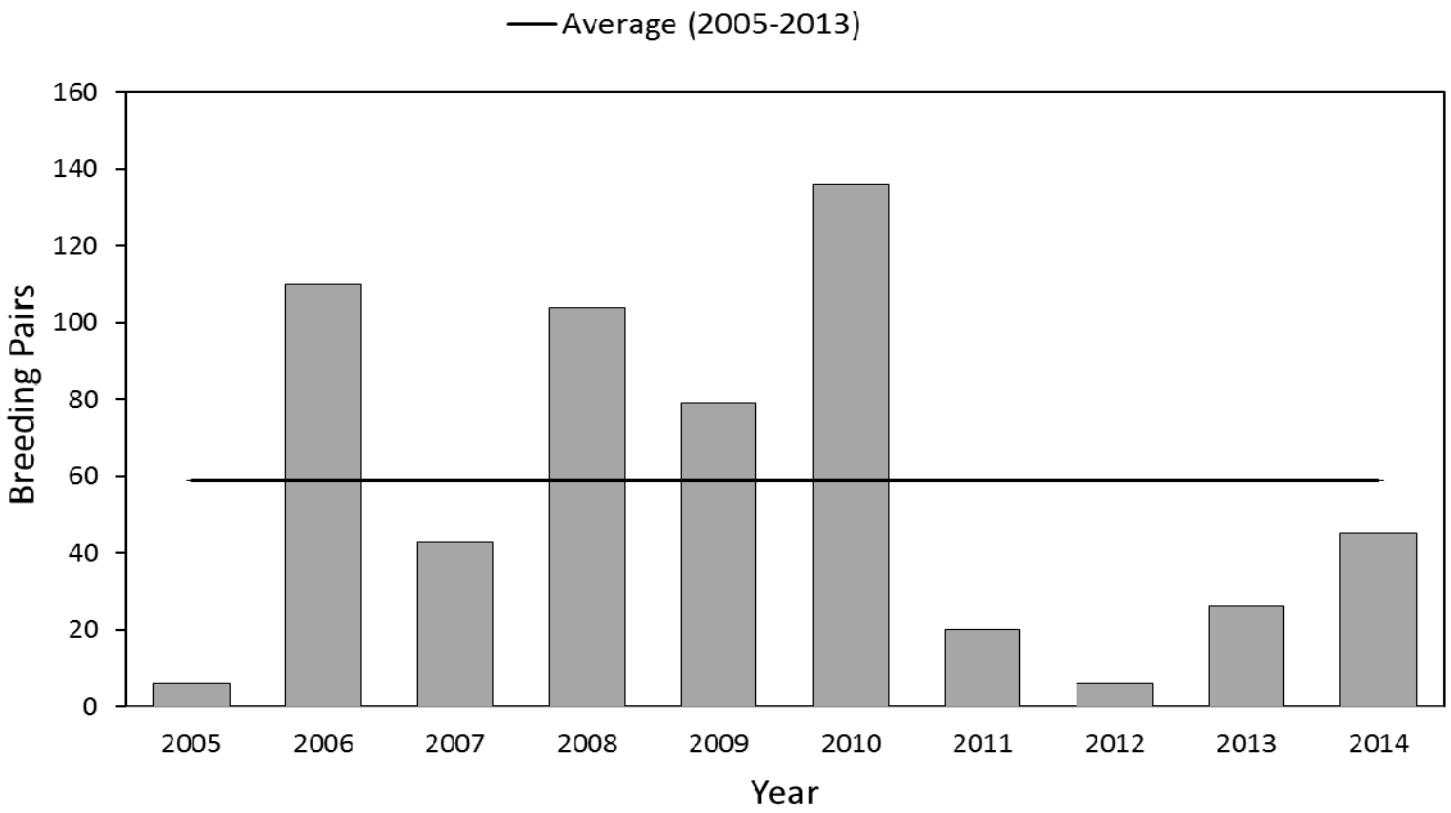


Figure 22. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock Islands in the mid-Columbia River during 2005-2014.

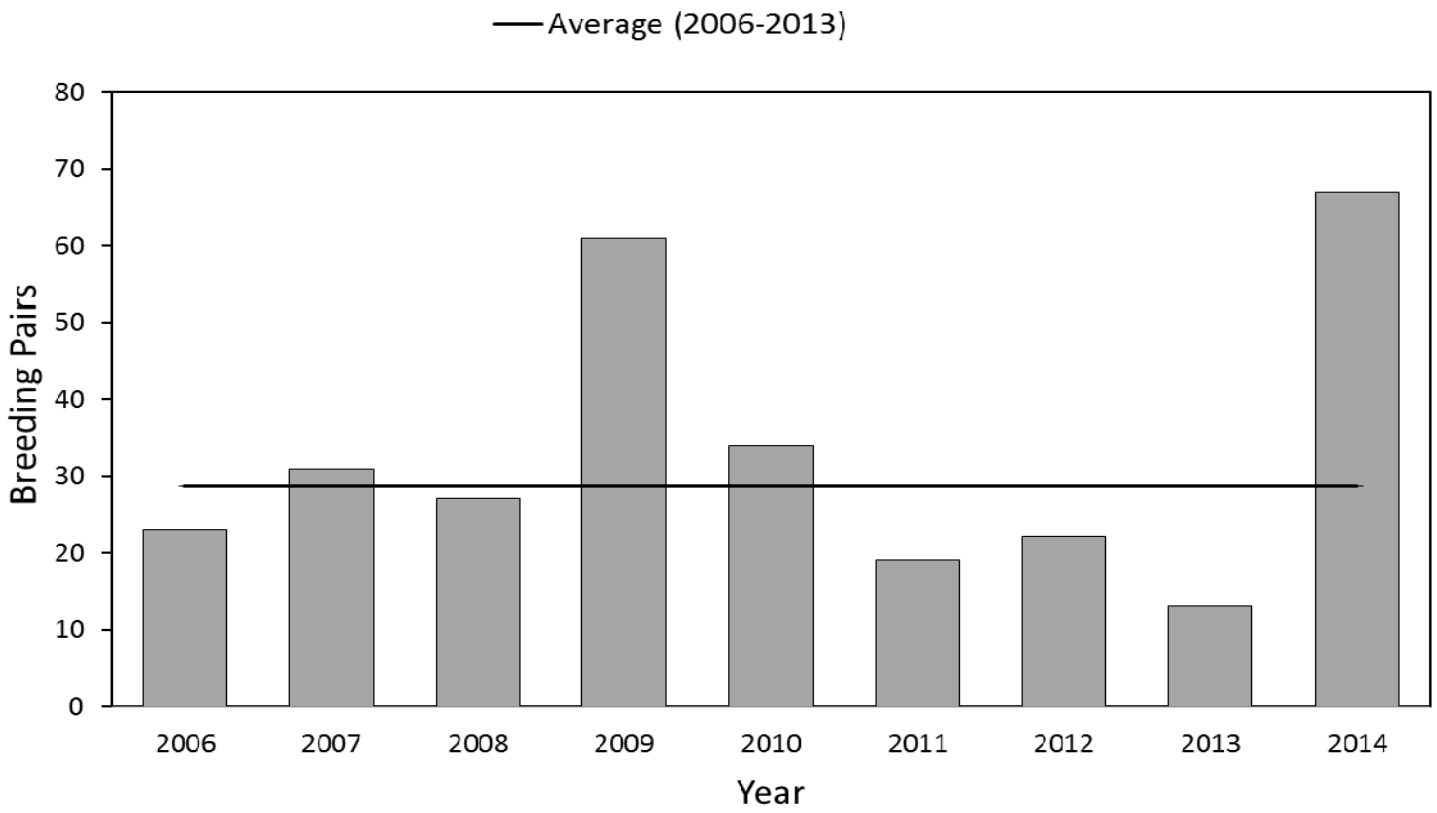


Figure 23. Size of the Caspian tern breeding colony (number of breeding pairs) at Twinning Island in Banks Lake during 2006-2014. In 2005, Caspian terns nested on two islands in Banks Lake (Twinning and Goose islands), and colony size was estimated to be less than 10 breeding pairs at each site.

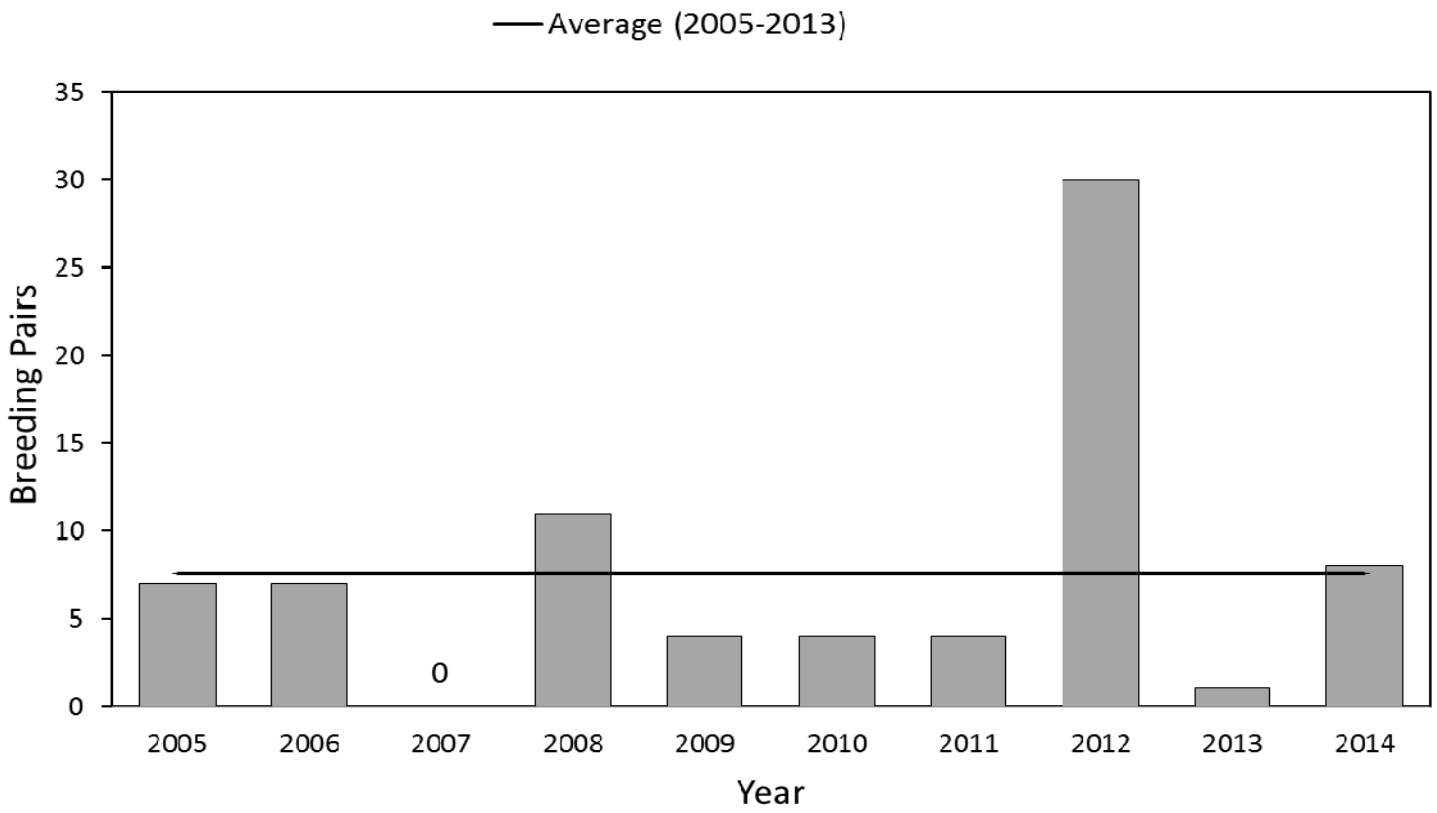


Figure 24. Size of the Caspian tern breeding colony (number of breeding pairs) at Harper Island in Sprague Lake during 2005-2014. Caspian terns did not attempt to nest on Harper Island in 2007.

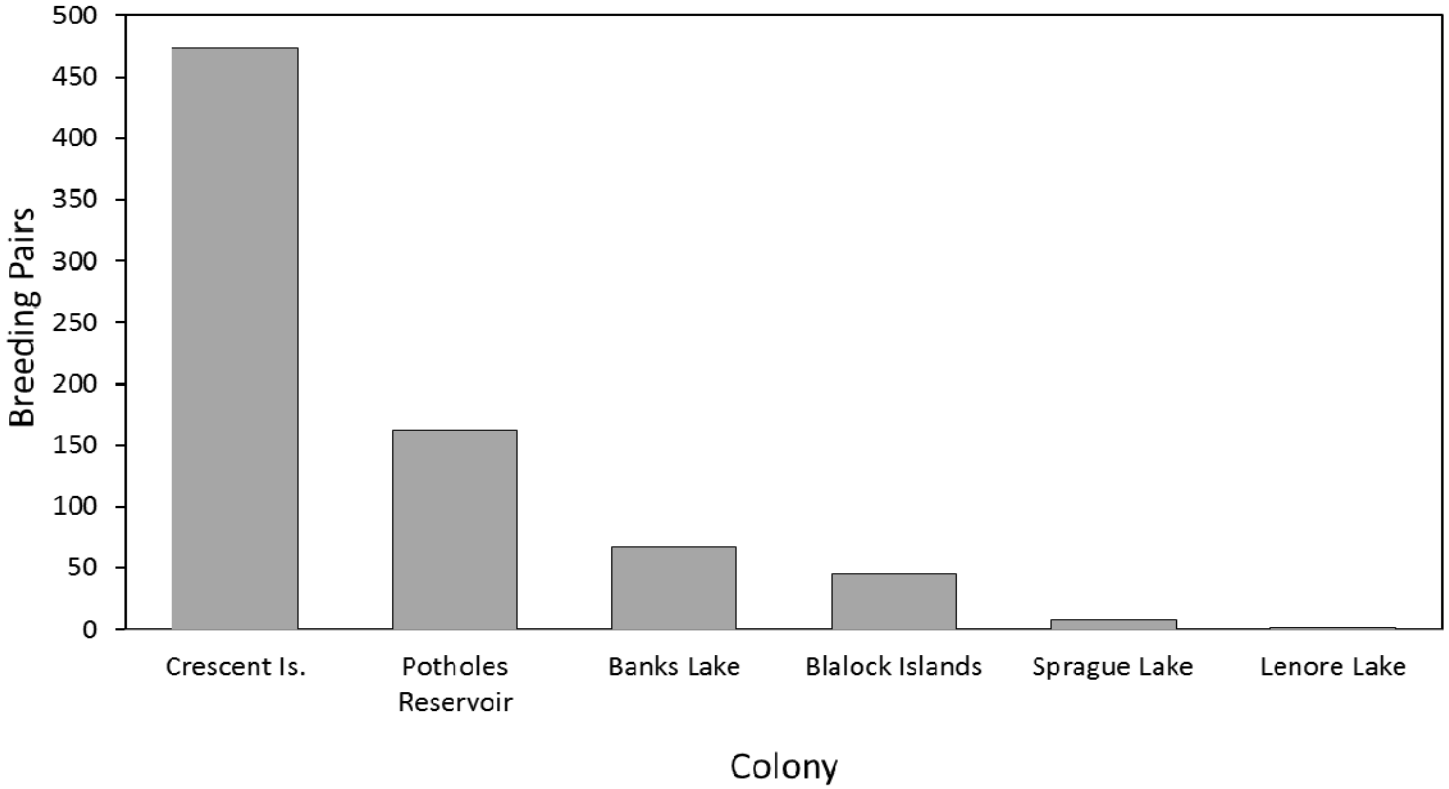


Figure 25. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the Columbia Plateau region during the 2014 breeding season.

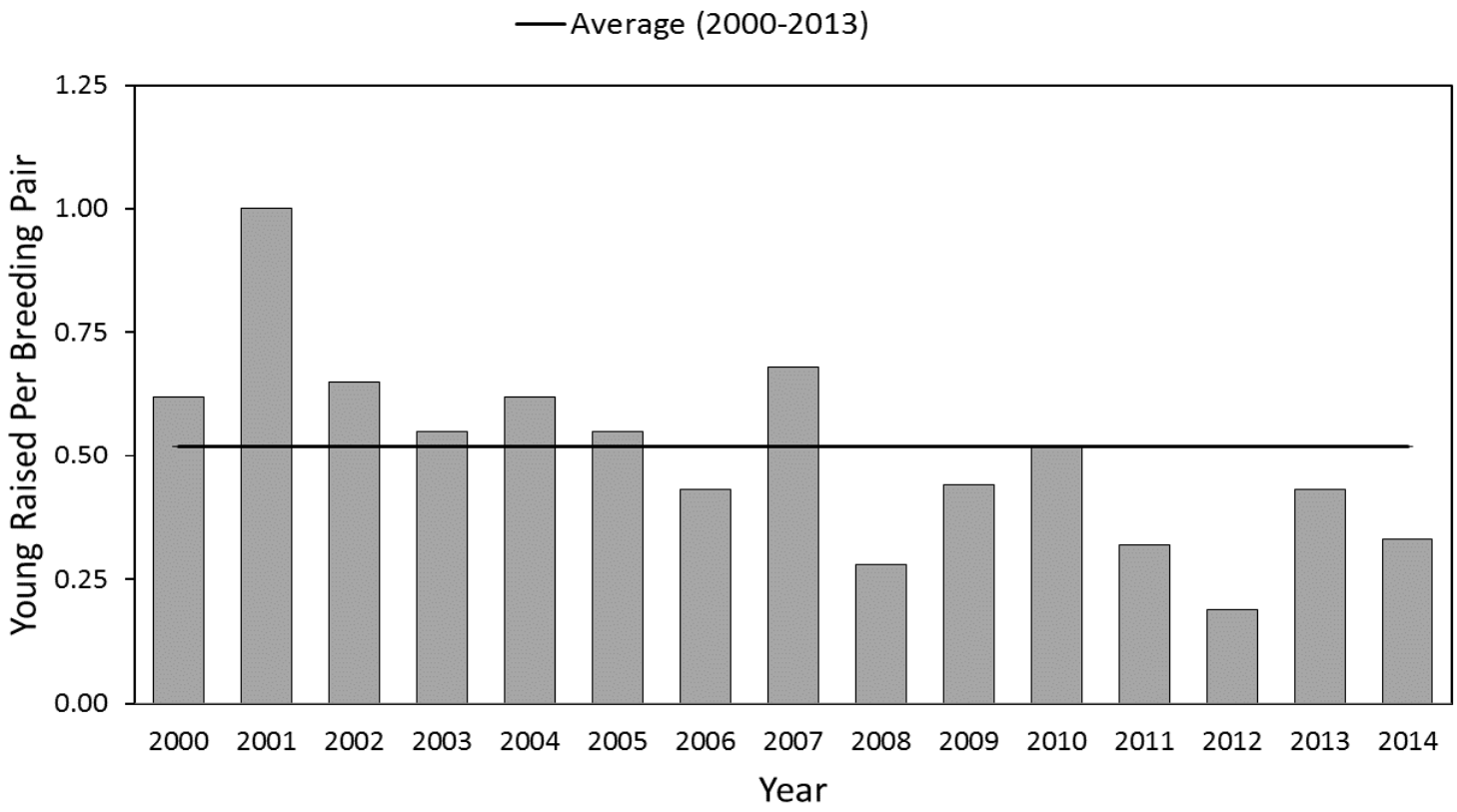


Figure 26. Nesting success of Caspian terns (average number of young raised per breeding pair) at the breeding colony on Crescent Island in the mid-Columbia River during 2000-2014.

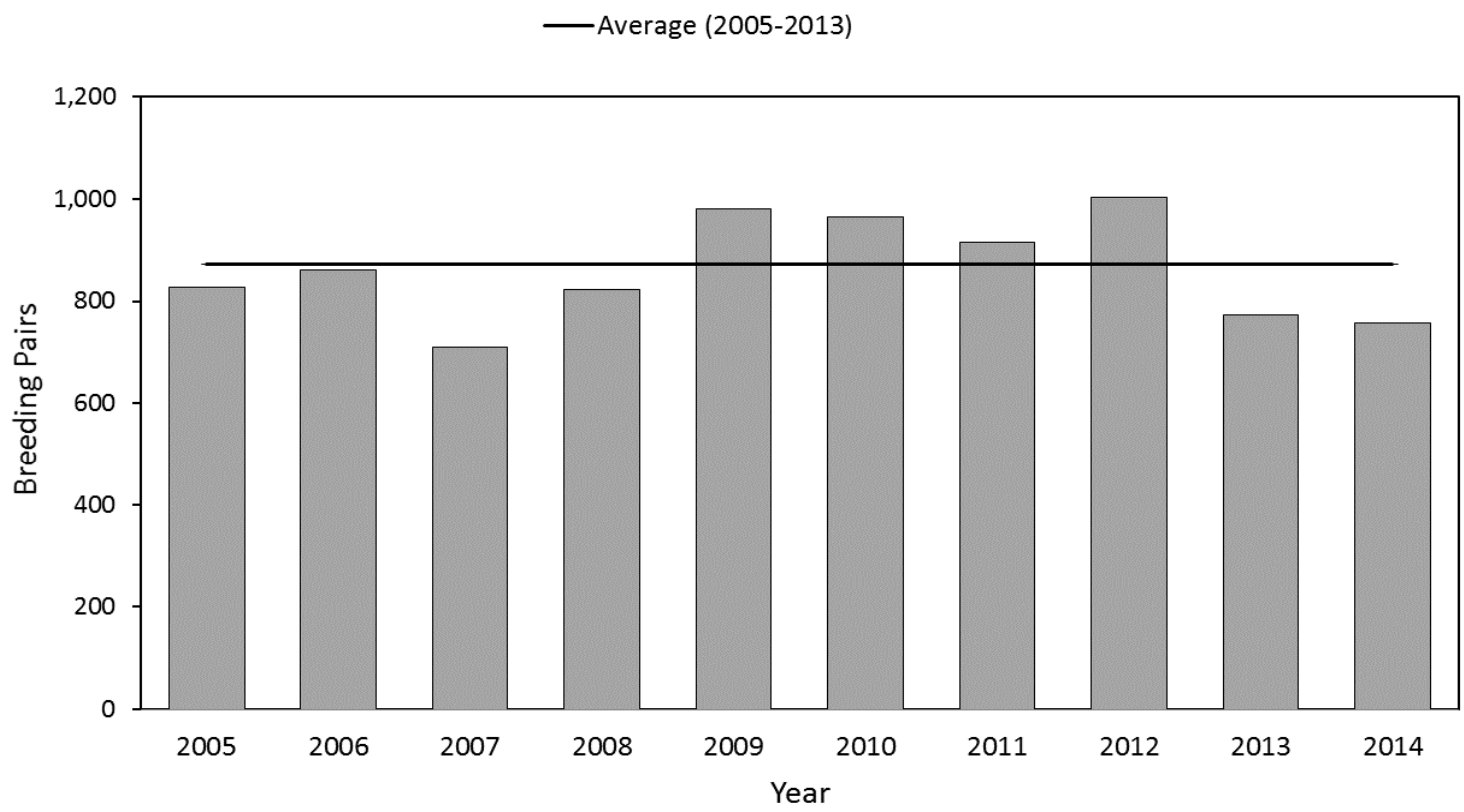


Figure 27. Total numbers of Caspian tern breeding pairs nesting at all known colonies in the Columbia Plateau region during 2005-2014.

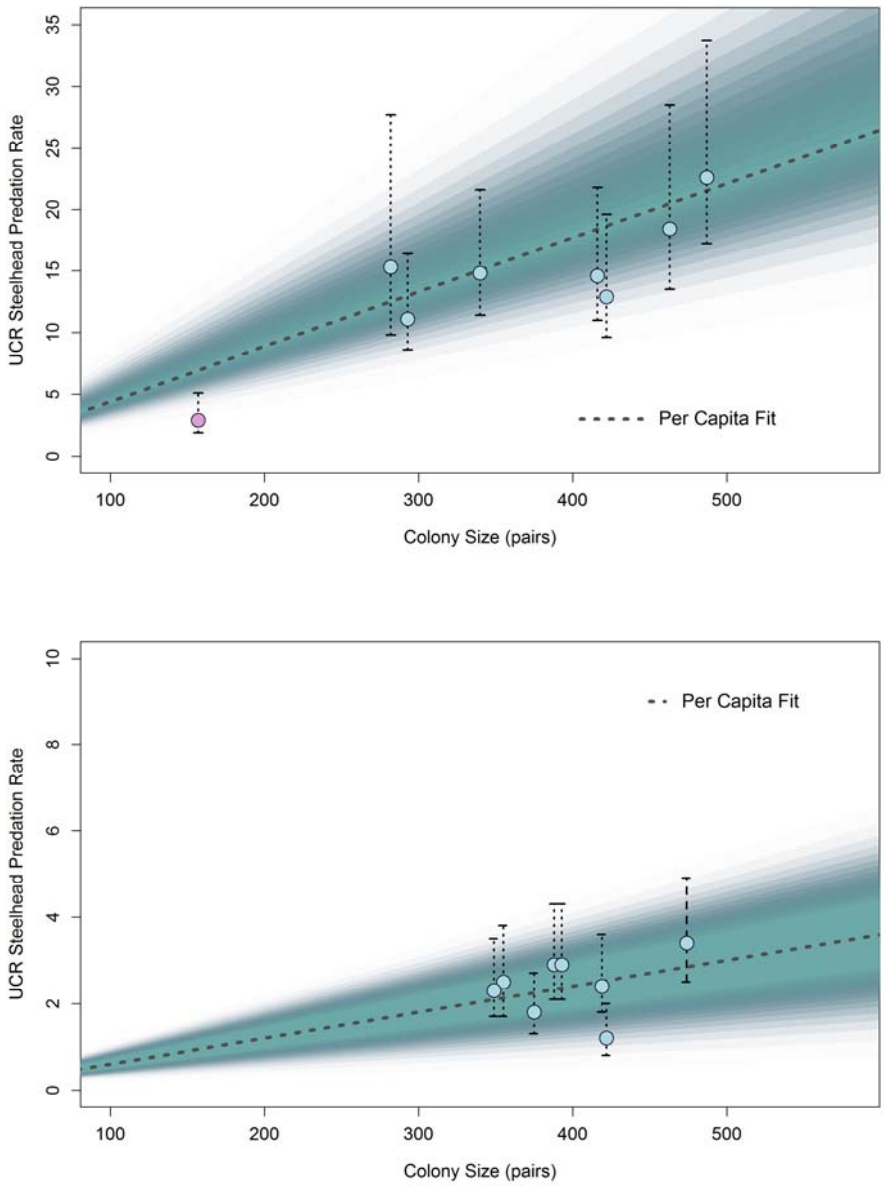


Figure 28. Predation rates (%) on Upper Columbia River (UCR) steelhead by Caspian terns as a function of colony size for the tern colonies at Potholes Reservoir (upper graph) and Crescent Island (lower graph) during 2007-2014. The dotted line represents the best fit per capita (per bird) relationship, with 95% prediction intervals. The pink dot is based on empirical data collected on Northwest Rocks, Potholes Reservoir in 2014, representing the post-management predation rate on UCR steelhead by Caspian terns nesting at Potholes reservoir.

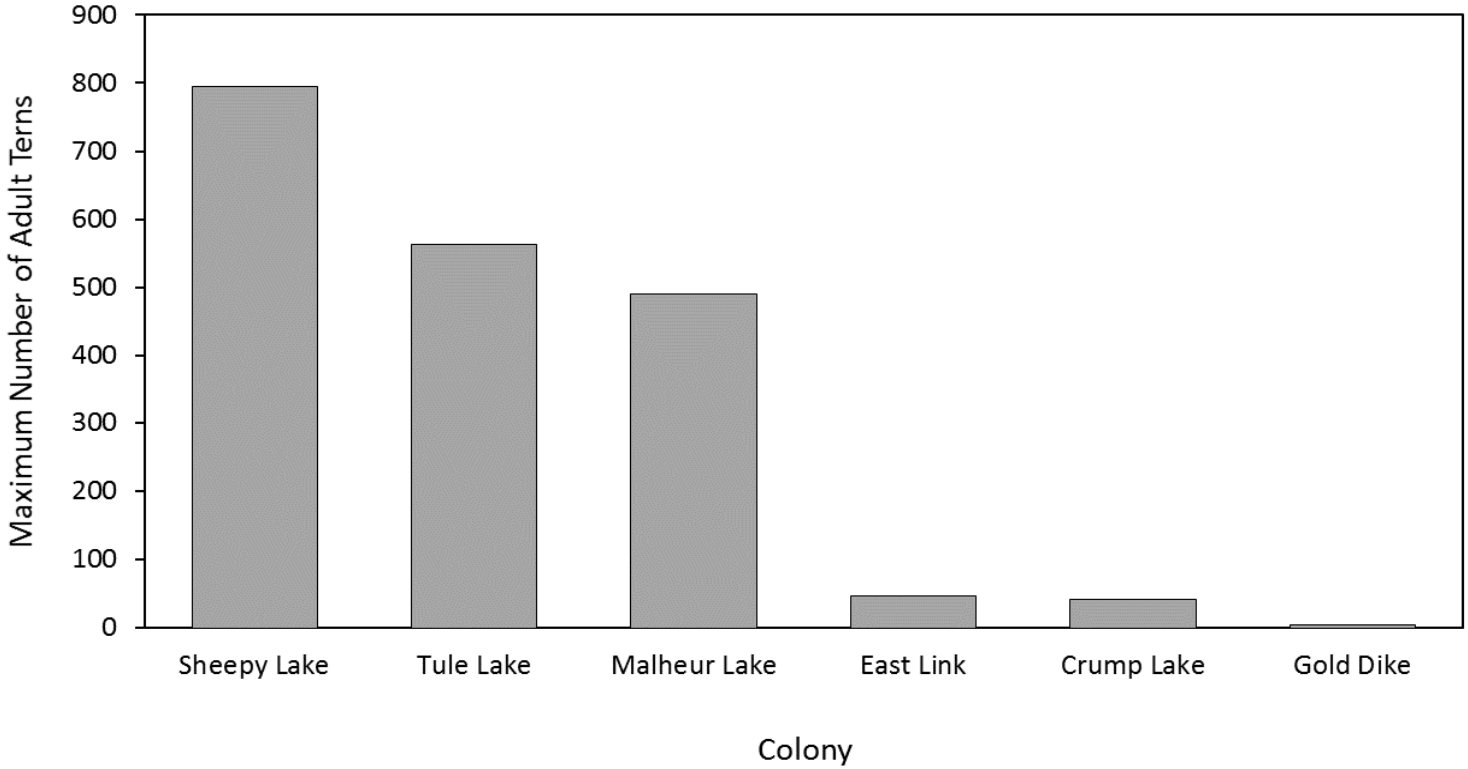


Figure 29. Maximum number of adult Caspian terns counted during the 2014 nesting season on Corps-constructed tern islands in interior Oregon and northeastern California. The Corps-constructed tern islands at Fern Ridge Reservoir and at Orems Unit in Lower Klamath National Wildlife Refuge were not monitored during 2013-2014.

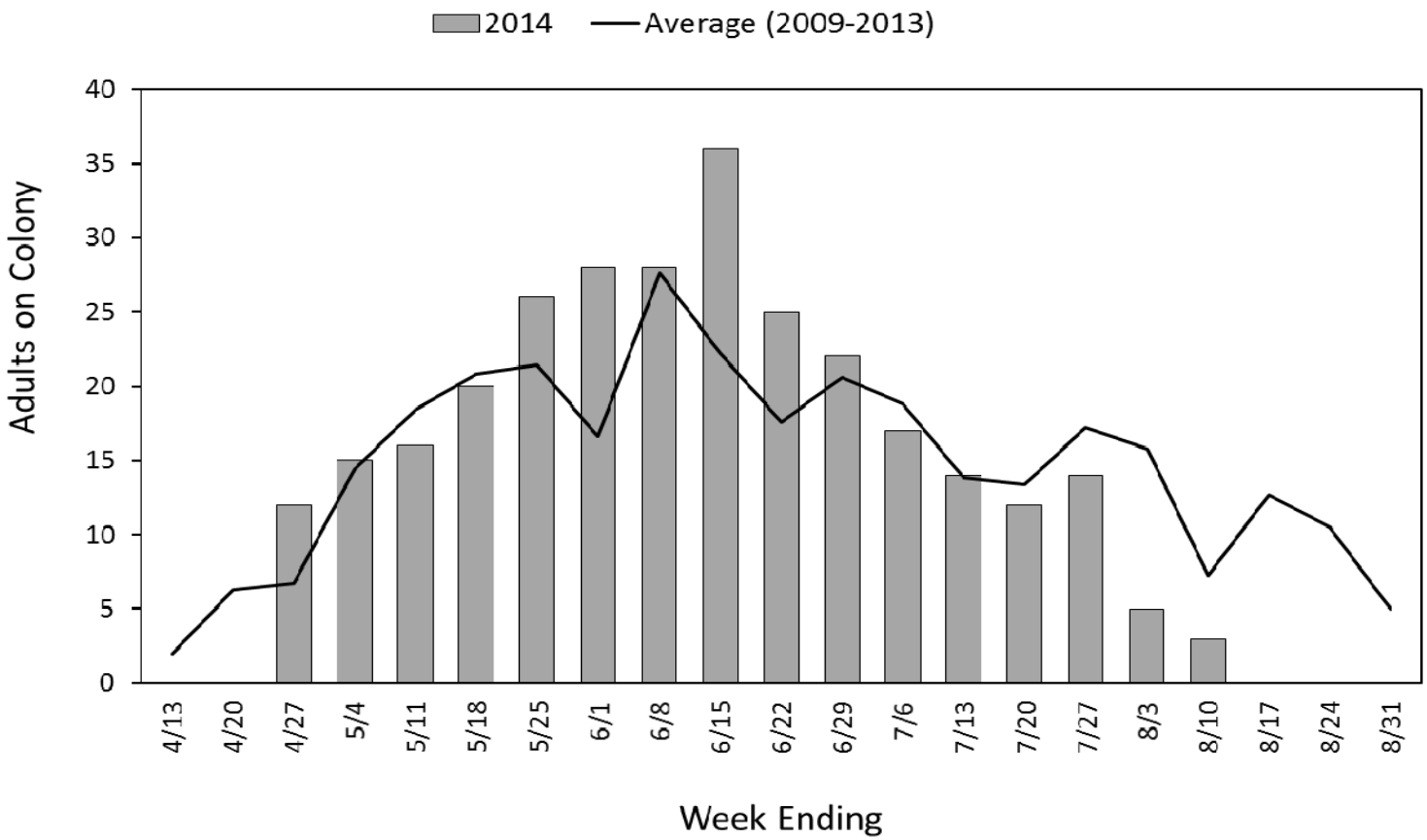


Figure 30. Estimates from the ground of the total number of adult Caspian terns on the Corps-constructed islands in East Link Impoundment and Gold Dike Impoundment at Summer Lake Wildlife Area, Oregon, by week during the 2014 breeding season.

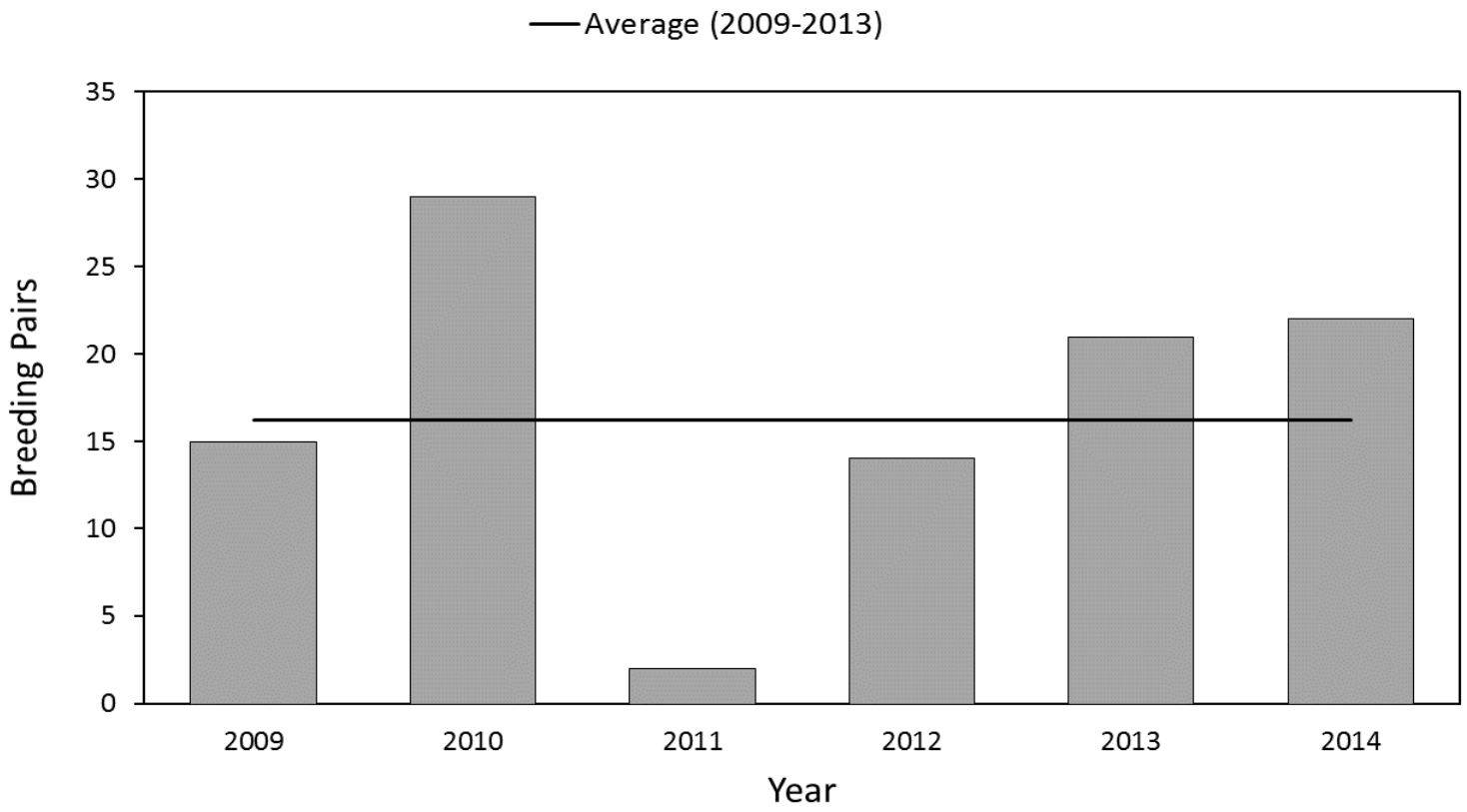


Figure 31. Total size of Caspian tern breeding colonies (number of breeding pairs) on Corps-constructed tern islands in East Link Impoundment, Gold Dike Impoundment, and Dutchy Lake at Summer Lake Wildlife Area, Oregon, during the 2009-2014 breeding seasons. Caspian terns did not nest on the Dutchy Lake tern island during 2010-2012, and the island was removed prior to the 2013 nesting season.

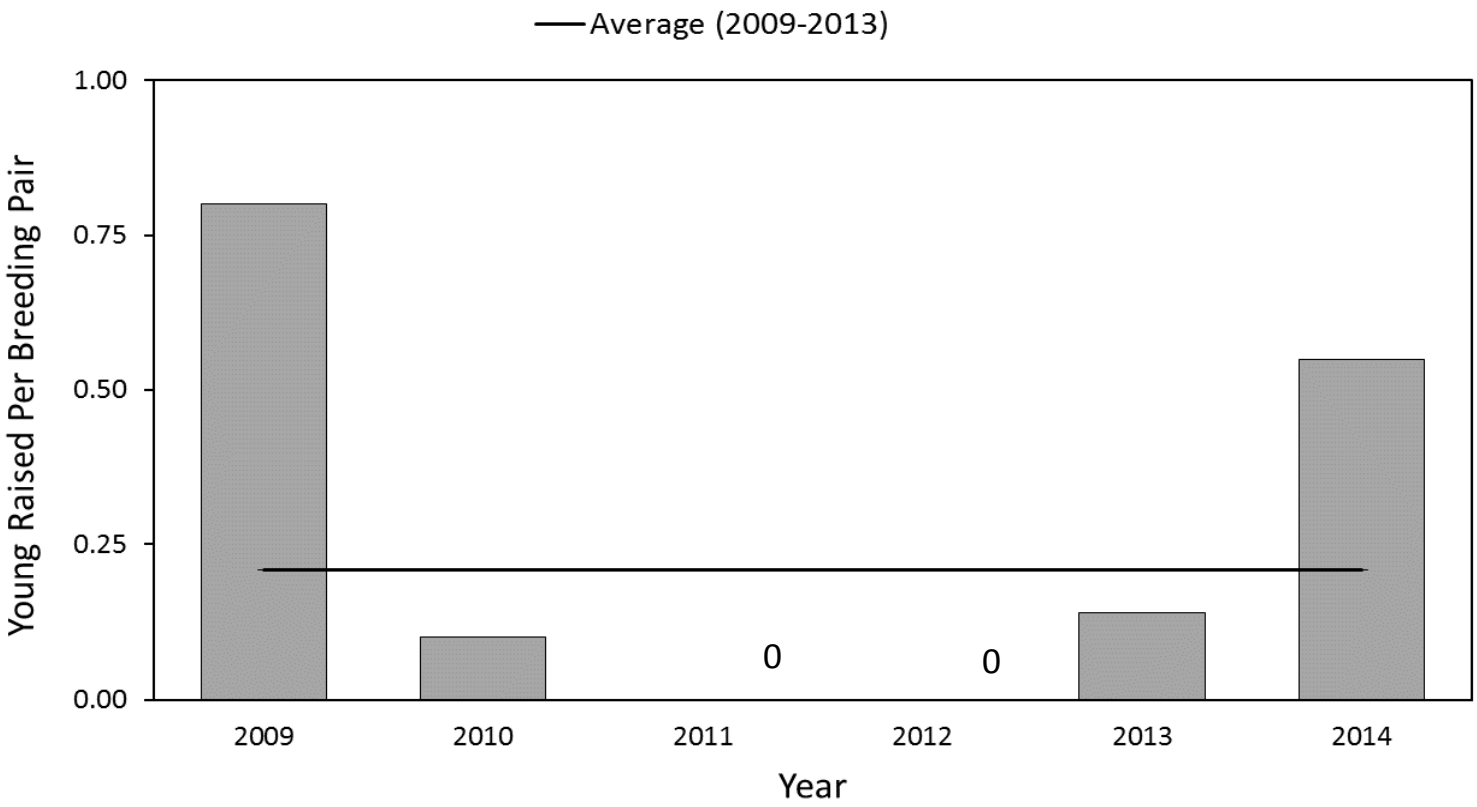


Figure 32. Caspian tern nesting success (average number of young raised per breeding pair) at Corps-constructed tern islands in Summer Lake Wildlife Area (i.e., tern islands in East Link Impoundment, Gold Dike Impoundment, and Dutchy Lake), Oregon, during 2009-2014. Caspian terns did not nest on the Dutchy Lake tern island during 2010-2012, and the island was removed prior to the 2013 nesting season. No young terns were fledged from the East Link tern island during 2011-2012 or the Gold Dike tern island during 2012-2014.

