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

Final 2011 Annual Report

This Final 2011 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 2011 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 Caspian tern (*Hydroprogne caspia*) management actions designed to reduce their impact on salmonid smolt survival in the estuary, (3) test management strategies to limit nesting habitat availability 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 colony on East Sand Island, the largest of its kind in the world, consisted of about 7,000 breeding pairs in 2011, a decline from 2010 (ca. 8,300 breeding pairs). The Caspian tern colony on East Sand Island did not produce a single fledgling in 2011, the first time that a complete breeding failure has been recorded at this colony. The proximal factors responsible for colony failure and the decline in colony size were intense disturbance by bald eagles (*Haliaeetus leucocephalus*) and associated gull predation on tern eggs and chicks. Climate conditions associated with a very strong La Niña and the resultant exceptionally high river flows also apparently contributed to the lack of nesting success through their effects on marine forage fish availability.

Juvenile salmonids continued to be a large part of the diet of Caspian terns nesting on East Sand Island, comprising 36% of the diet (percent of prey items) in 2011, somewhat higher than the average during 2000-2010 (30%). Despite complete colony failure, Caspian terns nesting at the East Sand Island colony consumed about 4.8 million juvenile salmonids (95% c.i. = 4.0 – 5.6 million) in 2011, lower than the 11-year average but not significantly different than the smolt consumption estimates from the previous two years. Further reductions in smolt consumption by Caspian terns nesting on East Sand Island will require further reductions in the size of the tern colony; future management plans are designed to reduce the size of the East Sand Island tern colony to about one-third its pre-management size (ca. 9,500 breeding pairs).

Management of Caspian tern nesting habitat at the East Sand Island colony continued in 2011, with the USACE further reducing the area of suitable tern nesting habitat on East Sand Island to 2.0 acres, 40% of the original area of managed tern nesting habitat on East Sand Island. This habitat restriction caused Caspian terns to nest at higher densities (0.85 nests/m^2) than previously recorded in the Columbia River estuary. Since early 2008, the Portland District of the USACE has built a total of eight new islands as alternative Caspian tern nesting sites to compensate for reductions in Caspian tern nesting habitat on East Sand Island; five of these new tern islands are in interior Oregon and three are in the Upper Klamath Basin of northeastern California. Six of the eight new tern islands were surrounded by water throughout the 2011 nesting season, and thus suitable as tern nesting habitat. Four of these six suitable islands supported nesting Caspian terns, including the new 2-acre rock-core island at Tule Lake Sump 1B in Tule Lake National Wildlife

Refuge, where 34 pairs nested. Adverse weather conditions (severe La Niña) and avian nest predators (gulls and great horned owls) limited Caspian tern nesting success and fledgling production at these alternative islands in 2011; however, a substantial number of terns banded at East Sand Island in the Columbia River estuary visited these sites, including 92 terns banded at East Sand Island that were seen at the Upper Klamath Basin tern islands during the 2011 breeding season.

Data on diet composition of Caspian terns nesting at colonies in interior Oregon and northeastern California indicated that in 2011 these colonies were primarily consuming cyprinids (i.e., chub *Gila* spp.), 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 terns nesting in interior Oregon (i.e., Crump Lake and Summer Lake) during 2011. Two juvenile suckers (species unknown) were observed at two Caspian tern colonies in northeastern California (i.e., Sheepy Lake and Tule Lake Sump 1B) during 2011. Suckers represented a very small percentage (< 0.1%) of identifiable prey items at these two tern colonies. No sucker PIT tags were recovered from Caspian tern colonies in either interior Oregon or northeastern California during 2011.

East Sand Island in the Columbia River estuary is also home to the largest double-crested cormorant colony in western North America, which consisted of about 13,000 breeding pairs in 2011, very similar to 2010 (ca. 13,600 breeding pairs). Juvenile salmonids represented about 19% of the diet (percent biomass) of double-crested cormorants nesting on East Sand Island in 2011, the highest percentage observed since 1999 (24.6% of the diet). Double-crested cormorants nesting at the East Sand Island colony consumed approximately 20.5 million juvenile salmonids (95% c.i. = 15.2 – 25.9 million) in 2011, the highest annual point estimate of smolt consumption for the East Sand Island cormorant colony so far recorded. During the past two years, smolt consumption by double-crested cormorants nesting on East Sand Island has been significantly greater than smolt consumption by Caspian terns nesting on East Sand Island.

In 2011, a pilot study was conducted to test the feasibility of a management strategy to limit the amount of nesting habitat available to double-crested cormorants at East Sand Island. An eight-foot-tall privacy fence was built to bisect the colony and visually separate 15% of the nesting area used by cormorants in 2010 from the remainder of the colony. Using human disturbance to haze cormorants during the nest initiation period (late April to mid-May), double-crested cormorants were successfully dissuaded from using this 15% of their former nesting area. Cormorants on the other side of the fence nested normally, apparently unaffected by the hazing activities. No detrimental effects of hazing activities were observed on non-target species that also use this portion of the island, including nesting Brandt's cormorants, nesting glaucous-winged/western gulls, and roosting California brown pelicans.

Further up-river in the Columbia Plateau region, Caspian terns and double-crested cormorants are also the two bird species responsible for most of the smolt losses to avian predators. Management options to reduce the impacts of these two avian predators on smolt survival along the mid-Columbia River and lower Snake River are currently being considered by resource managers. In 2011, the largest breeding colonies of Caspian terns in the Columbia Plateau region were at Crescent Island on the mid-Columbia River (in McNary Pool) and on Goose Island on Potholes Reservoir (near Othello, WA), where nearly equal numbers of breeding pairs (ca. 420) nested in 2011. Caspian tern nesting success at both colonies in 2011 was also similar (ca. 0.3 young raised per nesting pair). During the 2011 breeding season, salmonid smolts represented 84% of tern prey items at the Crescent Island colony, the highest percentage ever recorded at that colony, and 24% of tern prey items at the Goose Island/Potholes colony. Estimated consumption of juvenile salmonids by Caspian terns nesting at these two colonies was 440,000 smolts and 111,000 smolts, respectively.

The largest colony of double-crested cormorants on the mid-Columbia River was on Foundation Island in McNary Pool, where about 318 pairs nested in 2011. Diet sampling during 2005-2010 indicated that ca. 50% (by mass) of the diet of Foundation Island cormorants was juvenile salmonids during May (the peak of smolt out-migration), while less than 10% of the cormorant diet was salmonids during early April, June, and July. Using diet data collected during 2005-2010, and data on colony size and productivity in 2011, we estimated that Foundation Island cormorants consumed 24,700 kg of juvenile salmonids (95% c.i. = 19,100 – 30,300 kg) in 2011. As in previous years, this was significantly greater than salmonid consumption by the Crescent Island Caspian tern colony (14,700 kg in 2011; 95% c.i. = 12,200 – 17,200 kg).

An estimated 36,918 PIT tags from 2011 migration year salmonid smolts were deposited by birds on their nesting colonies in the Columbia Plateau region. PIT tag recoveries indicated that smolt losses in 2011 were highest due to Crescent Island Caspian terns (11,734 PIT tags), followed by Foundation Island double-crested cormorants (8,376 PIT tags) and Goose Island Caspian terns (6,387 PIT tags). PIT tags recovered from the Caspian tern colony on Goose Island in Potholes Reservoir were almost exclusively from upper Columbia River salmonid evolutionarily significant units (ESUs) or distinct population segments (DPSs), while PIT tags recovered on other bird colonies in the Columbia Plateau region consisted of smolts from Upper Columbia, Snake, and Middle Columbia ESUs or DPSs. PIT tag recovery results indicate that Caspian terns from the Goose Island colony in Potholes Reservoir consumed an estimated 8.9% of the ESA-listed steelhead (*O. mykiss*) smolts that were PIT-tagged and detected/released at Rock Island Dam on the upper Columbia River, the highest ESU-specific predation rate measured in 2011 for birds nesting at a colony in the Columbia Plateau region. Predation rates by Crescent Island terns on Snake River steelhead (ca. 1.9%) and by Foundation Island cormorants on Snake River steelhead (ca. 1.8%) were also notable in 2011 and comparable to those reported in previous years (2007-2010). Predation on salmonid smolts by American white pelicans nesting on Badger Island and California and ring-billed gulls nesting on Crescent Island and Miller Rocks during 2011 were relatively minor (generally < 0.5% per ESU or DPS) in comparison to that of Caspian terns and double-crested cormorant nesting at colonies in the Columbia Plateau region.

California and ring-billed gulls nest in large numbers on islands on or near the mid- and upper Columbia River, but these gulls have generally consumed few fish and even fewer juvenile salmonids compared to Caspian terns or double-crested cormorants nesting along the mid-Columbia River. In 2011, the number of gulls counted on the Miller Rocks colony was 5,750, up slightly from the 5,533 gulls counted on the colony during the 2010 breeding season. The number of gulls nesting on Miller Rocks has apparently increased by about 160% since 1998. Similarly, the American white pelican colony on Badger Island in McNary Pool has undergone dramatic growth since the late 1990's, increasing from ca. 100 adults on-colony in 1999 to ca. 2,200 adults on-colony in 2011. The numbers of smolt PIT tags recovered from both the Miller Rocks gull colony and the Badger Island pelican colony have increased commensurate with increases in colony size.

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). Caspian terns (*Hydroprogne caspia*) and double-crested cormorants (*Phalacrocorax auritus*) nesting at colonies on East Sand Island together consumed 6 million - 25 million smolts annually during 2003 – 2010, 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 2011). 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 2011, Lyons et al. 2011a,b). 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 (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 ESA-listed salmonid ESUs from throughout the Columbia River basin, compared to potential benefits of management of other colonies of piscivorous waterbirds. The Caspian tern colonies on Crescent Island (mid-Columbia River) and Goose Island (Potholes Reservoir) and the double-crested cormorant colony on Foundation 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 (*Oncorhynchus mykiss*; Antolos et al. 2005, BRNW 2011, Lyons et al. 2011a,b).

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 Rice Island Caspian tern colony, 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 terns shifted from Rice Island to East Sand Island in 2000, where juvenile salmonids comprised 47% of the prey items, compared to 90% of prey items at Rice Island (Roby et al. 2002). During 2001–2010, all Caspian terns nesting in the Columbia River estuary used East Sand Island (BRNW 2011). During 2001-2010, estimated consumption of juvenile salmonids by Caspian terns nesting on East Sand Island averaged 5.3 million smolts per year (SD = 1.0 million, n = 10 years), a ca. 62% reduction in annual consumption of smolts compared to when the Caspian tern colony was on Rice Island (BRNW 2011).

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 two-thirds 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 terns in the estuary by about two-thirds, while still maintaining the long-term viability of the Pacific Coast population of Caspian terns. The U.S. Army Corps of Engineers – Portland District has constructed eight islands, five in interior Oregon and three in northeastern California, as alternative nesting habitat for Caspian terns currently nesting on East Sand Island. The Corps has plans to construct additional tern nesting islands in the next 1-2 years. Concurrently, the Corps is gradually reducing the area of suitable nesting habitat for Caspian terns on East Sand Island from 5 acres to 1 acre, and hazing terns that attempt to establish new nesting colonies elsewhere in the Columbia River estuary.

Management options to reduce or limit smolt losses to the large double-crested cormorant colony on East Sand Island, which consumed about 19.2 million juvenile salmonids (95% c.i. = 14.6 million to 23.8 million; BRNW 2011) in 2010, are under consideration. In order to reduce predation on juvenile salmonids by double-crested cormorants in the Columbia River estuary, it will be necessary to reduce the size of the cormorant colony on East Sand Island. Non-lethal management approaches, such as relocating a portion of the colony to alternative colony sites along the Pacific coast, seem more appropriate in the context of the cormorant colony on East Sand Island, whose growth appears to have been largely at the expense of other colonies in the region (Adkins et al. 2010). The East Sand Island cormorant colony now consists of about 40% of all breeding pairs in the western North America population (Adkins et al. 2010). As was the case with Caspian tern management in the Columbia River estuary, any management of double-crested cormorants to reduce smolt losses in the estuary will require analysis under the National Environmental Policy Act (NEPA), including assessments of the (1) population status of Pacific Coast double-crested cormorants, (2) availability of suitable alternative nesting habitat outside the Columbia River basin, and (3) potential enhancement of recovery rates of ESA-listed salmonid ESUs from the Columbia River basin, should management of cormorants at East Sand Island be implemented.

The primary objectives of this project in 2011 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 nesting islands created for Caspian terns 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) Caspian terns nesting on Crescent Island, Goose Island/Potholes, and the Blalock Islands; (3) investigate the number 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 2011 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) seven recently constructed islands for Caspian tern nesting in interior Oregon (i.e., Fern Ridge Reservoir, Crump Lake, Dutchy Lake at Summer Lake Wildlife Area, and East Link impoundment at Summer Lake Wildlife Area) and northeastern California (i.e., Sheepy Lake at Lower Klamath National Wildlife Refuge, Orems Unit impoundment at Lower Klamath National Wildlife Refuge, and Tule Lake Sump 1B impoundment at 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, in the Columbia Plateau region, and at tern nesting 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 USACE, and NOAA Fisheries, sought to redistribute the majority of Caspian terns nesting at the colony on East Sand Island in the Columbia River estuary to alternative colony sites (islands) in interior Oregon/California and 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 tern nesting habitat on East Sand Island would be reduced from its historical size (approximately 5 acres) to 1.0 acre.

The specific objectives of the Plan are to reduce the size of the East Sand Island Caspian tern colony to 2,500-3,125 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 eight recently constructed tern colony sites in interior Oregon and northeastern California (i.e., Fern Ridge Reservoir, Crump Lake, Summer Lake Wildlife Area [3 separate islands], Tule Lake NWR, and Lower Klamath NWR [2 separate islands]. The Corps recently built a ninth island in Malheur Lake, Malheur NWR, which was completed after the 2011 nesting season. Plans for potentially building additional tern colony sites in the San Francisco Bay area are currently uncertain.

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 2 acres of nesting habitat for Caspian terns on East Sand Island in 2011 (Map 3). This 2-acre area was sprayed with herbicide in late September 2010 and then disked and harrowed to remove encroaching European beach grass and other invasive plants in late March 2011. 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 2011 was a reduction from the area of nesting habitat prepared for terns in 2010 (3.1 acres) and a 60% 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 3-acre reduction in area of nesting habitat was allowed due to the creation and availability of ≥ 6 acres of new Caspian tern nesting habitat outside the Columbia River estuary (USFWS 2005; see below).

Roughly 1 acre of bare sand or partially vegetated habitat surrounded the 2-acre area prepared for Caspian tern nesting prior to the 2011 nesting season. In early April, before terns initiated nests, ca. 620 meters of vertical fencing with black landscape fabric was erected in rows within this 1-acre area to dissuade tern nesting and restrict the amount of suitable tern nesting habitat on East Sand Island to 2 acres (Map 3). Rope and flagging were also added to enhance dissuasion of tern nesting outside the 2-acre tern colony area on East Sand Island.

Beginning in late April, Caspian terns began digging nest scrapes near the high tide line on the southeast beach at East Sand Island. This satellite colony was outside both the 2-acre colony area and the 1-acre area where fencing was used to dissuade tern nesting. We were directed by resource managers to erect stakes and flagging at the satellite tern colony to dissuade Caspian terns from nesting outside the core 2-acre colony area on East Sand Island.

As part of the Management Plan, Caspian terns were to be dissuaded from nesting at dredged material disposal islands (i.e., Rice Island, Miller Sands Spit, Pillar Rock Sands, and Puget Island) and/or other suitable nesting sites in the upper Columbia River estuary. As was the case in previous years, Caspian terns were observed in upland areas in the upper Columbia River estuary during the 2011 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 and terns were actively hazed from the Tongue Point pier. On 2 May, a USACE contractor assumed responsibility for 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 11 June, when the contract ended. Active hazing or passive measures to discourage tern nesting (i.e., stakes and flagging) were not necessary at other dredged material disposal sites in the upper Columbia River estuary (i.e., Miller Sands Spit, Pillar Rock Sands, Puget Island) during the 2011 nesting season.

1.1.2. Interior Oregon and Northeastern California

The USACE and its state and federal partners have so far completed construction of eight islands (a total of 7.3 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 and the other on 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 third half-acre island at Summer Lake Wildlife Area in the Gold Dike impoundment, 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. Of these eight tern islands, all but one island were suitable for tern nesting in 2011; the island at Gold Dike impoundment (Summer Lake Wildlife Area) was not surrounded by water in 2011. Social attraction techniques (i.e., decoys and audio playback systems; Kress 2000, Kress and Hall 2002, Roby et al. 2002) were used at each suitable site, 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 on the plots.

Nesting success (average number of young raised per breeding pair) at the East Sand Island tern colony has been estimated using aerial photography taken of the colony just prior to the fledging period. Because no Caspian tern young were raised to fledging age at the East Sand Island colony in 2011, aerial photography was not taken just prior to the fledging period.

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 6,969 breeding pairs of Caspian terns (95% c.i. = 5,765–7,822 breeding pairs) were nesting on East Sand Island at the peak of nesting activity (mid May) in 2011 (Figure 1). This estimate is lower than our best estimate of peak colony size at East Sand Island in 2010 (8,283 breeding pairs, 95% c.i. = 7,412–9,154 breeding pairs), and is the smallest colony size estimate measured at the tern colony since it became fully established in 2001 (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 three years, from approximately 5 acres in 2008 to 2 acres in 2011. Although nesting density of terns increased in 2011 (0.85 nests/m^2) relative to the previous four years (ca. 0.70 nests/m^2; Figure 3), suggesting that nesting habitat may have been limiting in 2011, tern nesting density at East Sand Island is still lower than what has been observed at other Caspian tern colonies in the Pacific Coast region (0.87–1.50 nest/m^2; BRNW unpublished data). Further reductions in the amount of Caspian tern nesting habitat provided on East Sand Island in 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.

The Caspian tern colony on East Sand Island did not produce a single fledgling in 2011, the first time complete breeding failure has been recorded at this colony. The proximal factors responsible for colony failure were intense disturbance by bald eagles and associated gull predation on tern eggs and chicks. La Niña climate conditions and exceptionally high river flows also may have negatively influenced tern nesting success in 2011 by reducing the availability of marine forage fishes in the estuary. 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 declining productivity of the East Sand Island tern colony: ocean conditions as they influence the availability of marine forage fishes and nest predation by gulls.

Caspian terns continued to prospect for nest sites at dredged material disposal sites in the upper Columbia River estuary during 2011. Active and passive measures used to dissuade terns from nesting in the upper estuary were successful until mid-June, when hazing of terns by the Corps' contractor was ended. Following the cessation of active tern hazing, terns returned to Rice Island in late June and initiated nesting there. On 11 July, 3 Caspian tern nests with a total of 4 eggs were discovered on Rice Island adjacent the old colony site and near areas that had previously been staked and flagged to prevent tern nesting. The USACE was notified and decided that no action would be taken to prevent terns from nesting at the site. On 14 August, ca. 460 adult Caspian terns (most were roosting) and 3 tern chicks were observed at the colony site on Rice Island. Caspian terns did not attempt to nest at any other sites in the upper estuary in 2011.

1.2.2. Columbia Plateau

Methods: 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 tern pairs, was based on the peak in the direct counts of incubating terns on each colony near the end of the incubation period. These counts were made from observation blinds situated on the outskirts of each tern colony. Nesting success was estimated from ground counts of all fledglings on the colony just prior to fledging. 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.

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, and Banks Lake; Map 1) were conducted during the breeding season to determine whether these colony sites had been re-occupied. 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. The colony area occupied by nesting terns on Anvil Island in the Blalock Islands was estimated by applying the nesting density at the Crescent Island tern colony in 2011 (breeding pairs per acre) to the maximum number of breeding pairs counted on Anvil Island (n = 20 pairs); this method assumes equal nesting density at the two colonies.

Results and Discussion: Caspian tern attendance at the Crescent Island colony in 2011 was below the average for 2000-2010 (Figure 5). Low colony attendance was associated with below average colony size (Figure 6) and nesting success (Figure 7) at the Crescent Island tern colony in 2011. About 419 breeding pairs of Caspian terns attempted to nest on Crescent Island in 2011, up slightly from the colony size in 2010. Caspian tern colony size on Crescent Island trended downward from 2001 to 2007, but has remained relatively stable thereafter (Figure 6). In 2011, the area occupied by nesting terns on Crescent Island was 0.088 acres.

For the second consecutive year, a satellite tern colony was initiated on Crescent Island on the upper beach in the cove southwest of the main colony. Up to 6 breeding pairs of Caspian terns occupied this satellite colony and 5 eggs were laid prior to nest failure and abandonment of the satellite colony in mid-May.

We estimated that 136 young terns fledged from the main Crescent Island tern colony in 2011, or 0.32 young raised per breeding pair (Figure 7). Nesting success at the Crescent Island Caspian tern colony was below the 10-year average (0.58 young raised per breeding pair) for the 4th consecutive year (Figure 7).

At Potholes Reservoir, Caspian terns nested at two disjunct colony sites on Goose Island in 2011; 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, one week earlier than was observed the previous year (Figure 8). Colony attendance at the Goose Island colony was generally higher in 2011 as compared to the 2010, when the colony experienced widespread nesting failure (Figure 8). We estimated that 422 breeding pairs attempted to nest on Goose Island in 2011, similar to the colony size estimate in 2010 (416 breeding pairs; Figure 9). The Goose Island colony was the largest Caspian tern colony in the Columbia Plateau region in both 2009 and 2010, and comparable in size to the Crescent Island tern colony (419 breeding pairs) in 2011. In 2011, the area occupied by nesting terns on Goose Island was 0.119 acres.

We estimated that 115 young fledged from the Goose Island tern colony in 2011, or 0.27 young raised per breeding pair (Figure 10). In 2010, virtually all Caspian tern nesting attempts at Goose Island failed, apparently because of 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 2011, the Caspian tern nesting colony on Anvil Island consisted of about 20 breeding pairs, a substantial decline in colony size from the previous year when 136 breeding pairs were counted (Figure 11). The Anvil Island Caspian tern colony completely failed in 2011, due to rising water levels in John Day Pool that flooded the colony site and possibly other unidentified factors. This is the sixth 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 to high water levels in John Day Pool during the incubation period. In 2011, the area occupied by nesting terns on Anvil Island was 0.004 acres.

For the first time since our intensive colony monitoring began in the Columbia Plateau region, Caspian terns attempted to nest at the upstream end of Badger Island in 2011. About 40 Caspian terns were first observed on Badger Island on 9 May and by early June numbers increased to 60 adults, including 33 that were sitting in nest scrapes. However, all tern nesting attempts on Badger Island failed and the site was abandoned by nesting terns on or before 22 June, apparently due to encroachment and nest trampling by American white pelicans. Inspection of aerial photography taken of the Badger Island pelican and tern colonies on 18 May confirmed that tern eggs were laid prior to nest abandonment.

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 2011. Nineteen pairs of Caspian terns nested on Twining Island in Banks Lake and 4 pairs nested on Harper Island in Sprague Lake in 2011. From 1997 to 2005, Caspian tern nesting at Banks Lake was on 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 above 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 less than 20 breeding pairs in 2011 (Figure 12). Caspian tern nesting in Sprague Lake was first documented in the late 1990's on Harper Island, where they have been nesting sporadically ever since. Since 2005, colony size estimates for Caspian terns on Harper Island have been generally small (<10 breeding pairs), with a declining trend in recent years (Figure 13). In 2011, based on limited data, Caspian terns nesting at Twining Island were successful in rearing 3 young to fledging or 0.16 young raised per breeding pair; at Harper Island terns failed to rear any young (cause of nest failure unknown). Caspian tern nesting success at Twining and Harper islands has been generally low in recent years (2008-2011), ranging from complete nest failure at Twining Island in 2010 and Harper Island in 2008 and 2011 to 0.33 young raised per breeding pair at Twining Island in 2008 and 2009.

We identified six active Caspian tern colonies in the Columbia Plateau region in 2011 (Figure 14), where a total of approximately 920 breeding pairs nested (Figure 15). This suggests that the number of Caspian terns nesting in the Columbia Plateau region has remained relatively stable over the last three years, but population size is slightly greater compared to 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, 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.

The numbers of Caspian terns breeding at sites in the Puget Sound and Salish Sea region of Washington were assessed by a combination of aerial photography and by conducting periodic ground-based surveys during the breeding season. The number of Caspian terns attempting to nest at Dungeness Spit in Dungeness National Wildlife Refuge, near the city of Sequim, WA; at the northern most dredge spoil island in Padilla Bay, near the city of Anacortes, WA; at the Trident Seafood warehouse in Seattle, WA; 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 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: Although Caspian terns were commonly observed foraging and roosting in Willapa Bay and Grays Harbor during the 2011 breeding season, 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.

During an aerial survey conducted on 3 June 2011, the Caspian tern colony on Dungeness Spit in Dungeness NWR was observed to have about 90 terns on-colony and 300 loafing on the adjacent mudflats. During subsequent site visits on 17 June, 24 June, and 7 July, field observers counted 16, 42, and 0 attended nests, respectively. Based on these observations, our best estimate of peak colony size at Dungeness Spit in 2011 was 42 breeding pairs on 24 June. The colony was completely abandoned on or before 7 July. As was the case in the previous two years, nest predation by coyotes (*Canis latrans*) appeared to be a significant contributing factor. During the 7 July visit observers detected coyote tracks as well as scat with eggshell fragments on the tern colony. In addition, bald eagles (*Haliaeetus leucocephalus*) were observed to cause colony flushes and glaucous-winged gulls were observed on the tern colony and chasing terns during visits when terns were actively nesting in 2011.

The Dungeness Spit 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 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 first formed in 2003.

During aerial surveys of the Puget Sound area conducted in 2011, we confirmed that nest dissuasion materials (silt fence barriers) had been erected on the former Caspian tern colony located at the abandoned Georgia-Pacific mill site at the Port of Bellingham, WA. This colony was first 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 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 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 0.5 - 1.0 fledglings per breeding pair. Nest predation, a major limiting factor for colony size and nesting success at other tern colonies in the region, was not a large factor at this site in 2010. However, due to plans to begin environmental cleanup of the site, Caspian terns were dissuaded from nesting at the Port of Bellingham site in 2011.

On the northern-most dredge spoil island in Padilla Bay, a breeding colony of Caspian terns formed in June of 2011. We estimated the colony size at 424 breeding pairs based on counts from aerial photography taken on 7 July. The colony consisted of three separate nesting areas: on the northeast, northwest, and southeast edges of the island where small areas of bare sand and driftwood lay alongside vegetated upland near the high high tide line. Both eggs and chicks were produced at the colony, but young in late stages of development were never observed, thus no fledglings are believed to have been produced. On 16 July, high water and erosion were noted as likely responsible for the loss of many of the nests in the northeast and northwest sub-colonies. By 28 July, the Padilla Bay Caspian tern colony had completely failed. Fresh eel grass and kelp were strewn across the former nesting areas, and most nest scrapes were washed away. Five tern chick carcasses and three tern eggs were found along the shoreline, apparently drowned. However, while flooding and erosion clearly contributed to breeding failure, broken eggs and river otter (*Lontra canadensis*) tracks and scat were also observed on the colony. In addition to this sign, a river otter was observed on the northern sub-colonies on 28 July.

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.

There is no history of Caspian terns nesting on Smith Island in the Strait of Juan de Fuca; however, there is some evidence that Caspian terns may have attempted to nest on Smith Island in 2011. During an aerial survey on 3 June, approximately 750 Caspian terns were observed on the island. Based on the review of aerial photography, it appeared that about five terns were attending nests. However, an aerial survey in early July indicated that no terns were using the site. We believe that the possible tern nests observed in the 3 June photography were below the high high tide line, and may have been swept away. Thus, similar to the colony site in Padilla Bay, nesting habitat for Caspian terns at Smith Island appears to be limited to a small area below vegetated upland that is prone to flooding or over-washing during high high tide events.

In 2011, a new Caspian tern colony was initiated on the rooftop of the Trident Seafood warehouse adjacent to Pier 90 in Seattle, WA. Based on inspection of 3 June aerial photography, the colony size was estimated to be 50-70 breeding pairs. However, attended nest counts varied over the subsequent site visits and complete colony failure was confirmed on 9 July, when no terns, tern eggs, or tern chicks were noted. A considerable number of broken eggs were observed on the colony during a visit on 8 June, and gulls and crows were observed loafing on the site on 9 July, when the site was no longer occupied by Caspian terns. These observations suggest nest predation by glaucous-winged gulls and American crows may have contributed to the failed breeding attempts and abandonment of the colony by early July. It was not confirmed, but human disturbance may have also played a role in breeding failure as the building was occupied and in use during the period when terns were attempting to breed at the site in 2011.

Loss of former breeding colony sites at Dungeness Spit and the Port of Bellingham likely contributed to the formation of new Caspian tern colonies at these three locations in the Salish Sea region in 2011. In addition, the complete failure of the large Caspian tern colony at East Sand Island in 2011, likely contributed to the numbers of Caspian terns prospecting for breeding sites in the region. Although more than 500 Caspian tern nesting attempts were documented at four different colonies in the Salish Sea region during 2011, all four colonies failed to raise any young to fledging age. During recent years, poor breeding performance and colonization attempts at fenced sites on the mainland and on rooftops in the Salish Sea region support the hypothesis that suitable nesting habitat for Caspian terns is very limited in the region. Continued monitoring in 2012 and beyond will be necessary to determine where Caspian terns displaced from the colonies at the Port of Bellingham and Dungeness Spit, plus terns emigrating from the managed colony on East Sand Island, may attempt to breed 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 island built for Caspian tern nesting in interior Oregon (i.e., Fern Ridge Reservoir, Crump Lake, Dutchy Lake at Summer Lake Wildlife Area, and East Link impoundment at Summer Lake Wildlife Area) and in northeastern California (i.e., Sheepy Lake at Lower Klamath National Wildlife Refuge, Orems Unit impoundment at Lower Klamath National Wildlife Refuge, and 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 of these newly built 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 implemented at the Crump Lake tern island in 2011 because managers decided that the Caspian tern colony at this site in 2009 had exceeded the target number of breeding pairs (500 pairs). Data on colony attendance, colony size, productivity, and factors limiting colony size and productivity were collected 3-7 days per week at each island, with the exception of Fern Ridge Reservoir. Because there has been no prior history of Caspian terns nesting at Fern Ridge Reservoir or elsewhere in the Willamette Valley, video cameras installed in the blind were used as the primary means to monitor the island, instead of direct observation by a field crew.

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 south-eastern Oregon and northeastern California (Map 4) were conducted during the 2011 nesting season in order to detect nesting attempts by Caspian terns and other colonial piscivorous waterbirds.

Results and Discussion: Caspian terns were observed during the 2011 nesting season at each of the seven suitable tern nesting islands built by the Corps in interior Oregon and northeastern California (Figure 16). Caspian terns attempted to nest at five of the seven suitable islands (Crump Lake, East Link, Sheepy Lake, Tule Lake, Orems Unit); the Caspian terns observed at the tern islands on Fern Ridge Reservoir and on Dutchy Lake did not attempt to nest at those two sites.

Colony attendance at the Crump Lake tern island in Warner Valley, Oregon during 2011 was well below the average for 2008-2010 (Figure 17). About 35 breeding pairs of Caspian terns attempted to nest at the Crump Lake tern colony in 2011, down considerably from the colony size estimates in 2008 (ca. 430 breeding pairs), 2009 (ca. 700 breeding pairs), and 2010 (ca. 70 breeding pairs; Figure 18). As was the case in 2008-2010, high gull 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 10 gulls that were preying on tern eggs were removed in 2011. We estimated that approximately 15 young Caspian terns fledged from the Crump Lake tern colony in 2011, or an average of 0.43 young fledged per breeding pair (Figure 19).

In 2011, Caspian terns attempted to nest at only one of the three tern islands built at Summer Lake Wildlife Area, the island in East Link impoundment. Although small numbers of Caspian terns (n = 1−8) were observed on the floating tern island at Dutchy Lake throughout the 2011 breeding season (late April through late August), no Caspian terns initiated nesting there, as was the case the previous year. The island in Gold Dike impoundment was not surrounded by water and therefore was unsuitable for tern nesting in 2011. Caspian tern colony attendance at the Summer Lake tern islands in 2011 was comparable to previous years during the early part of breeding season (through May) and lower during the later part of the breeding season (June through August; Figure 20). Two breeding pairs attempted to nest at the East Link tern island in 2011, down from a total of 29 breeding pairs in 2010 (Figure 21). No young terns were fledged from the East Link colony in 2011, the first complete nesting failure by Caspian terns observed at Summer Lake Wildlife Area since the tern islands were constructed prior to the 2009 breeding season (Figure 22).

Caspian terns attempted to nest at both of the islands constructed for tern nesting in Lower Klamath National Wildlife Refuge; the 0.8-acre floating island at Sheepy Lake and the 1.0-acre silt-core island in the Orems Unit impoundment. Compared to 2010, colony attendance by terns at the Sheepy Lake island in 2011 was lower during July-August (Figure 23). A total of about 188 breeding pairs attempted to nest at the Sheepy Lake tern island in 2011, down from about 258 breeding pairs in 2010 (Figure 24). As was the case at the Crump Lake tern colony, limited gull control was deemed necessary at the Sheepy Lake tern colony; forty-two California gulls and 3 ring-billed gulls that were repeatedly observed depredating tern eggs at the Sheepy Lake colony were shot under permit in 2011. Despite these efforts, nesting success at the Sheepy Lake tern colony was lower in 2011 (0.11 young raised per breeding pair) relative to the previous year (0.65 young raised per breeding pair; Figure 25). Caspian terns were first observed on the Orems Unit tern island on 8 May, where two breeding pairs laid eggs and attempted to nest, but ultimately failed.

Caspian terns were quick to colonize the 2-acre rock-core island at Tule Lake Sump 1B in Tule Lake National Wildlife Refuge in 2011 (Figure 27), where 34 breeding pairs nested. Nesting success at the Tule Lake colony was poor, however; only 4 young terns were raised to fledging age, or an average of 0.12 young raised per breeding pair.

In 2011, the total number of Caspian terns nesting at islands created as alternative habitat for Caspian terns displaced from East Sand Island was 259 breeding pairs, roughly a third the number of terns that nested at these sites in 2009 (712 breeding pairs; Figure 28). This decline occurred despite there being a 60% increase in the amount of suitable nesting habitat made available to Caspian terns in interior Oregon and northeastern California in 2010-2011 compared to 2009 (Table 1). Although gull predation on tern eggs and chicks was the most significant proximal factor limiting the size and productivity of Caspian tern colonies at tern islands in interior Oregon and northeastern California during 2011, adverse weather conditions and low forage fish availability associated with the strong La Niña were likely the ultimate causes for lower colony size and productivity at these sites in 2011.

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 2011: on an island in the eastern arm of Clear Lake Reservoir, Clear Lake NWR (< 15 breeding pairs) and on an island at the north end of Malheur Lake (ca. 150 breeding pairs; Map 4). Both of these Caspian tern colonies were within large, mixed-species colonies of double-crested cormorants, American white pelicans, and gulls. Caspian terns nesting at Malheur Lake were successful in fledging some young, whereas terns nesting at Clear Lake Reservoir laid eggs but were unsuccessful in fledging 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 using both lethal and non-lethal techniques on Caspian terns returning to the colony with whole fish carried in their bills (referred to hereafter as "collected bill loads"). Lethal sampling (n = 55 bill loads) was conducted from 18 April to 5 May by shooting terns and collecting the bill load fish. Non-lethal sampling (n = 390 bill loads), which utilized hazing shells to startle terns into dropping their fish, was conducted from 6 May to 30 July. 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 soft tissue and morphometric analysis.

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

Results and Discussion: Of the bill load fish identified at the East Sand Island Caspian tern colony during the 2011 nesting season (n = 4,148 bill loads), on average 36% 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 slightly higher than the 11-year average (30%; Figure 29). As in previous years, marine forage fishes (i.e., anchovies [Engraulidae], surf perch [Embiotocidae], smelt [Osmeridae], and herring [Clupeidae]) were most prevalent, together averaging 57% of all identified bill loads in the diet of terns nesting on East Sand Island in 2011 (Figure 30). The peak in the proportion of salmonids in the diet of Caspian terns nesting on East Sand Island occurred in the late-May 2-week period, whereas during the previous 11 years the peak in proportion of salmonids in the diet occurred during the early-May 2-week period (Figure 31). The proportion of salmonids in the tern diet was generally higher from late May through July in 2011 compared to the averages during the previous 11 years (Figure 31).

Our best estimate of total smolt consumption by Caspian terns nesting on East Sand Island in 2011 was 4.8 million smolts (95% c.i. = 4.0 – 5.6 million), below the average of the previous 11 years for the first time in six years (Figure 32). From 2000 to 2010, the average number of smolts consumed by Caspian terns nesting on East Sand Island was 5.3 million smolts per year (Figure 28). 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 in 2011, we estimate that 29% were coho salmon (best estimate = 1.4 million; 95% c.i. = 1.2 – 1.6 million), 28% were steelhead (best estimate = 1.3 million; 95% c.i. = 1.1 – 1.5 million), 27% were sub-yearling Chinook salmon (best estimate = 1.3 million; 95% c.i. = 1.0 – 1.5 million), 16% were yearling Chinook salmon (best estimate = 0.8 million; 95% c.i. = 0.6 – 0.9 million), and < 1% were sockeye salmon (best estimate = 0.03 million; 95% c.i. = 0.02 – 0.04 million; Figure 33).

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 50 and 100 bill load identifications per week, respectively (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 either steelhead or 'other salmonids' (i.e., Chinook salmon, coho salmon, or sockeye salmon). Steelhead 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 at the Crescent Island and Goose Island tern colonies due to the potential impact of lethal or non-lethal sampling on such small 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 construction 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 1/5 of the *O. mykiss* brought to the colony as steelhead smolts, leaving 4/5 of them as unidentified, either steelhead or resident rainbow trout. Uncertainty in the unidentified fish caused us to calculate consumption based on two different scenarios. First, we assumed 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 1/5 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 2011, on average 84% were juvenile salmonids (n = 2,186 identified bill loads), higher than has been previously observed at this colony (Figure 34). 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 terns nesting near the coast (e.g., East Sand Island). Juvenile salmonids were by far the most prevalent prey type in the diet of Caspian terns nesting on Crescent Island in 2011, followed by centrarchids (bass and sunfish, 11%) and cyprinids (carp and minnows, 2%; Figure 35). The proportion of juvenile salmonids in the diet of Crescent Island Caspian terns was highest in early May during 2011, a week later than the observed peak during the previous 11 years, and generally declined gradually thereafter (Figure 36). Seasonal changes in the proportion of salmonids in the diet probably reflect changes in availability of hatchery-reared smolts near the Crescent Island tern colony. 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 (Figure 31).

We estimated that Caspian terns nesting on Crescent Island consumed 440,000 juvenile salmonids in 2011 (95% c.i. = 360,000 – 520,000), not significantly greater than consumption of juvenile salmonids in 2010 (best estimate = 420,000, 95% c.i. = 300,000 – 530,000). 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 three years (Figure 37). In 2011, steelhead comprised an estimated 15% of the identifiable salmonid smolts consumed, or roughly 84,000 fish. While not significantly greater, this is the highest point estimate of steelhead consumption by the Crescent Island Caspian tern colony in recent years (Figure 38).

Of the bill load fish identified at the Goose Island Caspian tern colony, on average 24% were juvenile salmonids (n = 1,801 identified bill loads). Based on morphological characteristics of the salmonids identified at the colony, we estimate that a minimum of 72% 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 terns commuted over 100 km round trip from the nesting colony to the Columbia River to forage, corroborated by Maranto et al. (2010) and the PIT tag results presented here (see Section 1.4), suggests that availability of forage fish near the nesting colony was limited. In 2011, centrarchids (bass and sunfish) were the most prevalent prey type in the bill loads of Caspian terns nesting on Goose Island (67%), followed by salmonids (24%; Figure 39). The proportion of juvenile salmonids in bill loads of Goose Island Caspian terns was highest in early May (68% of identifiable bill loads), a week later than was observed the previous year (Figure 40). The proportion of salmonids in the bill loads of Goose Island Caspian terns was consistently lower throughout the breeding season compared to that of Caspian terns nesting on Crescent Island (Figure 36).

We estimated that Caspian terns nesting on Goose Island consumed between 97,000 (assuming 1/5 of identified *O. mykiss* were steelhead, the visually confirmed minimum) and 125,000 (assuming all identified *O. mykiss* were steelhead) anadromous juvenile salmonids from the Columbia River in 2011, roughly a quarter the number of juvenile salmonids consumed by Caspian terns nesting on Crescent Island during that same year. We estimate that salmon (i.e., Chinook, coho, or sockeye) comprised between 67% - 86% and steelhead comprised between 14% - 33% (depending on the ratio of steelhead to resident trout) of the total number of anadromous salmonid smolts consumed by Goose Island terns in 2011.

1.3.3. Coastal Washington

No diet composition data were collected for Caspian terns nesting along the Washington coast in 2011.

1.3.4. Interior Oregon and Northeastern California

Methods: The taxonomic composition of the diet of Caspian terns nesting on the tern islands at Crump Lake, East Link, Sheepy Lake, and Tule Lake Sump 1B 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 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. 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 = 1,668) were identified at the Crump Lake colony in 2011. The diet composition of Caspian terns nesting on the Crump Lake tern island in 2011 consisted primarily of centrarchids (crappie, sunfish, and bass; 61% of identifiable prey items), followed by cyprinids (chub, minnows, and carp; 20%) and ictalurids (catfish; 15%; Figure 41). Diet composition at the Crump Lake tern colony was markedly different in 2010-2011 as 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 67% of identifiable prey items during 2010-2011. During 2010-2011 no suckers were observed among the identified prey items. In 2008, five suckers were observed in the bill loads of Caspian terns nesting on the Crump Lake tern island (< 0.1% of identifiable prey items), one of which was positively identified as an ESA-listed Warner sucker (BRNW 2009b), whereas in 2009, one sucker was observed among the identified prey items. This sucker could not be positively identified as a Warner sucker (BRNW 2010b)..

A relatively small number of Caspian tern bill loads (n = 263) were identified at the East Link colony in Summer Lake Wildlife Area during 2011. As was the case in 2009-2010, the diet composition of Caspian terns nesting at Summer Lake Wildlife Area was dominated by cyprinids (primarily Tui chub; 77% of the identifiable prey items), followed by rainbow trout (17.8%; Figure 42). Based on fish watch observations and PIT tag recoveries, suckers were not detected in the diet of terns nesting at Summer Lake Wildlife Area in 2011. 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 relatively large number of Caspian tern bill loads (n = 1,947) were identified at the Sheepy Lake colony in 2011. The diet composition of Caspian terns nesting on the Sheepy Lake tern island was dominated by cyprinids (primarily chub and fathead minnows [*Pimephales promelas*]; 70% of the identifiable prey items), followed by centrarchids (primarily Sacramento perch [*Archoplites interruptus*]; 28% of identifiable prey items; Figure 43). 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.

Finally, a relatively large number of Caspian tern bill loads (n = 1,789) were identified at the Tule Lake Sump 1B colony in 2011. The diet composition of Caspian terns nesting on the Tule Lake Sump 1B tern island was dominated by cyprinids (primarily chub and fathead minnows; 63% of identifiable prey items), followed by centrarchids (primarily Sacramento perch; 36% of identifiable prey items; Figure 44). 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.

1.4. Predation Rates Based on PIT Tag Recoveries

PIT tags are placed in salmonids and other fishes to study their behavior and survival following tagging and release. 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 of using information collected from PIT tags for this study were to (1) determine colony-specific avian predation rates on different salmonid stocks, (2) evaluate whether avian predation rates differ by fish species or evolutionarily significant unit (ESU), (3) assess differences in predation rates based on the location of bird colonies, and (4) evaluate whether predation rates in 2011 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 birds 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 basin was conducted in collaboration with NOAA Fisheries (POC, Richard Ledgerwood) and focused on bird predation of ESA-listed juvenile salmonids. 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 Refuges (POC: 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.

1.4.1 Columbia River Estuary

Methods: The methods described in Evans et al. (2012) were used to recover and analyze PIT tags recovered from bird colonies in the Columbia River basin in 2011. PIT tag antennas were used to recover PIT tags *in situ* during August and September, 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 400 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 birds are subsequently deposited on their nesting colony. An unknown proportion of ingested PIT tags are damaged during digestion or are regurgitated or defecated off-colony at loafing, staging, or other areas utilized by birds during the nesting season (hereafter referred to as 'off-colony PIT tag deposition'). The proportion of consumed PIT tags deposited off-colony by avian predators in 2011 was unknown. Off-colony PIT tag deposition rates were measured for Caspian terns nesting at the Crescent Island colony during the 2004, 2005, and 2006 breeding seasons (BRNW 2007). Results indicated that Caspian terns, on average, deposited between 37% and 24% of ingested PIT tags off-colony during the nesting season. Off-colony PIT deposition rates of other colonial waterbird species (double-crested cormorants, California gulls, ring-billed gulls, American white pelicans, and Brandt's cormorants) evaluated here are unknown, although studies on double-crested cormorants and gulls are planned for 2012. Because data from the other bird species evaluated by this project are not available, the predation rate estimates presented here are minimum estimates of smolt losses based on the number of PIT tags deposited on-colony, corrected for detection efficiency.

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 2011. PIT-tagged smolts were grouped by anadromous salmonid ESU or DPS (hereafter combined and referred to as ESU), with each ESU representing a unique combination of species (Chinook, coho, sockeye, steelhead), run-type (spring, summer, fall, winter), and river-of-origin. The designation of ESUs followed those of NOAA (2011), which included both wild and hatchery-reared fish. All PIT-tagged salmonids that originated from within the geographic boundary of the NOAA-defined ESU were included in the study, as long as the fish was interrogated passing a dam upstream of the bird colony (see Evans et al. 2012 and below).

Availability of PIT-tagged smolts from each ESU 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 rates on PIT-tagged salmonids were calculated using a multi-step approach. First, for each ESA-listed ESU, the proportion of PIT-tagged fish consumed by avian predators on day *j* ($\hat{q}_j$) was estimated by dividing the number of PIT-tagged fish detected at a dam on day *j* that were subsequently recovered on a bird colony (recovered_j) by the total number of salmonids detected passing that dam on day *j* (available_j) (eq. 1).

$$(1)\quad \hat{q}_j = \frac{\text{recovered}_j}{\text{available}_j}$$

Second, we used logistic regression to estimate colony-specific daily detection efficiencies, whereby a binary response of detections (detected/not detected) was modeled as a function of time since control tags were placed on the bird colony (eq. 2):

$$(2)\quad \hat{p}_j = \frac{e^{(\beta_0 + \beta_1 t_j)}}{1 + e^{(\beta_0 + \beta_1 t_j)}}$$

where $\hat{p}_j$ is the probability of detecting a control 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 deposition date. Next, to calculate colony-specific adjusted daily predation rates ($\hat{r}_j$), the proportion of available PIT-tagged salmonids recovered on a bird colony on day *j* ($\hat{q}_j$) was corrected for colony-specific detection efficiency on day *j* ($\hat{p}_j$) (eq. 3).

$$(3)\quad \hat{r}_j = \frac{\hat{q}_j}{\hat{p}_j}$$

To calculate annual predation rates, daily estimates of the total number of PIT-tagged salmonids consumed were summed and divided by the total number of salmonids available within that same time period. Reach-specific (estuary, mid-Columbia, confluence of the Snake and Columbia rivers) predation rates were calculated by summing predation rates from bird colonies in the same reach per salmonid ESU. 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 the model calculation, with each iteration representing a unique bootstrap resample (random sample with replacement) of the observed detection efficiency and salmonid PIT tag datasets. The 2.5th and 97.5th quartiles were used to represent the limits of a bootstrapped 95% confidence interval. In all instances when a bird colony consumed < 0.1% of a given ESU, predation rates were noted as < 0.1%, and presented without confidence intervals due to the proximity of the estimate to zero.

To control for imprecise results that might arise from small sample sizes, estimates of predation rates were only calculated for ESUs when ≥ 500 PIT-tagged salmonids were interrogated passing an upstream dam in a given year. Additionally, only PIT-tagged salmonids 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 and Discussion: Following the nesting season, 19,401 PIT-tagged smolts from the 2011 migration year (Chinook, coho, sockeye, and steelhead combined from all release sites) were recovered on the East Sand Island Caspian tern colony (Table 2). This number expands to an estimated 25,098 smolts, once adjustments are made to account for on-colony PIT tag detection efficiency. Of the control tags sown on the East Sand Island tern colony to measure PIT tag detection efficiency (n = 300), 232 or 77.3% were detected after the nesting season (Table 2).

Based on predation rates of PIT-tagged smolts last detected passing Bonneville Dam (lowermost dam on the Columbia River) or Sullivan Dam (lowermost dam on the Willamette River; Map 1), steelhead were the most susceptible salmonid species to predation by East Sand Island terns in 2011, with minimum predation rates ranging from 6.4% to 8.4% (depending on steelhead ESU; Table 3). Predation rates on Chinook salmon (0.5% to 1.9%) and sockeye salmon (0.2%) ESUs were significantly lower compared to steelhead ESUs. Differences in predation rates among ESUs of the same species (steelhead, Chinook, sockeye) were less than differences among species.

Minimum predation rates on salmonid smolts by East Sand Island terns in 2011 were less than those observed during 2010 (BRNW 2011). In fact, of the ESA-listed ESUs evaluated here, only predation rates on upper Columbia River spring Chinook salmon were similar between 2011 (1.9%; 95% c.i. = 0.9 - 3.1%) and 2010 (2.1%; 95% c.i. = 1.7 - 2.5%, while predation rates on all other ESA-listed ESUs in 2011 were significantly less than those observed in 2010. The minimum predation rate on Snake River steelhead by East Sand Island terns in 2011 (8.4%) was the lowest recorded since 2004 (Evans et al. 2011).

Adequate sample sizes (≥ 500 PIT-tagged fish) were not available for all ESUs originating entirely above Bonneville or Sullivan dams in 2011. For example, there were no known-origin sockeye or winter steelhead PIT-tagged and released into the geographic range of the Lake Wenatchee, Okanogan River, or upper Willamette River ESUs in 2011. It should also be noted that data regarding the impacts of East Sand Island Caspian terns on PIT-tagged smolts originating from lower Columbia River ESUs are not presented here due to the paucity of in-stream PIT tag detectors below Bonneville and Sullivan dams. As such, the impacts of predation by East Sand Island Caspian terns on lower Columbia River ESUs, some of which are ESA-listed (i.e., coho, steelhead), are largely unknown. Sebring et al. (2011) reported minimum Caspian tern predation rates on coho and Chinook salmon released from hatcheries near East Sand Island of 3.1% and 3.6%, respectively, during 2010. How representative these predation rates are for all coho and Chinook salmon in the lower Columbia River ESUs is unknown.

A more comprehensive analysis of PIT tag recoveries on the East Sand Island Caspian tern colony, including an analysis of smolt susceptibility based on rear-type (hatchery, wild) and run-timing, is provided in Evans et al. (2011).

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 9,270 PIT-tagged smolts from the 2011 migration year (Chinook, coho, sockeye, and steelhead combined from all releases) were recovered on the Crescent Island Caspian tern colony (Table 2). This number expands to an estimated 11,734 smolts once adjustments are made to account for on-colony PIT tag detection efficiency. Of the control tags sown on the Crescent Island tern colony to measure PIT tag detection efficiency (n = 200), 158 or 79.0% were detected after the nesting season (Table 2).

Of the available PIT-tagged fish last detected passing Lower Monumental Dam (Snake River) or Rock Island Dam (upper Columbia River; Map 1), minimum predation rates by Crescent Island terns were highest for upper Columbia steelhead (1.7%; 95% c.i. = 1.4 - 2.0%) and Snake River steelhead (1.9%; 95% c.i. = 1.7 - 2.1%) ESUs (Table 4). Predation rates were significantly lower (< 0.6%) for other species (Chinook, sockeye) and ESUs (Table 4). Predation on smolts originating from rivers downstream of Lower Monumental and Rock Island dams but upstream of McNary Dam (i.e., within the foraging radius of Crescent Island terns) on the middle Columbia River are not included here, but are likely smaller because only a fraction of fish originating from these ESUs are susceptible to bird predation (i.e., large numbers of fish from middle Columbia River ESUs enter the river downstream of McNary Dam and are thus not susceptible to predation by Caspian terns nesting at Crescent Island).

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 other predators in McNary pool. This means the impact to each Snake River ESU from avian predation in McNary pool is less than indicated by the predation rate on the in-river migrating portion of the ESU. Transportation rates of Snake River smolts vary considerable by year, with between 20% and 65% of available Snake River smolts collected for transportation during 2007-2010 (FPC 2012). An estimate for 2011 is not yet available, but is likely closer to 20% than 65% due to unusually high river flows and spill regimes at Snake River dams in 2011 (FPC 2012). If 25% of Snake River steelhead were collected for transportation above Ice Harbor Dam in 2011, the in-river predation rate estimate of 1.9% by Crescent Island terns (Table 4) would translate into a predation rate of 1.4% on all (in-river and transported) Snake River steelhead in 2011. Because smolts originating from upper Columbia River ESUs are not collected for transportation above McNary Dam, the in-river estimated predation rate applies to all available fish (i.e., no correction is needed).

Minimum predation rates on ESA-listed ESUs of juvenile salmonids by Crescent Island terns in 2011 were similar to those during 2007-2010, indicating predation rates on salmonid smolts by Crescent Island terns have remained relative constant over the course of the last five nesting seasons. A more detailed analysis of PIT tag recoveries on the Crescent Island Caspian tern colony, including an analysis of smolt susceptibility based on rear-type (hatchery, wild) and run-timing, is provided in Evans et al. (2011).

In addition to Caspian terns nesting on Crescent Island in McNary pool, a small number of terns attempted to nest on Badger Island in 2011 (Map 1). The tern colony on Badger Island, however, was short-lived and did not successfully produce young (see Section 1.2.2). After the colony failed, American white pelicans were observed loafing and using the area where terns attempted to nest on Badger Island. We did scan for PIT tags in the area occupied by nesting terns and recovered 654 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2011 migration year. This number expands to an estimated 886 smolts once adjustments are made to account for on-colony PIT tag detection efficiency (Table 2). Due to the presence of American white pelicans on the tern colony, however, we could not calculate predation rates for terns alone on Badger Island in 2011. As such, minimum predation rates were calculated for a mixed species colony (terns and pelicans) and resulted in an estimated predation rate of ≤ 0.1% for all salmonid ESUs in 2011 (Table 4).

A total of 4,068 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2011 migration year were recovered on the Goose Island Caspian tern colony in Potholes Reservoir, WA (Table 2). This number expands to an estimated 6,837 smolts, once adjustments are made to account for on-colony PIT tag detection efficiency. Of the control tags sown on the Goose Island tern colony to measure PIT tag detection efficiency (n = 400), 238 or 59.5% were detected after the nesting season (Table 2).

Of the PIT-tagged fish last detected passing Rock Island Dam on the upper Columbia River, impacts by Goose Island terns were greatest on steelhead, with an estimated minimum predation rate of 8.9% (95% c.i. = 7.6 - 10.5%) in 2011 (Table 4). This is the highest colony-specific predation rate on a salmonid ESU that was observed in 2011 (Table 4). Predation rates on other salmonid species and ESUs by Caspian terns nesting on Goose Island were significantly lower (< 0.6% per ESU; Table 4) than those on steelhead. Predation by Goose Island terns on Snake River salmonids were especially low, with < 0.1% of available PIT-tagged smolts consumed (Table 4). Predation rates on upper Columbia River steelhead by terns nesting on Goose Island in 2011 were not significantly different from predation rates observed in 2010 (9.6%; 95% c.i. = 8.3 - 11.2%) but were generally lower than those observed in 2009 (Evans et al. 2011). A more detailed analysis of the impact of Goose Island Caspian terns on steelhead from the upper Columba River ESU during 2008-2011 is provided in Section 4 of this report.

Following the nesting season, a total of 302 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2011 migration year were recovered on the Blalock Islands Caspian tern colony (Table 2). This number expands to an estimated 368 PIT-tagged smolts once adjustments are made to account for on-colony PIT tag detection efficiency. Of the control tags sown on the Blalock Islands tern colony to measure PIT tag detection efficiency (n = 100), 82 or 82.0% were detected after the nesting season (Table 2). The estimate of 368 smolt PIT tags is the lowest number recovered on this colony since scanning was initiated in 2007 (Evans et al. 2011).

Caspian tern predation rates on the Blalock Islands in 2011 were also the lowest recorded since 2007 (Evans et al. 2011), with minimum predation rates ≤ 0.2% on all ESUs evaluated. Overall, results from 2011 indicated that the Blalock Islands tern colony posed little risk to salmonid smolt survival, especially compared to other tern colonies in the region. These low predation rates, however, are associated with the small size of the colony (ca. 20 breeding pairs; Figure 11) and the failure of the colony to produce any young (see Section 1.2.2) and not the colony's reliance on salmonids as a food source. For example, if the Blalock Islands tern colony were to expand, estimates of per capita predation rates suggest that terns at this colony would consumed a similar percentage of available smolts, per adult tern, to terns nesting on Crescent and Goose islands (Evans et al. 2012).

1.4.3 Coastal Washington

There was no attempt to recover smolt PIT tags from Caspian tern colonies in coastal Washington during 2011.

1.4.4 Interior Oregon and Northeastern California

Methods: Similar to salmonids in 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 2011 we continued to evaluate the impacts of Caspian terns nesting at the Summer Lake, Crump Lake, and Sheepy Lake (Map 2) tern islands on survival of suckers by recovering PIT tags after the nesting season. We also investigated the impact of tern predation on survival of suckers at the newly constructed Tule Lake Sump 1B tern island in Tule Lake NWR. 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.

