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

## 2008 Final Season Summary

This 2008 Final Season Summary has been prepared for the Bonneville Power Administration and the U.S. Army Corps of Engineers for the purpose of assessing project accomplishments. This report is not for citation without permission of the authors.


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## EXECUTIVE SUMMARY

This report describes investigations into predation by piscivorous colonial waterbirds on juvenile salmonids (*Oncorhynchus* spp.) from throughout the Columbia River basin during 2008. East Sand Island in the Columbia River estuary again supported the largest known breeding colony of Caspian terns (*Hydroprogne caspia*) in the world (approximately 10,700 breeding pairs) and the largest breeding colony of double-crested cormorants (*Phalacrocorax auritus*) in western North America (approximately 10,950 breeding pairs). The Caspian tern colony increased from 2007, but not significantly so, while the double-crested cormorant colony experienced a significant decline (20%) from 2007. Average cormorant nesting success in 2008, however, was down only slightly from 2007, suggesting that food supply during the 2008 nesting season was not the principal cause of the decline in cormorant colony size.

Total consumption of juvenile salmonids by East Sand Island Caspian terns in 2008 was approximately 6.7 million smolts (95% c.i. = 5.8 – 7.5 million). Caspian terns nesting on East Sand Island continued to rely primarily on marine forage fishes as a food supply. Based on smolt PIT tag recoveries on the East Sand Island Caspian tern colony, predation rates were highest on steelhead in 2008; minimum predation rates on steelhead smolts detected passing Bonneville Dam averaged 8.3% for wild smolts and 10.7% for hatchery-raised smolts. In 2007, total smolt consumption by East Sand Island double-crested cormorants was about 9.2 million juvenile salmonids (95% c.i. = 4.4 – 14.0 million), similar to or greater than that of East Sand Island Caspian terns during that year (5.5 million juvenile salmonids; 95% c.i. = 4.8 – 6.2 million). The numbers of smolt PIT tags recovered on the cormorant colony in 2008 were roughly proportional to the relative availability of PIT-tagged salmonids released in the Basin, suggesting that cormorant predation on salmonid smolts in the estuary was less selective than tern predation. Cormorant predation rates in excess of 30%, however, were observed for some groups of hatchery-reared fall Chinook salmon released downstream of Bonneville Dam.

Implementation of the federal plan "Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary" was initiated in 2008 with construction by the Corps of Engineers of two alternative colony sites for Caspian terns in interior Oregon: a 1-acre island on Crump Lake in the Warner Valley and a 1-acre island on Fern Ridge Reservoir near Eugene. We deployed Caspian tern social attraction (decoys and sound systems) on these two islands and monitored for Caspian tern nesting. Caspian terns quickly colonized the Crump Lake tern island; about 430 pairs nested there, including 5 terns that had been banded at the East Sand Island colony in the Columbia River estuary, over 500 km to the northwest. No Caspian terns nested at the Fern Ridge tern island in 2008, but up to 9 Caspian terns were recorded roosting on the island after the nesting season.

There were two breeding colonies of Caspian terns on the mid-Columbia River in 2008: (1) about 388 pairs nested at the historical colony on Crescent Island in the McNary Pool and (2) about 100 pairs nested at a relatively new colony site on Rock Island in the John Day Pool. Nesting success at the Crescent Island tern colony was only 0.28 young fledged per breeding pair, the lowest nesting success recorded at that colony since monitoring began in 2000, while only three fledglings were raised at the Rock Island tern colony. The diet of Crescent Island Caspian terns consisted of 68% salmonid smolts; total smolt consumption was estimated at 330,000. Since 2004, total smolt consumption by Crescent Island terns has declined by 34%, due

mostly to a decline in colony size, while steelhead consumption has increased 10% during this same period. In 2008, approximately 64,000 steelhead smolts were consumed by Caspian terns nesting at Crescent Island. Based on smolt PIT tag recoveries on the Crescent Island Caspian tern colony, the average predation rate on in-river migrants from the Snake River (all species and run types combined based on interrogations at Lower Monumental Dam) was at least 1.4%. Predation rates on PIT-tagged steelhead smolts were greater than those for other salmonid species; 6.0% of wild steelhead smolts from the Snake River were consumed by Crescent Island terns.

The double-crested cormorant colony on Foundation Island in the mid-Columbia River consisted of at least 360 pairs nesting in trees in 2008. The proportion of juvenile salmonids in stomach samples collected from cormorants nesting on Foundation Island during the peak of the smolt out-migration was about 45% of prey biomass. The average predation rate on in-river migrants from the Snake River (all species and run types combined based on interrogations at Lower Monumental Dam) by Foundation Island cormorants was at least 1.3%, similar to that for Crescent Island Caspian terns. Steelhead smolts from the Snake River were particular vulnerability to predation by Foundation Island cormorants.

Some double-crested cormorants over-winter on the Columbia Plateau along the Snake River. Boat surveys conducted from October 2008 to February 2009 indicated that an average of 281 cormorants were present on the lower Snake River over-winter, with the highest concentration of cormorants observed between Little Goose and Lower Granite dams during the months of October and November. Stomach contents indicated that juvenile salmonids comprised about 12.5% by mass of the diet of these double-crested cormorants. Genetic analyses of salmonid tissues removed from cormorant stomachs are in progress.

Other piscivorous colonial waterbirds that nest along the mid-Columbia River (i.e., California gulls, ring-billed gulls, American white pelicans) are having much less impact on the survival of juvenile salmonids from the Columbia and Snake rivers, compared to Caspian terns and double-crested cormorants. One gull colony that may be having an appreciable impact on salmonid smolt survival, however, is the large California and ring-billed gull colony (~ 4,500 nesting pairs) on Miller Rocks in The Dalles Pool, where an estimated 4,211 smolt PIT tags were deposited during the 2008 nesting season or 0.9 smolt PIT tags consumed per nesting adult. This colony's large size and proximity to John Day and The Dalles dams is of concern to some fisheries managers, especially given that the number of PIT tags recovered on Miller Rocks has increased in recent years.

At the American white pelican colony on Badger Island in the mid-Columbia River, an estimated 2,101 smolt PIT tags were deposited in 2008; this represents about 1.6 PIT-tagged smolts consumed per nesting adult at this growing colony. Although the number of smolt PIT tags recovered on Badger Island has increased in recent years (coincident with an increase in colony size), total numbers of recovered smolt PIT tags are still relatively low compared to the nearby Crescent Island Caspian tern colony and Foundation Island double-crested cormorant colony; per capita PIT tag consumption was 13.6 and 14.7 PIT tags per nesting adult on the tern and cormorant colonies, respectively.

In 2008 we investigated how smolt morphology, condition, and origin are related to differences in smolt vulnerability to avian predation. We condition scored and PIT-tagged 9,180 steelhead smolts on the lower Snake River and 7,271 steelhead smolts on the mid-Columbia River during the 2008 out-migration. Preliminary results indicate that 23% of the PIT-tagged steelhead that were released into the lower Snake River and 18% of the PIT-tagged steelhead that were released into the mid-Columbia River and survived to the Columbia River estuary were consumed by colonial waterbirds nesting in the estuary; the comparable percentages for lower Snake River steelhead smolts found on waterbird colonies in the McNary Pool and the John Day/The Dalles pools were 8.5% and 2.3%, respectively, and for mid-Columbia River steelhead smolts were 3.5% and 1.9%, respectively. Predation by Caspian terns nesting at an off-river colony in Potholes Reservoir, WA was an estimated 7.6% of steelhead smolts released into the mid-Columbia River. Smolt condition-scoring results demonstrated that smolts with severe external damage were, on average, 1.6 times more likely to be consumed by avian predators in McNary Pool compared to undamaged smolts.

A Columbia Basin-wide assessment of avian predation on juvenile salmonids indicates that the most significant impacts to smolt survival occur in the Columbia River estuary, with the combined consumption of juvenile salmonids by Caspian terns and double-crested cormorants nesting on East Sand Island estimated at between 7 and 16 million smolts annually. This represents approximately 10% of all the salmonid smolts that survive to the estuary in an average year. 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 on the mid-Columbia River. Additionally, when compared to the impact of avian predation on the Columbia Plateau, avian predation in the Columbia River estuary affects juvenile salmonids belonging to every ESA-listed stock of salmonid 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 populations from throughout the Columbia River basin, when compared to potential benefits of management of other populations of piscivorous waterbirds. The Caspian tern colonies on Crescent and Goose (Potholes Reservoir) islands and the double-crested cormorant colony on Foundation Island may be exceptions to this rule; management of these relatively small colonies on or near the mid-Columbia River may benefit certain salmonid populations, in particular steelhead.

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. Resource management agencies have not yet decided whether management of this large cormorant colony is warranted. Because the cormorant colony on East Sand Island constitutes nearly 50% of the entire Pacific Coast breeding population of double-crested cormorants, non-lethal management approaches, such as relocating a portion of the colony to alternative colony sites along the coast of Oregon and Washington, seem more appropriate than lethal control. 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 likely require an 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 salmonid recovery rates in the Columbia River basin should management of cormorants be implemented in the estuary. In 2008, work was initiated on an updated status assessment for the Pacific Coast population of double-crested cormorants.

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# SECTION 1: CASPIAN TERNS

## 1.1. Preparation and Modification of Nesting Habitat in the Columbia River Estuary

In 2008, the U.S. Army Corps of Engineers (USACE) began implementing the Caspian tern management actions outlined 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, seeks to redistribute a portion of the Caspian tern colony on East Sand Island in the Columbia River estuary (see Map 1) to alternative colony sites in interior Oregon and the San Francisco Bay area by 2015. Three northern California sites were added to the plan in 2008: Tule Lake NWR (1 island) and Lower Klamath NWR (2 islands). 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. 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).

As part of this plan, the USACE restored 5 acres of nesting habitat for Caspian terns at East Sand Island in late March 2008. Without annual restoration of the bare sand nesting habitat that Caspian terns prefer, the East Sand Island colony would be eliminated within a year or two by rapidly encroaching pioneer vegetation. Five acres of Caspian tern nesting habitat on East Sand Island was the amount of habitat stipulated in the Final Environmental Impact Statement (USFWS 2005: Chapt. 2, section 2.3.3).

On 8 April, a camp was set up on East Sand Island and was continuously occupied by two colony monitors throughout the tern nesting season. Although limited control of glaucous-winged/western gulls (*Larus glaucescens/occidentalis*) was performed during the 1999 and 2000 nesting seasons to enhance prospects for tern colony restoration on East Sand Island, no gull control has been conducted since 2000.

In previous years, work crews from NOAA Fisheries, Oregon Department of Fish and Wildlife, and USACE modified habitat to discourage nesting by Caspian terns on the former tern colony site on Rice Island and other dredge disposal sites in the upper estuary (i.e., Miller Sands Spit and Pillar Rock Sands; see Map 1) prior to the breeding season. Efforts to discourage tern nesting on Rice Island have not been necessary since 2002 because the former colony site on Rice Island (ca. 7 acres) has become completely vegetated and consequently is unsuitable for tern nesting. Prior to 2007, Caspian terns have attempted to nest on Miller Sands Spit or Pillar Rock Sands in every year since the tern colony was completely relocated from Rice Island to East Sand Island in 2001. This required the USACE to use passive and active measures to discourage tern nesting at those sites during those years. Caspian terns did not attempt to nest on either of these dredge spoil islands in 2007 or 2008, so no measures were taken during those breeding seasons to dissuade Caspian terns from nesting on dredge disposal islands in the Columbia River estuary.

## 1.2. Nesting Chronology, Colony Size, and Productivity of Caspian Terns

### 1.2.1. Columbia River Estuary

*Methods*: The number of Caspian terns breeding on East Sand Island in the Columbia River estuary in 2008 was estimated using low-altitude, high-resolution aerial photographs 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 photographs, 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 of the multiple counts from the aerial photographs and the variance in the ratios of incubating to non-incubating adults on the plots.

Nesting success (average number of young raised per breeding pair) at the East Sand Island tern colony was estimated using aerial photographs taken of the colony just prior to the fledging period. The average of 3 direct counts of all terns (adults and juveniles) on the colony in aerial photographs, corrected using ground counts of the ratio of fledglings to adults on 12 different plots within the colony area, was used to estimate the number of fledglings on the colony at the time of the photography. The total number of fledglings on-colony was then divided by the number of breeding pairs estimated from the late incubation photo census. Confidence intervals for nesting success were calculated using a Monte Carlo simulation procedure to incorporate the variance of the multiple counts from the aerial photographs and the variance of the fledgling to adult ratios on the plots.

In 2008, periodic boat-based and aerial surveys of the dredged material disposal islands in the upper estuary (i.e., Rice Island, Miller Sands Spit, Pillar Rock Sands; Map 1) were conducted in order to detect early signs of nesting by Caspian terns, should any nesting attempts occur.

*Results and Discussion*: Nesting chronology at the East Sand Island Caspian tern colony in 2008 was somewhat delayed compared to previous years; the dates when the first tern eggs hatched and first tern chick fledged in 2008 were the latest we have recorded at the East Sand Island tern colony (Figure 1). As was the case during 2001–2007, all nesting by Caspian terns in the Columbia River estuary occurred on East Sand Island in 2008. The colony attendance data suggest that the tern colony was smaller in 2008 compared to previous years (Figure 2), but this was not the case. Instead, extensive vegetation growth on the colony in 2008, greater than in previous years, concealed more adult terns from view and resulted in lower weekly estimates of colony attendance compared to previous years.

Based on the aerial photo census, we estimate that 10,668 breeding pairs of Caspian terns (95% c.i. = 9,923–11,413 breeding pairs) attempted to nest at East Sand Island in 2008. This estimate is higher than our best estimate of colony size at East Sand Island in 2007 (9,623 breeding pairs, 95% c.i. = 8,880–10,366 breeding pairs), but not significantly so. During 2000-2007 the size of the East Sand Island Caspian tern colony was relatively stable, averaging about 9,200 breeding pairs (Figure 3). In 2008 the best estimate eclipsed 10,000 breeding pairs for the first time (Figure 3), suggesting a possible trend toward increasing colony size. The East Sand Island tern colony is the largest known breeding colony of Caspian terns in the world.

We estimate that 6,081 fledglings (95% c.i. = 3,143–10,668 fledglings) were produced at the East Sand Island tern colony in 2008. This corresponds to an average nesting success of 0.57 young raised per breeding pair (95% c.i. = 0.31–0.83 fledglings/breeding pair), which is not significantly different from the estimate of nesting success for the East Sand Island tern colony in 2007 (0.66 fledglings/breeding pair, 95% c.i. = 0.56–0.76 fledglings/breeding pair; Figure 4). Nesting success at the East Sand Island Caspian tern colony peaked in 2001 and has trended downward since then (Figure 4). Two factors likely have contributed to declining productivity of the East Sand Island tern colony: ocean conditions and nest predation. The peak productivity year of 2001 followed a transition to favorable (colder) ocean conditions in 1999. In 2004, however, ocean conditions were less favorable (warmer) and marine forage fishes (for example, anchovy, herring) declined; these prey types are especially prevalent in tern diets during the chick-rearing period. A similar transition to colder ocean conditions occurred in 2007/2008, so tern nesting success may improve in coming years. But predation on tern eggs and chicks by glaucous-winged/western gulls has also gradually increased over the years. This is partly because no gull control has taken place on the Caspian tern colony at East Sand Island since 2000 and partly because nest predation by gulls tends to increase when alternative prey are scarcer, such as during warmer, less favorable ocean conditions.

As was the case in 2007, no aggregations of Caspian terns were observed on upland areas of dredged material disposal sites in the upper estuary (i.e., Rice Island, Miller Sands Spit, Pillar Rock Sands, Puget Island) during 2008.

### 1.2.2. Columbia Plateau

*Methods*: The number of breeding pairs of Caspian terns at Crescent Island (Maps 2 and 3) was estimated by averaging 6 independent ground counts of all incubating terns on the colony near the end of the incubation period. These counts were made from an observation blind situated on the outskirts of the tern colony. Nesting success was estimated from ground counts of all fledglings on the colony just prior to fledging.

Periodic boat-based and aerial surveys of former Caspian tern breeding colony sites (i.e., Three Mile Canyon Island, Rock Island, Miller Rocks, Cabin Island, Sprague Lake, Banks Lake, and Potholes Reservoir) were conducted during the 2008 nesting season to determine whether these colony sites had been re-occupied (Map 2). We also flew aerial surveys of the lower and middle Columbia River from The Dalles 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.

*Results and Discussion*: Colony attendance at the Crescent Island Caspian tern colony in 2008 was on a par with the average for past years until the end of April, when colony attendance dipped well below average and remained there for the remainder of the nesting season (Figure 5). This was associated with below average colony size (Figure 6) and nesting success (Figure 7) at the Crescent Island tern colony in 2008. About 388 breeding pairs of Caspian terns attempted to nest at the Crescent Island colony in 2008. Colony size at the Caspian tern colony on Crescent Island has trended downward since 2001 (Figure 6); by comparison, the number of terns nesting on East Sand Island in the Columbia River estuary has remained relatively stable over this same period (Figure 3). Despite this general trend, colony size at Crescent Island increased slightly in 2008 relative to 2007, when colony size was the lowest since 2000 (Figure 6). We estimated that 110 young terns fledged from the Crescent Island colony in 2008, or 0.28 young raised per breeding pair. Nesting success at the Crescent Island Caspian tern colony in 2008 was the lowest ever recorded, declining by nearly 60% relative to the previous year (Figure 7). The cause for low nesting success in 2008 is unknown, but is likely related to low food availability. Weather (specifically high winds and unseasonably low daytime temperatures) and above average nest predation by California gulls could also have contributed to low nesting success in 2008. Nesting chronology at the Crescent Island Caspian tern colony in 2008 was within the range of dates observed in previous years (Figure 8).

The Rock Island Caspian tern colony (located on the mid-Columbia River in the John Day Pool) consisted of about 100 breeding pairs in 2008, up from about 40 pairs in 2007. The Rock Island tern colony nearly failed in 2008, as only 3 young were fledged. Very low nesting success in 2008 was apparently due to unusually high water levels in John Day pool during the incubation period. This is the third consecutive year that the Rock Island Caspian tern colony has failed or nearly failed; in 2006 due to mink predation, and in 2007 due to avian predation. Tern nesting was first detected on Rock Island in 2005, when about 6 pairs of Caspian terns attempted to nest there.

Other than Crescent Island and Rock Island, we found no evidence of Caspian terns attempting to nest at other colony sites along the lower and mid-Columbia River or the lower Snake River in 2008. American mink disrupted tern nesting at Three Mile Canyon Island (Map 2) in 2000 and 2001, causing the colony to fail in both years. In 2001, Caspian terns were found nesting on Miller Rocks on the lower Columbia River just upstream of the mouth of the Deschutes River (Map 2); up to 20 breeding pairs attempted to nest on the edge of a large gull colony. We suspect that terns nesting on Miller Rocks in 2001 were failed breeders from the Three Mile Canyon Island colony. Cabin Island above Priest Rapids Dam (Map 2), where nesting Caspian terns have been previously recorded, was the site of a large ring-billed gull colony until the late 1990s, when USDA-Wildlife Services dispersed the colony by oiling eggs and disturbing nesting birds.

Caspian terns nested at three sites located on the Columbia Plateau off the Columbia and Snake rivers in 2008 (Table 1). The largest of these off-river colonies was on Goose Island in Potholes Reservoir (Map 2). We estimated that ca. 290 breeding pairs nested on Goose Island in 2008, roughly the same as our estimate in 2007 (282 nesting pairs). Nesting success on Goose Island in 2008 is unknown, but at least some of the nesting terns were successful in rearing young. Goose Island was first used by nesting Caspian terns in 2003; previously Caspian terns nested on another island in Potholes Reservoir (Solstice Island), where tern nesting was first confirmed in 2000.

During surveys of Banks Lake, as many as 27 adult Caspian terns were counted on Dry Falls Island (just above Dry Falls Dam near Coulee City; Map 2). Caspian terns were successful in raising an average of 0.33 young per breeding pair at this colony in 2008. Eleven Caspian terns attempted to nest on Harper Island in Sprague Lake (approximately 50 miles east of Moses Lake on I-90; Map 2) in 2008, but no young were fledged from that colony site. Tern nesting on Banks and Sprague lakes has been sporadic since nesting at both sites was first confirmed in 1997, with colony sizes ranging between 7-50 breeding pairs at each site.

The total number of Caspian terns nesting throughout the Columbia Plateau Region in 2008 was approximately 820 breeding pairs (Table 1). This suggests that the number of Caspian terns nesting throughout the Columbia Plateau has declined since 2000, when the number of breeding Caspian terns was estimated at over 1,000 breeding pairs (Figure 9).

### 1.2.3. Coastal Washington

*Methods*: Aerial surveys along the southern Washington Coast, including former Caspian tern colony sites in Willapa Bay and Grays Harbor (Map 1), were conducted on a periodic basis throughout the breeding season in order to detect formation of any new Caspian tern colonies outside the Columbia River estuary.

The number of Caspian terns breeding on Dungeness Spit (in Dungeness National Wildlife Refuge near the city of Sequim, WA; see Map 2) was estimated using aerial photographs of the colony taken early in the chick-rearing period. The count of adult terns in aerial photos of Dungeness Spit was corrected to estimate the number of breeding pairs on the colony using ground counts of the ratio of brooding to non-brooding terns on a portion of the colony area. The number of young produced at the Dungeness Spit Caspian tern colony was estimated using ground counts of black-capped chicks late in the chick-rearing period.

In 2008, USDA-Wildlife Services, under contract from the U.S. Navy, prevented any nesting by Caspian terns at the rooftop colony site at Naval Base Kitsap, Bremerton, where an estimated 117 pairs nested in 2007.

*Results and Discussion*: Although Caspian terns were commonly observed foraging and roosting in Willapa Bay and Grays Harbor throughout the 2008 breeding season, no nesting attempts by terns were detected in either area. This suggests that suitable tern nesting sites (i.e., island sites that are unvegetated, above high high tide levels, not currently occupied by other colonial nesting birds, and free of mammalian predators) are not available in either Willapa Bay or Grays Harbor.

The Caspian tern colony on Dungeness Spit in Dungeness NWR during 2008 was located close to the colony site used during 2003-2007. Our best estimate of the peak size of the Caspian tern colony at Dungeness Spit in 2008 was 883 breeding pairs, about 23% fewer compared to 2007. While this colony had experienced steady growth since 2003 (Roby et al. 2004, 2005, 2006, 2007), 2008 marks the first reduction in the number of breeding pairs in recent years. Nonetheless, Dungeness remains the second largest Caspian tern colony along the Pacific Coast of North America (after the colony on East Sand Island). Based on resightings of banded Caspian terns in earlier years, at least some of the past growth was from immigration of birds banded at colonies in the Columbia Basin (i.e., East Sand and Crescent islands) and Commencement Bay (Roby et al. 2004, 2005, 2006). A maximum of 154 chicks, about 70 of them older back-capped chicks, were counted on the Dungeness colony in 2008. This compares to a maximum of 317 black-capped chicks counted on the Dungeness Spit tern colony in 2007. Thus, in addition to a reduction in the size of the breeding colony since 2007, reproductive success appears to have declined as well.