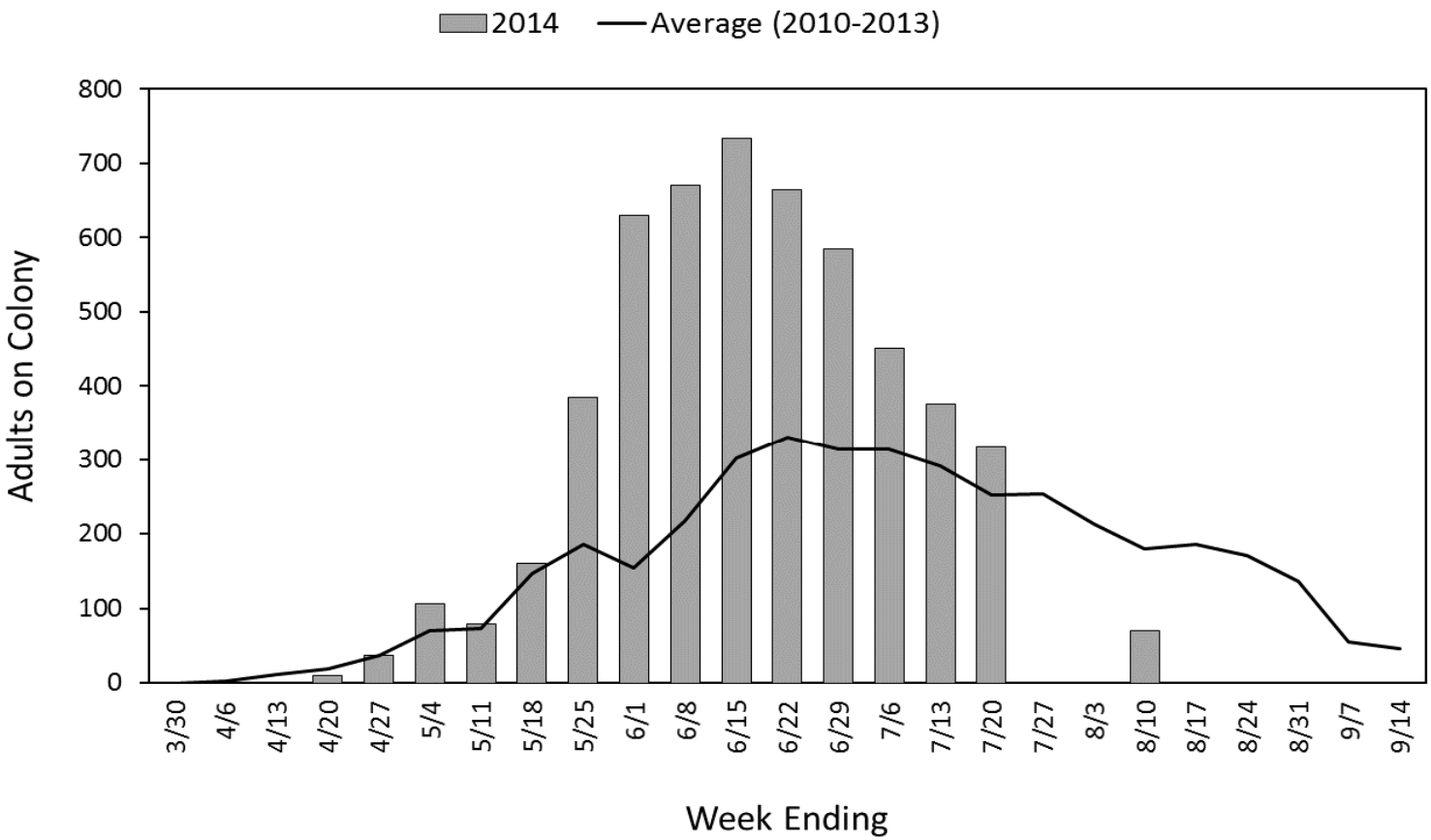


Figure 33. Estimates from the ground of the number of adult Caspian terns on the Corps-constructed tern island at Sheepy Lake in Lower Klamath National Wildlife Refuge, California, by week during the 2014 breeding season.

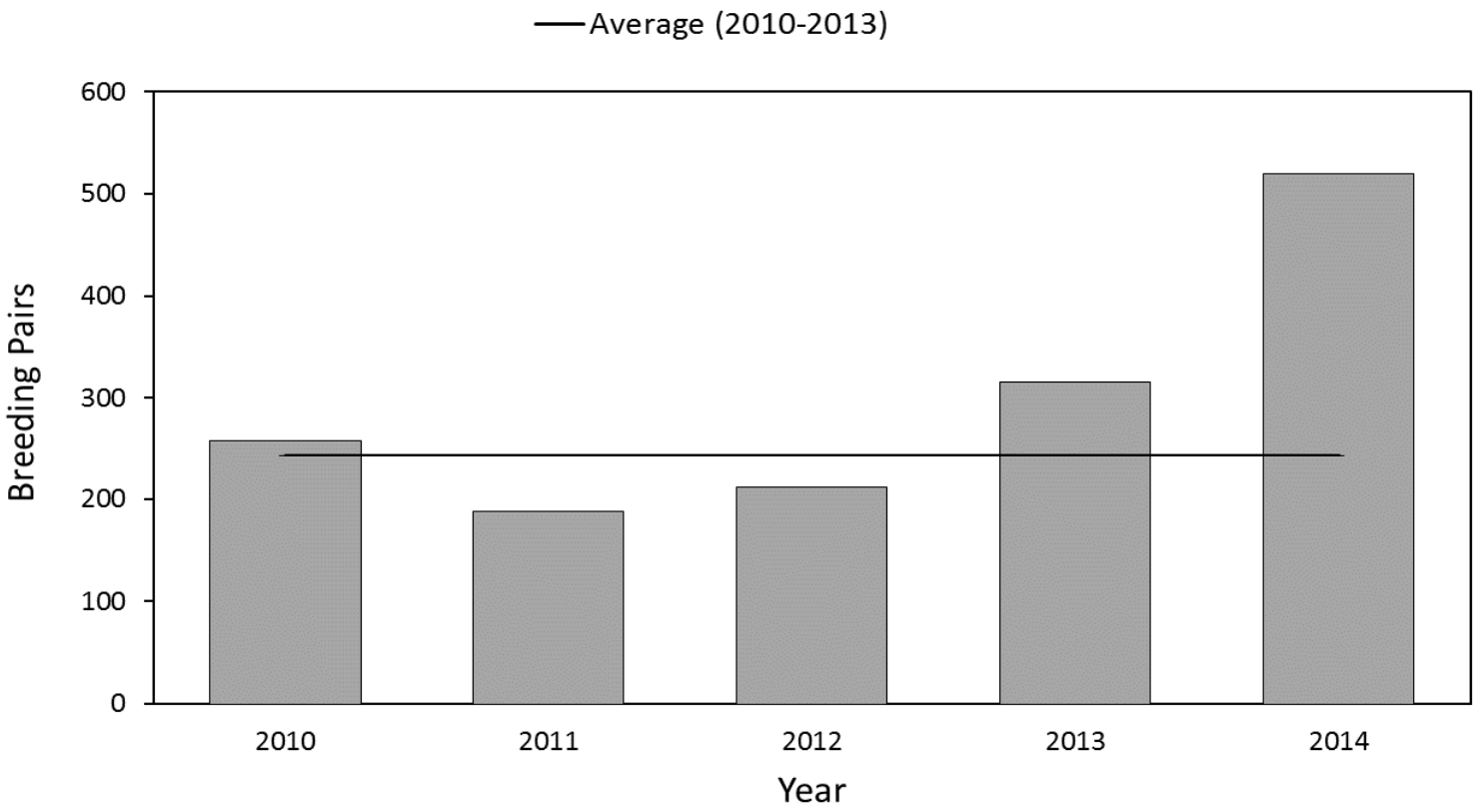


Figure 34. Size of the Caspian tern breeding colony (number of breeding pairs) on the Corps-constructed tern island at Sheepy Lake in Lower Klamath National Wildlife Refuge, California, during the 2010-2014 breeding seasons.

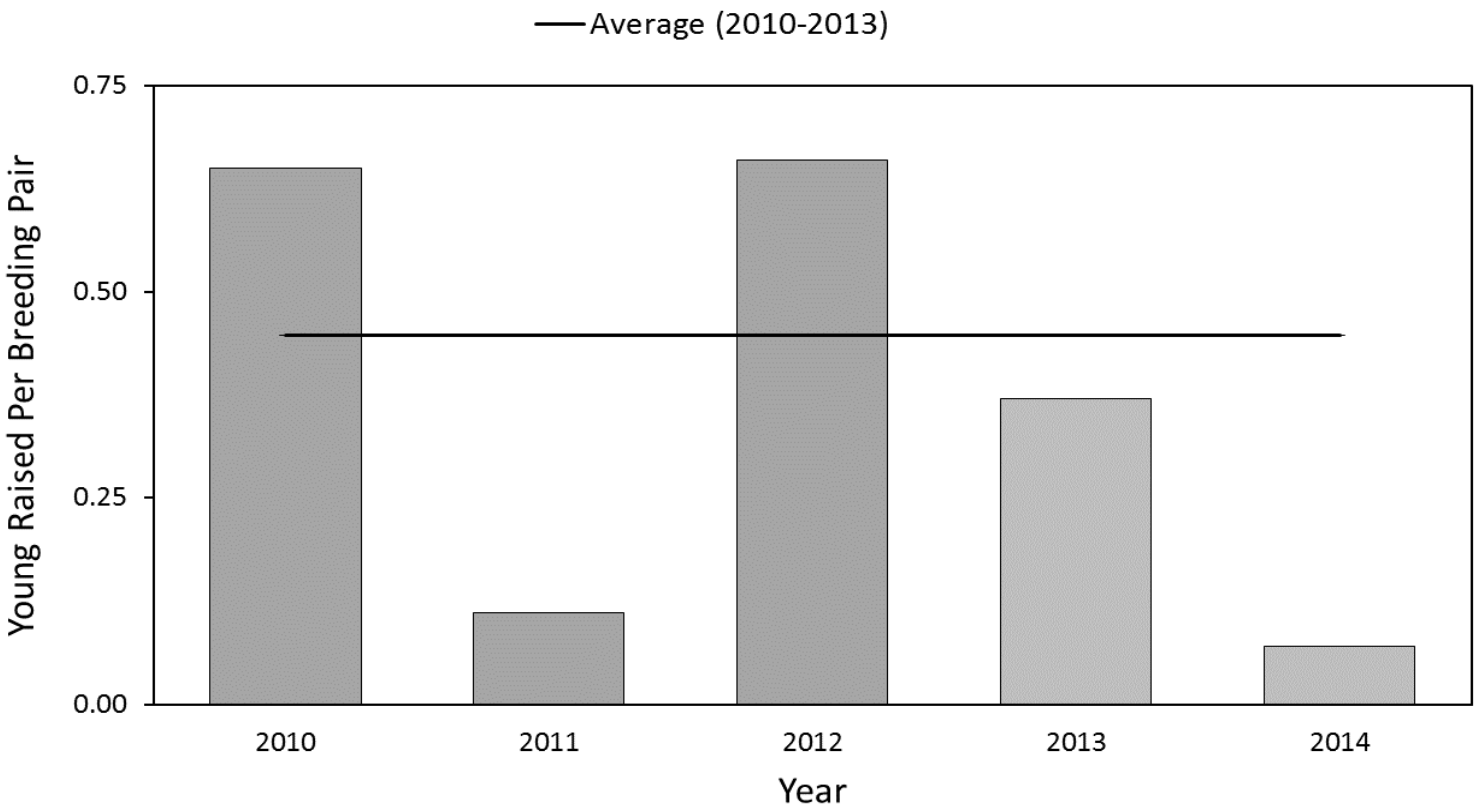


Figure 35. Caspian tern nesting success (average number of young raised per breeding pair) on the Corps-constructed tern island at Sheepy Lake in Lower Klamath National Wildlife Refuge, California, during 2010-2014.

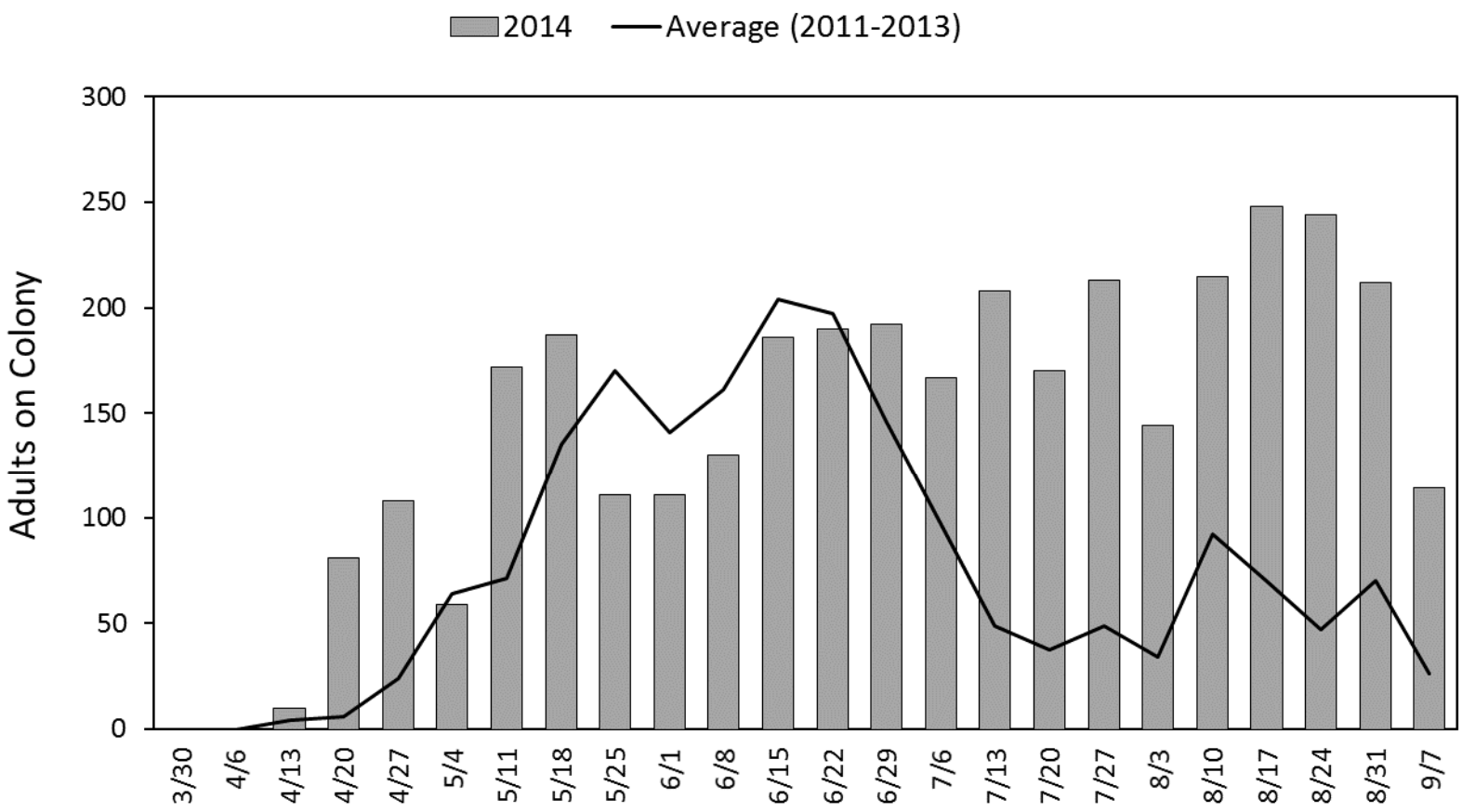


Figure 36. Estimates from the ground of the number of adult Caspian terns on the Corps-constructed tern island at Tule Lake Sump 1B in Tule Lake National Wildlife Refuge, California, by week during the 2014 breeding season.

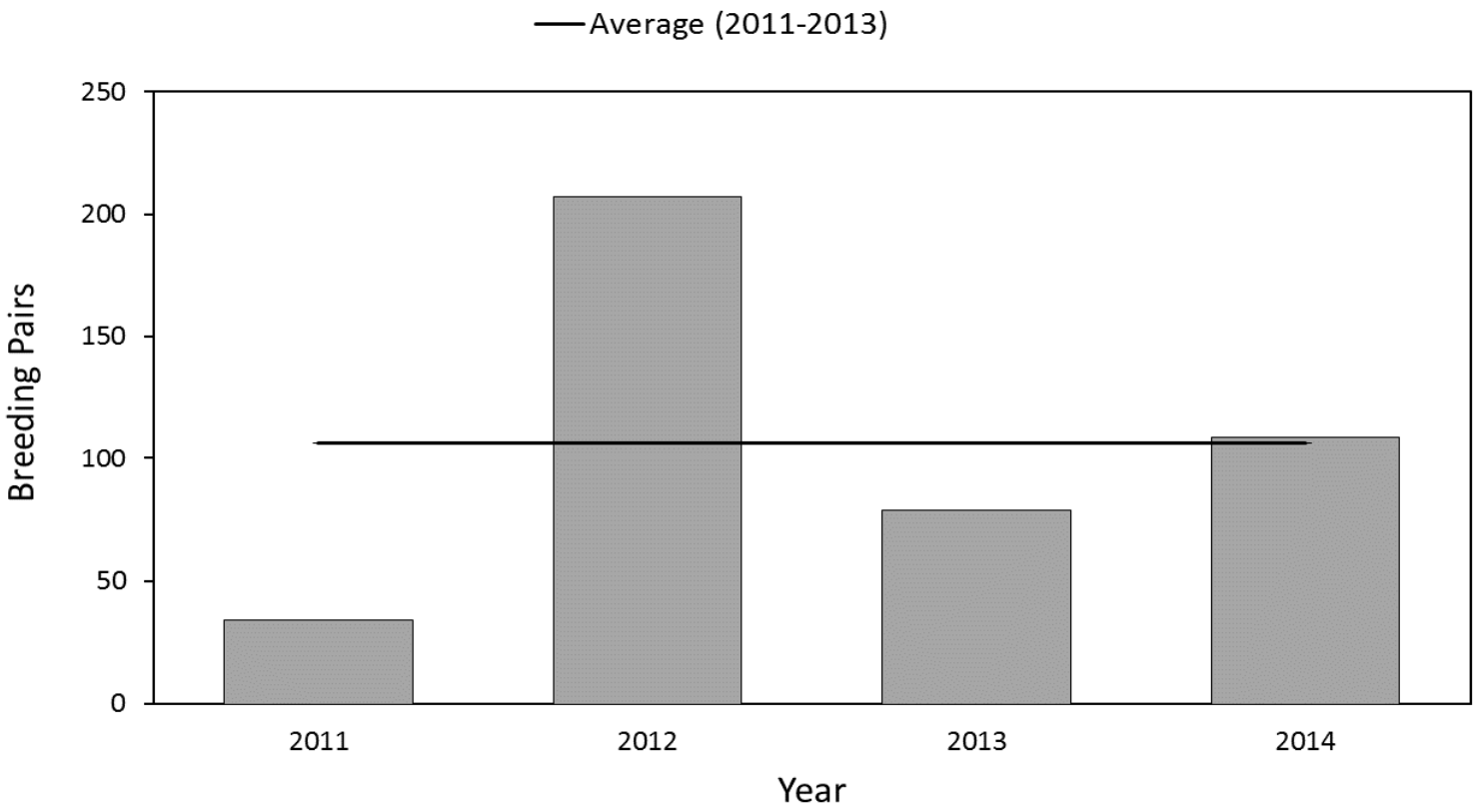


Figure 37. Size of the Caspian tern breeding colony (number of breeding pairs) on the Corps-constructed tern island at Tule Lake Sump 1B in Tule Lake National Wildlife Refuge, California, during the 2011-2014 breeding seasons.

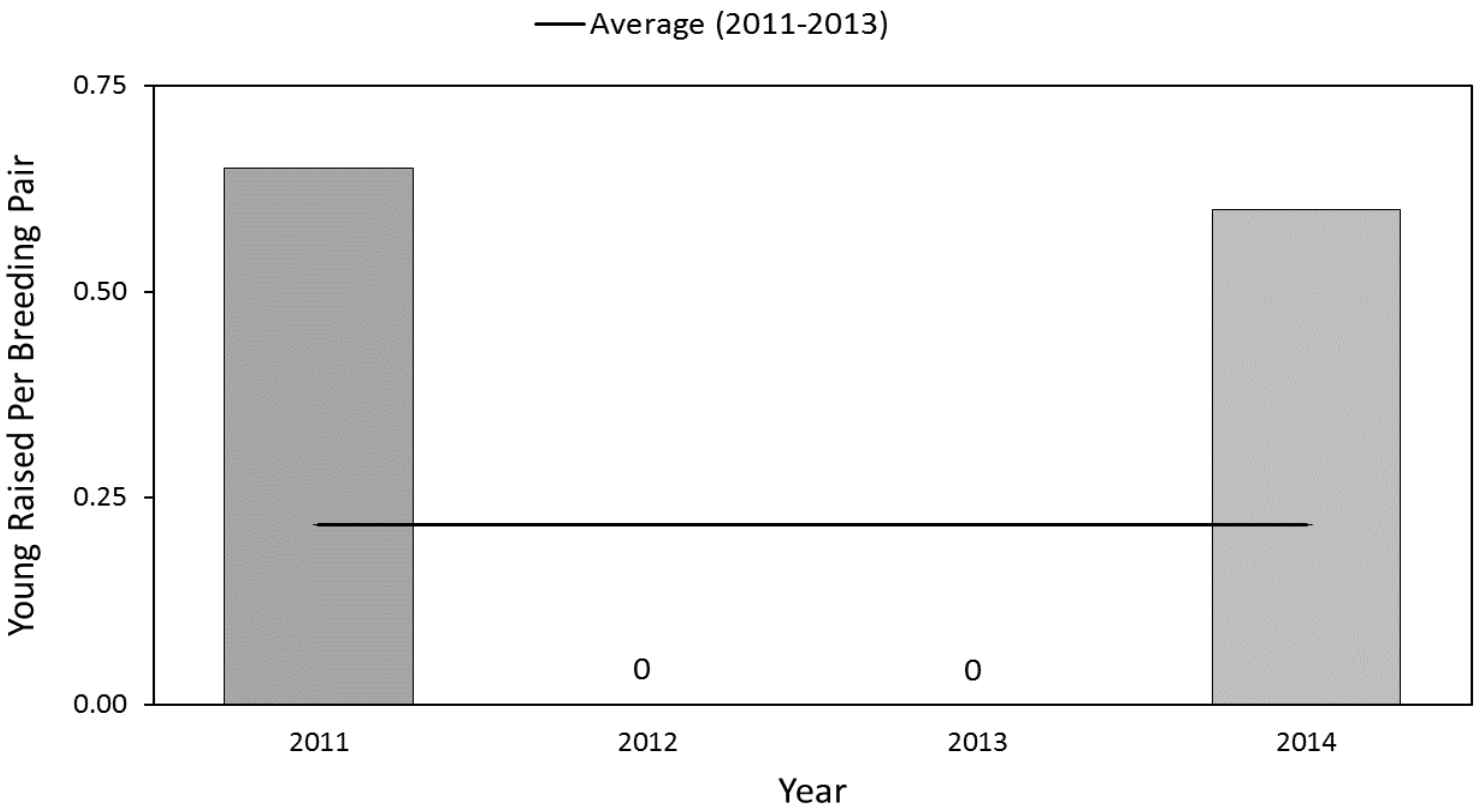


Figure 38. Caspian tern nesting success (average number of young raised per breeding pair) on the Corps-constructed tern island at Tule Lake Sump 1B in Tule Lake National Wildlife Refuge, California, during 2011-2014.

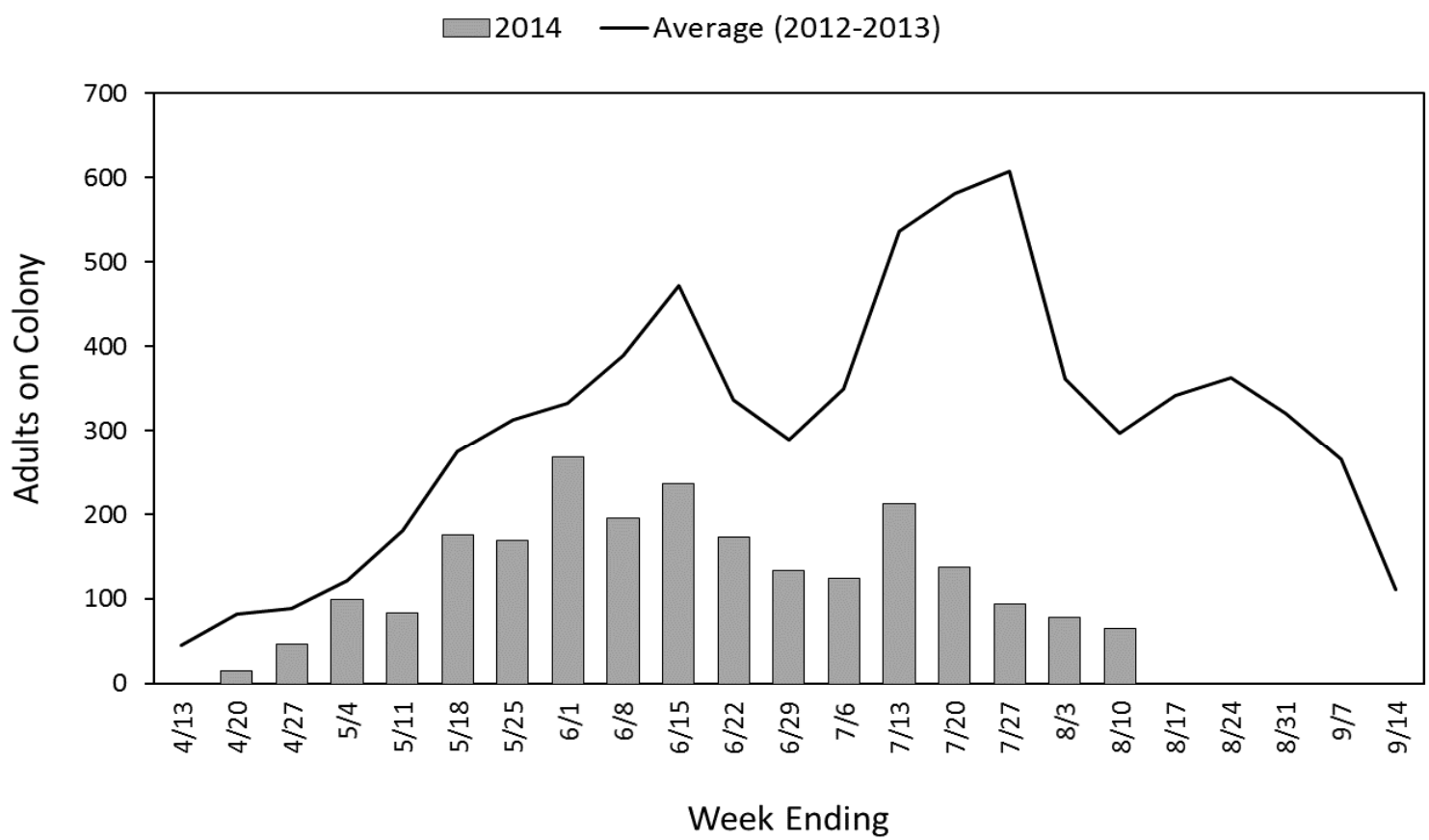


Figure 39. Estimates from the ground of the number of adult Caspian terns on the Corps-constructed tern island at Malheur Lake in Malheur National Wildlife Refuge, Oregon, by week during the 2014 breeding season.

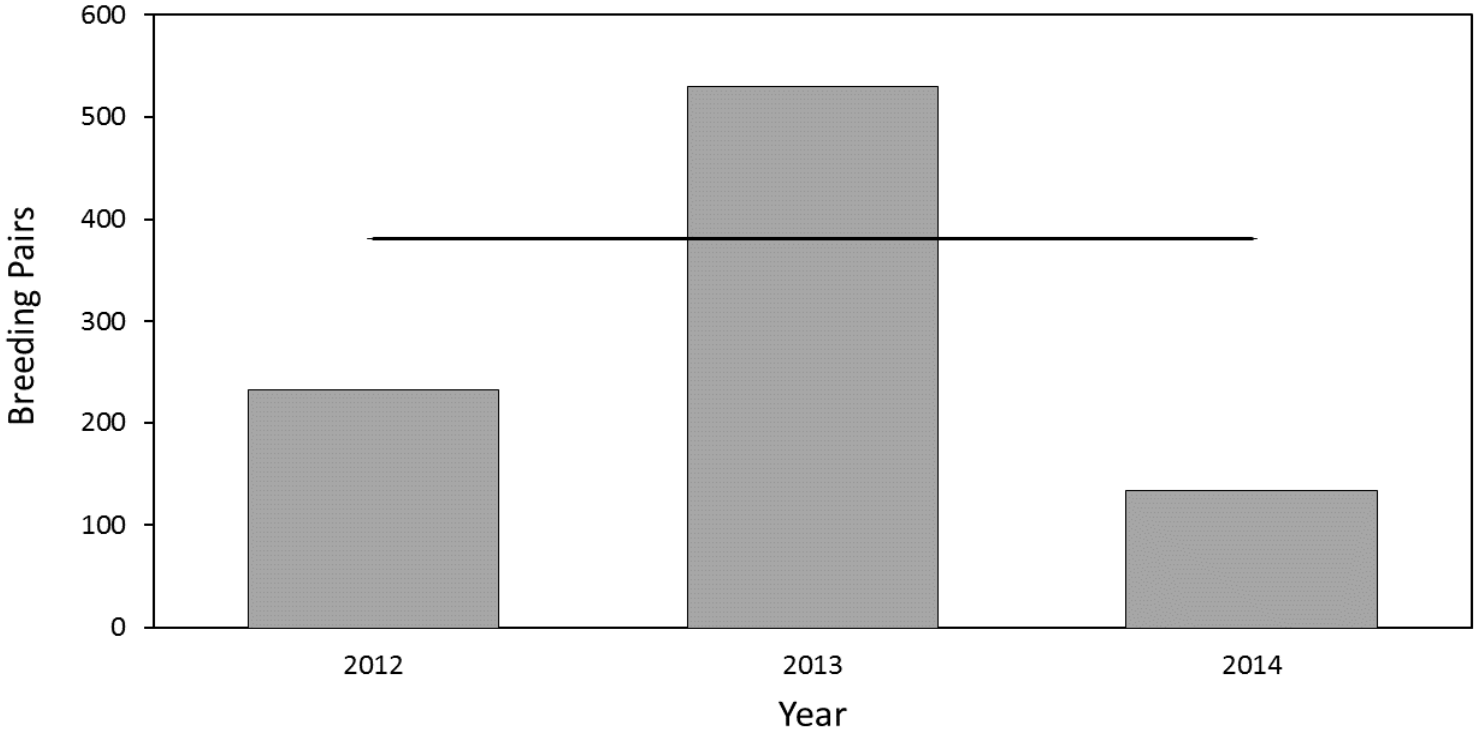


Figure 40. Size of the Caspian tern breeding colony (number of breeding pairs) on the Corps-constructed tern island at Malheur Lake in Malheur National Wildlife Refuge, Oregon, during the 2012-2014 breeding seasons.

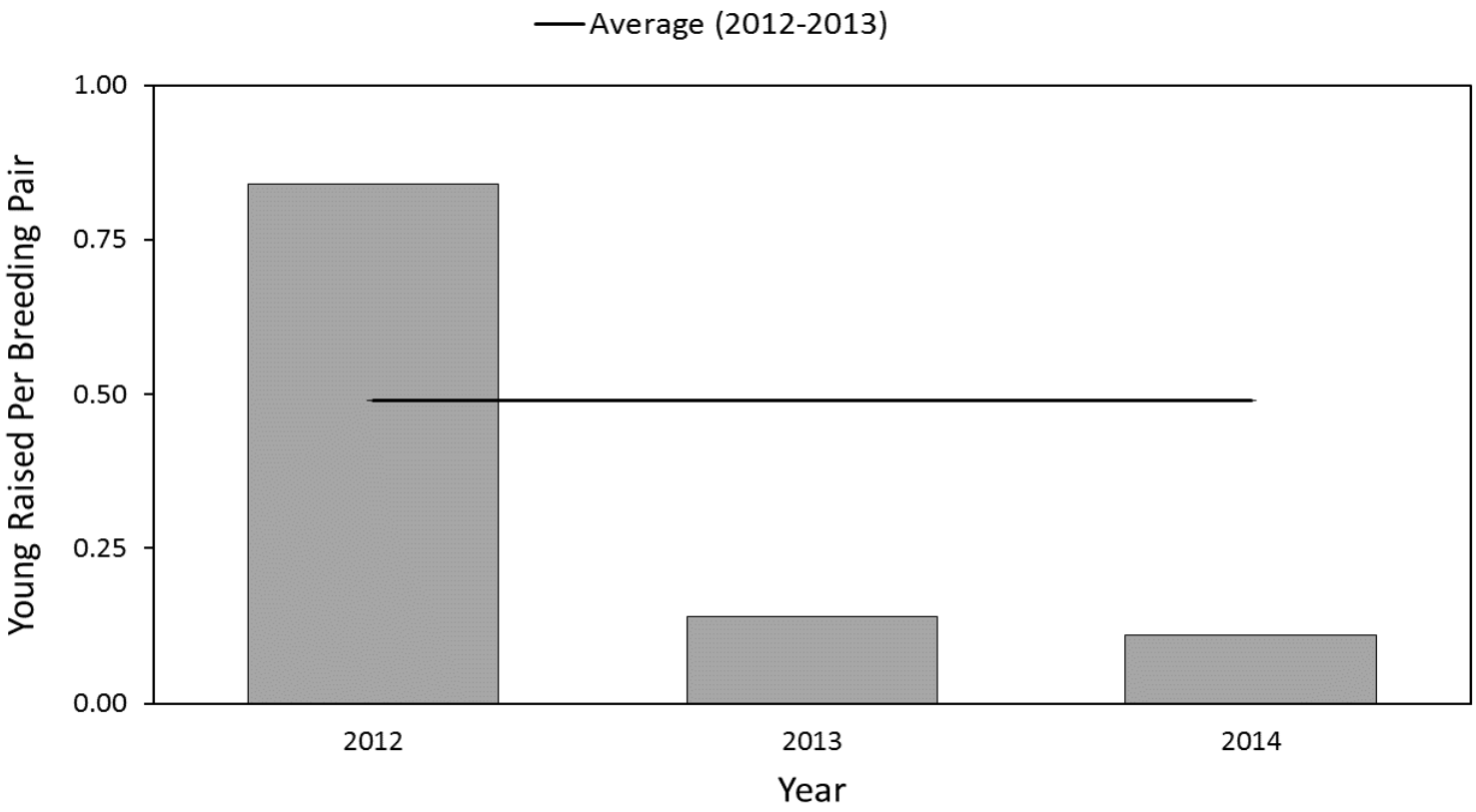


Figure 41. Caspian tern nesting success (average number of young raised per breeding pair) on the Corps-constructed tern island at Malheur Lake in Malheur National Wildlife Refuge, Oregon, during 2012-2014.

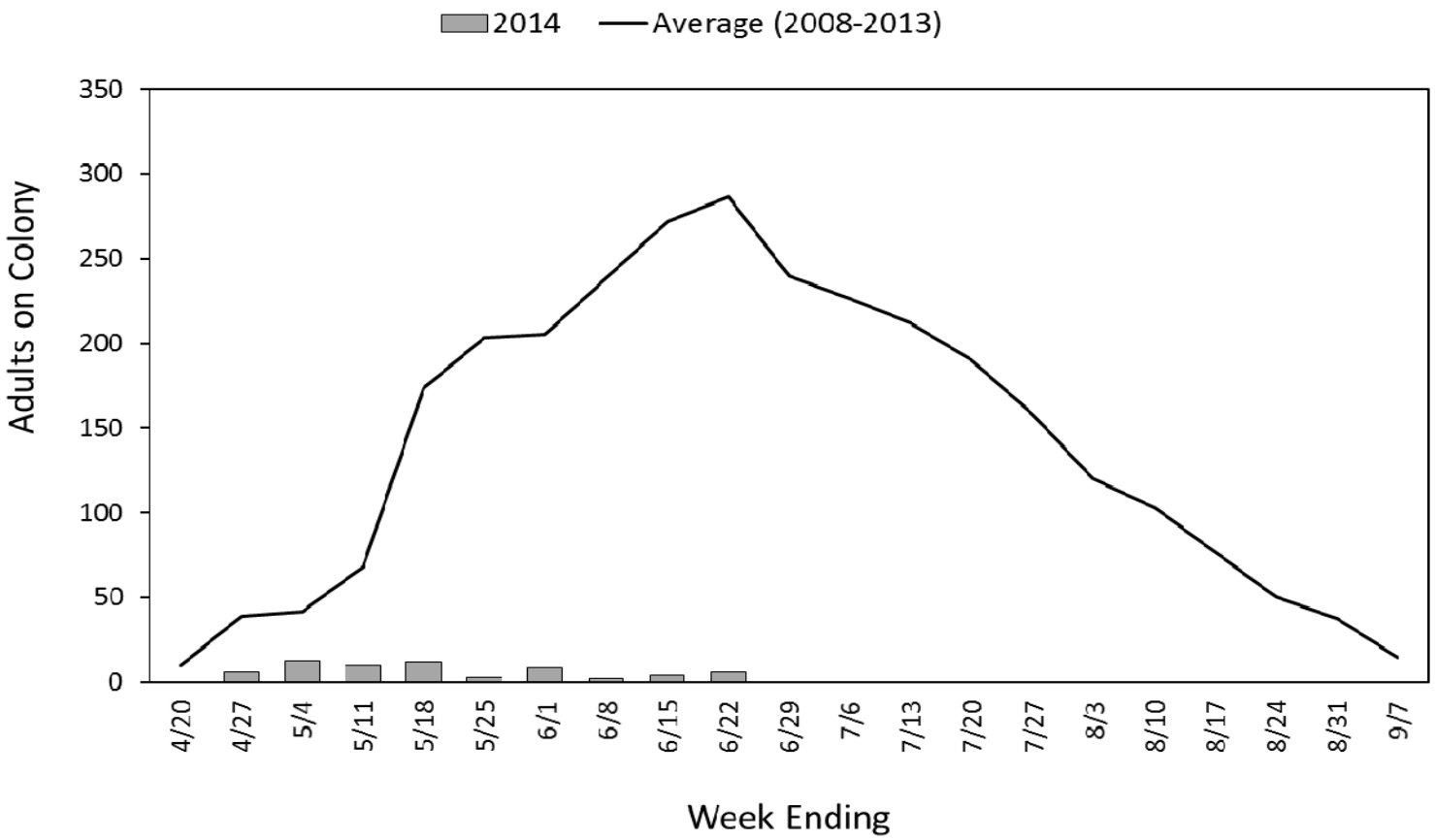


Figure 42. Estimates from the ground of the number of adult Caspian terns on the Corps-constructed tern island at Crump Lake in the Warner Valley, Oregon, by week during the 2014 breeding season.