PIT tag antennas were used to recover PIT tags *in situ* after birds dispersed from their nesting colonies (September to October). PIT tags were detected by systematically scanning the entire area occupied by birds during the nesting season, with a minimum of two passes made at each colony. Detection efficiency data were collected from Caspian tern colonies and, to a lesser extent, from double-crested cormorant, American white pelican, and other piscivorous waterbird colonies (see Sections 2.4 and 3.3) by intentionally sowing control tags on-colony (see Section 1.4 for details). Due to uncertainties regarding the date when PIT-tagged suckers were consumed by birds following their release and a lack of detection efficiency data at some colonies, however, it was not possible to model detection efficiency with logistic regression as a function of time (as was done for juvenile salmonids; see Section 1.4). Similarly, the total number of PIT-tagged suckers available to birds during the nesting season could not be precisely estimated due to a lack of in-season detection histories for PIT-tagged suckers. Each year, the total number of suckers available to birds was based on the number of suckers that were PIT-tagged and released within the basin (Klamath or Warner) where the bird colony was located. The total number of released suckers each year does not account for sources of mortality that occurred following release but prior to the bird breeding season, however, and therefore overestimates the availability of PIT-tagged suckers to avian predators to an unknown degree.

Data on the impact of tern colonies on sucker survival were evaluated to determine how many fish were consumed of each species (i.e., Lost River, shortnose, Warner, Klamath largescale, or unknown sucker species) and release location (i.e., Clear Lake, Upper Klamath Lake, Lower Klamath Lake, Crump Lake, Gerber Reservoir, Lake Ewauna, and their tributaries). Due to uncertainties regarding when sucker PIT tags were consumed and a lack of detection efficiency data at particular bird colonies, we did not attempt to correct the number of tags recovered by researchers for on-colony detection efficiency, although we provide results of detection efficiency trails where data are available. Similar to results from PIT-tagged juvenile salmonids (see Section 1.4), sucker PIT tag recoveries were not adjusted for the number of ingested tags that were deposited by birds off-colony (i.e., at loafing areas away from the colony) because data on off-colony deposition rate are not currently available. As such, the number of sucker PIT tags deposited on a bird colony that were subsequently recovered by researchers represents a minimum estimate of the number consumed by birds. In 2011, we continued to investigate the association between the size (fork-length) and age-class (juvenile, adult) of suckers consumed by birds and deposited on their colonies, when possible.

Results and Discussion: We searched the Crump Lake tern island (Map 2) for PIT tags following each of the 2008-2011 nesting seasons. Only one PIT tag was recovered during the four years, a sucker tag recovered following the 2008 nesting season. The PIT tag was from a 22-cm Warner sucker that was captured and released by ODFW into Crump Lake in June 2008. Based on PIT tags sown by researcher's prior to the nesting season (n = 50), detection efficiency on the Crump Lake tern island was estimated at 94.0% in 2008. No sucker PIT tags were recovered following the 2009-2011 nesting seasons on Crump Lake tern island.

A total of 930 Warner suckers were PIT-tagged and released into Warner Valley lakes (n = 131) or streams (n = 799) during 2008-2011 (P. Sheerer, ODFW, unpublished data). The small number (n = 1) and percentage (0.1%) 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.

We searched the Sheepy Lake Caspian tern island (Map 2) in Lower Klamath NWR for sucker PIT tags following the 2010 and 2011 nesting seasons. No sucker PIT tags have been found on the island to date. Detection efficiency of PIT tags sown on the island prior to and after the nesting season (n = 100) was 82% in 2011, indicating the probability of missing a sucker PIT tag deposited on-colony was low.

Similar to results from the Sheepy Lake tern colony, no sucker PIT tags were found at the newly established Caspian tern colony at Tule Lake Sump 1B in 2011. Detection efficiency of PIT tags at the Tule Lake tern island was also high, with 86% of PIT tags sown prior to and after the nesting season (n = 50) recovered by researchers.

Data from the Sheepy Lake and Tule Lake Caspian tern colonies suggest that sucker losses to Caspian terns were minimal in 2011. The US Geological Survey PIT-tagged and released a total of approximately 4,300 Lost River suckers and 2,500 shortnose suckers from the fall of 2010 to the spring/summer of 2011, plus there have been thousands of additional suckers PIT-tagged in years past (D. Hewitt, USGS, pers. comm.). Although no PIT-tagged suckers were found on the Sheepy Lake and Tule Lake tern islands in 2011, two juvenile suckers was observed as tern bill loads, one at the Sheepy Lake tern colony and one at Tule Lake tern colony in 2011 (see Section 1.3.4), indicating that terns did consume suckers, albeit rarely. Because these fish was not tagged, however, it is not known whether they were ESA-listed suckers or non-listed suckers (e.g., Klamath largescale sucker).

See Section 3.3.4 for additional information on sucker PIT tag recoveries on bird colonies in the Upper Klamath and Warner basins during 2009-2011.

1.5. Color banding and band re-sightings

In 2011, 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, age at first reproduction, and survival rates for Caspian terns in the Pacific Coast population. 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 2011, 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 – 2010) were re-sighted on the East Sand Island tern colony by researchers using binoculars and spotting scopes 5-7 days a week throughout the 2011 breeding season. In this report, numbers of terns re-sighted with a complete set of color bands, thus banding location, year, and age were identifiable, are presented.

Results and Discussion: In 2011, a total of 888 previously color-banded Caspian terns were re-sighted at the East Sand Island tern colony. Of the 888 re-sighted terns, 829 (93%) were banded at East Sand Island (316 as adults and 513 as chicks), 33 (4%) were banded at Crescent Island (5 as adults, 28 as chicks), 12 (1%) were banded as chicks at Dungeness Spit, 7 (< 1%) were banded as chicks at Brooks Island or Knight Island in San Francisco Bay, 5 (< 1%) were banded as chicks at Goose Island or Solstice Island in Potholes Reservoir, and 1 (< 1%) was banded as a chick at Crump Lake tern island. Band re-sightings at the East Sand Island tern colony indicate that terns are moving from both inland and coastal colonies to the East Sand Island colony.

Age at first breeding of Caspian terns banded as chicks at East Sand Island and observed breeding at their natal colony ranged from 4 to 9 years post-hatch. Apparent median age of first breeding was 6 years post-hatch, older than the previously reported age at first breeding (3-4 years post-hatch). The apparent (local) survival rate of terns banded as adults at East Sand Island was 0.95 (95% c.i. = 0.92-0.97).

1.5.2. Columbia Plateau

Methods: In 2011, 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 bird from a distance, such that the banding location (colony), banding year, and age of the bird at banding are known. Tern chicks that were too small to be color-banded were banded with a federal numbered metal band only.

Adults 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 2011 at the Crescent Island and Goose Island tern colonies 3 days/week throughout the breeding season.

Results and Discussion: At Crescent Island, 32 adult Caspian terns and 147 tern chicks near fledging age were color-banded and 12 smaller tern chicks were metal-banded in 2011. At Goose Island, 61 adult Caspian terns and 124 tern chicks near fledging age were color-banded and 11 smaller tern chicks were metal-banded in 2011.

In 2011, a total of 186 previously color-banded Caspian terns were re-sighted at the Crescent Island colony and 114 previously color-banded Caspian terns were re-sighted at the Goose Island colony. Of the 186 banded terns re-sighted at the Crescent Island colony, 166 (89%) were banded at Crescent Island (72 as adults and 94 as chicks), 13 (7%) were banded at Goose Island (12 as adults and 1 as a chick), 6 (3%) were banded at East Sand Island (3 as adults and 3 as chicks), and 1 (< 1%) was banded as a chick at Crump Lake tern island. Of the 114 banded terns re-sighted at Goose Island, 57 (50%) were banded at Goose Island or Solstice Island in Potholes Reservoir (41 as adults and 16 as chicks), 41 (36%) were banded at Crescent Island (7 as adults and 34 as chicks), and 16 (14%) were banded at East Sand Island (2 as adults and 14 as chicks).

Movements of adult Caspian terns between the colony at East Sand Island and the colonies in the Columbia Plateau region appeared to be mostly unidirectional up until 2011; little movement of banded adults from the Columbia River estuary to the Columbia Plateau colonies was confirmed, whereas some individuals banded as adults at Crescent Island were re-sighted at East Sand Island. In 2011, however, we confirmed movements of adults banded at East Sand Island to both Crescent Island and Goose Island. This is likely because of the intense disturbance by bald eagles and associated gull predation on tern eggs and chicks at the East Sand Island colony in 2011. Band re-sightings at the Crescent Island and Goose Island tern colonies indicate that there is substantial inter-colony movement of terns between these two colonies.

Age at first breeding of terns banded as chicks at Crescent Island and observed breeding at their natal colony ranged from 3 to 7 years post-hatch. Apparent median age of first breeding was 5 years post-hatch. Apparent survival rate of terns banded as adults at Crescent Island was 0.94 (95% c.i. = 0.90-0.96), similar to that of adults banded at East Sand Island.

1.5.3. Coastal Washington

Methods: In 2011, band re-sightings were conducted on four separate visits to the Dungeness Spit tern colony from early May to early July.

Results and Discussion: A total of 8 previously color-banded Caspian terns were re-sighted at the Dungeness Spit colony; 7 were banded at East Sand Island (2 as adults and 5 as chicks), and 1 was banded as a chick at Brooks Island in San Francisco Bay.

Terns banded at the Dungeness Spit colony were re-sighted at the East Sand Island colony and vice versa, as in previous years. This confirms continued movements between the two colonies.

1.5.4. Interior Oregon and Northeastern California

Methods: The methods for capture and banding of Caspian terns at colonies in northeastern California were the same as those described in Section 1.5.2. Most adult terns color-banded at the colonies on Sheepy Lake in Lower Klamath NWR and at Tule Lake Sump 1B in Tule Lake NWR were also fitted with GPS data loggers in order to test the feasibility of using remotely downloadable GPS data loggers to assess foraging behavior and habitat use by nesting Caspian terns (results from this feasibility study will be presented in a subsequent report). Terns that were color-banded in previous years were re-sighted at the Sheepy Lake tern island, Tule Lake Sump 1B tern island, Orems Unit tern island, Summer Lake tern islands (East Link and Dutchy Lake), and Crump Lake tern island 3 days per week throughout the 2011 breeding season.

Results and Discussion: In 2011, 22 adult Caspian terns were color-banded at colonies in northeastern California, 11 each at the Sheepy Lake and Tule Lake Sump 1B tern colonies. At the Sheepy Lake tern colony, 19 tern chicks near fledging age were color-banded. At the Tule Lake tern colony, 3 tern chicks near fledging age were color-banded and 2 smaller chicks were metal-banded.

In 2011, a total of 85 previously color-banded Caspian terns were re-sighted at the colony on Sheepy Lake tern island in Lower Klamath NWR; 44 (52%) were banded at East Sand Island (8 as adults and 36 as chicks), 17 (20%) were banded at Crump Lake (9 as adults and 8 as chicks), 12 (14%) were banded as chicks at Crescent Island, 6 (7%) were banded as chicks at Goose Island or Solstice Island in Potholes Reservoir, 3 (4%) were banded as adults at Sheepy Lake tern island, 1 (1%) was banded as an adult at East Link tern island in Summer Lake Wildlife Area, 1 (1%) was banded as a chick at Dungeness Spit, and 1 (1%) was banded as a chick at Knight Island in San Francisco Bay. A total of 89 previously color-banded Caspian terns were re-sighted at the colony on Tule Lake Sump 1B and 17 previously color-banded Caspian terns were re-sighted at the colony on Orems Unit. Of the 89 color-banded terns that were re-sighted at the Tule Lake Sump 1B colony, 42 (47%) were banded at East Sand Island (10 as adults and 32 as chicks), 18 were banded at Crescent Island (1 as an adult and 17 as chicks), 13 (15%) were banded at Crump Lake (7 as adults and 6 as chicks), 8 (9%) were banded at Goose Island or

Solstice Island in Potholes Reservoir (2 as adults and 6 as chicks), 3 (3%) were banded as adults at Sheepy Lake tern island, 2 (2%) were banded as chicks at Dungeness Spit, 2 (2%) were banded as chicks at Brooks Island in San Francisco Bay, and 1 (1%) was banded as a chick at a tern colony in the Copper River Delta, Alaska. Of the 17 color-banded terns that were re-sighted at the Orems Unit tern island, 6 (35%) were banded at Crescent Island (1 as an adults and 5 as chicks), 5 (30%) were banded at East Sand Island (2 as adults, 3 as chicks), 4 (24%) were banded a Crump Lake (3 as adults and 1 as a chick), 1 (6%) was banded as a chick at Goose Island in Potholes Reservoir, and 1 (6%) was banded as an adult at Sheepy Lake tern island.

A total of 58 previously color-banded Caspian terns were re-sighted at the Crump Lake tern island and 14 previously color-banded Caspian terns were re-sighted at the East Link tern island at Summer Lake Wildlife Area. Of the 58 color-banded terns that were re-sighted at the Crump Lake colony, 24 (41%) were banded at Crump Lake (18 as adults and 6 as chicks), 14 (24%) were banded at Crescent Island (1 as an adult and 13 as chicks), 6 (17%) were banded at East Sand Island (2 as adults and 8 as chicks), 7 (12%) were banded at Goose Island in Potholes Reservoir (2 as adults and 5 as chicks), 1 (2%) was banded as an adult at Summer Lake, 1 was banded as an adult at Sheepy Lake, and 1 (2%) was banded as a chick at Brooks Island in San Francisco Bay. Of the 14 color-banded terns that were re-sighted at East Link tern island in Summer Lake Wildlife Area, 4 (29%) were banded as chicks at Crescent Island, 4 (29%) were banded at Goose Island in Potholes Reservoir (1 as an adult and 3 as chicks), 4 (29%) were banded at East Sand Island (1 as an adult and 3 as chicks), and 2 (14%) were banded at Crump Lake tern island (1 as an adult and 1 as a chick).

Re-sightings of banded Caspian terns at the newly established colonies at Tule Lake Sump 1B in Tule Lake NWR and at Orems Unit in Lower Klamath NWR revealed that terns banded at several different colonies, both coastal and interior, were quick to find the new nesting habitat provided there. Terns originally banded at East Sand Island were re-sighted at five tern colonies on islands built for that purpose in interior Oregon and northeastern California; all of these tern islands are more than 400 km from East Sand Island. Movements of banded Caspian terns among the alternative tern nesting islands built in interior Oregon and northeastern California were also documented.

Continued banding and re-sighting at all Caspian tern colony sites in the region will be necessary to confirm whether observed trends in inter-colony movements, age at first breeding, and adult apparent survival rates are consistent across years and among colonies in the Columbia River basin and at alternative tern colony sites. Survival rates from fledging to one year post-hatch and from one year post-hatch to recruitment into the breeding population also need to be investigated to better understand the status and trend of the Caspian tern population in the region.

SECTION 2: DOUBLE-CRESTED CORMORANTS

2.1. Nesting Distribution and Colony Size

2.1.1. Columbia River Estuary

Methods: High resolution aerial photography of the double-crested cormorant colony on East Sand Island was taken late in the incubation period in order to estimate the peak size of the colony. Multiple counts of the number of attended nests were used to estimate the total number of breeding pairs. A major source of uncertainty in past bioenergetics estimates of smolt consumption by East Sand Island cormorants has been colony size across the breeding season (at times other than during late incubation, when the colony is censused from aerial photography). In previous years, we used estimates of colony size made from blinds or from boats just off shore. Such estimates are limited in precision due to poor visibility of birds behind vegetation, debris, and other birds. During 2008-2011, we implemented a new approach to estimating colony size across the breeding season by expanding the use of aerial photography. In addition to the photography taken during late incubation (early June), high resolution aerial photography of the colony was taken approximately every 2 weeks throughout the season, beginning in early May and concluding in early September. In total, aerial photography of the entire cormorant colony was taken nine times (including the late incubation photography). To count active nests in this additional aerial photography of the East Sand Island cormorant colony (as well as count aerial photography of other colonies of terns, gulls, etc.), we developed a GIS-equipped computer workstation where digitized photography could be viewed and birds counted.

Boat-based and aerial surveys of 12 navigational markers near Miller Sands Spit and Fitzpatrick Island (river km 38 and 53, respectively) were conducted 1 - 3 times per month from early April through late July in 2011. Because nesting chronology varied among the different channel marker groups, the number of 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 an 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 the navigational markers and check nests to estimate productivity.

Four boat-based surveys of the Astoria-Megler Bridge in the Columbia River estuary were conducted from mid-May to mid-July 2011. Our vantage point from a boat enabled us to get an exact count of the number of attended nests on the underside of the bridge; however, visual confirmation of eggs and very small chicks was not possible. Any well-maintained nest structure that was attended by an adult was considered active, along with any nests containing visible nestlings.

Periodic boat-, land-, and air-based surveys were also conducted to monitor the former social attraction sites where double-crested cormorants previously nested on Rice Island

and Miller Sands Spit. During these surveys researchers looked for indications of nesting activity by cormorants.

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 (Anderson et al. 2004; L. Wires, University of Minnesota, pers. comm.; T. King, USDA-Wildlife Services, pers. comm.). We estimated that 13,045 breeding pairs (95% c.i. = 12,517 – 13,573 breeding pairs) attempted to nest at East Sand Island in 2011, compared to 13,596 breeding pairs (95% c.i. = 13,130 – 14,062 breeding pairs) in 2010. The East Sand Island double-crested cormorant colony experienced unprecedented growth from 1997 to 2007, nearly tripling in size during that period (Figure 45). Then in 2008, the colony experienced an unexpected decline (20%) before rebounding to nearly its peak size by 2010 (Figure 45). 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 population trends at the East Sand Island colony.

Prior to 1999, 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 in satellite colonies in the adjacent low-lying habitat. Based on the apparent habitat preferences of nesting cormorants, there is currently ample unoccupied habitat on East Sand Island, which could support further expansion of the colony for the foreseeable 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 limit the size of the colony in the future.

In 2011, a maximum of 248 pairs of double-crested cormorants nested on 12 channel markers located in the upper Columbia River estuary near Miller Sands Spit (n = 8 channel markers) and near Fitzpatrick Island (n = 4 channel markers), similar to the count from the previous year (254 breeding pairs). Our counts of attended nests at the Miller Sands channel marker group peaked in late June, whereas the peak count at the Fitzpatrick Island channel markers occurred in early June.

In 2011, we again observed double-crested cormorants nesting near the pelagic cormorant colony on the Astoria-Megler Bridge. During three boat-based censuses from 17 May to 20 June, about 60 nests were attended by double-crested cormorants, similar to the peak attended nest count in June 2010.

2.1.2. Columbia Plateau

Methods: Counts of attended nest structures were used to estimate the size of the double-crested cormorant colony on Foundation Island in 2011 (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 in 2011.

In 2011, we conducted two aerial surveys (18-19 May and 2 July) in the Columbia Plateau region 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 nests to obtain an estimate of the number of breeding pairs at each colony.

Results and Discussion: In 2011, the double-crested cormorant colony on Foundation Island consisted of a minimum of 318 breeding pairs (Figure 46), similar to the size of this colony during the previous two years and still the largest cormorant 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 in 2009-2011 (Figure 46). Data on colony attendance indicated that, in 2011, the Foundation Island cormorant colony reached its maximum size in mid-May, two weeks later than the average, based on data from previous years (Figure 47).

On 20 April 2011, 15 double-crested cormorants were discovered in the trees on Crescent Island, one of which was attending a nest. We were not able to confirm if eggs were laid before the nest was abandoned early in the breeding season. Double-crested cormorants first attempted to nest on Crescent Island in 2010; all of these nesting attempts (2-3) subsequently failed on or before 14 June of that year. The cause of nest failure at this incipient colony is unknown.

On 25 June, two double-crested cormorants were attending nests on Miller Rocks, an island group on the Columbia River just upstream of the mouth of the Deschutes River. We were not able to confirm whether eggs were laid before the nests were abandoned in late July. Double-crested cormorants last attempted to nest on Miller Rocks in 2006, when five breeding pairs were counted. Factors limiting double-crested cormorant colony size and productivity at this incipient colony are unknown.

The largest double-crested cormorant colony in the entire Columbia Plateau region is on Potholes Reservoir in North Potholes Reserve, where ca. 900 breeding pairs nested in 2011 (Figure 48). This colony has gradually declined in size from ca. 1,150 breeding pairs in 2006 to 800-900 breeding pairs in 2009-2011 (Figure 48). 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 32 breeding pairs at this colony in 2011, larger than in 2010 (26 breeding pairs).

We estimated that 107 breeding pairs of cormorants nested at the colony on Harper Island in Sprague Lake in 2011, more than in 2010 (86 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, mid-, and upper Columbia River and lower Snake River revealed no other double-crested cormorant colonies in 2011.

There was of total of six active double-crested cormorant colonies in the Columbia Plateau region in 2011, where a total of approximately 1,350 breeding pairs nested (Figure 49). This suggests that the number of double-crested cormorants nesting in the Columbia Plateau region has remained relatively stable since 2005, when the number of breeding double-crested cormorants was estimated at ca. 1,150 breeding pairs (Figure 50).

2.1.3. Coastal Washington

Methods: In 2011, we surveyed for double-crested cormorant nests on 12 channel markers in Grays Harbor, WA during three aerial survey flights from early May to late June. No boat-based surveys of nesting cormorants were conducted in Grays Harbor during 2011. Three new channel markers were surveyed for cormorant nests in 2011.

Results and Discussion: We counted a maximum of 137 double-crested cormorant nests on eight different channel markers during the late June aerial survey of Grays Harbor.

2.1.4. Interior Oregon and Northeastern California

Methods: In 2011, we conducted three aerial surveys (15 June, 13 July, and 26 July) in interior Oregon and northeastern California (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 2011, double-crested cormorants were confirmed to be nesting at seven different locations; Upper

Klamath NWR (ca. 250 individuals at two different sites), Clear Lake NWR (ca. 95 individuals), Malheur Lake (ca. 140 breeding pairs at two different sites), Sheepy Lake in Lower Klamath NWR (ca. 55 individuals), Pelican Lake in the Warner Valley (38 breeding pairs), Meiss Lake, CA (ca. 35 individuals), and Swan Lake, OR (8 individuals).

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 2011 (Map 5). The blinds were accessed via above-ground tunnels to prevent disturbance to nesting cormorants and gulls, as well as roosting California brown pelicans.

In 2011, nesting attempts by 190 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.

Monitoring of nesting cormorants on channel markers in the upper estuary and on the Astoria-Megler Bridge was conducted periodically (1 – 4 times per month) from a boat.

Results and Discussion: We estimated that 17,385 fledglings (95% c.i. = 12,132 – 22,568 fledglings) were produced at the East Sand Island cormorant colony in 2011. This corresponds to an average productivity of 1.33 young raised per breeding pair (95% c.i. = 0.93 – 1.73 fledglings/breeding pair), significantly lower than productivity in the previous five years (Figure 51). While recent improvements in ocean conditions may have contributed to above average nesting success at the East Sand Island cormorant colony in recent years, predation and associated disturbance by bald eagles during late May and late June 2011 contributed to significant nest failure in some areas of the colony and lower overall productivity in 2011.

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 cormorant chicks were observed on 20 June on the channel markers and on 15 July on the Astoria-Megler Bridge during the 2011 nesting season. Due to poor vantage and infrequent visits, we were not able to estimate nesting success for cormorants that bred on the upper estuary channel markers or the Astoria-Megler Bridge.

2.2.2. Columbia Plateau

Methods: We monitored nesting attempts by 62 cormorant breeding pairs at the Foundation Island colony from the observation blind in 2011, employing weekly visits from mid-April through late July. Productivity was estimated from the number of chicks in monitored nests 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 chicks were approximately 10 days old when first observed. While productivity was not estimated at other cormorant colonies in the Columbia Plateau region, field visits and/or aerial surveys were conducted to assess the colony size and stage of breeding during the chick-rearing period.

Results and Discussion: Productivity at the Foundation Island cormorant colony averaged 2.71 fledglings/nest (95% c.i. = 2.41 – 3.01 fledglings/nest) in 2011, similar to the estimate from 2010, but high in comparison to productivity at this colony in previous years (Figure 52). Double-crested cormorants nesting at North Potholes Reservoir and Harper Island were successful in rearing young to fledging in 2011. At the Okanogan colony, several nests contained nestlings on 8 June, but the site was not checked subsequently.

2.2.3. Coastal Washington

Although it is unknown whether double-crested cormorants nesting on channel markers in Grays Harbor were successful in rearing young to fledging in 2011, chicks were observed on one channel marker in late June.

2.2.4. Interior Oregon and Northeastern California

Methods: Most of the breeding colonies of double-crested cormorants in interior Oregon and northeastern California were visited late in the breeding season to determine if they were successful in rearing young.

Results and Discussion: Double-crested cormorants nesting at Clear Lake NWR; Malheur Lake; and Pelican Lake, Warner Valley were successful in rearing young to fledging in 2011. Nesting success at the other cormorant colonies in interior Oregon and northeastern California (i.e., Upper Klamath NWR, Sheepy Lake in Lower Klamath NWR, Meiss Lake, CA, and Swan Lake, OR) in 2011 is unknown.

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 5-20 adult foregut (stomach and esophagus) contents samples per week. Immediately after collection, the 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.

Laboratory analysis 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 tissues. 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[1] analyses. Unidentifiable fish soft tissue samples were artificially digested (work that is ongoing) according to the methods of Petersen et al. (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 in 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 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 (after the Caspian tern model described in Roby et al. 2003). We used a Monte Carlo simulation procedure to estimate 95% confidence intervals for estimates of smolt consumption by cormorants.

Results and Discussion: Based on identifiable fish tissue in foregut samples, juvenile salmonids comprised 19% of double-crested cormorant diets (by mass) at East Sand Island in 2011 (n = 135 adult foregut samples or a total of 24,788 g of identifiable fish tissue). The annual proportion of juvenile salmonids in the diet of double-crested cormorants nesting on East Sand Island in 2011 was the second highest ever recorded at that colony (24.6% of biomass in 1999; Figure 53).

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 54) than that of Caspian terns nesting on the same island (Figure 30). On average, anchovy is the single most prevalent prey type for cormorants, followed by various marine and freshwater taxa (Figure 54). In 2011, the prey category "other" consisted of nine different taxa, all less than 3% of the diet, with the exception of stickleback, which was 12% of the diet. The peak in the proportion of salmonids in the diet of double-crested cormorants nesting on East Sand Island during 2011 was in late May, approximately two weeks later than was observed in previous years (Figure 55).

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[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). Samples identified as Chinook salmon were genotyped with 13 standardized microsatellite DNA markers (Seeb et al. 2007). Stock origins of individual Chinook salmon were estimated using standard genetic assignment methods (Van Doornik et al. 2007).

Our best estimate of total smolt consumption by double-crested cormorants nesting on East Sand Island in 2011 was 20.5 million smolts (95% c.i. = 15.2 – 25.9 million), a modest (and non-significant) increase in the number of smolts consumed during the previous year. This is the highest point estimate of annual smolt consumption by cormorants nesting on East Sand Island ever calculated (Figure 56). In general, annual smolt consumption by double-crested cormorants nesting on East Sand Island has been trending upward since 2003 (Figure 56). As in other recent years, estimates of smolt consumption by East Sand Island cormorants were significantly higher than that of Caspian terns nesting on East Sand Island in 2011 (Figure 32). Of the juvenile salmonids consumed in 2011, we estimated that 76% were sub-yearling Chinook salmon (best estimate = 15.6 million smolts; 95% c.i. = 10.6 – 20.7 million), 13% were coho salmon (best estimate = 2.7 million smolts; 95% c.i. = 2.1 – 3.4 million), 6% were steelhead (best estimate = 1.2 million smolts; 95% c.i. = 0.9 – 1.4 million), 4% were yearling Chinook salmon (best estimate = 0.9 million smolts; 95% c.i. = 0.7 – 1.1 million), and 0.4% were sockeye salmon (best estimate = 0.01 million smolts; 95% c.i. = 0.00 – 0.05 million; Figure 57).

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 2005-2010 breeding seasons. Double-crested cormorants were not lethally collected for diet composition analysis in 2011. 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 sampled during seven different time periods (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). Contents of these collected foreguts 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 percent 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 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 mass) at the Foundation Island colony in 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 58). On average, centrarchids (bass and sunfish) are the single most prevalent prey type for Foundation Island cormorants (Figure

59). 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, despite a somewhat smaller colony size and less specialization on salmonids as a food source, Foundation Island cormorants consumed more salmonid biomass than Caspian terns nesting on Crescent Island, due primarily to the larger body size of cormorants and consequent greater individual energy requirements (Lyons et al. 2011a, 2011b). Point estimates of salmonid biomass consumed annually by Foundation Island cormorants ranged from 19,600 kg to 24,700 kg during 2004-2009 (corresponding to approximately 470,000 to 880,000 smolts consumed annually). Using diet data collected during 2005-2010, and data on colony size and productivity in 2011, we estimated that Foundation Island cormorants consumed 24,700 kg of juvenile salmonids (95% c.i. = 19,100 – 30,300 kg) in 2011. As in previous years, this was significantly greater than salmonid consumption by the Crescent Island Caspian tern colony (14,700 kg in 2011; 95% c.i. = 12,200 – 17,200 kg).

2.3.3. Coastal Washington

No diet composition data were collected for double-crested cormorants nesting along the Washington coast in 2011.

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, 22,863 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2011 migration year were recovered on the East Sand Island double-crested cormorant colony (Table 2). This number expands to an estimated 31,843 PIT-tagged smolts once adjustments are made to account for on-colony PIT tag detection efficiency (Table 2). Of the control tags sown on the East Sand Island cormorant colony to measure PIT tag detection efficiency (n = 400), 287 or 71.8% were detected after the nesting season (Table 2). The estimated number of smolt PIT tags deposited on the East Sand Island cormorant colony was the greatest for all bird colonies scanned in the Columbia River basin in 2011, followed by the Caspian tern colony on East Sand Island and the Caspian tern colony on Crescent Island (Table 2).

Based on minimum predation rates of PIT-tagged smolts last detected passing Bonneville or Sullivan dams (Map 1), steelhead ESUs were the most susceptible salmonid species to predation by East Sand Island cormorants, with minimum predation rates of 2.6% to 5.5% (depending on steelhead ESU; Table 3). Predation rates on salmon ESUs were generally lower and ranged from 1.0% to 2.6%, with the exception of predation on Upper Willamette River spring Chinook at 0.1% (Table 3). Overall predation rates on salmonid ESUs by cormorants nesting on East Sand Island in 2011 were similar to those observed in 2010 (BRNW 2011). Compared to Caspian terns nesting on East Sand Island, predation by cormorants on salmon (Chinook, coho) ESUs were often significantly higher than predation by Caspian terns on the same salmon ESUs (Table 3). Conversely, predation rates by East Sand Island Caspian terns on steelhead ESUs were significantly greater compared to predation by East Sand Island cormorants on the same steelhead ESUs. This finding is supported by bioenergetics modeling results that indicated double-crested cormorants consumed more salmon but fewer steelhead relative to Caspian terns nesting on East Sand Island in 2011 (Figure 57).

Data regarding the impacts of East Sand Island cormorants on PIT-tagged smolts originating from lower Columbia River (LCR) ESUs are not presented here due to the paucity of in-stream PIT tag detectors below Bonneville and Sullivan dams. PIT tag data from Sebring et al. (2011) indicated that cormorant predation rates on fall Chinook salmon (ca. 16%) and coho salmon (ca. 11%) released from hatcheries near the East Sand Island colony were substantially higher than those of PIT-tagged fish last detected passing Bonneville Dam in 2010. Predation rate estimates for Chinook and coho salmon from the entire lower Columbia River ESUs, however, are not available because a representative sample of PIT-tagged fish by location (geographic boundary), by origin (hatchery, wild), and by outmigration timing are not available. Predation rates on hatchery-reared fall Chinook salmon smolts released in close proximity to the East Sand Island cormorant colony are likely higher than those on all fish from the LCR ESU because large numbers of LCR fall Chinook salmon originate upstream of Bonneville Dam (FPC 2012), where measured predation rates are considerably less than those reported by Sebring et al. (2011), and because predation rates on wild fish may be lower than those on hatchery-reared fish (Evans et al. 2011). More research is needed to understand the impact of cormorant predation on LCR ESUs, but the limited data currently available suggest these fish may be more susceptible to predation by double-crested cormorants on East Sand Island compared to ESUs originating further upriver.

Similar to the PIT tag data obtained from Caspian terns, it is important to note that the predation rates presented here do not account for off-colony PIT tag deposition (the proportion of ingested PIT tags that are damaged during digestion or deposited somewhere other than on the colony). We are currently conducting studies on the East Sand Island cormorant colony to more precisely quantity off-colony PIT tag deposition rates, and results from this study will be used to produce a more accurate estimate of predation rates based on PIT tag recoveries in the future.

A more comprehensive analysis of PIT tag recoveries on the East Sand Island double-crested cormorant colony, including an analysis of smolt susceptibility based on rearing-type (hatchery, wild) and run-timing, is provided in Evans et al. (2011).

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 the same as those described for Caspian terns in Section 1.4.1.

Results and Discussion: Following the nesting season, 4,481 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2011 migration year were recovered on the Foundation Island double-crested cormorant colony (Table 2). This number expands to an estimated 8,376 smolts once adjustments are made to account for on-colony PIT tag detection efficiency (Table 2). Of the control tags sown on the Foundation Island cormorant colony to measure PIT tag detection efficiency (n = 200), 107 or 53.5% were detected after the nesting season (Table 2). This is the lowest detection efficiency estimate recorded on Foundation Island since control tags were initially sown in 2004. Since detection efficiency peaked at 74% in 2008 (Evans et al. 2011), there has been a steady decline in detection efficiency each year. This decline is most likely associated with increasing PIT tag collision on the island, a phenomenon that renders PIT tags unreadable due to accumulating PIT tags on-colony (Evans et al. 2011). Storms, flooding, and other environmental factors may naturally remove or destroy these accumulating tags, which could reduce the effect of tag collision on detection efficiency at the Foundation Island cormorant colony.

Of the available PIT-tagged fish last detected passing Lower Monumental Dam or Rock Island Dam (Map 1), minimum predation rates by Foundation Island cormorants were highest on Snake River steelhead (1.8%), followed by predation rates on Snake River sockeye salmon (0.6%) and Snake River spring/summer Chinook salmon (0.6%; Table 4). Compared to predation rates on smolts from Snake River ESUs, predation rates on upper Columbia River salmonid ESUs by cormorants were negligible, with predation rates of just 0.1% of the available fish last detected passing Rock Island Dam (Table 4). Similar to results from Caspian terns on Crescent Island (see Section 1.4.2), however, minimum 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 are not transported around McNary pool; thus, predation rates by cormorants are on all fish (100%) from the upper Columbia River ESUs.

PIT tags from bull trout (*Salvelinus confluentus*) were once again found on the Foundation Island cormorant colony following the 2011 nesting season, the fourth consecutive year bull trout PIT tags have been found on the Foundation Island cormorant colony. A total of eight new bull trout PIT tags were recovered in 2011. Since 2008, a total of 32 PIT tags from bull trout have been recovered on the Foundation Island cormorant colony. Bull trout found on the cormorant colony ranged from 13 to 30 cm (fork length) at the time of tagging and release, with the majority of fish originating from the Walla Walla River basin. It is unknown, however, how large the fish were when they were actually consumed or where they were consumed (e.g., in the mainstem Walla Walla River, in a tributary of the Walla Walla River, or in the Columbia River). Over 11,000 bull trout from the Walla Walla River basin have been PIT-tagged since 2006, so the number recovered on the Foundation Island cormorant colony represents a small fraction of the number tagged. In addition to bull trout, PIT tags from two juvenile white sturgeon (*Acipenser transmontanus*) were also recovered on the Foundation Island cormorant colony in 2011. These fish 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. The fish were roughly 36 and 39 cm at the time of tagging and release.

A more comprehensive analysis of PIT tag recoveries on the Foundation Island double-crested cormorant colony, including an analysis of smolt susceptibility based on rearing-type (hatchery, wild) and run-timing, is provided in Evans et al. (2011).

The Foundation Island cormorant colony was one of two piscivorous waterbird colonies (i.e., the Foundation Island and Northern Potholes cormorant colonies) scanned for tags in 2011 that were located in trees, as opposed to on the ground. PIT tag recovery at the Foundation Island and North Potholes (see below) cormorant colonies were carried out with PIT tag antennas (as described above) used to scan the ground underneath the nesting colony. Because some egested PIT tags are likely retained within cormorant nests in the trees, predation rate estimates based on PIT tag recoveries at arboreal colonies likely underestimate the predation rates of cormorants nesting at that colony to a greater extent than at colonies of piscivorous waterbirds where nests were located on the ground.

Following the nesting season, 41 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2011 migration year were recovered on the North Potholes double-crested cormorant colony (Table 2). Due to high water levels in the reservoir following the nesting season, however, researchers were unable to scan the entire colony for PIT tags in 2011 because large areas of the habitat beneath nests were still underwater. Instead, researchers scanned between 10% and 20% of the area where cormorants nested. A measure of detection efficiency from the subsample of the colony that was scanned for PIT tags was 39.5% (n = 50). How representative results from this subsample are of the entire colony is unknown and precludes estimating a total number of smolt PIT tags deposited by cormorants nesting at the North Potholes colony in 2011. Similarly, because the entire colony was not scanned, estimated predation rates on smolts are unavailable for the 2011 migration year.

Of the 41 PIT tags recovered at the North Potholes cormorant colony, the majority (33 or 80%) were from fish released into the upper Columbia River upstream of Priest Rapids Dam, with just 3 (7%) from fish released into the Snake River. PIT tags from Chinook salmon were the most numerous (25 or 60%), following by steelhead (8 or 20%) and coho (8 or 20%). Interrogation histories of these 41 fish suggest they were consumed early during out-migration, with last known detections predominately in April and early May as opposed to late-May and June. This suggests cormorants nesting at North Potholes were not routinely commuting from the colony to the Columbia River to forage on salmonids. Sample sizes are limited, however, and more data are needed to test this hypothesis.

If water levels in Potholes Reservoir are average or below average in 2012, so that the habitat underneath the entire colony is exposed following the nesting season, we will scan for smolt PIT tags throughout the area where cormorants nest.

2.5. Color banding

Methods: In 2011, adult and juvenile double-crested cormorants were banded at 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 fourth year of a prospective long-term effort to collect information on the survival and movements of double-crested cormorants from the East Sand Island colony, and to study dispersal patterns and recruitment of cormorants to other colonies using re-sightings of banded individuals.

Prior to 2008, double-crested cormorants at East Sand Island had never been banded with field-readable plastic leg bands. Banding of nestling cormorants with federal metal leg bands had not been conducted on East Sand Island since 2000, when the U.S. Fish and Wildlife Service discontinued nocturnal pre-fledgling cormorant banding efforts due to concerns over potential impacts to roosting California brown pelicans, a species formerly listed under the ESA (de-listed in November 2009). Our banding efforts in 2008-2011 were conducted in such a way as to minimize disturbance to California brown pelicans that continue to use East Sand Island as a major night-time roost site.

Double-crested cormorants were captured using two methods in 2011. Prior to active hazing of adult cormorants on a portion of the East Sand Island colony in late April (see Section 2.6.2), night-time capture using large nets and spotlights was employed to collect adult cormorants for VHF radio-marking and banding in the experimental nest dissuasion area (see Map 5). Adult cormorants were also captured (May-July) from above-ground access tunnels that concealed our presence on the colony. Breeding adult cormorants were captured during late incubation, and again once chicks had hatched and were able to thermo regulate while the parent was being banded. Juvenile cormorants near fledging age (> 28 days post-hatch) were also captured for banding from the above-ground access tunnels located on-colony. All cormorants were captured at night from nests that were within arm's reach of the tunnels. Once captured, cormorants were transported to an adjacent processing area, banded, and released.

Results and Discussion: A total of 216 adult cormorants and 184 juvenile cormorants were captured, banded, and released at the East Sand Island colony in 2011. Of the adult cormorants that were banded in 2011, 91 were captured in the nest dissuasion area in late April (60 of which were also outfitted with VHF radio transmitters). The remaining 309 adult and juvenile cormorants were captured from tunnels located west of the privacy fence and dissuasion area (see Map 5). 2011 was the first year when a large-scale effort was mounted to color-band hatch-year cormorants at East Sand Island. Currently, we lack a sufficient number of banded cormorants on the East Sand Island colony to assess the inter-colony movements and demography of double-crested cormorants. We have received re-sight/recapture information from several banded cormorants thus far, however, with most observations occurring during the post-breeding season. Re-sighting locations included western British Columbia, the northern California coast, the lower Columbia River, and the Puget Sound area. Of particular note in 2011, one cormorant banded as a juvenile in 2010 on the East Sand Island colony was observed on the Sheepy Lake floating island in northeastern California. Continued efforts to band large numbers of cormorants at East Sand Island and increased efforts to re-sight previously banded individuals will provide important information on colony site fidelity, survival, and other factors important in determining the status of the Western North America Population of double-crested cormorants. Furthermore, these banding and re-sighting efforts will allow us to determine inter-colony movements of double-crested cormorants to both predict and assess the outcome of various prospective management strategies.

2.6. Management Feasibility Studies

2.6.1. Techniques to Encourage Nesting

Methods: In 2011, we continued studies to test the feasibility of potential management techniques for reducing losses of juvenile salmonids to predation by double-crested cormorants in the Columbia River estuary. These studies 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 where they have not previously nested and, if so, whether these techniques can be used to redistribute some of the double-crested cormorants nesting in the Columbia River estuary to alternative colony sites, should resource management agencies decide to reduce the size of the East Sand Island cormorant colony.

In 2011, 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 at Dutchy Lake in the Summer Lake Wildlife Area and, for the first time, on the artificial tern island in Sump 1B at Tule Lake National Wildlife Refuge in an attempt to attract double-crested cormorants to nest at those sites. We chose Dutchy Lake and Tule Lake Sump 1B for our continued feasibility studies because three previous attempts (during 2007-2009) to attract double-crested cormorants to nest at Fern Ridge Reservoir using similar techniques had failed, apparently due to frequent human disturbance. As is the case at Fern Ridge Reservoir, double-crested cormorants are summer residents but do not currently nest at Summer Lake Wildlife Area. However, double-crested cormorants have nested occasionally in small numbers at Summer Lake Wildlife Area and on a low-lying natural island near the new artificial island at Tule Lake Sump 1B.

On Dutchy Lake, a floating platform was again launched and anchored about 100 meters southwest of the observation blind at the Dutchy Lake tern island. The floating platform was about 10 m long by 5 m wide and was assembled in 2010 from sections of floating dock material. Plywood sideboards about 30-cm high were attached to the sides of the floating platform to retain material on the platform. Fifty-two old tires were placed on the platform, and sticks and other fine woody debris were placed in each tire for nesting material. In mid-April, 20 hand-painted double-crested cormorant decoys (Mad River Decoys, Vermont), two audio playback systems (Murremaid Music Boxes, Maine), each with two speakers, along with solar panels and deep cycle batteries necessary to power the audio systems, were placed on the platform. The tires on the nesting platform had been painted white in the previous year in an attempt to simulate cormorant excrement and make the platform more attractive to prospecting cormorants. The platform was checked from the observation blind on the Dutchy Lake tern island 2-4 times a week throughout the field season for any signs of cormorant nesting.

In early April, we placed 30 old tires, 22 hand-painted adult double-crested cormorant decoys (Mad River Decoys, Vermont), two audio playback systems with two speakers each (Murremaid Music Boxes, Maine), and associated solar panels and batteries on or near the rip-rap located on the southwest side of the tern island in Tule Lake Sump 1B. In early August, we added 34 double-crested cormorant chick decoys (Dave Smith Decoys, Oregon) within the tires. The cormorant social attraction plot was checked upon arrival and departure from the island and, during Caspian tern colony monitoring, was scanned hourly for 3 min for any signs of cormorant presence in or near the social attraction site.

Results and Discussion: Double-crested cormorants did not attempt to nest on the floating platform during the 2011 nesting season, and no cormorants were observed roosting on the floating platform despite observations on several occasions of double-crested cormorants roosting on the nearby Dutchy Lake floating island. Bald eagles and peregrine falcons (*Falco peregrinus*) were observed at Summer Lake Wildlife Area during the 2011 nesting season, but they were not observed near the cormorant nesting platform and likely were not a factor in the failure of cormorants to use the platform. Caspian terns did not nest on the Dutchy Lake tern island in 2011, perhaps due to adverse weather and/or poor forage fish availability during the 2011 nesting season. These same factors might explain why cormorants failed to nest on the platform or anywhere else in Summer Lake Wildlife Area in 2011.

During the 2011 breeding season, double-crested cormorants were regularly seen loafing at a natural island in Tule Lake Sump 1B, but did not nest on the Tule Lake Sump 1B tern island, where we had installed social attraction materials. Cormorants displayed interest in the social attraction materials, however, and were seen loafing in and flying over the social attraction site. Interestingly, gulls also did not nest on the Tule Lake Sump 1B tern island. Plus predation by great horned owls (*Bubo virginianus*) caused a near complete failure of the Caspian tern colony on the island in 2011. A tunnel was used to access the observation blind, but human activity on the island for Caspian tern monitoring, in addition to predator pressure at the site, may have been factors in the reluctance of double-crested cormorants to nest at the social attraction site.

Conclusions: Habitat improvements and social attraction (i.e., decoys, audio playback systems) have been shown to be highly effective in inducing Caspian terns to nest at sites where they have 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 employing habitat enhancement and social attraction to relocate nesting double-crested cormorants have shown some promise; cormorants were attracted to nest and nested successfully (raised young to fledging) on Miller Sands Spit and Rice Island, two islands in the upper Columbia River estuary where no previous successful cormorant nesting was known (Miller Sands Spit) or nesting had not occurred in recent years (Rice Island). Although habitat enhancement and social attraction techniques appear effective in establishing double-crested cormorant breeding colonies at sites where nesting attempts have previously occurred, results from the three-year study at Fern Ridge Wildlife Area, a two-year study at Dutchy Lake in Summer Lake Wildlife Area, and a one-year study at Tule Lake Sump 1B suggest that habitat enhancement and social attraction techniques may require longer periods to successfully attract cormorants to nest at sites with no prior history of cormorant nesting, especially if no established breeding colonies exist nearby.

The efficacy of habitat enhancement and social attraction techniques to establish new double-crested cormorant colonies outside the Columbia River basin remains uncertain. Additional study will be required to fully evaluate this methodology as a means to provide alternative nesting sites for double-crested cormorants as compensation for prospective reduction in the size of the cormorant colony at East Sand Island in the Columbia River estuary. Developing methodologies to enhance the size of existing double-crested cormorant colonies, along with reestablishing colonies using habitat enhancement and social attraction techniques at sites where cormorants have historically nested, may be necessary to shift cormorants from the large colony on East Sand Island to alternative colony sites where ESA-listed salmonids are not as susceptible to cormorant predation.

2.6.2. Techniques to Discourage Nesting

Methods: In 2011, we tested the feasibility of dissuading double-crested cormorants from nesting on East Sand Island in an area where approximately 15% of the colony nested in 2010. A 2.4-m high by 65-m long privacy fence was erected across the cormorant colony (Map 5) and an attempt was made to prevent cormorants from nesting on the east side of the fence, while minimizing the disturbance to cormorants nesting west of the visual barrier. Several techniques to dissuade cormorants from nesting on the east side of the privacy fence were investigated, including human disturbance, destruction of cormorant nest structures, and experimentation with a moving coyote effigy (artificial coyote on a zip-line). Reflective polyester tape was also evaluated as a method to dissuade cormorants from nesting in or near three small trees (< 2 m height) on East Sand Island.

The targeted dissuasion area was located at the eastern end of the double-crested cormorant breeding colony on East Sand Island, and 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 2010, approximately 1,500 double-crested cormorant nests were located in the 2011 dissuasion area.

In addition to the privacy fence, an observation blind and tunnel system were constructed to provide researchers access to an enclosed researcher camp without disturbing nesting cormorants outside of the targeted dissuasion area. The enclosed camp concealed all researcher activity from cormorants within the dissuasion area, as well as those cormorants nesting west of the privacy fence, and provided an elevated vantage point for observations on either side of the privacy fence. To augment the effectiveness of dissuasion efforts, all cormorant nest structures that were constructed in the dissuasion area prior to the start of hazing were destroyed by scattering the nesting material.

Cormorants were first observed in the dissuasion area on 23 April and hazing efforts began on 29 April. The dissuasion area was observed every half hour from civil twilight in the morning to civil twilight in the evening during each day. During each observation, 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) any double-crested cormorant exhibited a breeding behavior, (2) congregations of 50 or more loafing cormorants were observed in the dissuasion area, or (3) cormorants were present in the dissuasion area at civil twilight in the evening, in order to prevent overnight roosting in the dissuasion area. If no hazing occurred for two hours, the frequency of observations was reduced to every hour. To minimize disturbance to other wildlife, researchers remained on the colony until cormorants were dispersed and then immediately returned to base camp. Following dissuasion activities, researchers remained in the blind to conduct post-dissuasion observations to determine the effectiveness of hazing activities and to assess disturbance to cormorants nesting west of the fence. At least one researcher was stationed at the camp from 28 April until 12 May, when cormorant dissuasion activities ceased.

To evaluate the effectiveness of dissuasion efforts and to determine whether hazed double-crested cormorants left East Sand Island, we captured and marked 91 cormorants in the dissuasion area during 26 - 28 April, shortly after their arrival to this part of the colony. All 91 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 91 banded cormorants, 60 were also tagged with a VHF radio transmitter (7 g, 1 km detection range, 159 to 160 MHz). Radio tags were attached to central tail feathers as described in Anderson et al. (2004). All transmitters were programmed with a ‘mortality’ switch that would activate a unique audible signal if the tag remained motionless for 24 hours.

Researchers scanned for marked cormorants from observation blinds daily during the active hazing period (28 April - 12 May), and then several times per week once dissuasion activities ceased. Weekly scans were conducted until 15 July, 12 weeks after all marked cormorants were released. Scans were frequently conducted at dusk when cormorants were most likely to be on East Sand Island and within detection range.

We also tested the feasibility of using reflective polyester tape to dissuade cormorants from nesting in or near three small trees on East Sand Island. Several strands of tape were attached and haphazardly draped throughout the branches of each tree. The tape was left loose to create both a reflective visual and audible deterrent as it moved in the wind. Each tree was marked with approximately 6-8 strands of tape. All trees were within 50 m of an observation blind and were monitored daily to document any nesting attempts in or near the trees.

Results and Discussion: The human disturbance experiment, in concert with a large visual barrier and destruction of nest structures, was an effective method of preventing cormorants from nesting in the targeted dissuasion area. These methods also caused little apparent disturbance to cormorants nesting west of the privacy fence. For example, double-crested cormorants established nests just to the west of the privacy fence and successfully raised young within 10 m of the privacy fence (see Section 2.1.1). Small numbers of California brown pelicans roosted in the dissuasion area during active cormorant hazing and at no time during the feasibility study period were more than 100 pelicans flushed. Shortly after hazing activities were concluded, several hundred brown pelicans were observed using the dissuasion area and the adjacent riprap as a nighttime roost. Several hundred glaucous-winged/western gulls also nested in the dissuasion area, and quickly became habituated to our hazing activities. Observations suggested that nesting chronology of gulls in the dissuasion area was similar to those nesting elsewhere on East Sand Island.

Counts of double-crested cormorants east of the privacy fence decreased sharply after hazing began. After one week of hazing, counts of more than 2,000 cormorants in the dissuasion area prior to hazing dropped to less than 100 cormorants (Figure 60). Nest initiation by double-crested cormorants ceased within two weeks of the initiation of active hazing. An average of five (range: 1 - 9) hazing incursions occurred each day, with the number dependent upon the return and subsequent behavior of cormorants in the dissuasion area after a hazing incursion. Researchers continued daily monitoring of the targeted dissuasion area for two additional weeks to confirm that no additional nest initiation occurred, but did not flush any additional cormorants.

In the four weeks following the initiation of hazing activities, 80 - 93% of the cormorants outfitted with detectable transmitters (i.e., functioning transmitters; excluding those with active mortality signals) were detected daily on East Sand Island outside the dissuasion area (Figure 60). During this same four-week time period, more than 90% of all detectable cormorants were identified in every week. During the 12-week study period, 30 radio-tagged cormorants (50%) were detected at least once in 10 or more weeks, 17 or 28% were detected at least once in 5 or more weeks (includes two failed transmitters), 11 or 18% were detected in four or fewer weeks (includes five failed transmitters), and two or 3% cormorants were never detected post-release (Figure 60).

Two incidents of widespread cormorant nest failure may have contributed to irregular detections of radio-tagged cormorants on the East Sand Island colony (Figure 60). Bald eagle disturbance and subsequent gull predation on cormorant eggs caused a large portion of the cormorant colony to abandon their nests on 22 May, and again on 23 June. Many cormorants that were regularly detected during the first four weeks post-release presumably left East Sand Island following these disturbances. The lowest proportion of detected cormorants occurred following the second nest failure event on 25 June, when only 34% of detectable radio-tagged cormorants were re-sighted on East Sand Island (Figure 60). During that week, ca. 57% of detectable radio-tagged cormorants were detected at least once; the only week with a lower percent detected was the final week of the study period, when ca. 53% of active transmitters were detected.

Detections of radio-tagged cormorants and re-sightings of color-banded cormorants from the dissuasion area suggest that cormorants displaced from the dissuasion area were widely dispersed across the remainder of the breeding colony. Of the 91 double-crested cormorants captured and banded in the dissuasion area prior to hazing efforts, 26 or 29% were later re-sighted on East Sand Island, nine of which were confirmed to have at least re-nested outside the dissuasion area in 2011. No marked cormorants were observed away from East Sand Island during the 2011 breeding season, nor were any radio-tagged individuals detected during the two aerial surveys of other double-crested cormorant colonies in the Columbia River estuary and Grays Harbor.

The use of reflective polyester tape in trees on East Sand Island was not successful in preventing or delaying cormorants from nesting in or under those trees. Within two days most of the tape had began to deteriorate or was ripped from branches during high wind events. While some reflective material remained in the trees, cormorants initiated and successfully nested both in and under trees with polyester tape.

Summary: Since 2008 we have tested several techniques to discourage nesting by double-crested cormorants; human disturbance (2008-2009, 2011), destruction of nest structures prior to egg-laying (2011), pond liner installation (2009-2010), laser hazing (2008-2009), and reflective tape (2011). Of these techniques, only human disturbance in concert with nest destruction and a large visual barrier has been a feasible means to prevent cormorant nesting in a pre-defined area of the East Sand Island cormorant colony. Detections of radio-tagged cormorants and observations of banded cormorants displaced from the dissuasion area suggested the vast majority of cormorants hazed in the dissuasion area relocated west of the visual barrier and resumed nest initiation in 2011. A portion of the marked cormorants did appear to leave East Sand Island for one or more weeks during the breeding season; however, the timing of departure suggests the temporary colony abandonment was associated with bald eagle disturbance and subsequent cormorant nesting failure. Human disturbance is a viable option for effectively preventing cormorant nesting on part of the colony, but requires significant infrastructure and labor-intensive hazing and monitoring on a daily basis.

SECTION 3: OTHER PISCIVOROUS COLONIAL WATERBIRDS

3.1. Distribution

3.1.1. Columbia River Estuary

Methods: In 2011, land-based, boat-based, and aerial surveys were conducted throughout the breeding season to locate piscivorous waterbird colonies in the Columbia River estuary. Colony size estimates for gulls in 2010 and 2011 are not available; instead, results from 2009 colony counts are presented here. Peak numbers of California brown pelicans using East Sand Island as a night-time roost in 2011 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 waterbird species 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, night-time roost for California brown pelicans.

Gulls − Based on surveys conducted in 2011, glaucous-winged/western gulls nested on East Sand Island, Rice Island, and Miller Sands Spit, while ring-billed gulls nested on just East Sand Island (Map 1). Precise estimates of colony size in 2010-2011 are not available.

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 is 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), when the last comprehensive survey of gull colonies in the estuary was conducted (Collis et al. 2002a). Ring-billed gulls, which previously nested on Miller Sands Spit (Collis et al. 2002a), now nest on East Sand Island (ca. 2,250 adults counted on colony) and Rice Island (ca. 310 adults counted on colony) within the Columbia River estuary in 2009. 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).

California Brown Pelicans − East Sand Island is the largest known post-breeding night-time roost site for California brown pelicans, and the only known night roost for this species in the Columbia River estuary (Wright 2005). In 2011, the first California brown pelicans were observed roosting on East Sand Island on 22 April. The weekly count of brown pelicans roosting on East Sand Island peaked at about 14,224 on 8 August, more than the peak count in 2010 (ca. 11,500). Timing of the peak in numbers of brown pelicans roosting on East Sand Island was similar in 2010 and 2011, and in line with seasonal trends in earlier years (2003-2006), but later than the highest count ever recorded for the island (over 16,000) in 2009. We observed no breeding activity by brown pelicans on East Sand Island (i.e., courtship displays, nest-building, attempted copulations) in 2011. Bald eagle activity was the most common source of non-researcher related disturbance to brown pelicans roosting on East Sand Island in 2011.

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; 2011 is the second year that white pelicans successfully raised young at the site. On 11 July 2011, as part of pelican chick-banding operations, we conducted an on-colony survey of American white pelicans nesting on Miller Sands Spit. Based on a count of nests during a colony walk-though, plus the number of chicks present, we estimated a colony size of 97 breeding pairs in 2011.

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 has since increased steadily, and in 2011 about 1,491 pairs of Brandt's cormorants nested on East Sand Island (Figure 61). This Brandt's cormorant colony is now one of the largest of its kind in Oregon and Washington. 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 the pile dike in 1997, when a few pairs were found nesting there (Couch and Lance 2004).

At least 96 breeding pairs of pelagic cormorants nested on the Astoria–Megler Bridge in 2011. 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 2011, we conducted two aerial surveys (18-19 May and 2 July) 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.

Results and Discussion: A total of nine gull colonies and one American white pelican colony were identified in the Columbia Plateau region during 2011.

Gulls – In 2011, California and/or ring-billed gulls were confirmed nesting on six different islands on the Columbia River between The Dalles Dam and Rock Island Dam: Miller Rocks (river km 333), Three Mile Canyon Island (river km 413), Anvil Island (one of the Blalock Islands at river km 445), an unnamed island (one of the Blalock Islands north of Anvil Island at river km 445), Crescent Island (river km 510), and Island 20 (river km 545; Map 1). In 2011, all nesting attempts by gulls on Three Mile Canyon Island failed in early June; although the cause for this nest failure is unknown, fresh raccoon tracks and evidence of human presence on the island were discovered in late May, prior to nesting failure. 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 on islands in the mid- and upper Columbia River during 2011 were only available for Miller Rocks, where ca. 5,750 gulls, primarily California gulls, were counted on aerial photography of the colony.

