BPA, USACE – Portland District, and USACE – Walla Walla District

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

Final 2012 Annual Report

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This Final 2012 Annual Report has been prepared for the
Bonneville Power Administration and the U.S. Army Corps of Engineers
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EXECUTIVE SUMMARY

We conducted field studies in 2012 to (1) assess the impact of avian predation on survival of juvenile salmonids (*Oncorhynchus* spp.) in the Columbia River estuary, (2) monitor the efficacy of on-going management actions designed to reduce the impact of Caspian terns (*Hydroprogne caspia*) on salmonid smolt survival in the estuary, (3) test management strategies for limiting the availability of nesting habit for double-crested cormorants (*Phalacrocorax auritus*) at East Sand Island in the Columbia River estuary, and (4) evaluate the impacts on smolt survival of piscivorous colonial waterbirds (i.e., Caspian terns, double-crested cormorants, American white pelicans *Pelecanus erythrorhynchos*, California gulls *Larus californicus*, and ring-billed gulls *L. delawarensis*) that nest in the Columbia Plateau region.

The Caspian tern breeding colony on East Sand Island, the largest of its kind in the world, consisted of about 6,400 breeding pairs in 2012, continuing the downward trend in colony size from the peak of about 10,000 pairs in 2008. The Caspian tern colony on East Sand Island produced a total of about 410 fledglings in 2012, compared to complete breeding failure at this colony in 2011. The proximal factor responsible for colony failure in 2011 and very poor nesting success in 2012 (an average of only 0.06 young raised per breeding pair) was intense disturbance by bald eagles (*Haliaeetus leucocephalus*) and associated predation on tern eggs and chicks by glaucous-winged/western gulls (*L. glaucescens*/*occidentalis*). The average proportion of juvenile salmonids in the diet of Caspian tern diets during the 2012 nesting season was 34%, similar to 2009-2011. The estimated total smolt consumption by Caspian terns nesting at East Sand Island in 2012 was 4.9 million (95% c.i. = 3.9 - 5.8 million), similar to 2011. Recoveries of smolt passive integrated transponder (PIT) tags on the Caspian tern colony at East Sand Island indicated that tern predation rates in 2012 were highest on steelhead populations (7.4 – 10.0%, depending on the population), followed by salmon populations (0.7 – 2.2%, depending on the population), based on ESA-listed PIT-tagged smolts last interrogated passing Bonneville Dam on the Columbia River or Sullivan Dam on the Willamette River; there were indications that predation rates on some ESA-listed salmonid populations were trending lower in 2012 compared to 2010 and 2011. To further reduce the impacts of predation by Caspian terns nesting at East Sand Island on salmonid stocks from the Columbia River basin, more terns will need to be relocated to colonies outside the basin; the management objective is to reduce the size of the East Sand Island tern colony to 4,000 breeding pairs or less, < 40% its pre-management size (ca. 10,000 breeding pairs), while attracting the displaced Caspian terns to alternative colony sites built for terns elsewhere.

Caspian tern management actions continued in 2012, with the U.S. Army Corps of Engineers, Portland District (Corps) further reducing the area of suitable tern nesting habitat on East Sand Island to 1.58 acres, 32% of its former area. This habitat restriction caused Caspian terns to nest at higher densities (average of 1.06 nests/m^2) than

previously seen in the Columbia River estuary. The Corps has built a total of nine new islands as alternative Caspian tern nesting habitat since early 2008, six in interior Oregon and three in the Upper Klamath Basin region of northeastern California. Six of these nine new islands supported nesting Caspian terns in 2012, including the 1-acre rock-core island built early in 2012 on Malheur Lake in Malheur National Wildlife Refuge, where 232 pairs nested. Nest predators, both mammalian and avian, and apparent low forage fish availability at some sites (Crump Lake and Summer Lake Wildlife Area), limited Caspian tern colony size and nesting success at five of the six tern colonies that formed on the Corps' new islands in 2012. Substantial numbers of Caspian terns from the colony on East Sand Island in the Columbia River estuary, however, are visiting these new islands; 64 terns originally banded in the Columbia River estuary were re-sighted on the Corps' new Malheur Lake tern island and 83 were re-sighted on the Corps' Upper Klamath Basin tern islands in 2012.

Data on diet composition of Caspian terns nesting on Corps-constructed tern islands in interior Oregon and northeastern California indicated that in 2012 terns from these colonies primarily consumed cyprinids (i.e., chub *Gila* spp., fathead minnows *Pimephales promelas*, and common carp *Cyprinus carpio*), centrarchids (i.e., crappie *Pomoxis* spp.), and ictalurids (i.e., bullhead *Ameiurus* spp.). Catostomids (suckers), several species of which are listed under the Endangered Species Act, were not identified in the diet of Caspian terns nesting on Corps-constructed tern islands at Sheepy Lake, Tule Lake Sump 1B, and Summer Lake during 2012. One juvenile sucker (species unknown) was observed at the Caspian tern colony on the Corps-constructed tern island in Crump Lake during 2012; suckers represented a very small percentage (< 0.1%) of identifiable prey items at this Caspian tern colony. No sucker PIT tags were recovered from Caspian tern colonies on the Corps-constructed tern islands in either interior Oregon or northeastern California during 2012.

The double-crested cormorant colony on East Sand Island in the Columbia River estuary consisted of about 12,300 breeding pairs in 2012, the largest colony of its kind in western North America and similar in size to 2011 (ca. 13,000 breeding pairs). Juvenile salmonids represented about 20% (by biomass) of the double-crested cormorant diet in 2012, compared to about 19% in 2011. Our estimate of total smolt consumption by double-crested cormorants nesting on East Sand Island in 2012 was 18.9 million smolts (95% c.i. = 14.0 – 23.8 million), not significantly different from the number of smolts consumed by cormorants from this colony in 2011. Annual smolt consumption by double-crested cormorants nesting on East Sand Island has been trending upward since 2003, until 2012 when estimated consumption leveled off. As in other recent years, estimates of total smolt consumption by East Sand Island cormorants were significantly higher than that of Caspian terns nesting on East Sand Island in 2012. Recoveries of smolt PIT tags on the East Sand Island cormorant colony in 2012 indicated that population-specific predation rates ranged from 0.6% to 7.2% for populations originating upstream of Bonneville Dam on the Columbia River or upstream of Sullivan Dam on the Willamette River. Compared to predation rates on salmon populations by

Caspian terns nesting on East Sand Island, predation rates by double-crested cormorants nesting on East Sand Island (2% – 4%) were generally higher; however, the highest estimate of population-specific predation rates for East Sand Island cormorants was on steelhead from the upper Columbia River (7.2%), less than the maximum population-specific predation rate by East Sand Island terns (10.0%).

Using both bioenergetics-based estimates of smolt consumption at the level of the salmonid species and PIT tag-based estimates of population-specific predation rates on salmonids, it is possible to develop a more comprehensive understanding of the impacts of avian predators on survival of juvenile salmonids from across the basin. Population-specific predation rates based on PIT tag recoveries indicated that the impacts of Caspian terns and double-crested cormorants nesting on East Sand Island are substantial for several salmonid populations originating upstream of Bonneville Dam. Bioenergetics-based estimates of smolts consumed indicated that other salmonid populations from across the basin are also negatively affected, and some significantly so. Genetic identification of smolts in the diet of Caspian terns and double-crested cormorants indicated that salmonid populations from the basin that are infrequently PIT-tagged, but ESA-listed (e.g., Upper Willamette River steelhead, Lower Columbia River Chinook salmon), are also consumed in significant numbers by terns and cormorants nesting at East Sand Island. Overall smolt consumption by East Sand Island cormorants has been higher during 2010-2012 compared to the previous decade, while predation rates on ESA-listed populations originating upstream of Bonneville Dam have not shown this same trend. Impacts of double-crested cormorant predation on sub-yearling Chinook smolts originating downstream of Bonneville Dam, however, have been substantial during 2010-2012.

In 2012, the Corps expanded a pilot study initiated in 2011 to test possible strategies for limiting the size of the double-crested cormorant colony on East Sand Island. An eight-foot-high privacy fence was built to bisect the colony and visually separate 62% of the nesting area used by the colony in 2010 from the remainder of the colony. Using human disturbance to haze cormorants during the nest initiation period, cormorants were successfully dissuaded from using this 62% of their former nesting area. Some hazed cormorants were satellite-tagged or radio-tagged to follow their movements to prospective new nesting sites. About 55% of these tagged cormorants dispersed from the East Sand Island colony after tagging, but nearly all eventually returned to the Columbia River estuary and attempted to nest on East Sand Island. Tagged cormorants dispersing from East Sand Island were detected at colonies and roost sites (1) on the lower Columbia River below Bonneville Dam, (2) the outer Washington coast (Willapa Bay and Grays Harbor), (3) Puget Sound, and (4) northern Salish Sea (San Juan Islands; Strait of Georgia; Vancouver, BC area). Only one tagged cormorant was detected on the north coast of Oregon (Cannon Beach).

Caspian terns, double-crested cormorants, American white pelicans, California gulls, and ring-billed gulls are native piscivorous colonial waterbirds that nest in the Columbia

Plateau region. The total number of Caspian terns nesting in the Columbia Plateau region was about 1,000 breeding pairs at six colonies in 2012, as high as or higher than any other year during 2005-2011. The two largest Caspian tern breeding colonies were at Goose Island (463 pairs) in Potholes Reservoir, WA and at Crescent Island (422 pairs) on the mid-Columbia River. The third largest breeding colony was recently formed at Badger Island (60 pairs) on the mid-Columbia River. A small number of Caspian terns (n = 8) that were originally banded as adults on East Sand Island in the Columbia River estuary – where management actions to reduce the size of the colony are being implemented – were re-sighted at colonies in the Columbia Plateau region during 2011 and 2012; some of these banded terns (n = 4) were confirmed to be nesting at colonies in the Columbia Plateau region. The movement of banded Caspian terns that had previously nested on East Sand Island to colonies in the Columbia Plateau region was not seen during 2006-2010, before tern management intensified at East Sand Island. Natal dispersal of terns banded as chicks at East Sand Island to the colonies in the Columbia Plateau region has also been confirmed. Caspian tern movements from East Sand Island to colonies in the Columbia Plateau region, if substantial, could 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.

Total numbers of double-crested cormorants nesting in the Columbia Plateau region increased slightly in 2012, from an average of about 1,350 breeding pairs during 2005-2011 to about 1,550 breeding pairs at four colonies in 2012; the largest colonies were in the North Potholes Reserve (992 nesting pairs) and on Foundation Island in the mid-Columbia River (390 nesting pairs). Numbers of American white pelicans nesting on Badger Island in the mid-Columbia River, a colony that experienced rapid growth during 2004-2010, appear to have stabilized at about 2,100 adults. The numbers of gulls nesting on Miller Rocks, a colony located just downstream of John Day Dam on the Columbia River, were similar to those observed in recent years (ca. 4,500 adults). Following the abandonment of the large California gull colony on Three Mile Canyon Island (ca. 6,200 adults were counted on-colony in 2009), there was a commensurate increase in the number of California gulls nesting on islands in the Blalock Islands complex in 2012; in 2012 ca. 7,300 nesting California gulls were counted on one island in the Blalock Islands, whereas in 2009 no gulls nested there.

Salmonid smolts represented 83% of Caspian tern prey items at the Crescent Island colony and 30% of prey items at the Goose Island colony, resulting in an estimated 730,000 juvenile salmonids consumed by Caspian terns nesting at these two colonies combined in 2012. Estimates of predation rates based on PIT tag recoveries on Caspian tern colonies indicate that impacts were highest on survival of Upper Columbia River steelhead (estimated predation rate of 17.3% by Goose Island terns), Snake River steelhead (estimated predation rate of 2.8% by Crescent Island terns), and Upper Columbia River spring Chinook (estimated predation rate of 2.5% by Goose Island terns).

Smolt PIT tag recoveries on Caspian tern colonies located at Twining Island on Banks Lake (> 45 km from the Columbia River) and at Harper Island on Sprague Lake (> 65 km from the Snake River) indicated that Caspian terns from those two colonies commuted long distances to the mainstem rivers to consume ESA-listed juvenile salmonids.

Studies to refine estimates of avian predation rates based on smolt PIT tags recovered on colonies of double-crested cormorants, California gulls, and ring-billed gulls were conducted in 2012. These studies resulted in correction factors for PIT tag deposition rates, the proportion of PIT tags consumed by birds that were subsequently deposited on-colony, as opposed to off-colony. These correction factors are needed to more accurately measure predation rates on juvenile salmonids by these three species of piscivorous colonial waterbirds. Previously, estimates of PIT tag deposition rates were only available for Caspian terns. Deposition corrected results from 2012 indicated that predation rates on steelhead populations by gulls nesting at certain colonies in the Columbia Plateau region were as great or greater than those of nearby Caspian tern and double-crested cormorant colonies. For example, predation rate estimates indicate that ca. 4% of the available Snake River steelhead and Upper Columbia River steelhead were consumed by gulls nesting on Crescent Island in 2012; ca. 4% of available Snake River steelhead and ca. 6% of available Upper Columbia River steelhead were consumed by gulls nesting on Miller Rocks in 2012. Predation rates on most populations of salmon by gulls nesting at the Crescent Island and Miller Rocks colonies were, however, generally less than 1.0%, with the exception of the predation rate on Snake River sockeye salmon by gulls nesting on Miller Rocks (ca. 5%). PIT tag-derived predation rates by double-crested cormorants nesting on Foundation Island, corrected for PIT tag deposition rate, indicated that predation rates were highest on Snake River sockeye salmon (2.5%) and Snake River steelhead (2.4%). Data on PIT tag deposition rates for American white pelicans nesting at the colony on Badger Island are not currently available. Minimum predation rate estimates (not corrected for PIT tag deposition rates) indicate that American white pelicans consumed less than 0.3% of the available smolts in 2012, regardless of salmonid population.

Resource management agencies are currently developing a management plan aimed at reducing avian predation rates on ESA-listed salmonids in the Columbia Plateau region, especially on steelhead smolts from the Upper Columbia River and Lower Snake River populations. Previous and future research efforts will help inform this process so that the resultant management initiatives are science-based, defensible, cost-effective, and have a high probability of success.

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 2005a, 2006a, 2007, 2008, 2009a, 2010a, 2011, 2012). 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 – 2011, 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 2012). 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 (BRNW 2012, Lyons et al. 2011a, Lyons et al. 2011b). 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 Crescent Island (mid-Columbia River) and Goose Island (Potholes Reservoir), the double-crested cormorant colony on Foundation Island (mid-Columbia River), and the gull (*Larus* spp.) 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).

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 implemented in 2000 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 2001–2011, 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 4 eggs on Rice Island in 2011 (BRNW 2012). During 2001-2011, estimated consumption of juvenile salmonids by Caspian terns nesting on East Sand Island averaged 5.2 million smolts per year (SD = 0.9 million, n = 11 years), a ca. 58% reduction in annual consumption of salmonid smolts compared to when the Caspian tern colony was on Rice Island (12.4 million smolts 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 in the estuary, signed in November 2006, stipulated the redistribution of approximately 60% of the East Sand Island tern colony to alternative colony sites in Oregon and California (USFWS 2005, 2006). This management 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 2011 nesting season, the U.S. Army Corps of Engineers – Portland District had constructed eight islands, five in interior Oregon and three in northeastern California, as alternative nesting habitat for Caspian terns nesting on East Sand Island. The Corps constructed one additional tern nesting island during the winter of 2011-12, in Malheur Lake within Malheur National Wildlife Refuge. 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 2 acres in 2011, and hazing 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. 2010). During the period 1997-2011 the cormorant colony on East Sand Island increased 160% to ca. 13,000 breeding pairs, the largest known breeding colony for the species in western North America. Although juvenile salmonids represented only an average of ca. 11% of the diet (% biomass) of cormorants nesting on East Sand Island during 1999-2011, estimated smolt consumption by cormorants from the East Sand Island colony in 2011 (20.5 million smolts; 95% c.i. = 15.2 – 25.9 million) was far greater than that of Caspian terns from the East Sand Island colony. 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 and the greater food requirements of cormorants relative to Caspian terns. The double-crested cormorant colony on East Sand Island has experienced high nesting success (average of 1.9 young raised/breeding pair per year during 1997-2011), 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 warrants consideration. Reduction in the size of the double-crested cormorant colony on East Sand Island is one management option under consideration. A feasibility study to test techniques for dissuading double-crested cormorants from nesting on 15% of the area used by the East Sand Island colony in 2010 was successful in 2011. Following the success of this pilot study, resource managers decided to test the feasibility of dissuading cormorants from nesting on a larger proportion of their previous nesting area on East Sand Island.

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, or the Columbia Plateau region, began in 1997 (Collis et al. 2002a). 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 (e.g., river flows) and management regimes (e.g., smolt transportation levels and magnitudes of spill at hydropower facilities; 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 (Roby 2011).

As was the case in the Columbia River estuary, Caspian terns and double-crested cormorants were the two species of piscivorous waterbirds responsible for the majority of losses of salmonid smolts to avian predators in the Columbia Plateau region (Roby 2011; Evans et al. 2012). The Caspian tern colony on Crescent Island (Rkm 510) is one of the largest on the Columbia Plateau at about 420 breeding pairs (BRNW 2012). Also near the confluence of the Snake and Columbia rivers, Foundation Island (Rkm 519) is home to the largest double-crested cormorant colony on the mid-Columbia River, at more than 300 breeding pairs (BRNW 2012). While the size of the Crescent Island Caspian tern colony and Foundation Island cormorant colony have remained fairly stable during 2004-2011, the Goose Island (Potholes Reservoir) Caspian tern colony, located ca. 35 km east of the upper Columbia River, has grown roughly 4-fold during this same period, and was the largest colony of Caspian terns in the Columbia Plateau region during 2011 (BRNW 2012). ESU-specific predation rates by birds nesting at these three colonies indicated that steelhead were experiencing higher predation rates compared to other salmonid species. Estimated predation rates on steelhead smolts by Caspian terns nesting at Goose Island/Potholes reached as high as 15%, while predation rates on steelhead smolts by Caspian terns nesting at Crescent Island and by cormorants nesting at Foundation Island were 5% and 3%, respectively (Lyons et al. 2011b). Based on these data and an examination of potential benefits to salmonid ESUs of reducing avian predation associated with piscivorous waterbird colonies in the Columbia Plateau region, it was determined that management of the Goose Island and Crescent Island Caspian tern colonies would result in the greatest incremental benefit to steelhead survival (Lyons et al. 2011b).

The primary objectives of this project in 2012 were to (1) evaluate the efficacy of management initiatives implemented to reduce predation on juvenile salmonids by Caspian terns nesting on East Sand Island, including the monitoring of alternative Caspian tern nesting islands built by the Corps outside the Columbia Basin; (2) collect, compile, and analyze data needed to assist in completion of the NEPA analysis required for management of (a) double-crested cormorants nesting on East Sand Island and (b) avian predators in the Columbia Plateau region; (3) investigate the numbers of other piscivorous colonial waterbirds (e.g., Brandt's cormorants *Phalacrocorax penicillatus*, California brown pelicans *Pelecanus occidentalis californicus*, American white pelicans *Pelecanus erythrorhynchos*, and gulls *Larus* spp.) that use the Columbia River to nest or roost and assess their potential impacts on smolt survival; and (4) assist resource managers as technical advisors in the development of plans for long-term management of avian predation on juvenile salmonids from the Columbia River basin, as warranted.

STUDY AREA

The primary focus of our research and monitoring efforts in 2012 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 and double-crested cormorant colonies in the Columbia Plateau region (Map 1), and (3) six recently constructed islands for nesting Caspian terns in interior 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 Caspian terns along the Washington Coast; nesting Brandt's cormorants and roosting California brown pelicans on East Sand Island; nesting American white pelicans on Badger Island and the recently-formed colony on Miller Sands Spit in the Columbia River estuary; and various gull colonies in the Columbia River estuary, the Columbia Plateau region, and at Corps-constructed tern islands in interior Oregon and northeastern California; Maps 1 and 2).

SECTION 1: CASPIAN TERNS

1.1. Preparation and Modification of Nesting Habitat

Beginning in 2008, the U.S. Army Corps of Engineers (USACE) 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 U.S. Army Corps of Engineers, 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/California 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 (ESA).

The Caspian Tern Management Plan 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, the available nesting habitat for Caspian terns on East Sand Island would be reduced from its historical size (approximately 5 acres) 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 3,200-4,000 nesting 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). Terns displaced by habitat reduction on East Sand Island are expected to relocate to nine Corps-constructed tern islands, alternative colony sites recently provided 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 for potentially building additional tern colony sites in the San Francisco Bay area and elsewhere are under consideration.

1.1.1. Columbia River Estuary

As part of the Caspian Tern Management Plan for the Columbia River Estuary, the USACE – Portland District prepared just 1.58 acres of suitable nesting habitat for Caspian terns on East Sand Island in 2012 (Map 3). This 1.58 acre area was disked and harrowed to remove encroaching European beach grass and other invasive plants in early March 2012 and then was sprayed with pre-emergent herbicide in mid-April 2012. Without annual restoration of the bare sand nesting habitat that Caspian terns prefer, the East Sand Island tern colony would likely be eliminated within a few years by rapidly encroaching pioneer vegetation. The area of Caspian tern nesting habitat prepared on East Sand Island in 2012 was a reduction from the area of nesting habitat prepared for terns in 2011 (2 acres) and a 68% reduction from what had been provided in previous years (5 acres; Map 3). As stipulated in the Final Environmental Impact Statement (USFWS 2005: Chapter 2, Section 2.3.3), this reduction in area of nesting habitat was allowed due to the creation and availability of new Caspian tern nesting habitat outside the Columbia River estuary (USFWS 2005; see below).

About 0.5 acres of bare sand or partially vegetated habitat surrounded the 1.58-acre area prepared for Caspian tern nesting prior to the 2012 nesting season. In early April, before terns initiated nests, ca. 390 meters of vertical fencing with black landscape fabric was erected in rows within this 0.5-acre area to dissuade tern nesting and restrict the amount of suitable tern nesting habitat on East Sand Island to 1.58 acres (Map 3). Rope and flagging were also added between fence rows to enhance the dissuasion outside the 1.58-acre tern colony area on East Sand Island.

As in previous years, Caspian terns began digging nest scrapes near the high tide line on the beach to the east of the large Caspian tern colony at East Sand Island during early April. This satellite colony was outside both the 1.58-acre colony area and the area surrounding the colony area where fencing had been erected to dissuade tern nesting. We were directed by resource managers to erect stakes and flagging around satellite tern colonies on East Sand Island to dissuade Caspian terns from nesting outside the core 1.58-acre colony area. Despite our efforts to dissuade terns from nesting on the upper beach to the east, some Caspian tern nests were initiated in this satellite colony, eggs were laid, but no young were successfully raised. Beginning in late March, Caspian terns formed a satellite colony on the upland dunes at the west end of East Sand Island, in close proximity to the cormorant colony. No dissuasion of this incipient Caspian tern colony was attempted in order to avoid disturbance to nearby nesting cormorants. Despite this, Caspian terns abandoned this incipient satellite colony by late May.

As part of the Management Plan, Caspian terns were also dissuaded from nesting at dredged-material disposal islands (i.e., Rice Island, Miller Sands Spit, Pillar Rock Sands), as well as other dredged material disposal sites in the upper Columbia River estuary. This hazing of incipient Caspian tern breeding colonies in the upper Columbia River estuary was conducted by Newalen LLC, a Corps contractor, in 2012. As was the case in previous years, Caspian terns were observed in upland areas of dredged material disposal islands in the upper Columbia River estuary during the 2012 breeding season. Beginning in mid-April, terns appeared interested in nesting at two sites, on Rice Island near the former colony site that was used in the 1990s and on a pier at Tongue Point. Stakes and flagging were erected in the areas where terns were attempting to nest (digging nest scrapes) on Rice Island by Newalen LLC and terns were actively hazed from the Tongue Point pier. On 16 April, the Corps' contractor, Newalen LLC, initiated frequent (i.e., every other day) monitoring of these and other upper estuary sites and commenced active and passive hazing of terns attempting to nest on islands in the upper estuary until 15 June, when the contract ended. Active hazing or passive measures to discourage Caspian tern nesting (i.e., stakes and flagging) were not necessary at other dredged material disposal sites in the upper Columbia River estuary (e.g., Miller Sands Spit, Pillar Rock Sands) during the 2012 nesting season.

1.1.2. Interior Oregon and Northeastern California

By the beginning of the 2012 breeding season, the USACE and its state and federal partners had completed construction of nine islands (a total of 8.3 acres; Table 1) specifically designed for Caspian tern nesting as part of the Caspian Tern Management Plan (USFWS 2005). Two one-acre rock-core islands were built prior to the 2008 breeding season, one at Fern Ridge Reservoir in the Willamette Valley and the other at Crump Lake in the Warner Valley. These were followed by the construction of two half-acre islands prior to the 2009 breeding season in Summer Lake Wildlife Area (a rock-core island in East Link impoundment and a floating island in Dutchy Lake). Prior to the 2010 breeding season, four additional islands were built: a half-acre rock-core island at Gold Dike impoundment in Summer Lake Wildlife Area, a one-acre silt core island at Orems Unit in Lower Klamath NWR, a 0.8-acre floating island at Sheepy Lake in Lower Klamath NWR, and a two-acre rock-core island at Tule Lake Sump 1B in Tule Lake NWR. Finally, prior to the 2012 breeding season, a one-acre rock-core island was built at Malheur Lake in Malheur NWR. Of these nine tern islands, six were monitored for Caspian tern nesting in 2012; the island at the Orems Unit impoundment was not surrounded by water, the island at Dutchy Lake was heavily vegetated, and after four years of no detected Caspian tern nesting attempts at Fern Ridge Reservoir, monitoring ceased in 2012. Social attraction techniques (i.e., decoys and audio playback systems; Kress 1983, Kress 2000, Kress and Hall 2002, Roby et al. 2002) were used at each of the six monitored tern islands, with the exception of the Crump Lake tern island, to enhance prospects for Caspian terns to nest at each site.

1.2. Colony Size and Productivity

1.2.1. Columbia River Estuary

Methods: The number of Caspian terns breeding on East Sand Island in the Columbia River estuary was estimated using low-altitude, high-resolution aerial photography of the colony taken near the end of the incubation period. 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.

Given the small number of fledglings produced, nesting success (average number of young raised per breeding pair) at the East Sand Island tern colony was estimated by counting the total number of chicks on the colony on 15 July (counts conducted from observation blinds at the colony periphery), the day that the first fledgling tern was observed, minus those fledged terns that were subsequently found dead on the beaches surrounding the East Sand Island colony. The total number of fledglings on-colony was then divided by the number of breeding pairs estimated from the late incubation photo census. Uncertainty of the estimate (SE) was assumed to be 20% of the point estimate, based on our ability to directly measure the 95% confidence limits around the estimate in previous years. In most previous years, when more fledglings were produced, aerial photography was used to estimate the number of fledglings produced at this colony.

In 2012, we used limited gull control (50 glaucous-winged/western gulls collected under permit) on the Caspian tern colony at Easy Sand Island to help prevent the colony from completely failing (as it did in 2011) and to help prevent terns from re-nesting in the upper Columbia River estuary, where they are far more reliant on juvenile salmonids as a food source (Roby et al. 2002).

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) were conducted during the breeding season in order to detect signs of any nesting attempts by Caspian terns.

Results and Discussion: We estimate that 6,416 breeding pairs of Caspian terns (95% c.i. = 5,545 – 7,287 breeding pairs) were nesting on East Sand Island at the peak of nesting activity (mid-May) in 2012 (Figure 1). This total includes 56 breeding pairs that attempted to nest at a satellite colony near the high tide line on the beach to the east of the main colony at East Sand Island. The size of the Caspian tern colony on East Sand Island in 2012 was similar to our best estimate of peak colony size in 2011 (6,969 breeding pairs, 95% c.i. = 5,765 – 7,822 breeding pairs; Figure 2). To date, the East Sand Island tern colony continues to be the largest known breeding colony of Caspian terns in the world.

The size of the East Sand Island Caspian tern colony has gradually declined since 2008 (Figure 2), when the planned reduction in tern nesting habitat on East Sand Island commenced as part of implementation of the Caspian Tern Management Plan (USFWS 2005, 2006; see above). The amount of nesting habitat prepared for terns on East Sand Island has been incrementally reduced in each of the past four years, from approximately 5 acres in 2008 to 1.58 acres in 2012. Nesting density at the East Sand Island tern colony was 1.06 nests/m^2 in 2012, the highest nesting density ever observed at this colony (Figure 3). It is likely that suitable nesting habitat for Caspian terns on East Sand Island is limiting, particularly in the last two years. Further reductions in the amount of Caspian tern nesting habitat provided on East Sand Island will be necessary to realize the goal of reducing the size of the East Sand Island tern colony to 2,500 – 3,125 breeding pairs, as prescribed in the Caspian Tern Management Plan.

As was the case during 2010-2011, high predation rates on Caspian tern eggs and chicks by resident glaucous-winged/western gulls were observed at the East Sand Island tern colony; during disturbances to the tern colony caused by bald eagles, gulls preyed on tern egg and chicks. High rates of gull nest predation necessitated the removal of a few problem gulls (n = 50) using firearms (under permit) to prevent complete colony failure, as occurred at the colony the previous year; all gulls that were removed were observed preying on Caspian tern eggs or chicks at the East Sand island tern colony in 2012. Despite these efforts, Caspian tern nesting success at the East Sand Island colony in 2012 was poor. We estimate that about 410 fledglings (95% c.i. = 247 – 577 fledglings) were produced at the East Sand Island tern colony in 2012. This corresponds to an average nesting success of 0.06 young raised per breeding pair (95% c.i. = 0.04–0.09 fledglings/breeding pair), similar to the productivity recorded at the East Sand Island tern colony in 2010 (Figure 4). In 2011, the Caspian tern colony on East Sand Island did not produce a single fledgling, the first time complete breeding failure has been recorded at this colony. 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) nest predation by gulls, especially during colony disturbance events caused by bald eagles.

Caspian terns continued to prospect for nest sites at dredged material disposal sites in the upper Columbia River estuary during 2012. Active and passive measures used by the Corps' contractor to dissuade terns from nesting in the upper estuary were successful until mid-June, when active hazing of terns was discontinued. The Corps' contractors did collect six intact Caspian tern eggs and shells of two additional depredated eggs from Caspian tern nests on Rice Island. Following the cessation of active tern hazing, Caspian terns did not return to Rice Island to re-initiate nesting. Caspian terns did not attempt to nest at any other dredged material disposal sites in the upper estuary during 2012.

1.2.2. Columbia Plateau

Methods: Given the relatively small number of Caspian terns nesting at colonies in the Columbia Plateau region and our ability to view the entire colony from a blind, which is not the cases for bird colonies the Columbia River estuary, ground counts of active nests and chicks were used instead of counts from aerial photography to estimate colony size and nesting success. Caspian tern colony size at Crescent Island on the mid-Columbia River and Goose Island in Potholes Reservoir (Map 1), measured as the number of breeding pairs, was based on the peak number of incubating terns on each colony near the end of the incubation period. Nesting success was estimated from the peak number of fledging-aged birds on the colony just prior to the peak of fledging. These ground counts were made by researchers from observation blinds situated on the periphery of each tern colony. The colony area occupied by nesting Caspian terns at the Crescent Island and Goose Island colonies was estimated from geo-referenced aerial photography and was reported in acres. Currently, we do not have precise measures of variance for our estimates of colony size and nesting success for terns nesting at the colonies in the Columbia Plateau region.

Periodic boat-based and aerial surveys of former Caspian tern breeding colony sites in the Columbia Plateau region (i.e., Three Mile Canyon Island, 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 Rock Island Dam, the lower Snake River from its mouth to the confluence with the Clearwater River, and Potholes Reservoir searching for new or incipient Caspian tern colonies. If nesting Caspian terns were detected during aerial surveys at any of these traditional colony sites or at new colony sites, oblique photography was taken in order to estimate the number of nesting pairs.

Results and Discussion: Caspian tern attendance at the Crescent Island colony in 2012 was below the average for 2000-2011 (Figure 5). Low colony attendance (i.e., number of adults counted on colony throughout the 2012 breeding season relative to the average from previous years) was associated with below average colony size (Figure 6) and nesting success (Figure 7) at the Crescent Island tern colony in 2012. About 422 breeding pairs of Caspian terns attempted to nest on Crescent Island in 2012, similar to the colony size in 2011 (419 breeding pairs). Caspian tern colony size on Crescent Island trended downward from 2001 to 2007, but has remained relatively stable thereafter (Figure 6). While the colony area used by nesting terns on Crescent Island increased in 2012 (397 m^2 or 0.098 acres) compared to 2011 (356 m^2 or 0.088 acres), nesting density was lower in 2012 (1.06 nests/m^2) compared to 2011 (1.18 nests/m^2).

We estimated that 79 young terns fledged from the Crescent Island tern colony in 2012, or 0.19 young raised per breeding pair. This is the lowest nesting success ever recorded at this colony (Figure 7). Nesting success at the Crescent Island Caspian tern colony was below the 10-year average (0.56 young raised per breeding pair) for the 5th consecutive year (Figure 7), possibly due to low availability of juvenile salmonids as prey late in the chick-rearing period (Lyons et al. 2011a).

At Potholes Reservoir, Caspian terns nested on Goose Island at two separate colony sites in 2012; the main colony was located on the western lobe of the island and a smaller satellite colony was located on the small eastern lobe of the island. The peak in colony attendance at the Goose Island colony occurred in mid-May, as was observed in previous years (Figure 8). Colony attendance at the Goose Island colony was generally higher in 2012 compared to the previous two years (Figure 8). We estimated that 463 breeding pairs of Caspian terns attempted to nest on Goose Island in 2012, similar to the estimate of colony size in 2011 (422 breeding pairs; Figure 9). The Goose Island colony was the largest Caspian tern colony in the Columbia Plateau region during 2009-2012. While the colony area used by nesting terns on Goose Island declined in 2012 (457 m^2 or 0.113 acres) compared to 2011 (482 m^2 or 0.119 acres), nesting density increased in 2012 (1.01 nests/m^2) compared to 2011 (0.88 nests/m^2).

We estimated that 35 young fledged from the Goose Island tern colony in 2012, or an average of 0.08 young raised per breeding pair, down from 0.27 young raised per breeding pair in 2011 (Figure 10). Disturbance and/or predation by avian and mammalian predators could have been factors in the low tern productivity at Goose Island in 2012 (we found direct evidence of predation on gulls nesting at Goose Island). In 2010, virtually all Caspian tern nesting attempts at Goose Island failed, attributed to a combination of unseasonably cool, wet weather and nocturnal disturbance to nesting terns on the colony by great horned owls (*Bubo virginianus*) and at least three different American mink (*Neovison vison*).

Nesting by Caspian terns on the Blalock Island group, located on the mid-Columbia River in John Day Pool, was first detected in 2005 when six pairs attempted to nest on Rock Island. The Rock Island colony peaked at 104 breeding pairs in 2008 and fell to 79 breeding pairs in 2009 before terns abandoned the site and moved to Anvil Island (another island in the Blalock Island group) in 2010 (Figure 11). In 2012, the Caspian tern nesting colony on Anvil Island consisted of about 6 breeding pairs, a decline in colony size from 2011, when 20 breeding pairs were counted (Figure 11). The Anvil Island Caspian tern colony completely failed in both 2011 and 2012 due to rising water levels in John Day Pool that flooded the colony site, and possibly other unidentified factors. This is the seventh consecutive year that Caspian terns nesting at the Blalock Island group have failed or nearly failed to rear young, either due to nest predation by mammalian or avian predators, or due to high water levels in John Day Pool during the incubation period.

For the second consecutive year Caspian terns attempted to nest at the upstream end of Badger Island. Caspian terns were observed on Badger Island during visits from 9 March to 11 July. The first evidence of breeding was confirmed on 7 May when 11 terns were seen attending nests. Numbers of attended nests increased to a peak of 60 breeding pairs of Caspian terns on 1 June; on 7 June three tern chicks were seen. The actual colony size was probably between 60 and 100 breeding pairs because our vantage from the boat did not allow a complete view of the entire breeding colony. No Caspian tern eggs or chicks were observed during subsequent visits to Badger Island, and Caspian tern nest attendance at Badger Island declined each week until the colony was completely abandoned on 5 July. The highest colony attendance observed at the Badger Island Caspian tern colony in 2012 was 180 terns, based on a count of individuals from aerial photography taken on 18 May. The seasonal decline in numbers of Caspian tern nests at Badger Island may have been related to high water levels in mid-June, but it is also likely that encroachment and disturbance by American white pelicans also played a role in tern colony failure in 2012.

In addition to the Caspian tern colony on Goose Island in Potholes Reservoir, we identified two other Caspian tern colonies in the Columbia Plateau region off the Columbia and Snake rivers in 2012. Twenty-two pairs of Caspian terns nested on Twining Island in Banks Lake and 30 pairs nested on Harper Island in Sprague Lake in 2012. From 1997 to 2005, Caspian terns nesting at Banks Lake used Goose Island, north of Twining Island, where colony size ranged from 10 to 40 breeding pairs. In 2005, Caspian terns began nesting on Twining Island (also called Dry Falls Dam Island), which is located in Banks Lake just north of Dry Falls Dam. The colony at Twining Island grew from less than 10 breeding pairs in 2005 to 61 breeding pairs in 2009, before declining to ca. 20 breeding pairs in 2011 and 2012 (Figure 12). Nesting by Caspian terns on Harper Island in Sprague Lake was first documented in the late 1990's, where they have been nesting sporadically ever since. During 2005-2010, estimates of Caspian tern colony size on Harper Island were generally small (< 10 breeding pairs), before increasing about 6-fold in 2012 (Figure 13). In 2012, no young terns were apparently fledged from the colonies at either Twining Island or Harper Island; the cause[s] of colony failure is unknown. Caspian tern nesting success at Twining and Harper islands has been generally low, ranging from complete colony failures at both colonies in several years to 0.33 young raised per breeding pair at Twining Island in 2008 and 2009.

We identified a total of six active Caspian tern colonies in the Columbia Plateau region during 2012 (Figure 14), where a total of approximately 1,000 breeding pairs nested (Figure 15). The total number of Caspian terns nesting in the Columbia Plateau region has remained relatively stable over the last four years, but total numbers are slightly greater compared to those recorded during 2005-2008 (Figure 15).

1.2.3. Coastal Washington

Methods: Aerial surveys along the southern Washington Coast, Puget Sound, and the Salish Sea, including former and recent Caspian tern colony sites in Willapa Bay, Grays Harbor, Dungeness Spit, Smith Island, the Seattle waterfront, and the Port of Bellingham (Map 1), were conducted on a periodic basis throughout the breeding season in order to detect formation of Caspian tern colonies outside the Columbia River estuary. Survey frequency and methodology did not generally lend themselves to rigorous statistical estimation of measurement uncertainty in colony size or productivity.

The numbers of Caspian terns breeding at sites in the Puget Sound and Salish Sea region of Washington were assessed by a combination colony counts from aerial photography and periodic ground-based surveys during the breeding season. The number of Caspian terns attempting to nest at the Trident Seafood warehouse rooftop in Seattle, WA; the Kimberley-Clark warehouse rooftop in Everett, WA; the Fraser River Terminal warehouse rooftop in Richmond, British Columbia; and at Smith Island in San Juan

National Wildlife Refuge in the Strait of Juan de Fuca (Map 1) were estimated by counting the number of terns attending nests during each visit or by counting apparent attended nests on aerial photography. We also opportunistically assessed nesting chronology, productivity, and factors limiting colony size and nesting success at these colonies throughout the breeding season.

Results and Discussion: Caspian terns were commonly observed foraging and roosting in Willapa Bay and Grays Harbor during the 2012 breeding season, but no nesting attempts were detected in either area. This suggests that suitable Caspian tern nesting sites (i.e., islands that include unvegetated substrate above the high high tide level and free of mammalian predators) are not available in Willapa Bay or Grays Harbor.

Based on limited observations, it appeared that Caspian terns did not attempt to nest at Dungeness Spit in 2012. During an aerial survey conducted on 17 May approximately 75 Caspian terns were observed on and adjacent to the historical colony site. Photography taken on 5 June, during a second aerial survey, indicated that only 42 Caspian terns were on the colony site, of which 9 appeared to be in an incubation posture. The colony site was abandoned by the last aerial survey on 10 July, when 50 terns, all loafing below the high tide line, were observed. Based on these observations, we are confident that any Caspian tern nests that may have been initiated failed. Ground surveys were not conducted at Dungeness Spit in 2012 due to the small numbers of terns present during aerial surveys and the time/logistics required for colony site visitation. Nest predation by coyotes (*Canis latrans*) and bald eagles has been a direct cause of nest loss and colony failure in recent years, so it is likely that Caspian tern interest in the colony site has been affected by repeated colony failures from 2009 to 2011.

The Dungeness Spit Caspian tern colony grew steadily from 2003 to 2009, when it reached ca. 1,500 breeding pairs and was the second largest Caspian tern colony on the Pacific Coast of North America (after the colony on East Sand Island; BRNW 2010a). Based on re-sightings of banded Caspian terns, some growth in the Dungeness Spit tern colony was through immigration of birds from colonies in the Columbia River basin (i.e., East Sand and Crescent islands) and from Commencement Bay, Tacoma, WA (BRNW 2004, 2005b, 2006b, 2009b, 2010b). Despite repeated forays into the Dungeness Spit Caspian tern colony by mammalian predators in previous years, some terns were successful in raising young at the colony in every year until 2009, when coyotes and avian predators caused complete nesting failure for the first time since the colony formed in 2003.

During aerial surveys of the Puget Sound area conducted in 2012, we confirmed that no nesting by Caspian terns occurred at the site of a former Caspian tern colony on the old Georgia-Pacific mill site in the Port of Bellingham, WA for a second year. This colony first became established in 2009, when 200 adult terns, some with young, were counted at the site in early July. The colony was located on bare pavement and gravel at the location of a former waterfront warehouse that was demolished and removed in 2008.

The area used by nesting terns was fenced, providing some protection from mammalian predators. Our best estimate of colony size in 2010 was between ca. 1,400 and 2,000 breeding pairs. We suspect some terns that colonized the Port of Bellingham site were from the failed colony at Dungeness Spit, WA; however, re-sightings of previously banded terns indicated that terns also immigrated from colonies in the Columbia River estuary, San Francisco Bay, interior Oregon, and the Columbia Plateau region (see below). Caspian tern productivity at the Port of Bellingham colony was good; we estimated that 900 - 1,400 young terns fledged from the colony in 2010, or an average of 0.5 - 1.0 fledglings per breeding pair. Nest predation, a major limiting factor for colony size and nesting success at other Caspian tern colonies in the region, was not a major factor at this site in 2010. However, due to plans to begin environmental cleanup and development of the site, Caspian terns were actively dissuaded from nesting at the Port of Bellingham site in 2011 and 2012.

There was no evidence that Caspian terns attempted to nest on the Padilla Bay dredge spoil islands in 2012. During the only ground-based survey, on 12 May, a minimum of 20 Caspian terns were counted on the mudflat north of the colony site used in 2011. There were 66 Caspian terns loafing on or near the former colony site during an aerial survey on 17 May. All Caspian terns seen during the 5 June and 10 July aerial surveys were located below the high tide line, suggesting that any nests initiated in 2012 had failed by early June. Additional ground-based surveys were not conducted at this location in 2012 due to the small numbers of Caspian terns present and the apparent lack of attended nests at the site during aerial surveys.

On the northern-most dredge spoil island in Padilla Bay, a breeding colony of Caspian terns formed in 2011. The colony size was estimated to be 424 breeding pairs and consisted of separate nesting areas on the northeast, northwest, and southeast edges of the island. Eggs and chicks were confirmed, but no young were raised to fledging age. By late July, the Padilla Bay Caspian tern colony had completely failed. Flooding and erosion clearly contributed to breeding failure, but broken eggs and river otter (*Lontra canadensis*) tracks, scat, and a live animal were observed on the colony, suggesting mammalian predation may also have played a role in this colony failure.

Caspian terns were first recorded as nesting on the northernmost of four dredge spoil islands in southern Padilla Bay during the early 1990s. The colony grew to a maximum of about 126 nests in 1995. Site occupancy data were not available in all years since 1995; however, Caspian terns are known not to have nested at this site between 2004 and 2010.

In 2012, an aerial survey conducted on 17 May provided evidence that Caspian terns were again congregating in large numbers on Smith Island. Approximately 520 Caspian terns were counted during the survey and 37 appeared to be attending nests. Counts from aerial photography taken on 5 June indicated that there were 497 Caspian terns on the Smith Island colony site, 234 of which appeared to be incubating. On 19 June, during a field visit to Smith Island conducted by Peter Hodum (University of Puget Sound), Scott Pearson (WDFW), Tom Good (NOAA), and Cindy Roberts (USDA Forest Service), an on-colony survey was conducted and 50–70 nest scrapes were counted. Few of the nests contained eggs; only four nests contained one egg each. Observers found three large piles of depredated tern eggs amongst the driftwood at the edge of the colony, presumably created by gulls, and also observed nest predation by gulls and possibly crows during disturbances caused by bald eagles flying overhead. There were 692 terns on Smith Island during an aerial survey conducted by Sue Thomas (WMNWRC) on 29 June. However, by the date of the final BRNW aerial survey on 10 July, the Caspian tern colony had apparently completely failed. The 10 July photography showed that fewer than 50 Caspian terns were on the island and just two were on the colony site.

Aerial photography taken on 5 June was used to estimate a Caspian tern colony size of 234 breeding pairs on Smith Island in 2012. Complete colony failure by Caspian terns breeding at Smith Island appeared to be due to the combined effects of eagle disturbance and nest predation by gulls, but inundation of nests that were below the high high tide line may have also contributed.

Caspian terns first nested on Smith Island in the Strait of Juan de Fuca in 2011. Based on a review of the June 2011 aerial photography of Smith Island, approximately 750 terns were observed near the east end and five terns appeared to be attending nests. However, no Caspian terns were using the site during an aerial survey in early July, indicating that all tern nesting attempts failed in 2011. Nesting habitat for Caspian terns at Smith Island appears to be limited to a small area below the vegetated upland that is prone to flooding or inundation during high high tide events.

In 2012, a Caspian tern colony was confirmed for the second consecutive year on the rooftop of the Trident Seafood warehouse adjacent to Pier 90 in Seattle, WA. The size of the colony was estimated to be 50-70 breeding pairs in 2011, but no young fledged from the colony in 2011. In 2012, nearly 500 terns were estimated to be on the rooftop colony during a 17 May aerial survey. The maximum colony attendance recorded was 724 terns on 6 June, but subsequent counts of adult terns on-colony were all below 200. The peak in attended nest counts based on observations from the ground was 59 nests on June 6, but nest numbers declined considerably over the next month. Based on counts of older chicks late in the season, we estimate that 2 to 4 chicks fledged from this colony in 2012. We estimate that the colony size was 59–105 nests in 2012. Nesting success (average number of chicks raised per breeding pair) at the Seattle colony was estimated to be 0.02–0.07. Poor nesting success at this colony was probably due to a combination of factors. Approximately one disturbance to the colony per hour of monitoring was observed, a very high rate of disturbance. Over 20 abandoned eggs were scattered across the roof during the first ground survey in June, but the cause of abandonment was unknown. In addition, depredation of three tern eggs (possibly abandoned) was observed during our June survey; two were taken by a crow and one by a gull, indicating that avian predators were likely focused on the colony as a food source. Avian nest predators appeared to be a limiting factor for this Seattle tern colony during 2011 as well.

A new Caspian tern nesting colony was discovered during an aerial survey on 17 May on the Kimberley-Clark warehouse in Everett, WA. Counts from aerial photography indicated there were 481 Caspian terns on the colony site, 116 apparently incubating. There were 97 active nests counted during this first ground survey on 6 June, all located along short linear roof structures where debris had accumulated. The maximum recorded colony attendance was 627 terns on 10 July. Nest numbers decreased steadily throughout the breeding season, down to just 16 adult terns counted on 3 August. Based on counts of older chicks late in the season, it is likely that 12–17 chicks fledged from the Everett colony in 2012. We counted attended nests in aerial photography taken on 5 June to estimate colony size of the Everett Caspian tern colony at approximately 197 breeding pairs in 2012. Nesting success at the Everett colony was estimated to be 0.06–0.09 fledglings per breeding pair in 2012. Low productivity at this site may have been the result of flooding during heavy rains. During a ground-based survey on 6 June, 112 abandoned eggs (mostly intact) were scattered across the colony. This abandonment may have been caused in part by flooding of nests; the concave roof was observed to collect a large amount of water and drained slowly following a heavy rain event on 23 June. There was no evidence of nest loss due to avian predators.

A new Caspian tern colony was also discovered in Richmond, British Columbia during 2012 by a local birdwatcher, Richard Swanston. The colony was located on the Fraser River Terminal warehouse rooftop and was visited twice by BRNW personnel. Only about 75% of the colony was visible from the observation point. On 6 June, during a visit by BRNW personnel, there were 550–650 Caspian terns on the rooftop and at least 31 terns appeared to be incubating, but no eggs were observed. During the second survey by BRNW on 14 August the colony count was just 21 adults and no active nests were observed. Richard Swanson conducted 19 visits from 19 May to 29 June. He reported a maximum colony attendance of 674 Caspian terns on 7 July and a maximum of three eggs were observed during frequent colony disturbances. The Caspian tern colony flushed from 1-10 times during 15 visits to the colony by Richard Swanston, for a total of 60 colony flushes and an estimated flushing rate of two per hour of observation. We estimated that colony size in 2012 was at least 31 breeding pairs, but no young were raised to the fledgling stage. Colony failure was likely caused by factors associated with disturbance. There were eggshells scattered across the rooftop for much of the season and kleptoparasitism attempts by glaucous-winged gulls were regularly noted by observers. Potential predators observed in the vicinity of the colony during observations included gulls, crows, ravens, bald eagles, and peregrine falcons. In addition, there was a disturbance caused by a red-tailed hawk (*Buteo jamaicensis*) and one caused by a skateboarder. There was no evidence that mammals (including humans) accessed the rooftop.

Loss of former breeding colony sites at Dungeness Spit and the Port of Bellingham has likely contributed to the formation of new Caspian tern colonies at locations in the Salish Sea region over the last two years. In addition, the complete failure of the large Caspian tern colony at East Sand Island in 2011, and poor productivity in 2012, likely contributed to the numbers of Caspian terns prospecting for breeding sites in the Salish Sea region. Although 500-600 Caspian tern nesting attempts were documented at four different colonies in the Salish Sea region during 2011 and 2012, most colonies failed to raise any young to fledging age, and the colonies that did produce fledglings had extremely low productivity in 2012. The overall poor breeding performance by Caspian terns in the Salish Sea region, plus attempts to colonize fenced sites on the mainland and rooftops in urban areas support the hypothesis that suitable nesting habitat for Caspian terns is very limited in the region. Continued monitoring in 2013 and beyond will be necessary to determine where Caspian terns displaced from the former breeding colonies at the Port of Bellingham, Dungeness Spit, and Padilla Bay, plus terns emigrating from the managed colony on East Sand Island, may attempt to nest at new sites in the Salish Sea region.

1.2.4. Interior Oregon and Northeastern California

Methods: Observation blinds were built at the periphery of Caspian tern nesting habitat on each of the six islands suitable for Caspian tern nesting 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 National Wildlife Refuge) and in northeastern California (i.e., Sheepy Lake at Lower Klamath National Wildlife Refuge, Tule Lake Sump 1B at Tule Lake National Wildlife Refuge; Map 2). We used a combination of social attraction with tern decoys and audio playback of vocalizations, limited gull control, and continuous monitoring at most of these recently constructed islands to help establish and maintain Caspian tern colonies at each site (see Kress 1983 for further details on these methods). Social attraction methods were not used at the Crump Lake tern island in 2012 because managers decided that the Caspian tern colony had exceeded the target number of breeding pairs (500 pairs) in 2009, the last time social attraction was used at that site. Social attraction was not used at the Dutchy Lake or Orems Unit tern islands because they were not in a suitable condition for tern nesting in 2012. Data on colony attendance, colony size, productivity, and factors limiting colony size and productivity were collected 1-7 days per week at each of the six islands. Measurement uncertainty in colony size and colony productivity were not expressly estimated; however, repeatability of ground-based counts was generally within 5% or less. Because no nest attempts by Caspian terns had been detected at the Fern Ridge Reservoir tern island during 4 years of social attraction at that site (2008-2011), the Corps decided not to monitor the island for Caspian tern use during the 2012 nesting season.

The number of Caspian tern pairs breeding at colonies 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.

Periodic aerial, road-based, and boat-based surveys of other sites in central, south-central, and southeastern Oregon and northeastern California (Map 4) were conducted during the 2012 nesting season in order to detect nesting attempts by Caspian terns and other piscivorous colonial waterbirds.

Results and Discussion: Caspian terns were observed during the 2012 nesting season at seven of the nine tern nesting islands built by the Corps in interior Oregon and northeastern California (Figure 16). Caspian terns attempted to nest at all six of the islands that were suitable for Caspian tern nesting in 2012 (Crump Lake, East Link, Gold Dike, Sheepy Lake, Tule Lake, and Malheur Lake); the Caspian terns observed at the tern island on Dutchy Lake did not attempt to nest at that site.

Colony attendance at the Crump Lake tern island in Warner Valley, Oregon during 2012 was well below the average during 2008-2011 (Figure 17). About 115 breeding pairs of Caspian terns attempted to nest at the Crump Lake tern colony in 2012, up from the colony size estimates from the previous two years (71 and 35 breeding pairs in 2010 and 2011, respectively), but down from 2008 and 2009 (428 and 697 breeding pairs in 2008 and 2009, respectively; Figure 18). As was the case during 2008-2011, high predation rates on Caspian tern eggs were observed at the Crump Lake tern island; California gulls (*Larus californicus*) and, to a lesser extent, ring-billed gulls (*L. delawarensis*) were responsible for the egg predation. High rates of gull predation on tern eggs necessitated the removal of a few problem gulls using firearms (under permit); a total of 36 gulls that were preying on Caspian tern eggs were removed in 2012. We estimated that approximately 50 young Caspian terns fledged from the Crump Lake tern colony in 2012, or an average of 0.43 young fledged per breeding pair (Figure 19).

In 2012, Caspian terns attempted to nest at two of the three tern islands built at Summer Lake Wildlife Area, the islands in East Link and Gold Dike impoundments. Although small numbers of Caspian terns (n = 1−12) were observed on the floating tern island at Dutchy Lake throughout the 2012 breeding season (late April through late August), no Caspian terns initiated nesting there, as was the case in the previous two years. Caspian tern colony attendance at the Summer Lake tern islands in 2012 was highly variable, ranging from a high of 41 adults on colony in mid-June to less than 10 adults on colony in early and late June, which was similar to within season trends in colony attendance in previous years (Figure 20). Ten breeding pairs attempted to nest at the East Link tern island and four breeding pairs attempted to nest at the Gold Dike tern island in 2012, up from a total of two breeding pairs nesting at the East Link tern island in 2011 (Figure 21). No young terns were fledged from either island in 2012, the second consecutive year of complete nesting failure by Caspian terns breeding in Summer Lake Wildlife Area (Figure 22).

Caspian terns attempted to nest at one of the two islands constructed for tern nesting in Lower Klamath National Wildlife Refuge, the 0.8-acre floating island at Sheepy Lake. Compared to average Caspian tern colony attendance at the Sheepy Lake island during 2010-2011, the first two years when the island was available for tern nesting, colony attendance by terns in 2012 was generally higher throughout the breeding season (Figure 23). A total of about 212 breeding pairs attempted to nest at the Sheepy Lake tern island in 2012, similar to the average for the previous two years (Figure 24). As was the case at the Crump Lake tern colony, limited gull control was deemed necessary at the Sheepy Lake tern colony; 10 gulls that were repeatedly observed depredating tern eggs at the Sheepy Lake colony were shot under permit in 2012. Nesting success by Caspian terns at the Sheepy Lake colony was higher in 2012 (0.66 young raised per breeding pair) relative to the previous year (0.11 young raised per breeding pair) and similar to the estimate in 2010 (0.65 young raised per breeding pair; Figure 25). Caspian terns were not observed loafing or attempting to nest on the Orems Unit tern island during the 2012 breeding season (Figure 26), presumably because the island was land-bridged due to the lack of water in the Orems Unit impoundment.

Colony attendance at the Tule Lake Sump 1B tern island in Tule Lake National Wildlife Refuge was much higher in 2012 than in 2011, the first year when the island was available for tern nesting (Figure 27). The size of the Tule Lake Caspian tern colony was 207 breeding pairs in 2012, six times greater compared to the previous year (34 breeding pairs; Figure 28); however, all Caspian tern nesting attempts on the Tule Lake tern island failed in 2012 (Figure 29) due to disturbance and nest predation caused by a raccoon (*Procyon lotor*) that repeatedly visited the island at night.

Caspian terns were quick to colonize the 1-acre rock-core island at Malheur Lake in Malheur National Wildlife Refuge in 2012, the first year when the island was available for tern nesting (Figure 30). More than 1,300 adult Caspian terns were counted on the island at one time in late August. Colony size was estimated at 232 breeding pairs in 2012, the largest Caspian tern colony observed at the nine islands built by the Corps in interior Oregon and northeastern California as Caspian tern nesting habitat (Figure 31). The Malheur Lake tern island also supported the highest nesting success by Caspian terns (0.84 young raised per breeding pair) of any of the nine islands built for tern nesting (Figure 32).

In 2012, the total number of Caspian terns nesting at islands created as alternative nesting habitat for Caspian terns displaced from the East Sand Island colony was 780 breeding pairs, the highest number recorded since island construction commenced in 2008 (Figure 33). Although predation by gulls and other predators on tern eggs and chicks was the most significant proximal factor limiting the size and productivity of Caspian tern colonies at the Corps-constructed tern islands in interior Oregon and northeastern California during 2012, low forage fish availability associated with the strong La Niña of 2011 was also likely a contributing factor to small colony size and low productivity at some of these sites in 2012 (i.e., Crump Lake tern island and the tern islands at Summer Lake Wildlife Area).

Based on periodic boat-based and aerial surveys, Caspian tern nesting activity was detected at two additional sites in interior Oregon and northeastern California in 2012: on an island in the western arm of Clear Lake Reservoir, Clear Lake NWR (ca. 60 breeding pairs) and on an island at the north end of Malheur Lake, at Singhus Ranch just outside of Malheur NWR (ca. 85 breeding pairs). As in 2011, the Caspian tern colony at Singhus Ranch was located within a large, mixed-species colony of double-crested cormorants, American white pelicans, and gulls. The Caspian terns nesting at Clear Lake were located on a low-lying island and nested adjacent to a Forster's tern colony. The Caspian terns nesting at the colony on Singhus Ranch were successful in fledging some young, although the number is unknown. The colony of Caspian terns at Clear Lake Reservoir was apparently unsuccessful in raising any young.

1.3. Diet Composition and Salmonid Consumption

1.3.1. Columbia River Estuary

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 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 264 bill load fish was conducted from 28 April to 28 July. No lethal sampling of Caspian terns to determine diet composition was conducted in 2012. Salmonid bill loads were identified as either Chinook salmon (*Oncorhynchus tshawytscha),* sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), or unknown based on analyses of morphometrics, diagnostic bones, and 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 2012 nesting season (n = 4,750 bill loads), on average 34% were juvenile salmonids. This proportion of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island, averaged over the entire nesting season, was similar to but slightly higher than the 12-year average (31%; Figure 34). As in previous years, marine forage fishes (i.e., anchovies [Engraulidae], surf perch [Embiotocidae], smelt [Osmeridae], and herring [Clupeidae]) were most prevalent, together averaging 59% of all identified bill loads in the diet of terns nesting on East Sand Island in 2012 (Figure 35 and Figure 36). The peak in the proportion of salmonids in the diet of Caspian terns nesting on East Sand Island occurred during the 2-week period in the middle of May, whereas during the previous 12 years the peak in proportion of salmonids in the diet occurred during the 2-week period in early May (Figure 37). The proportion of salmonids in the tern diet during the latter half of May in 2012 was generally higher compared to the average proportion during the previous 12 years (Figure 37).

Genetic stock identification of salmonid bill load fish collected from East Sand Island Caspian terns in 2011-12 indicated that terns consumed smolts from many of the uniquely identifiable stocks across the basin. For Chinook salmon, the most common genetic stocks of origin for smolts depredated during April and May were the Mid-Columbia River and Upper Columbia River spring run and the Snake River spring run stocks (together 29 of 45 or 64% of Chinook salmon sampled during this period; Figure 38). During June and July, most depredated Chinook salmon smolts (20 of 32 or 63%) originated from the Lower Columbia River ESU (the Spring Creek Group fall run, West Cascades Tributary fall run, the introduced Rogue River fall run, and the West Cascades Tributary spring run stocks). Depredated steelhead trout originated from six stocks, with steelhead from the Snake River consisting of just over half of the identified samples (31 of 59 samples or 53%; Figure 39). Genetic stock identification was performed for only five coho salmon smolts collected from terns. Four coho originated from the Columbia River stock and one from the Washington Coast stock.

[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).

Our best estimate of total smolt consumption by Caspian terns nesting on East Sand Island in 2012 was 4.9 million smolts (95% c.i. = 4.0 – 5.8 million smolts), slightly below the average of the previous 12 years for the second consecutive year (Figure 40). From 2000 to 2011, the average number of smolts consumed by Caspian terns nesting on East Sand Island was 5.3 million smolts per year (Figure 40). This is less than half the annual consumption of juvenile salmonids by Caspian terns in the Columbia River estuary prior to 2000, when the breeding colony was located on Rice Island in the upper Columbia River estuary.

Of the juvenile salmonids consumed by East Sand Island Caspian terns in 2012, we estimate that 1.6 million or 32% were coho salmon (95% c.i. = 1.3 – 1.9 million smolts), 0.9 million or 18% were steelhead (95% c.i. = 0.7 – 1.1 million smolts), 1.3 million or 28% were sub-yearling Chinook salmon (95% c.i. = 1.1 – 1.6 million smolts), 1.0 million or 22% were yearling Chinook salmon (95% c.i. = 0.8 – 1.3 million), and 0.02 million or < 1% were sockeye salmon (95% c.i. = 0.016 – 0.024 million; Figure 41).

1.3.2. Columbia Plateau

Methods: The taxonomic composition of the diet of Caspian terns nesting on Crescent Island in the mid-Columbia River and Goose Island in Potholes Reservoir was determined by direct observation of adults as they returned to the colony with fish (i.e., bill load observations; described above). The target sample size at Crescent Island and Goose Island was 150 bill load identifications per week (see above for further details on the analysis of diet composition data). Prey items were identified to the taxonomic level of family. We identified prey to species, where possible, and salmonids were identified as steelhead trout or 'other salmonids' (i.e., Chinook salmon, coho salmon, or sockeye salmon). Trout were distinguished from 'other salmonids' by the shape of the caudal fin, body shape, coloration and speckling patterns, shape of parr marks, or a combination of these characteristics (see Antolos et al. 2005). The percent of identifiable prey items in tern diets 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 from these 2-week periods. Bill load fish were not collected nor were terns hazed at the Crescent Island and Goose Island tern colonies in order to assess diet composition of Caspian terns nesting at these two colonies because of the potential impact of lethal or non-lethal diet sampling on such small breeding colonies.

Estimates of annual smolt consumption by Caspian terns nesting at the Crescent Island and Goose Island colonies were calculated using a bioenergetics modeling approach (see Antolos et al. [2005] 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 terns at Crescent Island. For the Goose Island Caspian tern colony, both steelhead smolts from the Columbia River and resident rainbow trout stocked in Potholes Reservoir (and other nearby water bodies) were available to Goose Island terns. Based on the morphology (degree of smoltification) of each identified fish, it was possible to confidently classify 9% of the *O. mykiss* brought to the colony as steelhead smolts, leaving 91% as unidentified, either steelhead or resident rainbow trout. This uncertainty in the identification of bill load fish caused us to calculate consumption estimates based on two different scenarios. First, we assumed that all *O. mykiss* identified in tern bill loads were anadromous steelhead smolts from the upper Columbia River (upper bound of the anadromous salmonid consumption estimate) and, second, we assumed that only 9% were steelhead and the remainder were resident rainbow trout (lower bound of the anadromous salmonid consumption estimate).

Results and Discussion: Of the bill load fish identified at the Crescent Island Caspian tern colony in 2012 an average of 83% were juvenile salmonids (n = 2,098 identified bill loads). This proportion of salmonids in the diet was similar to 2011 (85% juvenile salmonids), but higher than the previous 12-year average (Figure 42). Each year, millions of juvenile salmonids are released from Columbia Basin hatcheries, which provide Crescent Island terns with a reliable and relatively consistent food supply, as compared to the food supply available to Caspian terns nesting at other inland colonies (e.g., Crump Lake tern island). Juvenile salmonids were by far the most prevalent prey type in the diet of Caspian terns nesting on Crescent Island in 2012, followed by centrarchids (bass and sunfish, 8%) and cyprinids (carp and minnows, 6%; Figure 43). The proportion of juvenile salmonids in the diet of Crescent Island Caspian terns was highest in mid-April during 2012, two weeks earlier than the observed peak during the previous 12 years (Figure 44). Seasonal declines in the proportion of salmonids in the diet probably reflect changes in availability of hatchery-reared smolts near the Crescent Island tern colony. Nevertheless, the proportion of salmonids in the diet of Crescent Island Caspian terns was consistently higher throughout the breeding season compared to that of Caspian terns nesting on East Sand Island in the Columbia River estuary (Figure 34).

We estimated that Caspian terns nesting on Crescent Island consumed ca. 530,000 juvenile salmonids in 2012 (95% c.i. = 420,000 – 640,000), the highest point estimate for smolt consumption since 2002 (Figure 45). Total smolt consumption by Caspian terns nesting on Crescent Island trended downward from 2001 to 2008, but point estimates have crept upwards over the past four years (Figure 45). In 2012, steelhead comprised an estimated 16% of the identifiable salmonid smolts consumed, or roughly 84,000 fish, similar to 2011 (Figure 46).

Of the bill load fish identified at the Caspian tern colony on Goose Island in Potholes Reservoir, an average of 30% were juvenile salmonids (n = 1,781 identified bill loads), the highest percentage ever observed at this colony (Figure 47). Based on morphological characteristics of the salmonids identified at the colony, we estimate that a minimum of 74% of the identified salmonids were anadromous fish (steelhead or salmon) from the

Columbia River, with some portion of the remainder being resident trout from Potholes Reservoir and perhaps other nearby lakes and reservoirs. The fact that Caspian terns commuted over 100 km round trip from the nesting colony to the Columbia River to forage, which has been corroborated by Maranto et al. (2010) and the recovery of passive integrated transponder (PIT) tags from salmonid smolts on-colony (see Section 1.4), suggests that availability of alternative forage fish prey near the nesting colony was limited. In 2012, centrarchids (bass and sunfish) were the most prevalent prey type in the bill loads of Caspian terns nesting on Goose Island (61%), followed by salmonids (30%; Figure 48). The proportion of juvenile salmonids in bill loads of Goose Island Caspian terns was highest in mid-May (83% of identifiable bill loads) during 2012, a week later than the peak in the proportion of salmonids in the diet during the previous two years (Figure 49). The proportion of salmonids in the bill loads of Caspian terns nesting on Goose Island was consistently lower throughout the breeding season compared to that of Caspian terns nesting on Crescent Island (Figure 44).

We estimated that Caspian terns nesting on Goose Island consumed between 180,000 anadromous juvenile salmonids (assuming 9% of identified *O. mykiss* were steelhead, the visually confirmed minimum) and 200,000 anadromous juvenile salmonids (assuming all unidentified *O. mykiss* were steelhead) from the Columbia River in 2012 (Figure 50). This is roughly one third of the number of juvenile salmonids consumed by Caspian terns nesting on Crescent Island during 2012 (Figure 45). Based on the species composition of Caspian tern bill loads at the colony on Goose Island-Potholes, we estimate that salmon smolts (i.e., Chinook, coho, or sockeye) comprised between 84% and 96% of the estimated total number of anadromous salmonid smolts consumed by Goose Island terns in 2012, or between 168,000 and 173,000 smolts. Based on identification of tern bill loads, steelhead comprised between 4% and 16% (depending on the ratio of steelhead to resident trout), or between 7,000 and 32,000 smolts (Figure 51). Estimates of predation rates on steelhead smolts by Goose Island Caspian terns based on smolt PIT tag recoveries on-colony indicate that steelhead consumption in 2012 was greater than 32,000 smolts (see section 1.4.2). A similar discrepancy between steelhead predation rates based on PIT tag recoveries and steelhead consumption estimates based on bioenergetics modeling was detected in 2010 and 2011.

1.3.3. Coastal Washington

No diet composition data were collected for Caspian terns nesting along the Washington coast in 2012.

1.3.4. Interior Oregon and Northeastern California

Methods: The taxonomic composition of the diet of Caspian terns nesting on the Corps' tern islands at Crump Lake, 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 we identified each week throughout the breeding season at each colony site (see above for further details on the analysis of diet composition data). Fish were identified to the lowest taxonomic grouping possible using visual observation. Visual identifications were verified using voucher specimens, whenever possible. Breakdown of diet composition in identified samples is provided below; measurement uncertainty was not estimated. In addition to the visual identification of fish, PIT tags were recovered on selected tern colonies to estimate tern predation rates on fish species of special concern to resource managers (e.g., Warner suckers [*Catostomus warnerensis*] at Crump Lake tern island and Lost River suckers [*Deltistes luxatus*] and shortnose suckers [*Chasmistes brevirostris*] at Sheepy Lake and Tule Lake Sump 1B tern islands; see Section 1.4.4.).

Results and Discussion: A large number of Caspian tern bill loads (n = 1,674) were identified at the Crump Lake Caspian tern colony in 2012. The diet composition of Caspian terns nesting on the Crump Lake tern island in 2012 consisted primarily of centrarchids (crappie, sunfish, and bass; 47% of identifiable prey items), followed by ictalurids (catfish; 35%) and cyprinids (chub, minnows, and carp; 16%; Figure 52). Diet composition at the Crump Lake tern colony was markedly different during 2010-2012 compared to 2008-2009; cyprinids (primarily Tui chub [*Gila bicolor*]) averaged 65% of identifiable prey items during 2008-2009, while centrarchids (primarily white crappie [*Pomoxis annularis*]) averaged 60% of identifiable prey items during 2010-2012. During 2010-2012, only one juvenile sucker was observed among the identified prey items at the Crump Lake tern island, and that unidentified sucker was observed in 2012. Six suckers were observed in the bill loads of Caspian terns at the Crump Lake colony during 2008-2009, five in 2008 alone (< 0.1% of identifiable prey items). Of all seven suckers identified in the diet of Caspian terns at the Crump Lake tern island during 2008-2012, only one could be positively identified as an ESA-listed Warner sucker, and it was observed in 2008 (see Section 1.4.4).

A small number of Caspian tern bill loads (n = 59) were identified at the East Link Caspian tern colony in Summer Lake Wildlife Area during 2012. As was the case in 2009-2011, the diet composition of Caspian terns nesting at Summer Lake Wildlife Area in 2012 was dominated by cyprinids (primarily Tui chub; 81% of identifiable prey items; Figure 53). In 2012, rainbow trout comprised only 4% of the diet of Caspian terns nesting at the Summer Lake Wildlife Area, compared to 15% during 2009-2011 (Figure 53). Based on fish watch observations, suckers were not detected in the diet of Caspian terns nesting at Summer Lake Wildlife Area in 2011 or 2012. One sucker (0.3% of identifiable prey items) was observed among the identified prey items at the East Link tern colony in 2010. It is unknown whether this sucker was an ESA-listed Warner sucker or an unlisted species. Warner suckers are not endemic to Summer Lake, 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 moderate number of Caspian tern bill loads (n = 1,209) were identified at the Sheepy Lake colony in 2012. The diet composition of Caspian terns nesting on the Sheepy Lake tern island was dominated by cyprinids (primarily chub and fathead minnows [*Pimephales promelas*]), at 83% of identifiable prey items), followed by centrarchids (primarily Sacramento perch [*Archoplites interruptus*]), at 12% of identifiable prey items (Figure 54). No juvenile suckers were detected in the diet of Caspian terns nesting at the Sheepy Lake colony in 2012, based on bill load identifications and sucker PIT tag recoveries (see Section 1.4.4). One juvenile sucker (< 0.1% of identifiable prey items) was observed among the identifiable prey items at the Sheepy Lake tern colony in 2011. The sucker seen at the Sheepy Lake tern colony could not be positively identified as either an ESA-listed Lost River sucker or an ESA-listed shortnose sucker. An un-listed species of sucker, the Klamath largescale sucker (*Catostomus snyderi*), is also found within foraging distance of the Sheepy Lake tern island.

A total of 784 Caspian tern bill loads were identified at the Tule Lake Sump 1B colony in 2012. 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 86% of identifiable prey items, followed by centrarchids (primarily Sacramento perch), at 13% of identifiable prey items (Figure 55). Based on bill load identifications and PIT tag recoveries (see Section 1.4.4), juvenile suckers were not detected in the diet of Caspian terns nesting at the Tule Lake Sump 1B colony in 2012. One juvenile sucker (< 0.1% of identifiable prey items) was observed among the identifiable prey items at the Tule Lake Sump 1B tern colony in 2011. As was the case at the Sheepy Lake tern colony, this sucker could not be identified as either an ESA-listed or unlisted sucker species.

A large number of Caspian tern bill loads (n = 2,748) were identified at the Malheur Lake colony in 2012. The diet composition of Caspian terns nesting on the Malheur Lake tern island was dominated by cyprinids (primarily common carp [*Cyprinus carpio*], at 86% of the identifiable prey items, followed by ictalurids (catfish), at 13% of identifiable prey items (Figure 56). Seventeen trout (0.6% of identifiable prey items) were identified among the bill loads at Malheur Lake. Based on the size (16 – 25 cm total length) and capture dates (May through early July) of these trout, most, if not all, were likely rainbow trout stocked in nearby lakes and reservoirs.

1.4. Predation Rates Based on PIT Tag Recoveries

Passive integrated transponder (PIT) tags are placed in salmonid smolts and other fishes to study their behavior and survival following tagging and release. Smolt PIT tags were first discovered on piscivorous waterbird colonies in the Columbia River basin during 1996 (Collis et al. 2001). Beginning in 1998, specially-designed electronics (antennas and transceivers) were developed and used to recover PIT tags *in situ* on bird colonies in the Columbia River basin (Ryan et al. 2001). PIT tags provide specific information on each tagged fish, including species, rear-type (hatchery or wild), run-timing, and temporal availability (based on detections of live fish passing PIT tag antenna arrays during out-migration). Recoveries of PIT tags on piscivorous bird colonies can be used to estimate predation rates and to compare the relative susceptibility of different fish populations to avian predation (Collis et al. 2001, Ryan et al. 2003, Evans et al. 2012).

The main objectives for using information collected from PIT tags for this study were to (1) determine colony-specific avian predation rates on particular salmonid ESUs (2) assess differences in predation rates on smolts based on bird species and location of bird nesting colonies, and (3) evaluate whether avian predation rates in 2012 were similar to those reported in previous years. Comparisons between current and historical predation rates were made in the context of on-going or proposed management initiatives for piscivorous colonial waterbirds as a means of evaluating the efficacy of those initiatives in reducing avian predation on salmonids and other fish of conservation concern.

Research aimed at recovering PIT tags from bird colonies in the Columbia River estuary was conducted in collaboration with NOAA Fisheries (POC: Jen Zamon). Research in interior Oregon and northeastern California was conducted in collaboration with the Oregon Department of Fish and Wildlife (POC: Paul Scheerer), the USGS-Klamath Falls Field Station (POC: Dave Hewitt), USFWS-Upper Klamath Basin National Wildlife Refuges (POCs: Dave Mauser and John Beckstrand), and the USFWS-Klamath Falls Field Station (POC: Ron Larson), and focused on avian predation on ESA-listed sucker species by Caspian terns nesting at the Corps' alternative colony sites located on Crump, Sheepy, and Tule lakes.

1.4.1 Columbia River Estuary

Methods: The methods described in Evans et al. (2012) were used to recover PIT tags from bird colonies in the Columbia River basin in 2012. Briefly, PIT tag antennas were used to recover PIT tags *in situ* during August through November, after birds dispersed from their breeding colonies. 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 made at each bird colony. The area occupied by birds on each colony was determined from aerial photography of the colony and visits to the colony during the nesting season.

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. Furthermore, the detection methods used to find 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 two to four discrete stages of the birds' nesting season: (1) prior to the initiation of egg-laying (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 August). 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 100 PIT tags to 200 PIT tags per colony. The number of discrete time periods when control tags were sown also varied, but was no less than two (at the beginning and end of the nesting season) and no more than four. During each release, control tags were haphazardly sown throughout the entire area occupied by nesting birds during the breeding season.

Not all PIT tags that are ingested by breeding birds are subsequently deposited on their nesting colony. A portion of the 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. The proportion of ingested smolt PIT tags that are subsequently deposited intact on the breeding colony is hereafter referred to as PIT tag "deposition rates". Methods and results from several studies aimed at quantifying on-colony PIT tag deposition rates for nesting Caspian terns, double-crested cormorants, and California gulls are presented in Appendix A (Deposition Studies). Briefly, on-colony deposition rates used to correct on-colony PIT tag recoveries in 2012 were 71% for Caspian terns (95% c.i. = 62 – 81%), 44% for double-crested cormorants (95% c.i. = 036 - 51%), and 17% for California gulls (95% c.i. = 13 – 21%; Table 2 and Appendix A). On-colony PIT tag deposition rates are not available for ring-billed gulls or Brandt's cormorants; due to similarities in size and foraging strategies, the deposition rates from California gulls and double-crested cormorants were applied to these two species, respectively (Table 2). At this time, there are no on-colony PIT tag deposition rate data available for either American white pelicans, California brown pelicans, or any other species with similar biology and behavior; thus, estimates of smolt predation rates based on PIT tag recoveries on-colony for these species remain minimum estimates (*sensu* Evans et al. 2012; Table 2 and Appendix A).

We queried the regional salmonid PIT Tag Information System database (PTAGIS 2012), maintained by the Pacific States Marine Fisheries Commission, to acquire data on PIT-tagged smolts released in the Columbia River basin during 2012. Following the methods of Evans et al. (2012), PIT-tagged smolts were grouped by ESU or DPS of anadromous salmonid, with each ESU/DPS representing a unique combination of species (Chinook salmon, coho salmon, sockeye salmon, or steelhead), run-type (spring, summer, fall, or winter), and river-of-origin (Columbia, Snake, or Willamette). The designation of ESUs and DPSs follows that of NOAA (2011), which includes both wild and hatchery-reared fish. All PIT-tagged salmonids that were tagged and released within the geographic boundary of the NOAA-defined ESU/DPS were included in the study, as long as the fish was interrogated passing a dam upstream of the bird colony of interest, following the methods of Evans et al. (2012).

Availability of PIT-tagged smolts from each ESU/DPS to avian predators nesting at different colonies was determined by detections of PIT-tagged smolts at the nearest upstream hydroelectric dam with juvenile fish interrogation capabilities (Map 1). Predation rate calculations were identical to those of Evans et al. (2012), but also incorporated estimates of PIT tag deposition rates (Appendix A). Incorporating estimates of PIT tag deposition rates removes the bias in estimating smolt predation rates based on on-colony PIT recoveries, and converts the estimates from minimum predation rates (*sensu* Evans et al. 2012) to best estimates of predation rates (Lyons et al. 2011b). In 2012, the first empirical estimates of on-colony deposition rates were available for two species of avian predators, double-crested cormorants and California gulls (see Appendix A). Predation rates in 2012 were adjusted for bird species-specific deposition rates, as 2012 was the first year that comparable estimates of PIT tag deposition rates were available for multiple bird species (Table 2; see Appendix A).