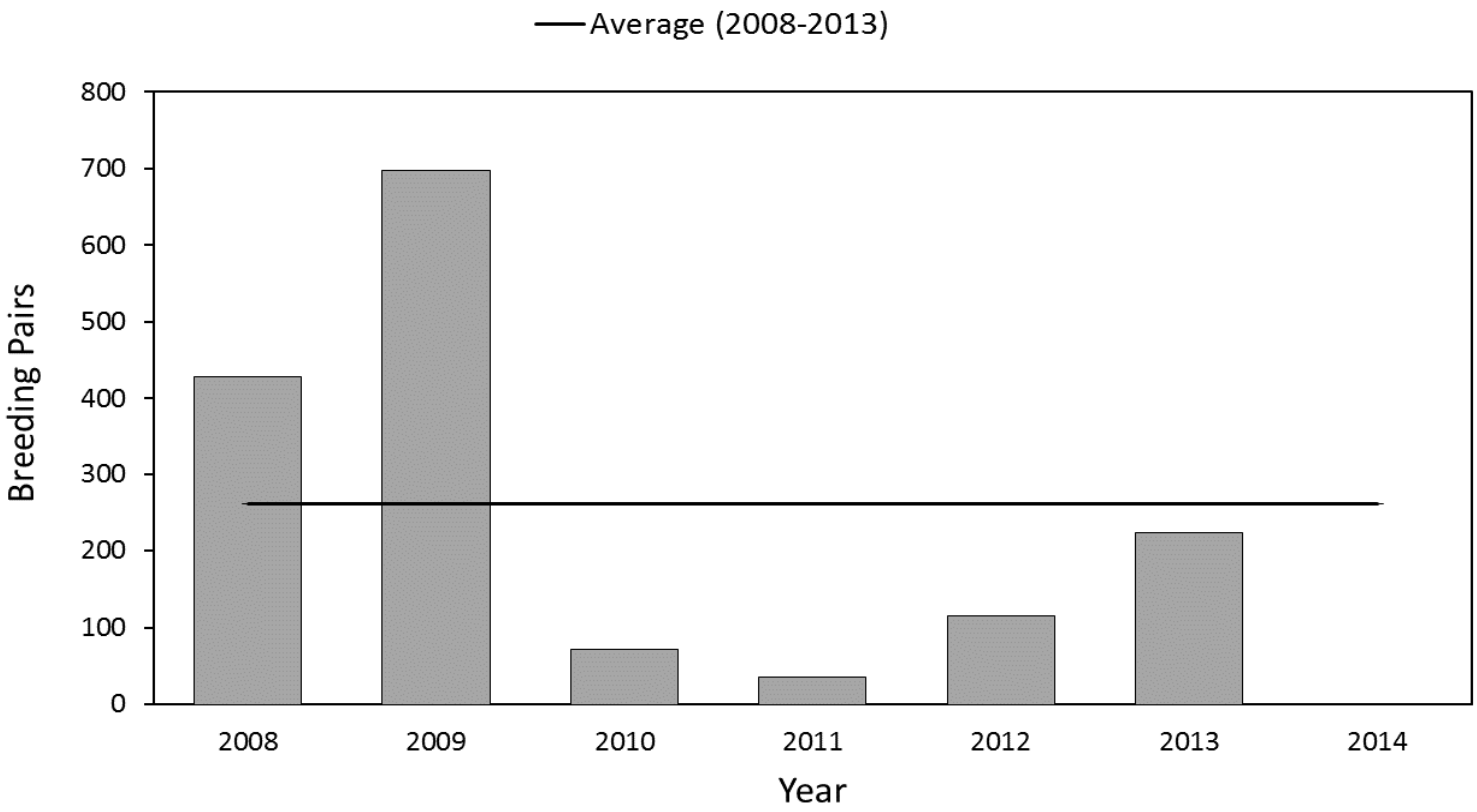


Figure 43. Size of the Caspian tern breeding colony (number of breeding pairs) on the Corps-constructed tern island at Crump Lake in the Warner Valley, Oregon, during the 2008-2014 breeding seasons.

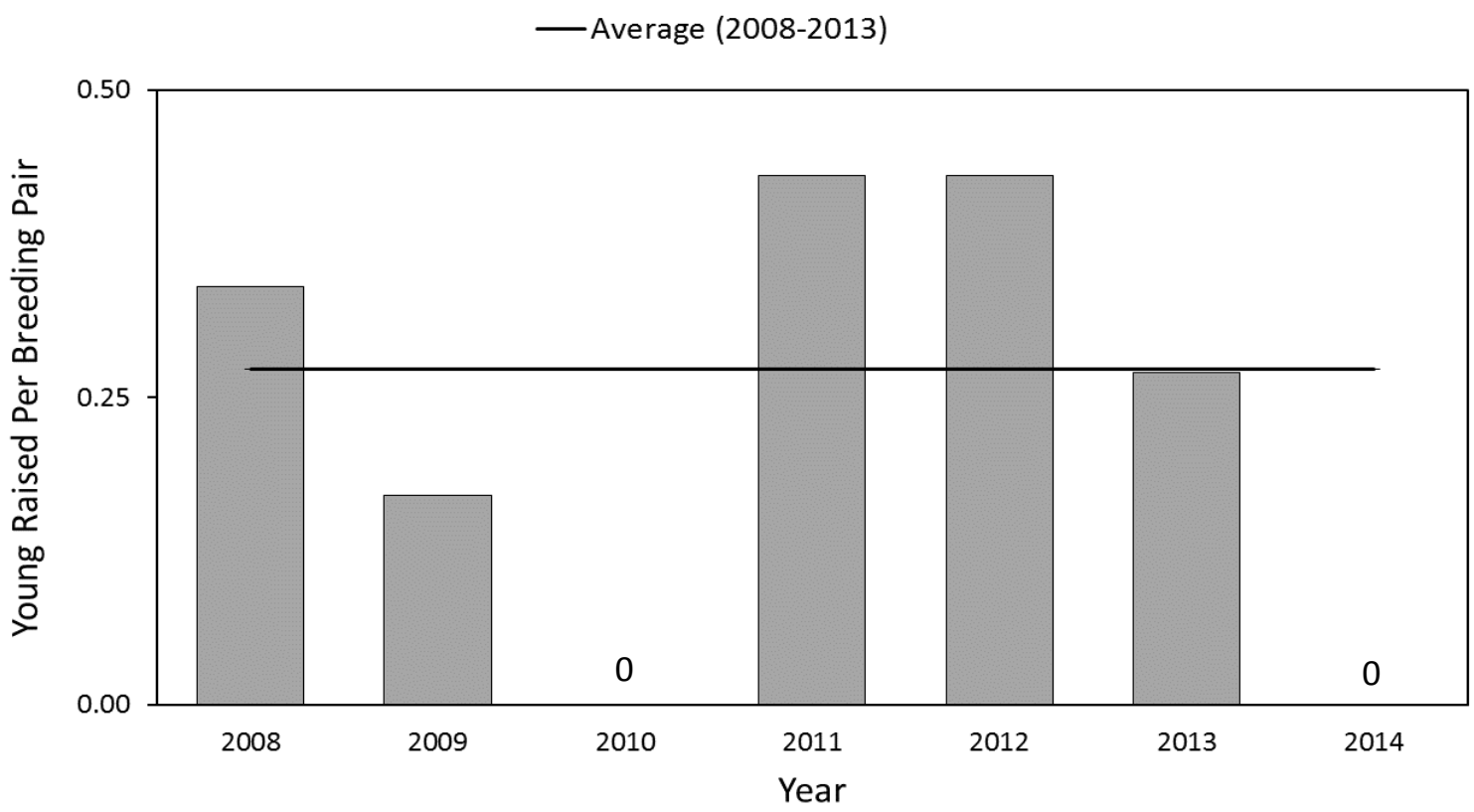


Figure 44. Caspian tern nesting success (average number of young raised per breeding pair) at the Corps-constructed tern island at Crump Lake in the Warner Valley, Oregon, during the 2008-2014 breeding seasons. Caspian terns failed to raise any young at the colony in 2010 and 2014.

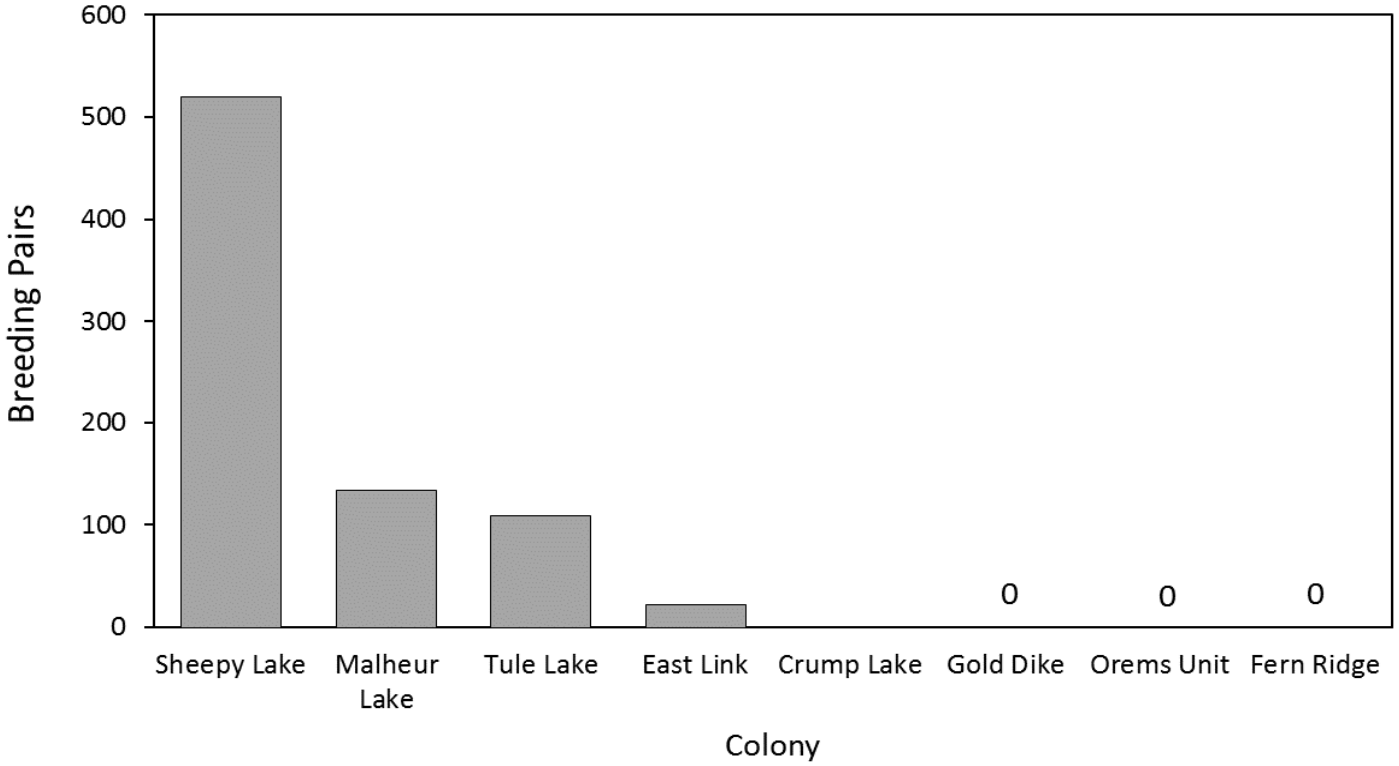


Figure 45. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) on Corps-constructed tern islands in interior Oregon and northeastern California during the 2014 breeding season.

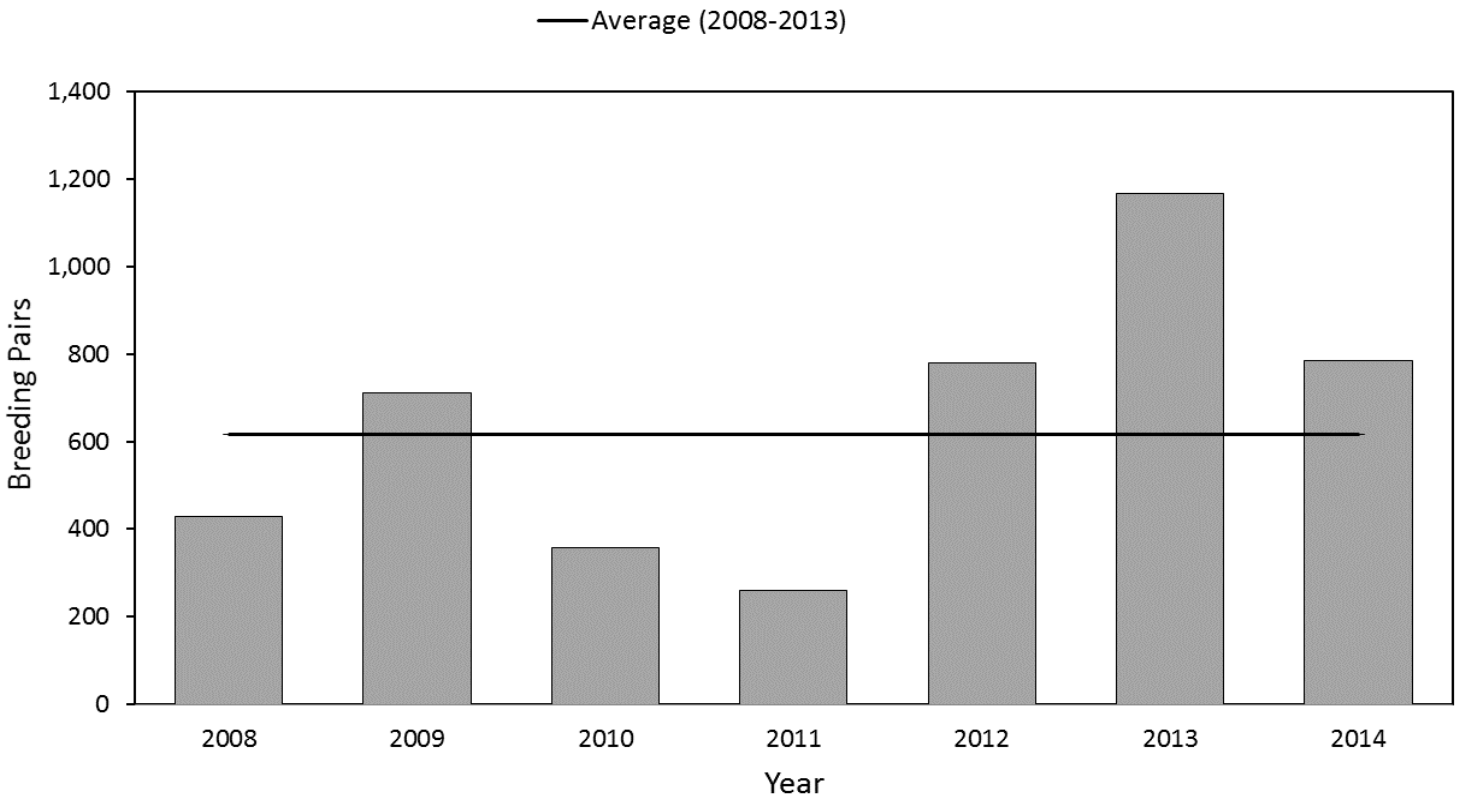


Figure 46. Total numbers of Caspian tern breeding pairs nesting on Corps-constructed tern islands in interior Oregon and northeastern California during 2008-2014.

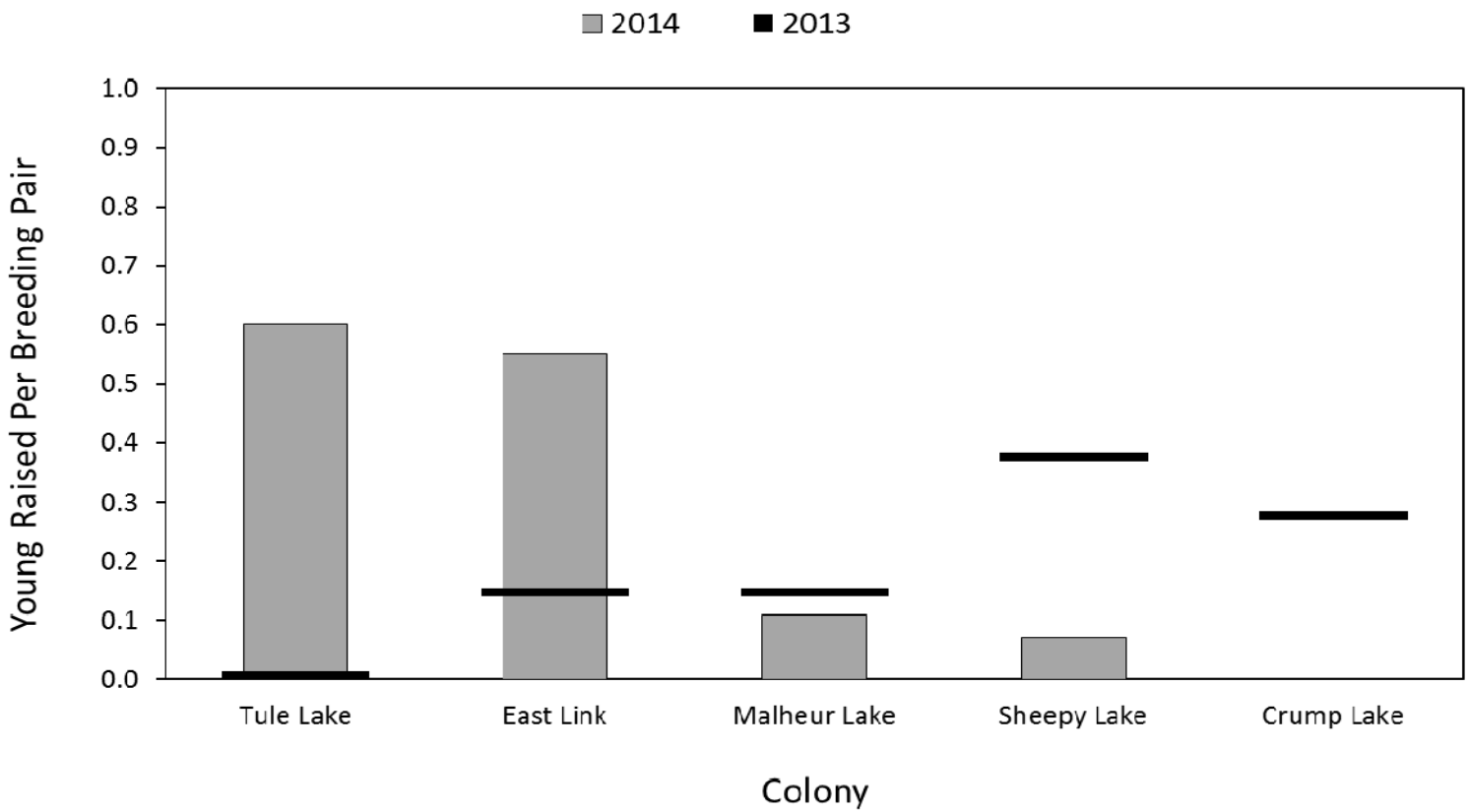


Figure 47. Caspian tern nesting success (average number of young raised per breeding pair) on Corps-constructed tern islands in interior Oregon and northeastern California during 2014 compared with 2013.

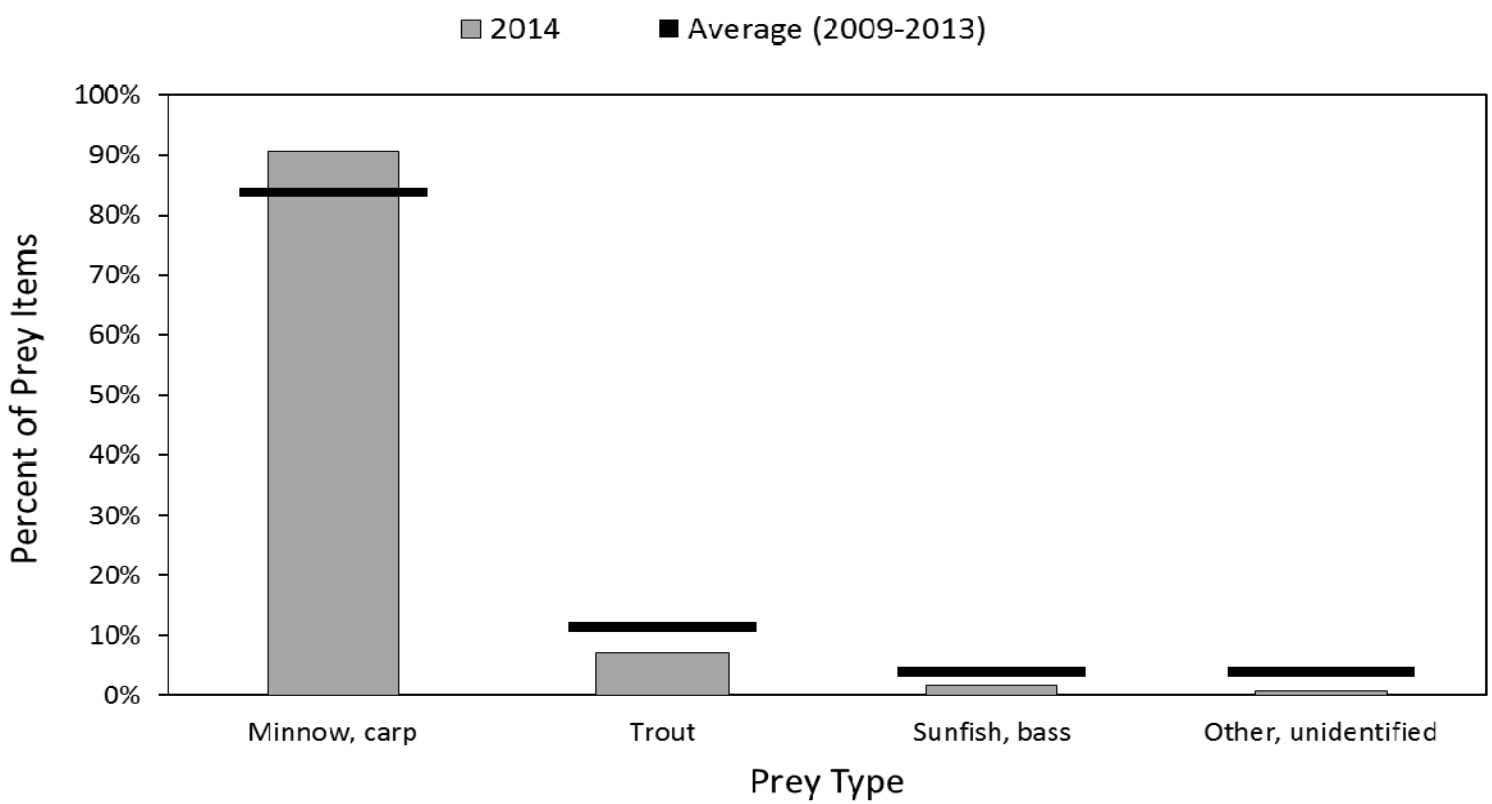


Figure 48. Diet composition (percent of prey items) of Caspian terns nesting on the Corps-constructed tern islands at Summer Lake Wildlife Area (East Link Impoundment) during the 2014 breeding season. Diet composition was based on fish identified in tern bill loads on-colony.

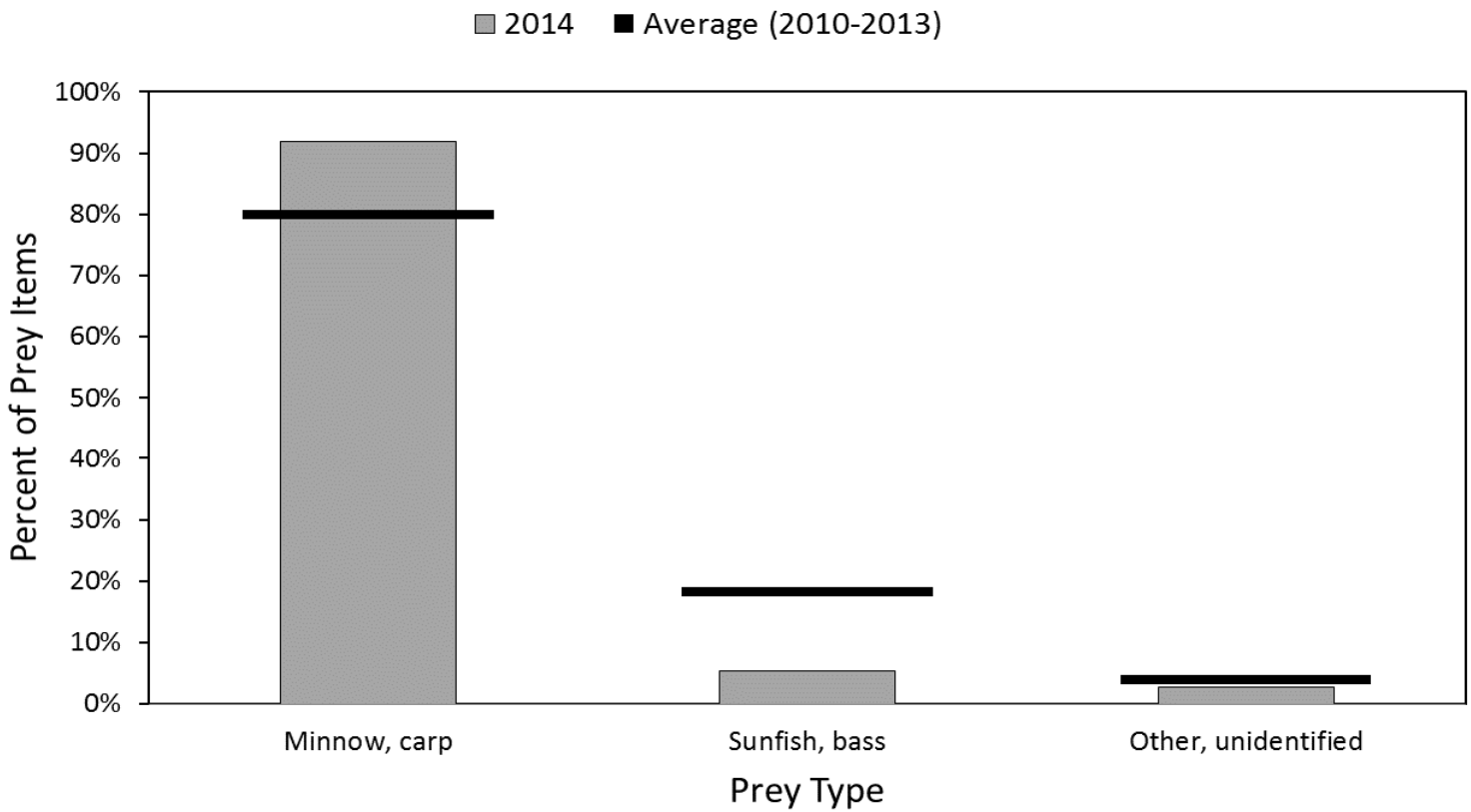


Figure 49. Diet composition (percent of prey items) of Caspian terns nesting on the Corps-constructed tern island at Sheepy Lake in Lower Klamath National Wildlife Refuge, California, during the 2014 breeding season. Diet composition was based on fish identified in tern bill loads on-colony.

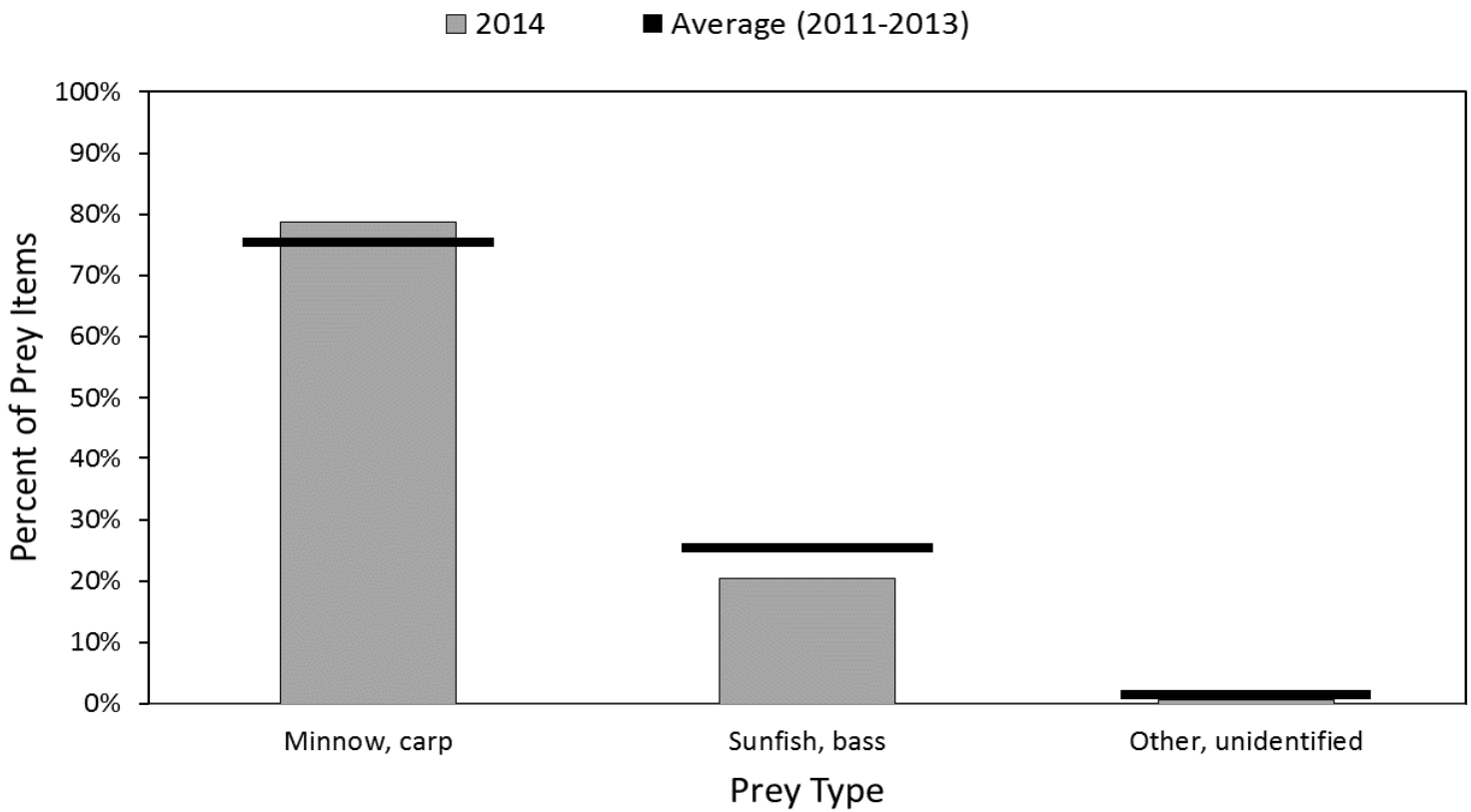


Figure 50. Diet composition (percent of prey items) of Caspian terns nesting on the Corps-constructed tern island at Tule Lake Sump 1B in Tule Lake National Wildlife Refuge, California during the 2014 breeding season. Diet composition was based on fish identified in tern bill loads on-colony.

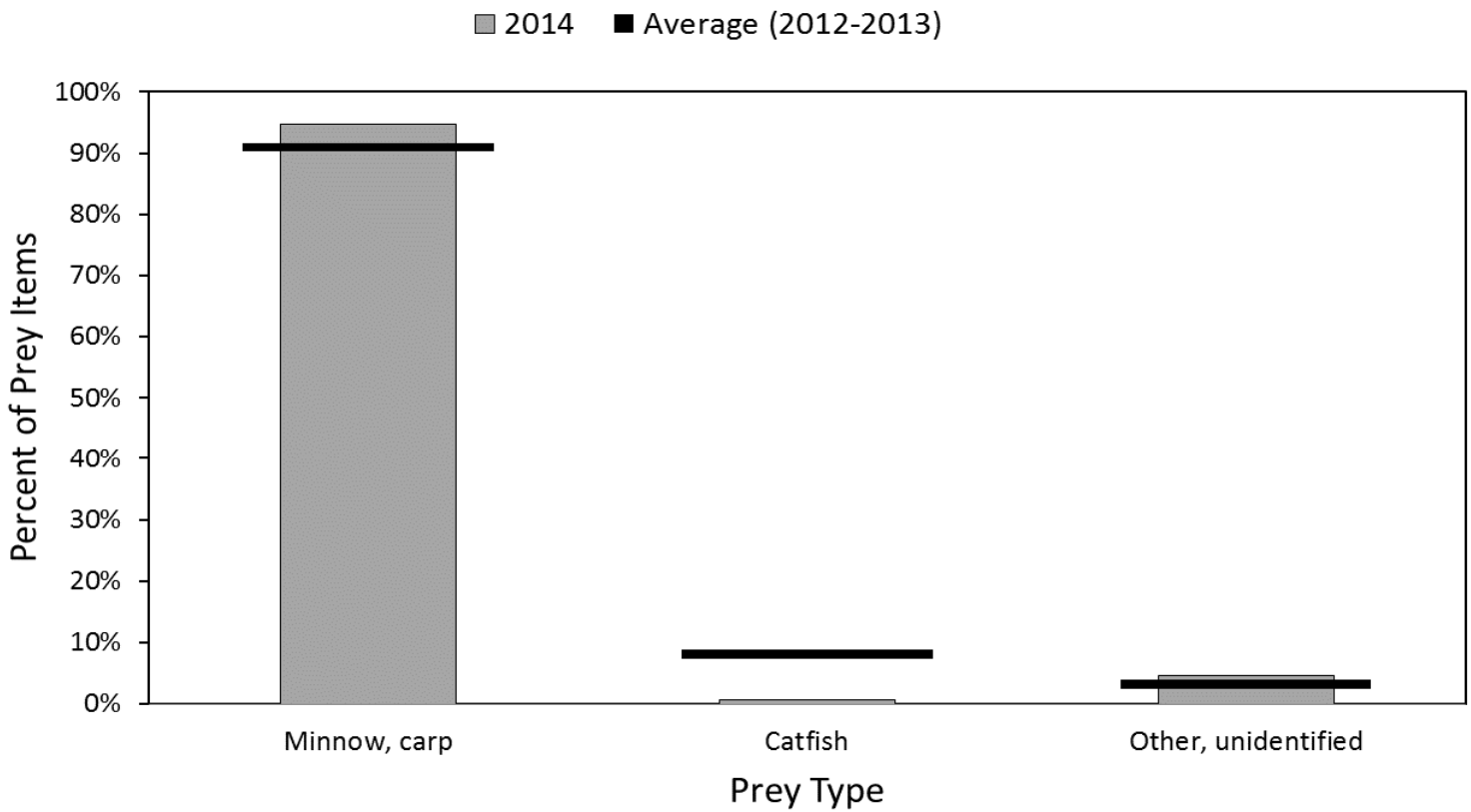


Figure 51. Diet composition (percent of prey items) of Caspian terns nesting on the Corps-constructed tern island at Malheur Lake in Malheur National Wildlife Refuge, Oregon, during the 2014 breeding season. Diet composition was based on fish identified in tern bill loads on-colony.

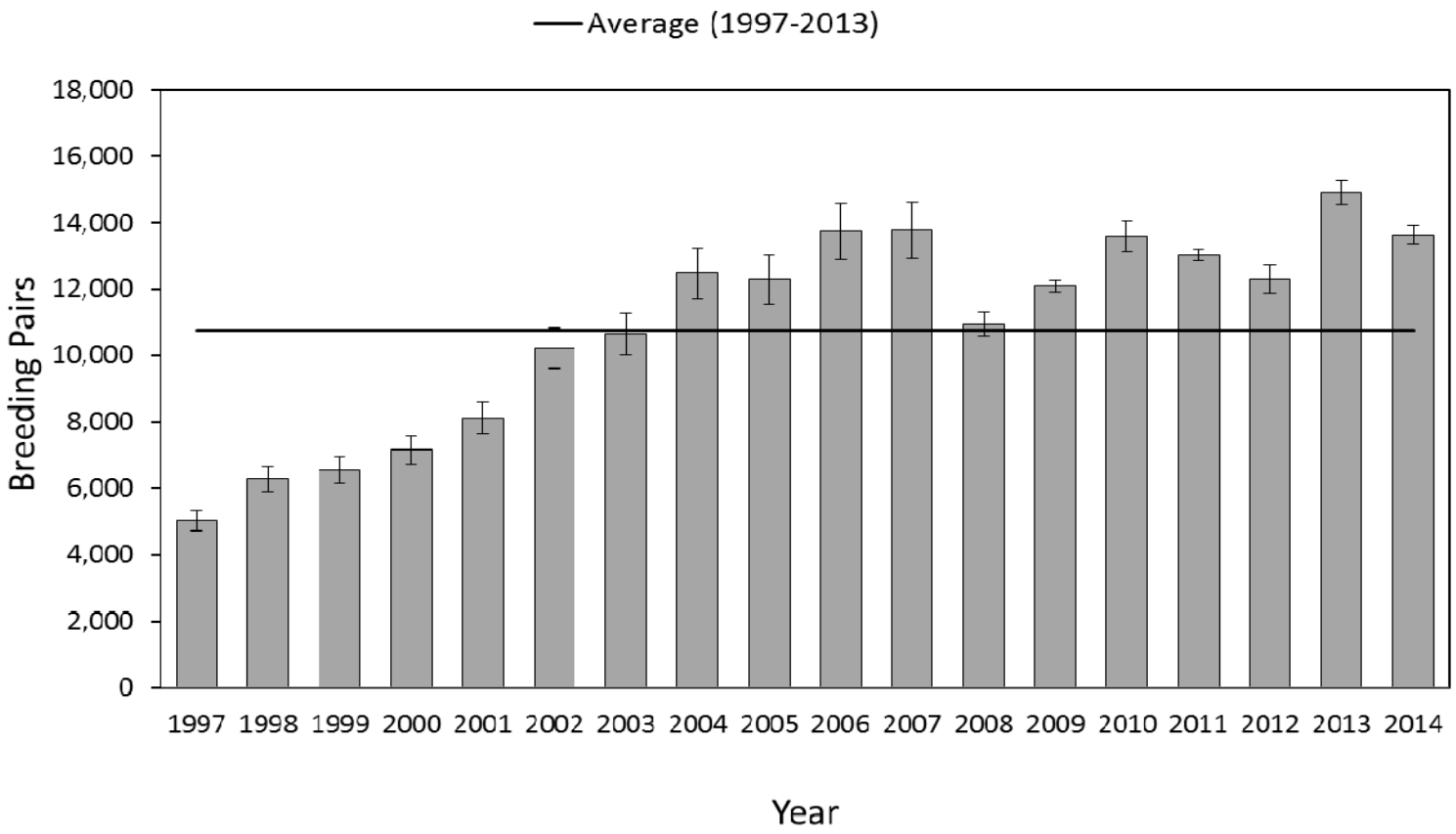


Figure 52. Size of the double-crested cormorant breeding colony (number of breeding pairs) on East Sand Island in the Columbia River estuary during the 1997-2014 breeding seasons. Error bars represent 95% confidence intervals for the number of breeding pairs.

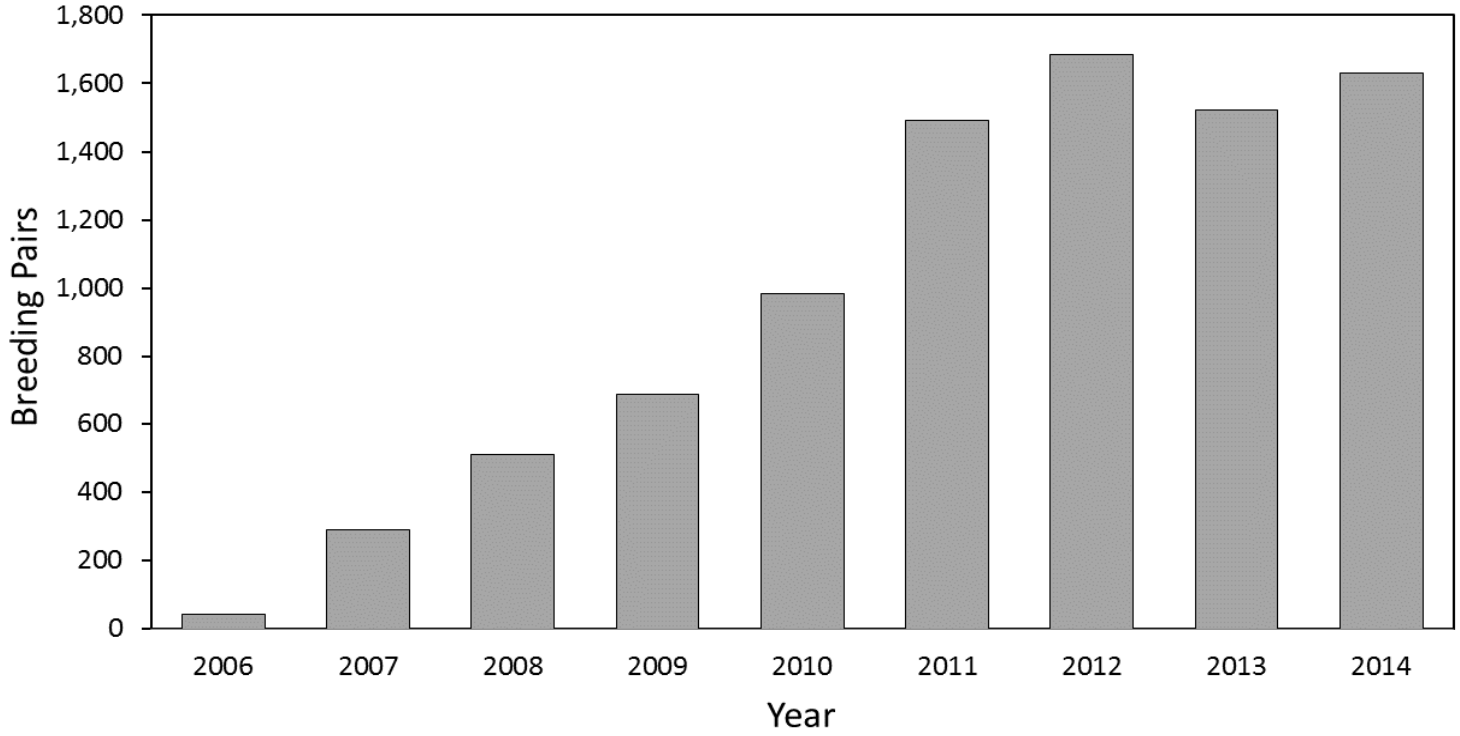


Figure 53. Size of the Brandt's cormorant breeding colony (number of breeding pairs) on East Sand Island in the Columbia River estuary during the 2006-2014 breeding seasons.