In 2009, a complete census of gull colonies on islands in the mid- and upper Columbia River was conducted and a total of ca. 41,700 adult gulls were counted on colonies from The Dalles Dam to Rock Island Dam (Figure 62), 22% fewer than the number counted at colonies in the same stretch of river during 1998 (ca. 53,200; Collis et al. 2002a). The decline in regional gull numbers on-colony was largely due to reductions in numbers on colonies in the Tri-Cities area (Islands 18, 19, and 20; ca. 35,000 gulls and ca. 19,000 gulls were counted at colonies on these islands in 1998 and 2009, respectively) and Three Mile Canyon Island (ca. 11,100 gulls and ca. 6,200 gulls were counted at this colony in 1998 and 2009, respectively; Figure 62, Collis et al. 2002a). Despite this overall decline in the number of gulls counted on colonies in the mid- and upper Columbia River from 1998 to 2009, three colonies increased in size during this period (Miller Rocks: ca. 2,200 gulls and ca. 6,000 gulls counted on-colony in 1998 and 2009, respectively; Blalock Islands: 0 gulls and ca. 1,600 gulls counted on-colony in 1998 and 2009, respectively; Crescent Island: ca. 4,600 gulls and ca. 8,600 gulls counted on-colony in 1998 and 2009, respectively; Figure 62, 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 about 50%. No gull breeding colonies were detected on the lower Snake River during 2009-2011, 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 on the mid- and upper Columbia River in 2009 was nearly equally divided between California gulls and ring-billed gulls (Figure 62).

Ring-billed and California gulls were also confirmed to be nesting on Goose Island in Potholes Reservoir, on Harper Island in Sprague Lake, and on Twining and Goose islands at the southern end of Banks Lake during 2011 (Map 1), but precise estimates of colony size were not available in 2010-2011. A total of ca. 21,500 gulls were counted at these off-river colonies in 2009, roughly half the number of gulls counted on colonies located on islands in the mid- and upper 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 2011 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 colony. High-resolution, vertical aerial photography was taken of the colony on 23 May, during the incubation period, in order to estimate colony size. 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 with Caspian terns), but 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 juveniles at the Badger Island pelican colony; it was not possible to estimate nesting success (number of young raised per breeding pair).

A mean of 2,228 adult American white pelicans were counted in the aerial photography taken on 23 May, up from 2,048 white pelicans counted on Badger Island in 2010. American white pelicans first nested on Badger Island in 1997 (ca. 20 breeding pairs), prior to that they nested on Crescent Island for several years (Figure 63). The Badger Island American white pelican colony experienced substantial growth from 1997 to 2011, increasing by more than two orders of magnitude during that period (Figure 63). Available nesting habitat on Badger Island does not appear to be a factor limiting pelican colony size, but additional monitoring will be necessary to determine whether growth of the Badger Island colony continues.

Our boat-based counts resulted in a maximum count of 165 juvenile white pelicans on 26 July. For comparison, our annual maximum counts of juvenile pelicans during boat-based surveys at Badger Island have ranged from 56-329 during the period 2002-2010.

3.1.3. Coastal Washington

Comprehensive surveys of nesting gulls, Brandt's cormorants, and pelagic cormorants were not conducted along the coast of Washington in 2011.

3.1.4. Interior Oregon and Northeastern California

Methods: In 2011, we conducted three aerial surveys (15 June, 13 July, and 26 July) in interior Oregon and northeastern California (Map 4) looking for colonies of piscivorous waterbird species other than Caspian terns and double-crested cormorants (i.e., ring-billed gulls, California gulls, and American white pelicans). Additionally, periodic land-and boat-based surveys were conducted throughout the breeding season to verify nesting by these other piscivorous waterbird species at sites identified in aerial surveys.

Results and Discussion: Based on aerial, land-, and boat-based surveys in 2011, gulls were confirmed to be nesting at nine different locations and American white pelicans were confirmed to be nesting at four different locations in interior Oregon and northeastern California.

Gulls – In 2011, ring-billed and California gulls nested at the Crump Lake tern island in the Warner Valley, OR (over 1,000 breeding pairs); the Sheepy Lake tern island in Lower Klamath NWR, CA (over 1,000 breeding pairs); the East Link tern island in Summer Lake Wildlife Area, OR (ca. 500 breeding pairs); the Orems Unit tern island in Lower Klamath NWR, CA (ca. 200 breeding pairs); Meiss Lake, CA (over 1,000 breeding pairs); Swan Lake, OR (over 1,000 breeding pairs); Clear Lake NWR, CA (ca. 500 breeding pairs); Pelican Lake in the Warner Valley, OR (ca. 100 breeding pairs); and Singhus Ranch in Malheur Lake, OR (< 100 breeding pairs). Gulls were observed at the Tule Lake Sump 1B tern island in Tule Lake NWR, CA, but gull numbers were always less than 100 individuals and, although nesting behaviors were observed, but no egg-laying by gulls confirmed at the site. Gulls were successful in rearing young at four of the nine colonies where nesting was confirmed (Crump Lake tern island, Sheepy Lake tern island, Pelican Lake, and Malheur Lake) and were unsuccessful in rearing young at two of the nine colonies (East Link tern island, Orems Unit tern island). Nesting failures at these two colonies were primarily attributed to predation by great horned owls at night. Nesting success at the other three gull colonies in interior Oregon and northeastern California (i.e., Swan Lake, Meiss Lake, and Clear Lake NWR) was not confirmed.

American White Pelicans – In 2011, American white pelicans nested at Upper Klamath NWR (< 10 breeding pairs), Clear Lake NWR (< 10 breeding pairs), Pelican Lake in the Warner Valley (ca. 60 breeding pairs), Singhus Ranch in Malheur Lake (ca. 40 individuals), and Baca Lake, Malheur NWR (< 10 breeding pairs). American white pelicans were successful in fledging some young at Singhus Ranch, Malheur Lake, whereas pelicans nesting at Pelican Lake failed to produce any young. Nesting success at the Upper Klamath NWR and Baca Lake pelican colonies in 2011 was not confirmed.

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, in contrast to the gulls nesting at colonies in the Columbia Plateau region (see below), 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% and 4% of the diet (by mass) of glaucous-winged/western gulls nesting on Rice Island/Miller Sands Spit and

East Sand Island, respectively. At least some of these fish 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 2011, kleptoparasitism rates (proportion of fish delivered by terns to the colony that were subsequently stolen by gulls) for salmonid smolts delivered to the East Sand Island tern colony averaged 12%; steelhead smolts were kleptoparasitized at a higher rate (19%) than salmon smolts (10%). These data indicate that gulls nesting in close proximity to Caspian terns on East Sand Island have an 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 (Emmett et al. 2006), and presumably these fish species comprise the majority of the diet of brown pelicans that roost on East Sand Island. In 2011, we attempted to recover smolt PIT tags from roost sites used by California brown pelicans on East Sand Island to better assess the impacts of brown pelicans on smolt survival. These results are provided below (see Section 3.3.1).

Brandt's and Pelagic Cormorants − We did not collect diet data on 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 they are 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 birds on survival of juvenile salmonids from the Columbia River basin are expected to be negligible. Smolt PIT tag recoveries on the East Sand Island Brandt's cormorant colony in 2011 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 lower and middle Columbia River 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 the mid- and upper Columbia River in 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 extant) 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 in the tailrace of The Dalles Dam (Zorich et al. 2010). Gulls from other up-river colonies may occasionally prey on juvenile salmonids when available in shallow pools or near 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.

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 own 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 2011, kleptoparasitism rates on salmonid smolts delivered by Caspian terns to the Crescent Island colony averaged 17%. As was observed at East Sand Island, kleptoparasitism rates were higher on steelhead smolts (41%) than on salmon smolts (15%), 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 vulnerability of different species of smolts to gull kleptoparasitism, but they are not representative of the proportion of all salmonid smolts caught by 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 available. Given that (1) California gulls nesting at Crescent Island significantly out-number Caspian terns nesting there, and (2) gulls kleptoparasitize only a small portion of the smolts captured by adult 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 Crescent Island gull colony.

Finally, smolt PIT tags that were recovered from several gull colonies in the Columbia Plateau region during 2007-2011 corroborate our conclusion that the majority of gulls nesting at colonies on the mid- and upper Columbia River pose little risk to salmonid survival, with the possible exception of the California gulls nesting on Miller Rocks and Crescent Island (Evans et al. in press; also see Section 3.3.2 below).

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 white pelican colony, however, pelicans do not appear to be a significant source of smolt mortality (see Section 3.3.2). Despite this, the Badger Island white pelican colony is growing and there is an increasing number of non-breeding white pelicans along the Columbia and Snake rivers, where they are often observed foraging below mainstem hydroelectric dams (Tiller et al. 2003, authors' unpublished data) and at sites in the Yakima River basin (A. Stephenson, Yakima Klickitat Fisheries Project, pers. comm.), presumably foraging on out-migrating juvenile salmonids. The impact of breeding and non-breeding white pelicans on survival of juvenile salmonids from some runs is not well understood.

3.2.3. Coastal Washington

Diet data were not collected at other piscivorous waterbirds 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 was collected from other piscivorous waterbirds in interior Oregon and northeastern California, PIT tags were recovered and used to evaluate impacts of avian predation on suckers (see Section 3.3.4).

3.3. Predation Rates Based on 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 East Sand Island Brandt's cormorant colony and the Miller Sands Spit American white pelican colony are the same as those described in Section 1.4.1.

PIT tags were also recovered from areas on East Sand Island where California brown pelicans were observed loafing and roosting in 2011. A subsection of habitat along southern shore of East Sand Island was scanned for PIT tags, a section exclusively used by brown pelicans as a loafing and nighttime roost during May to September 2011. Counts of brown pelicans on the island and within the subsection scanned for PIT tags were conducted weekly to determine brown pelican use of East Sand Island during periods when juvenile salmonids were present in the estuary.

Results and Discussion: Following the 2011 nesting season, 442 PIT tags from smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2011 migration year were recovered on the Brandt's cormorant colony at East Sand Island (Table 2). This number expands to an estimated 660 smolts once adjustments are made to account for on-colony PIT tag detection efficiency (Table 2). Of the control tags sown on the East Sand Island Brandt's cormorant colony to measure PIT tag detection efficiency (n = 100), 67 or 67.0% were detected after the nesting season (Table 2).

Of the PIT-tagged fish last detected passing Bonneville and Sullivan dams (Map 1), no greater than 0.2%, per ESU, were deposited on the Brandt's cormorant colony in 2011 (Table 3). Although minimum predation rates were highest on Middle Columbia River steelhead (0.2%), predation rates were so small that differences between species and ESUs were not readily discernible or biologically meaningful. Despite the small overall number of PIT tags and low estimated predation rates on salmonid ESUs, however, the total number of smolt PIT tags deposited on the Brandt's cormorant colony in 2011 was higher than the total number deposited by Brandt's cormorants in both 2010 (240 PIT-tagged smolts) and 2009 (176 PIT-tagged smolts). The increases are commensurate with the increasing number of Brandt's cormorants nesting on East Sand Island (see Section 3.1.1). Regardless of the increase, predation rates on smolts by Brandt's cormorants remained amongst the lowest of the 12 colonies of fish-eating birds evaluated in 2011 (Tables 3-5). In comparison to predation on smolts by Brandt's cormorants on East Sand Island, predation on smolts by double-crested cormorants on East Sand Island was significantly higher on all ESUs evaluated in 2011 (Table 2). Furthermore, per capita (per bird) predation rates on smolts were significantly higher for double-crested cormorants compared to Brandt's cormorants, indicating a difference in the diet composition of the two cormorant species.

For the third consecutive year, PIT tag results provide evidence that Brandt's cormorants consumed far fewer salmonid smolts than double-crested cormorants or Caspian terns nesting on East Sand Island (BRNW 2011). Several factors may account for this. First, 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 (FPC 2012). Second, differences in salmonid smolt consumption between Brandt's cormorants and other piscivorous waterbirds nesting on East Sand Island are likely attributable to differences in foraging habitat and diet composition. 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, the salmonid prey type comprises a smaller proportion of the diet of Brandt's cormorants compared to that of Caspian terns and double-crested cormorants. Third, relative to double-crested cormorants, Brandt's cormorants are smaller (by mass), with a lower daily energy requirement.

In 2011, an area along the southern shore of East Sand Island where brown pelicans were observed loafing and roosting during May to September was scanned for smolt PIT tags deposited by brown pelicans. Based on weekly boat surveys of East Sand Island, an average of 5,702 brown pelicans (range = 1,330 to 14,147 pelicans) were observed using East Sand Island as a daytime loafing site and nighttime roost. Of these, an average of 60 pelicans (range = 0 to 120 pelicans) or 1.1% were associated with the area scanned for PIT tags (hereafter referred to as the 'PIT tag plot'). Brown pelicans were the only fish-eating bird observed in the PIT tag plot (i.e., no other species of piscivorous waterbird was enumerated in the plot during weekly boat surveys). No PIT tags were found in the PIT tag plot following the 2011 roosting season. Of the control tags sown in the plot to measure PIT tag detection efficiency (n = 100), 138 or 69.0% were detected. This result suggests that if PIT tags were deposited by brown pelicans in the plot, they were likely to have been detected by researchers. In 2012, we propose to increase the size of the pelican PIT tag plot to increase the chances of finding PIT tags, should they be ingested by brown pelicans roosting in the Columbia River estuary.

A total of just 15 PIT-tagged smolts from the 2011 migration year (Chinook, coho, sockeye, and steelhead combined from all releases) were recovered on the Miller Sands

Spit American white pelican colony (Table 2). This number expands to an estimated 19 smolts once adjustments are made to account for on-colony PIT tag detection efficiency. Of the control PIT tags sown on the white pelican colony to measure PIT tag detection efficiency (n = 100), 80 or 80.0% were detected after the nesting season (Table 2).

Based on an estimated 19 PIT-tagged smolts deposited on the Miller Sands white pelican colony, predation rates were less than 0.1% for all available salmonid ESUs, the lowest estimated predation rates of the 12 colonies of fish-eating birds evaluated by this study in 2011. Relative to Caspian terns and double-crested cormorants nesting on East Sand Island, the small number of PIT tags and low smolt predation rates by American white pelicans nesting in the estuary were similar to those observed on the mid-Columbia River, where the number of PIT tags and ESU-specific predation rates at the American white pelican colony on Badger Island were significantly lower than those at the Caspian tern colony on Crescent Island or at the double-crested cormorant colony on Foundation Island. Compared to the white pelicans nesting on Badger Island (see Section 3.2.2), however, white pelicans nesting on Miller Sands Spit posed almost no risk to out-migrating juvenile salmonids in 2011.

<u>3.3.2 Columbia Plateau</u>

Methods: The methods for calculating predation rates on juvenile salmonids based on PIT tag recoveries at the gull colonies on Miller Rocks and Crescent Island and the American white pelican colony on Badger Island are the same as those described for Caspian tern colonies in Section 1.4.1.

Results and Discussion: Following the 2011 nesting season, a total of 1,759 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2011 migration year were recovered on the Miller Rocks gull colony (Table 2). This number expands to 2,227 smolt PIT tags once adjustments are made to account for on-colony PIT tag detection efficiency. Of the control tags sown on the colony prior to and after the nesting season to measure PIT tag detection efficiency (n = 200), 158 or 79.0% were detected on-colony (Table 2). The estimated total number of smolt PIT tags deposited on the Miller Rocks gull colony in 2011 was the lowest recorded since colony-wide scanning was initiated in 2007 (ranging from 2,227 smolt PIT tags in 2011 to 5,301 smolt PIT tags in 2009). Similarly, estimated predation rates on smolts by gulls nesting at Miller Rocks were the lowest since 2007; predation rates on all salmonid ESUs evaluated were no more than 0.8% per ESU in 2011 (Table 5). Estimates of predation rates on smolts by gulls nesting on Miller Rocks peaked in 2009 with an average predation rate on steelhead ESUs of 1.3% and average predation rates on salmon ESUs of 0.6%, about 2 to 6 times higher than the rates observed in 2011. In 2011, minimum predation rates were highest on steelhead populations from the Snake River (0.8%) and upper Columbia River (0.5%; Table 5). Predation rates on salmon ESUs in 2011 (Chinook, sockeye) ranged from 0.3% (Snake River sockeye) to just 0.1% (all other salmon ESUs; Table 5).

The factor(s) responsible for the much lower predation rates on smolts by Miller Rocks gulls in 2011 compared to 2007-2010 is unknown, but may be related to higher river flows and/or enhanced avian predator abatement measures (hazing and avian deterrent lines) implemented at John Day Dam in 2011. Estimates of the number of fish consumed by gulls at John Day Dam in 2011 (ca. 6,000 fish) were dramatically lower than estimates in 2010 (ca. 38,000 fish; N. Zorich, USACE, pers. comm.).

A total of 2,089 PIT-tagged smolts (Chinook, coho, sockeye, and steelhead combined from all releases) from the 2011 migration year were recovered on the Crescent Island gull colony (Table 2). This number expands to 3,072 smolt PIT tags once adjustments are made to account for on-colony PIT tag detection efficiency. Of the control tags sown on the colony to measure PIT tag detection efficiency (n = 200), 136 or 68.0% were detected after the nesting season (Table 2). Unlike the estimated number of smolt tags deposited on the Miller Rocks gull colony, a record low, the number deposited on the Crescent Island gull colony in 2011 was close to the average number deposited during 2007-2010 (average = 2,687; Evans et al., In press). 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 from smolts initially captured by terns that were subsequently kleptoparasitized by gulls. As such, the total number of smolt PIT tags on the Crescent Island gull colony, and the resultant predation rates on smolts, include smolts initially captured by Caspian terns but kleptoparasitized by gulls.

Of the PIT-tagged smolts last detected passing Lower Monumental Dam or Rock Island Dam (Map 1), on-colony deposition rates (predation rates plus kleptoparasitism rates) by Crescent Island gulls were highest on steelhead originating from the upper Columbia River (0.5%) and Snake River (0.5%; Table 4). By comparison, predation/kleptoparasitism rates on juvenile salmon (all ESUs) were significantly lower than that of juvenile steelhead, with salmon predation rates less than 0.2% of the available smolts lasted detected passing Lower Monumental or Rock Island dams (Table 4). Predation/kleptoparasitism rates on salmonid ESUs by gulls on Crescent Island were similar to those in previous years (Evans et al.2012).

Differences in predation/kleptoparasitism rates on steelhead compared to salmon ESUs by gulls nesting on Crescent Island could be directly 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, apparently 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 nesting season, 2,531 PIT-tagged smolts (Chinook, sockeye, coho, and steelhead combined from all releases) from the 2011 migration year were recovered on the Badger Island American white pelican colony (Table 2). Of the control PIT tags sown on the colony to measure PIT tag detection efficiency (n = 100), 74 or 74.0% were detected after the nesting season (Table 2). Consequently, the estimated number of smolt PIT tags deposited on the Badger Island pelican colony was 3,420 PIT tags, once adjustments were made to account for on-colony PIT tag detection efficiency.

Of the PIT-tagged smolts last detected passing Lower Monumental Dam or Rock Island Dam (Map 1), predation rates by Badger Island white pelicans on Snake River steelhead (0.3%) and Snake River sockeye (0.3%) were the highest of seven ESUs evaluated (Table 4). Predation rates on other salmonid ESUs were 0.2% or less (Table 4). Predation rates from 2011 were similar to those recorded during 2007-2010 (Evans et al., In press) and suggest smolt losses to Badger Island white pelicans were relatively minor in comparison to nearby Caspian tern and double-crested cormorant colonies on Crescent Island and Foundation Islands, respectively. 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 predation rates on upper Columbia River and Snake River salmonid populations. Furthermore, of the species of piscivorous waterbirds evaluated by this study, American white pelicans have the longest documented foraging radius (upwards of 300 km) and, as such, white pelicans could be commuting longer distances to forage on smolts. The total number of smolt PIT tags deposited (3,420 PIT-tagged smolts from all releases), however, suggests impacts are still considerably less than those of nearby double-crested cormorant and Caspian tern colonies (8,376 and 11,734 PIT tags from all releases for Foundation Island cormorants and Crescent Island terns, respectively; Table 2).

Although impacts to smolt survival from American white pelicans nesting on Badger Island are low compared to nearby tern and cormorant colonies, the number of PIT tags recovered on the Badger Island pelican colony has been steadily increasing since research was initiated there in 2005. For example, in 2005 an estimated 1,057 adult pelicans deposited 1,488 smolt PIT tags on-colony. By the 2011, an estimated 2,177 adult pelicans deposited 3,420 smolt PIT tags on-colony.

In addition to PIT tags from juvenile anadromous salmonids, six PIT tags from adult salmonids were deposited by Badger Island American white pelicans in 2011. PIT tags were from adult steelhead (n = 4) and adult sockeye (n = 2), fish tagged at the Bonneville Dam fishway during upstream migration or as post-spawn fish (kelts) returning to the ocean. The largest fish was a 70 cm steelhead kelt, indicating that pelicans, unlike Caspian terns (see Section 4), are capable of consuming large, adult-sized anadromous salmonids. Also of note in 2011 were five PIT tags from bull trout tagged and released into the Walla Wall River basin and tags from four juvenile white sturgeon tagged and released into the Columbia River upstream of Priest Rapids Dam.

A more comprehensive analysis of PIT tag recoveries on the Miller Rocks and Crescent Island gull colonies and the Badger Island American white pelican colony, including an analysis of smolt susceptibility based on rearing-type (hatchery, wild) and run-timing is provided in Evans et al. (In press).

SECTION 4: STEELHEAD SUSCEPTIBILITY STUDY

In 2011 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 fish's rearing-type and run-timing are linked to smolt susceptibility to avian predators. 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 predators. 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 they are the most vulnerable to predation by birds nesting on the Columbia River (Collis et al. 2001, Antolos et al. 2005, Evans et al. 2012) and are the species of salmonid most likely to benefit from avian management initiatives (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 ESUs.

Presented here are data collected in 2011. Results from 2011, however, are compared to data collected during 2008-2010 to provide a more comprehensive analysis of study results and to develop base-line information on avian predation on upper Columbia River steelhead in the event bird management initiatives are implemented to protect this threatened ESU in the coming years.

Methods: From 9 April through 18 June 2011, 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 dam's tailrace. Fish 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 severity. 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 ranks: good, fair, or poor. These condition rankings were based on the presence, abundance, 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 Goose Island/Potholes Caspian tern colony were used to determine if susceptibility to avian predation varied by external condition of steelhead used in this study. We focused analyses associating external fish condition 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. Logistic regression was used to evaluate whether the probability of recovering a steelhead on the tern colony was associated with individual fish characteristics, including external condition. Predation rates (Section 1.4.1) were generated for several bird 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 are adjusted for bias due to PIT tag detection efficiency, but not for deposition rate and are therefore minimum estimates of predation rates.

A more detailed description of the methods used to classify fish condition and analyze results can be found in Hostetter et al. (2011).

Results and Discussion: A total of 7,756 steelhead were PIT-tagged and released from Rock Island Dam (n = 5,961 hatchery-reared smolts, n = 1,795 wild smolts) in 2011. Sampling efforts were conducted in concert with the run-at-large, with the largest numbers of smolts PIT-tagged (n = 4,898 or 63% of all tagged fish) during the peak migration period of 13 May to 8 June (a period encompassing about 80% of the run enumerated while passing Rock Island Dam in 2011). Overall, 57% of the steelhead PIT-tagged as part of the study in 2011 were classified as in good condition, 32% were in fair condition, and 20% were in poor condition. A variety of external anomalies were evident in steelhead ranked as in poor condition, including superficial and open body injuries (64%), external symptoms of disease (27%), and moderate to severe de-scaling (26%). Steelhead ranked in fair condition primarily suffered from superficial body abrasions (54%) and moderate de-scaling (32%). Conversely, external damage among fish ranked as in good condition was limited to minor patches of de-scaling (9%).

Avian Predation on Upper Columbia River Steelhead - Of the 7,756 steelhead smolts PIT-tagged and released from Rock Island Dam, 812 (10.5%) were subsequently recovered on a bird colony somewhere in the Columbia River basin. This number increased to more than 1,300 (16.9%) when corrected for detection efficiency (Table 6). Avian predators consumed a minimum of 17.6% of the hatchery steelhead and 14.6% of the wild steelhead that were PIT-tagged and released from Rock Island Dam in 2011 (Table 6). Impacts from avian predation were evident from the high proportion of smolt PIT tags recovered on the East Sand Island tern and cormorant colonies in the Columbia River estuary, on the Crescent Island tern colony in McNary Pool, and on the Goose Island tern colony in Potholes Reservoir (Table 6). Recoveries of steelhead PIT tags on the Goose Island Caspian tern colony at Potholes Reservoir (an off-river colony) were notable, with estimated predation rates of 9.5% and 7.3% for hatchery and wild steelhead smolts, respectively (Table 6). Predation rates by Goose Island terns in 2011 (9.0% of PIT-tagged steelhead) were similar to 2010 estimates (9.6%), but lower than 2009 estimates (15.5%; Figure 64). Steelhead migrating during the peak out-migration period (May) were once again the least susceptible to predation by Caspian terns nesting at Goose Island/Potholes (Figure 64), a result consistent with predator swamping whereby individual smolt susceptibility to bird predation decreases with increasing smolt abundance (Hostetter et al. in-press). However, increases in predation rates during June were not as substantial compared to previous years (Figure 64), possibly due to high flows and increased abundance of out-migrating salmonids during June of 2011.

Results from this study indicate that susceptibility of smolts to avian predation was associated with external condition and morphology of steelhead smolts. Minimum predation rates by Caspian terns nesting at Goose Island during 2008-2011 indicated that predation rates were highest for steelhead with fork lengths of 15 - 24 cm, and lower for steelhead that were larger (> 24 cm fork length) and smaller (< 15 cm fork length; Figure 65). Minimum predation rates by Caspian terns nesting at Goose Island during 2008-2011 were also lower for steelhead classified as in good condition (9.9%, 95% c.i. = 9.1-10.9%) relative to steelhead in fair condition (13.2%, 95% c.i. = 11.6-14.9%) or in poor condition (12.0%, 95% c.i. = 10.3-13.9%). Taken together, these results support previous findings indicating that the susceptibility of steelhead smolts to Caspian tern predation is both length-dependent and condition-dependent (Hostetter et al. 2011).

In total, more than 29,000 PIT-tagged upper Columbia River steelhead have been released at Rock Island Dam during 2008-2011 as part of this study. Based on PIT tag recoveries on bird colonies in the Columbia River basin, avian predators have annually consumed a minimum of 16.9 - 26.5% of these steelhead (Figure 66). Annual minimum predation rates have varied substantially at the Caspian tern colony on Goose Island/Potholes, from a minimum of 7.7% in 2008 to a maximum of 15.5% in 2009 (Figure 66). Although minimum annual predation rates varied substantially at Goose Island, minimum predation rates remained relatively stable at other colonies in the Columbia River basin during 2008-2011 (Figure 66). For instance, minimum annual predation rates by all birds nesting on islands in the McNary Pool (Crescent, Foundation, and Badger islands combined) ranged from 2.5-2.9% during 2008-2011. Similarly, minimum annual predation rates by all birds nesting on islands in the John Day and The Dalles pools (Miller Rocks and the Blalock Islands combined) ranged from 0.5-1.1% of steelhead released at Rock Island Dam during 2008-2011 (Figure 66). In the Columbia River estuary (Caspian terns, double-crested cormorants, and Brandt's cormorants nesting on East Sand Island combined), minimum annual predation rates of steelhead released at Rock Island Dam during 2008-2011 have ranged from 4.8-7.8% (Figure 66). These predation rates were corrected for bias due to on-colony PIT tag detection efficiency (see Table 2), but not for steelhead survival to the vicinity of the bird colony or for off-colony PIT tag deposition, both of which would increase these estimates of annual avian predation rates.

Estimates of benefits to salmonid ESUs/DPSs from reduction in avian predation rates have identified the upper Columbia River steelhead DPS as the ESU/DPS that would receive the greatest benefit if reductions in predation by piscivorous waterbirds nesting on the Columbia Plateau occurred (Lyons et al. 2011a, 2012b).

Adult Returns: Since 2007, over 55,000 juvenile steelhead have been PIT-tagged and condition-scored on the lower Snake River and upper Columbia River as part of this study. Detections of PIT-tagged adults at Bonneville Dam indicate that 786 or 1.6% of the 47,698 PIT-tagged steelhead released in 2007-2010 have already returned as adults, with more expected in the coming years. Inter-annual differences in adult returns have been detected, with the highest percentage of adults returning in 2008 (3.1%), relative to 2007 (0.6%), 2009 (1.1%), and 2010 (0.7%). Continued adult returns of steelhead PIT-tagged as part of this study will enhance our understanding of how individual smolt characteristics and condition during out-migration are associated with mortality factors and adult returns of steelhead ESUs that are ESA-listed. This dataset can be used to evaluate relationships among smolt condition, avian predation, smolt survival, and adult returns of ESA-listed steelhead.

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

Methods: 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 2011 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 birds, along with information on the types of structures used as loafing or roosting sites were recorded during each survey. All major loafing sites identified during surveys were scanned for smolt PIT tags following the nesting season (August-September) 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: The vast majority of double-crested cormorants, Caspian terns, and American white pelicans observed in the McNary Pool during boat surveys were on or near their respective nesting islands (Map 6). Observations of double-crested cormorants indicated that 80% of cormorants were generally on or near Foundation Island (on-colony, upstream tip, or downstream tip). Similarly, 93% of Caspian tern observations were on Crescent Island or Badger Island (known tern breeding colonies in 2011). For white pelicans, 48% 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.

Loafing double-crested cormorants, Caspian terns, and American white pelicans were primarily observed on islands, sandbars, and secluded shorelines along the Columbia and Snake rivers (Map 6). Although use of artificial structures (e.g., bridges, channel markers, and docks) was documented, counts were never greater than 5 birds on any one structure during a survey. Areas regularly used by 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 rip rap and lagoon (Rkm 510; all 3 species), upstream and downstream tips of Foundation Island (Rkm 518) and Badger Island (Rkm 511; all 3 species), Wade Island near Kennewick (Rkm 525; primarily cormorants), and the downstream tip of Island 20 (Rkm 547; terns and pelicans; Map 6).

The largest aggregations of loafing double-crested cormorants off of Foundation Island were observed on the lower Snake River at Strawberry Island (Rkm 528), Goose Island (below Ice Harbor Dam; Rkm 536), and ephemeral sandbars near Strawberry Island (Rkm 528). Counts of double-crested cormorants in these areas during May-July, 2011 ranged from 5 - 80 cormorants loafing on Strawberry Island, 16 - 69 cormorants on ephemeral sandbars near Strawberry Island, and 1 - 29 cormorants on Goose Island (Map 6). Double-crested cormorants were also observed foraging on the Snake River near these islands (n = 2 - 65 cormorants; Map 6). American white pelicans also used Strawberry Island, Goose Island, and their associated sandbars on the Snake River during April – July (n = 7 - 95 loafing pelicans and 0 - 103 foraging pelicans, depending on date; Map 6). 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.

PIT tag recovery was conducted at all major double-crested cormorant, Caspian tern, and American white pelican loafing locations in the McNary Pool that were accessible in 2011. A total of 408 PIT tags from salmonid smolts migrating in 2011 were recovered from 11 different loafing sites (Table 7). The vast majority of these PIT tags (93% or 381 out of 408) were detected on loafing sites adjacent to cormorant, tern, or pelican nesting colonies (Table 7). All loafing sites scanned for PIT tags were used by multiple bird species – including cormorants, terns, pelicans, and/or California and ring-billed gulls – throughout the season, and therefore cannot be attributed to predation by a particular bird species (Table 7). Recoveries of PIT tags on loafing sites ranged from 3 - 195 tags, while recoveries of PIT tags on nesting colonies in McNary Pool were 1 - 3 orders of magnitude greater (2,089 - 9,270 PIT tags recovered in 2011; Table 2). 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 rarely depositing consumed PIT tags at loafing sites, or (3) low detection efficiency of PIT tags deposited at loafing sites. Detection efficiency at loafing sites may be lower relative to detection efficiency at nesting colonies due to regular inundation of most loafing sites; thus, PIT tag recoveries at loafing sites would underestimate predation impacts to an unknown degree. However, the lower relative use of loafing sites compared to colonies cannot be discounted, with maximum counts of birds at loafing sites ranging from 0 - 80 birds, and maximum counts at colonies regularly exceeding several hundred birds.

Since 2007, this project has scanned 22 different waterbird (double-crested cormorant, Caspian tern, American white pelican, and gull species) loafing locations in the Columbia Plateau region (Table 8). To date, more than 100 PIT tags have been recovered from just two of these loafing locations (Crescent Island lagoon and Swallows Park, in Clarkston, WA [Rkm 752]; Table 8). By comparison, annual PIT tag recoveries on double-crested cormorant, Caspian tern, and American white pelican colonies in the Columbia Plateau region are in the thousands annually (Table 2).

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LITERATURE CITED

Adkins, J.Y., and D.D. Roby. 2010. A status assessment of the double-crested cormorant (*Phalacrocorax auritus*) in western North America: 1998 – 2009. Report to U.S. Army Corps of Engineers, Portland, OR. Bird Research Northwest. Available on-line at www.birdresearchnw.org.

Adkins, J.Y., D.D. Roby, D.E. Lyons, Y. Suzuki, P.J. Loschl, K. Collis, and A.F. Evans. 2011. Colony size, nesting success, and limiting factors of piscivorous colonial waterbirds in the Columbia Plateau region, 2004-2009. Pages 8-37 *in* Roby, D.D. (ed.). Impacts of avian predation on salmonid smolts from the Columbia and Snake rivers: A synthesis report to the U.S. Army Corps of Engineers Walla Walla District. Bird Research Northwest. Available on-line at www.birdresearchnw.org.

Anderson, C.D., D.D. Roby, and K. Collis. 2004. Conservation implications of the large colony of double-crested cormorants on East Sand Island, Columbia River estuary, Oregon, USA. Waterbirds 27:155-160.

Anderson, S.K., D.D. Roby, D.E. Lyons, and K. Collis. 2007. Relationship of Caspian tern foraging ecology to nesting success in the Columbia River estuary, Oregon, USA. Estuarine, Coastal, and Shelf Science 73:447-456.

Antolos, M., D.D. Roby, D.E. Lyons, K. Collis, A.F. Evans, M. Hawbecker, and Brad A. Ryan. 2005. Caspian tern predation on juvenile salmonids in the Mid-Columbia River. Transactions of the American Fisheries Society 134:466-480.

Banish, N.P., B.J. Adams, and R.P. Shively. 2009. Distribution of habitat associations of radio-tagged adult Lost River suckers and shortnose suckers in upper Klamath Lake, Oregon. Transactions of the American Fisheries Society 138:153-168.

BRNW (Bird Research Northwest). 2004. Caspian tern nesting ecology and diet in San Francisco Bay and Dungeness National Wildlife Refuge. 2004 Annual Report submitted to the U.S. Fish and Wildlife Service, Region 1, Migratory Birds and Habitat Programs, Portland, OR. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2005a. Caspian Tern Research on the Lower Columbia River: 2004 Final Annual Report submitted to the Bonneville Power Administration and the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2005b. Caspian Tern Nesting Ecology and Diet at Colony Sites on the Olympic Peninsula. 2005 Annual Report submitted to the U.S. Fish and Wildlife Service, Region 1, Migratory Birds and Habitat Programs, Portland, OR. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2006a. Caspian Tern Research on the Lower Columbia River: 2005 Final Annual Report submitted to the Bonneville Power Administration and the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2006b. Observations of Caspian terns nesting at Dungeness National Wildlife Refuge and distribution of gull colonies in Puget Sound, Washington. 2006 Annual Report submitted to the U.S. Fish and Wildlife Service, Region 1, Migratory Birds and Habitat Programs, Portland, OR. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2007. Caspian Tern Research on the Lower Columbia River: 2006 Final Annual Report submitted to the Bonneville Power Administration and the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2008. Caspian Tern Research on the Lower Columbia River: 2007 Final Annual Report submitted to the Bonneville Power Administration and the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2009a. Caspian Tern Research on the Lower Columbia River: 2008 Final Annual Report submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2009b. Caspian Tern Nesting Ecology and Diet in San Francisco Bay and Interior Oregon: 2008 Final Annual Report submitted to the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2010a. Caspian Tern Research on the Lower Columbia River: 2009 Final Annual Report submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2010b. Caspian Tern Nesting Ecology and Diet in San Francisco Bay and Interior Oregon: 2009 Final Annual Report submitted to the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2011. Caspian Tern Research on the Lower Columbia River: 2010 Final Annual Report submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

Collis, K., D.D. Roby, D.P. Craig, B.A. Ryan, and R.D. Ledgerwood. 2001. Colonial waterbird predation on juvenile salmonids tagged with passive integrated transponders in the Columbia River estuary: vulnerability of different salmonid species, stocks, and rearing types. Transactions of the American Fisheries Society 130:385-396.

Collis, K., D.D. Roby, D.P. Craig, S. Adamany, J. Adkins, and D.E. Lyons. 2002a. Colony size and diet composition of piscivorous waterbirds on the lower Columbia River: Implications for losses of juvenile salmonids to avian predation. Transactions of the American Fisheries Society 131:537–550.

Collis, K., D.D. Roby, C.W. Thompson, D.E. Lyons, and M. Tirhi. 2002b. Barges as temporary breeding sites for Caspian terns: Assessing potential sites for colony restoration. Wildlife Society Bulletin 30:1140–1149.

Couch, S.L.L., and M.M. Lance. 2004. Diet composition and breeding success of Brandt's cormorants in the Columbia River estuary. Northwestern Naturalist 85:62-66.

Efron, B., and R. J. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science 1:54–77.

Emmet, R.L., G.K. Krutzikowski, P.J. Bently. 2006. Abundance and distribution of pelagic piscivorous fishes in the Columbia River plume during spring/early summer 1998–2003: Relationship to oceanographic conditions, forage fishes, and juvenile salmonids. Progress in Oceanography 68:1-26.

Evans, A.F., N.J. Hostetter, K. Collis, D.D. Roby, D.E. Lyons, B.P. Sandford, R.D. Ledgerwood, and S. Sebring. 2011. A system-wide evaluation of avian predation on salmonid smolts in the Columbia River basin based on recoveries of passive integrated transponder (PIT) tags. Pages 81-178 *in* Roby, D.D. (ed.). Impacts of avian predation on salmonid smolts from the Columbia and Snake rivers: A synthesis report to the U.S. Army Corps of Engineers, Walla Walla District. Bird Research Northwest. Available on-line at www.birdresearchnw.org.

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

FPC (Fish Passage Center). 2012. Fish Passage Center smolt passage index. Available on-line at www.fpc.org (October 2011).

Hansel, H.C., S.D. Duke, P.T. Lofy, and G.A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. Transactions of the American Fisheries Society 117:55-62.

Hodder, J. 2003. Pelagic Cormorant (*Phalacrocorax pelagicus*). Pp. 58-59 *in* Birds of Oregon: A General Reference. D.B. Marshall, M.G. Hunter, and A.L. Contreras, Eds. Oregon State University Press, Corvallis, OR.

Hostetter, N.J., A.F. Evans, K. Collis, and D.D. Roby. 2011. Susceptibility of juvenile steelhead (*Oncorhynchus mykiss*) to avian predation: The influence of individual fish characteristics and river conditions. Pages 147-178 *in* Roby, D.D. (ed.). Impacts of avian predation on salmonid smolts from the Columbia and Snake rivers: A synthesis report to the U.S. Army Corps of Engineers Walla Walla District. Bird Research Northwest. Available on-line at www.birdresearchnw.org.

Janney, E.C., R.S. Shively, B. H. Hayes, and P.M. Barry. 2008. Demographic analysis of Lost River sucker and shortnose sucker populations in upper Klamath Lake, Oregon. Transactions of the American Fisheries Society 137:1812-1825.

Jones, S.T., G.M. Starke, and R.J. Stansell. 1996. Predation by birds and effectiveness of predation control measures at Bonneville, The Dalles, and John Day dams in 1995. U.S. Army Corps of Engineers, Portland District, Operations Division, CENPP-CO-SRF. 10 pp.

Kress, S. W. 1983. The use of decoys, sound recordings, and gull control for re-establishing a tern colony in Maine. Colonial Waterbirds 6:185-196.

Kress, S.W. 2000. Colony site management techniques. Issue Report in the Managers Toolbox, North American Waterbird Conservation Plan. Available through the Internet at http//www.nawcp.org/plan/toolbox.html.

Kress, S.W., and C.S. Hall. 2002. Tern management handbook: Coastal Northeastern United States and Atlantic Canada. Draft Report submitted to U.S. Fish and Wildlife Service, Migratory Bird Division, Hadley, MA.

Lyons, D.E., D.D. Roby, J.Y. Adkins, P.J. Loschl, L.R. Kerr, T.K. Marcella, A.F. Evans, N.J. Hostetter, K. Collis, D.R. Kuligowski, and B.P. Sandford. 2011a. Impacts of piscivorous birds on native anadromous fishes in the Mid-Columbia River. Pages 38-63 *in* Roby, D.D. (ed.). Impacts of avian predation on salmonid smolts from the Columbia and Snake rivers: A synthesis report to the U.S. Army Corps of Engineers Walla Walla District. Bird Research Northwest. Available on-line at www.birdresearchnw.org.

Lyons, D.E., D.D. Roby, A.F. Evans, N.J. Hostetter, and K. Collis. 2011b. Benefits to Columbia River anadromous salmonids from potential reductions in avian predation on the Columbia Plateau: A report to the U.S. Army Corps of Engineers Walla Walla District. Bird Research Northwest. Available on-line at www.birdresearchnw.org.

Manly, B.F.J. 1998. Randomization, bootstrap and Monte Carlo methods in biology. Second edition. Chapman & Hall, London.

Maranto, C.J., T.P. Good, F.K. Wiese, and J.K. Parrish. 2010. Impact of the Potholes Reservoir Caspian tern breeding colony on out-migrating juvenile salmonids in the mid-Columbia River. Transactions of the American Fisheries Society 139:362-381.

NOAA (National Oceanic and Atmospheric Administration). 2011. Updated status of federally listed ESUs of West Coast salmon and steelhead. Available at on-line at http://www.nwr.noaa.gov/Publications/Biological-Status-Reviews/Salmon.cfm (September 2011).

Petersen, J.H., M.G. Mesa, J. Hall-Griswold, W.C. Schrader, G.W. Short, and T.P. Poe. 1990. Magnitude and dynamics of predators on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report of Research, 1989-1990. Contract DE-AI79-88BP91964, Bonneville Power Administration, Portland, Oregon.

Petersen, J.H., D.B. Jepsen, R.D. Nelle, R.S. Shively, R.A. Tabor, and T.P. Poe. 1991. System-wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report of Research, 1990. Contract DE-AI79-90BP07096, Bonneville Power Administration, Portland, Oregon.

PTAGIS (PIT Tag Information System). 2012. The Columbia Basin PIT Tag Information System. Available at on-line at www.ptagis.org (October 2011).

Purcell, M., G.G Mackey, E. LaHood, H.T Huber, and L. Park. 2004. Molecular methods for the genetic identification of salmonid prey from Pacific harbor seal (*Phoca vitulina richardsi*) scat. Fishery Bulletin 102:213-220.

Roby, D.D., K. Collis, D.E. Lyons, D.P. Craig, J. Adkins, A.M. Myers, and R.M. Suryan. 2002. Effects of colony relocation on diet and productivity of Caspian terns. Journal of Wildlife Management 66:662–673.

Roby, D.D., D.E. Lyons, D.P. Craig, K. Collis, and G.H. Visser. 2003. Quantifying the effect of predators on endangered species using a bioenergetics approach: Caspian terns and juvenile salmonids in the Columbia River estuary. Canadian Journal of Zoology 81:250-265.

Ruggerone, G.T. 1986. Consumption of migrating juvenile salmonids by gulls foraging below a Columbia River dam. Transactions of the American Fisheries Society 115:736-742.

Ryan, B. A., J. W. Ferguson, R. D. Ledgerwood, and E. P. Nunnallee. 2001. Detection of passive integrated transponder tags from juvenile salmonids on piscivorous bird colonies in the Columbia River basin. North American Journal of Fisheries Management 21:149-153.

Ryan, B.A., S.G. Smith, J.M. Butzerin, and J.W. Ferguson. 2003. Relative vulnerability to avian predation of juvenile salmonids tagged with Passive Integrated Transponders in the Columbia River estuary, 1998-2000. Transactions of the American Fisheries Society 132:275-288.

Scoppettone, G.G., P.H. Rissler, D. Withers, and M.C. Fabes. 2006. Fish tag recovery from the American white pelican nesting colony on Anaho Island, Pyramid Lake, Nevada. Great Basin Birds 8:6-10.

Sebring, S.H., R.D. Ledgerwood, M. Morrow, B.P. Sandford, and A.F. Evans. 2011. Detection of passive integrated transponder (PIT) tags on piscivorous avian colonies in the Columbia River basin, 2010. Annual report the U.S. Army Corps of Engineers Walla Walla District. NOAA Fisheries, Northwest Fisheries Science Center. Seattle, WA.

Seeb, L.W., A. Antonovich, M.A. Banks, T.D. Beacham, M.R. Bellinger, S.M. Blankenship, M.R. Campbell, N.A. Decovich, J.C. Garza, C.M. Guthrie III, T.A. Lundrigan, P. Moran, S.R. Narum, J.J. Stephenson, K.T. Supernault, D.J. Teel, W.D. Templin, J.K. Wenburg, S.F. Young, C.T. Smith. 2007. Development of a Standardized DNA Database for Chinook Salmon. Fisheries 32:540-552.

Tiller, B.L., I.D. Welch, J.E. Bernhard, and T.M. Degerman. 2003. Assessment of the extent of potential salmonid predation by American white pelicans in the pool and tailrace of McNary Dam 2002. 2002 Annual Report submitted to U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA.

Tyler, W.B., K.T. Briggs, D.B. Lewis, and G. Ford. 1993. Seabird distribution and abundance in relation to oceanographic processes in the California system. Pp. 48-60 *in* The status, ecology, and conservation of marine birds in the North Pacific. K. Vermeer, K.T. Briggs, K.H. Morgan, and D. Siegel-Causey, Eds. Canadian Wildlife Service Special Publication, Ottawa.

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

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

Van Doornik, D.M., D.J. Teel, D.R. Kuligowski, C.A. Morgan, and E. Casillas. 2007. Genetic analyses provide insight into the early ocean stock distribution and survival of juvenile coho salmon (Oncorhynchus kisutch) off the coasts of Washington and Oregon. North American Journal of Fisheries Management 27:220-237.

Wright, S.K. 2005. Disturbance and roosting ecology of California brown pelicans (*Pelecanus occidentalis californicus*) on East Sand Island in the Columbia River estuary. Unpubl. M.Sc. Thesis, Oregon State University, Corvallis, OR. 106 pp.

Zorich, N.A., M.R. Jonas, and P.L. Madson. 2010. Avian Predation at John Day Dam 2009: Estimated Fish Consumption Using Direct Observation With Diet Analysis. Report to USACE Walla Walla District.

PROJECT PUBLICATIONS AND SUBMITTED MANUSCRIPTS

Adrean, L.J., D.D. Roby, D.E. Lyons, K. Collis, and A.F. Evans. In press. Caspian tern (*Hydroprogne caspia*) predation on juvenile salmonids and other forage fishes in San Francisco Bay, California. Transactions of the American Fisheries Society 000:000-000.

Anderson, C.D., D.D. Roby, and K. Collis. 2004. Conservation implications of the large colony of double-crested cormorants on East Sand Island, Columbia River estuary, Oregon, USA. Waterbirds 27:155-160.

Anderson, C.D., D.D. Roby, and K. Collis. 2004. Foraging patterns of male and female double-crested cormorants nesting in the Columbia River estuary. Canadian Journal of Zoology 82:541-554.

Anderson, S.K., D.D. Roby, D.E. Lyons, and K. Collis. 2005. Factors affecting chick provisioning by Caspian terns nesting in the Columbia River estuary. Waterbirds 28:95-105.

Anderson, S.K., D.D. Roby, D.E. Lyons, and K. Collis. 2007. Relationship of Caspian tern foraging ecology to nesting success in the Columbia River estuary, Oregon, USA. Estuarine, Coastal, and Shelf Science 73:447-456.

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

Antolos, M., D.D. Roby, D.E. Lyons, K. Collis, A.F. Evans, M. Hawbecker, and B.A. Ryan. 2005. Caspian tern predation on juvenile salmonids in the Mid-Columbia River. Transactions of the American Fisheries Society 134:466-480.

Antolos, M., D.D. Roby, D.E. Lyons, S.K. Anderson, and K. Collis. 2006. Effects of nest density, location, and timing on breeding success of Caspian terns. Waterbirds 29:465-472.

Collis, K., D.D. Roby, D.P. Craig, B.A. Ryan, and R.D. Ledgerwood. 2001. Colonial waterbird predation on juvenile salmonids tagged with Passive Integrated Transponders in the Columbia River Estuary: Vulnerability of different species, stocks, and rearing types. Transactions of the American Fisheries Society 130:385–396.

Collis, K., D.D. Roby, D.P. Craig, S. Adamany, J. Adkins, and D.E. Lyons. 2002. Colony size and diet composition of piscivorous waterbirds on the lower Columbia River: Implications for losses of juvenile salmonids to avian predation. Transactions of the American Fisheries Society 131:537–550.

Collis, K., D.D. Roby, C.W. Thompson, D.E. Lyons, and M. Tirhi. 2002. Barges as temporary breeding sites for Caspian terns: Assessing potential sites for colony restoration. Wildlife Society Bulletin 30:1140–1149.

Collis, K., D.D. Roby, K.W. Larson, L.J. Adrean, K. Nelson, A.F. Evans, D. Battaglia, D.E. Lyons, T. Marcella, and A. Patterson. 2012. Trends in Caspian tern nesting and diet in San Francisco Bay: Conservation implications for terns and salmonids. Waterbirds 35:25-34.

Courtot, K.N., D.D. Roby, J.Y. Adkins, D.E. Lyons, D.T. King, and R.S. Larsen. In press. Colony connectivity of Pacific Coast double-crested cormorants based on post-breeding dispersal from the region's largest colony. Journal of Wildlife Management 000:000-000.

Evans, A.F., D.D. Roby, K. Collis, B.M. Cramer, J.A. Sheggeby, L.J. Adrean, D.S. Battaglia, and D.E. Lyons. 2011. Recovery of coded wire tags on a Caspian tern colony in San Francisco Bay: A technique to evaluate impacts of avian predation on juvenile salmonids. North American Journal of Fisheries Management 31:79-87.

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

Hostetter, N.J., A. F. Evans, D. D. Roby, K. Collis, M. Hawbecker, B. P. Sandford, D. E. Thompson and F. J. Loge. 2011. Relationship of external fish condition to pathogen prevalence and out-migration survival in juvenile steelhead. Transactions of the American Fisheries Society 140:1158-1171.

Hostetter, N.J., A. F. Evans, D. D. Roby, and K. Collis. In press. Susceptibility of juvenile steelhead (*Oncorhynchus mykiss*) to avian predation: The influence of individual fish characteristics and river conditions. Transactions of the American Fisheries Society 000:000-000.

Lyons, D.E., D.D. Roby, and K. Collis. 2005. Foraging ecology of Caspian terns in the Columbia River estuary, USA. Waterbirds 28:280-291.

Lyons , D.E., D.D. Roby, and K. Collis. 2007. Foraging patterns of Caspian terns and double-crested cormorants in the Columbia River estuary. Northwest Science 81:91-103.

Lyons, D.E., and D.D. Roby. 2011. Validating growth and development of a seabird as an indicator of food availability: captive-reared Caspian tern chicks fed ad libitum and restricted diets. Journal of Field Ornithology 82:88-100.

Matthews, S.E., D.P. Craig, K. Collis, and D.D. Roby. 2003. Double-crested Cormorant (*Phalacrocorax auritus*). Pp. 56-58 *in* D.B. Marshall, M.G. Hunter, and A.L. Contreras (eds.). Birds of Oregon: A General Reference. Oregon State University Press, Corvallis, OR.

Roby, D.D., K. Collis, D.E. Lyons, D.P. Craig, J. Adkins, A.M. Myers, and R.M. Suryan. 2002. Effects of colony relocation on diet and productivity of Caspian terns. Journal of Wildlife Management 66:662–673.

Roby, D.D., K. Collis, D.E. Lyons, D.P. Craig, and M. Antolos. 2003. Caspian Tern (*Sterna caspia*). Pp. 277-279 *in* D.B. Marshall, M.G. Hunter, and A.L. Contreras (eds.). Birds of Oregon: A General Reference. Oregon State University Press, Corvallis, OR.

Roby, D.D., K. Collis, and D.E. Lyons. 2005. Conservation and management for fish-eating birds and endangered salmon. Pp. 161-165 in C.J. Ralph and T.D. Rich (eds.). Bird conservation implementation and integration in the Americas: Proceedings of the Third International Partners in Flight Conference. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191.

Roby, D.D., D.E. Lyons, D.P. Craig, K. Collis, and G.H. Visser. 2003. Quantifying the effects of predators on endangered species using a bioenergetics approach: Caspian terns and juvenile salmonids in the Columbia River estuary. Canadian Journal of Zoology 81:250–265.

Suryan, R.M., D.P. Craig, D.D. Roby, N.D. Chelgren, K. Collis, W.D. Shuford, and D.E. Lyons. 2004. Redistribution and growth of the Caspian tern population in the Pacific coast region of North America, 1981-2000. Condor 106:777-790.

Wright, S.K., D.D. Roby, and R.G. Anthony. 2007. Responses of California brown pelicans to disturbances at a large Oregon roost. Waterbirds 30:479-487.