To control for imprecise results that might arise from small sample sizes of interrogated PIT-tagged smolts, estimates of predation rates were only calculated for ESUs/DPSs when ≥ 500 PIT-tagged salmonids were interrogated passing an upstream dam in a given year. Predation rates < 0.1% are presented without confidence intervals because of the proximity of the estimate to zero. Additionally, only PIT-tagged smolts detected at a dam during the bird nesting season (1 March to 31 August, depending on the colony) were included in these analyses, as these salmonids were believed to be available to birds nesting at the colony. Analyses were conducted using R statistical software, with statistical significance set at $\alpha = 0.05$.

Results from our multi-step modeling procedure for estimating avian predation rates on PIT-tagged salmonid smolts from the Columbia River basin were based on the following assumptions (see Evans et al. 2012 and Appendix A for additional information):

- A1. Salmonid release and detection information obtained from PTAGIS were complete and accurate.
- A2. PIT-tagged salmonids detected passing an upstream dam were available to avian predators nesting downstream of that dam.
- A3. The detection probability for control PIT tags sown on the colony was equal to that for PIT tags naturally deposited by birds on-colony.
- A4. On-colony PIT tag deposition rates obtained from study fish were equal to that of PIT-tagged smolts naturally consumed and deposited by birds.
- A5. PIT tags from consumed fish were deposited on a bird colony within a short time period (days, week) of the fish being detected passing the upstream dam.
- A6. PIT-tagged fish, by species, ESU, and detection site, were representative of non-tagged fish passing the upstream dam.

To verify the first assumption (A1), irregular entries were either validated by tagging coordinators 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 juvenile salmonids, the ability to standardize data across all sites, and the ability to define unique groups of salmonids by a known location and passage date (Assumption A2). Detection efficiency estimates (A3) were generally high at all colonies (see Results); thus, possible violations of assumption A3 would have little effect on estimates of predation rates. At this time there are no data available to support or refute assumption A4, other than to note that off-colony PIT tag deposition varies by predator and that this variation was incorporated into predation rates estimates (see Appendix A). Assumption A5 relates to the use of the last date of live detection as a proxy for the date a PIT tag was deposited on a bird colony and needed only to be roughly true because detection efficiency did not change dramatically on a daily basis (see Results). Assumption A6 relates to interference between PIT-tagged fish and all fish (tagged and untagged) susceptible to avian predation. Similar to A4, there are few empirical data to support or refute assumption A6, other than to note that the run-timing and abundance of PIT-tagged fish is often in concert with the run-timing and abundance of non-tagged fish passing dams on Columbia and Willamette rivers.

Results and Discussion: Following the nesting season, 15,919 PIT-tagged smolts from the 2012 migration year (Chinook salmon, coho salmon, sockeye salmon, and steelhead smolts combined from all release sites) were recovered on the East Sand Island Caspian tern colony (Table 3). Recoveries of control tags sown on the East Sand Island tern colony (n = 200) indicated that detection efficiency ranged from 45% to 91% for tags deposited between 1 March and 31 August (Table 4).

Based on predation rates of PIT-tagged smolts last detected passing Bonneville Dam (lower-most dam on the Columbia River) or Sullivan Dam (lower-most dam on the Willamette River; Map 1), steelhead were the most susceptible salmonid species to predation by Caspian terns nesting on East Sand Island in 2012; predation rates on particular steelhead DPSs ranged from 7.4% to 10.0% (Table 5). Predation rates on Chinook salmon (0.7% to 2.2%) and sockeye salmon (2.1%) ESUs were significantly lower compared to steelhead DPSs (Table 5). Differences in predation rates among ESUs/DPSs of the same species (e.g., steelhead, Chinook salmon) were generally less than differences among salmonid species (Table 5).

Predation rates on salmonid smolts by East Sand Island Caspian terns in 2012 were similar to those observed during 2011, but were generally lower than estimated predation rates during 2007-2010 (Appendix B; Historical Caspian tern predation rates). General reductions in ESU/DPS-specific predation rates during 2011 and 2012 coincided with comparable reductions in colony size (Figure 2) and consumption estimates (Figure 40) relative to 2007-2010. This suggests that Caspian tern management initiatives at the

East Sand Island colony to reduce nesting habitat are beginning to result in reductions in salmonid predation rates. One exception to an over-all decrease in ESU-specific predation rates seems to be Snake River sockeye (endangered), with predation rates by terns in 2012 higher than those observed in years past.

Adequate sample sizes (≥ 500 interrogated PIT-tagged smolts) were not available for all ESUs/DPSs originating entirely above Bonneville or Sullivan dams in 2012. For example, there were < 50 known-origin sockeye salmon or winter-run steelhead PIT-tagged and released within the geographic range of the Lake Wenatchee, Okanogan River, or upper Willamette River ESUs/DPSs that were subsequently detected at Bonneville or Sullivan dams in 2012. It should also be noted that data regarding the impacts of East Sand Island Caspian terns on survival of PIT-tagged smolts originating from lower Columbia River ESUs/DPSs are not presented here due to the paucity of in-stream PIT tag detectors below Bonneville Dam and an insufficient sample of released PIT-tagged fish (see Section 2.4.1 for details). As such, the impacts of predation by East Sand Island Caspian terns on Lower Columbia River ESUs/DPSs, some of which are ESA-listed (i.e., Chinook, coho, steelhead), are largely unknown and require a different analytical framework to evaluate (see Lyons et al. 2012).

1.4.2 Columbia Plateau

Methods: The methods for calculating predation rates on juvenile salmonids based on PIT tag recoveries at Caspian tern colonies in the Columbia Plateau region are the same as those described in Section 1.4.1.

Results and Discussion: Following the nesting season, a total of 7,285 PIT-tagged smolts from the 2012 migration year (Chinook, coho, sockeye, and steelhead combined from all releases) were recovered on the Crescent Island Caspian tern colony (Table 3). Control tags sown on the Crescent Island tern colony (n = 200) indicated that detection efficiency ranged from 33% to 93% for tags deposited between 1 April and 31 July (Table 4).

Of the available PIT-tagged fish last detected passing Lower Monumental Dam (Snake River) or Rock Island Dam (upper Columbia River; Map 1), predation rates by Crescent Island terns were highest for the following ESUs/DPSs: Snake River steelhead (2.8%; 95% c.i. = 2.4 – 3.5%), Snake River sockeye salmon (1.3%; 95% c.i. = 0.9 – 1.8%), and upper Columbia River steelhead (1.2%; 95% c.i. = 0.8 – 1.6%; Table 6). Predation rates were significantly lower (≤ 0.6%) for Chinook salmon ESUs (Table 6). Predation on smolts originating from rivers downstream of Lower Monumental Dam and Rock Island Dam, but upstream of McNary Dam (i.e., within the foraging range of Crescent Island terns) on the middle Columbia River are not included here, but are likely smaller because only a fraction of smolts originating from these ESUs are susceptible to bird predation (i.e., large numbers of smolts from middle Columbia River ESUs enter the river downstream of McNary Dam and thus are not susceptible to predation by Caspian terns nesting at Crescent Island; Evans et al. 2012).

Portions of all Snake River ESUs are captured at dams and put aboard barges for transportation downstream and release below Bonneville Dam. These transported fish are not exposed to predation by Crescent Island terns or by any other avian predators (e.g., double-crested cormorants nesting on Foundation Island) in McNary pool. This means the impact on each Snake River ESU/DPS from avian predation in McNary pool is less than indicated by the predation rate on the in-river migrating portion of the ESU/DPS. Transportation rates of Snake River smolts vary considerably by year and species, with between 20% and 65% of available Snake River smolts collected for transportation during 2007-2010 (FPC 2012). An estimate of transportation rates for Snake River smolts in 2012 is not yet available, but is likely close to the average of ca. 40% (FPC 2012). As a hypothetical example, if 40% of ESA-listed Snake River steelhead were collected for transportation above Ice Harbor Dam in 2012, the estimate of predation rate on in-river migrants by Crescent Island terns of 2.8% (Table 6) would translate into a population-wide predation rate of 1.7% (in-river smolts plus transported smolts). Because smolts originating from Upper Columbia River ESUs/DPSs are not collected for transportation above McNary Dam, the estimated predation rate on in-river migrants applies to all available fish belonging to the ESU/DPS (i.e., no correction is needed).

Predation rates on ESUs/DPSs of juvenile salmonids by Crescent Island terns in 2012 were similar to those during 2007-2011, indicating predation rates on salmonid smolts by Crescent Island terns have remained relatively constant over the last few nesting seasons (see Appendix B, historical Caspian tern predation rates).

In addition to the Caspian tern nesting colony on Crescent Island in McNary pool, Caspian terns attempted to nest on Badger Island in 2012 (Map 1). The Caspian tern colony on Badger Island, however, did not successfully produce young in 2012 (see Section 1.2.2). After the colony failed, American white pelicans were observed loafing and using the area where Caspian terns had attempted to nest on Badger Island. PIT tag recovery efforts in the area occupied by nesting Caspian terns detected 382 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2012 migration year. Although American white pelicans were observed using this area, the high density of PIT tags in this small area suggests that the vast majority of tags were deposited by Caspian terns. As such, predation rates were calculated and presented as those of Caspian terns, but may have included a small number of tags deposited by pelicans. Predation rates on ESUs/DPSs of juvenile salmonids by Badger Island Caspian terns were $\leq$ 0.2% for all ESUs/DPSs in 2012 (Table 6).

A total of 3,372 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2012 migration year were recovered on the Goose Island Caspian tern colony in Potholes Reservoir, WA (Table 3). Control tags sown on the

Goose Island tern colony (n = 400) indicated that detection efficiency ranged from 12% to 86% for tags deposited between 1 April and 31 July (Table 4).

Of the PIT-tagged smolts last detected passing Rock Island Dam on the upper Columbia River, impacts by Goose Island terns were greatest on steelhead, with an estimated predation rate of 17.3% (95% c.i. = 14.1 – 21.7%) in 2012 (Table 7). This is the highest colony-specific predation rate on a salmonid ESU/DPS observed in 2012 (Tables 5 - 9). Predation rates on other salmonid ESUs by Caspian terns nesting on Goose Island were significantly lower than those on upper Columbia River steelhead, with predation rates on upper Columbia River spring Chinook at 2.5% (95% c.i. = 1.0 – 4.4%), and predation rates on all other ESUs/DPSs $\leq$ 0.2% (Table 7). The predation rate estimate on upper Columbia River steelhead by terns nesting on Goose Island in 2012 was the second highest point estimate during 2007-2012 (Appendix B). Higher predation rates in 2012 coincided with increased numbers of Caspian terns nesting at Goose Island in 2012 (Figure 9), supporting the hypothesis of a positive relationship between annual predation rates on steelhead smolts and the number of Caspian tern breeding pairs at Goose Island.

There was a large discrepancy between estimated predation rates based on on-colony PIT tag recoveries and estimated smolt consumption based on bioenergetics modeling for steelhead depredated by Caspian terns nesting at Goose Island. At most Caspian tern colonies, estimated predation rates from PIT tag recovery and bioenergetics calculations from bill load observations are comparable, in cases where comparisons to the level of species can be made. At the Goose Island Caspian tern colony, however, the differences are striking. If we assume that 100% of the *O*. *mykiss* observed in bill loads were anadromous steelhead smolts from the Columbia River, estimated total consumption of salmonids was about 200,000 and consumption of steelhead smolts was about 32,000. The steelhead run below Rock Island Dam in 2012 consisted of between 600,000 and 1 million smolts, however, and based on PIT tag-derived predation rates (17%) the number of steelhead smolts taken by Goose Island Caspian terns below Rock Island Dam was at least 100,000. Consequently, the difference in steelhead smolt consumption between on-colony observations of steelhead in tern bill loads and recoveries of smolt PIT tags on-colony was more than a factor of three. This large discrepancy between estimates of steelhead smolt consumption from the two methods suggests that Caspian terns nesting at Goose Island are transporting disproportionately fewer steelhead smolts back to the colony than are captured by terns on the upper Columbia River. Caspian terns from this colony must commute at least 35 km to reach the Columbia River, the closest source of steelhead smolts to the Goose Island tern colony. Thus, Caspian terns foraging on the upper Columbia River may consume a disproportionate number of the steelhead smolts that they capture, and transport smaller prey to the Goose Island nesting colony that are captured closer to the colony. If this hypothesis is correct, the estimated predation rates on steelhead smolts that were derived from PIT tag recoveries on-colony are a less biased estimate of steelhead consumption than diet composition derived from on-colony observations of bill-load fish.

Following the nesting season, a total of 538 PIT tags from salmonid smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2012 migration year were recovered on the Caspian tern colony on Harper Island, Sprague Lake (Table 8). Harper Island is a privately-owned island and was not accessible for PIT tag recovery in previous years; thus, this is the first year Harper Island was scanned for PIT tags. Control tags, however, were not sown on the Harper Island tern colony due to limited access to the island. Detection efficiency was therefore estimated based on the average detection efficiency at all Caspian tern colonies in the Columbia Plateau region during 2012 (Table 4).

Sprague Lake is > 60 km from the mainstem Snake River, with the closest point located between Lower Granite Dam and Little Goose Dam (Map 1). Predation rates by Caspian terns nesting at Sprague Lake were based on smolts PIT-tagged or interrogated at Lower Granite Dam in 2012, the pool of available PIT-tagged smolts (Table 8). Evaluation of predation rates on Upper Columbia River ESUs/DPSs was not presented due to the paucity of PIT tags from Upper Columbia River ESUs/DPSs recovered on the Harper Island tern colony and the long distance from Sprague Lake to sections of the mainstem Columbia River that contain anadromous salmonids (about 120 km; Map 1). PIT tag recoveries indicated that Caspian terns nesting at the Sprague Lake colony commuted to and foraged in the mainstem Snake River. Predation rates by Caspian terns nesting at Sprague Lake were $\leq$ 0.5% for all salmonid ESUs/DPSs (Table 8). Low predation rates, however, were associated with the small size of the colony in 2012 (ca. 30 breeding pairs; Figure 13) and may not reflect expected impacts if the number of breeding Caspian terns at Sprague Lake increased substantially. Of the Snake River ESUs/DPSs available, predation rates were highest on steelhead and sockeye salmon (Table 8).

Smolt PIT tags were also recovered from the Caspian tern colony on Twining Island, Banks Lake, WA. Results from that study are summarized in Appendix C. In brief, recoveries of smolt PIT tags at the Caspian tern colony on Twining Island verified that terns nesting at this site commuted to the upper Columbia River and consumed juvenile salmonids, including consumption of steelhead from the ESA-listed Upper Columbia River DPS. Data limitations and differences in how fish availability was calculated, however, makes it difficult to compare predation rates by Banks Lake Caspian terns to that of other Caspian tern colonies in the Columbia Plateau region (see Appendix C).

PIT tag recovery was not conducted in the Blalock Islands this year, as only 6 pairs of Caspian terns attempted to nest there in 2012 (Figure 11); these breeding pairs failed to produce any young in 2012 (see Section 1.2.2).

1.4.3 Coastal Washington

There was no attempt to recover smolt PIT tags from Caspian tern colonies in coastal Washington during 2012.

1.4.4 Interior Oregon and Northeastern California

Methods: Similar to anadromous salmonids from the Columbia River basin, Warner suckers, Lost River suckers, shortnose suckers, and Klamath largescale suckers are PIT-tagged to evaluate their behavior and survival following release; with the exception of Klamath largescale suckers, all of these sucker species are ESA-listed. In 2012 we continued to evaluate the impacts of Caspian terns nesting at the islands built be the Corps at Crump Lake, Tule Lake, and Sheepy Lake (Map 2) on survival of suckers by recovering PIT tags after the nesting season. Due to differences in the life history, behavior, and monitoring of sucker populations compared to salmonid populations in the Columbia River basin, however, different analytical methods were needed to evaluate sucker losses due to Caspian tern predation via PIT tag recovery (see BRNW 2011 for details).

Results and Discussion: We searched the Crump Lake, Tule Lake and Sheepy Lake tern islands for PIT tags following each of the nesting seasons when breeding Caspian terns were present during 2008-2012. Only one sucker PIT tag was recovered during this five-year period, a tag recovered following the 2008 nesting season on the Crump Lake tern island. The PIT tag was from a 22-cm Warner sucker that was captured and released by ODFW into Crump Lake in June 2008 (Paul Sheerer, ODFW, pers. comm.). The small number (n = 1) and percentage (< 0.1%; BNRW 2012) of Warner sucker PIT tags recovered on the Crump Lake Caspian tern colony suggests that mortality of Warner suckers caused by Caspian terns nesting at Crump Lake has been extremely low since the island was build during the winter of 2007-08. Because the islands on Sheepy Lake and Tule Lake were not built until the winter of 2009-10, sucker PIT tags were not searched for until after the 2010, 2011, and 2012 nesting season. No sucker PIT tags have been recovered at either of these colony sites, which suggests that mortality of shortnose and Lost River suckers due to predation by Caspian terns in the Upper Klamath Basin either does not occur or is extremely rare.

Although no PIT-tagged suckers were found on the Corps' tern islands in 2012, juvenile suckers have been occasionally observed in Caspian tern bill loads (see Section 1.3.4), indicating that Caspian terns do consume suckers, albeit rarely. Because these suckers were not tagged, however, it is not known whether they were ESA-listed suckers or non-listed suckers (e.g., Klamath largescale sucker).

Sucker PIT tags have been found on the breeding colonies of piscivorous colonial waterbirds other than those of Caspian terns, both in the Warner Valley and in the Upper Klamath Basin, in previous years (see BRNW 2011 for details).

1.5. Color banding and band re-sightings

In 2012, we continued our efforts to band breeding adult Caspian terns and chicks near fledging age at multiple colony sites as part of an on-going demographic study. The banding efforts are also part of our continuing efforts to measure movement rates of adults 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.

1.5.1. Columbia River Estuary

Methods: In 2012, adult and fledgling Caspian terns were not banded at East Sand Island because of intense disturbance by bald eagles and associated gull predation on tern eggs and chicks.

Caspian terns that were color-banded in previous years (2001 – 2011) were re-sighted on the East Sand Island tern colony by researchers using binoculars and spotting scopes 5-7 days a week throughout the 2012 breeding season. Numbers of banded Caspian terns re-sighted with a complete set of color bands, thus identifying banding location, year, and age, are presented in this report. The age classes of banded terns when they were re-sighted are classified into two groups: (1) terns banded as adults and terns banded as chicks and ≥ 5-years-old in 2012 are hereafter referred as “adults,” and (2) terns banded as chicks and ≤ 4-years-old in 2012 are hereafter referred to as “young adults.” Median age at first reproduction estimated in our previous analysis of banded Caspian terns was 5-6 years post-hatch, which suggests that most young adults are non-breeders.

Results and Discussion: In 2012, a total of 804 previously color-banded Caspian terns were re-sighted at the East Sand Island tern colony. Of the 804 re-sighted terns, 747 (93%) had been banded at East Sand Island; 693 were classified as adults and 54 were classified as young adults when re-sighted. A total of 27 (3%) had been banded at Crescent Island; 25 were classified as adults and 2 as young adults when re-sighted. A total of 11 (1%) had been banded at Brooks Island or Knight Island in San Francisco Bay, CA; 10 were classified as adults and 1 as a young adult when re-sighted. Nine (1%) had been banded at Dungeness Spit; all were classified as adults when re-sighted. Seven (< 1%) had been banded at Goose Island in Potholes Reservoir, WA; all were classified as adults when re-sighted. Two (< 1%) had been banded at the Port of Bellingham, WA; both were classified as young adults when re-sighted. Finally, 1 (< 1%) had been banded at the Crump Lake tern island, and was re-sighted as an adult. Re-sightings of banded Caspian terns at the East Sand Island colony indicate that some terns are moving from both inland and coastal colonies to the East Sand Island colony.

Preliminary results from a multi-state analysis (Hestbeck et al. 1991, Brownies et al. 2013) using program MARK (White and Burnham 1999) to estimate inter-colony movement rates of Caspian terns banded as adults indicated that there was little movement of adult Caspian terns from the colony on East Sand Island to the colony on Crescent Island during 2006-2009. Movement rates from the East Sand Island colony to the Crescent Island colony increased during 2010-2012, ranging from 0.8% to 1.9%, with the highest movement rate recorded in 2012. Movement rates of adult Caspian terns from the East Sand Island colony to the Goose Island-Potholes colony ranged from < 0.01% to 0.6% during 2010-2012. Movement rates from the East Sand Island colony to alternative colony sites on the Corps-constructed 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 1.8% during 2008-2012, with the highest movement rate recorded in 2012. Higher movement rates of adult Caspian terns from the East Sand Island colony to other colonies in 2012 are likely due to increased disturbance from bald eagles, higher nest failure rates due to nest depredation by gulls, and reduced availability of nesting habitat on East Sand Island as part of the Caspian Tern Management Plan for the Columbia River Estuary.

1.5.2. Columbia Plateau

Methods: In 2012, adult and fledgling Caspian terns were banded with a federal numbered metal leg band and two plastic, colored leg bands on one leg and a plastic leg band engraved with a unique alphanumeric code on the other. This compliment of bands allows us to individually identify each banded tern from a distance, such that the banding location (colony), banding year, and age of the tern at banding are known. Tern chicks that were too small to be color-banded were banded with a federal numbered metal band only.

Adult Caspian terns were captured using noose mats placed around active nests. Tern chicks were captured by herding flightless young into holding pens located at the periphery of the colony. Once captured, Caspian terns were immediately transferred to small crates designed to hold birds until they were banded and released. Banding operations were conducted during periods of moderate temperatures to reduce the risk of heat stress for captive terns.

Terns that were color-banded in previous years were re-sighted in 2012 at the Crescent Island and Goose Island tern colonies 3 days/week throughout the breeding season.

Results and Discussion: At the Crescent Island colony in 2012, 61 adult Caspian terns and 85 tern chicks near fledging age were color-banded; 4 smaller tern chicks were only banded with metal leg bands. At the Goose Island colony in 2012, 53 adult Caspian terns and 36 tern chicks near fledging age were color-banded; 2 smaller tern chicks were only banded with metal leg bands.

In 2012, a total of 215 previously color-banded Caspian terns were re-sighted at the Crescent Island colony, and of these 191 (89%) had been banded at Crescent Island; 183 were re-sighted as adults and 8 were re-sighted as young adults). Thirteen of the re-sighted banded terns on Crescent Island (6%) had been banded at East Sand Island; 10 were re-sighted as adults and 3 as young adults. Ten of the re-sighted banded adults (5%) had been banded at Goose Island or Solstice Island in Potholes Reservoir; 9 were re-sighted as adults and 1 as a young adult. Finally, 1 of the re-sighted banded adults (< 1%) had been banded at Dungeness Spit, and it was an adult when re-sighted.

In 2012, a total of 224 previously color-banded Caspian terns were re-sighted at the Goose Island colony in Potholes Reservoir, and of these 121 (54%) had been banded at Goose Island or Solstice Island in Potholes Reservoir; 115 were re-sighted as adults and 6 were re-sighted as young adults. Fifty-five of the re-sighted banded terns on Goose Island (25%) had been banded on Crescent Island; 49 were re-sighted as adults and 6 were re-sighted as young adults. Finally, 48 of the re-sighted banded terns on Goose Island (21%) had been banded at East Sand Island; 43 were re-sighted as adults and 5 were re-sighted as young adults.

Preliminary results of a multi-state analysis (Hestbeck et al. 1991, Brownies et al. 2013) using program MARK (White and Burnham 1999) to estimate inter-colony movement rates of Caspian terns banded as adults indicated that movement rates of Caspian terns between the Crescent Island and Goose Island colonies were relatively high. Movement rates of adult terns from Crescent Island to Goose Island were as high as 10.2% during 2010-2012, while movement rates from Goose Island to Crescent Island were as high as 16.3% during 2011-2012. Movement rates of adult terns from the Crescent Island colony to the Corps' recently built alternative colony sites in interior Oregon and northeastern California were as high as 11.2% during 2008-2012; movement rates from the Goose Island colony to the alternative colony sites were as high as 15.5% during 2011-2012. Movement rates of adult terns from the Crescent Island colony to the East Sand Island colony were as high as 4.2% during 2006-2012; movement rates from the Goose Island colony to the East Sand Island colony were as high as 2.1% during 2011-2012. Movement rates of adult terns from the Crescent Island colony or the Goose Island colony to the East Sand Island colony were both higher than movement rates from East Sand Island to those inland colonies, but because the East Sand Island Caspian tern colony was more than a order of magnitude larger that the inland colonies, there was a greater net movement of adult terns from East Sand Island to the inland colonies than in the opposite direction.

A small number of terns (n = 8) that were originally banded as adults on East Sand Island in the Columbia River estuary – where management actions to reduce the size of the colony are being implemented – were re-sighted at colonies in the Columbia Plateau region during 2011 and 2012, half of which (n = 4) were confirmed nesters at the Columbia Plateau colonies; movement of banded Caspian terns that had nested on East Sand Island to colonies in the Columbia Plateau region was not seen during 2006-2010, before tern management intensified at East Sand Island. Natal dispersal of Caspian terns banded as chicks at East Sand Island to the colonies in the Columbia Plateau region have also been confirmed, but none that were < 5 years old when re-sighted were confirmed to be breeding. Caspian tern movements from East Sand Island to colonies in the Columbia Plateau region could 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.

1.5.3. Coastal Washington

Methods: In 2012, re-sightings of banded Caspian terns were conducted during two visits to the Fraser Terminal Warehouse in Richmond, British Columbia, Canada (one in June and one in August) and during three visits to the Trident Seafood Warehouse in Seattle, Washington (all during June-August). Caspian terns nested on the rooftops of large warehouse buildings at both locations. Re-sighting of banded Caspian terns was also attempted at a tern colony on the Kimberly-Clark warehouse rooftop in Everett, Washington, but observers could not access a vantage point near enough to the rooftop to re-sight banded terns at this colony.

Results and Discussion: A total of 26 color-banded Caspian terns were re-sighted at the Fraser Terminal Warehouse colony; 20 had been banded at East Sand Island (11 were re-sighted as adults and 9 as young adults), 4 had been banded at Crescent Island (2 were re-sighted as adults and 2 as young adults), and 2 had been banded at the Port of Bellingham, WA (both were re-sighted at young adults). A total of 3 color-banded Caspian terns were re-sighted at the Trident Seafood Warehouse colony in Seattle; all 3 had been color-banded at East Sand Island and were re-sighted as adults.

1.5.4. Interior Oregon and Northeastern California

Methods: The methods for capture and banding of Caspian tern chicks at colonies on Corps-constructed islands in interior Oregon and northeastern California were the same as those described in Section 1.5.2. Caspian terns that were color-banded in previous years were re-sighted during three days per week throughout the 2012 nesting season at the Corps-constructed tern islands on Sheepy Lake, Tule Lake Sump 1B, and Crump Lake. Previously banded Caspian terns were re-sighted at the Corps-constructed tern island on Malheur Lake during five days per week and at the Corps-constructed islands in Summer Lake Wildlife Area (East Link and Gold Dike) during one day per week throughout the 2012 breeding season.

Results and Discussion: A total of 345 Caspian tern chicks near fledging age were color-banded and 22 smaller chicks were banded with metal leg bands only at three colonies on the Corps-constructed tern islands in interior Oregon and northeastern California during 2012: Sheepy Lake, Crump Lake, and Malheur Lake. At the Sheepy Lake tern colony, 128 tern chicks were color-banded and 7 smaller chicks were banded with metal leg bands only. At the Crump Lake tern colony, 37 tern chicks were color-banded and 5 smaller chicks were banded with metal leg bands only. Finally, at the Malheur Lake tern colony, 180 tern chicks were color-banded and 10 smaller chicks were banded with metal leg bands only.

A total of 109 color-banded Caspian terns were re-sighted at the colony on Sheepy Lake tern island in Lower Klamath NWR during 2012; 42 (39%) had been banded at East Sand Island (35 were re-sighted as adults and 7 as young adults), 27 (25%) were banded at Crescent Island (21 were re-sighted as adults and 6 as young adults), 11 (10%) had been banded at the Sheepy Lake tern island (9 were re-sighted as adults and 2 as young adults), 11 (10%) had been banded at Goose Island in Potholes Reservoir (9 were re-sighted as adults and 2 as young adults), 10 (9%) had been banded at the Crump Lake tern island (4 were re-sighted as adults and 6 as young adults), 5 (5%) had been banded at the Tule Lake tern island (all were re-sighted as adults), 1 (1%) had been banded at the East Link tern island in Summer Lake Wildlife Area (it was re-sighted as an adult), 1 (1%) had been banded at the Port of Bellingham, WA (it was re-sighted as a young adult), and 1 (1%) had been banded at Dungeness Spit, WA (it was re-sighted as an adult).

A total of 119 color-banded Caspian terns were re-sighted at the colony on the Corps-constructed island at Tule Lake Sump 1B in Tule Lake NWR during 2012; 39 (33%) had been banded at East Sand Island (28 were re-sighted as adults and 11 as young adults), 22 (18%) had been banded at Crescent Island (15 were re-sighted as adults and 7 as young adults), 17 (14%) had been banded at the Crump Lake tern island (3 were re-sighted as adults and 14 as young adults), 14 (12%) had been banded at Goose Island in Potholes Reservoir (8 were re-sighted as adults and 6 as young adults), 8 (7%) had been banded at the Sheepy Lake tern island (all were re-sighted as adults), 8 (7%) had been banded at the Tule Lake tern island (all were re-sighted as adults), 6 (5%) had been banded at Brooks Island in San Francisco Bay (2 were re-sighted as adults and 4 as young adults), 3 (3%) had been banded at the Port of Bellingham (all were re-sighted as young adults), and 2 (2%) had been banded at Dungeness Spit (both were re-sighted as adults).

A total of 83 color-banded Caspian terns were re-sighted at the Corps-constructed tern island at Crump Lake during 2012; 37 (45%) had been banded at Crump Lake (14 were re-sighted as adults and 23 as young adults), 19 (23%) had been banded at Crescent Island (16 were re-sighted as adults and 3 as young adults), 11 (13%) had been banded at East Sand Island (9 as adults and 2 as young adults), 7 (8%) had been banded at Goose Island or Solstice Island in Potholes Reservoir (6 were re-sighted and 1 as a young adult), 6 (7%) had been banded at the Sheepy Lake tern island (all were re-sighted as adults), 2 (2%) had been banded at the Tule Lake tern island (both were re-sighted as adults), and 1 (1%) had been banded at Summer Lake (it was re-sighted as an adult).

A total of four color-banded Caspian terns were re-sighted at the Corps-constructed tern islands in Summer Lake Wildlife Area during 2012, three on East Link tern island and one on Gold Dike tern island. Of the 3 color-banded terns that were re-sighted at the East Link tern island, 2 had been banded at Crescent Island (both were re-sighted as adults) and 1 had been banded at Goose Island, Potholes Reservoir (it was re-sighted as an adult). The one color-banded tern that was re-sighted on Gold Dike tern island had been banded at Goose Island in Potholes Reservoir, and was re-sighted as a young adult.

A total of 324 color-banded Caspian terns were re-sighted at the Corps-constructed tern island in Malheur Lake during 2012; 139 (43%) had been banded at Crescent Island (106 were re-sighted as adults and 33 as young adults), 73 (23%) had been banded at Goose Island or Solstice Island in Potholes Reservoir (59 were re-sighted as adults and 14 as young adults), 63 (19%) had been banded at East Sand Island (51 were re-sighted as adults and 12 as young adults), 41 (13%) had been banded at the Crump Lake tern island (12 were re-sighted as adults and 29 as young adults), 3 (1%) had been banded at the Tule Lake tern Island (all were re-sighted as adults), 2 (1%) had been banded at the Port of Bellingham, WA (both were re-sighted as young adults), 2 (1%) had been banded at Brooks Island in San Francisco Bay, CA (both were re-sighted as young adults), and 1 (< 1%) had been banded at the Sheepy Lake tern island (it was re-sighted as an adult).

Re-sightings of banded Caspian terns at the newly established colony on the recently constructed island in Malheur Lake revealed that Caspian terns banded at several different colonies, both coastal and interior, were quick to find the new nesting habitat provided there. Caspian terns banded at East Sand Island were re-sighted at four different islands built by the Corps as 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 East Sand Island. Movements of banded Caspian terns among the Corps-constructed alternative nesting islands in interior Oregon and northeastern California were also documented.

Continued banding and re-sighting of Caspian terns at all breeding colony sites in the region will be necessary to evaluate how the on-going Caspian Tern Management Plan for the Columbia River Estuary and other factors influence inter-colony movements, demographic characteristics, and, consequently, the metapopulation dynamics of the Pacific Coast population of Caspian terns. Survival rates from fledging to one year post-hatch and from one year post-hatch to recruitment into the breeding population are both still needed in order to understand the demography, status, and population trend of the Caspian tern population in western North America.

SECTION 2: DOUBLE-CRESTED CORMORANTS

2.1. Nesting Distribution and Colony Size

2.1.1. Columbia River Estuary

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 nests visible on aerial photography were used to estimate the total number of breeding pairs; standard errors from these counts were used to estimate a confidence interval for this estimate. A major source of uncertainty in past bioenergetics estimates of smolt consumption by double-crested cormorants nesting at the East Sand Island colony was variation in colony size across the breeding season (when aerial photography was not available). In previous years, we used estimates of colony size made from blinds or from boats just offshore, but these estimates were limited in precision due to poor visibility of birds behind vegetation, debris, and other birds. Beginning in 2008, we expanded the use of aerial photography to estimate colony size across the entire breeding season. High resolution aerial photography of the cormorant colony were taken approximately every 2 weeks from early May to early September in 2012. Aerial photography that included the entire East Sand Island cormorant colony was taken nine times during the 2012 nesting season (including the photography taken late in incubation to estimate peak colony size). We developed a custom application in ArcGIS to count nests or individual birds on all of the aerial photography of the East Sand Island cormorant colony, as well as to count aerial photography of breeding colonies of other piscivorous colonial waterbirds (e.g., terns, gulls, and pelicans).

Boat-based and aerial surveys of double-crested cormorants nesting on 12 navigational markers near Miller Sands Spit and Fitzpatrick Island (river km 38 and 53, respectively) in the Columbia River estuary were conducted 1 - 2 times per month from mid-April through early July in 2012. Because nesting chronology varied among the different channel 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 2012. 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.

Periodic boat-, land-, and air-based surveys were also conducted to monitor the sites where double-crested cormorants previously nested on Rice Island and on Miller Sands Spit. During these surveys, researchers looked for indications of cormorant nesting activity.

Results and Discussion: 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 and Roby 2010). We estimate that 12,300 breeding pairs (95% c.i. = 12,035 – 12,567 breeding pairs) attempted to nest at the East Sand Island colony in 2012, compared to 13,045 breeding pairs (95% c.i. = 12,781 – 13,309 breeding pairs) in 2011. The size of the East Sand Island double-crested cormorant colony grew rapidly from 1997 to 2007, nearly tripling in size (Figure 57). In 2008, however, the colony experienced an unexpected decline (20%) before rebounding to nearly the previous peak in colony size by 2010 (Figure 57). 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, most of which are stable or declining. The available data suggest that much of the early growth of the East Sand Island colony was caused by immigration from colonies outside the Columbia River estuary. More data are needed to assess the extent to which factors limiting the size and reproductive success of colonies throughout the Pacific Northwest are influencing the size of the double-crested cormorant colony on East Sand Island.

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 5). Despite availability of habitat to support continued colony expansion, bald eagle disturbance and predation, plus the associated nest predation by glaucous-winged/western gulls (*Larus glaucescens/occidentalis*), may currently be limiting the size of the double-crested cormorant colony on East Sand Island.

In 2012, we surveyed for double-crested cormorants nesting on 12 channel markers located in the upper Columbia River estuary, eight near Miller Sands Spit and four near Fitzpatrick Island. A maximum of 245 pairs of double-crested cormorants nested on 10 of these channel markers, seven near Miller Sands Spit and three near Fitzpatrick Island; this total number of active nests is very similar to the count from 2011 (248 breeding pairs). Counts of attended cormorant nests at both groups of channel markers peaked in late June or early July.

Double-crested cormorants continued nesting near the pelagic cormorant colony on the Astoria-Megler Bridge in 2012. In addition, thousands of double-crested cormorants were observed roosting on the bridge at various times throughout the breeding season, possibly associated with the nest dissuasion activities on East Sand Island in 2012 (see Section 2.6.2). During five boat-based censuses from 22 April to 6 July, a maximum 139 active double-crested cormorant nests were counted on the Astoria-Megler Bridge; this count was a large increase from 2010 and 2011, when less than half this number of double-crested cormorant nests were counted on the bridge.

2.1.2. Columbia Plateau

Methods: Counts of attended cormorant nest structures were used to estimate the size of the double-crested cormorant colony on Foundation Island in the mid-Columbia River during 2012 (Map 1). To enhance the accuracy of nest counts and our ability to monitor individual nests, we constructed an observation blind in the water, approximately 25 m off the eastern shore of the island. Nest counts and observations of nest contents were conducted each week from the observation blind during the 2012 nesting season.

In 2012, we conducted two aerial surveys of the Columbia Plateau region (14-15 May and 28 June) looking for new breeding colonies of double-crested cormorants. Additionally, periodic land- and boat-based surveys were conducted throughout the breeding season to verify nesting by cormorants at sites identified during aerial surveys. At each site we counted attended cormorant nests to obtain an estimate of the number of breeding pairs at each colony. Although it is possible that some small colonies (i.e., < 20 breeding pairs) may have been missed during these surveys, we are confident that all breeding colonies of consequence within the study area, that did not fail early in the nesting season, were identified.

Results and Discussion: In 2012, the double-crested cormorant colony on Foundation Island consisted of a minimum of 390 breeding pairs, the highest number of breeding pairs ever recorded at this colony (Figure 58). Foundation Island continues to be the largest cormorant breeding colony on the mid-Columbia River. All nesting at this cormorant colony occurs in trees. During 2003-2006 the Foundation Island cormorant colony gradually grew from about 250 breeding pairs to about 360 breeding pairs, before leveling off and then declining to about 310 breeding pairs during 2009-2011 (Figure 58). The increase in colony size observed at the Foundation Island cormorant colony in 2012 was the first measurable increase observed at this colony in the past four years. Data on colony attendance in 2012 indicated that the Foundation Island cormorant colony reached its maximum size in early-May, one week later than the average, based on data from previous years (Figure 59).

No nesting by double-crested cormorants was observed on the mid-Columbia River at either Crescent Island or Miller Rocks in 2012. In 2011, cormorants attempted to nest at both of these sites (1 and 2 breeding pairs, respectively) and subsequently failed in their nesting attempts. The cause(s) of nest failure at these incipient colonies was not determined.

The largest double-crested cormorant colony in the entire Columbia Plateau region is at Potholes Reservoir in the North Potholes Reserve, where ca. 1,000 breeding pairs nested in 2012 (Figure 60). This colony was in decline from its peak colony size in 2006 (ca. 1,150 breeding pairs) to 2009 (ca. 810 breeding pairs) and has since been gradually increasing in every year (Figure 60). As with the Foundation Island colony, cormorants at the North Potholes colony nest in trees, and at North Potholes the trees are flooded for much of the nesting season. Although this colony is the largest of its kind in the region, there is little evidence that these birds commute to the Columbia River to forage on juvenile salmonids, based on the scarcity of salmonid PIT tags beneath the colony.

Based on our counts of attended cormorant nests at the Okanogan cormorant colony at the mouth of the Okanogan River, we estimate that there was a minimum of 40 breeding pairs at this colony in 2012, slightly more than in 2011 (32 breeding pairs).

We estimated that 146 breeding pairs of double-crested cormorants nested at the colony on Harper Island in Sprague Lake during 2012, more than in 2011 (107 breeding pairs). We first observed cormorants nesting on Harper Island in 2008, when an estimated 38 breeding pairs nested on the island. Double-crested cormorants were also recorded nesting on Harper Island in the early 1990s (M. Monda, Washington Department of Fish and Wildlife, pers. comm.). Harper Island is also home to a large California and ring-billed gull colony and a small Caspian tern colony.

Aerial surveys of the lower and middle Columbia River from Bonneville Dam to Rock Island Dam, the lower Snake River from its mouth to the confluence with the Clearwater River revealed no other breeding colonies of double-crested cormorants in 2012.

There was of total of four active double-crested cormorant colonies in the Columbia Plateau region during 2012, where a total of approximately 1,570 breeding pairs nested (Figure 61). This suggests that the number of double-crested cormorants nesting in the Columbia Plateau region has gradually increased since 2009, and is currently above the average for the previous seven years (Figure 62).

2.1.3. Coastal Washington

Methods: In 2012, we surveyed for double-crested cormorant nests on 12 channel markers in Grays Harbor, WA during three aerial survey flights from late April to early July. No boat-based surveys of nesting cormorants in Grays Harbor were conducted during 2012.

Results and Discussion: We counted a maximum of 143 double-crested cormorant nests on nine different channel markers during the aerial survey of Grays Harbor in early July.

2.1.4. Interior Oregon and Northeastern California

Methods: In 2012, we conducted three aerial surveys of interior Oregon and northeastern California (13 June, 12 July, and 3 August; Map 4) looking for breeding colonies of double-crested cormorants. Additionally, periodic land- and boat-based surveys were conducted throughout the breeding season to verify nesting by cormorants at sites identified in aerial surveys.

Results and Discussion: Based on aerial, land, and boat-based surveys in 2012, double-crested cormorants were confirmed nesting at seven different locations: Upper Klamath NWR (ca. 850 individuals counted at six colony sites), Clear Lake NWR (ca. 285 individuals), Malheur NWR (ca. 445 breeding pairs at two colony sites, Sodhouse Farm and Singhus Ranch), Carmine Ditch near Burns, OR (1 breeding pair), Sheepy Lake in Lower Klamath NWR (ca. 115 breeding pairs), Pelican Lake in the Warner Valley (23 breeding pairs), and River's End Ranch near Valley Falls, OR (8 breeding pairs).

2.2. Nesting Success

2.2.1. Columbia River Estuary

Methods: Elevated blinds located in the East Sand Island cormorant colony were used to observe nesting cormorants in 2012 (Map 5). These blinds were accessed via above-ground tunnels to prevent disturbance to nesting cormorants and gulls, as well as roosting California brown pelicans.

In 2012, nesting attempts by 218 pairs of double-crested cormorants in eight separate plots were monitored for productivity. Observations of nest contents were recorded each week from mid-April through July to determine nesting chronology and monitor nesting success. Productivity was measured as the number of nestlings in each monitored nest at 28 days post-hatching. Cormorant chicks older than 28 days are capable of leaving their nests. Productivity was averaged for each plot and the standard error of those averages was used to calculate a confidence interval for the overall productivity estimate.

Monitoring of nesting cormorants on channel markers in the upper estuary and on the Astoria-Megler Bridge was conducted periodically (1 – 2 times per month) from a boat.

Results and Discussion: We estimated that 15,492 fledglings (95% c.i. = 13,757 – 17,227 fledglings) were produced at the East Sand Island cormorant colony in 2012. This corresponds to an average productivity of 1.26 young raised per breeding pair (95% c.i. = 1.12 – 1.40 fledglings/breeding pair), similar to the productivity in 2011, but significantly lower than average productivity during 2006-2010 (Figure 63). While recent improvements in ocean conditions may have contributed to above average nesting success at the East Sand Island cormorant colony during 2006-2010, predation and associated disturbance by bald eagles during late May and late June contributed to significant nest failure in some areas of the colony and lower overall productivity in both 2011 and 2012.

Confirmation of eggs in cormorant nests on channel markers and on the Astoria-Megler Bridge was not possible from our vantage on the water, but the first double-crested cormorant chicks were observed on 23 June at both the channel markers and the Astoria-Megler Bridge colonies during the 2012 nesting season. Due to poor vantage and infrequent visits, we were not able to estimate nesting success for double-crested cormorants that nested on the upper estuary channel markers or on the Astoria-Megler Bridge.

2.2.2. Columbia Plateau

Methods: We monitored nesting attempts by 63 cormorant breeding pairs at the Foundation Island colony from the observation blind during the 2012 nesting season. The colony was visited 2 – 3 days per week from mid-April through late July to record nest attendance and numbers of chicks present in each monitored nest. Productivity was estimated as the number of chicks in each nest at an estimated 28 days post-hatching. Because of the distance of the blind from the colony and our vantage point from below the elevation of the nests, we assumed the chicks in a monitored nest were approximately 10 days old when first observed. While productivity was not estimated at the other three cormorant colonies in the Columbia Plateau region, field visits and/or aerial surveys were conducted to assess the colony size and stage of nesting during the chick-rearing period.

Results and Discussion: Productivity at the Foundation Island cormorant colony in 2012 averaged 1.86 fledglings/nest (95% c.i. = 1.57 – 2.15 fledglings/nest), significantly lower than the estimated productivity in 2010 and 2011 (ca. 2.71 fledglings/nest; Figure 64). Although estimates of nesting success are not available for the double-crested cormorant colonies at North Potholes Reserve, Harper Island, and the mouth of the Okanogan River, these three colonies were successful in raising young to fledging age in 2012.

2.2.3. Coastal Washington

It is unknown whether double-crested cormorants nesting on channel markers in Grays Harbor were successful in raising young to fledging age in 2012. No aerial surveys were conducted over Grays Harbor during the chick-rearing or fledging periods.

2.2.4. Interior Oregon and Northeastern California

Methods: Breeding colonies of double-crested cormorants in interior Oregon and northeastern California were photographed during aerial surveys or visited late in the breeding season to determine if they were successful in raising young.

Results and Discussion: Double-crested cormorants nesting at Clear Lake NWR, Malheur Lake, Pelican Lake in Warner Valley, Upper Klamath NWR, and Sheepy Lake in Lower Klamath NWR were likely successful in raising young to fledging age in 2012. Nesting success at the other cormorant colonies in interior Oregon and northeastern California (i.e., Meiss Lake, CA, River's End Ranch, OR, Carmine Ditch, OR, Swan Lake, OR, and Crane Prairie Reservoir, OR) during 2012 was not determined.

2.3. Diet Composition and Salmonid Consumption

2.3.1. Columbia River Estuary

Methods: Lethal sampling techniques were necessary to assess the diet composition of double-crested cormorants nesting on East Sand Island. The best method to obtain a random sample of the diet is to collect adult birds commuting toward the colony from foraging areas throughout the breeding season. The target sample size for collections was 5-15 samples of adult foregut (stomach and esophagus) contents per week. This sampling effort was selected to adequately capture seasonal changes in diet while minimizing the impact of lethal sampling to the colony as a whole. Immediately after collection, each cormorant's abdominal cavity was opened, the foregut removed, and the contents of the foregut emptied into a whirl-pak. Each foregut sample was weighed, labeled, and stored frozen for later sorting and analysis in the laboratory.

Analysis in the laboratory of semi-digested diet samples was conducted at Oregon State University. Samples were partially thawed, removed from whirl-paks, re-weighed, and separated into identifiable and unidentifiable fish soft tissue. Fish in foregut samples were identified to genus and species, whenever possible. Intact salmonids in foregut samples were identified as Chinook salmon, sockeye salmon, coho salmon, steelhead, or unknown based on genetics analyses[2]. Unidentifiable fish soft tissue samples were artificially digested (work that is ongoing) according to the methods of Petersen et al.

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[2] 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).

(1990, 1991). Once digested, diagnostic bones (i.e., otoliths, cleithra, dentaries, and pharyngeal arches) were removed from the sample and identified to species using a dissecting microscope (Hansel et al. 1988). Unidentified fish soft tissue samples that did not contain diagnostic bones and samples comprised of bones only (i.e., no soft tissue) were excluded from diet composition analysis. Taxonomic composition of double-crested cormorant diets was expressed as % of identifiable prey biomass. The prey composition of cormorant diets was calculated for each 2-week period throughout the nesting season. The diet composition of double-crested cormorants over the entire breeding season was based on the average of these 2-week percentages.

Estimates of annual smolt consumption by double-crested cormorants nesting at the East Sand Island colony were calculated using a bioenergetics modeling approach (Lyons 2010). We used a Monte Carlo simulation procedure to estimate 95% confidence intervals for estimates of smolt consumption by double-crested cormorants.

Results and Discussion: Based on identifiable fish tissue in foregut samples (91% of the collected biomass of stomach contents), juvenile salmonids comprised 20% of the diet (by biomass) of double-crested cormorants nesting at East Sand Island in 2012 (n = 134 adult foregut samples or a total of 21,331 g of identifiable fish tissue). The annual proportion of juvenile salmonids in the diet of double-crested cormorants nesting on East Sand Island in 2012 was similar to the estimate from 2011 (19%) and the second highest proportion ever recorded at this colony (24.6% of biomass in 1999; Figure 65).

The diet of double-crested cormorants, which forage by pursuit-diving throughout the water column, at the East Sand Island colony is more diverse (Figure 66) than that of Caspian terns nesting on the same island (Figure 35). On average, anchovy was the single most prevalent prey type for double-crested cormorants nesting at East Sand Island in 2012, followed by various marine and freshwater taxa (Figure 66 and Figure 67). In 2012, the prey category “other” consisted of five different taxa, all less than 2% of the diet, with the exception of stickleback, which was 12% of the diet by biomass. In recent years, the proportion of the diet consisting of salmonids has increased from a low of 2% of identifiable biomass in 2005, to a high of 20% in 2012. Over this time period, anchovy has been the single most important prey type in cormorant diets, but annual values have varied from 23-34% of the diet by biomass. The increasing proportion of salmonids in cormorant diets in recent years has generally been associated with small declines in many of the less common prey types (e.g., surf perch, cyprinids, others). The seasonal peak in the proportion of salmonids in the diet of double-crested cormorants nesting on East Sand Island during 2012 was in late May, later than was observed in previous years on average (Figure 68).

Genetic stock identification of salmonid samples collected from double-crested cormorant stomachs during 2011-12 indicated that cormorants consumed smolts from many of the uniquely identifiable stocks from across the basin. For Chinook salmon, the most common genetic stock of origin during April and May was the Snake River spring

Chinook stock (13 of 24 or 54% of Chinook samples from this period; Figure 69). During June and July, most identified Chinook salmon (11 of 13 or 85%) originated from the lower Columbia River (the Spring Creek Group fall run, West Cascades Tributary fall run, and the introduced Rogue River fall run stocks). Identified steelhead trout originated from five stocks, with steelhead from the Snake River consisting of just over half of the identified samples (31 of 58 samples or 53%; Figure 70). A majority of coho salmon were of Columbia River origin; however, coho identified as originating from the Oregon coast stock made up 25% of samples (15 of 60), and one sample was identified as originating from the Washington coast stock.

Our estimate of total smolt consumption by double-crested cormorants nesting on East Sand Island in 2012 was 18.9 million smolts (95% c.i. = 14.0 – 23.8 million), similar to 2011 (Figure 71). Of the ca. 18.9 million juvenile salmonids consumed in 2012, we estimated that 10.8 million smolts or 57% were sub-yearling Chinook salmon (95% c.i. = 6.8 – 14.8 million), 4.8 million smolts or 26% were coho salmon (95% c.i. = 3.5 – 6.0 million), 1.7 million smolts or 9% were steelhead (95% c.i. = 1.3 – 2.1 million), 1.5 million smolts or 8% were yearling Chinook salmon (95% c.i. = 1.0 – 2.0 million), and 0.1 million smolts or 0.6% were sockeye salmon (95% c.i. = 0.00 – 0.3 million; Figure 72). In general, annual smolt consumption by double-crested cormorants nesting on East Sand Island has been trending upward since 2003 (Figure 71). During 2010-2012, estimates of smolt consumption by East Sand Island cormorants have been significantly higher than that of Caspian terns nesting on East Sand Island (Figure 40), and higher than consumption by cormorants in the previous four years (2006-2009; Figure 71). Cormorant colony size has been relatively stable since 2006, so changes in colony size do not explain recent increases in cormorant smolt consumption. The primary factor driving increased estimates of smolt consumption by cormorants during 2010-2012 has been a greater proportion of smolts in the cormorant diet in these years (Figure 65). Salmonids made up 9-11% of the annual cormorant diet (by biomass) during 2006-2009, but salmonids have been 16-20% of the diet during 2010-2012. This nearly doubling of the prevalence of smolts in the diet is largely reflected in the higher estimates of smolt consumption.

2.3.2. Columbia Plateau

Methods: For double-crested cormorants nesting on Foundation Island, we lethally sampled small numbers of adult cormorants commuting back to the colony after foraging trips during the 2005-2010 breeding seasons. Double-crested cormorants were not lethally collected for diet composition analysis during 2011-2012. Because of small sample sizes of collected foregut samples and uneven distribution of collected samples across the breeding season within any particular sample year, samples were pooled across years. During 2005-2010, a total of 140 adult cormorants were collected during seven different periods of the nesting season (n = 9 in early April, n = 22 in late April, n = 38 in early May, n = 26 in late May, n = 20 in early June, n = 16 in late June, and n = 9 in early July). The foregut contents of these collected cormorants were removed and other tissues were sampled as well. All diet samples were analyzed in our laboratory at

Oregon State University to estimate diet composition of cormorants nesting on Foundation Island during 2005-2010 (see section 2.3.1 for description of diet analysis). The taxonomic composition of double-crested cormorant diets was expressed as the percentage of identifiable prey biomass and calculated for five 2-week periods during the nesting season. The diet composition of cormorants over the entire 10-week nesting season was based on the average of these 2-week percentages for samples collected during 2005-2010. Bioenergetics estimates of smolt consumption by double-crested cormorants nesting on Foundation Island during 2005-2010 are presented in separate reports (see Lyons et al. 2011a, 2011b).

Results and Discussion: Based on identifiable fish tissue in foregut samples, juvenile salmonids comprised 22% of double-crested cormorant diets (by biomass) at the Foundation Island colony during 2005-2010 (n = 140 adult foregut samples, or a total of 32,188 g of identifiable fish tissue). The peak in the proportion of salmonids in the diet of double-crested cormorants nesting on Foundation Island during 2005-2010 apparently occurred in early May and declined thereafter (Figure 73). On average, centrarchids (bass and sunfish) were the single most prevalent prey type for Foundation Island cormorants (Figure 74). These diet composition results should be interpreted cautiously, however, because they are based on relatively small sample sizes and are pooled across several years.

Previous studies have shown that Foundation Island cormorants consumed more salmonid biomass than Caspian terns nesting on Crescent Island, despite the somewhat smaller size of the cormorant colony and less specialization by cormorants on salmonids as a food source. The higher biomass consumption of salmonids by double-crested cormorants nesting on Foundation Island was due primarily to the larger body size of cormorants and their consequent greater individual energy requirements (Lyons et al. 2011a, 2011b). Best estimates of salmonid consumption by Foundation Island cormorants ranged from 470,000 to 880,000 smolts annually (based on pooled data collected during 2005-2009; Lyons et al. 2011a).

2.3.3. Coastal Washington

No diet composition data were collected for double-crested cormorants nesting along the Washington coast in 2012.

2.3.4. Interior Oregon and Northeastern California

Although no diet composition data were collected for double-crested cormorants nesting outside the Columbia River basin, PIT tags from ESA-listed suckers were recovered on mixed piscivorous waterbird colonies (which included double-crested cormorants) in interior Oregon and northeastern California; see Section 3.3.4 for those results.

2.4. Predation Rates Based on PIT Tag Recoveries

2.4.1. Columbia River Estuary

Methods: The methods for calculating predation rates on juvenile salmonids based on PIT tag recoveries at the East Sand Island double-crested cormorant colony are the same as those described for Caspian terns in Section 1.4.1.

Results and Discussion: Following the nesting season, 13,827 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2012 migration year were recovered on the East Sand Island double-crested cormorant colony (Table 3). An additional 128 smolt PIT tags were recovered from a segment of the island where double-crested cormorants were dissuaded from nesting in 2012 (see Section 2.6.2); indicating use of the dissuasion area by cormorants during the smolt migration period was limited. Control tags sown on the East Sand Island cormorant colony (n = 200) indicated that detection efficiency ranged from 56% to 81% for tags deposited between 1 March and 31 August (Table 4).

Predation rates on PIT-tagged smolts last detected passing Bonneville Dam on the Columbia River or Sullivan Dam on the Willamette River (Map 1) indicated that distinct population segments (DPSs) of steelhead from the upper Columbia River and the Snake River were the most susceptible salmonids to predation by double-crested cormorants nesting at East Sand Island; estimated predation rates were 7.2% and 5.4%, respectively, in 2012 (Table 5). Predation rates on salmon evolutionarily significant units (ESUs) were generally lower and ranged from 0.6% to 4.2% in 2012 (Table 3). Overall predation rates on salmonid DPSs/ESUs by double-crested cormorants nesting on East Sand Island in 2012 were similar to those observed in 2011 (BRNW 2012). Compared to Caspian terns nesting on East Sand Island, predation by double-crested cormorants on ESUs of salmon (Chinook, sockeye) were often higher (Table 5). Conversely, predation rates by East Sand Island Caspian terns on DPSs of steelhead were often greater compared to predation by East Sand Island double-crested cormorants. This finding is supported by results from the bioenergetics modeling, which indicated that double-crested cormorants nesting on East Sand Island consumed more salmon but fewer steelhead compared to Caspian terns nesting on East Sand Island (Figures 41 and 72).

Data regarding the impacts of predation by double-crested cormorants and Caspian terns nesting on East Sand Island (see Section 1.4.1) on survival of PIT-tagged smolts from the DPSs/ESUs of salmonids from the Lower Columbia River (LCR) are not available in 2012. Estimates of predation rates for LCR DPSs/ESUs are 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 predation rates on LCR DPSs/ESUs conducted by Lyons et al.

(2012), which attempted to account for these data gaps as best as possible, indicated that 26% and 28% of available LCR Chinook and coho, respectively, were annually depredated by double-crested cormorants nesting on East Sand Island during 2007-2010. Although Lyons et al. (2012) concluded that more research was needed to understand the impact of double-crested cormorant predation on LCR DPSs/ESUs, the limited data available suggest LCR Chinook and coho may be more susceptible to predation by double-crested cormorants nesting on East Sand Island compared to DPSs/ESUs originating further upriver (i.e., upstream of Bonneville and Sullivan dams).

Similar to the PIT tag data obtained from the Caspian tern colony on East Sand Island, it is important to note that predation rates presented in 2012 account for on-colony PIT tag deposition rates (i.e., the proportion of ingested PIT tags that are neither damaged during ingestion nor deposited elsewhere than on the colony; Appendix A). Additional studies are currently planned to replicate these studies in another year and to more precisely quantify on-colony PIT tag deposition rates and the inter-annual variation in those estimates. Results from these studies will be used to produce a more accurate estimate of cormorant predation rates on juvenile salmonids based on PIT tag recoveries from both future studies and retrospective analyses.

2.4.2 Columbia Plateau

Methods: The methods for calculating predation rates on salmonid smolts based on PIT tag recoveries at the Foundation Island double-crested cormorant colony are similar to those described for Caspian terns in Section 1.4.1. One notable exception is the use of deposition rate data, whereby deposition results obtained from double-crested cormorants nesting on East Sand Island, a ground-nesting colony, were applied to cormorants nesting on Foundation Island, an arboreal-nesting colony (see Table 2). The degree to which deposition rates differ between ground- and arboreal-nesting cormorants is not known. It's likely, however, that some proportion of PIT tags remain in arboreal nests where researchers cannot readily detect them. If true, on-colony deposition rates could be higher in ground-nesting cormorants because researchers can scan the actual nest cup and not just the ground underneath the nest. None-the-less, deposition rate data obtained from cormorants on East Sand Island is currently the best available and was applied to all double-crested cormorant colonies in the region.

Results and Discussion: Following the nesting season, 2,873 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2012 migration year were recovered on the Foundation Island double-crested cormorant colony (Table 3). Control PIT tags sown on the Foundation Island cormorant colony (n = 200) indicated that detection efficiency ranged from 35% to 41% for tags deposited between 1 April and 31 July (Table 4). Detection efficiency estimates were some of the lowest recorded on Foundation Island since control tags were first sown on this colony in 2004. Reduced detection efficiency is most likely associated with increasing PIT tag collision on the colony, a phenomenon that renders deposited PIT tags progressively unreadable due to accumulating PIT tags on-colony (Evans et al. 2012).

Of the available PIT-tagged salmonids last detected passing Lower Monumental Dam on the Snake River or Rock Island Dam on the Columbia River (Map 1), predation rates by Foundation Island cormorants were highest on Snake River sockeye salmon (2.5%) and Snake River steelhead (2.4%; Table 6). Predation rates on all other ESUs/DPSs were < 1.0% (Table 6). Compared to predation rates on Snake River steelhead (2.4%), predation rates on upper Columbia River steelhead by Foundation Island cormorants were negligible; the estimated predation rate on available steelhead smolts last detected passing Rock Island Dam was just 0.5% (Table 6). Comparisons of ESU/DPS-specific predation rates between Foundation Island cormorants and Caspian terns nesting at nearby Crescent Island indicate that impacts were similar between the two colonies, although predation on salmon ESUs was generally higher for cormorants, while predation on steelhead DPSs was generally higher for Caspian terns. Similar to results from Caspian terns nesting on Crescent Island (see Section 1.4.2), however, predation rates on Snake River smolts are specific to in-river migrants and a proportion of available Snake River smolts were collected and transported around the bird colonies in McNary pool. Conversely, upper Columbia River ESUs/DPSs are not transported around McNary pool; thus, predation rates by Foundation Island cormorants are on all smolts (100%) from the upper Columbia River ESUs/DPSs.

Unlike previous years, only one PIT tag from a bull trout (*Salvelinus confluentus*) was found on the Foundation Island cormorant colony in 2012, a substantial reduction from the 32 bull trout PIT tags found on-colony during 2008-2011 (see BRNW 2012). This apparent reduction in cormorant predation rates on bull trout may instead be due to a reduction in the number of bull trout PIT-tagged and released in the region during 2012. In addition to one bull trout PIT tag, one tag from a juvenile white sturgeon (*Acipenser transmontanus*) was also recovered on the Foundation Island cormorant colony in 2012. Sturgeon were tagged and released upstream of Priest Rapids Dam as part of an effort to bolster the white sturgeon population in the mid-Columbia River. Due to the paucity of bull trout and white sturgeon tags found on the cormorant colony in 2012, no additional analysis were conducted (but see BRNW [2012] for a more thorough discussion of bull trout and sturgeon tags recovered on the Foundation Island cormorant colony during 2008-2011).

Following the nesting season, 126 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2012 migration year were recovered on the North Potholes double-crested cormorant colony (Map 1; Table 3). Control PIT tags sown on the North Potholes cormorant colony (n = 200) indicated that detection efficiency ranged from 21% to 29% for tags deposited between 1 April and 31 July (Table 4). Low detection efficiency of deposited PIT tags was likely attributable to tags being sown directly over water, as most of the area beneath nests were inundated during the nesting season.

Of the available PIT-tagged smolts last detected passing Lower Monumental Dam on the Snake River or Rock Island Dam on the Columbia River (Map 1), predation rates by North Potholes cormorants were $\leq$ 0.3% (Table 7). Predation rates on upper Columbia steelhead were 0.3% (95% c.i. = < 0.1 – 0.8%), while predation rates on all other DPSs/ESUs were $\leq$ 0.1% (Table 7). Results suggest that, unlike Caspian terns nesting at Potholes Reservoir, cormorants nesting at Potholes Reservoir were not routinely commuting to the Columbia River to forage on salmonids, which has positive implications for salmonid smolt survival given that the North Potholes cormorant colony is largest in the Columbia Plateau region (Figure 61).

Following the nesting season, a total of just 11 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2012 migration year were recovered on the double-crested cormorant colony on Harper Island, Sprague Lake (Table 2). Harper Island is a privately-owned island and was not accessible for PIT tag data collection in previous years. Control PIT tags were not sown on the Harper Island cormorant colony due to restricted access to the island. PIT detection efficiency from the East Sand Island double-crested cormorant colony was used in place of detection efficiency at the Harper Island colony because the East Sand Island colony is the only other ground nesting cormorant colony where empirical detection efficiency values were available in 2012 (Table 2).

Harper Island on Sprague Lake is > 60 km from the mainstem Snake River, with the closest point located between Lower Granite Dam and Little Goose Dam (Map 1). Predation rates by double-crested cormorants nesting at Sprague Lake was based on recovery of smolt PIT tags interrogated or released at Lower Granite Dam in 2012 (Table 8). Evaluation of predation rates on upper Columbia River ESUs/DPSs was not feasible due to the paucity of upper Columbia River PIT tags recovered on the colony and the long distance from Sprague Lake to sections of the mainstem Columbia River that contain anadromous salmonids (about 120 km; Map 1). PIT tag recoveries indicated that cormorants nesting at the Harper Island colony did not regularly forage in the mainstem Snake River, as predation rates were $\leq$ 0.1% on all salmonid ESUs/DPSs from the Snake River (Table 8). Both Caspian terns (see Section 1.4.2) and double-crested cormorants nested on Harper Island in Sprague Lake during 2012. Predation rates associated with Caspian tern and double-crested cormorant colonies at Sprague Lake supported conclusions from studies at Potholes Reservoir, where Caspian terns regularly commuted > 30 km to forage on juvenile salmonids in the mainstem Columbia River, but cormorants nesting nearby appeared to rarely, if ever, commute to the mainstem to forage on juvenile salmonids.

2.5. Color banding

Methods: In 2012, adult and juvenile double-crested cormorants were banded at the nesting colony on East Sand Island in the Columbia River estuary with a federal numbered metal leg band on one leg and a field-readable plastic leg band engraved with a unique alphanumeric code on the other. This was the fifth year of a prospective long-term effort to collect information on the survival, movements, and demography of double-crested cormorants from the East Sand Island colony, and to study dispersal patterns and recruitment of double-crested cormorants to other nesting colonies using re-sightings of banded individuals.

Double-crested cormorants were captured for banding using several methods in 2012. Prior to active hazing of pre-nesting adult cormorants on a portion of the East Sand Island colony during late April (see Section 2.6.2), night-time capture using large landing nets and spotlights was employed to obtain adult cormorants for banding and tagging from the dissuasion area (Map 5). Adult cormorants were also captured at night (May-July) from above-ground access tunnels that concealed our presence on the portion of the cormorant colony where nesting occurred. Breeding adult cormorants were captured during late incubation and again during late chick-rearing. Juvenile cormorants near fledging age (> 28 days post-hatch) were also captured at night from the above-ground tunnels for banding purposes. Finally, juvenile cormorants were captured for banding when they were near fledging age during a daytime round-up near the perimeter of the cormorant colony. Once captured, cormorants were transported to an adjacent processing area, banded, and released.

To date, re-sighting efforts for previously-banded double-crested cormorants from East Sand Island have been opportunistic and less than the re-sighting effort for banded Caspian terns in the region (see Section 1.5).

Results and Discussion: A total of 264 adult double-crested cormorants and 438 juvenile double-crested cormorants were captured, banded, and released at the East Sand Island colony in 2012. Of the 264 adult cormorants that were banded in 2012, 149 (56%) were captured in the nest dissuasion area during late April (138 of which were also fitted with VHF radio transmitters [n = 126] or satellite tags [n = 12]; see Section 2.6.2). An additional 125 adult cormorants were captured from tunnels located on the active portion of the cormorant colony, west of the privacy fence (see Map 5). Of the 438 juvenile cormorants banded in 2012, 220 (50%) were captured from the above-ground tunnels and 218 were captured during the daytime round-up.

Since 2008 we have banded 1,387 double-crested cormorants (662 adults and 725 juveniles) with field-readable color bands. To date, an estimated 2-3% of all breeding adult double-crested cormorants nesting at East Sand Island have been banded. In 2012, 89% of all adult double-crested cormorants banded at East Sand Island during 2010-2012 (n = 662) were observed at least once on East Sand Island. While significant effort to re-sight banded cormorants occurs at East Sand Island during the breeding season, re-sighting efforts at other regional colonies remains infrequent and opportunistic. Encounters with banded cormorants away from East Sand Island are limited, but have increased in recent years with most observations occurring after the breeding season, most of which are reported by the public. To date we have received 29 re-sighting records from eight different regions outside the Columbia River estuary: the Salish Sea/Puget Sound region (n = 7 banded cormorants re-sighted), western British Columbia (n = 5), outer Washington Coast (n = 4), California coast (n = 4), lower Columbia River (n = 4), interior California (n = 3), northern Oregon Coast (n = 1), and Willamette River valley (n = 1). Currently, no banded double-crested cormorants have been observed at any cormorant colonies in the Columbia Plateau region. Continued banding and re-sighting efforts will allow us to measure inter-colony movement rates of double-crested cormorants to both predict and assess the outcome of various prospective management strategies for double-crested cormorants nesting on East Sand Island.

2.6. Management Feasibility Studies

2.6.1. Habitat Enhancement and Social Attraction Studies

Methods: In 2012, we continued studies to test the feasibility of potential management techniques to help reduce losses of juvenile salmonids to predation by double-crested cormorants in the Columbia River estuary. These studies have sought to determine whether habitat enhancement and social attraction techniques can be used to induce double-crested cormorants to nest at alternative colony sites outside the Columbia River estuary, in particular at sites where cormorants are not known to have previously nested.

In 2012, habitat enhancement (i.e., placement of old tires filled with nesting material) and social attraction techniques (i.e., cormorant decoys and audio playback systems; Kress 2000, Kress and Hall 2002, Roby et al. 2002) were used for a second year on the Corps' tern island in Sump 1B at Tule Lake National Wildlife Refuge and, for the first time, on the Corps' new tern island in Malheur Lake National Wildlife Refuge in an attempt to attract double-crested cormorants to nest at those two sites. We chose Tule Lake Sump 1B and Malheur Lake to continue feasibility studies after previous attempts to attract double-crested cormorants to nest using similar techniques on a floating platform had failed at both Fern Ridge Reservoir in the Willamette Valley (2007-2009) and at Dutchy Lake in the Summer Lake Wildlife Area (2010-2011). Human disturbance and a paucity of breeding age cormorants in these two areas were believed to have played a role in the lack of cormorant nesting activity at either of these sites. We thought that these factors might not pertain at the tern islands on Tule Lake Sump 1B or on Malheur Lake given that double-crested cormorants have previously nested near both of these new tern islands. There is an established arboreal colony of double-crested cormorants at Sodhouse Ranch, which is within sight of the newly-constructed artificial island in Malheur Lake. In addition, high water levels in 2011, the year before the artificial island at Malheur Lake was constructed, created a natural island on the north side of the lake at the Singhus Ranch property, whereupon a small double-crested cormorant nesting colony quickly formed.

At the tern island in Tule Lake Sump 1B during mid-April, we added an additional 6 tires to the 30 tires already in place, and deployed 40 hand-painted decoys of adult double-crested cormorants (Mad River Decoy, Vermont), and two audio playback systems (Murremaid Music Boxes, Maine) on or near the rip-rap located on the southwest side of the island. At the Malheur Lake tern island, we deployed 32 old tires filled with nesting material, 40 hand-painted decoys of adult double-crested cormorants (Mad River Decoys, Vermont), and two audio playback systems (Murremaid Music Boxes, Maine) on or near the rip-rap located on the southeast side of the island. Each audio playback system consisted of a weather-proof box that housed the electronics and batteries, two outdoor speakers, and a solar panel.

Concurrent with monitoring of the Caspian tern colonies on these two islands, the cormorant social attraction plots were scanned each hour for any signs of cormorant presence or activity in or near the cormorant social attraction plots. In addition to the hourly scans, opportunistic observations of cormorants on or around the islands and any disturbance events affecting cormorants that were using the island were recorded.

Results and Discussion: During the 2012 breeding season, double-crested cormorants were regularly seen loafing at the south end of the tern island in Tule Lake Sump 1B, with up to 98 individuals counted on one occasion. Despite this, cormorants did not initiate nesting on or near the social attraction plot in 2012. It should be noted, however, that gulls also did not nest on the tern island in Tule Lake Sump 1B and predation by a raccoon (*Procyon lotor*) caused complete failure of the Caspian tern colony on the island in 2012. The tern colony on the Tule Lake island also failed in 2011, but due to great horned owl (*Bubo virginianus*) predation. These factors, in addition to human activity on the island during monitoring of the Caspian tern colony, could have deterred double-crested cormorants from nesting at the site during 2011-2012, despite the use of social attraction.

Double-crested cormorants were frequently observed loafing at the new Malheur Lake tern island during the 2012 breeding season, with up to 185 individuals counted on the island. Cormorants were also regularly seen flying to and from the social attraction plot during the colony monitors' approach to the island. One cormorant was observed carrying nesting material to the social attraction plot in late June, but no cormorant nesting on the Malheur Lake tern island, either in the social attraction plot or elsewhere, was confirmed. Approximately 430 pairs of double-crested cormorants, however, nested at the Singhus Ranch colony in 2012. Based on the frequency and direction of cormorant flights observed by colony monitors at the Malheur Lake tern island, it is likely that the cormorant social attraction plot on the newly-constructed tern island on Malheur Lake was used by cormorants from the Singhus Ranch colony as a loafing site during foraging trips.

Conclusions: Habitat enhancement and social attraction (i.e., decoys, audio playback systems) have been shown to be highly effective at inducing Caspian terns to nest at sites where they had not previously nested (Kress 2000, Kress and Hall 2002, Roby et al. 2002, Collis et al. 2002b). Pilot studies designed to test the feasibility of using habitat enhancement and social attraction to relocate nesting double-crested cormorants have shown some promise in the past. Using these methods, double-crested cormorants were attracted to nest and nested successfully (raised young to fledging) at two islands, Miller Sands Spit and Rice Island, in the upper Columbia River estuary. Cormorants had made previous attempts to nest at Miller Sands Spit without success prior to the pilot study. They had previously nested successfully at Rice Island, but had been absent from that site for several years before the pilot study enticed them to return. Habitat enhancement and social attraction techniques appear to be effective at establishing double-crested cormorant breeding colonies at sites where nesting attempts have previously occurred. However, results from the three-year feasibility study at Fern Ridge Wildlife Area and the two-year feasibility study at Dutchy Lake in Summer Lake Wildlife Area, plus two years of feasibility studies at Tule Lake Sump 1B and one year of feasibility study at Malheur Lake suggest that these techniques may require longer periods of time to be successful at attracting double-crested cormorants to nest at sites where there is no prior nesting history, especially if there are no other established breeding colonies nearby. As such, the efficacy of habitat enhancement and social attraction techniques to establish new double-crested cormorant colonies outside the Columbia River basin remains uncertain.

2.6.2. Feasibility Studies of Nest Dissuasion Techniques

Methods: In 2012, we repeated and expanded efforts to test the feasibility of dissuading double-crested cormorants from nesting on a portion of their nesting colony on East Sand Island. In 2011, double-crested cormorants were dissuaded from nesting in 15% of the area used by nesting double-crested cormorants in 2010. The dissuasion area was increased in 2012 to 62% of the area used by nesting cormorants in 2010. A privacy fence (2.4 m high by 25 m long) was erected across the cormorant colony (Map 5) and an attempt was made to prevent cormorants from nesting to the east of the fence, while minimizing the disturbance to cormorants nesting to the west of the fence. Two techniques to dissuade cormorants from nesting on the east side of the privacy fence were investigated in concert: human disturbance and destruction of existing cormorant nests (i.e. scattering of sticks used to form nests using rakes or other implements).

The targeted dissuasion area was located on the eastern half of the double-crested cormorant breeding colony on East Sand Island; this area has been occupied by nesting cormorants for several years (Map 5). Nesting substrate was a mix of rocky terrain (rip rap), woody debris, open sandy areas, and vegetated areas characterized by small shrubs. In 2011, approximately 8,400 double-crested cormorant nests were located in the 2012 dissuasion area. The dissuasion area encompassed an area of approximately 6.5 acres, and the linear distance from the privacy fence east to where the eastern-most cormorants nested in 2010 was 0.65 kilometers.

In addition to the privacy fence, a camp, two observation blinds, and a tunnel system were constructed to provide researchers access to the area without disturbing nesting cormorants outside of the targeted dissuasion area. The camp concealed all routine non-hazing researcher activity from cormorants within the dissuasion area, as well as those cormorants nesting west of the privacy fence, and the blinds provided an elevated vantage point for observations of either side of the privacy fence.

Cormorants were first observed in the dissuasion area on 16 April and hazing efforts began on 28 April. The dissuasion area was scanned every half hour from dawn to dusk during each day. During each scan, researchers counted cormorants in the dissuasion area and recorded breeding behaviors (i.e., courtship display, nest building, copulation). Researchers flushed cormorants from the dissuasion area when (1) double-crested cormorants exhibited breeding behaviors, (2) aggregations of 100 or more loafing cormorants were observed in the dissuasion area, or (3) cormorants were present in the dissuasion area prior to civil twilight in the evening; the latter was in order to prevent overnight roosting in the dissuasion area. If no hazing occurred for two hours, the frequency of scans was reduced to every hour. To minimize disturbance to other birds in the dissuasion area (i.e., roosting brown pelicans and nesting glaucous-winged/western gulls) researchers only remained visible on the cormorant colony until cormorants had dispersed and then immediately returned to camp. Following dissuasion activities, researchers remained in the blind to conduct post-dissuasion observations to determine the effectiveness of hazing activities, enumerate any disturbance to brown pelicans, and assess disturbance to cormorants nesting west of the fence. At least one researcher was stationed at the camp from 20 April until 12 June, when daily cormorant dissuasion activities ceased for the season. Under permit, a limited number of double-crested cormorant eggs (not to exceed 250) could be removed from nests in the dissuasion area, if some cormorants laid eggs despite efforts to prevent egg-laying. Egg take would be used to enhance the prospects of successful nest dissuasion on a portion of the East Sand Island cormorant colony and was not used as a means of limiting or reducing nesting success at the colony.

To evaluate where displaced double-crested cormorants might prospect for alternative nest sites if they left the East Sand Island colony, we captured and marked 149 adult double-crested cormorants in the dissuasion area during 20 - 28 April, shortly after their arrival to that part of the colony. All captured double-crested cormorants were banded with a federal numbered metal leg band on one leg and a field-readable plastic leg band engraved with a unique alphanumeric code on the other. Of the 149 banded double-crested cormorants, 12 were fitted with satellite transmitters and 126 were fitted with VHF radio transmitters.

Battery-powered satellite tags weighing ca. 50 g were attached as backpacks using a harness made of Teflon ribbon (Dunstan 1972), modified as described by King et al. (2000). The satellite tags were programmed to collect nighttime roost locations every other night for ca. 50 days, and then once a week for the remainder of their expected battery life of 14 months. The tags transmitted nighttime roost location data to the ARGOS satellite network and data was later retrieved from the website of CLS America, Inc.

VHF radio tags weighing ca. 8 g (1-km detection range, 159 to 160 MHz) were attached to central tail feathers with glue and zip ties as described by Anderson et al. (2004). During several aerial surveys over Washington, Oregon, and northern California, we actively searched for VHF radio-tagged cormorants that might have left the Columbia River estuary. Surveys (n = 12) were conducted between 29 April and 11 July along the Washington Coast (n = 2 surveys), along the Oregon Coast (n = 2), along the lower Columbia River (n = 5), in the Salish Sea/Puget Sound region (n = 3), over the Columbia Plateau (n = 2), and over much of interior Oregon/northeastern California (n = 2). Surveys specifically targeted current and historical double-crested cormorant nesting colonies. We also conducted opportunistic road- and boat-based surveys of several cormorant colonies and roost locations along the northern Oregon coast and lower Columbia River. Finally, weekly scans were conducted at two Columbia Plateau double-crested cormorant colonies, on Foundation Island and at North Potholes Reserve.

In addition to efforts to locate tagged cormorants away from East Sand Island, we regularly scanned for VHF-tagged cormorants at the East Sand Island colony, to identify what portion of tagged cormorants remained at the colony. Researchers scanned for banded and VHF-tagged cormorants from observation blinds daily during the active hazing period (28 April - 12 June), and then several times per week once daily dissuasion activities had ceased. Scans were regularly conducted at dusk when cormorants were most likely to be roosting on East Sand Island, and therefore within detection range of the VHF receivers. To supplement this VHF scanning effort at East Sand Island, we also conducted regular observations from blinds throughout the colony to identify color-banded cormorants that remained at the East Sand Island colony that lacked VHF tags (e.g., the satellite tagged cormorants, cormorants captured in the dissuasion area but not tagged [n = 11], or cormorants with failed/shed VHF or satellite tags).