Dungeness Spit was one of the alternative Caspian tern colony sites outside the Columbia River basin where managers sought to actively relocate terns from the East Sand Island colony as part the Draft EIS for Caspian tern management in the Columbia River estuary (see below). The site was dropped from the Final EIS and RODs, however, because of concerns about the potential for increased tern predation on ESA-listed Puget Sound Chinook salmon and Hood Canal chum salmon (USFWS 2005, 2006). Although no attempts will be made to improve tern nesting habitat or actively attract terns to the existing Dungeness Spit colony, it is likely that at least some of the displaced terns from East Sand Island will relocate there on their own. Alternatively, because the Dungeness Spit tern colony is located on a spit and not an island, it may continue to experience poor nesting success and disappear before the size of the East Sand Island colony is reduced and terns forced to nest elsewhere. Continued monitoring of the existing colony at Dungeness Spit is necessary to determine whether the colony survives and, if so, whether tern immigration from East Sand Island causes the colony to increase dramatically.

### 1.3. Diet Composition and Salmonid Consumption of Caspian Terns

#### 1.3.1. Columbia River Estuary

*Methods*: Caspian terns transport single whole fish in their bills to their mates (courtship meals) and 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. Fish watches 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 percent of the 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 for the 2-week periods.

To assess the relative proportion of the various salmonid species in tern diets, we collected bill load fish near the East Sand Island tern colony by shooting Caspian terns returning to the colony with whole fish carried in their bills (referred to hereafter as "collected bill loads"). 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 or 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, on average 29% were juvenile salmonids (n = 4,696 bill loads). The proportion of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island, averaged over the entire nesting season, has remained relatively stable at about 30% over the last three years (Figure 10). The proportion of salmonids in the diet of East Sand Island terns was highest in 2000 (ca. 47%) and lowest in 2004 (ca. 17%; Figure 10). As in previous years, marine forage fishes (i.e., anchovies [Engraulidae], herring [Clupeidae], shiner perch [Embiotocidae], and smelt [Osmeridae]) were prevalent, together averaging 60% of all identified bill loads in the diets of terns nesting on East Sand Island in 2008 (Figure 11). The peak in the proportion of salmonids in the diet of Caspian terns nesting on East Sand Island came later in 2008 (during mid- to late May) compared to previous years and remained higher than average during the latter half of July (Figure 12), when primarily fall Chinook were consumed. This result likely reflects the delay in run timing for smolts in 2008 relative to previous years.

Our best estimate of total smolt consumption by Caspian terns nesting on East Sand Island in 2008 was 6.7 million smolts (95% c.i. = 5.8 – 7.5 million), higher than in any previous year when all Caspian terns in the estuary nested on East Sand Island (Figure 13). Since 2000, the average number of smolts consumed by terns nesting on East Sand Island was 5.2 million smolts per year (Figure 13). 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 estuary.

Of the juvenile salmonids consumed in 2008, we estimate that 42% were coho salmon (best estimate = 2.8 million; 95% c.i. = 2.4 – 3.2 million), 21% were yearling Chinook salmon (best estimate = 1.4 million; 95% c.i. = 1.2 – 1.6 million), 18% were steelhead (best estimate = 1.2 million; 95% c.i. = 1.0 – 1.4 million), 18% were sub-yearling Chinook salmon (best estimate = 1.2 million; 95% c.i. = 1.0 – 1.4 million), and < 1% were sockeye salmon (best estimate = 0.04 million; 95% c.i. = 0.03 – 0.05 million; Figure 14). Most salmonids were consumed during the period from mid-April through mid-June, with the peak in smolt consumption occurring in mid-May (Figure 15). This period of high smolt consumption generally corresponds to the peak of the steelhead and yearling Chinook out-migration through the estuary.

1.3.2. Columbia Plateau

*Methods*: The taxonomic composition of the diet of Caspian terns nesting on Crescent Island 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 was 150 bill load identifications per week (see above for further details on the analysis of diet composition data). Prey items were identified to the taxonomic level of family. We identified prey to species, where possible, and salmonids were identified as 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 anal and caudal fins, body shape and size, coloration and speckling patterns, shape of parr marks, or a combination of these characteristics. 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 tern colony due to the potential impact of lethal sampling on such a small colony.

Estimates of annual smolt consumption for the Crescent Island Caspian tern colony 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. Temporal trends in steelhead consumption by Crescent Island terns were also investigated relative to the estimated fish passage index at McNary Dam (FPC 2008), a gross measure of smolt availability near Crescent Island.

*Results and Discussion*: Of the bill load fish identified at the Crescent Island Caspian tern colony, on average 68% were juvenile salmonids (n = 2,326 bill loads). The annual proportion of juvenile salmonids in the diet of Caspian terns nesting on Crescent Island has been strikingly consistent (about 66%) over the last 9 years (Figure 16). 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 are by far the most prevalent prey type in the diet of Caspian terns nesting on Crescent Island, followed by centrarchids (bass and sunfish, 19%) and cyprinids (carp and minnows, 8%; Figure 17). The proportion of juvenile salmonids in the diet of Crescent Island Caspian terns was high throughout April and the first half of May in 2008; in most years this peak came in early May and declined thereafter (Figure 18). 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 on Crescent Island Caspian terns was consistently higher throughout the breeding season compared to that of terns nesting on East Sand Island (Figure 12).

We estimated that Caspian terns nesting on Crescent Island consumed 330,000 juvenile salmonids in 2008 (95% c.i. = 230,000 – 444,000), somewhat less but not significantly so compared to 2007 (best estimate = 360,000, 95% c.i. = 250,000 – 460,000). Total smolt consumption by Caspian terns nesting on Crescent Island has trended downward since 2001 (Figure 19), commensurate with downward trends in tern colony size (Figure 6) and nesting success (Figure 7). The number of smolts consumed by Crescent Island terns in 2008 was at the lowest level recorded since our monitoring began (Figure 19). Despite this decline in the total number of juvenile salmonids consumed by Crescent Island terns, tern consumption of steelhead smolts has not declined in recent years (Figure 20). Since 2004, total smolt consumption by Crescent island terns has declined 34%, while steelhead consumption has increased 10% during this same period. In 2008, steelhead comprised an estimated 19% of the identifiable salmonid smolts, or roughly 64,000 fish. Within-season temporal patterns in consumption of all salmonids (all species/types) have been qualitatively similar over the past four years, but the pattern in 2007 and 2008 was somewhat less peaked than in previous years (Figure 21).

While the bioenergetics estimate of total consumption of steelhead in 2008 by Crescent Island Caspian terns (roughly 63,000 smolts) approached that of 2007 (73,000) and was higher than other recent years (44,000 – 57,000 steelhead smolts/year during 2004 – 2006), the within-season temporal pattern of consumption was somewhat different than past years. Consumption of steelhead peaked early in the season and was higher during the period of 10 April – 7 May than during any other recent year (2004 – 2007; Figure 22). Conversely, however, steelhead consumption after 8 May was lower than any other recent year. The relatively low steelhead consumption during the tern chick rearing period likely contributed to poor fledgling production at the colony in 2008. Presumably, river conditions in 2008 influenced the availability of steelhead to terns later in the terns' nesting season. The winter of 2007 – 2008 saw heavy snowpack accumulation and a cold, late spring across the Columbia Basin, which resulted in a large but delayed spring freshet. River flows measured at McNary Dam peaked in late May and early June and at levels higher than seen since at least 1999. These high flows and low temperatures likely moved steelhead rapidly through the river system and out of the McNary Pool, greatly reducing their availability to Crescent Island terns during the chick-rearing period.

### 1.4. Salmonid Predation Rates by Caspian Terns

Each spring, millions of downstream migrating juvenile salmonids in the Columbia River basin are tagged with Passive Integrated Transponder (PIT) tags to gather information on their survival and behavior. Each tag contains a unique 14-digit alphanumeric code that provides data on the species of fish, run of fish (if known), release date, and release location, among other information. Each year, thousands of these PIT-tagged fish are consumed by colonial waterbirds and many of the ingested tags are subsequently deposited on piscivorous waterbird colonies throughout the Columbia River basin. The recovery of PIT tags on bird colonies can be used as a measure of predation rates on salmonid ESUs that are listed under the Endangered Species Act (ESA), and these data can be used to assess the relative vulnerability of various salmonid species, stocks, and rearing types to avian predators (Collis et al. 2001, Ryan et al. 2003, Antolos et al. 2005). Furthermore, PIT tag recovery data can be used to test hypotheses on the effects of smolt morphology, condition, abundance, and origin on vulnerability to avian predation (see Section 4). Data collected as part this research will help regional fishery managers determine the magnitude of avian predation on different groups of PIT-tagged smolts from the Snake and Columbia rivers, plus identify, and potentially address, those intrinsic factors that influence smolt vulnerability to avian predators.

Previous estimates of predation rates based on PIT tag recoveries were considered minimums because not all tags consumed by birds are deposited on their nesting colony and not all tags deposited on the colony are detected by researchers. From 2004 to 2008, we have worked collaboratively with NOAA Fisheries to generate more accurate and defensible estimates of avian predation rates based on PIT tag recoveries. This was accomplished by (1) physically removing tags from colonies where PIT tag collision is believed to significantly reduce PIT tag detection efficiency; (2) systematically sowing test PIT tags with known tag codes on bird colonies in order to directly measure PIT tag detection efficiencies; and (3) conducting experiments to measure on-colony deposition rates of PIT tags ingested by Caspian terns (measured in 2004-2006).

#### 1.4.1. Smolt PIT Tag Recoveries

*Methods*: Predation rate estimates based on smolt PIT tag recoveries were corrected for the biases associated with PIT tag collision, detection efficiency, and deposition rate. PIT tag collision (where tags in close proximity on a colony are rendered unreadable by electronic equipment) was addressed by physically removing and then individually hand scanning tags from the Crescent Island and Goose Island (Potholes Reservoir) tern colonies by passing large magnets (which gather the PIT tags) over the colony surface. Detection efficiency was measured by systematically sowing PIT tags on tern colonies (Goose Island, Dry Falls Dam Island, Crescent Island, Rock Island, and East Sand Island) throughout the nesting season and then recovering tags after the nesting season. The sowing of test tags were conducted (1) prior to the birds' arrival on colony (March), (2) during egg incubation (May), (3) during chick fledging (June), and (4) once the birds had left the colony following the nesting season (July to August). Detection efficiency estimates were then analyzed relative to the sowing date, thereby describing temporal variation in detection efficiency. Finally, not all smolt PIT tags consumed by terns are deposited on the nesting colony; some proportion of consumed PIT tags is regurgitated by terns while they are not on-colony, for example during flight or at off-colony loafing areas. In 2004-2006, we conducted experiments to measure on-colony deposition rates of PIT tags ingested by terns nesting on Crescent Island. First, we allowed terns to forage on PIT-tagged fish confined to net pen enclosures and then scanned for those tag codes at the Crescent Island tern colony following the nesting season. Secondly, we captured nesting adult terns on the Crescent Island tern colony and force-fed them PIT-tagged fish and then scanned for those tag codes following the nesting season. Based on these previous studies (see CBR 2007 for detailed methods), we estimate that the on-colony deposition rate of PIT tags consumed by Crescent Island terns is 63% (± 5%). Where noted, results from the current and previous years were used to correct our predation rate estimates for terns to account for these known sources of bias.

Following the 2008 nesting season, electronic PIT tag detection equipment (antennas and transceivers) were used to detect tags *in situ* that were not removed physically using magnets (see Sebring et al. [2008] for a detailed description of NOAA Fisheries' PIT tag recovery methods). Tag recovery efforts at avian colonies in the Columbia River estuary were conducted primarily by NOAA Fisheries, while recovery efforts on the Columbia Plateau (e.g., Crescent Island, Goose Island, and Rock Island tern colonies) were conducted primarily by OSU/RTR.

*Results and Discussion*: In total, approximately 114,626 unique or newly discovered PIT tags were recovered on avian colonies in the Columbia basin following the 2008 nesting season. In addition to PIT tags, 174 radio tags, 286 hydro-acoustic tags, and 35 floy or spaghetti tags were also recovered. All PIT tag codes recovered from avian colonies in the Columbia basin were uploaded to the regional smolt PIT tag database (PTAGIS 2008) and the owners of other fish tags (e.g., telemetry tags) were notified, whenever possible.

*East Sand Island Caspian terns* – Following the 2008 nesting season, NOAA Fisheries used specially designed electronics (see Sebring et al. 2008 for details) to detect 45,513 functional, previously undetected PIT tags on the East Sand Island Caspian tern colony. Of these, 42,340 or 92.9% were from smolts tagged and released during the 2008 migration year (Table 2). Of the test tags sown on the East Sand Island tern colony in 2008 (n = 600), 556 or 92.7% were subsequently detected on-colony (Table 3). Detection efficiency ranged from 87.0% for tags sown during the chick-rearing period to 98.0% for tags sown post-season. There was no evidence that detection efficiency increased as a linear function of the date when the tags were sown on-colony ($R^2 = 0.128$, $P = 0.6219$). This result is similar to those described for East Sand Island in 2004 – 2007, suggesting that differences in detection efficiency are not related to when tags are deposited on the East Sand Island Caspian tern colony within a given nesting season.

*Crescent Island Caspian terns* – Following the 2008 nesting season, we physically removed (via magnets) 4,161 PIT tags, 145 radio tags, and 76 hydro-acoustic tags from the Crescent Island tern colony. Following physical removal, an additional 10,067 functional PIT tags were detected on the tern colony using specially-designed electronics (see Sebring et al. 2008 for details). In total, 14,228 PIT tags were removed from or detected on the Crescent Island tern colony following the 2008 nesting season. Of these functional tags, 8,675 (60.9%) were unique or previously undetected (i.e., tags not detected in past recovery efforts). Of these newly detected tags, 7,191 (82.4%) were from smolts released during the 2008 migration year (Table 2). Of the test tags sown on the Crescent Island tern colony in 2008 (n = 800), 496 or 62.0% were subsequently detected on-colony (Table 3). Detection efficiency ranged from as low as 24.0% for tags sown pre-season to as high as 99.0% for tags sown post-season. Average detection efficiency during the nesting season (i.e., during the period when terns were observed on the colony and were ingesting PIT tags) was 62.9% (linear fit). Similar to data collected during 2004-2007, there was a positive association between the Julian date when test tags were sown and detection efficiency ($R^2 = 0.8909$, $P < 0.01$), with tags sown late in the nesting season more likely to be detected than tags sown early in the nesting season. Detection efficiency results suggest that PIT tags from early-migrating smolts that were deposited on the Crescent Island colony by terns are less likely to be detected on-colony as compared to PIT tags from late-migrating smolts.

*Rock Island Caspian terns* – Following the 2008 nesting season, we detected 5,187 PIT tags using hand-held electronic scanners/detectors. Of these, 1,266 (24.5%) were from smolts released during the 2008 migration year (Table 2). Of the test tags intentionally sown on the Rock Island tern colony to measure detection efficiency in 2008 (n = 100), 93 or 93.0% were subsequently detected on-colony (Table 3). Average yearly detection efficiency was slightly higher in 2008 relative to 2007 (ca. 88.0%), with no statistically significant temporal trend detected in either year.

*Goose Island Caspian terns* – Following the nesting season, we detected 2,021 PIT tags from 2008 migration year smolts using both physical and hand-held electronic detection methods (Table 2). In addition to PIT tags, 3 radio and 208 hydro-acoustic tags were recovered on the tern colony. Of the test tags sown on the tern colony in 2008 (n = 400), 254 or 63.5% were subsequently detected on-colony (Table 3). Average detection efficiency was higher in 2008 relative to 2007 (ca. 53.0%) but comparable to that of 2006 (ca. 64.5%). Similar to Crescent Island, there was evidence of a positive association between Julian release date and detection efficiency ($R^2 = 0.7204$, $P < 0.01$). This finding, however, was driven by the low detection of tags (n = 100) sown during the pre-season (ca. 33.0%), after which average detection efficiency was relatively consistent and non-linear (ca. 71.0%, 77%, and 73% for tags released during late incubation, chick-rearing, and post-fledging, respectively).

*Banks Lake Caspian terns* – A total of 52 PIT tags were detected from 2008 migration year smolts following the nesting season (Table 2). Of the test tags sown on the tern colony in 2008 (n = 100), 52 or 52% were recovered following the nesting season (Table 3). In addition to PIT tags, 35 floy tags were also recovered. Floy tags were from hatchery rainbow trout released into Banks Lake and nearby streams by researchers from Eastern Washington University (Candace Hultberg, pers. comm.). The small number of salmonid PIT tags recovered from the Banks Lake tern colony in 2008 is similar to the number recovered following the 2007 nesting season (ca. 31 PIT tags).

*Loafing Areas (basin wide)* – In addition to finding tags associated with a particular tern colony, PIT tags were also detected at two locations where terns and other avian predators are known to congregate or loaf during the nesting season: (1) the lagoon/beach associated with Crescent Island and (2) a series of rock out-croppings in Wanapum pool on the mid-Columbia River. A total of 526 and 55 PIT tags from 2008 migration year smolts were recovered in the Crescent Island lagoon and the Wanapum pool loafing area, respectively. No measure of PIT tag detection efficiency was available for these loafing areas and tags found in these areas cannot be associated with a particular bird colony or species. The detection of tags at these known loafing areas, however, provides empirical evidence of off-colony PIT tag deposition in 2008. Other loafing areas in the Columbia River basin, in addition to the Crescent lagoon and Wanapum rocks, were identified in 2008, but these areas had either limited bird use (e.g., southern tip of Foundation Island) or were regularly inundated by moving water (e.g., the mouth of the Walla Walla River), a process that buries and/or removes tags and makes them unreadable by conventional methods.

### 1.4.2. Predation Rates on Smolts

*Methods:* In collaboration with NOAA Fisheries, we used PIT tag recoveries on Caspian tern colonies to evaluate the relative vulnerability of various salmonid species and run-types to tern predation. PIT tag data were also used to estimate predation rates on threatened and endangered salmonid populations, when sample sizes were sufficient. Preliminary analyses of tags recovered from Caspian tern colonies in 2008, with comparisons to data collected during 2004-2007, are presented here. These data will be analyzed in greater detail – including a multi-year synthesis – in this project's Final Report, in NOAA Fisheries' Annual Reports, and in articles published in peer-reviewed scientific journals.

We queried the regional PIT tag database (PTAGIS 2008) on 21 October 2008 to acquire data on the species of fish, run of fish (if known), origin of fish (hatchery, wild, or unknown), tagging date, tagging location, and in-river interrogation history for all PIT-tagged fish released into the Columbia River Basin in 2008. We calculated predation rates on different salmonid species, run types, and stocks (as defined by NOAA Fisheries' Evolutionarily Significant Units or ESUs), based on the total number of released fish that were subsequently recovered on tern colonies (here after referred to as "stock-specific" predation rates). For Caspian terns nesting downstream of collector dams (i.e., dams that collect and subsequently transport smolts around the Federal Columbia River Power System), predation rates were generated for only the in-river component of the run (i.e., excludes all PIT-tagged smolts that were transported). These stock-specific predation rate estimates do not account for mortality that took place between the fish's tagging and release location and the detection site (i.e., the tern colony) and, as such, under-estimate predation rates relative to a given river reach because the numbers of smolts susceptible to tern predation are inflated to an unknown degree.

A more precise measure of tern predation rate was calculated by limiting the analysis to actively-migrating smolts that were last detected within the general foraging range of the tern colony (here after referred to as "reach-specific" predation rate estimates) during the nesting season (April to August). For the East Sand Island tern colony, this was done by calculating a predation rate for just those PIT-tagged smolts that were interrogated passing Bonneville Dam (located 227 Rkm up-river above East Sand Island), plus those

PIT-tagged smolts that were transported and released into the Bonneville Dam tailrace. For the Crescent Island tern colony, this was done by calculating a predation rate for just those PIT-tagged smolts that were interrogated passing Lower Monumental Dam (located on the Snake River, 80 Rkm up-river from Crescent Island), Rock Island Dam (located on the mid-Columbia River; 210 Rkm up-river from Crescent Island), and PIT-tagged smolts released into the mid-Columbia River between the confluence of the Snake and Columbia rivers (located 12 Rkm up-river from Crescent Island) and McNary Dam (located on the Columbia River, 39 Rkm down-river from Crescent Island). These reach-specific estimates, however, are still minimum predation rates because they do not account for in-river mortality between the interrogation site and the vicinity of the tern colony, a distance of upwards of 200 Rkm for particular ESUs and the corresponding tern colony. Reach-specific estimates also assume that predation rates based on smolts using the juvenile bypass are representative of other PIT-tagged smolts that use alternative routes to pass any particular dam (i.e., spillway, powerhouse).

Temporal trends in predation were investigated by using the interrogation date of PIT-tagged fish passing these dams relative to the recovery of PIT tags at downstream tern colonies. Temporal trends in predation by terns were also investigated relative to the estimated fish passage index at the dam, intended to be a gross measure of fish availability. Non-parametric tests (e.g., Chi-square, Fisher Exact, and odds ratio comparisons; Ramsey and Schafer 1997) were used to compare weekly (week = Sunday to Saturday) predation rates among fish of different rear-types (hatchery versus wild). Simple modeling techniques (e.g., regression analysis) were also used to evaluate various trends and associations relating to predation of PIT-tagged fish. Per-capita consumption rates of PIT-tagged fish were also calculated for tern colonies based on the number of 2008 migration years smolt recovered divided by the number of breeding adults on a given tern colony.

All predation rate estimates presented here were corrected for on-colony PIT tag detection efficiency, based on the results of PIT tag detection efficiency studies described above (see Section 1.4.1). When noted, results for Crescent Island terns are also corrected for PIT tag deposition rates, based on results from a previous study (see CBR 2007). For reach-specific predation rate estimates, we used the weighted monthly average derived from the passage timing of smolts at each interrogation site to calculate on-colony detection efficiency based on the linear fit of detection efficiency as a function of deposition date for terns on Crescent Island. This approach ensured that the detection efficiencies used to correct PIT tag recovery rates for particular smolt runs were adjusted for the differences in out-migration timing among various runs. Because no temporal trend was evident from test tags sown on other tern colonies, we used the average detection efficiency to estimate detection for all runs, regardless of timing. Confidence intervals for predation rate estimates were derived using variation (in this case, the standard error of the mean) obtained from multiple release groups of PIT-tagged fish of the same species, origin, and run-type.

*Results and Discussion:* Approximately 2.4 million PIT-tagged juvenile salmonids were released into the Columbia River basin in 2008 (PTAGIS 2008). The majority of these fish were released into the Snake River (1.7 million), followed by the Columbia River (0.4 million) and upper Columbia River (0.2 million). As in previous years, the smallest numbers of PIT-tagged fish were released into the lower Columbia River below Bonneville Dam (0.02 million) and the Willamette River (0.03 million; PTAGIS 2008), which limits the usefulness of PIT tag recoveries on bird colonies for determining the relative vulnerability of fish originating from these two major river systems. Of the 2.4 million PIT-tagged juvenile salmonids released in the basin, 76.1% were Chinook salmon, 19.6% were steelhead, 3.7% were coho salmon, 0.5% were sockeye salmon, and the remaining 0.1% were other salmonid species (e.g., sea-run cutthroat) or unknowns (PTAGIS 2008). Most of the PIT-tagged fish were of hatchery origin (84.6%), although wild smolts of many different species and run-types were tagged in 2008 (PTAGIS 2008). Some important exceptions to this were wild sockeye salmon from the Snake (n = 945), wild steelhead from Willamette (n = 2), and wild Chinook salmon from the lower Columbia River (n = 1); these stocks and species are listed as threatened or endangered and information regarding predation by piscivorous waterbirds is lacking. Overall, the total number of PIT-tagged fish released in 2008 was higher than that of the previous four years, when approximately 2.0 million or fewer fish were released annually into the basin (PTAGIS 2008).