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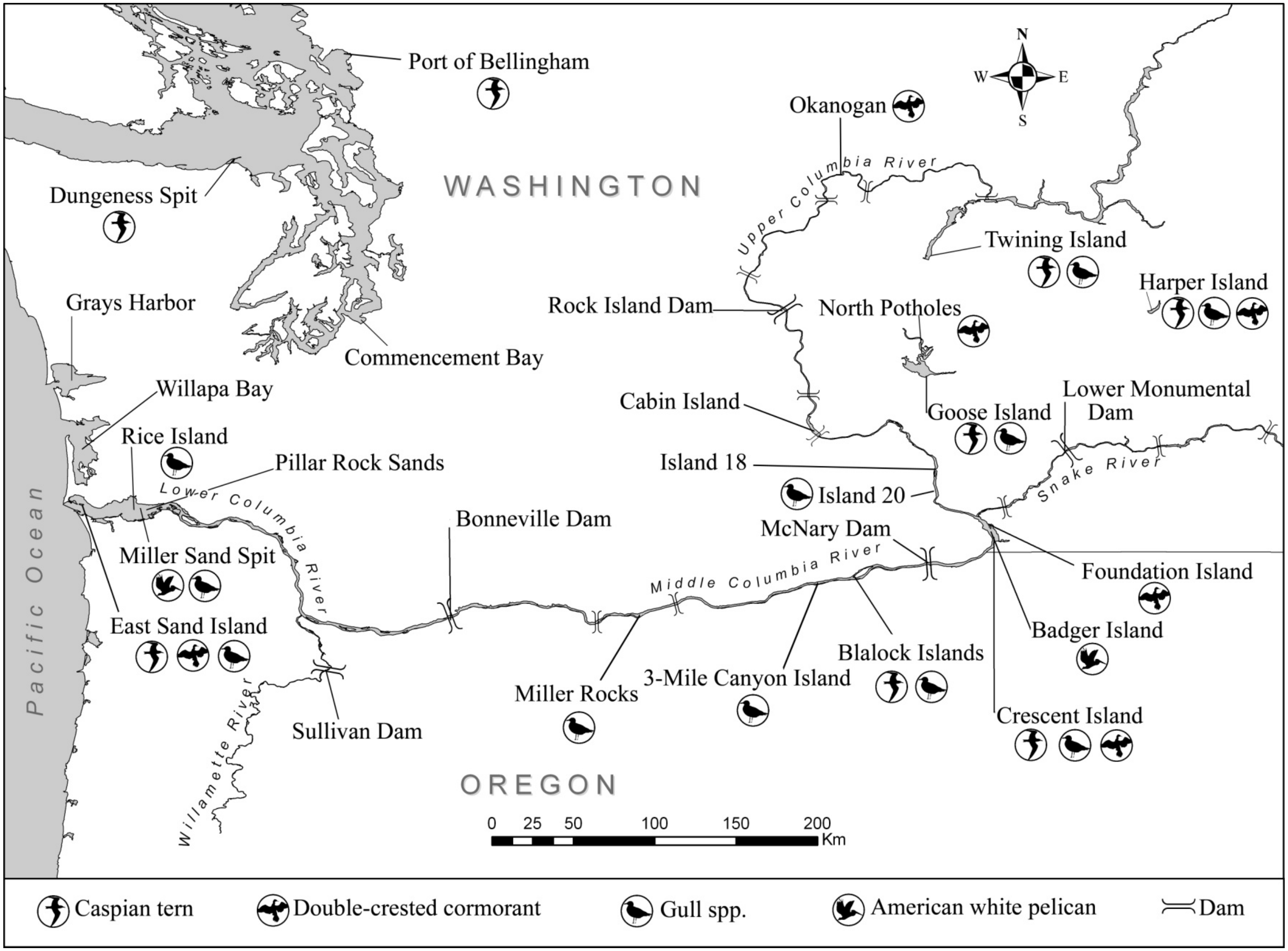
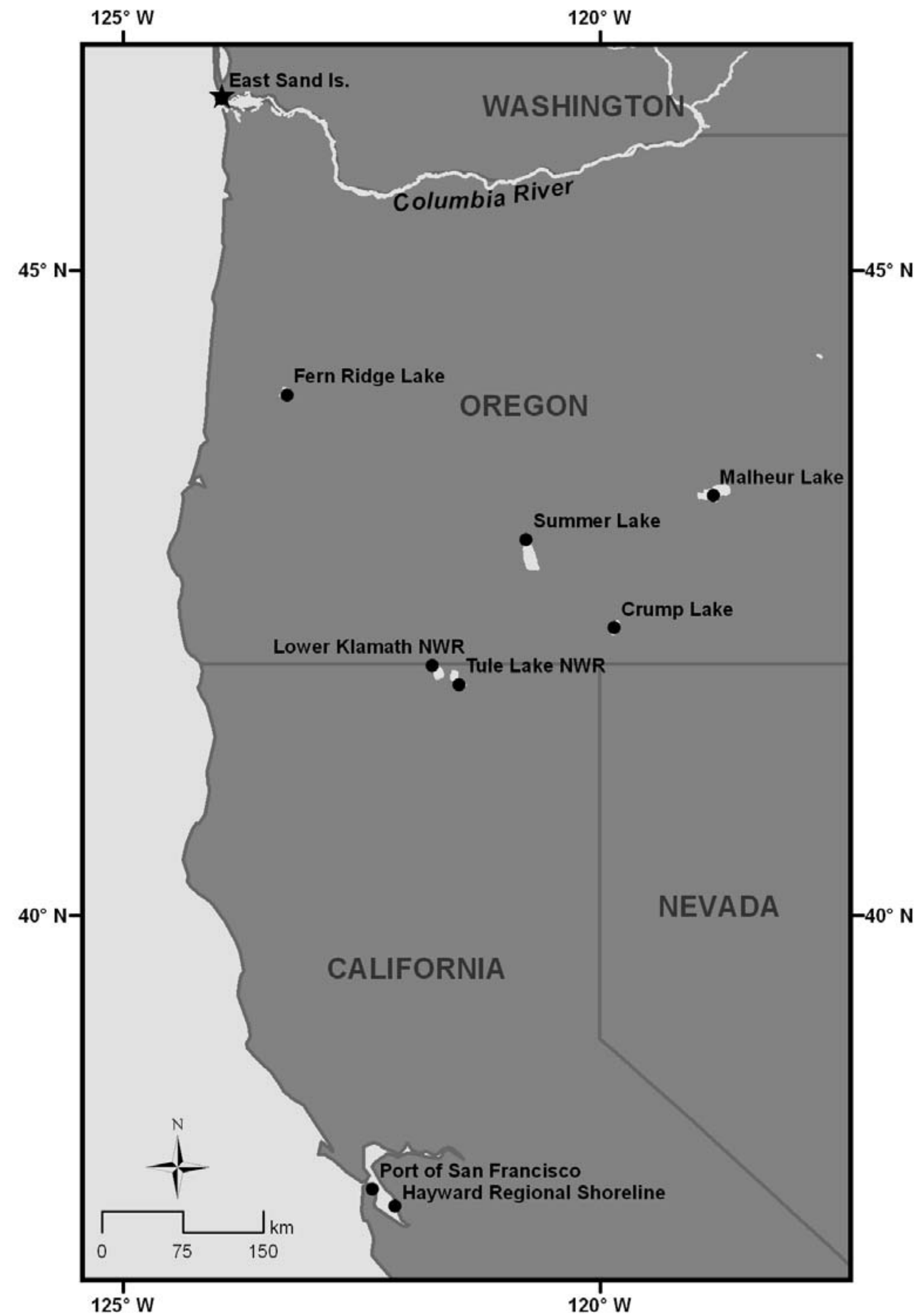
	Funding Contribution by Agency			
	BPA	USACE Portland District	USACE Walla Walla District	BOR
Caspian Terns				
1.1. Preparation and Modification of Nesting Habitat				
1.1.1. Columbia River Estuary		x		
1.1.2. Interior Oregon and Northeastern California		x		
1.2. Colony Size and Productivity				
1.2.1. Columbia River Estuary	x			
1.2.2. Columbia Plateau			x	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	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	BOR
Caspian Terns (cont.)				
1.4. Predation Rates Based on PIT Tag Recoveries				
1.4.1. Columbia River Estuary	x			
1.4.2. Columbia Plateau			x	x
1.4.3. Coastal Washington				
1.4.4. Interior Oregon and Northeastern California		x		
1.5. Color Banding and Band Resightings				
1.5.1. Columbia River Estuary	x			
1.5.2. Columbia Plateau			x	x
1.5.3. Coastal Washington		x		
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	

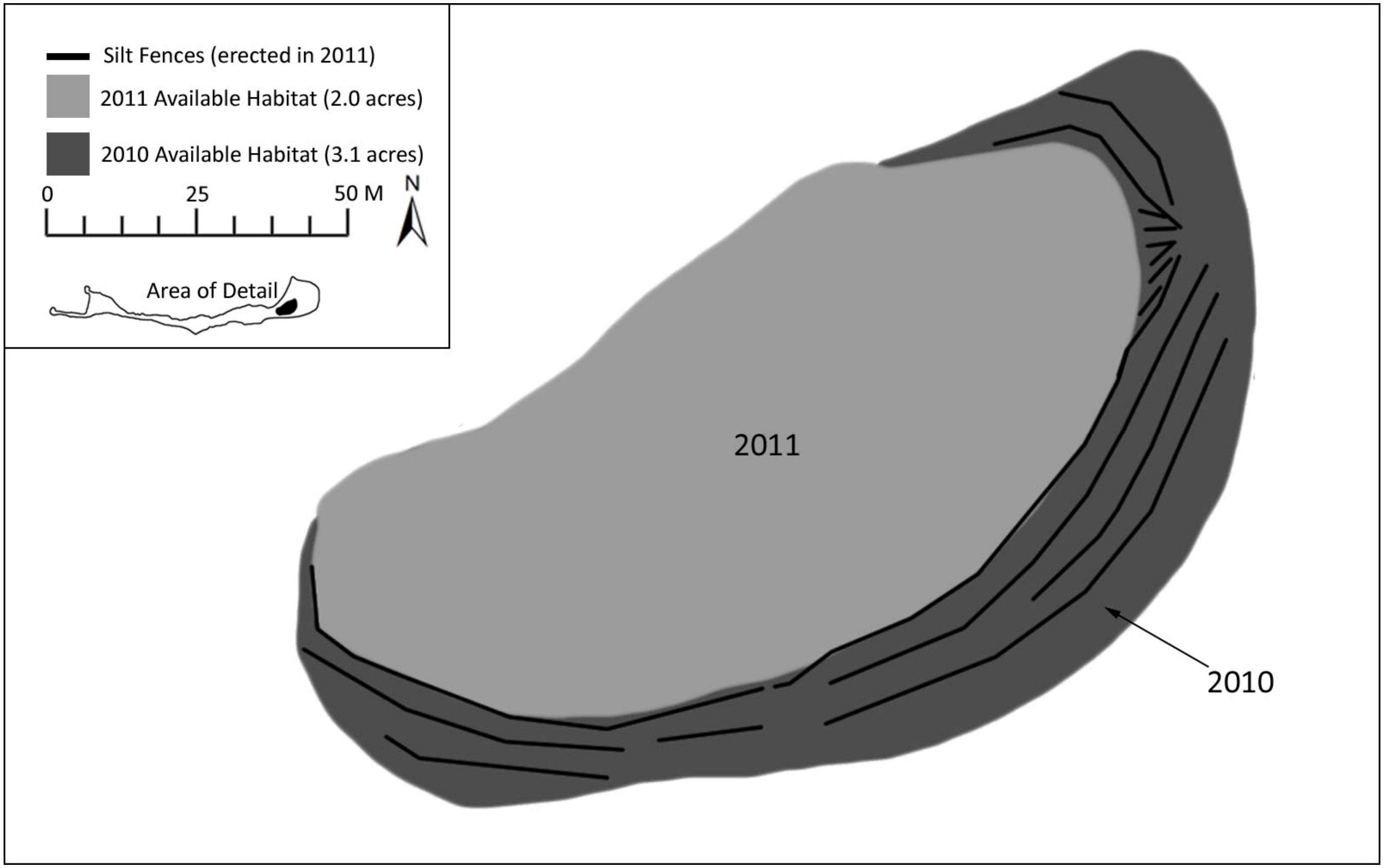
	Funding Contribution by Agency			
	BPA	USACE Portland District	USACE Walla Walla District	BOR
Double-crested Cormorants (cont.)				
2.4. Predation Rates Based on PIT Tag Recoveries				
2.4.1. Columbia River Estuary	x	x		
2.4.2. Columbia Plateau			x	
2.5. Color Banding		x		
2.6. Management Feasibility Studies				
2.6.1. Techniques to Encourage Nesting		x		
2.6.2. Techniques to Discourage Nesting		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	x			
3.1.4. Interior Oregon and Northeastern California		x		
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	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.

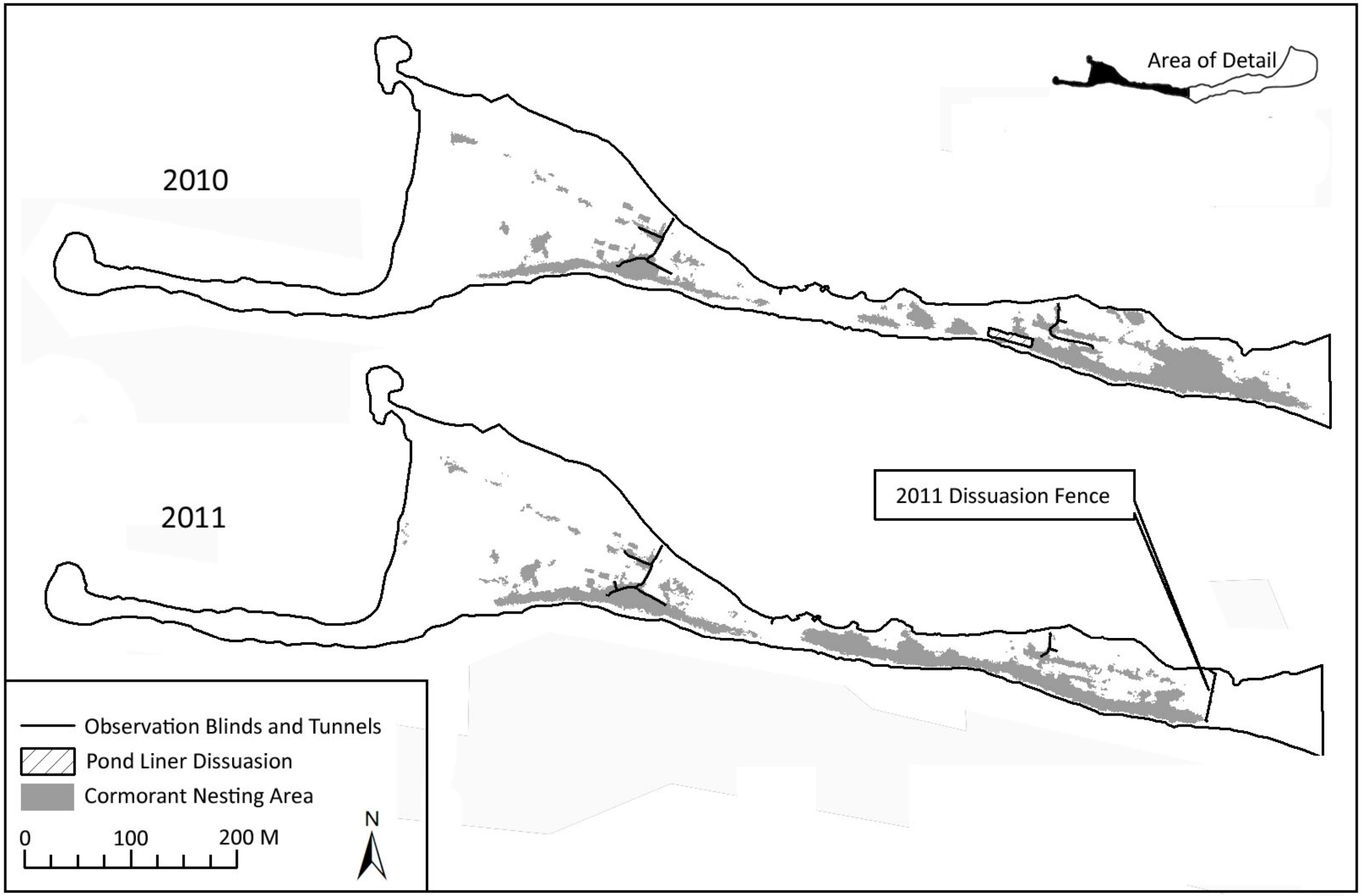


Map 2. Locations of existing recently-built and proposed islands designated for Caspian tern nesting as part of the federal agencies' Caspian Tern Management Plan for the Columbia River estuary (USFWS 2005, 2006).

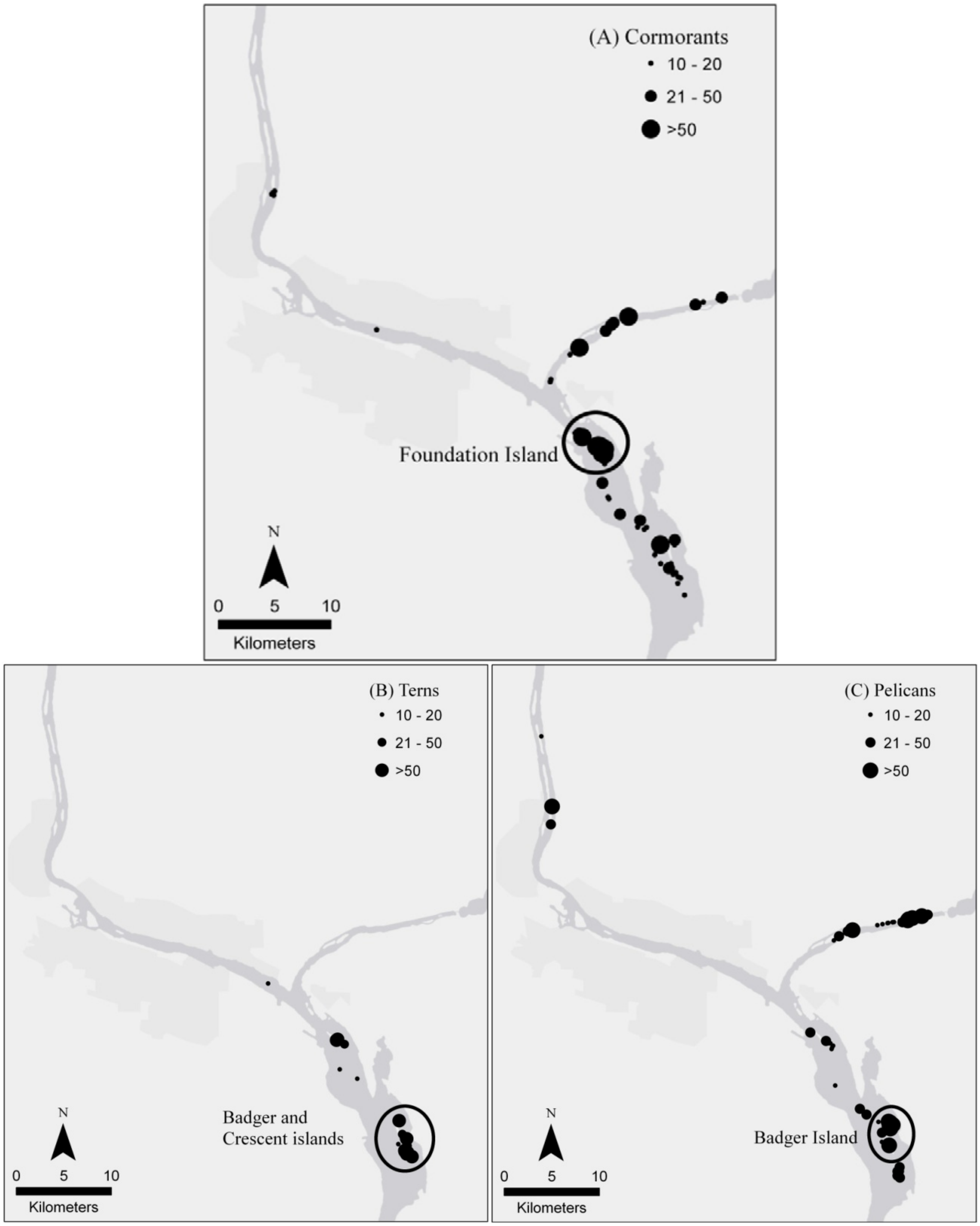


Map 3. Nesting habitat prepared for Caspian terns on the eastern end of East Sand Island in the Columbia River estuary during 2010 and 2011. Silt fencing was erected on a portion of the nesting habitat used by terns in 2010 to further reduce the amount of nesting habitat made available to terns in 2011 (see text for details). In 2010-2011, 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 and northeastern California 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 and 2011 breeding seasons. Also shown are the locations of observation blinds and access tunnels, plus the area used for a nest dissuasion experiment (see text for details). In 2010-2011, cormorants nested only on the western half of East Sand Island (shown here) and not elsewhere on the island.



Map 6. Counts of loafing and foraging (a) double-crested cormorants, (b) Caspian terns, and (c) American white pelicans 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 2011. Only aggregations of 10 or more birds are shown. Observations of birds loafing on or near their respective nesting islands are circled.

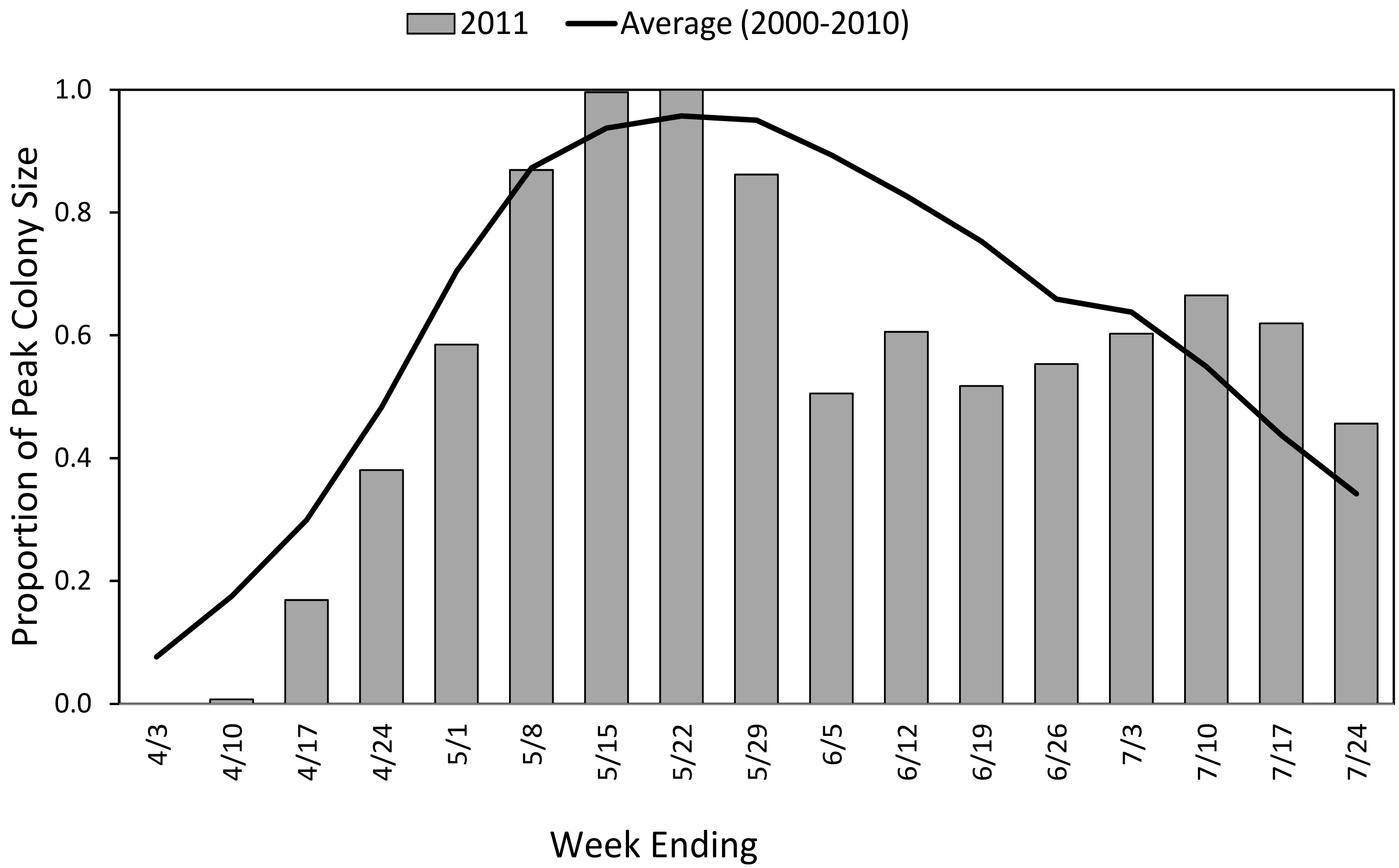


Figure 1. Weekly estimates from the ground of the number of adult Caspian terns on the East Sand Island colony during the 2011 breeding season, relative to peak colony attendance determined from counts of aerial photography taken late in incubation.

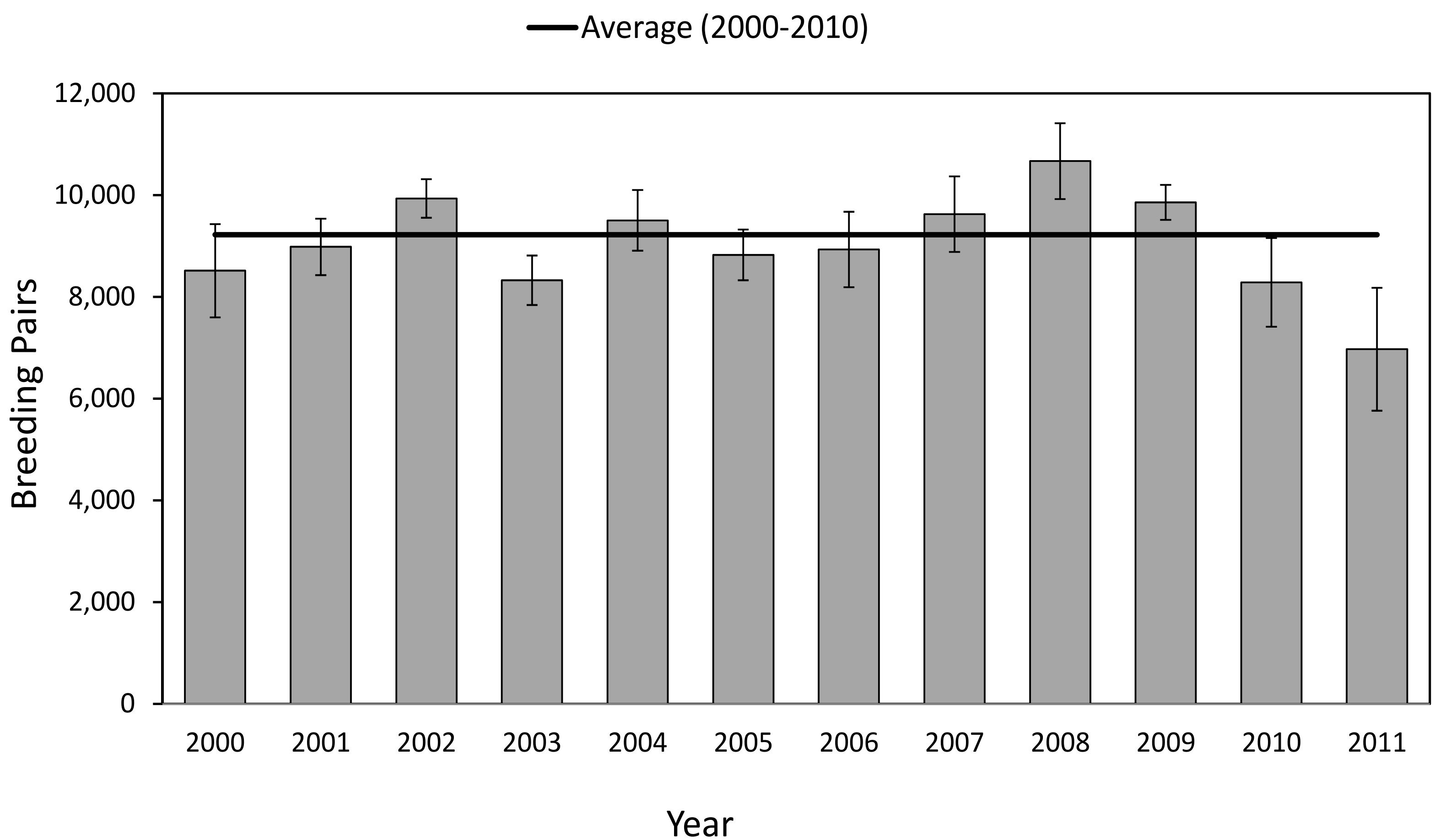


Figure 2. Caspian tern colony size on East Sand Island in the Columbia River estuary during 2000-2011. The error bars represent 95% confidence intervals for the number of breeding pairs.

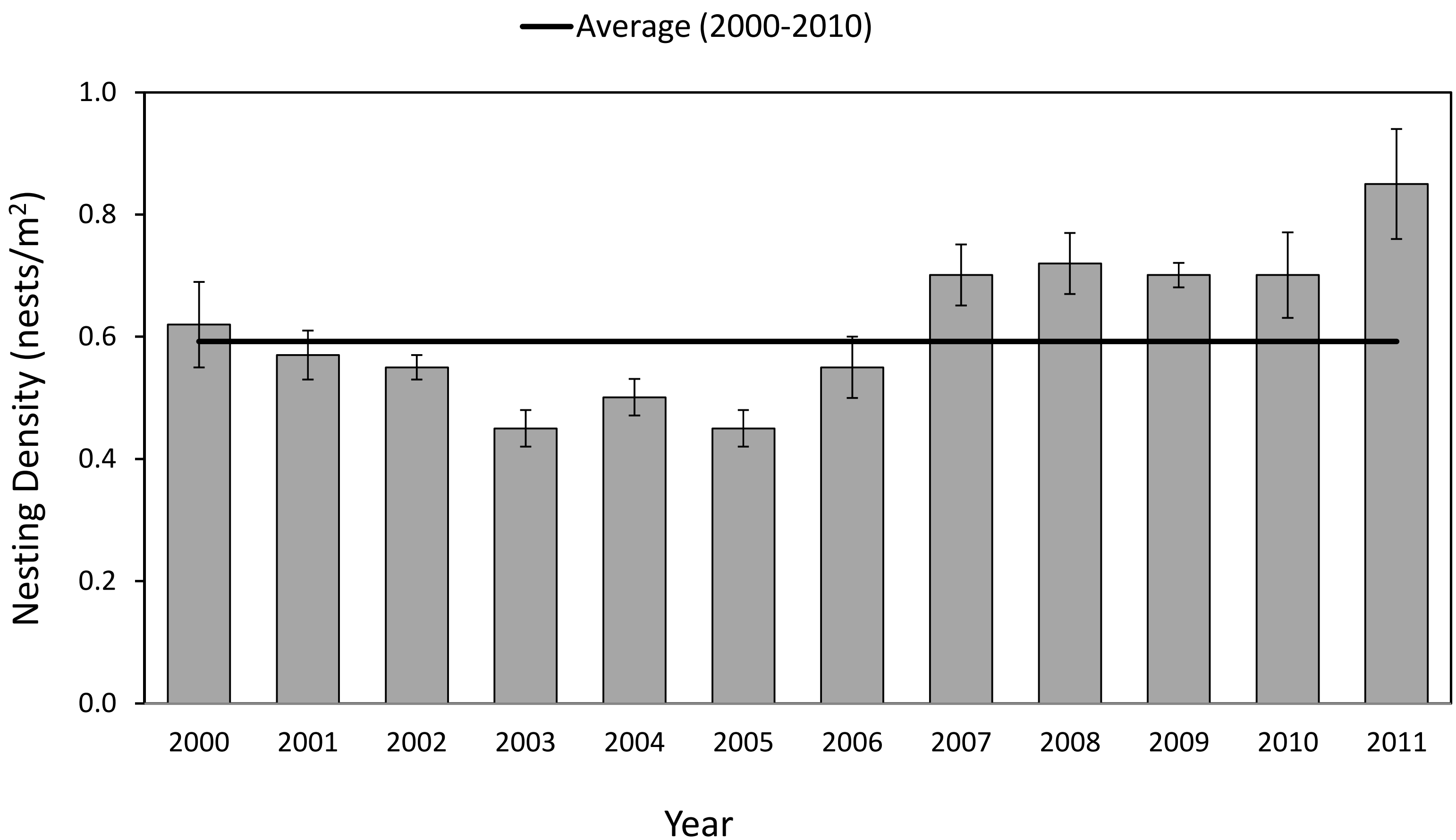


Figure 3. Caspian tern nesting density at the breeding colony on East Sand Island, Columbia River estuary during 2000-2011. The error bars represent 95% confidence intervals for nesting density (error estimate not available for 2011).

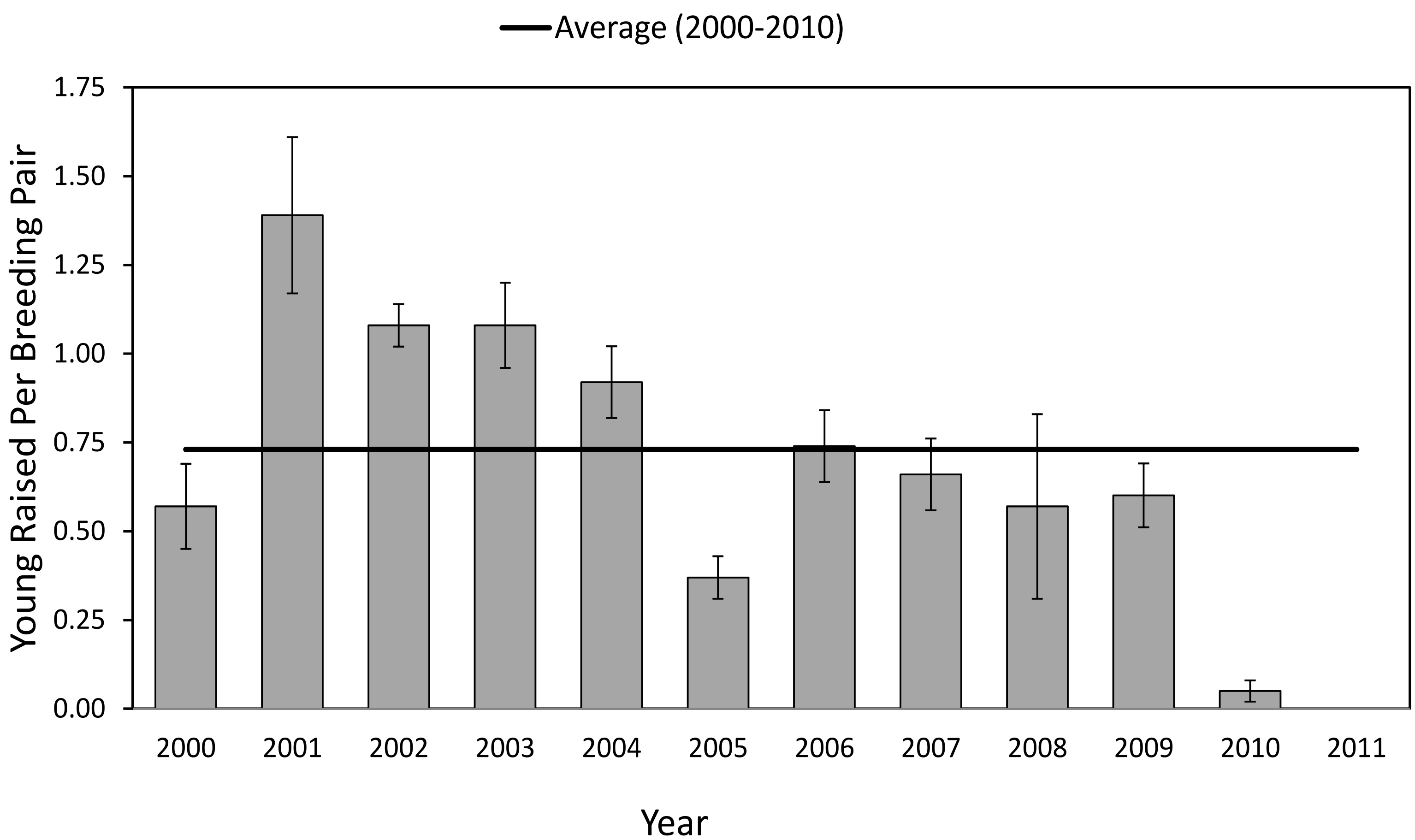


Figure 4. Caspian tern nesting success at the breeding colony on East Sand Island in the Columbia River estuary during 2000-2011. The error bars represent 95% confidence intervals for the number of young raised per breeding pair.

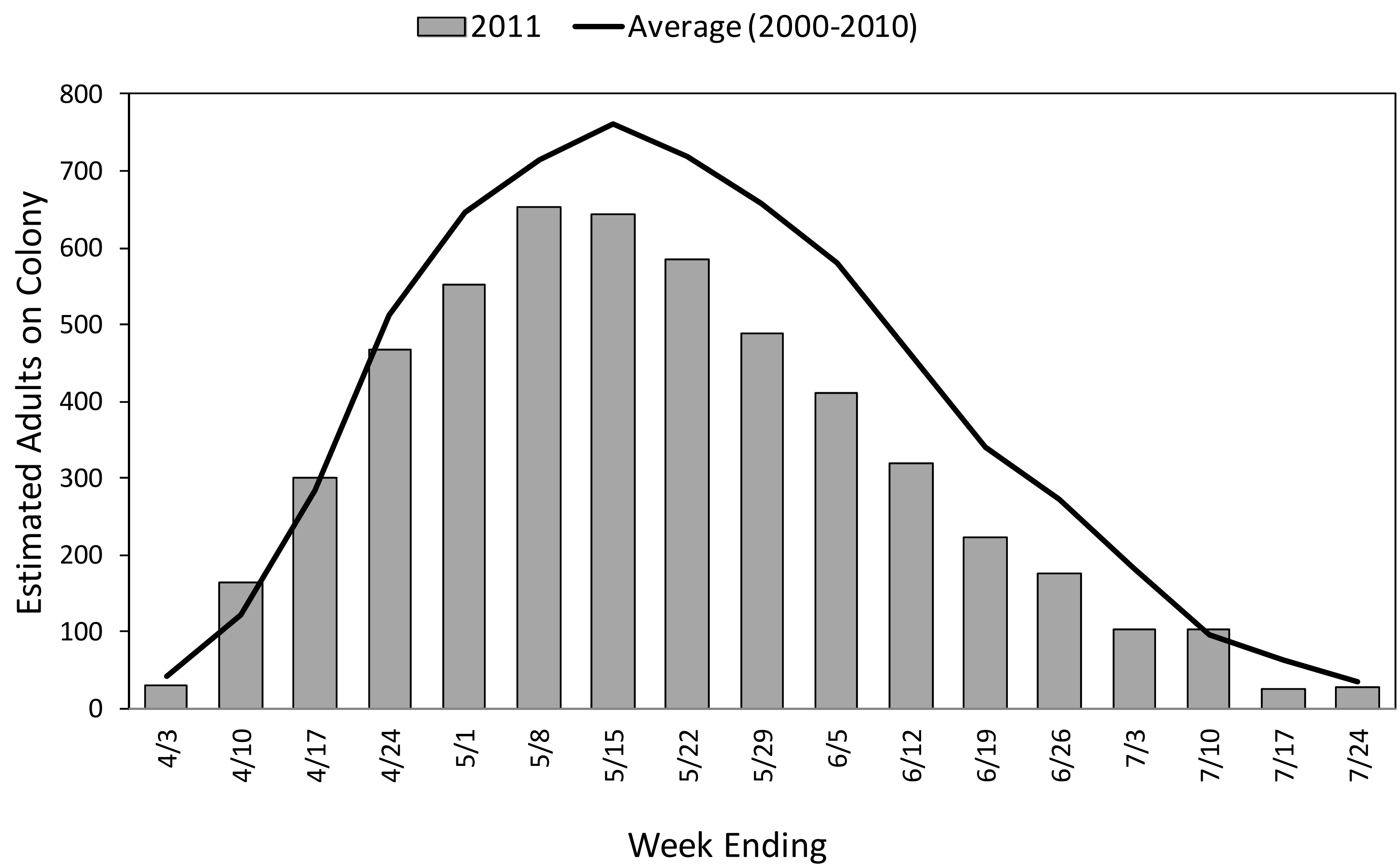


Figure 5. Estimates from the ground of the number of adult Caspian terns on the Crescent Island breeding colony on the mid-Columbia River, by week during the 2011 breeding season.

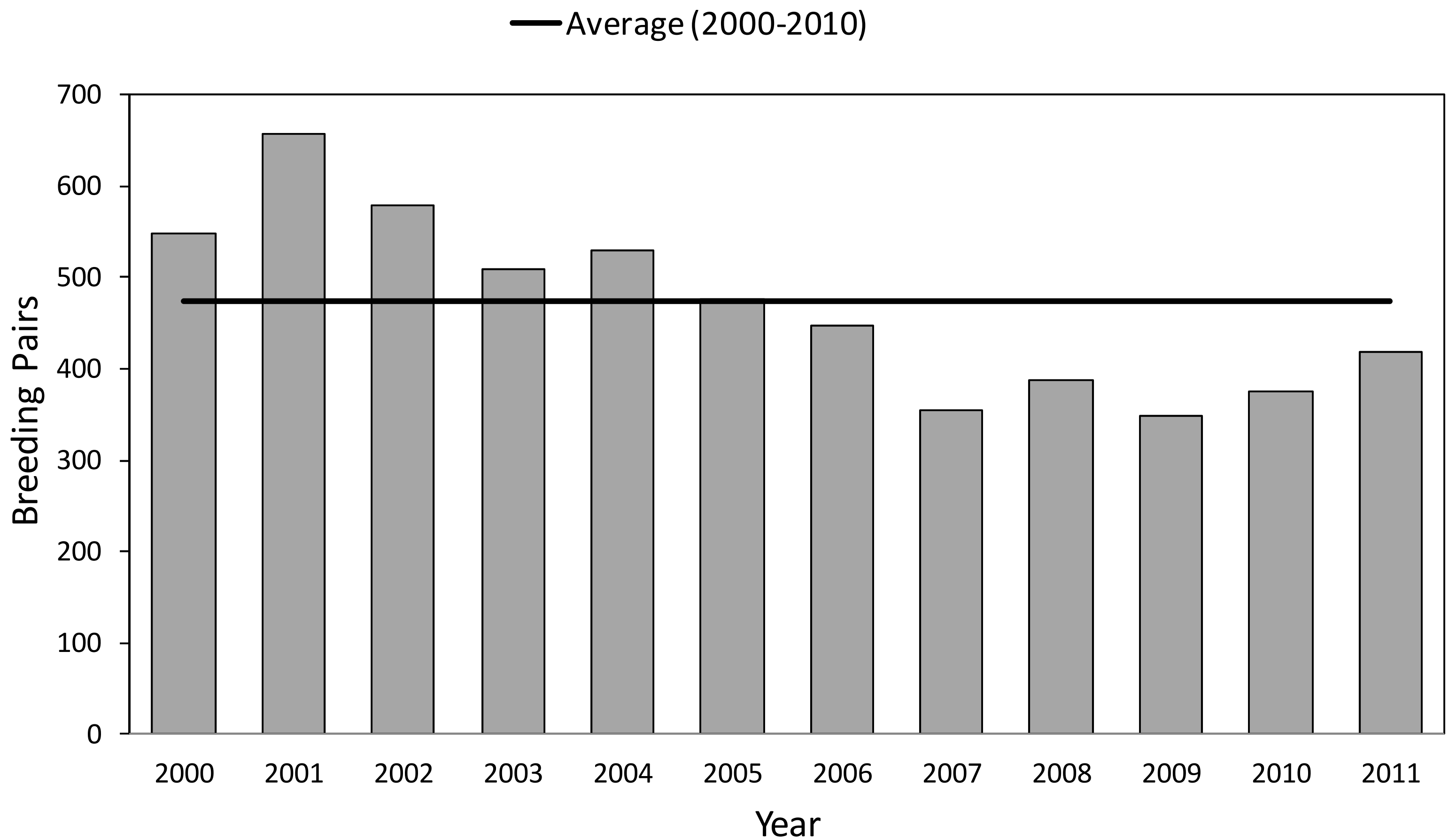


Figure 6. Size of the Caspian tern breeding colony on Crescent Island in the mid-Columbia River during 2000-2011.

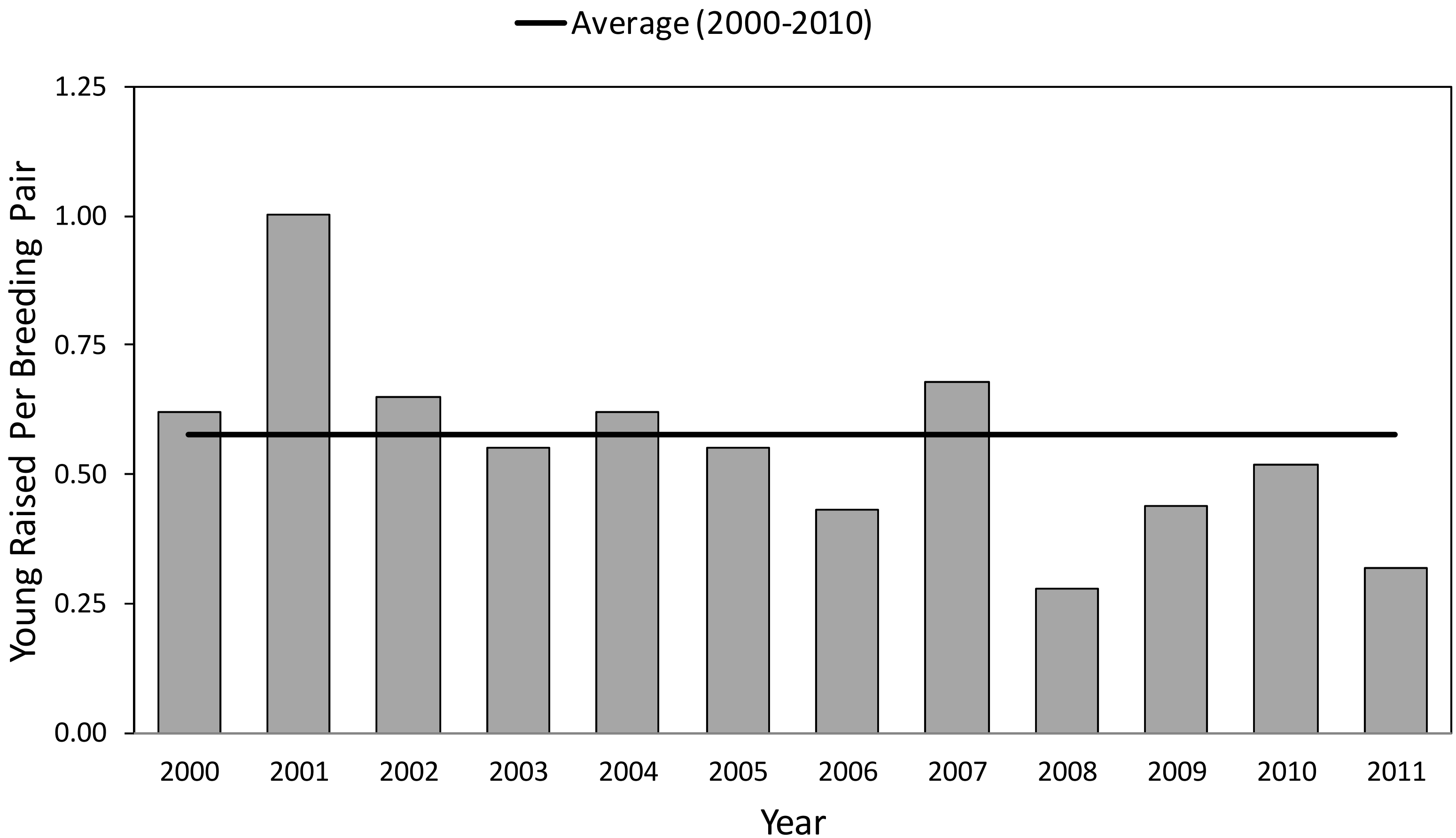


Figure 7. Nesting success of Caspian terns at the breeding colony on Crescent Island in the mid-Columbia River during 2000-2011.

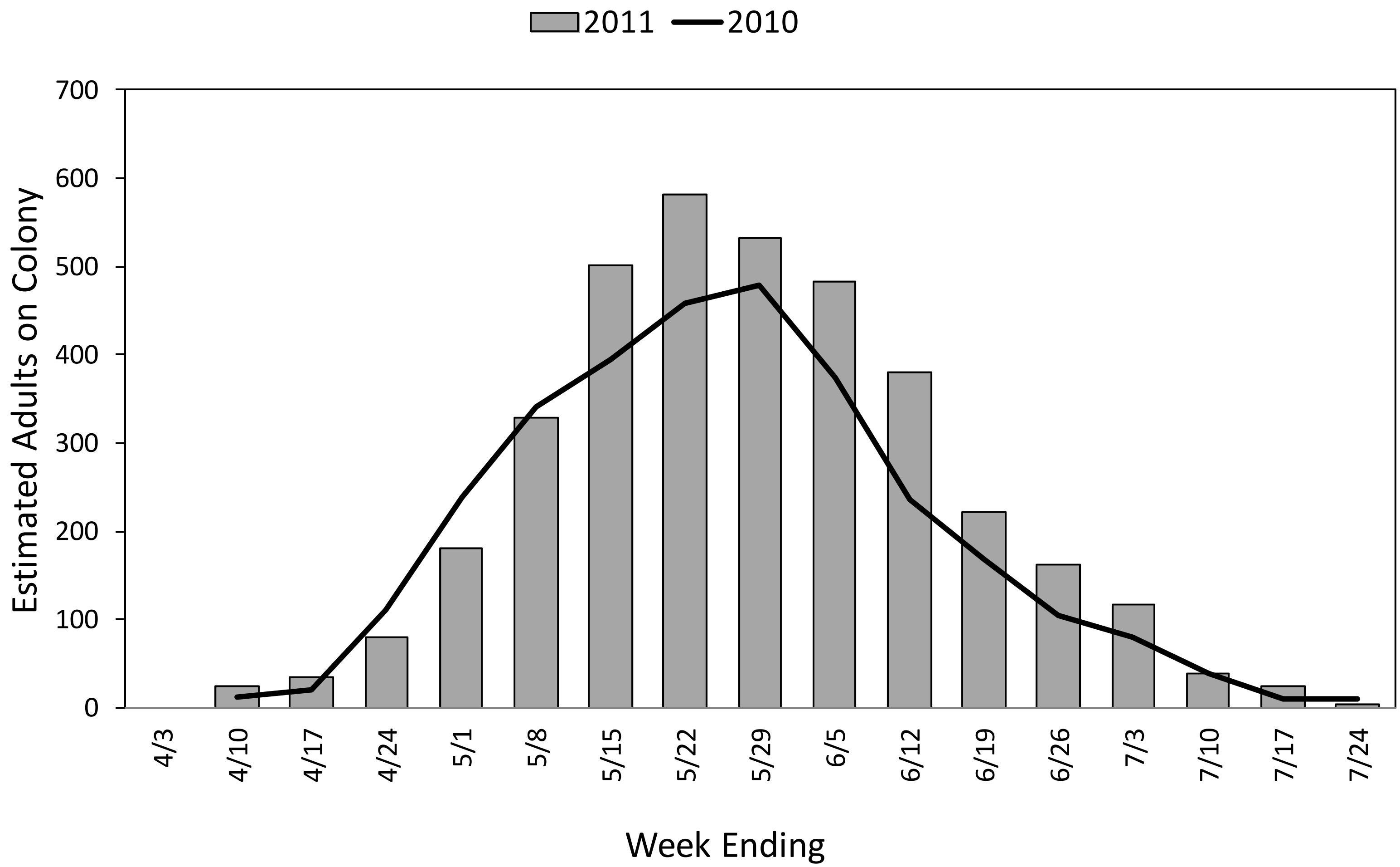


Figure 8. Estimates from the ground of the number of adult Caspian terns at the breeding colony on Goose Island in Potholes Reservoir, by week during the 2011 breeding season.

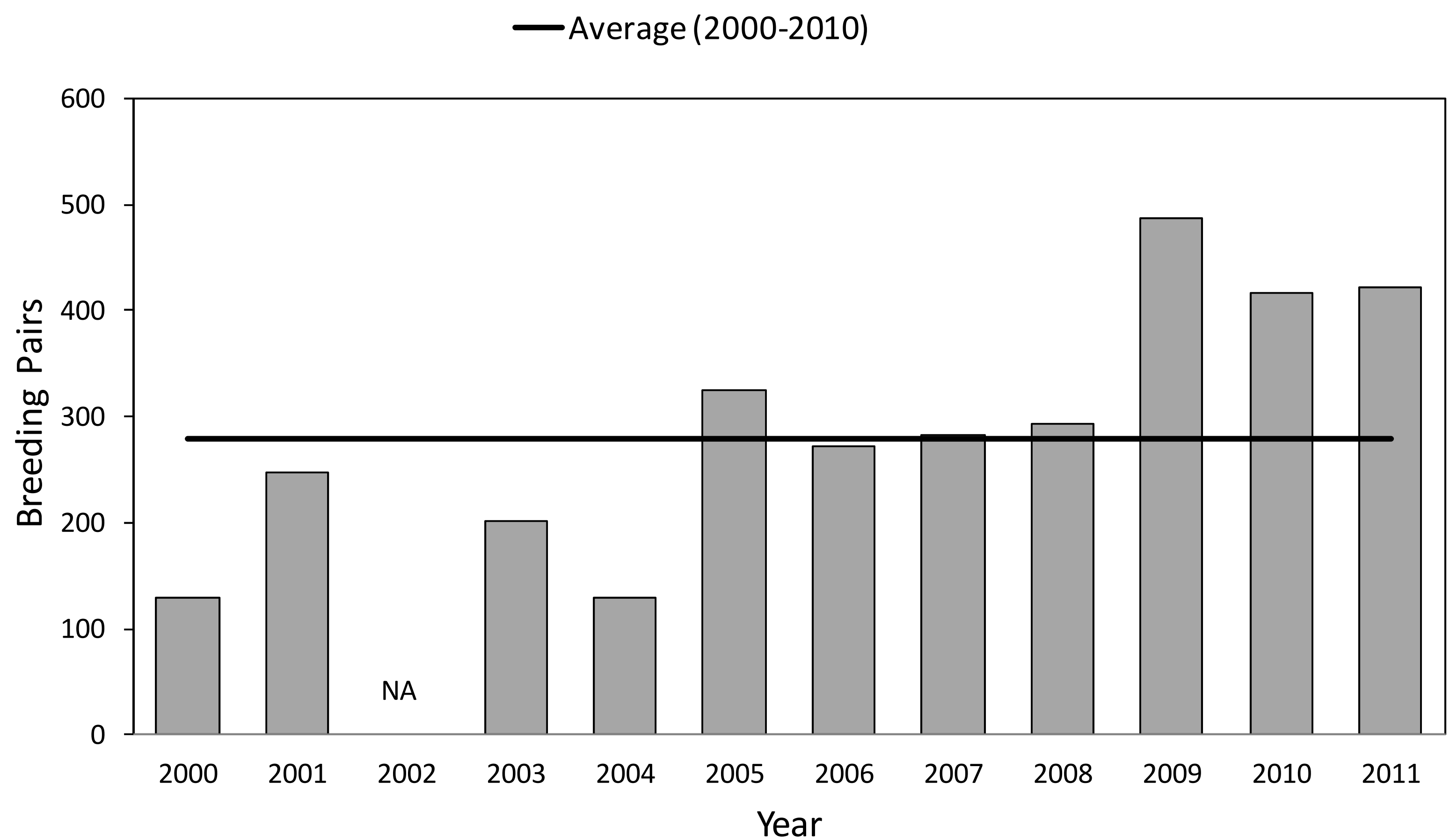


Figure 9. Size of the Caspian tern breeding colony on Goose Island in Potholes Reservoir during 2000-2011. Colony size in 2002 is unknown.

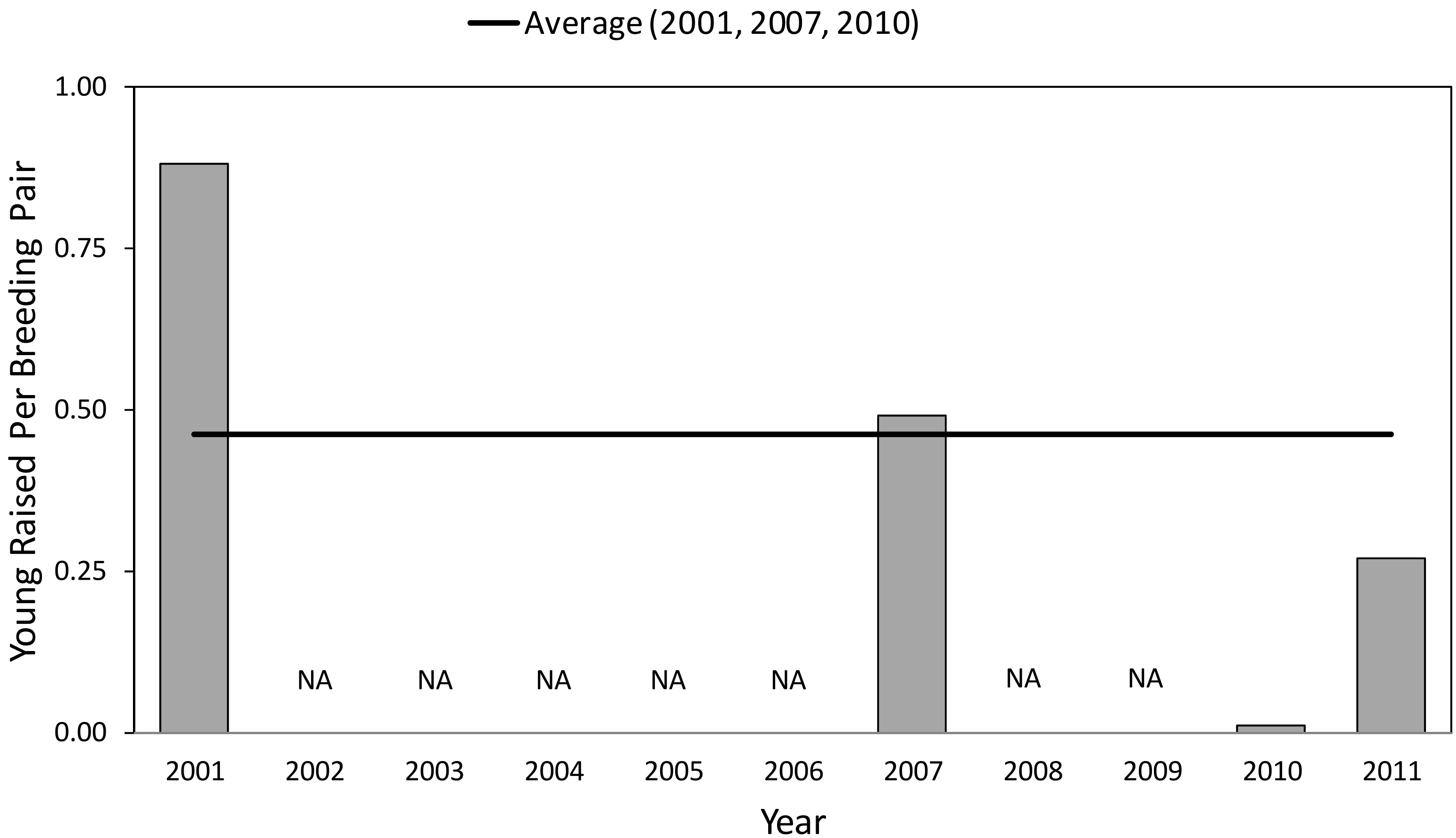


Figure 10. Caspian tern nesting success at the Goose Island breeding colony in Potholes Reservoir during 2001-2011. Nesting success during 2002-2006 and 2008-2009 is unknown.

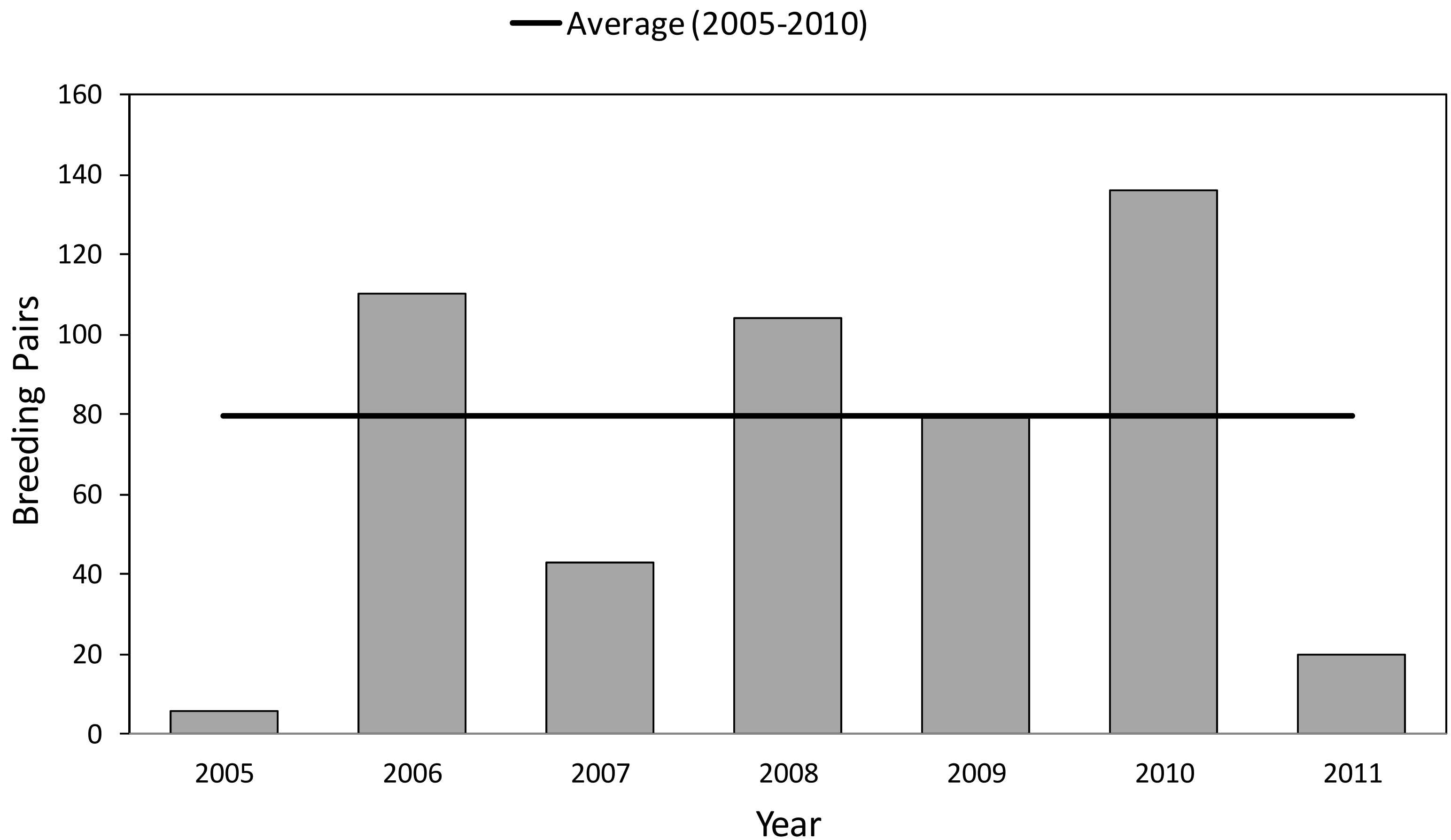


Figure 11. Size of the Caspian tern breeding colony at the Blalock Islands in the mid-Columbia River during 2005-2011.