Results and Discussion: The feasibility study on human disturbance as a means to dissuade nesting double-crested cormorants, in concert with a large visual barrier and destruction of nest structures, was effective at preventing cormorants from nesting in the targeted dissuasion area, which consisted of 62% of the area used by nesting cormorants in 2010. Up to 4,500 cormorants were observed in the dissuasion area prior to hazing, and a maximum of 2,400 individuals were observed in the dissuasion area once hazing began. An average of five (range = 1-19) hazing incursions were conducted in the dissuasion area each day, with the number dependent upon the return rate and subsequent behavior of cormorants in the dissuasion area. While cormorants continued to prospect and initiate nests in the dissuasion area throughout the study period, only four cormorant eggs were known to have been laid in the dissuasion area; three were consumed by gulls and one was collected under permit. No lethal take of cormorant chicks or adults occurred as part of the feasibility study on dissuasion of nesting cormorants.

The necessary hazing period was substantially longer in 2012 (28 April – 12 June) than in 2011 (29 April – 12 May). Several factors may have contributed to a greater need for continued hazing in 2012, including (1) a greater number of cormorants displaced from the dissuasion area, (2) greater site fidelity to nesting areas that had been in use for a longer period, and (3) large scale nest failure in the far western portion of the colony in 2012 due to eagle disturbance (see section 2.2.1) and fewer preferred nesting opportunities west of the 2012 dissuasion fence.

Dissuasion activities caused little or no disturbance to cormorants nesting west of the privacy fence. For example, double-crested and Brandt's cormorants established nests within 1 meter of the privacy fence on the west side of the fence and successfully raised young at those nests. California brown pelicans roosted in and adjacent to the dissuasion area throughout the active hazing period for cormorants, with up to 1,500 brown pelicans observed roosting in the dissuasion area at times. Brown pelicans were disturbed during 22 cormorant hazing events; a maximum of 450 individual brown pelicans were flushed in the largest scale event. Several hundred glaucous-winged/western gulls also nested and raised young in the cormorant dissuasion area.

Based on detections of satellite-tagged and VHF radio-tagged cormorants that had been captured in the dissuasion area, many displaced cormorants conducted dispersal trips of one to several weeks following capture and/or large scale nest failure on the western end of the East Sand Island colony. Immediately following deployment of satellite tags and VHF radio tags on double-crested cormorants captured in the dissuasion area, some of the tagged cormorants left the Columbia River estuary (defined as from the mouth of the river [Rkm 0] upriver to Puget Island; Rkm 74.5). In the first three weeks following capture and tagging, 6 of 11 (55%) satellite-tagged double-crested cormorants were detected outside the Columbia River estuary. Also, 27 of 126 (21%) VHF radio-tagged double-crested cormorants were detected outside the estuary during aerial and ground-based telemetry surveys. Most of the tagged cormorants that left the estuary, however, had returned to the estuary within a month and were regularly detected there during the remainder of the breeding season. In total, satellite-tagged double-crested cormorants visited 21 sites outside the Columbia River estuary in three primary regions (Map 6): the Lower Columbia River, Coastal Washington, and Coastal British Columbia. Similarly, detections of VHF radio-tagged cormorants outside the Columbia River estuary documented the use of 11 sites in the same three regions. Tagged cormorants visited active cormorant breeding colonies in the Columbia River estuary (Astoria-Megler Bridge, channel markers), lower Columbia River (Troutdale transmission towers), coastal Washington (Grays Harbor channel markers, Snohomish River pilings), and coastal British Columbia (Second Narrows Bridge transmission tower). Of note, two VHF-tagged double-crested cormorants relocated to the cormorant colony on the Astoria-Megler Bridge and were regularly detected there throughout the breeding season. No confirmed detections of satellite- or radio-tagged cormorants came from inland sites east of Bonneville Dam, or coastal sites south of Cannon Beach, OR.

Summary: Human hazing, in concert with nest destruction and a large visual barrier, proved to be a feasible method of preventing double-crested cormorants from nesting in a pre-defined area of the East Sand Island cormorant colony. Preventing cormorants from nesting in 62% of their former nesting area was achieved, with little impact to cormorants nesting west of the visual barrier. Compared to the pilot study conducted in 2011, however, cormorant dissuasion activities across a much larger area in 2012 required significant additional effort. Cormorants continued to initiate nests in the dissuasion area for up to eight weeks following the onset of hazing, compared to less than three weeks in 2011. The extended period of prospecting by cormorants could have been due to several factors, including a greater number of cormorants displaced from the dissuasion area, greater site fidelity to nesting areas that had been in use for a longer period, and large scale nest failure in the far western portion of the colony in 2012 due to eagle disturbance and fewer preferred nesting opportunities west of the 2012 dissuasion fence. Human disturbance remains a viable option for effectively preventing cormorants from nesting on a portion of the East Sand Island colony, but requires significant infrastructure, labor-intensive hazing, and daily monitoring of the area for extended periods during the nesting season.

Tracking studies of satellite-tagged and radio-tagged double-crested cormorants, plus observations of banded cormorants displaced from the dissuasion area, suggest that for some cormorants, capture and hazing and/or nest failure were sufficient to induce dispersal trips away from East Sand Island during the cormorant nest initiation period. A large proportion of tagged double-crested cormorants left East Sand Island immediately following tagging, and explored areas of the lower Columbia River, coastal Washington, and coastal British Columbia during these dispersal trips. We identified 21 specific sites where cormorants may aggregate in these regions during prospecting trips. In addition, we did not observe cormorants exploring the Columbia Plateau region or the Oregon Coast (with the exception of one bird detected during one day near Cannon Beach).

Despite dispersal trips outside of the Columbia River estuary by at least 33 tagged cormorants, we found no evidence of permanent emigration from the estuary, however. The only evidence of permanent emigration from East Sand Island was the persistent detection of two VHF tagged cormorants on the Astoria-Megler Bridge. The general pattern of aborted dispersal trips and subsequent high return rates to East Sand Island, suggest that cormorants may display high colony site fidelity if resource managers decide to permanently reduce available nesting habitat in the future. High colony site fidelity may be a result of prolonged nesting history at the site (many individual cormorants having nested at East Sand Island their entire lives), social facilitation by this very large colony, or the lack of suitable nesting opportunities elsewhere. To induce prolonged prospecting or permanent emigration from the Columbia River estuary, it may be necessary to further restrict nesting habitat on East

Sand Island and prevent greater use of alternative nesting sites within the estuary (e.g., the Astoria-Megler Bridge). See BRNW (2013a, 2013b) for more information on the nest dissuasion feasibility studies on East Sand Island during 2008-2012. Data on the dispersal of radio- and satellite-tagged double-crested cormorants from the colony on East Sand Island to other locations, dispersal that was associated with the feasibility studies of nest dissuasion techniques on East Sand Island, can be found in a geospatial database currently in development under contract with the USACE - Portland District.

SECTION 3: OTHER PISCIVOROUS COLONIAL WATERBIRDS

3.1. Distribution

3.1.1. Columbia River Estuary

Methods: In 2012, land-based, boat-based, and aerial surveys were conducted throughout the breeding season to locate piscivorous waterbird colonies in the Columbia River estuary. When possible, ground or photo counts were conducted to estimate the number of adult birds or the number of active nests on colony in 2012. Precise counts of the number of adults on colony are available for gulls in 2009 (based on multiple counts of adults on colony in aerial photos; see Section 1.2.1 for a description of methods), and are presented here. Peak numbers of California brown pelicans using East Sand Island as a nighttime roost in 2012 were determined by periodic boat-based surveys conducted in the evening from mid-May through mid-September.

Results and Discussion: A total of seven nesting colonies of piscivorous waterbirds other than Caspian terns and double-crested cormorants (i.e., glaucous-winged/western gulls, ring-billed gulls, Brandt's cormorants, pelagic cormorants, and American white pelicans) were identified at four different locations in the Columbia River estuary: East Sand Island, Rice Island, Miller Sands Spit, and the Astoria-Megler Bridge. In addition, East Sand Island was once again the location of a large post-breeding, nighttime roost for California brown pelicans.

Gulls − Based on surveys conducted in 2012, glaucous-winged/western gulls nested at colonies on East Sand Island, Rice Island, and Miller Sands Spit, while ring-billed gulls nested just on East Sand Island (Map 1). Based on one count of aerial photography taken of East Sand Island on 10 June, we estimate that ca. 3,400 glaucous-winged/western gulls and ca. 1,500 ring-billed gulls were on their respective colonies.

In 2009, glaucous-winged/western gulls nested on East Sand Island (ca. 6,200 adults counted on colony), Rice Island (ca. 1,750 adults counted on colony), and Miller Sands Spit (ca. 160 adults counted on colony). In total, there were ca. 8,100 adult glaucous-winged/western gulls counted on colonies in the Columbia River estuary during the

2009 nesting season, which was a 15% increase in the number of glaucous-winged/western gulls counted on colonies in the Columbia River estuary compared to 1998 (ca. 7,050 gulls). The most recent year prior to 2009 when a comprehensive survey of gull colonies in the estuary was conducted was 1998 (Collis et al. 2002a). There has been a major increase in the number of ring-billed gulls nesting in the Columbia River estuary since 1998; 2,550 ring-billed gulls were counted on colonies in the Columbia River estuary during the 2009 nesting season, compared to less than 100 in 1998 (Collis et al. 2002a). Ring-billed gulls, which only nested on Miller Sands Spit in 1998 (Collis et al. 2002a), nested on East Sand Island (ca. 2,250 adults counted on colony) and Rice Island (ca. 310 adults counted on colony) during 2009.

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 2012, the first California brown pelicans were observed roosting on East Sand Island on 17 March, more than a month earlier than was observed in 2011. The weekly count of brown pelicans roosting on East Sand Island peaked in late July at about 10,600 roosting birds, less than the peak counts in 2010 (ca. 11,500 individuals) and 2011 (ca. 14,225 individuals). As was the case in 2009 and 2010, we observed breeding behavior by brown pelicans roosting on East Sand Island (i.e., courtship displays, nest-building, attempted copulations) in 2012, but there has been no evidence of egg-laying by brown pelicans on East Sand Island in any year. Bald eagle activity was the most common source of non-researcher related disturbance to brown pelicans roosting on East Sand Island in 2012.

American White Pelicans – The first nesting record of American white pelicans in the Columbia River estuary occurred at Miller Sands Spit in the upper Columbia River estuary during 2010; roughly 100 adults were counted on colony on 1 July 2010. In 2011, the number of American white pelicans nesting at Miller Sands Spit colony was about 97 breeding pairs, based on counts of nests during chick-banding. In 2012, the colony size was estimated to be 122 breeding pairs, based on counts of attended nests visible in aerial photography taken of the colony near the peak of the incubation period. While estimates of nesting success are not available, American white pelicans were successful in raising some young at the Miller Sands Spit colony in each year during 2010-2012.

Brandt's and Pelagic Cormorants − A small colony of Brandt's cormorants consisting of 44 breeding pairs became established on East Sand Island within the double-crested cormorant colony in 2006. The numbers of Brandt's cormorants breeding on East Sand Island have since increased steadily, and in 2012 about 1,684 pairs of Brandt's cormorants nested on East Sand Island (Figure 75). This Brandt's cormorant colony is now one of the largest of its kind in Oregon and Washington, and the only site in the Columbia River estuary where Brandt's cormorants are known to nest. 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).

At least 106 breeding pairs of pelagic cormorants nested on the Astoria–Megler Bridge in 2012. 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.

3.1.2. Columbia Plateau

Methods: In 2012, we conducted aerial surveys in the Columbia Plateau region looking for colonies of piscivorous waterbird species other than Caspian terns and double-crested cormorants (i.e., California gulls, ring-billed gulls, and American white pelicans). Additionally, periodic land- and boat-based surveys were conducted throughout the breeding season to verify nesting by piscivorous waterbirds at colony sites identified during aerial surveys. For colonies of special interest, high-resolution, vertical aerial photography was taken during the late incubation period and three independent counts of individual birds were conducted using an in-house GIS workstation to estimate colony size in 2012. The last comprehensive survey of colony size for gulls on the mid-Columbia River was conducted in 2009 (based on multiple counts of adults on colony in aerial photography; see Section 1.2.1 for a description of methods), and the 2009 gulls counts are presented here.

Results and Discussion: A total of 10 gull colonies and one American white pelican colony were identified in the Columbia Plateau region during 2012.

Gulls – In 2012, California and/or ring-billed gulls were confirmed nesting at colonies at four different islands in the Columbia River between The Dalles Dam and Rock Island Dam: Miller Rocks (river km 333), Blalock Islands ("Anvil Island" and Straight Six Island; river km 445), Crescent Island (river km 510), and Island 20 (river km 545; Map 1). In addition, California and/or ring-billed gulls were confirmed nesting at colonies on five different islands located in the Columbia Plateau region off the mid-Columbia River: Goose Island in Potholes Reservoir, Harper Island in Sprague Lake, and three different islands near the southern end of Banks Lake (i.e., Twining Island, Goose Island, and an unnamed island). In 2011, all nesting attempts by gulls on Three Mile Canyon Island in the John Day Pool failed in early June, and they did not attempt to renest there in 2012. Although the causes for nest failure and colony abandonment at Three Mile Canyon Island are unknown, fresh raccoon tracks and evidence of human presence on the island were discovered in late May of 2011. Following the abandonment of the large California gull colony on Three Mile Canyon Island (ca. 6,200 adults were counted on-colony in 2009), there was a commensurate increase in the number of California gulls nesting in the Blalock Islands in 2012. In 2009 no nesting California gulls were noted nesting on the island in the Blalock Islands (“Anvil Island”) where ca. 7,300 adults were counted on-colony in 2012. The large gull colony on Island 18 (river km 553) was abandoned in 2008, due apparently to a combination of coyote predation and human disturbance, and has not been re-colonized since. Precise estimates of gull colony size (i.e., adults on colony) on islands in the Columbia Plateau region during 2012 were only obtained for Miller Rocks, Crescent Island, and Goose Lake/Potholes, where ca. 4,500 individuals, ca. 7,200 individuals, and ca. 12,000 individuals, respectively, were counted. The vast majority of gulls nesting at colonies on Miller Rocks and Crescent Island were California gulls, while the gulls nesting at Goose Island/Potholes were a mix of ca. 31% California gulls and ca. 69% ring-billed gulls.

In 2009, a complete census of gull colonies on islands in the Columbia Plateau region was conducted, and a total of ca. 41,700 adult gulls were counted on colonies on the mid-Columbia River from The Dalles Dam to Rock Island Dam (Figure 76), 22% fewer than the number counted at colonies in the same stretch of river during 1998 (ca. 53,200; Collis et al. 2002a). The apparent decline in regional gull breeding population was largely due to reductions in numbers of gulls counted on colonies in the Richland, WA area (Islands 18, 19, and 20) and on Three Mile Canyon Island. At the Richland Islands ca. 35,000 gulls were counted in 1998 and ca. 19,000 gulls were counted in 2009, while at Three Mile Canyon Island ca. 11,100 gulls were counted in 1998 and ca. 6,200 gulls were counted in 2009 (Figure 76, Collis et al. 2002a). Despite this overall decline in the number of gulls counted on breeding colonies in the mid-Columbia River from 1998 to 2009, three colonies increased in size during this period. The gull colony on Miller Rocks increased from ca. 2,200 gulls counted on-colony in 1998 to ca. 6,000 gulls in 2009. The gull colony in the Blalock Islands increased from 0 nesting gulls present in the island group during 1998 to ca. 1,600 gulls counted on-colony in 2009. The gull colony on Crescent Island increased from ca. 4,600 gulls counted on-colony in 1998 to ca. 8,600 gulls in 2009 (Figure 76, Collis et al. 2002a). The near doubling in the size of the California gull colony on Crescent Island over the last decade is particularly interesting because there has been a concurrent decline in the size of the Crescent Island Caspian tern colony by nearly 50%. No gull breeding colonies were detected on the lower Snake River during 2009-2012, nor has there been any confirmed breeding by gulls on the lower Snake River since our research began in 1997 (Collis et al. 2002a). The total number of gulls nesting at colonies on the mid-Columbia River in 2009 was approximately equally divided between California gulls and ring-billed gulls (Figure 76).

In 2009, California and ring-billed gulls were also nesting at colonies on Goose Island in Potholes Reservoir (ca. 13,000 adults counted on-colony), on Harper Island in Sprague Lake (ca. 6,300 adults counted on-colony), and on Twining Island (ca. 250 adults counted on-colony) and Goose Island (ca. 2,600 adults counted on-colony), both at the southern end of Banks Lake (Map 1). A total of ca. 22,200 gulls were counted on these four off-river colonies in 2009, roughly half the number of gulls counted on colonies located on islands in the mid-Columbia River.

American White Pelicans – We conducted boat-based counts of American white pelicans at the colony on Badger Island in the mid-Columbia River each week during the 2012 nesting season (Map 1). Badger Island is the site of the only known nesting colony of American white pelicans in the State of Washington, and the species is listed as endangered by the State. Consequently, the island is closed to both the public and researchers in order to avoid human disturbance to nesting pelicans that might cause pelicans to abandon the breeding colony. High-resolution, vertical aerial photography was taken of the colony during the incubation period in order to estimate colony size in 2012. Complete counts of active pelican nests on Badger Island are not possible from the water or from the air because most nests are located in the interior of the island and many are concealed under thick, brushy vegetation. However, most pelicans present on the island were visible in the aerial photography. We did not correct counts of adult pelicans from aerial photography to estimate the number of breeding pairs (as we do for Caspian terns), but instead used numbers of adult pelicans from the aerial photography as an index to the number of breeding pairs utilizing Badger Island. As it was only possible to obtain index counts of adults and juvenile pelicans at the Badger Island colony; it was not possible to estimate nesting success (average number of young raised per breeding pair).

A mean of 2,083 adult American white pelicans were counted in the aerial photography taken in 2012, down from 2,228 white pelicans counted on Badger Island in 2011. American white pelicans first nested on Badger Island in 1997 (ca. 20 breeding pairs); prior to 1997 white pelicans nested on nearby Crescent Island for several years (Figure 77). The American white pelican colony on Badger Island experienced substantial growth from 1997 to 2011, increasing by more than two orders of magnitude during that period, before leveling off in 2012 (Figure 77). Available nesting habitat on Badger Island does not appear to be a factor limiting the size of the white pelican colony.

Our boat-based counts resulted in a maximum count of 207 juvenile white pelicans on 16 July 2012. For comparison, our annual maximum counts of juvenile pelicans during boat-based surveys of the Badger Island colony have ranged from 56 to 329 during the period 2002-2011.

3.1.3. Coastal Washington

Comprehensive surveys of nesting gulls, Brandt's cormorants, or pelagic cormorants were not conducted along the coast of Washington in 2012.

3.1.4. Interior Oregon and Northeastern California

Methods: In 2012, we conducted three aerial surveys (13 June, 10 July, and 3 August) in interior Oregon and northeastern California (Map 4) looking for breeding colonies of piscivorous waterbird species in addition to Caspian terns and double-crested cormorants (i.e., ring-billed gulls, California gulls, and American white pelicans). We also conducted periodic land- and boat-based surveys throughout the breeding season to verify nesting by these piscivorous colonial waterbird species at sites that were identified during aerial surveys.

Results and Discussion: Based on aerial, land-based, and boat-based surveys in 2012, gulls were confirmed to be nesting at 12 different locations and American white pelicans were confirmed to be nesting at five different locations in interior Oregon and northeastern California.

Gulls – In 2012, ring-billed and California gulls nested at six Corps-constructed islands that had been built as alternative nesting habitat for Caspian terns: the Crump Lake tern island in the Warner Valley, OR (> 1,000 breeding pairs of California and ring-billed gulls); the Sheepy Lake tern island in Lower Klamath NWR, CA (> 1,000 breeding pairs of California and ring-billed gulls); the Tule Lake tern island in Sump 1B at Tule Lake NWR, CA (1 breeding pair of ring-billed gulls); the East Link tern island in Summer Lake Wildlife Area, OR (ca. 500 breeding pairs of California and ring-billed gulls); the Gold Dike tern island in Summer Lake Wildlife Area, OR (< 20 breeding pairs of ring-billed gulls), and the recently constructed tern island at Malheur NWR, OR (ca. 5 breeding pairs of ring-billed gulls). In addition, gull breeding colonies were noted at six additional sites during aerial surveys: Meiss Lake, CA (> 1,000 breeding pairs); Swan Lake, OR (> 500 breeding pairs); Clear Lake NWR, CA (> 500 breeding pairs); Big Sage Reservoir, CA (ca. 200 breeding pairs); Pelican Lake in the Warner Valley, OR (ca. 100 breeding pairs); and Singhus Ranch in Malheur Lake, OR (> 500 breeding pairs). Counts of gulls on the Tule Lake Sump 1B tern island in Tule Lake NWR, CA usually numbered between 50 and 100 individuals, but only one gull nest was confirmed on the island. Gulls were successful in rearing at least some young on at least six of the 12 colonies where nesting was confirmed (Crump Lake tern island, Sheepy Lake tern island, East Link tern island, Malheur Lake tern island, Pelican Lake, and Singhus Ranch), but were unsuccessful in rearing young at four of the 12 gull colonies (Tule Lake tern island, Gold Dike tern island, Meiss Lake, and Swan Lake). Nesting failures at Meiss Lake and Swan Lake were primarily attributable to dropping water levels at these two colony sites after nest initiation, which left the islands land-bridged and susceptible to terrestrial predators. Nest failure at the Tule Lake tern island can be attributed to predation by a raccoon (*Procyon lotor*). The cause of the gull nesting failure at the Gold Dike tern island was not conclusively determined, but was also likely due to disturbance by avian and/or mammalian predators. Nesting success at the other two gull colonies in interior Oregon and northeastern California (i.e., Big Sage Reservoir and Clear Lake NWR) was not confirmed.

American White Pelicans – In 2012, American white pelicans nested at Upper Klamath NWR (> 200 breeding pairs), Sheepy Lake in Lower Klamath NWR (ca. 75 breeding pairs), Clear Lake NWR (ca. 800 breeding pairs), Pelican Lake in the Warner Valley (ca. 90 breeding pairs), and Singhus Ranch at the north side of Malheur Lake (ca. 800 breeding pairs). American white pelicans were successful in fledging some young at all of these colonies in 2012.

3.2. Diet Composition

3.2.1. Columbia River Estuary

Gulls − We have not collected diet composition data for gulls nesting in the Columbia River estuary for over a decade. Our previous research indicated that glaucous-winged/western gulls nesting in the Columbia River estuary consumed primarily fish (Collis et al. 2002a). In general, gulls nesting on Rice Island (river km 34) ate mostly riverine fishes, whereas gulls nesting on East Sand Island (river km 8) ate primarily marine fishes. In 1997 and 1998, juvenile salmonids comprised 11% of the diet (by mass) of glaucous-winged/western gulls nesting on Rice Island/Miller Sands Spit and 4% of the diet of glaucous-winged/western gulls nesting on East Sand Island. At least some of the juvenile salmonids found in stomach samples of gulls from Rice Island/Miller Sands Spit had been kleptoparasitized (i.e., stolen) from Caspian terns, which nested at the nearby colony on Rice Island throughout the 1990s (Collis et al. 2002a). In 2012, kleptoparasitism rates (proportion of fish delivered by Caspian terns to the East Sand Island colony that were subsequently stolen by gulls) for salmonid smolts averaged 8%; steelhead smolts were kleptoparasitized by gulls at a higher rate (27%) than were salmon smolts (7%). These data indicate that gulls nesting in close proximity to Caspian terns on East Sand Island have a small impact on survival of juvenile salmonids by reducing the number of salmonid smolts successfully delivered to the tern colony.

California Brown Pelicans − Brown pelicans feed primarily on schooling marine forage fishes and, near their breeding grounds in southern California, the diet of brown pelicans consists almost entirely of anchovies (Engraulidae) and sardines (Clupeidae; Tyler et al. 1993). There is an abundance of these and other schooling marine forage fishes near East Sand Island during the summer (Emmett et al. 2006), and presumably these forage fish species comprise the majority of the diet of brown pelicans that roost on East Sand Island.

Brandt's and Pelagic Cormorants − We have not collected diet data from Brandt's or pelagic cormorants nesting in the Columbia River estuary as part of this study. Based on a study conducted in 2000, the frequency of occurrence of juvenile salmonids in the diet of Brandt's cormorants nesting in the Columbia River estuary was estimated at 7.4% (Couch and Lance 2004). Very little is known about the diet of pelagic cormorants along the Oregon coast (Hodder 2003), but the species is believed to forage primarily on marine and estuarine fishes. Due to small colony sizes and the previously-documented diet preferences of Brandt's and pelagic cormorants, the impacts of these two cormorant species on survival of juvenile salmonids from the Columbia River basin are expected to be negligible. Smolt PIT tag recoveries on the Brandt's cormorant colony on East Sand Island in 2012 support this conclusion (see Section 3.3.1).

3.2.2. Columbia Plateau

Gulls – We have not collected diet composition data from gulls nesting on islands in the Columbia River above Bonneville Dam for over a decade. Our previous research indicated that there were small amounts of fish in general, and salmonids in particular, in the diets of California and ring-billed gulls nesting at colonies on islands in the mid- and upper Columbia River during the late 1990s (Collis et al. 2002a). The only Columbia River gull colonies where juvenile salmonids were found in diet samples were the California gull colonies on Little Memaloose Island (15% of total biomass from stomach contents; this colony is no longer active) and Miller Rocks (3% of total biomass from stomach contents; Collis et al. 2002a). Gulls from these two colonies were known to prey on juvenile salmonids at the nearby The Dalles and John Day dams (J. Snelling, OSU, pers. comm.; Zorich et al. 2010, 2011, 2012). Gulls from other up-river colonies may occasionally prey on juvenile salmonids when available in shallow pools or near hydroelectric dams (Ruggerone 1986; Jones et al. 1996), but our results from the late 1990s suggested that, at the level of the breeding colony, juvenile salmonids were a minor component of the diet. Despite this, gull colonies in the Columbia Plateau region can be large (several thousand breeding pairs; Figure 76) and impacts to survival of juvenile salmonids may, in some cases, be comparable to those of nearby Caspian tern and double-crested cormorant colonies, which are much smaller. For example, pilot studies of PIT-tag recovery on gull colonies conducted in 2012 (see Section 3.2.2 and Appendix A) suggest that predation rates on salmonids by gulls nesting at certain colonies in the Columbia Plateau region may be comparable to those of Caspian terns and double-crested cormorants nesting at colonies in the same region.

California gulls that nest at the periphery of the Caspian tern colony on Crescent Island may have a negative effect on survival of juvenile salmonids because some individuals kleptoparasitize (i.e., steal) juvenile salmonids from terns as they return to the colony to feed their mates and young. On an average foraging trip, however, breeding adult terns catch several fish and, of these fish, the majority are consumed by the adult away from the colony in order to meet the adult's energy requirements. A minority of the fish captured by a breeding adult tern are brought back to the colony to feed its mate (pre-chick rearing) or young. Only these fish are subject to kleptoparasitism by gulls. In 2012, kleptoparasitism rates on salmonid smolts delivered by Caspian terns to the Crescent Island colony averaged 19%. As was observed at East Sand Island, kleptoparasitism rates were higher on steelhead smolts (55%) than on salmon smolts (14%), suggesting that gulls prefer, or find it easier, to steal larger fish. These rates are useful in comparing gull kleptoparasitism rates among tern colonies and evaluating the relative susceptibility of different species of smolts to gull kleptoparasitism, but they are not representative of the proportion of all salmonid smolts caught by Caspian terns that were subsequently stolen by gulls (i.e., the vast majority of fish captured by terns are not subject to gull kleptoparasitism). Therefore, empirical data on the cumulative impacts on smolt survival associated with gull kleptoparasitism are not readily available. Given that (1) California gulls nesting at Crescent Island significantly out-number Caspian terns nesting there, and (2) gulls kleptoparasitize only a small proportion of the smolts captured by adult Caspian terns nesting at the colony (most smolts captured by terns are immediately consumed by the tern and thus not available for gulls to steal), it is unlikely that smolts kleptoparasitized by gulls fulfill more than a very small fraction of the food and energy requirements of the California gulls nesting on Crescent Island.

American White Pelicans – We did not collect data on diet composition of American white pelicans nesting on Badger Island because of the conservation status of this species in Washington. Based on smolt PIT tag detections on the Badger Island pelican colony, white pelicans do not appear to be a substantial source of mortality for smolts out-migrating in the mid-Columbia River; however, data on the rates at which PIT tags ingested by white pelicans are subsequently deposited on the Badger Island breeding colony are currently lacking (see Section 3.3.2). Regardless, the Badger Island white pelican colony may continue to grow, and an increasing number of non-breeding white pelicans have been noted along the mid-Columbia and lower Snake rivers, where they are often observed foraging below mainstem hydroelectric dams (Tiller et al. 2003, authors' unpublished data). In addition, significant numbers of white pelicans have been observed at several sites in the Yakima River basin (A. Stephenson, Yakima Klickitat Fisheries Project, pers. comm.) and elsewhere on the mid-Columbia and Snake rivers (see Section 5), pelicans that were presumably foraging on out-migrating juvenile salmonids. The impact of breeding and non-breeding American white pelicans on survival of juvenile salmonids from the upper Columbia River and Snake River basins is therefore not well understood.

3.2.3. Coastal Washington

Diet data were not collected at other piscivorous waterbird colonies along the Washington coast (see Section 3.2.1 for a general description of the diet of other piscivorous waterbirds nesting at estuary/coastal colonies).

3.2.4. Interior Oregon and Northeastern California

Although no diet data were collected at colonies of other piscivorous waterbirds in interior Oregon and northeastern California, PIT tags were recovered and used to evaluate impacts of avian predation on sucker species of conservation concern (see Section 3.3.4).

3.3. Predation Rates Based on Smolt PIT tag Recoveries

3.3.1. Columbia River Estuary

Methods: The methods for calculating predation rates on juvenile salmonids based on PIT tag recoveries at the Brandt's cormorant colony on East Sand Island are the same as those described in Section 1.4.1.

Efforts to recover PIT tags from the American white pelican colony on Miller Sands Spit were planned for 2012. Dredged material deposited on Miller Sands Spit after the nesting season and prior to PIT tag recovery, however, prevented this work in 2012. Efforts to recover PIT tags from areas on East Sand Island that were used by roosting brown pelicans were also planned for 2012, but these areas were heavily used by roosting double-crested cormorants and glaucous-winged/western gulls throughout the season, which compromised our ability to attribute recovered PIT tags to a specific bird species (i.e., brown pelicans).

We applied estimates of smolt PIT tag deposition rates from double-crested cormorants nesting on East Sand Island to estimate predation rates on smolts by Brandt's cormorants nesting on East Sand Island, as there are currently no estimates of on-colony PIT tag deposition rates by Brandt's cormorants (Table 2).

Results and Discussion: Following the 2012 nesting season, 506 smolt PIT tags (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2012 migration year were recovered on the Brandt's cormorant colony at East Sand Island (Table 5). In 2012, the Brandt's cormorant colony and the double-crested cormorant colony on East Sand Island were highly intermixed; thus, detection efficiency was measured for both colonies using the same groups of sown control tags (Table 4). Unlike previous years, recoveries of smolt PIT tags in 2012 could not be definitively separated into tags deposited by Brandt's cormorants versus those deposited by double-crested cormorants due to the intermixing of nests of the two species on the colony. Estimates of smolt predation rates associated with the Brandt's cormorant colony in 2012 were therefore based on tags recovered from "mixed use" areas and may over-estimate (inflate) the impacts of predation by Brandt's cormorants on survival of salmonid smolts because an unknown number of the PIT tags recovered from these mixed use areas were deposited by double-crested cormorants, not Brandt's cormorants.

Of the PIT-tagged juvenile salmonids last detected passing Bonneville or Sullivan dams (Map 1), predation rates by Brandt's cormorants were $\leq$ 0.2% per ESU, based on PIT tag recoveries on the mixed-use Brandt's cormorant colony in 2012 (Table 5). Although predation rates were highest on Middle Columbia River steelhead (0.2%) and upper Willamette spring Chinook (0.2%), predation rates were so small that differences between species and ESUs were not readily discernible nor likely biologically meaningful. Again, deposition of some PIT tags by double-crested cormorants likely inflates predation rate estimates for Brandt's cormorants to an unknown degree. Even with this caveat, however, predation rates on smolts by Brandt's cormorants nesting on East Sand Island remained among the lowest estimates of all the piscivorous waterbird colonies evaluated in 2012 (Tables 5 - 9).

PIT tags collected from the Brandt's cormorant colony on East Sand Island during 2009-2012 provide evidence that Brandt's cormorants consumed far fewer salmonid smolts per capita than double-crested cormorants or Caspian terns nesting on East Sand Island (BRNW 2012). Several factors may account for this. First, Brandt's cormorants are considered a pelagic seabird that usually forages for prey in the marine environment, where non-salmonid prey types (e.g., anchovy, herring, smelt, and others) are common. 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 from that of Caspian terns and double-crested cormorants in the 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 (FPC 2012). Finally, relative to double-crested cormorants, Brandt's cormorants are smaller (by body mass), and have lower daily food requirements.

3.3.2 Columbia Plateau

Methods: The methods for calculating predation rates on juvenile salmonids based on PIT tag recoveries at the American white pelican colony on Badger Island and at gull colonies on Miller Rocks, Crescent Island, and Goose Island/Potholes Reservoir are similar to those described for Caspian tern and double-crested cormorant colonies in Section 1.4.1 and 2.4.1. One notable difference, however, relates to the use of PIT tag deposition rates to correct or adjust minimum estimates of avian predation rates on smolts to best estimates of avian predation rates. No deposition rate data exist for American white pelicans and, consequently, only minimum estimates of predation rates (those adjusted for detection efficiency, but not for deposition rate) were available in 2012.

Data on PIT tag deposition rates for California gulls were collected as part of pilot studies at gull colonies on Crescent Island and Miller Rocks in 2012 (see Table 2; Appendix A); these preliminary estimates of PIT tag deposition rates were applied to all gull colonies (California and ring-billed gulls) scanned for PIT tags on the Columbia Plateau following the 2012 nesting season.

Results and Discussion: Following the 2012 nesting season, a total of 2,423 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead, combined from all releases) from the 2012 migration year were recovered on the Miller Rocks gull colony, a colony where the vast majority of nesting gulls are California gulls (Table 3). Control tags sown on the colony prior to and after the nesting season (n = 100) indicated that detection efficiency ranged from 68% to 91% for tags deposited between 1 April and 31 July (Table 4).

Once adjusted for PIT tag detection rates and deposition rates (Table 2; Appendix A), predation rates on smolts by gulls nesting at Miller Rocks ranged from 6.2% for Upper Columbia River steelhead to 0.5% for Snake River spring/summer Chinook salmon (Table 5). Predation rates on Upper Columbia River steelhead (6.2%; 95% c.i. = 3.9 – 8.9%), Snake River sockeye (5.4%; 95% c.i. = 3.1 – 8.3%), and Snake River steelhead (3.9%; 95% c.i. = 2.7 – 5.5%) were particularly notable because these estimates are substantially higher than previously-reported estimates that either did not incorporate corrections for PIT tag deposition rate (Evans et al. 2012) or used a deposition rate measured for Caspian terns (Lyons et al. 2011b). For example, using an assumed deposition rate of 70% (the best available data at the time), Lyons et al. (2011b) estimated gull predation rates of ≤ 2% on all salmonids ESUs during 2007-2010. Based on a deposition rate of 17% (the average estimated gull deposition rate based on 2012 pilot studies), however, predation rates by gulls nesting on Miller Rocks are similar to or greater than predation rates by Caspian tern and double-crested cormorants nesting at Crescent Island and Foundation Island, respectively, in McNary Pool during 2012 (Table 6). As described in Appendix A (Deposition Studies), however, results for gull PIT tag deposition rates were from a single year of study and may be revised as further data on smolt PIT tag deposition rates are collected and analyzed. Finally, due to the large size of the Miller Rocks gull colony (ca. 4,500 adults counted on colony), estimates of per capita (per bird) predation rates remain substantially less than those of Caspian terns nesting at either Crescent Island or Goose Island, or double-crested cormorants nesting at Foundation Island in the Columbia Plateau region because these tern and cormorant colonies are an order of magnitude smaller.

A total of 2,132 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead, combined from all releases) from the 2012 migration year were recovered on the Crescent Island gull colony (Table 3), a colony where the vast majority of nesting gulls are California gulls. Control tags sown on the colony (n = 100) indicated that detection efficiency ranged from 46% to 96% for tags deposited between 1 April and 31 July (Table 4). Because of the presence of the Caspian tern colony on Crescent Island, however, some of the smolt PIT tags recovered on the Crescent Island gull colony were likely from smolts initially captured by Caspian terns and subsequently kleptoparasitized by gulls. Consequently, the total number of smolt PIT tags on the Crescent Island gull colony, and the resultant estimates of predation rates on smolts, include smolts initially captured by Caspian terns and kleptoparasitized by gulls.

Similar to estimates of smolt predation rates by gulls nesting at Miller Rocks, the use of on-colony PIT tag deposition rates from pilot studies on gulls increased the estimate of smolt predation rates by Crescent Island gulls nearly six-fold (Table 6), when compared to minimum estimates of gull predation rates that only included adjustments for PIT tag detection efficiency. Once adjusted for PIT tag deposition rates as well, smolt predation rates by gulls nesting at Crescent Island ranged from 4.1% for Snake River steelhead to < 0.1% for Upper Columbia River summer/fall Chinook salmon (Table 6). Predation rates on Snake River steelhead (4.1%; 95% c.i. = 2.6 – 5.6%) and Upper Columbia River steelhead (4.0%; 95% c.i. = 2.3 – 5.9%) were particularly notable because these estimated predation rates are substantially higher than previously reported (Evans et al. 2012), and similar to or greater than estimated predation rates by Caspian terns and double-crested cormorants nesting at colonies in McNary Pool during 2012 (Table 6). Similar to results from the Miller Rocks gull colony, per capita (per bird) impacts of Crescent island gulls on smolt survival are considerably less than those of Crescent Island terns and Foundation Island cormorants because the size of the Crescent Island gull colony was much larger (ca. 7,200 adults) in 2012.

Higher predation rates on steelhead ESUs compared to salmon ESUs by gulls nesting on Crescent Island could be related to gulls disproportionately kleptoparasitizing steelhead smolts compared to salmon smolts from Caspian terns nesting on Crescent Island. Adkins et al. (2011) observed that kleptoparasitism rates by Crescent Island gulls on steelhead smolts were 2 to 3 times higher than those on salmon smolts, presumably because of the larger average size of steelhead smolts compared to salmon smolts. An unknown but potentially large fraction of all smolt PIT tags annually deposited on the Crescent Island gull colony may be from smolts originally captured by Caspian terns nesting on Crescent Island. Unlike Crescent Island gulls, gulls nesting on Miller Rocks must capture their own fish prey, as there is no Caspian tern colony on or near Miller Rocks.

Following the 2012 nesting season, a total of 164 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead, combined from all releases) from the 2012 migration year were recovered on the gull colony at Goose Island/Potholes Reservoir (Table 3), a colony that consists of both ring-billed and California gulls. Control tags sown on the colony prior to and after the nesting season (n = 100) indicated that detection efficiency ranged from 16% to 64% for tags deposited between 1 April and 31 July (Table 4). Similar to gull predation rates at the Crescent Island gull colony, predation rates for gulls nesting at the Goose Island colony included PIT tags from smolts initially captured by Caspian terns nesting on Goose Island that were subsequently kleptoparasitized by gulls.

Predation rates by gulls nesting at Goose Island were ≤ 0.1% for all salmonid ESUs, except Upper Columbia River steelhead (Table 7), even after adjusting for detection efficiency (Table 4) and on-colony PIT tag deposition rate (17%; Table 2). Estimated predation rate by gulls nesting at Goose Island/Potholes on Upper Columbia River steelhead were 2.8% (95% c.i. = 1.1 – 5.6%; Table 7). The much higher predation rates on steelhead smolts, compared to smolts of other salmonid ESUs, by gulls nesting at Goose Island were similar to results from the Crescent Island gull colony. At both of these gull colonies, higher predation rates on steelhead ESUs compared to salmon ESUs could be related to gulls disproportionately kleptoparasitizing steelhead smolts compared to salmon smolts (Adkins et al. 2011). Smolt predation rates at the Goose Island gull colony supported this hypothesis because predation rates were extremely low ($\leq$ 0.1%) for all salmonid ESUs except Upper Columbia River steelhead, the ESU known to be subject to high predation rates by Caspian terns nesting on Goose Island/Potholes (Table 7).

Following the nesting season, 2,682 PIT-tagged smolts (Chinook, sockeye, coho, and steelhead, combined from all releases) from the 2012 migration year were recovered on the American white pelican colony on Badger Island (Table 3). Pelicans first arrived at the Badger Island colony in early March during 2012, earlier than in previous years, which precluded access to the island and prevented the sowing of control PIT tags to estimate detection efficiency. Consequently, the estimate of PIT tag detection efficiency used in 2012 was the average detection efficiency measured on Badger Island during 2006 – 2010 (Table 4).

Unlike all other estimates of predation rates derived from on-colony PIT tag recoveries in 2012, estimates of predation rate by American white pelicans nesting on Badger Island were not adjusted for on-colony PIT tag deposition rates, and therefore are minimum estimates (Table 2). At this time, no data are available to evaluate on-colony PIT tag deposition rates by American white pelicans, and use of deposition rates based on studies of Caspian terns, double-crested cormorants, or California gulls as a proxy would be highly suspect because inter-specific differences in deposition rates have been large. Furthermore, American white pelicans are very different in body size, breeding biology, and nesting behavior compared to Caspian terns, double-crested cormorants, or California gulls.

Of the PIT-tagged smolts last detected passing either Lower Monumental Dam on the Snake River or Rock Island Dam on the Columbia River (Map 1), minimum predation rates by Badger Island white pelicans were $\leq$ 0.2% for each salmonid ESU evaluated (Table 6). Minimum predation rates from 2012 were similar to those recorded during 2007-2011 (Evans et al. 2012, BRNW 2012). Minimum predation rates on smolts originating from Middle Columbia River ESUs (fish that enter the mainstem river downstream of Lower Monumental and Rock Island dams), however, are unknown and may differ from minimum predation rates on Upper Columbia River and Snake River salmonid populations. Furthermore, of the species of piscivorous colonial waterbirds evaluated by this study, American white pelicans have the greatest documented foraging radius from their breeding colony (upwards of 300 km) and, consequently, white pelicans could be commuting longer distances from the Badger Island colony to forage on smolts.

In addition to PIT tags from juvenile anadromous salmonids, we continue to find PIT tags from adult anadromous salmonids on the Badger Island white pelican colony; 12 PIT tags from adult salmonids were deposited by Badger Island pelicans in 2012. PIT tags were from adult steelhead (n = 6), adult sockeye salmon (n = 5), and adult Chinook salmon (n = 1 jack salmon) tagged at the Bonneville Dam fishway during upstream migration or as post-spawn steelhead (kelts) returning to the ocean. Fish ranged in size from 48 cm (sockeye salmon tagged at Bonneville fishway) to 65 cm (steelhead tagged at Bonneville fishway).

SECTION 4: STEELHEAD SUSCEPTIBILITY STUDY

In 2012 we continued a study initiated in 2007 to investigate how smolt condition, origin, and run-timing influence smolt susceptibility to avian predation. We hypothesized that the probability of smolt mortality due to avian predation increases with decreasing physical condition of the fish. We also hypothesized that a smolt's rearing-type and run-timing are linked to its susceptibility to avian predation. Data collected as part this research will help regional fishery managers identify and potentially address those intrinsic and extrinsic factors that influence smolt susceptibility to avian predation. Results will also more accurately quantify smolt losses to bird predation through the capture, tagging, and release of smolts that best represent the run-at-large. Steelhead were selected as the model species for this study because prior research has demonstrated that this species is the most susceptible salmonid species to predation by birds nesting on the Columbia River (Collis et al. 2001, Antolos et al. 2005, Evans et al. 2012), and is the species of salmonid most likely to benefit from management initiatives targeting avian predation (Lyons et al. 2011a, b). Furthermore, we are likely to recover a sufficient number of PIT tags from steelhead on bird colonies along the Columbia River to address a multitude of predation-related questions, more so than any other salmonid species. Finally, a better understanding of those factors responsible for the higher susceptibility of steelhead to avian predation will help resource managers implement measures to reduce avian predation on ESA-listed steelhead DPSs.

Presented here are data collected in 2012. Results from 2008-2011 are also summarized and presented to assist in the interpretation of 2012 results.

Methods: From 14 April through 16 June 2012, run-of-the-river steelhead smolts were collected and PIT-tagged at the juvenile fish collection facility at Rock Island Dam on the mid-Columbia River. Steelhead were captured in concert with the run passing the dam, with more fish captured as the number of fish passing the dam increased. Steelhead were PIT-tagged, measured (mm, fork length), weighed (g), photographed, and placed in a recovery tank, where they were held for up to 12 hours before being released into the tailrace of the dam. Steelhead were selected for tagging regardless of their condition or origin, to best represent the run-at-large. To reduce handling time, digital photographs were taken of each side of the steelhead, which allowed for a detailed classification of the external condition of the fish by type and magnitude. We assessed the incidence and severity of different anomalies (e.g., externally visible physical damage, disease, and parasite load) for each tagged fish using the methods of Hostetter et al. (2011). Each fish was assigned to one of three overall condition categories: good, fair, or poor. These condition categories were based on the incidence, prevalence, and severity of all the various anomalies observed in each fish, and are defined as follows: good = no noticeable external damage, de-scaling < 10%; fair = minor external damage, de-scaling 10% – 50%; poor = open body injuries, external symptoms of disease (fungal, bacterial, or viral infections), parasite infestations, or de-scaling > 50%.

As described in Section 1.4.1, piscivorous waterbird colonies were scanned for PIT tags following the breeding season. Recoveries of PIT tags on the Caspian tern colony at Goose Island/Potholes Reservoir were used to determine if susceptibility to avian predation varied by individual steelhead characteristics (i.e., condition and fork length). We focused analyses associating individual steelhead characteristics with susceptibility to predation by Caspian terns nesting on the Goose Island colony because we were unable to track possible changes in smolt condition during out-migration. However, predation rates (Section 1.4.1) were generated for several other bird species nesting at different colonies throughout the Columbia River basin. Weekly predation rates were also generated using the release date of PIT-tagged steelhead at Rock Island Dam. As previously noted (Section 1.4.1), predation rates were adjusted for bias due to PIT tag detection efficiency rates (Table 4) and on-colony deposition rates (Table 2), where estimates of these rates were available (see Appendix A).

Results and Discussion: A total of 6,712 steelhead smolts were PIT-tagged and released from Rock Island Dam in 2012 (n = 5,107 hatchery-reared smolts, n = 1,605 wild smolts). Sampling efforts were conducted in concert with the run-at-large, with the largest numbers of smolts PIT-tagged during the peak migration period of 30 April to 29 May (n = 5,479 or 81% of all tagged fish), a period encompassing about 80% of the total steelhead run enumerated while passing Rock Island Dam in 2012. Overall, 66% of the steelhead PIT-tagged as part of the study in 2012 were classified as in good condition, 21% were in fair condition, and 13% were in poor condition. A variety of external anomalies were evident in steelhead classified as in poor condition, including ecto-parasite infestations (67% of all steelhead in poor condition), superficial and open body injuries (37%), moderate to severe de-scaling (16%), and external symptoms of disease (14%). Steelhead that were classified as in fair condition primarily suffered from superficial body abrasions (77%) and moderate de-scaling (40%). Conversely, external damage among fish that were classified as in good condition was limited to moderate de-scaling (6%).

Avian Predation on Upper Columbia River Steelhead - Of the 6,712 steelhead smolts PIT-tagged and released from Rock Island Dam, 597 (8.9%) were subsequently recovered on a piscivorous waterbird colony somewhere in the Columbia River basin. This number increased to 2,443 (36.4%; Table 10) when corrected for colony-specific detection efficiency (Table 4) and species-specific on-colony deposition rates (Table 2). The estimate of predation rate by Caspian terns nesting at Goose Island/Potholes Reservoir in 2012 (17.0%) was higher than the estimate in 2011 (12.7%), and was the second highest estimate since this study began in 2008 (Table 11). Higher predation rates in 2012 coincided with increased numbers of Caspian terns nesting at Goose Island/Potholes in 2012, supporting a suggestive positive relationship between annual predation rates on steelhead and the number of Caspian tern breeding pairs at the Goose Island/Potholes colony (Table 11).

The Upper Columbia River steelhead DPS is the population of salmonids most likely to benefit from management actions to reduce avian predation in the Columbia Plateau region (Lyons et al. 2011b). Caspian terns nesting at Goose Island/Potholes have had the highest predation rates on Upper Columbia River steelhead smolts released at Rock Island Dam during each year of the study (10.8% to 21.9%; Table 10). Avian predation on this DPS was not limited to birds from a single breeding colony, however, with predation rates at other colonies ranging from < 0.1% to 9.0% (Table 10). In total, 31.0% to 47.3% of Upper Columbia River steelhead smolts released at Rock Island Dam were consumed by avian predators before reaching the ocean (Table 10).

A growing body of evidence suggests that behavioral and physical traits associated with hatchery-raised salmonids enhance susceptibility to predation (Olla and Davis 1989, Johnsson and Abrahams 1991, Fritts et al. 2007, Hostetter et al. 2012). Predation rates by Caspian terns nesting at Goose Island/Potholes during 2008-2012 were consistently higher for hatchery-reared steelhead smolts compared to wild steelhead smolts (Table 11). For instance, predation rates by Caspian terns nesting at Goose Island/Potholes in 2012 were significantly higher for hatchery-reared steelhead smolts (19.4%; 95% c.i. = 15.7 - 24.5%) compared to wild steelhead smolts (9.5%; 95% c.i. = 6.5 - 13.8%; Table 11). In 2012, a total of 41.1% of the hatchery-reared smolts and 21.5% of the wild smolts from the Upper Columbia River steelhead DPS that were PIT-tagged and released at Rock Island Dam were consumed by avian predators before reaching the ocean (Table 12). Several intrinsic (e.g., length) and extrinsic (e.g., run-timing) factors likely contributed to the lower predation rates on wild steelhead smolts relative to hatchery-reared steelhead smolts in 2012 (see below).

Within Pacific salmonid populations, higher susceptibility to avian predation has been attributed to differences in fish behavior, condition, size, rearing, 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, steelhead smolts out-migrating later in the season (late-May through June) were generally the most susceptible to predation by Caspian terns nesting at Goose Island/Potholes (Figure 78). Conversely, Caspian tern predation rates were often lowest during the peak out-migration period (as seen during 2008-2011) or early in the season (2010 and 2012; Figure 78). Earlier out-migration of wild smolts relative to hatchery smolts likely contributed to lower avian predation rates on wild smolts. For instance, higher late-season avian predation rates often had little influence on survival of wild steelhead smolts (Figure 78). These trends were particularly evident in 2012 due to the relatively high predation rates on late-season migrants, which consisted almost entirely of hatchery-reared smolts (Figure 78).

Individual smolt characteristics, such as fork length and external condition, were often associated with differences in susceptibility to avian predation. In 2012, predation rates by Caspian terns nesting at Goose Island/Potholes were highest on steelhead with fork lengths of 17 - 24 cm, and lower for steelhead that were longer (> 24 cm fork length) or shorter (< 15 cm fork length; Figure 79). Reduced predation rates on longer and shorter steelhead smolts were also observed in 2008, 2010, and 2011, although the trends were not as strong as those observed in 2012 (Figure 79). Wild steelhead smolts were often shorter than their hatchery-reared counterparts (Figure 79), which may have further contributed to lower Caspian tern predation rates on wild smolts. Due to the observational nature of this study, however, it is not known whether decreased predation rates on shorter steelhead smolts were due to predator foraging strategies (i.e., selection for fish of certain lengths) or prey behavior (i.e., behavioral differences between shorter, often wild smolts and longer, often hatchery-raised smolts).

Caspian terns nesting at the Goose Island/Potholes colony have often, but not always, disproportionately consumed steelhead in degraded condition. External condition of out-migrating steelhead smolts has previously been used as a metric of health and linked to internal fish condition (Hostetter et al. 2011, Connon et al. 2012), steelhead survival during out-migration (Hostetter et al. 2011), and susceptibility to avian predation (Hostetter et al. 2012). In this study, steelhead exhibiting increased levels of de-scaling (i.e., 5-20% or > 20% de-scaling) often suffered higher avian predation rates compared to steelhead with < 5% de-scaling (Figure 80). Smolt condition alone did not explain all differences in avian predation rates, however, especially given the low prevalence of steelhead with increased levels of de-scaling and the documented avian predation of steelhead with little to no sign of de-scaling (Figure 80). See BRNW (2012) for an evaluation of steelhead susceptibility to Goose Island/Potholes Caspian tern predation based on other fish condition factors (e.g., body injuries, parasite load, and external symptoms of disease).

Ultimately, the probability of an individual fish 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 examinations were, however, able to identify several individual fish characteristics and environmental factors that were correlated with increased susceptibility to avian predation. Differences in avian predation rates as a function of smolt 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 required to accurately estimate the impact of avian predation at the level of the salmonid ESU/DPS; such estimates are a valuable source of information for fisheries managers and salmonid population monitoring programs.

SECTION 5: DISTRIBUTION OF FORAGING AND LOAFING PISCIVOROUS COLONIAL WATERBIRDS IN McNARY POOL, MID-COLUMBIA RIVER

Methods: In 2012 we continued a study initiated in 2011 to determine the number, spatial distribution, and habitat use of piscivorous colonial waterbirds that are foraging, loafing, or roosting at sites in McNary Pool during the breeding season. Deposition of smolt PIT tags at loafing and roosting sites was also documented by scanning for PIT tags in areas where large numbers or high densities of piscivorous birds were observed loafing or roosting.

Using protocols developed in 2011 (BRNW 2012), we conducted 14 boat-based surveys to determine the number and spatial distribution of double-crested cormorants, Caspian terns, and American white pelicans foraging, loafing, or roosting in the McNary Pool of the mid-Columbia River during the 2012 breeding season (April-July). Surveys covered the area from the mouth of the Walla Walla River (Rkm 509, Columbia River) upstream to Ice Harbor Dam (Rkm 538, Snake River) and to the upstream end of the Richland Islands (Rkm 545, Columbia River). The GPS coordinates of bird aggregations, along with information on the types of structures used as loafing or roosting sites, were recorded during each survey. Loafing sites where large aggregations of birds were identified and that were accessible to researchers were scanned for smolt PIT tags to evaluate whether PIT tag recovery at loafing sites could contribute to our understanding of the impact of avian predation on survival of salmonid smolts.

Results and Discussion: Double-crested cormorants, Caspian terns, and American white pelicans were observed loafing and foraging throughout McNary Pool (Map 7). Observations of double-crested cormorants indicated that 75% of loafing and foraging cormorants were generally on or near Foundation Island (on-colony, upstream tip, or downstream tip), the site of the largest cormorant colony on the mid-Columbia River. Similarly, 94% of Caspian tern observations were on Crescent Island or Badger Island, the two sites where Caspian terns had breeding colonies on the mid-Columbia River in 2012). For American white pelicans, 53% of observations were on or near Badger Island; however, boat-based counts of Badger Island pelicans were obstructed by vegetation and significantly underestimate the number of white pelicans associated with Badger Island.

Double-crested cormorants, Caspian terns, and American white pelicans loafing off-colony were primarily observed on islands, sandbars, and secluded shorelines along the Columbia and Snake rivers (Map 7). Although use of artificial structures (e.g., channel markers) was documented, counts were never greater than 5 birds on any one structure during a survey. Areas used by aggregations of roosting double-crested cormorants, Caspian terns, and American white pelicans in the McNary Pool included Strawberry Island (Rkm 528; cormorants and pelicans), Goose Island below Ice Harbor Dam (Rkm 536; cormorants and pelicans), the tailrace at Ice Harbor Dam (Rkm 538; cormorants and pelicans), Crescent Island shoreline rip-rap and lagoon (Rkm 510; all 3 species), upstream and downstream tips of Foundation Island (Rkm 518; all 3 species), the upstream and downstream tips of Badger Island (Rkm 511; all 3 species), trees and channel markers on or near Wade Island near Kennewick (Rkm 525; primarily cormorants), and the shorelines of Island 18, 19, and 20 (Rkm 547 - 549; cormorants and pelicans; Map 7).

The largest aggregations of loafing double-crested cormorants off of Foundation Island were observed on the upstream and downstream tips of Badger Island, West Side Island (across the shipping channel from Foundation Island; Rkm 517), and on the lower Snake River at Strawberry Island (Rkm 528) and Goose Island (below Ice Harbor Dam; Rkm 536). Counts of loafing double-crested cormorants in these areas during April-July 2012 ranged from 1 - 64 cormorants on Badger Island, 2 - 31 cormorants on West Side Island, 1 -78 cormorants on Goose Island, and 1 - 11 cormorants on Strawberry Island (Map 7). Double-crested cormorants were also observed foraging on the reach of the Snake River from Strawberry Island to the tailrace of Ice Harbor Dam (n = 1 - 52 cormorants; Map 7). American white pelicans also used Strawberry Island and Goose Island on the Snake River during April – July (n = 1 - 87 loafing pelicans and 0 - 93 foraging pelicans, depending on date and location; Map 7). Peak abundances of off-colony double-crested cormorants and American white pelicans on the Snake River were observed during May – July, overlapping the period when salmonid smolts were out-migrating through these areas.

In both years of this study (2011 and 2012), the greatest numbers of double-crested cormorants, Caspian terns, and American white pelicans were observed on or near the islands where their respective breeding colonies were located. Double-crested cormorants and American white pelicans were also consistently observed loafing at Strawberry and Goose islands on the Snake River. Counts in both years indicated that more double-crested cormorants and American white pelicans foraged on the mainstem Snake River compared to the Columbia River above its confluence with the Snake River (Map 7).

PIT tag recovery was conducted at double-crested cormorant, Caspian tern, and American white pelican loafing sites that were accessible in 2012. A total of 177 PIT tags from salmonid smolts migrating in 2012 were recovered from six different loafing sites (Table 13). All loafing sites scanned for PIT tags were used by multiple bird species - including, but not limited to, double-crested cormorants, Caspian terns, American white pelicans, and/or California and ring-billed gulls – throughout the season, and therefore cannot be attributed to predation by a particular bird species (Table 13). Recoveries of PIT tags on loafing sites ranged from 15 - 61 tags, while recoveries of PIT tags on nesting colonies in McNary Pool were often orders of magnitude greater (382 – 7,285 PIT tags recovered in 2012; Table 3).

The paucity of PIT tags recovered at loafing sites relative to nesting colonies may be due to a number of factors, including (1) lower relative use of loafing sites relative to nesting colonies, (2) birds disproportionately depositing consumed PIT tags at nesting sites, or (3) low detection efficiency of PIT tags deposited at loafing sites. Detection efficiency at loafing sites may be much lower relative to detection efficiency at nesting colonies due to the repeated inundation of most loafing sites; thus, PIT tag recoveries at loafing sites would underestimate the impacts of avian predation to an unknown degree. The lower relative use of loafing sites compared to colonies is another major factor in the low PIT tag detection rates, however, with maximum counts of piscivorous waterbirds at each loafing site ranging from 0 - 64 individuals per species, and maximum counts at colonies regularly exceeding several hundred to several thousand individuals.

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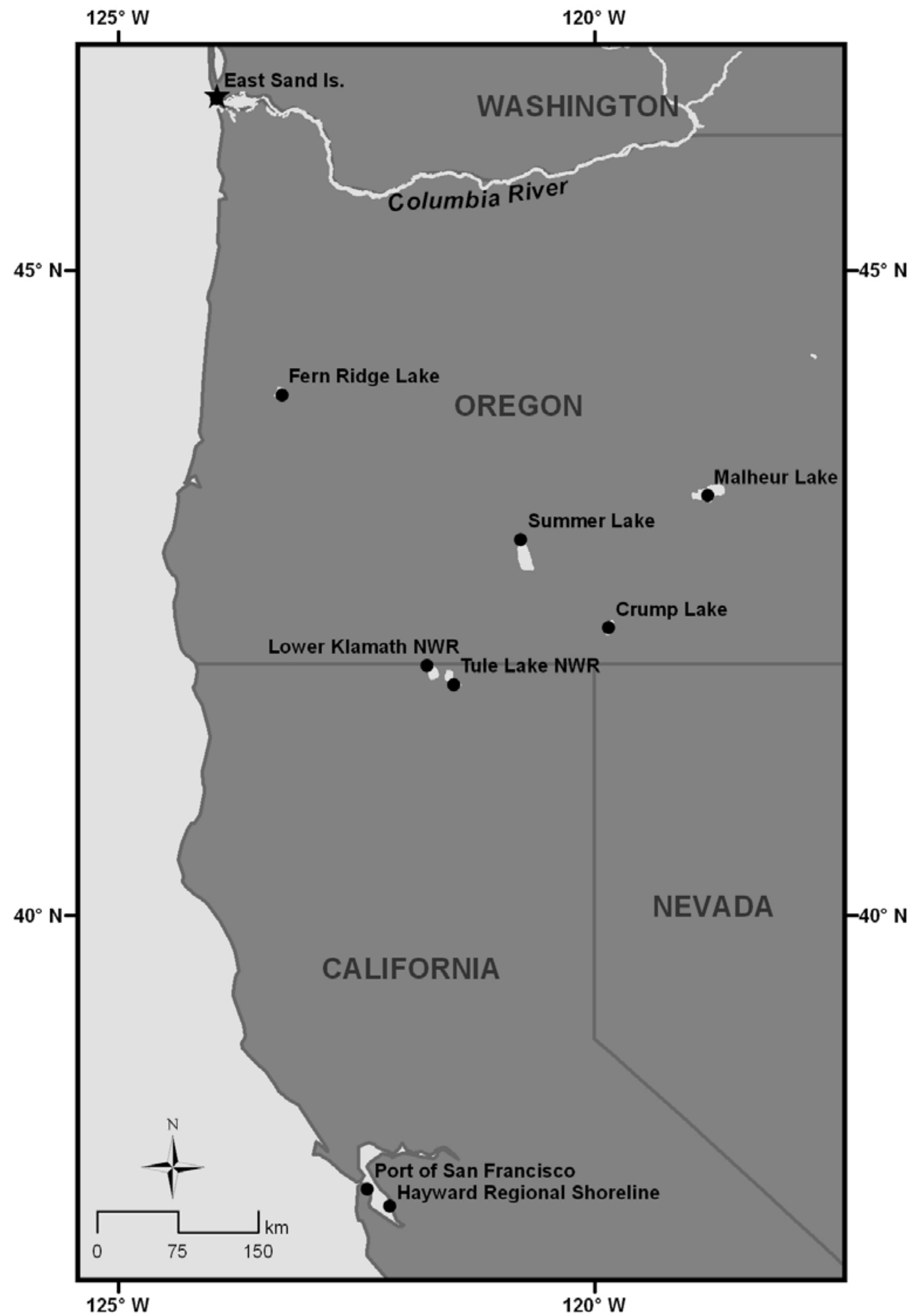
	Funding Contribution by Agency		
	BPA	USACE Portland District	USACE Walla Walla District
Caspian Terns			
1.1. Preparation and Modification of Nesting Habitat			
1.1.1. Columbia River Estuary		**x**	
1.1.2. Interior Oregon and Northeastern California		**x**	
1.2. Colony Size and Productivity			
1.2.1. Columbia River Estuary	**x**		
1.2.2. Columbia Plateau			**x**
1.2.3. Coastal Washington		**x**	
1.2.4. Interior Oregon and Northeastern California		**x**	
1.3. Diet Composition and Salmonid Consumption			
1.3.1. Columbia River Estuary	**x**		
1.3.2. Columbia Plateau			**x**
1.3.3. Coastal Washington			
1.3.4. Interior Oregon and Northeastern California		**x**	

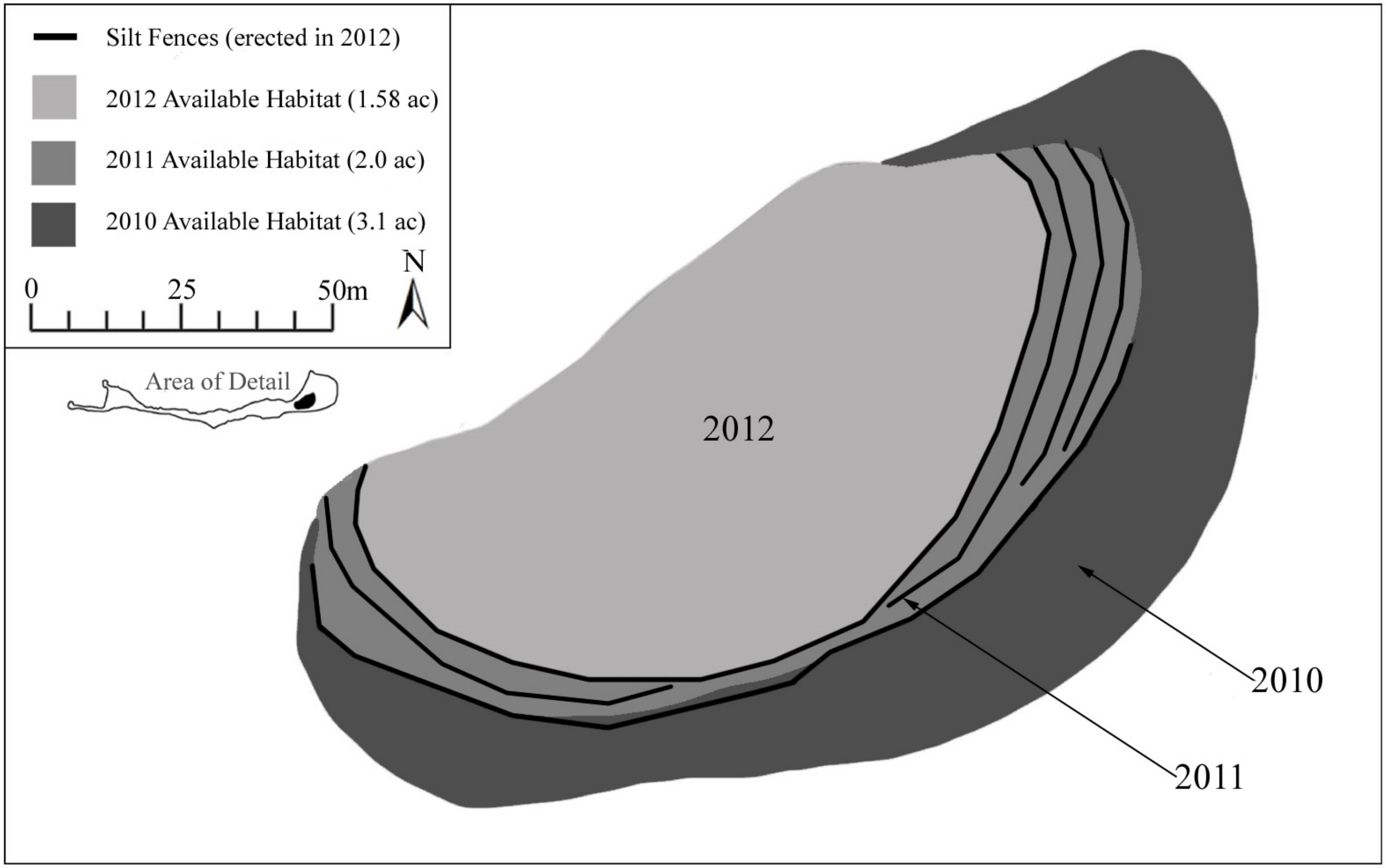
	Funding Contribution by Agency		
	BPA	USACE Portland District	USACE Walla Walla District
Caspian Terns (cont.)			
1.4. Predation Rates Based on PIT Tag Recoveries			
1.4.1. Columbia River Estuary	**x**	**x**	
1.4.2. Columbia Plateau			**x**
1.4.3. Coastal Washington			
1.4.4. Interior Oregon and Northeastern California		**x**	
1.5. Color Banding and Band Re-sightings			
1.5.1. Columbia River Estuary	**x**		
1.5.2. Columbia Plateau			**x**
1.5.3. Coastal Washington			
1.5.4. Interior Oregon and Northeastern California		**x**	
Double-crested Cormorants			
2.1. Nesting Distribution and Colony Size			
2.1.1. Columbia River Estuary	**x**	**x**	
2.1.2. Columbia Plateau			**x**
2.1.3. Coastal Washington		**x**	
2.1.4. Interior Oregon and Northeastern California		**x**	
2.2. Nesting Success			
2.2.1. Columbia River Estuary	**x**	**x**	
2.2.2. Columbia Plateau			**x**
2.2.3. Coastal Washington		**x**	
2.2.4. Interior Oregon and Northeastern California		**x**	
2.3. Diet Composition and Salmonid Consumption			
2.3.1. Columbia River Estuary	**x**	**x**	
2.3.2. Columbia Plateau			**x**
2.3.3. Coastal Washington			
2.3.4. Interior Oregon and Northeastern California			

	Funding Contribution by Agency		
	BPA	USACE Portland District	USACE Walla Walla District
Double-crested Cormorants (cont.)			
2.4. Predation Rates Based on PIT Tag Recoveries			
2.4.1. Columbia River Estuary	**x**	**x**	
2.4.2. Columbia Plateau			**x**
2.5. Color Banding		**x**	
2.6. Management Feasibility Studies			
2.6.1. Habitat Enhancement and Social Attraction Studies		**x**	
2.6.2. Nest Dissuasion Feasibility Studies		**x**	
2.7. Foraging Distribution in McNary Pool			**x**
Other Piscivorous Waterbirds			
3.1. Distribution			
3.1.1. Columbia River Estuary	**x**		
3.1.2. Columbia Plateau			**x**
3.1.3. Coastal Washington			
3.1.4. Interior Oregon and Northeastern California		**x**	
3.2. Diet Composition			
3.2.1. Columbia River Estuary			
3.2.2. Columbia Plateau			
3.2.3. Coastal Washington			
3.2.4. Interior Oregon and Northeastern California			
3.3. Predation Rates Based on PIT Tag Recoveries			
3.3.1. Columbia River Estuary	**x**		
3.3.2. Columbia Plateau			**x**
Steelhead Susceptibility Study			**x**
Distribution of Piscivorous Waterbirds in McNary Pool			**x**

Map 1. Study area in the Columbia River basin and coastal Washington showing the locations of active and former breeding colonies of piscivorous colonial waterbirds mentioned in this report. A Caspian tern colony was also discovered on a warehouse rooftop at the Fraser River Terminal near Richmond, British Columbia (not shown on map).

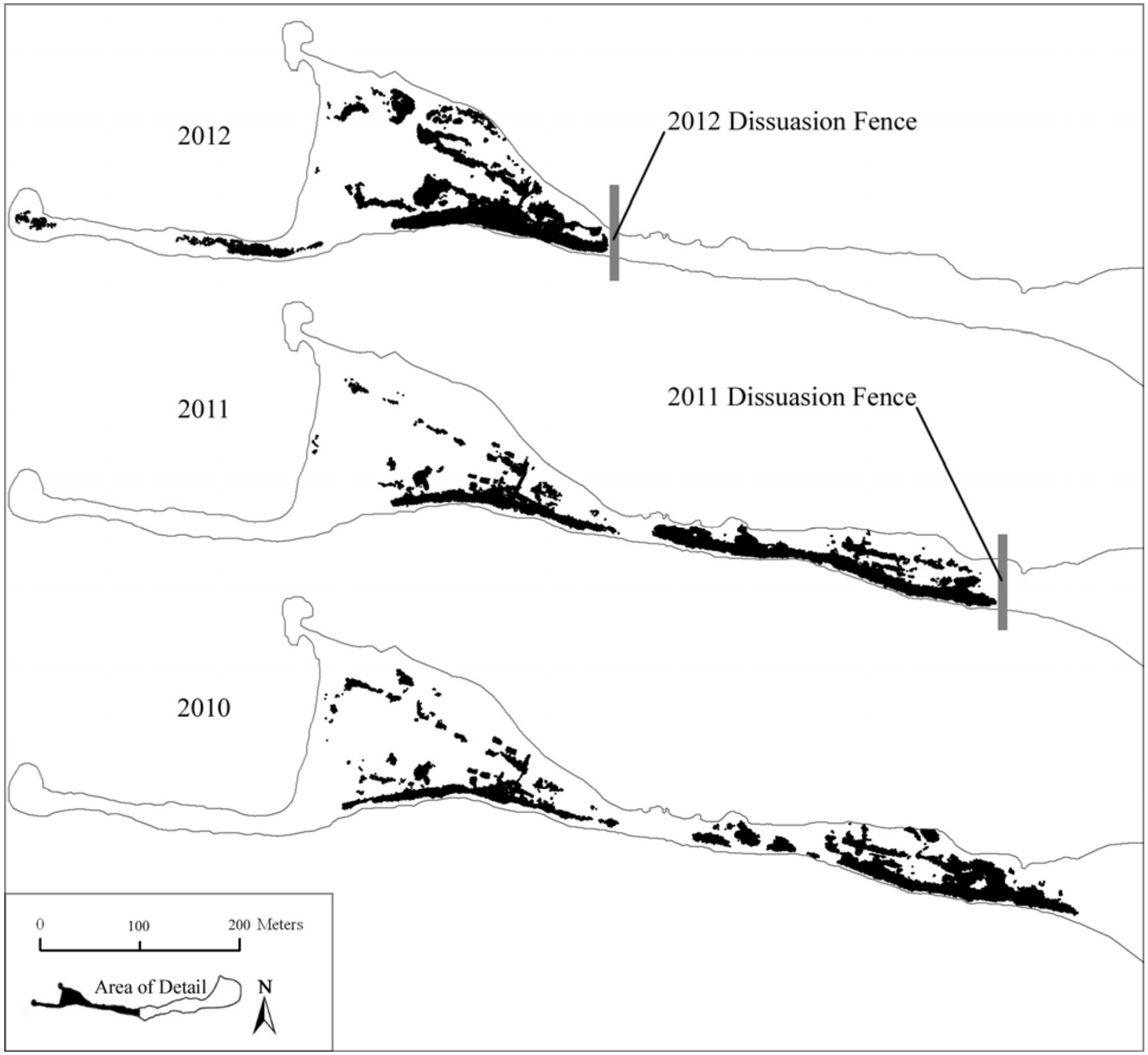


Map 2. Locations of recently-built and proposed Corps-constructed islands for Caspian tern nesting as part of the federal agencies' Caspian Tern Management Plan for the Columbia River estuary (USFWS 2005, 2006).

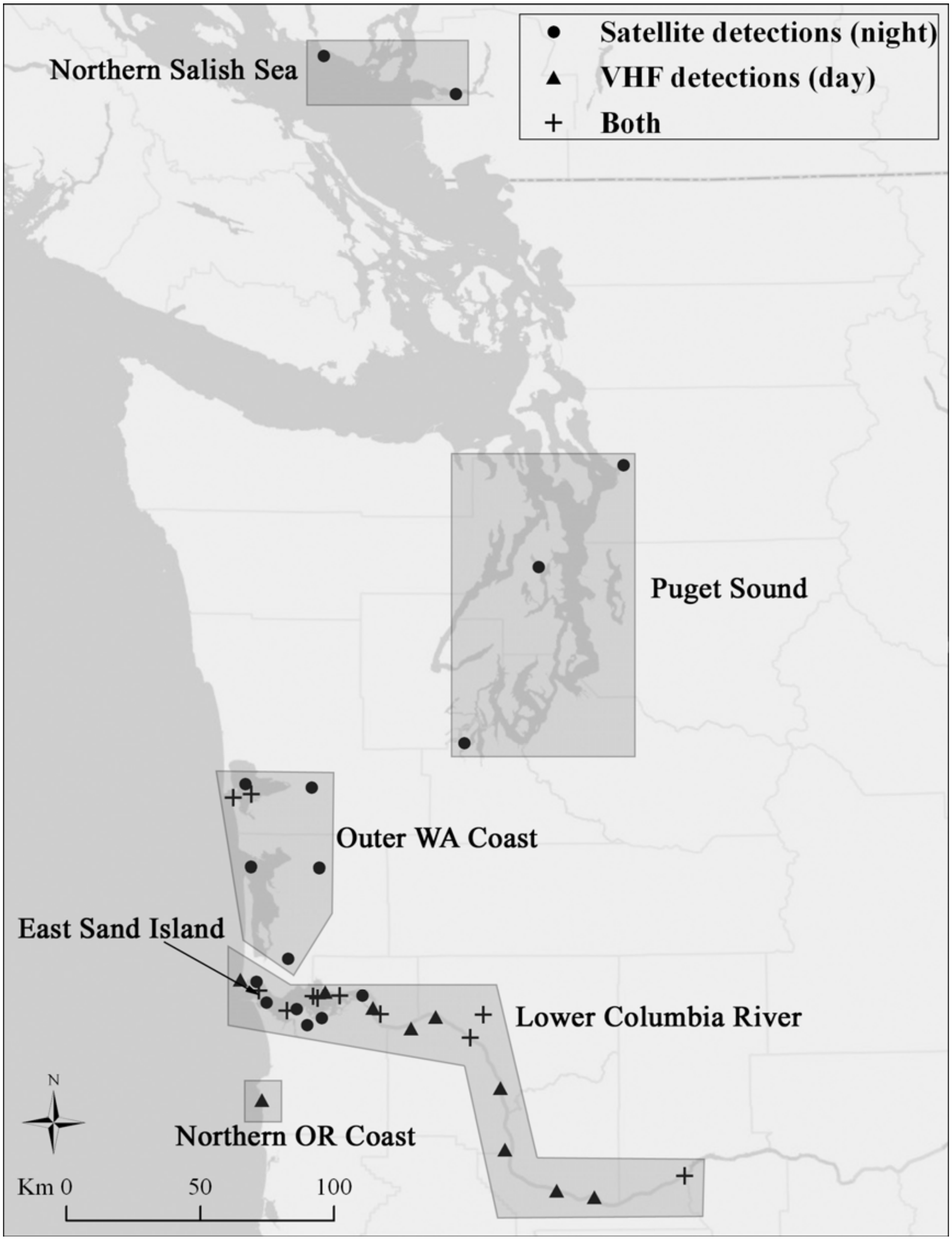


Map 3. Nesting habitat prepared for Caspian terns on the eastern end of East Sand Island in the Columbia River estuary during 2010-2012. Silt fencing was erected on a portion of the nesting habitat used by terns in 2010-2011 to further reduce the amount of nesting habitat made available to Caspian terns in 2012 (see text for details). In 2010-2012, Caspian terns nested only on the eastern end of East Sand Island (shown here) and not elsewhere on the island.

Map 4. Study area in interior Oregon, northeastern California, and southern Washington and locations of piscivorous waterbird colonies mentioned in this report.



Map 5. Distribution of cormorant nests on western East Sand Island in the Columbia River estuary during the 2010-2012 breeding seasons. Also shown are the locations of observation blinds and access tunnels, plus the areas used for feasibility studies of nest dissuasion techniques (see text for details). During 2010-2012, cormorants nested only on the western half of East Sand Island (shown here) and not elsewhere on the island.



Map 6. Off-colony detection locations of radio- and satellite-tagged double-crested cormorants from East Sand Island in the Columbia River estuary during the breeding season (April-August) in 2012. Birds were captured for tagging on a portion of the colony where cormorants were prevented from nesting, east of the dissuasion fence (i.e., dissuasion area; see Map 5).

Map 7. Aggregations of loafing and foraging double-crested cormorants (A), Caspian terns (B), and American white pelicans (C) on the Columbia and Snake rivers from the mouth of the Walla Walla River (Rkm 509, Columbia River) upstream to Ice Harbor Dam (Rkm 538, Snake River) and to the upstream end of the Richland Islands (Rkm 545, Columbia River) during April-July 2012. Only aggregations of 5 or more birds are shown. Observations of birds loafing on or near their respective nesting islands are circled.