*East Sand Island Caspian terns* – Of the approximately 2.4 million PIT-tagged fish that were released into the Columbia River basin in 2008, 1.8% (n = 42,340) were recovered on the East Sand Island tern colony (Table 2). Of the 42,340 tags recovered, 50.5% were from steelhead, 33.9% were from Chinook salmon (including sub-yearlings and yearlings), 1.9% from coho salmon, and 0.1% from sockeye salmon. As in previous years, steelhead were the most vulnerable to East Sand island tern predation of the PIT-tagged salmonid species in 2008, with predation rates in excess of 10% (Table 4). Predation rates on wild populations of steelhead (in-river migrants originating up-river of Bonneville Dam) in 2008 (ca. 9.7%) were slightly lower than those observed in 2006 (ca. 13.3%; CBR 2007) and 2007 (ca. 14.1%; CBR 2008). Hatchery coho salmon smolts that migrated in-river were the next most vulnerable to tern predation (ca. 4.1% of PIT-tagged smolts; Table 4). Data from the limited numbers of PIT-tagged fish released into the lower Columbia River (down-river of Bonneville Dam) suggest predation rates of 4.2% and 10.5% on hatchery fall Chinook and steelhead, respectively.

As was the case in previous years, there was evidence that predation rates differed between hatchery and wild smolts, with rates consistently higher among hatchery fish (Table 4 and Figure 23). Despite these differences, temporal trends in predation suggest that weekly predation rates on steelhead and Chinook smolts remained relatively constant throughout the nesting season (Figure 23). One possible exception was predation rate on steelhead smolts, which decreased during the peak passage period in May (Figure 23). Although predation rates for steelhead decreased as fish abundance increased, this should not be interpreted as a decrease in the number of smolts consumed in those weeks, but instead a decrease in an individual fish's probability of being consumed. Finally, the per-capita consumption rate of PIT-tagged juvenile salmonids by East Sand Island terns (2.1 tags per breeding adult) was less by a factor of 6 to 7 compared to cormorants and terns that nested on the Columbia Plateau (13.6-14.7 tags per breeding adult; Table 5). This was also the case in 2006 and 2007, when per-capita consumption of East Sand Island terns was 3 to 8 times less than for cormorants and terns nesting further up-river (CBR 2007, CBR 2008). This suggests that salmonid smolts comprise a larger proportion of the diet for terns and cormorants nesting up-river relative to the same two species nesting on East Sand Island; a conclusion supported by diet composition results presented for the two species (see Sections 1.3 and 2.3).

*Crescent Island Caspian terns* – We estimate that 0.6% (n = 11,432; adjusted for detection efficiency) of in-river migrating PIT-tagged juvenile salmonids released up-river of McNary Dam in 2008 were consumed by Crescent Island terns. Similar to data collected during 2004-2007, steelhead were by far the most vulnerable species to predation by Crescent Island terns, with minimum predation rate estimates of 6.0%, 1.5%, and 1.7% for wild, in-river steelhead smolts belonging to the Snake River, Upper Columbia, and Middle Columbia ESUs, respectively (Table 6). These predation rates increased to 9.4%, 2.4%, and 2.7%, respectively, for each listed ESU, once adjusted for both PIT tag detection efficiency and PIT tag deposition. Predation rates on other wild, ESA-listed species were comparatively low (ranging from 0.3% – 2.5%; Table 6). Substantial stock-specific differences were noted, with predation rates highest on steelhead stocks originating from the Snake River (Table 7), although survival differences to McNary Pool were not considered in this analysis and likely contributed to these relative differences in vulnerability among stocks and ESUs.

Predation rates on steelhead and Chinook salmon smolts from the Snake River (based on interrogation histories at Lower Monumental Dam) differed with both the abundance of fish available and passage timing. As was the case in previous years, there was a negative association between predation rates on steelhead and the Lower Monumental Fish Passage Index, with predation rates by Crescent Island terns decreasing as the number of available fish increased (Figure 24). There was also evidence that predation rates changed throughout the season, with predation rates being higher during the later portion of the run for both steelhead and Chinook smolts (Figure 24). The number of fish available, however, is a covariate with passage timing, as fish numbers were also lowest during the later portion of the run (Figure 24). Although predation rates decreased as fish abundance increased, this should not be interpreted as a decrease in the number of smolts consumed. In fact, consumption estimates during 2008 derived from bioenergetics modeling indicated that within a given season the Crescent Island tern colony consumed steelhead in proportion to their availability in-river, with peak consumption coinciding with the peak passage periods (Figure 22). In other words, within a given year, evidence suggests that as more fish become available, more are consumed by terns nesting on Crescent Island. There was also evidence of temporal trends in the relative vulnerability between hatchery and wild smolts, particularly steelhead, to predation by terns nesting on Crescent Island in 2008. During the peak passage periods in April and May, hatchery smolts from the Snake River were more vulnerable to tern predation relative to their wild counterparts (Figure 24). This trend, however, reversed as the run progressed, with predation on wild fish higher than on hatchery fish during the month of June (Figure 24). These data, particularly those involving temporal trends and fish abundance, will be analyzed in greater detail in the project’s final report.

Overall, predation rates by Crescent Island terns on PIT-tagged smolts traveling through McNary pool in 2008 were similar to those reported in 2007 (CBR 2008). Estimated reach-specific predation rates, however, have been in decline since 2004. For example, in 2004 predation rates on in-river steelhead were 35.5%, 6.2%, and 6.5% for steelhead smolts (hatchery and wild combined) from the Snake River, Upper Columbia, and Middle Columbia, respectively (corrected for detection efficiency and deposition rate). Comparable rates from these three river segments in 2008 were just 8.7%, 3.3%, and 2.7%, respectively. Lower predation rates in 2007 and 2008 are likely a result of several factors. First, the size of the Crescent Island tern colony has been declining (ca. 27% reduction since 2004, with declines observed in 2005, 2006, and 2007). Second, evidence from research during the previous four years suggests that tern predation rates on steelhead smolts are lower in years of high river flows (Antolos et al. 2005; CBR 2005, 2006, 2007) and/or when large numbers of steelhead migrate past Crescent Island in a relatively short period of time (CBR 2005, CBR 2008). Passage index data on steelhead from the Snake River in 2007 and 2008 indicates that the vast majority of the run passed during a two to three week period, compared to the more protracted, bimodal run timing observed in years past (e.g., 2004). Finally, it is important to note that although predation rates have declined since peaking in 2004, this does not mean the impact to the over-all population has declined proportionally. This is because the estimates of predation rate apply to the in-river component of each species/run-type and does not include the component of the run transported around McNary Pool in barges and therefore unavailable to Crescent Island terns. Since 2004, the number of smolts originating from the Snake River that have been left to migrate in-river has increased dramatically. For example, in 2004 an estimated 3.6% of the Snake River steelhead run remained in-river. This proportion increased to approximately 58.6% in 2007 (NOAA Fisheries, unpublished data). This change in relative availability of smolts in the Snake River helps explains why predation rates fluctuate so much from one year to the next.

Unlike juvenile salmonids from the Snake River, smolts originating from the mid- and upper Columbia are not collected above McNary Dam and transported around McNary Pool, making these salmonid runs more susceptible to avian predators in McNary Pool relative to Snake River smolts, especially in years of high transportation for Snake River stocks. Not surprisingly, predation rates on steelhead from these two non-transported ESUs have remained relatively constant compared to predation rates on Snake River stocks; average predation rates ranged from 2% to 6% for mid- and upper Columbia River stocks, compared to predation rates from 5% to 35% for Snake River stocks (CBR 2005, 2006, 2007, 2008).

*Rock Island Caspian terns* – Of the PIT-tagged fish released into the Columbia River basin up-river of John Day Dam in 2008 (excluding transported fish), < 0.1% (n = 1,361 tags; adjusted for detection efficiency) were deposited on the Rock Island Caspian tern colony during the nesting season. Similar to the Crescent Island Caspian tern colony, steelhead were the most vulnerable salmonid species, with predation rates (based on interrogations of fish passing McNary Dam) averaging 0.3% and 0.6% for wild and hatchery steelhead, respectively. Predation rates on all other species and run-types were

< 0.3%, with hatchery fall Chinook the next most vulnerable species and run-type to predation by terns nesting of Rock Island. However, Rock Island terns ranked third among Columbia Basin bird colonies in estimated per-capita consumption of PIT-tagged smolts in 2008 (after the Crescent Island tern colony and Foundation Island cormorant colony; Table 5), suggesting that the small size of the Rock Island colony, rather than the prevalence of salmonids in the diet, limits its impact on salmonid smolt survival. Similar low over-all impact on salmonid survival but high per-capita consumption were documented for this tern colony in both 2006 and 2007 (CBR 2008).

*Goose Island Caspian terns* – Salmonid PIT tags were detected at the Potholes Reservoir tern colony on Goose Island (~ 45 km east of the Columbia River; Map 2). A total of 2,021 smolt PIT tags from the 2008 migration year were recovered. This number increases to 3,183 tags when adjusted for detection efficiency (Table 2). Of the tags recovered on-colony, the vast majority was from steelhead smolts (n = 1,425 or 71%) and from smolts released into the Columbia River up-river of Wanapum Dam (ca. 1,840 or 91.0% of all tags recovered). Of the remaining 596 PIT tags recovered, 445, 143, and 8 were from Chinook salmon, coho salmon, and sockeye salmon smolts, respectively. We calculated reach-specific predation rates on run-of-the-river smolts captured, tagged/interrogated, and released into the tailrace of Rock Island Dam. Similar to terns elsewhere in the region, predation rates by Potholes Reservoir terns on steelhead smolts were far greater than on other salmonid species, with estimated predation rates (adjusted for detection efficiency) of 8.2% and 5.9% for hatchery and wild steelhead, respectively (see Section 4 for a more detailed analysis of steelhead smolts consumed by terns nesting on Potholes Reservoir in 2008). Predation rates were dramatically less for Chinook (ca. 0.5%) and sockeye smolts (ca. 0.4%). Predation rates were higher, however, for coho smolts (ca. 2.4%), but sample sizes were relatively small (n = 547, with 13 tags deposited on the tern colony).

Predation rates on steelhead smolts by Caspian terns nesting in Potholes Reservoir are surprisingly high and of special concern because these smolts belong to an ESU that is listed as endangered under the ESA. Research to better quantify the impact of this tern colony on the Upper Columbia Steelhead ESU in 2008 (see Section 4 for details) indicated smolts were susceptible throughout the period when the run was passing Rock Island Dam. Although predation rates were consistently higher on hatchery steelhead, evidence suggests a significant proportion of the wild smolts was consumed by this relatively small tern colony (ca. 290 nesting pairs) in 2008. Data presented on steelhead predation by terns nesting on Potholes Reservoir are, however, preliminary and incomplete until further research and analysis is conducted. For example, data presented here is from the first of a three-year study to investigate avian predation on steelhead from the Upper Columbia Steelhead ESU. Larger sample sizes, data collaboration (e.g., steelhead behavior and survival data being collected by Grant and Chelan County PUDs), and study replication will be needed before study results and impacts of avian predation can be fully evaluated (see Section 4 for additional details).

*Banks Lake Caspian terns* –Salmonid PIT tags were also detected at a small colony of Caspian terns (27 breeding pairs) located on Dry Falls Dam Island in Banks Lake, WA (~

70 km southeast of the Columbia River; Map 2). A total of 52 smolt PIT tags from the 2008 migration year were recovered on-colony following the 2008 nesting season (Table 2). This number increases to 98 PIT tags when adjusted for on-colony detection efficiency (Table 3). A similar number of PIT tags (n = 31) were recovered following the 2007 nesting season. Similar to results from terns nesting on Potholes Reservoir, the majority of tags (n = 48 or 92%) were from smolts released in the Columbia River up-river of Wanapum Dam, with steelhead smolts being the dominant species (n = 23 or 44%). Of the remaining tags, 17 and 12 were from Chinook and coho smolts, respectively. An estimate of per-capita consumption of PIT-tagged smolts by Banks Lake terns was 1.8, suggesting that Caspian terns nesting on Banks Lake had little impact on the survival of salmonid smolts from the Columbia Basin relative to other tern colonies on the Columbia Plateau (Table 5). This is likely a result of the distance of this colony from the Columbia River (~ 70 km) and the apparent abundance of forage fish within Banks Lake and the surrounding area.

### 1.5. Dispersal and Survival of Caspian Terns

*Methods:* In 2008, adult Caspian terns were banded at East Sand Island in the Columbia River estuary and fledgling Caspian terns were banded at East Sand Island and at Crescent Island in the Columbia River basin. These banding efforts are part of our continuing objective to measure survival rates, post-breeding dispersal, and movements among colonies for Caspian terns in the Pacific Coast population. Adult and fledgling 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.

As part of this study, tern chicks that were near fledging were color-banded at East Sand Island (n = 406) and Crescent Island (n = 86). In addition, 42 and 13 smaller chicks were banded only with a federal numbered metal leg band at East Sand Island and Crescent Island, respectively. Tern chicks were captured on-colony by herding flightless young into holding pens. Adult terns were captured at East Sand Island (n = 52) for banding using noose mats placed around active nests. Once captured, terns were immediately transferred to holding crates until they were banded and released. Tern banding operations were conducted only during periods of moderate temperatures to reduce the risk of heat stress for captive terns.

Terns that were color-banded in previous years (2000 – 2007) were re-sighted on various breeding colonies by researchers throughout the 2008 breeding season. Re-sightings of banded terns at other locations were reported to us through our project web page (2000-2007: www.columbiabirdresearch.org; 2008-present: www.birdresearchnw.org), by phone, or by e-mail.

*Results and Discussion*: In 2008, 330 previously-banded Caspian terns were re-sighted at the East Sand Island colony and 114 banded terns were re-sighted at the Crescent Island colony. All 444 re-sightings of banded terns were identified such that the banding year, age class when banded (i.e., adult or chick), and banding location were known. Of the

330 banded individuals that were re-sighted at East Sand Island, 312 (95%) were banded in the Columbia River estuary (143 as adults and 169 as chicks), 5 (2%) were banded at the former ASARCO colony in Commencement Bay, WA (4 as adults and 1 as a chick; Map 2), 11 (3%) were banded at Crescent Island (4 as adults and 7 as chicks), 1 (0.3%) was banded at Crump Lake in Adel, OR (as a chick), and 1 (0.3%) was banded at Brooks Island in San Francisco Bay, CA (as a chick). Of the 114 banded terns that were re-sighted at the Crescent Island colony, 113 (99%) were banded at Crescent Island (95 as adults and 18 as chicks), and 1 (1%) was banded at East Sand Island (as a chick).

In addition to these re-sightings, 22 banded Caspian terns were re-sighted at the colony on Dungeness Spit, WA (Map 2). Of these, 19 (86%) were banded at East Sand Island (1 as an adult and 18 as chicks) and the 3 others (14%) were banded at Dungeness Spit as chicks; the first confirmation of terns banded at Dungeness Spit returning to their natal colony.

The age at first reproduction for Caspian terns was reported to be 3 years of age by Gill and Mewaldt (1983). The large cohorts of fledgling Caspian terns produced at the East Sand Island colony in 2001, 2002, and 2003 led to predictions that the East Sand Island colony would increase rapidly in size due to recruitment of these large cohorts into the breeding population within 3 - 4 years. The first confirmed breeding by terns banded as chicks in 2001 and 2002 was noted at East Sand Island and Goose Island in 2006, and the first breeding by a tern banded as a chick in 2003 was confirmed at East Sand Island in 2007. A tern banded as a chick in 2002 at Crescent Island was also confirmed breeding at its natal colony in 2007, the first confirmation of breeding by a tern that was banded as a chick at Crescent Island. In 2008, the first breeding of a chick banded in 2004 was confirmed at Crump Lake. Our observations suggest that for this population the average age of first reproduction may be 5 years of age or older. This delay in onset of breeding, compared to what has been reported in the literature (i.e., Gill and Mewaldt 1983) may be one of the reasons why the East Sand Island tern colony has remained stable in size despite the large cohorts of fledglings produced at the colony during 2001-2003. Other potential factors responsible for the stable population size at the East Sand Island tern colony in recent years include (1) lower than expected survival rates for young terns prior to recruitment into the breeding population, (2) higher than expected adult mortality during the non-breeding season, and (3) terns fledged from the East Sand Island colony are recruiting to colonies other than their natal colony.

Analysis of the band re-sighting data is on-going and will allow us to estimate adult survival, juvenile survival, average age at first reproduction, colony site fidelity, and other factors important in determining the status of the Pacific Coast population of Caspian terns, and whether current nesting success is likely to result in an increasing, stable, or declining population. Moreover, by tracking movements of breeding adult terns among colonies, either within or between years, we can better assess the consequences of various management strategies

## 1.6. Caspian Tern Management Plan

### 1.6.1. Background

In 2008, the U.S. Army Corps of Engineers (USACE) began implementing the management actions outlined 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 USACE, the U.S. Fish and Wildlife Service, and NOAA Fisheries, seeks to redistribute a portion of the Caspian tern colony on East Sand Island in the Columbia River estuary to alternative colony sites in interior Oregon and the San Francisco Bay area by 2015. 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. 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 calls for the creation of approximately 7-8 acres of new or restored Caspian tern nesting habitat in interior Oregon (specifically Fern Ridge Lake, Crump Lake, and Summer Lake) and the San Francisco Bay area (specifically Don Edwards National Wildlife Refuge, Hayward Regional Shoreline, and Brooks Island) 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 will be reduced from its current size (approximately 5 acres) to 1.0 - 1.5 acres.

Creation of tern nesting habitat at alternative colony sites and the reduction of nesting habitat at East Sand Island will be accomplished in phases at a ratio of two new acres of habitat provided for each acre of habitat reduction on East Sand Island. Once fully implemented, the management plan is expected to reduce the East Sand Island Caspian tern colony from its current size (approximately 10,700 nesting pairs in 2008) to about 3,125 – 4,375 nesting pairs, or a reduction in colony size of 60% - 70%. A reduction in the size of the East Sand Island Caspian tern colony to 3,125 – 4,375 pairs is estimated by NOAA Fisheries to increase the annual population growth rate of three ESA-listed ESUs of Columbia Basin steelhead by 1% or greater. Steelhead were the focus of NOAA Fisheries' analysis because previous studies have revealed that Caspian tern predation rates on juvenile steelhead exceed those of other salmonid species in the Columbia Basin. The reduction in the size of the Caspian tern colony at East Sand Island is expected to reduce annual consumption of juvenile salmonids (smolts) from the Columbia River basin by 2.5 – 3.0 million fish. Annual consumption of juvenile salmonids by Caspian terns during the period 2001-2007 has averaged approximately 5 million smolts.

The potential for reduction in Caspian tern nesting habitat at East Sand Island to 1 acre is addressed in the RODs. Before nesting habitat on East Sand Island can be reduced below 1.5 acres, additional alternative sites for tern nesting would need to be developed (the criteria for selection of alternative sites are described in Appendix G of the FEIS). If potential new colony sites that have not already been analyzed in the FEIS are identified, an environmental assessment would be prepared for each site. A reduction in tern colony size to 2,500 - 3,125 pairs could be accomplished with development of alternative tern nesting habitat at two potential additional sites in northeastern California, Tule Lake National Wildlife Refuge and Lower Klamath National Wildlife Refuge, which are currently undergoing environmental assessment.

1.6.2. Management Initiatives Implemented in 2008

The USACE completed construction of a 1-acre island specifically designed for Caspian tern nesting at Fern Ridge Lake near Eugene, Oregon in February 2008. Restoration of a 1-acre Caspian tern nesting island on Crump Lake in the Warner Valley northeast of Lakeview, Oregon was completed in March 2008. The restored island in Crump Lake was at the location of a former island that supported colonial-nesting waterbirds prior to its destruction by human and natural causes. Following island construction and before the arrival of terns from their wintering grounds, Caspian tern decoys and audio playback systems that broadcast tern calls were deployed on both islands to attract terns to nest. In addition, an observation blind was constructed on the edge of each island so that tern colony size, nesting success, diet composition, and factors limiting colony size and nesting success could be monitored without disturbing nesting birds.

There has been no prior history of Caspian tern nesting at Fern Ridge Lake or elsewhere in the Willamette Valley, so we suspected that Caspian terns might not nest on the Fern Ridge Lake tern island during the first breeding season following construction. Consequently, video cameras were used to monitor the island instead of direct observation by a field crew, and the island was visited periodically throughout the breeding season by project staff. Review of video footage revealed that Caspian terns visited the island after the breeding season, presumably once post-breeding terns dispersed from their nesting colonies. During the month of August the Fern Ridge Lake tern island was visited by Caspian terns on 23 different days, with as many as 9 terns observed on the island at one time. We will attempt to attract Caspian terns to nest at Fern Ridge Lake again in 2009, and we are hopeful that some terns will attempt to breed on this new island in years to come.

There is a history of Caspian terns attempting to nest at Crump Lake in the Warner Valley of south-central Oregon. Although we expected that some Caspian terns might attempt to nest on the new Crump Lake tern island during the first breeding season, we were not prepared for what occurred. During May, a Caspian tern breeding colony formed on the Crump Lake island and grew to about 150 breeding pairs. Concurrently, about 500 pairs of California gulls, 850 pairs of ring-billed gulls, and 10 pairs of double-crested cormorants initiated nesting on the new island. In early June the Caspian tern colony dropped to a low of 23 nesting pairs due to nest predation by gulls that were nesting nearby. We began to selectively remove gulls that were observed to depredate tern eggs, once the required depredation permits had been issued. In total, 10 gulls were lethally removed from the tern colony (shot) during the month of June. Subsequently, the Caspian tern colony expanded to 428 breeding pairs, which ultimately raised about 145 young terns to fledging age. Hundreds of pairs of nesting California and ring-billed gulls and one pair of cormorants also successfully raised young on the Crump Lake island.

Thirty of the Caspian terns that colonized the newly constructed island in Crump Lake had been previously banded. Of these, 18 had been banded at the Crescent Island Caspian tern colony on the mid-Columbia River near Tri-Cities, Washington, about 450 km to the north. Five of the banded terns on Crump Lake island had been banded on East Sand Island in the Columbia River estuary, over 500 km to the northwest. These band re-sightings demonstrate that Caspian terns can be recruited to new colony sites from existing breeding colonies over considerable distances.

The diet of Crump Lake Caspian terns, based on 2,909 identified bill-load fish, consisted primarily of tui chub (*Gala bicolor*; 59%), introduced bullhead catfish (*Ameiurus* spp.; 23%), and introduced crappie (*Pomoxis* spp.; 16%); however, 1 floy-tagged Warner sucker (*Catostomus warnerensis*; 0.03%), a threatened species, was identified in the diet. Four other non-tagged suckers were also identified; they were either Warner suckers or Sacramento suckers from Goose Lake. Juvenile lamprey were also part of the diet of Caspian terns nesting on Crump Lake island. The closest site to the Warner Valley where lampreys are found is Goose Lake, indicating that at least some Caspian terns were commuting from Crump Lake to Goose Lake to forage, and Sacramento suckers, a non-listed species, are present in Goose Lake.