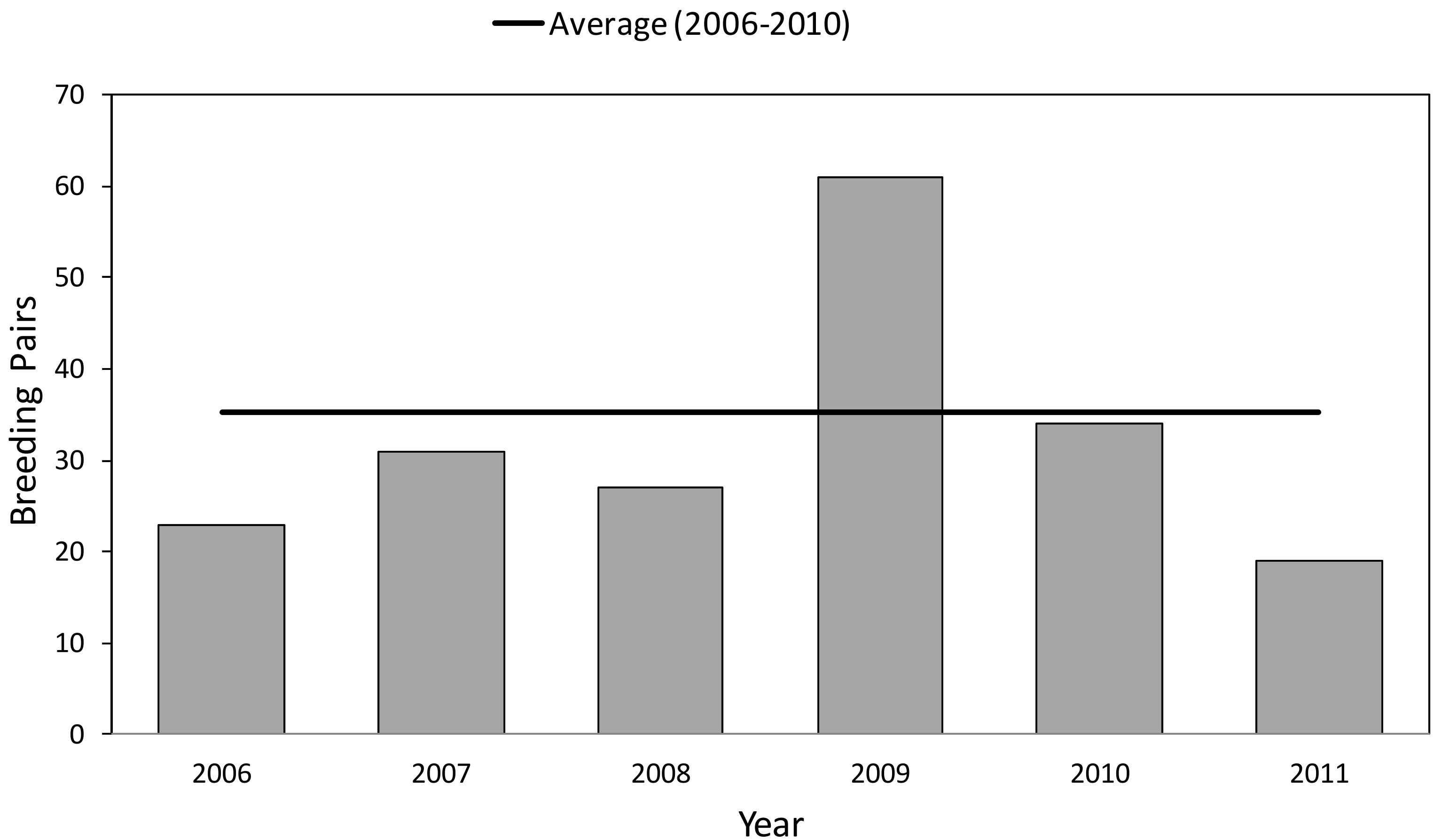


Figure 12. Size of the Caspian tern breeding colony at Twining Island in Banks Lake during 2006-2011. In 2005, Caspian terns nested on two islands in Banks Lake (Twining and Goose islands) where colony size was estimated to be less than 10 breeding pairs at each site.

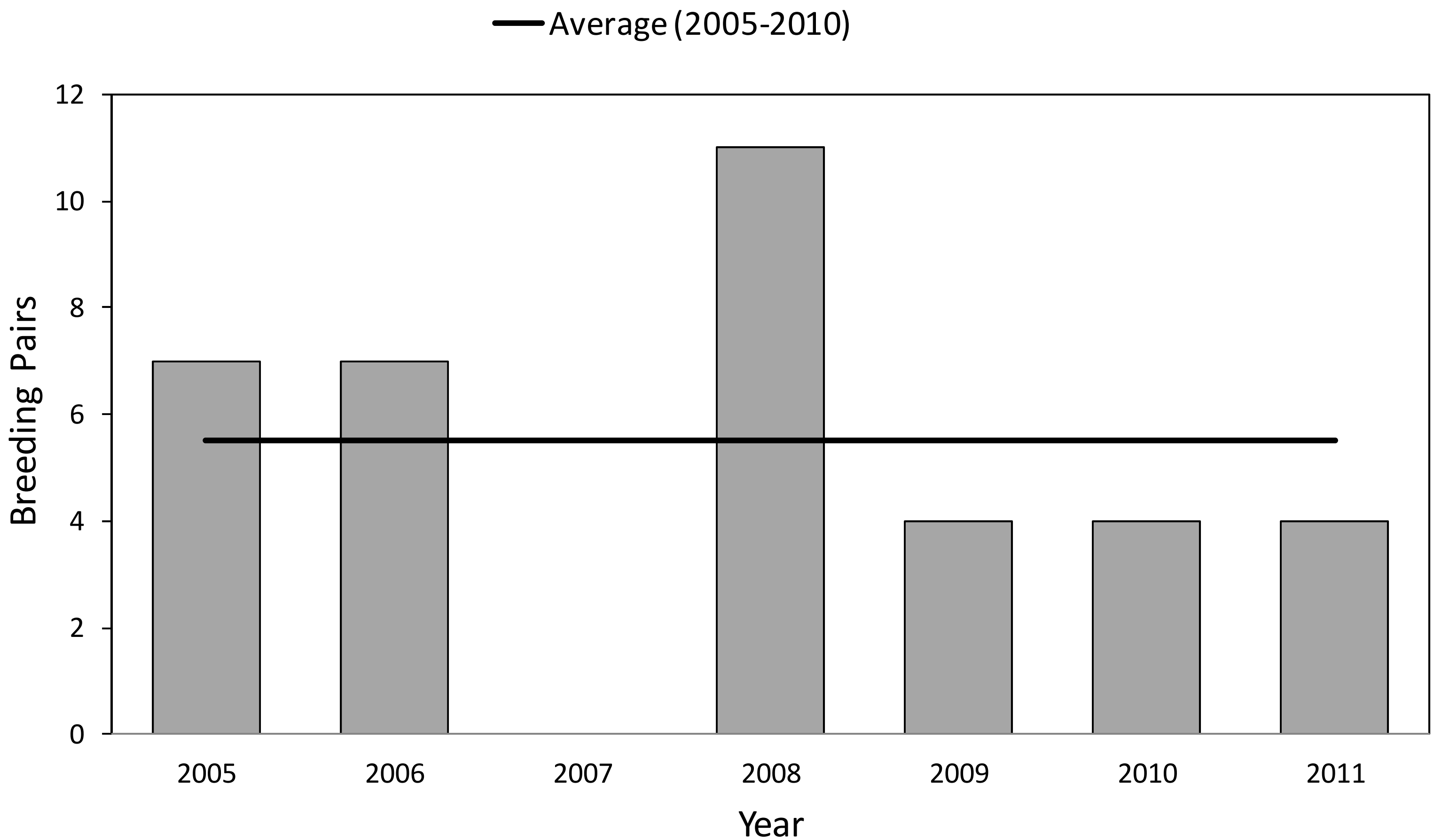


Figure 13. Size of the Caspian tern breeding colony at Harper Island in Sprague Lake during 2005-2011. Caspian terns did not attempt to nest on Harper Island in 2007.

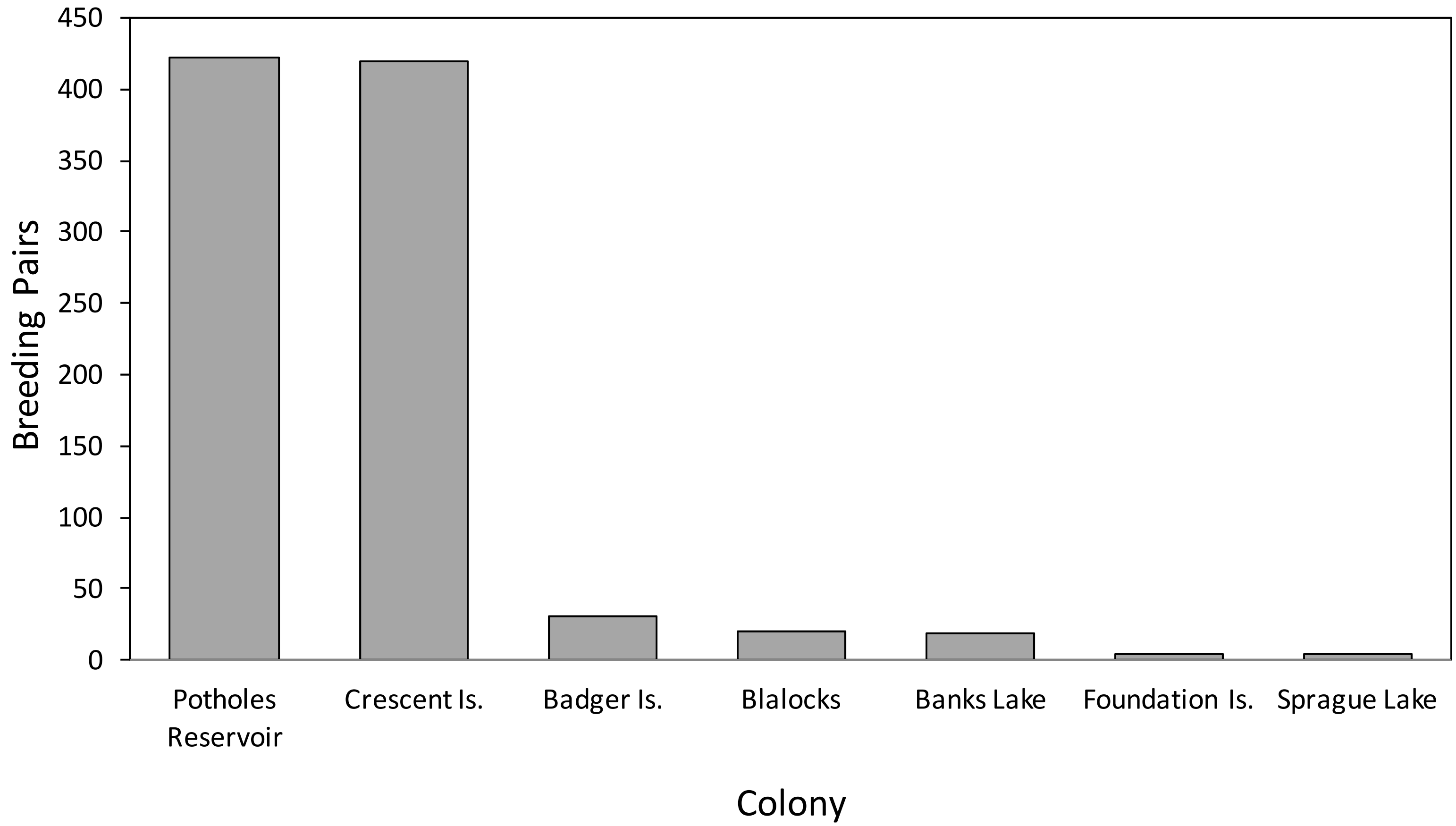


Figure 14. Sizes of Caspian tern breeding colonies in the Columbia Plateau region during the 2011 breeding season.

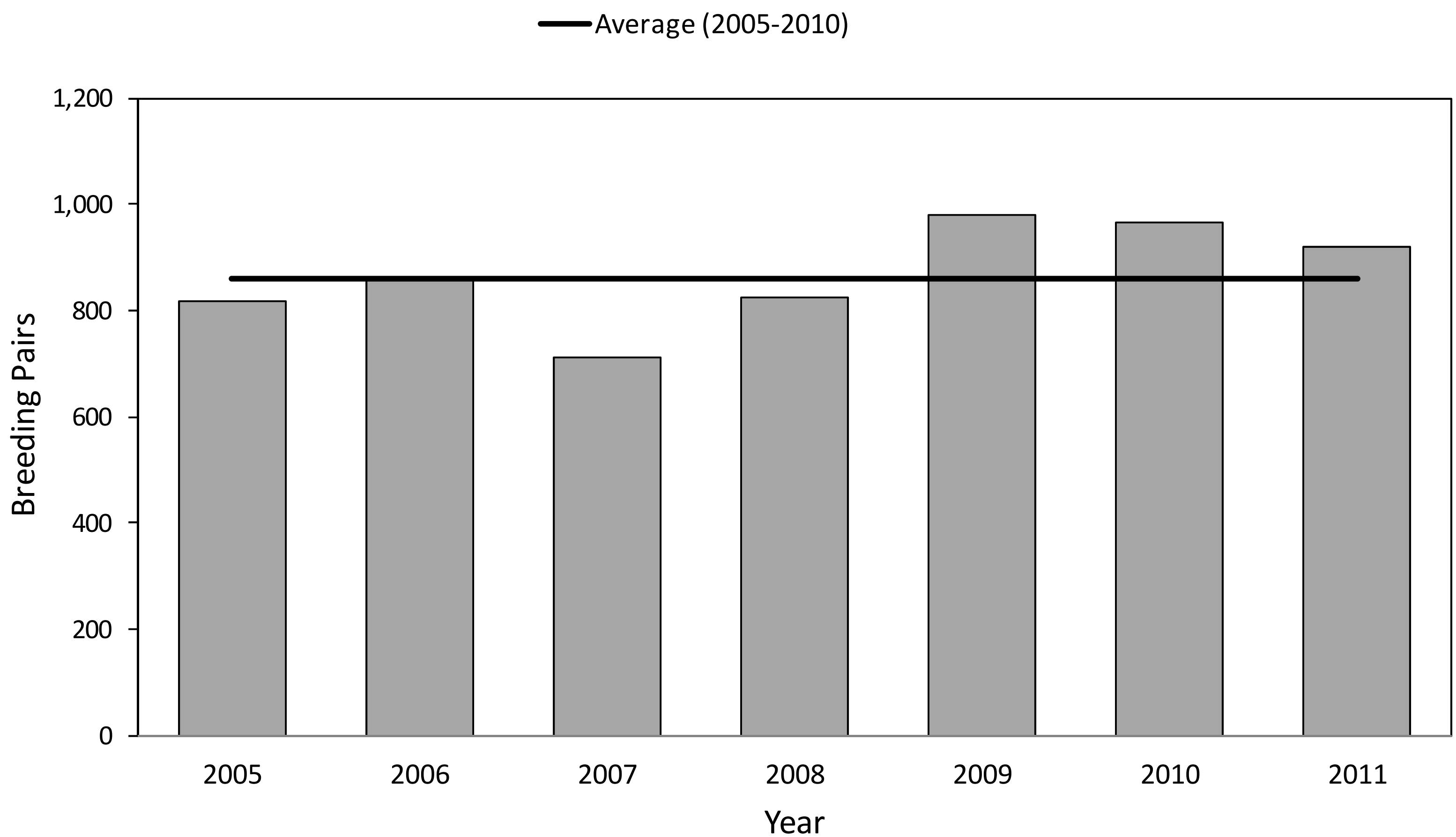


Figure 15. Total number of Caspian tern breeding pairs nesting at all colonies in the Columbia Plateau region during 2005-2011.

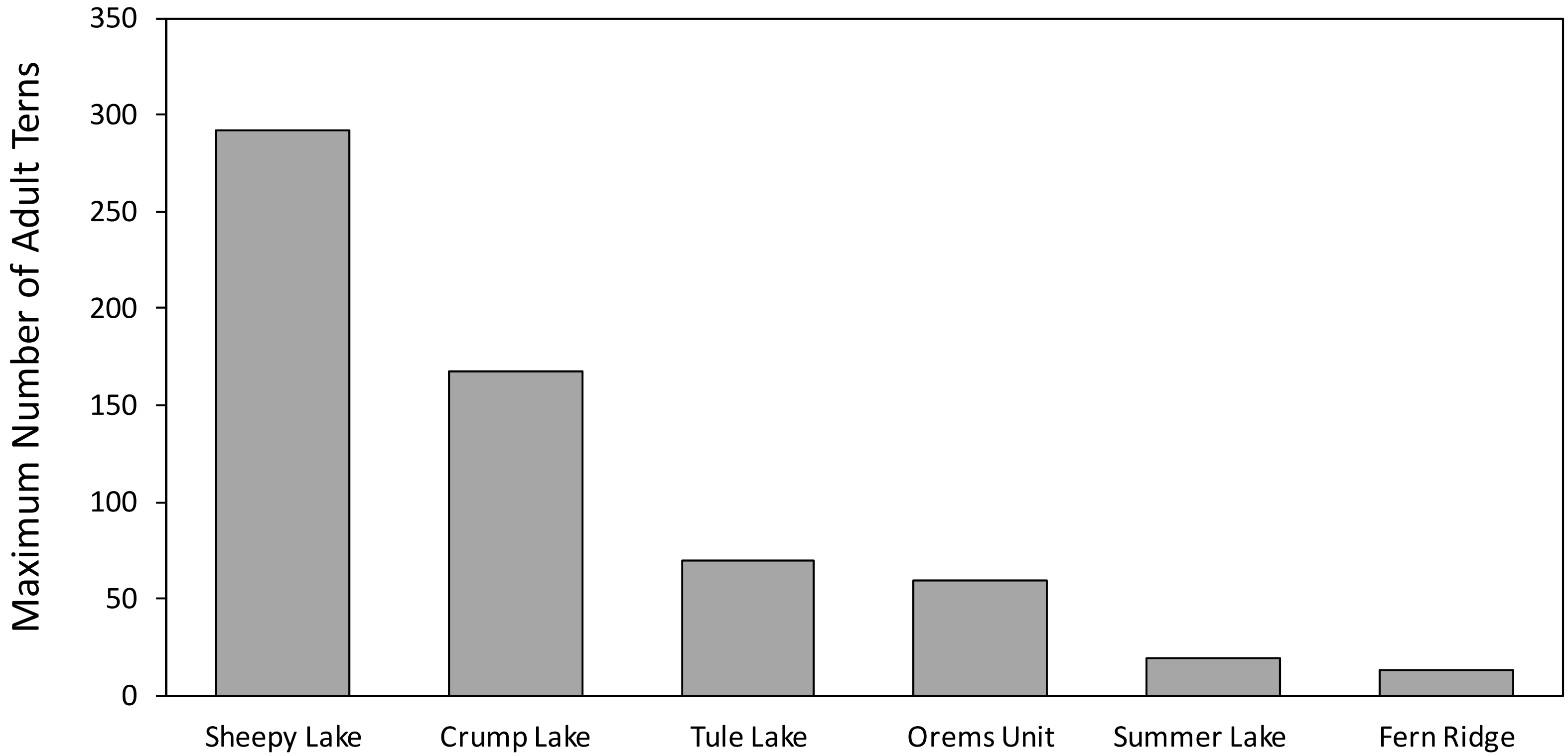


Figure 16. Maximum number of adult Caspian terns counted during 2011 on tern islands recently constructed in interior Oregon and northeastern California. Caspian terns did not attempt to nest on the either the Fern Ridge island or the Dutchy Lake island/Summer Lake in 2011.

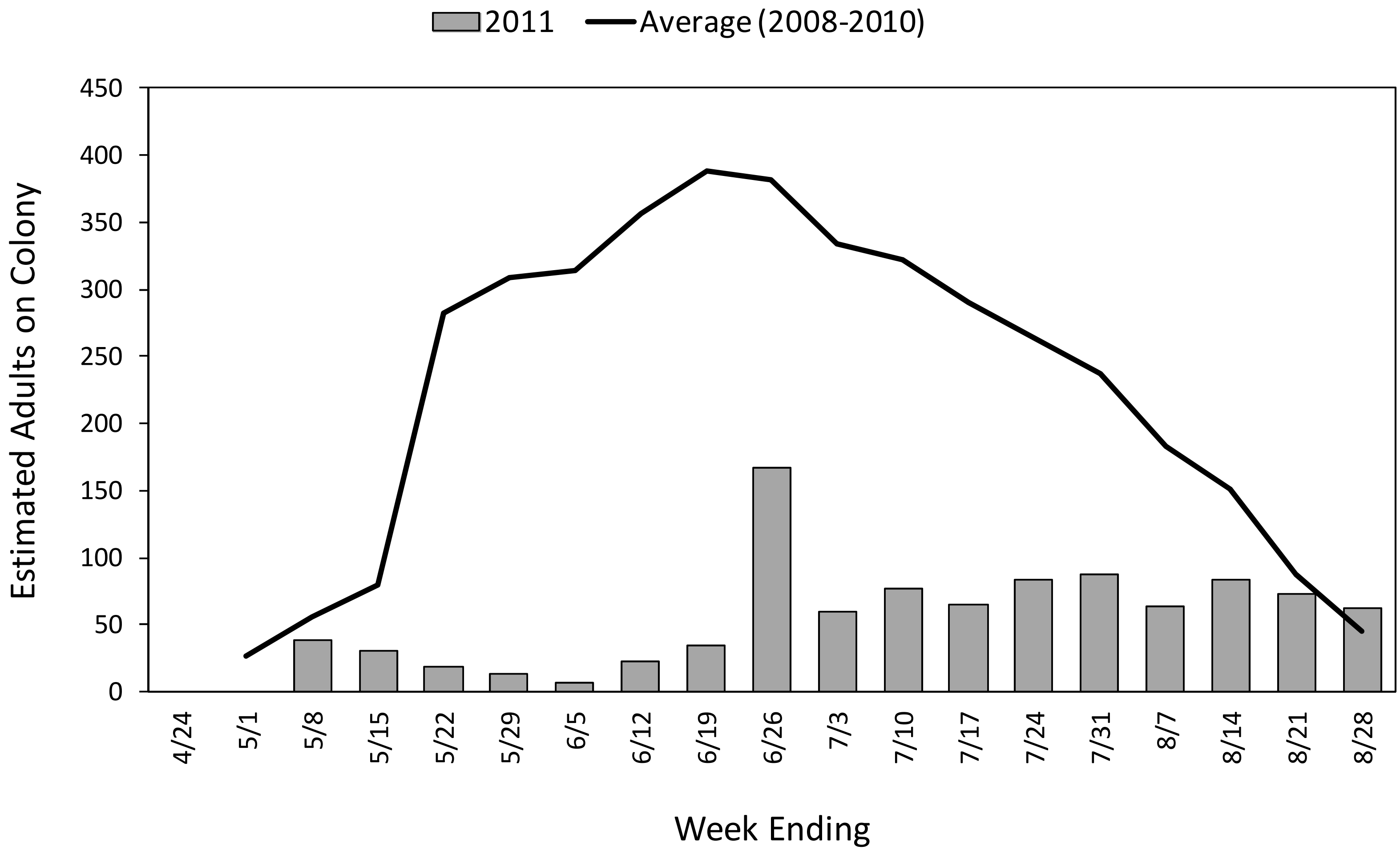


Figure 17. Estimates from the ground of the number of adult Caspian terns on the Crump Lake tern island in Warner Valley, Oregon, by week during the 2011 breeding season.

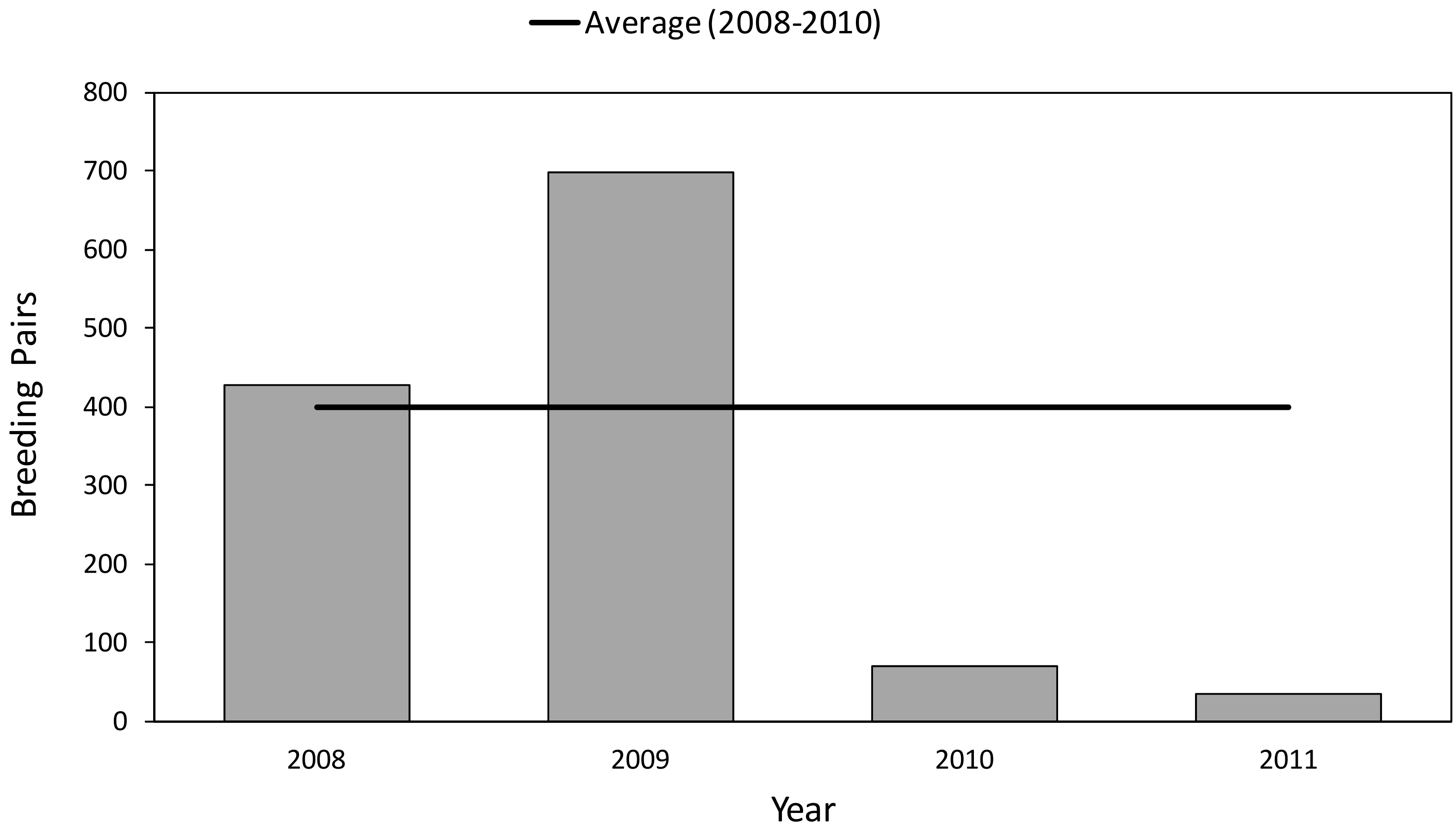


Figure 18. Size of the Caspian tern breeding colony on the Crump Lake tern island, Warner Valley, Oregon during the 2008-2011 breeding seasons.

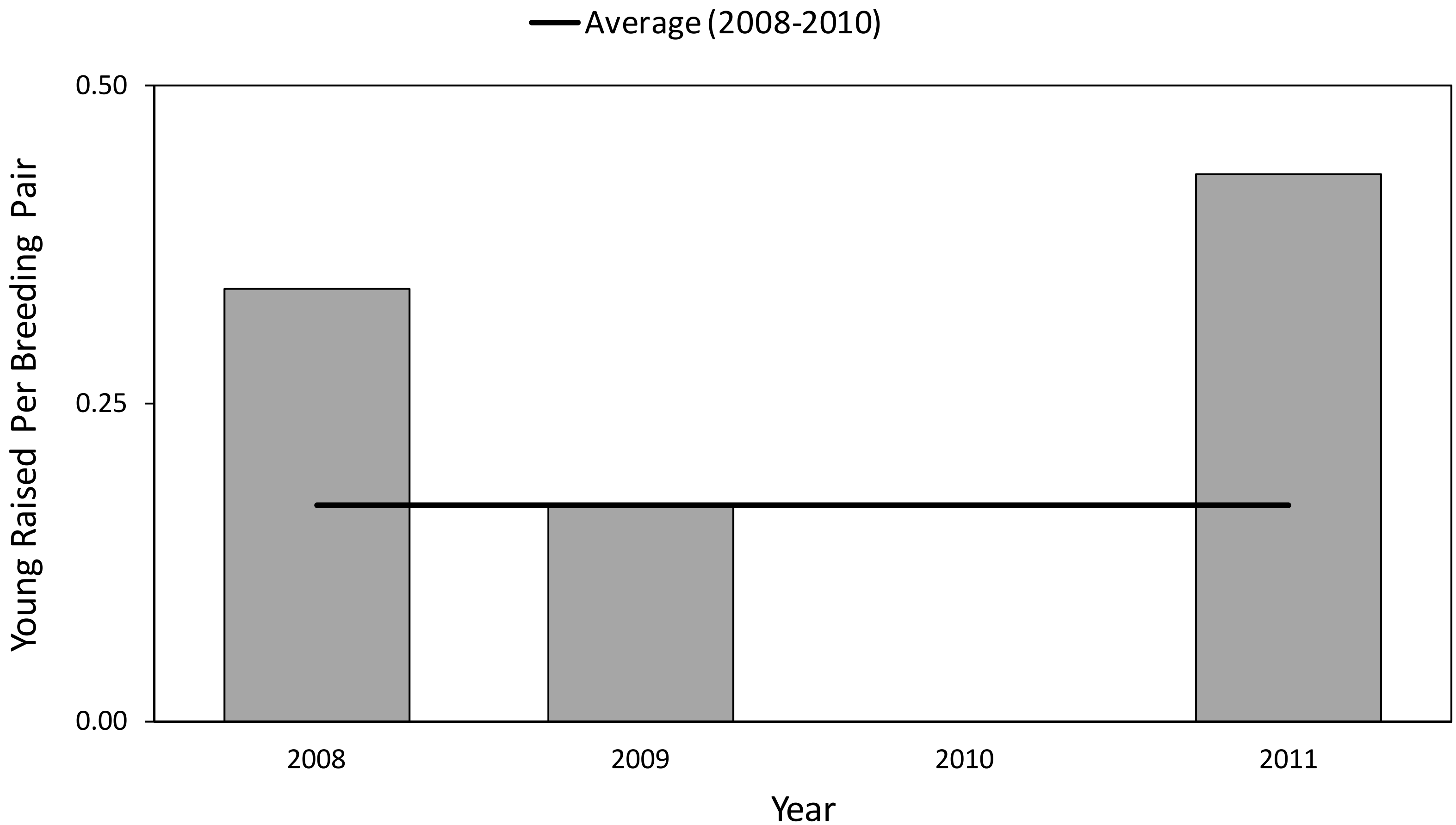


Figure 19. Caspian tern nesting success at the Crump Lake tern island in Warner Valley, Oregon during the 2008-2011 breeding seasons. Caspian terns failed to raise any young at the colony in 2010.

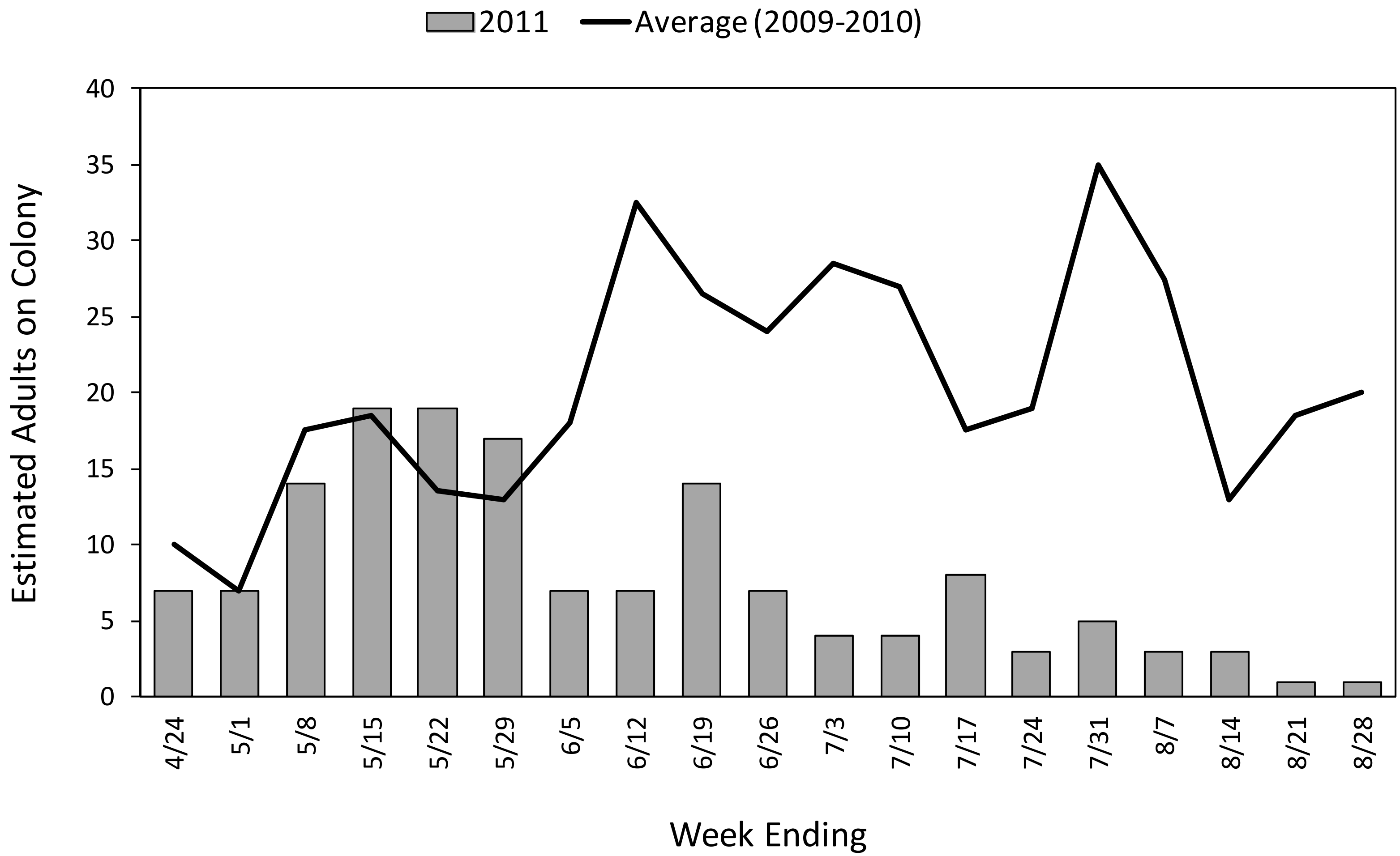


Figure 20. Estimates from the ground of the number of adult Caspian terns on the East Link and Dutchy Lake tern islands in Summer Lake Wildlife Area, Oregon, by week during the 2011 breeding season.

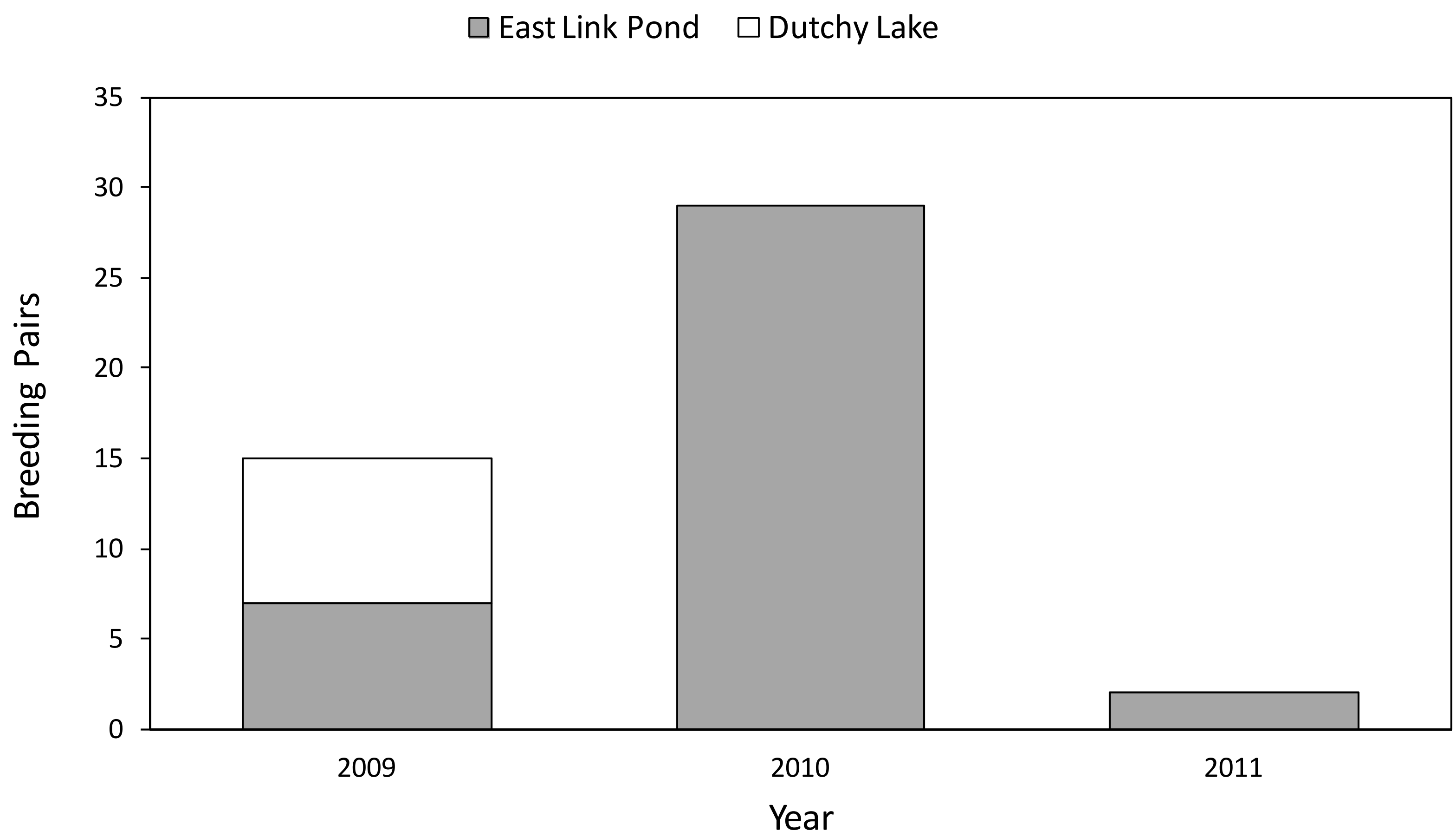


Figure 21. Size of Caspian tern breeding colonies on the East Link and Dutchy Lake tern islands in Summer Lake Wildlife Area during the 2009-2011 breeding seasons.

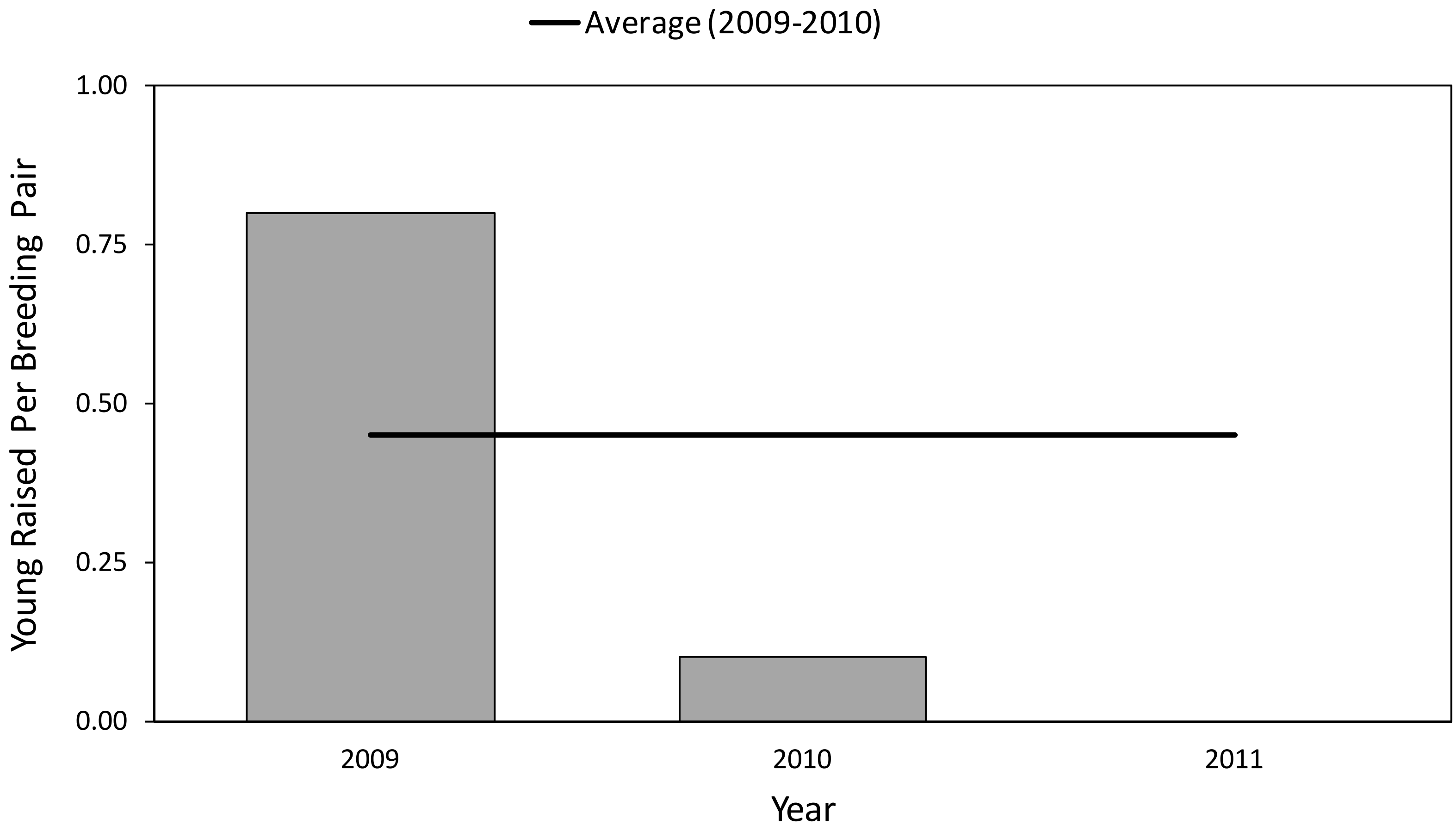


Figure 22. Caspian tern nesting success at the Summer Lake Wildlife Area tern islands (i.e., East Link and Dutchy Lake tern islands), Oregon during 2009-2011. Caspian terns did not nest on the Dutchy Lake tern island in 2010 or 2011. No young terns were fledged from the East Link tern island in 2011.

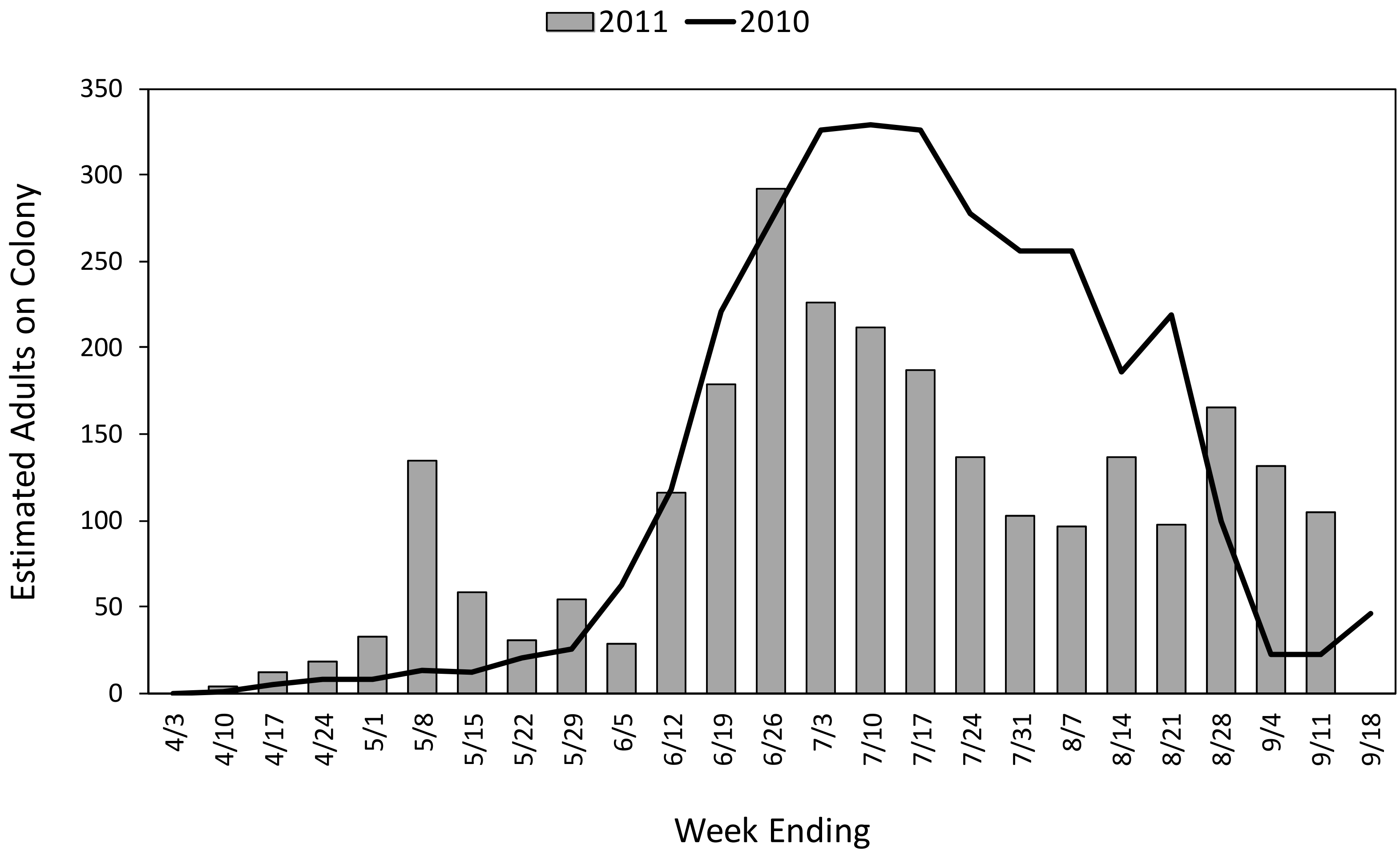


Figure 23. Estimates from the ground of the number of adult Caspian terns on the Sheepy Lake tern island in Lower Klamath NWR, California, by week during the 2011 breeding season.

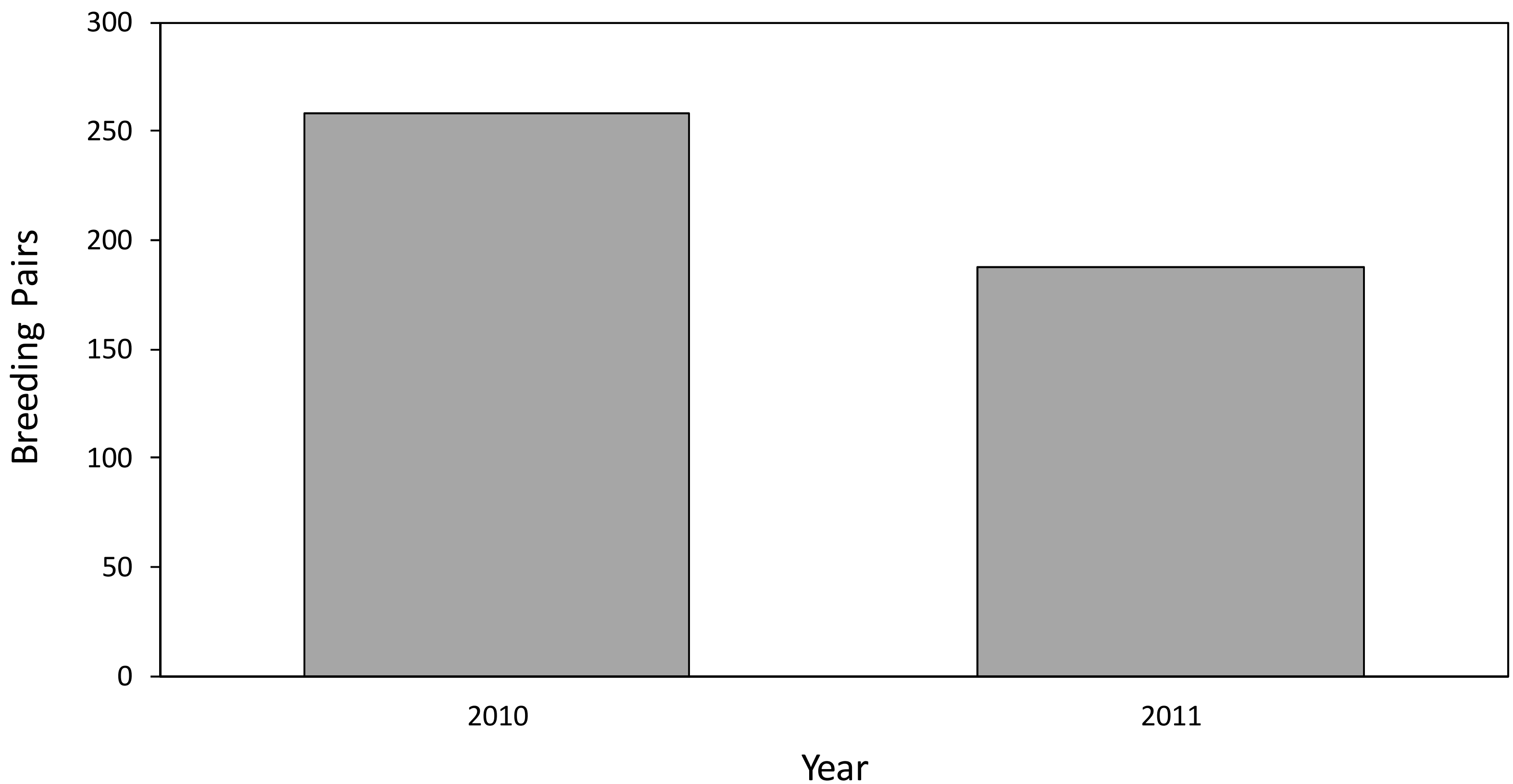


Figure 24. Size of the Caspian tern breeding colony on Sheepy Lake tern island in Lower Klamath NWR, California during the 2010 and 2011 breeding seasons.

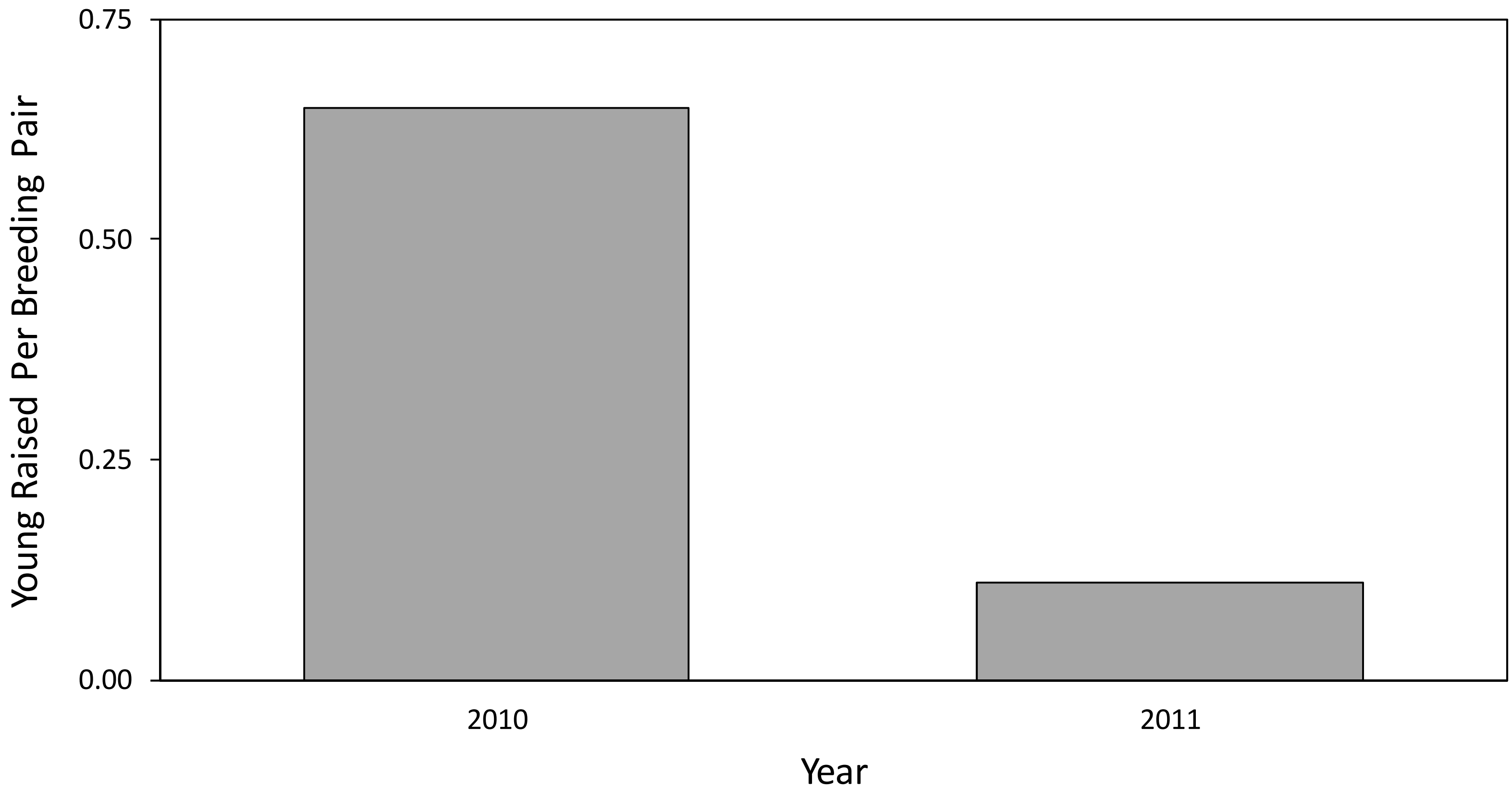


Figure 25. Caspian tern nesting success at the Sheepy Lake tern island in Lower Klamath NWR, California during 2010 and 2011.