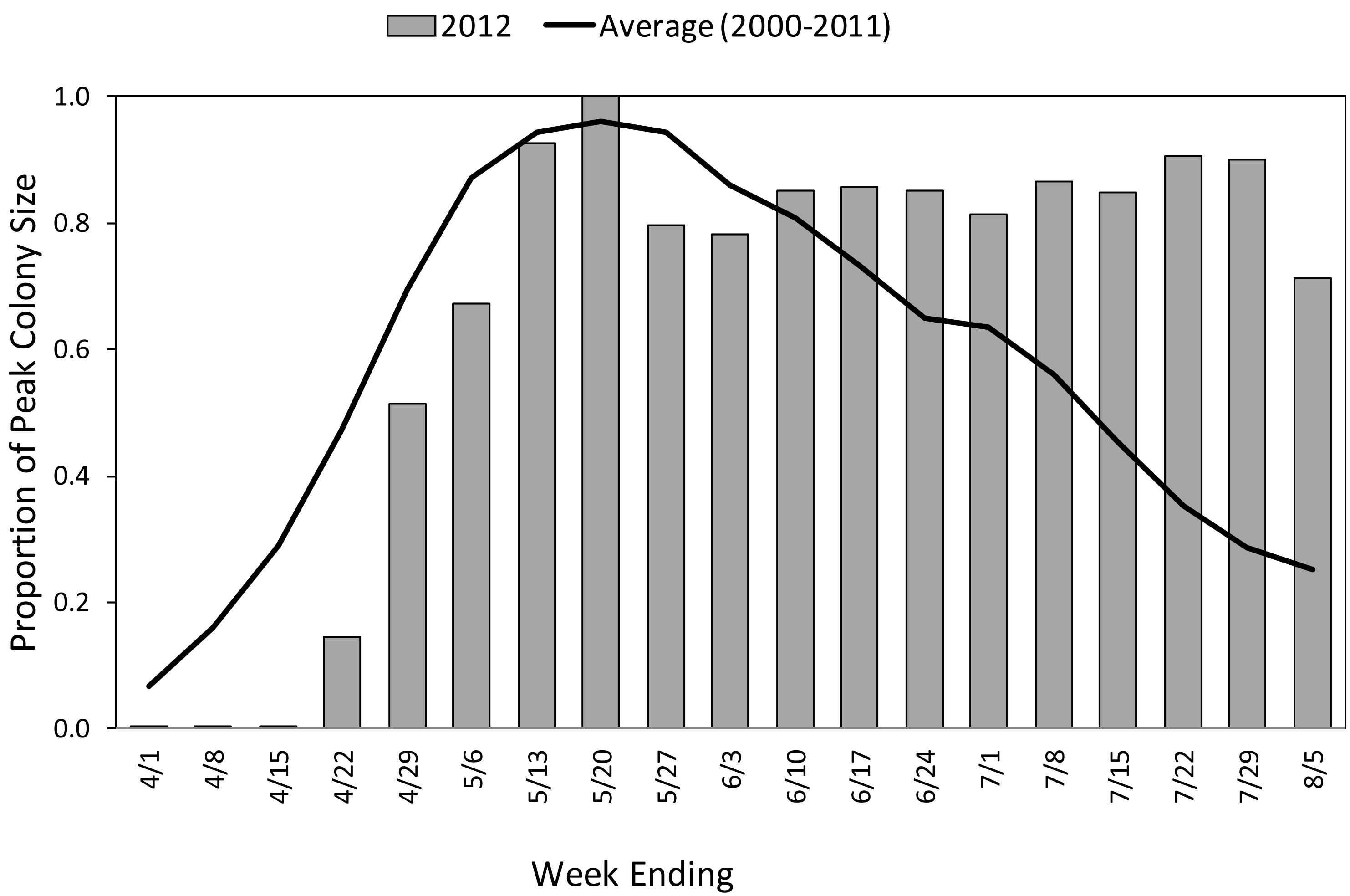


Figure 1. Weekly estimates from the ground of the number of adult Caspian terns on the East Sand Island colony during the 2012 breeding season, relative to peak colony attendance determined from counts of aerial photography taken late in the incubation period.

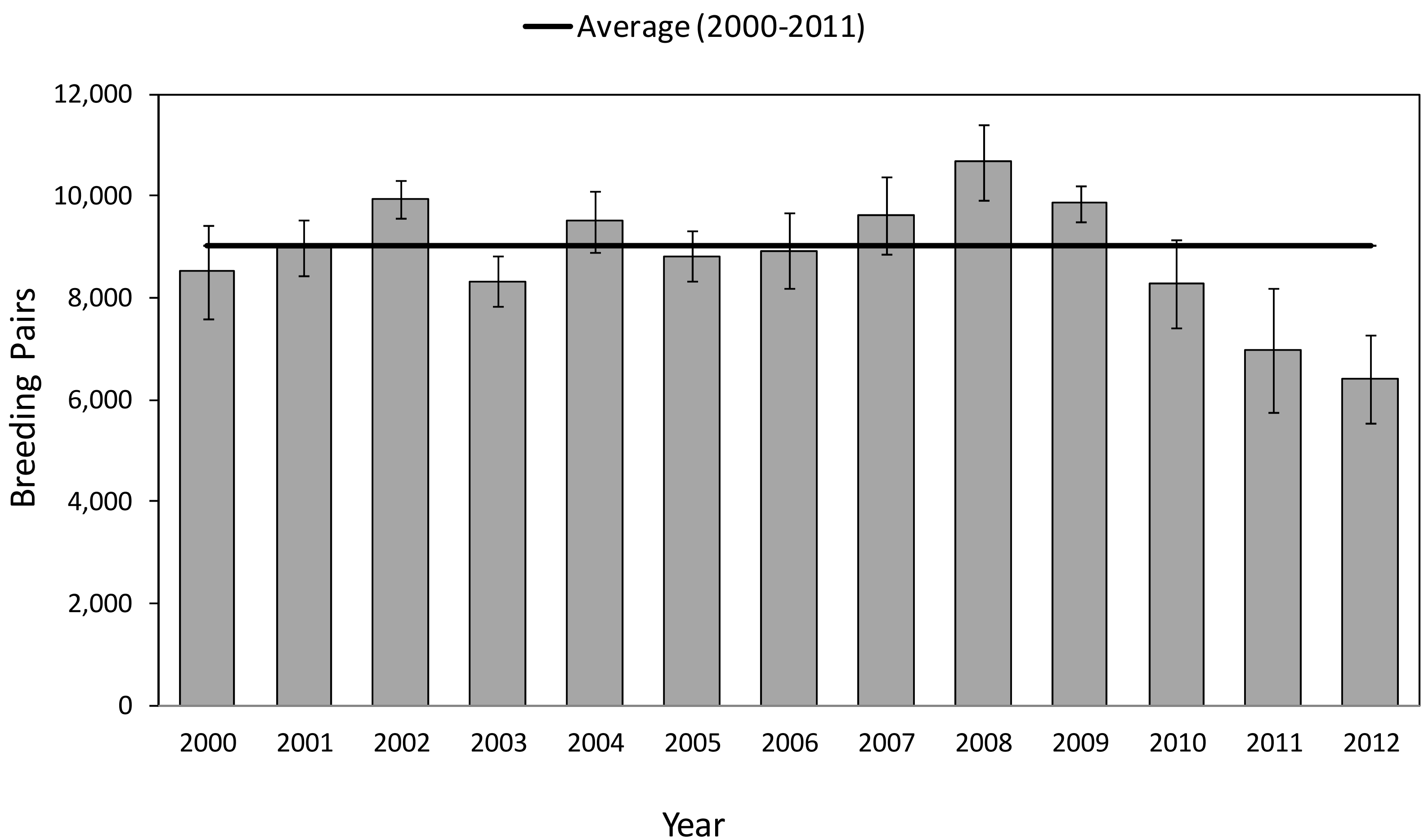


Figure 2. Caspian tern colony size on East Sand Island in the Columbia River estuary during 2000-2012. The error bars represent 95% confidence intervals for the number of breeding pairs.

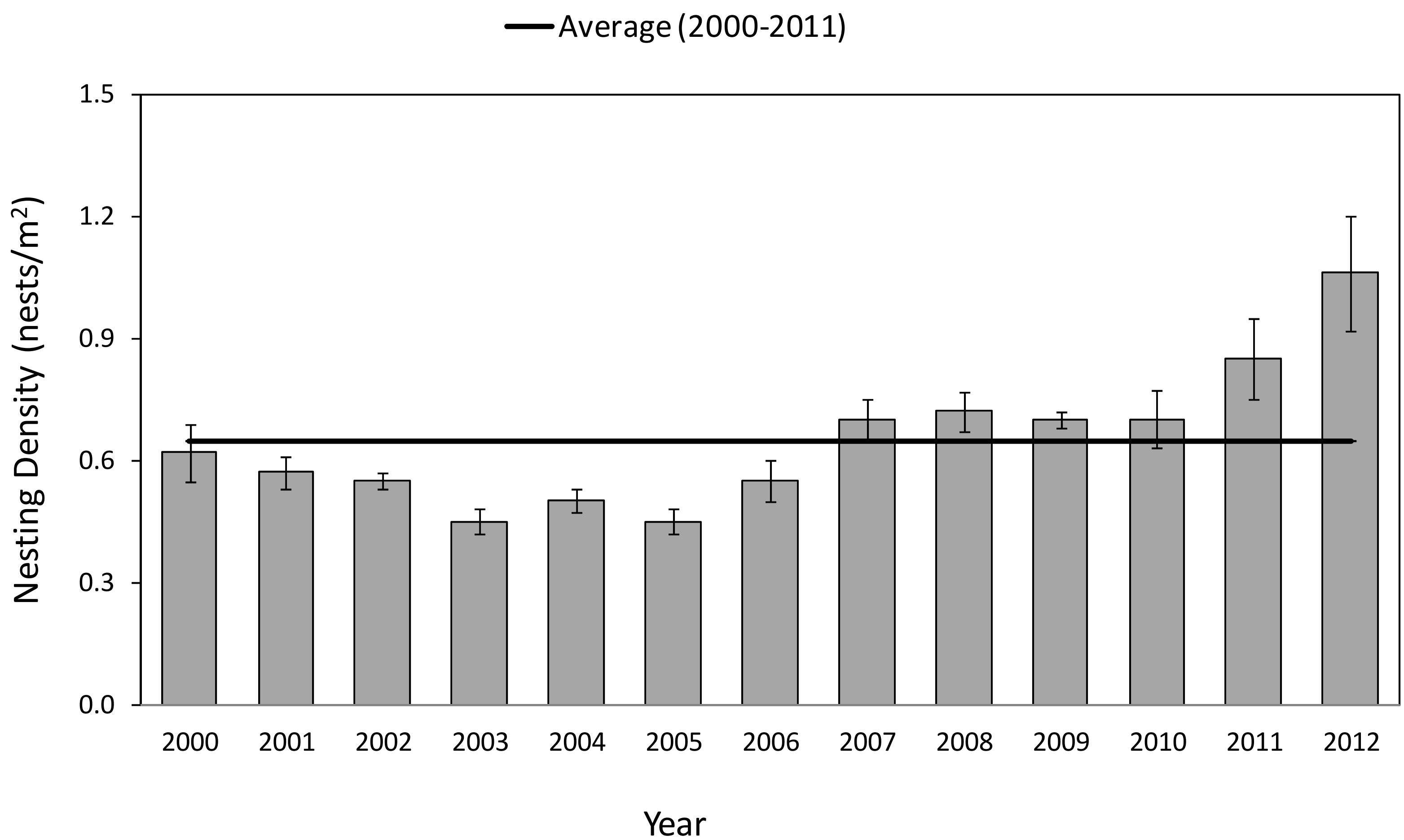


Figure 3. Caspian tern nesting density at the breeding colony on East Sand Island, Columbia River estuary during 2000-2012. The error bars represent 95% confidence intervals for nesting density (error estimate not available for 2011 and based on 2012 error estimate).

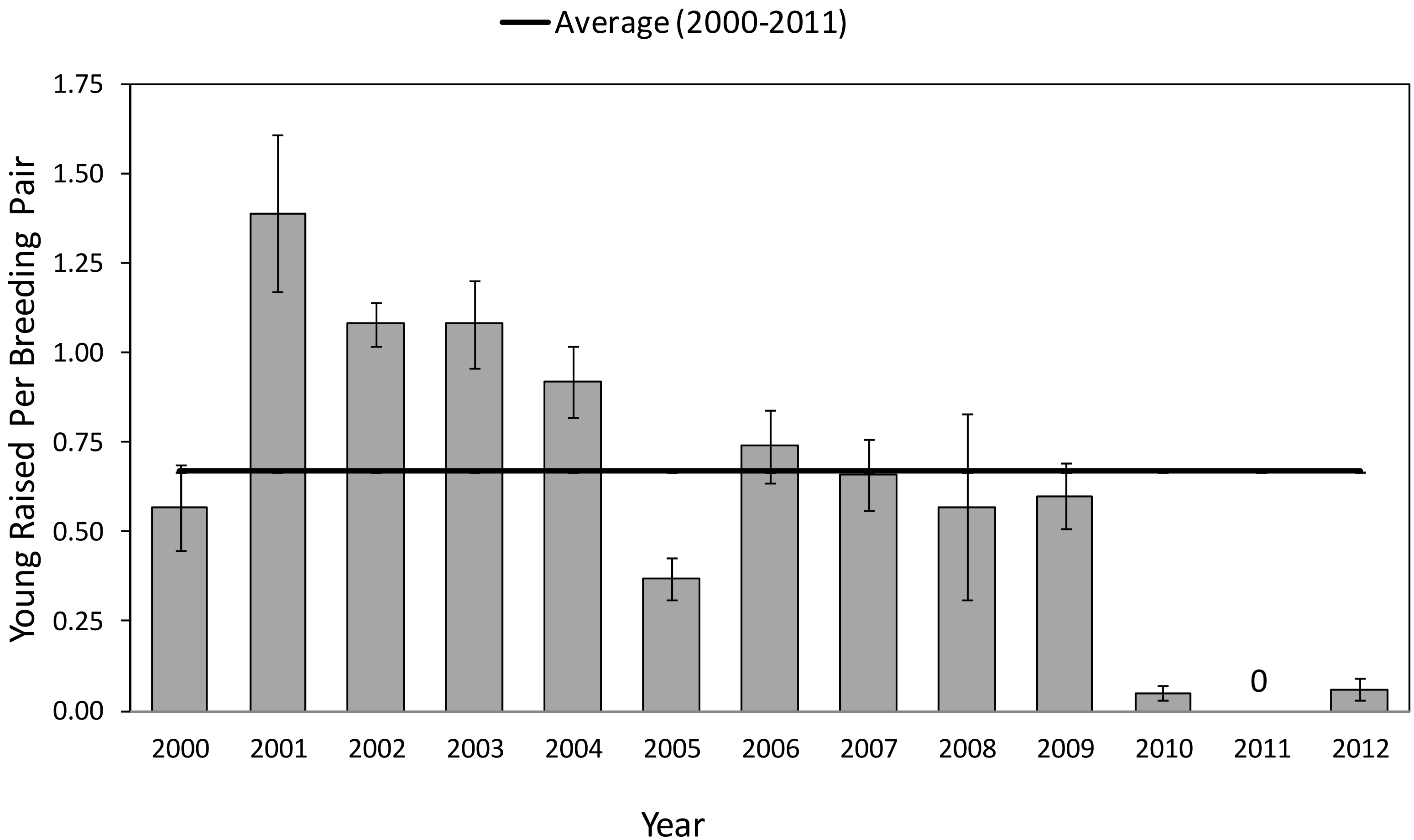


Figure 4. Caspian tern nesting success (average number of young raised per breeding pair) at the breeding colony on East Sand Island in the Columbia River estuary during 2000-2012. The error bars represent 95% confidence intervals.

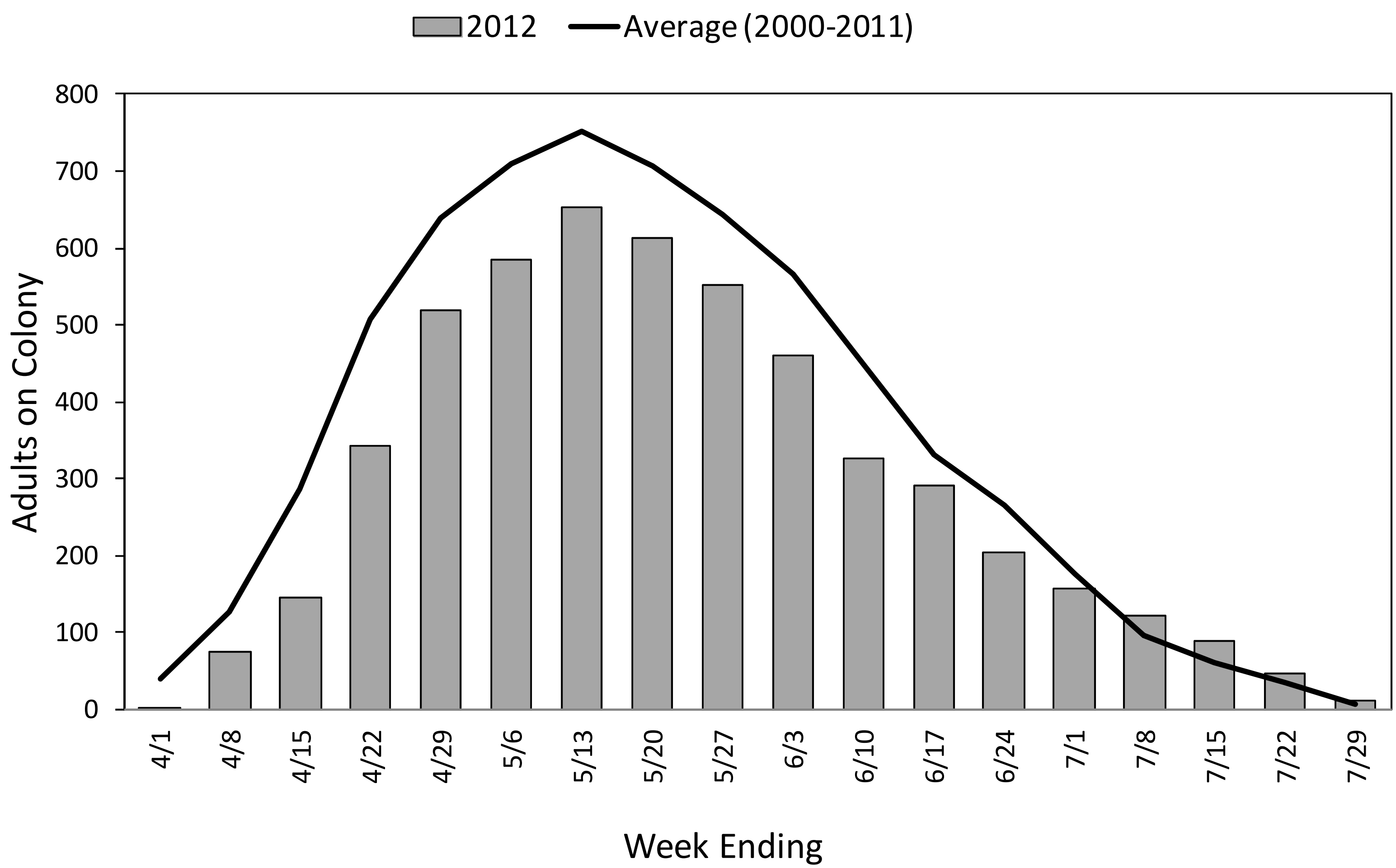


Figure 5. Estimates from the ground of the number of adult Caspian terns on the Crescent Island breeding colony in the mid-Columbia River, by week during the 2012 breeding season.

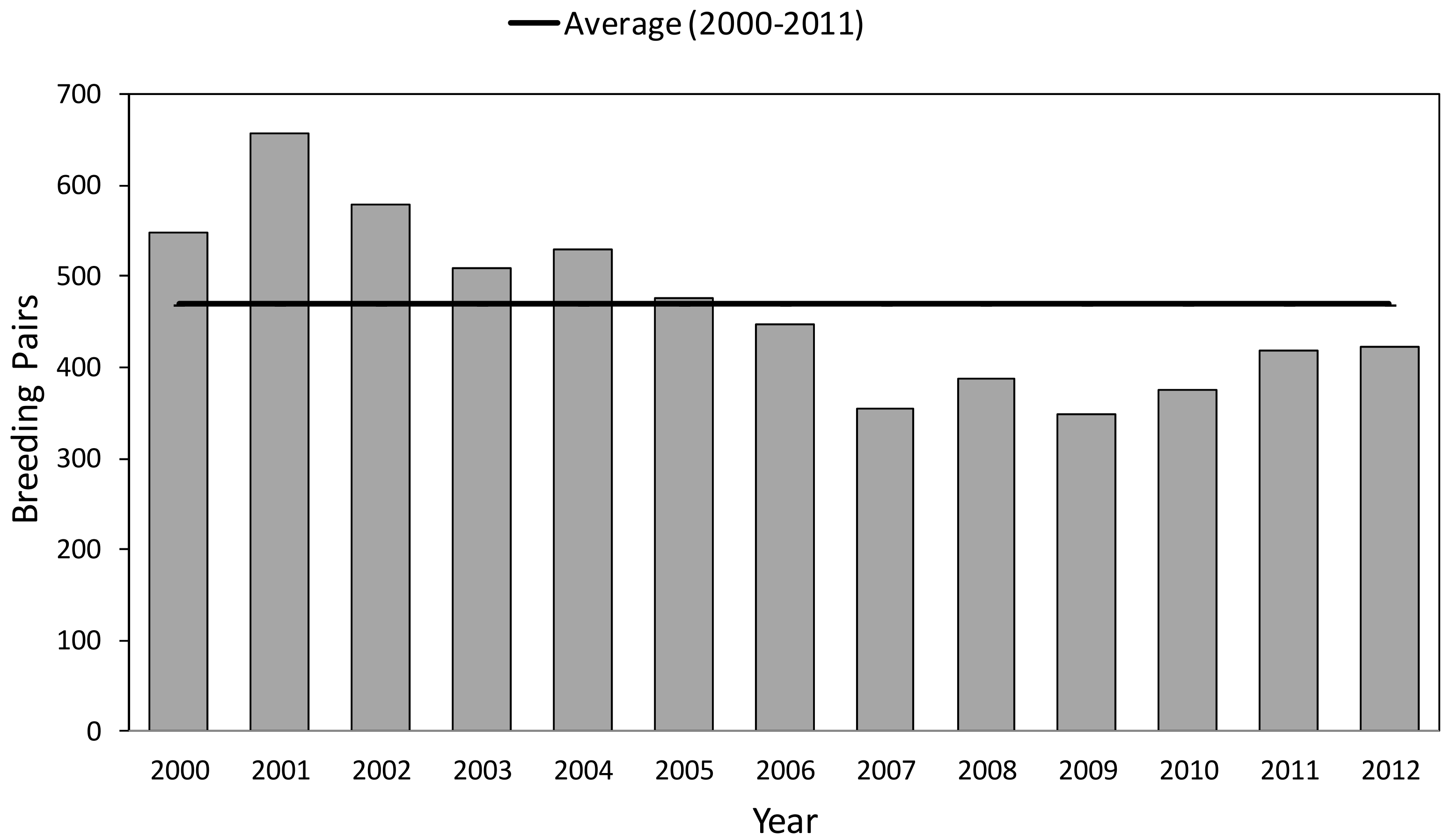


Figure 6. Size of the Caspian tern breeding colony (numbers of breeding pairs) on Crescent Island in the mid-Columbia River during 2000-2012.

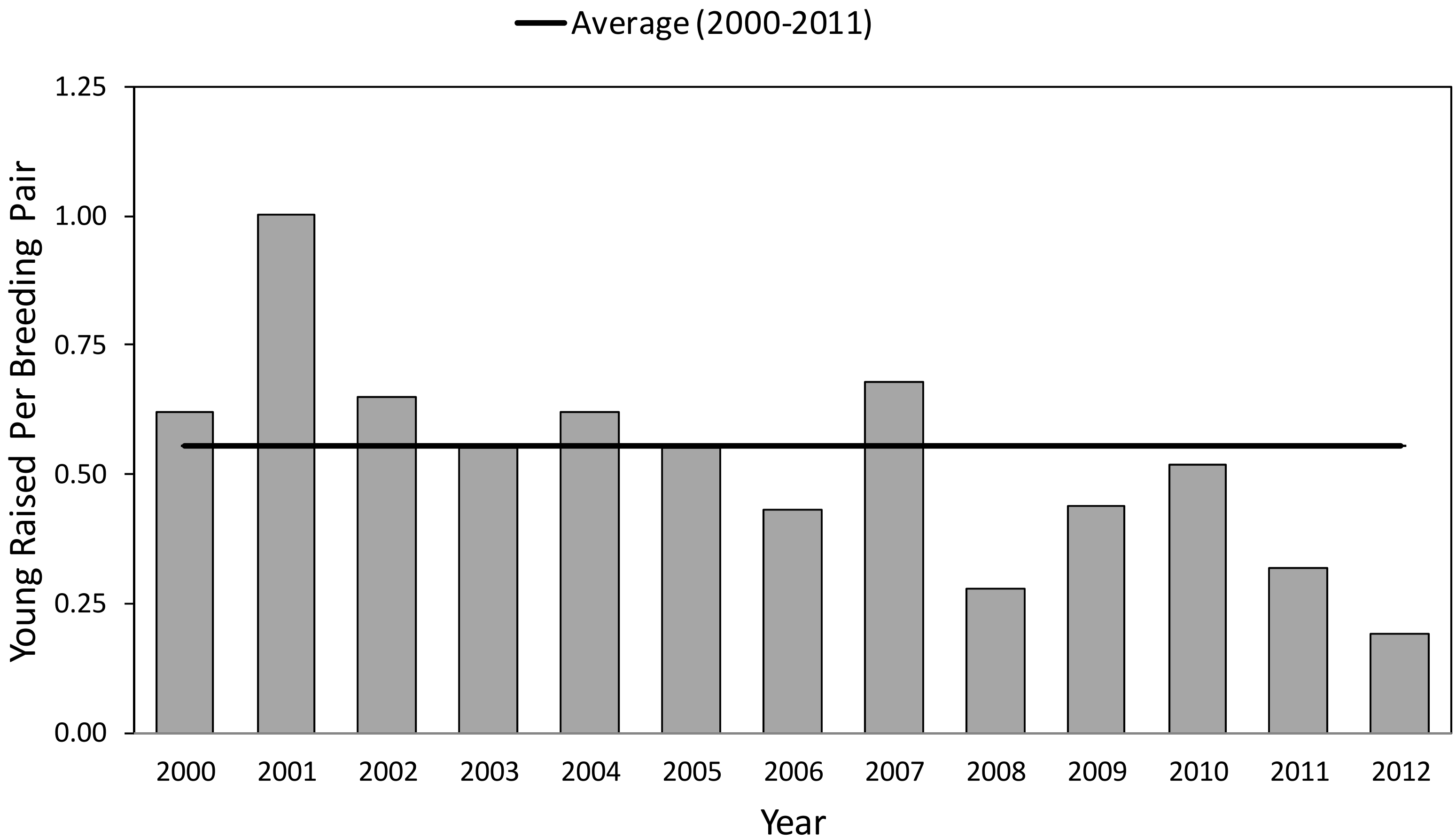


Figure 7. Nesting success of Caspian terns (average number of young raised per breeding pair) at the breeding colony on Crescent Island in the mid-Columbia River during 2000-2012.

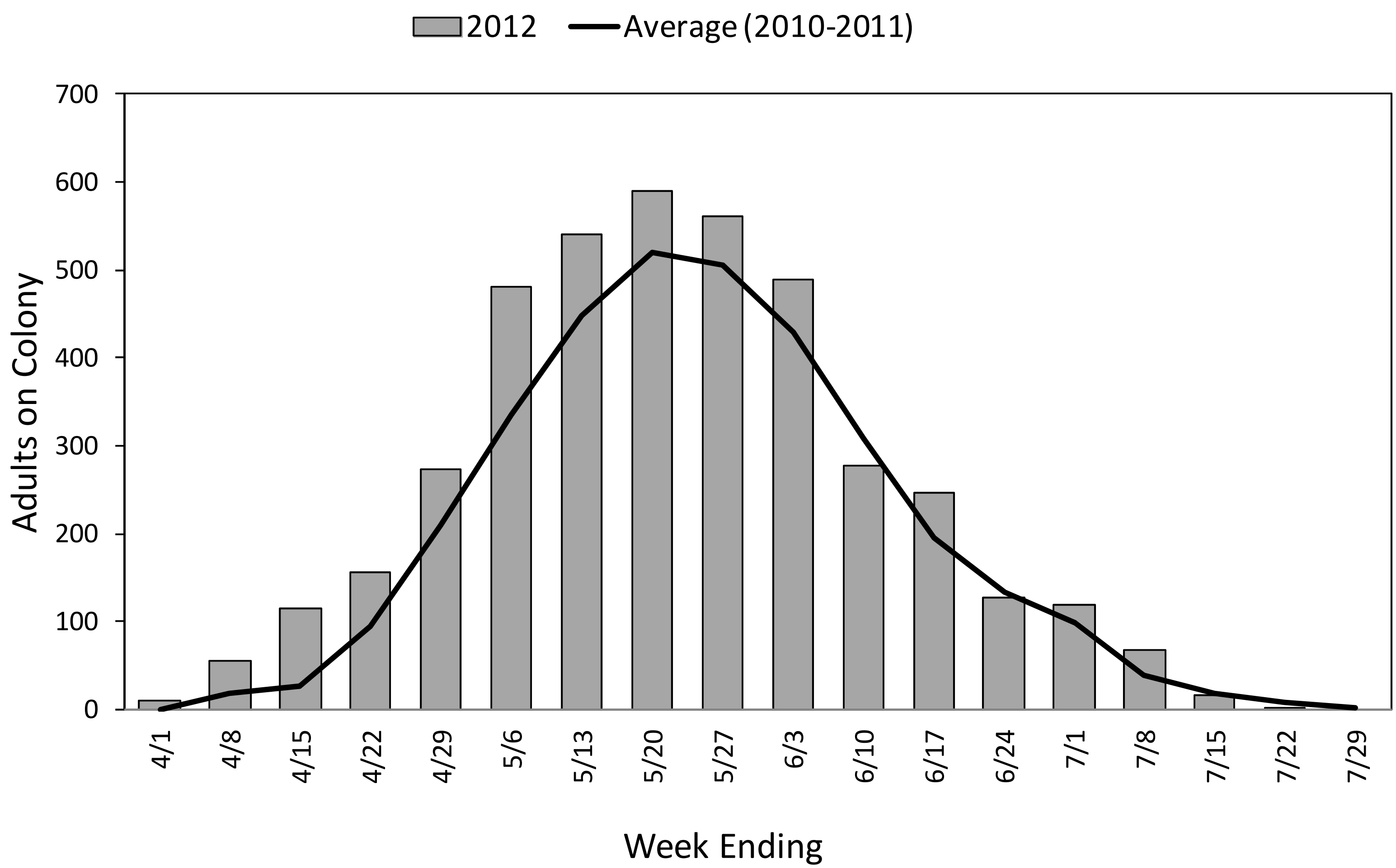


Figure 8. Estimates from the ground of the number of adult Caspian terns at the breeding colony on Goose Island in Potholes Reservoir, by week during the 2012 breeding season.

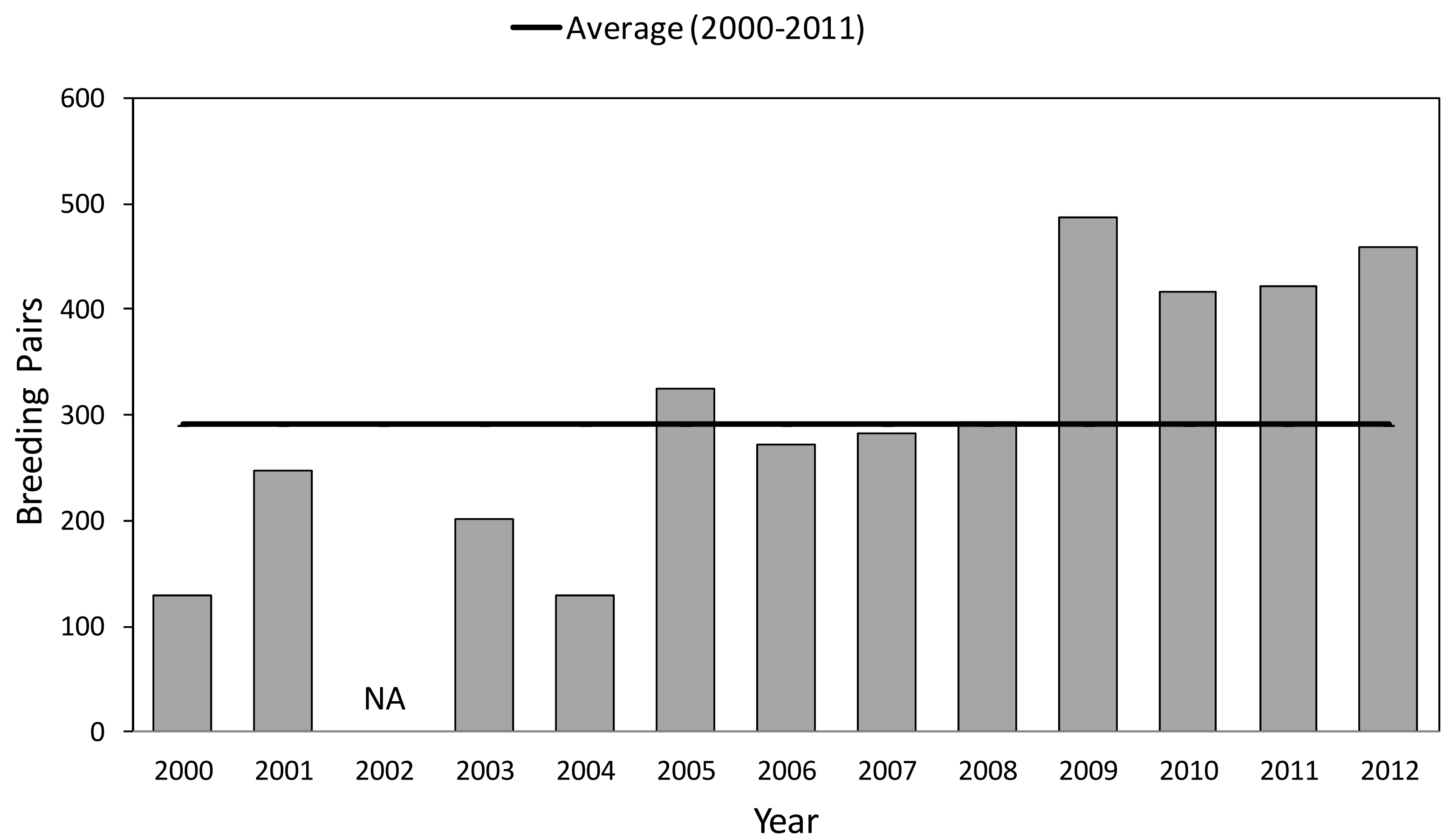


Figure 9. Size of the Caspian tern breeding colony (number of breeding pairs) on Goose Island in Potholes Reservoir during 2000-2012. Colony size in 2002 is not known.

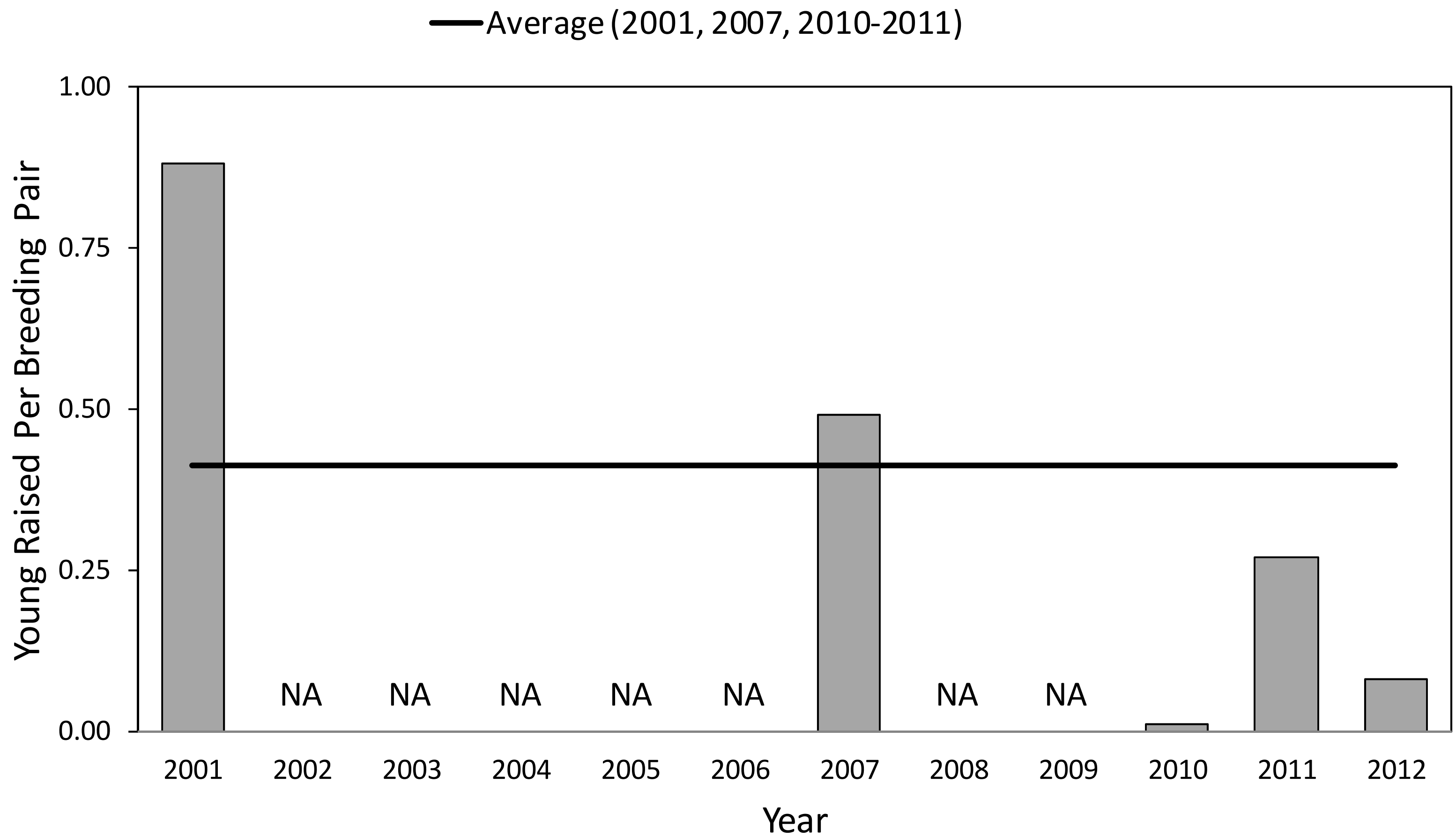


Figure 10. Caspian tern nesting success (average number of young raised per breeding pair) at the breeding colony on Goose Island in Potholes Reservoir during 2001-2012. Nesting success during 2002-2006 and 2008-2009 is not known.

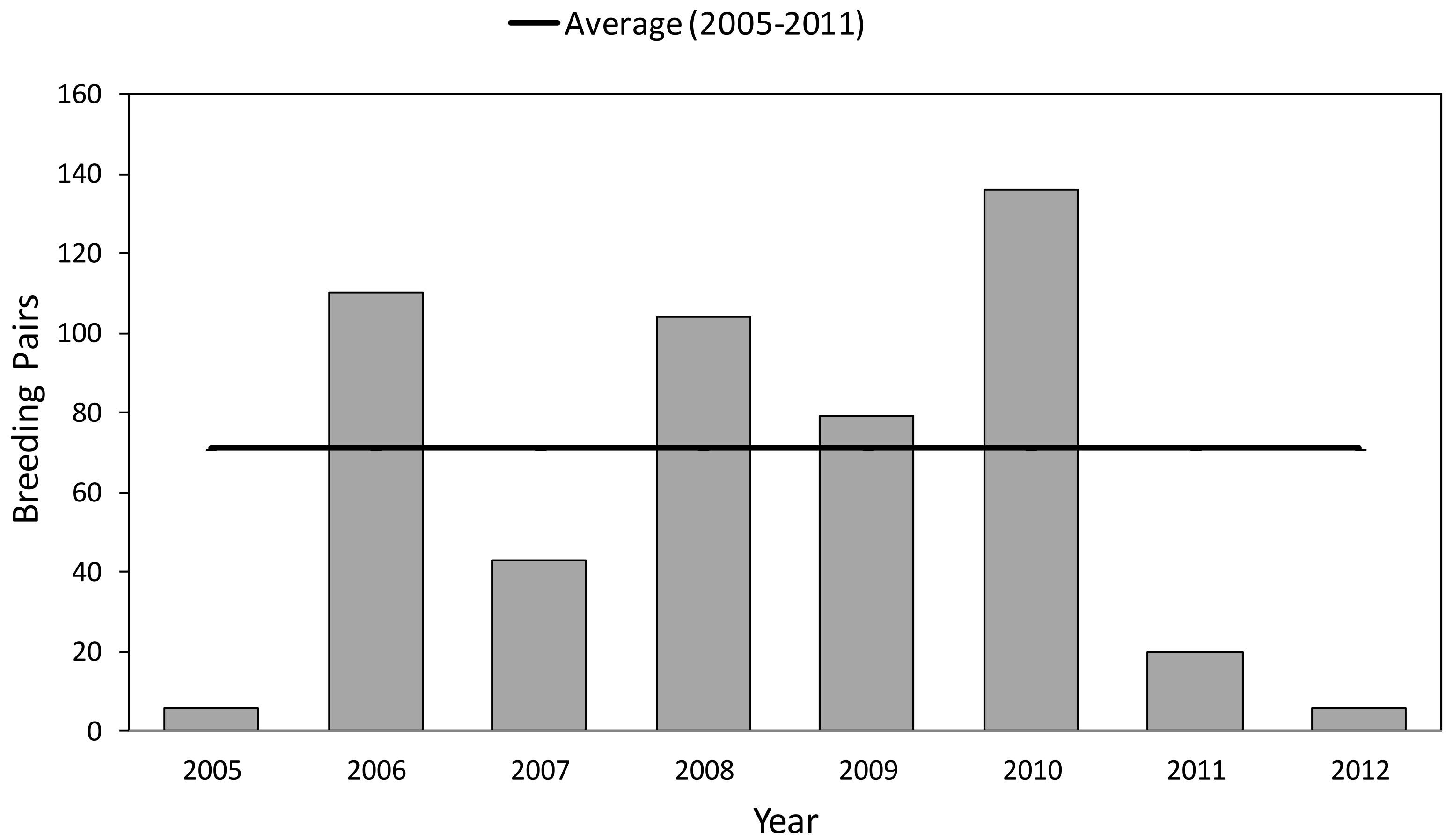


Figure 11. Size of the Caspian tern breeding colony (number of breeding pairs) at the Blalock Islands in the mid-Columbia River during 2005-2012.

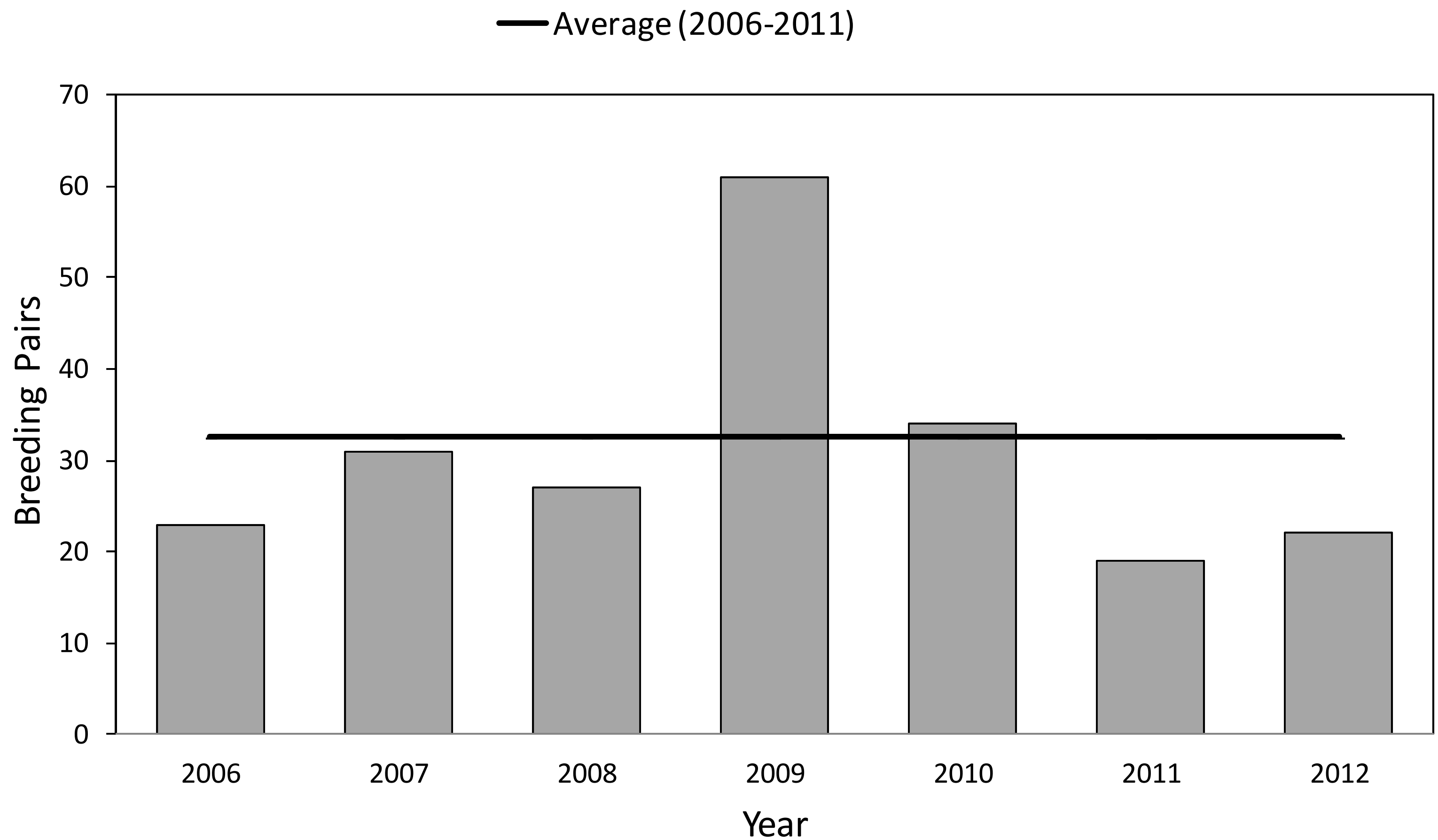


Figure 12. Size of the Caspian tern breeding colony (number of breeding pairs) at Twining Island in Banks Lake during 2006-2012. In 2005, Caspian terns nested on two islands in Banks Lake (Twining and Goose islands), and colony size was estimated to be less than 10 breeding pairs at each site.

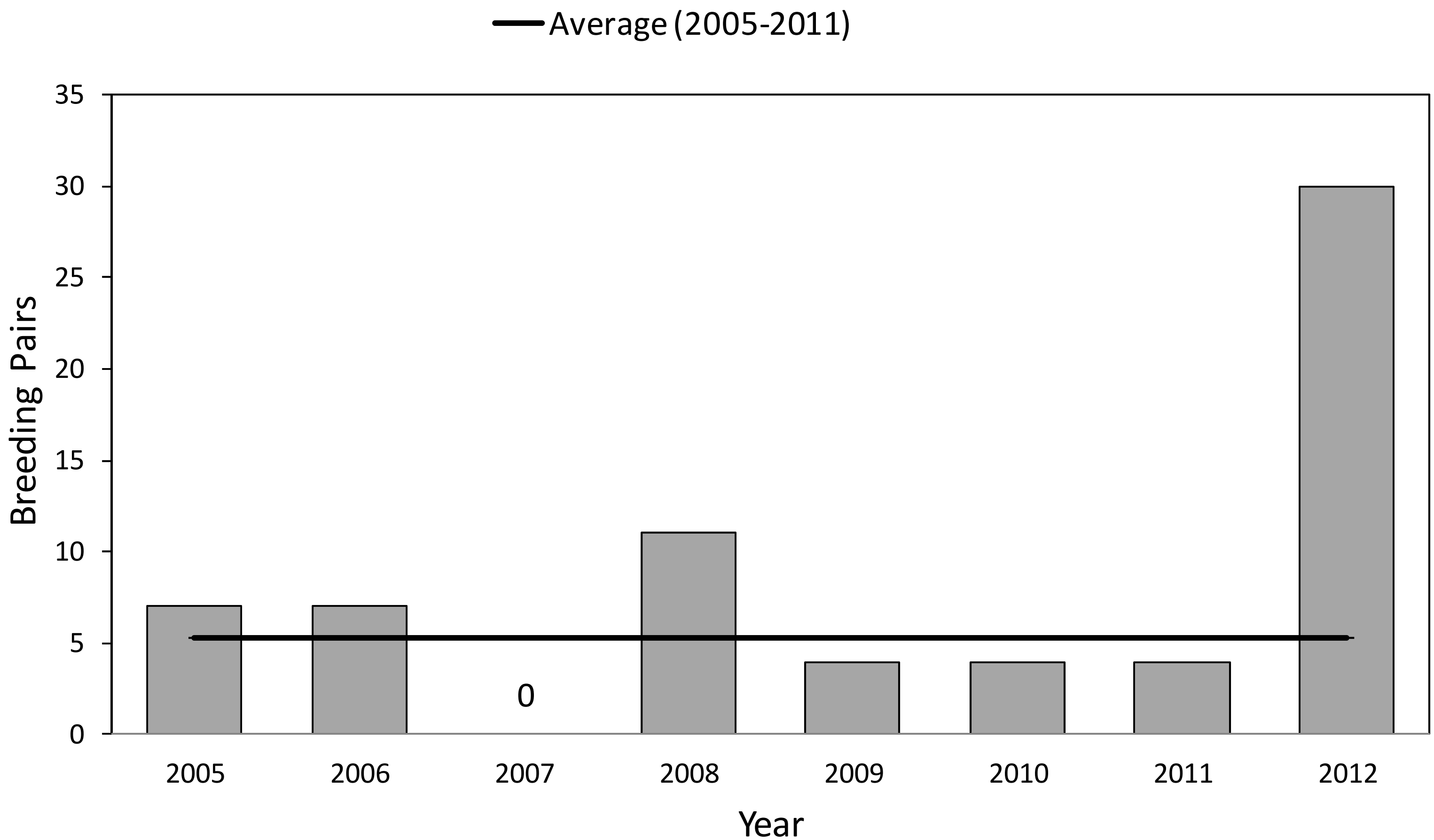


Figure 13. Size of the Caspian tern breeding colony (number of breeding pairs) at Harper Island in Sprague Lake during 2005-2012. Caspian terns did not attempt to nest on Harper Island in 2007.

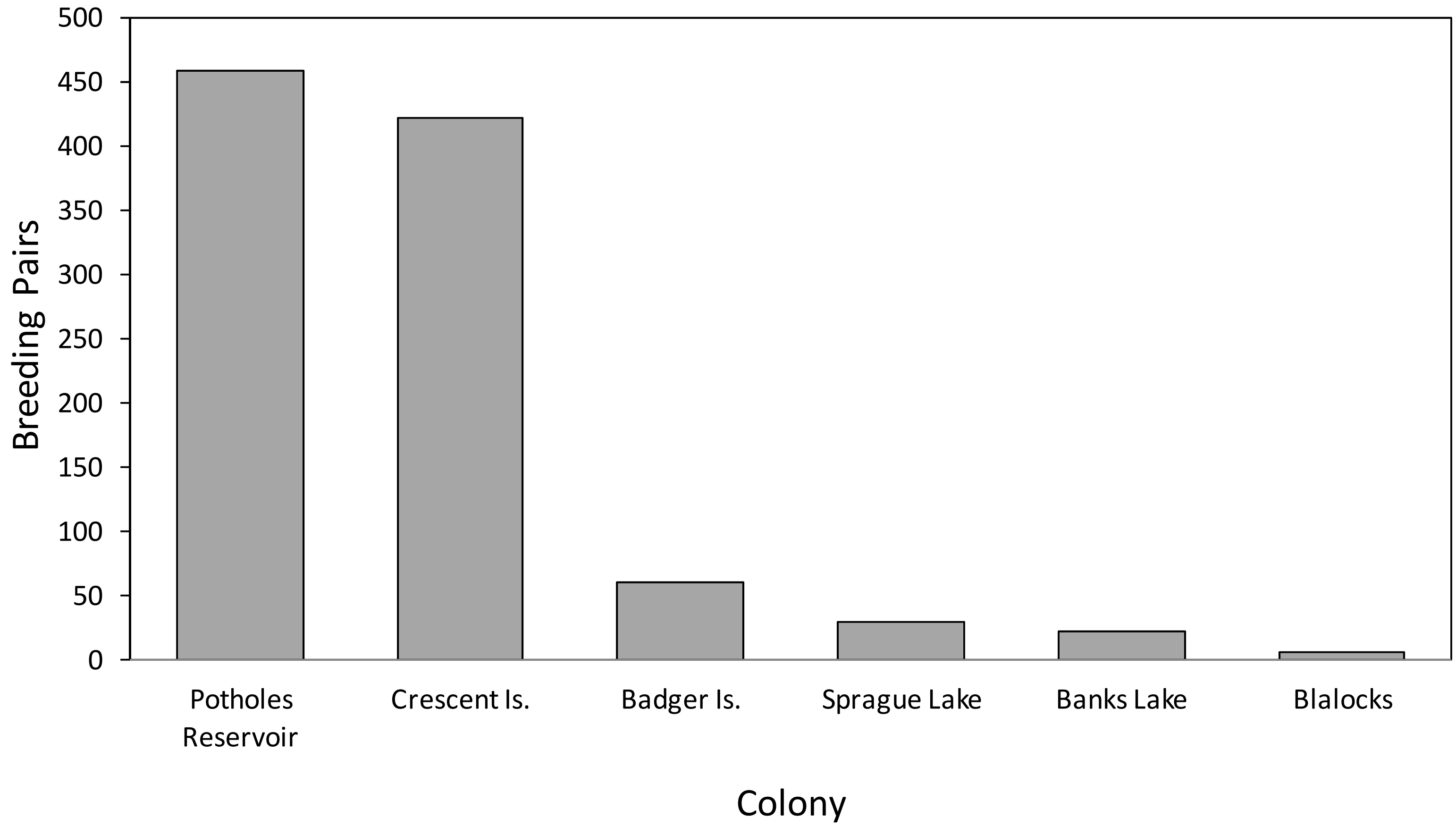


Figure 14. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) in the Columbia Plateau region during the 2012 breeding season.

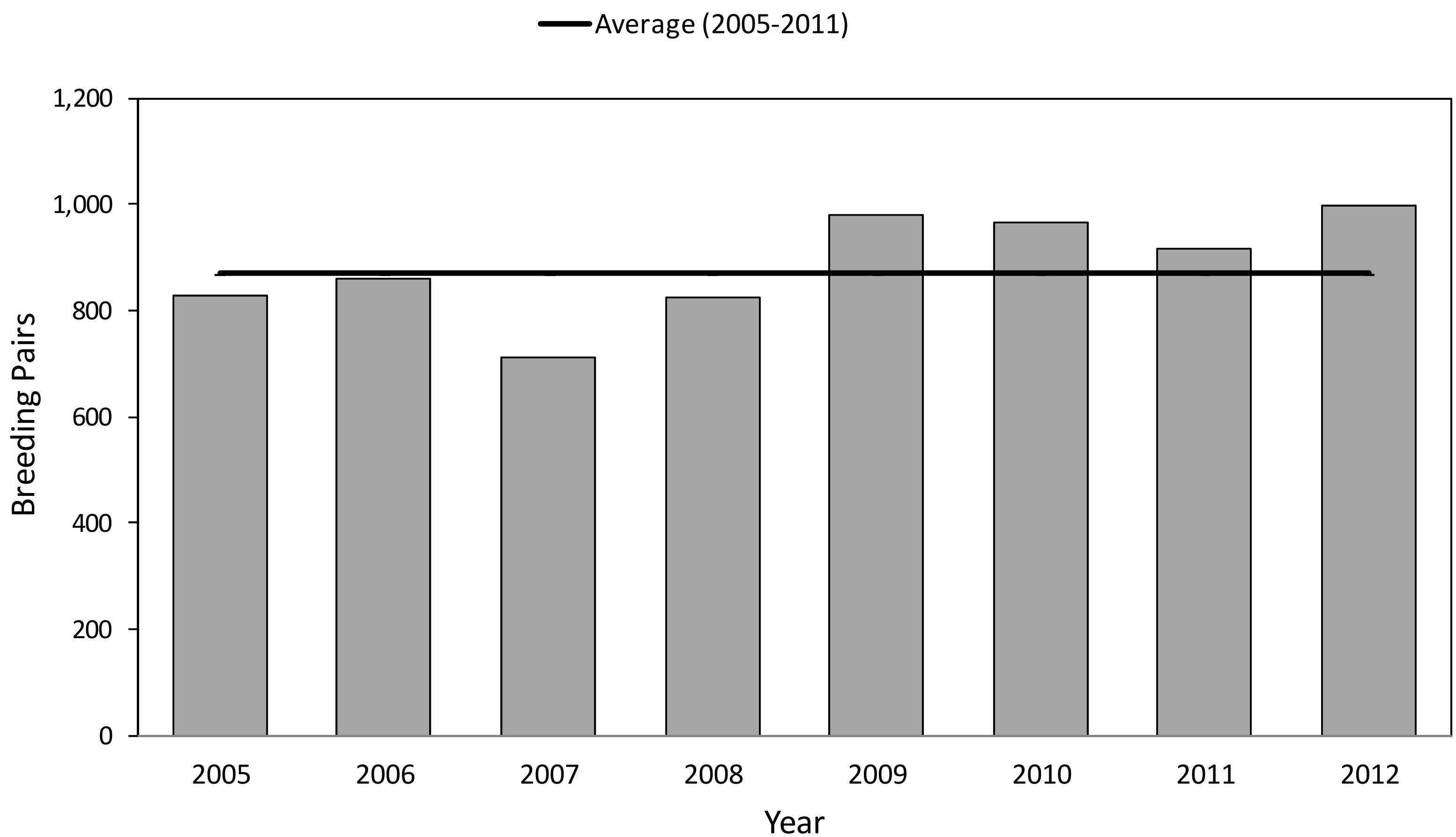


Figure 15. Total numbers of Caspian tern breeding pairs nesting at all colonies in the Columbia Plateau region during 2005-2012.

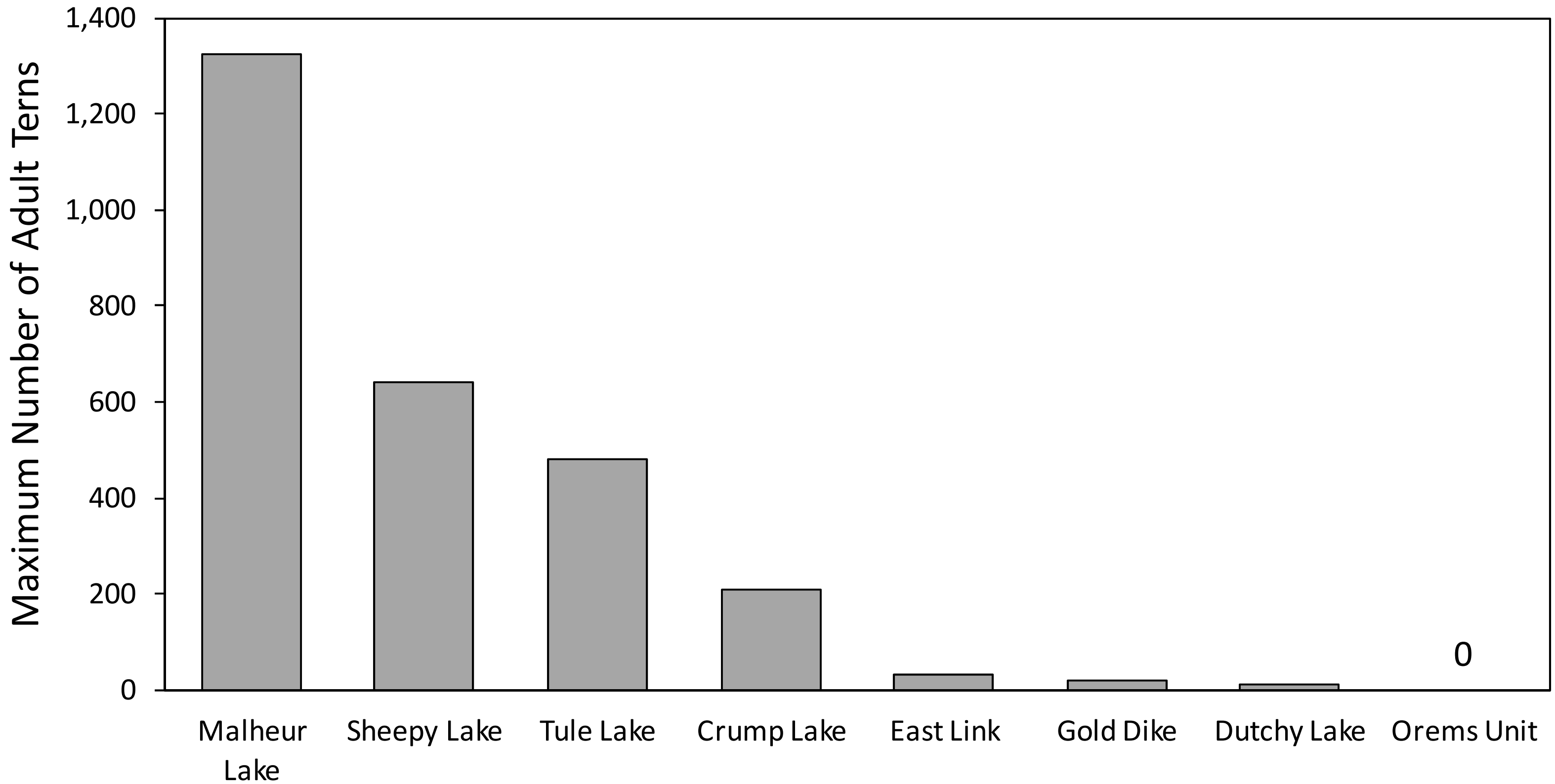


Figure 16. Maximum number of adult Caspian terns counted during 2012 on tern islands recently constructed by the Corps in interior Oregon and northeastern California. The Corps-constructed tern island at Fern Ridge Reservoir was not monitored in 2012.

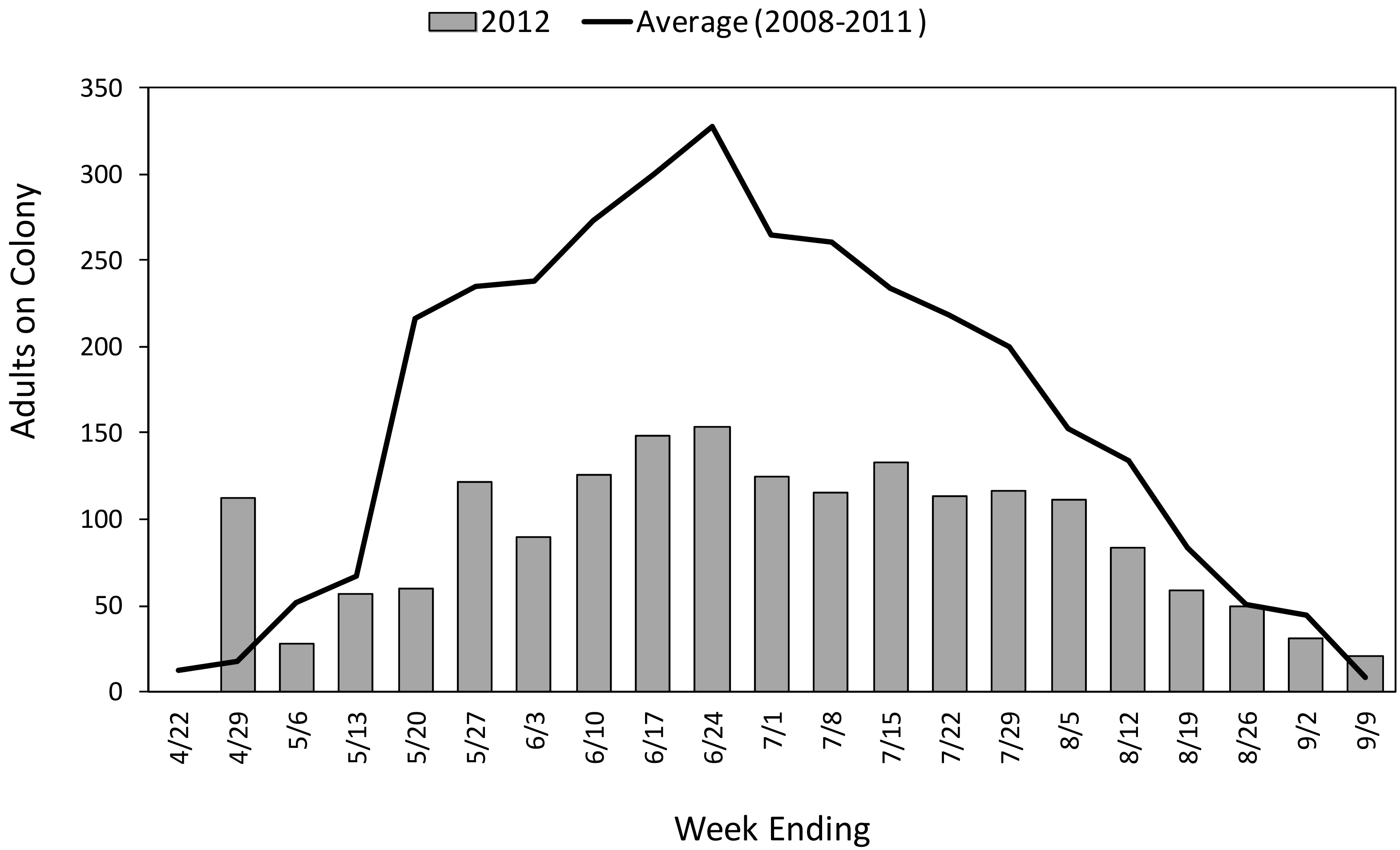


Figure 17. Estimates from the ground of the number of adult Caspian terns on the Corps-constructed tern island at Crump Lake in the Warner Valley, Oregon, by week during the 2012 breeding season.

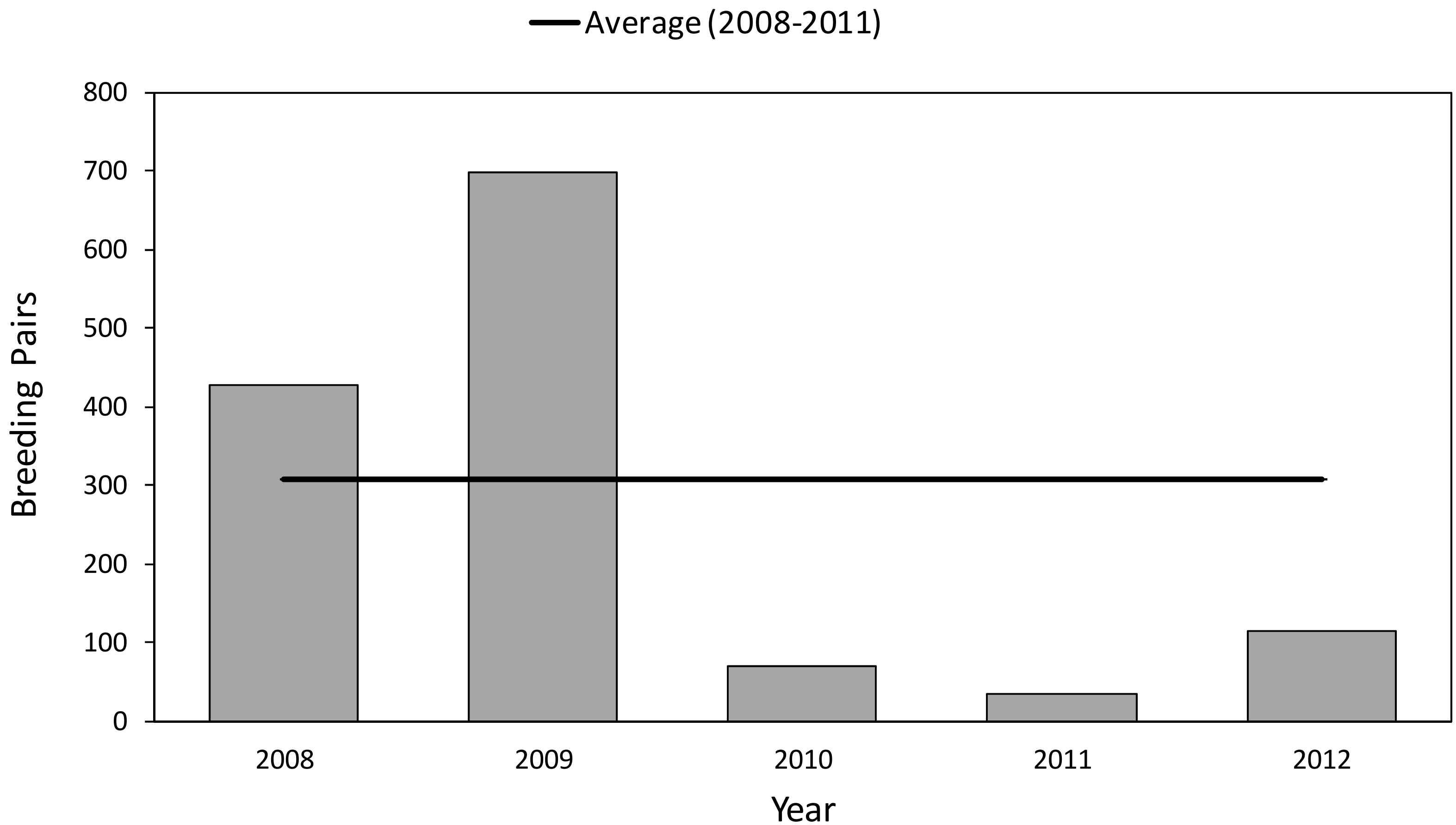


Figure 18. Size of the Caspian tern breeding colony (number of breeding pairs) on the Corps-constructed tern island at Crump Lake in the Warner Valley, Oregon during the 2008-2012 breeding seasons.

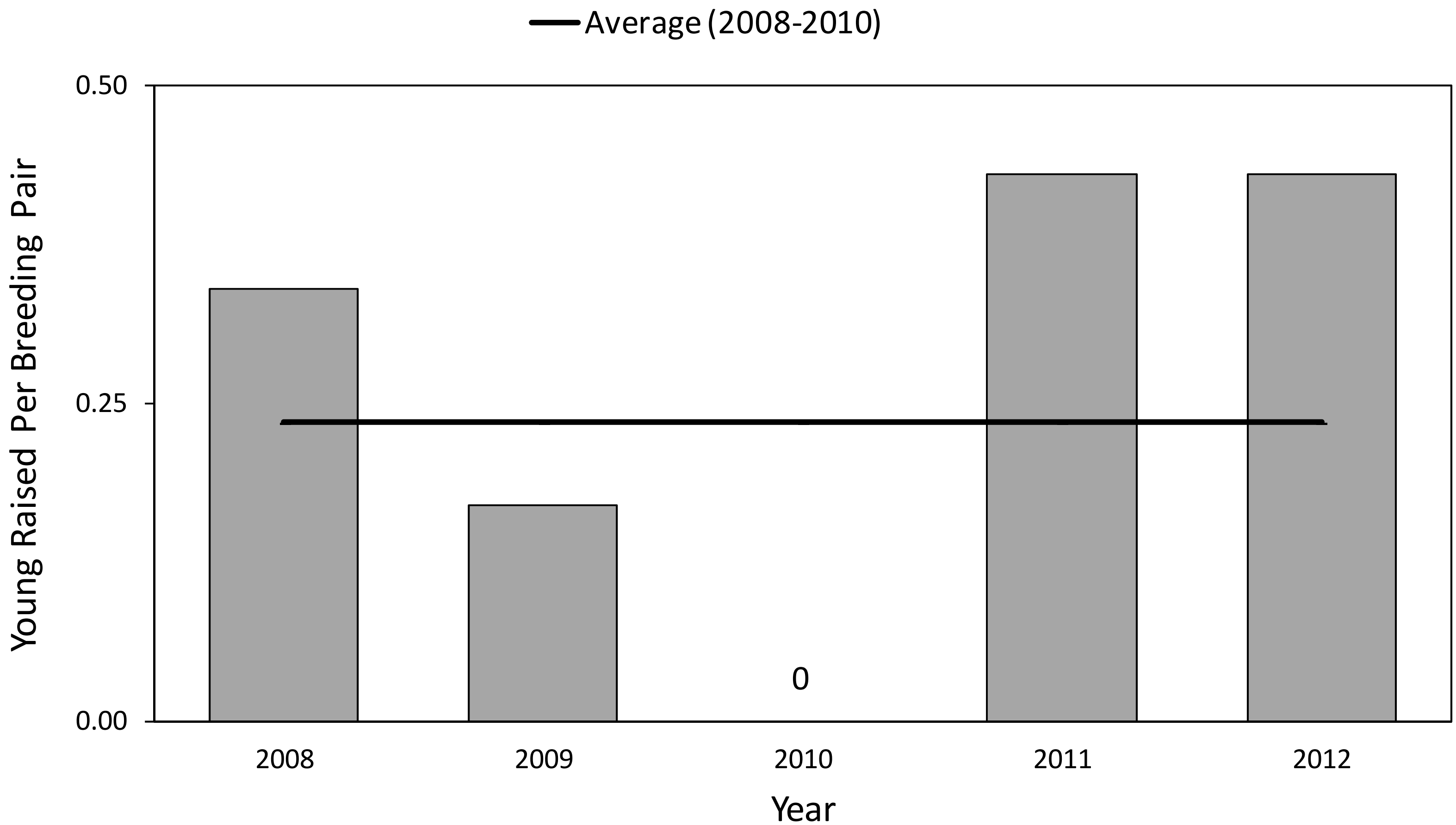


Figure 19. Caspian tern nesting success (average number of young raised per breeding pair) at the Corps-constructed tern island at Crump Lake in the Warner Valley, Oregon during the 2008-2012 breeding seasons. Caspian terns failed to raise any young at the colony in 2010.

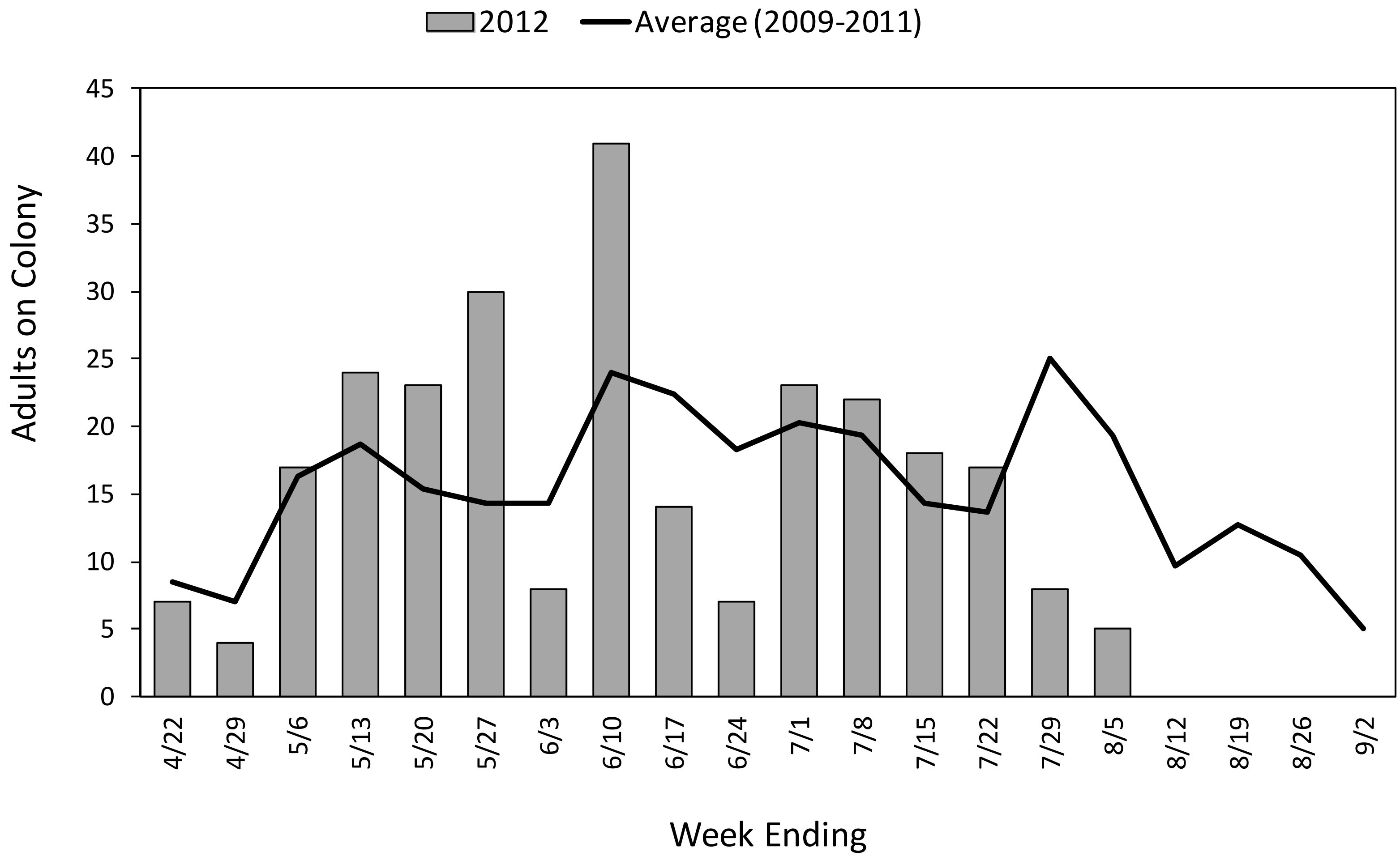


Figure 20. Estimates from the ground of the total number of adult Caspian terns on the Corps-constructed islands in East Link Impoundment, Gold Dike Impoundment, and Dutchy Lake at Summer Lake Wildlife Area, Oregon, by week during the 2012 breeding season.