The USACE prepared five acres of nesting habitat for Caspian terns at East Sand Island in late March 2008, as specified in the Final EIS. Without annual restoration of the bare sand nesting habitat that Caspian terns prefer, the East Sand Island colony would be eliminated within a year or two by rapidly encroaching pioneer vegetation. The USACE also precluded Caspian terns from nesting on other dredged material disposal sites in the Columbia River estuary, and plans to continue to do so in the future as the available tern nesting habitat on East Sand Island is gradually reduced.
See Roby et al. 2009 for further information on the results of tern management initiatives implemented in 2008.

1.6.3. Future Management Actions

The USACE, in partnership with the Oregon Department of Fish and Wildlife, created about 1 acre of nesting habitat for Caspian terns at Summer Lake Wildlife Area near Paisley, Oregon prior to the 2009 nesting season. Construction of two 0.5-acre islands at the Summer Lake Wildlife Area in south-central Oregon was initiated in December 2008 and completed by early March 2009. Caspian terns have intermittently nested in small numbers on the Summer Lake Wildlife Area during the last two decades, but suitable nesting habitat is very limited. A half-acre island was constructed in East Link Management Unit, the site of the most recent tern nesting activity on the Summer Lake Wildlife Area (5 nesting pairs in 2003 and 3 pairs in 2005). A second half-acre island has been built on Dutchy Lake; this island consists of a floating platform instead of a fill island because Dutchy Lake is a permanent body of water. Prior to the 2010 nesting season, an additional half-acre island will be constructed in the Gold Dike Management

Unit in Summer Lake Wildlife Area. This island will provide alternative nesting habitat for terns nesting on the island in East Link Management Unit in years when the impoundment is drained for management purposes.

The USACE plans to build about 3 acres of Caspian tern nesting habitat in southern San Francisco Bay prior to the 2011 nesting season. In partnership with the U.S. Fish and Wildlife Service, the USACE is planning to build two 1-acre islands on working salt ponds within Don Edwards National Wildlife Refuge. In partnership with East Bay Regional Parks, the USACE plans to enhance the habitat on two existing islands in former salt ponds at Hayward Regional Shoreline to create a total of about 1 acre of suitable nesting habitat for Caspian terns. Restoration of Caspian tern nesting habitat at Brooks Island in central San Francisco Bay is pending further study of the potential impact of an expanded Brooks Island Caspian tern colony on survival of juvenile salmonids from the Sacramento River basin, some stocks of which are listed under the Endangered Species Act.

Potential additional sites for alternative tern nesting habitat were identified in 2008 in northeastern California; these new sites would increase the total acreage of new Caspian tern nesting habitat outside the Columbia River basin. Environmental documentation to address the potential for developing tern nesting habitat at Tule Lake and Lower Klamath National Wildlife Refuges (NWRs) in northeastern California are in preparation for public review and comment. The potential exists for the construction of three islands totaling four acres at these two NWRs, an area historically used by Caspian terns for nesting. At Tule Lake, the USACE is tentatively planning to build a 2-acre tern island prior to the 2010 nesting season, in partnership with the U.S. Fish and Wildlife Service. The Corps and the Fish and Wildlife Service are also tentatively planning to build a 1-acre tern island in the Orems Unit and a second 1-acre island in Sheepy Lake, both in Lower Klamath NWR, prior to the 2010 nesting season. The Sheepy Lake island is planned to be a floating island that would serve as an alternative breeding site for Caspian terns when the Orems Unit is drained for management purposes.

Once island construction is completed at each of the above alternative colony sites, social attraction consisting of Caspian tern decoys and audio playback systems will be used to help establish and maintain a tern breeding colony. All colony sites will be monitored on nearly a daily basis to determine colony size, nesting habitat use, diet composition, nesting success, and factors limiting colony size and nesting success. If nest predation by gulls becomes prevalent enough to threaten an incipient tern colony at any of these sites, then limited gull control may be conducted under depredation permits to enhance the chances of establishing Caspian tern colonies. Once all the alternative Caspian tern colony sites have been built, tern nesting habitat at East Sand Island will be reduced to 1.5 acres, as described above. If the amount of new alternative nesting habitat provided for Caspian terns exceeds the 7 acres stipulated in the Records of Decision, then the acreage of tern nesting habitat on East Sand Island may be reduced to 1 acre, with the objective of providing nesting habitat for approximately 2,500 to 3,125 pairs of Caspian terns at the mouth of the Columbia River.

The main driver behind the plan to relocate a majority of the Caspian tern colony that currently nests on East Sand Island in the Columbia River estuary is to increase the survival of juvenile salmonids from throughout the Columbia River basin. There are, however, significant benefits to the Pacific Coast population of Caspian terns that may be realized by implementation of the Caspian Tern Management Plan. Currently, approximately two-thirds of all Caspian terns belonging to the Pacific Coast population nest on East Sand Island. Consequently, the tern population is more vulnerable to local catastrophes (for example, storms, disease outbreaks, oil spills, predation events, human disturbance) than it would be if it were distributed over a broader geographic area and a larger number of nesting sites. Redistributing the existing breeding population of Caspian terns to a number of smaller colonies over a larger geographic area will reduce risks to both terns and Columbia Basin salmonids. Close monitoring of this plan throughout its implementation is necessary to determine whether the intended benefits to both salmonids and terns are realized and, if not, what adaptive modifications to management actions may be warranted to achieve desired results.

# SECTION 2: DOUBLE-CRESTED CORMORANTS

## 2.1. Nesting Distribution and Colony Size of Double-crested Cormorants

### 2.1.1. Columbia River Estuary

*Methods*: In order to estimate the peak size of the double-crested cormorant colony on East Sand Island in 2008, high resolution aerial photography of the colony was taken late in the incubation period. Counts of the number of stick nests within delineated boundaries of the breeding colony were conducted by staff in Geospatial Services at the Bonneville Power Administration. In addition, researchers from Oregon State University proofed the counts of stick nests in the photography to improve the precision of the estimate of numbers of breeding pairs.

Boat-based surveys of eight navigational markers near Miller Sands Spit (river km 38; Map 1) were conducted 4 - 9 times monthly from early April through late July in 2008. Because nesting chronology varied among the different channel markers, the number of nesting pairs at each marker was estimated using the greatest number of attended nests observed on each of the markers throughout the season. Any well maintained nest structure attended by an adult and/or chicks 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.

Monthly boat-based surveys of the Astoria-Megler Bridge (Map 1) were conducted in May and June 2008. Our vantage point on the water 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.

In 2008, frequent boat-, land-, and air-based surveys were also conducted to monitor the cormorant social attraction site at Miller Sands Spit and the historic social attraction site at Rice Island. During these surveys researchers looked for indications of nesting activity by double-crested cormorants.

*Results and Discussion*: In 1989, fewer than 100 pairs of double-crested cormorants nested on East Sand Island. Growth in the breeding population 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 10,950 breeding pairs (95% c.i. = 10,668 – 11,232 breeding pairs) attempted to nest at East Sand Island in 2008, a 20% decline from our estimate of colony size in 2007 (13,771 breeding pairs, 95% c.i. = 12,945 – 14,597 breeding pairs). The reason for this decline is unknown, but likely relates to lower overwinter survival during a La Niña year and/or a reduction in immigration rate to the East Sand Island cormorant colony from other colonies outside the Columbia River estuary. Regardless, the East Sand Island cormorant colony was nearly three times larger in 2007 than when we first estimated the size of this colony in 1997 (Figure 25). 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 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.

During 2003-2004, increases in the size of the East Sand Island cormorant colony were associated with increases in colony area (Figure 26), as opposed to increases in nest density (Figure 27). In 2005-2008, double-crested cormorants nesting on East Sand Island used less total area for nesting (Figure 26) and nested at higher densities (Figure 27) compared to previous years. The smaller area encompassed by the cormorant colony and the higher nesting density in 2005-2008 was apparently caused by increased disturbance and predation pressure from bald eagles (*Haliaeetus leucocephalus*). Prior to 1999, cormorants on East Sand Island nested exclusively amongst the boulder riprap and driftwood on the southwest shore of the island. After 1999 they began nesting in satellite colonies in the adjacent low-lying habitat (see Map 4 for distribution of nesting cormorants in 2008). 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. Despite availability of habitat to support continued colony expansion, bald eagle disturbance and predation, plus the associated nest predation by glaucous-winged/western gulls, may limit the size of the colony in the future.

In 2008, a total of 174 pairs of double-crested cormorants nested on eight channel markers located in the upper estuary near Miller Sands Spit. In 2007, 155 cormorant pairs nested on the same channel markers. Peak nest counts on individual markers were recorded during 8 May - 25 July in 2008. The asynchrony in nesting chronology among the different channel marker colonies was likely due to differences among channel marker colonies in the incidence of disturbance and predation by bald eagles.

In 2008, we again observed double-crested cormorants nesting on the Astoria-Megler Bridge, immediately south of the established pelagic cormorant (*Phalacrocorax pelagicus*) colony on the bridge. During boat-based censuses on 12 May and 28 June, 10 and 20 nests were attended by double-crested cormorants, respectively. In 2007, 11 nests with attending double-crested cormorants were confirmed during boat surveys in June.

In 2008, double-crested cormorants were successfully attracted to an experimental social attraction plot created on the downstream end of Miller Sands Spit in the upper estuary. Habitat enhancement through preparation of nesting substrate (old tires) and placement of cormorant decoys for social attraction (no audio playback systems were deployed) were used to encourage nesting on the island. Approximately 129 breeding pairs of double-crested cormorants nested on the Miller Sands Spit experimental plot site. No chicks were successfully fledged from the experimental plot due to colony abandonment in early June, most likely due to either human disturbance or bald eagle disturbance.

2.1.2. Columbia Plateau

*Methods*: To estimate the size of the double-crested cormorant colony on Foundation Island in 2008 (Map 3), periodic boat-based and land-based counts of attended nest structures were conducted off the eastern shore of the island. To improve nest count accuracy 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 2008.

Periodic boat- and land-based surveys were conducted at sites where cormorant nesting had been reported previously, such as the mouth of the Okanogan River (referred to as the "Okanogan colony") and in Potholes Reservoir within the North Potholes Reserve (referred to as the "North Potholes colony"; see Map 2). At each site we counted attended nests to obtain a rough estimate of the number of breeding pairs at each colony. We also flew aerial surveys of the lower and middle Columbia River from The Dalles Dam to Rock Island Dam, and of the lower Snake River from the confluence with the Clearwater River to its mouth, searching for new double-crested cormorant colonies.

*Results and Discussion*: In 2008, the double-crested cormorant colony on Foundation Island consisted of a minimum of about 360 pairs, the largest cormorant colony on the mid-Columbia River. Size of the double-crested cormorant colony at Foundation Island has been trending upward since monitoring began in 2002 (Figure 28). In contrast, the number of Caspian terns nesting on nearby Crescent Island has been declining over this same period (Figure 6). As was the case in previous years, all cormorant nests at this colony were in trees at the south end of the island.

In 2008, the largest cormorant colony in the entire Columbia Plateau Region was on Potholes Reservoir in the North Potholes Reserve (ca. 1,000 breeding pairs), roughly similar in size to the previous two years. Cormorants at this colony nest in trees that are flooded for much of the nesting season. In general, this colony has been increasing in size over the last decade but 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 near the colony.

Based on our counts of cormorant nests at the Okanogan colony, we estimate that there was a minimum of 33 nesting pairs at that colony in 2008 up from the previous year (10 nesting pairs).

Aerial surveys of the lower and mid-Columbia River and lower Snake River revealed one new double-crested cormorant colony in 2008; on Harper Island in Sprague Lake (see Map 2). We estimate that there was a minimum of 38 nesting pairs on Harper Island in 2008, an island that is also home to a large California/ring-billed gull colony and a small Caspian tern colony. The one new cormorant colony discovered in 2007 (in a tree on the east bank of the Columbia River in the Wahluke Unit of the Hanford Reach National Monument) had been destroyed by wildfire and was not active in 2008. There still appears to be a fairly sizable non-breeding population of cormorants on the Columbia Plateau, with roosts of breeding and non-breeding birds observed at the mouth of the Yakima River and at several of the mid-Columbia and lower Snake River dams.

#### 2.1.3. Coastal Washington

*Methods:* In 2008, we counted cormorant nests on channel markers in Grays Harbor, WA during three aerial survey flights between late April and early July. No boat-based surveys of cormorant nesting success were conducted in Grays Harbor during 2008.

*Results and Discussion:* We counted a total of 52 cormorant nests on 11 different channel markers during aerial surveys in Grays Harbor. Because we did not visit Grays Harbor by boat later in the breeding season (after hatch and near the fledging period), we were unable to assess nesting success for cormorant nests located on channel markers in Grays Harbor during 2008.

### 2.2. Nesting Chronology and Productivity of Double-crested Cormorants

#### 2.2.1. Columbia River Estuary

*Methods*: Two elevated blinds located at the periphery of the East Sand Island cormorant colony were used to observe nesting cormorants in 2008 (Map 4 for blind locations). The blinds were accessed via above-ground tunnels to prevent disturbance to nesting cormorants and gulls, as well as roosting California brown pelicans (*Pelecanus occidentalis californicus*), an endangered subspecies. In 2008, 129 individual cormorant nests in 5 separate plots were monitored for productivity. Visual 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 – 8 times each month) from a boat.

*Results and Discussion*: In 2008, double-crested cormorants arrived at the East Sand Island colony later than in any other year since 2003 (Figure 29). Despite the late arrival, the dates of the first cormorant egg, chick, and fledgling in 2008 were within the range of dates observed in previous years (Figure 29).

We estimate that 24,704 fledglings (95% c.i. = 22,644 – 26,764 fledglings) were produced at the East Sand Island colony in 2008. This corresponds to an average productivity of 2.26 young raised per breeding pair (95% c.i. = 2.10 - 2.42 fledglings/breeding pair). Nesting success at the East Sand Island double-crested colony has trended upward since we first started collecting data there in 1997 (Figure 30). Nesting success declined somewhat in 2008 compared to the previous year (Figure 30), but nesting success at the East Sand Island cormorant colony in 2007 was the highest recorded in the previous decade. Recent improvements in ocean conditions may have contributed to above average nesting success at the East Sand Island cormorant colony.

Confirmation of eggs in nests on the channel markers in the upper Columbia River estuary was not possible from our vantage on the water, but small chicks (7-14 days post-hatch) were observed on markers on 12 June in 2008, which is later than the nesting chronology of cormorants on East Sand Island. Nests on the Astoria-Megler Bridge were likely initiated later than nests on East Sand Island or the upper estuary channel markers; chicks were observed during our boat survey on 28 June. Due to our poor vantage and infrequent visits, we were unable to estimate nesting success for either the nests on the upper estuary channel markers or on the Astoria Bridge.

2.2.2. Columbia Plateau

*Methods*: In 2008, we monitored 50 cormorant nests on Foundation Island each week from the observation blind (see Map 3). Productivity was estimated from the number of chicks in monitored nests at 28 days post-hatching. Because of the distance of the blind from the colony and our vantage below the elevation of the nests, we assumed that chicks were approximately 10 days old when first observed.

*Results and Discussion*: In 2008, Foundation Island cormorants were on-colony earlier, but laid eggs and hatched chicks later than during the previous 2 years (Figure 31). The first chick was observed at the Foundation Island colony on 22 April (Figure 31), more than a month before the first cormorant chick was observed on East Sand Island (Figure 29). Productivity on Foundation Island was moderate in 2008 (1.94 ± 0.14 fledglings/nest), less than in 2007 or 2005 (2.23 ± 0.16 and 2.30 ± 0.13 respectively) but higher than in 2006 (1.37 ± 0.17 fledglings/nest; Figure 32).

## 2.3. Diet Composition and Salmonid Consumption of Double-crested Cormorants

### 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 fore-gut (stomach and esophagus) samples per week. Immediately after collection, the cormorant's abdominal cavity was opened, the fore-gut removed, and the contents of the fore-gut emptied into a whirl-pak. Each fore-gut 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 fore-gut samples were identified to genus and species, whenever possible. Intact salmonids in fore-gut samples were identified as Chinook salmon, sockeye salmon, coho salmon, steelhead, or unknown based on otolith[1] and/or genetics[2] analyses. Unidentifiable fish soft tissue samples were artificially digested (work that is ongoing) according to the methods of Peterson 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 included 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 for the East Sand Island cormorant 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.

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

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[1] Susan Crockford and staff at Pacific Identifications, Inc. (Victoria, B.C.) conducted the otolith analysis used to identify salmonid species found in diets of piscivorous waterbirds.

[2] Genetic analyses were conducted by NOAA Fisheries (POC: David Kuligowski) at the Manchester Field Station genetics laboratory. Species identifications were carried out by amplifying (PCR) the mitochondrial DNA fragment COIII/ND3 as outlined in Purcell et al. (2004). 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).

other than late incubation, when the colony is largest). In past years we have used estimates of colony size made from blinds or from boats just off shore. Such estimates are limited due to poor visibility of birds behind vegetation, debris, and other birds. In 2008 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 cormorant colony was taken 9 times (including the late incubation photography). To count active nests in these additional aerial photographs of the East Sand Island cormorant colony (s well as to count aerial photography of other colonies of terns, gulls, etc.), we developed a GIS-equipped computer workstation where digitized photos could be viewed and birds counted. Counts of birds in these photos are pending and will be presented in a subsequent report.

Estimates of smolt consumption by the East Sand Island cormorant colony in 2008 are pending and will be presented in a subsequent report.

*Results and Discussion*: Based on identifiable fish tissue in fore-gut samples, juvenile salmonids comprised 11% of double-crested cormorant diets (by mass) at East Sand Island in 2008 (n = 128 adult fore-gut samples or a total of 21,069 grams of identifiable fish tissue). The annual proportion of juvenile salmonids in the diet of double-crested cormorants nesting on East Sand Island has remained relatively stable (ca. 10%) in the last three years (Figure 33). The proportion of salmonids in the diet of East Sand Island cormorants was highest in 1999 (about 25%) and lowest in 2005 (about 2%; Figure 33). The diet of double-crested cormorants, which feed throughout the water column, is more diverse at East Sand Island (Figure 34) than that of Caspian terns nesting on the same island (Figure 11). On average, anchovy is the single most prevalent prey type for cormorants, followed by various marine and freshwater taxa. In 2008, the prey category "other" consisted of 7 different taxa, all less than 7% of the diet, with the exception of stickleback, which was 14% of the diet. The peak in the proportion of salmonids in the diet of double-crested cormorants nesting on East Sand Island in 2008 came later (in late May) compared to previous years and remained higher than average in late July (Figure 35), when primarily fall Chinook were being consumed. This result, which was also observed in diets of Caspian terns nesting on East Sand Island (Figure 12), is due in part to a delay in run timing of smolts in 2008, relative to previous years.

Annual smolt consumption by double-crested cormorants nesting on East Sand Island has been trending upward since 2003 (Figure 36). Estimates of total smolt consumption by East Sand Island cormorants in 2008 are pending, but in 2007 East Sand Island cormorants consumed about 9.2 million juvenile salmonids (95% c.i. = 4.4 – 14.0 million), similar to the 2006 estimate (9.1 million smolts; 95% c.i. = 4.1 – 14.2 million). Current estimates of smolt consumption by East Sand Island cormorants are now equivalent to, or exceed, that of Caspian terns nesting on East Sand Island. Of the juvenile salmonids consumed in 2007, we estimate that 44% were sub-yearling Chinook salmon (best estimate = 4.1 million; 95% c.i. = 1.9 – 6.3 million), 29% were coho salmon (best estimate = 2.7 million; 95% c.i. = 1.0 – 4.3 million), 14% were steelhead (best estimate = 1.3 million; 95% c.i. = 0.6 – 2.1 million), 12% were yearling Chinook salmon (best estimate = 1.1 million; 95% c.i. = 0.4 – 1.7 million), and < 1% were sockeye salmon (best estimate = 0.03 million; 95% c.i. = <0.01 – 0.05 million; Figure 37).

Twenty-four individual salmonids that were removed from the stomachs of 7 cormorants collected at East Sand Island during 2007 were identified to species and, for Chinook salmon, stock of origin. Chinook salmon were the most frequent salmonid in the cormorant stomach samples (38% of identified salmonids), followed by steelhead (33%) and coho salmon (25%). One cutthroat trout (4%) was also identified. Chinook salmon from cormorant stomachs that were identified to stock included Snake River spring Chinook, Spring Creek Group fall Chinook, and West Cascade Tributaries spring Chinook. Ongoing collaboration with David Kuligowski at NOAA Fisheries will allow us to more precisely identify the salmonid portion of the cormorant diet, both at East Sand Island (by processing samples from additional years and including samples with genetic materials extracted from bone) and at other cormorant colonies on the Columbia River (i.e., the Foundation Island colony on the mid-Columbia River). These more precise breakdowns of the taxonomic composition of the salmonid portion of the diet will enhance our ability to estimate the numbers of salmonids consumed by species and type using the bioenergetics modeling approach.

2.3.2. Columbia Plateau

*Methods*: During the 6-week period (early May to mid June) when nestlings were being fed by their parents at the Foundation Island cormorant colony, we lethally sampled adult cormorants commuting back to the colony from a foraging bout. A total of 45 adult cormorants were sampled on four different occasions (n = 7 on 6 May, n = 10 on 21 May, n = 10 on 5 June, and n = 9 on 20 June) and contents of their fore-gut and other tissues were sampled. All diet samples were analyzed in our laboratory at Oregon State University to investigate the diet composition of cormorants nesting on Foundation Island in 2008.

In 2007, using diet composition data from lethally-sampled adult cormorants, we were able to estimate salmonid consumption for the Foundation Island cormorant colony using a bioenergetics modeling approach (after the Caspian tern model described in Roby et al. 2003). At present, data to breakdown salmonid consumption into individual species and numbers of smolts consumed are not available, so we estimated consumption in units of salmonid biomass consumed and compared to salmonid biomass consumed by the Crescent Island Caspian tern colony. Bioenergetics estimates of smolt consumption by double-crested cormorants nesting on Foundation Island in 2008 are not yet available and will be presented in a subsequent report.

*Results and Discussion*: Salmonids made up 45% of identifiable prey biomass in the fore-gut contents of the 45 collected adults. The proportion of juvenile salmonids in the stomach contents samples collected from double-crested cormorants nesting on Foundation Island in 2008 was considerably higher than observed in 2006 or 2007 (Figure 38). At least some of this apparent increase is an artifact of sample timing; in

2008 diet samples were not collected in late April, when the proportion of juvenile salmonids in the diet is typically low. On average, centrarchids (specifically bass and sunfish) are the most prevalent single prey type for double-crested cormorants nesting on Foundation Island, followed by catfish and salmonids (Figure 39). In 2008, more salmonids and centrarchids and fewer catfish, cyprinids (specifically carp and minnows), and suckers were consumed compared to previous years (Figure 39). In 2008, the peak in the proportion of salmonids in the diet of double-crested cormorants nesting on Foundation Island apparently occurred in early May and remained high through May, compared to previous years (Figure 40). In general, the proportion of juvenile salmonids in the diet of Foundation Island cormorants varies widely across the nesting season, ranging from 20-85% in May to 0-7% in June (Figure 40). These diet composition results should be interpreted cautiously, however, because they are based on small sample sizes.