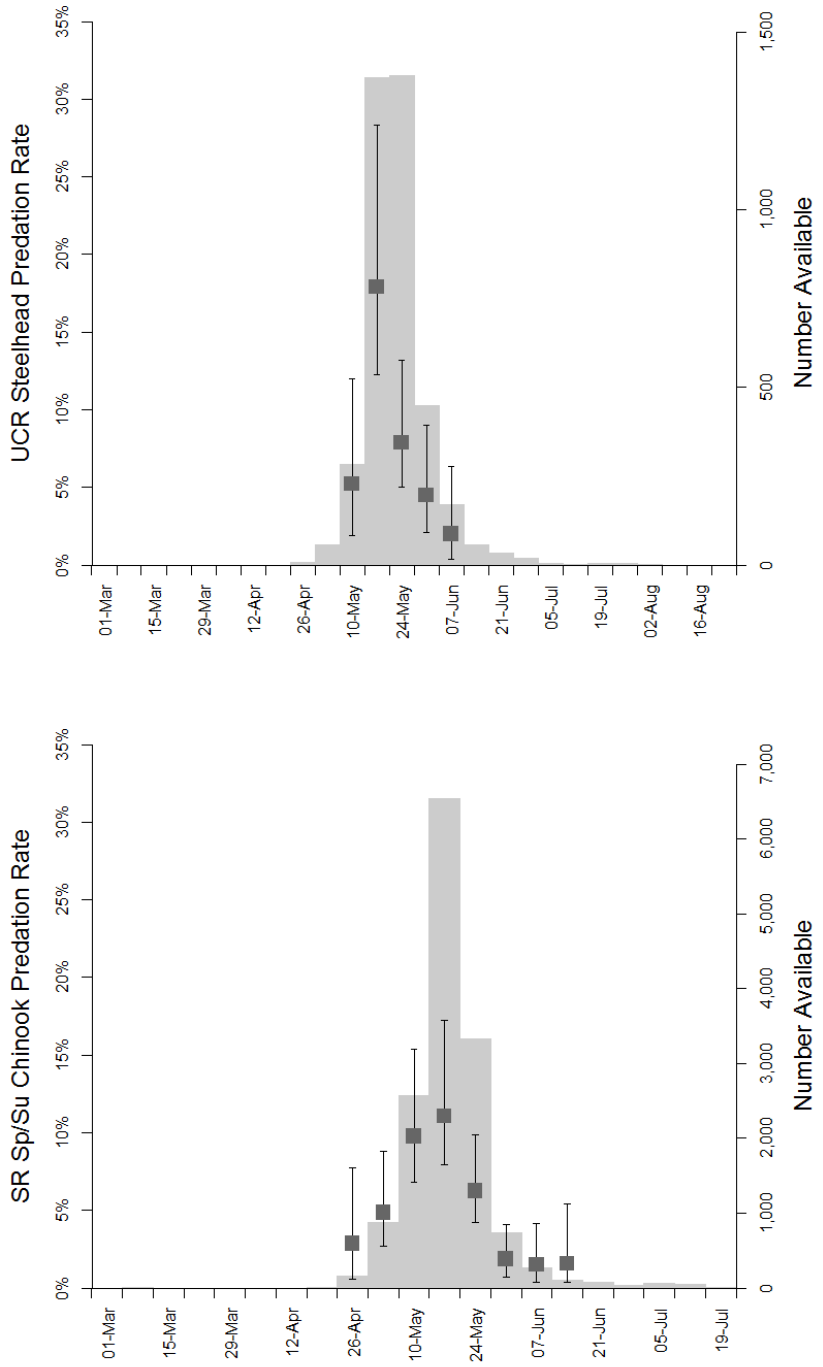


Figure 54. Weekly predation rates (squares with error bars) by double-crested cormorants nesting at East Sand Island on PIT-tagged Upper Columbia River (UCR) steelhead and Snake River (SR) spring/summer Chinook salmon detected passing Bonneville Dam (number available; indicated by gray bars) during 2014. Error bars represent 95% credible intervals.

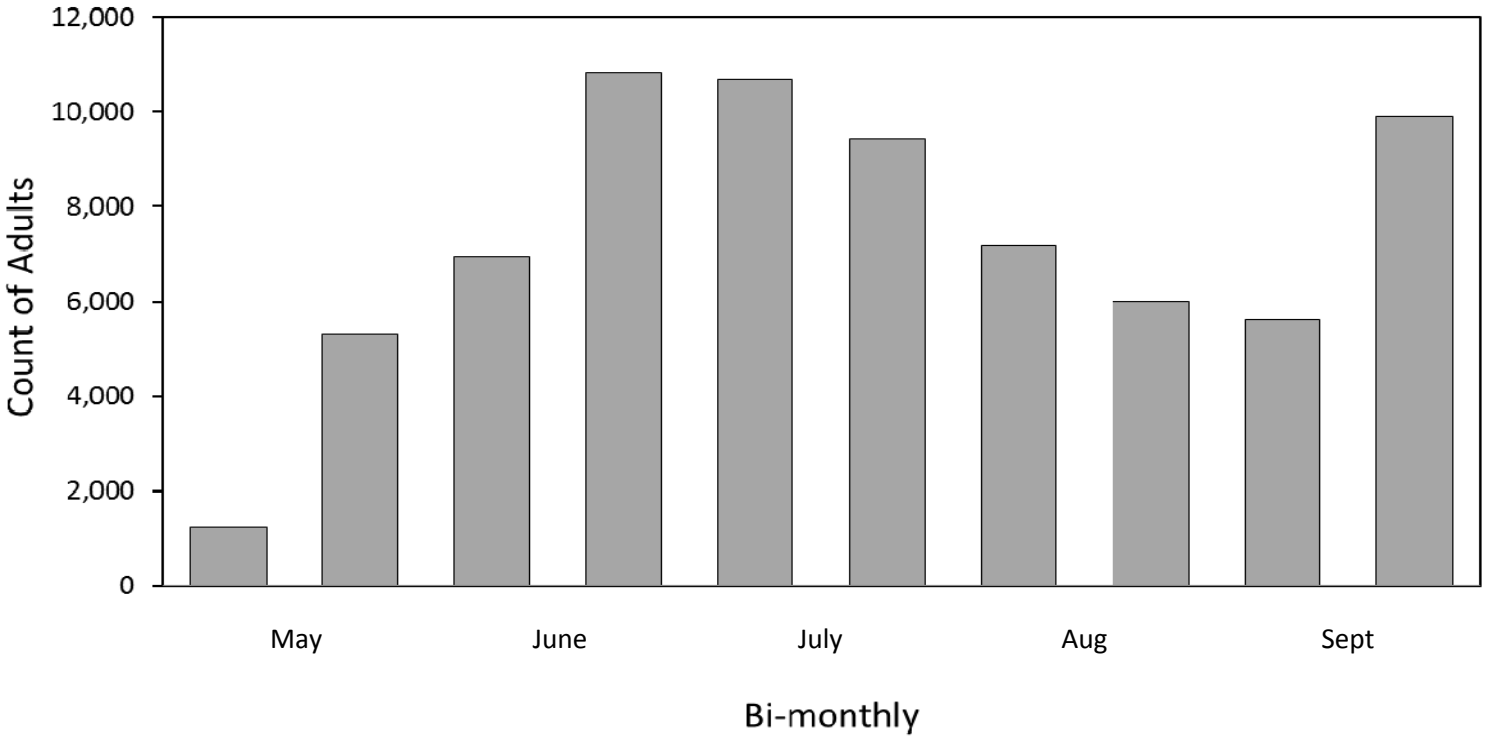


Figure 55. Estimates from boat-based surveys of the number of roosting California brown pelicans on East Sand Island, by 2-week period during the 2014 field season.

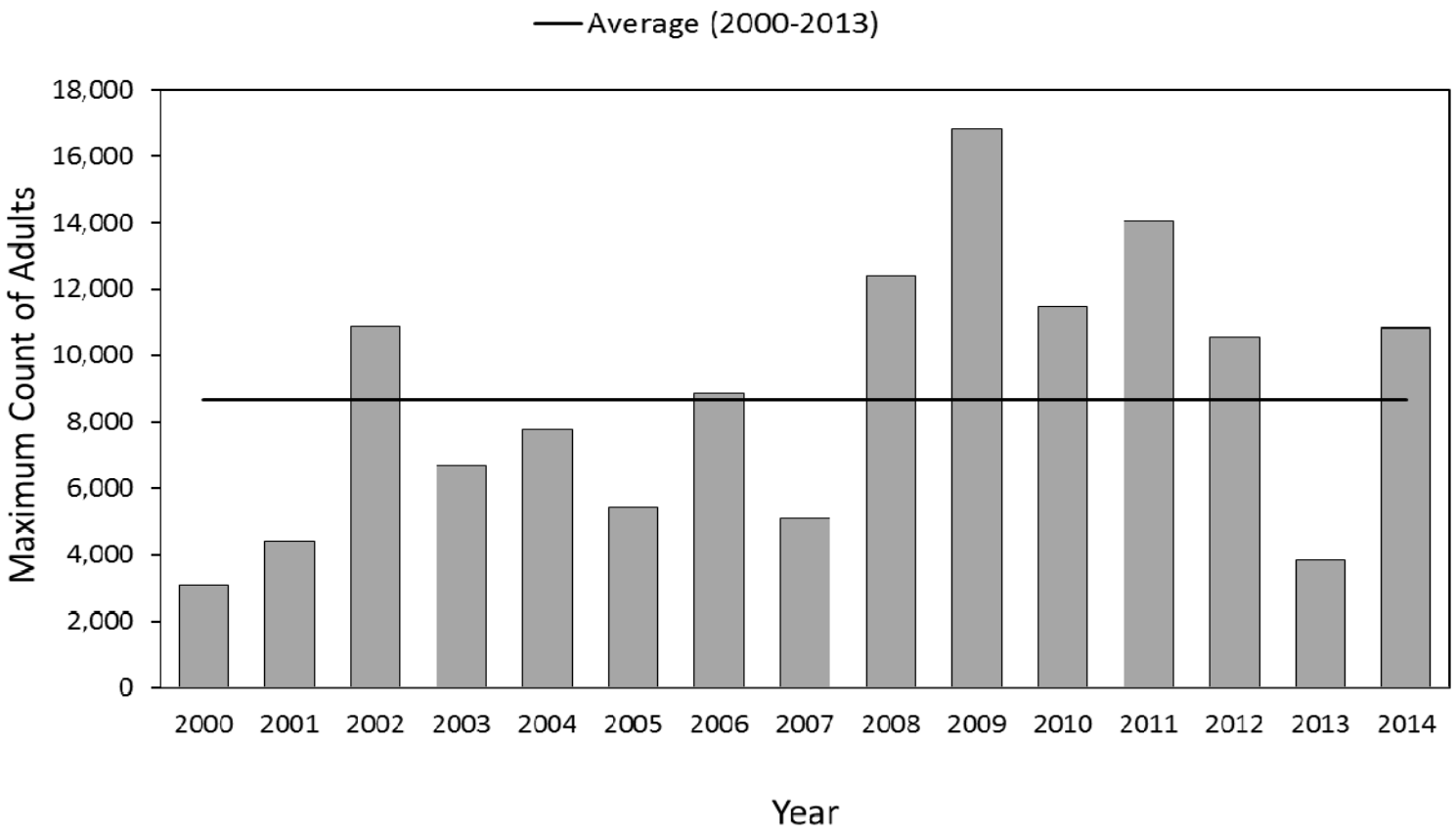


Figure 56. Maximum number of roosting California brown pelicans counted during boat-based surveys at East Sand Island in the Columbia River estuary during the 2000-2014 field seasons.

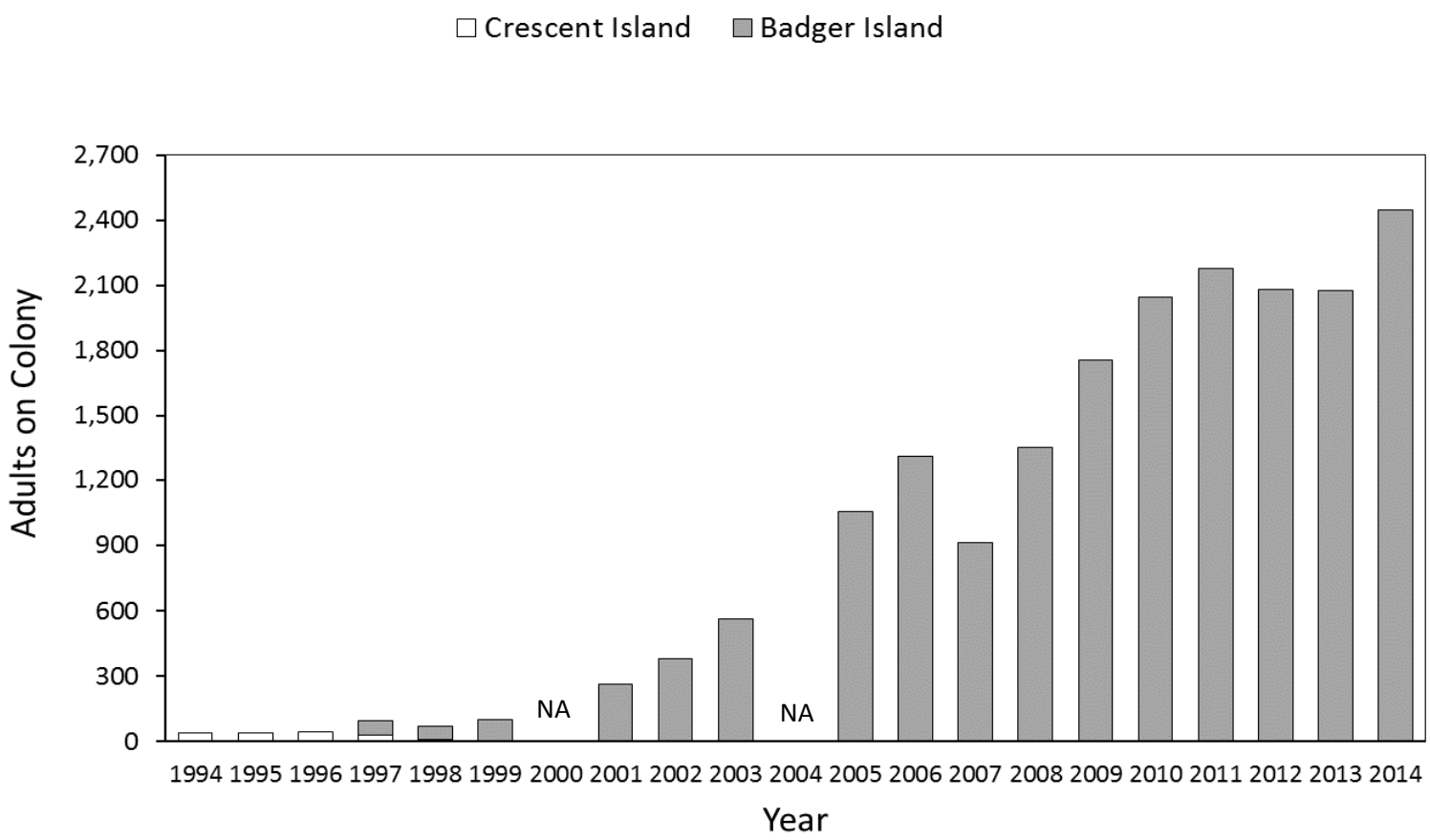


Figure 57. Numbers of adult American white pelicans counted in aerial photography of two colonies on the mid-Columbia River, Badger Island and Crescent Island, during the 1994-2014 breeding seasons. Photography was taken late in the incubation period. Numbers of pelicans on the Badger Island colony were not determined in 2000 and 2004.

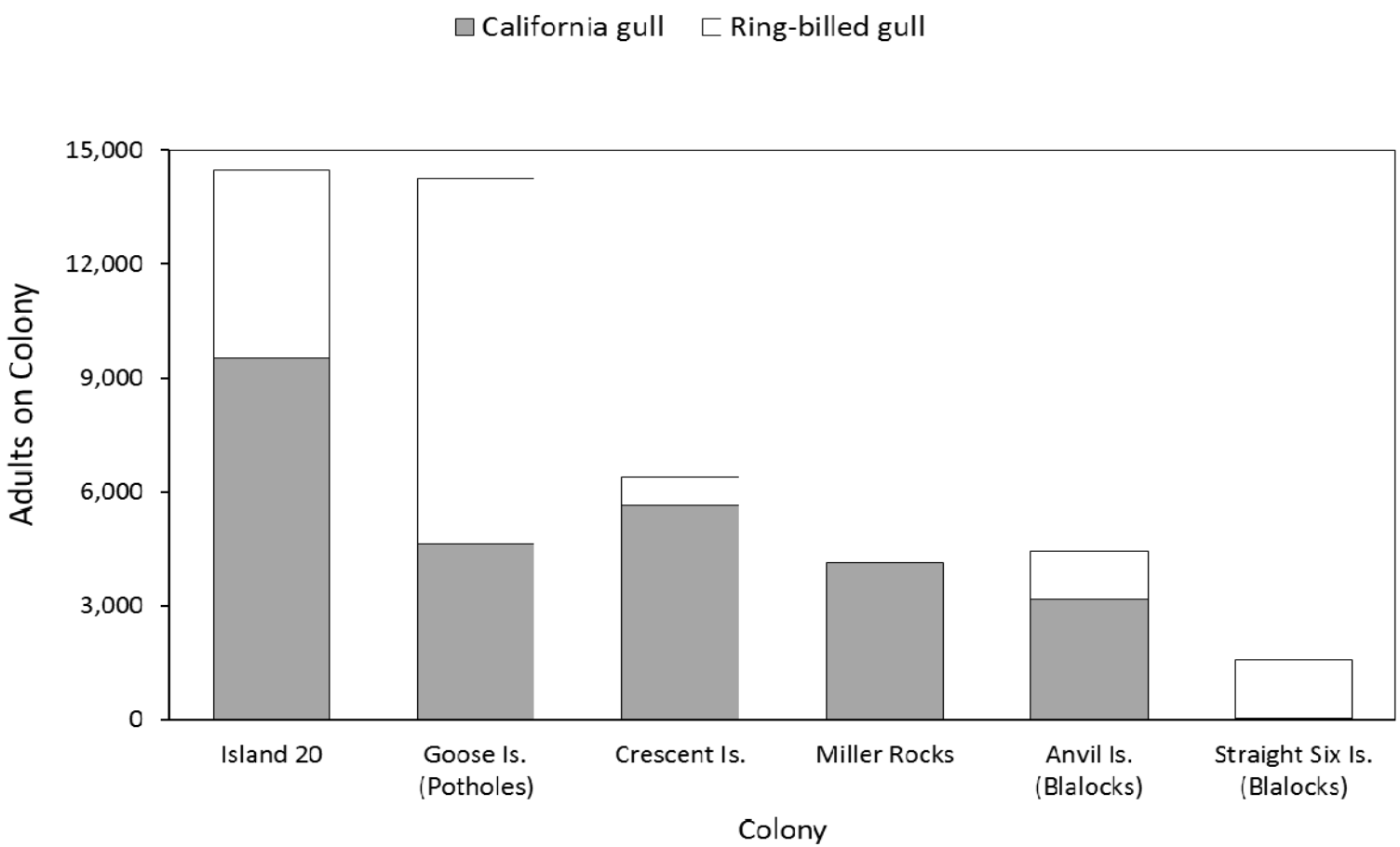


Figure 58. Numbers of adult California and ring-billed gulls counted on aerial photography of six different breeding colonies in the Columbia Plateau region during the 2014 breeding season. Photography was taken late in the incubation period. Four other gull colonies were active in the Columbia Plateau region in 2014, but were not counted: the Harper Island colony in Sprague Lake; the Twinning Island and Goose Island colonies in Banks Lake; and a small colony in Lenore Lake.

Table 1. Estimated colony size (number of breeding pairs) and nesting density (nests/m^2) for Caspian terns nesting on East Sand Island in the Columbia River estuary during 2000-2014. Potential error of the estimates is expressed as the 95% confidence limits (CL).

Year	Colony Size	Lower 95% CL	Upper 95% CL	Nesting Density	Lower 95% CL	Upper 95% CL
2000	8,513	7,597	9,429	0.62	0.55	0.69
2001	8,982	8,427	9,537	0.57	0.53	0.61
2002	9,933	9,552	10,314	0.55	0.53	0.57
2003	8,325	7,838	8,812	0.45	0.42	0.48
2004	9,502	8,905	10,099	0.50	0.47	0.53
2005	8,822	8,325	9,319	0.45	0.42	0.48
2006	8,929	8,188	9,670	0.55	0.50	0.60
2007	9,623	8,880	10,366	0.70	0.65	0.75
2008	10,668	9,923	11,413	0.72	0.67	0.77
2009	9,854	9,509	10,199	0.70	0.68	0.72
2010	8,283	7,412	9,154	0.70	0.63	0.77
2011	6,969	5,759	8,179	0.85	0.75	0.95
2012	6,416	5,545	7,287	1.06	0.92	1.20
2013	7,387	6,776	7,998	1.17	1.06	1.28
2014	6,269	5,858	6,680	1.06	0.99	1.13
Average (2000-2013)	8,729	8,535	8,922	0.68	0.67	0.70

Table 2. Estimated proportional stock composition and lower and upper 95% confidence limits (CL) for Chinook salmon consumed by Caspian terns at East Sand Island in the Columbia River estuary during 2011- 2014. Data are separated into the early (April/May; n = 88) and late (June/July; n = 60) outmigration periods. Confidence intervals are derived from 100 bootstrap resampling iterations of baseline and mixture genotypes.

	Early(April/May)			Late (June/July)		
	Estimate	Lower 95% CL	Upper 95% CL	Estimate	Lower 95% CL	Upper 95% CL
Deschutes River – Fall	0.0%	0.0%	2.3%	0.0%	0.0%	10.4%
West Cascades Tributary - Fall	0.0%	0.0%	4.3%	18.2%	8.1%	27.2%
West Cascades Tributary - Spring	8.9%	3.7%	12.9%	1.6%	0.0%	7.8%
MCR & UCR – Spring[1]	28.6%	15.7%	38.4%	3.2%	0.0%	8.3%
Spring Creek Group - Fall	14.7%	8.4%	21.4%	24.9%	14.3%	36.7%
Snake River - Fall	3.7%	0.0%	10.2%	16.1%	3.3%	24.0%
Snake River - Spring	28.6%	17.9%	41.1%	1.7%	0.0%	5.0%
UCR - Summer/Fall[1]	6.5%	0.0%	11.1%	16.1%	7.1%	31.2%
Willamette River - Spring	9.1%	4.6%	14.1%	0.0%	0.0%	1.2%
Rogue River	0.0%	0.0%	0.0%	18.3%	6.6%	26.7%

[1] MCR = Middle Columbia River; UCR = Upper Columbia River

Table 3. Estimated proportional stock composition and lower and upper 95% confidence limits (CL) for steelhead consumed by Caspian terns (n = 130) during 2011- 2014 and by double-crested cormorants (n = 63) during 2011- 2013 at East Sand Island in the Columbia River estuary (cormorant diet data were not collected in 2014). Confidence intervals are derived from 100 bootstrap resampling iterations of baseline and mixture genotypes.

	Caspian terns			Double-crested cormorants		
	Estimate	Lower 95% CL	Upper 95% CL	Estimate	Lower 95% CL	Upper 95% CL
Lower Columbia River	25.8%	16.1%	32.4%	20.6%	9.2%	31.8%
Middle Columbia River	12.1%	6.1%	19.9%	16.2%	7.9%	30.9%
Snake River	49.7%	37.9%	59.4%	48.5%	29.7%	57.2%
Upper Columbia River	3.8%	0.0%	11.0%	8.2%	0.1%	17.6%
Willamette River	8.4%	2.8%	13.4%	6.5%	0.0%	13.9%
Washington Coast	0.2%	0.0%	2.3%	0.0%	0.0%	2.2%

Table 4. Estimated proportional stock composition and upper and lower 95% confidence limits (CL) for coho salmon consumed by Caspian terns (n = 57) during 2011- 2014 and by double-crested cormorants (n = 108) during 2011- 2013 at East Sand Island in the Columbia River estuary (cormorant diet data were not collected in 2014). Confidence intervals are derived from 100 bootstrap resampling iterations of baseline and mixture genotypes.

	Caspian terns			Double-crested cormorants		
	Estimate	Lower 95% CL	Upper 95% CL	Estimate	Lower 95% CL	Upper 95% CL
Washington Coast	8.9%	1.9%	24.6%	1.4%	0.0%	11.9%
Columbia River	58.1%	36.3%	69.5%	74.4%	57.5%	80.2%
North Oregon Coast	33.0%	16.5%	47.5%	24.3%	14.3%	35.8%

Table 5. Number of 2014 migration year PIT-tagged juvenile salmonids (Chinook salmon, coho salmon, sockeye salmon, and steelhead) recovered (using physical and electronic methods; see section 1.1.4) on bird colonies in the Columbia River basin following the 2014 nesting season. Piscivorous waterbird breeding colonies scanned for PIT tags included both estuary and inland colonies of Caspian terns (CATE), and estuary colonies of double-crested cormorants (DCCO) and Brandt's cormorants (BRAC).

River Segment	Location	Bird Species	Recovered
Estuary	East Sand Island	DCCO	22,069
		CATE	13,059
		BRAC[1]	927
John Day Pool	Blalock Islands (Anvil Is.)	CATE	1,130
McNary Pool	Crescent Island	CATE	7,270
Off-river	Northwest Rocks, Potholes Res.	CATE	874
	Twinning Island, Banks Lake	CATE	131
Total			45,460

[1] Recoveries on the Brandt's cormorant colony at East Sand Island likely included some PIT tags deposited by double-crested cormorants (see Results).

Table 6. Range of detection efficiency estimates for PIT tags sown on bird colonies during the 2014 nesting season. Results were used to calculate estimates of the proportion of PIT tags deposited by birds on their nesting colony that were subsequently detected by researchers on the colony following the nesting season (see Figure 13). Sample sizes and the number of discrete release periods for sown tags are provided. Piscivorous waterbird species include Caspian terns (CATE), double-crested cormorants (DCCO), and Brandt's cormorants (BRAC).

River Segment	Location	Colony	Sample Size (# released)	Date Range	Detection Efficiency
Estuary	East Sand Island	CATE	300 (3)	3/1 - 8/31	40 – 82%
		DCCO[1]	400 (2)		63 – 84%
		BRAC[1]	400 (2)		63 – 84%
John Day Res.	Blalock Islands (Anvil Is.)	CATE	50 (1)[2]	4/1-8/31	84 – 86%
McNary Res.	Crescent Island	CATE	200 (4)		67 – 95%
Off-river	NW Rocks, Potholes Res.	CATE	50 (1)[2]		23 – 98%
	Twinning Island, Banks L.	CATE	50 (1)[2]		21 – 94%

[1] The same detection efficiency values were used to estimate predation rates for both double-crested cormorants and Brandt's cormorants nesting on East Sand Island (see Methods).
[2] PIT tags were only sown by researchers after the breeding season; pre-season detection efficiency was inferred using data from previous years (see Methods).

Table 7. Mean on-colony PIT tag deposition rate (DR [95% credible interval]) for nesting Caspian terns, double-crested cormorants, and Brandt's cormorants. Results were used to calculate estimates of the proportion of PIT tags consumed by birds that were subsequently deposited on their nesting colony (see Figure 13). Sample sizes (n) of consumed PIT-tagged fish used to estimate deposition rate and the years when studies of deposition rates were conducted are provided. PIT-tagged fish were consumed during different periods of the day (morning, evening) and throughout the period of smolt out-migration in each study year (April to June; see Hostetter et al. [2015] for a detailed description of methods and results).

Species	Colony	Study Years	n	DR (95% c.i.)
Caspian terns	East Sand Is., Blalock Is., Crescent Is., NW Rocks, Twinning Is.	2004-2006	456	71% (51 - 89%)
Double-crested cormorants	East Sand Is.	2012-2013	428	51% (34 - 70%)
Brandt's cormorants	East Sand Is.	DR for double-crested cormorants was used		

Table 8. Estimated predation rates (95% credible interval) of PIT-tagged salmonid smolts last detected at Bonneville Dam on the Columbia River or Sullivan Dam on the Willamette River by fish-eating birds nesting at colonies on East Sand Island in the Columbia River estuary in 2014. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiency (see Table 6) and deposition rates (see Table 7). Species of fish-eating birds include Caspian terns (CATE), double-crested cormorants (DCCO), and Brandt's cormorants (BRAC). The number of PIT-tagged smolts interrogated at Bonneville or Sullivan dams (n) and current U.S. Endangered Species Act (ESA) status of each evolutionarily significant unit (ESU) or distinct population segment (DPS) are provided. Only ESUs/DPSs with > 500 PIT-tagged smolts interrogated while passing either dam were evaluated.

ESU/DPS[1]	ESA[2]	n	East Sand Is. CATE	East Sand Is. DCCO	East Sand Is. BRAC[3]
SR Sockeye	E	1,739	1.6% (0.8-3.0)	4.5% (2.7-7.7)	0.6% (0.2-1.5)
SR Spr/Sum Chinook	T	14,828	1.1% (0.8-1.7)	8.5% (6.1-13.2)	0.3% (0.2-0.5)
UCR Spr Chinook	E	2,297	1.4% (0.7-2.5)	6.1% (3.9-10.1)	0.4% (0.1-1.2)
MCR Spr Chinook	NW	3,407	0.9% (0.5-1.7)	5.0% (3.3-8.1)	0.1% (<0.1-0.5)
SR Fall Chinook	T	2,800	1.0% (0.5-1.9)	2.4% (1.5-4.2)	0.2% (0.1-0.7)
UCR Sum/Fall Chinook	NW	5,519	1.1% (0.7-1.8)	4.2% (2.9-6.6)	0.2% (<0.1-0.5)
UWR Spr Chinook	T	1,587	1.2% (0.5-2.5)	1.8% (0.9-3.6)	0.1% (<0.1-0.6)
SR Steelhead	T	8,812	8.6% (6.7-12.5)	7.8% (5.6-12.0)	0.2% (0.1-0.5)
UCR Steelhead	T	3,841	11.4% (8.5-16.8)	10.4% (7.3-16.3)	0.4% (0.1-0.9)
MCR Steelhead	T	1,119	9.5% (6.5-14.5)	6.4% (3.7-10.7)	0.4% (<0.1-1.5)

[1] MCR = Middle Columbia River, SR = Snake River, UCR = Upper Columbia River, UWR = Upper Willamette River

[2] E = Endangered, T = Threatened, NW = Not Warranted

[3] Includes some PIT tags deposited by double-crested cormorants (see Results)

Table 9. Predation rates (95% credible interval) by Caspian terns (CATE) and double-crested cormorants (DCCO) nesting at colonies in the Columbia River estuary and Columbia Plateau region on various populations (ESUs/DPSs) of Columbia Basin salmonids in 2014. Predation rates are separated by smolt rearing-type (hatchery, wild) for comparison purposes. Predation rates were adjusted for tag loss due to on-colony PIT tag detection efficiency (see Table 6) and deposition rates (see Table 7). Predation rates are based on numbers of PIT-tagged fish, per ESU/DPS, last interrogated passing dams on the Columbia or Snake rivers. Dams include Bonneville Dam (BON), Lower Monumental Dam (LMN), and Rock Island Dam (RIS). Only ESUs/DPSs with > 500 PIT-tagged hatchery-reared and wild smolts interrogated at an up-river dam were evaluated. Only colonies with predation rates > 1.0% (see Tables 8, 10, and 11), those deemed high enough to compare for biologically meaningful differences, were evaluated.

				Predation Rate	
Island	Bird Species	Salmonid ESU/DPS[1]	Interrogation Site	Hatchery-reared	Wild
East Sand Is.	CATE	SR steelhead	BON	8.4% (6.3-12.7)	10.5% (7.6-16.2)
		SR Spr. Chinook		1.2% (0.8-1.8)	0.9% (0.4-2.0)
		UCR Spr. Chinook		1.7% (0.9-3.1)	0.7% (0.1-2.7)
	DCCO	SR steelhead	BON	8.4% (5.9-13.6)	6.7% (4.3-11.2)
		SR Spr. Chinook		9.3% (6.7-14.8)	3.8% (2.3-6.7)
		UCR Spr. Chinook		6.4% (4.0-10.7)	6.2% (3.1-12.3)
Crescent Is.	CATE	SR steelhead	LMN	4.4% (3.4-6.5)	5.8% (4.5-8.6)
		UCR steelhead	RIS	3.5% (2.6-5.3)	3.1% (2.0-5.0)
NW Rocks	CATE	UCR steelhead	RIS	3.4% (2.2-5.8)	2.4% (1.3-4.5)

[1] SR = Snake River; UCR = Upper Columbia River;

Table 10. Estimated predation rates (95% credible interval) on in-river migrating PIT-tagged salmonid smolts last detected at Lower Monumental Dam on the lower Snake River or Rock Island Dam on the middle Columbia River by Caspian terns nesting at Crescent Island (McNary Reservoir), Northwest Rocks (Potholes Reservoir), and Twinning Island (Banks Lake). Predation rates were adjusted to account for tag loss due to on-colony detection efficiency (see Table 6) and deposition rates (see Table 7). The number of PIT-tagged smolts interrogated at Lower Monumental Dam or Rock Island Dam (n) and current U.S. Endangered Species Act (ESA) status of each evolutionarily significant unit (ESU) or distinct population segment (DPS) are provided. Only ESUs/DPSs with > 500 PIT-tagged smolts that were interrogated while passing one of these dams were evaluated.

ESU/DPS[1]	ESA[2]	n	Crescent Is. Caspian terns	NW Rocks Caspian terns	Twinning Is. Caspian terns
SR sockeye	E	3,118	0.7% (0.4-1.3)	< 0.1%	< 0.1%
SR Spr/Sum Chinook	T	37,226	0.5% (0.3-0.7)	< 0.1%	< 0.1%
UCR Spr Chinook	E	641	0.7% (0.2-2.1)	0.5% (0.1-2.2)	0.5% (<0.1-7.9)
SR Fall Chinook	T	7,264	0.5% (0.3-0.8)	< 0.1%	< 0.1%
UCR Sum/Fall Chinook	NW	3,129	0.1% (<0.1-0.4)	< 0.1%	< 0.1%
SR steelhead	T	21,393	4.7% (3.7-6.9)	< 0.1%	< 0.1%
UCR steelhead	T	7,757	3.4% (2.5-4.9)	2.9% (1.9-5.1)	1.2% (0.3-6.4)

[1]SR = Snake River, UCR = Upper Columbia River

[2]E = Endangered, T = Threatened, NW = Not Warranted

Table 11. Estimated predation rates (95% credible interval) of in-river migrating PIT-tagged salmonid smolts last detected at McNary Dam on the Columbia River by Caspian terns nesting at Anvil Island in the Blalock Islands, John Day Reservoir. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiency (see Table 6) and deposition rates (see Table 7). The number of PIT-tagged smolts interrogated at McNary Dam (n) and current U.S. Endangered Species Act (ESA) status of each evolutionarily significant unit (ESU) or distinct population segment (DPS) are provided. Only ESUs/DPSs with > 500 PIT-tagged smolts that were interrogated while passing McNary Dam were evaluated.

ESU/DPS[1]	ESA[2]	n	Blalock Is. (Anvil Is.) Caspian terns
SR sockeye salmon	E	1,922	0.4% (0.1 - 1.1%)
SR Spr/Sum Chinook salmon	T	41,109	0.1% (0.1 - 0.2%)
UCR Spr Chinook salmon	E	4,611	0.2% (0.1 - 0.5%)
SR Fall Chinook salmon	T	10,293	0.3% (0.1 - 0.5%)
UCR Sum/Fall Chinook salmon	NW	13,372	0.3% (0.2 - 0.5%)
SR steelhead	T	10,389	0.4% (0.2 - 0.7%)
UCR steelhead	T	2,686	0.6% (0.3 - 1.2%)

[1] SR = Snake River, UCR = Upper Columbia River

[2] E = Endangered, T = Threatened, NW = Not Warranted

Table 12. Caspian tern nesting islands that were built by the U.S. Army Corps of Engineers in 2008-2012 as part of the federal agencies' Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006). Available acreage during the 2008 – 2014 nesting seasons are indicated; a blank indicates that the island was not available for tern nesting (i.e. either not yet constructed, not watered, or constructed and subsequently dismantled) during that year.

Location	Site	Construction Date	Island Type	Island Size (acres)	Available Acreage						
					2008	2009	2010	2011	2012	2013	2014
Fern Ridge Reservoir, OR	Fern Ridge	Feb 2008	Rock Core	1.0	1.0[1]	1.0[1]	1.0[1]	1.0[1]	1.0[1]	1.0[1]	1.0[1]
Crump Lake, Warner Valley, OR	Crump Lake	Mar 2008	Rock Core	1.0	1.0[1]	1.0[1]	1.0[2]	1.0[2]	1.0[2]	1.0[2]	
Summer Lake Wildlife Area, OR	East Link	Jan 2009	Rock Core	0.5		0.5[1]	0.5[1,2]	0.5[1]	0.5[1,2]	0.5[1,2]	0.5[1,2]
Summer Lake Wildlife Area, OR	Dutchy Lake	Mar 2009	Floating	0.5		0.5[1]	0.5[1]	0.5[1]			
Summer Lake Wildlife Area, OR	Gold Dike	Sep 2009	Rock Core	0.5					0.5[1]	0.5[1,2]	0.5[1,2]
Tule Lake NWR, CA	Tule Lake	Aug 2009	Rock Core	2.0				2.0[1]	2.0[1,2]	2.0[1,2]	2.0[1,2]
Lower Klamath NWR, CA	Orems Unit	Sep 2009	Silt Core	1.0				1.0[1]			
Lower Klamath NWR, CA	Sheepy Lake	Mar 2010	Floating	0.8			0.8[1,2]	0.8[1,2]	0.8[1,2]	0.8[1,2]	0.8[1,2]
Malheur NWR, OR	Malheur Lake	Feb 2012	Rock Core	1.0					1.0[1,2]	1.0[1,2]	1.0[1,2]
			Total	8.3	2.0	3.0	3.8	6.8	6.8	6.8	5.8

[1] Social attraction deployed
[2] Predator management enacted

Table 13. Estimated colony size (number of breeding pairs) for Caspian terns nesting at nine Corps-constructed tern islands in interior Oregon and northeastern California during 2008-2014. A blank indicates that the island was not available/suitable for tern nesting (i.e. either island not yet constructed, island dismantled, island vegetated, or island not surrounded by water) during that year. A zero indicates that the island was available but not used by nesting Caspian terns during that year.

Year	Fern Ridge[1]	Crump Lake[2]	East Link[3]	Dutchy Lake[3]	Gold Dike[3]	Tule Lake[4]	Orems Unit[5]	Sheepy Lake[5]	Malheur Lake[6]	TOTAL
2008	0	428								428
2009	0	697	7	8						712
2010	0	71	29	0				258		358
2011	0	35	2	0		34	2	188		261
2012	0	115	10		4	207		212	232	780
2013	0	223	21		0	79		316	530	1,169
2014	0	1	22		0	109		520	134	786
Average	0	224	15	3	1	107	2	299	299	642

[1] In Fern Ridge Reservoir near Eugene, Oregon; data provided by separately funded NWP project (Fern Ridge Project)
[2] In the Warner Valley near Adel, Oregon
[3] In the Summer Lake Wildlife Area near Summer Lake, Oregon
[4] In Tule Lake National Wildlife Refuge near Tulelake, California
[5] In Lower Klamath National Wildlife Refuge near Klamath Falls, Oregon
[6] In Malheur National Wildlife Refuge near Burns, Oregon

Table 14. Pre- and in-season management strategies used to facilitate successful nesting at Caspian tern nesting islands built by the U.S. Army Corps of Engineers prior to the 2014 nesting season as part of the federal agencies' Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006); (a) qualitative assessment of management strategies implemented at each site in 2014 ("x" denotes strategies that were attempted but were unsuccessful and "**X**" denotes strategies that were either partially or completely successful in 2014) and (b) specifics on management strategies implemented at each site in 2014.

(a)

	Sheepy Lake	Tule Lake	East Link	Gold Dike	Malheur Lake	Crump Lake
	Pre-season Management Strategy					
Trap and remove mammals from island						
Dissuade gulls using human disturbance and/or bird exclusion netting on island	**X**					
Vegetation removal on island	**X**		**X**	**x**		**X**
	In-season Management Strategy					
Lethal removal of gulls from island	**X**	**X**	**X**	**X**	**X**	
Lethal removal of mammals from island	x	**X**	x	x		
Nocturnal colony monitoring		**X**	**X**	**X**	**X**	
Trap and relocate owls visiting island		**X**	x	x		
Provide chick shelters on island	**X**	**X**	**X**	**X**	**X**	**X**

(b)

	Sheepy Lake	Tule Lake	East Link	Gold Dike	Malheur Lake	Crump Lake
	Pre-season Management Strategy					
Trap and remove mammals						
Erect gull exclusion area (area in square feet)	5,000					
Vegetation removal (ca. acres)	0.1		0.25	0.5		0.1
	In-season Management Strategy					
Lethal removal of gulls (number)	10	1	13	0	9	
Lethal removal of mammals (number, type)	0	4 raccoons	17 deer mice	0		
Nocturnal colony monitoring		Frequent	Frequent	Infrequent	Infrequent	
Trap and relocate owls (number)	0	1	0	0		
Provide chick shelters (number)	11	11	8	9	10	5

Table 15. Inter-colony movement probabilities of Caspian terns between 2013 and 2014. Data used in movement probability estimates were from terns banded as adults during 2005-2013 and re-sighted during 2006-2014. The numbers of individuals that moved between 2013 and 2014 were estimated from movement probabilities between those years multiplied by estimated numbers of adults present at source colonies in 2013.