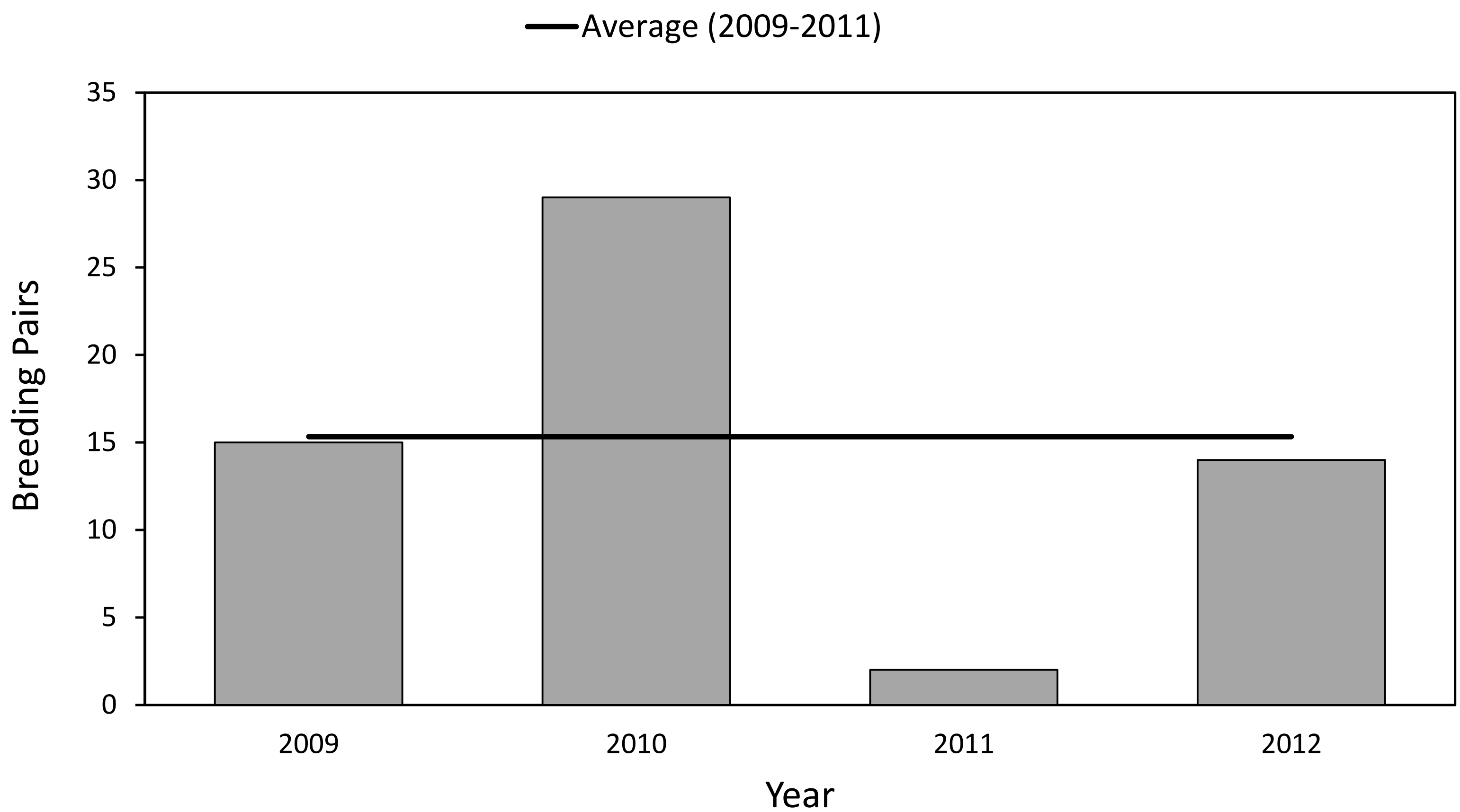


Figure 21. Total size of Caspian tern breeding colonies (number of breeding pairs) on Corps-constructed tern islands in East Link Impoundment, Gold Dike Impoundment, and Dutchy Lake at Summer Lake Wildlife Area, Oregon during the 2009-2012 breeding seasons. Caspian terns did not nest on the Dutchy Lake tern island during 2010-2012.

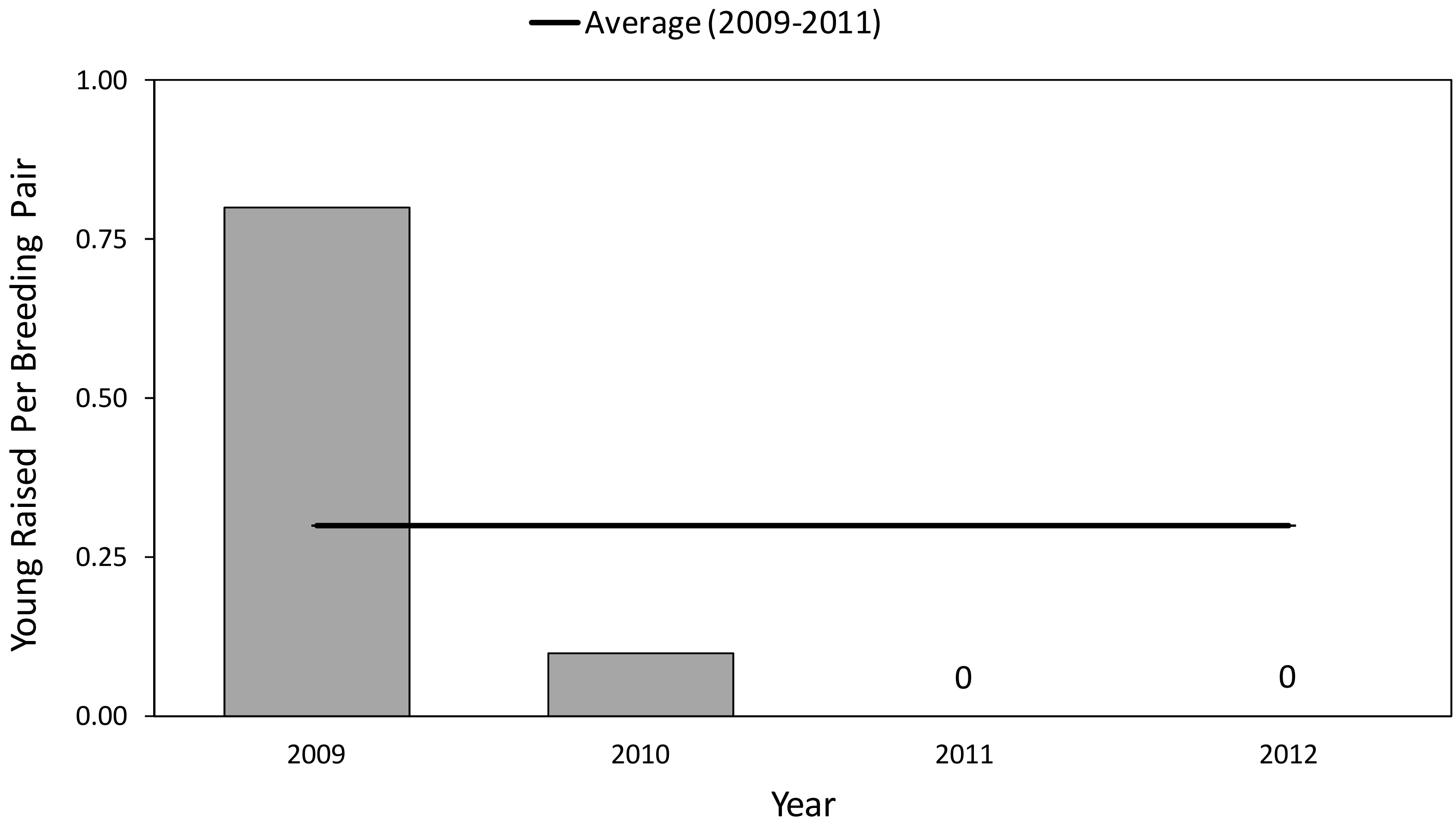


Figure 22. Caspian tern nesting success (average number of young raised per breeding pair) at Corps-constructed tern islands in Summer Lake Wildlife Area (i.e., tern islands in East Link Impoundment, Gold Dike Impoundment, and Dutchy Lake), Oregon during 2009-2012. Caspian terns did not nest on the Dutchy Lake tern island in 2010-2012. No young terns were fledged from the East Link and Dutchy Lake tern islands in 2011-2012 or the Gold Dike tern island in 2012 (the first year the Gold Dike tern island was available).

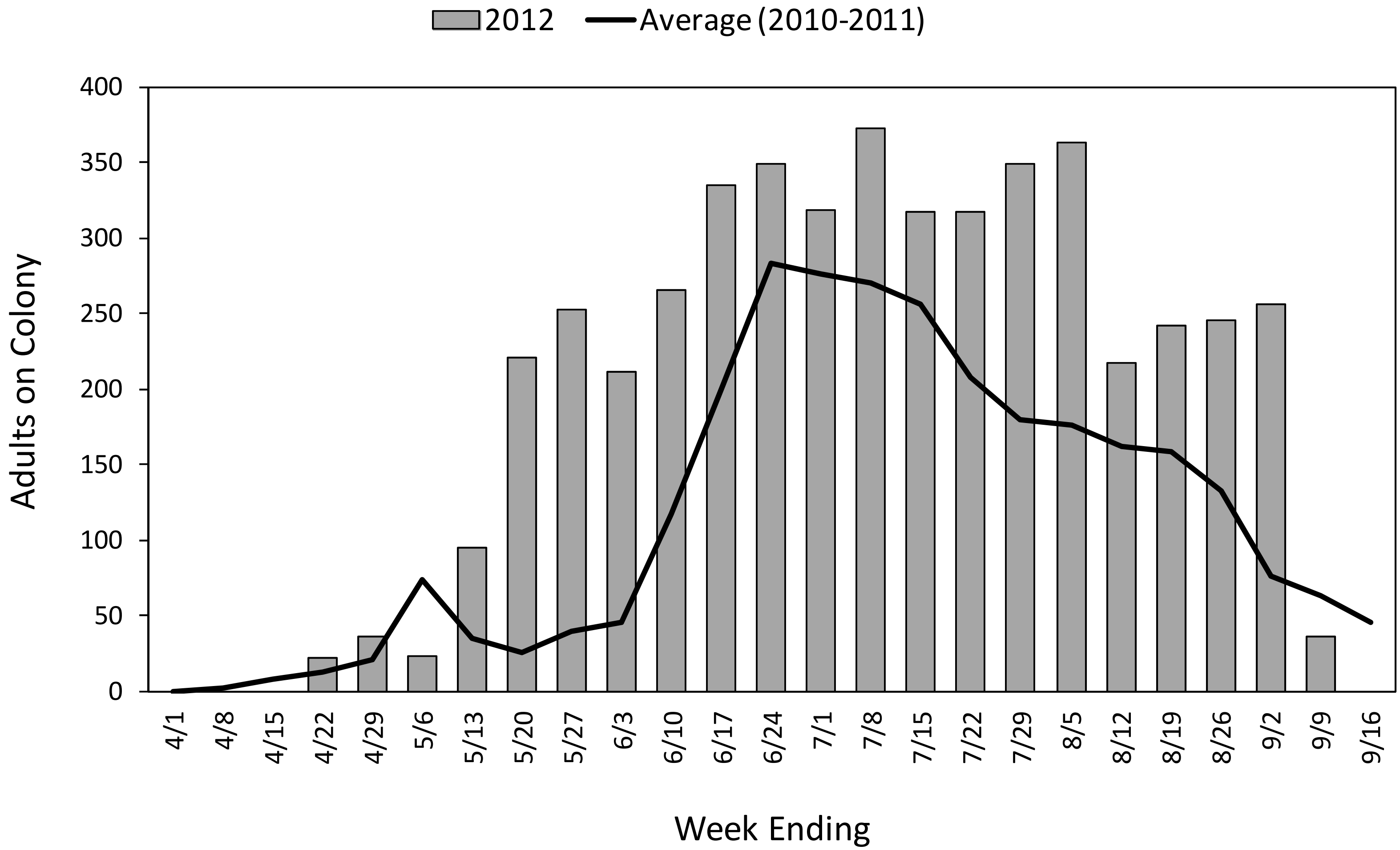


Figure 23. Estimates from the ground of the number of adult Caspian terns on the Corps-constructed tern island on Sheepy Lake in Lower Klamath NWR, California, by week during the 2012 breeding season.

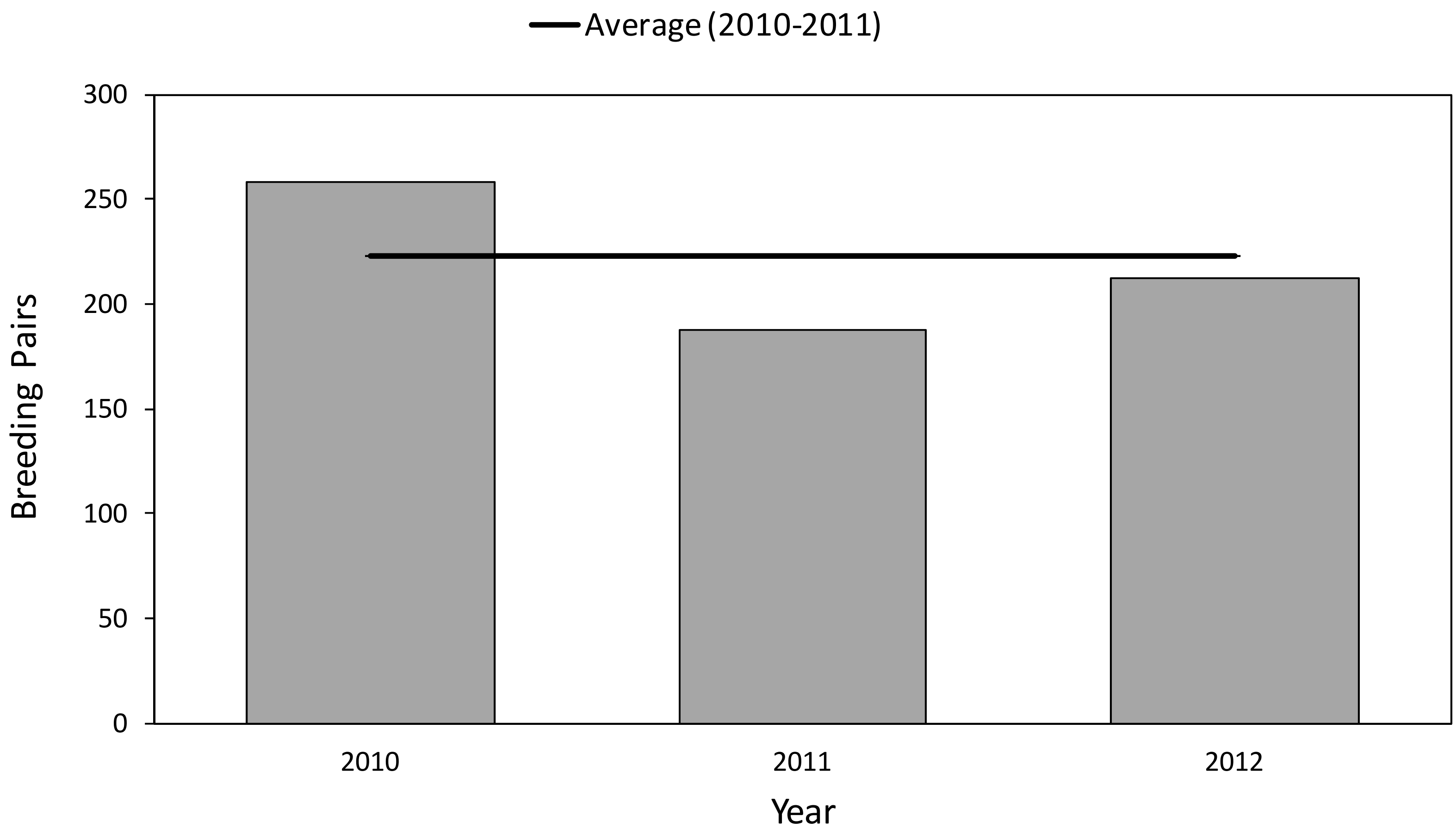


Figure 24. Size of the Caspian tern breeding colony (number of breeding pairs) at the Corps-constructed tern island on Sheepy Lake in Lower Klamath NWR, California during the 2010-2012 breeding seasons.

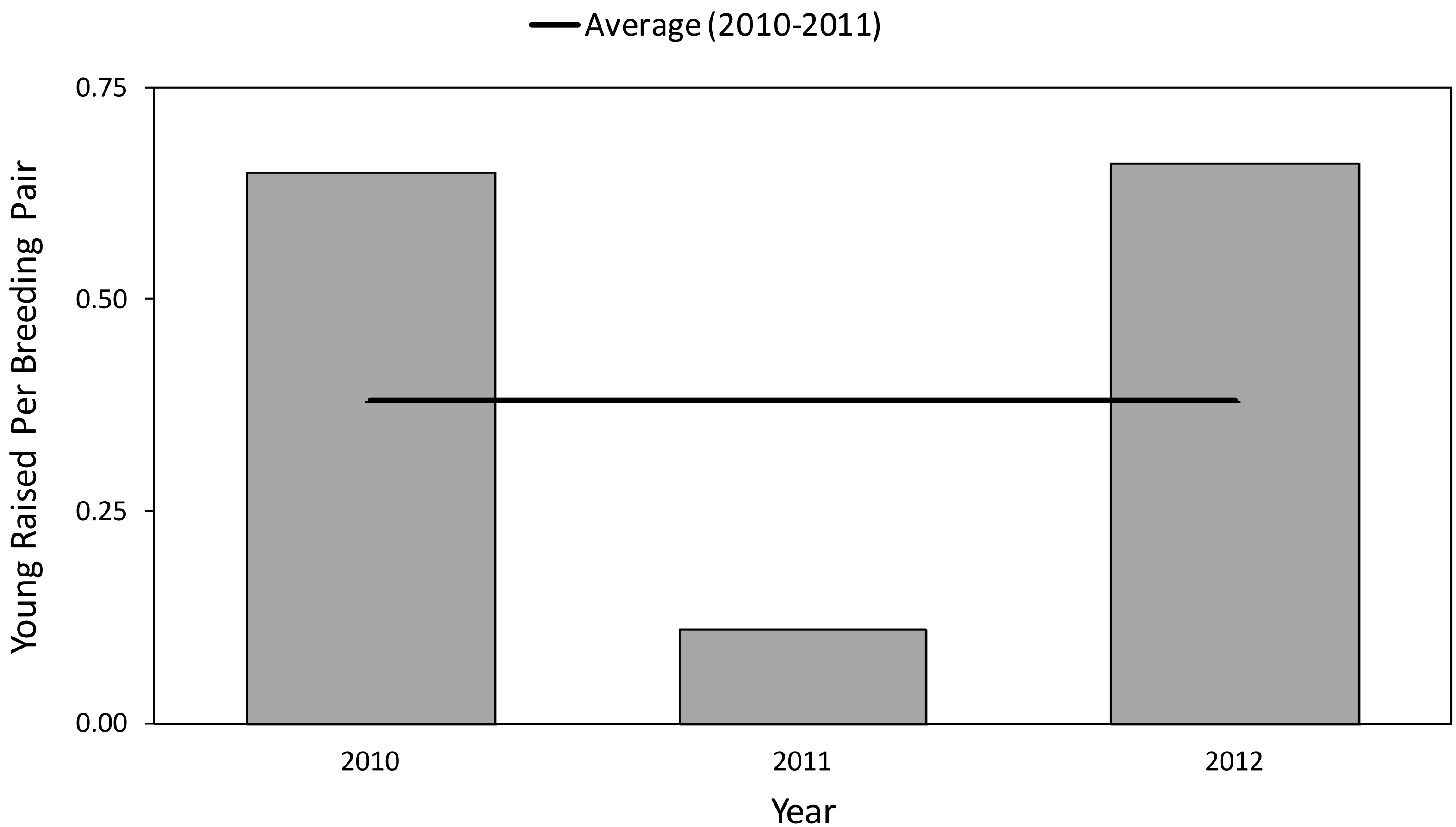


Figure 25. Caspian tern nesting success (average number of young raised per breeding pair) at the Corps-constructed tern island on Sheepy Lake in Lower Klamath NWR, California during 2010-2012.

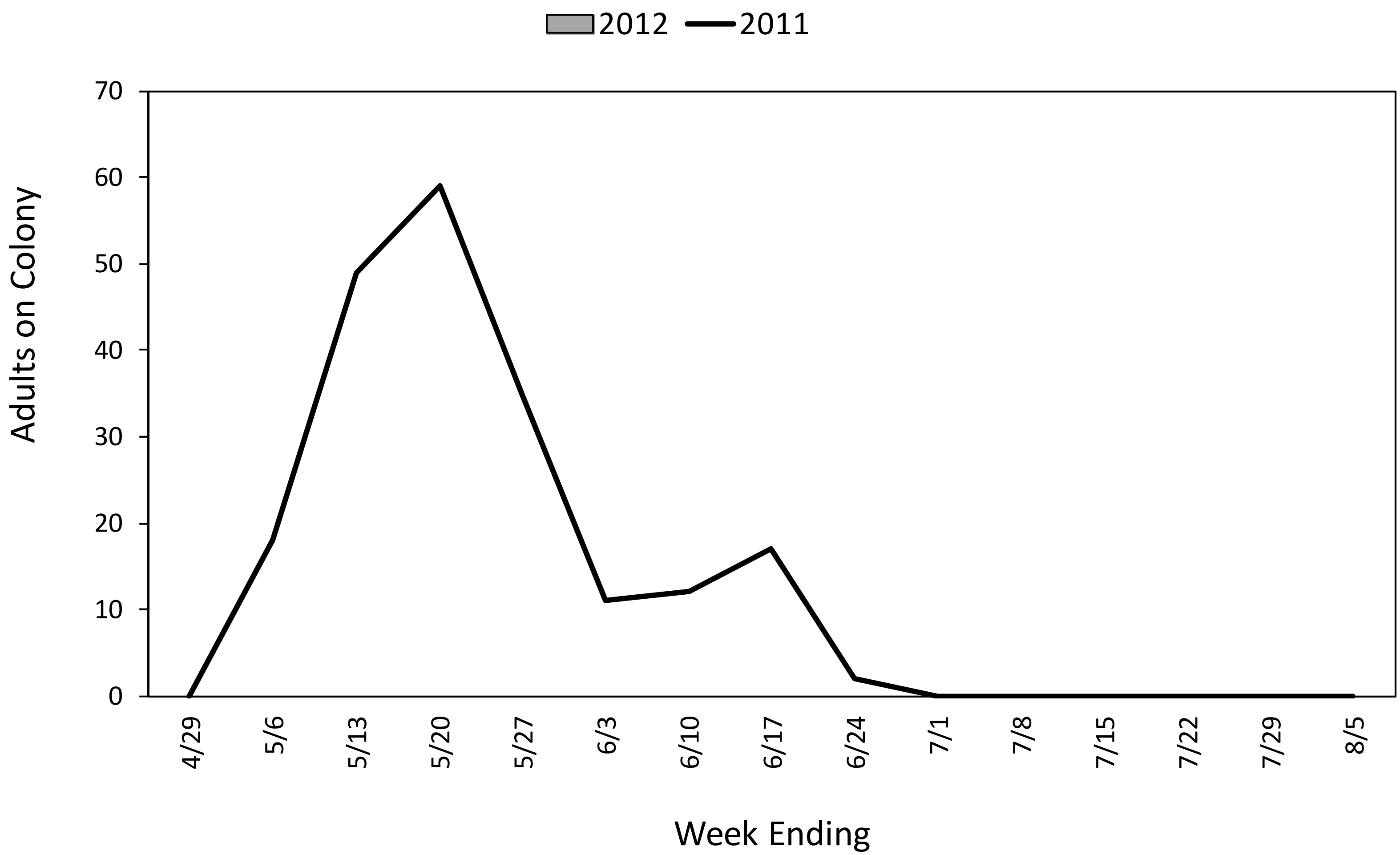


Figure 26. Estimates from the ground of the number of adult Caspian terns on the Corps-constructed tern island at Orems Unit in Lower Klamath NWR, California, by week during the 2011 breeding season. Caspian terns were not observed on the Orems Unit tern island in 2012.

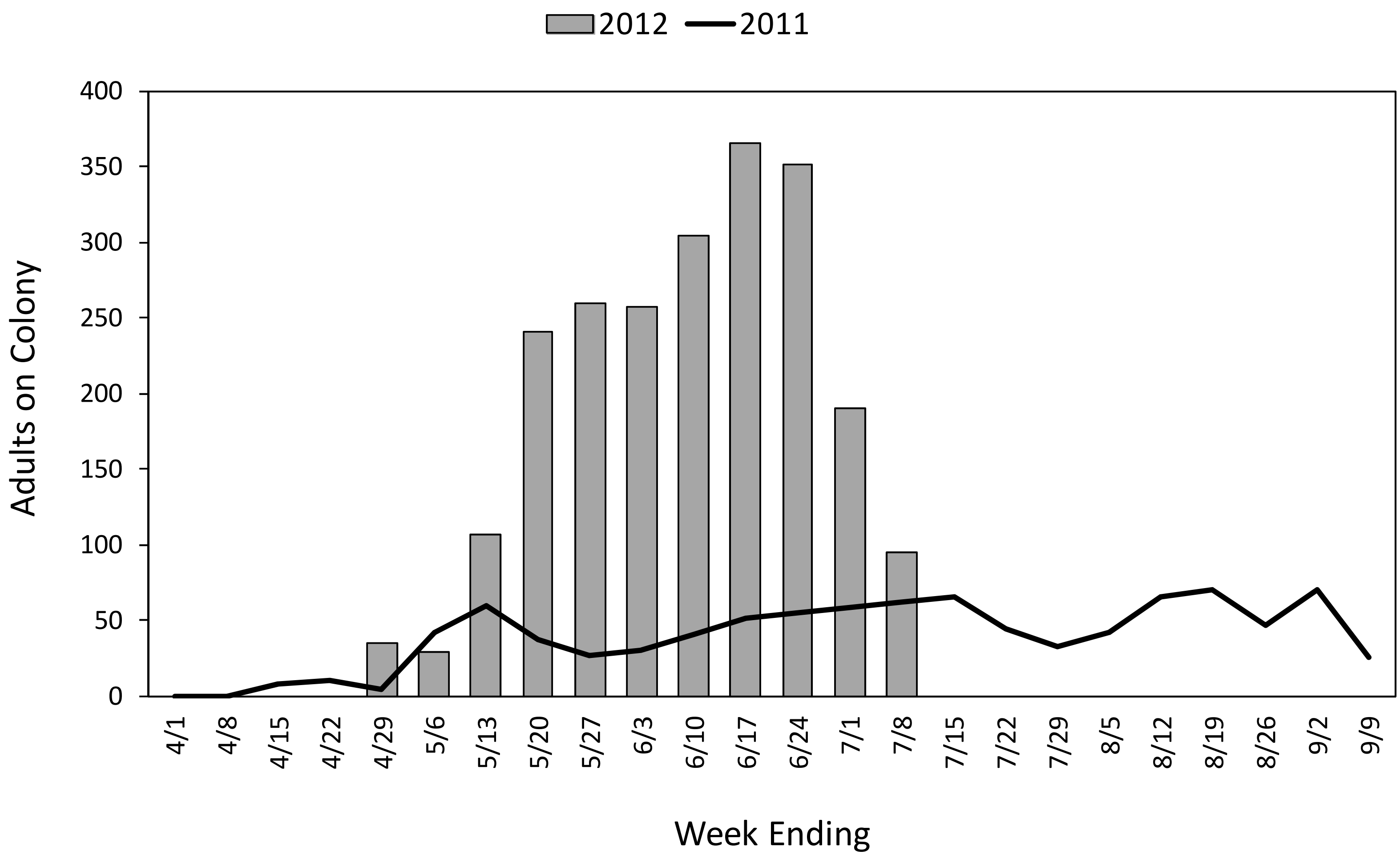


Figure 27. Estimates from the ground of the number of adult Caspian terns on the Corps-constructed tern island at Tule Lake Sump 1B in Tule Lake NWR, California, by week during the 2012 breeding season.

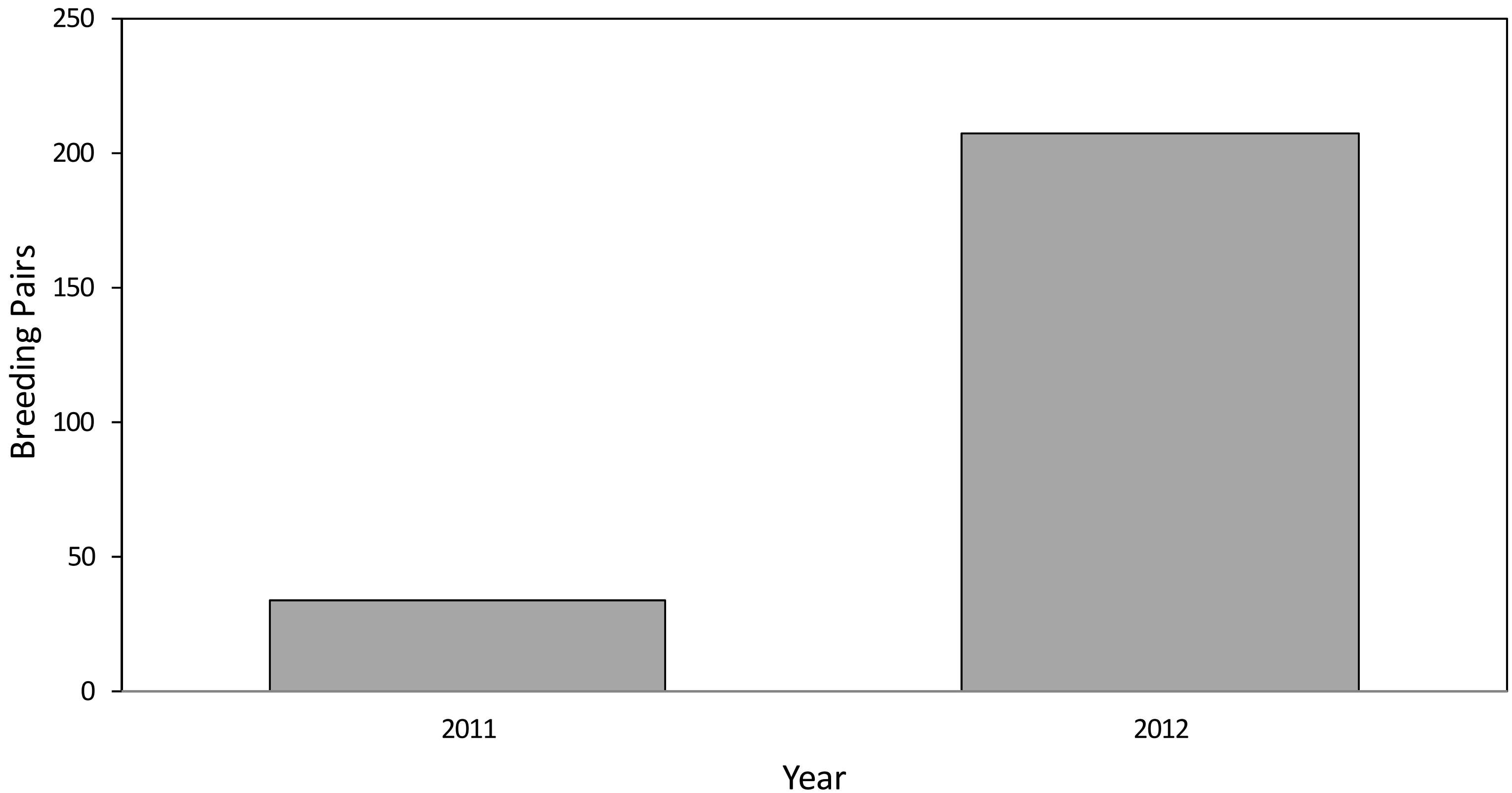


Figure 28. Size of the Caspian tern breeding colony (number of breeding pairs) on the Corps-constructed tern island at Tule Lake Sump 1B in Tule Lake NWR, California during the 2011-2012 breeding seasons.

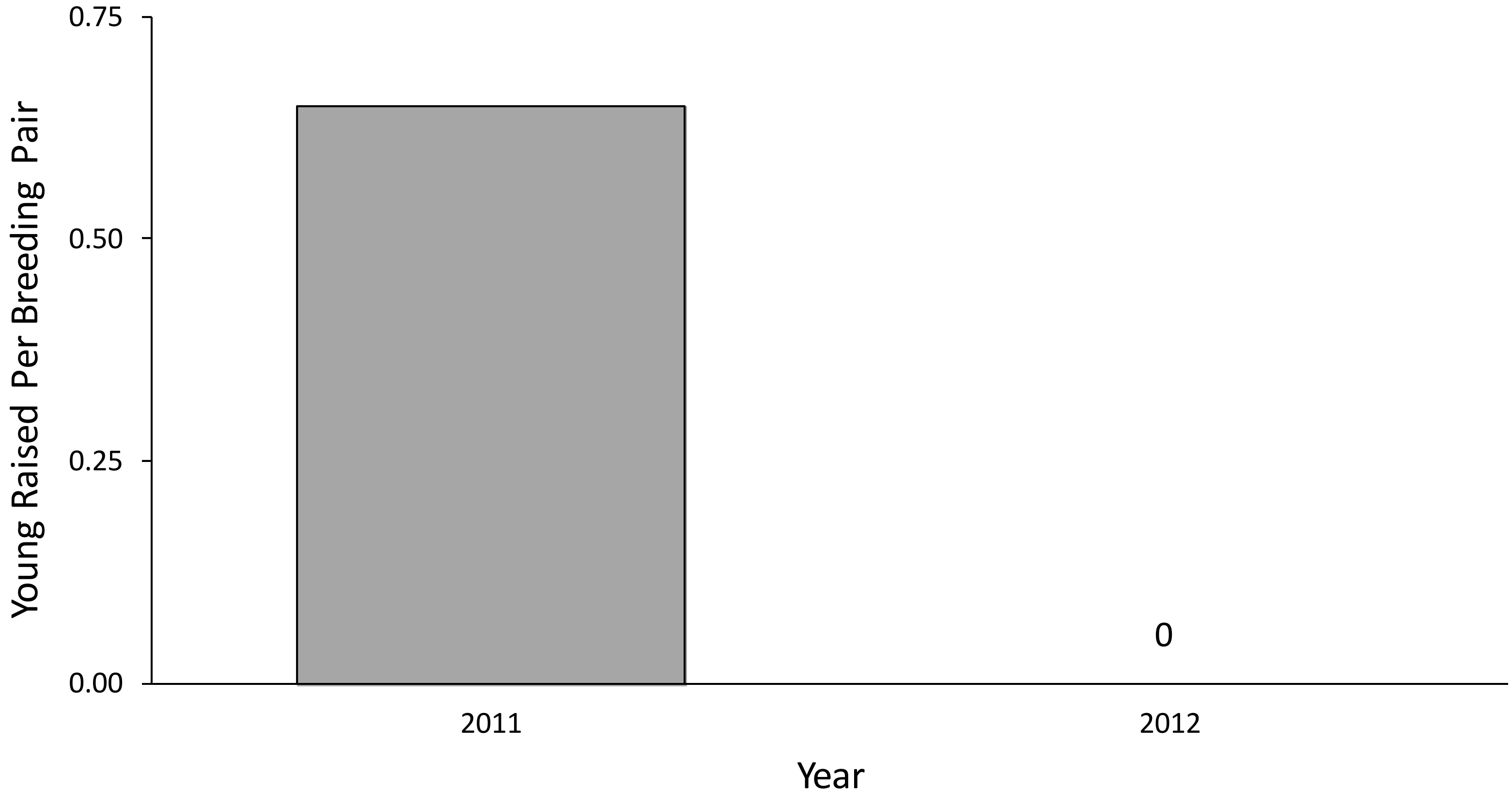


Figure 29. Caspian tern nesting success (average number of young raised per breeding pair) at the Corps-constructed tern island at Tule Lake Sump 1B in Tule Lake NWR, California during 2011-2012.

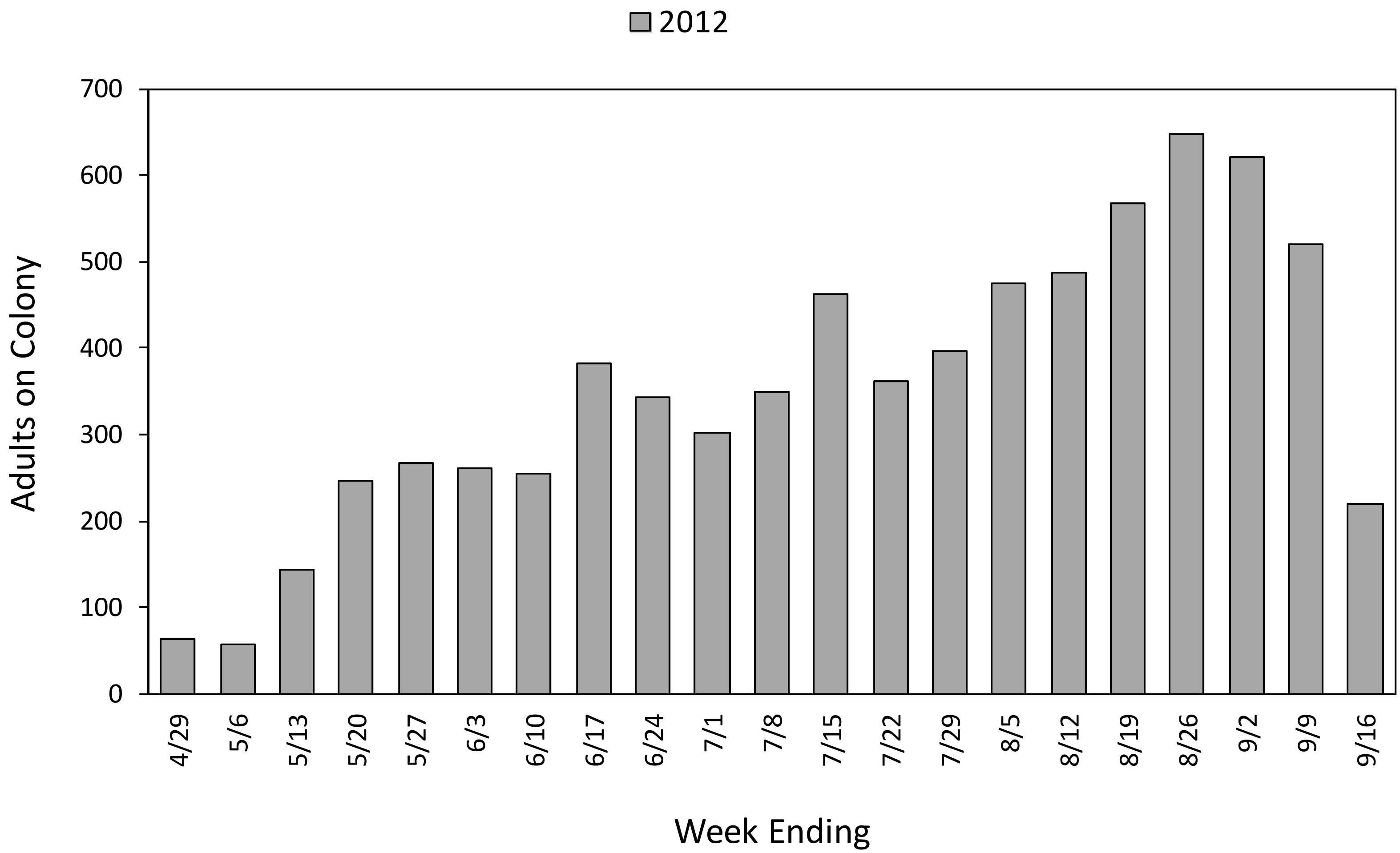


Figure 30. Estimates from the ground of the number of adult Caspian terns on the Corps-constructed tern island on Malheur Lake in Malheur NWR, Oregon, by week during the 2012 breeding season.

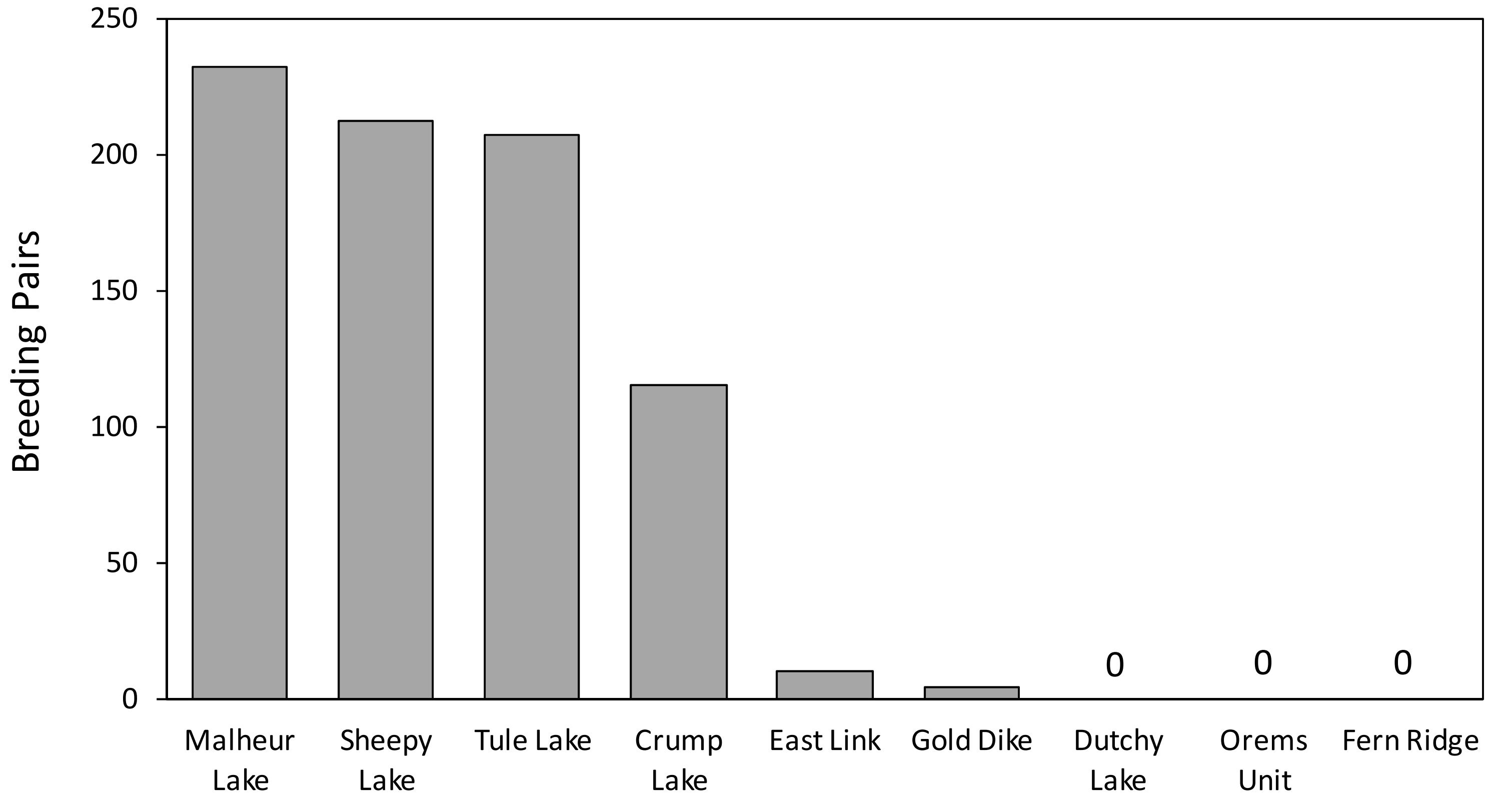


Figure 31. Sizes of Caspian tern breeding colonies (numbers of breeding pairs) on Corps-constructed tern islands in interior Oregon and northeastern California during the 2012 breeding season.

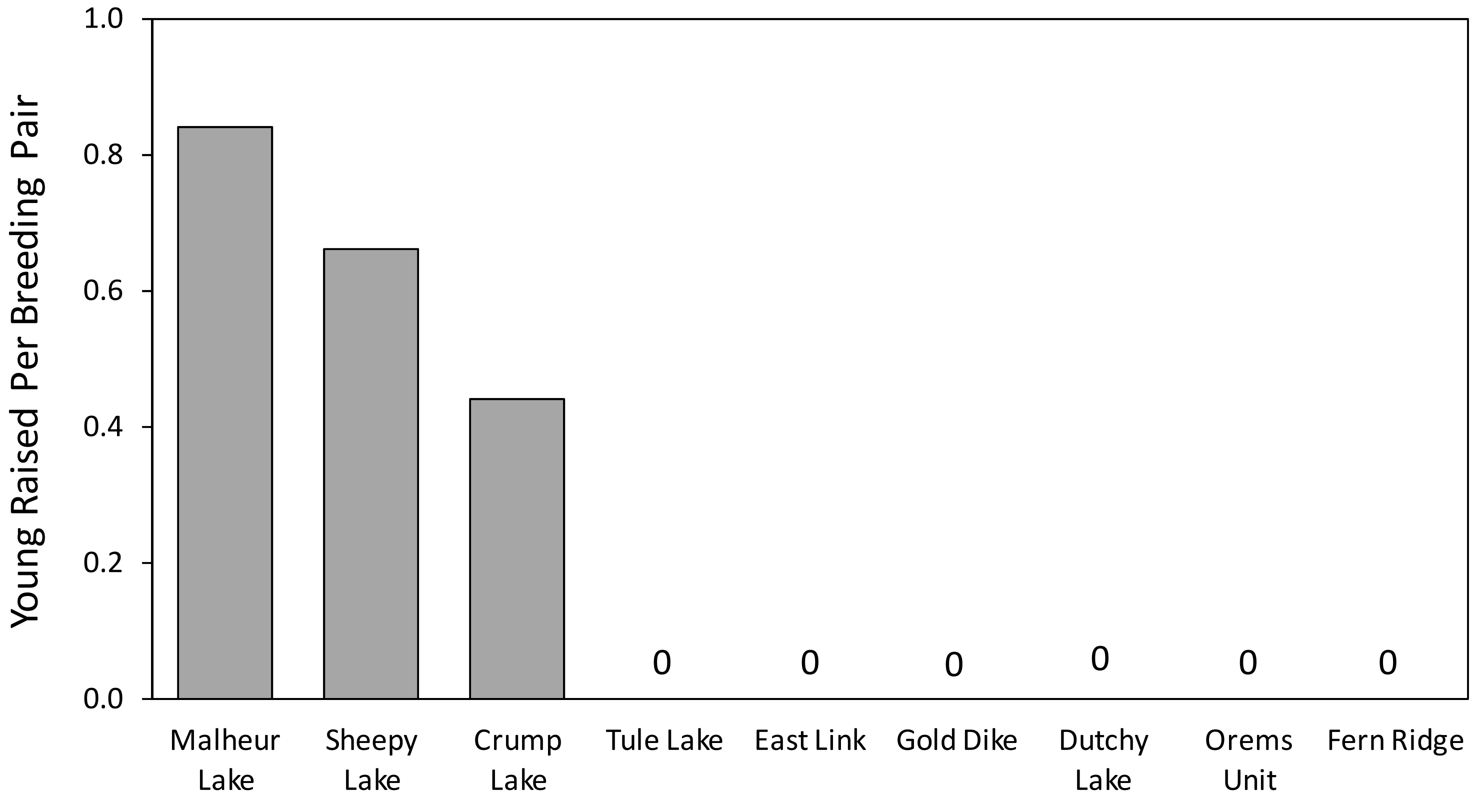


Figure 32. Caspian tern nesting success (average number of young raised per breeding pair) at Corps-constructed tern islands in interior Oregon and northeastern California during the 2012 breeding season.

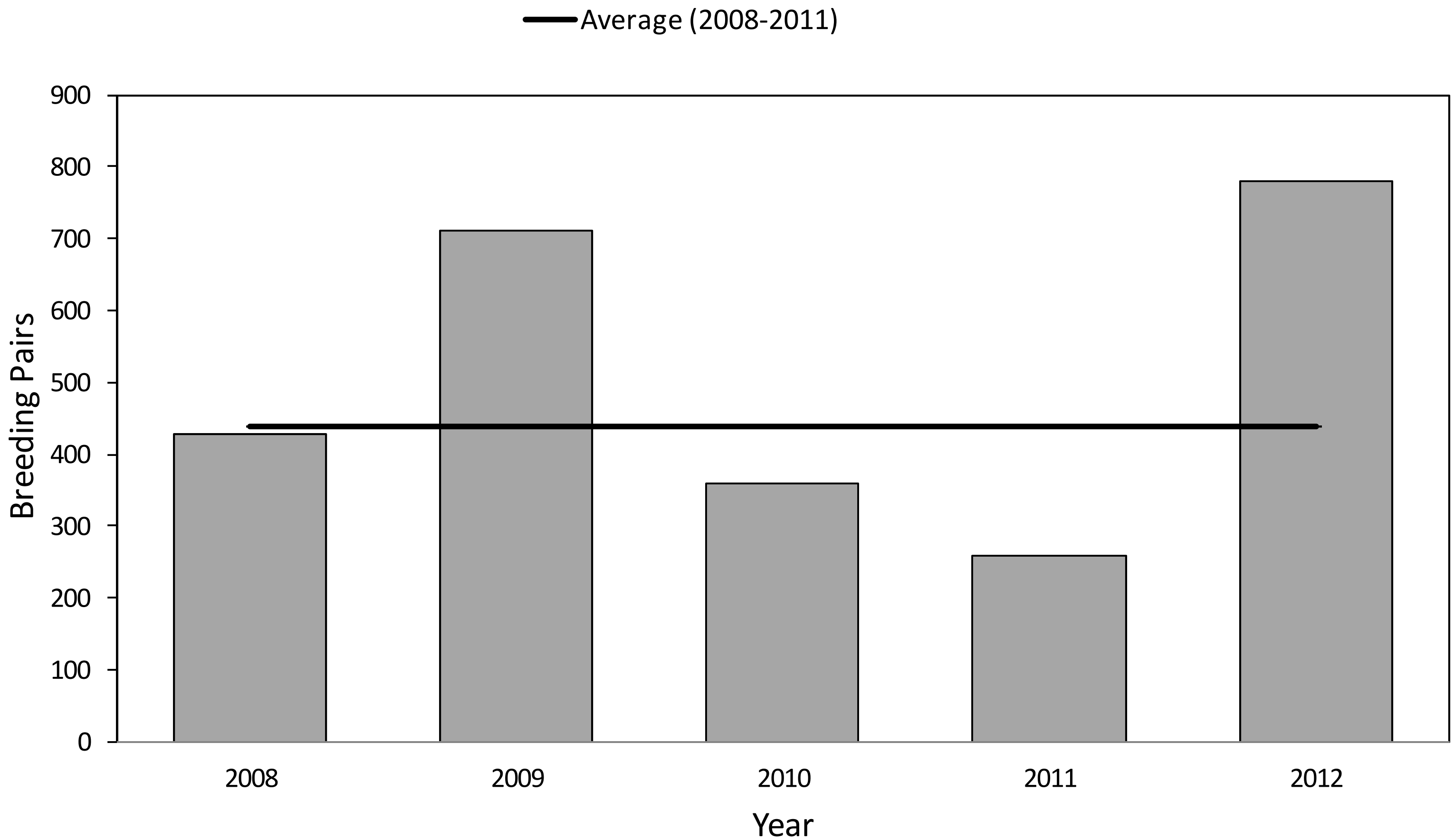


Figure 33. Total numbers of Caspian tern breeding pairs nesting at Corps-constructed tern islands in interior Oregon and northeastern California during 2008-2012.

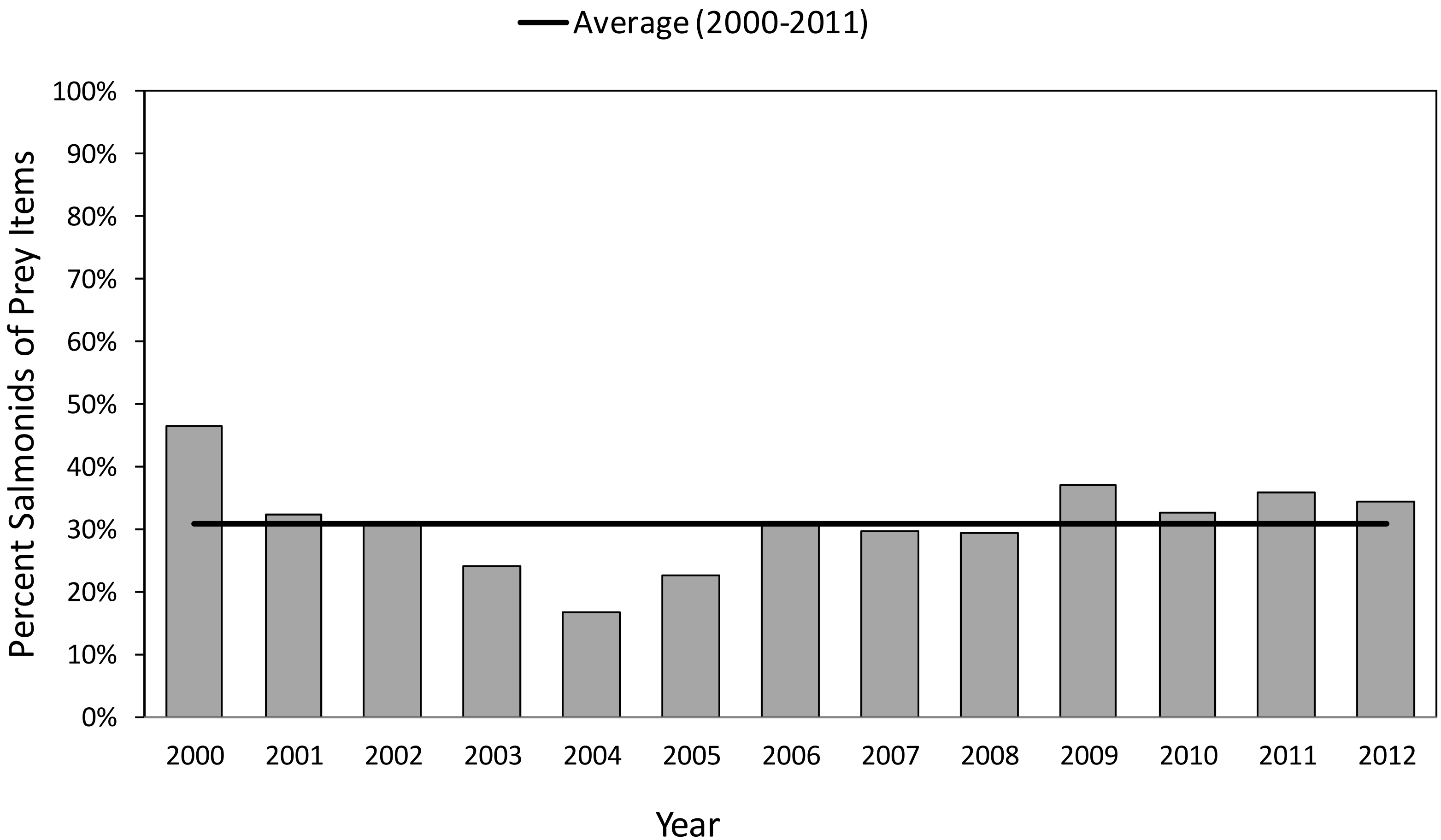


Figure 34. Average annual proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2012 breeding seasons.

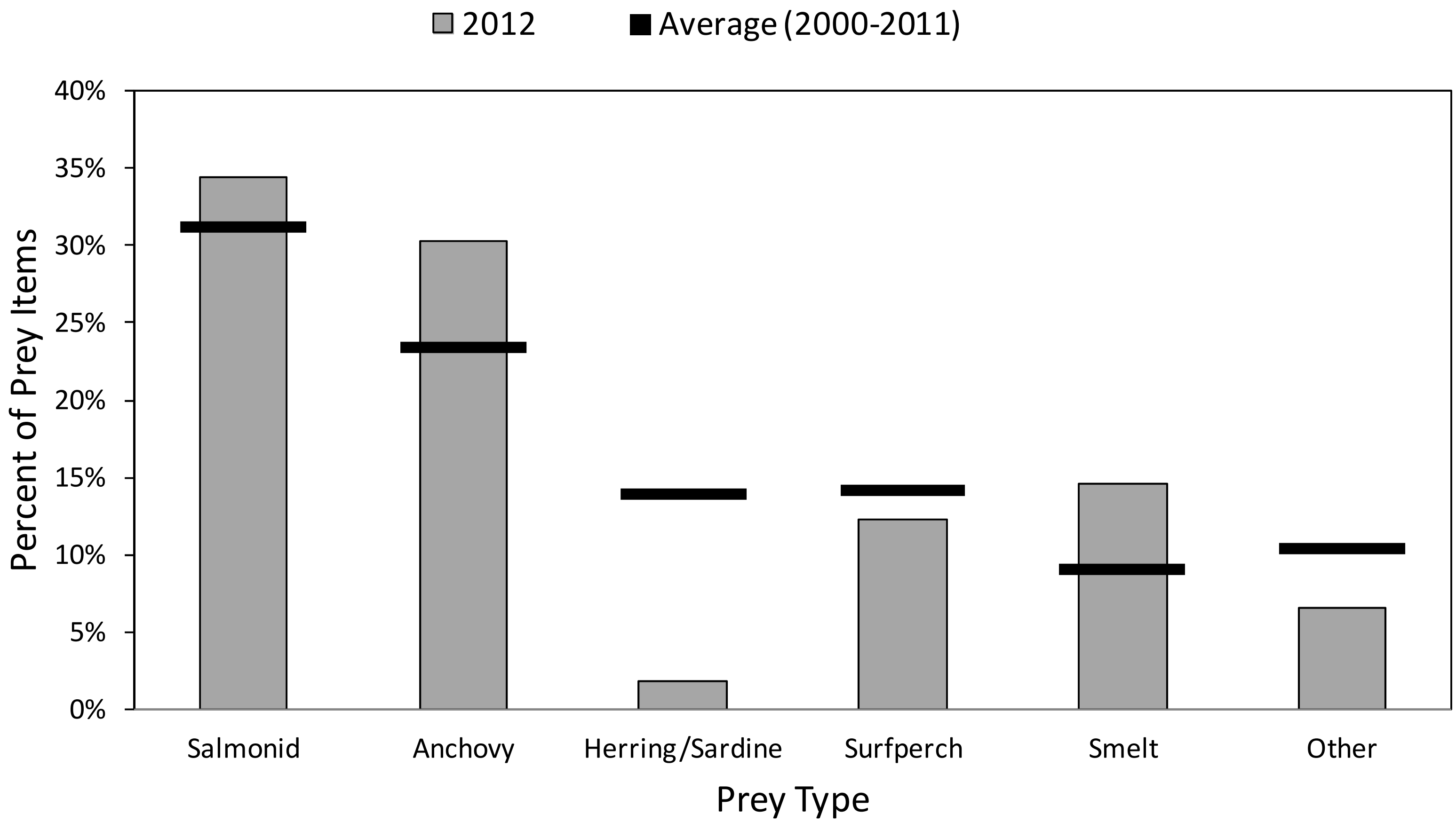


Figure 35. Diet composition (percent of identified prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2012 breeding season. Diet composition was based on fish identified on-colony in Caspian tern bill-loads.

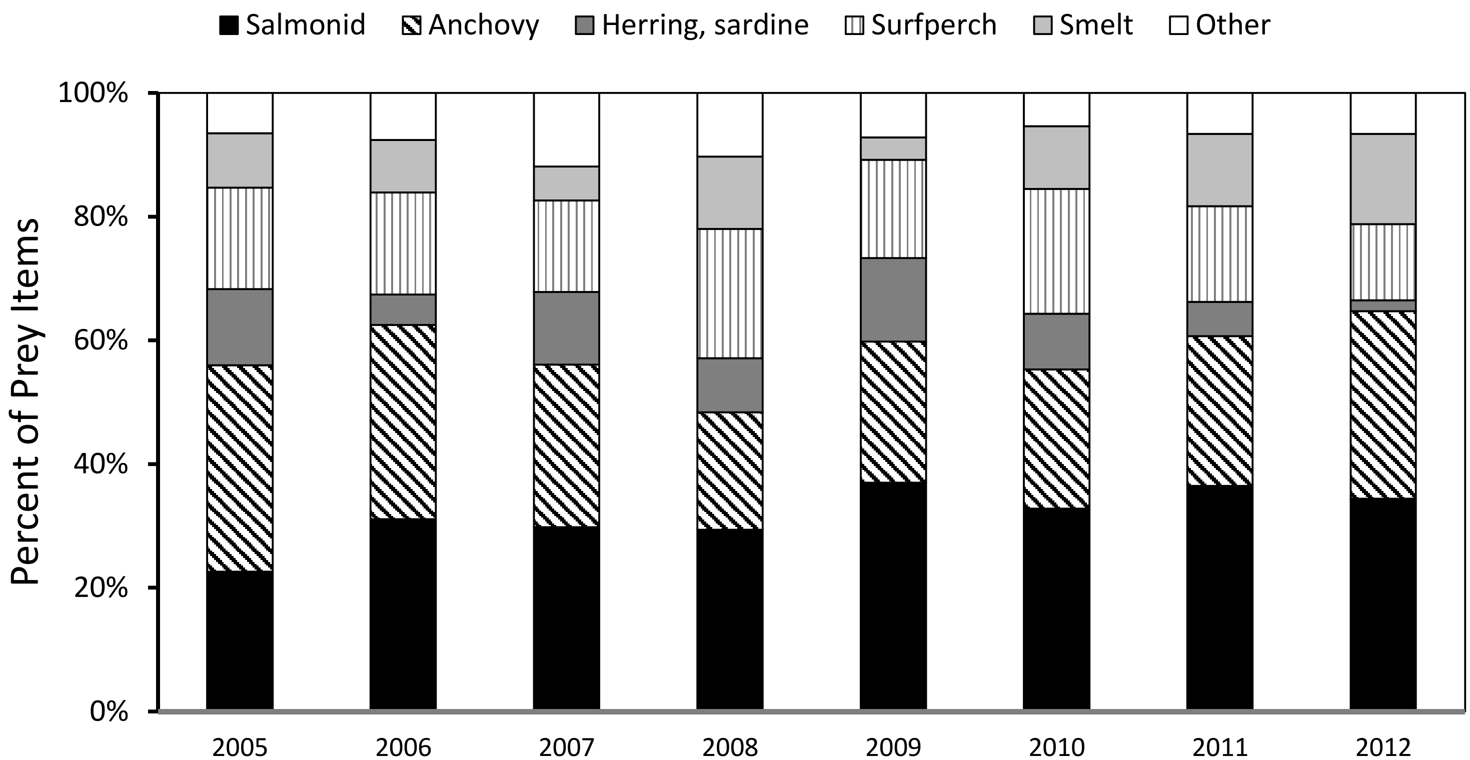


Figure 36. Annual diet composition (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2005 - 2012 breeding seasons. Diet composition was based on fish identified on-colony in Caspian tern bill-loads.

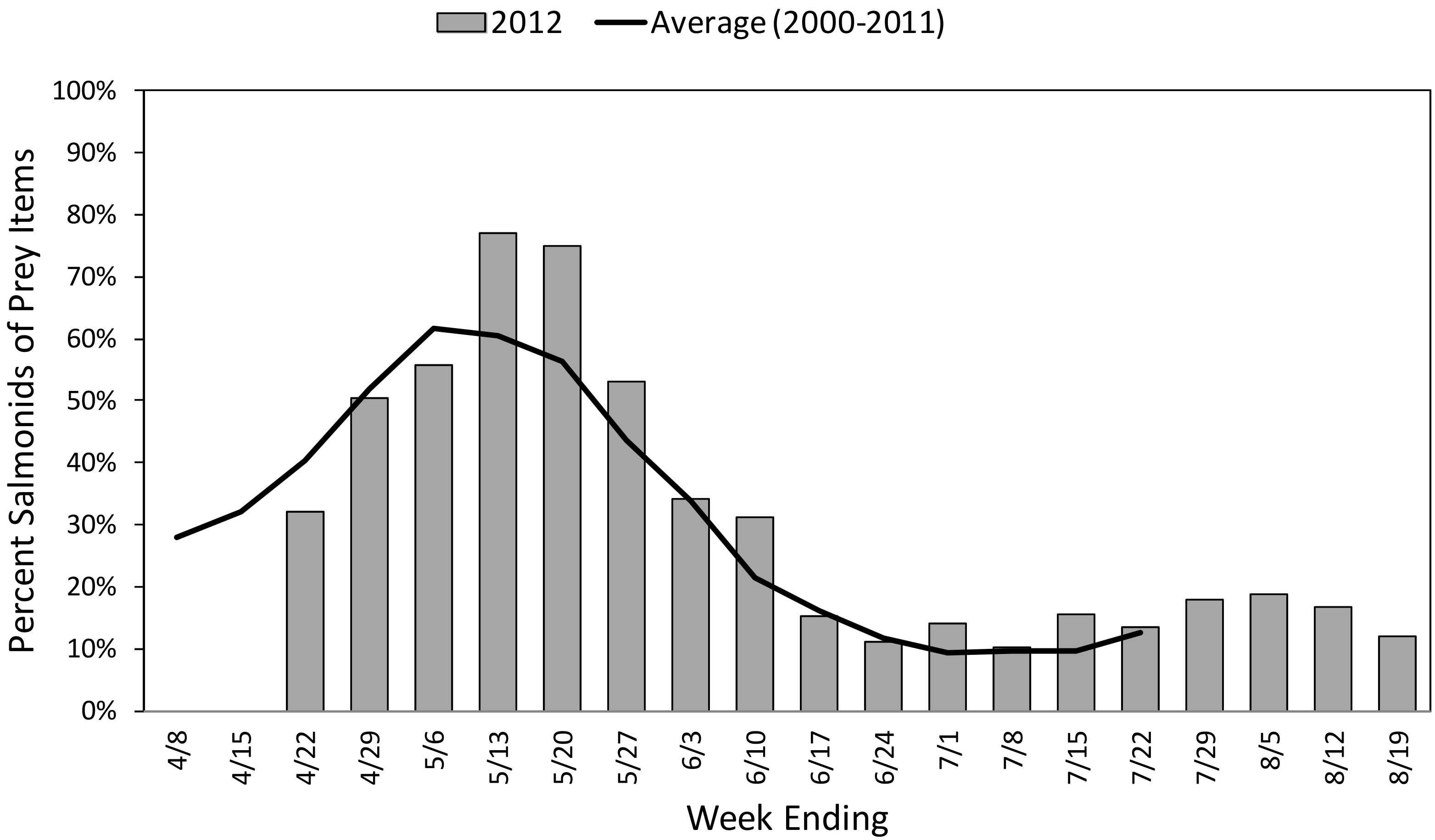
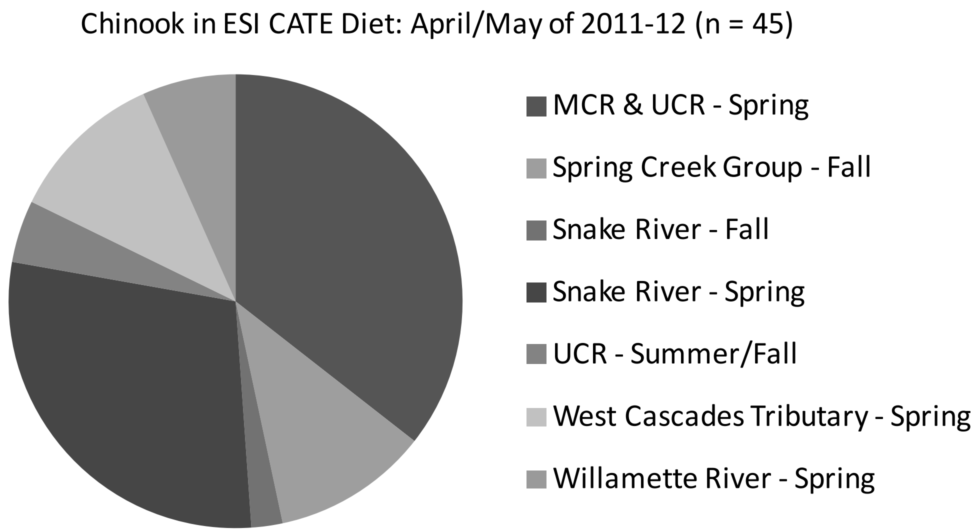


Figure 37. Proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary, by week during the 2012 breeding season.



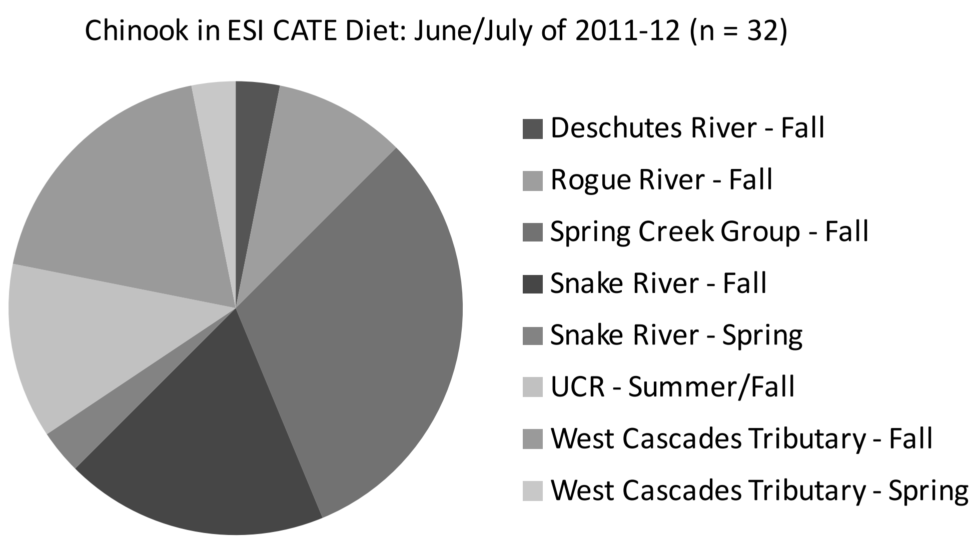
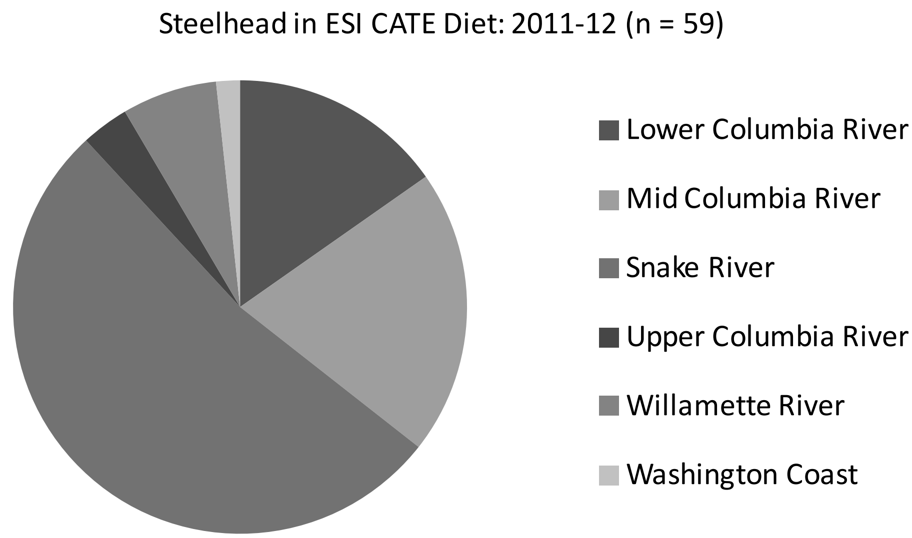


Figure 38. Genetic stock of origin for Chinook salmon in the diet of Caspian terns (CATE) nesting at East Sand Island (ESI) in the Columbia River estuary. Genetic stock identification of salmonids was performed by D. Kuligowski, NOAA Fisheries, on bill-load fish obtained from Caspian terns returning to the East Sand Island colony during the 2011 and 2012 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).



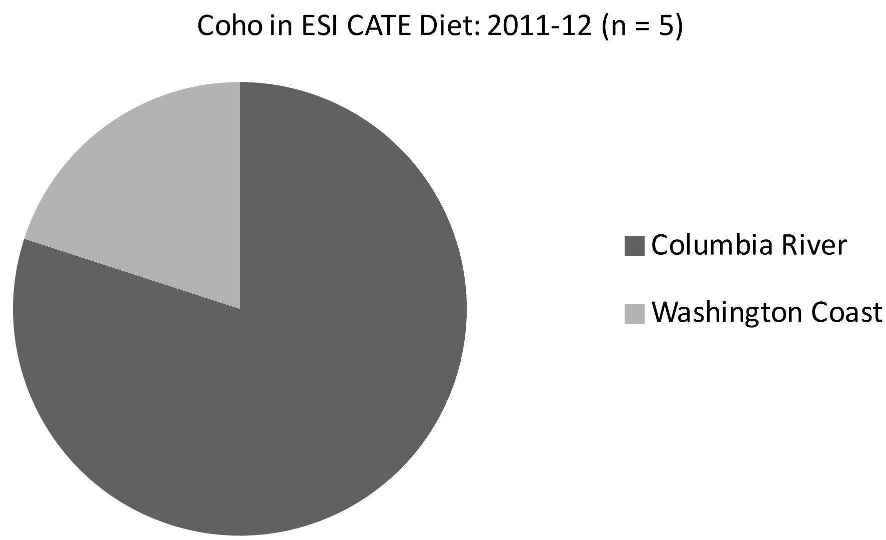


Figure 39. Genetic stock of origin for steelhead trout and coho salmon in the diet of Caspian terns (CATE) nesting on East Sand Island (ESI) in the Columbia River estuary. Genetic stock identification of salmonids was performed by D. Kuligowski, NOAA Fisheries, on bill-load fish obtained from Caspian terns returning to the East Sand Island colony during the 2011 and 2012 breeding seasons. Only a small sample of coho salmon collected from Caspian terns (n = 5) was submitted for genetic analysis.

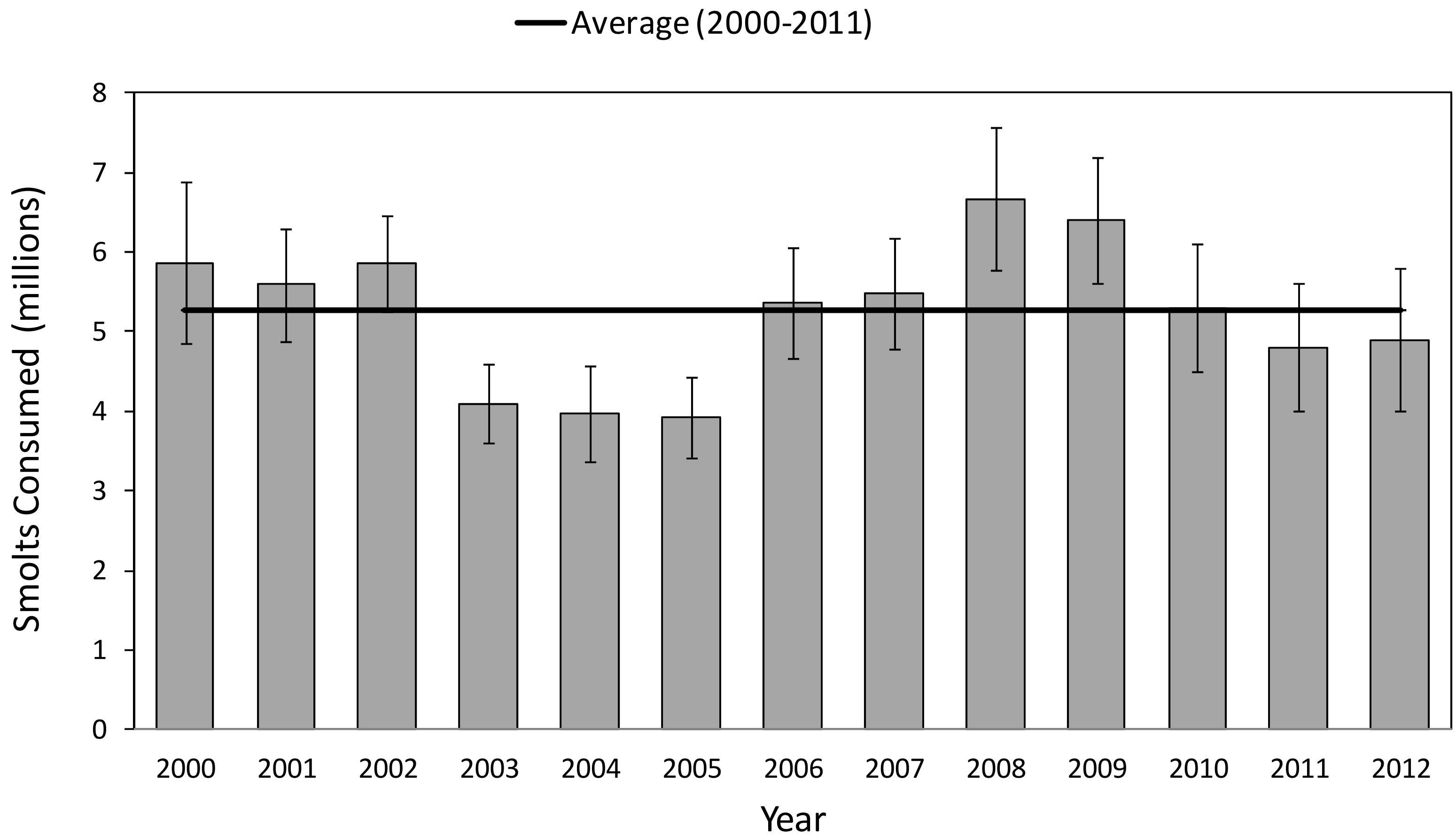


Figure 40. Estimated total annual consumption of juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2012 breeding seasons. Estimates are based on fish identified in tern bill-loads on-colony and bioenergetics calculations. Error bars represent 95% confidence intervals for the number of smolts consumed.

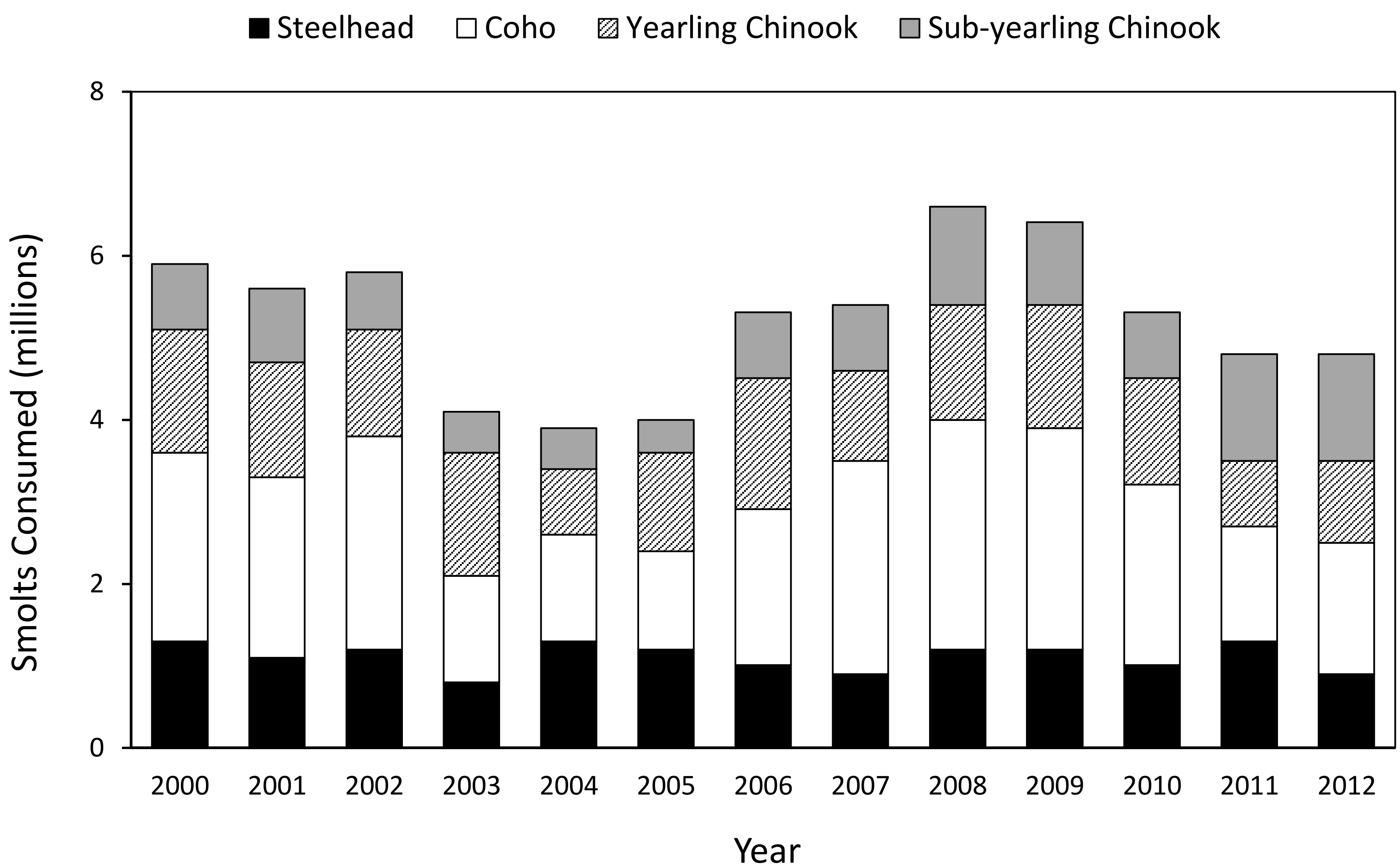


Figure 41. Estimated total annual consumption of four species/run types of juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2012 breeding seasons. Estimates are based on fish collected from tern bill-loads near the colony and bioenergetics calculations.