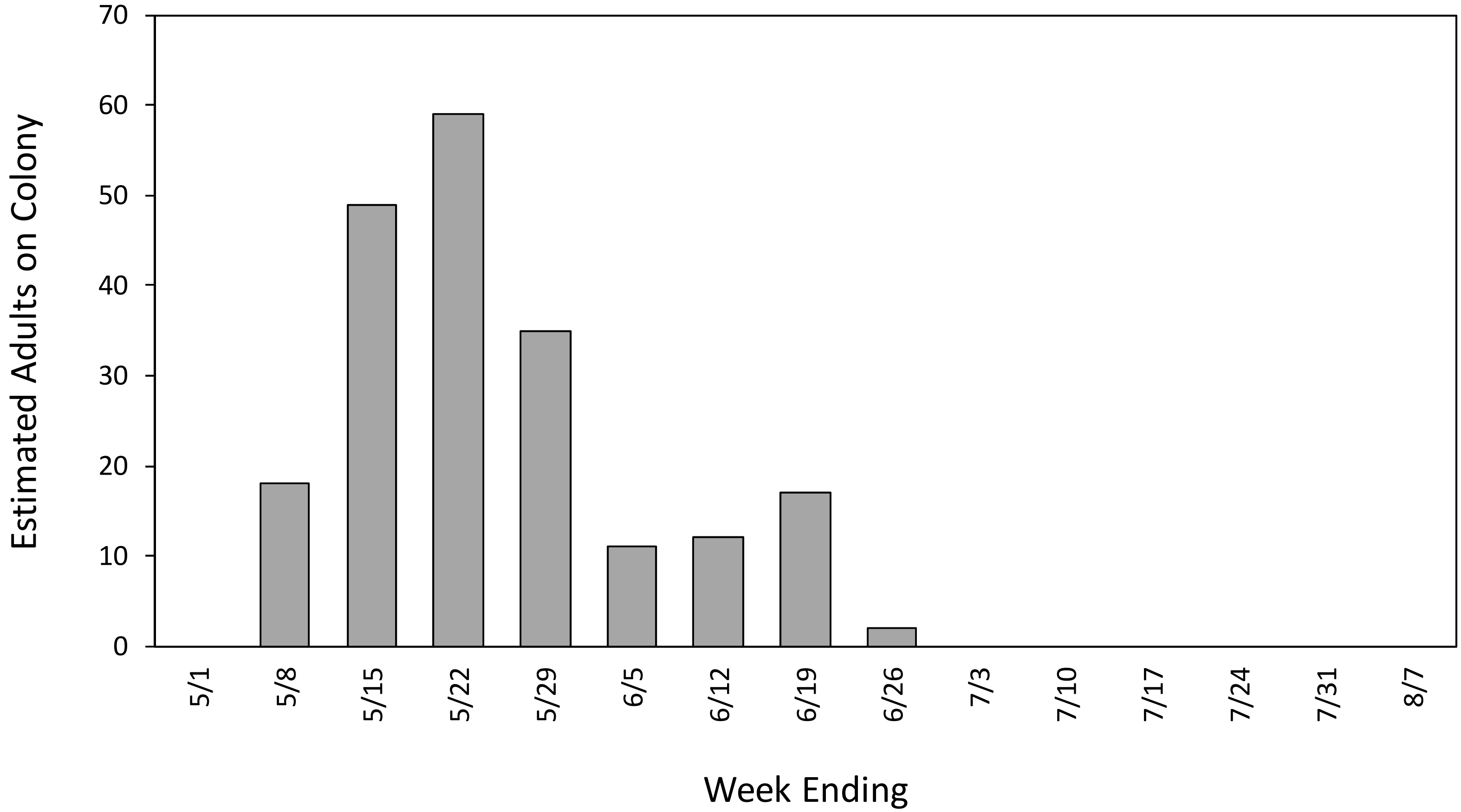


Figure 26. Estimates from the ground of the number of adult Caspian terns on the Orems Unit tern island in Lower Klamath NWR, California, by week during the 2011 breeding season.

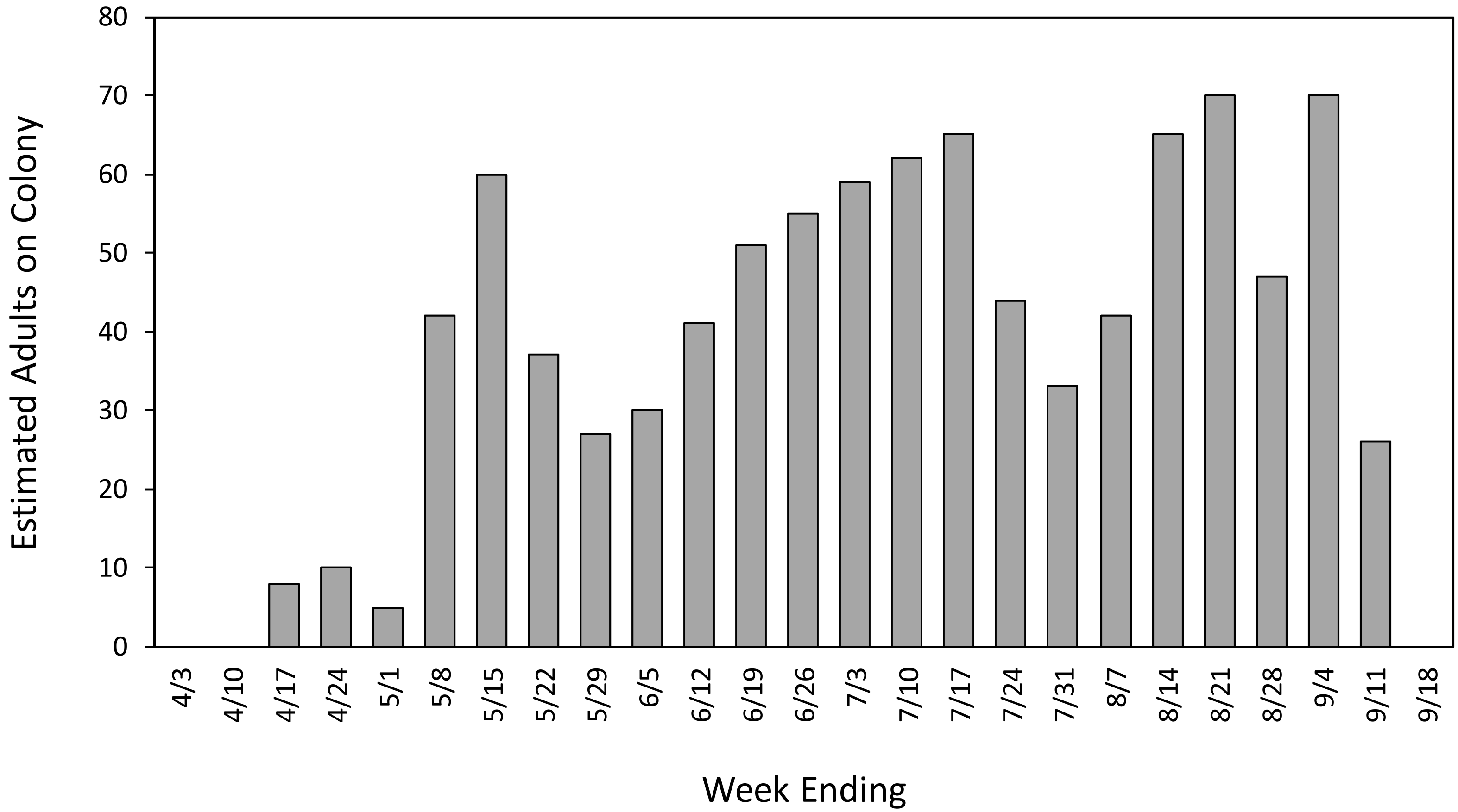


Figure 27. Estimates from the ground of the number of adult Caspian terns on the Tule Lake Sump 1B tern island in Tule Lake NWR, California, by week during the 2011 breeding season.

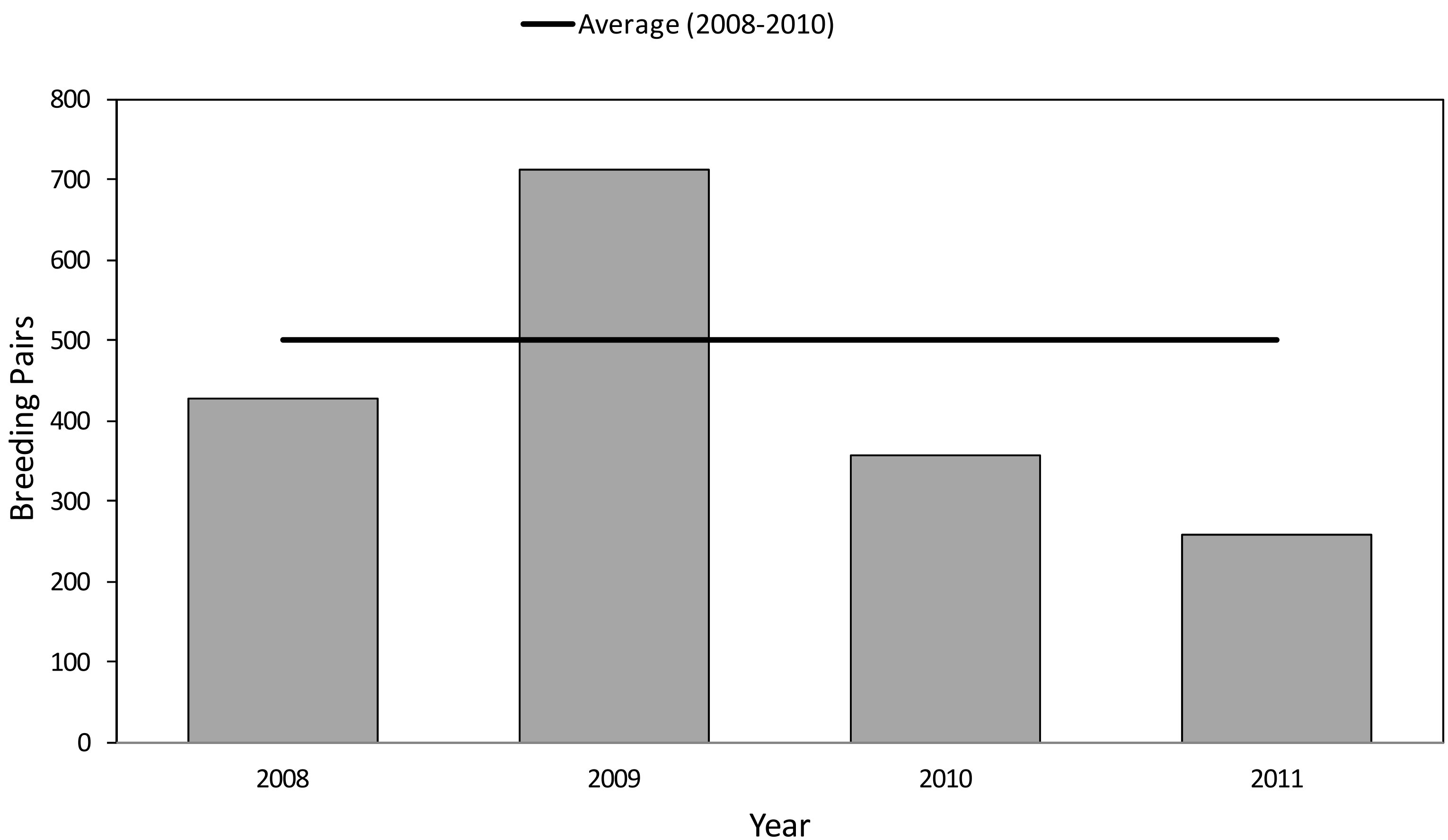


Figure 28. Total number of Caspian tern breeding pairs nesting at new tern islands in interior Oregon and northeastern California during the 2008-2011 breeding seasons.

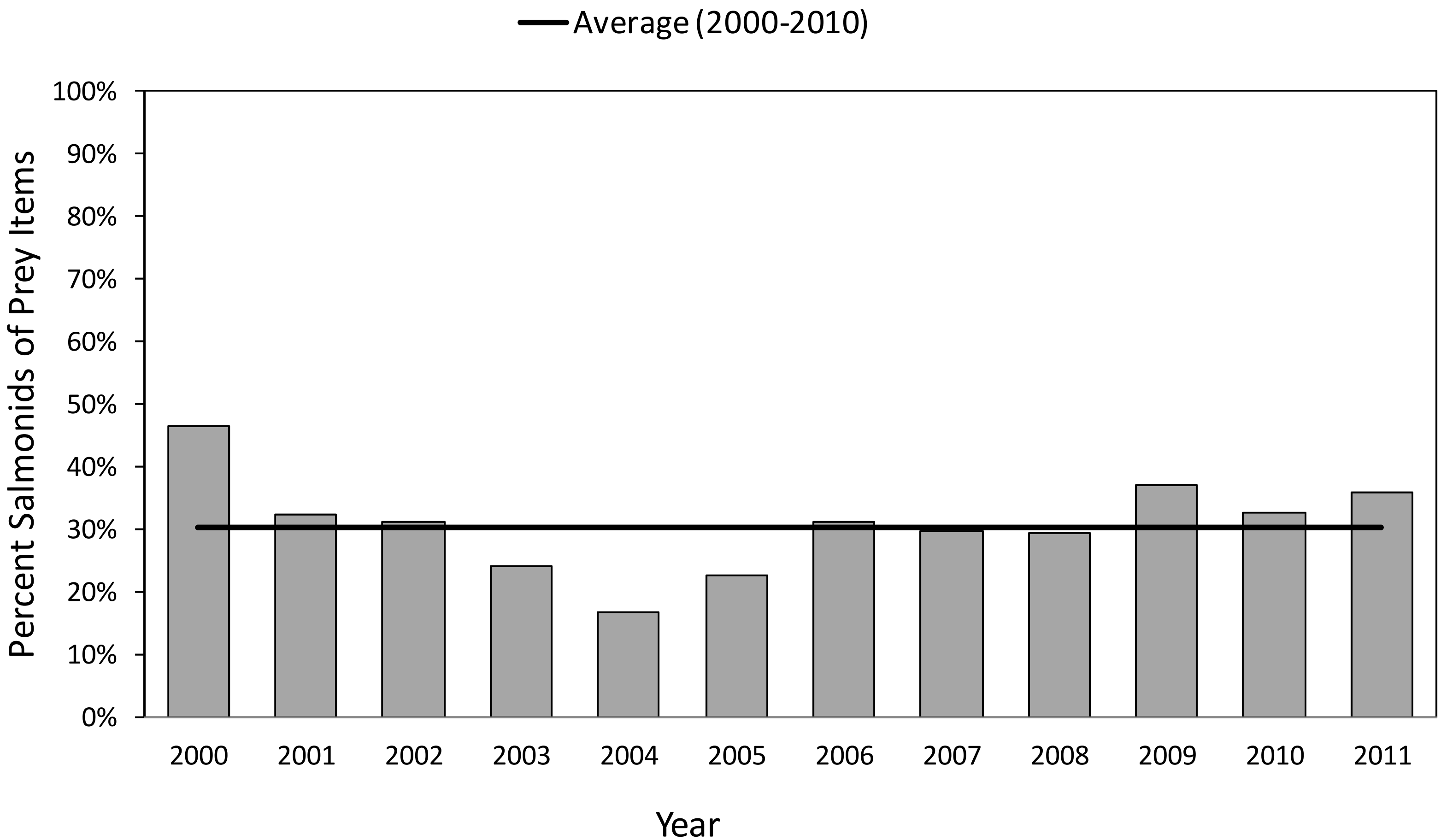


Figure 29. Average annual proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during 2000-2011.

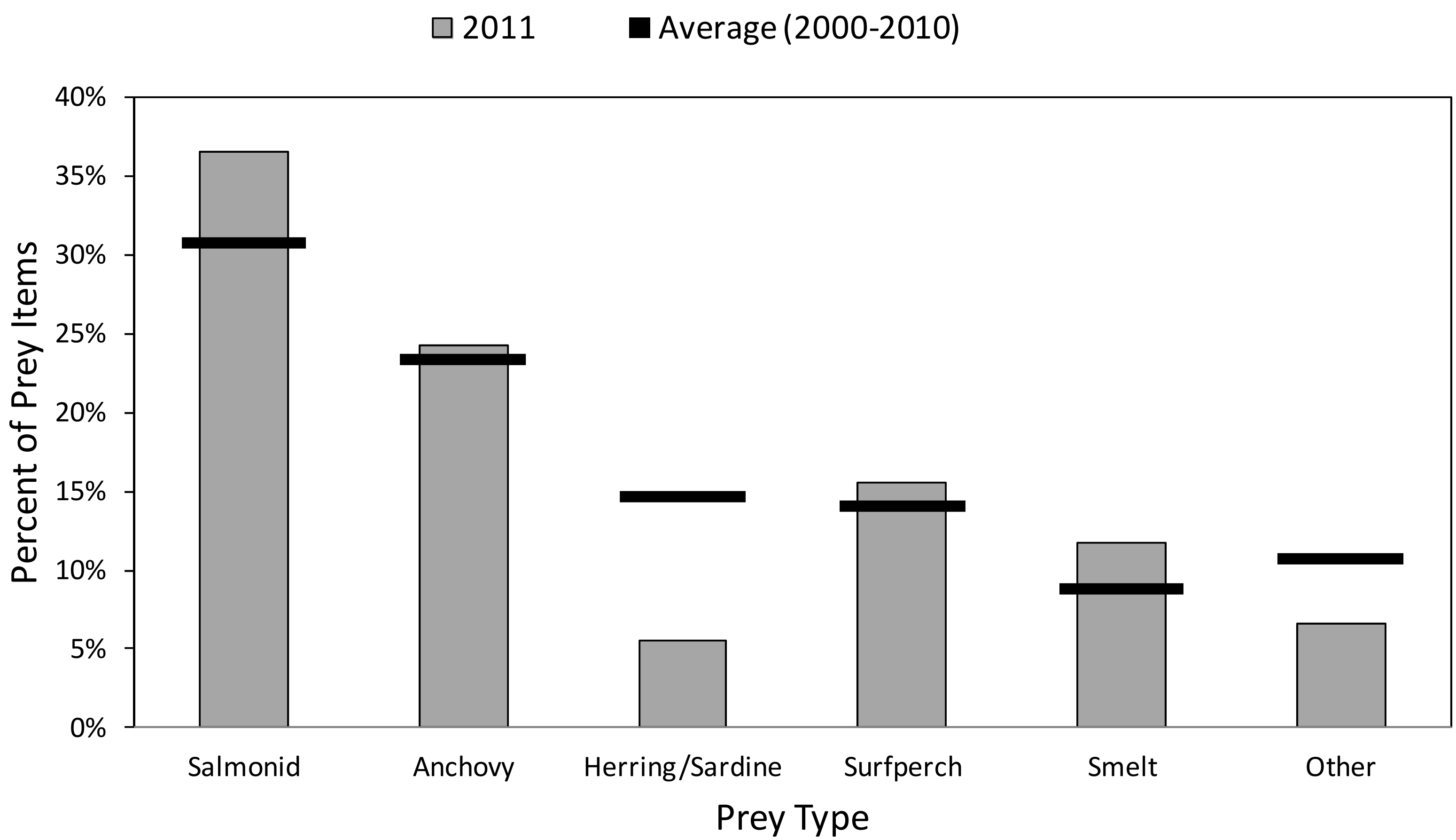


Figure 30. Diet composition of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2011 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

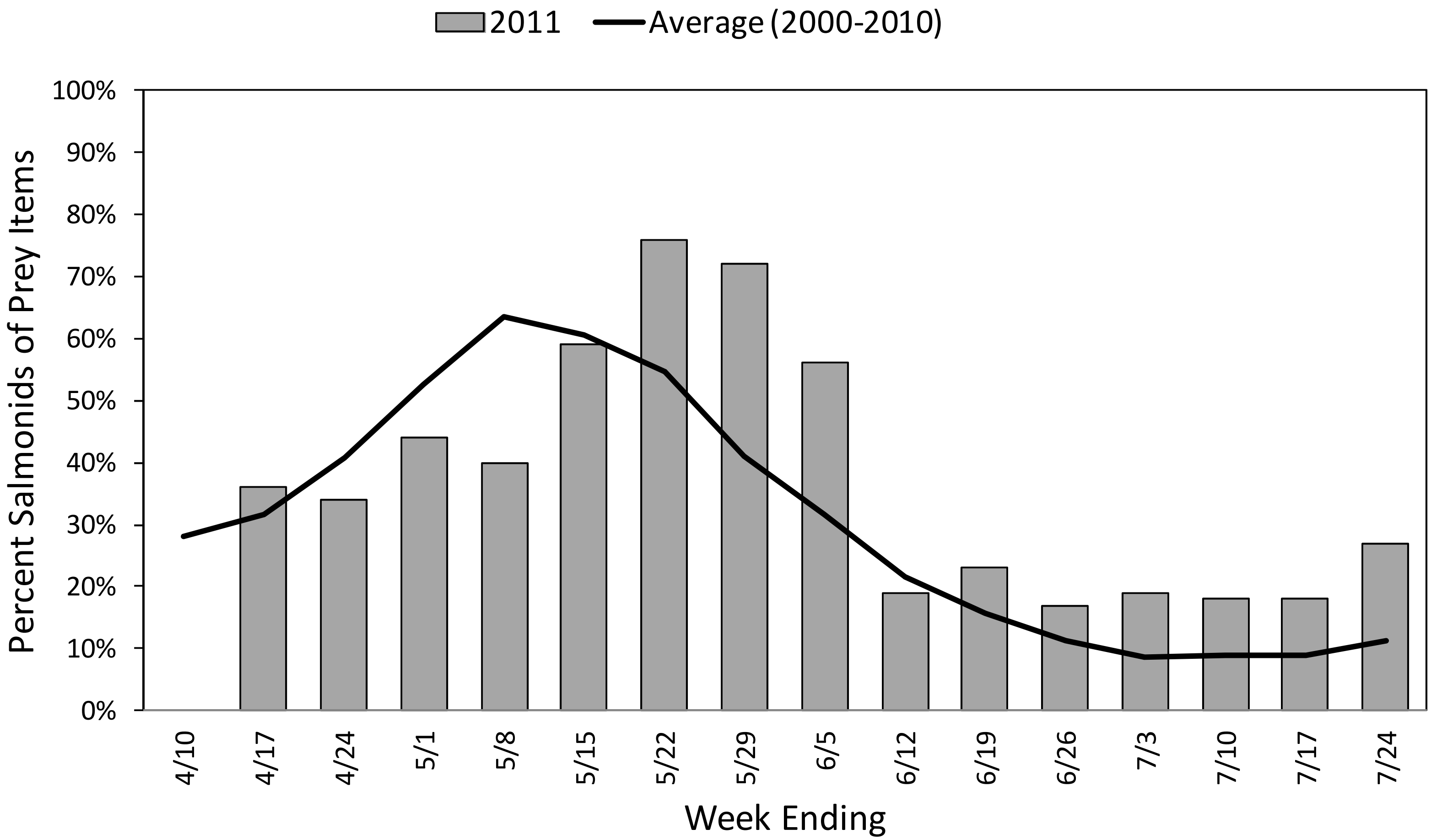


Figure 31. Proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary, by week during the 2011 breeding season.

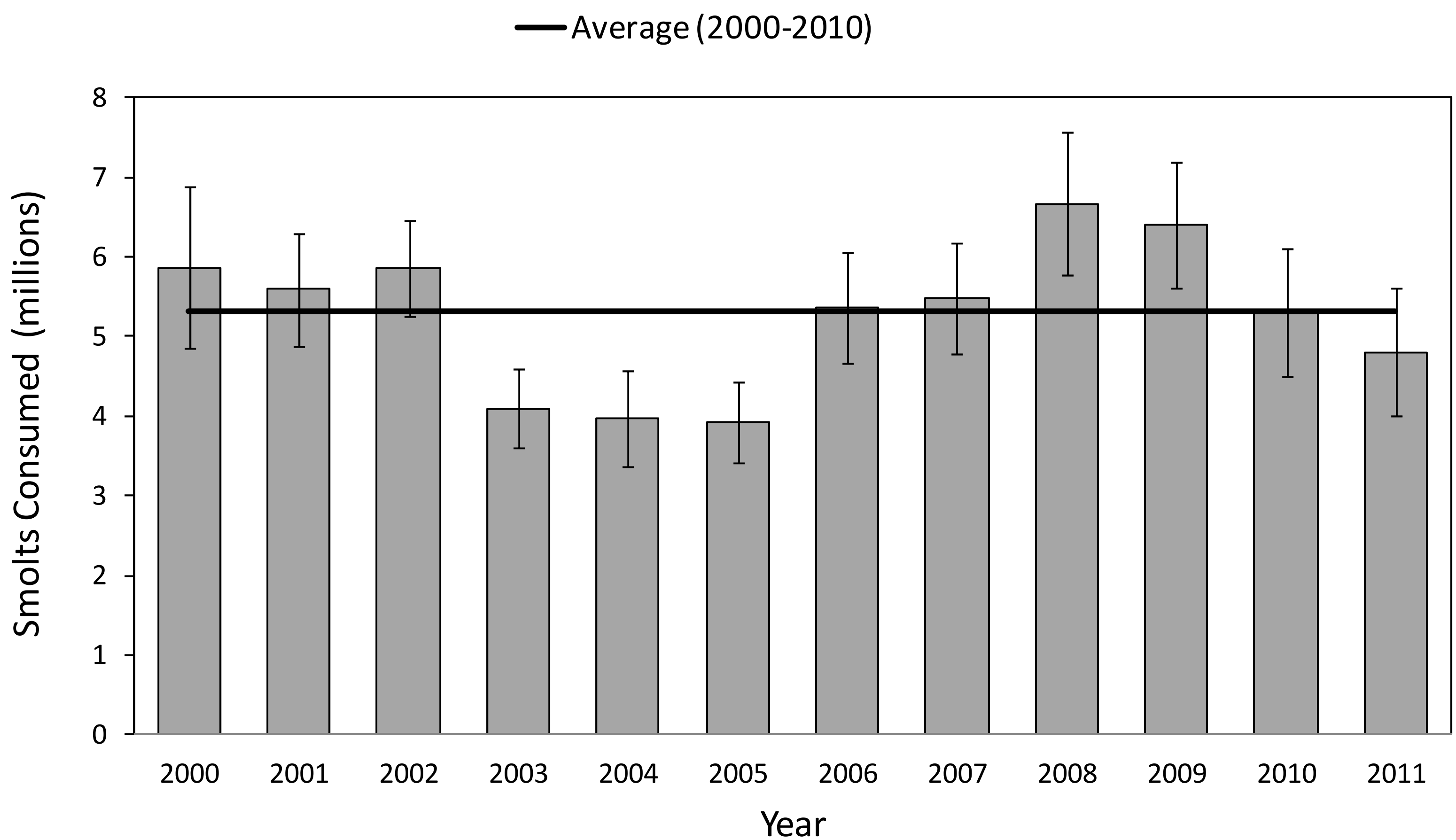


Figure 32. Estimated total annual consumption of juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2011 breeding seasons. Error bars represent 95% confidence intervals for the number of smolts consumed.

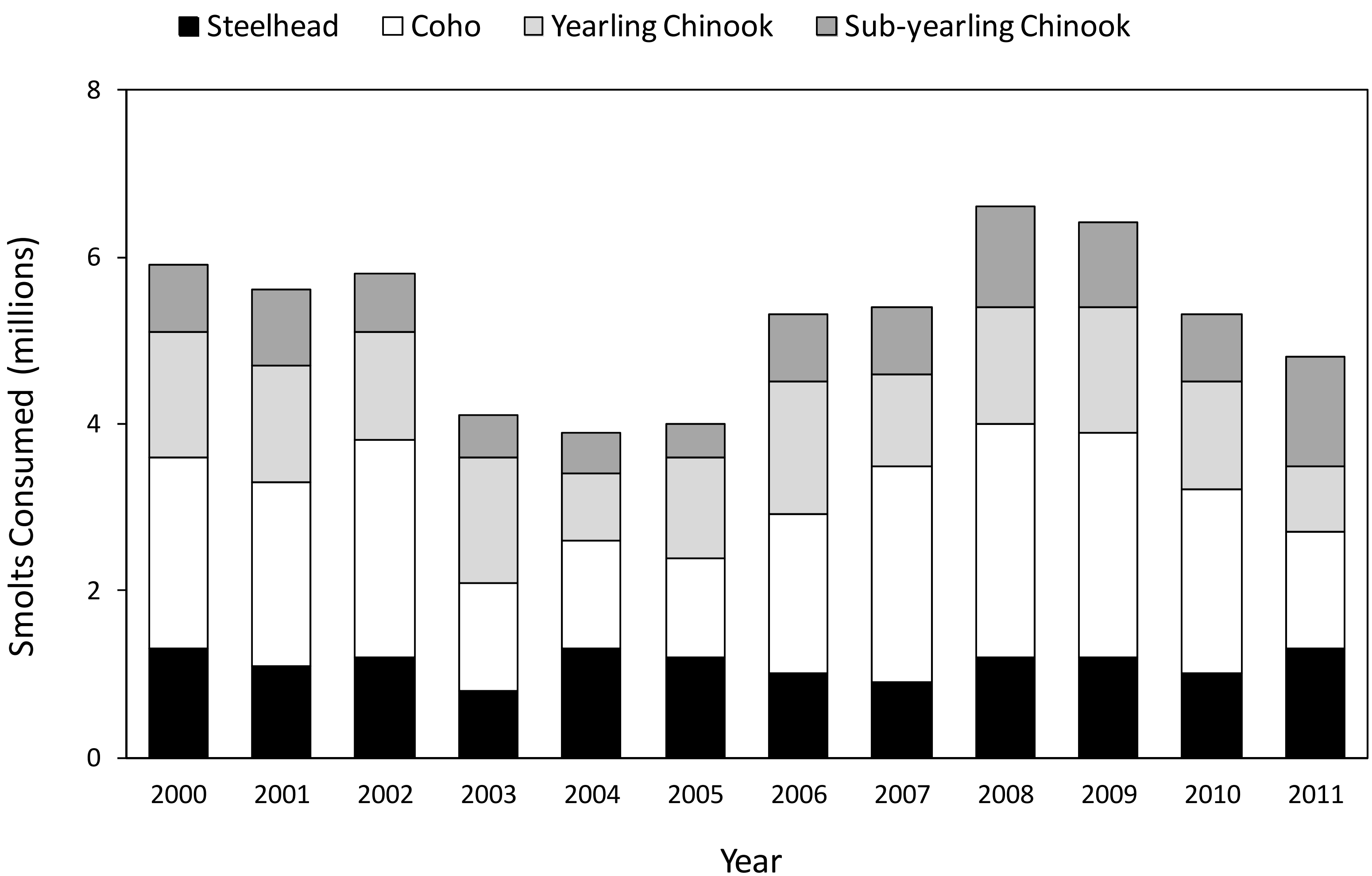


Figure 33. Estimated total annual consumption of four species/run types of juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2011 breeding seasons. Estimates are based on fish identified in tern bill-loads on-colony and bioenergetics calculations.

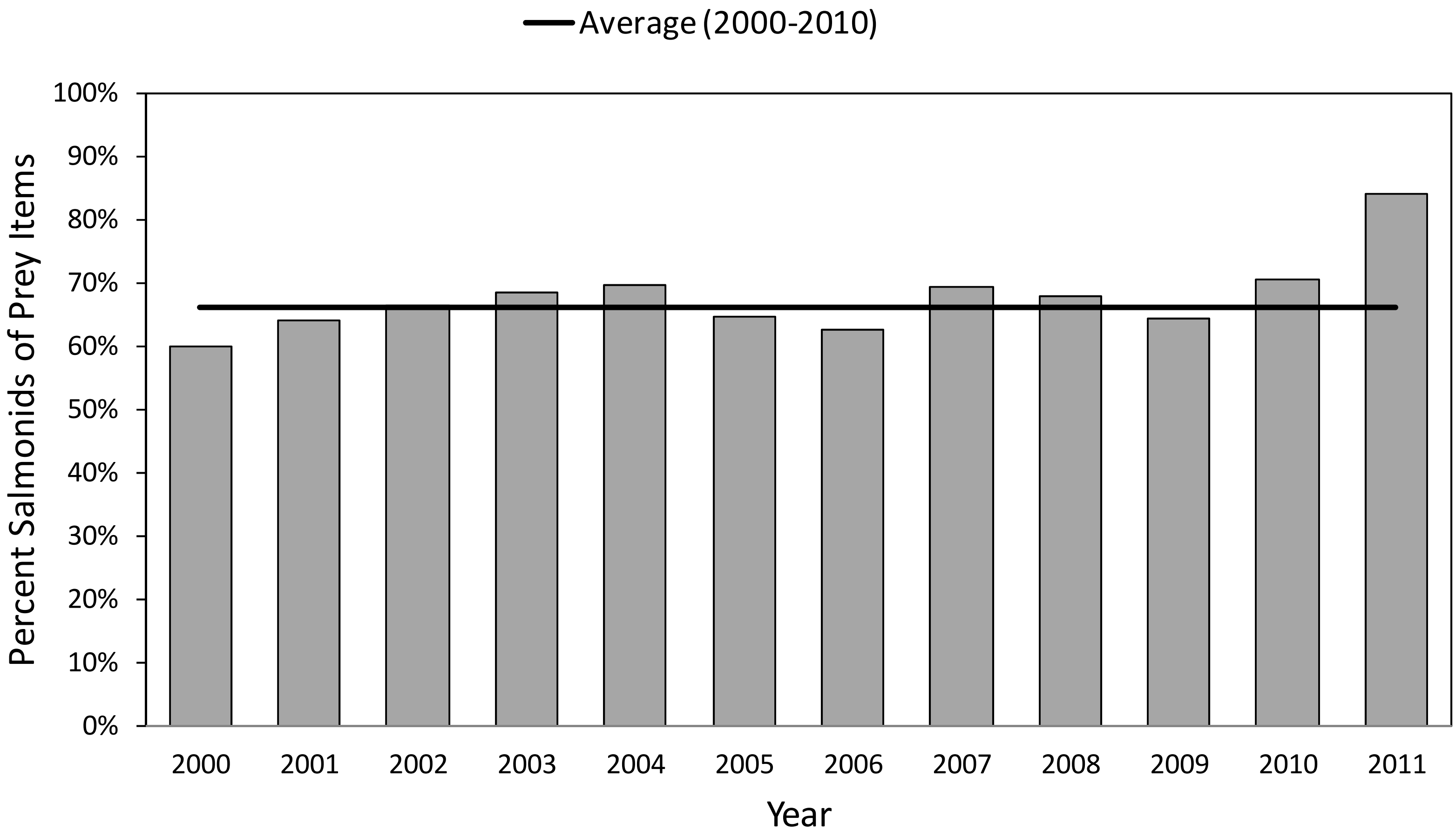


Figure 34. Average annual proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on Crescent Island, mid-Columbia River, during the 2000-2011 breeding seasons.

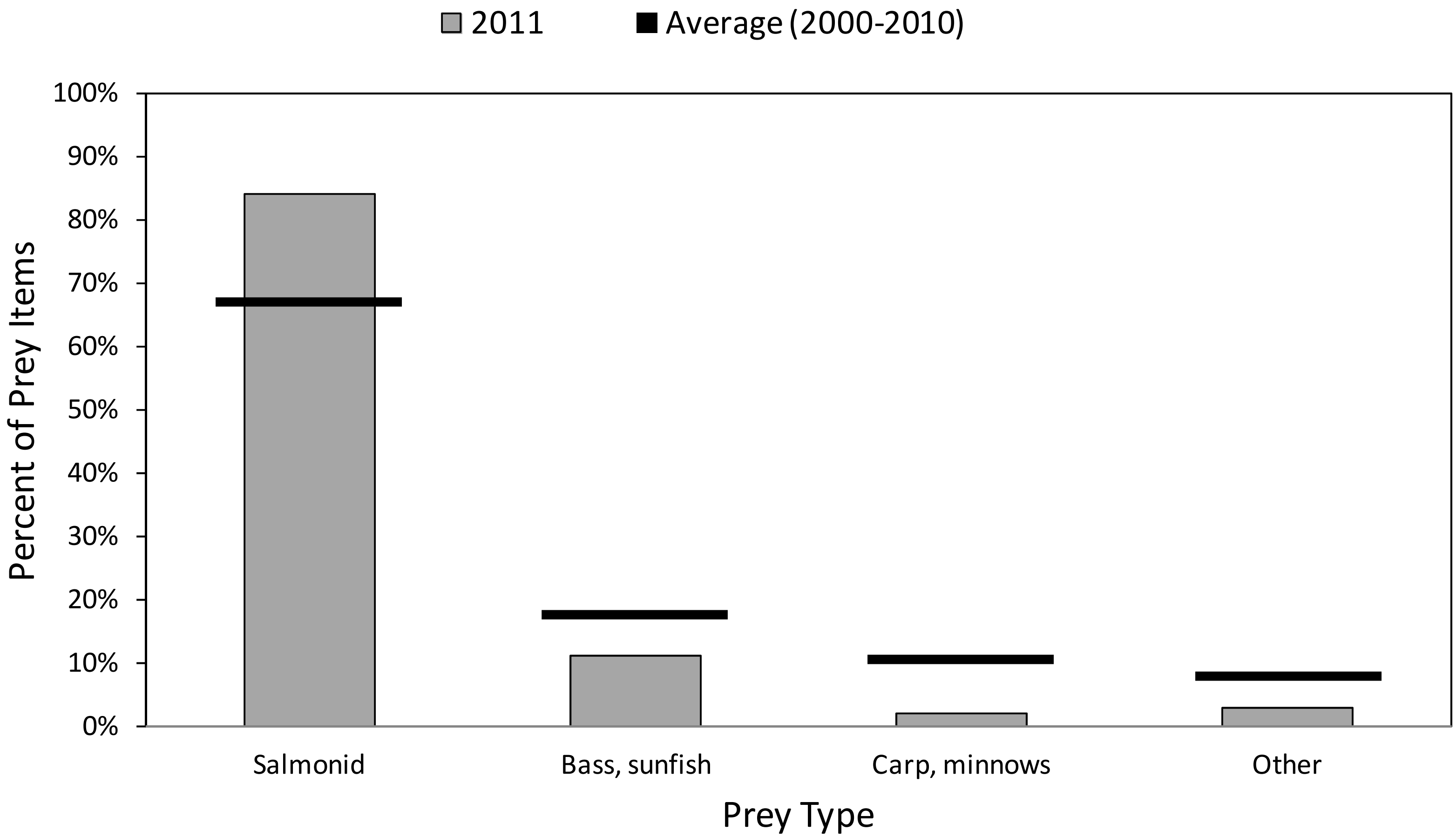


Figure 35. Diet composition (percent of prey items) of Caspian terns nesting on Crescent Island in the mid-Columbia River during the 2011 breeding season. Diet composition was based on fish identified in tern bill-loads

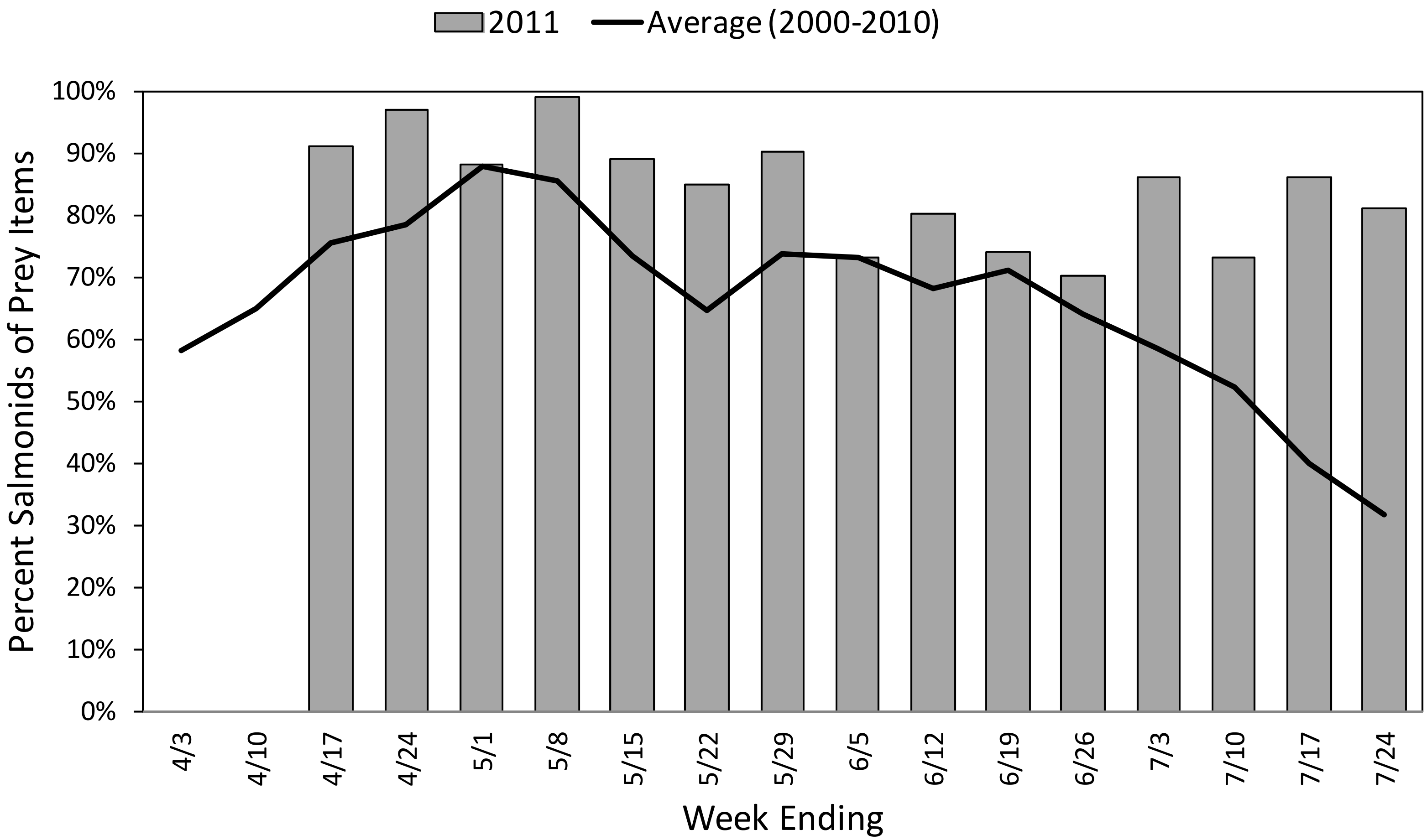


Figure 36. Proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on Crescent Island in the mid-Columbia River during the 2011 breeding season, by week. Diet composition data were not collected during the first two weeks of the field season in 2011.

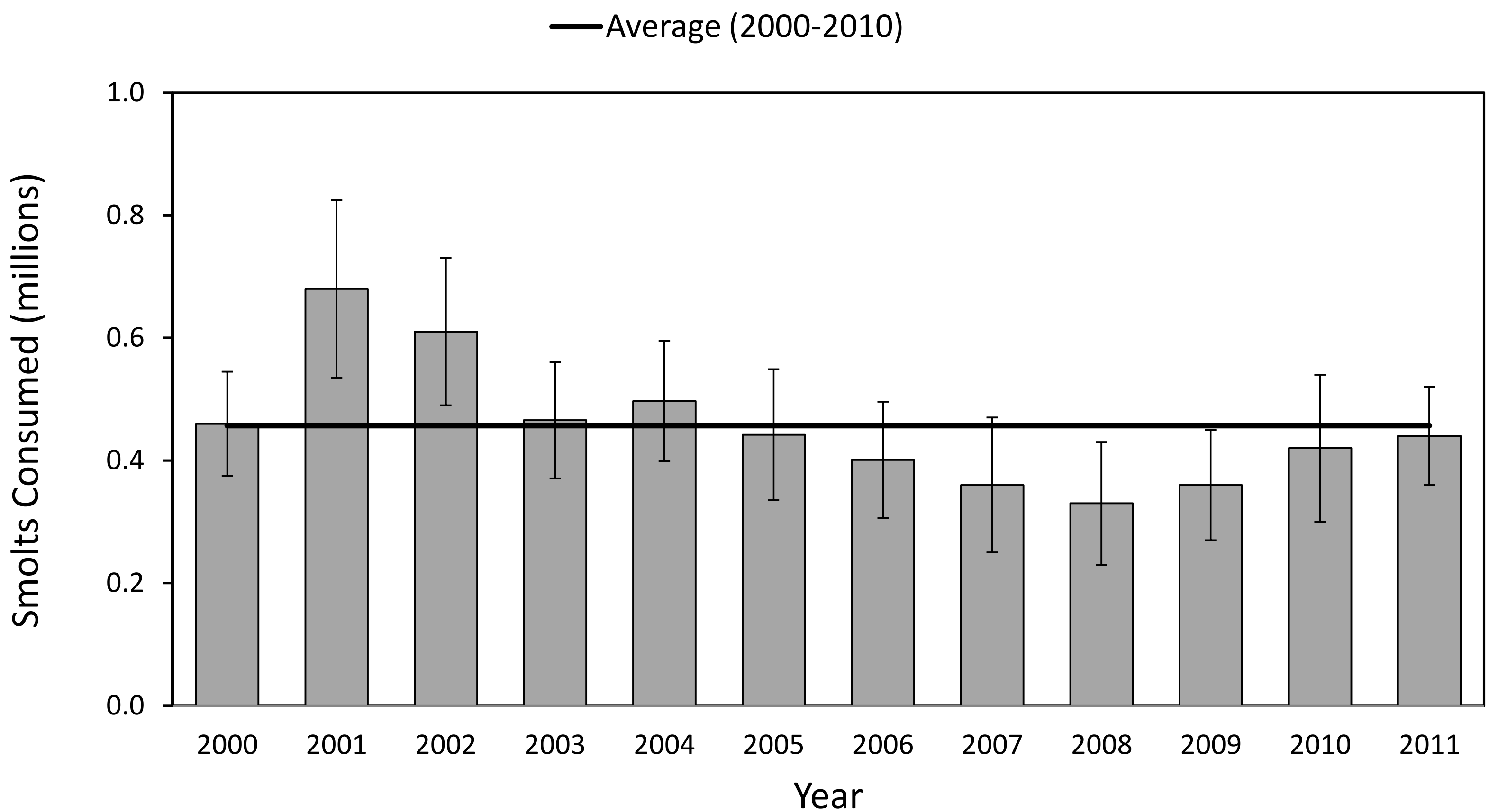


Figure 37. Estimated total annual consumption of juvenile salmonids by Caspian terns nesting on Crescent Island in the mid-Columbia River during the 2000-2011 breeding seasons. Error bars represent 95% confidence intervals for the number of smolts consumed.

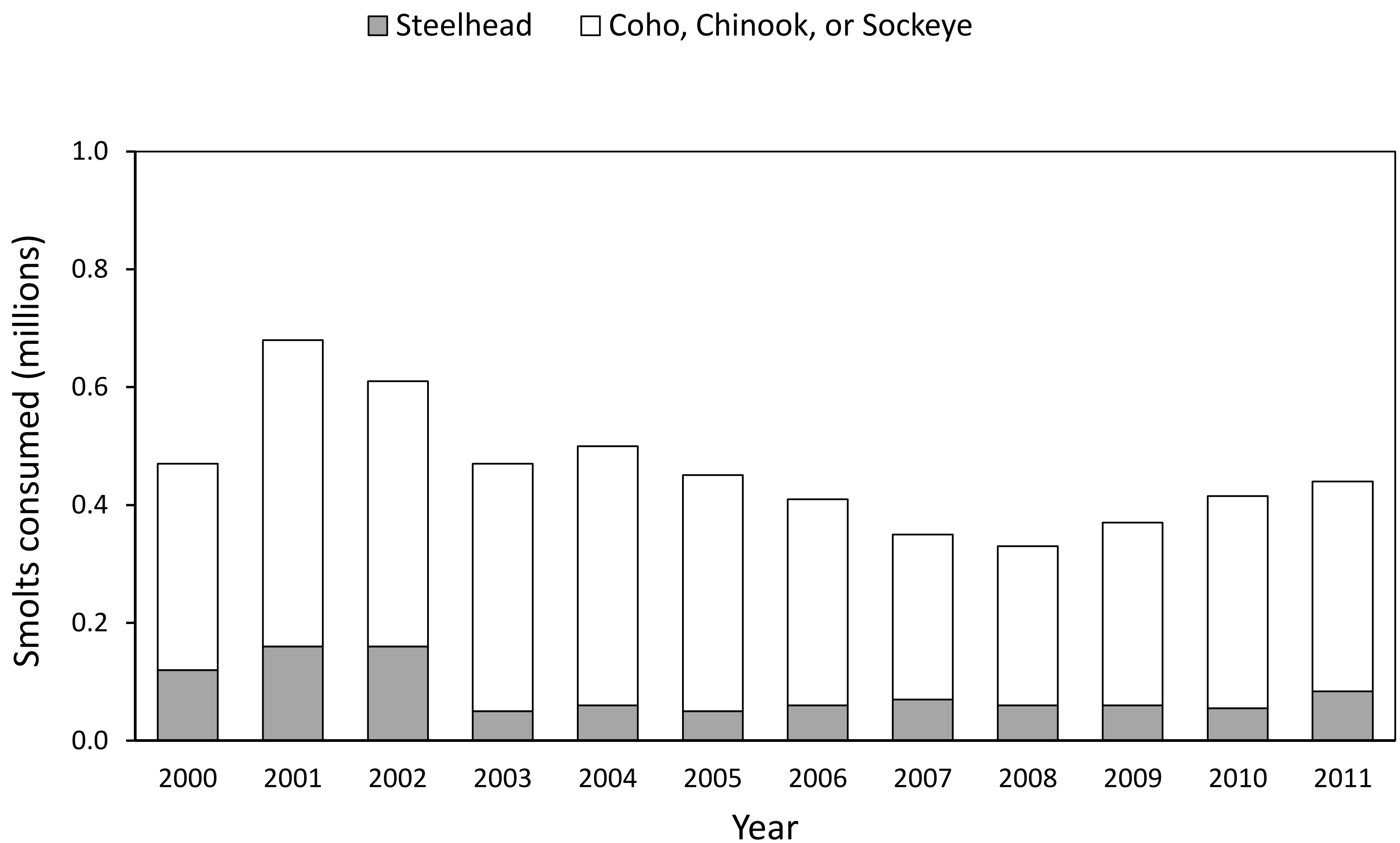


Figure 38. Estimated total annual consumption of steelhead and salmon (coho, Chinook, or sockeye) by Caspian terns nesting on Crescent Island in the mid-Columbia River during the 2000-2011 breeding seasons. Estimates are based on fish identified in tern bill-loads on-colony and bioenergetics calculations.

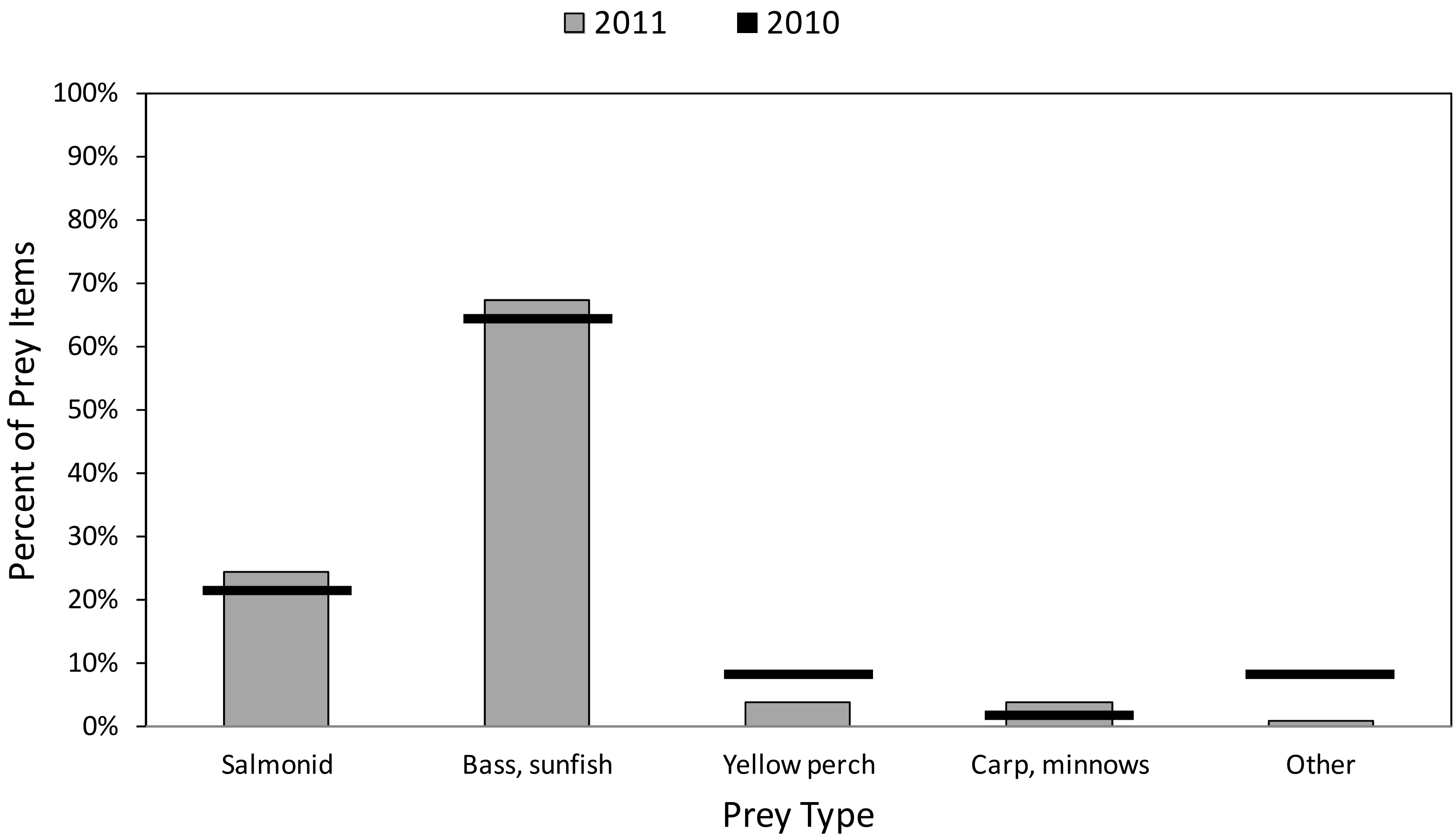


Figure 39. Diet composition (percent of prey items) of Caspian terns nesting on Goose Island in Potholes Reservoir during the 2011 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

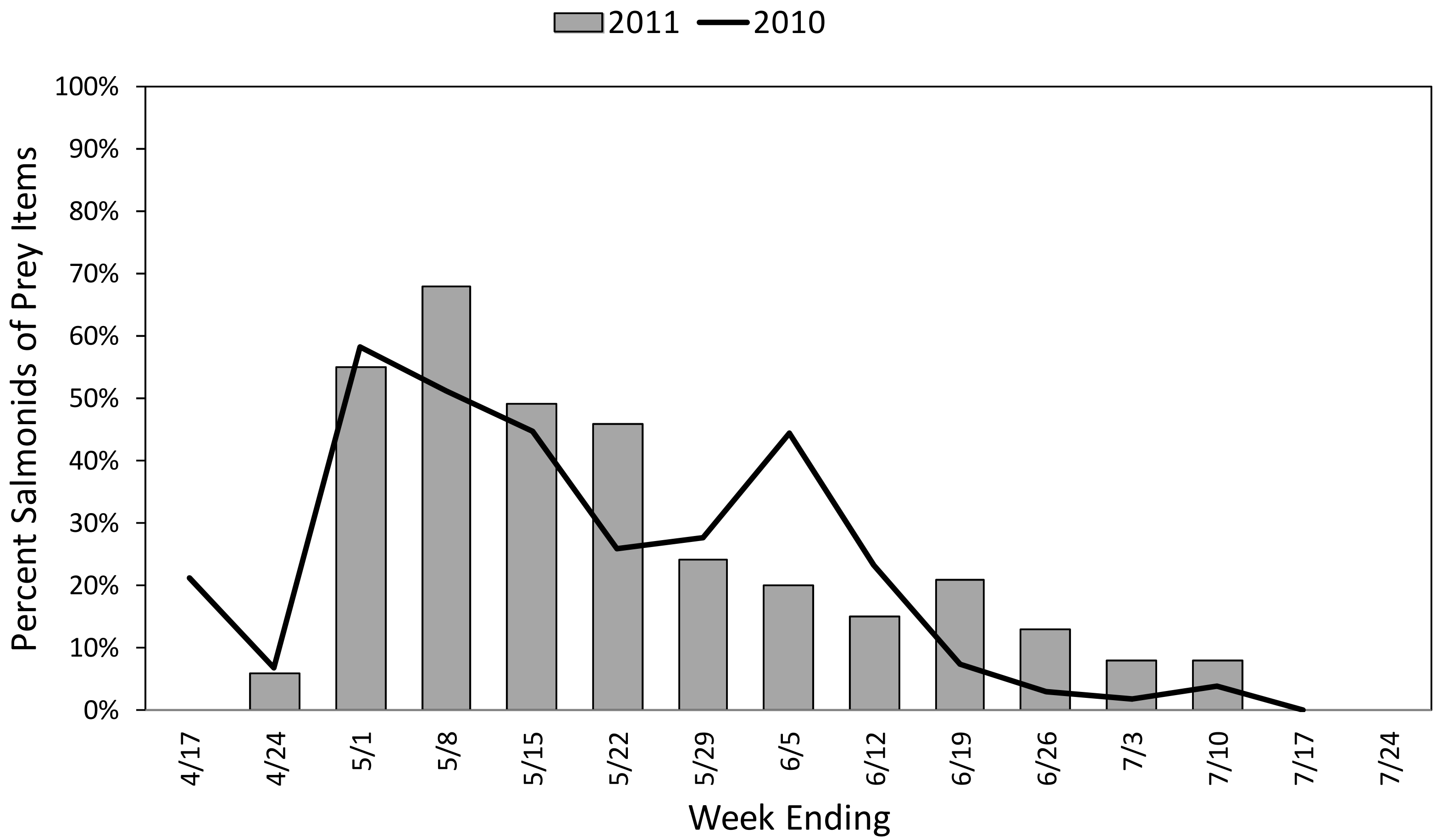


Figure 40. Proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on Goose Island in Potholes Reservoir during the 2011 breeding season, by week.