Bioenergetics modeling suggested that cormorants nesting at Foundation Island consumed 10.9 Mg (million grams) of salmonids (95% c.i.: 7.6 – 14.3 Mg) in 2007. This was similar to that consumed by Crescent Island terns (point estimate: 12.0 Mg; 95% c.i.: 8.5 – 15.6 Mg) in the same year. Despite salmonids making up a much smaller portion of the diet of Foundation Island cormorants (16%) compared with Crescent Island terns (69%), the larger body size and brood size of cormorants, and the consequent greater food requirements per breeding adult, caused smolt consumption by the cormorant colony to approach that of the tern colony (95% CI: 250,000 – 460,000 smolts). Bioenergetics estimates of smolt consumption by Foundation Island double-crested cormorants in 2008 are not yet available and will be presented in a subsequent report.

### 2.4. Salmonid Predation Rates by Double-crested Cormorants

#### 2.4.1. Columbia River Estuary

*Methods:* The recovery/detection of smolt PIT tags on cormorant colonies is more difficult than on Caspian tern colonies. Unlike Caspian terns, which nest primarily on bare sand, cormorants nest in a wide array of habitat types, such as in trees, on the ground amongst vegetation and woody debris, on rip-rap, on bridges, and on channel markers. This poses significant challenges for the on-colony recovery or detection of PIT tags egested by nesting cormorants. Previous measures of detection efficiency at the East Sand Island cormorant colony have been less than 40% (B. Ryan, NOAA Fisheries, unpublished data). To improve the efficiency of PIT tag recovery at the East Sand Island cormorant colony, we prepared cormorant nesting plots within the boundaries of the colony and used social attraction techniques to encourage cormorants to nest in the plots (see Section 2.5 for details regarding social attraction). We reasoned that if we could attract cormorants to nest in the plots, the detection efficiency of smolt PIT tags within the plots would be considerably greater than the colony as a whole. Furthermore, if we knew how many cormorant breeding pairs nested in each plot, we could calculate an accurate per-capita PIT tag consumption rate for East Sand Island cormorants, which could be used, along with our estimate of colony size, to estimate total consumption of PIT-tagged smolts by cormorants nesting on East Sand Island.

Prior to the 2008 breeding season, we set up four cormorant nesting plots (each measuring 10 m x 5 m) near the observation tower at the west end of East Sand Island (Map 4). A 4-m wide trench was dug around each plot to discourage birds from nesting immediately adjacent to the plots. Each plot contained old truck and car tires with cormorant stick nests from the 2007 nesting season or fine woody debris, providing nest sites for cormorants in each plot. Cormorant decoys were also placed on the plots to further encourage nesting. Nesting chronology, number of breeding pairs, and nesting success of cormorants on each plot were recorded throughout the nesting seasoning (April to September). Detection efficiency for PIT tags on the plots (a parameter needed to adjust/correct PIT tag recovery results; see Section 1.4.1) was measured by sowing test PIT tags (n = 400 for the plots and n = 200 for the trenches) at two different times: before nest building (5 April) and immediately following fledging (9 September), with equal numbers of tags sown during each time period. In addition to sowing test tags on the plots, test tags were also sown (n = 200) on the larger cormorant colony to test our hypothesis that detection efficiency is higher on the plots relative to the colony at large. Test tags were sown on two different habitat types used by nesting cormorants on East Sand Island: boulder rip-rap and bare sand. Tags were sown haphazardly within the two different habitat types. Similar to tags sown on the plots, test tags spread on the colony were sown at two different times: before nest building (5 April) and immediately following fledging (9 September).

PIT tags were recovered following the nesting season by NOAA Fisheries using hand-held electronic scanners (see Sebring et al. 2008 for details). Estimates of predation rates were generated using the methods described in Section 1.4.2. Predation rates were adjusted for detection efficiency, but not deposition rate, and therefore are minimum estimates.

*Results and Discussion:* The detection efficiency of sown test PIT tags on the cormorant nesting plots averaged 87.0% (± 3.5; Table 3). Detection efficiency was 66.0% (± 7.9; Table 3) from tags spread haphazardly colony-wide onto rip-rap and bare sand nesting habitat; this finding supports our hypothesis that tag recovery from specially-designed nesting plots is greater than from the habitat types where cormorants typically nest on East Sand Island.

A total of 21,320 salmonid PIT tags from 2008 migration year smolts were recovered from the double-crested cormorant colony on East Sand Island by NOAA Fisheries in 2008 (Table 2). Of these tags, 68.4% were from Chinook salmon (including sub-yearlings and yearlings), 29.3% from steelhead, 2.1% from coho salmon, and 0.2% from sockeye salmon. As observed in previous years, the relative proportions of PIT tags from different salmonid species recovered on the East Sand Island cormorant colony were similar to the proportions of different salmonids PIT-tagged and released throughout the Columbia Basin in 2008 (ca. 76.1% Chinook, 19.6% steelhead, 3.7% coho, and 0.5% sockeye), suggesting that cormorants consume salmonids in similar proportions to their relative abundance. Some preference towards steelhead was evident in 2008, but due to uncertainties regarding the relative survival of various species and groups of PIT-tagged smolts from their release location to the estuary, the relative proportions of PIT-tagged smolts at release are only rough approximations of relative abundance in the estuary. Nonetheless, the data suggest that cormorants are less selective and more generalist predators compared to Caspian terns, which consume steelhead smolts in much greater proportion to their relative abundance (see Section 1.4.2).

Per-capita PIT tag consumption by East Sand Island cormorants was estimated to be 1.7 tags per breeding adult (Table 5), based on the total number of PIT tags recovered from the plots (n = 1,043; corrected for detection efficiency) and the number of breeding birds in the plots (n = 610). Based on this estimate of per-capita PIT tag consumption by East Sand Island cormorants and our overall estimate of colony size (21,900 breeding adults), we estimate that cormorants deposited ca. 37,449 tags on the colony during the 2008 nesting season. This suggests that colony-wide detection efficiency was approximately 57.2% (21,320/37,246) in 2008, the highest detection efficiency value recorded for this colony to date. The estimated total number of PIT tags from salmonids deposited on the East Sand Island cormorant colony in 2008 (ca. 37,246) was significantly greater compared to 2007 (ca. 16,250). Annual fluctuations in the number of PIT tags detected on bird colonies are due mostly to variation in three factors: (1) the number of PIT-tagged fish available, (2) colony size and productivity, and (3) the preponderance of juvenile salmonids in the diet of avian predators. For example, 1.6 times as many PIT-tagged fish were released in 2008 compared to 2007 and the proportion of salmonid smolts in the cormorant diet (based on foregut contents; see Section 2.3.1) was 1.3 times higher in 2008 relative to 2007. As such, it is not surprising the total number of salmonid tags deposited on the East Sand Island cormorant colony was higher 2008 relative to 2007, despite the smaller size of the cormorant colony in 2008.

Estimates of predation rates based on PIT-tagged smolts released from barges below Bonneville Dam or detected passing Bonneville Dam indicated that steelhead and fall Chinook salmon smolts were the most vulnerable to predation from East Sand Island cormorants (Table 4). Results for coho and sockeye salmon, particularly wild smolts, are limited by small sample sizes, but averaged 2.5% and 2.6% for each species, respectively (Table 4). It should also be noted that most of the coho smolts in the Basin originate below Bonneville Dam and were generally not PIT-tagged in 2008. Data from the limited number of PIT-tagged fish that were released downstream of Bonneville indicated predation rates were generally higher on those stocks relative to inland stocks last detected passing Bonneville Dam. For example, predation rates of 12.6% (n = 2,112) and 39.1% (n = 12,958) were observed for hatchery coho and hatchery fall-run Chinook smolts released into rivers within 40 Rkm of the mouth of the Columbia River. Again, similar data from wild, ESA-listed smolts from the lower Columbia or Willamette rivers are generally lacking because of the very small number of smolts PIT-tagged in these runs.

2.4.2. Columbia Plateau

*Methods*: In 2008, PIT tags were recovered at the Foundation Island double-crested cormorant colony in order to calculate smolt predation rates. The methods used to generate these estimates were similar to those described for Crescent Island terns (see

Section 1.4.2). Unlike the Crescent Island tern colony, however, test tags used to evaluate detection efficiency were not sown on discrete plots within the colony because double-crested cormorants nest in trees on Foundation Island. Instead, test tags (n = 400) were sown haphazardly under nesting trees on four different occasions: (1) prior to arrival of birds on the colony (14 March), (2) early in the chick-rearing period (2 May), (3) during fledging (7 June), and (4) after the birds had left the colony following nesting (25 July). Predation rates were corrected for PIT tag detection efficiency, but not deposition rate; consequently, these estimated predation rates are minimums. Furthermore, an unknown proportion of smolt PIT tags are likely retained within the arboreal nests (primarily from small chicks being unable to regurgitate castings outside the nest), a phenomenon that further reduces tag recovery and thus underestimates predation rates.

To address the concern that tag recovery is reduced by tags being retained in arboreal nests, we initiated a study whereby an artificial nesting platform was constructed on Foundation Island to improve our ability to recover PIT tags at this colony, similar to the plot approach used on East Sand Island (see Section 2.4.1). Prior to the 2008 nesting season, we constructed a platform elevated 14 feet above ground level, measuring 6 m x 6 m x 6 m, at the north end of the Foundation Island cormorant colony. The platform, which was covered with sand, contained 30 old tires filled with fine woody debris, and was surrounded by a 10-cm high side wall to prevent tags from blowing or washing off the platform during the nesting season. Cormorant decoys and two audio playback systems broadcasting sounds of a cormorant colony were used to attract nesting pairs to the platform. As was done underneath the nesting trees on Foundation Island, PIT tags (n = 200) were spread on the platform to measure detection efficiency.

*Results and Discussion*: Of the 400 test PIT tags sown on Foundation Island in 2008, 297 or 74.3% were subsequently recovered on-colony after the nesting season (Table 3). Detection efficiency ranged from as low as 68.0% for tags sown during the post-season period to 81.0% for tags sown during the chick-rearing period. For the fourth consecutive year, there was no evidence of a correlation between the Julian date when test tags were sown and detection efficiency ($R^2 = 0.1781$, $P = 0.5731$), indicating that test tags sown early in the nesting season were just as likely to be recovered as test tags sown late in the nesting season.

For the second consecutive year, no cormorants were attracted to nest on the artificial platform on Foundation Island in 2008. It is unclear why the platform was unsuccessful, especially because the height of the platform was similar to, although slightly lower than, the height of active cormorant nests on Foundation Island and the platform itself was less than 10 m from active nests. We know, however, that similar experiments in the Columbia River estuary (see Section 2.5.1) have demonstrated that cormorants may take several years before colonizing a new site where habitat enhancement and social attraction have been used. Based on this, we propose to repeat the experiment on Foundation Island in 2009. We also plan to increase the amount of woody debris on and near the platform with the hopes of making the structure appear more “tree-like”.

A total of 7,250 PIT tags from 2008 migration year smolts were recovered on the Foundation Island cormorant colony following the nesting season. These tags represent 0.4% of the in-river PIT-tagged smolts released upstream of McNary Dam. This proportion increased to 0.5% (n = 9,764) once the correction was made for PIT tag detection efficiency. Foundation Island cormorants consumed an estimated 1.3% (1,374/109,041) of all the PIT-tagged smolts interrogated while passing Lower Monumental Dam from 1 April to 31 July 2008. Like Crescent Island Caspian terns, predation rates were higher for Snake River and Middle Columbia Steelhead ESUs (ca. 1.8% and 2.9% for wild fish, respectively) relative to other species and run-types originating up-river of McNary Dam (Table 6). Predation rates on all other salmonid species and run-types were generally around 1.0% (Table 6). Predation, however, was surprisingly low on fish originating from the upper Columbia River ESUs (≤ 0.2% average for all species and run-types) relative to fish originating from the mid-Columbia river downstream of confluence of the Snake (ca. 1.3% average for all species and run-types). Of fish originating from this section of the mid-Columbia River, most predation was targeted on fish from the Walla Walla River, with predation rates as high as 6.2% for hatchery steelhead (Table 7).

Despite large seasonal fluctuations in smolt abundance in the lower Snake River, weekly predation rates on steelhead and Chinook salmon smolts (based on interrogation histories at Lower Monumental Dam) remained relatively constant throughout the cormorant nesting season (Figure 24). Weekly predation rates on PIT-tagged steelhead ranged between 2% and 4% throughout the 13-week nesting period (Figure 24), while weekly predation rates on Chinook salmon ranged from 1% to 2% for most weeks (although predation rate dropped off to less than 1% for the last four weeks of the nesting season; Figure 24). Although predation rates on steelhead and Chinook smolts remained relatively constant throughout the nesting season, this should not be interpreted as steady consumption throughout the nesting season. In fact, diet data collected from Foundation Island cormorants in 2008 indicates that the proportion of salmonids in the diet peaked during the peak period of salmonid out-migration in May (Figure 40), suggesting that Foundation Island cormorants consumed more fish during the peak out-migration period. Seasonal differences in the relative vulnerability of hatchery and wild PIT-tagged fish were observed, with hatchery smolts often (but not always) preyed upon at higher rates relative to their wild counterparts (Figure 24). These data will be analyzed in greater detail in the project's final report to the Corps.

Similar numbers of salmonid PIT tags were deposited on the Foundation Island cormorant colony (9,764 PIT tags) and the Crescent Island tern colony (11,432 PIT tags) in 2008 and the two colonies were roughly equal in size (ca. 360 pairs and 388 pairs, respectively). Consequently, estimated per-capita consumption of PIT-tagged smolts was similar for the two breeding colonies: 13.6 PIT-tagged smolts per nesting individual for Foundation Island cormorants and 14.7 PIT tagged smolts for Crescent Island terns. These were the two highest per-capita consumption rates for PIT-tagged smolts of all bird colonies in the Columbia River basin in 2008, including the colonies in the Columbia River estuary (Table 5). The number of PIT tags recovered, however, and the resultant estimates of predation rate by Foundation Island cormorants are now similar to those of

Crescent Island Caspian terns. Prior to the 2007 nesting season, the number of smolt PIT tags recovered on the Foundation Island cormorant colony was 50% to 80% less than the number recovered on the Crescent Island tern colony. The recent increase in the impact of the Foundation Island cormorant colony on smolt survival relative to the impact of the Crescent Island tern colony is likely associated with the slow but steady decline in the size of the tern colony (Figure 6), the gradual increase in the size of the Foundation Island cormorant colony (Figure 28), and the apparent increase in the proportion of juvenile salmonids in the diet of Foundation Island cormorants (Figure 38).

For the first time since 2002, PIT tags from bull trout (*Salvelinus confluentus*) were found on the Foundation Island cormorant colony. In total, five bull trout PIT tags were recovered following the 2008 nesting season. In 2002 a single bull trout PIT tag was recovered on-colony. Together, these six tags represent the only confirmed PIT-tagged bull trout found on a tern, cormorant, pelican or gull avian colony in the Columbia River basin since scanning was initiated in 1997. All five of the tags recovered in 2008 were from bull trout captured, tagged, and released in the Walla Walla River basin. Three of the five fish were from releases in 2007, while one fish was from a 2006 release and one from a 2008 release. In total, 4,778 PIT-tagged bull trout were captured and released into the Walla Walla River basin from 2006 to 2008, resulting in a minimum predation rate of just 0.15% (corrected for detection efficiency). PIT-tagged bull trout recovered on the cormorant colony ranged from 13 to 30 cm at the time of release. It is unknown, however, how large the fish were when they were actually consumed or where within the river they were consumed (e.g., in the mainstem Walla Walla River, in a tributary of the Walla Walla River, or in the Columbia River).

## 2.5. Management Feasibility Studies for Double-crested Cormorants

### 2.5.1. Techniques to Encourage Nesting

*Methods*: In 2008, we continued studies to test the feasibility of potential management techniques for reducing losses of juvenile salmonids to cormorant predation in the Columbia River estuary. This study seeks to determine whether habitat enhancement and social attraction techniques can be used to induce double-crested cormorants to nest in an area 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 outside the estuary, if deemed necessary by resource management agencies.

We continued using habitat enhancement (i.e., placement of old tires filled with nesting material) and social attraction techniques (i.e., decoys and audio playback systems; Kress 2000, Kress 2002, Roby et al. 2002) on a floating platform in Fern Ridge Reservoir, near Eugene, OR (see Map 2) in 2008. In 2007, we selected Fern Ridge Wildlife Area near Eugene, Oregon for this study because it supported significant numbers of cormorants during the non-breeding season and we were able to obtain permission to use a floating platform launched and anchored in the Fisher Butte impoundment cell #2, where public access is restricted. A floating platform, about 30 feet long by 15 feet wide, was assembled in 2007 from sections of floating dock material. Plywood sideboards about one foot high were attached to the sides of the floating platform to retain material on the platform. Forty-eight old tires were placed on the platform, and sticks and other fine woody debris were placed in each tire for nesting material. The floating platform was anchored in about four feet of water, about 500 feet from the nearest dike. The platform and tires with sticks were left in place after the 2007 season for the second year of the feasibility study in 2008. On 17 March, 2008, 38 hand-painted double-crested cormorant decoys were secured on the platform and two audio playback systems, each with two speakers, were placed on the platform, along with the solar panels and deep cycle batteries necessary to power the audio systems. The platform was checked from the dike once a week until mid-April and every other week thereafter throughout the season for any signs of cormorant nesting.

*Results and Discussion:* Cormorants did not attempt to nest on the floating platform and cormorants were not observed perching on the floating platform during the nesting season in 2008. Although small numbers of double-crested cormorants were observed in Fisher Butte cell #2 during April, larger numbers of cormorants (approximately 100 individuals) were only observed in Kirk Pond at the north end of Fern Ridge Lake, and mainly in March and April. Bald eagles were observed in the vicinity of the floating platform in Fisher Butte, and may have served as a deterrence for prospecting adult cormorants. Although public access to the area was closed during the nesting season, a person was observed walking through the area on at least one occasion, which also might have disturbed prospecting cormorants in the area of the floating platform.

*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 nested previously (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 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 successful cormorant nesting attempts had been recorded recently. Although habitat enhancement and social attraction techniques are effective in establishing double-crested cormorant breeding colonies at sites where nesting attempts have previously occurred, results from the two-year study at Fern Ridge Lake suggest that habitat enhancement and social attraction techniques may require several years to successfully attract cormorants to nest at sites with no prior history of cormorant nesting, especially if no well-established colonies exist nearby.

The efficacy of habitat enhancement and social attraction techniques to establish new cormorant colonies outside the Columbia River basin remains uncertain. Additional study will be required to fully evaluate this methodology as a means to reduce cormorant predation rates on juvenile salmonids in the Columbia River estuary. Developing methodologies to enhance the size of existing double-crested cormorant colonies, along with establishing new colonies using habitat enhancement and social attraction techniques, may be necessary to shift cormorants from the large and growing colony on

East Sand Island to alternative colony sites where ESA-listed salmonids are not as vulnerable to cormorant predation.

2.5.2. Techniques to Discourage Nesting

*Methods:* In 2008, we investigated two techniques to discourage nesting by double-crested cormorants on East Sand Island. The first technique, human disturbance, was used on a discrete portion of the breeding colony and only prior to the onset of egg-laying. The second technique, hazing with a green laser, was used on cormorants that were roosting on beaches adjacent to the colony, and not necessarily nesting.

Isolated human disturbance was tested as a potential method to discourage double-crested cormorant nesting on East Sand Island. On April 2, prior to the initiation of any breeding, a visual barrier (a fence of black plastic fabric, 1.5-m tall) was erected to isolate a small section of the eastern-most end of the double-crested cormorant colony. In 2007, this section of the colony was roughly 1,150 $m^2$ and was comprised of approximately 1,000 nests (ca. 7% of the 2007 colony size). An above-ground tunnel was built prior to the nesting season to allow researcher access to this area of the colony without detection by nesting cormorants. Beginning on 1 May, and on multiple occasions during the week immediately prior to the expected first laying of eggs, a single researcher emerged from the tunnel onto this section of the cormorant colony, thereby flushing cormorants from the area. The researcher remained in view of cormorants for a short period, initially less than 3 minutes, before withdrawing into the tunnel. During these disturbances, additional researchers situated at three different vantage points observed the reaction of the cormorants, recording the number of cormorants affected (including any non-target individuals) and the duration of absence from the disturbed area. Because this was a pilot study, the length and frequency of the disturbances was varied in order to achieve the desired impact. Disturbances ceased as soon as evidence of egg-laying was detected.

In addition to human disturbance, we tested the efficacy of a green laser (LEM50 laser torch) for dispersing targeted double-crested cormorants from roosting locations on East Sand Island. The laser was acquired in the first week of May, after double-crested cormorants had initiated egg laying; therefore, testing of the laser for hazing cormorants was limited to roosting individuals and flocks that were encountered off-colony. Technicians attempted to haze roosting cormorants daily and to vary the time of day, weather, range to target birds, and light conditions under which the laser was tested. We recorded the response of target individuals and flocks. Tests that resulted in a flushing response by some or all of the target cormorants were considered successful.

*Results and discussion:* For human disturbance tests, the limited ability to observe this section of the colony prior to the onset of disturbances did not allow us to accurately predict when the first cormorant eggs would be first laid. Consequently, our disturbances began after many cormorants within the study area were defending nest territories and had well-established pair bonds. A total of 6 human disturbances were carried out over three days prior to the observation of eggs in nests within the area.

We found that during this late pre-laying period, short duration human disturbance (< 5 minutes) successfully flushed cormorants from the area, but after the disturbance was terminated (i.e., the researcher re-entered the tunnel), the cormorants re-landed on the disturbed nesting area within two minutes. Human disturbance was most effective at keeping cormorants off the colony when maintained for extended periods of time and repeated frequently. Disturbances lasting longer than 10 minutes kept cormorants out of the nesting area for greater than 10 minutes. Additionally, when the disturbances were repeated directly after cormorants re-landed, the length of time the birds remained off the colony increased again. In order to preclude egg-laying by cormorants during this late pre-laying stage, disturbance duration and/or frequency would have to be much higher than was employed in this pilot study; (i.e., > 15 minutes/day or > 2 events/day. Presumably, initiating disturbance earlier in the pre-laying period would also be more effective in discouraging nesting.

The use of a fence as a visual barrier was successful at limiting the portion of the colony affected by human disturbance. Cormorants on the west side of the visual barrier were successfully screened from viewing the researcher when s/he was outside of the tunnel, but these cormorants did react at times to the alarm behavior of cormorants on the east side of the visual barrier, with an unobstructed view of the researcher. Occasionally, cormorants < 5 m to the west of the visual barrier flushed when target cormorants flushed. Within the targeted area, cormorants in view of the researcher consistently flushed.