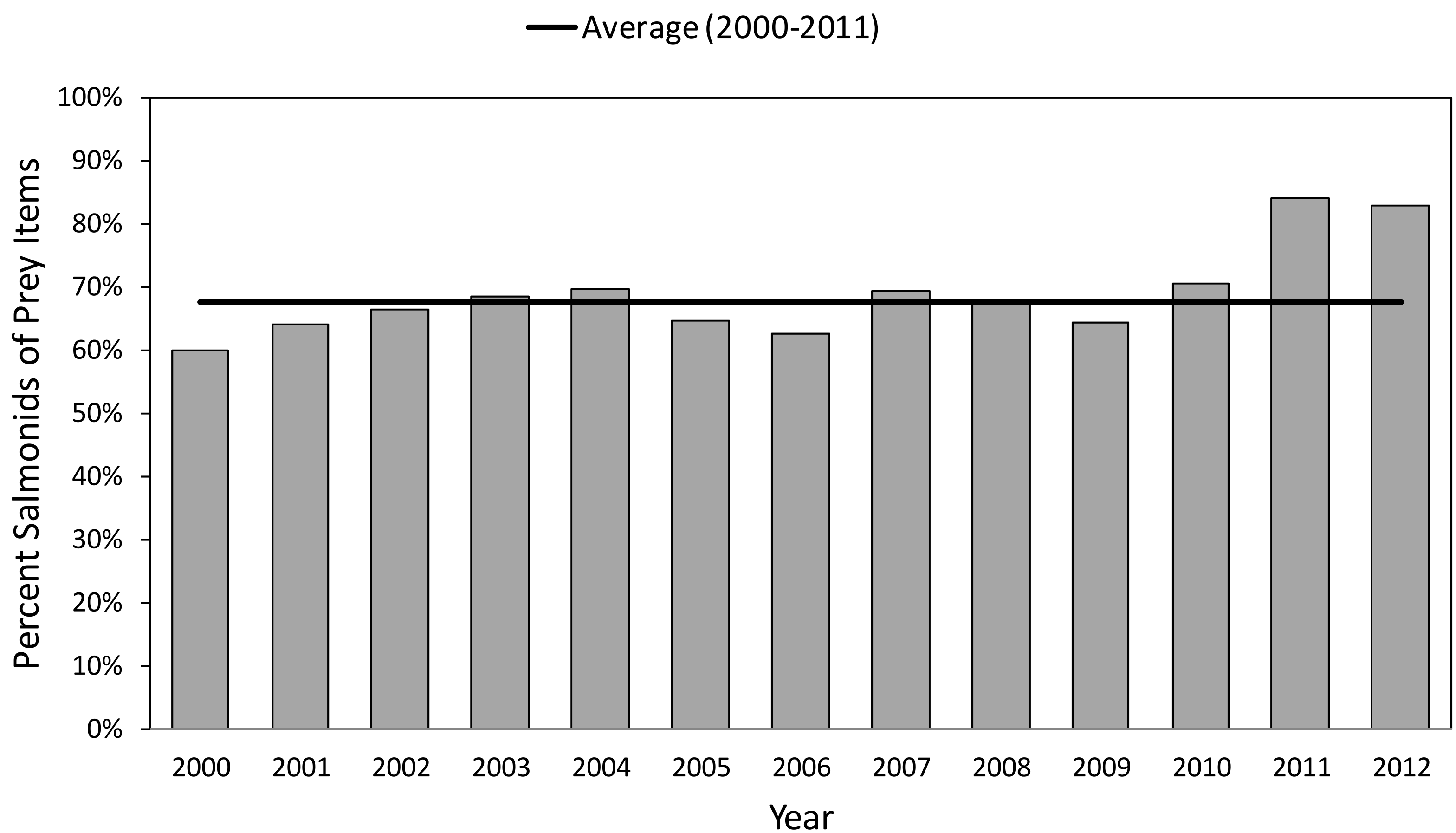


Figure 42. Average annual proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on Crescent Island, mid-Columbia River, during the 2000-2012 breeding seasons.

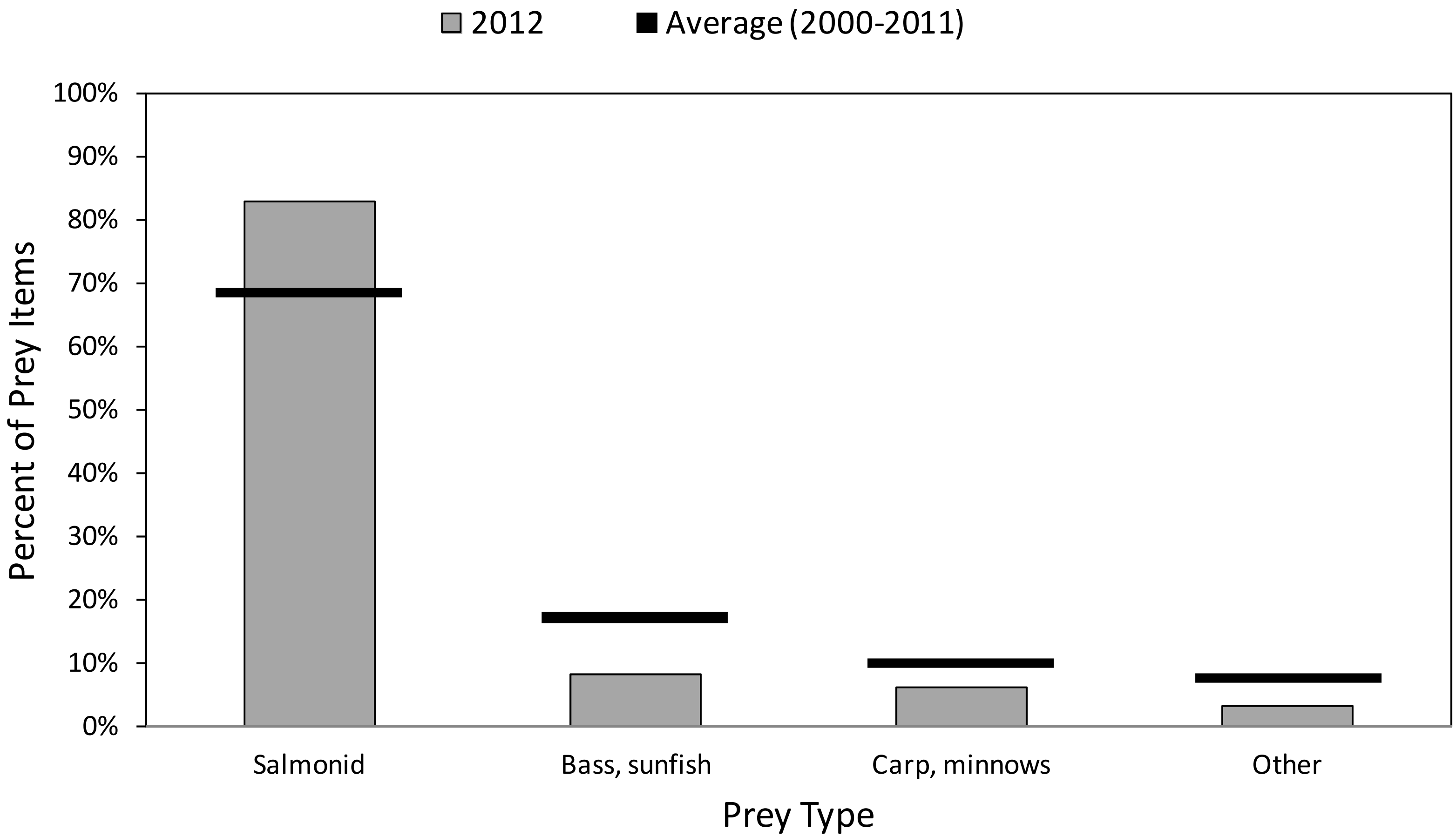


Figure 43. Diet composition (percent of identified prey items) of Caspian terns nesting on Crescent Island in the mid-Columbia River during the 2012 breeding season. Diet composition was based on fish identified on-colony in Caspian tern bill-loads.

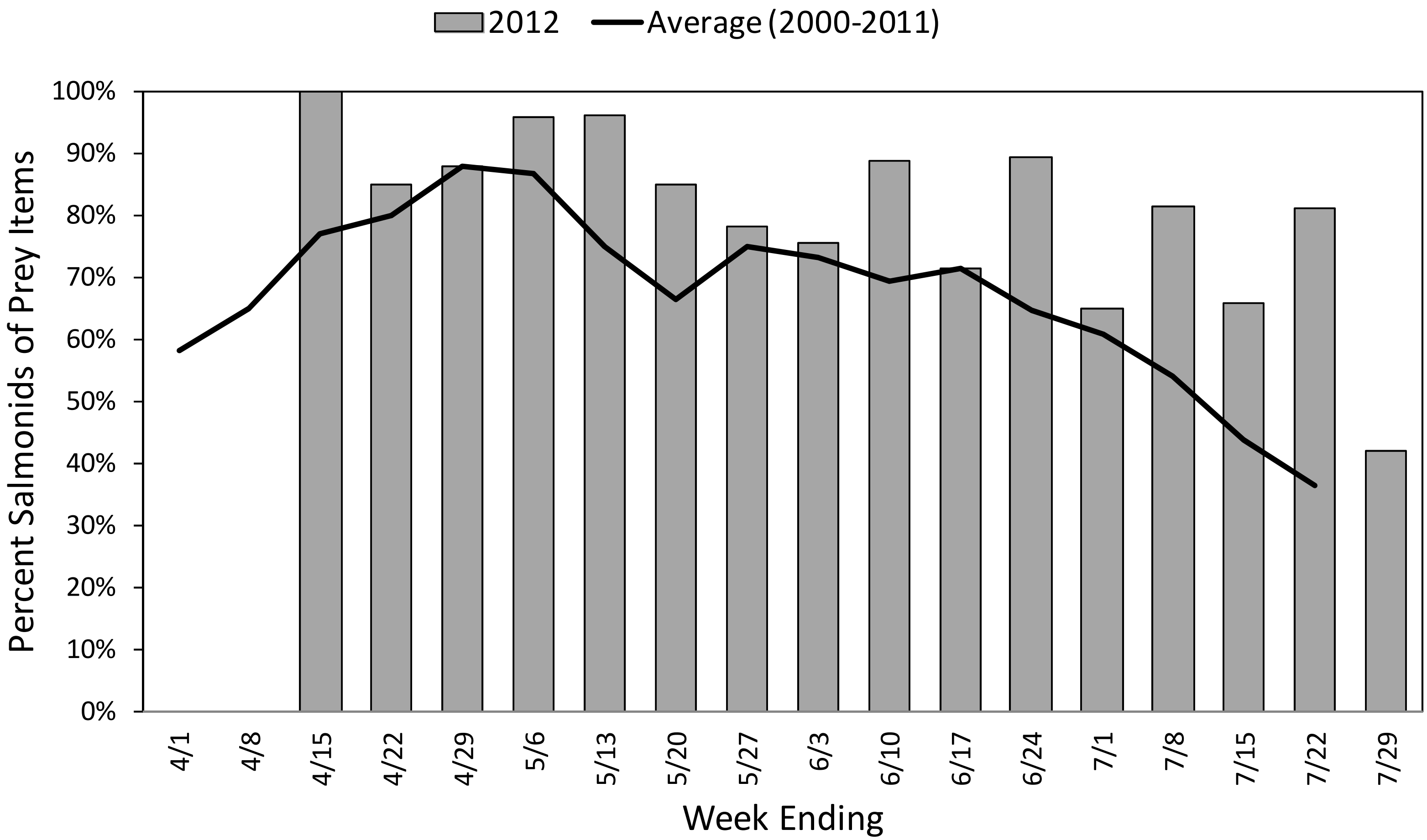


Figure 44. Proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on Crescent Island in the mid-Columbia River during the 2012 breeding season, by week. Diet composition data were not collected during the first two weeks of the field season in 2012.

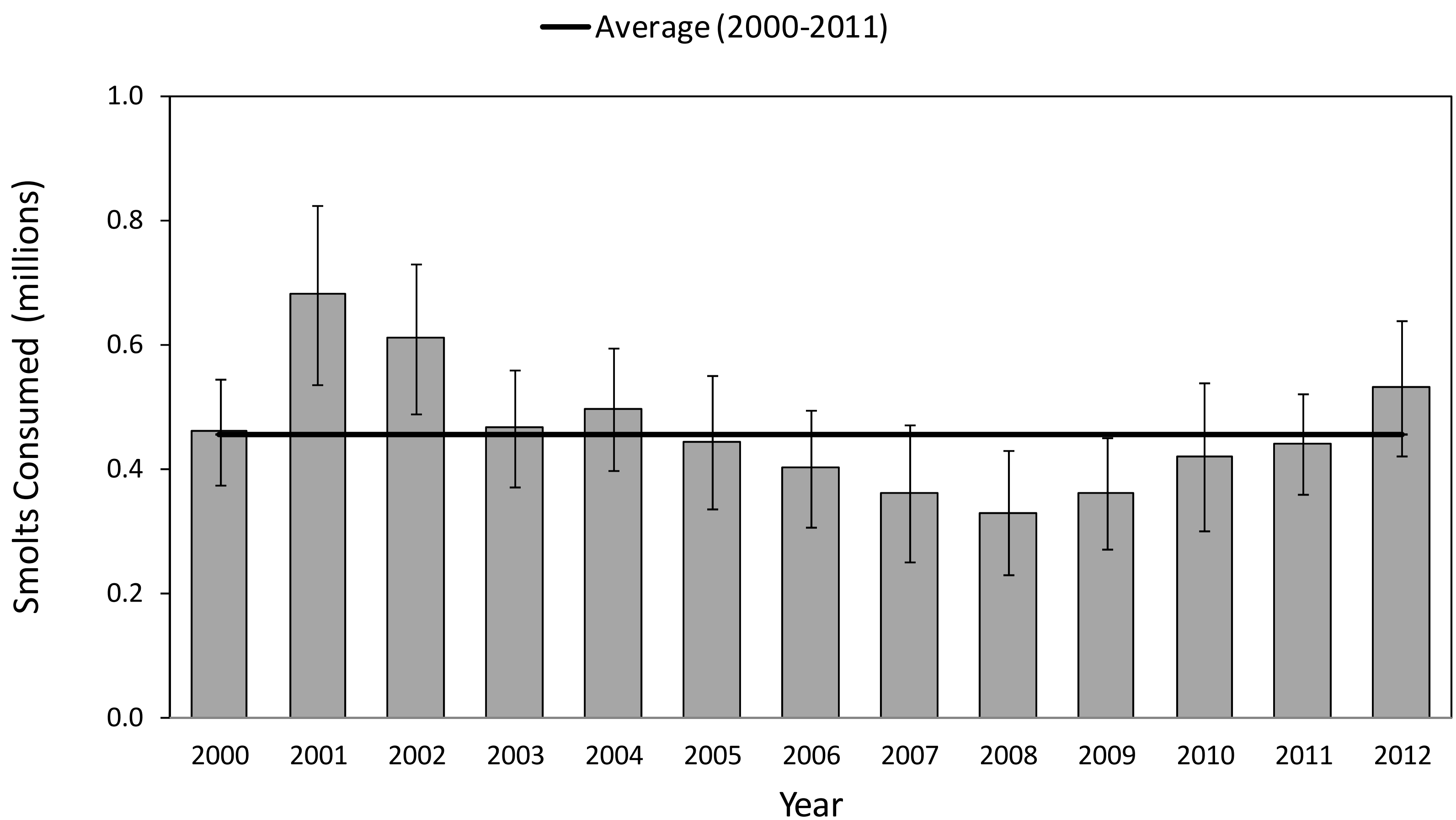


Figure 45. Estimated total annual consumption of juvenile salmonids by Caspian terns nesting on Crescent Island in the mid-Columbia River during the 2000-2012 breeding seasons. Estimates are based on fish identified in tern bill-loads on-colony and bioenergetics calculations. Error bars represent 95% confidence intervals for the number of smolts consumed.

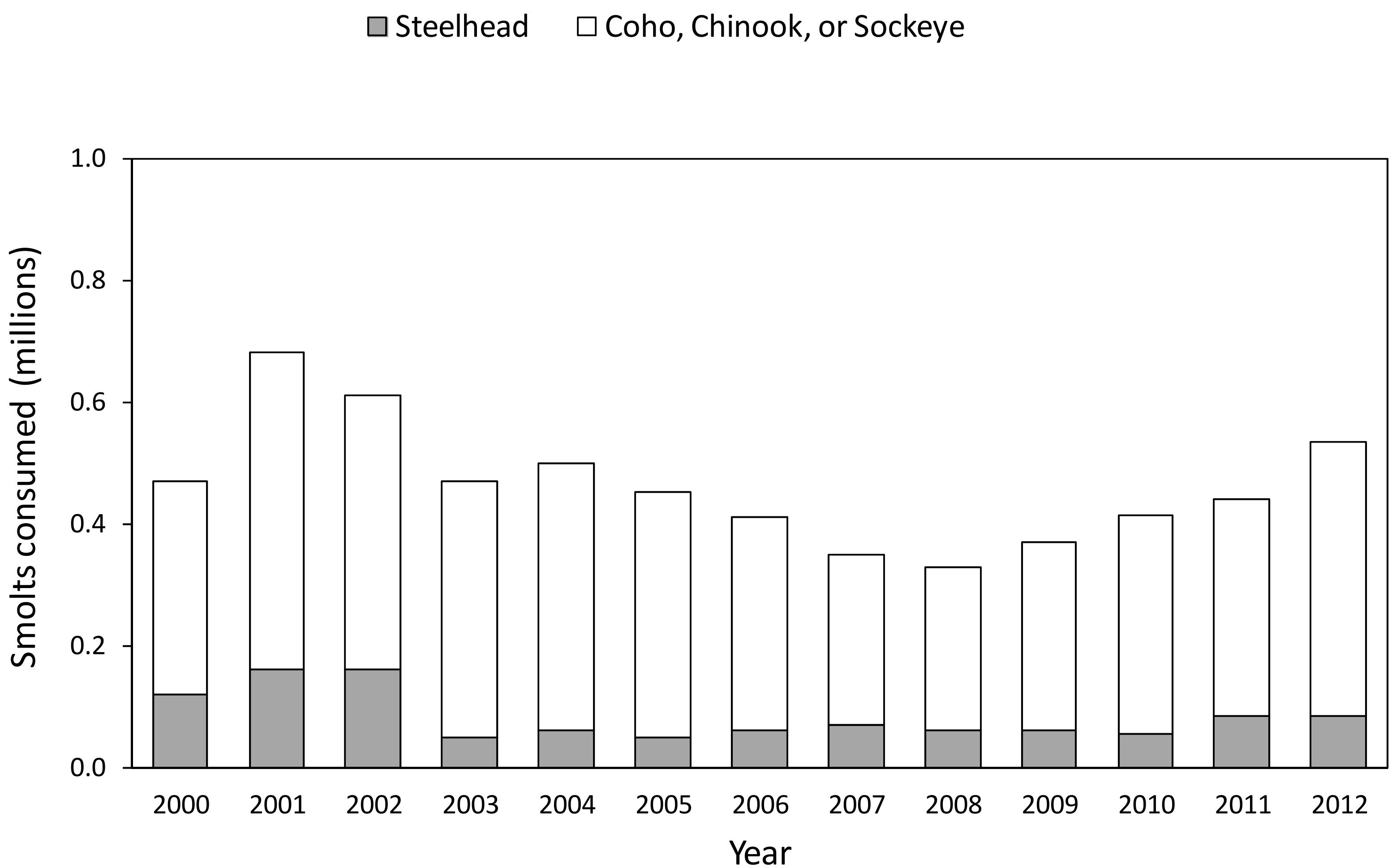


Figure 46. Estimated total annual consumption of steelhead and salmon (coho, Chinook, or sockeye) smolts by Caspian terns nesting on Crescent Island in the mid-Columbia River during the 2000-2012 breeding seasons. Estimates are based on fish identified in tern bill-loads on-colony and bioenergetics calculations.

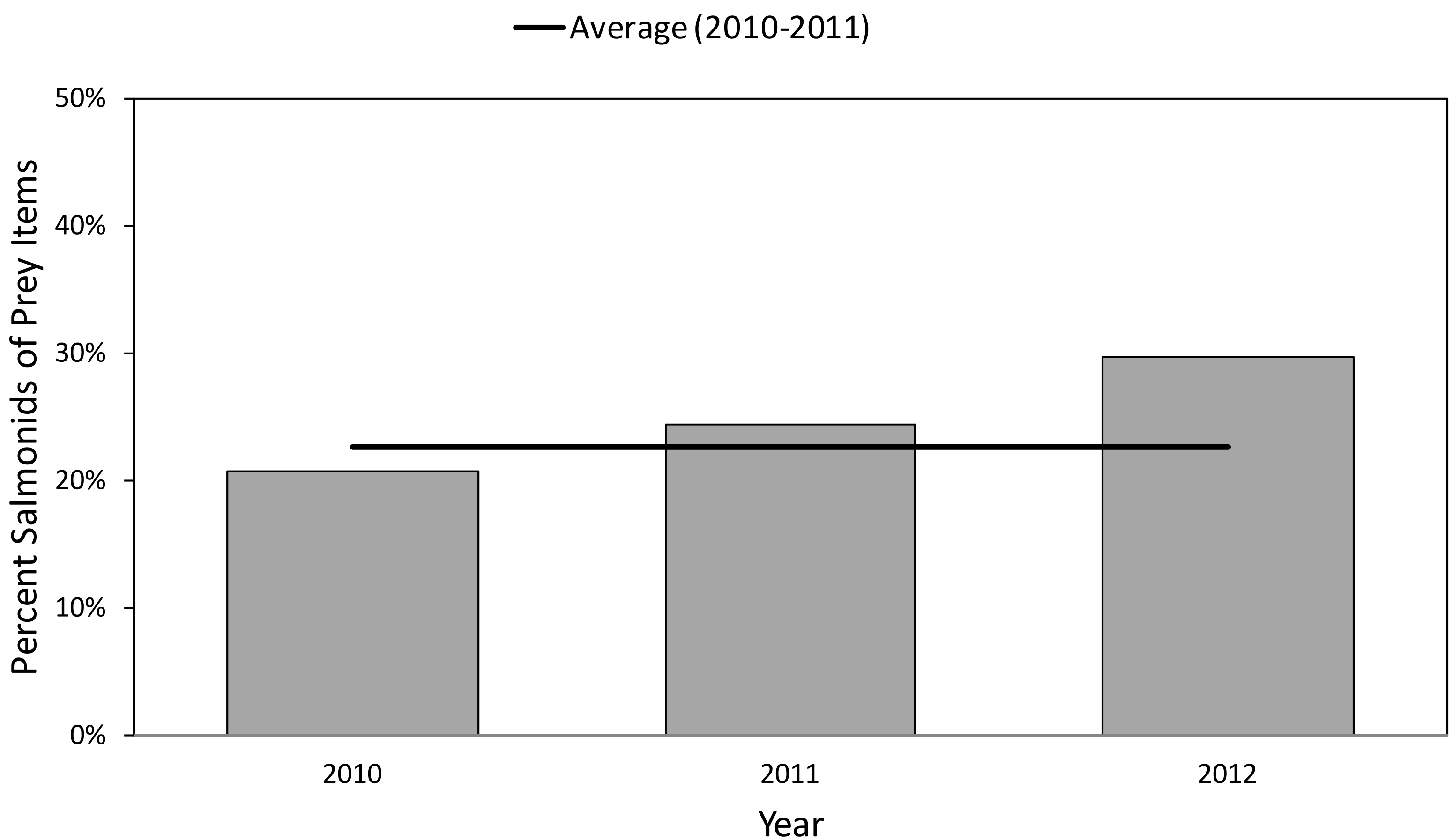


Figure 47. Average annual proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on Goose Island in Potholes Reservoir, Washington during the 2010-2012 breeding seasons. Diet composition was based on fish identified in tern bill-loads on-colony.

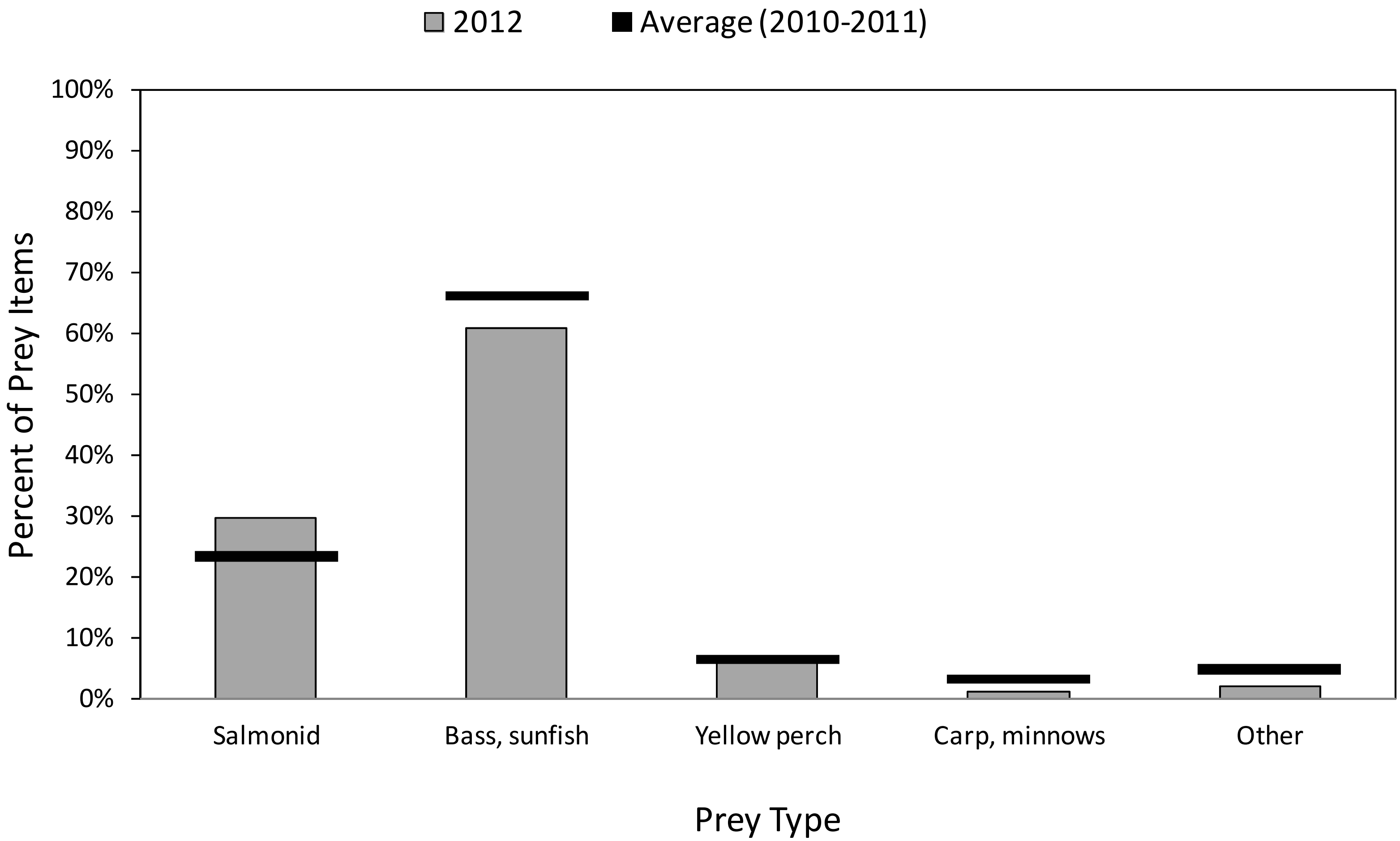


Figure 48. Diet composition (percent of prey items) of Caspian terns nesting on Goose Island in Potholes Reservoir, Washington during the 2012 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

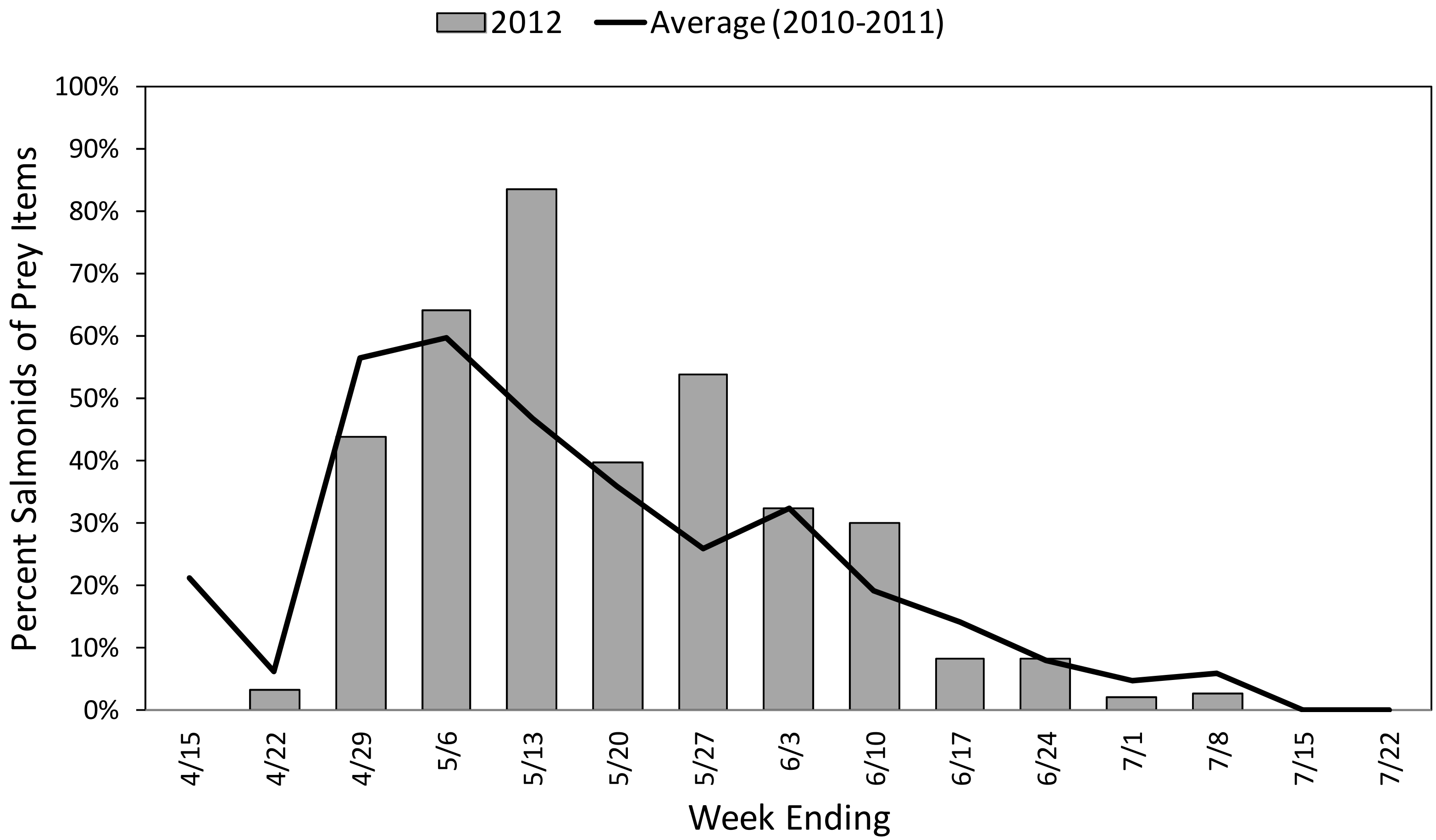


Figure 49. Proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on Goose Island in Potholes Reservoir, Washington during the 2012 breeding season, by week. Diet composition was based on fish identified in tern bill-loads on-colony.

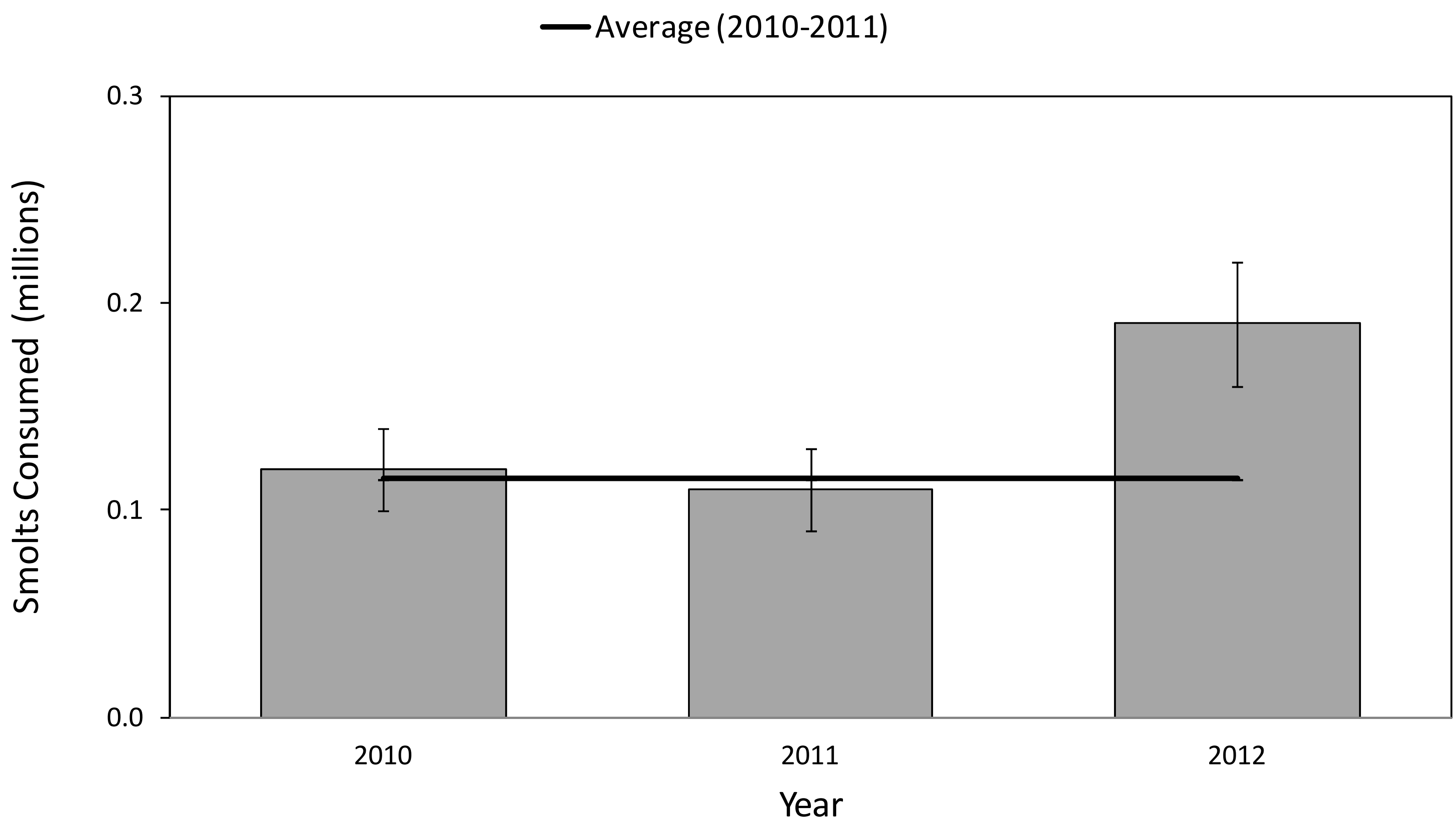


Figure 50. Estimated total annual consumption of juvenile salmonids by Caspian terns nesting on Goose Island in Potholes Reservoir, Washington during the 2010-2012 breeding seasons. Estimates are based on fish identified in tern bill-loads on-colony and bioenergetics calculations. Error bars represent 95% confidence intervals for the number of smolts consumed.

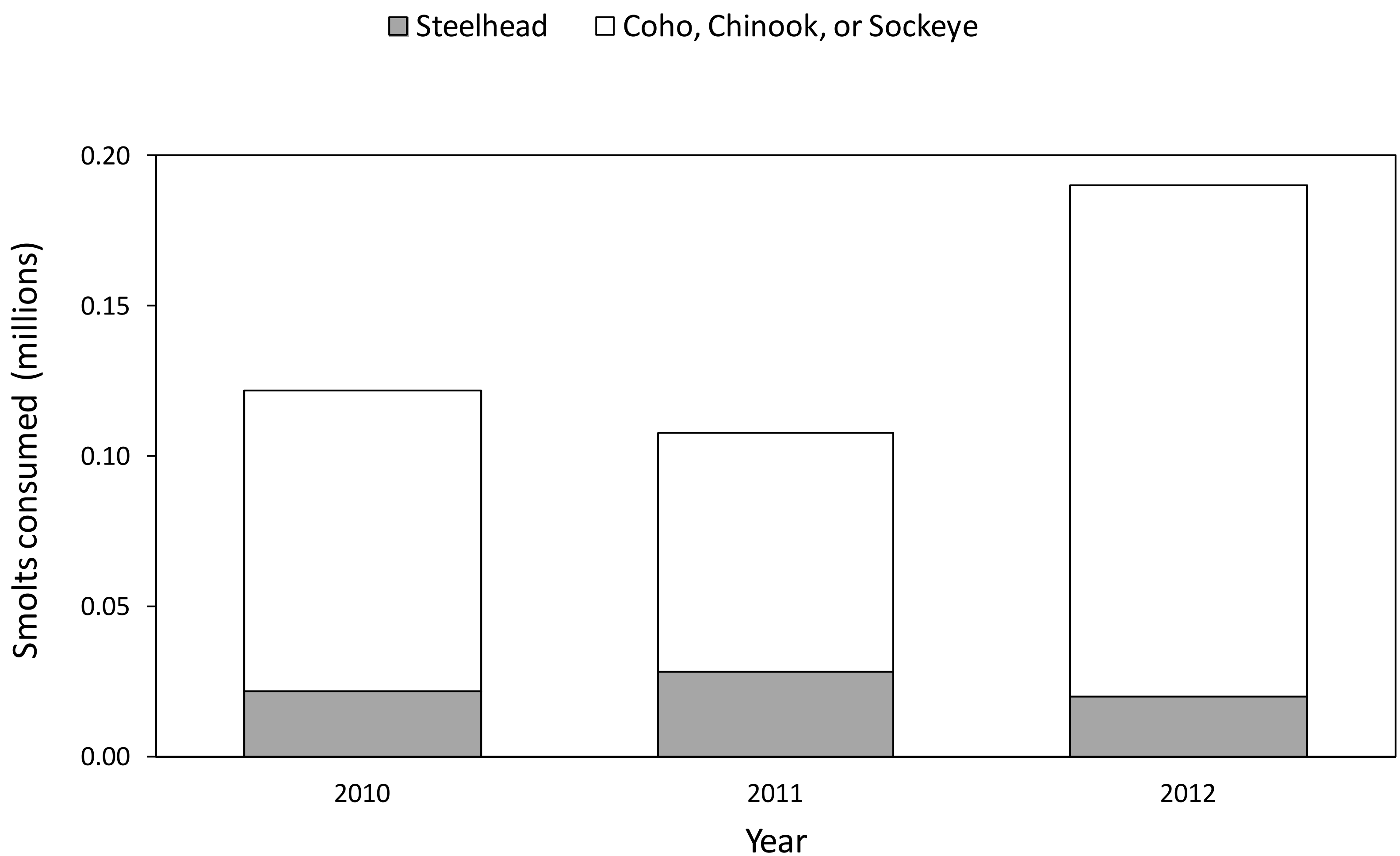


Figure 51. Estimated total annual consumption of steelhead and salmon (coho, Chinook, or sockeye) smolts by Caspian terns nesting on Goose Island in Potholes Reservoir, Washington during the 2010-2012 breeding seasons. Estimates are based on fish identified in tern bill-loads on-colony and bioenergetics calculations.

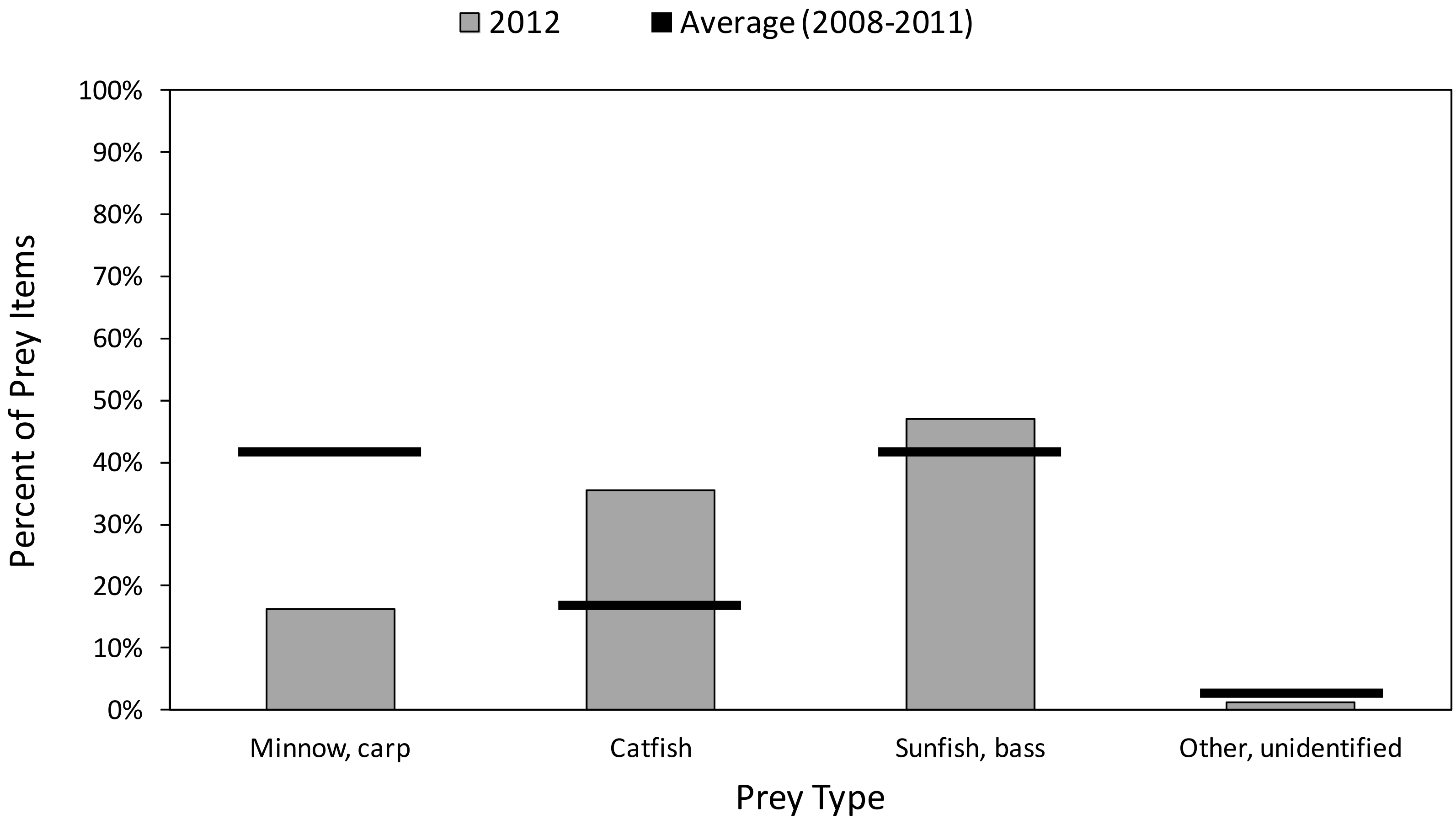


Figure 52. Diet composition (percent of prey items) of Caspian terns nesting on the Corps-constructed tern island at Crump Lake in Warner Valley, Oregon during the 2012 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

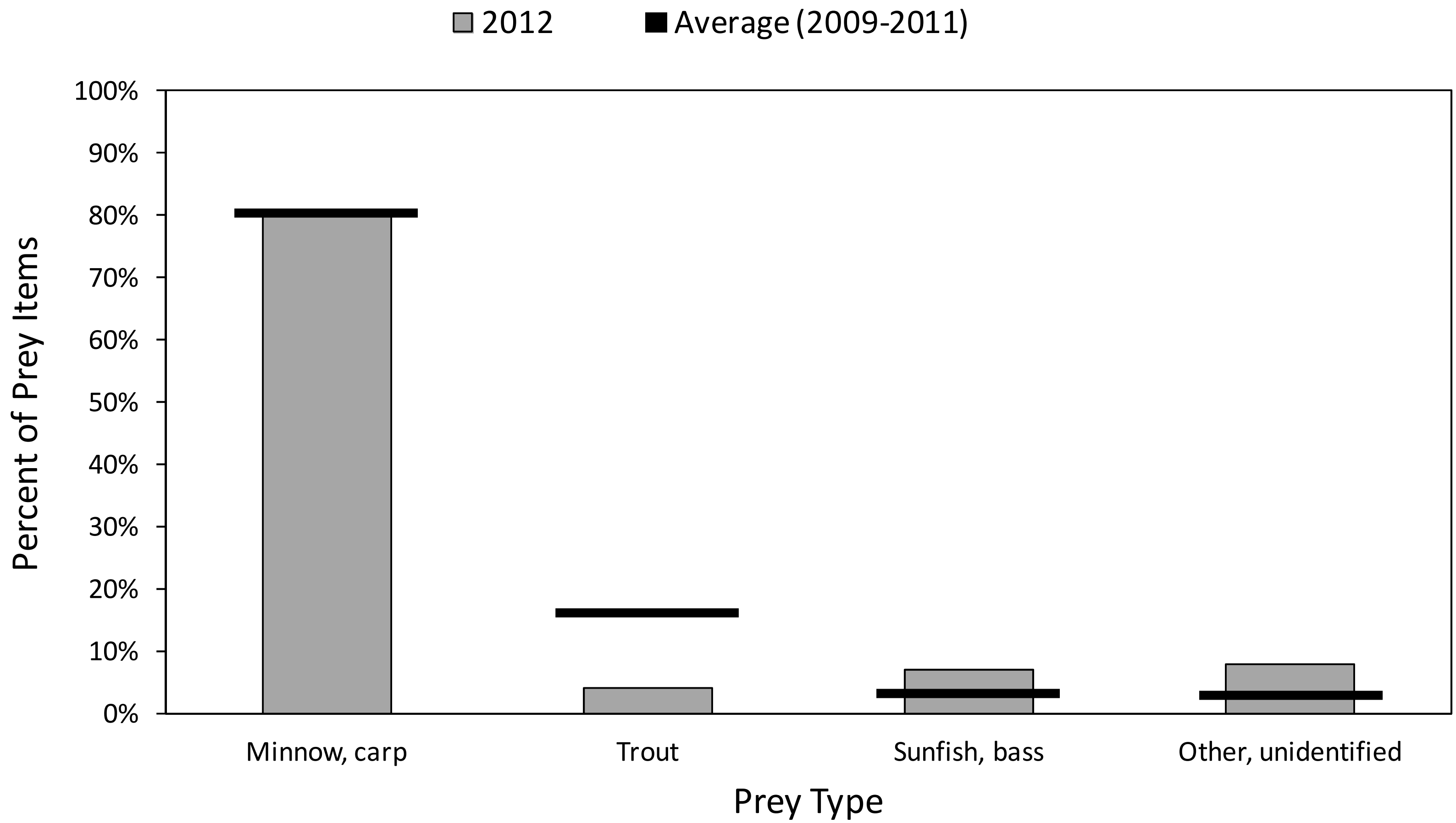


Figure 53. Diet composition (percent of prey items) of Caspian terns nesting on the Corps-constructed tern islands at Summer Lake Wildlife Area (East Link, Gold Dike, and Dutchy Lake) during the 2012 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

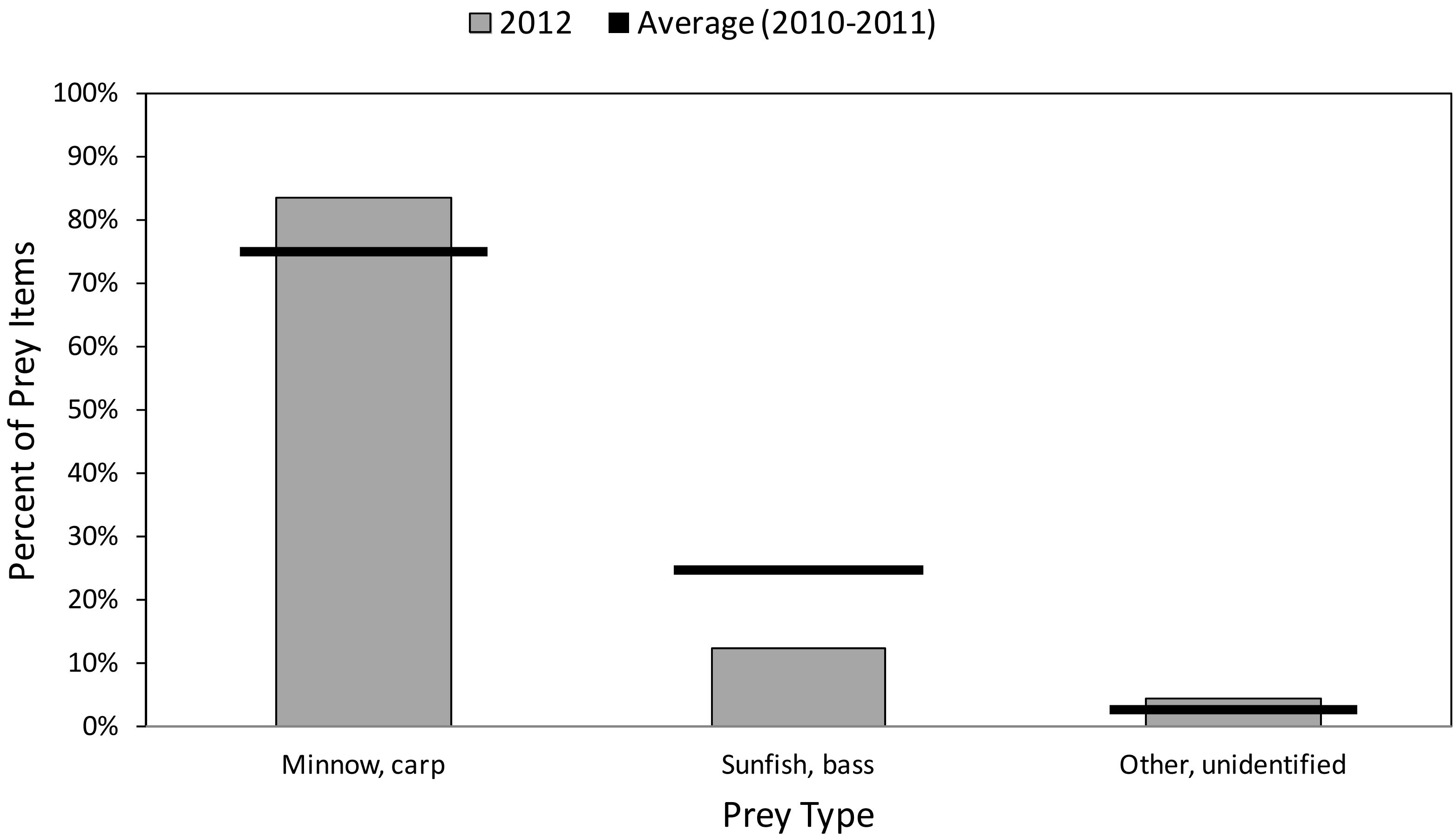


Figure 54. Diet composition (percent of prey items) of Caspian terns nesting on the Corps-constructed tern island at Sheepy Lake in Lower Klamath NWR, California during the 2012 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

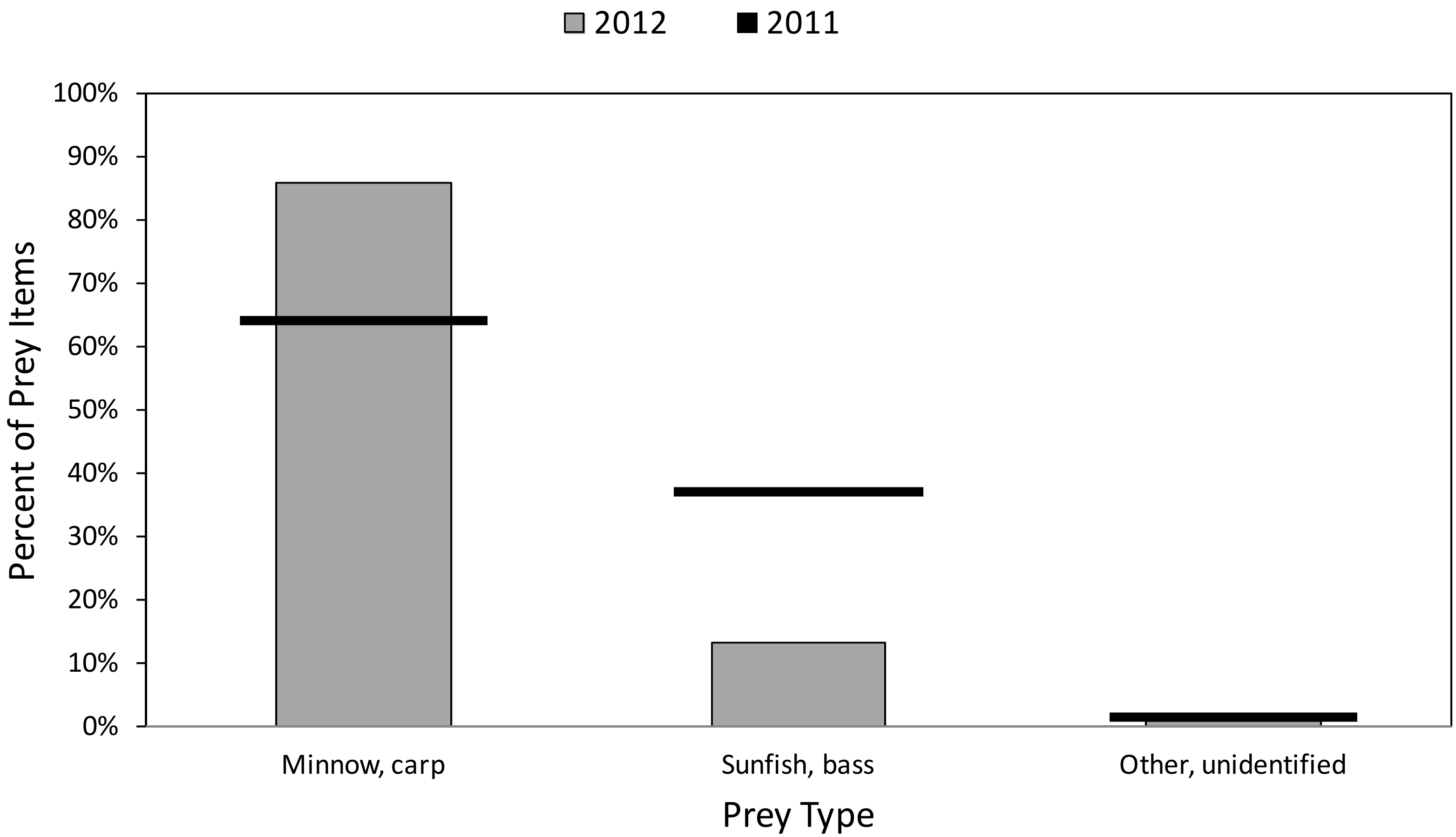


Figure 55. Diet composition (percent of prey items) of Caspian terns nesting on the Corps-constructed tern island at Tule Lake Sump 1B in Tule Lake NWR, California during the 2012 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

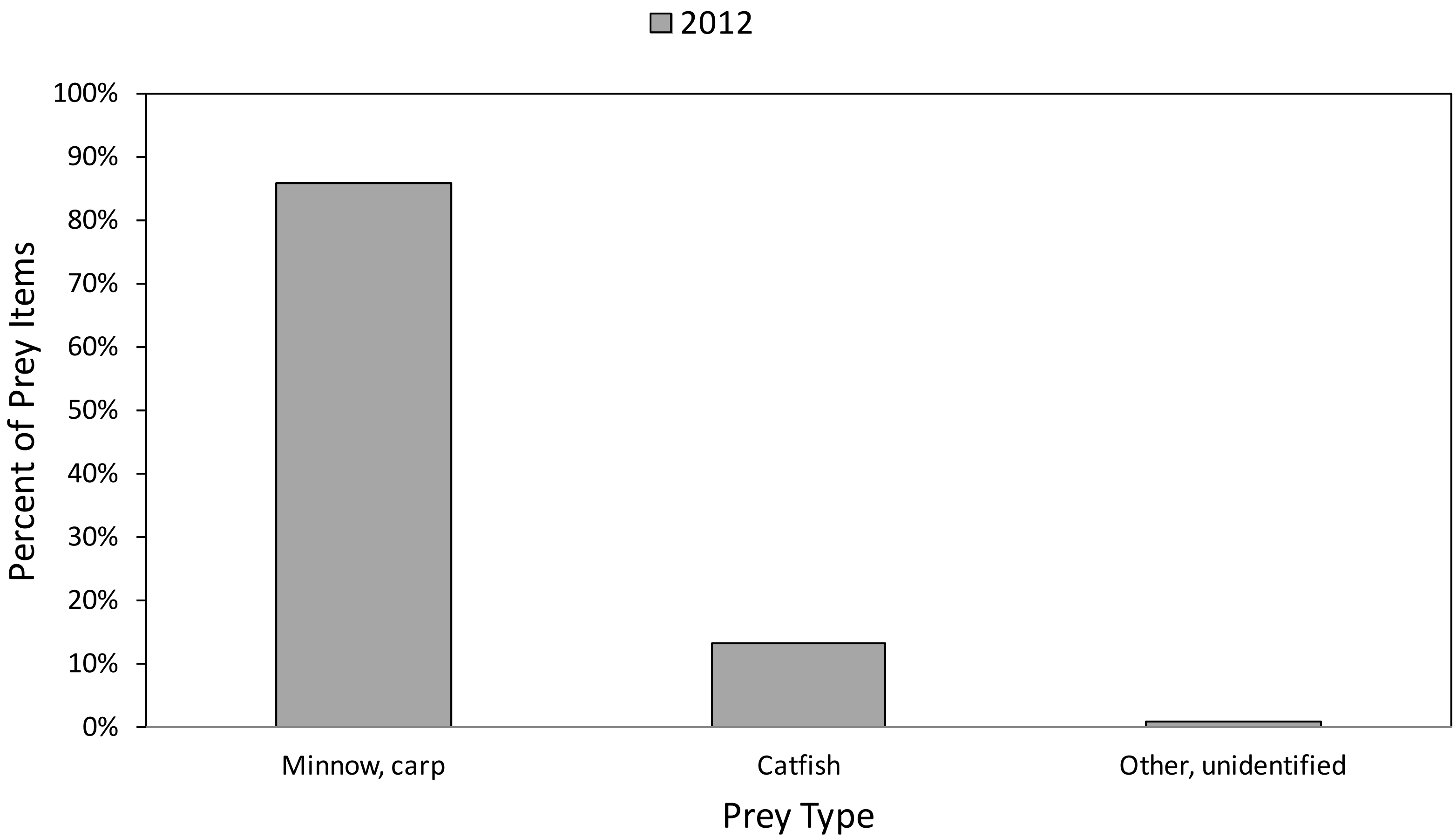


Figure 56. Diet composition (percent of prey items) of Caspian terns nesting on the Corps-constructed tern island at Malheur Lake in Malheur NWR, Oregon during the 2012 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

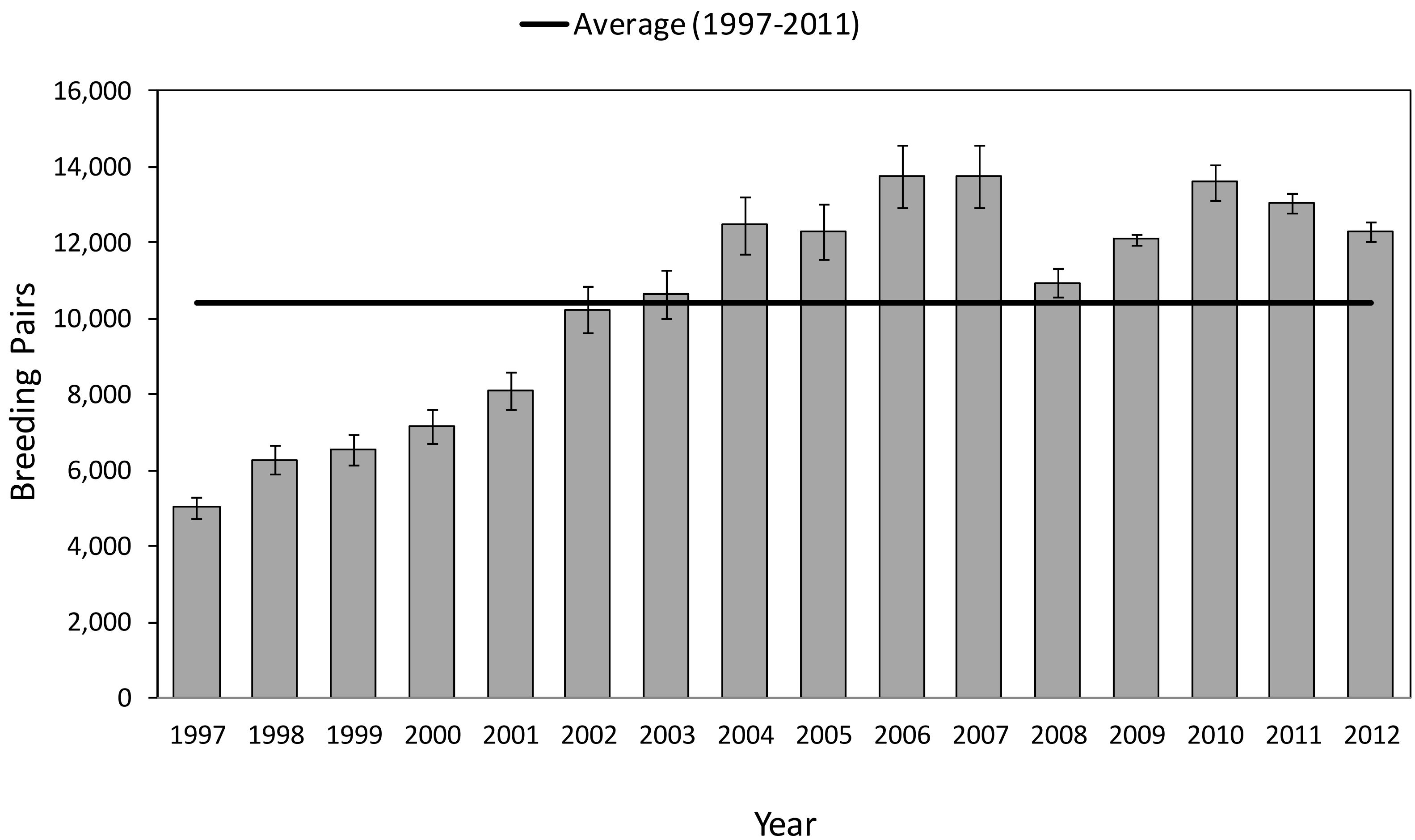


Figure 57. Size of the double-crested cormorant breeding colony (number of breeding pairs) on East Sand Island in the Columbia River estuary during the 1997-2012 breeding seasons. Error bars represent 95% confidence intervals for the number of breeding pairs.

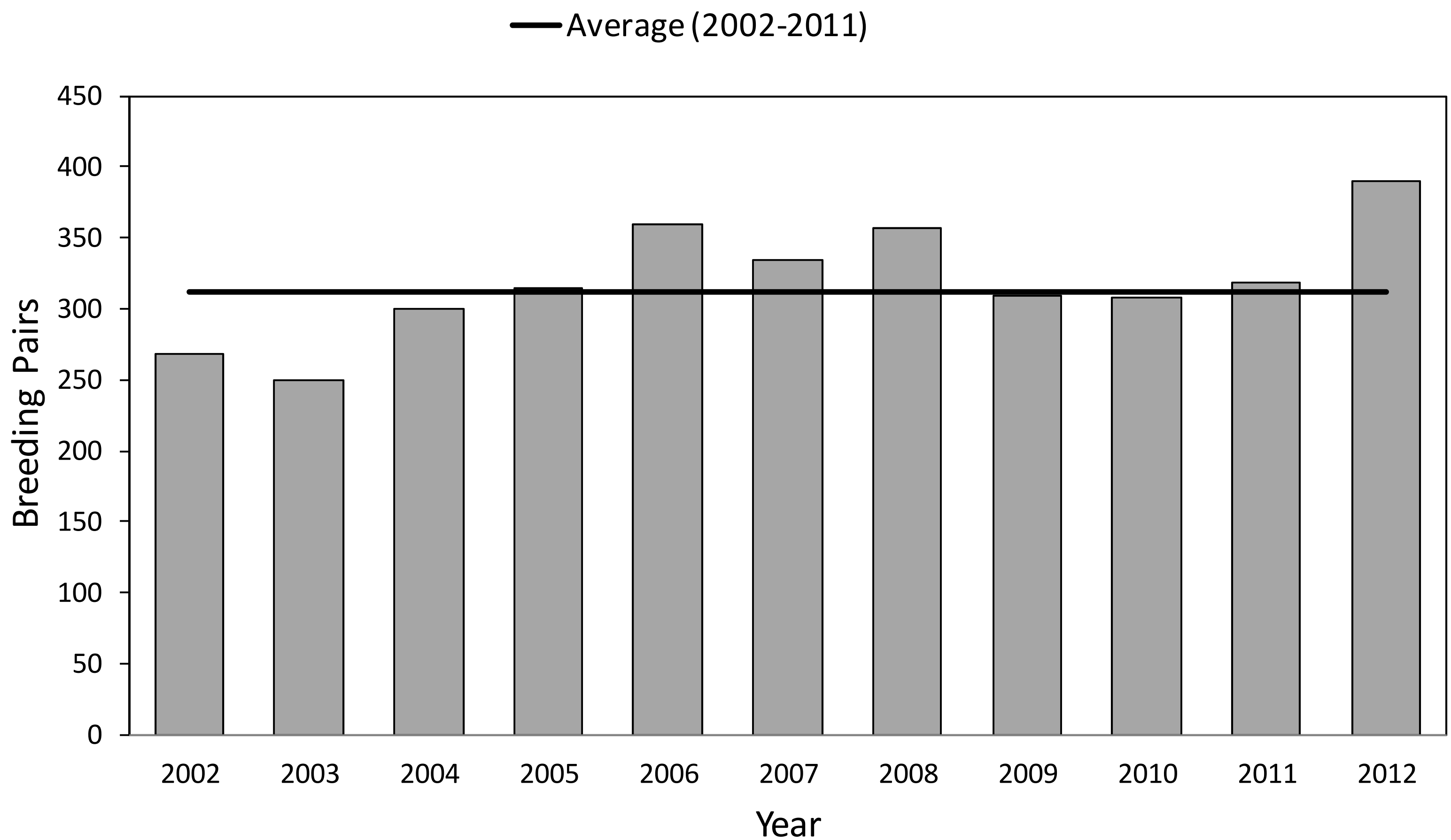


Figure 58. Size of the double-crested cormorant breeding colony (number of breeding pairs) on Foundation Island in the mid-Columbia River during the 2002-2012 breeding seasons.

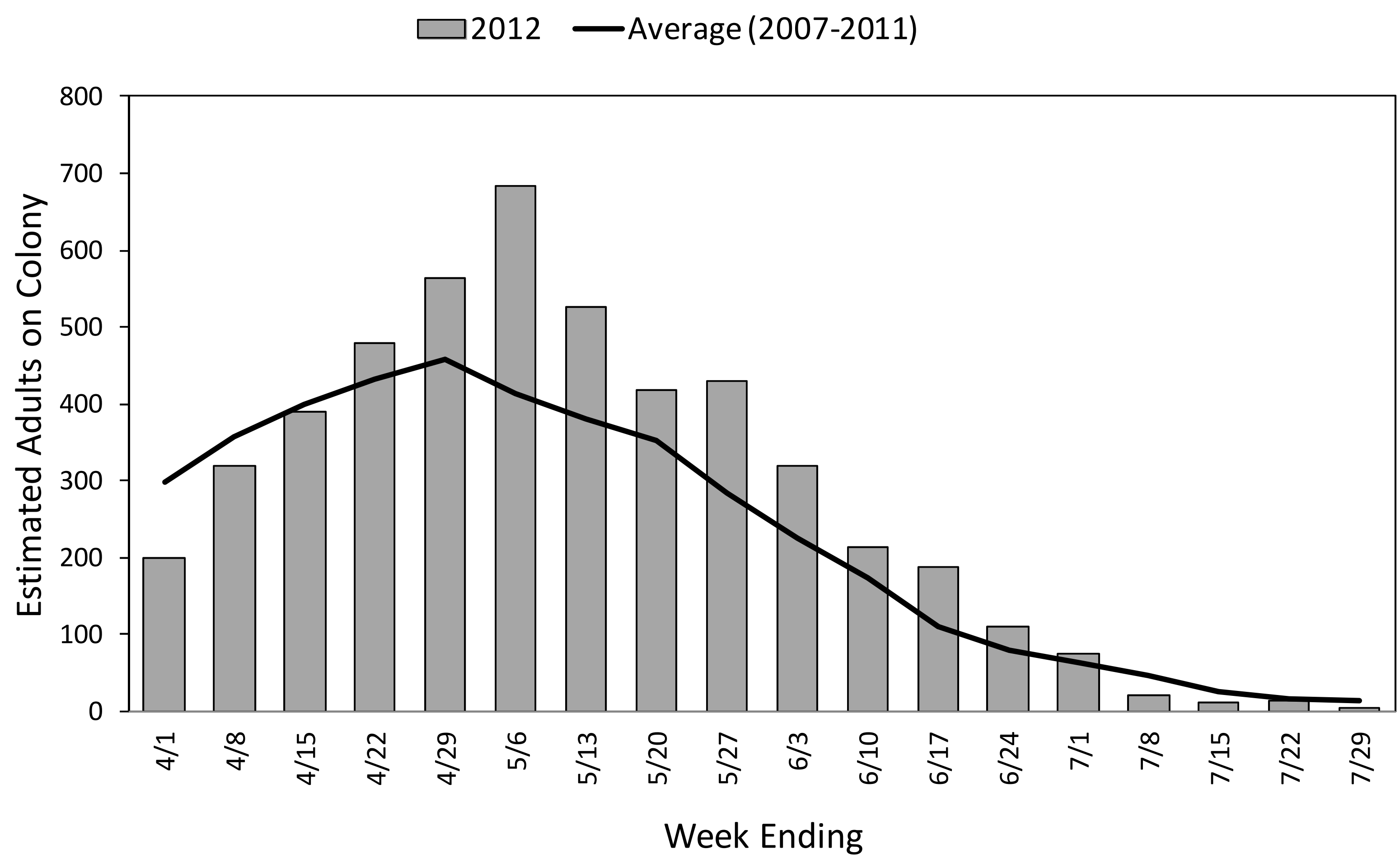


Figure 59. Weekly estimates from the ground of the number of adult double-crested cormorants on the Foundation Island breeding colony in the mid-Columbia River during the 2012 breeding season.

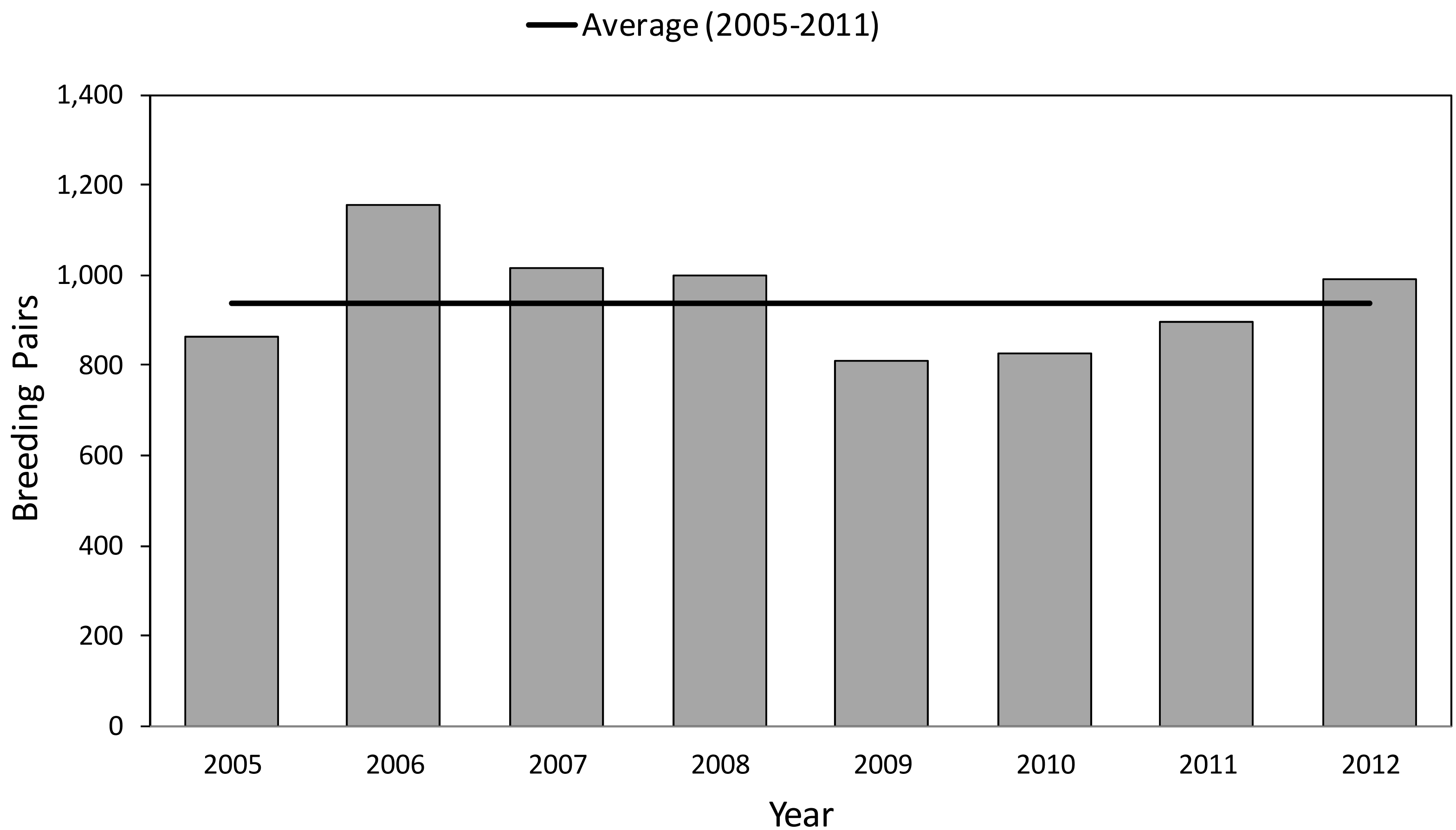


Figure 60. Estimated size of the double-crested cormorant breeding colony (number of breeding pairs) in North Potholes Reserve, Potholes Reservoir, Washington during the 2005-2012 breeding seasons.

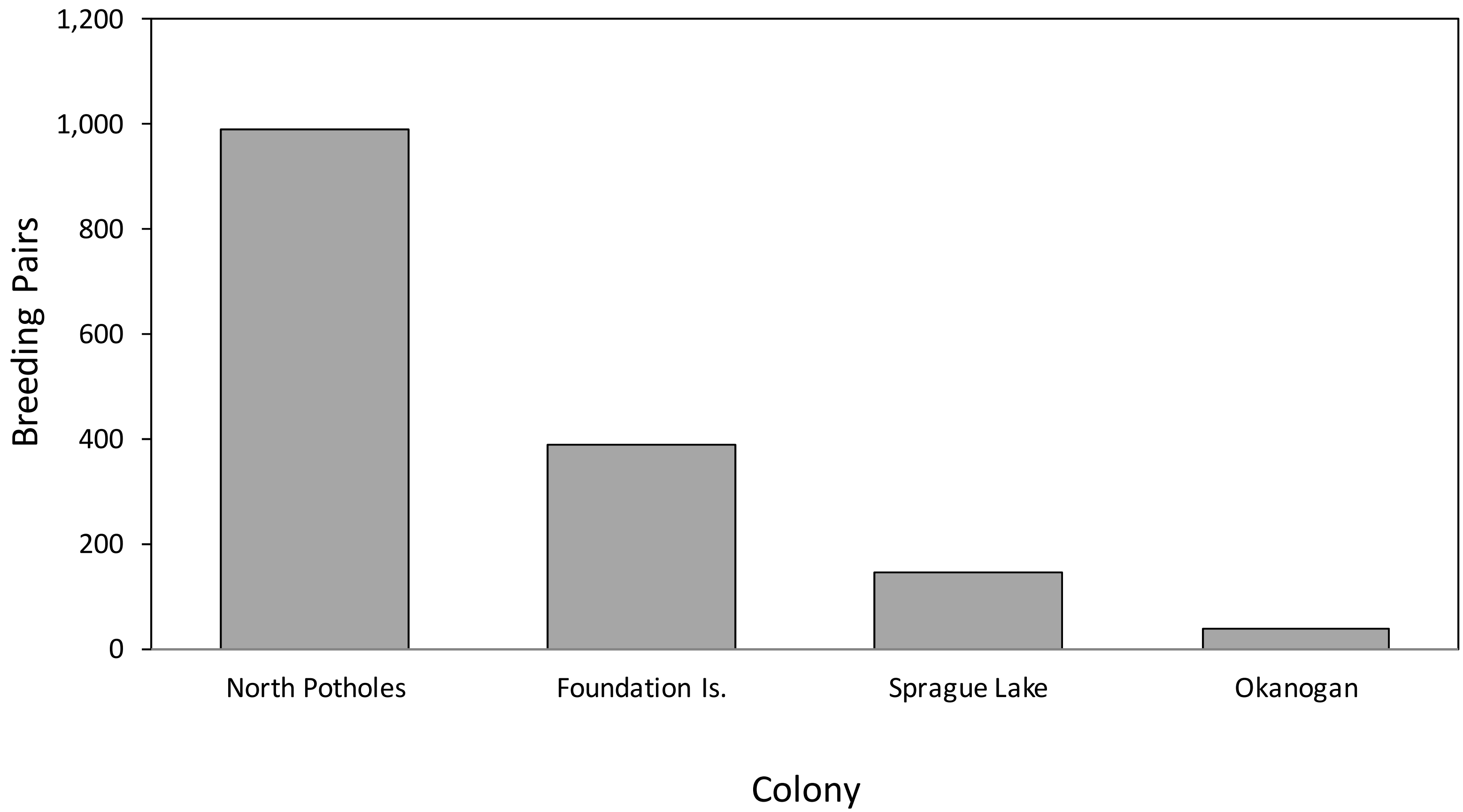


Figure 61. Size of the double-crested cormorant breeding colonies (number of breeding pairs) in the Columbia Plateau region during the 2012 breeding season.