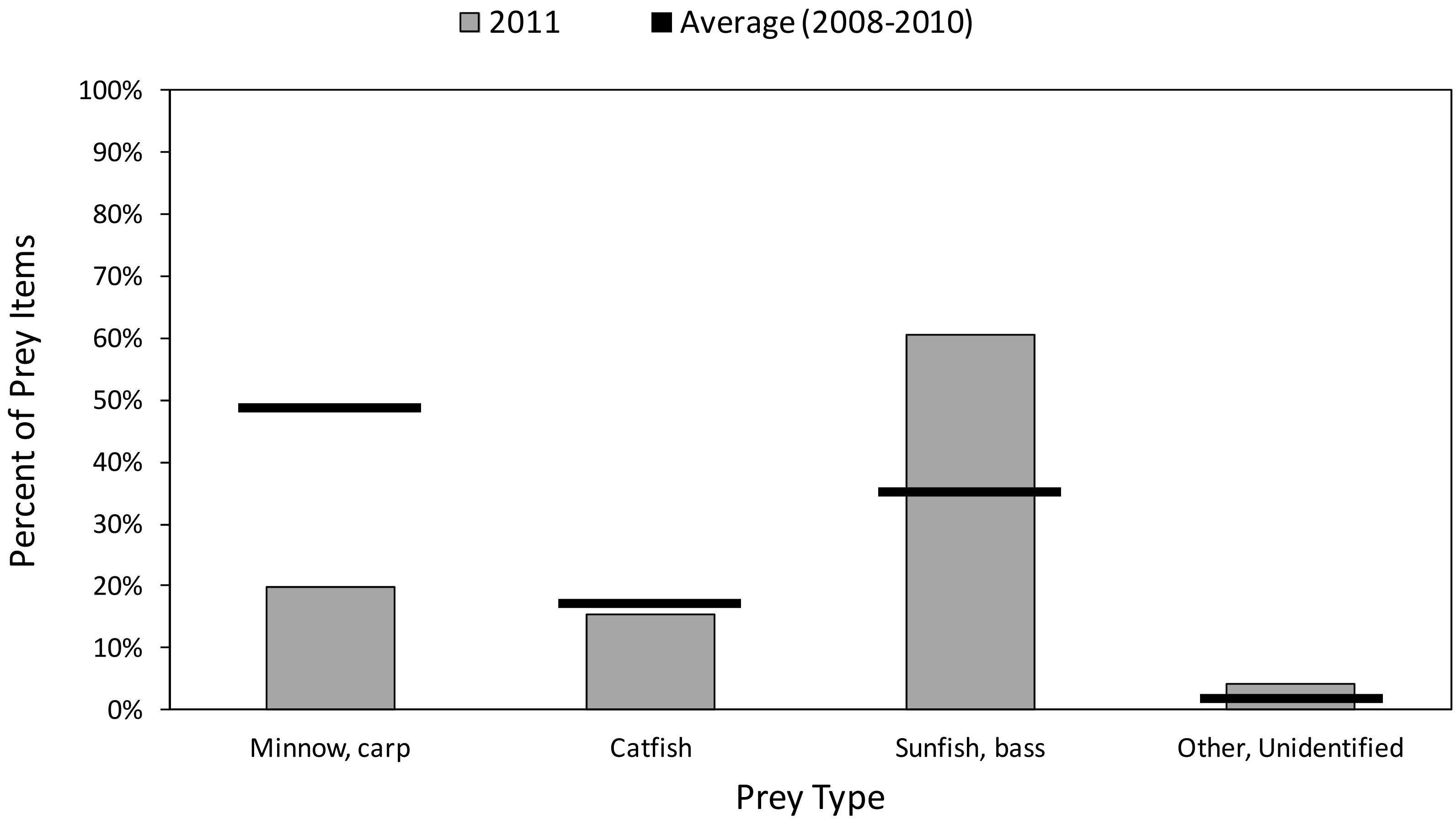


Figure 41. Diet composition (percent of prey items) of Caspian terns nesting on Crump Lake tern island, Warner Valley, Oregon during the 2011 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

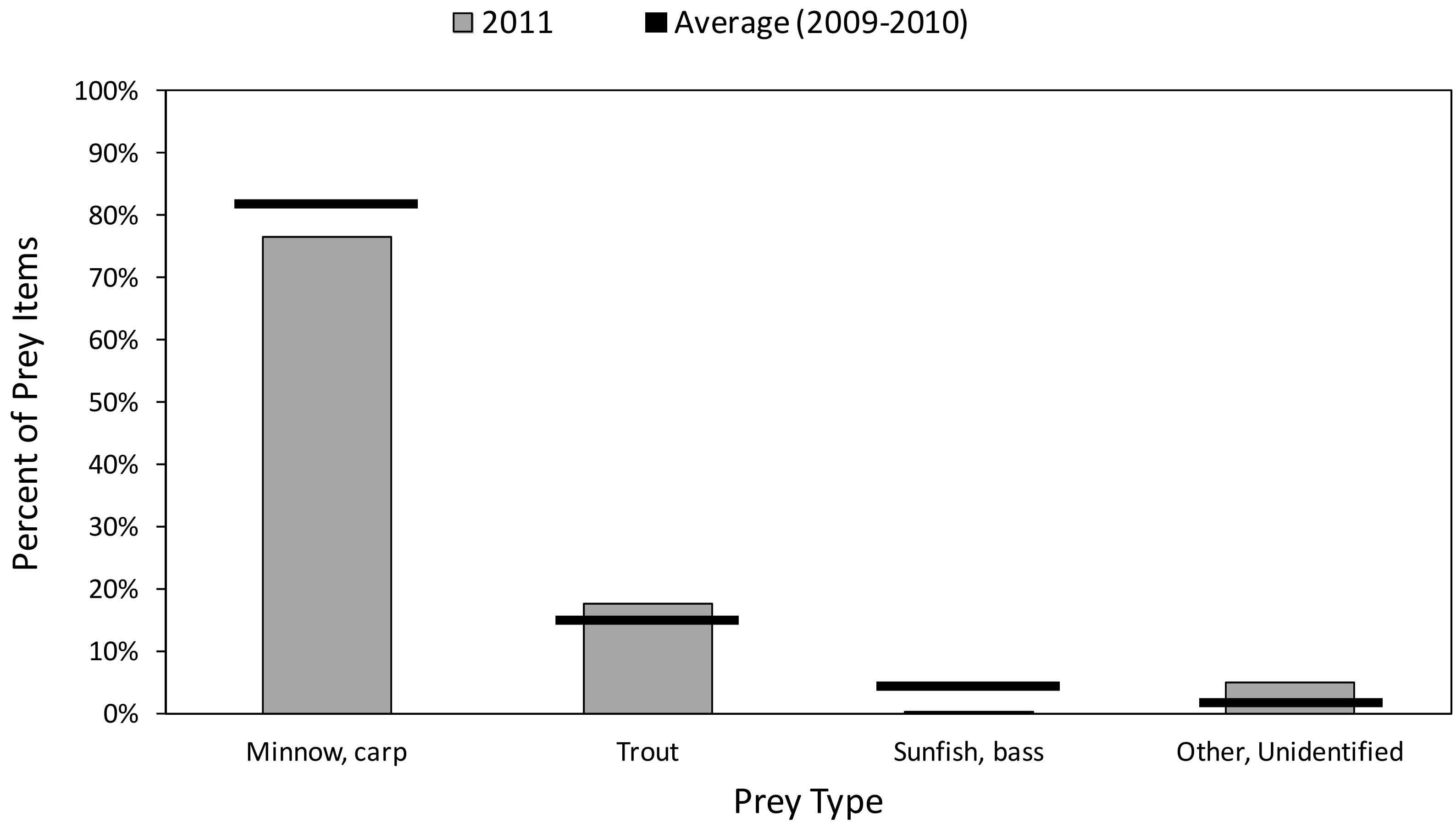


Figure 42. Diet composition (percent of prey items) of Caspian terns nesting on the Summer Lake Wildlife Area tern islands (East Link and Dutchy Lake) during the 2011 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

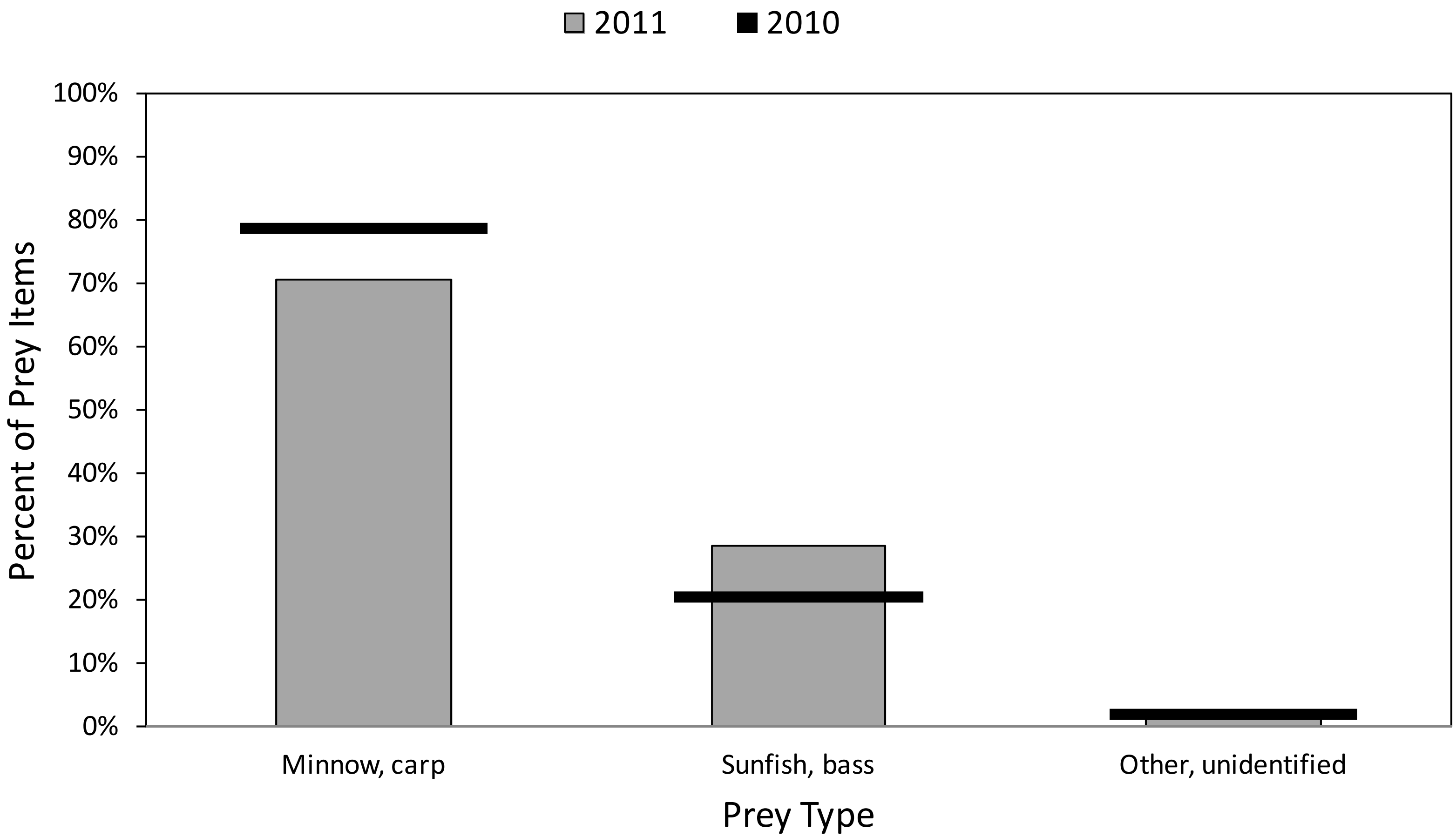


Figure 43. Diet composition (percent of prey items) of Caspian terns nesting on the Sheepy Lake tern island in Lower Klamath NWR, California during the 2011 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

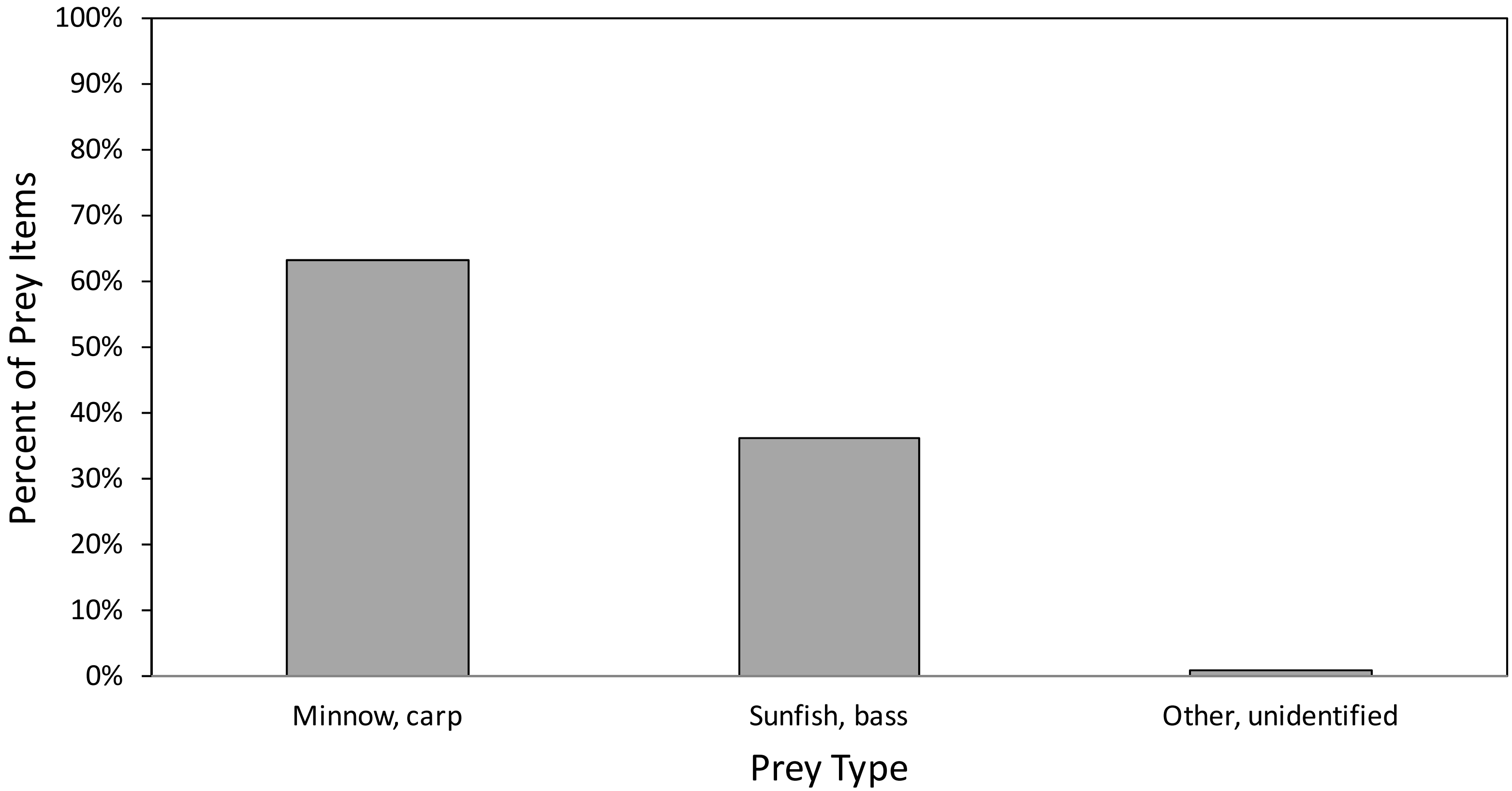


Figure 44. Diet composition (percent of prey items) of Caspian terns nesting on the Tule Lake Sump 1B tern island in Tule Lake NWR, California during the 2011 breeding season. Diet composition was based on fish identified in tern bill-loads on-colony.

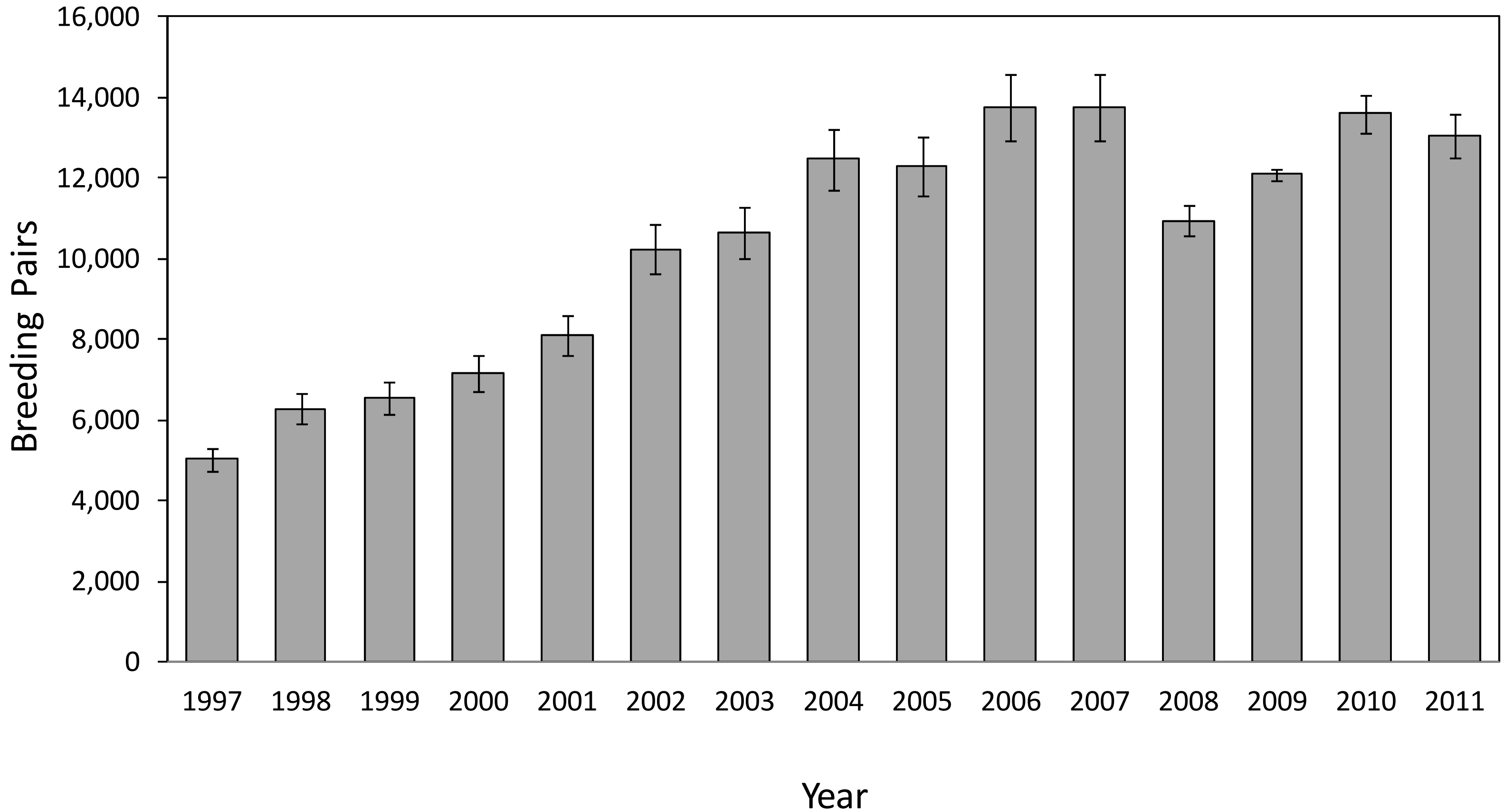


Figure 45. Size of the double-crested cormorant breeding colony on East Sand Island in the Columbia River estuary during the 1997-2011 breeding seasons. Error bars represent 95% confidence intervals for the number of breeding pairs.

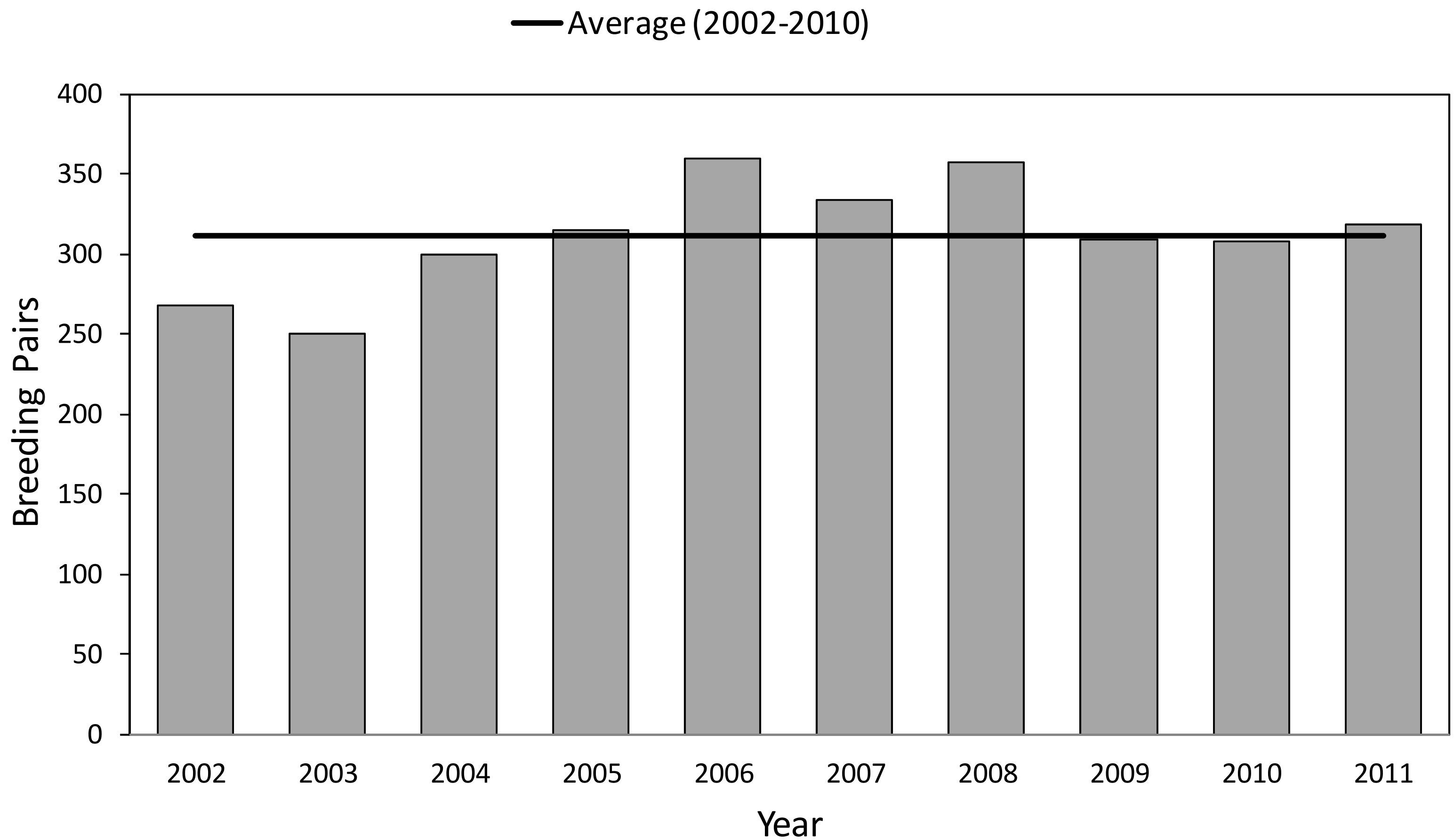


Figure 46. Size of the double-crested cormorant breeding colony on Foundation Island in the mid-Columbia River during the 2002-2011 breeding seasons.

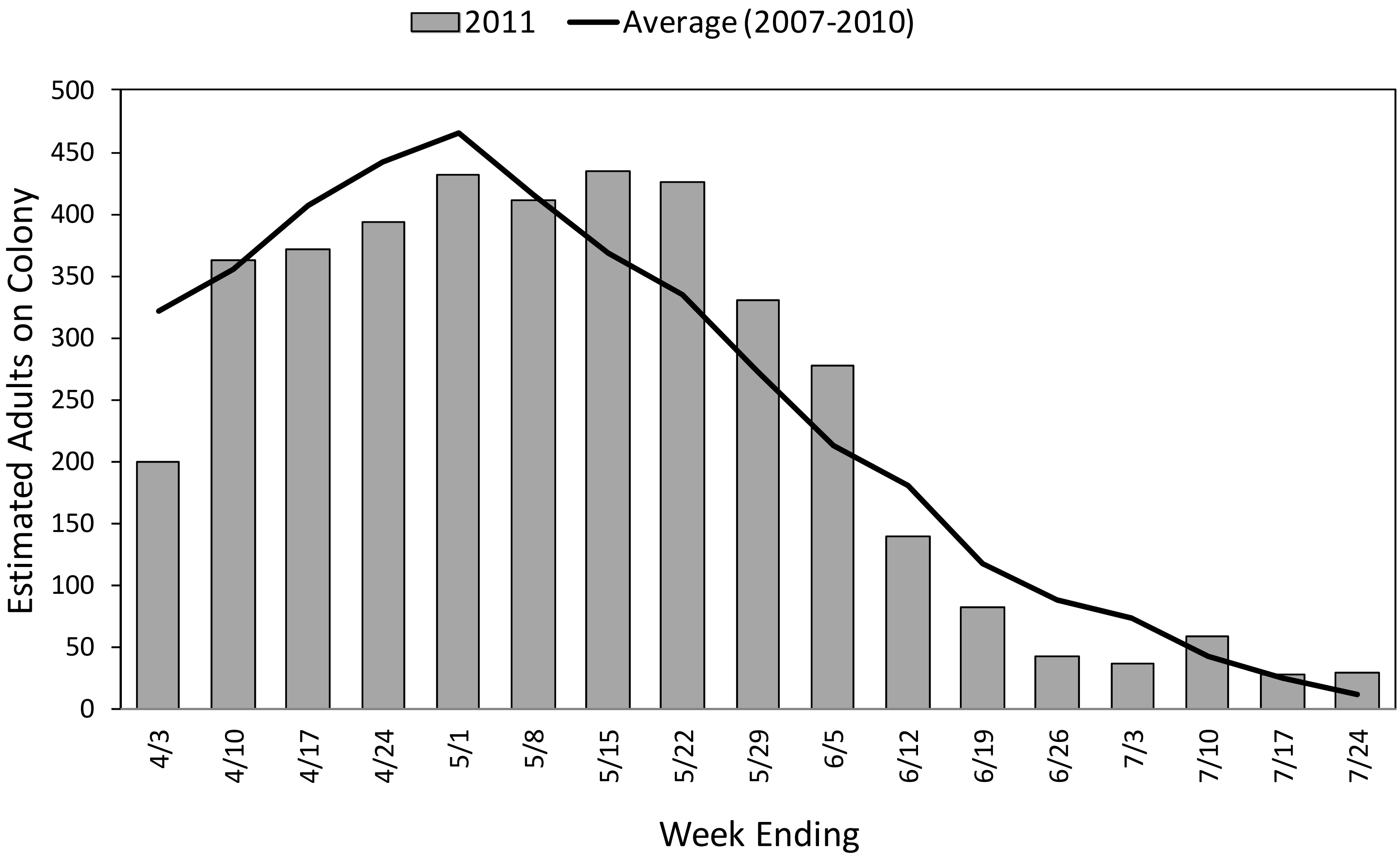


Figure 47. Weekly estimates from the ground of the number of adult double-crested cormorants on the Foundation Island colony in the mid-Columbia River during the 2011 breeding season.

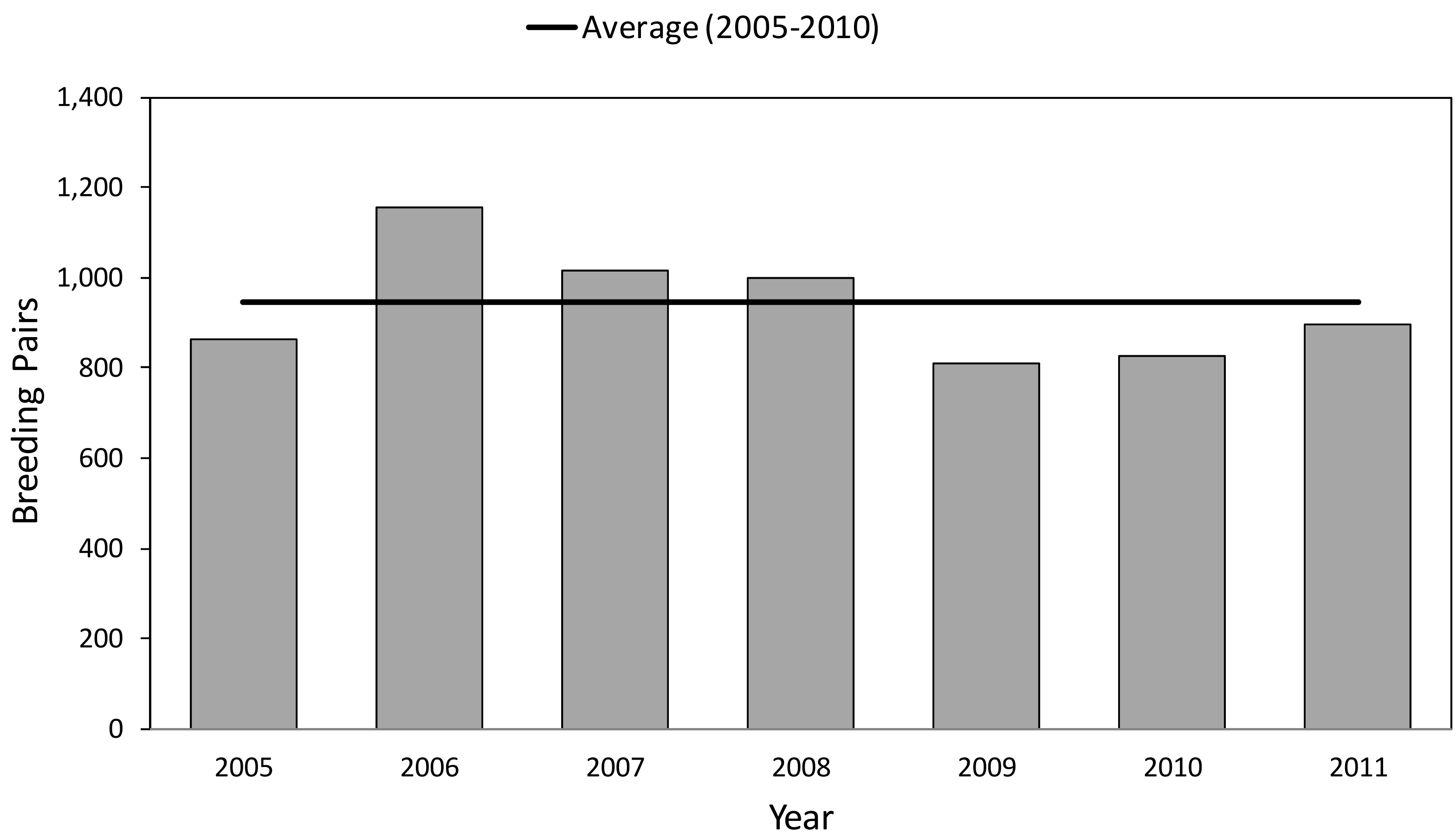


Figure 48. Size of the double-crested cormorant breeding colony in North Potholes Reserve, Potholes Reservoir during the 2005-2011 breeding seasons.

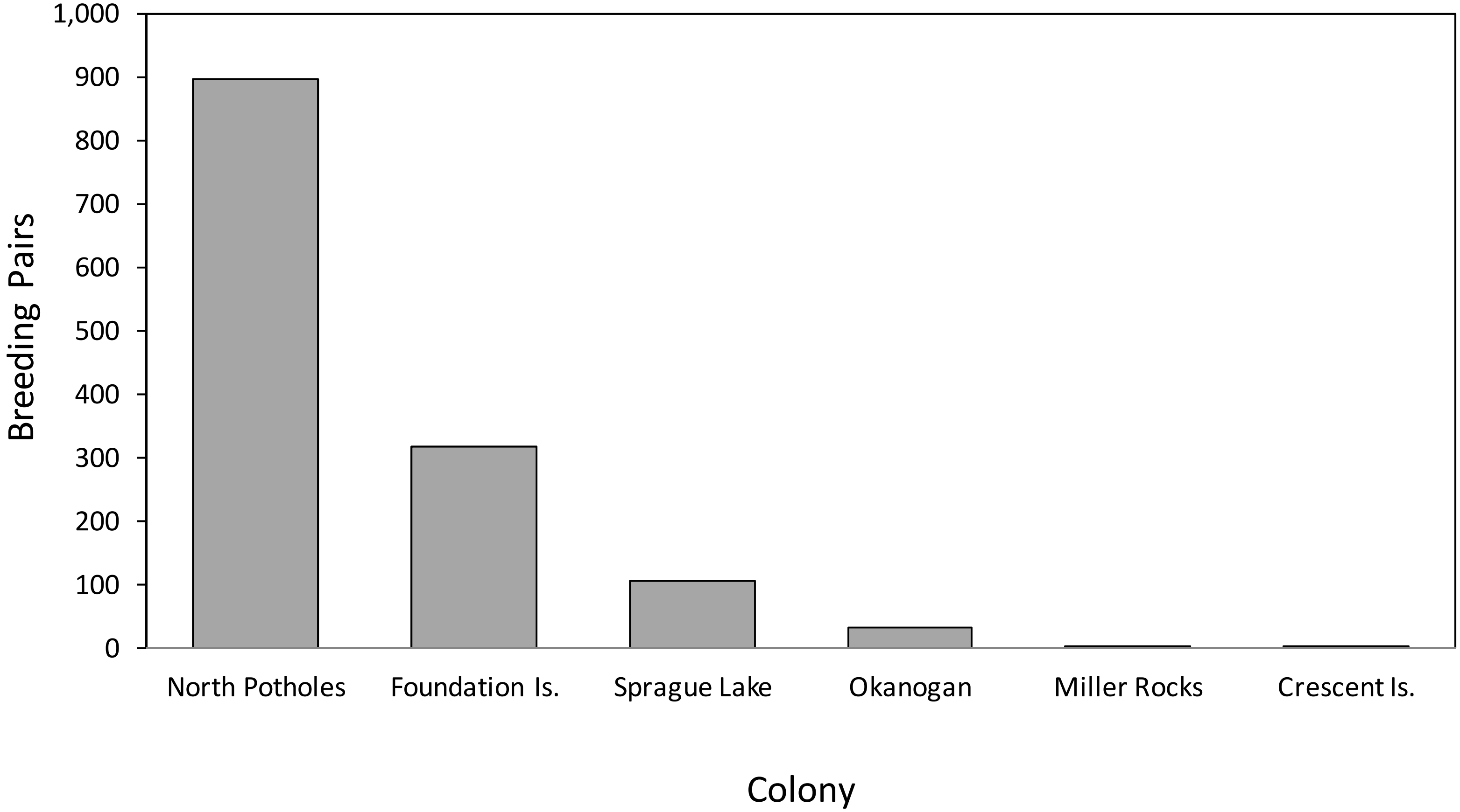


Figure 49. Size of the double-crested cormorant breeding colonies in the Columbia Plateau region during the 2011 breeding season.

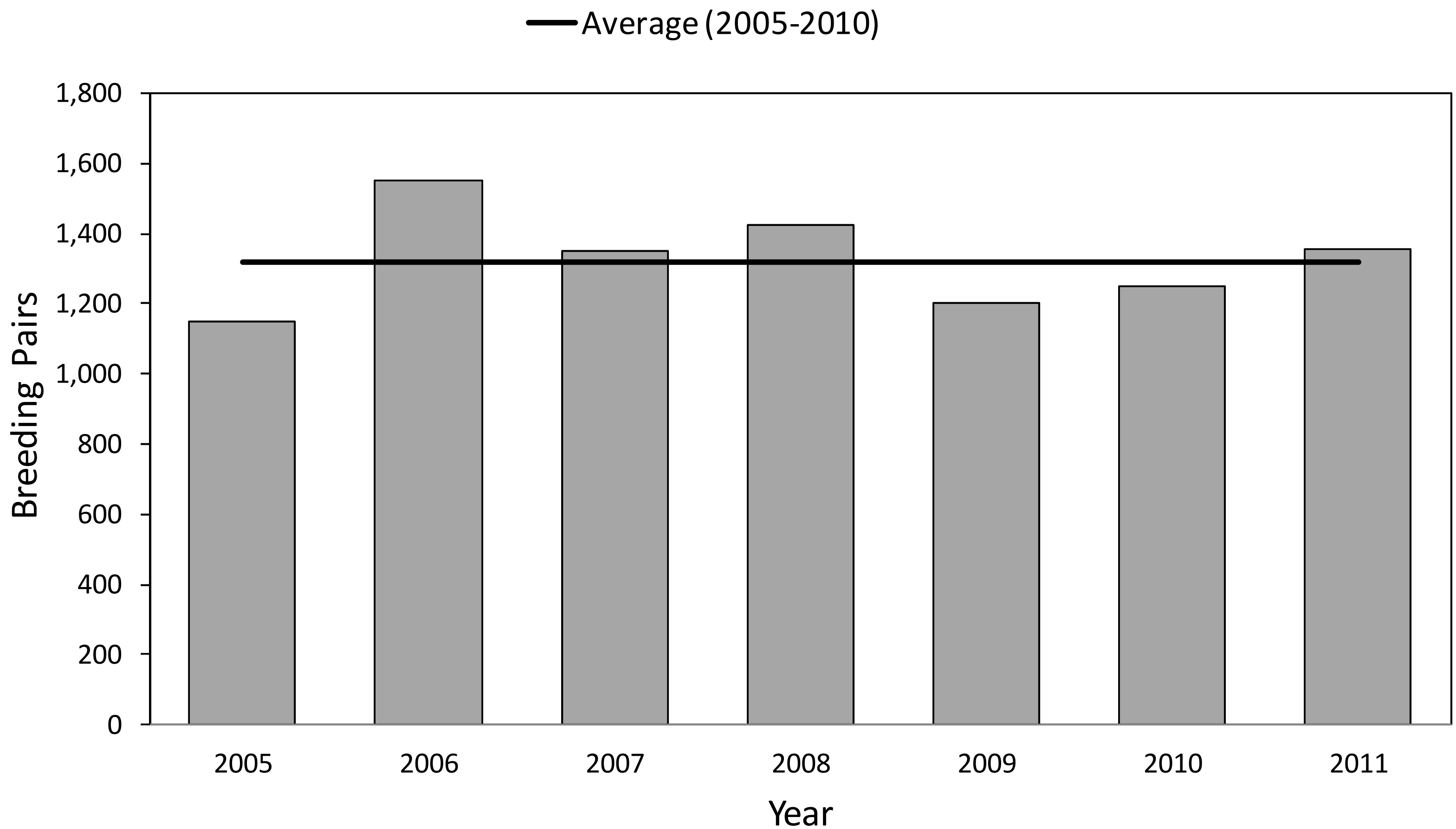


Figure 50. Total number of double-crested cormorant breeding pairs nesting at colonies in the Columbia Plateau region during the 2005-2011 breeding seasons.

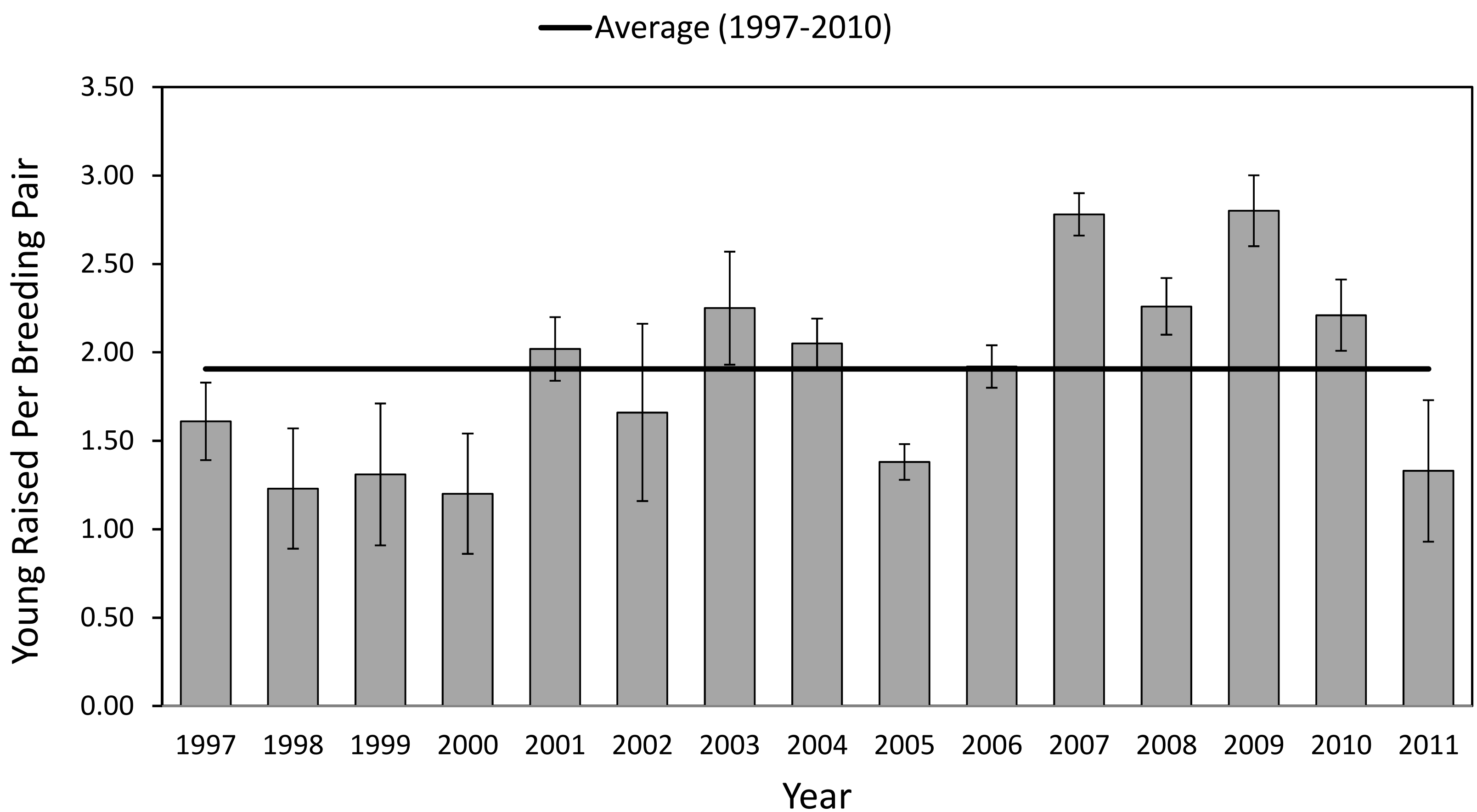


Figure 51. Double-crested cormorant nesting success at the East Sand Island colony in the Columbia River estuary during the 1997-2011 breeding seasons. Error bars represent 95% confidence intervals for the average number of young raised per breeding pair.

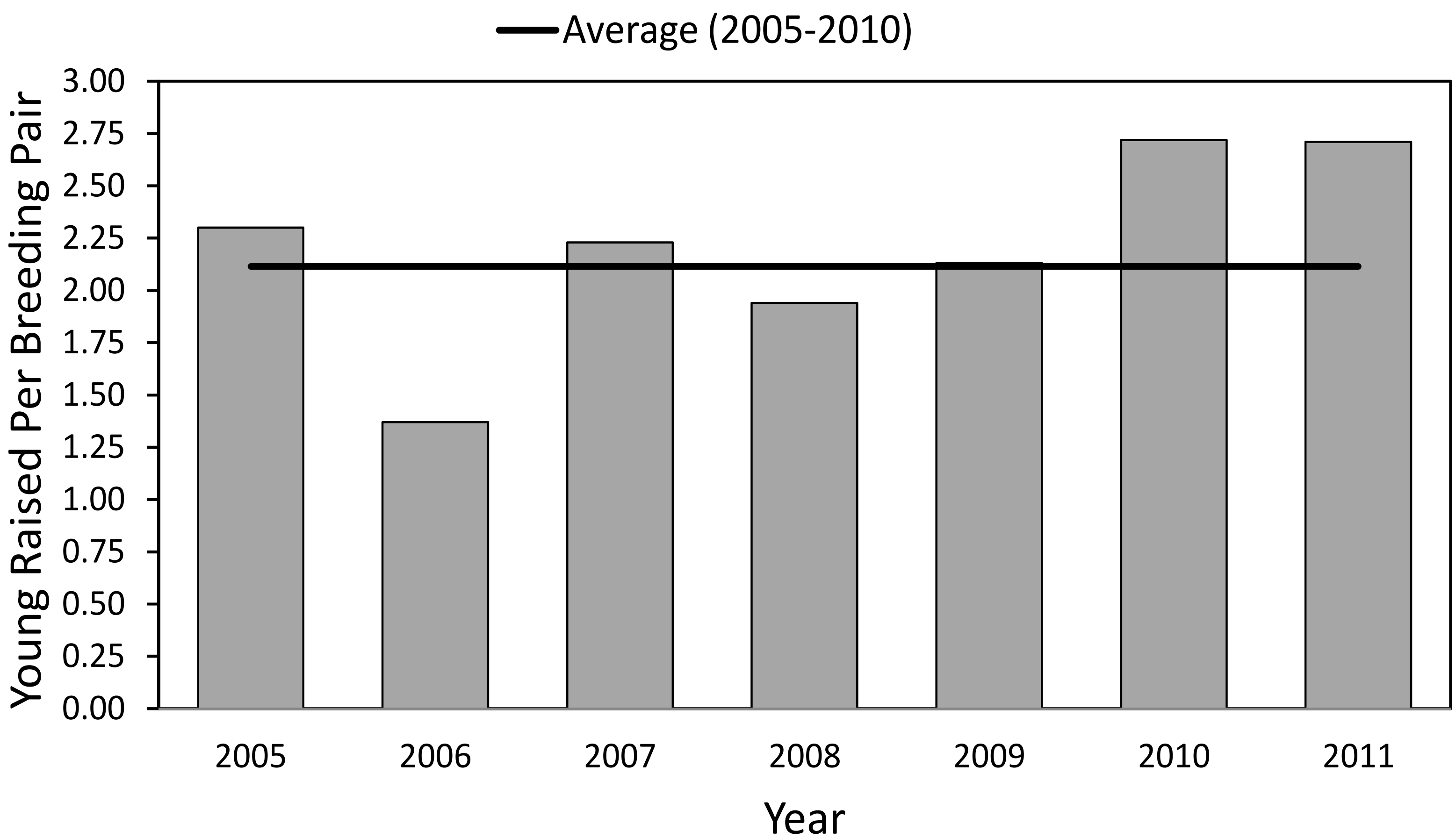


Figure 52. Double-crested cormorant nesting success at the Foundation Island colony in the mid-Columbia River during the 2005-2011 breeding seasons.

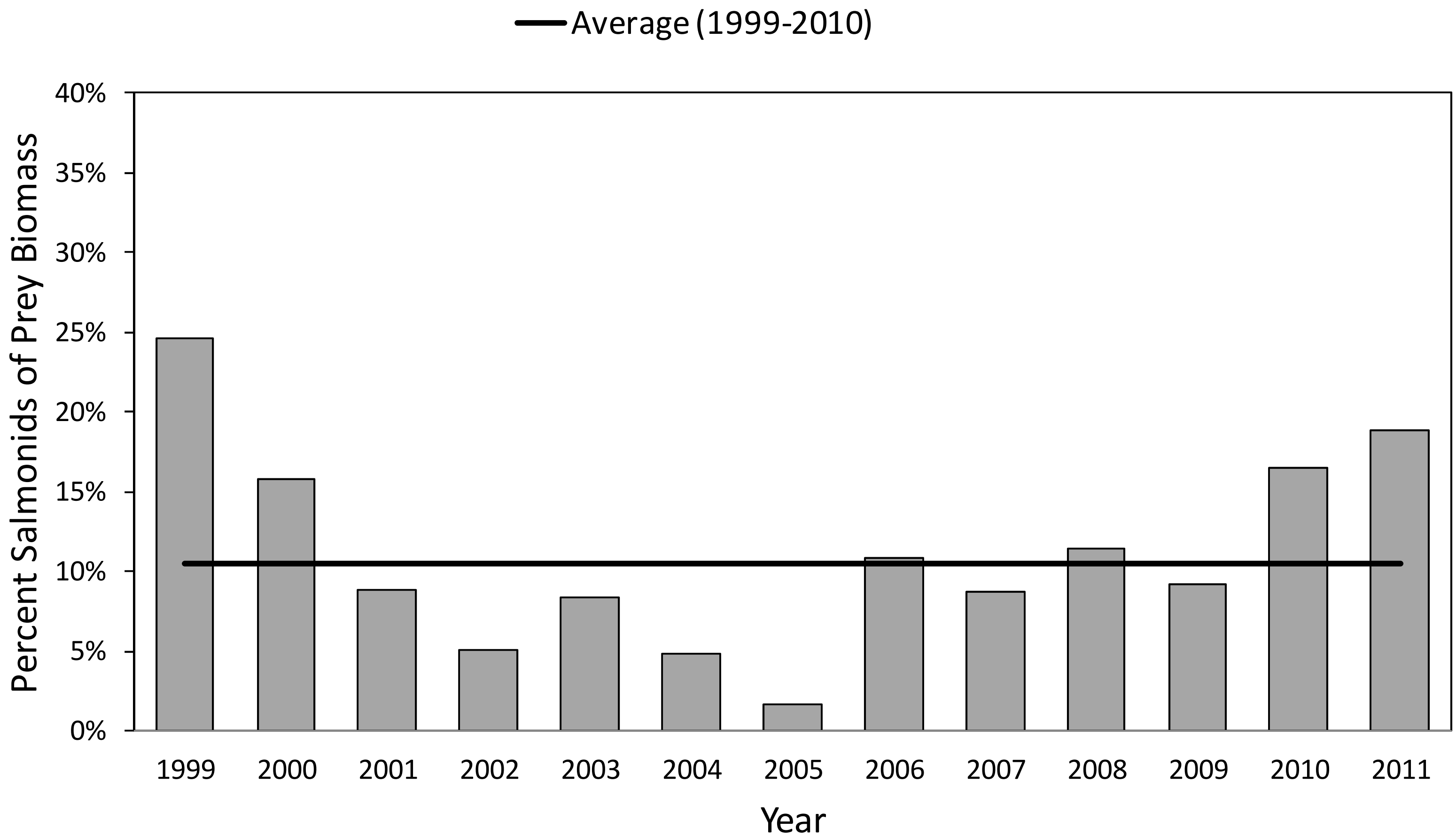


Figure 53. Average annual proportion of juvenile salmonids in the diet (percent of prey biomass) of double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 1999-2011 breeding seasons.

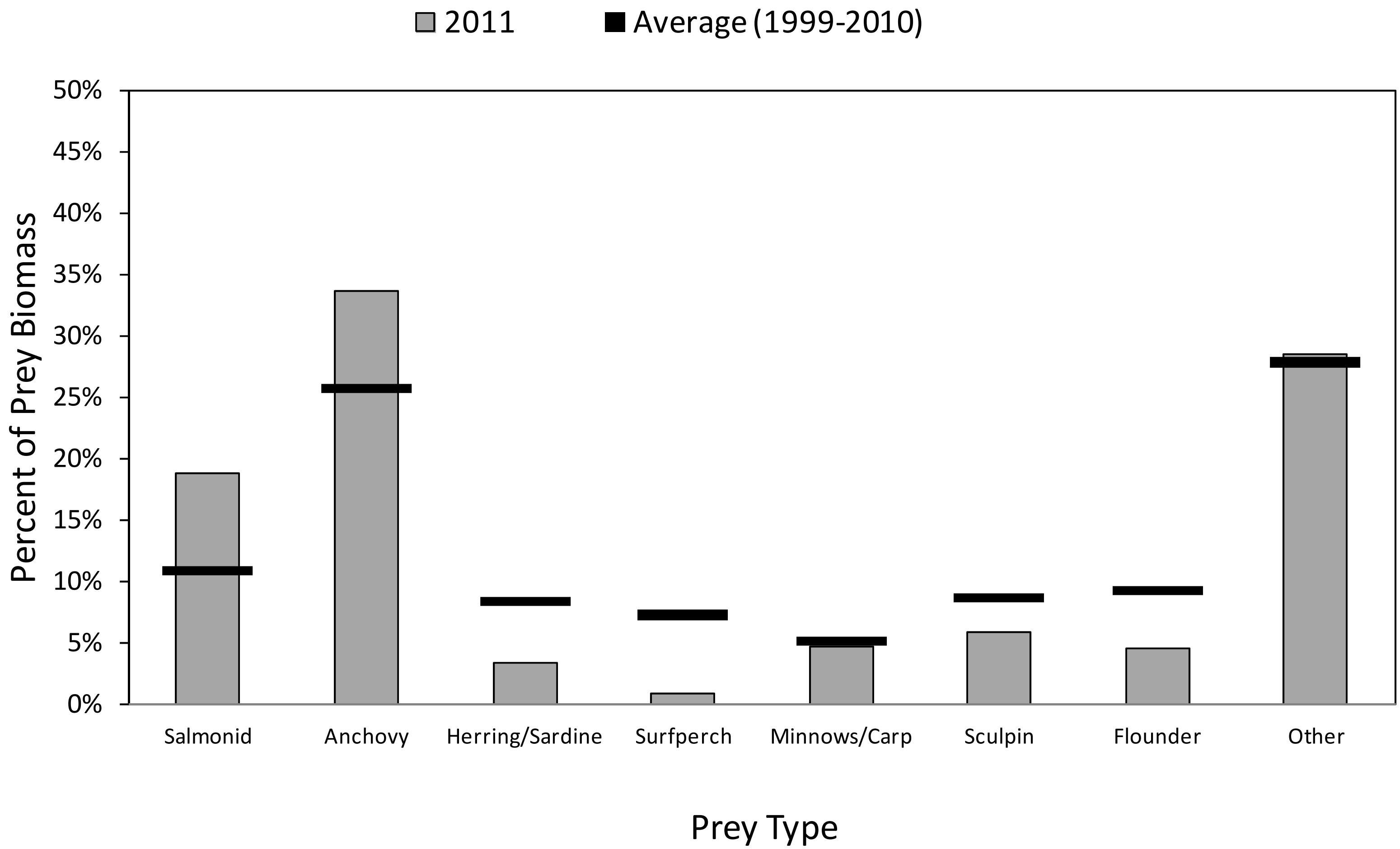


Figure 54. Diet composition (percent of prey biomass) of double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 2011 breeding season. Diet composition was based on fish identified in cormorant foregut samples.

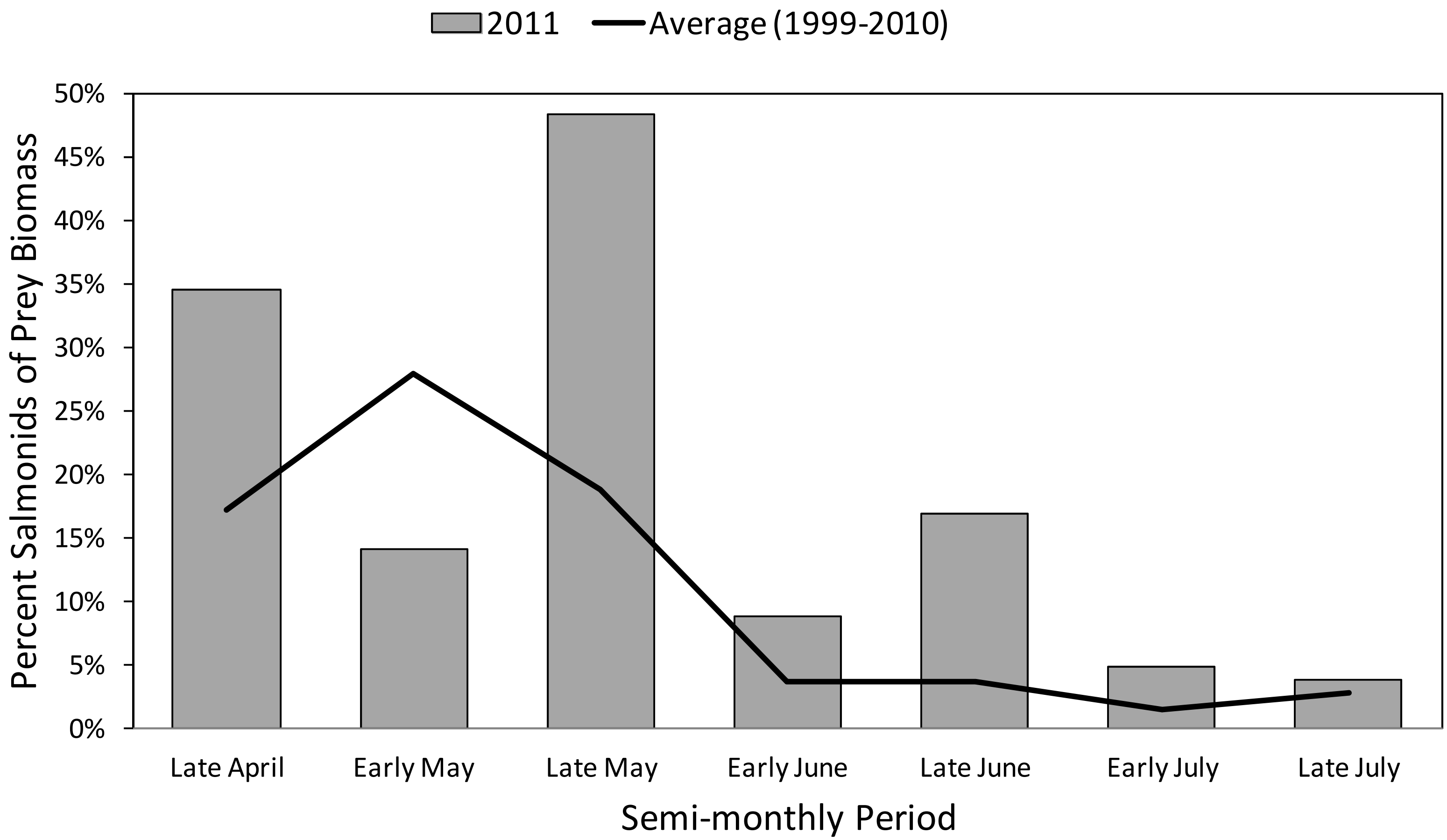


Figure 55. Seasonal trend in the proportion of juvenile salmonids in the diet (percent of prey biomass) of double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 2011 breeding season, by half-month period.