Technicians monitoring the double-crested cormorant colony carried the green laser to and from the colony daily, but had limited success conducting tests of this technique. This was primarily due to the researchers' low encounter rates with roosting double-crested cormorants when traveling to and from the colony. Most tests were conducted on cormorants that were roosting on the north beach of East Sand Island with observers applying the laser from just inside or near the mouth of the low fabric tunnel used to access the main observation tower.

Seventeen tests with the LEM50 were completed, of which five were successful. All successful tests were done early or late in the day; three were done at 2100 or later, and two at 0840 and 0845. All of the successful tests were done at a distance to the roosting cormorants of 55 m or less; four successful tests were done at a distance of 30 m or less. For the successful test done at 55 m, only half of the target cormorants flushed, while the other half ran to the water. Cloud cover during successful tests was 40% or more. Three unsuccessful tests were conducted under conditions that resulted in successful flushing of cormorants on additional attempts at closer range (distances of 40 to 80 m). During one of these three tests (the one at 80 m), the cormorants saw the laser and ran away from it, but didn't flush. The remaining nine tests, all with no effect, were conducted between 09:20 and 18:46 under varying lighting conditions and distances.

*Conclusions:* Both of the disturbance measures that we tested were effective at flushing cormorants, but each was initiated too late in the breeding cycle to adequately determine its effectiveness to deter nest initiation and egg-laying. For human disturbance, we suspect that effects were limited because cormorants had already established a moderate to high level of commitment to nesting territories and pair bonds. Short duration (< 5 minutes) human disturbances were not effective at keeping cormorants off the colony for periods that were likely to inhibit nest initiation. However, we cannot be certain that short disturbances would not have been effective if initiated earlier in the breeding cycle. Future efforts to apply human disturbance to deter egg-laying on a portion of a double-crested cormorant colony should be initiated much earlier in the breeding cycle, before pair bonds and nest territories have been established.

As described by the manufacturer, the green laser was most effective in low light conditions. All tests that were successful in flushing double-crested cormorants were conducted early or late in the day under a minimum of 40% cloud cover. Under the conditions tested, the laser appeared to be most effective at close range (< 60 m) relative to its potential range, which according to the manufacturer may exceed 2 km. Preliminary field tests of the LEM (early in the day under low light) at a site in the Willamette Valley confirmed the unit is capable of flushing ducks from wetland areas at a distance of 500 m (P. Loschl, pers. comm.). Based on these results and the results of the human disturbance tests, any attempt to use green laser hazing to deter egg-laying on part of a colony should be: (1) initiated early in the breeding cycle, before pair bonds and nest territories have been established, (2) carried out during low light conditions before 08:30 and after 21:00 daily, at a minimum, and (3) employed for as long as necessary to clear the target area of any prospecting, pre-breeding cormorants.

### 2.6. Post-breeding Distribution and Diet of Double-crested Cormorants on the Columbia Plateau

Unlike Caspian terns, which depart the Columbia Basin during the non-breeding season, some double-crested cormorants over-winter on the Columbia and Snake rivers. Over-wintering cormorants could potentially affect the survival of hold-over fall Chinook salmon smolts, particularly in the Snake River. Genetic analysis of salmonid tissues found in cormorant stomachs sampled in 2007 confirmed that fall Chinook were present, although they were not the most common salmonid species and run-type identified.

*Methods*: In 2008 we continued and expanded upon a pilot study initiated in 2007 to determine the distribution, behavior, and diet composition of double-crested cormorants during the post-breeding season. Research in 2007 indicated that several hundred cormorants were over-wintering on the lower Snake River and could potentially be reducing the survival of hold-over fall Chinook in the region. To further assess these impacts, we conducted monthly boat surveys to count the number, location, and behavior (roosting, foraging, or in-flight) of cormorants on the lower Snake River from October 2008 to February 2009. Boat surveys were conducted from the Snake River near Clarkston, WA to its confluence with the Columbia River near Pasco, WA. This entire 224-km river segment was delineated into five river reaches separated by the four hydroelectric dams on the lower Snake River. At the end of each monthly river survey, approximately 15 cormorants were lethally collected between Lower Monumental and Lower Granite dams (the river reach with the highest numbers of cormorants) in order to assess diet composition. Foregut samples collected from these cormorants were processed and analyzed as described in Section 2.3 of this report. In addition to boat-based counts, opportunistic counts of roosting and foraging cormorants at Lower Monumental and Lower Granite dams were conducted by biologists with the U.S. Army Corps of Engineers from September 2008 to February 2009.

*Results and Discussion*: Double-crested cormorants were observed in all five river reaches during the five-month study (Table 8). On average, 281 cormorants were observed on the lower Snake River, with the highest concentrations of cormorants observed between Little Goose and Lower Granite dams (Table 8). Overall there was a decreasing trend of cormorants observed as the winter progressed, with the maximum number counted in November (n = 395) and the minimum number counted in February (n = 161; Table 8).

At the dams, cormorants used the navigation lock walls, log booms, trash-shear walls, and spillway guide walls to roost and stage before foraging. The maximum number of cormorants counted at each dam varied both spatially (i.e., forebay versus tailrace) and temporally. Counts of cormorants ranged from 1 – 38 in the forebay and from 8 – 20 in the tailrace at Lower Granite Dam (based on counts conducted by USACE biologists at Lower Granite Dam). At Lower Monumental Dam, counts of cormorants ranged from 0 – 17 in the forebay and from 9 – 90 in the tailrace (based on counts conducted by USACE biologists at Lower Monumental Dam). More cormorants were observed in the forebay of both dams early in the season. Later in the season this remained true at Lower Monumental, but not at Lower Granite, where cormorants became more numerous in the tailrace than the forebay. The distribution of cormorants at dams relative to areas away from the dam also changed as the season progressed, with fewer cormorants observed in close proximately (within 2 Rkm) of the dams later in the winter (Table 9). In fact, the majority of cormorants observed during the study were seen at locations several kilometers away from the dams regardless of the month (Table 9). Cormorants commonly used bridges, channel markers, trees, and other semi-submerged woody debris in areas away from dams to roost and stage before foraging.

In addition to collecting data on double-crested cormorants, we also enumerated the abundance of other piscivorous waterbirds during each river survey. The most commonly observed piscivorous waterbird species were California and ring-billed gulls (seasonal average = 405), followed by double-crested cormorants (seasonal average = 281) and western and Clark's grebes (seasonal average = 274; Table 10). Smaller numbers of American white pelicans and common mergansers were also observed throughout the course of the study (Table 10).

Based on identifiable fish tissue in foregut samples (n = 57), juvenile salmonids comprised 12.5% by mass of the diet of double-crested cormorants foraging between Lower Monumental and Lower Granites dams during the winter of 2008-09 (Table 11). Centrarchids (sunfish and smallmouth bass) were the most abundant fish found, representing 28.8% of prey biomass, followed by cyprinids (minnows and carp) at 13.4% (Table 11). Centrarchids were the predominate prey type in most months, with the exceptions of salmonids in November (ca. 37.8% by mass) and juvenile shad in December (ca. 39.9% by mass; Table 11). The highest proportions of salmonids were found in cormorants foraging near Lyons Ferry Hatchery and the mouth of the Tucannon River.

The proportion of salmonid smolts found in the diet of cormorants in 2008-09 was similar to that of 2007 (ca. 11.8% salmonids by mass; CBR 2008). In 2007, juvenile shad were the most prevalent prey type found in foregut contents (ca. 47.7% of prey biomass; CBR 2008), while in 2008 shad comprised only 10% of the cormorant diet. Genetic analysis of four salmonid smolts found in 2007 samples confirmed that one of the fish was a fall Chinook. The remaining fish consisted of two coho (presumably hatchery fish) and one large (> 170 grams) rainbow trout (possibly a hold-over wild or hatchery steelhead); suggesting that among salmonids, fall Chinook may not be the most abundant prey type consumed. In 2008, a total of 10 salmonid smolts were collected from cormorant stomach contents. Tissue samples from these fish have been submitted for genetic analysis and results are pending.

Results from 2008 and 2007 suggest that moderate numbers of cormorants over-winter in the lower Snake River, with the highest numbers over-wintering between Little Goose and Lower Granite dams during the months of October and November. Diet data suggests that salmonids make up a small proportion (< 15%) of cormorant diets. It should be noted, however, that the diet composition results from 2007 and from 2008-09 are based on small sample sizes. Additional diet data from the winter of 2009-10 (our third and final year of this study) and genetic analysis of salmonid smolts from cormorant stomachs collected in 2008-09 and 2009-10 will allow a more reliable evaluation of system-wide and seasonal impacts of cormorants over-wintering on the lower Snake River.

### 2.7. Post-breeding Movements and Dispersal of Double-crested Cormorants from East Sand Island

*Methods:* In order to track post-breeding season movements and dispersal of double-crested cormorants from East Sand Island, a pilot satellite-tracking study was initiated during the 2008 breeding season. During June and July, 28 adult double-crested cormorants that were attending active nests were captured at East Sand Island, equipped with a transmitter, and released within 1 to 6 hours of capture. As this was the first effort to satellite-tag cormorants from this colony, we sought to identify the tag type and attachment configuration that were best suited for future studies involving satellite tagging. Seven satellite-tags in each of four configurations were deployed: (1) battery-powered, abdominally-implanted transmitters weighing 33 grams (expected battery life = ca. 6 months, (2) battery-powered, abdominally-implanted transmitters weighing 46 grams (expected battery life = ca. 11 months), (3) battery-powered, harness-attached transmitters weighing 60 grams, and (4) solar-powered, harness-attached transmitters weighing 60 grams. All satellite-tags were duty-cycled to collect nighttime roosting locations once weekly, with the exception of the solar-powered tags, which were programmed to collect nighttime locations 4 times weekly.

Surgical implantation of transmitters was performed by Drs. Scott Larsen and Jennifer Waldoch (University of California Davis). Cormorants were anesthetized and satellite transmitters were implanted into the abdomen with a percutaneous antenna protruding from the dorsal side of the cormorant near the pubic bone; after recovery from anesthesia birds were released on land (see Mulcahy and Esler 1999 for detailed methods).

Harnesses were constructed following Dunstan (1972) as modified by King et al. (2000). Briefly, harnesses were constructed with Teflon ribbon and consisted of two loops, one that encircled the body just below the neck and one that encircled the body at the abdomen. A strap connected the two loops on the ventral side of the bird. The transmitter sat on the dorsal side of the bird with the anterior end centered between the scapula, and with the two harness loops passing through built-in tubes at the anterior and posterior ends of the transmitter. D. Tommy King (USDA, National Wildlife Research Center, Mississippi State) traveled to East Sand Island to demonstrate and train our research group on harness attachment methods that have been used successfully to track double-crested cormorants during previous studies in the Midwest and Southeast regions of the U.S.

*Results and Discussion:* After 120 days the configuration with the highest percentage of tags that continued to provide locations was the harness-attached, battery-powered tags (86%), followed by the 33-gram implants (67%), the 46-gram implants (57%), and the solar-powered, harness-attached tags (0%). Some premature tag failure was expected, particularly as this was the pilot year for this study. The causes of early tag failures were difficult to pinpoint, but data from the tag's sensors and observations from the field provided some clues. Harness failure was not a likely cause of the early failure of solar-powered tags because the external battery-powered tags were deployed using the same harness design. It is possible that the PTT enclosures or solar panels were compromised as a result of pressure and/or abrasions/punctures incurred during foraging (cormorants are known for being rough on externally-attached PTTs); antenna breakage from preening may also have caused early failure of these tags. Cormorant mortality, harness or transmitter/battery failure, and antenna breakage are being investigated as potential causes of failure for all tag types. We will be able to more definitively identify the causes of failure and potentially make modifications for future deployments if previously tagged cormorants are re-sighted on the East Sand Island colony during the 2009 nesting season. Given the current results and evaluations of nesting success and behavior, the battery-powered, harness-deployed tags have been identified as the most suitable tagging option for tracking double-crested cormorants through the 2009 post-breeding season.

By the end of December 2008, double-crested cormorants tracked from East Sand Island had traveled north to estuaries along the Washington coast, the greater Puget Sound region, and along the Fraser River in British Columbia, Canada (Map 5). Cormorants also moved up the Columbia River to locations near Kalama, WA and Portland, OR (Map 5), and south to California in the San Francisco Bay region and inland along the Russian River near Duncan Springs (Map 6). Of locations outside the Columbia River estuary, Willapa Bay, WA was visited by the greatest number of individuals (n = 9), followed by Grays Harbor, WA (n = 6). Both the greater Puget Sound area (Puget Sound, and Harbo and Georgia straits) and the lower Columbia River between Kalama, WA and Gresham, OR were used by 5 individuals. Three cormorants traveled to California, two of which used roosting sites in the San Francisco Bay area and one that remained along the Russian River near Duncan Springs. Individual cormorants utilized the areas along the Fraser River (inland British Columbia), the Strait of Juan de Fuca, and inland Washington near Burlington. No tracked cormorants have traveled east of the Cascades to the Columbia Plateau or south of the San Francisco Bay area.

Preliminary analyses of tracking data show that during the breeding season (June – August) some cormorants, both those attending active nests and those whose nest had failed, traveled between roosting sites in the Columbia River estuary and estuaries along the Washington coast. Although some individuals moved north after their nest at East Sand Island failed, others appeared to remain resident within the Columbia River estuary for the duration of the breeding season and into the post-breeding season (i.e., no locations outside of region during the programmed on-cycles), despite the lack of nesting obligations at East Sand Island. By December 1st all tagged cormorants still being tracked (n = 10) had left the Columbia River estuary.

Although cormorants moved north to the estuaries along the Washington coast by early July and into the Puget Sound region within 1 to 3 weeks of being tagged, no cormorants moved south into California until November. Cormorants that utilized the Puget Sound region roosted on or near cormorant colonies that were active during 2008 (e.g., Viti Rocks, Mandarte Island, and a jetty near Blaine, WA), as well as historical cormorant breeding colonies (e.g., Bird Rocks). The three tagged cormorants that moved into California traveled no further north than Willapa Bay before migrating south. The > 800-km migration between the Columbia River estuary and roost sites in California were completed in less than a week (within one transmitter off-cycle), indicating that no roost sites between the Columbia River estuary and California were utilized for extended periods of time by tagged cormorants.

These preliminary data support the hypothesis that some double-crested cormorants nesting on East Sand Island originated from breeding colonies to the north along the coast of Washington, which is thought to have contributed to the rapid growth of the double-crested cormorant colony at East Sand Island. In addition, sites utilized by tagged cormorants may help to identify potential locations and/or suitable habitats for future colony enhancements to encourage nesting by double-crested cormorants, if redistribution of a portion of the population nesting in the Columbia River estuary to alternative colony sites outside the estuary is deemed necessary by resource management agencies. Finally, these preliminary data will contribute to the updated Status Assessment for Double-crested Cormorants, in that sites used by tagged cormorants that have not been previously surveyed or not surveyed in recent years will be added to 2009 cormorant survey routes being planned to complete this task. Data collection from tagged cormorants is ongoing; at the close of 2008 tracking data were still being collected from 5 satellite-tagged cormorants.

# SECTION 3: OTHER PISCIVOROUS COLONIAL WATERBIRDS

## 3.1. Distribution

### 3.1.1. Columbia River Estuary

*Gulls*: During land-based, boat-based, and aerial surveys in 2008, breeding colonies of glaucous-winged/western gulls (*Larus glaucescens/occidentalis*) and ring-billed gulls (*L. delawarensis*) were confirmed at several sites in the Columbia River estuary (Table 1). Glaucous-winged/western gulls nested on three islands in 2008: East Sand Island, Rice Island, and Miller Sands Spit; the East Sand Island colony was by far the largest of the three gull colonies in the estuary (Table 1). Ring-billed gulls, which previously nested on Miller Sands Spit (Collis et al. 2002a), now nest solely on East Sand Island within the Columbia River estuary (Table 1).

*California Brown Pelicans*: East Sand Island is the largest known post-breeding night-time roost site for California brown pelicans (*Pelecanus occidentalis californicus*), and the only known night roost for this ESA-listed endangered species in the Columbia River estuary (Wright 2005). In 2008, the first California brown pelicans were observed roosting on East Sand Island on 13 April. The number of brown pelicans roosting on East Sand Island peaked at about 12,395 on 9 September, the largest number of brown pelicans counted on East Sand Island to date. We observed breeding behavior by brown pelicans roosting on East Sand Island (i.e., courtship displays, nest-building, attempted copulations), but there was no evidence of egg-laying. Bald eagle activity was the most common source of non-researcher caused disturbance to brown pelicans roosting on East Sand Island in 2008.

*Brandt's and Pelagic Cormorants*: A small colony of Brandt's cormorants (*P. penicillatus*) consisting of 44 nesting pairs became established on East Sand Island amidst the double-crested cormorant colony in 2006. In 2007, this colony grew to 288 nesting pairs (Table 1), and grew again to 508 nesting pairs in 2008. This was the only site in the Columbia River estuary where Brandt's cormorants were known to nest. Formerly, a small breeding colony of Brandt's cormorants existed on a pile dike at the western end of East Sand Island, but this site was abandoned in 2006 because of storm damage to the pile dike during the winter of 2005-2006. Brandt's cormorants were first documented to nest on that pile dike in 1997, when a few pairs were found nesting there (Couch and Lance 2004).

About 111 nesting pairs of pelagic cormorants (*P. pelagicus*) nested on the Astoria–Megler Bridge in 2008. This is the only site in the Columbia River estuary where pelagic cormorants are known to nest (Table 1). 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

*Gulls*: Based on aerial, boat-based, and land-based surveys along the mid-Columbia and lower Snake rivers during the 2008 nesting season, gulls (primarily California and ring-billed) were confirmed nesting on five 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), Rock Island (river km 445), Crescent Island (river km 510), and Island 20 (river km 545; see Map 2 and Table 1). The large gull colony on Island 18 ([river km 553) was abandoned in 2008, due apparently to a combination of coyote disturbance and human disturbance. The gull colonies on Miller Rocks, Three Mile Canyon Island, Crescent Island, and Island 20 were the largest colonies identified along the mid-Columbia River in 2008 (Table 1). The California gull colony on Little Memaloose Island on the lower Columbia River (river km 315) was again inactive in 2008; his colony was last active in the late 1990's (Collis et al. 2002a; Map 2). No gull colonies were observed on the lower Snake River in 2008, nor has there been any confirmed breeding by gulls on the lower Snake River since our research began in 1997 (Collis et al. 2002a).

An unknown number of 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 in Banks Lake during 2008 (see Map 2 and Table 1).

*American White Pelicans*: We conducted boat-based counts of American white pelicans (*Pelecanus erythrorhynchos*) at the colony on Badger Island each week during the 2008 nesting season (Map 3). 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. Aerial photography was taken of the colony on 19 May during the incubation period in order to estimate colony size. Complete counts of the number of active pelican nests on Badger Island are not possible from the water because most nests are concealed by the thick, brushy vegetation on the island. Most, but probably not all, pelicans present on the island were visible in the aerial photography; however, we could not correct counts from aerial photography to estimate the number of breeding pairs (as with Caspian terns) because we were unable to obtain representative counts of incubating and non-incubating pelicans from the water. Thus counts of adult pelicans from the aerial photos are an index to the number of breeding pairs utilizing Badger Island, rather than a count of nesting pairs. In 2008 we refined the photo count process by using an in-house GIS workstation and conducting 3 independent counts of pelicans at the colony. 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 total of 1,327 adult American white pelicans were counted in the aerial photography taken on 19 May (SE = 11.3). This is a minimum count of adults present on the colony at the time of the photography. The pelicans were divided among four nesting areas on the island: 401 pelicans were counted near the middle of the eastern shore of the island, 154 and 144 pelicans were counted in two distinct groups in the interior of the middle of the island, and 503 pelicans were counted in an area near the northern (up-river) end of the island. The count of 1,327 adult white pelicans recorded in 2008 was the highest total ever recorded at Badger Island, exceeding the count of 1,310 white pelicans in 2006 (aerial photography was initiated in 2001, when 263 white pelicans were counted on the island). The 2008 count reversed the decline observed in 2007, when only 913 white pelicans were counted.

Our boat-based counts resulted in a maximum count of 510 adults on 16 May, and a maximum count of 225 juveniles on 25 July. Annual maximum counts of juvenile pelicans during boat-based surveys have ranged from 141 – 329 during the period 2002 – 2007, suggesting that nesting success in 2008 was moderate compared to previous years.

## 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 several years. Our previous research indicated that, in contrast to the gulls nesting at up-river locations (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 10.9% and 4.2% 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 2008, 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 16.6%; steelhead smolts were kleptoparasitized at a higher rate (27.2%) than salmon smolts (15.2%). 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.

Recoveries of PIT tags from plots set up within the glaucous-winged/western gull colonies at Rice Island and East Sand Island in 2008 suggest gulls in the estuary are consuming juvenile salmonids, albeit in smaller proportions relative to terns and cormorants. On Rice Island, a total of 19 salmonid PIT tags (from 2008 migration year smolts) were deposited by 28 adult gulls, yielding a per capita PIT tag consumption estimate 0.7 PIT tags per nesting adult. This was the second highest per capita estimate from a gull colony in 2008, second only to gulls nesting on Miller Rocks in The Dalles Pool (ca. 0.9 PIT tags per nesting adult). Of the 19 salmonids PIT tags deposited, 17 or 89.5% were steelhead. On East Sand Island a total of just 3 salmonid PIT tags were deposited by 30 nesting adults, yielding a per capita consumption estimate of 0.1. All three tags were from steelhead smolts. Small sample sizes limit the usefulness of these data in a broader context (e.g., to generate predation rates or to make comparisons regarding relative vulnerability of salmonid species to predation by gulls); additional research is planned for 2009.

*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.

*Brandt's and Pelagic Cormorants*: As part of this study, we did not collect diet data on Brandt's or pelagic cormorants nesting in the Columbia River estuary. 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 know 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.

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 several years. 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 up-river colonies in the late 1990's. The only up-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 stomachs; this colony is no longer extant) and Miller Rocks (3% of total biomass). Gulls from these colonies were known to prey on juvenile salmonids in the tailrace of The Dalles Dam (J. Snelling, OSU, pers. comm.). 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 in the late 1990's 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. Breeding adult terns may catch one to several fish on a successful foraging trip. 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 is brought back to the colony to feed its mate (pre-chick rearing) or young. These fish are subject to kleptoparasitism by gulls. In 2008 kleptoparasitism rates on salmonid smolts delivered by terns to the Crescent Island colony averaged 20.2%. As was observed at East Sand Island, kleptoparasitism rates were higher on steelhead smolts (38.5%) than on salmon smolts (18.0%), suggesting that gulls prefer, or find it easier, to steal larger fish. These rates are useful in evaluating the relative vulnerability of different smolts to gull kleptoparasitism, but they are not representative of the proportion of all smolts caught by terns that were stolen by gulls. 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 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 on the Columbia Plateau in 2008 corroborate our conclusion that the majority of gulls nesting at up-river locations pose little risk to salmonid survival (Collis et al. 2002a), with the possible exception of the California gulls nesting on Miller Rocks and Crescent Island (Table 5; see Section 3.3).