Source colony	Receiving colony	Movement probabilities (%)	Estimated number of individuals that moved
East Sand Island	Crescent Island	0.5	70
East Sand Island	Goose Island	0.4	65
East Sand Island	Corps-constructed islands	3.1	461
Crescent Island	East Sand Island	3.9	30
Crescent Island	Goose Island	2.1	16
Crescent Island	Corps-constructed islands	3.0	23
Goose Island	East Sand Island	2.3	15
Goose Island	Crescent Island	18.0	122
Goose Island	Corps-constructed islands	2.5	17
Corps-constructed islands	East Sand Island	14.0	328
Corps-constructed islands	Crescent Island	6.4	149
Corps-constructed islands	Goose Island	2.5	59

Table 16. Estimated colony size (number of breeding pairs) for double-crested cormorants nesting on East Sand Island in the Columbia River estuary during 1997-2014. Errors in the estimates are 95% confidence limits (CL).

Year	Colony Size	Lower 95% CL	Upper 95% CL
1997	5,023	4,722	5,324
1998	6,285	5,908	6,662
1999	6,561	6167	6,955
2000	7,162	6,732	7592
2001	8,120	7,633	8,607
2002	10,230	9616	10844
2003	10,646	10,007	11,285
2004	12,480	11,731	13,229
2005	12,287	11,550	13,024
2006	13,738	12,914	14,562
2007	13,771	12,945	14,597
2008	10,950	10,585	11,315
2009	12,087	11,929	12,245
2010	13,596	13,130	14,062
2011	13,045	12,881	13,209
2012	12,301	11,886	12,716
2013	14,916	14,545	15,287
2014	13,626	13,334	13,918
Average (1997-2013)	10,776	10,648	10,906

Table 17. Number of active double-crested cormorant nests on the Astoria-Megler Bridge and on 12 channel/navigational markers located in the upper Columbia River estuary (UECM) in 2014 (see Map 5). Number of active double-crested cormorant nests were estimated during boat-surveys (for Astoria-Megler Bridge and UECM #1 - 8) and counts of active nests in aerial photography (for UECM #9 - 12).

				Number of active nests			
Site	Lat	Long	River km	April	May	June	July
Astoria-Megler Bridge	46.2120	-123.8603	15	73	318	313	333
UECM #1	46.2341	-123.7142	34	8	7	7	10
UECM #2	46.2329	-123.7134	34	3	22	28	25
UECM #3	46.2351	-123.7057	34	2	0	0	0
UECM #4	46.2558	-123.6769	37	19	51	47	45
UECM #5	46.2565	-123.6685	37	1	8	4	5
UECM #6	46.2617	-123.6656	39	22	68	71	66
UECM #7	46.2611	-123.6417	40	5	5	0	0
UECM #8	46.2624	-123.6365	40	8	16	16	3
UECM #9	46.2527	-123.5434	47	0	-	0	-
UECM #10	46.2517	-123.5293	48	15	-	26	-
UECM #11	46.2607	-123.5155	48	33	-	53	-
UECM #12	46.2616	-123.5029	50	48	-	66	-
UECM (TOT)				164		318	

APPENDIX A:

CASPIAN TERN RESPONSE TO MANAGEMENT AT GOOSE ISLAND, POTHOLES RESERVOIR, AS INDICATED USING SATELLITE TELEMETRY

Introduction

In the Columbia Plateau region, avian predators consume substantial numbers of juvenile salmonids (*Oncorhynchus* spp.) belonging to multiple populations, several of which are listed as threatened or endangered under the U.S. Endangered Species Act (ESA; Antolos et al. 2005, Weise et al. 2008, Maranto et al. 2010, Lyons et al. 2011a, Evans et al. 2012). In particular, Caspian terns (*Hydroprogne caspia*) nesting on Goose Island in Potholes Reservoir have been documented to consume in excess of 15% of the available steelhead (*O. mykiss*) population below Rock Island Dam in some years (Evans et al. 2012). Lyons et al. (2011b) estimated that the annual population growth rate (λ) of the Upper Columbia River steelhead distinct population segment could be increased by up to 4.2% (for the hatchery-raised portion of the population) and 3.2% (for the wild portion of the population) if predation by Caspian terns nesting at the Goose Island colony was completely eliminated and if other mortality factors did not compensate for the reduction in tern predation. These results have led resource managers to develop a management plan to reduce tern predation on ESA-listed juvenile salmonids by Caspian terns across the Columbia Plateau, including by terns that have nested at Potholes Reservoir (USACE 2014).

Caspian terns are colonial fish-eating waterbirds that were first documented nesting in the Columbia Plateau region in 1929 (Kitchin 1930). Since 2000, terns have nested on at least 11 islands across the Columbia Plateau (Adkins et al. 2014, BRNW 2014). One of the largest Caspian tern colonies on the Columbia Plateau is located at Goose Island in Potholes Reservoir, WA. The Goose Island colony ranged from 87 to 487 breeding pairs during 2004-2013, exceeding 200 breeding pairs in all but 2004, the year of initial colonization (BRNW 2014).

Caspian terns nesting at Potholes Reservoir were first documented to consume Columbia River juvenile salmonids in 2000, by the discovery of salmonid Passive Integrated Transponder (PIT) tags at the nesting colony on Solstice Island (Antolos et al. 2004). Remarkably, the Columbia River is >30 km from Potholes Reservoir, requiring a lengthy commute by nesting terns. Subsequent studies have documented predation rates on PIT-tagged samples of Chinook salmon (*O. tshawytscha*) and steelhead (Maranto et al. 2010, Evans et al. 2012) from Upper Columbia River populations. In 2013, Caspian terns nesting at Goose Island were tracked during the steelhead outmigration period using telemetry tags that regularly recorded Global Positioning System (GPS) locations (BRNW 2014). Just over half of the tagged terns foraged in the Columbia River, with concentrated foraging activity occurring in the reservoirs impounded by Wanapum and Priest Rapids dams and around islands in the Hanford reach. In addition, a small proportion of actively nesting tagged terns were tracked to foraging locations ~90 km away on the Snake River – the longest foraging trips documented for the species.

Survival standards for juvenile salmonids established under the 2004 Biological Opinion for the Priest Rapids Project (Wanupum Dam and Priest Rapids Dam and their associated reservoirs; operated by the Grant County Public Utility District [GPUD] No. 2) require at least 93% survival for juvenile salmonids through each hydropower development (one dam and reservoir; NMFS 2004). Studies have indicated that survival standards for steelhead were not met in the Priest Rapids development during 2008-2010 and in the Wanapum development in 2010 (Timko et al. 2011, Thompson et al. 2012). Estimates of predation rates by Goose Island Caspian terns on steelhead smolts tagged and released by GPUD during these years ranged from 10.8% to 21.9% of available steelhead smolts below Rock Island Dam (Evans et al. 2013), indicating that predation by Caspian terns was a substantial source of smolt mortality.

In response to the 2008/2010 Biological Opinion on the operation of the Federal Columbia River Power System (NOAA 2008, 2010), the U.S. Army Corps of Engineers – Walla Walla District and the U.S. Bureau of Reclamation developed an Inland Avian Predation Management Plan (IAPMP; USACE 2014) to reduce avian predation on juvenile anadromous salmonids, particularly that by Caspian terns on the Columbia Plateau. This plan outlined steps to be taken to dissuade Caspian terns from nesting on two islands in the region: Goose Island at Potholes Reservoir and Crescent Island in the McNary Pool of the mainstem Columbia River. In 2014 the primary management objective was to reduce the size of the Goose Island colony. A combination of techniques were used to accomplish this colony reduction: passive habitat manipulation (placement of stakes, ropes, and flagging across more than half of Goose Island and all of the former Caspian tern colony), active hazing (human presence, shining of a green laser over roosting birds), and limited egg removal (three eggs were collected under permit within 24 hours of laying). With the exception of the three nascent nests where eggs were collected, Caspian terns were prevented from nesting on Goose Island proper. Caspian terns were not dissuaded from nesting on a small rocky islet immediately adjacent (ca. 100m offshore) to Goose Island, however, and eventually 156 breeding pairs of terns nested there.

Wildlife telemetry tags capable of transmitting to the ARGOS satellite network have been used to track the activity of a variety of species, including large waterbirds (e.g., Courtot et al. 2012), for over 20 years. Technology miniaturization in recent years has resulted in satellite telemetry tags small enough to be fitted onto medium-sized birds, including Caspian terns. Tags using the ARGOS satellite network deliver less location precision (ca. 1 km) than GPS-based technology (ca. 10s of m), but benefit from lower power consumption and consequently offer greater flexibility in tag lifetime and weight. ARGOS-based satellite tags with a small solar panel incorporated to recharge the on-board battery can achieve extended lifetimes (> 1 year).

In this study, we captured and tagged a sample of adult Caspian terns at the Goose Island colony site prior to the beginning of the 2014 breeding season and tracked them through the subsequent breeding period. Our objectives were to (1) describe the different types of responses by terns to the loss of nesting habitat at Goose Island, (2) quantify how much of the activity of these terns still occurred on the Columbia Plateau region and specifically in foraging areas traditionally used by terns nesting at Goose Island, and (3) identify where terns that left

Goose Island might seek to nest. Collectively, these observations allow for an evaluation of the efficacy of Caspian tern management plan at Goose Island by providing data on dispersal patterns and by providing data on whether or not terns continue to forage on juvenile salmonids in the Columbia Plateau region.

Methods

Tagging

Caspian terns were captured using a Netblaster compressed-air powered net launcher (Wildlife Control Supplies, East Granby, CT) at the former colony site on Goose Island in Potholes Reservoir (Figure A1). Materials covering the colony to dissuade tern nesting (stakes, ropes, and flagging erected in early March) were temporarily moved aside from a portion of the former colony approximately 15 m x 15 m in size on 31 March to allow deployment of the net launcher. Terns were captured in small groups during 2 – 11 April. On 11 April, immediately following the final capture session, the dissuasion materials were redeployed across the former colony and all capture materials removed. No terns were observed landing on or near the former colony area following redeployment of dissuasion materials and no terns nested there during the 2014 breeding season. Capture and tagging of terns was completed 12 days before any Caspian terns were observed to lay eggs anywhere in Potholes Reservoir (23 April).

We attached satellite tags to a subsample of captured Caspian terns using one of two harness configurations. Initially, 10 tags were deployed using a backpack-style harness used previously on royal terns (*Thalasseus maximus*) and black skimmers (*Rynchops niger*; L. Ferguson, The Wetlands Institute, Stone Harbor, NJ). Terns fitted with backpack harnesses experienced a 24-48 hour acclimation period, and one tagged bird was found depredated along the shoreline of Potholes Reservoir within 48 hours of release. Consequently, the remainder of deployments used a leg-loop harness attachment previously used on south polar skuas (*Catharacta maccormicki*) and northern fulmars (*Fulmarus glacialis*; Mallory and Gilbert 2008). Terns fitted with a leg-loop harness rapidly adjusted to carrying the tag and resumed normal behavior shortly, if not immediately, following release. The tag recovered from the depredated tern was redeployed on 11 April, resulting in a total of 28 tags deployed on terns: 9 with back-pack harnesses and 19 with leg-loop harnesses.

Satellite tags were manufactured by Microwave Telemetry Inc. (Columbia, MD) and programmed to operate on a 32 hour duty cycle, with 6 hours on and 26 hours off, transmitting at a 60 second repetition rate during the on period of each cycle. Each tag incorporated a small solar panel that recharged a battery allowing transmission during daylight or nighttime hours. Tags weighed 12.4 – 12.9 g, not including harness materials, and were ≤ 2.2% of body mass for all individuals tagged (body mass of tagged terns ranged from 590 to 720 g).

We collected 5-7 breast feathers from tagged terns for DNA-based gender identification (Avian Biotech International, Tallahassee, FL).

Data Filtering and Analyses

Raw position fixes of tagged terns were reported daily by the Argos System (CLS America, Inc., Largo, MD). We used the Douglas Argos-Filter Algorithm (Douglas et al. 2012) to remove unlikely raw locations, using criteria similar to other seabird satellite telemetry studies. For example, consecutive locations that would have required flight speeds > 80 km/h were discarded. Across all tags, a median of 8 filtered locations were retained during each 6 h on cycle (range: 1 – 14 locations).

Foraging Activity

To describe the response of tagged Caspian terns to the reduction in nesting habitat at Goose Island, we characterized their activity within three geographic extents of potential interest:

- Foraging areas of terns nesting at Goose Island in the past, prior to tern management activities
- The Columbia and Snake rivers defined by the Federal Columbia River Power System (FCRPS) above The Dalles Dam, near The Dalles, OR
- The Columbia Plateau region (Figure A1)

To represent foraging areas of terns nesting at Goose Island in the past, we used results from a tagging study conducted at Goose Island in 2013 (BRNW 2014). In that study, terns nesting at Goose Island were captured during the peak steelhead smolt outmigration period in May (FPC 2014) and fitted with tags that collected location data using the Global Positioning System (GPS) satellite network. We used a 95% contour interval for a kernel density estimate based on all GPS locations within 60 km of the colony but excluding locations within 500 m of the colony. The resulting extent included foraging areas on the Columbia River (Wanapum and Priest Rapids dam reservoirs, Hanford Reach), Potholes Reservoir, Moses Lake, and Scooteney Reservoir.

To describe use of the FCRPS we used geographic extents for the Columbia and Snake rivers (available from the U.S. Geological Survey National Hydrography Dataset at nhd.usgs.gov) from The Dalles Dam (Columbia River rkm 309) upstream to Lower Granite Dam (Snake River rkm 177). An additional buffer width of 5 km per side were added to the river extent to account for tag location uncertainty.

Finally, to describe use of the broad region, we defined the Columbia Plateau to include the Columbia Plateau ecoregion boundary (as defined by the U.S. Environmental Protection Agency's Level III ecoregion classifications at www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm), truncated at the Washington/Idaho border to the east, the Washington/Oregon border to the south, and The Dalles Dam to the west (Figure A1). This extent captures all the areas of the upper Columbia Basin where anadromous salmonid smolts have been found to be susceptible to predation by Caspian terns, and includes all of the colony sites used in recent years (Goose Island in Potholes Reservoir,

Crescent and Badger islands in the McNary Pool of the Columbia River, the Blalock Islands in the John Day Pool, as well as colonies on islands in Banks Lake and Sprague Lake; see Map 1 of the main report). As with the FCRPS extent, an additional 5 km buffer was added to the extent to allow for tag location uncertainty.

For each of these geographic extents we quantified the presence of each tagged tern during the primary smolt outmigration period (April 18 – May 31). Specifically, we classified a tagged tern to be present during a given on-cycle if any of the locations recorded were within the given geographic extent. For each tagged individual, we calculated the proportion of on-cycles in which the tern was present in each extent. Potential differences in these metrics between males and females and between those with backpack and leg-loop harnesses were examined using Mann-Whitney rank-sum tests.

Colony Associations

To assess the potential breeding response to habitat loss at Goose Island, we characterized the association of birds with known colony sites across the Pacific Northwest. We considered possible use of 24 currently or recently active colony sites including those in the Columbia Plateau region, western Washington, southern British Columbia, Oregon, and northern California. It was not possible to exhaustively identify nesting status at the various colony sites through site visits and visual monitoring; however, anecdotal observations were collected in a few cases. Instead of visual observations, we used nighttime location data to infer associations of tagged terns with specific colony sites. Nighttime location data provided an incomplete record of activity, however, as location data were collected only during 2-5 nights per week due to the 32 hour duty cycle. We defined a tagged individual to be associated with a specific colony on a particular day of the season if it had been positively located at that colony on at least 3 of the previous 9 nights and had not been located at any other colonies during those 9 nights. This definition of colony association was consistent with limited visual observations at colonies which were regularly monitored (primarily the rocky islet immediately adjacent to Goose Island and at Crescent Island).

Results

Of the 29 Caspian terns captured and tagged in early April, 11 were previously banded with leg-bands (external bands with emblazoned codes). Leg bands indicated that, ten tern had been captured and banded as adults at Goose Island during 2010 – 2013, with the other captured and banded as an adult at Crescent Island in 2005. All 11 had been observed nesting at Goose Island in one or more years during 2010 – 2013. Based on genetic analysis of feathers, of the 28 terns tracked, 14 were males and 14 were females. Four tags quit transmitting data during the April-July period; a tern carrying one of these tags was found dead in Everett, WA, but the cause of tag failure could not be confirmed in the other three cases. The last days of transmission for these tags were 30 May, 5 June, 15 June, and 30 June. Three of the four failed tags had been attached using a backpack configuration, including the tern found dead.

Half (n = 14) of the tagged birds were visually observed displaying nesting behavior (nest scraping, copulating, incubating eggs, or attending chicks) during the course of the season, including six terns that were observed incubating eggs or attending chicks. The majority of nesting behavior was observed at the rocky islet adjacent to Goose Island, although three birds were seen displaying nesting behavior at Crescent Island. Nesting behavior was not visually confirmed at other colony sites; limited access, poor visibility, and infrequent visits made such observations unlikely.

On average, 58% of the filtered locations of individual satellite-tagged terns were within the previously documented foraging areas of Caspian terns nesting at Goose Island (range: 6 – 100%; Figure A2). An average of 21% of locations were within the reaches of the Columbia and Snake rivers defined by the FCRPS above The Dalles Dam (range: 0 – 88%; Figure A3). On a regional scale, on average, 90% of locations were within the Columbia Plateau region (range: 6 – 100%; Figure A4), with half (n = 14) of the tagged terns only detected on the Plateau, and 24 terns located on the Plateau in more than 75% of all locations. Based on rank-sum tests, no statistical differences (alpha > 0.05) in these measures were detected between male and female tagged terns, or between terns carrying tags affixed with a backpack or leg-loop harness.

After a brief period of dispersal from Goose Island, a majority of tagged terns returned and were associated with that colony site for days, weeks, or in a few cases for the entire breeding season (Figure A5). In early to mid-May, during the peak of steelhead out-migration period (see Figure 17 of the main report), the majority of tagged terns (18-22 individuals) were regularly associated with the Goose Island colony. This number declined throughout the month, and only three tagged terns were consistently associated with the Goose Island at the end of May. Some tagged terns were often associated with other colony sites on the Columbia Plateau. A peak of six tagged terns were associated with the Banks Lake colony around 28 May and a peak of five tagged terns with the Sprague Lake colony around 4 June. Smaller numbers of tagged terns (1-2 individuals at a time) were associated with the Crescent Island and Blalock Islands colonies. Most tagged terns that associated with the Banks Lake colony had ended their association with that site by 4 June; the last tern associated with the Sprague Lake colony ended its association around 18 June. Boat-based surveys, along with periodic aerial surveys, indicated that up to 67 breeding pairs of terns attempted to nest at the Banks Lake colony and up to 8 breeding pairs attempted to nest at the Sprague Lake colony. Terns were observed on nests at the Banks Lake colony as late as 18 June but on 22 June the nesting area had been abandoned. One tagged tern remained associated with the Banks Lake colony until 24 June, however. Observations off the Sprague Lake colony indicated that terns were apparently nesting at the site as late as June 24th, but during a visit on June 29th it was observed that the apparent nesting area had been abandoned. Tagged terns were associated with Crescent Island and the Blalock Islands as late as 11 June and 1 June, respectively. As tagged terns ended their associations with other sites on the Columbia Plateau, they frequently resumed an association with the Goose Island colony. The number of tagged terns associated with Goose Island grew from just three at the beginning of June to thirteen by 20 June – just over half of the tags still functional at that date (n = 25).

This large number of tagged terns associated with Goose Island was consistent for approximately a month, with 12 tagged terns still associated with the colony site as late as 24 July, when numbers began to decline. Colony associations of male and female tagged terns both followed the general pattern described above.

Across the breeding season, tagged individuals were also intermittently associated with colony sites in coastal Washington, including at the Port of Bellingham, the Everett waterfront, the Seattle waterfront, and in Grays Harbor. These associations typically lasted for 7-10 days and with only one individual associated with any given coastal site at a time.

The median date of final departure from the Columbia Plateau during the 2014 breeding season, for those tags that provided location data through the entire breeding season, was 7 July. The earliest final departure occurred on 25 May and the latest on 31 August.

Discussion

The Caspian terns we tracked in this study displayed three general responses to nesting habitat dissuasion at the Goose Island colony where they were captured: (1) stay and compete for reduced nesting habitat, (2) move and associate with another colony; returning if that colony fails, or (3) nomadically wander without a sustained association with any colony.

The small amount of nesting habitat left available at the rocky islet adjacent to Goose Island allowed some tagged terns to nest in the vicinity of Goose Island despite the dissuasion that prevented nesting at the former colony site. Almost half of the tagged terns were visually observed displaying breeding behavior at the rocky islet adjacent to Goose Island and two were ultimately observed attending near fledging-aged chicks. Other tagged terns sought nesting opportunities elsewhere, as suggested by prolonged associations with other colony sites and visually confirmed at the Crescent Island colony. These associations with other colonies, presumably nesting attempts for at least some individuals, were temporary in all cases, either due to colony failure, as in the case of tagged terns associated with Banks or Sprague lakes, or individual nest failure, as in the case of at least one tagged tern at Crescent Island. None of the tagged terns were associated with other colonies long enough to have successfully reared chicks. Finally, about half of the tagged terns left Goose Island during April or May and did not have any sustained associations with any colony after that departure. These terns visited colonies both on the Columbia Plateau and elsewhere, but lengthy (a week or more) associations were not observed. It is possible that these terns could have initiated brief nesting attempts, but if so their attempts were only short investments. Without exception, tagged individuals that displayed a dispersal response to the habitat dissuasion at Goose Island did not successfully raise young in 2014, and presumably in some cases did not even initiate a nesting attempt (i.e., lay eggs). Caspian terns are a long-lived species (some birds live > 25 years; Cuthbert and Wires 1999), so one year of foregone reproduction is not catastrophic at the population level, and is presumably consistent with the species' evolved use of ephemeral nesting habitat.

Based on the distribution of tagged Caspian terns during the primary smolt outmigration period of late-April to May, the initial implementation of the Inland Avian Predation Management Plan was successful in shifting the foraging activity of some terns away from areas where they traditionally preyed upon juvenile salmonids. In particular, tagged terns shifted almost half of their activity away from areas used by terns nesting at Goose Island in 2013, and specifically reduced foraging activity in the reaches of the mid-Columbia River impounded by Priest Rapids and Wanapum dams. The Upper Columbia River population of steelhead trout has been documented to be particularly susceptible to predation by Goose Island Caspian terns in these areas (Evans et al. 2013). The tern activity we tracked suggested that predation would have been lower in 2014 compared with 2013; a finding supported by steelhead PIT tag predation rate data that indicated ca. 80% reduction in steelhead predation rates by terns nesting in Potholes Reservoir in 2014 compared with 2013 (see Appendix B, Table B2, of the main report). Presumably, if tern nesting is prevented anywhere in the proximity of Goose Island in future years, an even greater portion of tern activity will be shifted away from traditional foraging areas in the mid-Columbia River.

Reductions in smolt predation rates by tern nesting in Potholes Reservoir observed in 2014 were lower than those implied by a reduction in colony size alone (see Figure 17 of this report). Numerous factors have been linked to juvenile salmonid susceptibility to Caspian tern predation, including fish abundance, run-timing, and abiotic river conditions (see Section 1.2.3 of the main report and Hostetter et al. 2012). Another possible factor influencing both tern foraging activity and predation rates on smolts in 2014 was the drawdown of the Wanapum Pool to facilitate repair of faults found in Wanapum Dam. Lower water levels and increased river flows could have result in shorter transit times of smolts and ultimately may have made steelhead less susceptible to tern predation in 2014 relative to years past. Tagged terns were still tracked to the Wanapum pool in 2014, but less efficient foraging there could have contributed to a reduction in tern presence. This factor is difficult to assess using data from 2014 alone; additional data collection in 2015 (when normal water management practices are expected) may improve our understanding of the importance of water levels and river flows in the Wanapum Pool on tern foraging behavior and predation rates.

At a larger scale, the 2014 dissuasion of nesting habitat at Goose Island did little to shift tern activity away from the Columbia Plateau during the smolt outmigration period. A notable portion of the activity of tagged terns (21% on average) was in the reaches of the Columbia and Snake rivers defined by the Federal Columbia River Power System. That shift in activity within the Plateau region could shift predation pressure onto other Columbia Basin populations of salmon and steelhead, or partially compensate for improvements in smolt survival in the Wanapum and Priest Rapids pools. The planned dissuasion of nesting habitat at Crescent Island (Phase 2 of the IAPMP) is expected to prevent a long-term shift of terns from Potholes Reservoir to this portion of the Columbia River, however.

We cannot completely rule out the possibility that the behavior of tagged terns was affected by the burden of carrying the satellite transmitter. Terns tagged using the backpack harness

configuration experienced an initial acclimation period, and one bird was depredated with 48 hours of tagging and release. Following that initial acclimation period, and typically immediately upon release for birds tagged using a leg-loop harness configuration, our visual observations of the behavior of tagged terns (mostly at the rocky islet adjacent to Goose Island, but also at Crescent Island and other monitored colonies in the region) indicated that terns quickly resumed normal behavior. Given limited opportunities, observing breeding behavior for half of the tracked terns suggested that breeding was in general not substantially inhibited. We also saw no differences in the distribution, or colony associations, of terns tagged using either harness configuration. Finally, tagged terns displayed high mobility during the breeding season and fall migration. A total of 23 of the tracked individuals reached their overwintering locations in Mexico apparently without incident.

In conclusion, Caspian terns tracked as part of this study suggested that the IAPMP achieved some success in the initial year of implementation. Tern foraging activity was reduced in areas of the mid-Columbia River where terns have previously had substantial impacts on Upper Columbia River steelhead. Displaced terns did not leave the larger Columbia Plateau region at an appreciable rate during the primary smolt outmigration period, however. Consequently, some predation may have been shifted to other locations and/or other Columbia Basin salmonid populations. Additional IAPMP actions to be implemented in 2015, including an expansion of nest dissuasion from Goose Island to the nearby adjacent islets, initiation of nest dissuasion at Crescent Island, and enhancement of nesting habitat for Caspian terns in San Francisco Bay, appear poised to address several of the factors limiting the displacement of terns from the Columbia Plateau. Marginal nesting habitat at Banks Lake, Sprague Lake, or in the Blalock Islands in the Columbia River (John Day Pool) may be a continued draw for displaced Caspian terns, however. The inability of tagged terns to nest successfully anywhere away from the rocky islet adjacent to Goose Island in 2014 suggests that the long-term goal of reducing tern predation on Columbia Basin salmonids by encouraging fidelity to nest sites outside the Columbia Basin will likely require a sustained, multi-year effort.

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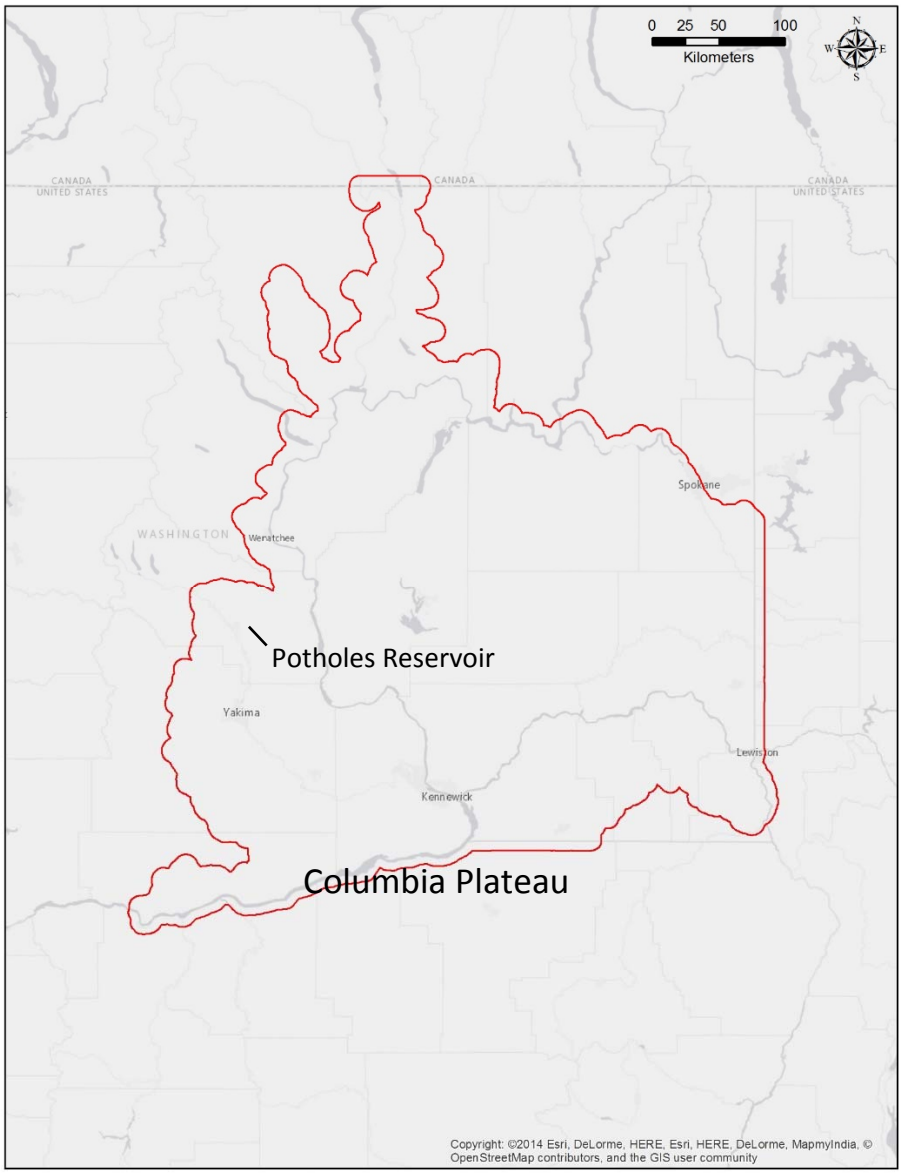

Figure A1. Columbia Plateau region of eastern Washington State (red polygon). Caspian terns were captured, tagged, and released at Goose Island in Potholes Reservoir during 2 – 11 April, 2014.

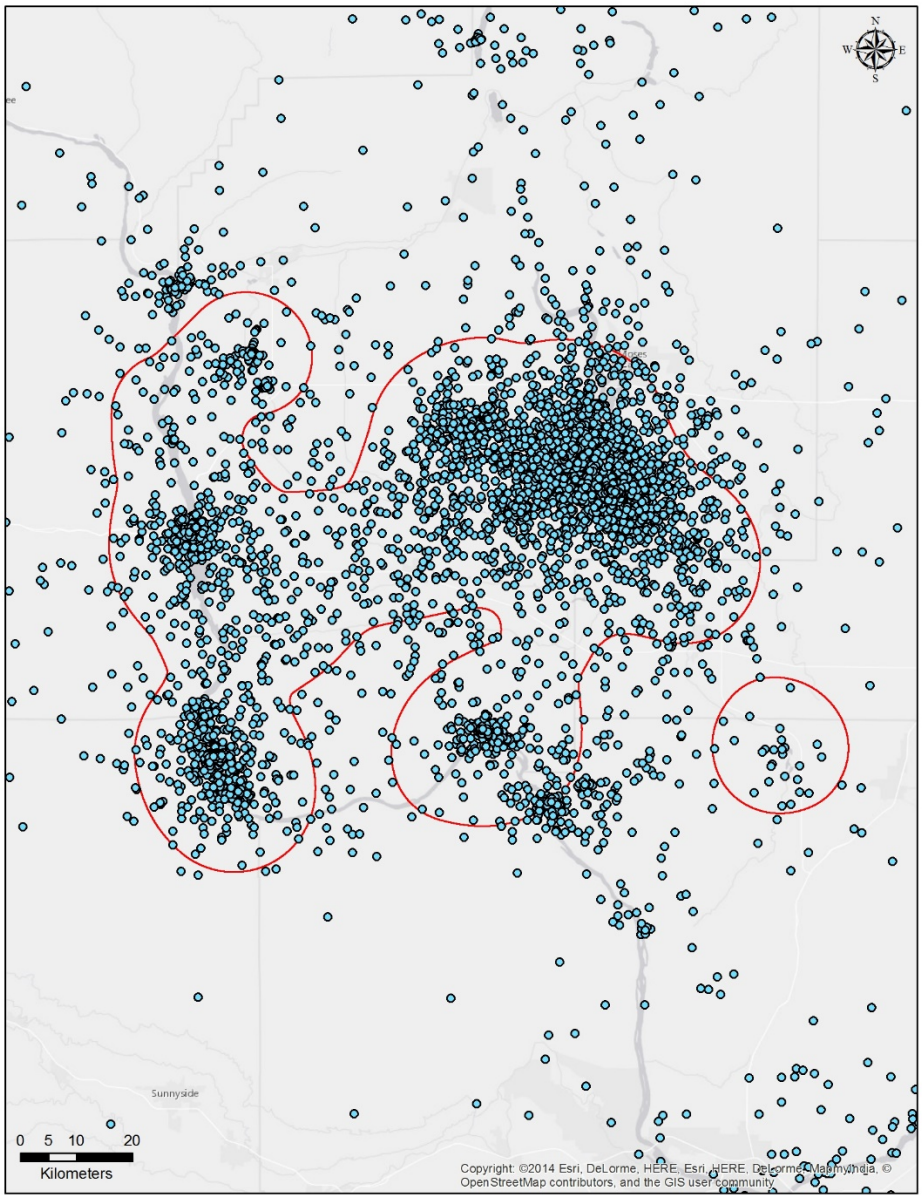

Figure A2. Locations of satellite-tagged Caspian terns during 18 April – 31 May, 2014 (points), in relation to the previously documented foraging areas of Caspian terns nesting at Goose Island, Potholes Reservoir (red polygons). Data to define the foraging areas of nesting terns were collected in 2013 by using GPS telemetry tags fitted to a sample of terns nesting at Goose Island. The foraging area used is a 95% contour interval for a kernel density estimate based on all GPS locations within 60 km of the colony but excluding locations within 500 m of the colony. A mean of 58% of locations of satellite-tagged terns (range 6 – 100%) were within the previously documented foraging areas.

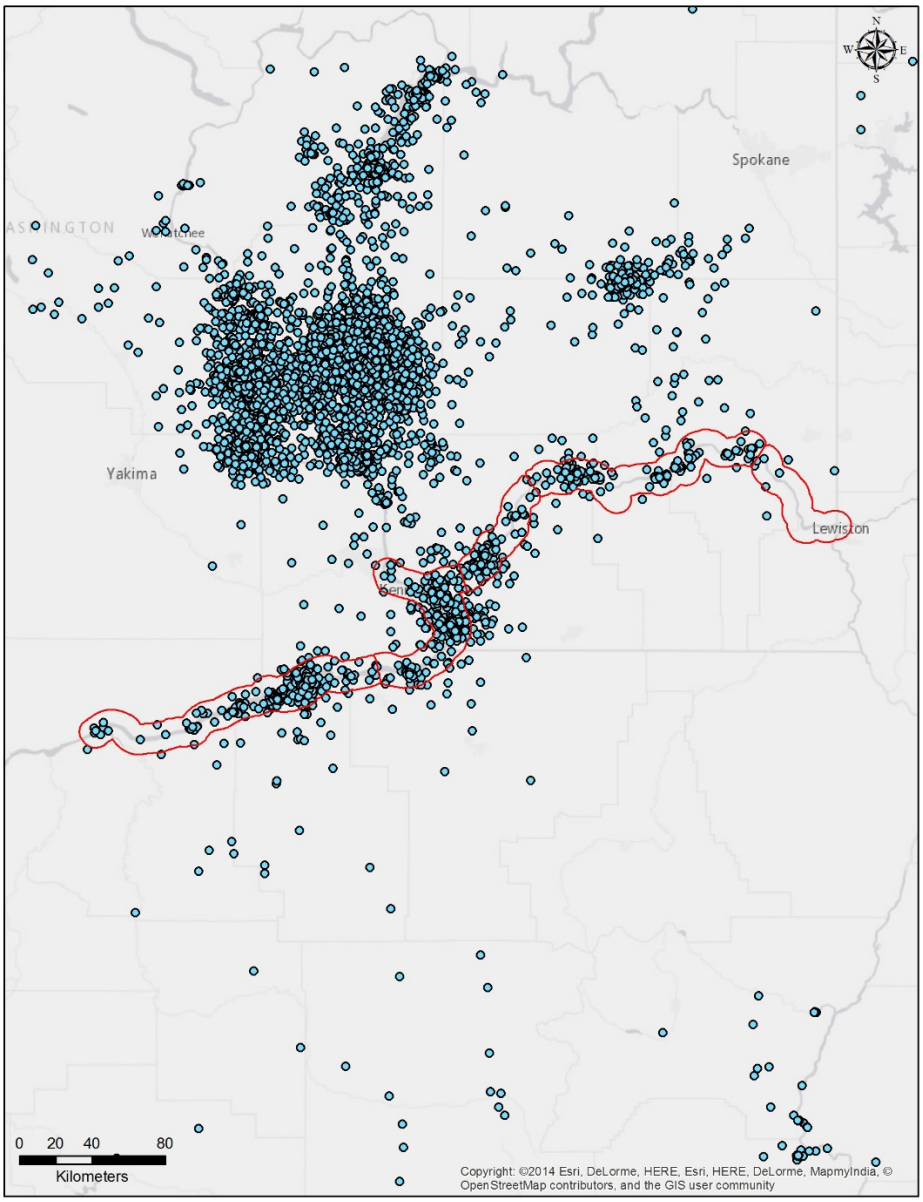

Figure A3. Locations of satellite-tagged Caspian terns during 18 April – 31 May, 2014 (points), in relation to reaches of the Columbia and Snake rivers defined by the Federal Columbia River Power System (FCRPS), above The Dalles Dam (red polygon). A mean of 21% of locations of satellite-tagged terns (range 0 – 88%) were within the region defined by the FCRPS.

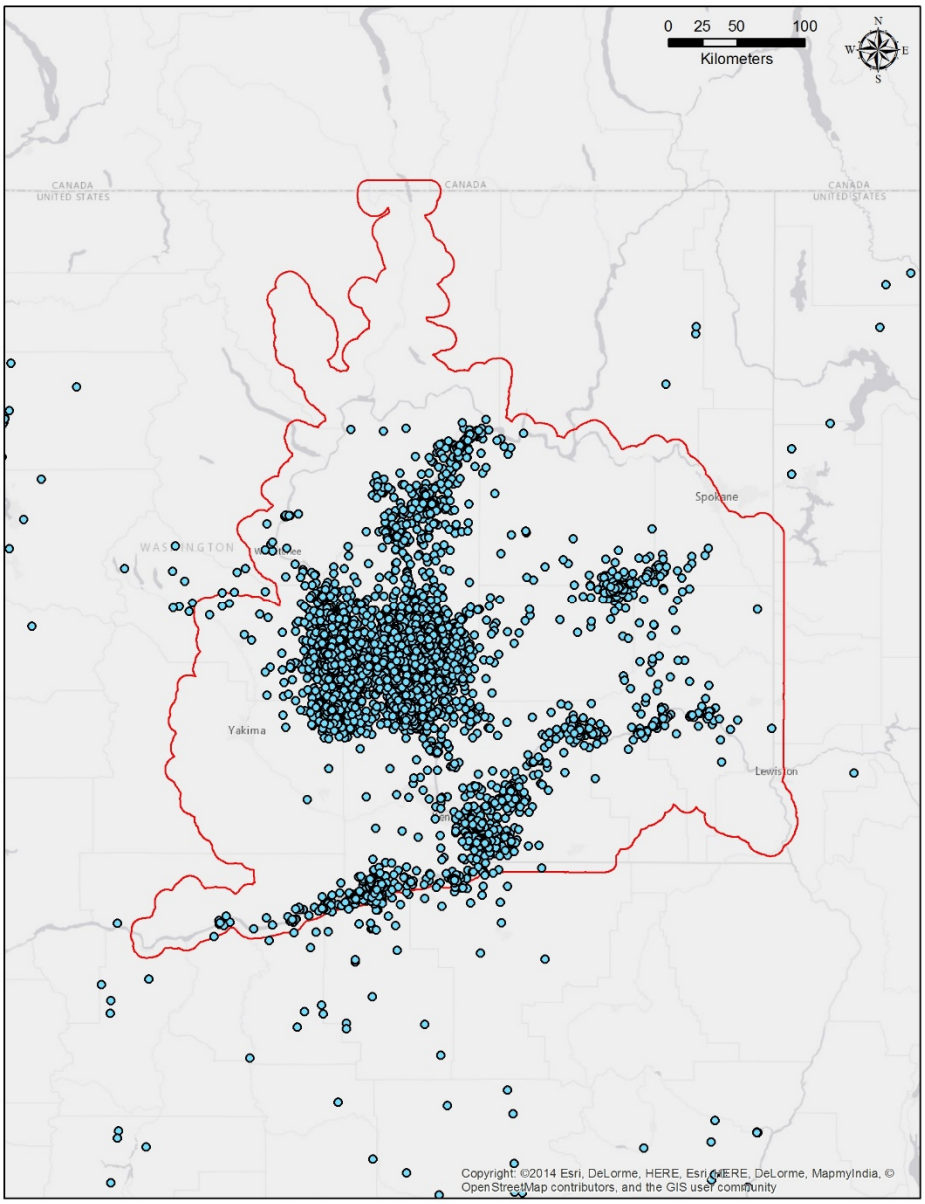

Figure A4. Locations of satellite-tagged Caspian terns during 18 April – 31 May, 2014 (points) in relation to the Columbia Plateau region (red polygon). A mean of 90% of locations of satellite-tagged terns (range 6 – 100%) were within the Columbia Plateau region, with half of all tagged terns (n = 14) only detected on the Plateau and 24 tagged terns located on the Plateau in more than 75% of all locations.