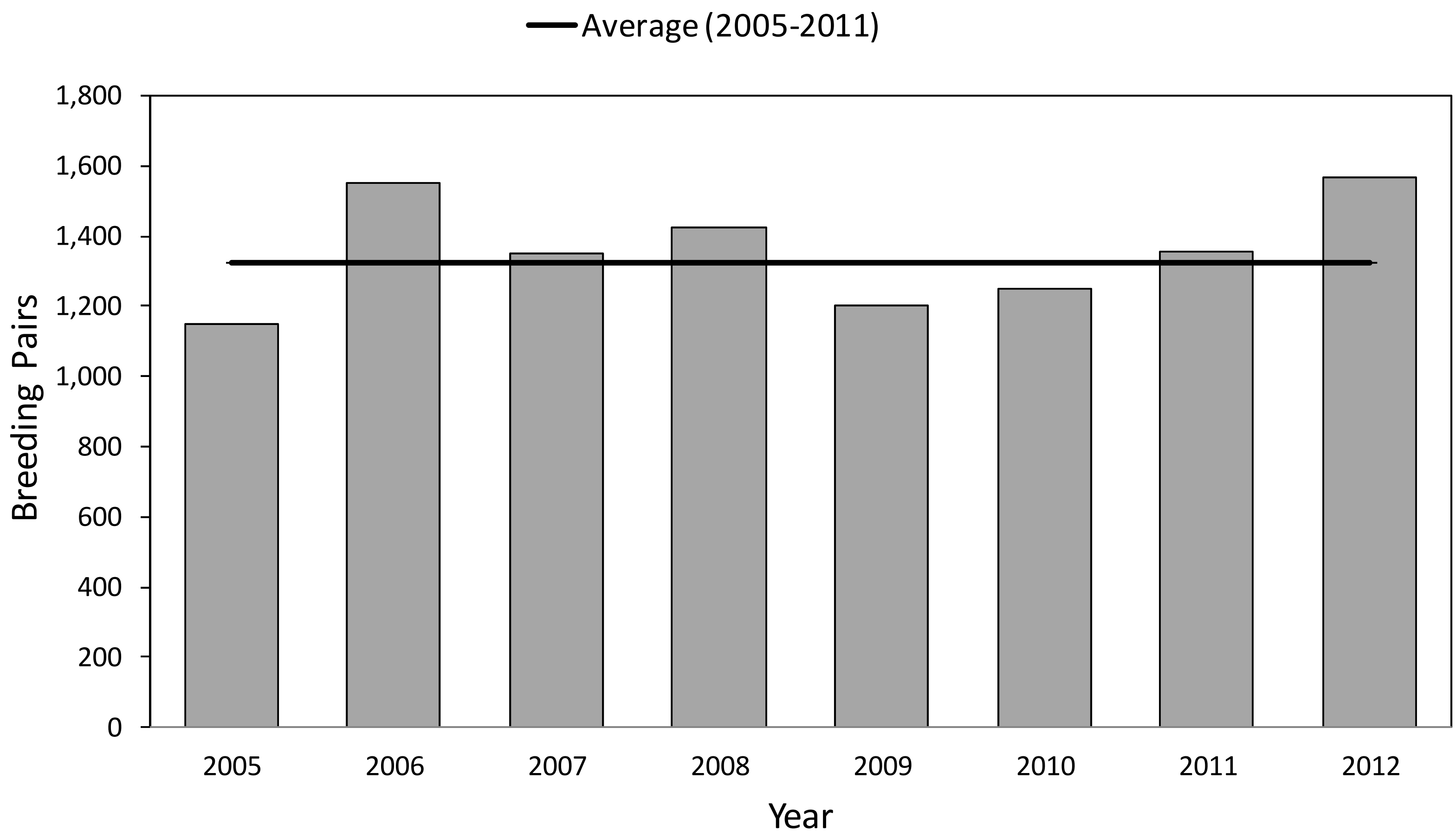


Figure 62. Estimated total number of breeding pairs of double-crested cormorant nesting at colonies in the Columbia Plateau region during the 2005-2012 breeding seasons.

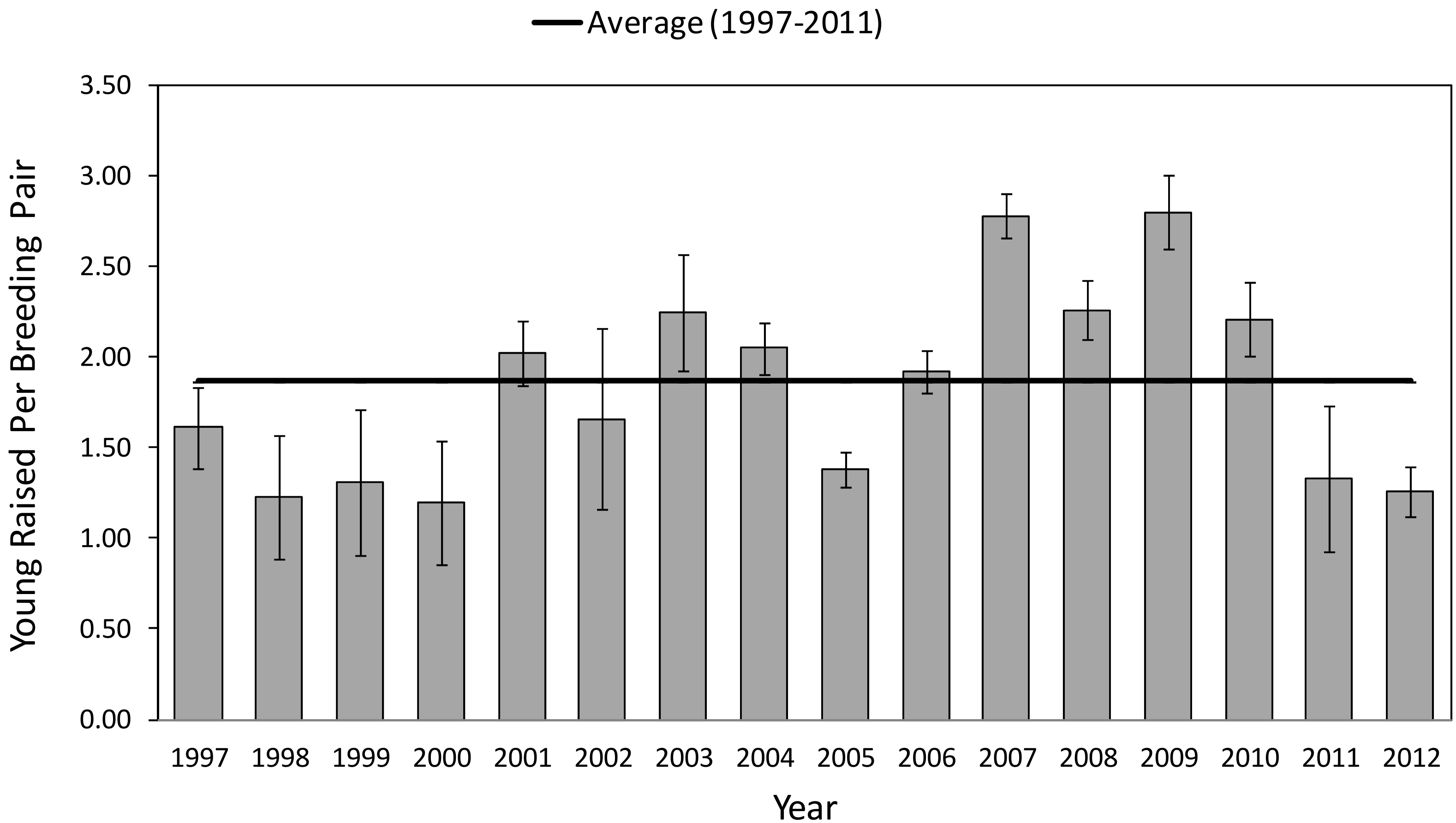


Figure 63. Double-crested cormorant nesting success (average number of young raised per breeding pair) at the colony on East Sand Island in the Columbia River estuary during the 1997-2012 breeding seasons. Error bars represent 95% confidence intervals.

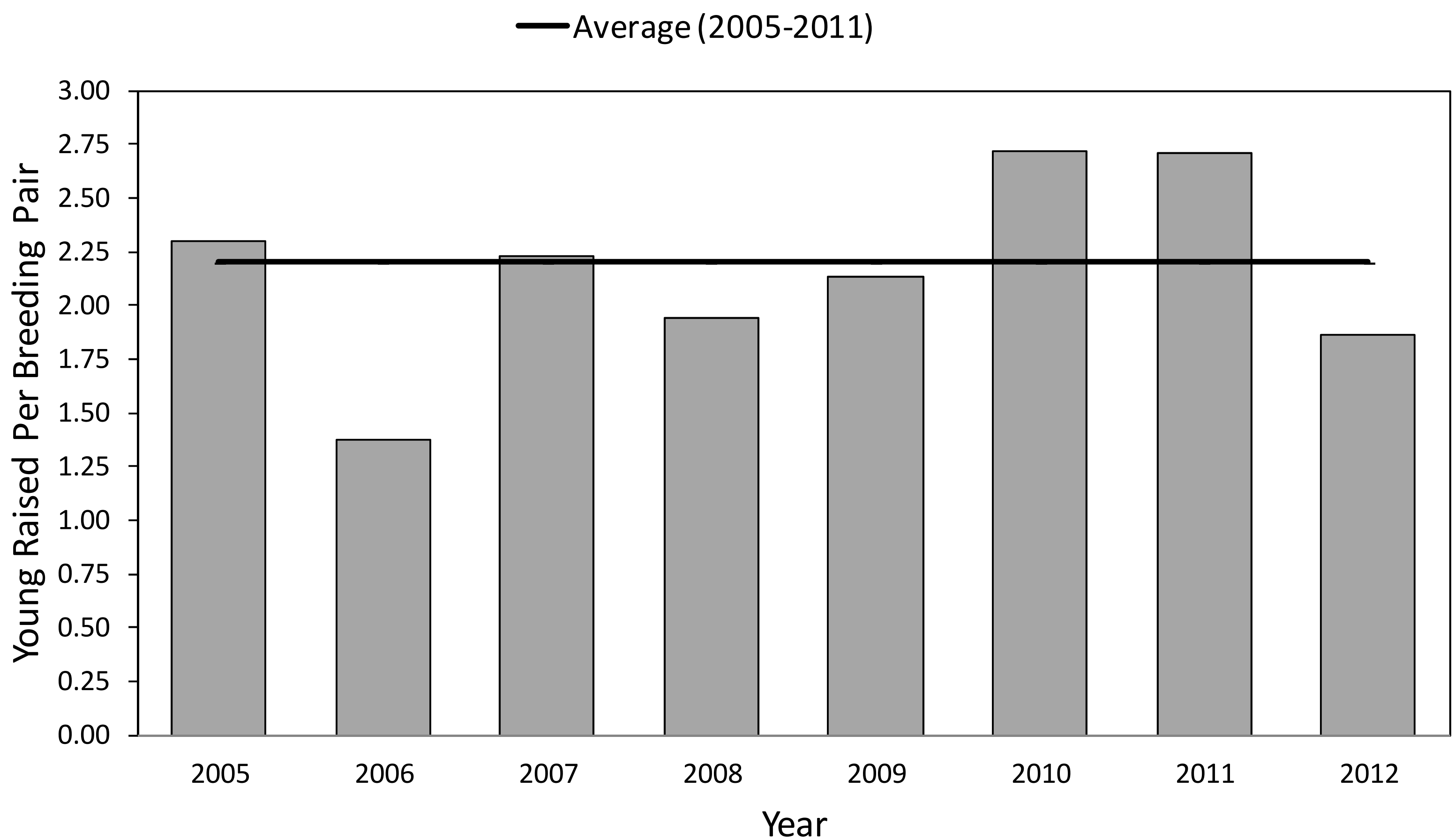


Figure 64. Double-crested cormorant nesting success (average number of young raised per breeding pair) at the Foundation Island colony in the mid-Columbia River during the 2005-2012 breeding seasons.

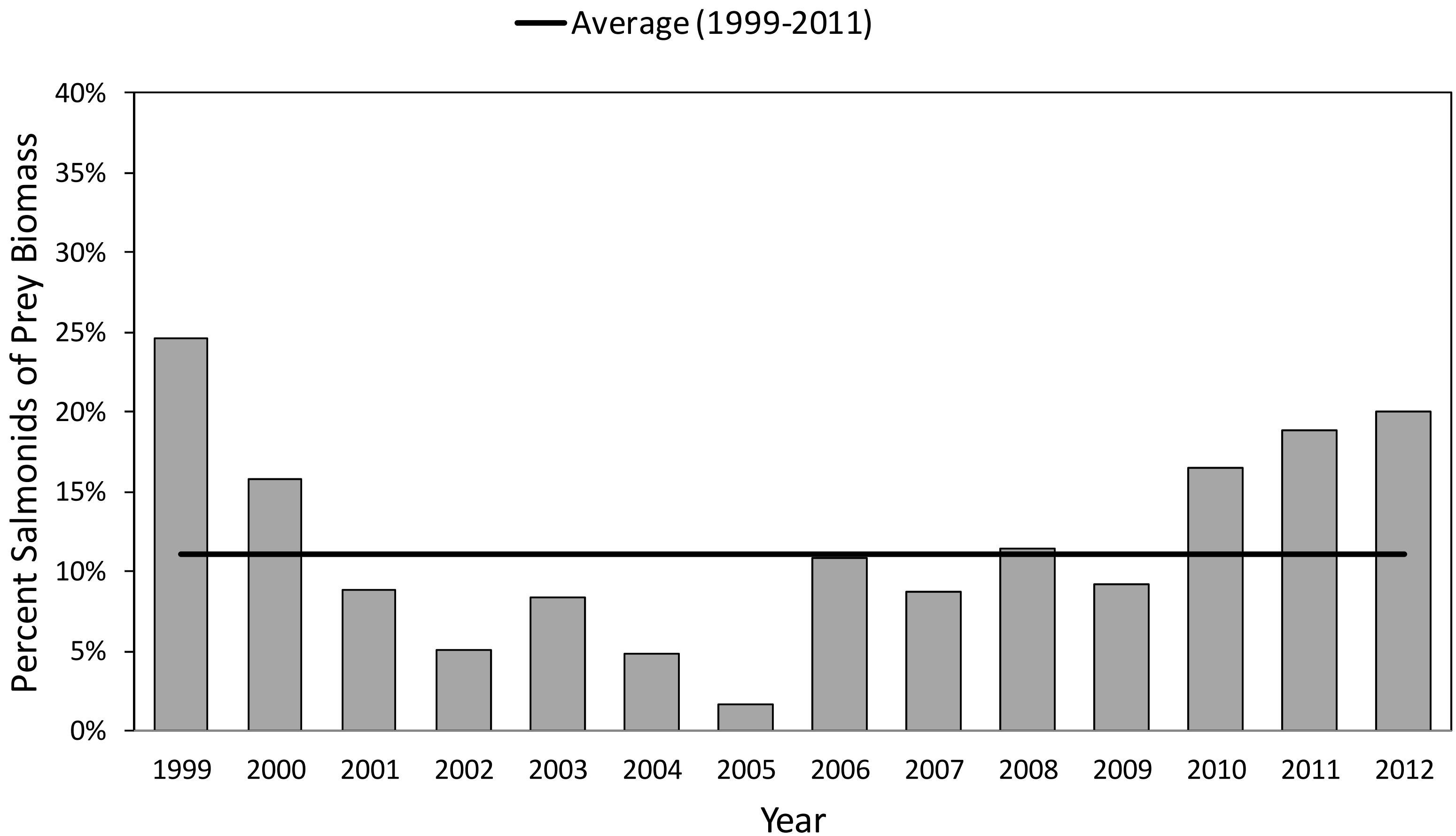


Figure 65. Average annual proportion of juvenile salmonids in the diet (percent of prey biomass) of double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 1999-2012 breeding seasons. Diet composition is based on analysis of stomach contents samples collected near the cormorant colony.

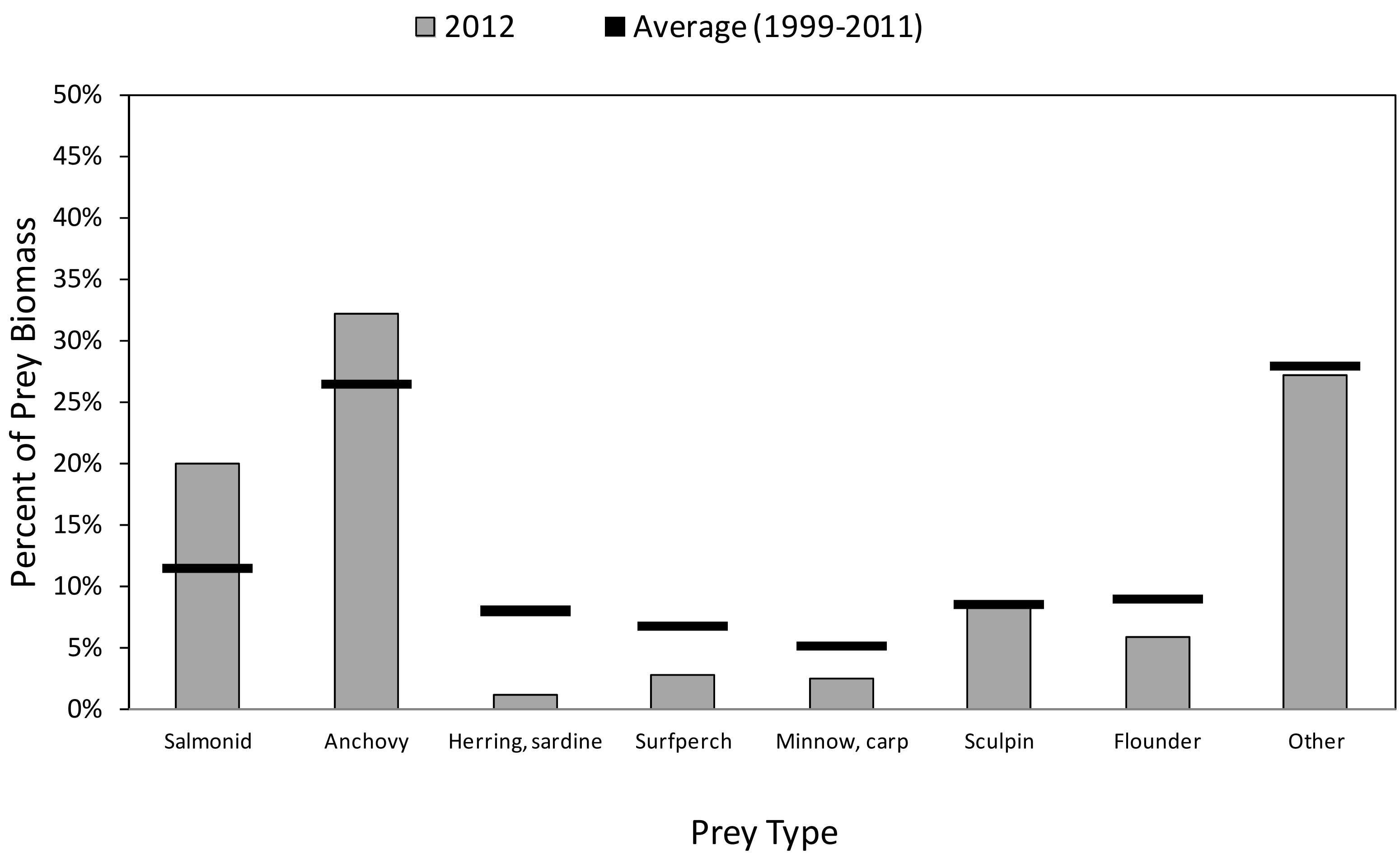


Figure 66. Diet composition (percent of prey biomass) of double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 2012 breeding season. Diet composition was based on fish identified in cormorant foregut samples.

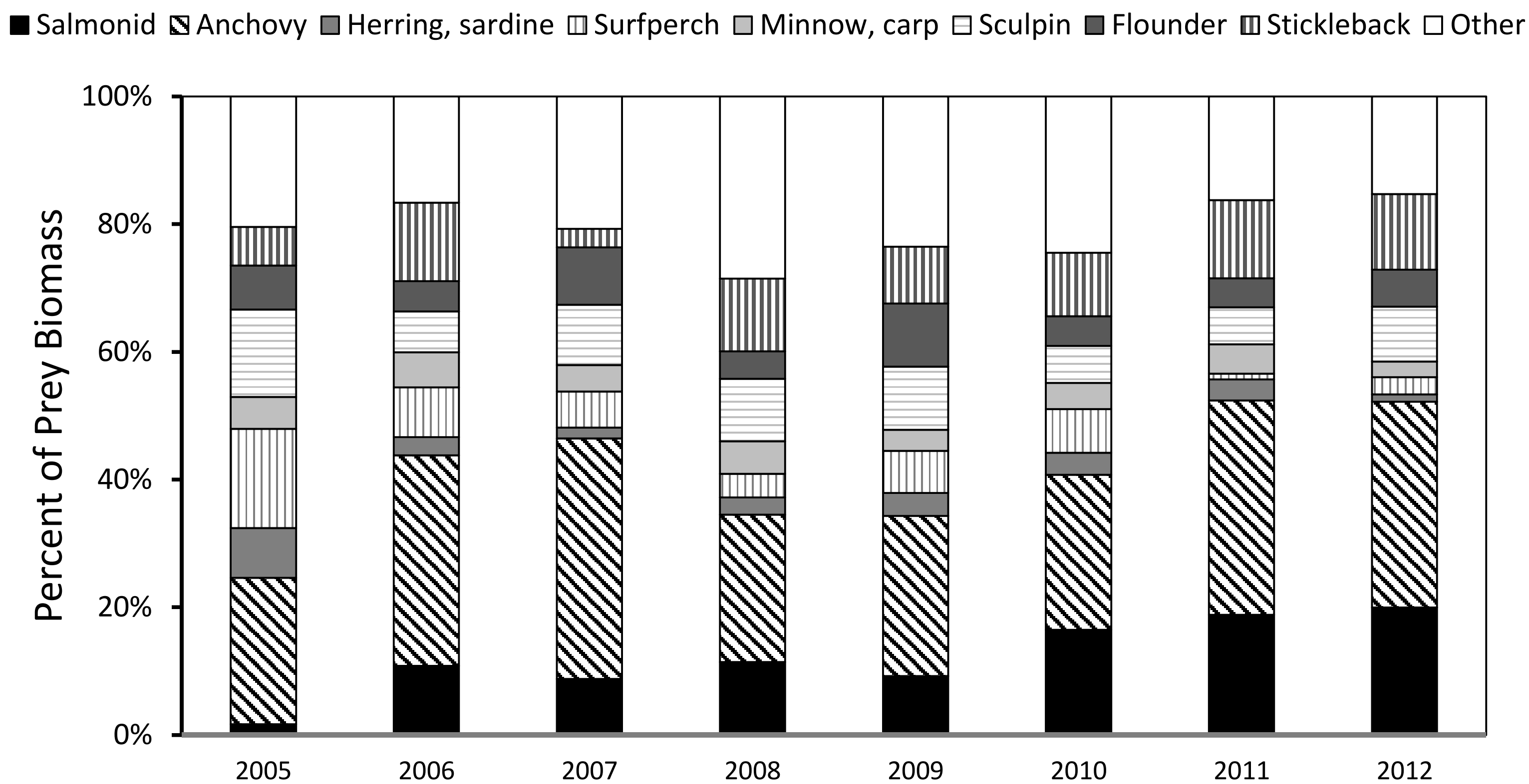


Figure 67. Annual diet composition (percent of prey biomass) of double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 2005 - 2012 breeding seasons. Diet composition was based on fish identified in cormorant foregut samples.

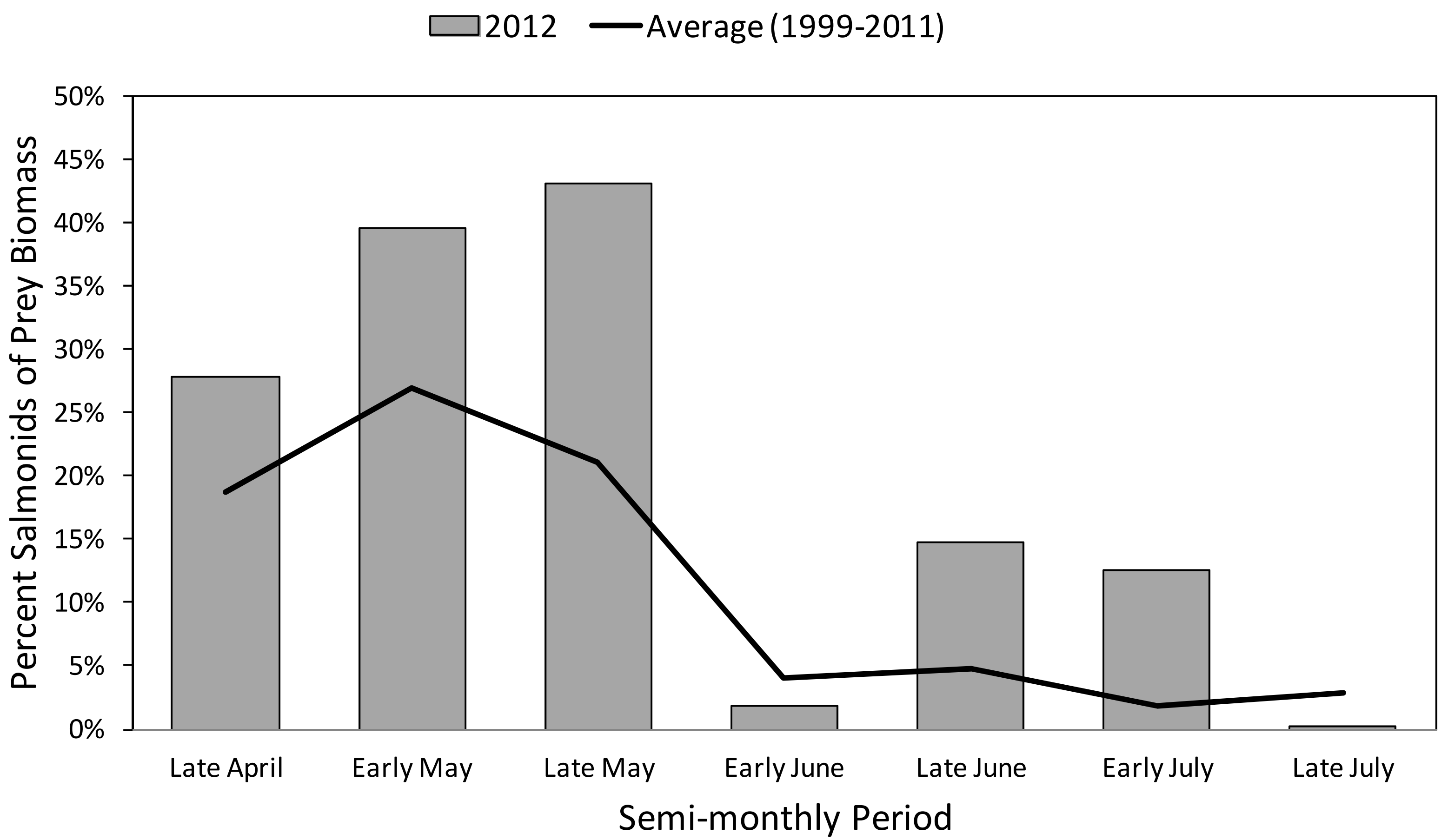
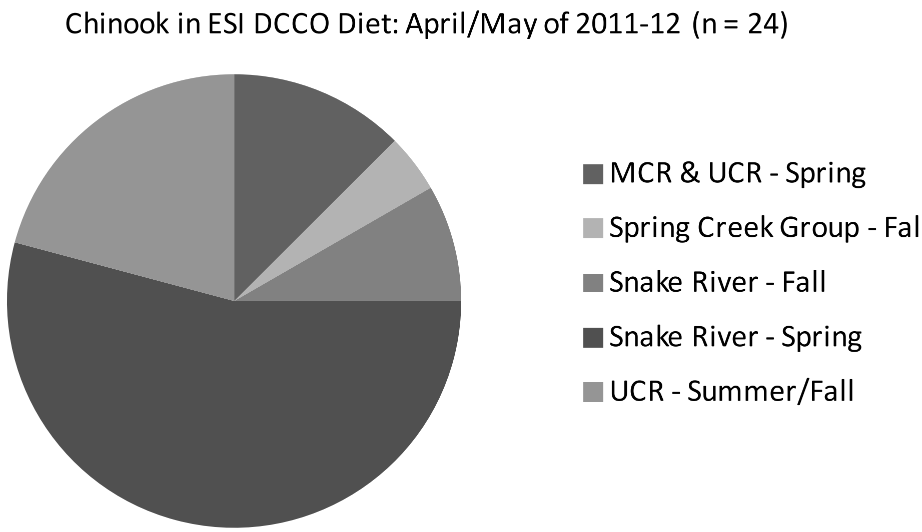


Figure 68. Seasonal trend in the proportion of juvenile salmonids in the diet (percent of prey biomass) of double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 2012 breeding season, by half-month period. Diet composition was based on fish identified in cormorant foregut samples.



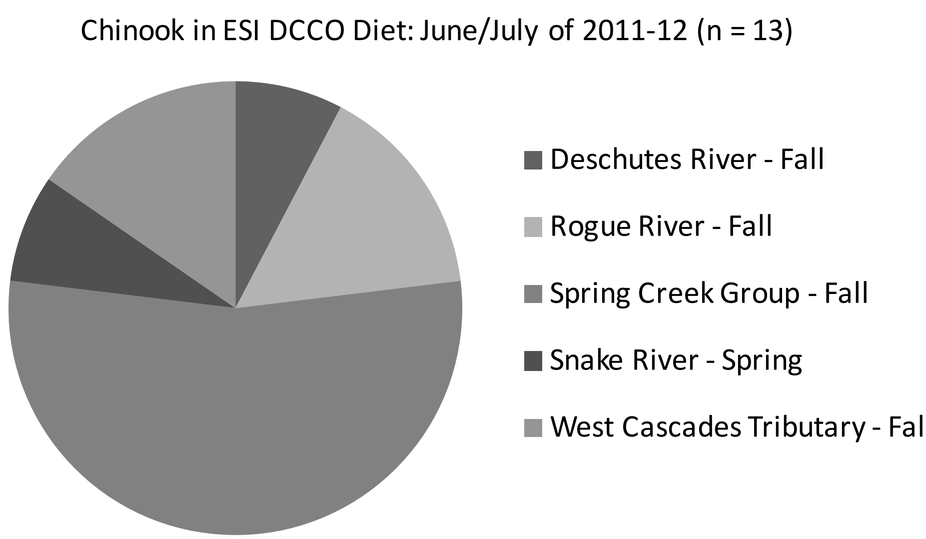
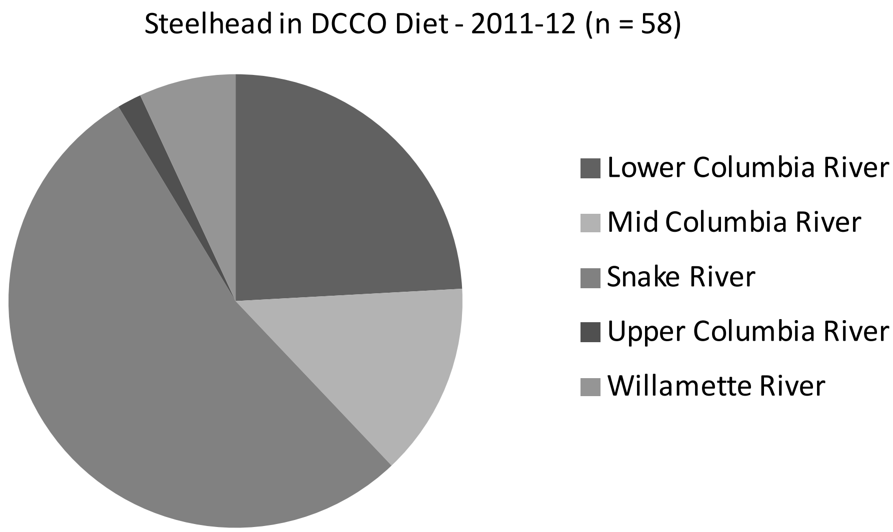


Figure 69. Genetic stock of origin for Chinook salmon in the diet of double-crested cormorants (DCCO) nesting on East Sand Island (ESI) in the Columbia River estuary. Genetic stock identification of salmonids was performed by D. Kuligowski, NOAA Fisheries, on salmonids in stomach contents samples collected from double-crested cormorants returning to the East Sand Island colony during the 2011 and 2012 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).



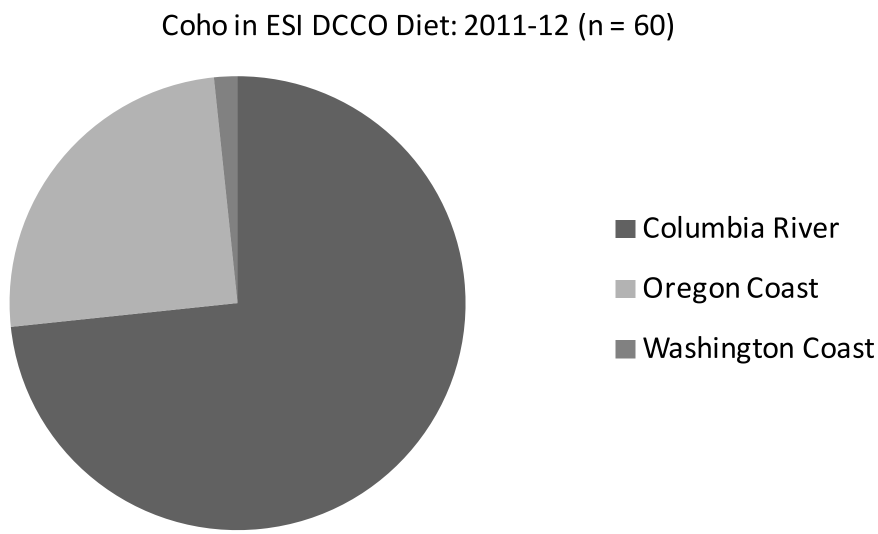


Figure 70. Genetic stock of origin for steelhead trout and coho salmon in the diet of double-crested cormorants (DCCO) nesting on East Sand Island (ESI) in the Columbia River estuary. Genetic stock identification of salmonids was performed by D. Kuligowski, NOAA Fisheries, on salmonids in stomach contents samples collected from double-crested cormorants returning to the East Sand Island colony during the 2011 and 2012 breeding seasons.

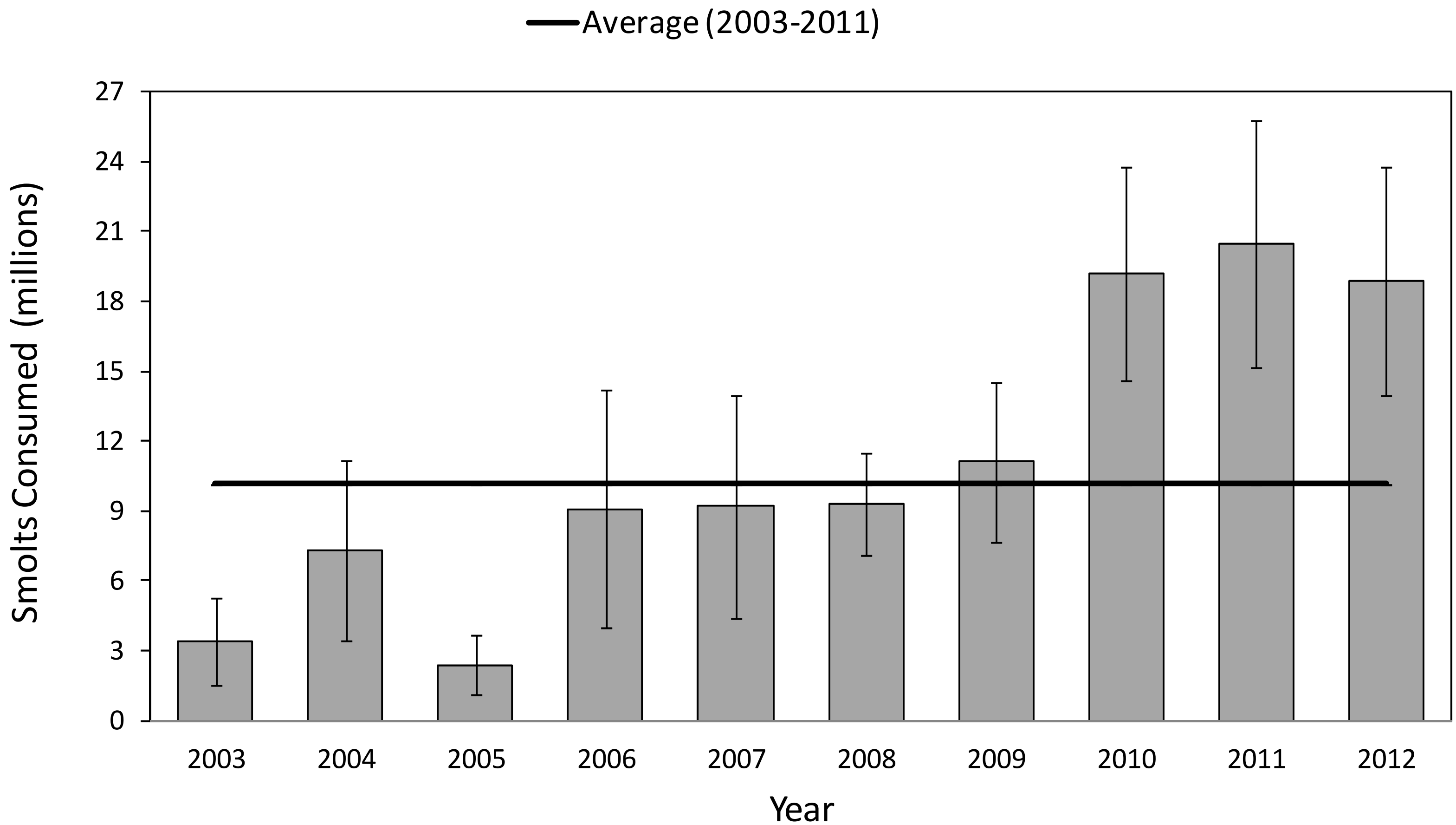


Figure 71. Estimated total annual consumption of juvenile salmonids by double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 2003-2012 breeding seasons. Estimates are based on fish identified in cormorant stomach contents samples collected near the colony and bioenergetics calculations. Error bars represent 95% confidence intervals for the number of smolts consumed.

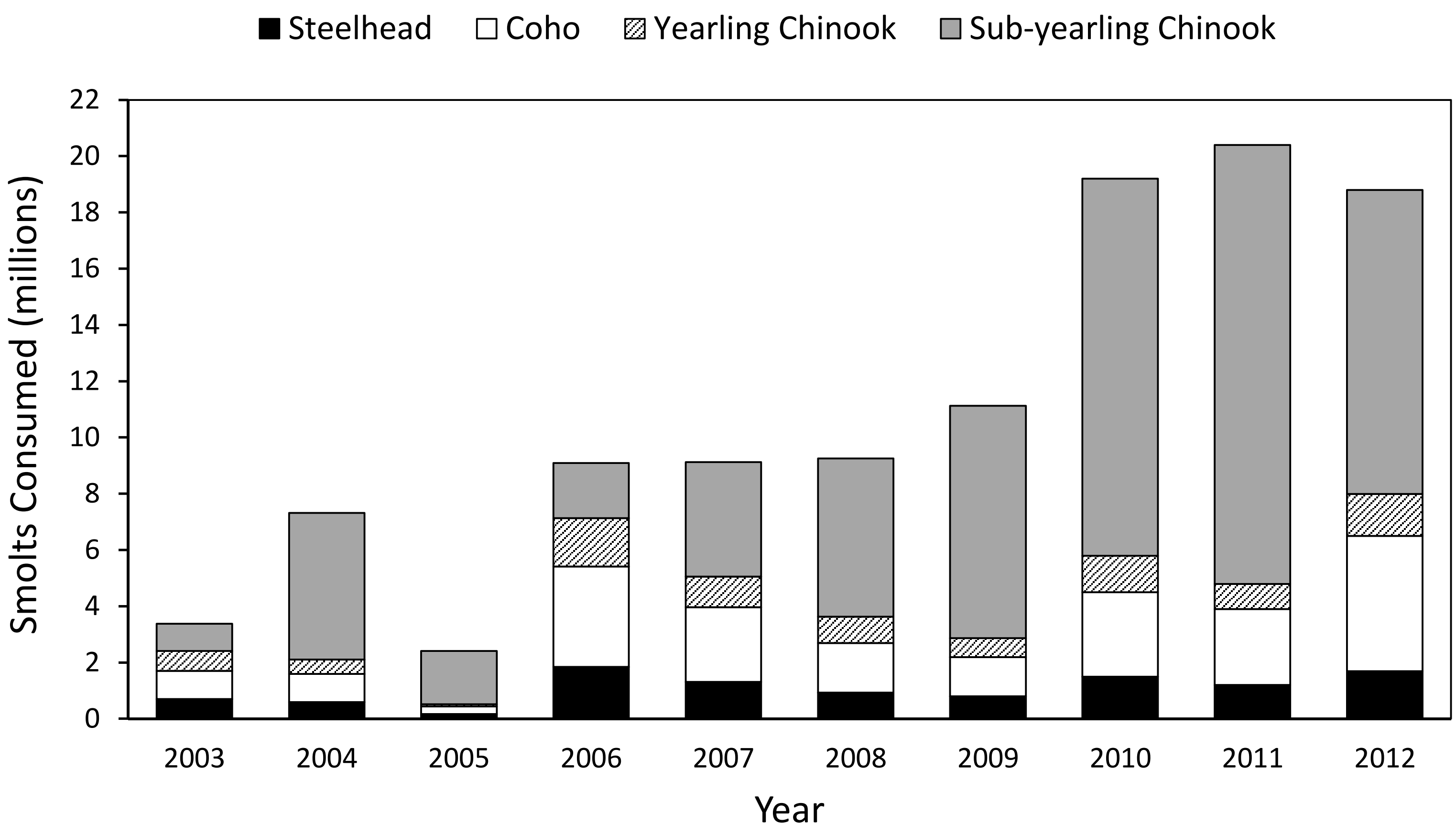


Figure 72. Estimated total annual consumption of four species/run types of juvenile salmonids by double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 2003-2012 breeding seasons. Estimates are based on fish identified in cormorant foregut samples and bioenergetics calculations.

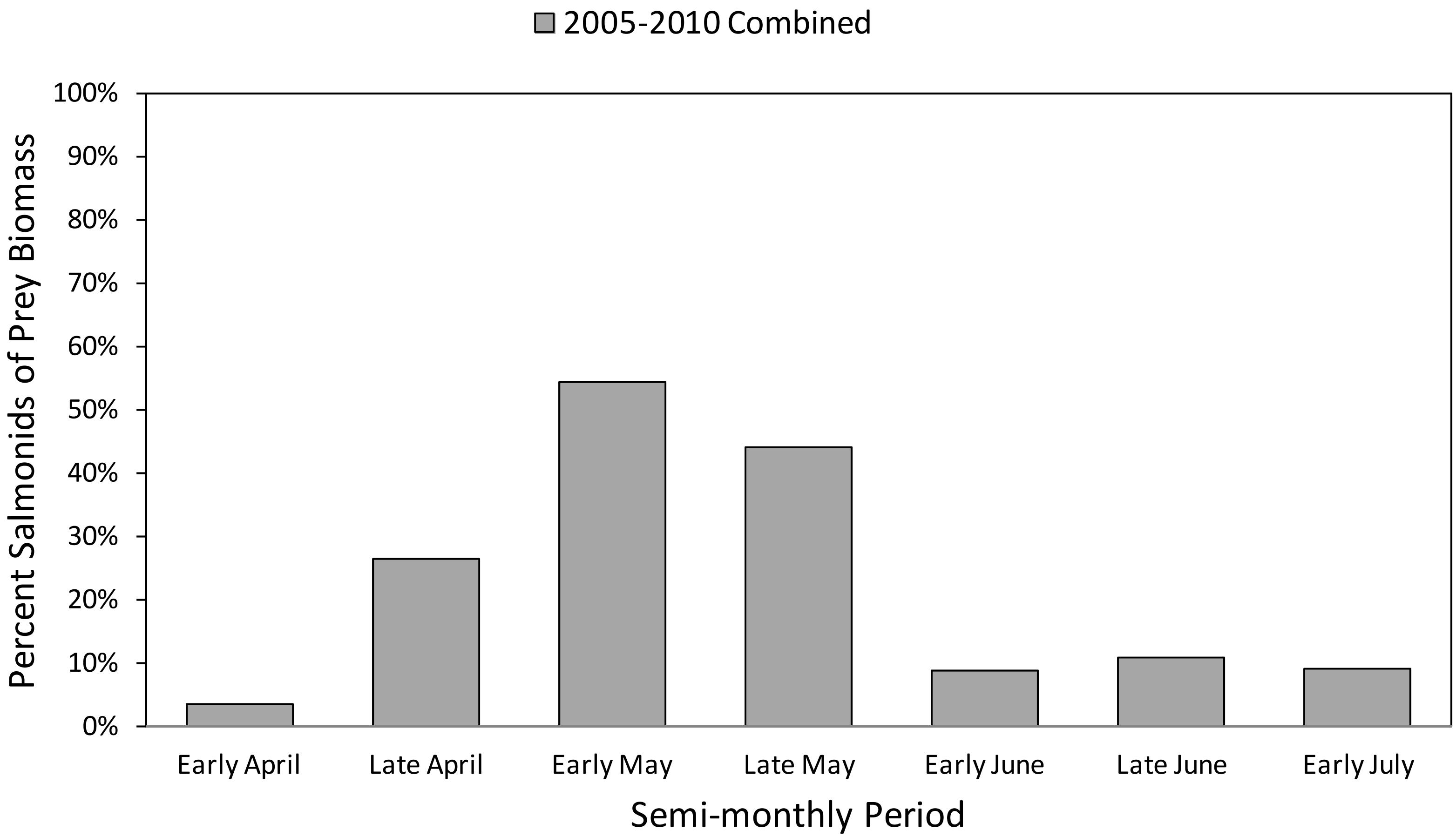


Figure 73. Average proportion of juvenile salmonids in the diet (percent of prey biomass) of double-crested cormorants nesting on Foundation Island in the mid-Columbia River during the 2005-2010 breeding seasons, by half-month period. Diet composition was based on fish identified in cormorant foregut samples collected near the colony. Cormorant foregut samples collected during the six-year study period are combined.

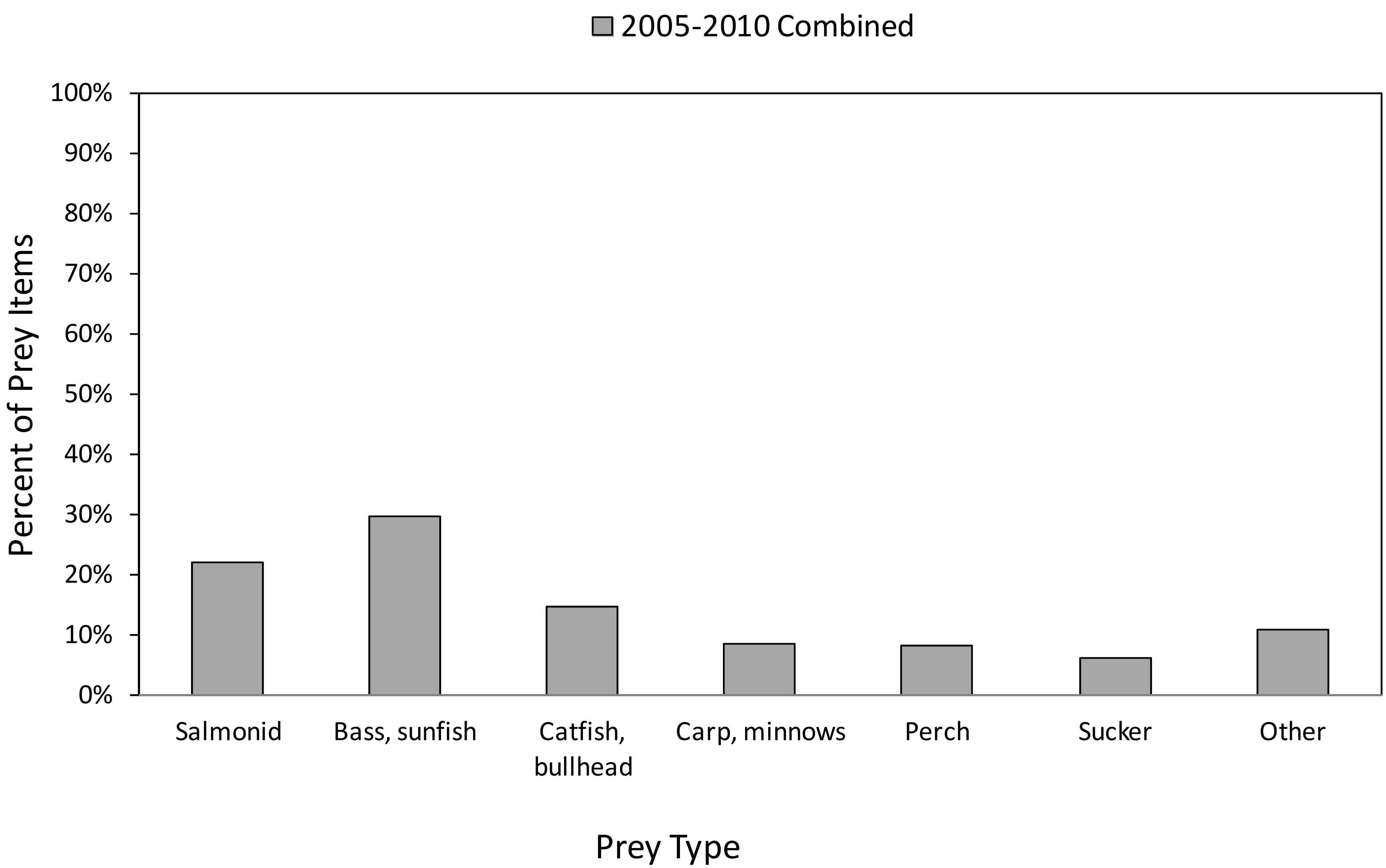


Figure 74. Diet composition (percent of prey biomass) of double-crested cormorants nesting on Foundation Island in the mid-Columbia River during the 2005-2010 breeding seasons. Diet composition was based on fish identified in cormorant foregut samples collected near the colony. Diet samples collected during the six-year study period are combined.

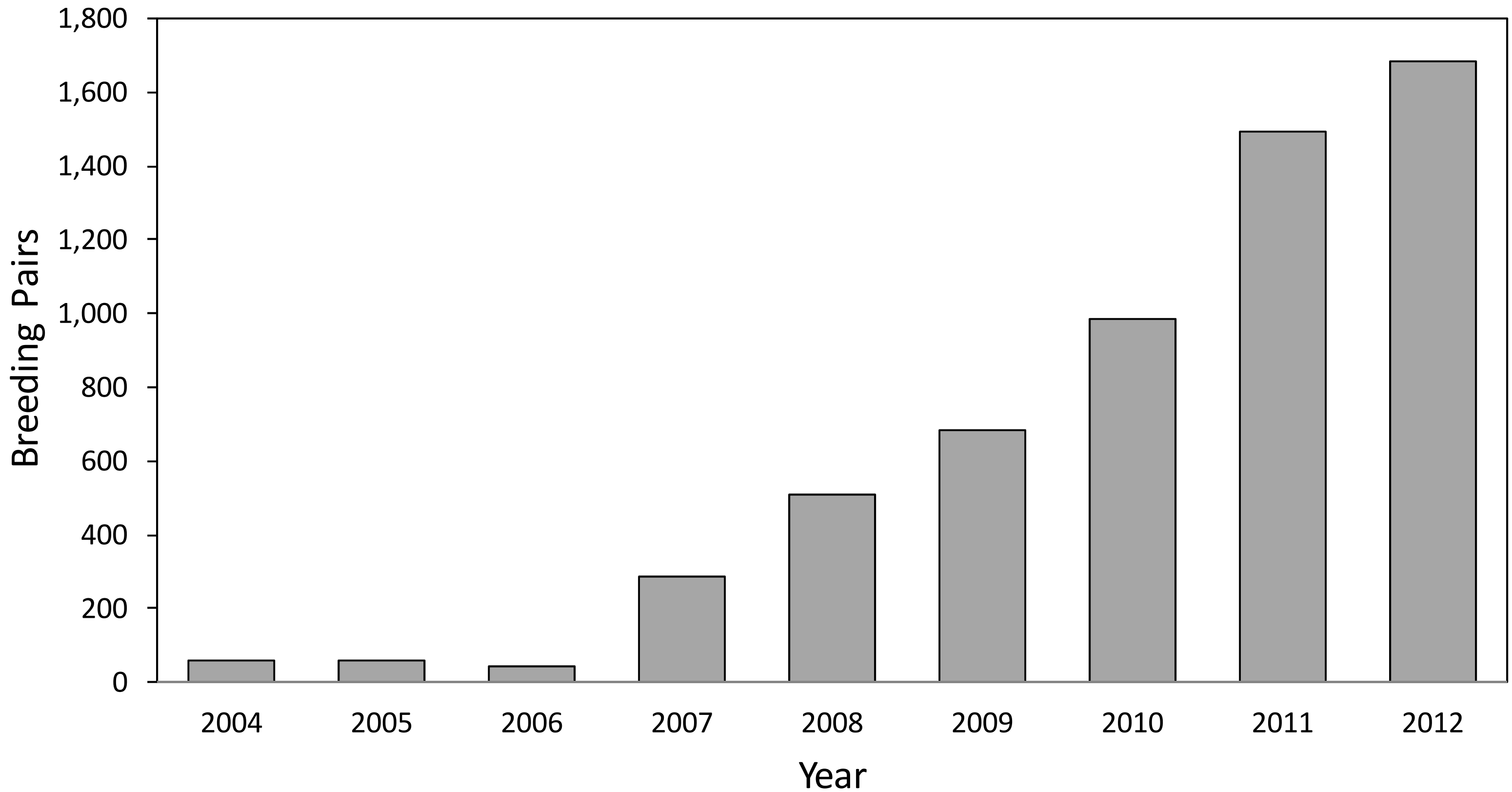


Figure 75. Size of the Brandt's cormorant breeding colony (number of breeding pairs) on East Sand Island in the Columbia River estuary during the 2004-2012 breeding seasons.

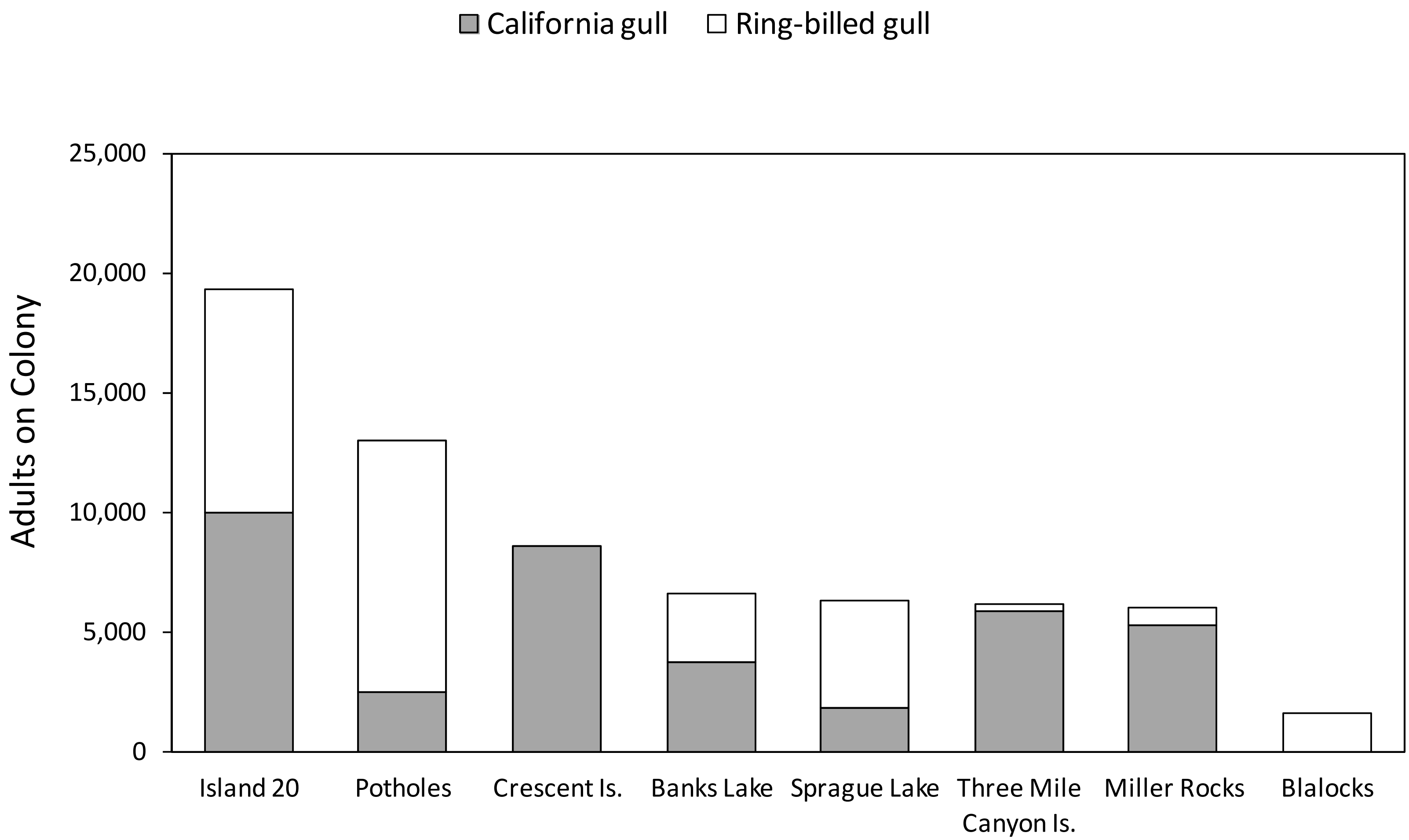


Figure 76. Numbers of adult California and ring-billed gulls counted on aerial photography of eight different breeding colonies in the Columbia Plateau region during the 2009 breeding season. Photography was taken late in the incubation period.

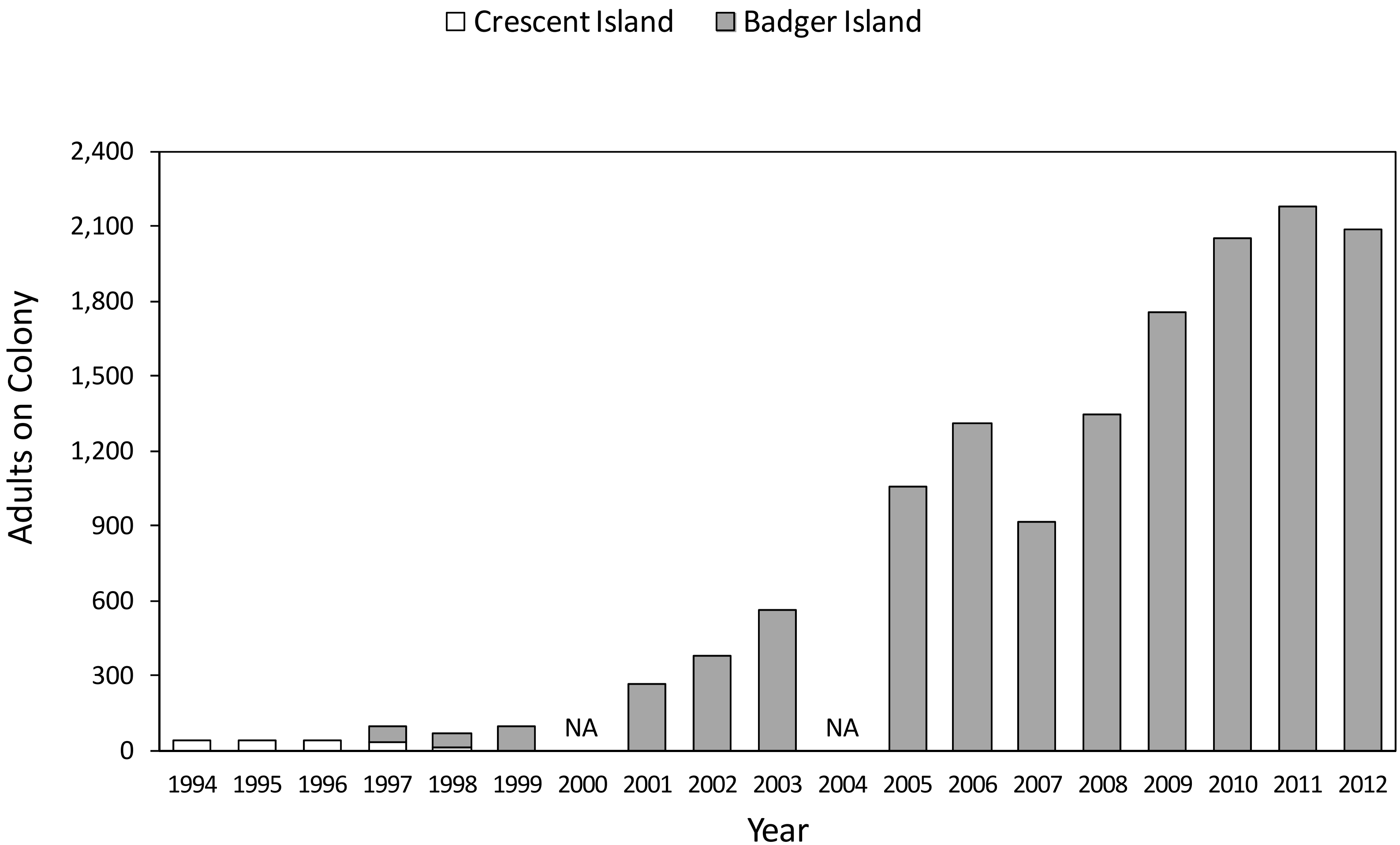


Figure 77. Numbers of adult American white pelicans counted in aerial photography of two colonies on the mid-Columbia River, Badger Island and Crescent Island, during the 1994-2012 breeding seasons. Photography was taken late in the incubation period. Numbers of pelicans on the Badger Island colony were not determined in 2000 and 2004.

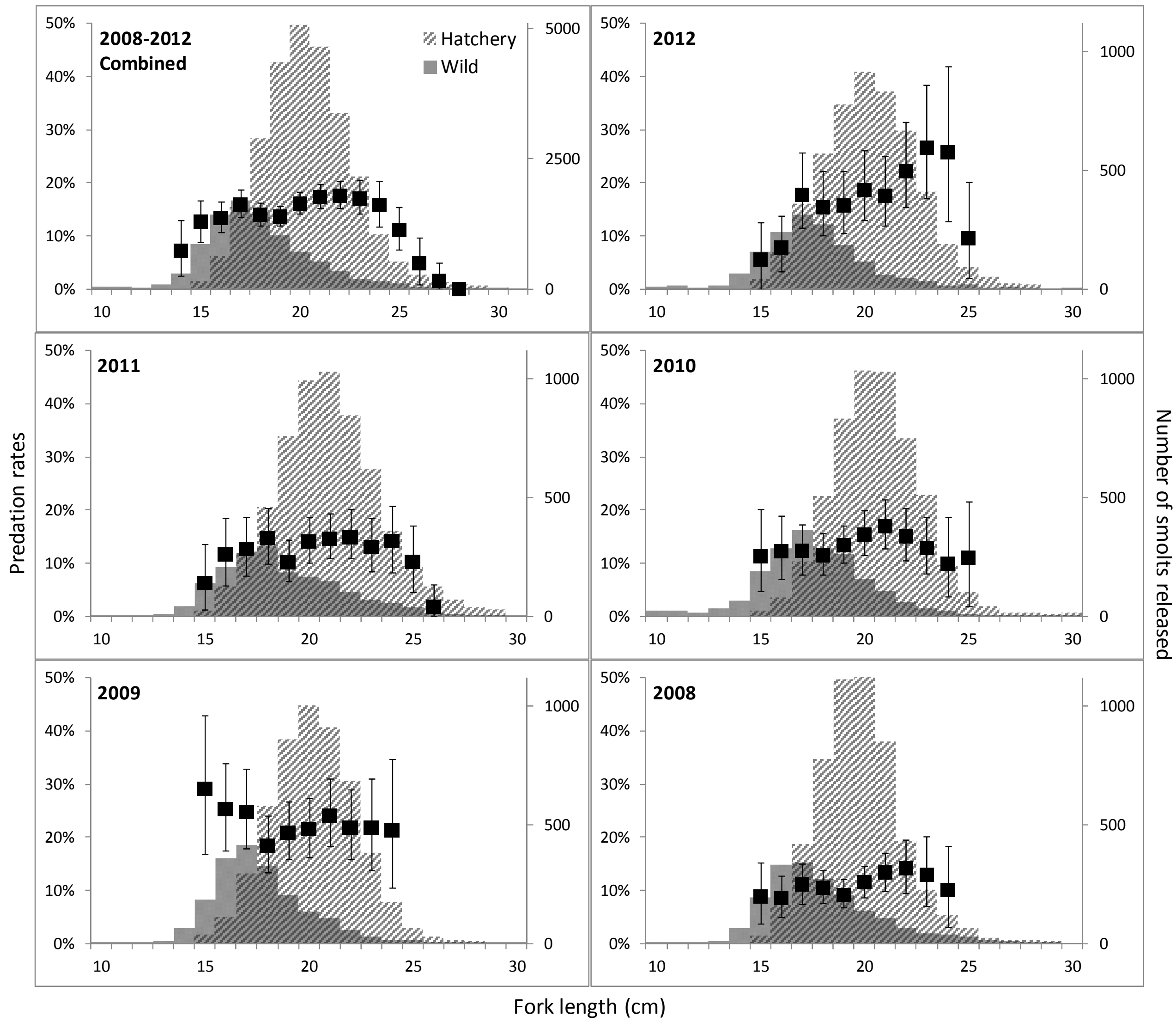


Figure 78. Fork length-specific predation rates on PIT-tagged Upper Columbia River steelhead (released at Rock Island Dam) by Caspian terns nesting at Goose Island, Potholes Reservoir, WA during 2008-2012 (boxes). Only fork length groups with more than 100 PIT-tagged steelhead released from Rock Island Dam per year are shown. Error bars represent 95% confidence intervals. The numbers of hatchery (thatched) and wild (grey) steelhead smolts PIT-tagged and released at Rock Island Dam per fork length interval are also shown.

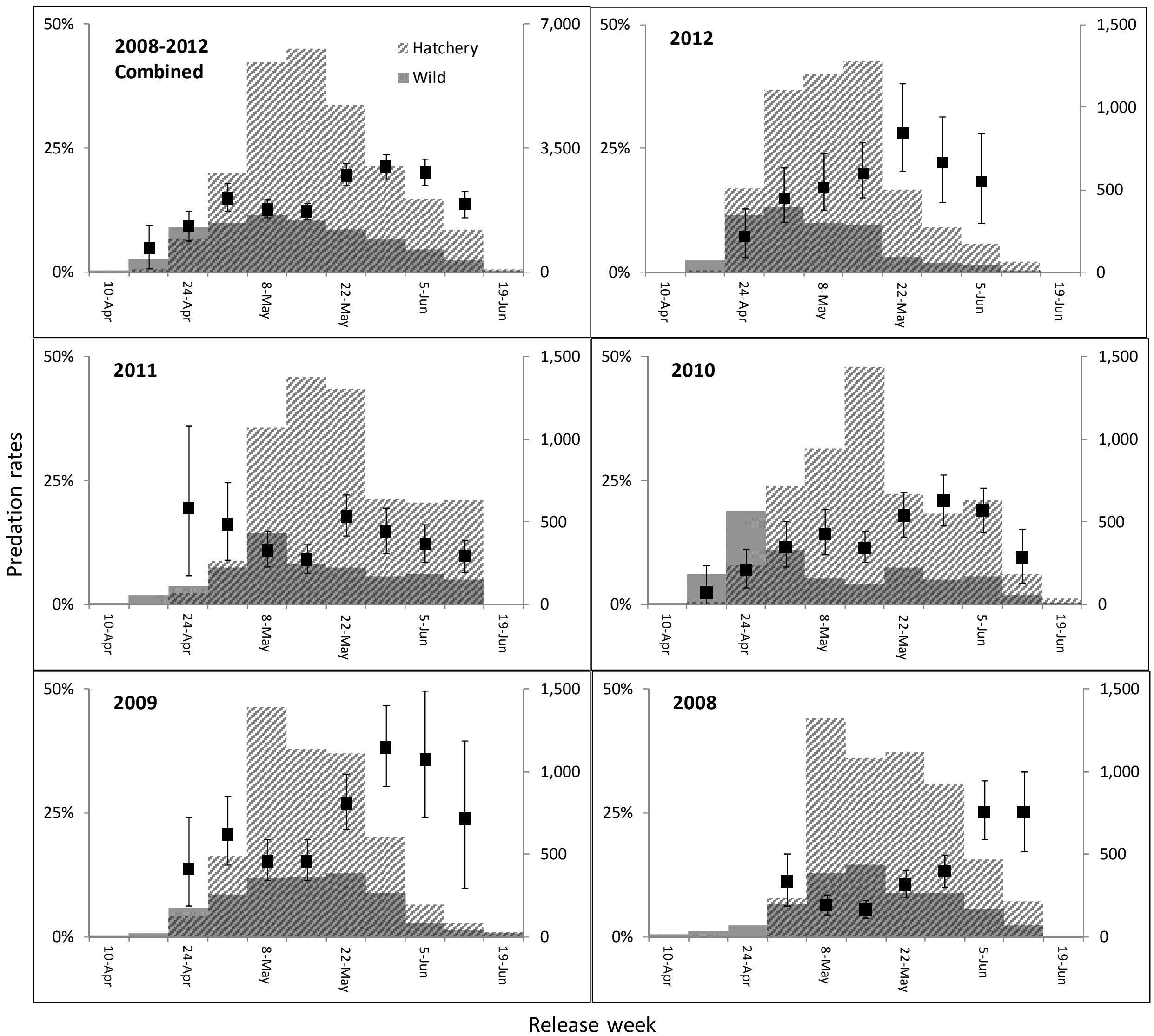


Figure 79. Weekly predation rates on PIT-tagged Upper Columbia River steelhead (released at Rock Island Dam) by Caspian terns nesting at Goose Island, Potholes Reservoir, WA during 2008-2012 (squares). Only weeks with more than 100 PIT-tagged steelhead released from Rock Island Dam are shown. Error bars represent 95% confidence intervals. The numbers of hatchery (thatched) and wild (grey) steelhead smolts PIT-tagged and released at Rock Island Dam per week are also shown.

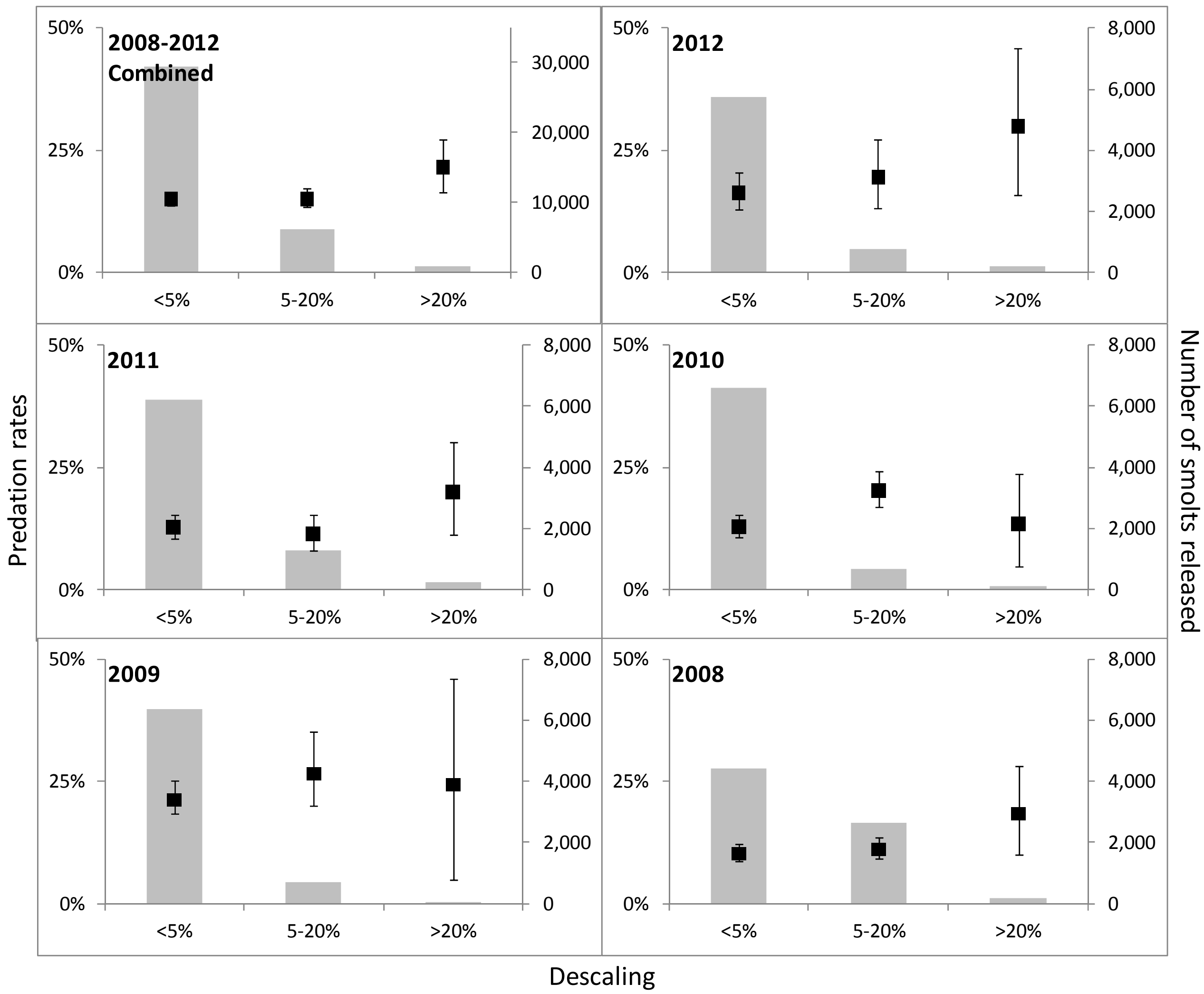


Figure 80. Predation rates on PIT-tagged Upper Columbia River steelhead (released at Rock Island Dam) by Caspian terns nesting at Goose Island in Potholes Reservoir, WA during 2008-2012 (boxes) separated by the magnitude of steelhead de-scaling. Error bars represent 95% confidence intervals. The numbers of steelhead smolts released in each de-scaling category are also shown.

Table 1. Caspian tern nesting islands that were built by the U.S. Army Corps of Engineers prior to the 2012 nesting season as part of the federal agencies' Caspian Tern Management Plan for the Columbia River Estuary (USFWS 2005, 2006).

Location	Site	Construction Date	Island Type	Island Size (acres)	Acreage Available in 2012	Notes:
Fern Ridge Reservoir, OR	Fern Ridge	Feb 2008	Rock core	1.0	1.0	Not monitored
Crump Lake, Warner Valley, OR	Crump Lake	Mar 2008	Rock core	1.0	1.0	No social attraction
Summer Lake Wildlife Area, OR	East Link	Jan 2009	Rock core	0.5	0.5	
Summer Lake Wildlife Area, OR	Dutchy Lake	Mar 2009	Floating island	0.5	0.0	Overgrown w/vegetation
Summer Lake Wildlife Area, OR	Gold Dike	Sep 2009	Rock core	0.5	0.5	
Tule Lake NWR, CA	Sump 1B	Aug 2009	Rock core	2.0	2.0	
Lower Klamath NWR, CA	Orems Unit	Sep 2009	Silt core	1.0	0.0	Land-bridged, Low water
Lower Klamath NWR, CA	Sheepy Lake	Mar 2010	Floating island	0.8	0.8	
Malheur NWR, OR	Malheur Lake	Feb 2012	Rock core	1.0	1.0	
			TOTAL	**8.3**	**6.8**	

Table 2. On-colony PIT tag deposition rates (DR) by piscivorous colonial waterbird species. Results were used to adjust predation rate estimates for the number of consumed PIT tags that were destroyed by birds during ingestion or were deposited by birds at locations other than their nesting colony. Studies used to measure deposition rates varied by species and colony. Sample sizes (n) of known consumed PIT-tagged fish used to estimate deposition rates are provided. See Appendix A for complete description of methods and results of deposition rate studies.

Species	Colony	Years	n	DR (95% c.i.)
Caspian tern	East Sand Is., Crescent Is.	2005-06	362	71% (62-81%)
Double-crested cormorant[1]	East Sand Is.	2012	301	44% (36-51%)
California gull[2]	Miller Rocks, Crescent Is.	2012	611	17% (13-21%)
Ring-billed gull	Unknown; California gull deposition rate was applied			
Brandt's cormorant	Unknown; double-crested cormorant deposition rate was applied			
American white pelican	Unknown; predation rates were not adjusted for deposition rate and are therefore minimums			
Brown pelican	Unknown; predation rates were not adjusted for deposition rate and are therefore minimums			

[1] Deposition rate was applied to both ground-nesting and arboreal-nesting (i.e., cormorants on Foundation Island) double-crested cormorant colonies
[2] Data based on results from a pilot study

Table 3. Number of juvenile salmonid (Chinook, coho, sockeye, and steelhead) PIT tags from 2012 migration year smolts recovered on bird colonies in the Columbia River basin following the 2012 nesting season. Piscivorous waterbird breeding colonies include American white pelicans (AWPE), Brandt's cormorants (BRAC), Caspian terns (CATE), double-crested cormorants (DCCO), and California and ring-billed gulls (GULLS).

River Segment	Location	Bird Species	Recovered
Estuary	East Sand Island	CATE	15,919
		DCCO	13,827
		BRAC[1]	506
The Dalles Pool	Miller Rocks	GULLS	2,423
McNary Pool	Crescent Island	CATE	7,285
		GULLS	2,132
	Badger Island	AWPE	2,682
		CATE[2]	382
	Foundation Island	DCCO	2,873
Off-river	Potholes Reservoir	CATE	3,372
		GULLS	164
		DCCO	126
	Banks Lake	CATE	63
	Sprague Lake	CATE	538
		DCCO	11
Total			52,303

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

[2] Recoveries on the Caspian tern colony at Badger Island likely included some tags deposited by American white pelicans (see Results).

Table 4. Range of daily detection efficiency estimates for PIT tags sown on bird colonies during the 2012 nesting season. Results were used to adjust predation rate estimates for the number of tags deposited by birds on their nesting colony that were not detected by researchers on the colony following the nesting season. Sample sizes of sown tags are provided. Piscivorous waterbird colonies include American white pelicans (AWPE), double-crested cormorants (DCCO), Caspian terns (CATE), and California and ring-billed gulls (GULLS). Sample sizes in parentheses denote values extrapolated from other sites or years due to a lack of empirical data in 2012.

River Segment	Location	Colony	Sample Size	Date Range	Detection Efficiency
Estuary	East Sand Island	CATE	200	3/1 - 8/31	45 - 91%
		DCCO[1]	200	3/1 - 8/31	56 - 81%
The Dalles Pool	Miller Rocks	GULLS	100	4/1 - 7/31	68 - 91%
McNary Pool	Crescent Island	CATE	200	4/1 - 7/31	33 - 93%
		GULLS	100	4/1 - 7/31	46 - 96%
	Badger Island	AWPE	(100)[2]	4/1 - 7/31	65 - 74%
		CATE	(100)[2]	4/1 - 7/31	65 - 74%
	Foundation Island	DCCO	200	4/1 - 7/31	35 - 41%
Off-river	Potholes Reservoir	CATE	400	4/1 - 7/31	12 - 86%
		GULLS	100	4/1 - 7/31	16 - 64%
		DCCO	200	4/1 - 7/31	21 - 29%
	Banks Lake	CATE	(100)[3]	4/1 - 7/31	15 - 98%
	Sprague Lake	CATE	(50)[4]	4/1 - 7/31	20 - 96%
		DCCO	(200)[5]	4/1 - 7/31	61 - 78%

[1] Values used for both double-crested cormorant and Brandt's cormorant predation rates
[2] Detection efficiency values based on 2006-2010 detection efficiency estimates at Badger Island
[3] Detection efficiency values based on 2008-2010 detection efficiency estimates at Twining Island, Banks Lake
[4] Detection efficiency values based on 2012 detection efficiency estimates at Columbia Plateau Caspian tern colonies
[5] Detection efficiency values based on 2012 detection efficiency estimates at the East Sand Island double-crested cormorant colony, a ground-nesting cormorant colony

Table 5. Estimated predation rates (95% confidence interval) on PIT-tagged salmonid smolts, last detected at Bonneville Dam on the Columbia River or Sullivan Dam on the Willamette River, by avian predators nesting at colonies on East Sand Island in the Columbia River estuary. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiency (Table 4) and on-colony PIT tag deposition rates (Table 2). Species 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 passing a dam were evaluated.