*American White Pelicans*: We do 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 white pelican colony, however, pelicans do not appear to be a significant source of smolt mortality (Table 5; see Section 3.3). Despite this, the Badger Island white pelican colony appears to be growing and there appears to be an increasing number of non-breeding white pelicans along the mid-Columbia River, where they are often observed foraging below mid-Columbia River dams (Tiller et al. 2003) and at sites in the Yakima River basin (A. Stephenson, Yakima Klickitat Fisheries Project, pers. comm.), presumably foraging on out-migrating juvenile salmonids. The total impacts of breeding and non-breeding white pelicans on survival of juvenile salmonids from some runs are not well understood.

### 3.3. Salmonid Predation Rates

*Gulls:* Salmonid PIT tags were recovered from six different gull colonies in the Columbia River basin in 2008: (1) Goose Island in Potholes Reservoir (off-river location; see Map 2), (2) Island 20 (Rkm 555 in the McNary Pool), (3) Crescent Island (Rkm 510 in the McNary Pool; see Map 2), (4) Miller Rocks (Rkm 333 in The Dalles Pool; see Map 2), (4) Rice Island (Rkm 34 in the Columbia River estuary), and (5) East Sand Island (Rkm 8 in the Columbia River estuary; see Map 2). These gull colonies were scanned for PIT tags because prior research indicated they were relative large, stable breeding colonies, known to consume juvenile salmonids. Tag recovery at Rice and East Sand islands was limited to small plots or sub-sections of the colony, while efforts at the other colonies were colony-wide (i.e., the entire surface area occupied by birds during the nesting season was scanned). Test PIT tags were sown (n = 200) prior to and immediately following the nesting season to measure detection efficiency at each of the colonies. The one exception was Goose Island, Potholes Reservoir, where tags spread on the tern colony (which is situated in the middle of the gull colony) were used as a surrogate measure of detection efficiency. PIT tags were recovered using hand-held electronic equipment and flat-plat detectors (see Section 4.1.1 for details). Similar to the analytical approach used for Foundation Island cormorants, estimates of predation rate estimates by gull colonies were adjusted for bias due to PIT tag detection efficiency, but not for deposition rate. As such, estimates of predation rates presented here are minimums.

*Results and Discussion*: A total of 5,142 PIT tags from 2008 migration year smolts were recovered from the six gull colonies and plots in the basin in 2008, with the largest number (n = 3,474 or 68.0% of all tags from gull colonies) found on the Miller Rocks gull colony in The Dalles pool (Table 2). The second largest number of tags was recovered from the Crescent Island gull colony (n = 1,444 or 28.1% of all tags from gull colonies; Table 2). Surprisingly small numbers of PIT tags were recovered from the large gull colonies on Goose Island, Potholes Reservoir (n = 66) and on Island 20 (n = 140) in the McNary Pool below Priest Rapids Dam. Scanning a small sub-sample of the Rice Island and East Sand Island gull colonies yielded 16 and 3 tags, respectively (Table 2). Tags from these two colonies, however, were from plots, so the small number is not indicative of colony-wide impacts on smolt survival.

Tag recovery results suggest that Crescent Island gulls consumed roughly 1/6$^{th}$ (1,965/11,432; adjusted for PIT tag detection efficiency) as many PIT-tagged smolts as Crescent Island terns and 1/5$^{th}$ (1,965/9,764; adjusted for PIT tag detection efficiency) as many as Foundation Island cormorants in 2008. Results suggest that Miller Rocks gulls consumed roughly 1/3$^{rd}$ (4,211/11,432; adjusted for PIT tag detection efficiency) as many PIT-tagged smolts as Crescent Island terns and 1/2 (4,211/9,764) as many as Foundation Island cormorants in 2008. Predation rates on salmonid smolts by Crescent Island gulls, however, were generally less than 0.5%, with the highest rate observed for hatchery steelhead originating from the Snake River (ca. 0.8%) and upper Columbia River (ca. 0.5%; Table 6). Based on smolt interrogations at John Day Dam (located just 12 Rkm ups-river of Miller Rocks), predation rates by gulls nesting on Miller Rocks were also marginal, with rates less than 0.5% for most species and run-types interrogated passing the dam. Two exceptions to this general rule were hatchery steelhead, where predation rate was 1.1%, and hatchery coho, where predation rate was 0.9%. These rates may be somewhat misleading, however, due to the proximity of the gull colony to the John Day Dam, making it feasible for birds to forage in both the tailrace and forebay of the dam (interrogated smolts used to derive predation rate estimates are only indicative of predation in the dam's tailrace).

Estimates of per-capita consumption of smolt PIT tags were twice as high for gulls nesting on Miller Rocks (ca. 0.9) compared to gulls nesting on Crescent Island (ca. 0.4; Table 5) and 10 times higher than that of gulls nesting on Island 20 (< 0.1; Table 5). Comparisons of per-capita consumption rates for gulls nesting on the Columbia Plateau suggest that gulls consume far fewer PIT-tagged fish per-capita compared to nearby tern and cormorant colonies (Table 5). The overall number of nesting gulls, however, on these colonies far exceeds that of terns and cormorants in the McNary Pool, and this should be taken into account when evaluating impacts on the survival of juvenile salmonids. Counts of the total number of gulls that nested on Rice Island and East Sand Island were not available, but counts of nesting gulls were made within the plots or sub-sections of the colony to generate per-capita consumption estimates. Estimates of per-capita PIT tag consumption were 0.7 (the second highest of the six gull colonies examined here) and 0.1 for Rice Island and East Sand Island gulls, respectively (Table 5). This indicates that gulls in the estuary are consuming salmonid smolts, but small sample sizes prohibit a meaningful comparison to gull colonies up-river. More research is needed in 2009 to evaluate the impacts of these estuary gulls colonies on smolt survival.

Of the gull colonies studied in this region in previous years (see Collis et al. 2001), both Miller Rocks and Crescent Island gull colonies were identified as colonies that consumed salmonid smolts in relatively high numbers compared to other gull colonies in the region. Effects of Crescent Island gull predation are associated in part with nesting Caspian terns, from which the gulls kleptoparasitize fish, while the effects of Miller Rocks gull predation are solely from the gulls foraging on smolts themselves. The surprising number of smolt PIT tag found on Miller Rocks in both 2007 (see CBR 2008) and 2008 suggests that the colony maybe negatively affecting salmonid smolt survival, especially when compared to other gull colonies in the region. None-the-less, the impacts are far less compared to those of the Caspian tern and double-crested cormorant colonies in the region.

*American White Pelicans*: Smolt PIT tags were recovered from the Badger Island American white pelican colony in order to estimate their impact on survival of juvenile salmonids in 2008. The methods used to generate these estimates were similar to those described for Crescent Island terns (see Section 1.4.2) and Foundation Island cormorants (see Section 2.4.2). Test PIT tags (n = 100 per release) were sown on both the southern and northern nesting areas on 13 March (prior to the nesting season) and on 14 November (when pelicans had completely abandoned the island after the nesting season). Test tags could not be sown on Badger Island during the nesting season, as white pelicans are very sensitive to human disturbance on the colony. PIT tags were recovered in November 2008, after birds had completely left the island following the breeding season. Similar to the analytical approach used for Foundation Island cormorants, predation rate estimates from the Badger Island pelican colony were adjusted for bias due to PIT tag detection efficiency, but not for deposition rate. As such, estimates of predation rates presented here are minimums.

*Results and Discussion*: Of the 200 test tags sown on the Badger Island pelican colony in 2008, 68.0% were subsequently recovered on-colony (Table 3). There was little evidence of difference between detection rates of tags sown pre-season (ca. 62.0%) and post-season (ca. 74.0%). Detection efficiency in 2008 was similar to that of 2007 (64.5%), 2006 (64.5%), and 2005 (58.0%).

An estimated 2,101 PIT tags (corrected for detection efficiency) from 2008 migration year smolts were deposited by white pelicans on Badger Island during the nesting season. These tags represent < 0.1% of all the PIT-tagged fish released into the Columbia River basin upstream of McNary Dam (excluding transported fish). Overall, Badger Island pelicans consumed just 94 (0.1%) of the PIT-tagged smolts interrogated passing Lower Monumental Dam on the lower Snake River from 1 April to 31 July. Estimated predation rates by Badger Island pelicans were similar to those of gulls on Crescent Island and the second lowest rate among bird colonies studied in McNary Pool during 2008 (Tables 6 and 7). Data suggest that sub-yearling Chinook salmon from the Columbia River (not listed) were the most vulnerable (ca. 3.8% predation rate; Table 7) to white pelicans nesting on Badger Island, followed by hatchery steelhead from the Snake River (ca. 0.3%; Table 6). The estimated per-capita consumption rate of PIT-tagged salmonid smolts by Badger Island pelicans (ca. 1.6) also suggested that the effects of white pelicans on survival of juvenile salmonids are minimal compared to most other piscivorous waterbirds investigated as part of this study (Table 5). Similar results and conclusions were drawn from the analysis of PIT tag recovery data from the white pelican colony during 2004 – 2007 (CBR 2007), although it should be noted that the number of PIT tags recovered on the colony continues to increase each year in concert with the growing breeding colony of American white pelicans on Badger Island (Figure 41).

## SECTION 4: STEELHEAD VULNERABILITY STUDY

In 2008 we continued and expanded upon a study initiated in 2007 to investigate how smolt morphology, condition, and origin might influence smolt vulnerability 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 river conditions and dam operations may be linked in some way to smolt vulnerability 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 vulnerability to avian predators. Steelhead were selected as the model species for this study because prior research has shown that they are the most vulnerable to predation by birds nesting on the Columbia River (Collis et al. 2001; Ryan et al. 2003; Antolos et al. 2005). The benefits of using steelhead for this study are three-fold: (1) we were 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 or run), (2) the incidence of morphological abnormalities (e.g., fungal infections, de-scaling, parasites, body injuries, etc.) tends to be greater in steelhead relative to other salmonid species (USACE, unpublished data), and (3) a better understanding of those factors responsible for the higher vulnerability of steelhead to avian predation will help resource managers implement measures to reduce avian predation on ESA-listed steelhead ESUs, if warranted and feasible. In addition, the tagging of steelhead as part of this study has the benefit of refining estimates of smolt predation rates (see Sections 1.4, 2.4, and 3.3) on run-of-the-river fish, including fish of varying conditions, origins, and stocks that constitute the Snake River and Upper Columbia River Steelhead ESUs.

Data presented for 2008, the second of a three-year study, are preliminary and incomplete until further research and analysis is conducted. For example, we are still compiling and analyzing environmental data regarding river conditions and dam operational strategies. Larger sample sizes and study replication are also needed before study results can be finalized and interpreted. Results from this study will be fully analyzed in the project’s final comprehensive report and in peer-reviewed journal publications, and should be considered preliminary at this time.

*Methods*: From 1 April through 3 July 2008, run-of-the-river steelhead smolts were collected and PIT-tagged at juvenile fish facilities located at Rock Island Dam, Lower Monumental Dam, and Ice Harbor Dam. At the Rock Island Dam juvenile fish facility, steelhead were sampled 6-7 days per week for 11 weeks starting in early April and ending in mid June. At the Lower Monumental Dam juvenile fish facility, steelhead were sampled 5-7 days per week for 13 weeks starting in early April and ending in early July. Steelhead were sampled 1-2 days per week at Ice Harbor Dam, from mid-April to late June. Sampling at all locations stopped when steelhead numbers were too low for productive sampling.

Steelhead were PIT-tagged, measured (mm, fork length), weighed (g), photographed, and placed in a recovery tank, where they were held up to 20 hours before being released into the dam's tailrace. Two general release times, morning and night, were used at each of three release locations to account for possible diurnal passage and predation effects. To reduce handling time, digital photographs were taken of each side of the steelhead, which allowed for subsequent detailed classification of external conditions by type and severity. We assessed the incidence and severity of different anomalies (e.g., external physical damage, disease, and parasite load) for each tagged fish. In addition, each fish was assigned to one of four overall condition ranks: excellent, 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: excellent = no noticeable external damage, de-scaling < 10%; good = minor external damage, de-scaling 10% – 50%; fair = open body injuries or fungal infection, parasite or external indications of a bacterial infection, de-scaling > 50%; and poor = substantial fungal infections, parasites, bacterial lesions or body injuries, clinical abnormalities that suggested the fish was moribund.

As described in Section 1.4.1, piscivorous waterbird colonies were scanned for PIT tags following the breeding season. Recoveries of PIT tags on bird colonies above McNary Dam were used to determine if susceptibility to avian predation varied by the differing physical conditions and morphological characteristics of the steelhead used in this study. A chi-square test was used to determine whether differences in the proportions of steelhead recovered on bird colonies were associated with external condition severity. Odds ratios were constructed to compare the increased likelihood of predation on steelhead with various external conditions. In-river survival of steelhead from release to the vicinity of downstream bird colonies was calculated by using downstream detections of fish at McNary and Bonneville dams. Survival estimates were generated using the Cormack-Jolly-Seber estimation approach based on downstream interrogation histories. Survival estimates were generated by Ben Sandford of NOAA Fisheries. Predation rates were adjusted for bias due to PIT tag detection efficiency, but not for deposition rate; therefore, estimates of predation rates presented here are minimums.

Finally, in order to validate our scoring of fish condition based on physical anomalies in external appearance, we conducted a pilot study whereby a sub-sample of the steelhead collected from Lower Monumental Dam were evaluated for disease prevalence as a measure of fish health. Such tests were designed to help determine whether a fish's external condition – as determined at the time of examination at the dams – is correlated with incidence and intensity of disease or other indices of fish health. Pathology screening and histopathology analysis was conducted by Dr. Frank Loge at the University of California Davis.

*Results and Discussion:* A total of 16,451 steelhead were tagged and released from Lower Monumental Dam (n = 6,753 hatchery-raised smolts and n = 1,173 wild smolts), Ice Harbor Dam (n = 1051 hatchery and n = 203 wild) and Rock Island Dam (n = 5,373 hatchery and n = 1,898 wild) in 2008. Sampling efforts were conducted in concert with the run-at-large, with the largest numbers of fish tagged (n = 12,723 or 77.3% of all tagged fish) during the peak migration period of 4 May to 7 June (a period encompassing 87.6% of the run enumerated while passing Lower Monumental and Rock Island dams in 2008). Overall (all release sites combined), 69.2% of the steelhead PIT-tagged as part of the study were classified as in excellent condition, 19.3% were in good condition, 11.0 % were in fair condition, and 0.5% were in poor condition. Due to low disease incidence in 2008, steelhead placed in condition ranks of fair and poor were combined into one category (fair) to allow for sufficient sample size during analysis. A variety of external anomalies were evident in steelhead ranked as fair, including body injuries (34.6%), de-scaling (28.5%), and fungal infections (27.1%). Steelhead ranked in good condition primarily suffered from moderate de-scaling (69.7%) and superficial body abrasions (21.4%). Conversely, external damage among fish in excellent condition was limited to minor patches of de-scaling (7.2%). There was some evidence that the early segment of the run (as defined by fish passing the dams in April) contained fish in better overall condition (75.1% of sampled fish were in excellent condition) relative to fish passing the dams in June (54.1% were in excellent condition).

*Upper Columbia River Steelhead Releases* - Of the 7,271 steelhead tagged and released from Rock Island Dam, 1,057 or 14.5% were subsequently recovered on a bird colony in the Columbia River basin. This number increased to 1,427 or 19.6% when corrected for detection efficiency. Avian predators consumed a minimum of 21.3% of the hatchery steelhead and 15.5% of the wild steelhead that we tagged and released from Rock Island Dam in 2008 (Table 12). Impacts from predation were evident from the large numbers of smolt PIT tags recovered on tern and cormorant colonies located in the Columbia River estuary and from the Crescent Island tern colony in McNary Pool (Table 12). However, recoveries of steelhead were also notable at a Caspian tern colony on Goose Island at Potholes Reservoir (an off-river colony), with estimated predation rates of 8.2% and 5.9% for hatchery steelhead and wild steelhead smolts, respectively (Table 12). The magnitude of these predation rates is surprising given the small size of the Goose Island Caspian tern colony (290 nesting pairs) and the colony's distance from the Columbia River (nearest distance = 45 km). After accounting for changes in the numbers of PIT-tagged steelhead available to avian predators within a given reach or segment (based on mortality of steelhead during in-river out-migration), the greatest impact from avian predation on Upper Columbia River steelhead occurred in the Columbia River estuary, where an estimated 18.8% of steelhead that survived to the estuary were consumed (Figure 42). Conversely, predation by gulls and American white pelicans was relatively minor (ranging from 0.1% to 0.8%) in comparison to that by terns and cormorants (Table 12). Survival-adjusted estimates of predation rates indicated that, of steelhead PIT-tagged and released into the tailrace of Rock Island Dam, 7.6% were consumed by piscivorous colonial waterbirds nesting at colonies off-river, 3.5% by waterbirds from colonies in McNary Pool, 1.9% by waterbirds from colonies in The Dalles and John Day pools, and 18.8% by waterbirds from colonies in the Columbia River estuary (Figure 42).

Preliminary results indicated that the condition and morphology of juvenile steelhead were associated with vulnerability of smolts to avian predation. PIT tag detections on bird colonies located up-river of McNary Dam suggest that avian predation is partially condition dependent, with diseased or injured steelhead more likely to be consumed than steelhead with little or no external evidence of injury or disease. For example, steelhead released into the tailrace of Rock Island Dam in good or fair condition were, on average, 1.7 times (95% c.i.: 1.3 – 2.1 times) more likely to be detected on a bird colony above McNary Dam, compared to fish with little or no signs of external damage. Vulnerability of Upper Columbia River steelhead smolts to avian predation was also related to different types of external damage, including severity of fungal infection ($p = 0.002$) and degree of body injury ($p < 0.001$; Figure 43). No comparison between external condition and smolt vulnerability to avian predation was attempted for colonies below McNary Dam, as there was no means to track fish condition as smolts migrated through the hydrosystem.

*Snake River Steelhead Releases*- Of the 9,180 steelhead tagged and released from Lower Monumental and Ice Harbor dams, 1,306 or 14.2% were subsequently recovered on a bird colony in the Columbia River basin. This number increased to 1,709 or 18.6% when corrected for detection efficiency. Avian predators consumed a minimum of 19.1% of the hatchery and 18.0% of the wild steelhead released from Lower Monumental and Ice Harbor dams in 2008 (Table 12). Similar to steelhead smolts originating from the Upper Columbia ESU, predation on Snake River steelhead was much higher for tern and cormorant colonies relative to gull and pelican colonies (Table 12). Survival-adjusted predation estimates indicated that 8.5%, 2.2%, and 22.9% of steelhead released below Lower Monumental Dam were consumed by colonial waterbirds nesting in the McNary Pool, in John Day/The Dalles pools, and in the Columbia River estuary, respectively (Figure 42). Caspian terns nesting on East Sand Island consumed the largest percentage of available Snake River steelhead (16.8%), followed by cormorants on East Sand Island (6.5%), and Caspian terns on Crescent Island (5.2%; Figure 42).

Similar to steelhead originating from the upper Columbia River, evidence suggested that avian predation on Snake River steelhead was partially condition dependent. Snake River steelhead in good condition were, on average, 1.2 times (95% c.i.: 1.0 – 1.5 times) more likely and Snake River steelhead in fair condition were 1.4 times (95% c.i.: 1.0 – 1.7 times) more likely to be consumed by an avian predator than fish with little or no signs of external damage. Vulnerability of Snake River steelhead smolts to avian predation was also related to different types of external damage, including severity of fungal infection ($p < 0.01$), degree of body injury ($p = 0.03$), and extent of de-scaling ($p = 0.02$; Figure 43). In addition to condition dependent selection by avian predators, there was also evidence of an association between fish size and vulnerability to avian predation. For Caspain terns (all tern colonies in the Basin), steelhead between 160 and 240 mm were the most vulnerable, with predation as a function of steelhead length fitting a polynomial model ($p < 0.01$, based on a simple least squares regression; Figure 44). Conversely, PIT tags from small steelhead (< 160 mm) and from large steelhead (> 250 mm) were rarely detected on tern colonies. Interestingly, this polynomial relationship between fork length and susceptibility to avian predation was not found for double-crested cormorants, where large differences in steelhead size were neither strongly positively or negatively associated with predation rates (Figure 44).

A comparison of avian predation between Snake River and Upper Columbia River steelhead ESUs suggests similar vulnerabilities between groups once they reach McNary Dam, with predation rates very similar from tern, cormorant, and gull colonies downstream of McNary Dam (Figure 42). This result suggests that these two steelhead ESUs (Snake River and Upper Columbia River) experience similar predation intensities from downstream bird colonies. Conversely, large differences in predation rate were observed between Snake River and Upper Columbia steelhead ESUs by avian predators nesting up-river of McNary Dam (Figure 42). These differences were primarily associated with the unexpectedly high predation rate on Upper Columbia River steelhead by Caspian terns nesting on Potholes Reservoir (an off-river colony; Table 12 and Figure 42) and by high predation rates on Snake River steelhead by terns and cormorants nesting on islands in McNary Pool (Table 12 and Figure 42). Interesting, none of the steelhead released from Lower Monumental or Ice Harbor dams were recovered on the Potholes tern colony and only 9 or 0.1% of the steelhead released from Rock Island Dam were deposited on the Foundation Island cormorant colony (Table 12).

*External Conditions as Indices of Fish Health:* To evaluate the relationship between the external condition of steelhead smolts and overall smolt health, necropsies were performed on 222 run-of-the-river Snake River steelhead smolts collected at the Lower Monumental Dam juvenile fish facility between 24 April and 22 June 2008. Overall, steelhead smolts collected for this study appeared relatively healthy. For instance, even though 99 of the 222 (45%) steelhead smolts collected had moderate to severe external damage or disease, qPCR techniques detected *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease, in only 18 (8%) steelhead smolts. Bacterial kidney disease was not associated with external condition ranks, but prevalence of several other pathogens did increase as smolt condition decreased. Pathogens related to external condition ranks were primarily from a group of infectious diseases, including dermatitis, sanguinicoliasis, and amebiasis. Decreased smolt condition was related to increased diagnosis frequency of these infectious diseases, with histological diagnosis rates of 0.16, 0.26, 0.52, and 0.90 for steelhead in external condition ranks of excellent, good, fair, or poor, respectively. Further analyses will better elucidate possible links between external measures of steelhead condition and overall smolt health.

# SECTION 5: SYSTEM-WIDE OVERVIEW

## 5.1 Avian Predator Population Trajectories

The numbers of Caspian terns nesting in the Columbia River basin have remained fairly stable over the past decade. In contrast, the numbers of double-crested cormorants nesting on East Sand Island have more than doubled during the same period to ca. 11,000 breeding pairs, the largest known breeding colony of double-crested cormorants in western North America (Figure 45). Based on current habitat use by double-crested cormorants nesting on East Sand Island, there appears to be ample unused nesting habitat for colony expansion. Similarly, unused suitable nesting habitat for double-crested cormorants appears available on the Columbia Plateau, potentially supporting continued expansion of the breeding population in the Columbia Basin. Productivity at the East Sand Island and Foundation Island cormorant colonies has also been consistently higher than productivity at the Caspian tern colonies in the estuary and on the Columbia Plateau (Figure 46). In 2008, the U.S. Army Corps of Engineers began implementing the management actions outlined in the Final EIS (FEIS) and the Records of Decision (RODs) for Caspian tern management in the Columbia River estuary, a plan to redistribute a portion of the East Sand Island Caspian tern colony to alternative colony sites in interior Oregon and San Francisco Bay, California by 2015 (USFWS 2005, 2006). A substantial increase in the numbers of nesting Caspian terns along the mid-Columbia River as a result of tern management in the estuary is unlikely due to the paucity of suitable nesting habitat for terns in that region. Based on these results, it is possible that the cormorant breeding population will continue to expand for the foreseeable future, while numbers of Caspian terns nesting in the estuary and up-river will remain stable or decline as the RODs are implemented. The trajectories of other piscivorous colonial waterbird populations along the Columbia River (i.e., gulls and pelicans) is less clear, and efforts will be made in 2009 to investigate the population trajectories of selected colonies where predation on salmonid smolts is believed to be significant (e.g., the gull colony on Miller Rocks).