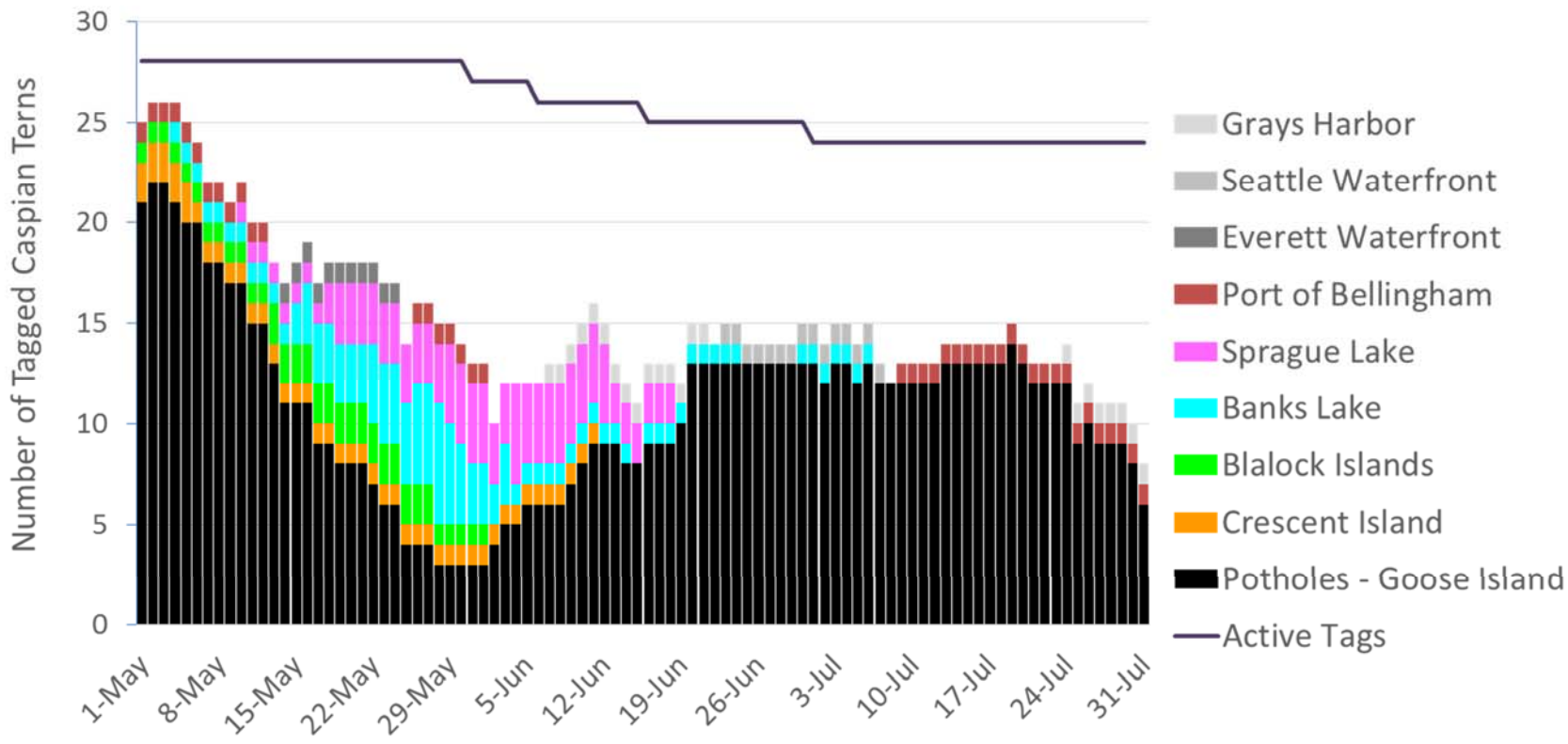

Figure A5. Colony associations of satellite-tagged Caspian terns during 1 May – 31 July, 2014. A tagged individual was considered to be associated with a specific colony on a particular day of the season if it had been positively located at that colony on at least 3 of the previous 9 nights and had not been located at any other colonies during those 9 nights.

APPENDIX B:

HISTORICAL PREDATION RATES ON PIT-TAGGED JUVENILE SALMONIDS CALCULATED USING A BAYESIAN ANALYTICAL FRAMEWORK

This appendix provides smolt PIT tag predation rates for managed bird colonies (Caspian terns nesting on East Sand Island and Goose Island) or colonies were management actions have been proposed (Caspian terns nesting on Crescent Island or double-crested cormorants nesting on East Sand Island) during the 2007-2014 breeding seasons (Tables B1-B4). Predation rates were calculated using a Bayesian analytical framework and are corrected for PIT detection efficiency and deposition rates (see Section 1.1.4). Predation rates based on Bayesian methods differ slightly from those reported by BRNW in years past (see Appendix B of BRNW 2014a), whereby Bayesian estimates incorporate greater uncertainty in deposition rates and detection efficiencies, which often results in wider 95% credible intervals.

Table B1. Estimated annual predation rates (95% credible intervals) of PIT-tagged, ESA-listed salmonid smolts by Caspian terns nesting on East Sand Island in the Columbia River estuary during 2007-2014. Predation rates are based on numbers of PIT-tagged fish (N) interrogated passing Bonneville Dam on the Columbia River or Sullivan Dam on the Willamette River. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiency and deposition rates. Only salmonid populations with ≥ 500 PIT-tagged smolts interrogated passing a dam were evaluated in any given year. Dashes denote populations with < 500 PIT-tagged fish available. Salmonid populations originating from the Snake River (SR), Upper Columbia River (UCR), Middle Columbia River (MCR) and Upper Willamette River (UWR) were evaluated, with runs of spring (Sp), summer (Su), and fall (Fa) fish included, where applicable. Management actions on East Sand Island Caspian terns were initiated in 2011.

Year	SR Sp/Su Chinook (Threatened)	SR Fa Chinook (Threatened)	UCR Sp Chinook (Endangered)	UWR Sp Chinook (Threatened)	SR Sockeye (Endangered)	MCR Steelhead (Threatened)	SR Steelhead (Threatened)	UCR Steelhead (Threatened)
2007	3.1% (2.5-4.4)	3.4% (2.3-5.3)	1.9% (1.2-3.2)	1.4% (0.8-2.5)	-	18.7% (14.6-26.8)	22.6% (18.2-32.4)	15.7% (12.4-22.6)
N	*23,830*	*2,005*	*2,268*	*1,505*		*2,234*	*6,391*	*3,042*
2008	2.5% (1.9-3.6)	1.9% (1.5-2.7)	1.7% (1.0-2.9)	4.4% (3.2-6.7)	-	13.5% (10.6-19.2)	14.2% (11.5-19.9)	16.7% (13.1-24.2)
N	*11,425*	*24,136*	*1,662*	*2,509*		*2,291*	*19,572*	*2,513*
2009	4.7% (3.7-6.9)	2.0% (1.5-2.9)	3.7% (2.5-5.6)	1.7% (1.2-2.7)	1.3% (0.7-2.2)	14.1% (11.1-20.0)	14.5% (11.9-20.1)	20.0% (15.6-29.3)
N	*17,396*	*16,314*	*2,064*	*5,573*	*1,845*	*2,700*	*23,311*	*2,265*
2010	3.4% (2.7-4.8)	0.7% (0.5-1.1)	2.9% (2.2-4.3)	1.8% (0.6-4.4)	1.6% (0.8-2.9)	11.9% (9.4-17.4)	14.3% (11.3-20.4)	13.7% (11.0-19.3)
N	*38,441*	*17,974*	*5,972*	*510*	*1,382*	*8,515*	*40,024*	*12,284*
2011	2.5% (1.8-3.6)	0.7% (0.5-1.1)	2.9% (1.4-5.3)	0.9% (0.3-2.0)	0.4% (0.1-1.3)	9.6% (6.6-14.7)	12.0% (9.4-17.3)	9.1% (6.9-13.4)
N	*6,557*	*12,327*	*704*	*1,119*	*826*	*865*	*7,028*	*2,419*
2012	2.2% (1.7-3.3)	0.7% (0.5-1.1)	1.2% (0.7-2.1)	0.7% (0.4-1.3)	2.1% (1.2-3.7)	9.4% (6.5-14.4)	10.2% (7.7-14.9)	7.5% (5.6-11.3)
N	*17,929*	*10,742*	*3,227*	*3,731*	*1,457*	*1,084*	*4,768*	*3,357*
2013	1.2% (0.8-1.8)	0.9% (0.5-1.6)	0.7% (0.3-1.4)	1.0% (0.5-1.8)	0.8% (0.3-2.0)	9.9% (7.0-15.3)	12.7% (9.6-18.5)	8.9% (6.6-13.4)
N	*16,167*	*4,465*	*3,112*	*2,629*	*1,454*	*1,865*	*8,516*	*4,473*
2014	1.1% (0.8-1.7)	1.0% (0.5-1.9)	1.4% (0.7-2.5)	1.2% (0.5-2.5)	1.6% (0.8-3.0)	9.5% (6.5-14.5)	8.6% (6.7-12.5)	11.4% (8.5-16.8)
N	*14,828*	*2,800*	*2,297*	*1,587*	*1,739*	*1,119*	*8,812*	*3,841*

Table B2. Estimated annual predation rates (95% credible interval) of PIT-tagged, ESA-listed salmonid smolts by Caspian terns nesting in Potholes Reservoir during 2007-2014. Predation rates are based on numbers of PIT-tagged fish (N) interrogated passing Rock Island Dam on the middle Columbia River or Lower Monumental Dam on the lower Snake River. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiencies and deposition rates. Only salmonid populations with ≥ 500 PIT-tagged smolts interrogated passing a dam were evaluated in any given year. Dashes denote populations with < 500 PIT-tagged fish available. Salmonid populations originating from the Snake River (SR) or Upper Columbia River (UCR), with runs of spring (Sp), summer (Su), and fall (Fa) fish included, where applicable. Management actions on Goose Island (Potholes Reservoir) Caspian terns were initiated in 2014.

Year	SR Sp/Su Chinook (Threatened)	SR Fa Chinook (Threatened)	UCR Sp Chinook (Endangered)	SR Sockeye (Endangered)	SR Steelhead (Threatened)	UCR Steelhead (Threatened)
2007	<0.1%	0.3% (<0.1-1.1)	-	-	0.1% (<0.1-0.2)	15.3% (9.8-27.7)
N	*22,730*	*2,147*			*17,122*	*3,782*
2008	<0.1%	<0.1%	-	0.4% (<0.1-1.6)	<0.1%	11.1% (8.6-16.4)
N	*30,142*	*22,968*		*767*	*28,653*	*8,403*
2009	<0.1%	<0.1%	5.5% (2.7-10.7)	0.1% (<0.1-0.4)	0.1% (<0.1-0.1)	22.6% (17.2-33.7)
N	*20,753*	*27,198*	*738*	*2,651*	*52,220*	*8,025*
2010	<0.1%	<0.1%	2.0% (0.7-4.4)	0.3% (<0.1-1.4)	<0.1%	14.6% (11.0-21.8)
N	*8,562*	*38,709*	*929*	*568*	*10,951*	*8,382*
2011	<0.1%	<0.1%	0.6% (0.1-1.9)	<0.1%	<0.1%	12.9% (9.6-19.6)
N	*65,140*	*55,096*	*1,567*	*15,787*	*59,948*	*8,002*
2012	<0.1%	<0.1%	2.6% (1.2-5.4)	0.1% (<0.1-0.4)	0.2% (0.1-0.4)	18.4% (13.5-28.5)
N	*48,043*	*29,751*	*1,812*	*5,043*	*27,767*	*6,845*
2013	<0.1%	0.1% (<0.1-0.3)	2.5% (1.1-5.2)	0.1% (<0.1-0.5)	0.1% (<0.1-0.3)	14.8% (11.4-21.6)
N	*21,611*	*6,423*	*992*	*1,697*	*11,958*	*6,023*
2014	< 0.1%	< 0.1%	0.5% (0.1-2.2)	< 0.1%	< 0.1%	2.9% (1.9-5.1)
N	*37,226*	*7,264*	*641*	*3,118*	*21,393*	*7,757*

Table B3. Estimated annual predation rates (95% credible interval) of PIT-tagged, ESA-listed salmonid smolts by Caspian terns nesting on Crescent Island in McNary Reservoir during 2007-2014. Predation rates are based on numbers of PIT-tagged fish (N) interrogated passing Rock Island Dam on the middle Columbia River or Lower Monumental Dam on the lower Snake River. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiencies and deposition rates. Only salmonid populations with ≥ 500 PIT-tagged smolts interrogated passing a dam were evaluated in any given year. Dashes denote populations with < 500 PIT-tagged fish available. Salmonid populations originating from the Snake River (SR) or Upper Columbia River (UCR), with runs of spring (Sp), summer (Su), and fall (Fa) fish included, where applicable. Management actions for Crescent Island terns are scheduled to commence in 2015.

Year	SR Sp/Su Chinook (Threatened)	SR Fa Chinook (Threatened)	UCR Sp Chinook (Endangered)	SR Sockeye (Endangered)	SR Steelhead (Threatened)	UCR Steelhead (Threatened)
2007	0.4% (0.3-0.6)	0.9% (0.4-1.7)	-	-	3.9% (3.1-5.6)	2.5% (1.7-3.8)
N	*22,730*	*2,147*			*17,122*	*3,782*
2008	0.9% (0.7-1.3)	1.6% (1.2-2.3)	-	1.7% (0.6-3.7)	5.9% (4.7-8.5)	2.9% (2.1-4.3)
N	*30,142*	*22,968*		*767*	*28,653*	*8,403*
2009	1.5% (1.1-2.2)	1.1% (0.8-1.6)	0.2% (<0.1-1.2)	1.0% (0.5-1.7)	4.6% (3.7-6.6)	2.3% (1.7-3.5)
N	*20,753*	*27,198*	*738*	*2,651*	*52,220*	*8,025*
2010	0.4% (0.3-0.7)	1.0% (0.7-1.4)	0.9% (0.3-2.3)	1.5% (0.5-3.5)	4.0% (3.1-5.9)	1.8% (1.3-2.7)
N	*8,562*	*38,709*	*929*	*568*	*10,951*	*8,382*
2011	0.7% (0.5-1.0)	0.5% (0.4-0.8)	0.5% (0.1-1.2)	0.7% (0.5-1.1)	2.7% (2.1-4.0)	2.4% (1.8-3.6)
N	*65,140*	*55,096*	*1,567*	*15,787*	*59,948*	*8,002*
2012	0.6% (0.4-0.9)	0.5% (0.4-0.8)	0.2% (<0.1-0.8)	1.3% (0.9-2.2)	2.8% (2.1-4.1)	1.2% (0.8-2.0)
N	*48,043*	*29,751*	*1,812*	*5,043*	*27,767*	*6,845*
2013	0.5% (0.4-0.8)	0.7% (0.4-1.1)	0.4% (0.1-1.2)	0.6% (0.2-1.4)	2.9% (2.2-4.3)	2.9% (2.1-4.3)
N	*21,611*	*6,423*	*992*	*1,697*	*11,958*	*6,023*
2014	0.5% (0.3-0.7)	0.5% (0.3-0.8)	0.7% (0.2-2.1)	0.7% (0.4-1.3)	4.7% (3.7-6.9)	3.4% (2.5-4.9)
N	*37,226*	*7,264*	*641*	*3,118*	*21,393*	*7,757*

Table B4. Estimated annual predation rates (95% credible interval) of PIT-tagged, ESA-listed salmonid smolts by double-crested cormorants nesting on East Sand Island in the Columbia River estuary during 2007-2014. Predation rates are based on numbers of PIT-tagged fish (N) interrogated passing Bonneville Dam on the Columbia River or Sullivan Dam on the Willamette River. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiencies and deposition rates. Only salmonid populations with ≥ 500 PIT-tagged smolts interrogated passing a dam were evaluated in any given year. Dashes denote populations with < 500 PIT-tagged fish available. Salmonid populations originating from the Snake River (SR), Upper Columbia River (UCR), Middle Columbia River (MCR) and Upper Willamette River (UWR) were evaluated, with runs of spring (Sp), summer (Su), and fall (Fa) fish included, where applicable. Management actions for double-crested cormorants on East Sand Island are proposed for 2015.

Year	SR Sp/Su Chinook (Threatened)	SR Fa Chinook (Threatened)	UCR Sp Chinook (Endangered)	UWR Sp Chinook (Threatened)	SR Sockeye (Endangered)	MCR Steelhead (Threatened)	SR Steelhead (Threatened)	UCR Steelhead (Threatened)
2007	1.7% (1.1-2.7)	1.6% (0.7-3.3)	2.7% (1.5-5.1)	1.0% (0.3-2.6)	-	2.8% (1.5-5.2)	3.5% (2.3-5.8)	3.4% (2.1-6.1)
N	*23,830*	*2,005*	*2,268*	*1,505*		*2,234*	*6,391*	*3,042*
2008	3.5% (2.4-5.5)	2.6% (1.9-4.2)	3.6% (2.0-6.6)	3.3% (1.9-5.8)	-	14.0% (9.5-23.2)	14.7% (10.6-23.2)	6.2% (4.0-10.4)
N	*11,425*	*24,136*	*1,662*	*2,509*		*2,291*	*19,572*	*2,513*
2009	6.8% (4.9-10.7)	4.5% (3.2-7.1)	2.7% (1.5-4.9)	1.4% (0.8-2.4)	5.7% (3.5-9.8)	14.9% (10.3-23.8)	16.6% (12.0-25.7)	7.2% (4.7-12.0)
N	*17,396*	*16,314*	*2,064*	*5,573*	*1,845*	*2,700*	*23,311*	*2,265*
2010	5.3% (3.9-8.4)	3.9% (2.7-6.1)	3.3% (2.3-5.4)	4.2% (1.6-9.2)	2.6% (1.3-4.9)	8.2% (5.8-13.1)	7.5% (5.5-12.0)	6.8% (4.9-10.6)
N	*38,441*	*17,974*	*5,972*	*510*	*1,382*	*8,515*	*40,024*	*12,284*
2011	4.3% (2.9-6.9)	1.9% (1.3-3.1)	5.6% (2.9-10.8)	0.4% (0.1-1.5)	4.8% (2.4-9.1)	7.8% (4.6-14.0)	5.3% (3.7-8.5)	11.4% (7.8-18.6)
N	*6,557*	*12,327*	*704*	*1,119*	*826*	*865*	*7,028*	*2,419*
2012	3.7% (2.6-6.0)	2.6% (1.8-4.2)	2.1% (1.2-3.7)	0.6% (0.3-1.3)	3.7% (2.0-6.9)	3.3% (1.7-6.4)	4.9% (3.2-8.1)	6.5% (4.3-10.8)
N	*17,929*	*10,742*	*3,227*	*3,731*	*1,457*	*1,084*	*4,768*	*3,357*
2013	3.6% (2.5-5.7)	2.2% (1.3-3.7)	3.0% (1.8-5.3)	1.0% (0.4-2.0)	3.3% (1.8-6.2)	2.1% (1.0-4.1)	2.5% (1.7-4.0)	3.4% (2.2-5.7)
N	*16,167*	*4,465*	*3,112*	*2,629*	*1,454*	*1,865*	*8,516*	*4,473*
2014	8.5% (6.1-13.2)	2.4% (1.5-4.2)	6.1% (3.9-10.1)	1.8% (0.9-3.6)	4.5% (2.7-7.7)	6.4% (3.7-10.7)	7.8% (5.6-12.0)	10.4% (7.3-16.3)
N	*14,828*	*2,800*	*2,297*	*1,587*	*1,739*	*1,119*	*8,812*	*3,841*

APPENDIX C:

CUMMALTIVE PREDATION IMPACTS ON PIT-TAGGED JUVENILE STEELHEAD AND YEARLING CHINOOK RELEASE AT ROCK ISLAND DAM, 2014

Introduction

A study to evaluate mortality of smolts tagged using the Juvenile Salmonid Acoustic Telemetry System (JSATS) in the Columbia River Basin has been funded to better understand where (spatially) and when (temporally) smolt mortality occurs and what fraction of that mortality is related to piscivorous colonial waterbird predation. Research associated with study resulted in the recovery of not only JSATS-tagged smolts on bird colonies but also PIT-tagged only smolts, including hatchery and wild steelhead and yearling Chinook released as part of our tagging study at Rock Island Dam in 2014 (see Section 1.1.4). Presented here are predation rates on Rock Island Dam released steelhead and yearling Chinook by 14 different bird colonies in 2014. Colonies range from those within foraging distance of the middle Columbia River all the way to the Columbia River estuary. Results provide valuable insight regarding the over-all or cumulative impact of colonial waterbird predation on smolt survival during outmigration, including predation by Caspian tern, double-crested cormorant, California and ring-billed gull, and American white pelican colonies.

Methods

Methods to calculate predation rates are the same as those described in Section 1.1.4, with a few exceptions that are noted below. Colonies scanned for PIT tags include Caspian terns nesting on Twinning Island, Goose Island-Northwest Rocks, Crescent Island, Blalock Islands, and East Sand Island. Double-crested cormorants nesting on Foundation Island and East Sand Island. Brandt's cormorants nesting on East Sand Island. California and ring-billed gulls nesting on Island 20, Crescent Island, Anvil Island (Blalock islands), Straight Six Island (Blalock islands), and Miller Rocks Island and American white pelicans nesting on Badger Island (Table C1).

Fish availability to all 14 colonies were based on the number of PIT-tagged steelhead (n = 7,757) and yearling Chinook (n = 5,446) sampled, and released into the tailrace of Rock Island Dam (RIS) from 12 April to 13 June as part of Avian Predation Project (see Section 1.2.3). As defined herein, availability is not adjusted for downstream survival of fish to the vicinity of each bird colony, as was the case for predation rates presented elsewhere in this report (see Section 1.1.4, 1.2.3, and 2.1.3). For instance, predation rates by double-crested cormorants nesting on East Sand Island in the Columbia River estuary are based on the number of fish available in the tailrace of RIS (Rkm 729) and not the number available in the tailrace of Bonneville Dam (Rkm 234). This approach standardizes fish availability for all colonies, resulting in a cumulative measure of predation impacts on juvenile steelhead and yearling Chinook during outmigration

from Rock Island Dam to the Columbia River estuary. Since Rock Island Dam is considered the start of the migration corridor for ESA-listed Upper Columbia River steelhead and spring Chinook, impacts are considered during the entire smolt life history stage for these two salmonid populations.

Detection efficiency data used to calculate predation rates are based on methods and results described in Sections 1.1.4, 1.2.3, and 2.1.2 (see Table 2). Detection efficiency estimates (range of daily values; sample size) for gull, cormorant, and pelicans colonies – those not provided in Table 6 – were as follows: Island 20 gulls (59-93%; n = 50), Foundation Island cormorants (20-20%; n = 100), Badger Island white pelicans (66-70%; n = 50), Crescent Island gulls (50-99%; n=100), Anvil Island gulls (83-98%; n = 100), Straight Six Island gulls (77-98%; n = 100), and Miller Rock Island gulls (81-87%; n = 100). Values reflect daily ranges in detection efficiency from 1 April to 31 July, 2014.

Deposition data used to calculate predation rates are based on methods and results described in Section 1.1.4 (see Table 7). Data on PIT tag deposition rates for California gulls – data not presented in Table 7 – were those reported in Hostetter et al. (2015) with a mean deposition rate of 15% (95% c.i. = 11-21%; n = 1,812). No deposition estimate exits for ring-billed gulls but since gull colonies scanned for PIT tags in 2014 were numerically dominated by California gulls and not ring-billed gulls and since the size, foraging behavior, and nesting chorology of ring-billed gulls is similar to that of California gulls (Winkler 1996), the California gull deposition estimate was applied. No deposition estimate currently exist for American white pelicans on Badger Island, and since the size, foraging behavior, and nesting chronology of white pelicans differ substantially from that of terns, gulls, and cormorants, no attempt was made to adjust American white pelican predation rates for deposition rates. As such, predation rates presented below for white pelicans represent minimum estimates (those adjusted for detection efficiency, but not for deposition rates).

Results and Discussion

Predation rates were highly variable by salmonid species (steelhead, Chinook), bird species (tern, cormorant, gull, pelican), and colony site (Rkm), ranging from < 0.1% to 6.8% (95% c.i. = 4.6-10.4) of available fish in the tailrace of RIS. Predation impacts were consistently greater on juvenile steelhead compared with yearling Chinook, with steelhead disproportionally consumed in nearly all cases (Table C1). This finding is consistent with relative differences in steelhead versus salmon predation susceptibility observed in other ESUs in 2014 (e.g., Snake River steelhead versus Snake River spring/summer Chinook; Table 4, 5, and 7). A discussion of factors that influence the greater susceptibility of steelhead to avian predation can be found Section 1.2.3.

Predation impacts by the large Caspian tern and double-crested cormorant colony on East Sand Island were some the highest observed in 2014, particularly impacts to steelhead (6.6%; 95% c.i. = 5.0-9.7) by Caspian terns and impacts to yearling Chinook (4.8%; 95% c.i. = 3.3-7.7) by

double-crested cormorants (Table C1). Again, impacts reported herein apply to the available sample of fish passing RIS and suggest that relative to other bird colonies, many of which are closer in proximity to RIS, predation in the estuary is major source of smolt mortality. If availability is adjusted for survival to the estuary – by limiting the analysis to the number of fish last detected passing Bonneville Dam – predation impacts on Upper Columbia River steelhead and Chinook roughly double (11.4% and 8.5% by terns and cormorants on upper Columbia River steelhead and spring Chinook, respectively, see Table 4) compared with impacts not adjust for downstream survival (i.e., those presented in Table C1). Similar to results presented in Section 2.1.2, predation impacts by Brandt's cormorants were significantly lower than those reported for terns and double-crested cormorants on East Sand Inland and were some of lowest observed at any colony in 2014 (Table 4 and Table C1).

Predation impacts by some gull colonies were similar to or greater than those of tern and cormorant colonies (Table C1). For instance, predation by Crescent Island gulls on steelhead (6.8%; 95% c.i. = 4.6-10.4) was the highest individual estimate of the 14 bird colonies evaluated (D1). Hostetter et al. (In press) reported that impacts from gulls, a generalist predator, were higher than previously reported in the published literature because previous estimates did not include a measure of on-colony PIT tag deposition. Data from BRNW (2014) indicates that PIT tag deposition rates are low in gulls because gulls macerate PIT tags during digestion, resulting in a small fraction of ingested tags being egested on-colony. High predation impacts by gull colonies were likely associated with the colonies large size (ca. 4,100 to 14,500 adults counted, depending on the colony; see Section 3.2) and behavior flexibility to exploit temporally available prey (Ruggerone 1986; Osterback et al. 2013). Not all of the gull colonies evaluated, however, had high predation impacts on juvenile steelhead and yearling Chinook released at RIS, with predation rates by gulls nesting on Island 20 and the Blalock islands (Anvil and Straight Six) generally lower than those of other bird colonies evaluated (Table C1).

Similar to data reported by Evans et al (2012), of the various bird species evaluated, impacts were the lowest by American white pelicans nesting on Badger Island. Evans et al. (2012) hypothesized that several factors may account for low predation impacts by American white pelicans on particular smolt DPSs/ESUs, including (1) a reliance on larger fish or on fish that congregate in shallow-water habitats, (2) differences in foraging behavior that reduce the habitat overlap between Badger Island pelicans and out-migrating salmonids from the upper Columbia River, or (3) a combination of these. It's important to note, however, that white pelican predation estimates presented here and those of Evans et al. (2012) do not incorporate tag loss due to off-colony deposition and thus represent minimum impacts. In a study of trout predation by nesting American white pelicans in Idaho, Larson et al. (2013) estimated that deposition and detection efficiency of PIT-tagged trout consumed < 200 Km from a pelican colony was approximately 30% (range = 10-60%). Applying this correction factor to the raw, unadjusted number of yearling Chinook and steelhead smolts PIT tags recovered on Badger Island, however, would not change predation rates in a meaningful way, as predation rates would still be < 0.1% for both species. In fact, even if deposition values for white pelicans were lower than those of California gulls (15%), predation impacts by pelicans would still be the lowest reported herein because so few steelhead (n = 1) and Chinook (n = 0) PIT tags were

recovered on the white pelican colony in 2014. This does not mean white pelicans nesting on Badger Island do not consume other salmonid DPSs/ESUs or age-classes of fish (in fact, large numbers of PIT tags implanted in subyearling Chinook and adult sockeye were recovered on Badger Island in 2014) but simply that impacts to upper Colombia River juvenile steelhead and yearling Chinook were low in 2014.

Taken together (all colonies combined), 36.0% (95% c.i. = 31.2-44.1) and 11.6% (95% c.i. = 9.0-16.0) of the steelhead and yearling Chinook, respectively, released into the tailrace of Rock Island Dam were consumed by one of the 14 bird colonies evaluated in 2014 (Table C1). For steelhead, about half of the predation losses (16% of released fish) were from birds nesting on colonies upstream of McNary Dam (Rkm 470; Table C1). For yearling Chinook, losses were generally smaller and more evenly distributed throughout the migration corridor, with the exception of predation by double-crested cormorants in the Columbia River estuary (4.8% of released fish; Table C1). This estimate does not account for other sources of mortality (piscine predation, dams, disease, or other sources) that occurred during out-migration from Rock Island Dam to the Columbia River estuary, indicating that predation by these 14 colonies was a substantial mortality factor for these fish during the smolt life history stage. For instance, relative to non-avian documented mortality factors, mortality associated with avian predation reported herein is comparable to or higher than that reported for piscine predation (generally < 5% per reservoir; Ward et al. 1995, Thompson et al. 2012) and passage mortality associated with individual dams on the Columbia and lower Snake rivers (generally < 4% per dam; Ferguson et al. 2006; Timko et al. 2011; Skalski 2009).

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Table C1. Cumulative estimated predation rates (95% credible interval) of steelhead and yearling Chinook released into the tailrace of Rock Island Dam by 14 different piscivorous waterbird colonies in the Columbia River Basin in 2014. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiency and deposition rates (see Methods). Predation rates were calculated based on the number of fish available (n) in the tailrace of at Rock Island Dam (river kilometer [RKM] 729) and were thus not adjusted for survival to the vicinity of the downstream colony. Bird species include Caspian tern (CATE), double-crested cormorants (DCCO), Brandt's cormorants (BRAC), ring-billed and California gulls (Gulls), and American white pelican (AWPE).

Location	Colony	RKM	Steelhead (n = 7,757)	Yearling Chinook (n = 5,446)
Twinning Island	CATE	Off-river	1.2% (0.3-6.4)	0.4% (<0.1-3.6)
Goose Island (NW Rocks)	CATE	Off-river	2.9% (1.9-5.1)	0.3% (0.1-0.7)
Island 20	Gulls	545	1.6% (0.9-2.9)	0.3% (<0.1-0.9)
Foundation Island	DCCO	518	0.2% (<0.1-0.8)	<0.1%
Badger Island	AWPE[1]	512	<0.1%	0.1% (<0.1-0.2)
Crescent Island	CATE	510	3.4% (2.5-4.9)	0.2% (0.1-0.5)
	Gulls	510	6.8% (4.6-10.4)	0.5% (0.2-1.4)
Blalock Islands (Anvil Is.)	CATE	441	0.7% (0.5-1.3)	<0.1%
	Gulls	441	1.6% (0.9-2.8)	0.4% (0.1-1.0)
Blalock Islands (Straight Six Is.)	Gulls	439	0.4% (0.1-1.0)	0.4% (0.1-1.0)
Miller Rocks Island	Gulls	331	4.6% (3.0-7.2)	2.0% (1.1-3.7)
East Sand Island	CATE	8	6.6% (5.0-9.7)	1.3% (0.8-2.1)
	BRAC	8	0.2% (0.1-0.4)	0.1% (<0.1-0.4)
	DCCO	8	4.6% (3.2-7.1)	4.8% (3.3-7.7)
Total			36.0% (31.2-44.1)	11.6% (9.0-16.0)

[1] Predation rates by American white pelicans were not adjusted for deposition rates and should be considered minimum estimates.

APPENDIX D:

SURVEYS FOR FORAGING CASPIAN TERNS IN NORTHEASTERN CALIFORNIA AND SOUTHEASTERN OREGON, 2012-2014

Introduction

As part of the Caspian Tern Management Plan (USFWS 2005), a reduction of suitable nesting habitat for Caspian Terns (*Hydroprogne caspia*) on East Sand Island (ESI) is expected to displace some individuals that historically bred there to islands constructed by US Army Corp of Engineers (USACE) in the Interior of Oregon and northeastern California. While suitable nesting habitat may influence nesting success and distribution of terns, food availability may also play an important role (Suryan et al, 2000, Suryan et al. 2002, Ainley et al. 2003). The Corps-constructed islands in interior Oregon and northeastern California are located in a high elevation, semi-arid region with a large degree of inter-annual variability in both water and prey availability. Variability in foraging conditions may force Caspian terns to travel long distances to find suitable prey and profitable foraging locations (Catsadorakis et al. 1996). Increases in foraging distances also increase foraging time requirements, which may affect the amount of time that chicks are exposed to predation or the elements at the nest, as well as chick growth rates, provisioning rates, and ultimately chick survival (Burke and Montevecchi 2009). We conducted Foraging Waterbird Surveys during the 2012, 2013, and 2014 Caspian tern breeding seasons to help identify foraging hotspots, foraging habitat (i.e., water availability), and local prey limitations in the larger region around Corps-constructed Caspian tern nesting sites in interior Oregon and northeastern California.

Study Area

Surveys were conducted in the region surrounding the six Corps-constructed islands monitored in 2012 -2014 in the interior of Oregon (Crump Lake in the Warner Valley, East Link impoundment in Summer Lake Wildlife Area, Gold Dike Impoundment in Summer Lake Wildlife Area, and Malheur Lake in Malheur National Wildlife Refuge) and northeastern California (Sheepy Lake in Lower Klamath National Wildlife Refuge, and Tule Lake Sump 1B in Tule Lake National Wildlife Refuge; Figures D1 – D19).

Methods

We typically conducted surveys for foraging Caspian terns 1-2 times a week. We were not able to visit all locations every week, but each location (n=85) was visited at least once per month throughout the 2012-2014 breeding seasons (Figure D20). The number of visits to at each site differed, and we suspended survey visits to locations once they became dry due to drought. We used binoculars and spotting scopes to identify and count Caspian terns. Observations at each

survey location lasted for ≥ 10 minutes during which age-class (juvenile, adult), number of terns present, behavior (foraging, loafing, commuting), and percent terns foraging were recorded.

Results and Discussion

Spatial Distribution of Foraging Caspian Terns

Malheur Lake Region

In 2014, we observed the highest average number of foraging terns at Beulah Reservoir and Warms Springs Reservoir (Figure D2, Figure D17, and Table D1). Whereas, in 2012 and 2013, we observed the highest average numbers of foraging terns at: Moon Reservoir, Warm Springs Reservoir, and Malheur River, Chickahominy Reservoir and Mud Lake (Table D1). We observed fewer foraging terns at survey locations in 2014, compared to 2012 and 2013 (Table D1). However, despite recording fewer foraging terns on average in 2014, we still detected terns at all previously documented foraging sites in 2014 (Table D1). The number of foraging terns in the region appears to have correlated with the size of the breeding colony at the Corps-constructed island at Malheur Lake (232 nesting pairs 2012, 530 nesting pairs in 2013, 134 nesting pairs 2014).

Data from the foraging surveys identified four foraging hotspots (Warm Springs, Malheur River, Moon Reservoir, and Beulah Reservoir) for Caspian Terns during the 2012-2014 breeding seasons (Table D1). On average we consistently observed the greatest numbers of terns foraging at these sites. These foraging hotspots maintained water levels and therefore likely provided a reliable food source for nesting terns in this region. However, these four sites require relatively long comminuting distances from the Corps-constructed Island at Malheur Lake (ca. 60 km to Warms Reservoir and Malheur River, ca. 85 km to Beulah Reservoir, and ca. 50 km to Moon Reservoir; Figure D1). Our foraging surveys indicated that terns may be traveling longer distances from the Malheur Island to foraging hotspots than terns in the other regions in Interior Oregon and Northeastern California. The increased foraging distance required by terns nesting at the Malheur tern island might be indicative of a lower quality of prey (i.e. common carp) or suboptimal foraging conditions compared with other sites.

Crump and Summer Lake Region

In 2014, the average number of terns observed foraging in the region surrounding Corps-constructed islands at Crump Lake and the Summer Lake Wildlife Area were the lowest out of the last three years of surveying (Figure D19). Severe regional drought resulted in a high number of our surveyed waterbodies drying out completely in 2014, of which, seven of were areas where terns were observed regularly foraging in previous years. We were, however, still able to identify a number of foraging hotspots in the region in 2014 that included Drews Reservoir, the lake complex in the Warner Valley Lake near the Crump Lake Terns Island, and impoundments near the East Link tern colony (Figures D6 and D10). The 2013 breeding season

had the highest average number of terns observed foraging, and the most diverse number of survey locations out of the three year survey period (Table D1). Foraging hotspots in 2013 were at Gerber Reservoir, Drews Reservoir, Priday Lake, Summer Lake, and Campbell Lake (Table D1).

Klamath Lake Region

Unlike other regions surrounding Corps-constructed islands in 2014, the Klamath Lake region had a greater average number of foraging terns observed than in the previous two years (Table D1 and Figure D18). However, this region was also the only area to have an increase in the size of the breeding colonies in 2014 compared to the previous two years. The 2014 foraging hotspots were at Lake Ewauna, Tule Lake Sump 1A, and Clear Lake Reservoir (Figure D14). In 2013, the hotspots were located at Tule Lake 1A, Lower Klamath River, and Williamsons Delta (Figure D15). In 2012, foraging hotspots were at Lake Ewauna and Tule Lake Sump 1A (Figure D16). Our surveys of foraging terns identified Lake Ewauna and Tule Lake as important tern foraging areas during the 2012-2014 nesting periods (Figure D18 and Table D1). The water levels at these sites are highly managed and provided consistent foraging habitat during the three year period. The foraging hotspots (Figures D14-D16) in the region throughout 2012-2014 tern breeding season were consistent with the 2011 foraging study (Patterson et al. 2013) that found that 89% of the GPS-tagged terns nesting at the Corps-constructed island in Tule Lake Sump 1B foraged within 10 km of that island.

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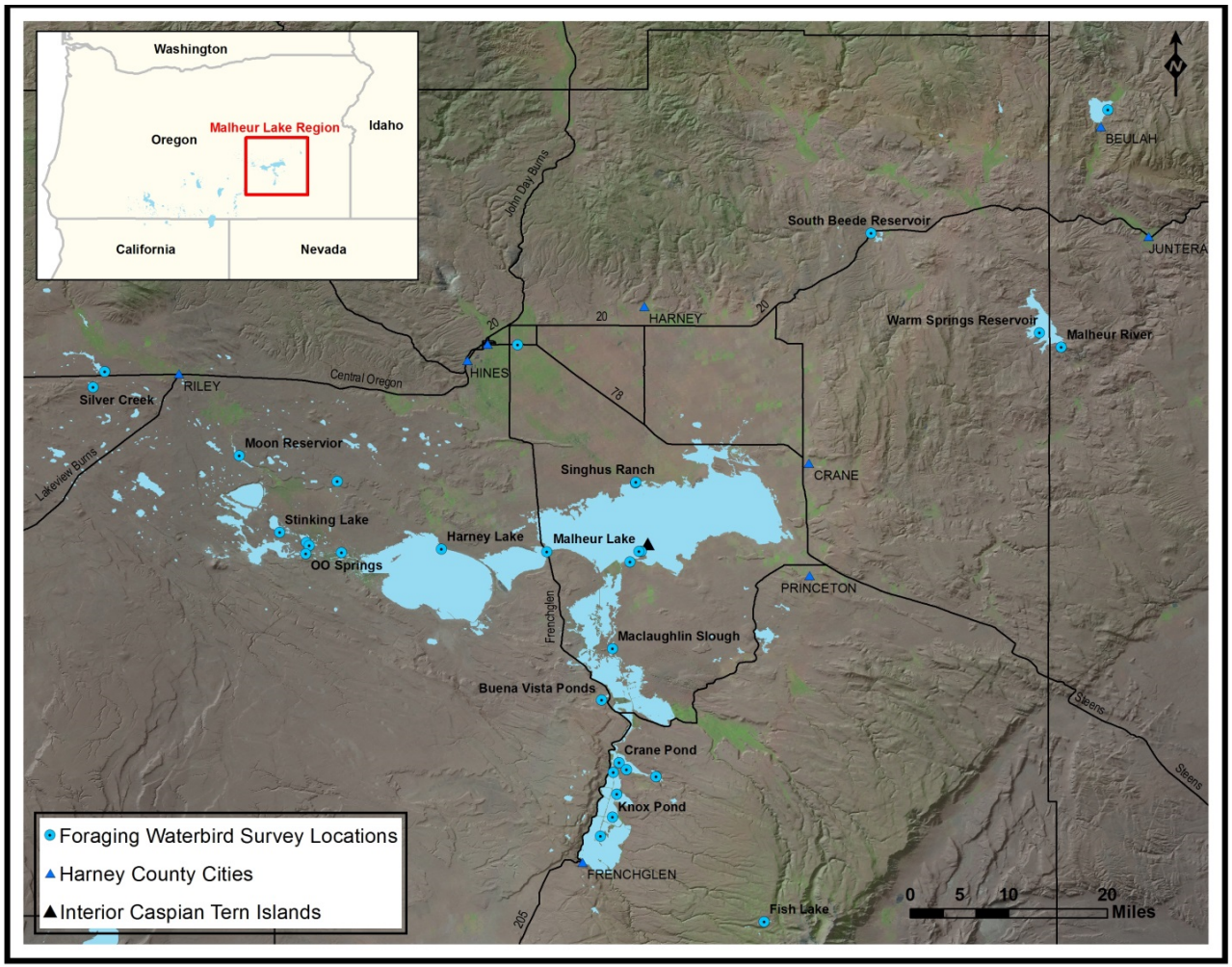

Figure D1. Foraging water bird survey sites in the Malheur Lake region of Harney and Malheur Counties, Oregon during the 2012-2014 Caspian tern breeding seasons.