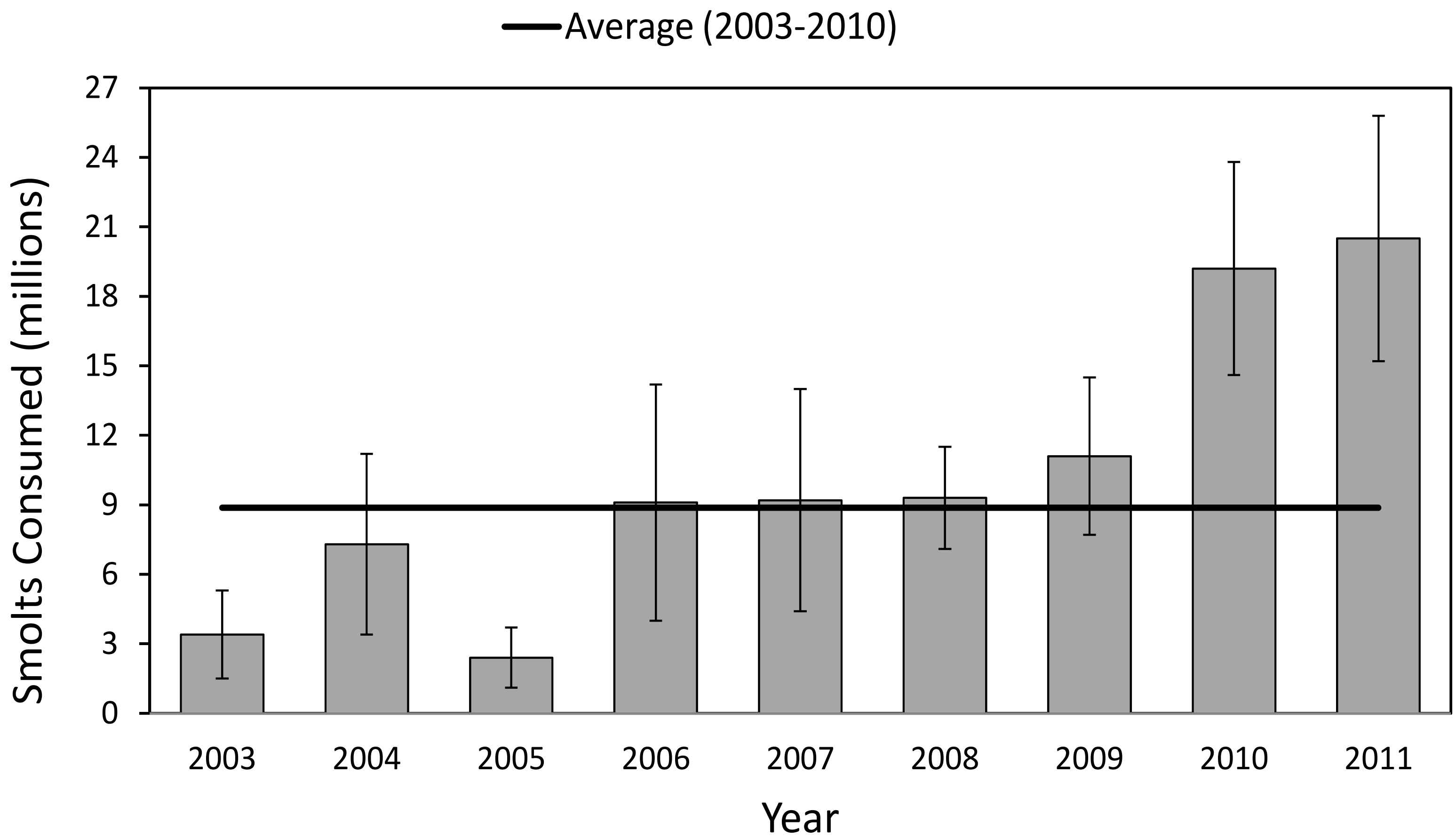


Figure 56. Estimated total annual consumption of juvenile salmonids by double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 2003-2011 breeding seasons. Error bars represent 95% confidence intervals for the number of smolts consumed.

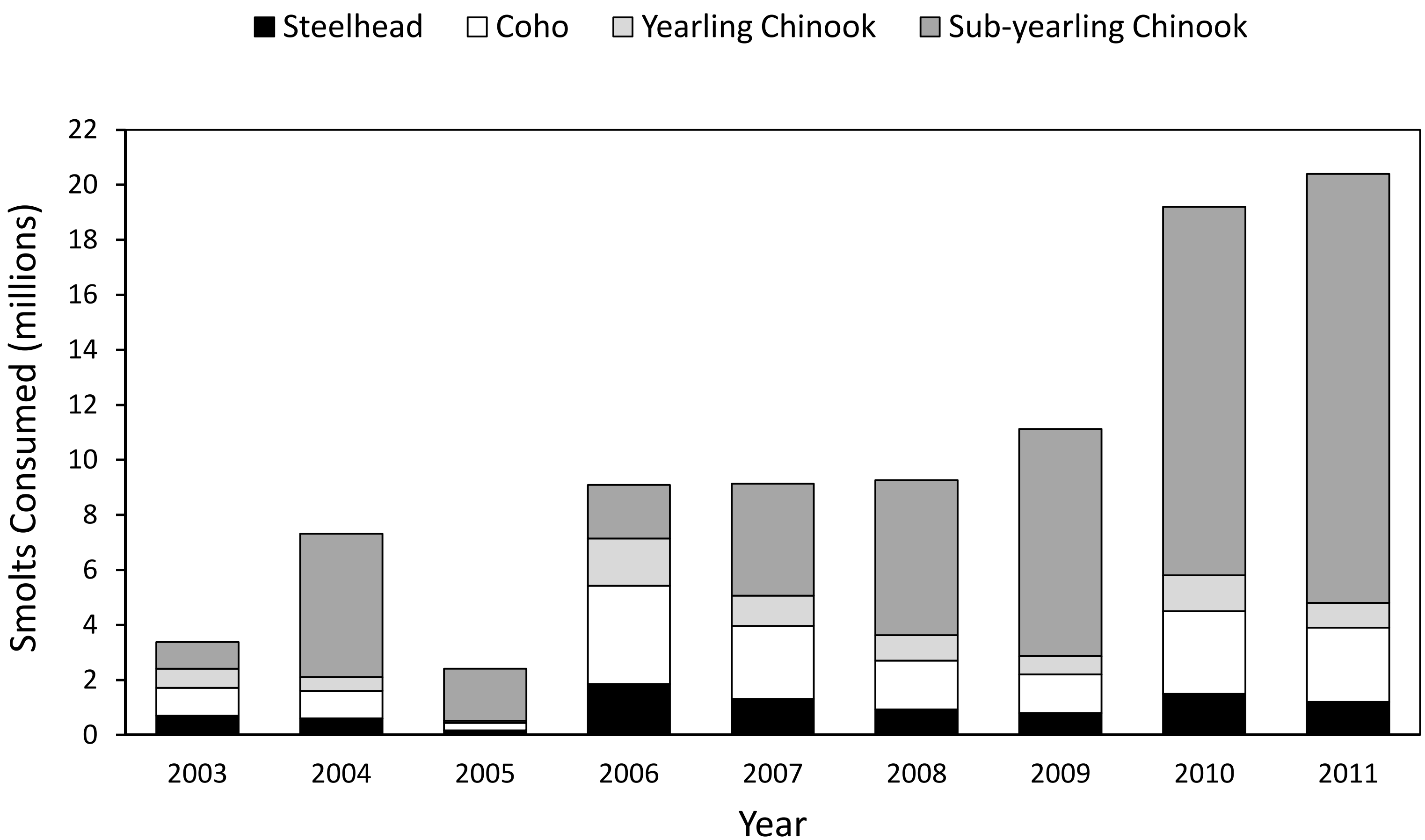


Figure 57. Estimated total annual consumption of four species/run types of juvenile salmonids by double-crested cormorants nesting on East Sand Island in the Columbia River estuary during the 2003-2011 breeding seasons. Estimates are based on fish identified in cormorant foregut samples and bioenergetics calculations.

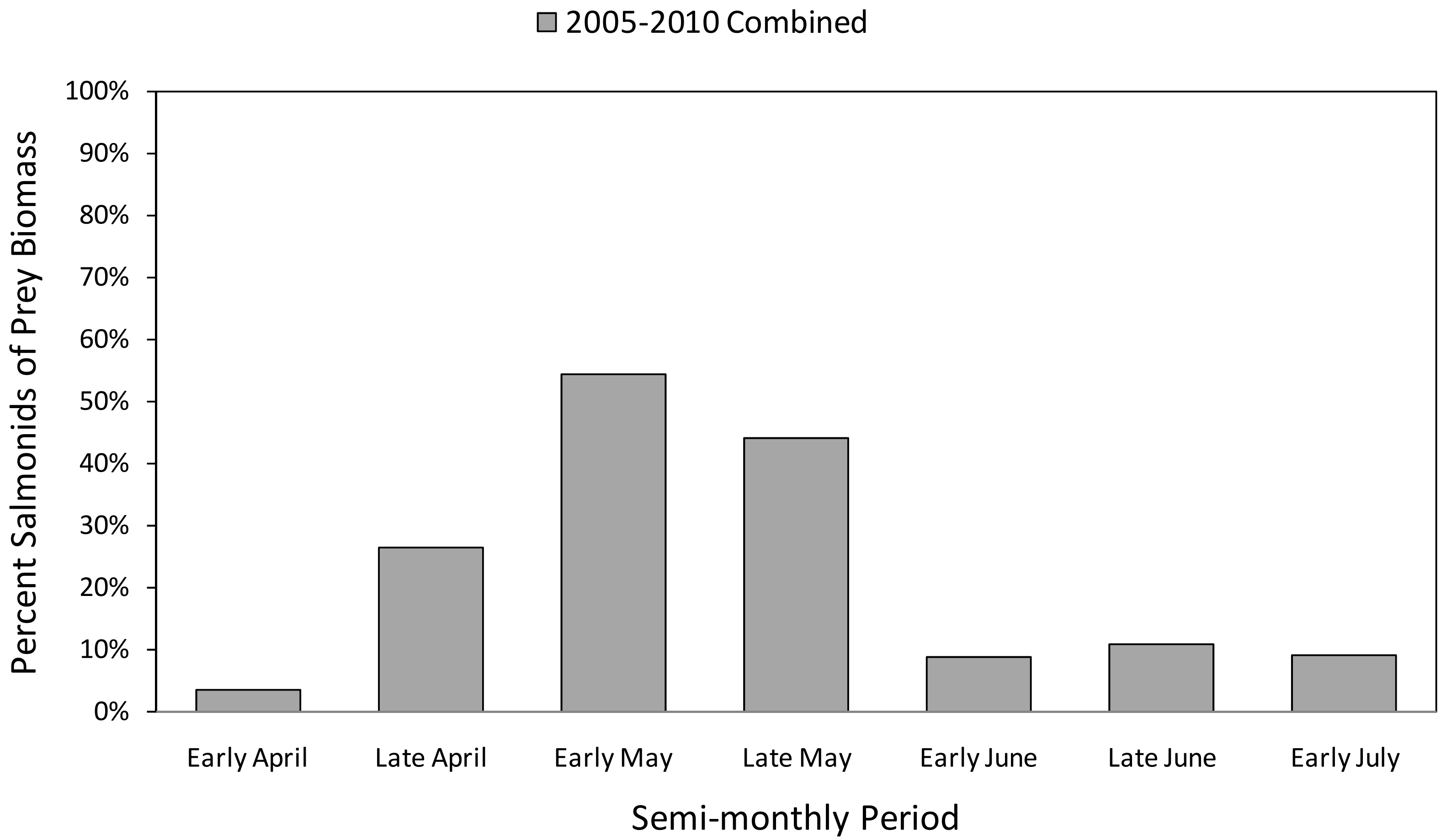


Figure 58. Average proportion of juvenile salmonids in the diet (percent of prey biomass) of double-crested cormorants nesting on Foundation Island in the mid-Columbia River during the 2005-2010 breeding seasons, by half-month period. Diet samples collected during the six-year study period are combined.

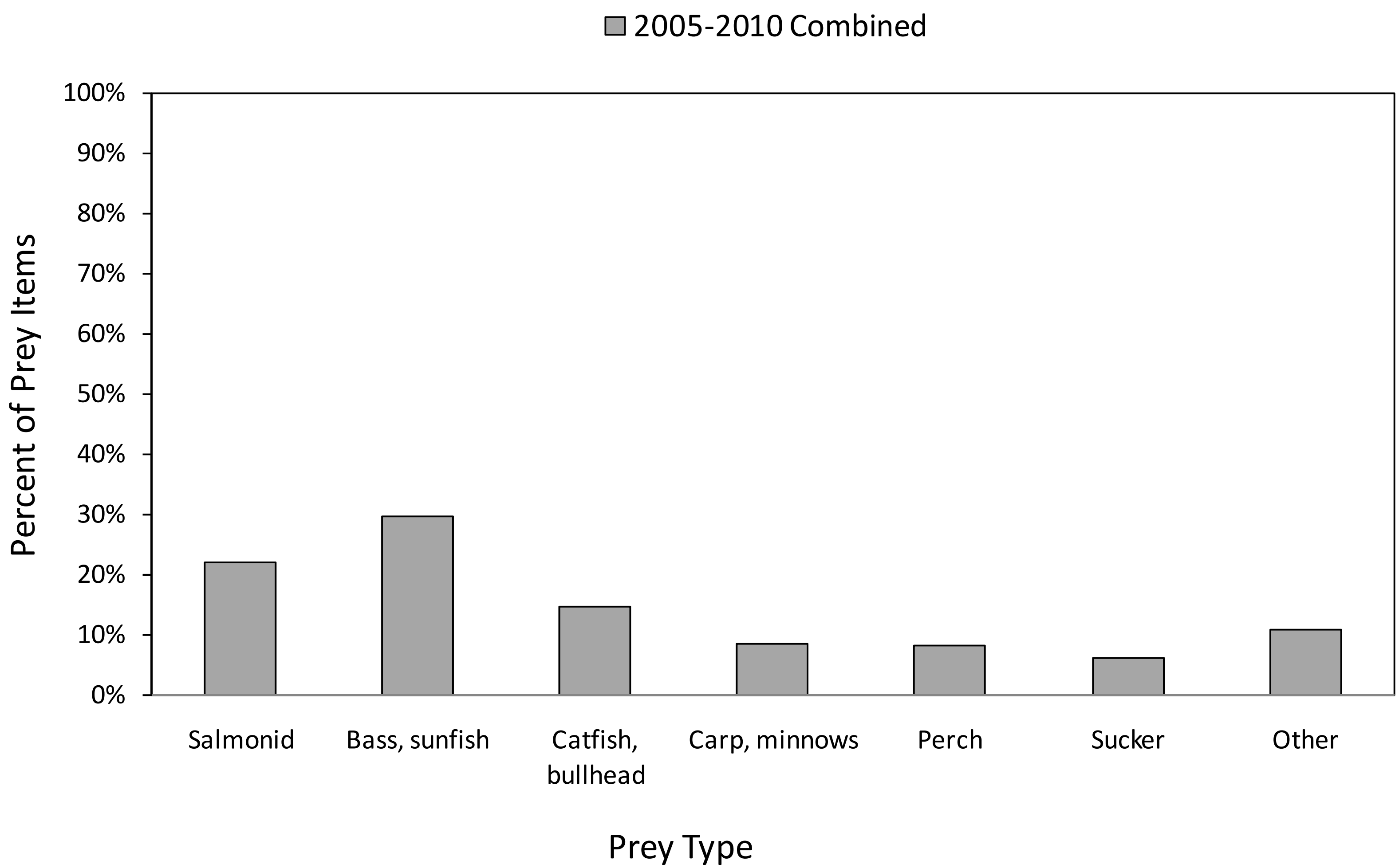


Figure 59. Diet composition (percent of prey biomass) of double-crested cormorants nesting on Foundation Island in the mid-Columbia River during the 2005-2010 breeding seasons. Diet samples collected during the six-year study period are combined.

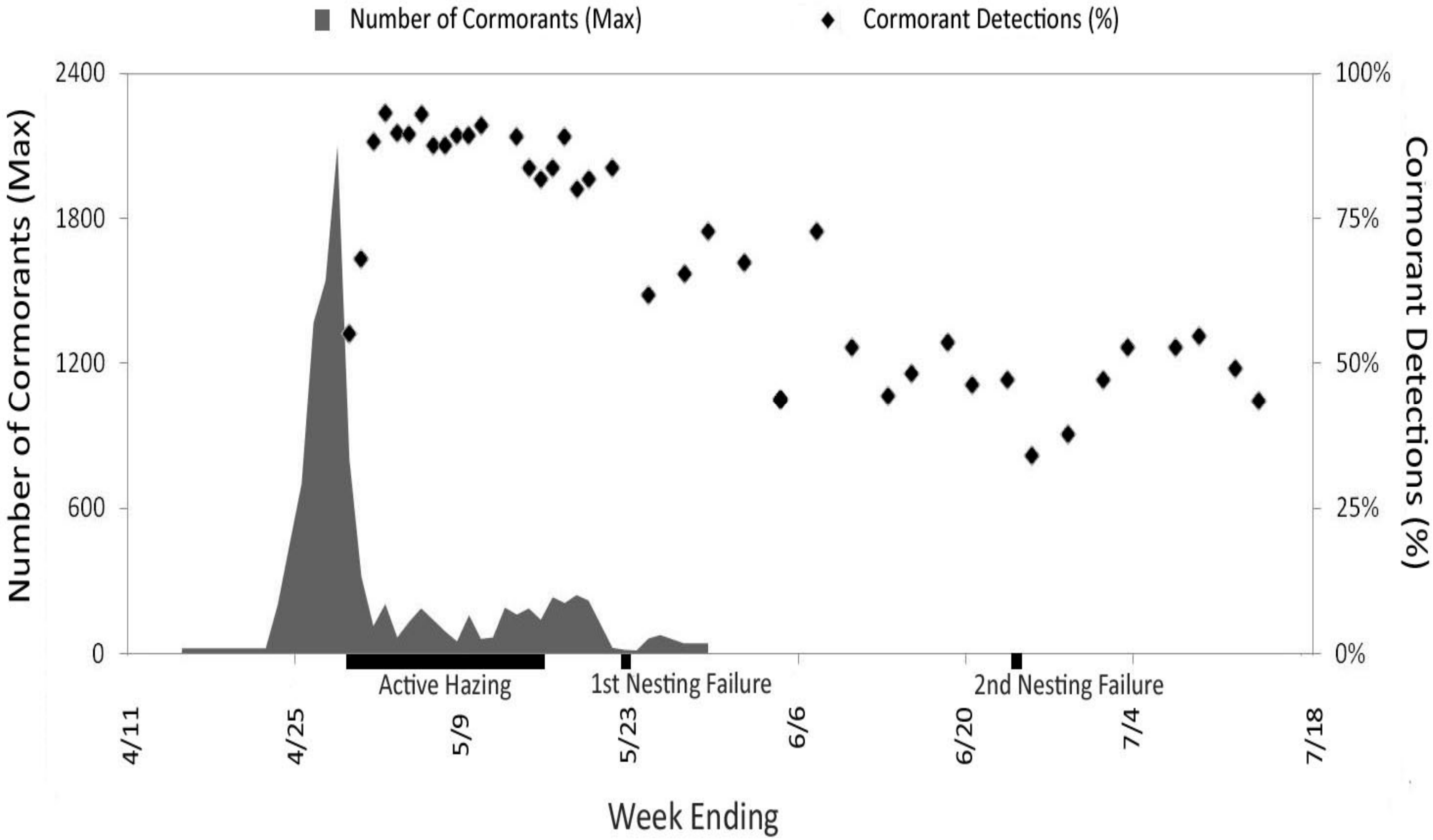


Figure 60. Estimates from the ground of the maximum number of adult double-crested cormorants in the dissuasion area on the East Sand Island breeding colony and the percent of radio-tagged cormorants (n = 60) detected on East Sand Island during and following active hazing of cormorants within the dissuasion area in 2011. All detections of radio-tagged cormorants on East Sand Island were from outside the dissuasion area. Also noted were major colony events, including active hazing in the dissuasion area (29 April – 12 May) and two nesting failure events (22 May and 23 June) caused by bald eagle disturbance and subsequent nest predation by gulls.

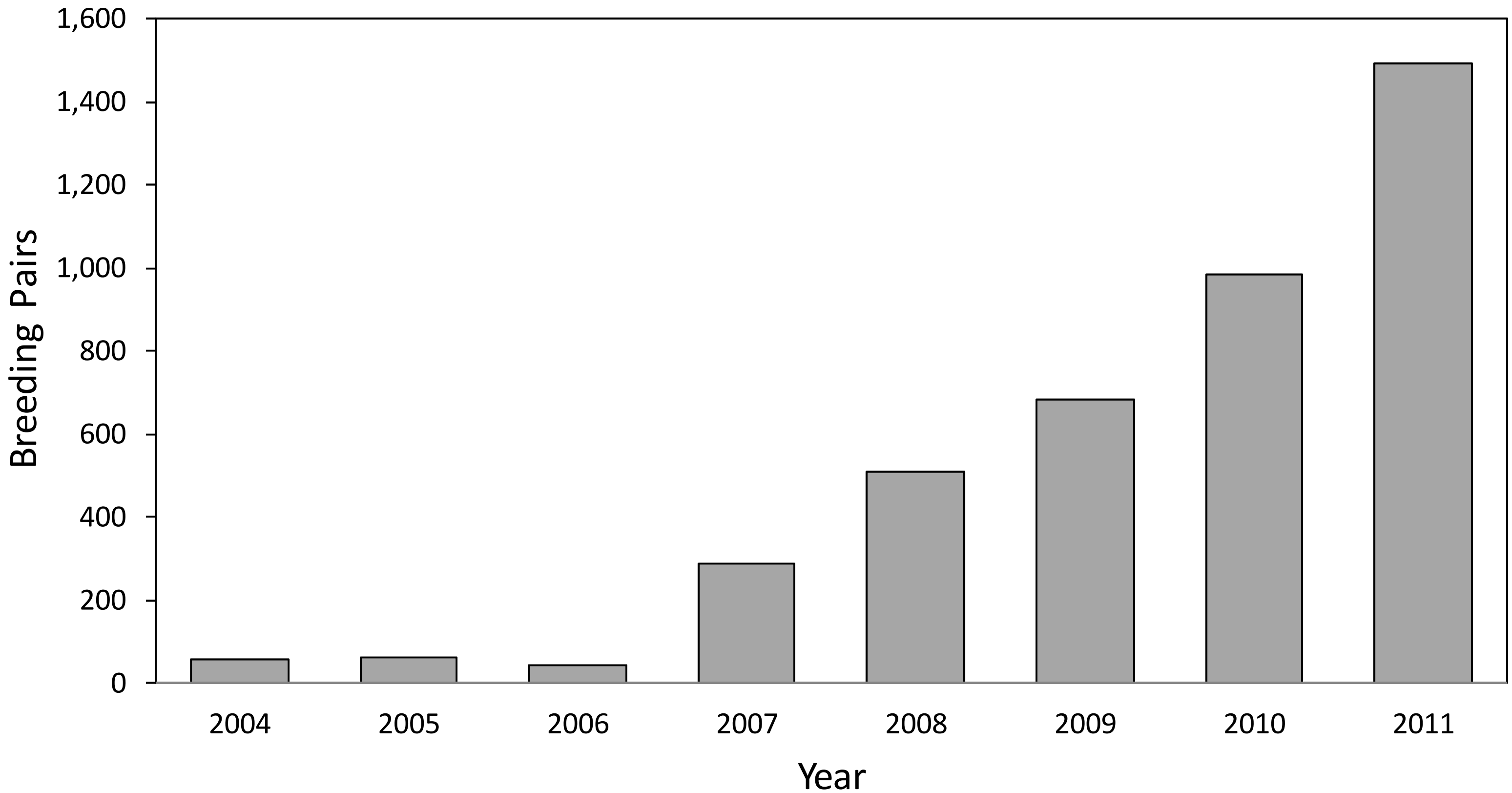


Figure 61. Size of the Brandt's cormorant breeding colony on East Sand Island in the Columbia River estuary during the 2004-2011 breeding seasons.

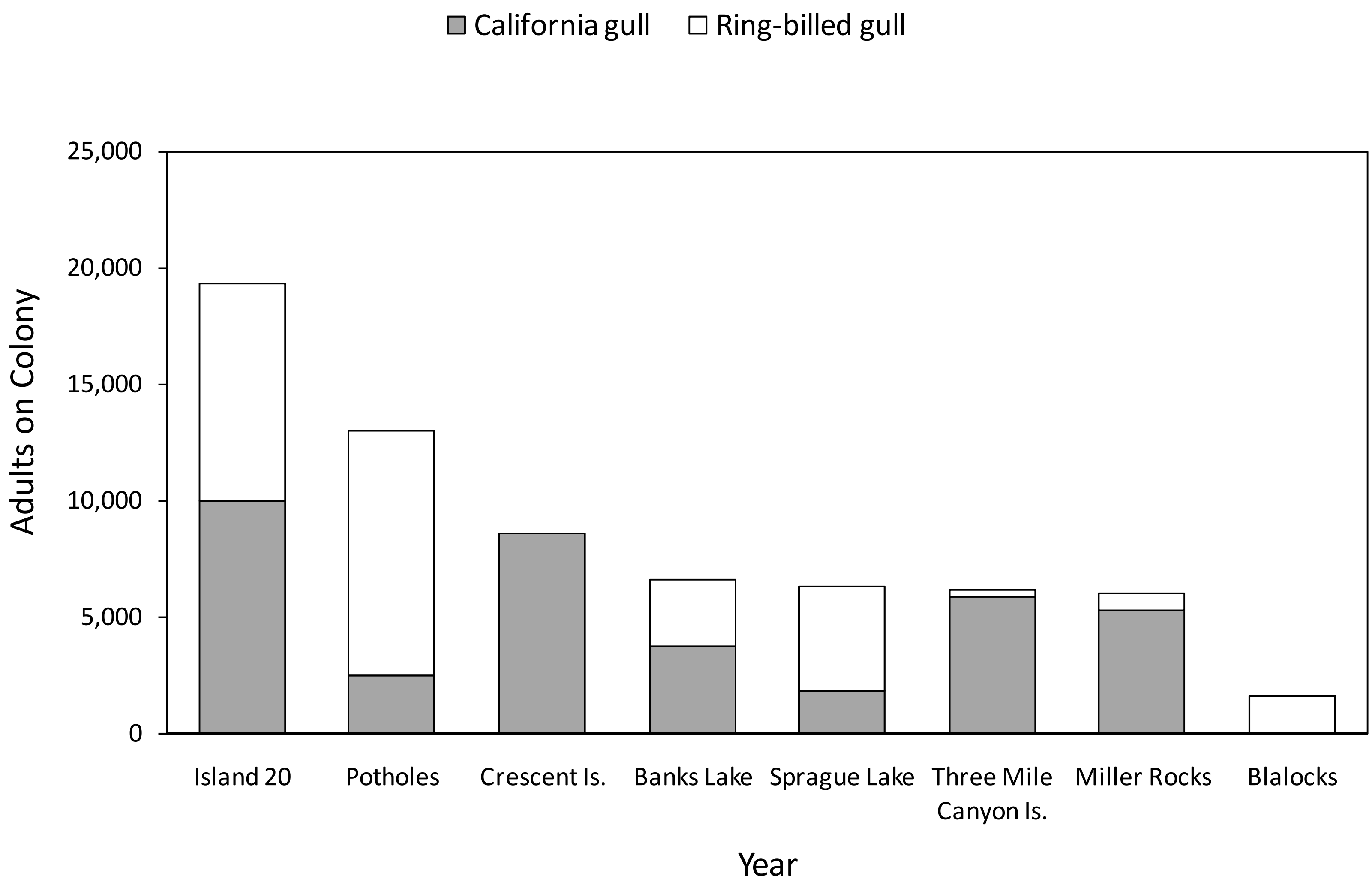


Figure 62. Numbers of adult California and ring-billed gulls counted on aerial photography of eight different colonies in the Columbia Plateau region during the 2009 breeding season. Photography was taken late in the incubation period.

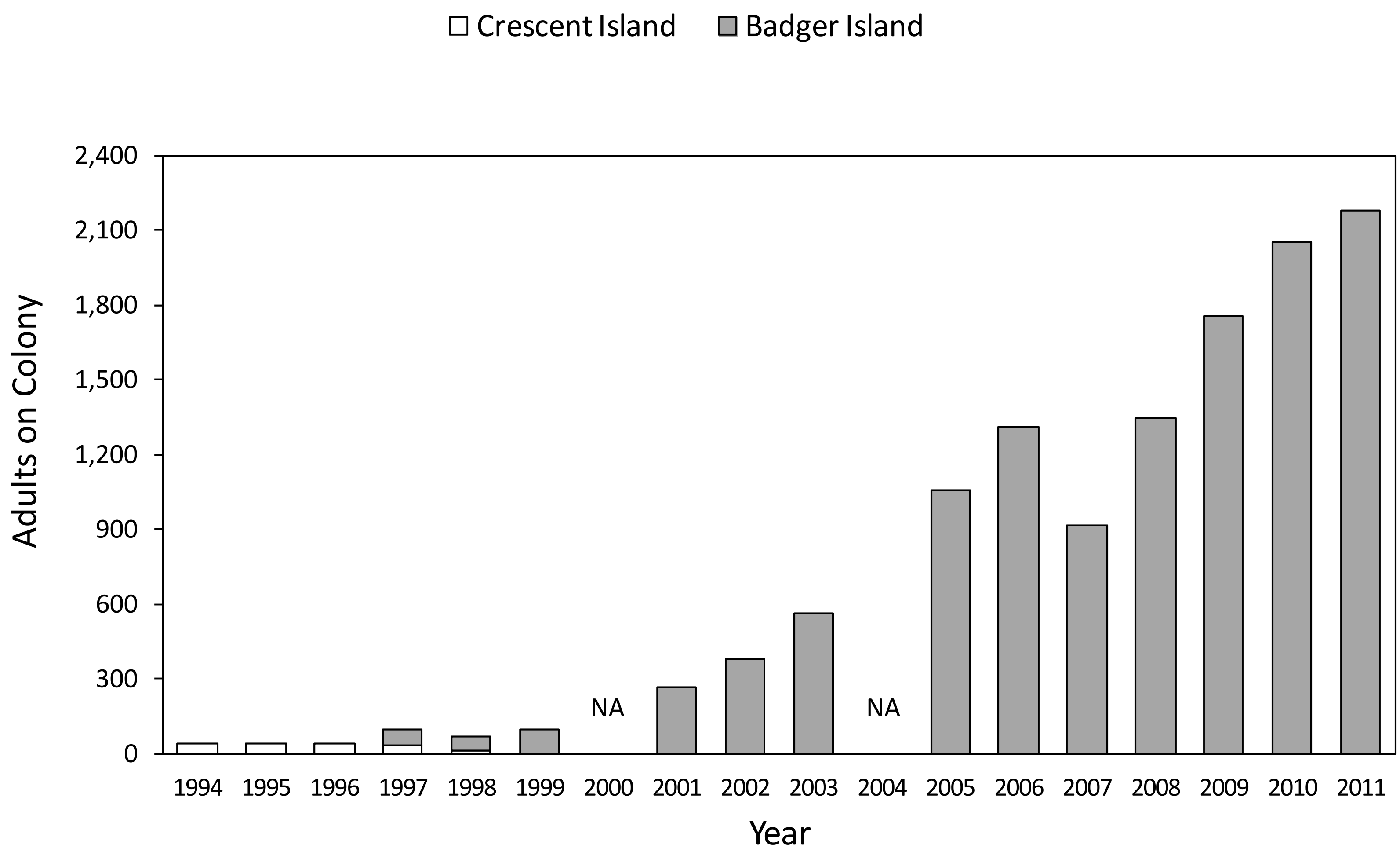


Figure 63. Numbers of American white pelicans counted in aerial photography of two colonies on the mid-Columbia River, Badger Island and Crescent Island, during the 1994-2011 breeding seasons. Photography was taken late in the incubation period. Numbers of pelicans on the Badger Island colony were not determined in 2000 and 2004.

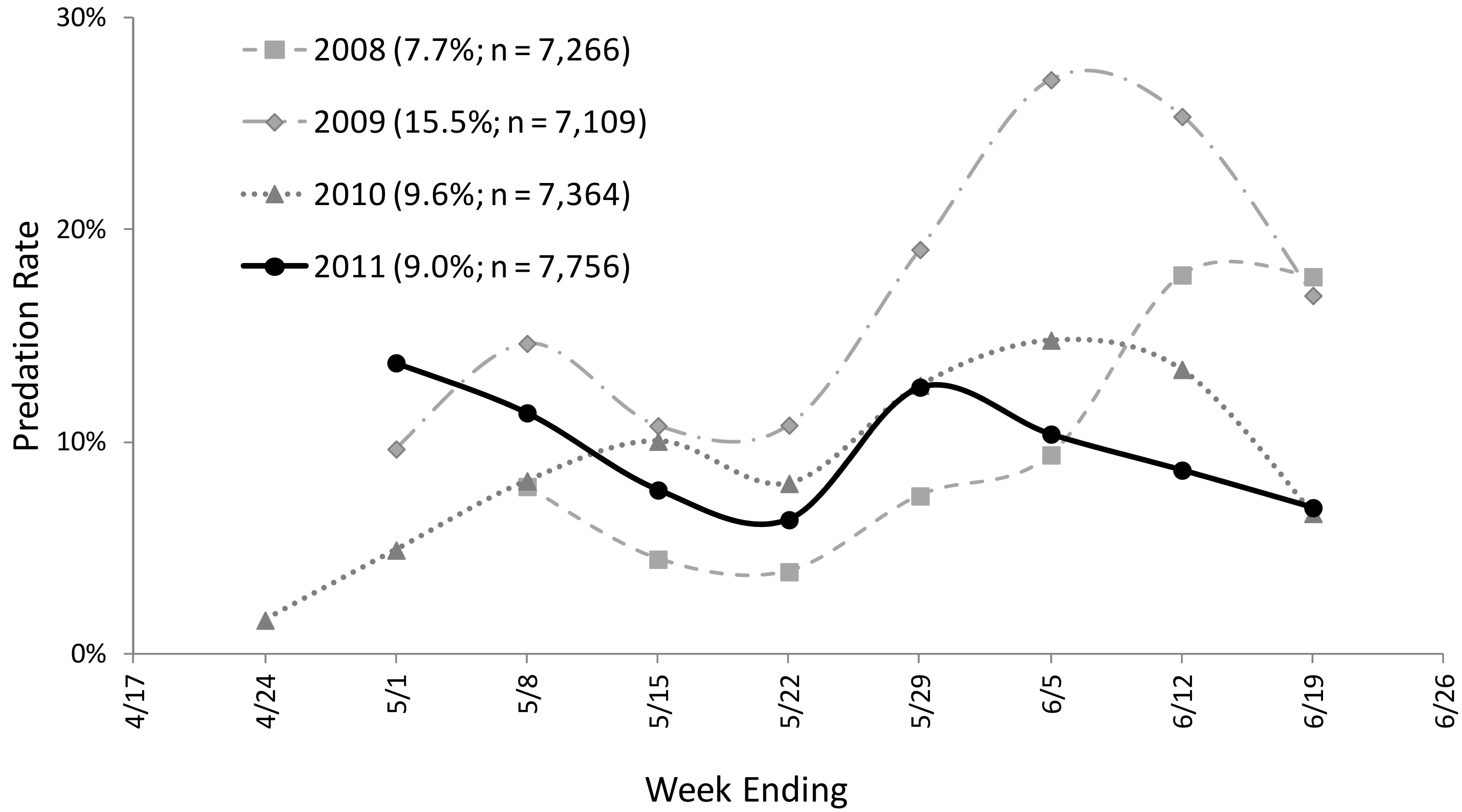


Figure 64. Minimum weekly predation rates of PIT-tagged upper Columbia River steelhead (released at Rock Island Dam on the upper Columbia River) by Goose Island Caspian terns. Estimates are separated by migration year, with annual predation rates and number of released steelhead in parentheses. Percentages were corrected for bias due to on-colony PIT tag detection efficiency (see Table 2), but not for deposition rates, and therefore are minimums. Only weeks when more than 100 PIT-tagged steelhead were released from Rock Island Dam are shown.

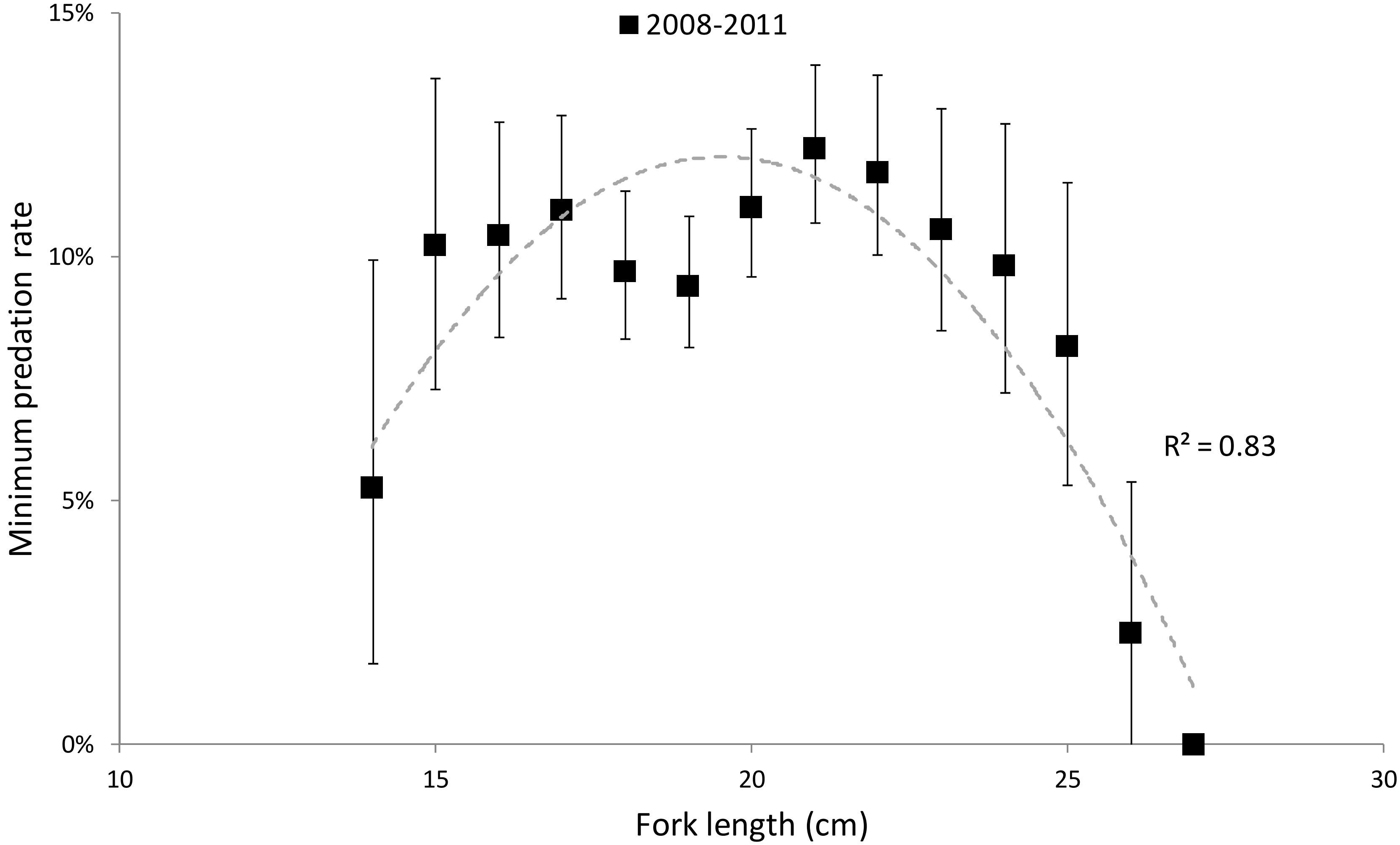


Figure 65. Minimum predation rates of PIT-tagged upper Columbia River steelhead (released at Rock Island Dam) by Goose Island Caspian terns during 2008-2011; minimum predation rates are separated by steelhead fork length. Only fork lengths with more than 100 PIT-tagged steelhead released from Rock Island Dam are shown. Error bars represent 95% confidence intervals.

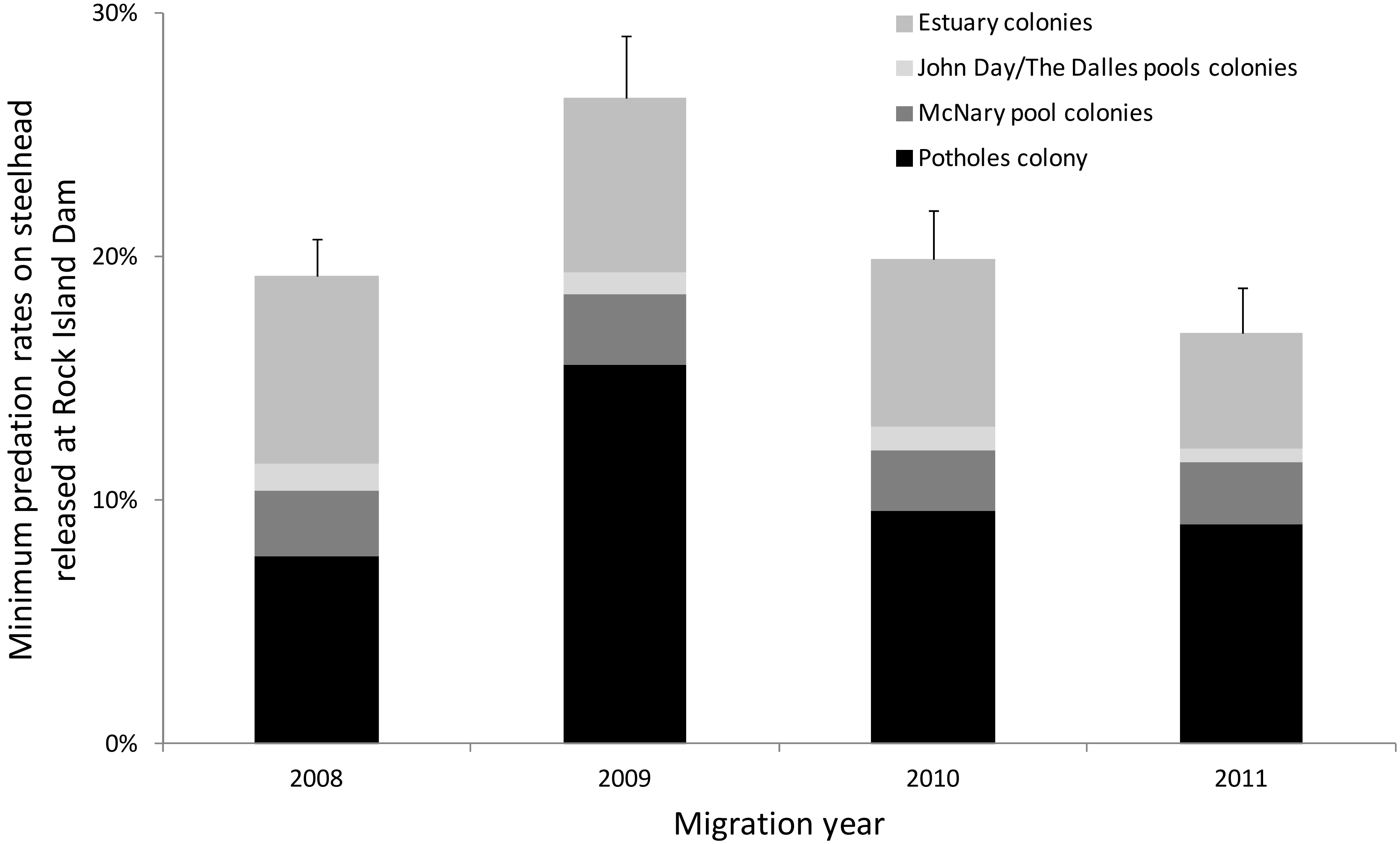


Figure 66. Minimum predation rates on steelhead PIT-tagged and released at Rock Island Dam by piscivorous waterbirds nesting at colonies in the Columbia River basin during 2008-2011. Minimum predation rates were corrected for bias due to on-colony PIT tag detection efficiency (see Table 2), but not for steelhead survival to the vicinity of the bird colony or off-colony deposition of PIT tags, and therefore are minimum estimates. Error bars represent the upper 95% confidence interval.

Table 1. Caspian tern nesting islands that were completed prior to the 2011 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 2011	Notes:
Fern Ridge Reservoir, OR	Fern Ridge	Feb 2008	Rock core	1.0	1.0	
Crump Lake, Warner Valley, OR	Crump Lake	Mar 2008	Rock core	1.0	1.0	
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	0.5	
Summer Lake Wildlife Area, OR	Gold Dike	Sep 2009	Rock core	0.5	0.0	No water
Tule Lake National Wildlife Refuge, CA	Sump 1B	Aug 2009	Rock core	2.0	2.0	
Lower Klamath National Wildlife Refuge, CA	Orems Unit	Sep 2009	Silt core	1.0	1.0	
Lower Klamath National Wildlife Refuge, CA	Sheepy Lake	Mar 2010	Floating island	0.8	0.8	
			TOTAL	**7.3**	**6.8**	

Table 2. Number of juvenile salmonid (Chinook, coho, sockeye, or steelhead) PIT tags recovered and on bird colonies in the Columbia River basin during the 2011 breeding season. The number of PIT tags deposited by birds on-colony was estimated based on a correction factor for average PIT tag detection efficiency (standard deviation). Piscivorous waterbird breeding colonies include American white pelicans (AWPE), Brandt's cormorants (BRAC), Caspian terns (CATE), double-crested cormorants (DCCO), California and ring-billed gulls (Gulls), or a mixture of different species (Mixed).

			Salmonid PIT Tags		
River Segment	Location	Colony	Recovered	Deposited	Detection Efficiency
Estuary	East Sand Island	CATE	19,401	25,098	77.3% (11.1)
		DCCO	22,863	31,843	71.8% (0.4)
		BRAC	442	660	67.0% (12.7)
	Miller Sands Spit	AWPE	15	19	80.0% (0.0)
The Dalles Pool	Miller Rocks	Gulls	1,759	2,227	79.0% (9.9)
John Day Pool	Blalock Islands	CATE	302	368	82.0% (2.8)
McNary Pool	Crescent Island	CATE	9,270	11,734	79.0% (19.1)
		Gulls	2,089	3,072	68.0% (25.5)
	Badger Island	AWPE	2,531	3,420	74.0% (NA)
		Mixed	654	884	74.0% (NA)
	Foundation Island	DCCO	4,481	8,376	53.5% (26.2)
Off-river	Potholes Reservoir	CATE	4,068	6,837	59.5% (33.8)

Table 3. Estimated minimum predation rates (95% confidence interval) of PIT-tagged salmonid smolts last detected at Bonneville Dam on the Columbia River or at Sullivan Dam on the Willamette River by avian predators nesting at colonies on East Sand Island (ESI) or Miller Sands Spit (MSS) in the Columbia River estuary. Colonies include Caspian terns (CATE), double-crested cormorants (DCCO), Brandt's cormorants (BRAC), and American white pelicans (AWPE). The number of PIT-tagged smolts interrogated at Bonneville Dam or Sullivan Dam (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.

			Predation Rates				
ESU[1]	ESA-status[2]	N	ESI CATE	ESI DCCO	ESI BRAC	MSS AWPE	All
SR Sockeye	E	826	0.2% (0-0.5)	2.2% (1.1-3.4)	<0.1%	<0.1%	2.4% (1.2-3.6)
SR Spring/Summer Chinook	T	6,558	1.7% (1.4-2.2)	2.1% (1.7-2.5)	<0.1%	<0.1%	3.9% (3.3-4.5)
UCR Spring Chinook	E	704	1.9% (0.9-3.1)	2.6% (1.4-4.0)	<0.1%	<0.1%	4.4% (2.8-6.3)
MCR Spring Chinook	NW	3,354	1.4% (0.9-1.9)	1.0% (0.6-1.5)	0.1% (0.0-0.3)	<0.1%	2.5% (1.9-3.2)
SR Fall Chinook	T	12,327	0.5% (0.4-0.6)	1.0% (0.7-1.2)	<0.1%	<0.1%	1.4% (1.2-1.7)
UCR Summer/Fall Chinook	NW	3,148	0.8% (0.5-1.2)	2.2% (1.6-2.8)	0.1% (0.0-0.2)	<0.1%	3.0% (2.3-3.8)
UWR Spring Chinook	T	1,119	0.6% (0.1-1.1)	0.1% (0.0-0.4)	<0.1%	<0.1%	0.7% (0.2-1.3)
SR Summer Steelhead	T	7,028	8.4% (7.5-9.4)	2.6% (2.2-3.1)	<0.1%	<0.1%	11.0% (10.0-12.2)
UCR Summer Steelhead	T	2,419	6.4% (5.3-7.7)	5.5% (4.4-6.6)	<0.1%	<0.1%	11.9% (10.3-13.6)
MCR Summer Steelhead	T	866	6.8% (4.9-8.9)	3.7% (2.3-5.2)	0.2% (0.0-0.7)	<0.1%	10.7% (8.3-13.3)

[1] MCR = Middle Columbia River, SR = Snake River, UCR = Upper Columbia River, WR = Willamette River
[2] E = Endangered, T = Threatened, NW = Not Warranted

Table 4. Estimated minimum predation rates (95% confidence interval) of 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 (CSI), Potholes Reservoir (PTI), Foundation Island (FDI), or Badger Island (BGI) near the confluence of the Snake and Columbia rivers. Colonies include Caspian terns (CATE), double-crested cormorants (DCCO), California and ring-billed gulls (GULL), American white pelicans (AWPE), or a mixture of different species (MIX). 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.

			Predation Rates						
ESU[1]	ESA-status[2]	N	CSI CATE	PTI CATE	FDI DCCO	CSI GULL	BGI AWPE	BGI MIX	All
SR Sockeye	E	15,787	0.5% (0.4-0.6)	<0.1%	0.6% (0.4-0.8)	0.2% (0.1-0.3)	0.3% (0.2-0.4)	0.1% (0.0-0.1)	1.7% (1.4-2.0)
SR Spr/Sum Chin	T	65,140	0.5% (0.4-0.6)	<0.1%	0.6% (0.5-0.8)	0.1% (0.1-0.2)	0.2% (0.2-0.3)	<0.1%	1.5% (1.3-1.7)
UCR Spring Chin	E	1,568	0.3% (0.0-0.6)	0.5% (0.0-1.3)	0.1% (0.0-0.5)	<0.1%	<0.1%	<0.1%	0.9% (0.3-1.7)
SR Fall Chinook	T	55,096	0.4% (0.3-0.4)	<0.1%	0.5% (0.4-0.6)	0.1% (0.1-0.1)	0.1% (0.1-0.2)	<0.1%	1.1% (1.0-1.2)
UCR Sum/Fall Chin	NW	3,058	0.1% (0.0-0.3)	0.1% (0.0-0.2)	0.1% (0.0-0.2)	<0.1%	<0.1%	<0.1%	0.3% (0.1-0.5)
SR Sum Steelhead	T	59,948	1.9% (1.7-2.1)	<0.1%	1.8% (1.5-2.3)	0.5% (0.4-0.6)	0.3% (0.3-0.4)	0.1% (0.1-0.1)	4.6% (4.2-5.2)
UCR Sum Steelhead	T	8,002	1.7% (1.4-2.0)	8.9% (7.6-10.5)	0.1% (0.0-0.2)	0.5% (0.3-0.8)	0.1% (0.0-0.1)	0.1% (0.0-0.2)	11.4% (10.1-13.1)

[1] SR = Snake River, UCR = Upper Columbia River
[2] E = Endangered, T = Threatened, NW = Not Warranted

Table 5. Estimated minimum predation rates (95% confidence interval) of PIT-tagged salmonid smolts last detected at McNary Dam on the Columbia River by avian predators nesting at colonies on the Blalock Islands (BLI) or Miller Rocks (MRK) on the middle Columbia River. Colonies include Caspian terns (CATE) and California and ring-billed gulls (GULL). 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) are provided. Only ESUs with > 500 PIT-tagged smolts interrogated passing McNary Dam were evaluated.

			Predation Rates		
ESU[1]	ESA-status[2]	N	BLI CATE	MRK GULL	All
SR Sockeye	E	2,769	0.2% (0.0-0.4)	0.3% (0.1-0.5)	0.5% (0.2-0.8)
SR Spring/Summer Chinook	T	38,629	<0.1%	0.1% (0.1-0.2)	0.2% (0.1-0.2)
UCR Spring Chinook	E	3,981	<0.1%	0.1% (0.0-0.3)	0.1% (0.0-0.3)
SR Fall Chinook	T	41,007	0.1% (0.1-0.1)	0.1% (0.1-0.1)	0.2% (0.1-0.2)
UCR Summer/Fall Chinook	NW	13,032	<0.1%	0.1% (0.1-0.2)	0.2% (0.1-0.2)
SR Summer Steelhead	T	16,759	0.1% (0.0-0.1)	0.8% (0.6-0.9)	0.8% (0.7-1.0)
UCR Summer Steelhead	T	5,155	<0.1%	0.5% (0.3-0.8)	0.6% (0.3-0.8)

[1] SR = Snake River, UCR = Upper Columbia River
[2] E = Endangered, T = Threatened, NW = Not Warranted

Table 6. Minimum predation rates of steelhead PIT-tagged and released at Rock Island Dam (n = 7,756) by piscivorous waterbirds nesting at colonies in the Columbia River basin during 2011. Minimum predation rates are listed separately for wild and hatchery-reared steelhead. Minimum predation rates were corrected for bias due to on-colony PIT tag detection efficiency (see Table 2), but not for steelhead survival to the vicinity of the bird colony or for off-colony deposition of PIT tags; therefore these estimates are minimum predation rates.

Location	Island	Bird Species	Hatchery	Wild	All
Potholes Reservoir	Goose Island	Caspian terns	9.5% (8.1-11.3)	7.3% (5.4-9.6)	9.0% (7.7-10.7)
McNary Pool	Crescent Island	Caspian terns	1.8% (1.4-2.1)	1.6% (1.0-2.3)	1.7% (1.4-2.1)
		California gulls	0.6% (0.4-0.9)	0.3% (0.1-0.7)	0.5% (0.3-0.8)
	Foundation Island	Double-crested cormorants	0.1% (0.0-0.3)	<0.1%	0.1% (0.0-0.2)
	Badger Island	American white pelicans	0.1% (0.0-0.2)	<0.1%	0.1% (0.0-0.1)
		Mixed	0.1% (0.0-0.2)	0.2% (0.0-0.4)	0.1% (0.0-0.2)
John Day Pool	Blalock Island	Caspian terns	<0.1%	0.1% (0.0-0.2)	<0.1%
The Dalles Pool	Miller Rocks	California/ring-billed gulls	0.6% (0.4-0.8)	0.2% (0.0-0.5)	0.5% (0.3-0.7)
Estuary	East Sand Island	Caspian terns	2.9% (2.5-3.5)	2.3% (1.5-3.1)	2.8% (2.4-3.2)
		Double-crested cormorants	1.8% (1.4-2.2)	2.5% (1.6-3.4)	1.9% (1.5-2.3)
		Brandt's cormorants	0.1% (0.0-0.1)	0.2% (0.0-0.5)	0.1% (0.0-0.2)
	Miller Sands	American white pelicans	<0.1%	<0.1%	<0.1%
ALL			17.6% (15.9-19.6)	14.6% (12.1-17.3)	16.9% (15.4-18.7)

Table 7. PIT tag recoveries on piscivorous waterbird (mixed species) loafing locations in the McNary Pool in 2011.

Location	River Kilometer	Active Colony on Island	Bird species	Recovered PIT Tags
Crescent Island - lagoon	510	Yes	Mixed	195
Crescent Island - rip rap	510	Yes	Mixed	73
Foundation Island - upstream tip	518	Yes	Mixed	51
Badger Island - upstream tip	511	Yes	Mixed	37
Foundation Island - downstream tip	518	Yes	Mixed	21
Wade Island (near blue bridge in Kennewick)	525	No	Mixed	11
West Side Island (across channel from Foundation Is.)	517	No	Mixed	5
Island 20 (Richland)	547	No	Mixed	5
Badger Island - downstream tip	511	Yes	Mixed	4
Strawberry Island (Snake River, near confluence)	528	No	Mixed	3
Goose Island (Snake River near Ice Harbor Dam)	536	No	Mixed	3
Total Recovered on loafing areas				408
Total Recovered on loafing areas with no active colony				27

Table 8. PIT tag recoveries on piscivorous waterbird loafing locations on the Columbia Plateau during 2007-2011. Piscivorous waterbird species observed loafing at each location are listed (Mixed = multiple bird species, DCCO = double-crested cormorants).

	River Kilometer	Bird Species	Year	Recovered PIT Tags
Swallows Park (Idaho)	752	DCCO	2009	555
Crescent Island – lagoon	510	Mixed	2008	526
Crescent Island – lagoon	510	Mixed	2009	259
Crescent Island – lagoon	510	Mixed	2010	231
Crescent Island – lagoon	510	Mixed	2011	195
Crescent Island – rip rap	510	Mixed	2011	73
Crescent Island – lagoon	510	Mixed	2007	72
Goose Island (Potholes Reservoir) - beach	Off-river	Mixed	2011	57
Goose Island (Priest Rapids Dam forebay)	641	Mixed	2008	55
Foundation Island – upstream tip	518	Mixed	2011	51
Badger Island - upstream tip	511	Mixed	2011	37
Foundation Island – downstream tip	518	Mixed	2011	21
Foundation Island – downstream tip	518	Mixed	2007	19
Wade Island (near blue bridge in Kennewick)	525	Mixed	2011	11
Ice Harbor Dam – island in tailrace	538	Mixed	2007	6
Island 20 (Richland)	547	Mixed	2011	5
West Side Island (across channel from Foundation Is.)	517	Mixed	2011	5
Badger Island - downstream tip	511	Mixed	2011	4
Goose Island (below Ice Harbor Dam)	536	Mixed	2011	3
Rocky Island (below Lower Monumental Dam)	587	Mixed	2008	3
Strawberry Island (below Ice Harbor Dam)	528	Mixed	2011	3
Beverly Islands (5 islands below Wanapum Dam)	665	Mixed	2008	2
Channel Marker below Lower Monumental Dam	364	DCCO	2008	0
Middle Hog Island (Idaho)	761	Mixed	2009	0
Mattawa Islands (below Wanapum Dam)	658	Mixed	2008	0
Island near confluence of Crab Creek and Columbia River	660	Mixed	2008	0