			Predation Rates					
			East Sand Island CATE		East Sand Island DCCO		East Sand Island BRAC[1]	
ESU/DPS[2]	ESA[3]	N	Deposited[4]	Predation rate	Deposited[4]	Predation rate	Deposited[4]	Predation rate
SR Sockeye	E	1,457	1.5% (0.8-2.3)	2.1% (1.1-3.2)	1.7% (1.0-2.6)	4.0% (2.2-6.1)	<0.1%	<0.1%
SR Spr/Sum Chinook	T	17,929	1.6% (1.3-1.9)	2.2% (1.8-2.7)	1.8% (1.5-2.1)	4.2% (3.4-5.2)	<0.1%	<0.1%
UCR Spr Chinook	E	3,227	0.8% (0.5-1.2)	1.2% (0.7-1.7)	1.0% (0.6-1.4)	2.3% (1.4-3.4)	<0.1%	<0.1%
MCR Spr Chinook	NW	4,433	1.1% (0.7-1.6)	1.6% (1.0-2.2)	1.0% (0.7-1.5)	2.4% (1.5-3.4)	0.1% (<0.1-0.2)	0.1% (<0.1-0.2)
SR Fall Chinook	T	10,742	0.5% (0.3-0.6)	0.7% (0.5-0.9)	1.3% (1.0-1.6)	3.0% (2.3-3.8)	<0.1%	0.1% (<0.1-0.1)
UCR Sum/Fall Chinook	NW	3,986	1.0% (0.7-1.4)	1.4% (0.9-2.0)	1.0% (0.6-1.3)	2.2% (1.3-3.1)	<0.1%	0.1% (<0.1-0.2)
UWR Spr Chinook	T	3,731	0.5% (0.3-0.7)	0.7% (0.4-1.1)	0.3% (0.1-0.5)	0.6% (0.2-1.2)	0.1% (<0.1-0.3)	0.2% (<0.1-0.4)
SR Steelhead	T	4,768	7.1% (6.0-8.4)	10.0% (8.4-11.9)	2.3% (1.8-3.0)	5.4% (4.0-7.0)	<0.1%	<0.1%
UCR Steelhead	T	3,357	5.3% (4.2-6.3)	7.4% (6.0-9.1)	3.2% (2.4-4.0)	7.2% (5.4-9.6)	0.1% (<0.1-0.2)	0.1% (<0.1-0.3)
MCR .Steelhead	T	1,084	6.6% (4.8-8.4)	9.3% (6.7-12.3)	1.5% (0.7-2.5)	3.4% (1.6-5.8)	0.1% (<0.1-0.4)	0.2% (<0.1-0.6)

[1] May include tags deposited by double-crested cormorants (see Results)
[2] MCR = Middle Columbia River, SR = Snake River, UCR = Upper Columbia River, UWR = Upper Willamette River
[3] E = Endangered, T = Threatened, NW = Not Warranted
[4] Values not adjusted for deposition rate and therefore analogous to minimum predation rate estimates presented in previous BRNW Annual Reports

Table 6. Estimated predation rates (95% confidence interval) on PIT-tagged salmonid smolts, last detected at Lower Monumental Dam on the Snake River or Rock Island Dam on the upper Columbia River, by avian predators nesting at colonies on Crescent Island, Foundation Island, or Badger Island near the confluence of the Snake and Columbia rivers. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiency (Table 4) and on-colony PIT tag deposition rates, where available (Table 2). Colonies include those of Caspian terns (CATE), double-crested cormorants (DCCO), California and ring-billed gulls (GULLS), and American white pelicans (AWPE). The number of PIT-tagged smolts interrogated at Lower Monumental or Rock Island 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 that were interrogated while passing a dam were evaluated.

			Predation Rates									
			Crescent Island CATE		Crescent Island GULLS		Foundation Island DCCO		Badger Island AWPE		Badger Island CATE	
ESU/DPS[1]	ESA[2]	N	Deposited[3]	Predation rate	Deposited[3]	Predation rate[4]	Deposited[3]	Predation rate	Deposited[3]	Predation rate[5]	Deposited[3]	Predation rate
SR Sockeye	E	5,043	0.9% (0.6-1.3)	1.3% (0.9-1.8)	0.1% (<0.1-0.2)	0.6% (0.1-1.3)	1.1% (0.6-1.7)	2.5% (1.4-4.0)	<0.1%	NA	<0.1%	<0.1%
SR Spr/Sum Chin	T	48,043	0.4% (0.3-0.5)	0.6% (0.4-0.8)	0.1% (0.1-0.2)	0.8% (0.4-1.1)	0.4% (0.3-0.5)	0.8% (0.6-1.2)	<0.1%	NA	<0.1%	<0.1%
UCR Spr Chin	E	1,812	0.1% (<0.1-0.3)	0.1% (<0.1-0.4)	0.2% (<0.1-0.5)	1.0% (<0.1-2.8)	0.2% (<0.1-0.5)	0.3% (<0.1-1.2)	0.1% (<0.1-0.3)	NA	<0.1%	<0.1%
SR Fall Chinook	T	29,751	0.4% (0.3-0.5)	0.5% (0.4-0.7)	0.1% (<0.1-0.1)	0.4% (0.2-0.7)	0.2% (0.1-0.4)	0.5% (0.3-0.8)	<0.1%	NA	<0.1%	<0.1%
UCR Sum/Fall Chin	NW	2,533	<0.1%	<0.1%	<0.1%	<0.1%	0.2% (<0.1-0.5)	0.5% (<0.1-1.2)	<0.1%	NA	<0.1%	<0.1%
SR Steelhead	T	27,767	2.0% (1.7-2.5)	2.8% (2.4-3.5)	0.7% (0.4-0.9)	4.1% (2.6-5.6)	1.1% (0.8-1.4)	2.4% (1.8-3.3)	0.2% (0.1-0.3)	NA	0.1% (0.1-0.2)	0.2% (0.1-0.3)
UCR Steelhead	T	6,845	0.8% (0.6-1.2)	1.2% (0.8-1.6)	0.7% (0.4-1.0)	4.0% (2.3-5.9)	0.2% (<0.1-0.4)	0.5% (0.1-0.9)	0.1% (<0.1-0.2)	NA	<0.1%	0.1% (<0.1-0.2)

[1] SR = Snake River, UCR = Upper Columbia River
[2] E = Endangered, T = Threatened, NW = Not Warranted
[3] Values not adjusted for deposition rate and therefore analogous to minimum predation rate estimates presented in previous BRNW Annual Reports
[4] Based on deposition results from a pilot study (see Table 2 and Appendix A)
[5] On-colony PIT tag deposition rates are not available for American white pelicans

Table 7. Estimated predation rates (95% confidence interval) on PIT-tagged salmonid smolts last detected at Rock Island Dam on the upper Columbia River by avian predators nesting at colonies in Potholes Reservoir, WA. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiency (Table 4) and on-colony PIT tag deposition rates (Table 2). Colonies include Caspian terns (CATE), double-crested cormorants (DCCO), and California and ring-billed gulls (GULLS). The number of PIT-tagged smolts interrogated at 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 the dam were evaluated.

			Predation Rates					
			Potholes Reservoir CATE		Potholes Reservoir GULLS		Potholes Reservoir DCCO	
ESU[1]	ESA[2]	N	Deposited[3]	Predation rate	Deposited[3]	Predation rate[4]	Deposited[3]	Predation rate
SR Sockeye	E	5,043	<0.1%	0.1% (<0.1-0.2)	<0.1%	<0.1%	<0.1%	<0.1%
SR Spr/Sum Chin	T	48,043	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
UCR Spr Chin	E	1,812	1.8% (0.7-3.2)	2.5% (1.0-4.4)	<0.1%	<0.1%	<0.1%	<0.1%
SR Fall Chinook	T	29,751	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
UCR Sum/Fall Chin	NW	2,533	0.1% (<0.1-0.2)	0.1% (<0.1-0.2)	<0.1%	<0.1%	<0.1%	<0.1%
SR Steelhead	T	27,767	0.1% (<0.1-0.2)	0.2% (0.1-0.3)	<0.1%	0.1% (<0.1-0.3)	<0.1%	<0.1%
UCR Steelhead	T	6,845	12.2% (10.1-15.2)	17.3% (14.1-21.7)	0.5% (0.2-1.0)	2.8% (1.1-5.6)	0.1% (<0.1-0.3)	0.3% (<0.1-0.8)

[1] SR = Snake River, UCR = Upper Columbia River
[2] E = Endangered, T = Threatened, NW = Not Warranted
[3] Values not adjusted for deposition rate and therefore analogous to minimum predation rates estimates presented in previous BRNW Annual Reports
[4] Based on deposition rate results from a pilot study (see Table 2 and Appendix A)

Table 8. Estimated predation rates (95% confidence interval) on PIT-tagged salmonid smolts last detected or released at Lower Granite Dam on the Snake River by avian predators nesting at colonies on Harper Island, Sprague Lake, WA. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiency (Table 4) and on-colony PIT tag deposition rates (Table 2). Colonies include Caspian terns (CATE) and double-crested cormorants (DCCO). The number of PIT-tagged smolts interrogated at Lower Granite 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 the dam were evaluated.

			Predation Rates			
			Sprague Lake CATE		Sprague Lake DCCO	
ESU[1]	ESA[2]	N	Deposited[3]	Predation rate	Deposited[3]	Predation rate
SR Sockeye	E	4,335	0.3% (0.1-0.6)	0.5% (0.1-1.0)	<0.1%	<0.1%
SR Spr/Sum Chin	T	50,441	<0.1%	<0.1%	<0.1%	<0.1%
SR Fall Chinook	T	39,844	<0.1%	<0.1%	<0.1%	<0.1%
SR Steelhead	T	56,770	0.4% (0.2-0.6)	0.5% (0.3-0.9)	<0.1%	<0.1%

[1] SR = Snake River
[2] E = Endangered, T = Threatened, NW = Not Warranted
[3] Values not adjusted for deposition rate and therefore analogous to minimum predation rates estimates presented in previous BRNW Annual Reports

Table 9. Estimated predation rates (95% confidence interval) on PIT-tagged salmonid smolts last detected at McNary Dam on the Columbia River by California and ring-billed gulls (GULLS) nesting on Miller Rocks in the middle Columbia River. Predation rates were adjusted to account for tag loss due to on-colony PIT tag detection efficiency (Table 4) and on-colony PIT tag deposition rates (Table 2). 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 the dam were evaluated.

			Predation Rates	
			Miller Rocks GULLS	
ESU[1]	ESA[2]	N	Deposited[3]	Predation rate[4]
SR Sockeye	E	2,492	0.9% (0.5-1.4)	5.4% (3.1-8.3)
SR Spr/Sum Chinook	T	40,168	0.1% (0.1-0.1)	0.5% (0.3-0.8)
UCR Spr Chinook	E	6,800	0.2% (0.1-0.4)	1.3% (0.6-2.1)
SR Fall Chinook	T	25,017	0.1% (0.1-0.2)	0.6% (0.4-0.9)
UCR Sum/Fall Chinook	NW	10,196	0.1% (<0.1-0.2)	0.6% (0.2-1.0)
SR Steelhead	T	8,840	0.7% (0.5-0.9)	3.9% (2.7-5.5)
UCR Steelhead	T	3,804	1.1% (0.7-1.5)	6.2% (3.9-8.9)

[1] SR = Snake River, UCR = Upper Columbia River
[2] E = Endangered, T = Threatened, NW = Not Warranted
[3] Values not adjusted for deposition rate and therefore analogous to minimum predation rates estimates presented in previous BRNW Annual Reports
[4] Based on deposition rate results from a pilot study (see Table 2 and Appendix A)

Table 10. Estimated predation rates (95% confidence interval) on steelhead PIT-tagged and released at Rock Island Dam by piscivorous waterbirds nesting at colonies in the Columbia River basin during 2008-2012. Predation rates were adjusted for bias due to PIT tag detection efficiency (see Table 4 for 2012 values; BRNW 2009-2011 for other values) and species-specific on-colony deposition rates (DR), where available (Table 2). Annual predation rates were calculated for the number of PIT-tagged steelhead released (n), but were not adjusted for steelhead survival to the vicinity of the bird colony (river kilometer [RKM]). Dashes indicate the colony was not scanned for PIT tags in that year.

			Predation rates				
Location	Bird species[1]	RKM	2008 (n = 7,266)	2009 (n = 7,109)	2010 (n = 7,364)	2011 (n = 7,756)	2012 (n = 6,712)
Banks Lake	CATE	Off-river	0.1% [4]	0.1% (<0.1-0.2)	0.1% (<0.1-0.3)	-	0.1% (<0.1-0.3)
Harper Is.	CATE	Off-river	-	-	-	-	<0.1%
Harper Is.	DCCO	Off-river	-	-	-	-	<0.1%
N. Potholes	DCCO	Off-river	-	-	-	-	0.3% (<0.1-0.8)
Goose Is.	CATE	Off-river	10.8% (9.4-12.5)	21.9% (18.7-25.6)	13.5% (11.5-16.1)	12.7% (10.7-15.2)	17.0% (13.7-21.5)
Goose Is.	GULLS[3]	Off-river	-	-	-	-	2.8% (1.2-6.1)
Foundation Is.	DCCO	518	0.3% (0.1-0.6)	0.3% (0.1-0.5)	0.1% (<0.1-0.4)	0.3% (0.1-0.6)	0.5% (0.1-0.9)
Badger Is.	AWPE[2]	512	0.1% (<0.1-0.2)	0.3% (0.1-0.4)	0.1% (<0.1-0.2)	0.1% (<0.1-0.1)	0.1% (<0.1-0.2)
Badger Is.	CATE	512	-	-	-	0.7% (0.2-1.4)	0.2% (<0.1-0.7)
Crescent Is.	CATE	510	2.9% (2.3-3.6)	2.2% (1.7-2.7)	1.7% (1.3-2.2)	2.4% (1.9-2.9)	1.2% (0.8-1.7)
Crescent Is.	GULLS[3]	510	2.2% (1.3-3.3)	5.6% (3.9-7.7)	6.2% (4.5-8.4)	3.1% (1.9-4.7)	3.9% (2.1-5.7)
Blalock Islands	CATE	441	0.5% (0.3-0.7)	0.2% (0.1-0.4)	0.4% (0.3-0.6)	<0.1%	-
Miller Rocks	GULLS[3]	331	4.1% (2.8-5.8)	4.3% (2.9-6.2)	3.6% (2.5-5.3)	2.8% (1.8-4.1)	2.7% (1.6-4.0)
Miller Sands Spit	AWPE[2]	38	-	-	-	<0.1%	-
East Sand Is.	CATE	8	9.0% (8.0-10.0)	8.3% (7.3-9.4)	7.6% (6.6-8.7)	3.9% (3.3-4.7)	3.3% (2.6-4.1)
East Sand Is.	BRAC	8	-	<0.1%	<0.1%	0.2% (<0.1-0.4)	0.1% (<0.1-0.2)
East Sand Is.	DCCO	8	3.2% (2.4-4.3)	2.9% (2.0-3.8)	3.5% (2.6-4.5)	4.4% (3.4-5.5)	3.7% (2.8-4.9)
Total			33.6% (30.9-36.8)	47.3% (43.1-52.1)	37.5% (34.4-41.7)	31.0% (28.0-34.7)	36.4% (31.7-42.6)

[1] CATE = Caspian tern; DCCO = double-crested cormorant; BRAC = Brandt's cormorant; GULLS = ring-billed and California gulls; AWPE = American white pelican
[2] Predation rates by American white pelicans were not adjusted for deposition rate due to lack of empirical data and should be considered minimum estimates (analogous to previous BRNW reports; see Table 2).
[3] Based on deposition rate results from a pilot study (see Table 2 and Appendix A)
[4] Confidence interval unstable due to high degree of uncertainty in on-colony detection efficiency estimates during 2008

Table 11. Estimated predation rates (95% confidence interval) on steelhead PIT-tagged and released at Rock Island Dam by Caspian terns nesting on Goose Island, Potholes Reservoir during 2008-2012. Predation rates were adjusted for bias due to PIT tag detection efficiency (Table 4) and species-specific on-colony deposition rates (Table 2).

Year	PIT tags Released	Number of breeding pairs[1]	Predation rate		
			Hatchery	Wild	All
2008	7,266	293	11.6% (10.0-13.7)	8.6% (6.6-10.9)	10.8% (9.4-12.5)
2009	7,109	487	22.4% (19.0-26.8)	20.5% (16.4-25.6)	21.9% (18.7-25.6)
2010	7,364	416	15.4% (13.1-18.5)	8.3% (6.1-11.1)	13.5% (11.5-16.1)
2011	7,756	422	13.4% (11.4-16.3)	10.3% (7.5-13.8)	12.7% (10.7-15.2)
2012	6,712	463	19.4% (15.7-24.5)	9.5% (6.5-13.8)	17.0% (13.7-21.5)

[1] Estimates from Adkins et al. 2011 and this report (Figure 9)

Table 12. Estimated predation rates (95% confidence interval) on steelhead PIT-tagged and released at Rock Island Dam (n = 6,712) by piscivorous waterbirds nesting at colonies in the Columbia River basin during 2012. Predation rates are listed separately for wild and hatchery-reared smolts. Predation rates were adjusted for bias due to PIT tag detection efficiency (Table 4) and species-specific on-colony deposition rates (DR), where available (Table 2), but not for steelhead survival to the vicinity (river kilometer [RKM]) of the bird colony. Only colonies scanned for PIT tags in 2012 are shown.

Location	Bird species[1]	RKM	Hatchery	Wild	All
Banks Lake	CATE	Off-river	<0.1%	0.4% (<0.1-1.0)	0.1% (<0.1-0.3)
Harper Is.	CATE	Off-river	<0.1%	<0.1%	<0.1%
Harper Is.	DCCO	Off-river	<0.1%	<0.1%	<0.1%
N. Potholes	DCCO	Off-river	0.4% (<0.1-1.1)	<0.1%	0.3% (<0.1-0.8)
Goose Is.	CATE	Off-river	19.4% (15.7-24.5)	9.5% (6.5-13.8)	17.0% (13.7-21.5)
Goose Is.	GULLS[2]	Off-river	3.7% (1.5-8.4)	<0.1%	2.8% (1.2-6.1)
Foundation Is.	DCCO	518	0.6% (0.1-1.3)	<0.1%	0.5% (0.1-0.9)
Badger Is.	AWPE[3]	512	0.1% (<0.1-0.2)	<0.1%	0.1% (<0.1-0.2)
Badger Is.	CATE	512	0.2% (<0.1-0.6)	0.5% (<0.1-1.7)	0.2% (<0.1-0.7)
Crescent Is.	CATE	510	1.6% (1.1-2.1)	0.1% (<0.1-0.4)	1.2% (0.8-1.7)
Crescent Is.	GULLS[2]	510	4.8% (2.6-7.3)	1.0% (<0.1-2.7)	3.9% (2.1-5.7)
Miller Rocks	GULLS[2]	331	2.7% (1.6-4.2)	2.7% (0.8-5.3)	2.7% (1.6-4.0)
East Sand Is.	CATE	8	2.9% (1.8-4.3)	3.4% (2.6-4.3)	3.3% (2.6-4.1)
East Sand Is.	BRAC	8	<0.1%	0.2% (<0.1-0.7)	0.1% (<0.1-0.2)
East Sand Is.	DCCO	8	3.6% (2.6-5.0)	4.1% (2.3-6.4)	3.7% (2.8-4.9)
Total			41.1% (35.6-48.4)	21.5% (16.8-27.3)	36.4% (31.7-42.6)

[1] CATE = Caspian tern; DCCO = double-crested cormorant; BRAC = Brandt's cormorant; GULLS = ring-billed and California gulls; AWPE = American white pelican
[2] Based on deposition rate results from a pilot study (see Table 2 and Appendix A)
[3] Predation rates by American white pelicans were not adjusted for deposition rates and should be considered minimum estimates (analogous to previous BRNW Reports; see Table 2)

Table 13. PIT tags from 2012 migration year smolts recovered on piscivorous waterbird (mixed species) loafing locations in the McNary Pool during 2012.

Location	River Kilometer	Bird spp.	Recovered PIT Tags
Crescent Is. - lagoon	510	Mixed	61
Foundation Is. - upstream tip	518	Mixed	35
Badger Is. - upstream tip	511	Mixed	34
Foundation Is. - downstream tip	518	Mixed	16
Badger Is. - downstream tip	511	Mixed	16
Crescent Is. - rip rap	510	Mixed	15
Total PIT tags recovered			177

APPENDIX A:

Incorporation of PIT Tag Deposition Rate Data to Quantify Avian Predation Rates

ABSTRACT

Numerous studies have used mark-recovery techniques to evaluate avian predation rates on fish populations. Studies that recover fish tags from bird colonies, however, often produce minimum estimates of predation rate because an unknown and unaccounted for proportion of tags implanted in fish and consumed by birds are deposited at off-colony areas or are damaged and rendered un-readable during passage through the bird's gut. During 2005–2012 we conducted multiple studies to quantifying on-colony PIT tag deposition rates for nesting Caspian terns (*Hydroprogne caspia)*, double-crested cormorants (*Phalacrocorax auritus*), and California gulls (*Larus californicus*). In the first study, adult Caspian terns nesting at Crescent Island and East Sand Island were captured and force-fed 191 trout (*Oncorhynchus mykiss*) tagged with passive integrated transponder (PIT) tags during 2005-2006. Recoveries of these tags on the breeding colonies indicated that on-colony deposition rates by Caspian terns were 86% (95% confidence interval [c.i.] = 73 – 100%). In the second study, live PIT-tagged trout were placed in net pens near the Caspian tern colony on Crescent Island. Recoveries of PIT-tagged trout depredated by terns from the net pens (n = 171 trout) during 2005-2006 suggested that tern on-colony deposition rates were 54% (95% c.i. = 42 – 67%), substantially lower than results from force-feeding studies. On-colony deposition rates for nesting cormorants were 44% (95% c.i. = 36 – 51%), based on 301 PIT-tagged trout volitionally-consumed by cormorants at East Sand Island in 2012. California gull deposition rates were the lowest among the three species investigated, with on-colony deposition rates of 17% (95% c.i. = 13 – 21%), based on 611 PIT-tagged trout volitionally-consumed by gulls nesting at Crescent Island (n = 308 trout) and Miller Rocks (n = 303 trout) in 2012. Incorporation of on-colony deposition rates into predation rate models increased estimates of avian predation rates by a factor of 1.4 for Caspian terns, by a factor of 2.3 for double-crested cormorants, and by a factor of 5.8 for California gulls compared to previously published estimates based on different models. Preliminary results suggest that on-colony deposition rates vary substantially by study method and among bird species, and updated models of avian predation rates, those that incorporate PIT tag deposition rates, will provide more accurate and reliable estimates of avian predation rates on PIT-tagged fish populations.

INTRODUCTION

Mark-recovery techniques have been used to quantify impacts of avian predation on fish populations (Collis et al. 2011, Ryan et al. 2003, Boström et al. 2009, Jepsen et al. 2010, Evans et al. 2012, Frechette et al. 2012). Quantification of avian predation rates often involve recovery of fish tags on bird colonies (e.g., Collis et al. 2001, Ryan et al. 2003, Evans et al. 2011, Evans et al. 2012, Frechette et al. 2012). Currently-available published models to estimate avian predation rates from fish tags recovered on bird colonies, however, produce minimum predation rate estimates (Evans et al. 2011, Evans et al. 2012, Frechette et al. 2012). Accurate estimation of avian predation rates from these types of studies need to incorporate several important metrics, including (1) the number of tagged fish available (e.g., released or interrogated in the vicinity of a bird colony), (2) the number of available tagged fish recovered on the bird colony, (3) estimate(s) of detection efficiency (i.e., probability of detecting a tag if it was deposited on the colony), and (4) on-colony deposition rate estimates (i.e., probability a consumed tag will be deposited on-colony).

Avian predation on salmonid (*Oncorhynchus spp.*) smolts has been identified as one of several factors limiting recovery of salmonid evolutionarily significant units (ESUs) and distinct population segments (Waples 1991) within the Columbia River basin that are listed as threatened or endangered under the U.S. Endangered Species Act (ESA; Roby et al. 2003, Lyons 2010). Management efforts to reduce the impact of avian predation on survival of juvenile salmonids within the Columbia River basin are currently being implemented (Roby et al. 2002, USFWS 2006). Evaluation of benefits from management actions, however, often use either minimum avian predation rate estimates from recoveries of passive integrated transponder (PIT) tags (USFWS 2006) or by applying deposition rates from one species (Caspian terns *Hydroprogne caspia*) to several other bird species (Lyons et al. 2011). Proper estimation of benefits from management of avian predation requires accurate estimates of avian predation rates that incorporate several important uncertainties, such as on-colony detection efficiencies of tags (*sensu* Evans et al. 2012) and bird species-specific tag deposition rates.

Presented here are methods and results from several studies aimed at quantifying on-colony PIT tag deposition rates for nesting Caspian terns (hereafter “terns”), double-crested cormorants (*Phalacrocorax auritus*; hereafter “cormorants”), and California gulls (*Larus californicus*; hereafter “gulls”). Objectives of this study were to (1) quantify PIT tag deposition rates for nesting terns, cormorants, and gulls and (2) develop PIT tag predation rate models that incorporate bird species-specific deposition rates and the uncertainty in those estimates. Objective 1 was accomplished via field studies, while Objective 2 evaluated predation rate models through a case study of avian predation on out-migrating salmonid smolts conducted in 2012.

STUDY AREA

Deposition rates were evaluated at five different breeding colonies of piscivorous waterbirds located in the Columbia River basin: terns nesting at Crescent Island (CI) on the mid-Columbia River and East Sand Island (ESI) in the Columbia River estuary, cormorants nesting at ESI in the Columbia River estuary, and gulls nesting at CI on the mid-Columbia River and Miller Rocks (MIR) on the lower Columbia River (Figure A1).

METHODS

Fish Consumption

Caspian Terns

During 2005 and 2006, two experiments were conducted to measure PIT tag deposition rates for terns. In the first study, nesting adult terns were captured at CI and ESI using monofilament noose mats placed around active nests. Trapping of nesting terns was conducted during late incubation to minimize nest abandonment due to disturbance (Sirdevan and Quinn 1997). Once captured, each adult tern was force-fed one euthanized, PIT-tagged (12 mm, 134.2 kHz full-duplex) hatchery trout (*O. mykiss*; length = 80 – 225 mm, n = 191 trout), and then the tern was held in captivity for up to an hour to insure the trout was not regurgitated, and released back onto the colony.

In the second study, live hatchery trout (length = 80 – 225 mm, n = 3,076 trout) were PIT-tagged and placed in one of three net pen enclosures anchored in backwater areas of the Columbia or Snake rivers less than 23 km from CI, the only tern colony within their maximum foraging range (maximum of 80 km [Adrean 2011], Adkins et al. 2011; Figure A1). Net pens were monitored daily (8 to 15 hrs/day) from a nearby blind to record the number of fish captured by terns from the net pens. When the observers were not present, each net pen was covered with nylon mesh to prevent terns and other birds from foraging at the net pens. In 2005, two net pens, one located on Burbank Slough on the mainstem Columbia River and the other on Ice Harbor Slough on the Snake River, (Figure A1) were monitored from 21 April to 1 July. In 2006, two net pens, one located on Burbank Slough and the other on Peninsula Slough in the mainstem Columbia River (Figure A1), were monitored from 28 April to 28 June. Only trout verified as depredated by a tern were included in this study (n = 171 trout; Table A1).

Double-crested Cormorant

In 2012, a cormorant colony at ESI was monitored at least once per week to document nesting chronology. Nesting periods were categorized as nest building, egg incubation, or chick-rearing depending on the behavior of the majority of nesting cormorants. Hatchery rainbow trout (length = 100 – 205 mm) were euthanized, PIT-tagged, and thrown to cormorants nesting in one of three plots adjacent to observation blinds during each of the chronology periods. Trout were thrown <1 to 5 meters from each blind in various directions, an area encompassing roughly 250 – 300 nesting pairs of cormorants. Only trout consumed by nesting adult cormorants were included in the study (n = 33 – 34 trout $plot^{-1}$ $period^{-1}$ for a total of 301 consumed trout in 2012; Table A2).

California Gull

In 2012, gull colonies at CI and MRI were monitored at least once per week to document nesting chronology. Nesting periods were categorized using the same methods as those presented for cormorants. Similar to cormorants, hatchery rainbow trout (length = 100 – 205 mm) were euthanized, PIT-tagged, and thrown to gulls nesting in an area adjacent to an observation blind on each island during one of the three breeding chronology periods. Trout were thrown 3 to 20 meters from the blind in all directions, an area encompassing roughly 200 – 250 nesting pairs of gulls. Only trout consumed by nesting adult gulls were included in the study (n = 99 – 109 trout colony^{-1} period^{-1} for a total of 611 consumed trout in 2012; Table A3).

PIT Tag Recovery

Recoveries of PIT tags from bird colonies followed the methods of Ryan et al. (2001) and Evans et al. (2012) and are only briefly summarized here. PIT tags were recovered from each bird colony after birds dispersed following the nesting season (August to November) during 2005 – 2012. Flat-plate or pole-mounted PIT tag antennas were used to detect PIT tags in situ by systematically scanning the area that was occupied by birds during the nesting season. The area occupied by birds on each colony was determined by aerial photographs of the colony and visits to the colony during the nesting season.

Detection Efficiency

Not all PIT tags deposited on-colony by birds are subsequently found by researchers after the nesting season. For example, 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. Furthermore, the detection methods used to find PIT tags on bird colonies are not 100% efficient, with some proportion of detectable tags missed by researchers during the scanning process (Ryan et al. 2003). 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 quantify PIT tag detection efficiency. Control tags were the same dimension and length as PIT tags used to mark trout used in this study (12 mm, 134.2 kHz full-duplex). The total number of control tags sown varied by colony and year, with sample sizes ranging from 100 to 800 control tags colony^{-1} year^{-1}. The number of discrete time periods when control tags were sown also varied due to limited accessibility to bird colonies, but was no less than two (at the beginning and end of the nesting season) and no more than four (see Evans et al. 2012).

Deposition Rate Estimation

Deposition rates of PIT-tagged trout were calculated using an iterative multistep approach. First, logistic regression was used to interpolate colony-specific detection efficiencies for time periods of interest, whereby a binary response of control tag detections (detected or not detected) was modeled as a function of time since control tags were placed on the bird colony (eq. 1).

$$(1)\quad \widehat{p_J} = \frac{e^{(\beta_0 + \beta_1 t_j)}}{1 + e^{(\beta_0 + \beta_1 t_j)}}$$

where $\widehat{p_j}$ is the probability of detecting a tag deposited on day *j*, β_0 is the regression intercept, β_1 is the regression slope, and t_j is the independent variable for date *j*. Second, the estimated number of trout PIT tags deposited on-colony was calculated by dividing the number of recovered trout tags originally consumed on day *j* (r_j) by the probability of detecting a tag deposited on-colony on day *j* ($\widehat{p_J}$) (eq. 2)

$$(2)\quad \widehat{d_J} = {r_j}/{\widehat{p_J}}$$

Deposition rates ($\widehat{n_J}$) were estimated for each time period (days *m* to *n*) by summing the total number of trout tags deposited on the colony ($\widehat{d_J}$; eq. 2) during a given time period and dividing that total by the sum of trout consumed (a_j) during that same time period (eq. 3):

$$(3)\quad \widehat{n_w} = {\sum_{j=m}^{n} \widehat{d_J}}/{\sum_{j=m}^{n} a_j}$$

Confidence intervals for deposition rates were estimated by a bootstrapping simulation technique (Efron & Tibshirani 1986, Manly 1998). The bootstrapping analysis consisted of 2,000 iterations of all calculations, with each iteration representing a unique bootstrap resample (random sample with replacement) of all datasets. The 2.5th and 97.5th quartiles were used to estimate the limits of a 95% deposition rate confidence interval. Deposition rates were considered significantly different if there was no overlap between 95% confidence intervals.

Predation Rate Estimation

Predation rates on PIT-tagged salmonids, those corrected for detection efficiency and deposition rates, were also calculated using a multistep approach. First, logistic regression was used to interpolate daily colony specific detection efficiencies (previously described in eq. 1). Second, the estimated number of salmonid PIT tags deposited on the colony on day *j* ($\widehat{d_J}$) was calculated by dividing the number of recovered PIT tags that were last detected alive on day *j* (r_j) by the probability of detecting a tag deposited on day *j* ($\widehat{p_J}$) (previously described in eq. 2). Recoveries of tags on an avian colony (r_j; eq. 2) only included those recovered during the same year as their last alive detection since on-colony detection probability ($\widehat{p_J}$) was calculated on an annual basis (eq. 1). Next, to determine the total number of tagged salmonids consumed on day *j* ($\widehat{c_J}$), the estimated number of PIT tags deposited on the colony ($\widehat{d_J}$) was adjusted for deposition rates specific to the bird species and period of interest ($\widehat{n_w}$) (eq. 4).

$$(4)\quad \hat{c}_j = \hat{d}_j \Big/ \widehat{n_w}$$

Best estimates of predation rates for any given time period were calculated as (eq. 5):

$$(5)\quad \sum_{j=m}^{n} \hat{c}_j \Big/ \sum_{j=m}^{n} a_j$$

where the estimated total number of PIT-tagged salmonids consumed ($\hat{c}_j$; eq. 4) is summed across the days of interest (days *m* to *n*) and divided by the total number of PIT-tagged salmonids available (a_j) during that same time period. These calculations were conducted independently for each bird colony and salmonid ESU of interest.

Confidence intervals for predation rates were estimated by a bootstrapping simulation technique (Efron & Tibshirani 1986, Manly 1998). The bootstrapping analysis consisted of 2,000 iterations of all calculations, with each iteration representing a unique bootstrap resample (random sample with replacement) of all datasets: detection efficiency, on-colony deposition, salmonid releases, and tag recoveries on a bird colony. The 2.5th and 97.5th quartiles were used to represent the limits of a 95% predation rate confidence interval.

Using this method, we investigated avian predation rates at two of the bird colonies where deposition data was collected: terns and gulls nesting at CI. We also investigated predation rates at a nearby cormorant colony on Foundation Island (Figure A3). Species specific deposition rates applied in these case studies were the pooled deposition rate estimates for each species: terns (71%; 95% c.i. = 62 – 81%), gulls (17%; 95% c.i. = 13 – 21%), and cormorants (44%; 95% c.i. = 36 – 51%; Figure A2).

RESULTS

Deposition Rates

<u>Caspian Tern</u>

Adult terns nesting at CI consumed 117 PIT-tagged trout during 2005 (n = 59 trout) and 2006 (n = 58 trout) during force feeding studies. During force feeding studies at ESI, terns consumed 74 PIT-tagged trout during 2005 (n = 31 trout) and 2006 (n = 43 trout; Table A1). There were no significant differences in deposition rates among years or colonies (Table A1), thus deposition rates were pooled for a single deposition rate of 86% (95% c.i. = 73 – 100%) after adjusting for on-colony detection efficiency (Table A1; Figure A2).

In the net pen study, adult terns depredated 171 PIT-tagged trout during 2005 (n = 91 trout) and 2006 (n = 80 trout). Deposition rates of net pen trout were 54% (95% c.i. = 42 – 67%) after adjusting for on-colony detection efficiency (Table A1; Figure A2). No significant differences in deposition rates were observed between 2005 (59%; 95% c.i. = 46 – 72%) and 2006 (48%; 95% c.i. = 28 – 71%; Table A1).

Tern deposition rates were significantly lower in net pen studies compared to force feeding studies (Table A1). Gulls nesting at CI frequently kleptoparasitized fish brought back by terns at CI (Antolos et al. 2005). Lower deposition rates from net pen studies (54%; 95% c.i. = 42 – 67%) compared to force feeding studies (86%; 95% c.i. = 73 – 100%) were likely due to kleptoparasitism of net pen fish. For instance, kleptoparasitism rates were zero for force feeding studies since trout were consumed by the tern prior to release. Recoveries of PIT tags from net pen trout depredated by terns on the CI gull colony confirm some proportion of net pen trout were in fact kleptoparasitized by gulls (author's unpublished data). Kleptoparastism rates are known to vary among tern colonies, with kleptoparasitism rates at CI higher than other tern colonies in the Columbia River basin (Antolos et al 2006). To address these possible sources of variation among tern colonies, three tern deposition rates were estimated: force feeding study (86%; 95% c.i. = 73 – 100%), net pen study (54%; 95% c.i. = 42 – 67%), and an intermediated pooled value (71%; 95% c.i. = 62 – 81%; Table A1; Figure A2).

Double-crested Cormorant

Adult cormorants nesting at ESI consumed 301 PIT-tagged trout during volitional feeding studies in 2012 (Table A2). No significant differences in deposition rates were observed among nesting chronology periods after controlling for differences among plots (Table A2). On-colony deposition rates differed among plots, with deposition rates lower in the plot 1 (26%, 95% c.i. = 15 – 37%), compared to plot 2 (53%; 95% c.i. = 40 – 67%) and plot 3 (52%; 95% c.i. = 39 – 66%; Table A2). Numerous factors may have contributed to among plot differences in deposition rates (e.g., bird behavior, disturbances during the nesting season, nest density, etc.), but could not be precisely identified in this study. If periods and plots are combined, a single estimate of on-colony deposition rates for cormorants was 44% (95% c.i. = 36 – 51%; Table A2).

California Gull

Adult gulls consumed 611 PIT-tagged trout during 2012 volitional feeding studies at CI (n = 308 trout) and MRI (n = 303 trout; Table A3). There was no significant difference in annual deposition rates between gulls nesting at CI (15%; 95% c.i. = 10 – 21%) and MRI (19%; 95% c.i. = 14 – 24%). Deposition rates for gulls nesting at MRI did vary within season, with deposition rates during the chick rearing period (38%; 95% c.i. = 26 – 50%) significantly higher than deposition rates during nest building (5%; 95% c.i. = 1 – 10%) and egg incubation (16%; 95% c.i. = 8 – 25%) periods (Table A3). There was no evidence, however, that deposition rates varied among nesting chronology periods for gulls nesting at CI (Table A3). If colonies and periods are combined, a single estimate of on-colony deposition rates for gulls was 17% (95% c.i. = 13 – 21%; Table A3).

Predation Rates

Incorporation of deposition rates increased minimum predation rate estimates and also increased the uncertainty in those estimates (Table A4). Predation rates that incorporated off colony deposition values were 1.4 times higher for terns, 2.3 times higher for cormorants, and 5.8 times higher for gulls compared to previously published methods that produce minimum predation rates. Predation rates by gulls displayed the greatest increase the due to the very low gull deposition rate estimate (Table A4). Application of deposition rates specific to each bird species suggested that predation rates by gulls nesting at CI were much greater than previously estimated (Evans et al. 2012) and were now similar to or greater than predation rates by terns or cormorants nesting nearby (Table A4).

DISCUSSION

A technique to measure PIT tag deposition rates in Caspian terns, California gulls, and double-crested cormorants was developed and could potentially be applied to better estimate predation rates by piscivorous waterbird species. This study demonstrated that there is substantial variation in deposition rates between avian predator species, with deposition rates significantly higher for terns, followed by cormorants, and lowest for gulls. Results, especially those from double-crested cormorants and California gulls, however, could be strengthened with replication in another study year and collection of data at other colonies. Detailed information on the breeding status of birds at each colony would also help to validate and refine deposition estimates.

Species-specific deposition rates can be influenced by numerous factors, including differences in the rate of PIT tag damage during digestion or egestion, or rates of deposition at off-colony areas utilized by birds during the breeding season. For instance, the diet of terns and cormorants is nearly strictly piscivorous (Collis et al. 2002), while the diet of gulls is much more diverse and often includes items that could damage tags during digestion (e.g., cherry pits, small stones, and other hard parts which help macerate food during digestion; Winkler 1996, Collis et al. 2002). The observational nature of this study could not identify mechanisms influencing deposition rates, but provides empirical evidence that on-colony PIT tag deposition rates are less than 100% and vary substantially among bird species.

Birds are often top predators in aquatic ecosystems (Steinmetz et al. 2003), however tag recovery studies often only produced minimum estimates of avian predation rates on fish populations (Collis et al. 2011, Ryan et al. 2003, Evans et al. 2011, Evans et al. 2012, Frechette et al. 2012). Detections of fish tags on bird colonies have identified avian predation as a substantial source of fish mortality in multiple freshwater and estuarine ecosystems (Collis et al. 2001, Evans et al. 2011, Evans et al. 2012, Frechette et al. 2012). In all of these studies however, predation rates were considered minimal estimates due to a lack of on-colony deposition rates. The study herein provides estimates of PIT tag deposition rates for three bird species and methods to incorporate those rates into predation rate estimations. Incorporation of on-colony deposition rates into predation rate models increased avian predation rates by 1.4 times for terns, 2.3 times for cormorants, and 5.8 times for gulls compared to estimates using previous published models. It should be noted that many of the large gull colonies on the Columbia River have only been sporadically and partially been scanned for PIT tags (e.g., Island 20, Three Mile Canyon) and some have never been scanned for PIT tags (e.g., Blalock islands); collection of PIT tag data at these colonies would be important in understanding the relative predation impacts of Columbia Basin gulls on smolt survival.

Studies are needed to quantify on-colony PIT tag deposition rates by other avian species in order to improve estimates of predation on fish species of conservation concern, including but not limited to: American white pelicans (*Pelecanus erythrorhynchos*; predation rates presented in Evans et al. 2012), Brandt's cormorants (*Phalacrocorax penicillatus*; Frechette et al. 2012), great cormorants (*Phalacrocorax carbo*; Koed et al. 2006), northern gannets (*Sula bassanus*; Montevecchi et al. 1988), ring-billed gulls (*Larus delawarensis*; Evans et al. 2012), and western gulls (*Larus occidentalis*; Frechette et al. 2012). Similarly, methods used in this study could be replicated to estimate deposition rates of other fish tags, such as acoustic tags (used to evaluate avian predation in Halfyard et al. 2012), Carlin tags (Boström et al. 2009), coded wire tags (Lovvorn et al. 1999, Evans et al. 2011), and radio tags (Jepsen et al. 1998, Kaeding 2002, Schreck et al. 2006).

Predation is a key ecological process influencing fish populations (Sih 1987). Impacts of avian predation on fish populations can be quantified using mark-recovery techniques uniquely adapted to specific obstacles within a given system. Incorporation of on-colony tag deposition rates, however, is required to properly estimate avian predation rates and their associated impacts on fish survival when recovering tags from bird colonies. Accurately quantifying causes of mortality will aid in the development of management strategies that contribute to the understanding of important population parameters and management plans to recover of ESA-listed fish populations.

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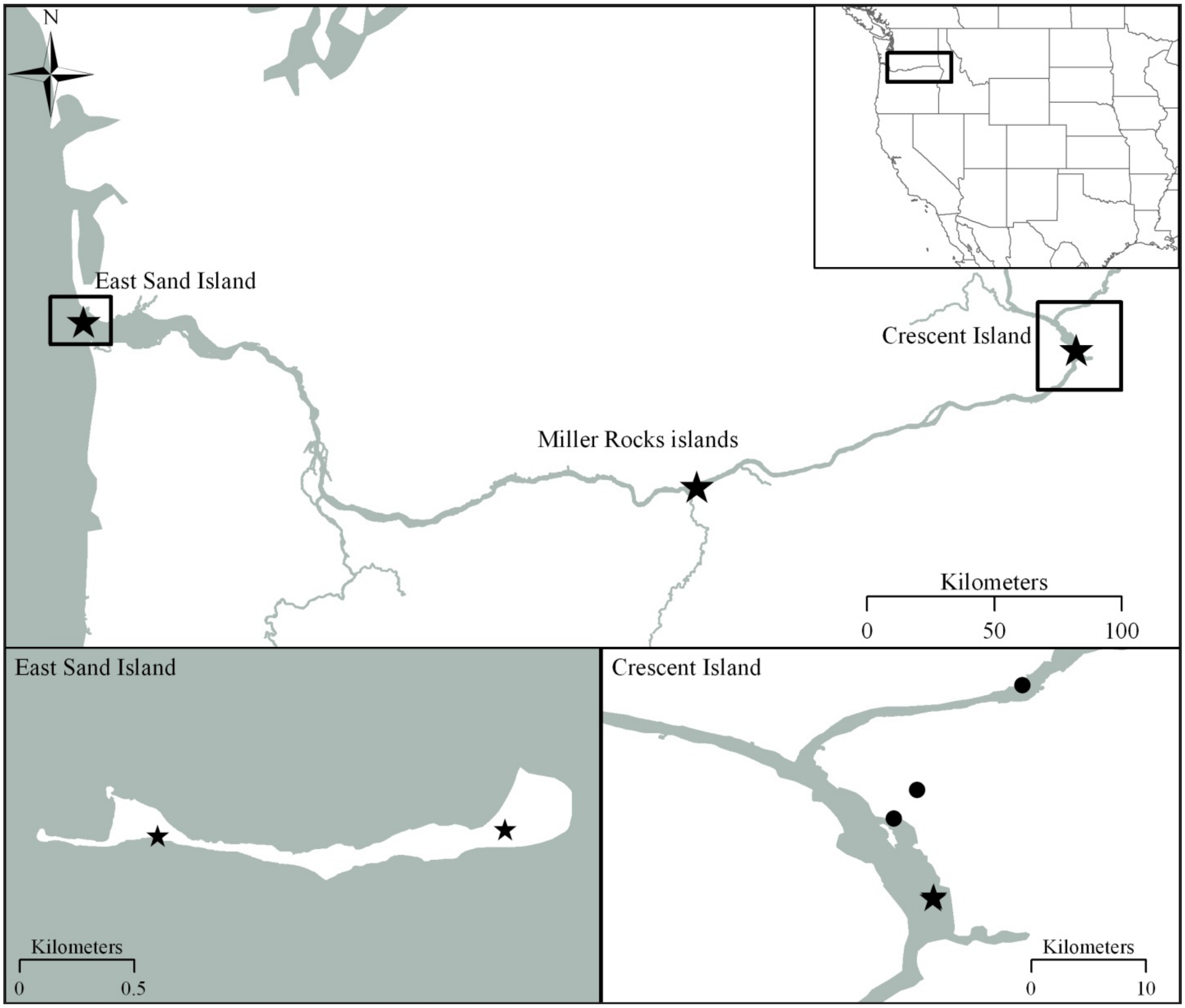

Figure A1. Locations of the bird colonies (stars) used to evaluate on-colony PIT tag deposition rates. Caspian tern colonies were located at the east end of East Sand Island and on Crescent Island, the double-crested cormorant colony was located at the west end of East Sand Island, and the California gull colonies were located at Miller Rocks and Crescent Island. Net pen locations (circles) are shown in the Crescent Island inset map.

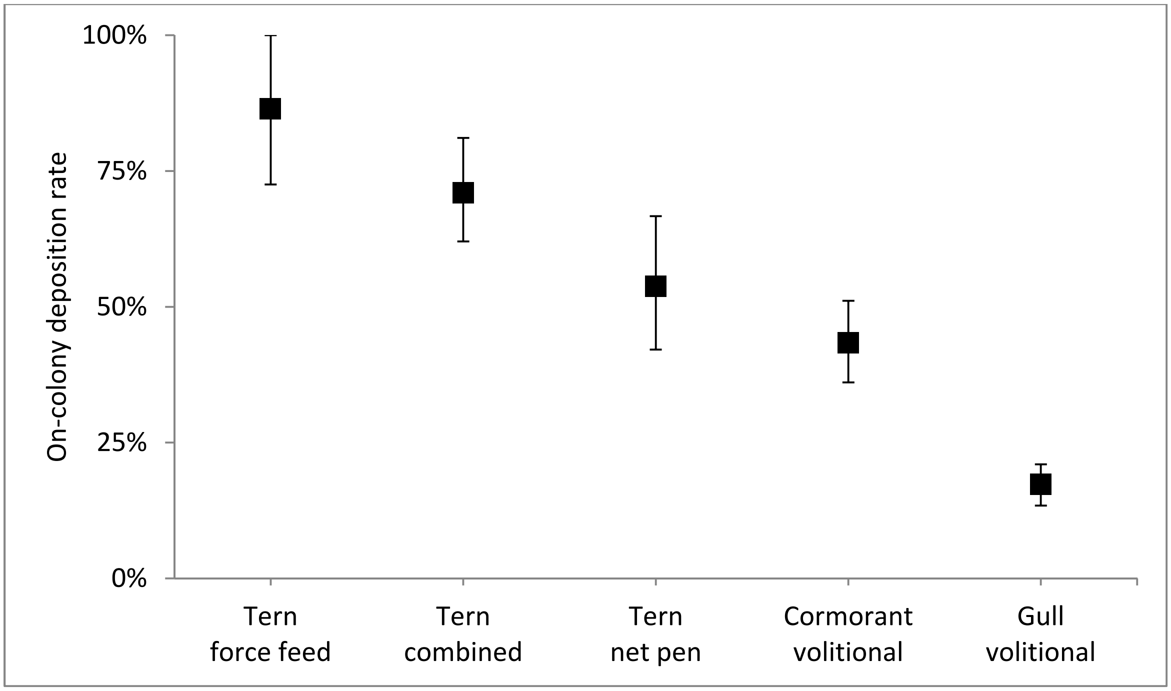

Figure A2. Annual estimates of on-colony PIT tag deposition rates for Caspian terns (tern), double-crested cormorants (cormorant), and California gulls (gull). Estimates for terns are provided by study type (force-fed, net pen, volitional, or combined; see Methods). Error bars represent 95% confidence intervals.

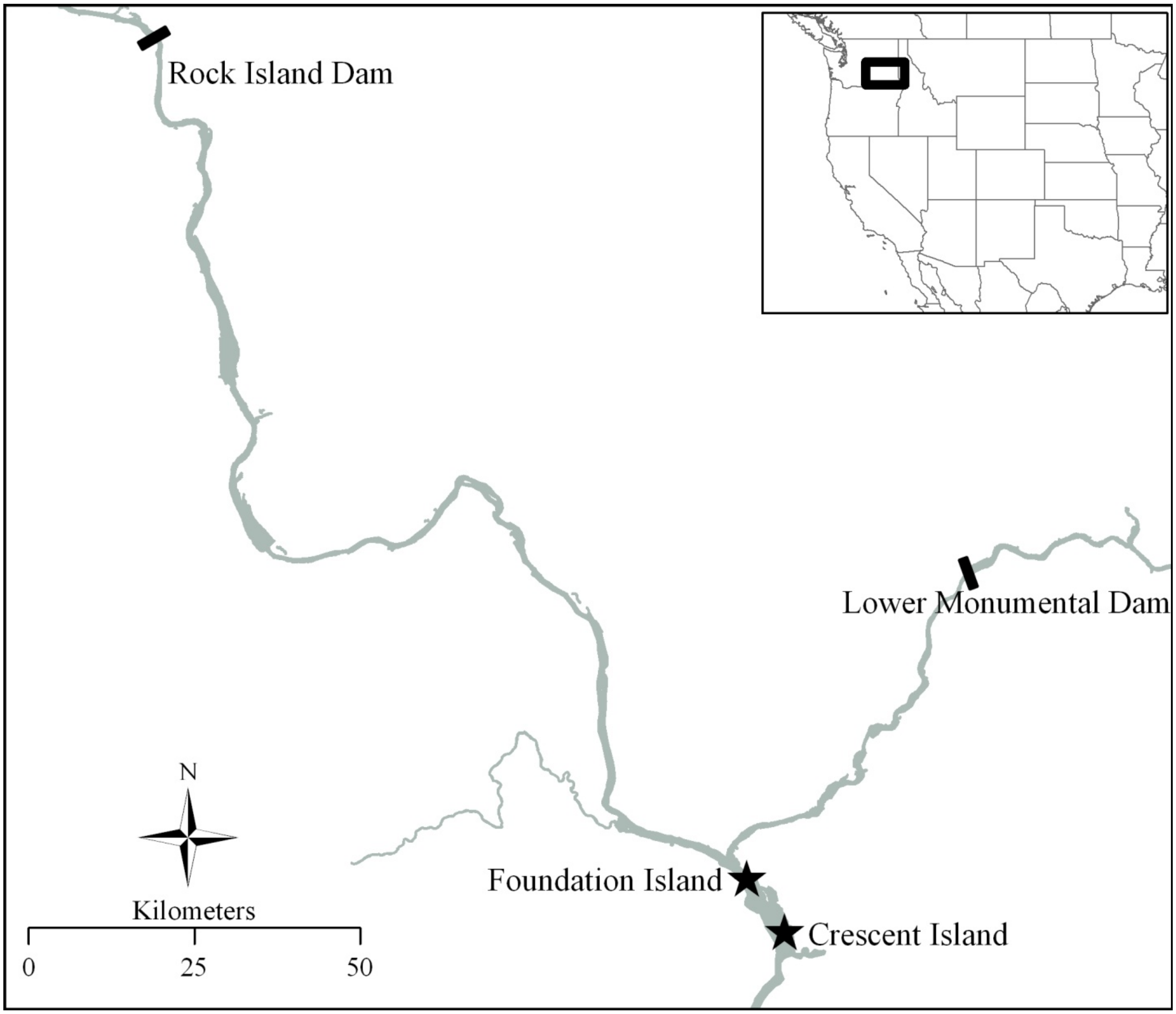

Figure A3. Map of the mainstem Columbia and Snake rivers, showing locations of the hydroelectric dams (bars) and bird colonies (stars) used to estimate predation rates. The Caspian tern colony and California gull colony were located at Crescent Island and the double-crested cormorant colony was located at Foundation Island.

Table A1. On-colony PIT tag deposition rates for Caspian terns nesting at Crescent Island and East Sand Island during 2005-2006. Experiments were conducted by either stocking net pens with PIT-tagged trout (Net pen) or force-feeding trout to terns captured on-colony (Force-fed). PIT tags recovered (Recovered) were adjusted for date and colony-specific detection efficiency (DE) to estimate the total number of tags deposited on the island (Deposited) and the deposition rate.

Location	Method	Year	Period	Date	Eaten	Recovered	DE	Deposited	Deposition Rate (95% c.i.)
Crescent Is.	Net pen	2005	Annual	4/21 – 7/1	91	43	0.80	54	59% (46 – 72%)
Crescent Is.	Net pen	2006	Annual	4/28 – 6/28	80	16	0.42	38	48% (28 – 71%)
Crescent Is.	Net pen	2005-06	Annual	-	171	59	-	92	54% (42 – 67%)
Crescent Is.	Force-fed	2005	Incubation	5/9	59	32	0.67	48	81% (62 – 100%)
Crescent Is.	Force-fed	2006	Incubation	5/13	58	16	0.31	52	90% (53 – 100%)
Crescent Is.	Force-fed	2005-06	Incubation	-	117	48	-	100	86% (65 – 100%)
East Sand Is.	Force-fed	2005	Incubation	5/18	31	20	0.83	24	78% (56 – 100%)
East Sand Is.	Force-fed	2006	Incubation	5/28	43	26	0.63	41	95% (73 – 100%)
East Sand Is.	Force-fed	2005-06	Incubation	-	74	46	-	65	88% (73 – 100%)
Combined	Force-fed	2005-06	Incubation	-	191	94	-	165	86% (73 – 100%)
Combined	Combined	2005-06	Annual	-	362	153	-	257	71% (62 – 81%)

Table A2. On-colony PIT tag deposition rates for double-crested cormorant nesting at East Sand Island in 2012. Experiments were conducted by feeding PIT-tagged trout to actively nesting cormorants in one of three nesting locations (Volitional). PIT tags recovered (Recovered) were adjusted for date and colony-specific detection efficiency (DE) to estimate the total number of tags deposited on the island (Deposited) and the deposition rate.

Location	Method	Year	Period	Date	Eaten	Recovered	DE	Deposited	Deposition Rate (95% c.i.)
ESI - plot 1	Volitional	2012	Nest building	5/2	34	5	0.66	8	22% (5 – 42%)
ESI - plot 1	Volitional	2012	Incubation	5/24	34	4	0.69	6	17% (4 – 35%)
ESI - plot 1	Volitional	2012	Chick	6/13	34	9	0.72	12	38% (17 – 60%)
ESI - plot 1	Volitional	2012	Annual	-	102	18	-	26	26% (15 – 37%)
ESI - plot 2	Volitional	2012	Nest building	5/2	33	9	0.66	14	41% (19 – 66%)
ESI - plot 2	Volitional	2012	Incubation	5/24	33	13	0.69	19	57% (33 – 83%)
ESI - plot 2	Volitional	2012	Chick	6/13	34	15	0.72	21	61% (39 – 86%)
ESI - plot 2	Volitional	2012	Annual	-	100	37	-	53	53% (40 – 67%)
ESI - plot 3	Volitional	2012	Nest building	5/2	33	10	0.66	15	46% (22 – 71%)
ESI - plot 3	Volitional	2012	Incubation	5/24	33	9	0.69	13	39% (19 – 62%)
ESI - plot 3	Volitional	2012	Chick	6/13	33	17	0.72	24	71% (47 – 96%)
ESI - plot 3	Volitional	2012	Annual	-	99	36	-	52	52% (39 – 66%)
ESI - combined	Volitional	2012	Nest building	5/2	100	24	0.66	36	36% (24 – 50%)
ESI - combined	Volitional	2012	Incubation	5/24	100	26	0.69	37	37% (25 – 51%)
ESI - combined	Volitional	2012	Chick	6/13	101	41	0.72	57	56% (43 – 71%)
ESI - combined	Volitional	2012	Annual	-	301	91	-	131	44% (36 – 51%)

Table A3. On-colony PIT tag deposition rates for California gulls nesting at Crescent Island and Miller Rocks in 2012. Experiments were conducted by feeding PIT-tagged trout to actively-nesting gulls (Volitional). PIT tags recovered (Recovered) were adjusted for date and colony-specific detection efficiency (DE) to estimate the total number of tags deposited on the island (Deposited) and the deposition rate.

Location	Method	Year	Period	Date	Eaten	Recovered	DE	Deposited	Deposition Rate (95% c.i.)
Crescent Is.	Volitional	2012	Nest building	4/13	109	11	0.54	20	19% (8 – 31%)
Crescent Is.	Volitional	2012	Incubation	5/9	100	8	0.71	11	11% (4 – 20%)
Crescent Is.	Volitional	2012	Chick	6/23	99	14	0.89	16	16% (8 – 24%)
Crescent Is.	Volitional	2012	Annual	-	308	33	-	47	15% (10 – 21%)
Miller Rocks	Volitional	2012	Nest building	4/11	105	4	0.71	6	5% (1 – 10%)
Miller Rocks	Volitional	2012	Incubation	5/8	99	12	0.78	15	16% (8 – 25%)
Miller Rocks	Volitional	2012	Chick	6/21	99	32	0.86	37	38% (26 – 50%)
Miller Rocks	Volitional	2012	Annual	-	303	48	-	58	19% (14 – 24%)
Combined	Volitional	2012	Nest building	-	214	15	NA	26	12% (6 – 20%)
Combined	Volitional	2012	Incubation	-	199	20	NA	27	13% (8 – 20%)
Combined	Volitional	2012	Chick	-	198	46	NA	53	27% (20 – 34%)
Combined	Volitional	2012	Annual	-	611	81	NA	106	17% (13 – 21%)

Table A4. Estimated avian predation rates (95% confidence interval) on PIT-tagged salmonid smolts last detected at Lower Monumental Dam on the Snake River or Rock Island Dam on the upper Columbia River. Rates are presented as minimum estimates based on the number PIT-tagged fish deposited on-colony (deposited) and the number deposited on and off-colony (predation rate). Colonies include Caspian terns (Tern) nesting on Crescent Island (CI), double-crested cormorants (Cormorant) nesting on Foundation Island (FI), and California and ring-billed gulls (Gull) nesting at Crescent Island (CI). The number of PIT-tagged smolts interrogated at Lower Monumental or Rock Island dams (N) and current U.S. Endangered Species Act (ESA) status of each evolutionarily significant unit (ESU) are provided. Only ESUs with > 500 PIT-tagged smolts interrogated passing a dam were evaluated (see Evans et al. 2012).

			Predation Rates					
			CI Tern		CI Gull		FI Cormorant	
ESU[1]	ESA-status[2]	N	Deposited[3]	Predation rate	Deposited[3]	Predation rate	Deposited[3]	Predation rate
SR Sockeye	E	5,043	0.9% (0.6-1.3)	1.3% (0.9-1.8)	0.1% (<0.1-0.2)	0.6% (0.1-1.3)	1.1% (0.6-1.7)	2.5% (1.4-4.0)
SR Spr/Sum Chin	T	48,043	0.4% (0.3-0.5)	0.6% (0.4-0.8)	0.1% (0.1-0.2)	0.8% (0.4-1.1)	0.4% (0.3-0.5)	0.8% (0.6-1.2)
UCR Spring Chin	E	1,812	0.1% (<0.1-0.3)	0.1% (<0.1-0.4)	0.2% (<0.1-0.5)	1.0% (<0.1-2.8)	0.2% (<0.1-0.5)	0.3% (<0.1-1.2)
SR Fall Chinook	T	29,751	0.4% (0.3-0.5)	0.5% (0.4-0.7)	0.1% (<0.1-0.1)	0.4% (0.2-0.7)	0.2% (0.1-0.4)	0.5% (0.3-0.8)
UCR Sum/Fall Chin	NW	2,533	<0.1%	<0.1%	<0.1%	<0.1%	0.2% (<0.1-0.5)	0.5% (<0.1-1.2)
SR Steelhead	T	27,767	2.0% (1.7-2.5)	2.8% (2.4-3.5)	0.7% (0.4-0.9)	4.1% (2.6-5.6)	1.1% (0.8-1.4)	2.4% (1.8-3.3)
UCR Steelhead	T	6,845	0.8% (0.6-1.2)	1.2% (0.8-1.6)	0.7% (0.4-1.0)	4.0% (2.3-5.9)	0.2% (<0.1-0.4)	0.5% (0.1-0.9)

[1] SR = Snake River, UCR = Upper Columbia River
[2] E = Endangered, T = Threatened, NW = Not Warranted
[3] Values analogous to minimum predation rate estimates presented in Evans et al. (2012)

APPENDIX B:

Previous Estimates of Caspian Tern Predation Rates Adjusted for PIT Tag Deposition Rate, 2007-2012

SUMMARY

Recoveries of passive integrated transponder (PIT) tags on Caspian tern colonies have been used to estimate minimum predation rates on specific evolutionarily significant units and distinct population segments of salmonids based on PIT-tagged smolts last interrogated passing dams upstream of the colony (BRNW 2012, Evans et al. 2012). Minimum predation rates were previously provided due to a lack of data on the proportion of ingested PIT tags that were deposited on-colony (hereafter referred to as "deposition rates") versus PIT tags that were damaged during digestion or excreted off-colony (see Section 1.4 and Appendix A). Methods and results from several studies designed to quantifying on-colony PIT tag deposition rates for nesting Caspian terns are presented in Appendix A (Deposition Studies). Appendix B provides revised historical predation rate estimates for all Caspian tern colonies previously analyzed by Bird Research Northwest during 2007-2012, using an on-colony PIT tag deposition rate of 0.71 (95% c.i. = 0.62 – 0.81; Table B1; see Appendix A for additional details).

LITERATURE CITED

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Table B1. Estimates of predation rates by Caspian terns on various evolutionarily significant units (ESUs) of Columbia Basin salmonids during 2007-2012, adjusted for on-colony PIT tag detection efficiencies and PIT tag deposition rates. Predation rates presented here update the minimum predation rate estimates presented in Evans et al. (2011 and 2012) and BRNW 2012; the predation rates in this table are our best, unbiased estimates of Caspian tern predation rates. Dashes indicate years when sample sizes of interrogated smolts at an upstream dam were too small (< 500 interrogated smolts) for analysis. NA denotes colonies that were not scanned for PIT tags in that year. Values in parentheses are 95% confidence intervals about the best estimate. Data from 2012 are presented here and in Tables 5, 6, and 7 of the 2012 Annual Report.

Salmonid ESU[1]	Status[2]	2007	2008	2009	2010	2011	2012
Predation by Caspian Terns on East Sand Island in the Columbia River Estuary based on PIT-tagged smolts last interrogated at Bonneville or Sullivan dams							
SR Chinook $_{fall}$	T	3.3% (2.3-4.3)	1.9% (1.6-2.1)	2.0% (1.7-2.3)	0.7% (0.6-0.9)	0.7% (0.5-0.9)	0.7% (0.5-0.9)
SR Chinook $_{spr/sum}$	T	3.1% (2.8-3.5)	2.5% (2.1-2.9)	4.6% (4.2-5.2)	3.4% (3.0-3.8)	2.4% (1.9-3.0)	2.2% (1.8-2.7)
SR Sockeye	E	-	-	1.2% (0.6-1.9)	1.5% (0.7-2.4)	0.2% (<0.1-0.7)	2.1% (1.1-3.2)
SR Steelhead	T	22.6% (20.6-24.8)	14.3% (13.2-15.6)	14.6% (13.5-16.0)	14.0% (12.8-15.4)	11.8% (10.4-13.6)	10.0% (8.4-11.9)
UCR Steelhead	T	15.6% (13.7-17.7)	16.5% (14.5-18.8)	19.5% (17.1-22.3)	13.8% (12.4-15.2)	9.1% (7.3-11.1)	7.4% (6.0-9.1)
UCR Chinook $_{spr}$	E	1.9% (1.2-2.6)	1.7% (0.9-2.5)	3.6% (2.6-4.8)	2.9% (2.3-3.5)	2.6% (1.2-4.4)	1.2% (0.7-1.7)
UCR Chinook $_{sum/fall}$	NW	2.1% (1.3-3.1)	2.7% (1.9-3.5)	2.7% (1.9-3.5)	2.0% (1.7-2.3)	1.1% (0.7-1.6)	1.4% (0.9-2.0)
LW Sockeye	NW	2.1% (0.9-3.5)	0.8% (<0.1-1.7)	1.0% (0.2-1.9)	-	-	-
MCR Chinook $_{spr}$	NW	1.7% (1.2-2.3)	4.2% (3.4-5.0)	3.5% (2.8-4.3)	4.6% (3.9-5.3)	1.9% (1.3-2.7)	1.6% (1.0-2.2)
MCR Steelhead	T	18.4% (16.1-21.0)	13.6% (11.6-15.8)	14.1% (12.2-16.2)	11.9% (10.6-13.3)	9.6% (6.8-12.8)	9.3% (6.7-12.3)
UWR Chinook $_{spr}$	T	1.3% (0.7-2.1)	4.4% (3.4-5.5)	1.7% (1.3-2.2)	1.5% (0.3-3.2)	0.8% (0.2-1.5)	0.7% (0.4-1.1)
UWR Steelhead $_{winter}$	T	-	-	-	-	-	-
DR Chinook $_{sum/fall}$	NW	-	-	-	-	-	-
OR Sockeye	NW	-	-	-	-	-	-
Predation by Caspian Terns on Blalock Islands in the Columbia River based on PIT-tagged smolts last interrogated at McNary Dam							
SR Chinook $_{fall}$	T	0.1% (<0.1-0.2)	0.1% (0.1-0.1)	<0.1%	<0.1%	0.1% (0.1-0.2)	NA
SR Chinook $_{spr/sum}$	T	0.1% (<0.1-0.1)	0.1% (0.1-0.2)	0.3% (0.2-0.3)	0.1% (<0.1-0.1)	0.1% (<0.1-0.1)	NA
SR Steelhead	T	0.9% (0.6-1.1)	0.7% (0.6-0.9)	0.6% (0.5-0.7)	0.9% (0.7-1.1)	0.1% (<0.1-0.2)	NA

UCR Steelhead	T	0.9% (0.5-1.4)	0.6% (0.3-1.0)	0.5% (0.2-0.8)	0.9% (0.5-1.3)	0.1% (<0.1-0.2)	NA
UCR Chinook $_{spr}$	E	<0.1%	<0.1%	0.2% (<0.1-0.3)	<0.1%	<0.1%	NA
UCR Chinook $_{sum/fall}$	NW	0.1% (<0.1-0.2)	0.3% (0.1-0.4)	<0.1%	0.1% (0.1-0.2)	<0.1%	NA
SR Sockeye	E	-	-	<0.1%	0.1% (<0.1-0.4)	0.3% (0.1-0.6)	NA
LW Sockeye	NW	<0.1%	<0.1%	<0.1%	<0.1%	-	NA
OR Sockeye	NW	-	-	-	-	-	NA
Predation by Caspian Terns on Crescent Island in the Columbia Rivers based on PIT-tagged smolts last interrogated at Lower Monumental or Ice Harbor dams							
SR Chinook $_{fall}$	T	0.8% (0.4-1.4)	1.5% (1.3-1.8)	1.0% (0.9-1.2)	0.9% (0.8-1.1)	0.5% (0.4-0.6)	0.5% (0.4-0.7)
SR Chinook $_{spr/sum}$	T	0.4% (0.3-0.5)	0.9% (0.7-1.1)	1.4% (1.2-1.7)	0.4% (0.2-0.6)	0.7% (0.6-0.8)	0.6% (0.4-0.8)
SR Steelhead	T	3.9% (3.4-4.4)	5.8% (5.2-6.6)	4.5% (4.0-5.0)	3.9% (3.3-4.6)	2.6% (2.3-3.0)	2.8% (2.4-3.5)
UCR Steelhead	T	2.4% (1.8-3.1)	2.8% (2.2-3.4)	2.2% (1.7-2.7)	1.7% (1.3-2.1)	2.4% (1.9-2.9)	1.2% (0.8-1.6)
SR Sockeye	E	-	1.4% (0.3-2.7)	0.9% (0.5-1.4)	1.2% (0.3-2.6)	0.7% (0.5-0.9)	1.3% (0.9-1.8)
UCR Chinook $_{sum/fall}$	NW	-	-	0.1% (<0.1-0.4)	0.1% (<0.1-0.2)	0.2% (<0.1-0.4)	<0.1%
UCR Chinook $_{spr}$	E	-	-	<0.1%	0.6% (<0.1-1.5)	0.4% (<0.1-0.9)	0.1% (<0.1-0.4)
LW Sockeye	NW	-	-	-	-	-	-
OR Sockeye	NW	-	-	-	-	-	-
Predation by Caspian Terns on Goose Island in Potholes Reservoir, WA based on PIT-tagged smolts last interrogated at Rock Island Dam							
SR Chinook $_{fall}$	T	0.2% (<0.1-0.8)	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
SR Chinook $_{spr/sum}$	T	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	-
SR Steelhead	T	<0.1%	<0.1%	0.1% (<0.1-0.1)	<0.1%	<0.1%	0.2% (0.1-0.3)
UCR Steelhead	T	12.9% (8.5-20.6)	10.7% (9.3-12.2)	22.0% (19.1-25.9)	13.7% (11.8-16.3)	12.6% (10.6-15.1)	17.3% (14.1-21.7)
SR Sockeye	E	-	0.3% (<0.1-0.8)	<0.1%	<0.1%	<0.1%	0.1% (<0.1-0.2)
UCR Chinook $_{sum/fall}$	NW	-	-	0.3% (<0.1-0.9)	0.3% (<0.1-0.6)	0.1% (<0.1-0.3)	0.1% (<0.1-0.2)
UCR Chinook $_{spr}$	E	-	-	5.0% (2.1-8.6)	1.4% (0.3-2.9)	0.5% (<0.1-1.3)	2.5% (1.0-4.4)
LW Sockeye	NW	-	-	-	-	-	-
OR Sockeye	NW	-	-	-	-	-	-

[1] DR = Deschutes River, LW = Lake Wenatchee, MCR = Middle Columbia River, OR = Okanagan River, SR = Snake River, UCR = Upper Columbia River, UWR = Upper Willamette River

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

APPENDIX C:

Predation on Juvenile Salmonids by Caspian Terns Nesting at Banks Lake, 2007-2012

INTRODUCTION

Recoveries of passive integrated transponder (PIT) tags at the Caspian tern colony on Twining Island, Banks Lake in central Washington State confirmed that Caspian terns nesting at this site commute to the Columbia River to depredate juvenile salmonids, including the consumption of ESA-listed upper Columbia River steelhead. Numerous dataset limitations, however, make it difficult to quantify impacts of predation on juvenile salmonids by Caspian terns nesting at Banks Lake. Data limitations include (1) variable and non-representative PIT-tagging of smolt populations, (2) a lack of information on foraging behavior and diet of Caspian terns nesting at Banks Lake, and (3) difficulty quantifying fish availability, especially because the foraging range of Caspian terns nesting at Banks Lake is unknown and the tagging and release of juvenile salmonids in tributaries upstream of Rock Island Dam (Rkm 730) is non-representative.

METHODS

The methods described in Section 1.4 (Predation Rates) of the 2012 Annual Report were used to recover and analyze PIT tags from the Caspian tern colony on Twining Island, Banks Lake (Figure C1). PIT tag antennas were used to recover PIT tags *in situ* during July-August of each year, after terns dispersed from the island following the nesting season. PIT tag recovery occurred during 2007-2010 and in 2012. We queried the regional salmonid PIT Tag Information System database (PTAGIS 2012), maintained by the Pacific States Marine Fisheries Commission, to acquire data on PIT-tagged smolts released in the Columbia River basin during those years. Unlike the methods presented in Section 1.4 of the 2012 Annual Report and in Evans et al. (2012), however, there was no single interrogation location (e.g., a juvenile bypass facility) that could be used to estimate the availability of PIT-tagged smolts because the foraging range of Caspian terns nesting at Banks Lake is not known (Figure C1). Instead, estimates of smolt availability incorporated all PIT-tagged smolts released into tributaries of the upper Columbia River during the time period when Caspian terns were present at the Banks Lake colony (April – July). Variable and non-representative PIT-tagging of upper Columbia River salmonid populations, coupled with the small number of PIT tags recovered on the Caspian tern colony created numerous challenges when estimating predation rates. Given this, only upper Columbia River steelhead (ESA-listed as threatened) were evaluated. Uncertainty in steelhead availability and migration timing, however, prevented development of confidence intervals about these estimates. Estimates are therefore presented as (1) PIT tag recoveries adjusted for on-colony detection efficiency (comparable to Evans et al. 2012), (2) predation rates, which are adjusted for on-colony detection efficiency and on-colony deposition rates of smolt PIT tags, and (3) per capita (per tern) predation rates. Per capita predation rates were estimated by dividing predation rates by the number of Caspian tern breeding pairs at Twining Island; that number was then multiplied by 100 to estimate predation rates per 100 pairs, depicting impacts by a larger Caspian tern breeding colony that is more typical of the Columbia Plateau region.

RESULTS AND DISCUSSION

A total of 216 PIT tags from anadromous salmonids were recovered at the Caspian tern colony on Twining Island, Banks Lake during 2007-2010 and 2012. Tag recoveries on the Banks Lake tern colony confirm predation on numerous salmonid ESU's, including upper Columbia steelhead, upper Columbia River spring Chinook, upper Columbia River summer/fall Chinook, and Wenatchee/Okanogan sockeye. Upper Columbia River steelhead, however, were the only ESU where sufficient numbers of smolts had been PIT-tagged, released, and recovered to allow for further analyses of predation rates.

Analyses of PIT tag recoveries suggest that some upper Columbia River steelhead populations may be especially susceptible to predation by Caspian terns nesting at Banks Lake (Table C1). For instance, per capita predation rates on steelhead from the Okanogan River watershed, the Methow River watershed, and the Entiat River watershed were generally higher than estimates for steelhead tagged further downstream in the Wenatchee River watershed (Table C1). Fish from all four watersheds, however, were depredated to some degree. Foraging behavior of Caspian terns, distance of the tributaries from the colony, tagging effort, and fish behavior may all contribute to per capita differences in predation rates by watershed, but currently no data are available to evaluate these factors.

Overall, major limitations in the currently available data prevent a reliable and defensible evaluation of the impact of Banks Lake Caspian terns on the survival of juvenile salmonids. For instance, releases of PIT-tagged steelhead in the Okanogan River watershed often only occurred on one day each year in Omak Creek; thus extrapolating these results to the entire run of Okanogan steelhead (spatially and temporally) should be done with extreme caution. PIT-tagged steelhead originating in the Methow and Wenatchee rivers were often released at upstream tributaries; estimates of survival and travel time to the Columbia River were unavailable, information that is required to accurately estimate predation impacts (Evans et al. 2012). The vast majority of PIT-tagged steelhead are also of hatchery origin and impacts to wild or naturally produced steelhead are largely unknown and may differ significantly. Release and interrogation dates of PIT-tagged steelhead do suggest that terns using Banks Lake consume upper Columbia River steelhead throughout the nesting season (April – July), which corresponds with the steelhead smolt out-migration period (April – June). Data on terns nesting at Banks Lake were, however, severely limited; we lack information on foraging locations or diet composition of terns nesting at Banks Lake, and estimates of colony size, chronology, and nesting success were derived from only 1 – 2 aerial surveys and/or infrequent boat surveys each breeding season. In summary, if fisheries managers need data to more accurately estimate predation impacts, studies specifically designed to address predation on smolts by terns nesting on Banks Lake are needed to address these data major data gaps and uncertainties.

Table C1. Estimated predation rates on PIT-tagged steelhead smolts released at various locations in the upper Columbia River basin by Caspian terns nesting at Twining Island, Banks Lake, WA during 2007 – 2010 and 2012. The proportion of tags deposited on the colony (Est. deposited) was adjusted for on-colony detection efficiency, while predation rates were adjusted for both on-colony detection efficiency and off-colony deposition of PIT tags. Steelhead predation rates were divided by the number of Caspian tern breeding pairs at Twining Island and multiplied by 100 to estimate predation rates per 100 pairs of terns at Banks Lake.

Release site	Year	Est. deposited[1]	Predation rate	Breeding pairs	Predation rate per 100 breeding pairs
Okanogan watershed	2007	0.2%	0.3%	31	1.0%
Methow watershed	2007	0.2%	0.2%	31	0.8%
Entiat watershed	2007	<0.1%	<0.1%	31	<0.1%
Wenatchee watershed	2007	0.1%	0.1%	31	0.4%
Okanogan watershed	2008	<0.1%	<0.1%	27	<0.1%
Methow watershed	2008	0.2%	0.2%	27	0.8%
Entiat watershed	2008	0.1%	0.1%	27	0.4%
Wenatchee watershed	2008	0.0%	0.1%	27	0.2%
Okanogan watershed	2009	0.2%	0.3%	61	0.4%
Methow watershed	2009	0.1%	0.1%	61	0.1%
Entiat watershed	2009	<0.1%	<0.1%	61	<0.1%
Wenatchee watershed	2009	0.1%	0.1%	61	0.2%
Okanogan watershed	2010	0.8%	1.1%	34	3.4%
Methow watershed	2010	0.1%	0.1%	34	0.3%
Entiat watershed	2010	<0.1%	<0.1%	34	<0.1%
Wenatchee watershed	2010	0.1%	0.2%	34	0.5%
Okanogan watershed	2012	0.2%	0.2%	22	1.1%
Methow watershed	2012	0.2%	0.2%	22	1.1%
Entiat watershed	2012	0.3%	0.4%	22	1.7%
Wenatchee watershed	2012	0.0%	0.0%	22	0.2%

[1] Analogous to Evans et al. (2012) minimum predation rates

Figure C1. Map of the upper Columbia River region. Text boxes note several tributaries that produce ESA-listed upper Columbia River steelhead and approximate straight-line distances to the Caspian tern colony on Twining Island, Banks Lake (star). Actual flight paths used by terns are currently unknown.