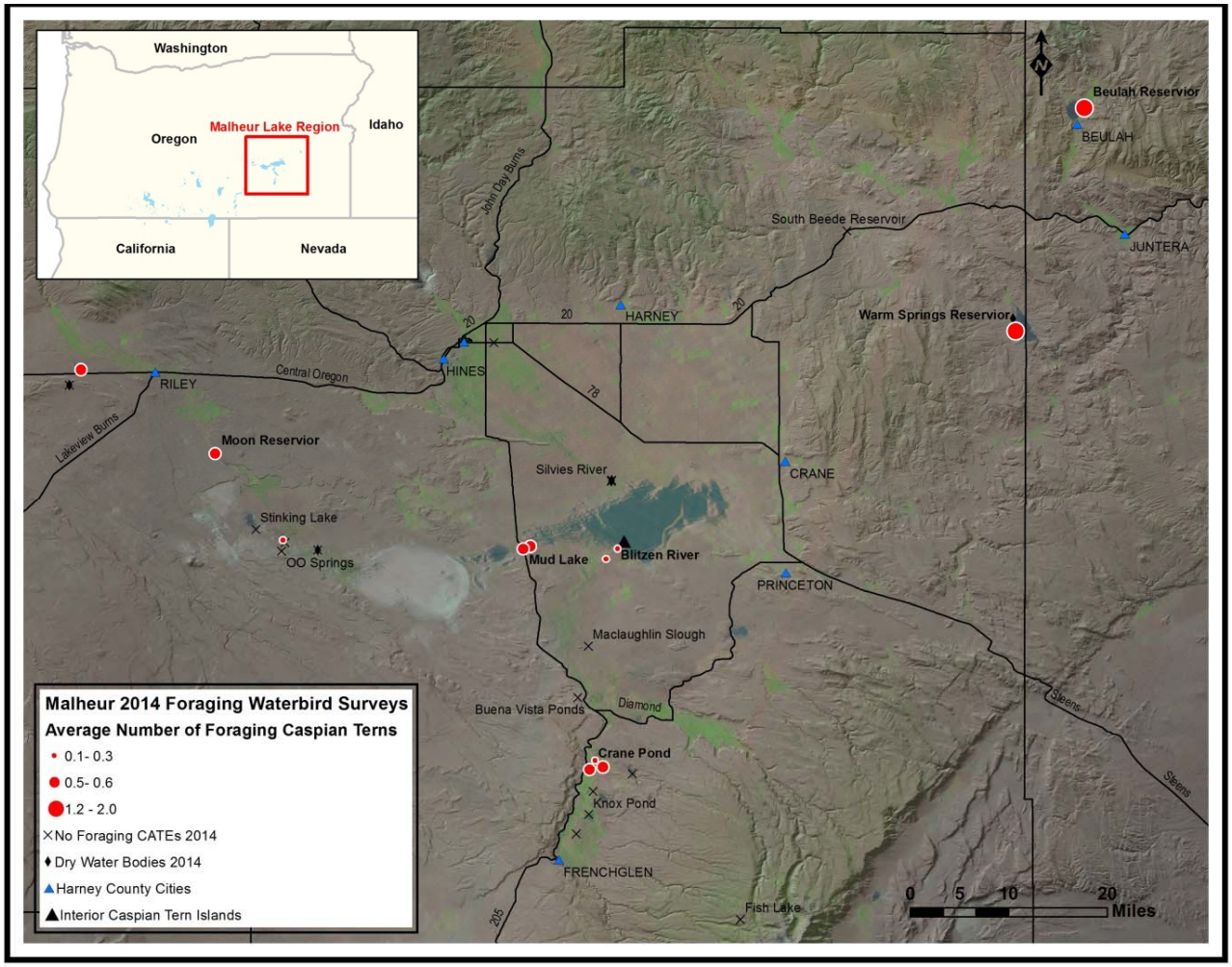

Figure D2. Average number of foraging Caspian terns observed at each survey location during the 2014 breeding season in the Malheur Lake region of Harney and Malheur counties, Oregon. Data points are overlaid Landsat imagery from June 2014 to illustrate regional water availability during the peak period for Caspian tern at the Corps-constructed island at Malheur National Wildlife Refuge.

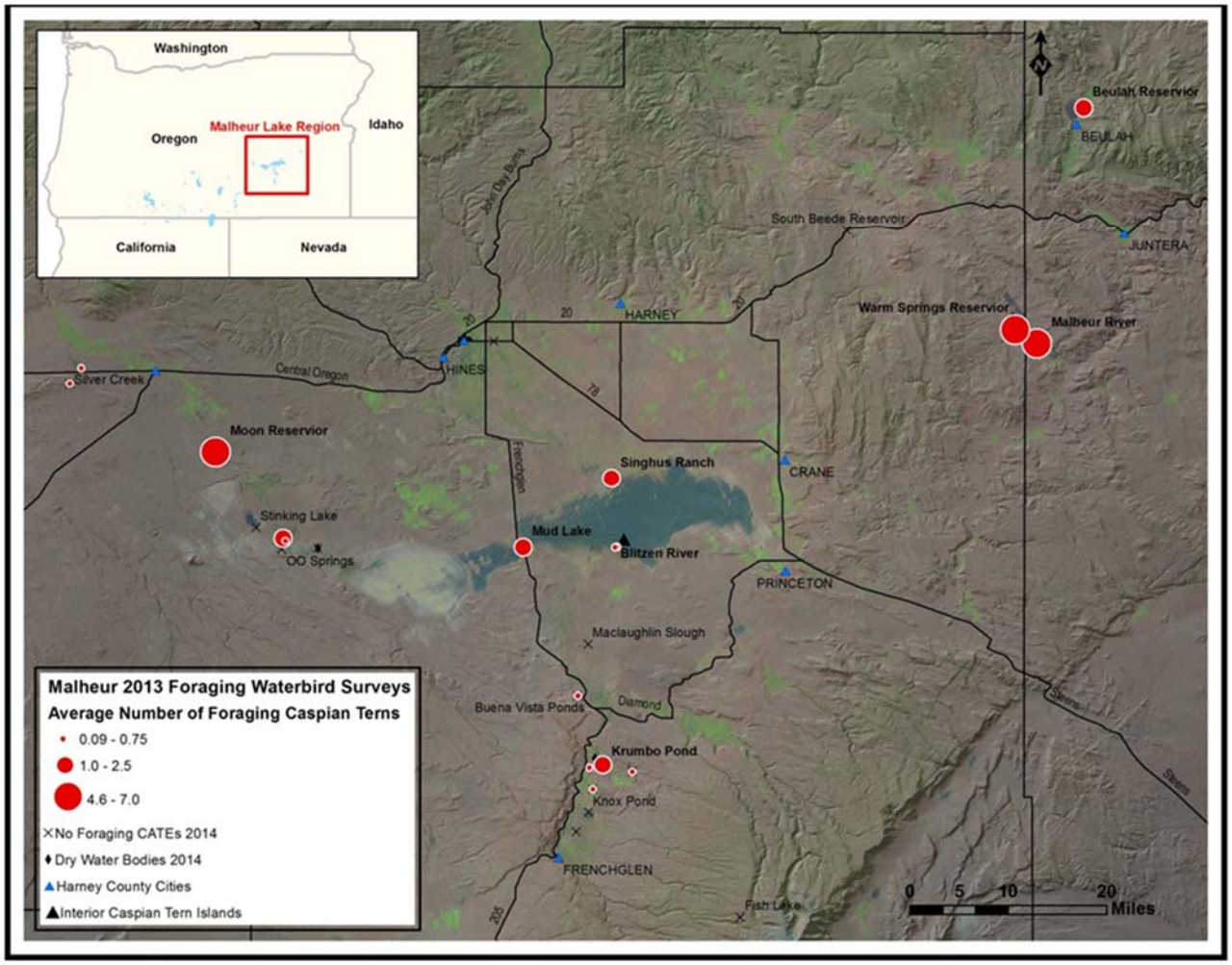

Figure D3. Average number of foraging Caspian terns observed at each survey location during the 2013 breeding season in the Malheur Lake region of Harney and Malheur Counties, Oregon. Data points are overliad Landsat imagery from June 203 to illustrate regional water availbility during the peak breeding perion for Caspian terns at the Corps-constructed island at Malheur National Wildlife Refuge.

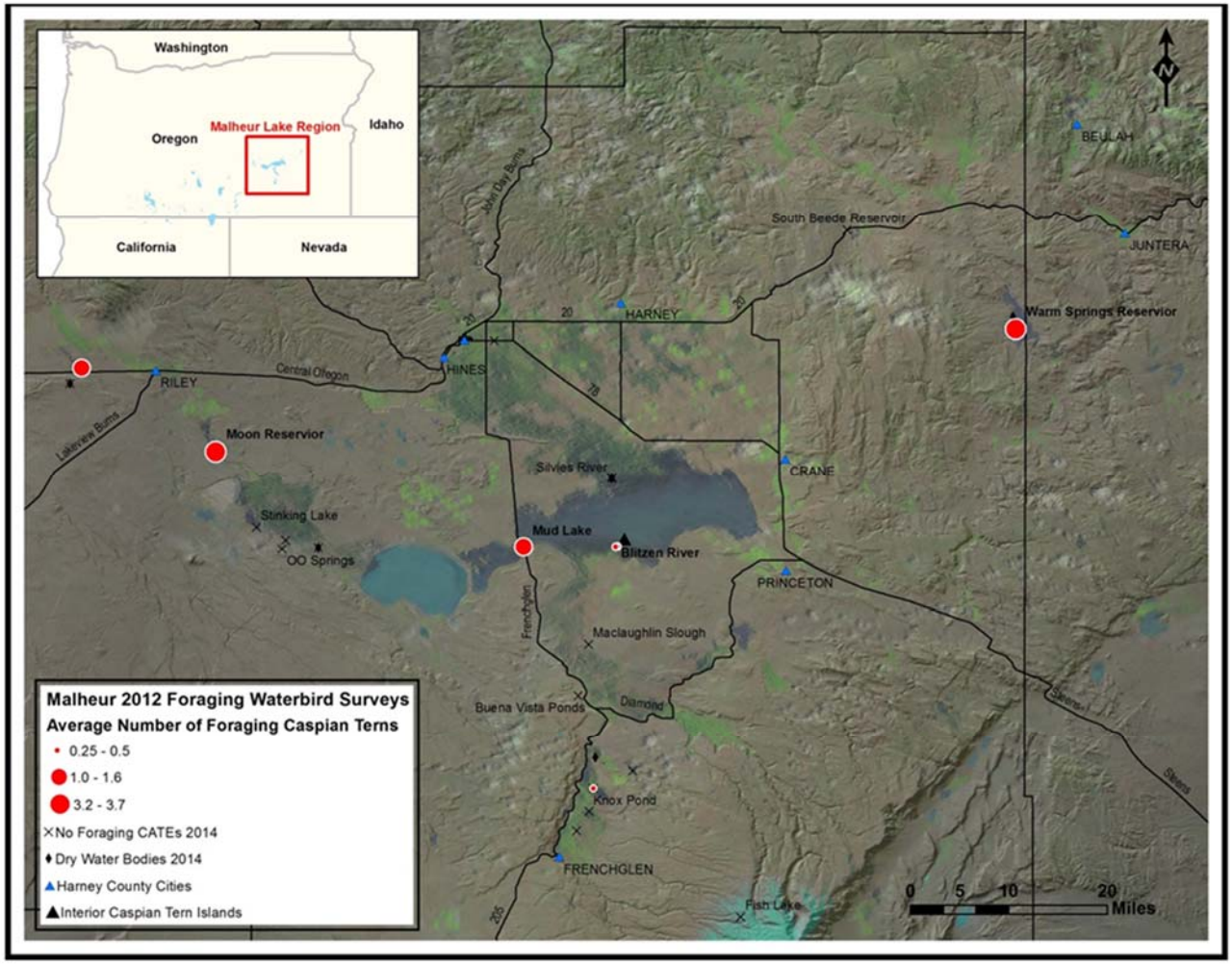

Figure D4. Average number of foraging Caspian terns observed at each survey location during the 2012 breeding season in the Malheur Lake region of Harney and Malheur Counties, Oregon. Data points are overlaid Landsat imagery from June 2012 to illustrate regional water availability during the peak breeding period for Caspian terns at the Corps-constructed island at Malheur National Wildlife Refuge.

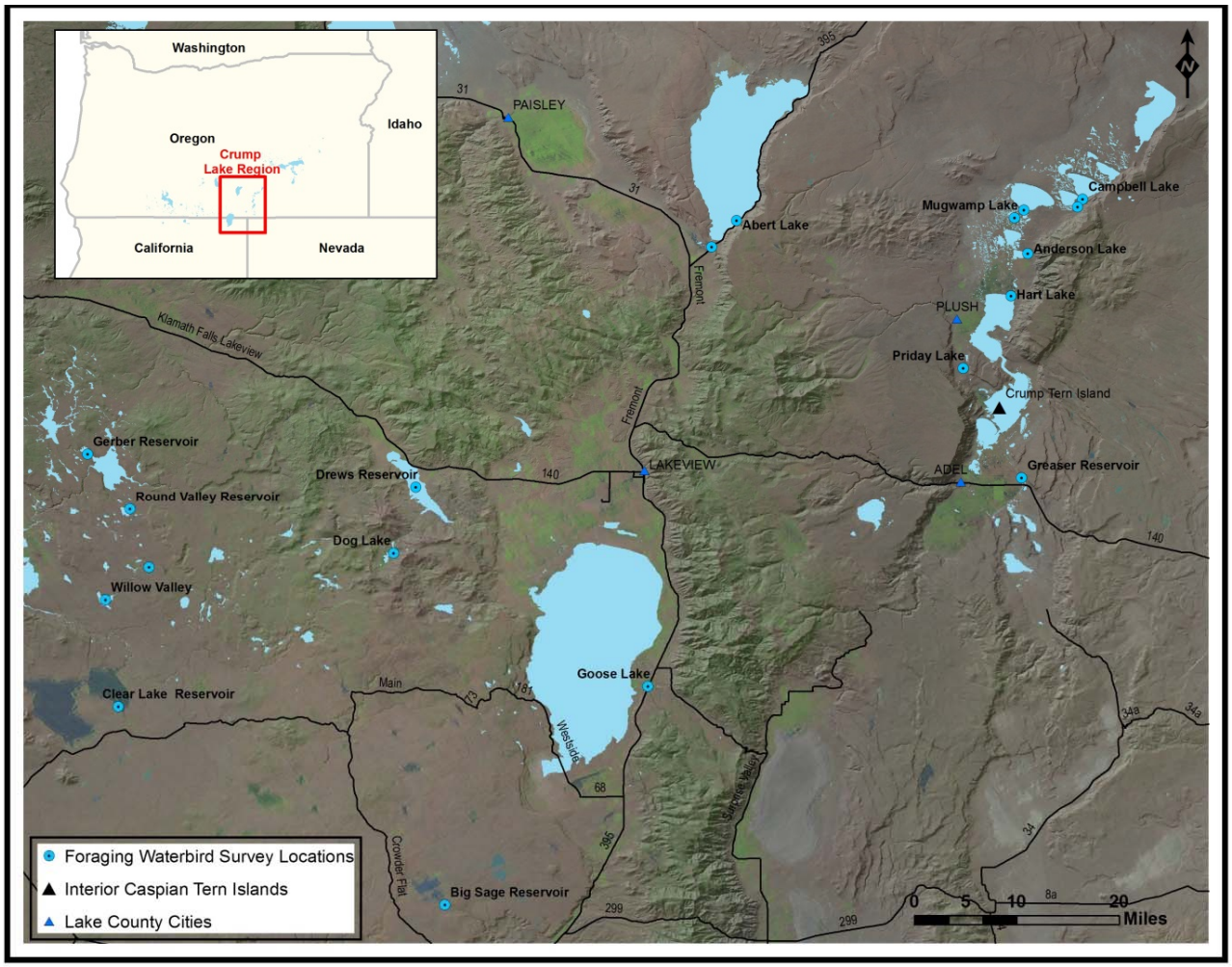

Figure D5. Foraging water bird survey sites in the Crump Lake region of Lake County, Oregon and Modoc County, California during the 2012-2014 Caspian tern breeding seasons.

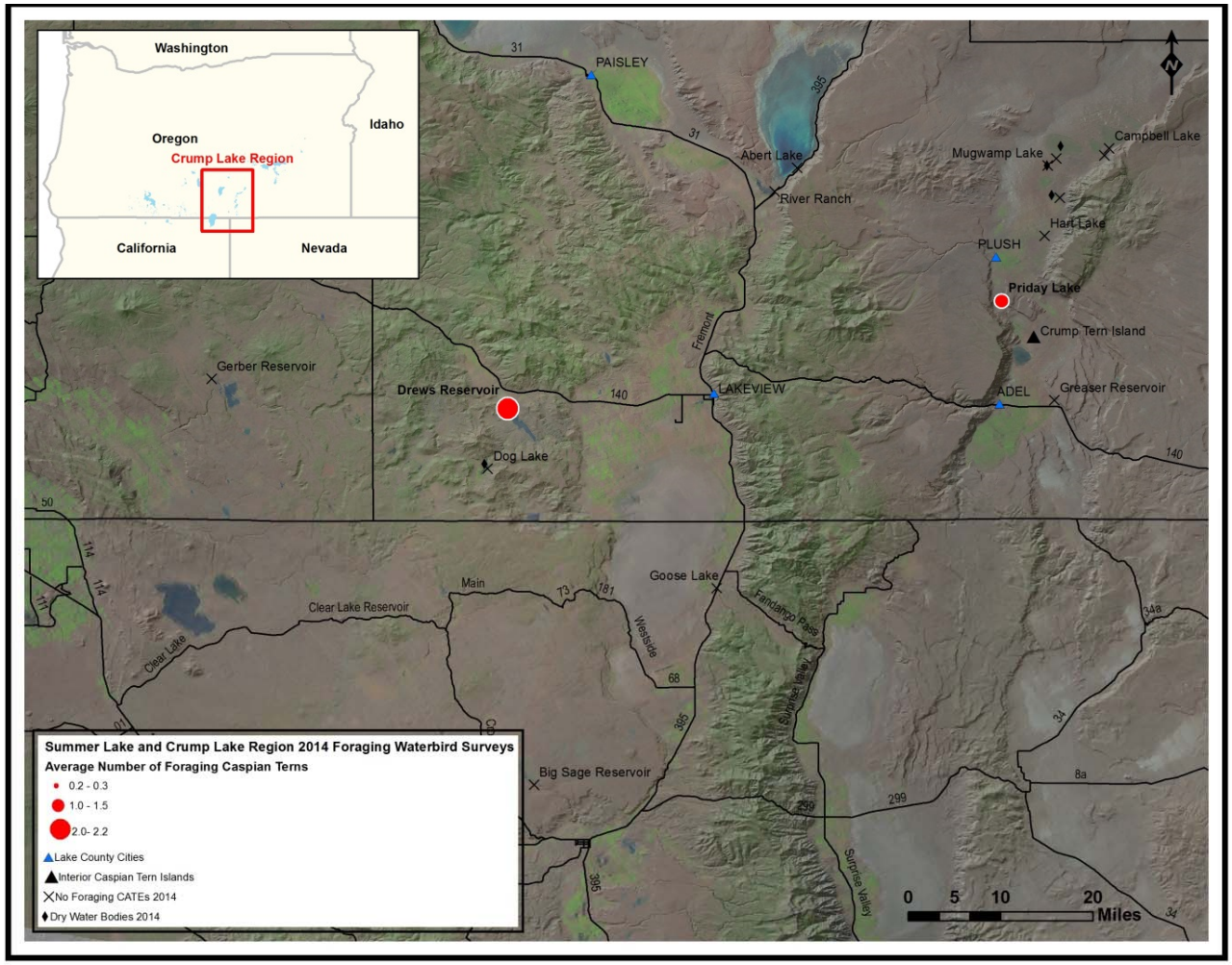

Figure D6. Average number of foraging Caspian terns observed at each survey location during the 2014 breeding season in the Crump Lake region of Lake County, Oregon and Modoc County, California. Data points are overlaid Landsat imagery from June 2014 to illustrate regional water availability during the peak breeding period for Caspian terns at the Corps-constructed island at Crump Lake.

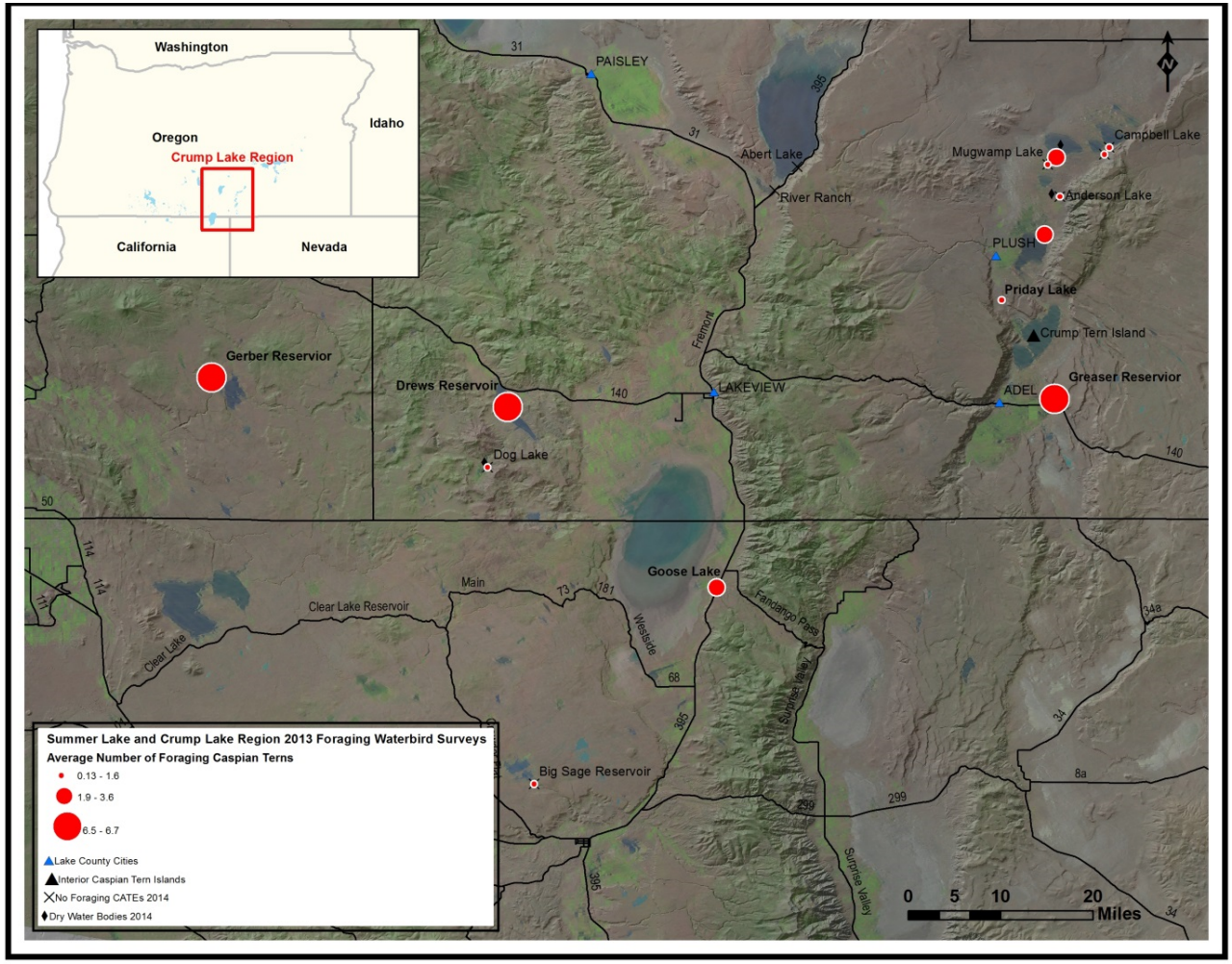

Figure D7. Average number of foraging Caspian terns observed at each survey location during the 2013 breeding season in the Crump Lake region of Lake County, Oregon and Modoc County, California. Data points are overlaid Landsat imagery from June 2013 to illustrate regional water availability during the peak breeding period for Caspian terns at the Corps-constructed island at Crump Lake.

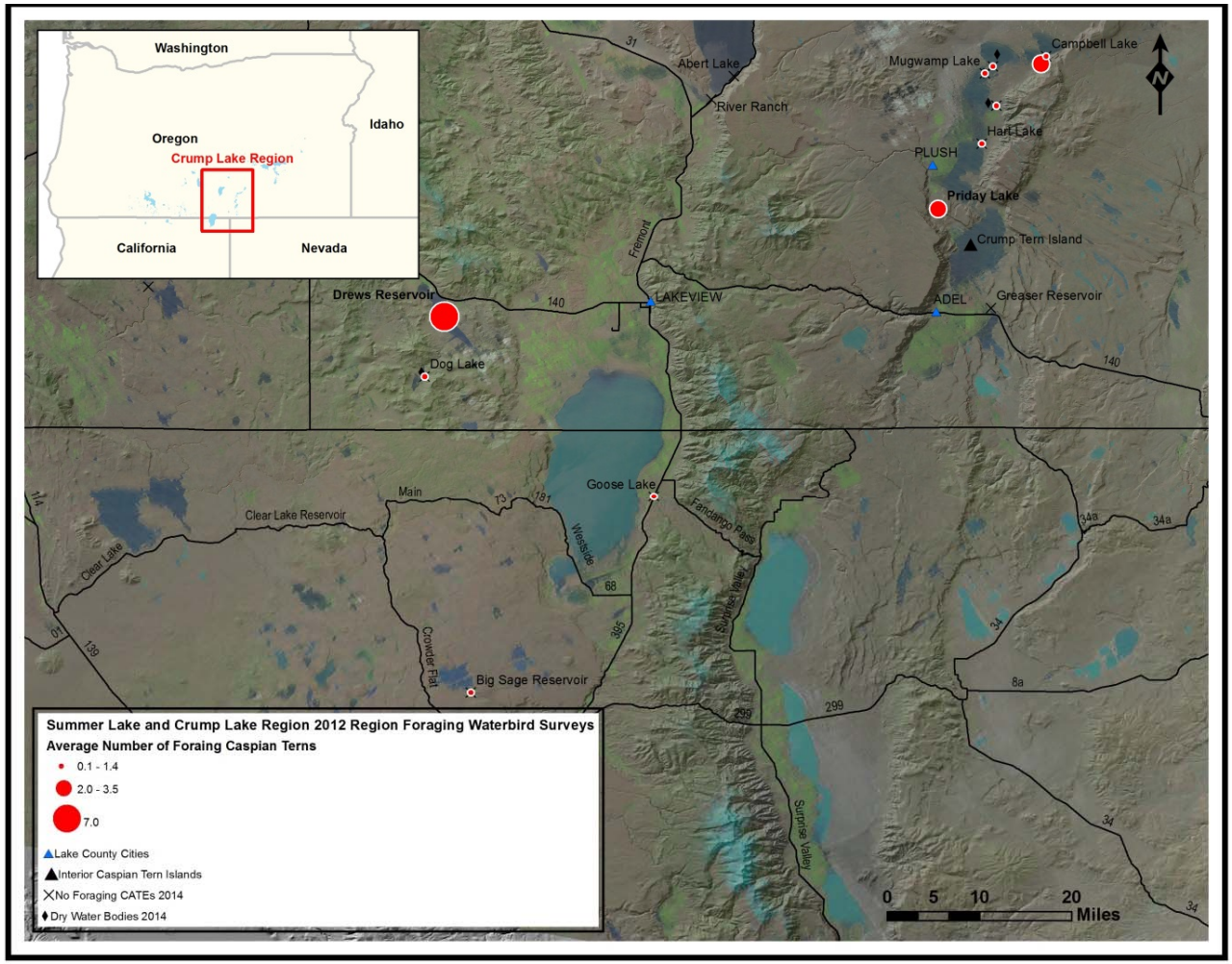

Figure D8. Average number of foraging Caspian terns observed at each survey location during the 2012 breeding season in the Crump Lake region of Lake County, Oregon and Modoc County, California. Data point are overlaid Landsat imagery from June 2012 to illustrate region water availability during the peak breeding period for Caspian terns at the Corps-constructed island at Crump Lake.

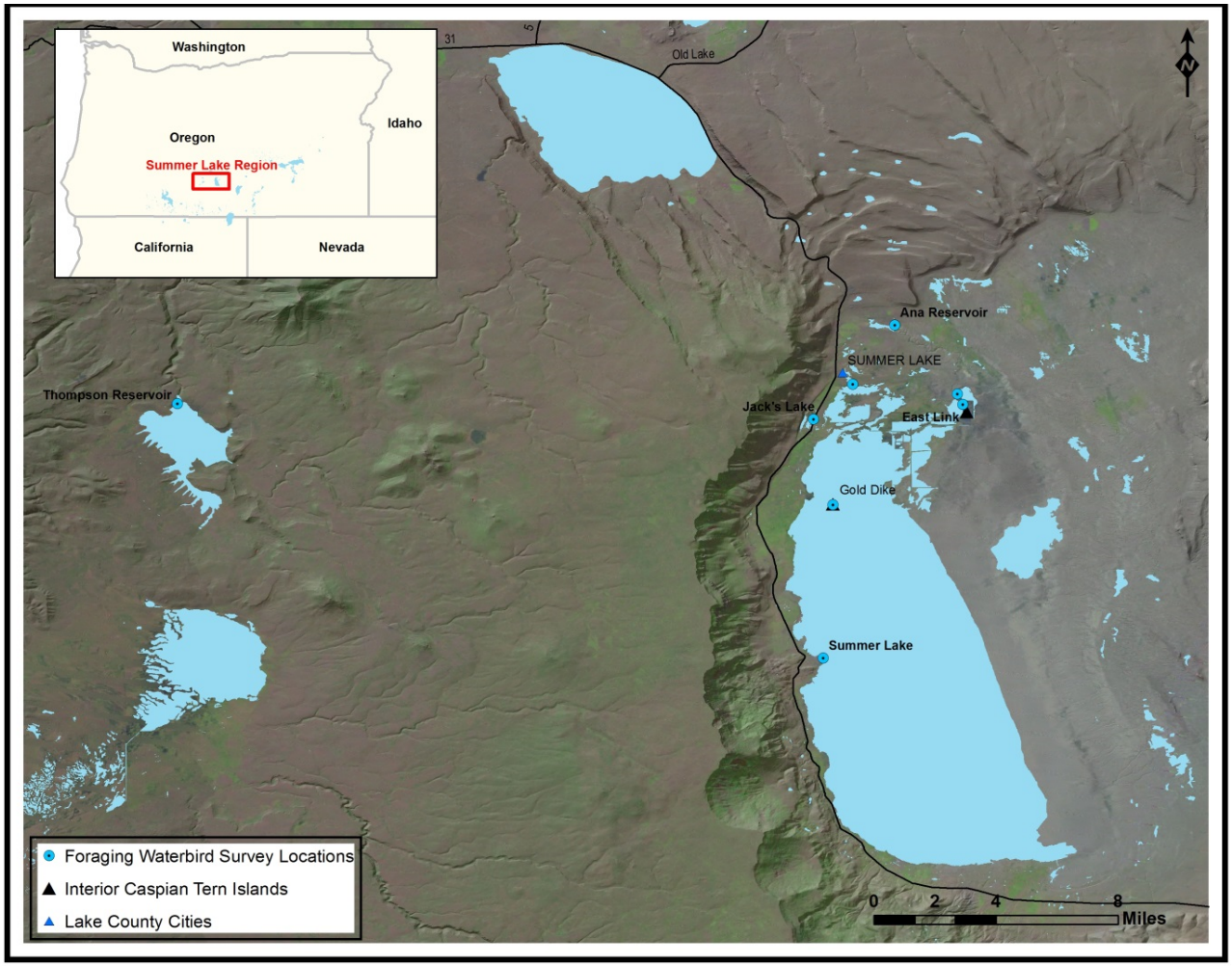

Figure D9. Foraging water bird survey sites in the Summer Lake region of Lake County, Oregon during the 2012-2014 Caspian tern breeding seasons.

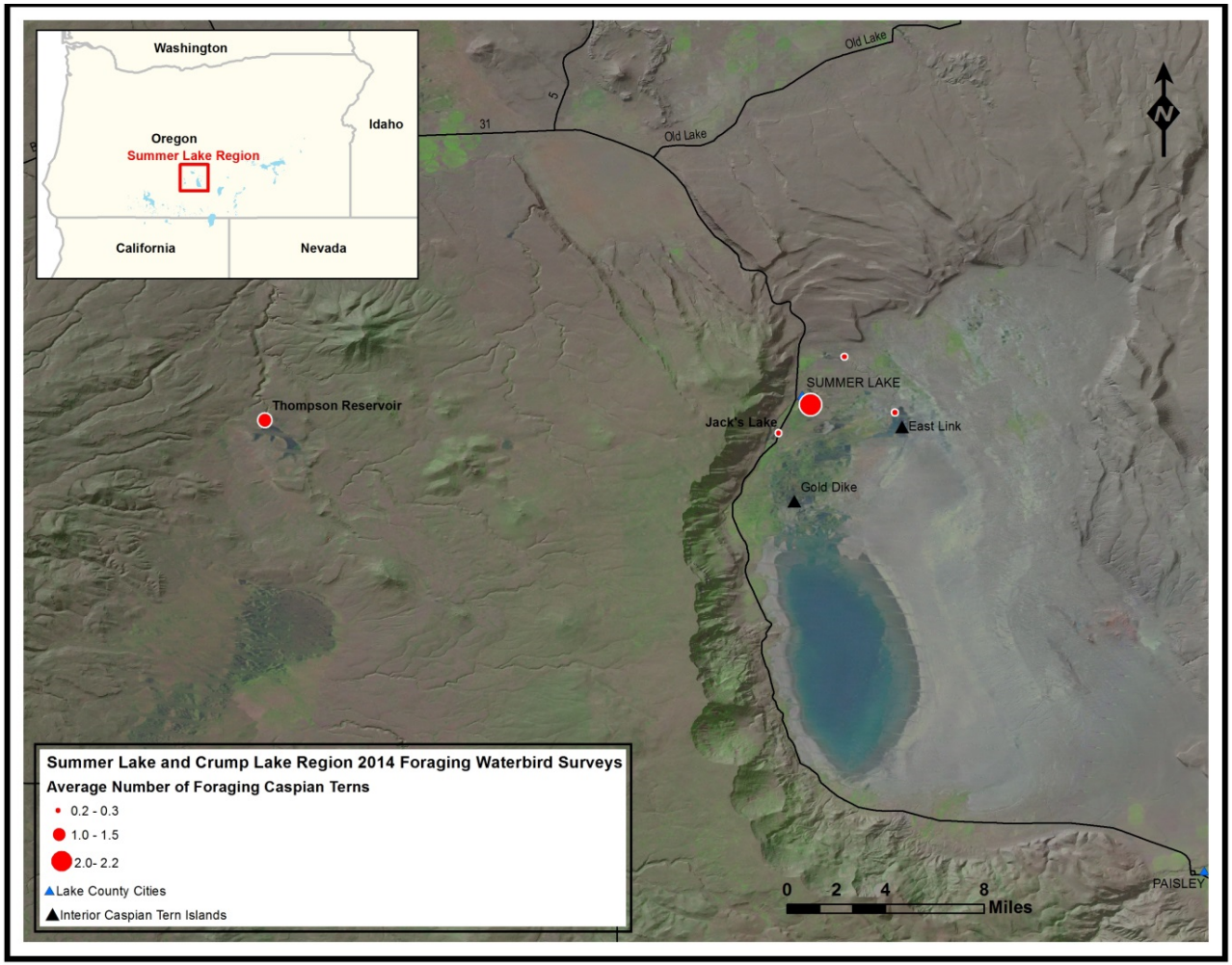

Figure D10. Average number of foraging Caspian tern observed at each survey location during the 2014 breeding season in the Summer Lake region of Lake County, Oregon. Data points are overlaid Landsat imagery from June 2014 to illustrate regional water availability during the peak breeding period for Caspian terns at the Corps-constructed islands at Summer Lake Wildlife Area.

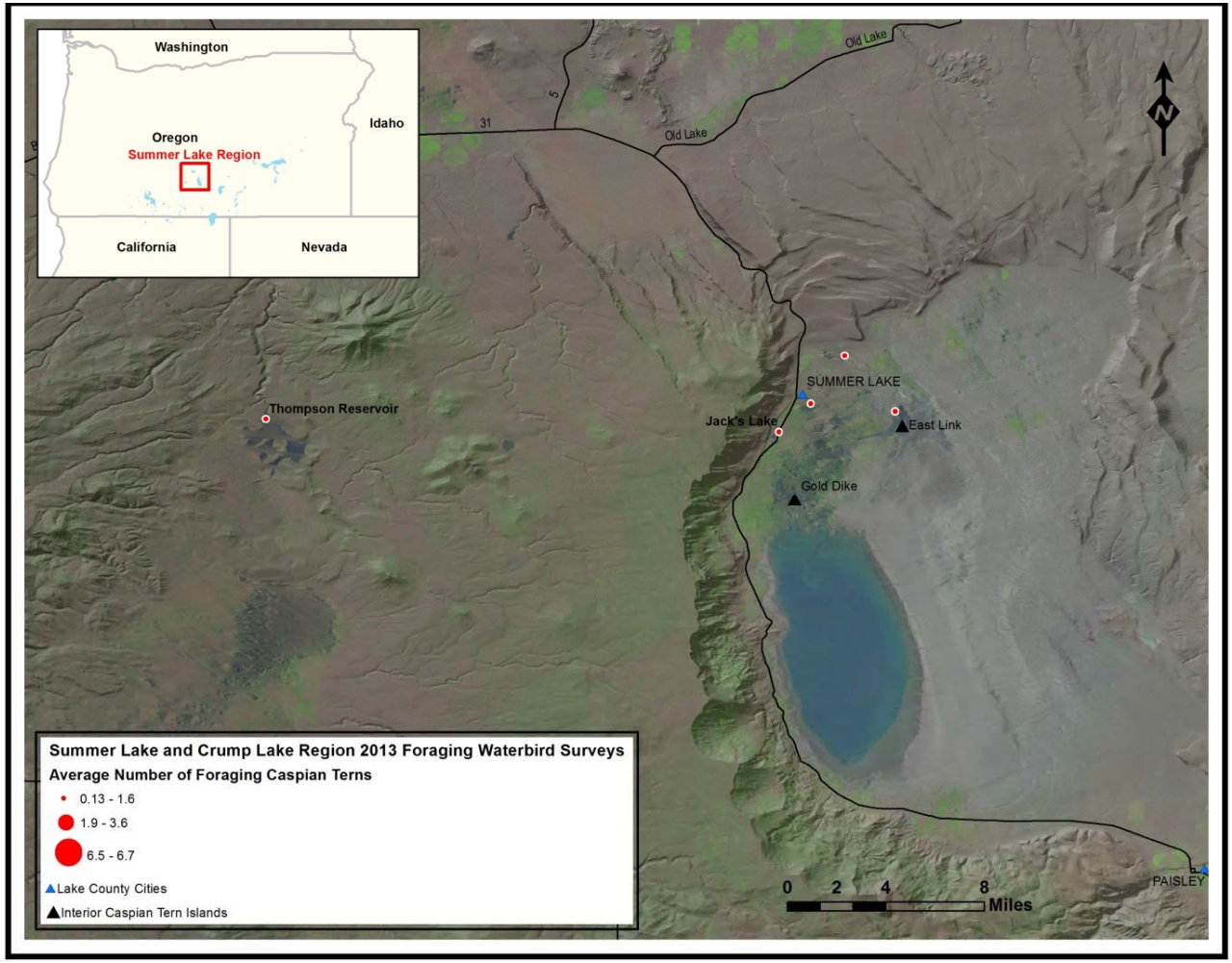

Figure D11. Average number of foraging Caspian terns observed at each survey location during the 2013 breeding season in the Summer Lake region of Lake County, Oregon. Data points are overlaid Landsat imagery from June 2013 to illustrate regional water availability during the peak breeding period for Caspian terns at the Corps-constructed islands at Summer Lake Wildlife Area.

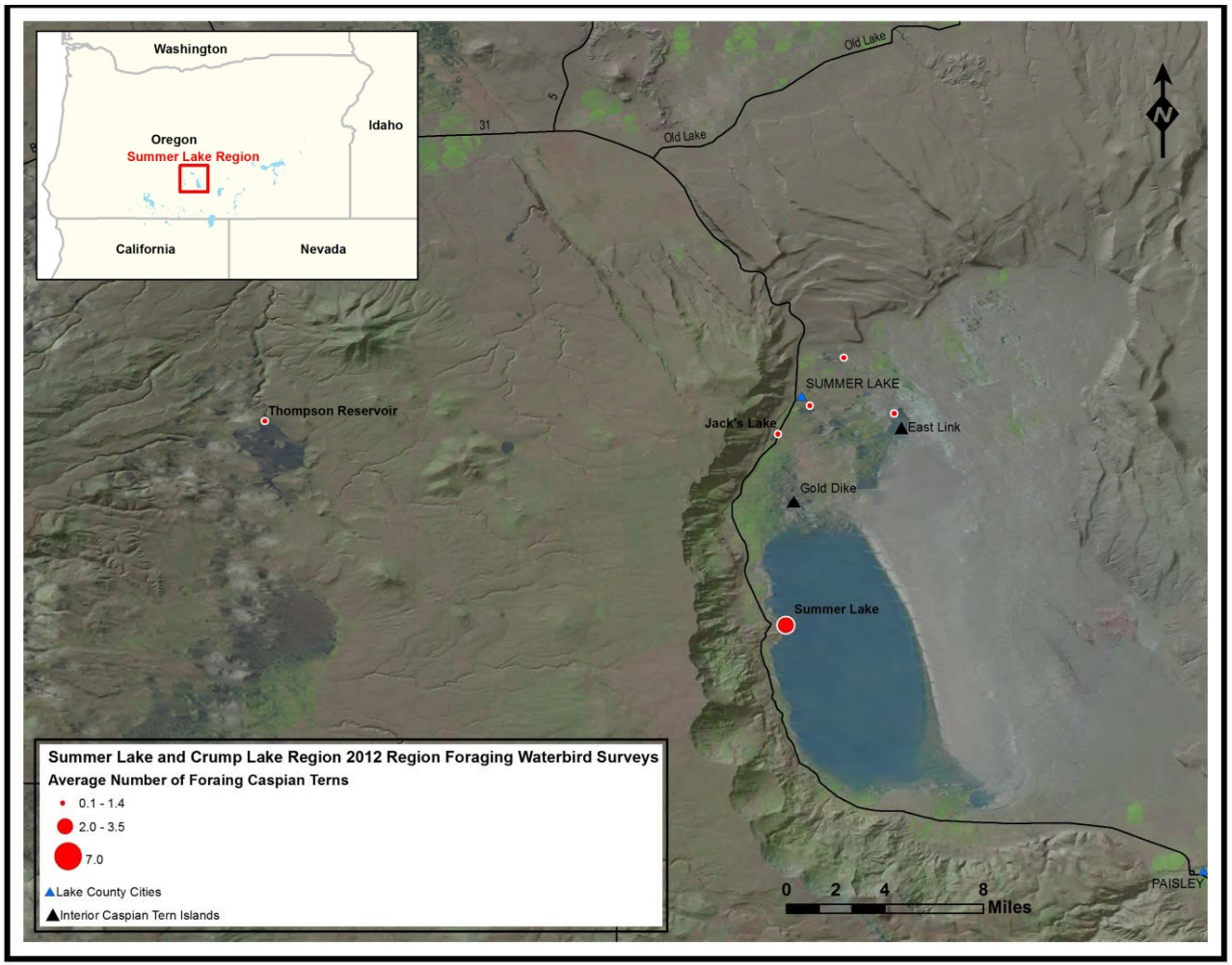

Figure D12. Average number of foraging Caspian terns observed at each survey location during the 2012 breeding season in the Summer Lake region of Lake County, Oregon. Data points are overlaid Landsat imagery June 2012 to illustrate regional water availability during the peak breeding period for Caspian terns at the Corps-constructed islands at Summer Lake Wildlife Area

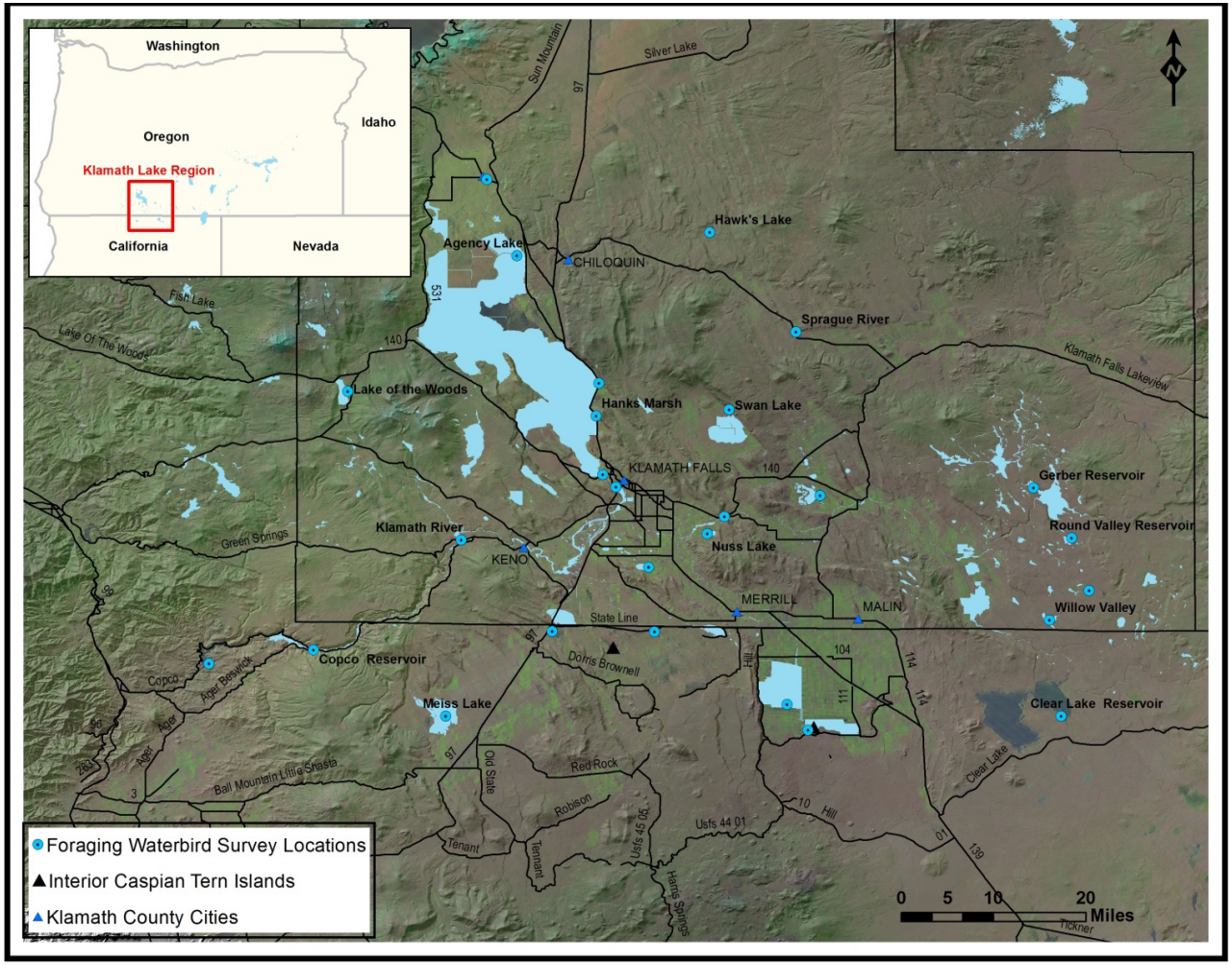

Figure D13. Foraging water bird survey sites in the Klamath Lake region of Klamath County, Oregon and Siskiyou County, California during the 2012-2014 Caspian tern breeding seasons.

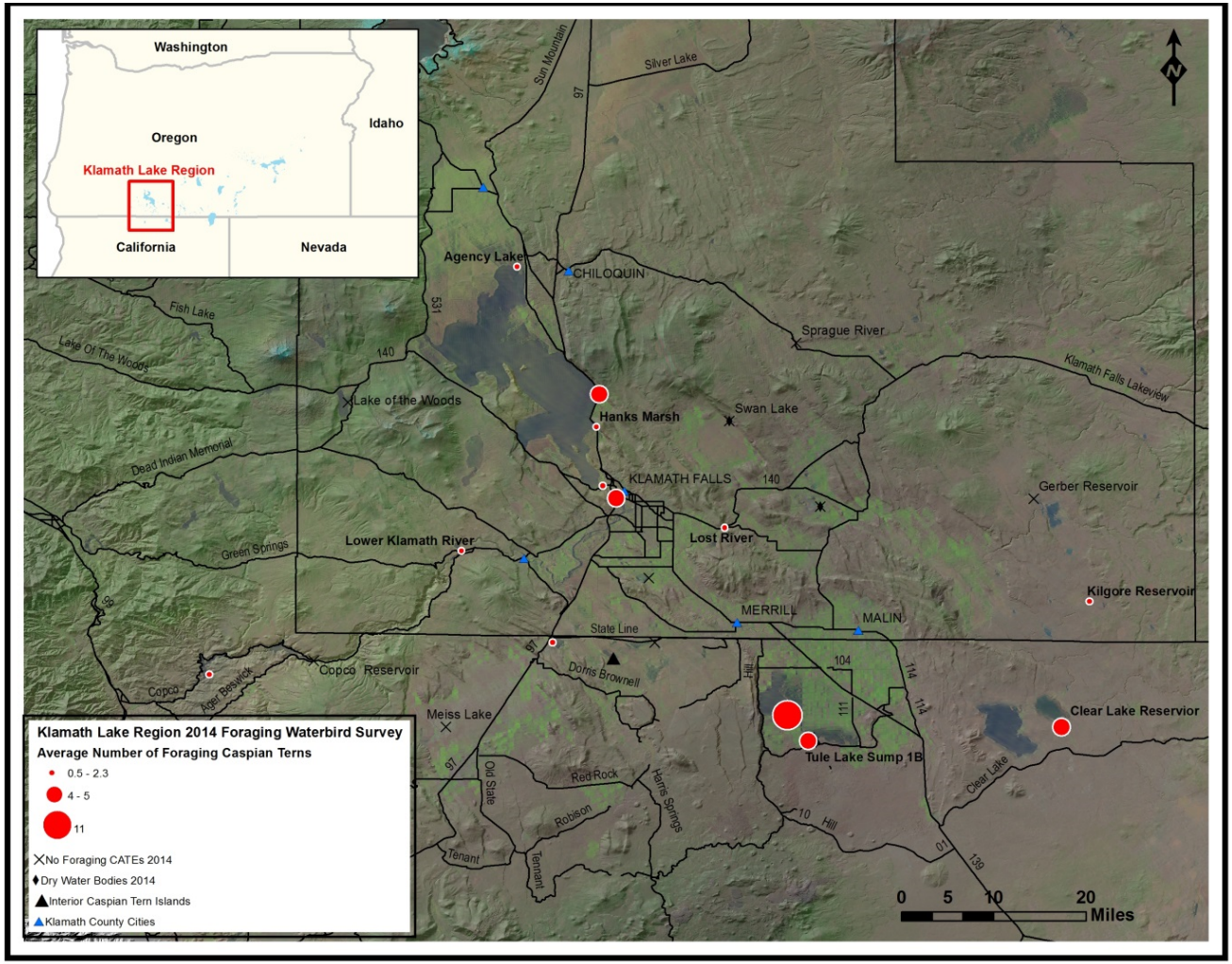

Figure D14. Average number of foraging Caspian terns observed at each survey location during the 2014 breeding season in the Klamath Lake region of Klamath County, Oregon and Siskiyou County, California. Data points are overlaid Landsat imagery from June 2014 to illustrate regional water availability during the peak breeding period for Caspian terns at the Corps-constructed islands at Lower Klamath and Tule Lake National Wildlife Refuges.

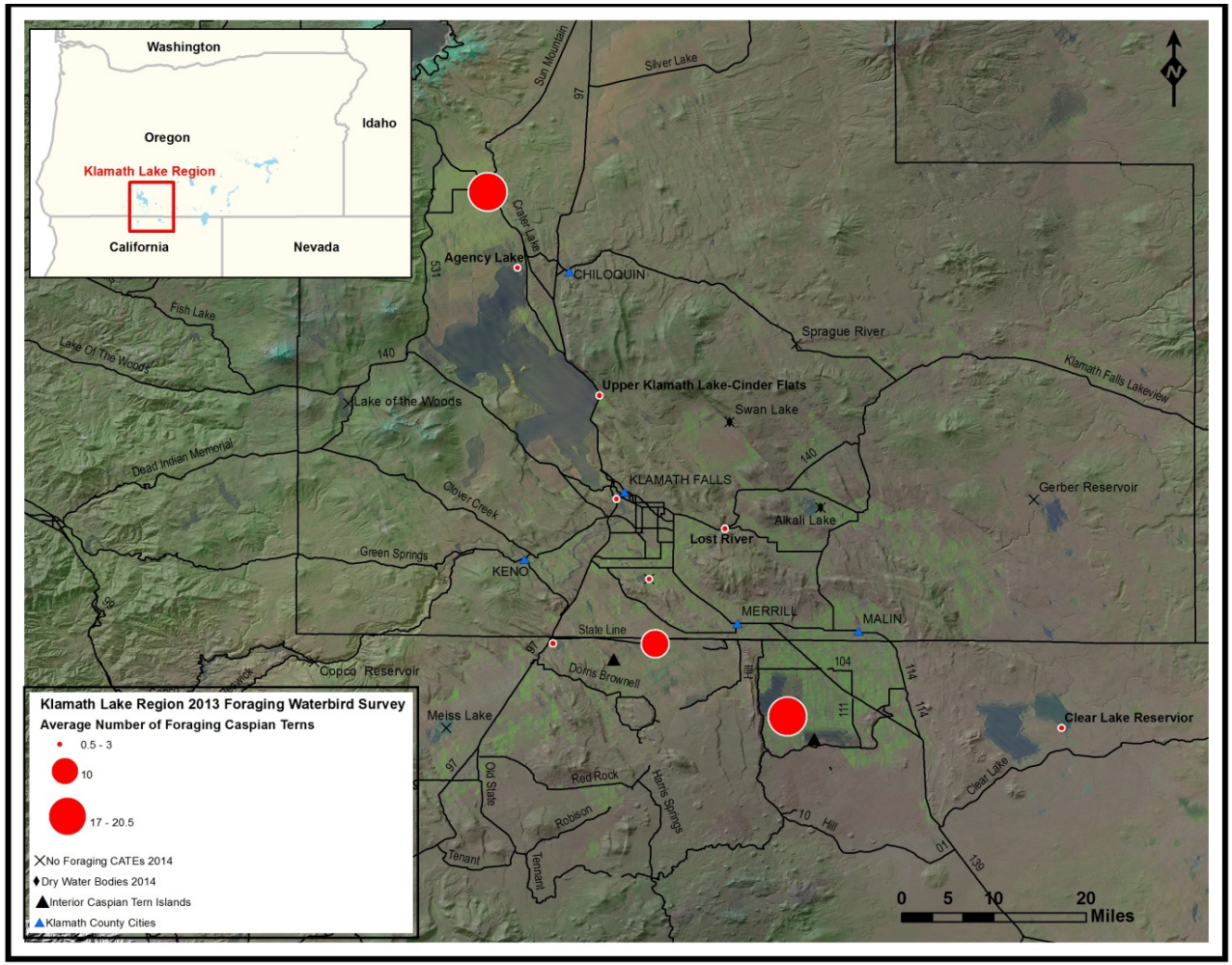

Figure D15. Average number of foraging Caspian terns observed at each survey location during the 2013 breeding season in the Klamath Lake region of Klamath County, Oregon and Siskiyou County, California. Data points are overlaid Landsat imagery from June 2013 to illustrate regional water availability during the peak breeding period for Caspian terns at eh Corps-constructed islands at Lower Klamath and Tule Lake National Wildlife Refuges.

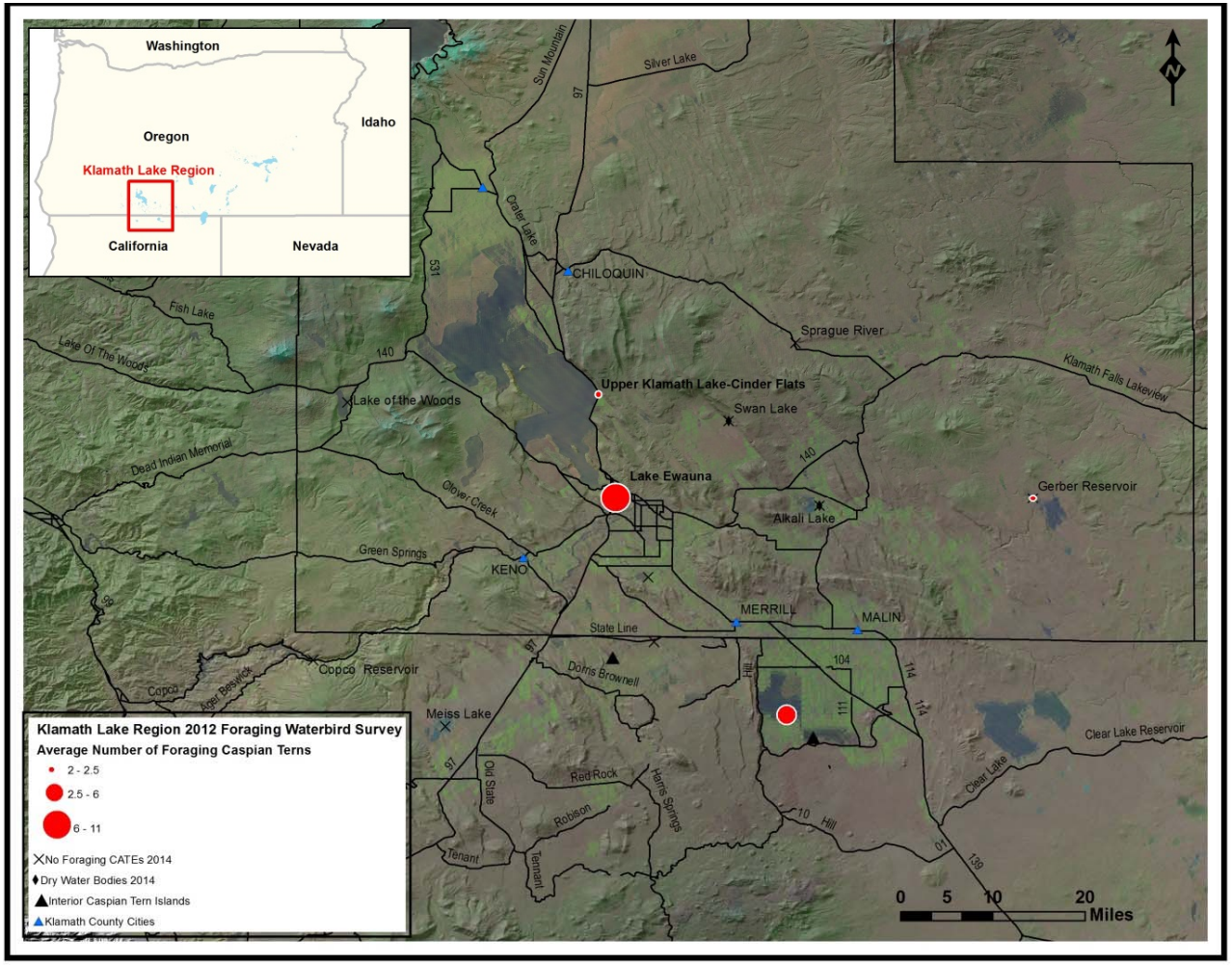

Figure D16. Average number of foraging Caspian terns observed at each survey location during the 2012 breeding season in the Klamath Lake region of Klamath County, Oregon and Siskiyou County, California. Data points are overlaid Landsat imagery from June 2012 to illustrate regional water availability during the peak breeding period for Caspian terns at the Corps-constructed islands at Lower Klamath and Tule Lake National Wildlife Refuge.

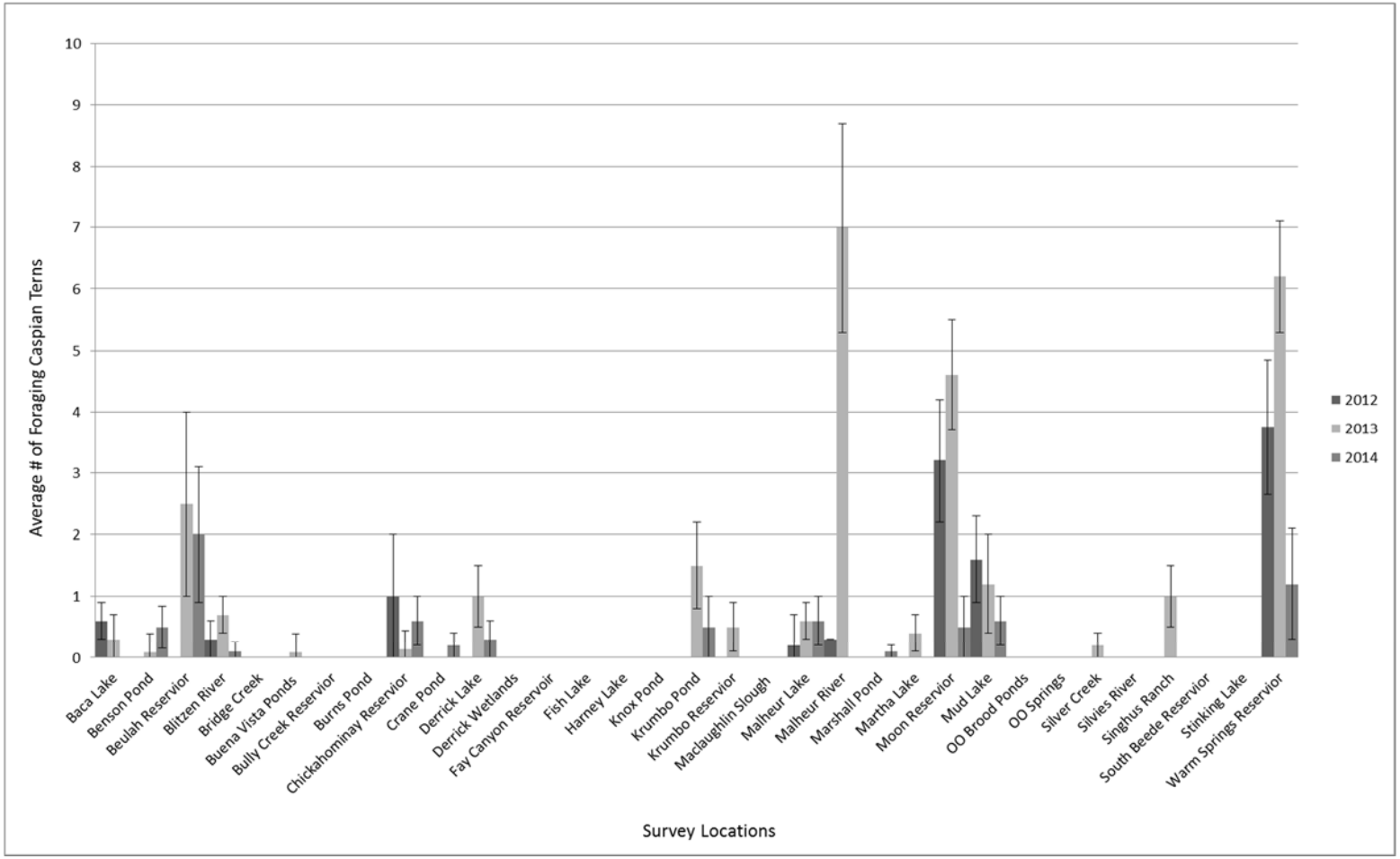

Figure D17. Average number (+/- 1 SE) of Caspian observed at each foraging survey sites in the Malheur Lake region of Harney and Malheur County, Oregon during the 2012, 2013, and 2014 breeding seasons.

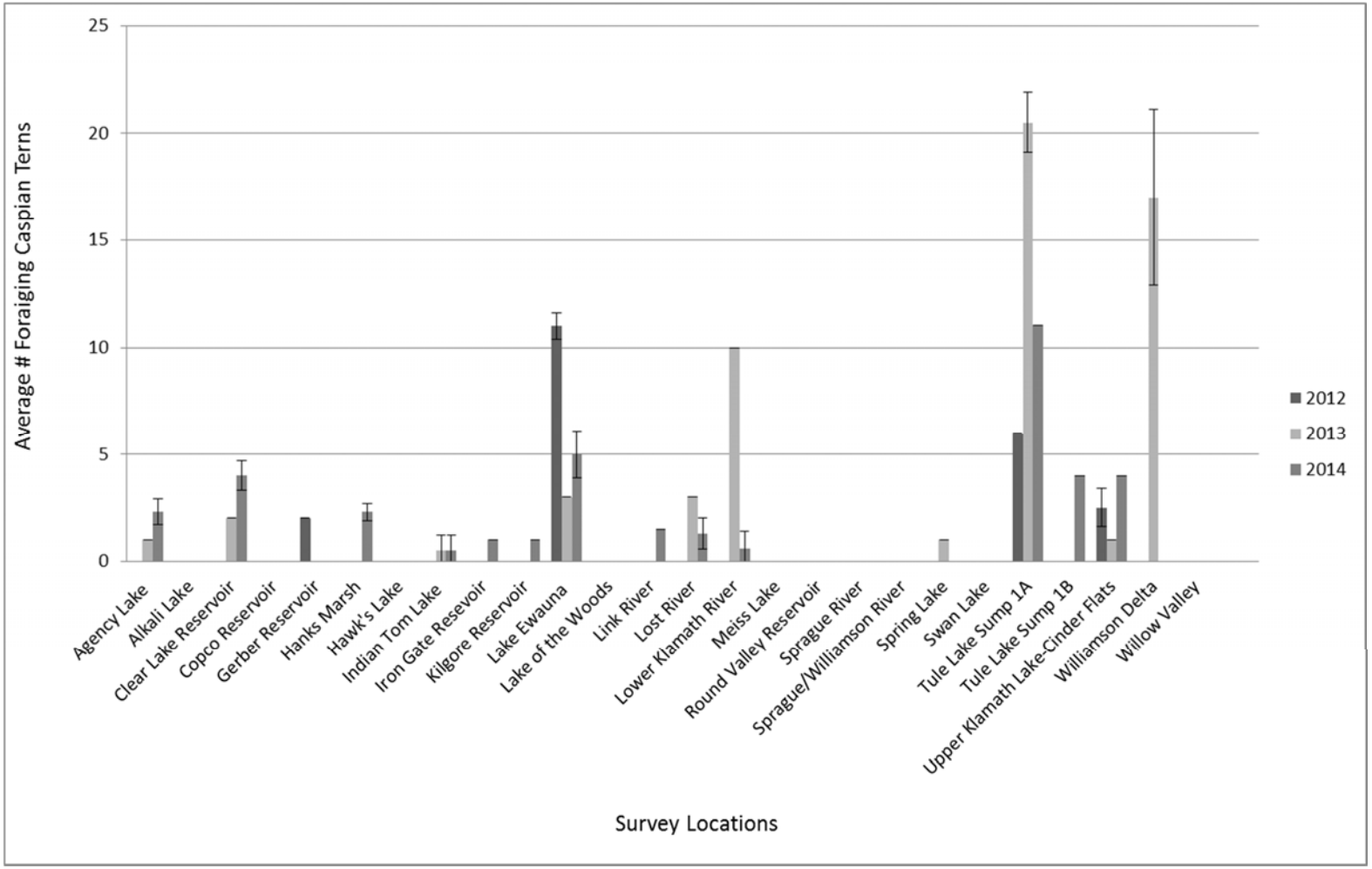

Figure D18. Average number (+/- 1 SE) of Caspian Terns observed at each foraging survey site in the Klamath region of Klamath County, Oregon and Siskiyou County, California during the 2012, 2013, and 2014 breeding seasons.

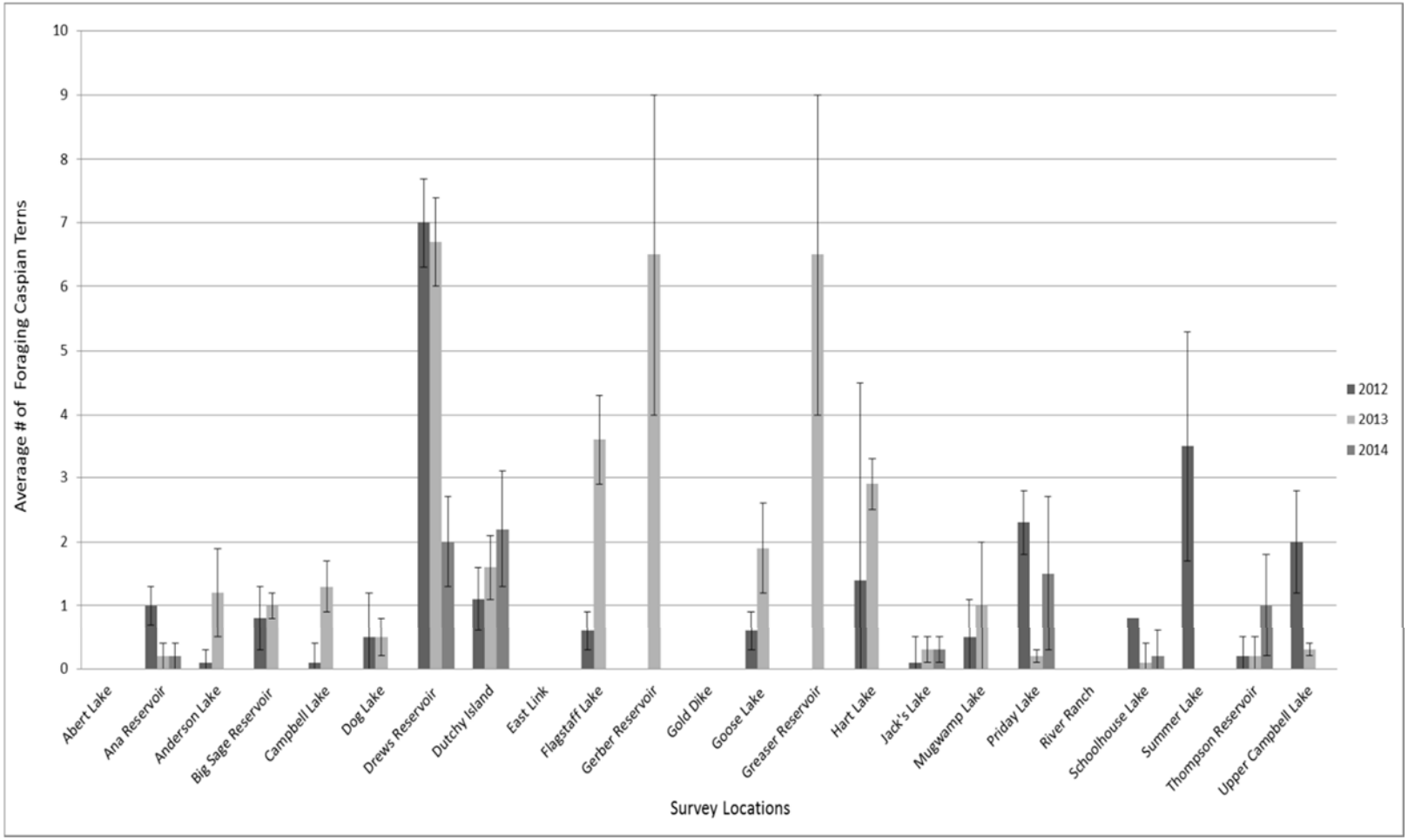

Figure D19. Average number (+/-1 SE) of Caspian terns observed at each foraging survey sites in the Crump and Summer Lake regions of Lake County, Oregon and Modoc County, California during 2012, 2013, and 2014 breeding seasons.

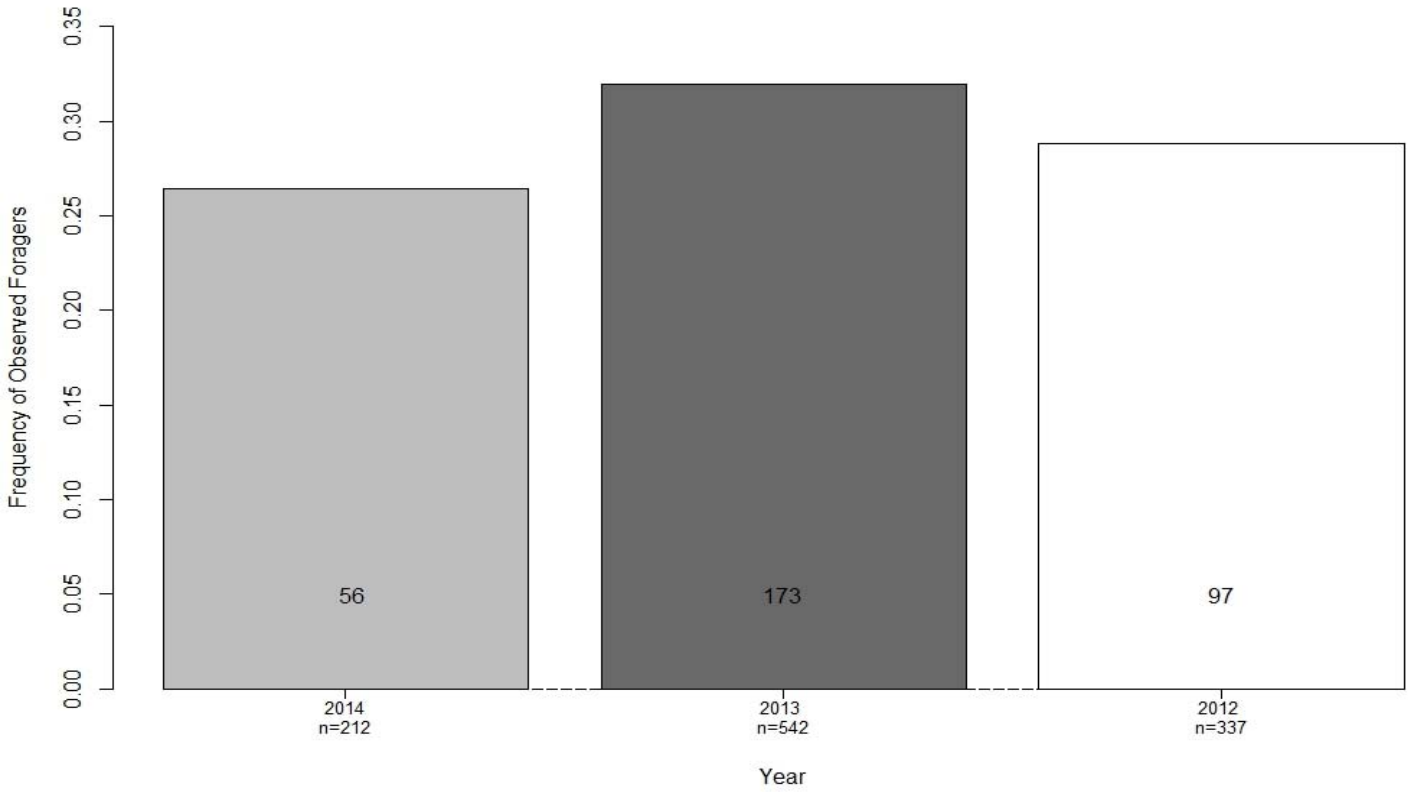

Figure D20. Frequency of observations during 2012-2014 Caspian tern breeding seasons at the foraging water bird survey locations associated with the Corps-constructed islands in the Interior of Oregon and Northeastern California. Number within the bars represent the number of occasions during surveys that foraging Caspian terns were recorded each year.

Table D1. Foraging water bird survey locations and yearly average number of Caspian terns observed foraging at each survey site during 2012-2014 breeding seasons. Survey of foraging Caspian terns were conducted in the region around each of the six Corps-constructed island in interior Oregon and northeastern California monitored in 2014. The regions were: (a) Klamath Lake Region, (b) Summer Lake and Crump Lake, and (c) Malheur Lake.

(a) Klamath Lake Region

	2012			2013			2014		
Survey Locations	Total	Average	Total # of Samples	Total	Average	Total # of Samples	Total	Average	Total # of Samples
Agency Lake	--	--	--	1	1	1	7	2.3	4
Alkali Lake	--	--	--	0	0	2	0	0	1
Clear Lake Reservoir	--	--	--	4	2	2	4	4	2
Copco Reservoir	--	--	--	--	--	--	0	0	1
Gerber Reservoir	2	2	1	0	0	1	0	0	3
Hank's Marsh	--	--	--	0	0	1	4	2.3	2
Indian Tom Lake	0	0	1	1	.5	2	1	.5	2
Iron Gate Reservoir	--	--	--	--	--	--	1	1	1
Kilgore Reservoir	0	0	1	--	--	--	1	1	1
Hawk's Lake	0	0	1	--	--	--	--	--	--
Lake Ewauna	21	11	2	3	3	1	10	5	2
Lake of the Woods	--	--	--	--	--	--	0	0	2
Link River	--	--	--	--	--	--	3	1.5	1
Lost River	--	--	--	3	3	1	4	1.3	4
Lower Klamath River	--	--	--	10	10	1	2	0.6	2
Meiss Lake	0	0	1	-	-	-	-	-	-
Nuss Lake	--	--	--	0	0	2	0	0	2

Round Valley Reservoir	0	0	1	--	--	--	--	--	--
Sprague River	0	0	1	--	--	--	0	0	1
Sprague River/Williamson	0	0	1	--	--	--	--	--	--
Spring Lake	--	--	--	2	1	2	0	0	1
Swan Lake	--	--	--	--	--	--	0	0	1
Tule Lake Sump 1A	6	6	1	41	20.5	2	11	11	1
Tule Lake Sump 1B	--	--	--	--	--	--	4	4	1
Upper Klamath Lake-Cinder Flats	5	2.5	2	2	1	2	4	4	1
Williams Delta	--	--	--	34	17	2	0	0	1
Willow Valley	0	0	1	0	0	1	0	0	1

(b) Summer Lake and Crump Regions

	2012			2013			2014		
Survey Locations	Total	Average	Total # of Samples	Total	Average	Total # of Samples	Total	Average	Total # of Samples
Abert Lake	0	0	14	0	0	21	0	0	1
Ana Reservoir	13	1	12	4	.2	15	2	.2	10
Anderson Lake	2	.1	16	12	1.2	10	0	0	1
Big Sage Reservoir	13	.8	16	6	1	6	0	0	1
Campbell Lake	2	.1	16	32	1.3	23	--	--	--
Dog Lake	3	.5	6	9	.5	17	0	0	2
Drews Reservoir	99	7	14	115	6.7	17	4	2	2
Dutchy Lake	9	1.1	8	24	1.6	15	22	2.2	10

East Link	0	0	3	--	--	--	--	--	--
Flagstaff Lake	9	.6	15	84	3.6	23	0	0	1
Gerber Reservoir	0	0	1	13	6.5	2	0	0	2
Gold Dike	0	0	1	--	--	--	--	--	--
Goose Lake	10	.6	15	31	1.9	16	0	0	1
Greaser Reservoir	0	0	15	98	6.5	15	0	0	1
Hart Lake	28	1.4	19	65	2.9	22	0	0	1
Jack's Lake	2	.1	11	5	.3	15	3	.3	10
Mugwamp Lake	9	.5	16	15	1	10	0	0	1
Priday Reservoir	40	2.3	17	5	.2	22	3	1.5	2
River Ranch	--	--	--	0	0	2	--	--	--
Schoolhouse Lake	9	.8	11	2	.1	15	2	.2	10
Summer Lake	7	3.5	2	--	--	--	--	--	--
Thompson Reservoir	3	.2	11	4	.2	15	8	1	8
Upper Campbell Lake	31	2	16	7	.3	22	--	--	--

(c) Malheur Lake Region

	2012			2013			2014		
Survey Location	Total	Average	Total # of Samples	Total	Average	Total # of samples	Total	Average	Total # of samples
Baca Lake	4	.6	7	5	.3	8	0	0	4
Benson Pond	--	--	--	1	.09	11	3	.5	6
Beulah Reservoir	0	0	1	5	2.5	2	8	2	4
Blitzen River	2	0.3	6	12	.7	16	1	.1	6

Bridge Creek	--	--	--	0	0	5	0	0	3
Buena Vista Ponds	0	0	3	1	.09	11	0	0	6
Bully Creek Reservoir	--	--	--	0	0	1	-	--	--
Burns Pond	0	0	4	0	0	13	0	0	5
Chickahominay Reservoir	1	1	1	1	.14	8	3	.6	5
Crane Pond	0	0	1	0	0	8	2	.2	5
Derrick Lake	0	0	2	6	1	6	1	.3	3
Derrick Wetlands	--	--	--	0	0	5	0	0	3
Fay Canyon Reservoir	0	0	2	0	0	3	--	--	--
Fish Lake	0	0	4	0	0	3	0	0	3
Harney Lake	--	--	--	0	0	1	-	--	--
Knox Pond	0	0	4				0	0	5
Krumbo Pond	0	0	3	15	1.5	11	3	.5	6
Krumbo Reservoir	0	0	6	6	.5	10	0	0	6
Maclaughlin Slough	--	--	--	0	0	11	0	0	1
Malheur Lake	1	.2	5	7	.6	2	3	.6	5
Malheur River	--	--	--	35	7	11	-	--	--
Marshall Pond	--	--	--	0	0	6	1	.1	6
Martha Lake	--	--	--	3	.4	5	0	0	5
Moon Reservoir	13	3.2	4	42	4.6	9	2	.5	4
Mud Lake	10	1.6	6	18	1.2	14	3	.6	5
OO Brood Ponds	1	0.5	2	0	0	6	0	0	6
OO Springs	--	--	--	0	0	6	0	0	6
Silver Creek	--	--	--	2	.2	10	0	0	4

Silvies River	0	0	3	0	0	13	0	0	4
Singhus Ranch	0	0	1	3	1	3	0	0	4
S.Beede Reservoir	0	0	2	0	0	3	0	0	2
Stinking Lake	--	--	--	0	0	2	0	--	--
Warm Springs Reservoir	15	3.7	3	25	6.2	4	5	1.2	4