## 5.2. Relative Impact of Avian Predators on Salmonid Smolt Survival

Caspian terns that nest on Crescent Island were found to have the highest proportion of juvenile salmonids in their diet, much higher than Caspian terns or double-crested cormorants that nest in the Columbia River estuary (Figure 47). Nevertheless, a system-wide assessment of avian predation indicated that the most significant impact to survival of juvenile salmonids occurs in the estuary, with Caspian terns and double-crested cormorants nesting on East Sand Island combining to consume ca. 7-16 million smolts annually during 2003 – 2007 (Figure 48). Although estimates of smolt consumption by East Sand Island cormorants in 2008 are not yet available, combined smolt losses to terns and cormorants nesting on East Sand Island in 2008 are likely within this range. Estimated smolt losses to piscivorous birds that nest further up-river are more than an order of magnitude less than losses due to avian predation in the estuary. Additionally, when compared to the impact of avian predation on smolt survival further up-river, avian predation in the estuary affects juvenile salmonids that have survived freshwater migration to the ocean and presumably have a higher probability of survival to return as adults compared to those fish that have yet to complete out-migration. Finally, juvenile salmonids from every ESA-listed stock in the Columbia River basin are susceptible to predation in the estuary because all surviving fish must migrate in-river through the estuary. For these reasons, management of terns and cormorants nesting on East Sand Island has the greatest potential to benefit ESA-listed salmonid populations from throughout the Columbia River basin, when compared to potential management of other populations of piscivorous birds. The Caspian tern colonies on Crescent and Goose islands (Potholes Reservoir) and the double-crested cormorant colony on Foundation Island may be exceptions to this rule; management of these small, up-river colonies may benefit certain salmonid stocks, particularly steelhead stocks. Finally, although the current impact on smolt survival of double-crested cormorants nesting on the Columbia Plateau is small relative to the cormorant colony on East Sand Island, the cormorant population on the Columbia Plateau appears to be expanding and there is ample unoccupied nesting habitat for cormorants in the region. Monitoring of double-crested cormorants on the Columbia Plateau to determine if they pose an increasing risk to salmonid survival may be warranted, both during and after the birds' nesting season.

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# APPENDIX A

## Pacific Coast Double-crested Cormorant Status Assessment: 2008 Progress Report

In March 2008 work was initiated on the updated status assessment for the Pacific Coast population of double-crested cormorants. The geographic area to be included in the status assessment extends east from the Pacific Coast to the Continental Divide, north into British Columbia following the breeding range, and south to the international border with Mexico. The objectives for the status assessment are five-fold: (1) define management units incorporating results from Dacey Mercer's M.S. thesis research on the population genetic structure and taxonomic identity of the double-crested cormorant in North America, (2) locate and document active colony sites greater than or equal to 25 breeding pairs by conducting aerial and ground surveys, as well as through collaboration with other agencies and individuals, (3) estimate the current size of these breeding colonies, (4) assess the connectivity between colony sites based on tracking cormorants nesting on East Sand Island using satellite telemetry, and (5) assess demographic trends for the entire management unit, as well as for local or regional populations. Ample progress was made on objectives one through four in 2008.

**Objective 1.** Dacey Mercer completed her M.S. thesis research in the fall of 2008. Collecting genetics samples in northwestern Washington/southern British Columbia and southern California/northern Baja California during the 2009 breeding season will help to fill in information gaps and will further aid in defining management units.

**Objective 2.** We completed aerial surveys in the Puget Sound region and in interior Washington and Oregon during the 2008 breeding season. Multiple active colonies were located during these flights and we digitally photographed all colonies. In 2008 we also coordinated with the Oregon Coast National Wildlife Refuge Complex (OCNWRC) in order to avoid duplicating efforts to conduct aerial surveys for cormorant colonies along the Oregon coast. The OCNWRC had planned to survey and photograph all cormorant breeding colonies along the coast of Oregon in 2008; however, helicopter repair problems, then issues with fog on survey days, and finally camera malfunctions prevented accurate estimates for most colonies in 2008. We will coordinate with the OCNWRC again in 2009 in order to ensure that successful surveys are completed and colonies are photographed in this area.

**Objective 3.** We have counted all digital photographs taken during 2008 aerial surveys conducted by Oregon State University personnel in order to estimate the size of cormorant breeding colonies documented during these surveys. We are coordinating with researchers from the University of California, Santa Cruz (UCSC) to have archived digital photographs of 2008 coastal California cormorant breeding colonies counted. The most recent census data for coastal California cormorant colonies is from 2001 (south of Point Conception) and 2003 (north of Point Conception). Additionally, we are continuing to make contact with individuals from other agencies, universities, refuges, etc. who might have information on double-crested cormorant breeding colonies, particularly in areas where we are not conducting surveys, such as the interior states.

**Objective 4.** Satellite-tracking data from a 2008 pilot study demonstrated that double-crested cormorants from East Sand Island visit current and historical breeding colonies outside of the Columbia River estuary, particularly to the north in the Puget Sound region. See main Season Summary text for further details on the movements of satellite-tagged cormorants.

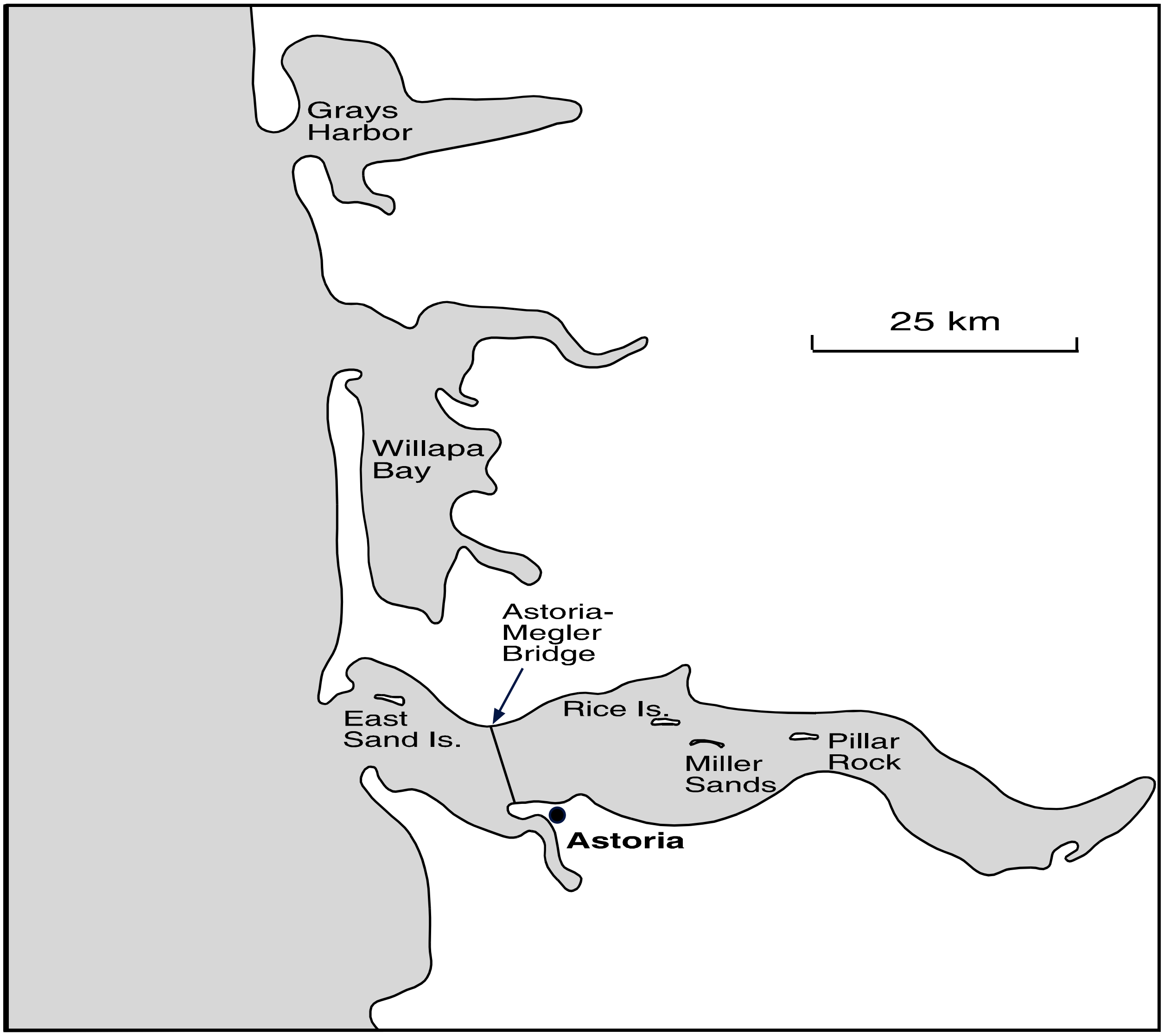
## PROGRAM FUNDING

Funding for the work presented here was provided by the Bonneville Power Administration (BPA), the U.S. Army Corps of Engineers (USACE) - Portland District, and the U.S. Army Corps of Engineers - Walla Wall District; see below for the program funding responsibilities of each agency). In general, funding for work done at colonies in the Columbia River estuary was from BPA and the USACE – Portland District and funding for work done at upriver colonies was from USACE – Walla Walla District. We thank Dorothy Welch (BPA), Geoff Dorsey (USACE – Portland District), and Scott Dunmire (USACE – Wall Walla District) for their help in administering these contracts.

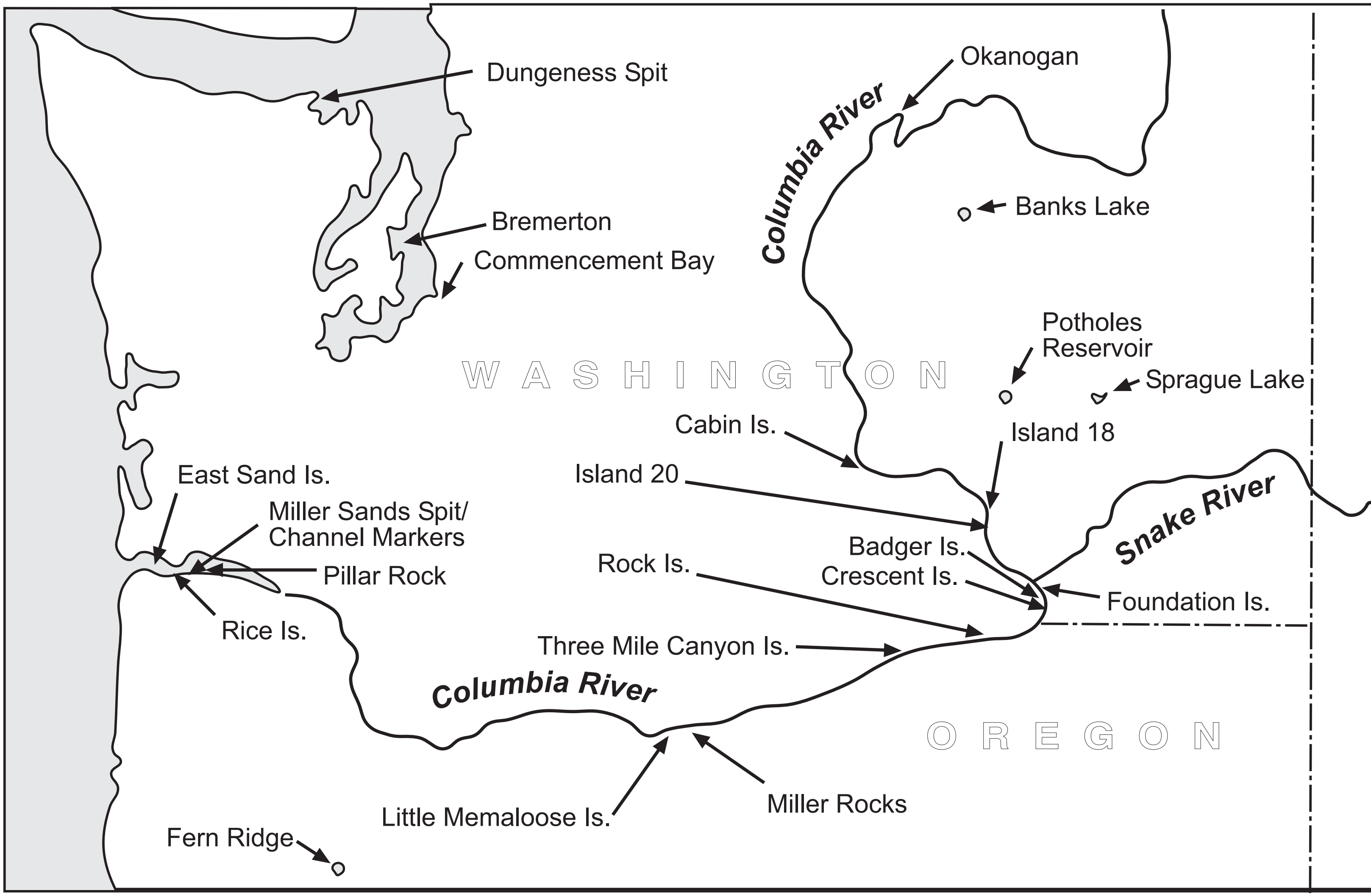
| | Funding Responsibility by Agency | | |
|---|---|---|---|
| | BPA | USACE Portland District | USACE Walla Walla District |
| **Caspian terns** | | | |
| 1.1. Preparation and Modification of Nesting Habitat in the CRE | | x | |
| 1.2. Nesting Chronology, Colony Size, and Productivity | | | |
| 1.2.1. Columbia River Estuary | x | x | |
| 1.2.2. Columbia Plateau | x | | x |
| 1.2.3. Coastal Washington | x[1] | | |
| 1.3. Diet Composition and Salmonid Consumption | | | |
| 1.3.1. Columbia River Estuary | x | | |
| 1.3.2. Columbia Plateau | x | | x |
| 1.4. Salmonid Predation Rates | | | |
| 1.4.1. Smolt PIT Tag Recoveries | | | x |
| 1.4.2. Avian Predation Rates on Smolts | x | | x |
| 1.5. Dispersal and Survival | x | | |
| 1.6. Caspian Tern Management Plan | | | |
| 1.6.1. Background | x | | x |
| 1.6.2. Management Initiative Implemented in 2008 | | | x |
| 1.6.3. Future Management Actions | | | x |

| | Funding Responsibility by Agency | | |
|---|---|---|---|
| | BPA | USACE Portland District | USACE Walla Walla District |
| **Double-crested Cormorants** | | | |
| 2.1. Nesting Distribution and Colony Size | | | |
| 2.1.1. Columbia River Estuary | x | | |
| 2.1.2. Columbia Plateau | | | x |
| 2.1.3. Coastal Washington | x | | |
| 2.2. Nesting Chronology and Productivity | | | |
| 2.2.1. Columbia River Estuary | x | | |
| 2.2.2. Columbia Plateau | | | x |
| 2.3. Diet Composition and Salmonid Consumption | | | |
| 2.3.1. Columbia River Estuary | x | | |
| 2.3.2. Columbia Plateau | | | x |
| 2.4. Salmonid Predation Rates | | | |
| 2.4.1. Columbia River Estuary | x | | |
| 2.4.2. Columbia Plateau | | | x |
| 2.5. Management Feasibility Studies | | | |
| 2.5.1. Techniques to Encourage Nesting | x | | |
| 2.5.2. Techniques to Discourage Nesting | x | | |
| 2.6. Post-breeding Distribution and Diet on the Columbia Plateau | | | x |
| 2.7. Post-breeding Movements and Dispersal of Cormorants from ESI | | | x |

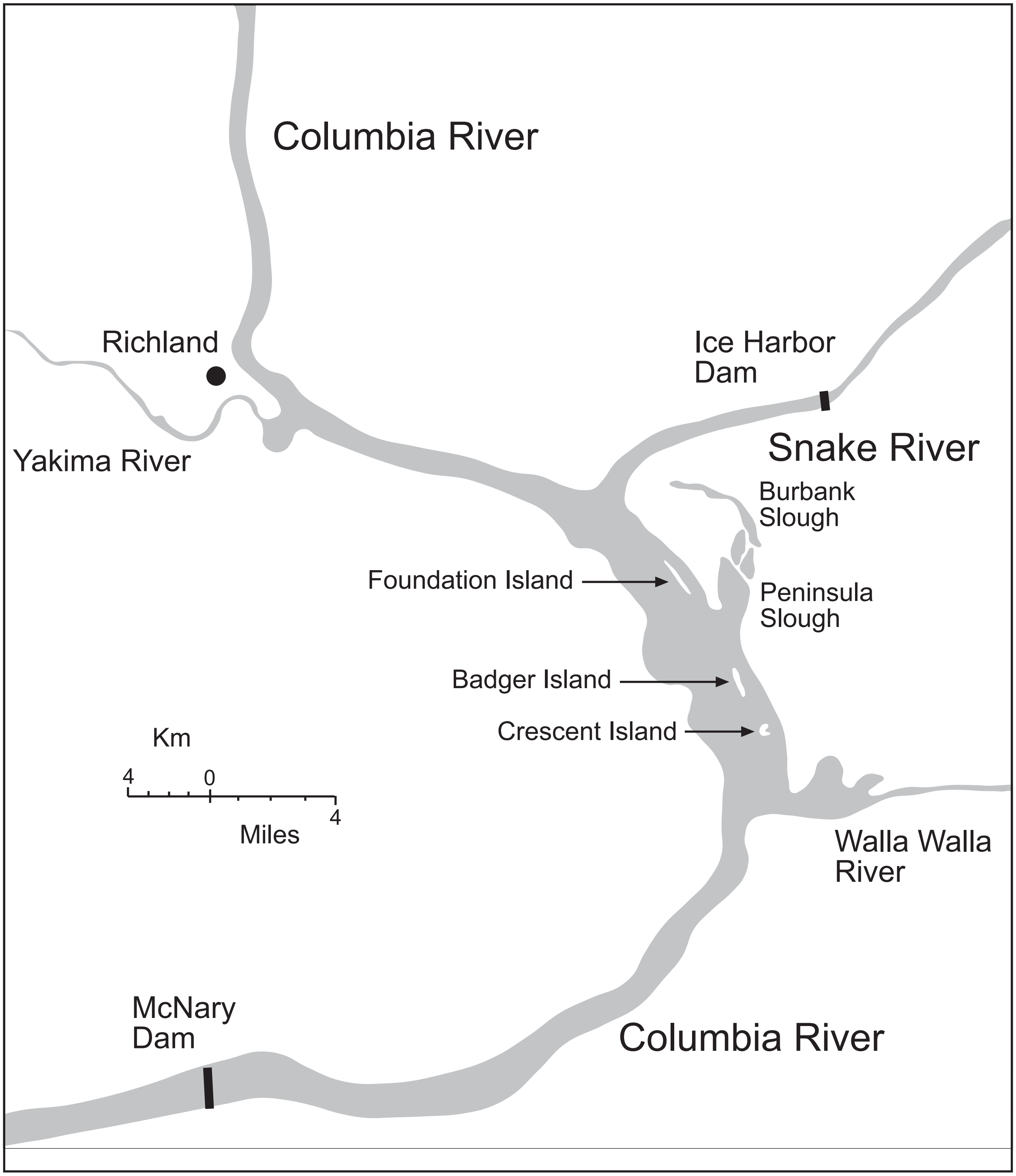
| | Funding Responsibility by Agency | | |
|---|---|---|---|
| | BPA | USACE Portland District | USACE Walla Walla District |
| **Other Piscivorous Colonial Waterbirds** | | | |
| 3.1. Distribution | | | |
| 3.1.1. Columbia River Estuary | x | | |
| 3.1.2. Columbia Plateau | | | x |
| 3.2. Diet Composition | | | |
| 3.2.1. Columbia River Estuary | x | | |
| 3.2.2. Columbia Plateau | | | x |
| 3.3. Salmonid Predation Rates | | | x |
| **Steelhead Vulnerability Study** | | | x |



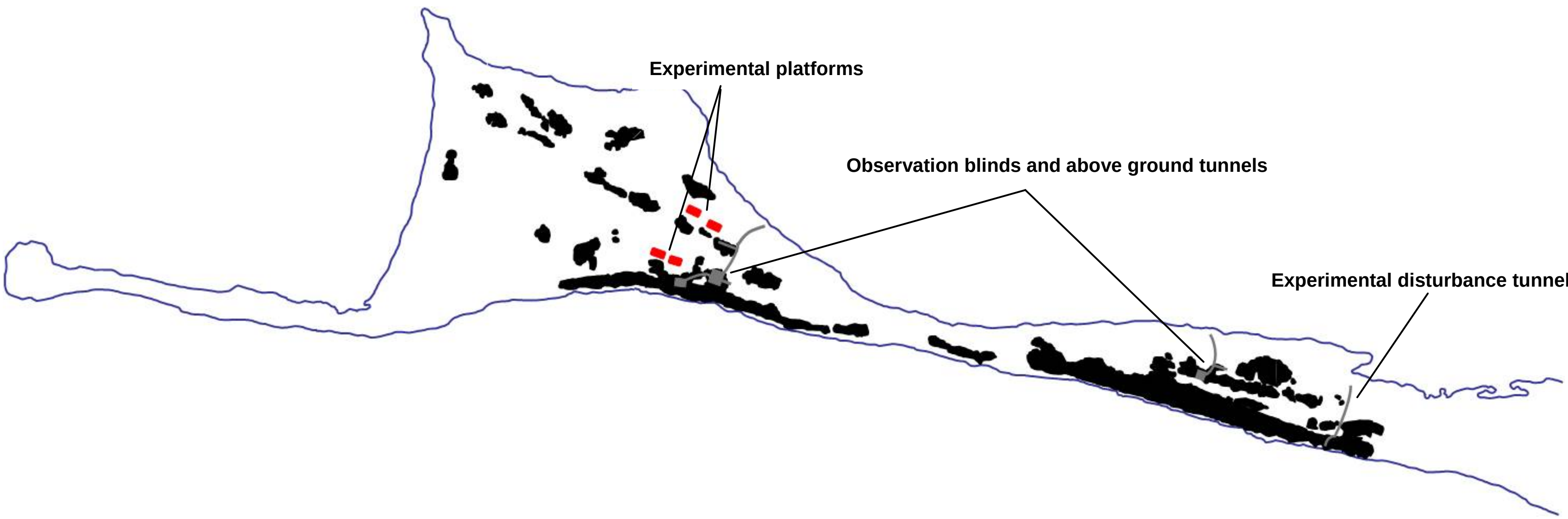

Map 1. Study area in the Columbia River estuary and along the southwest coast of Washington.



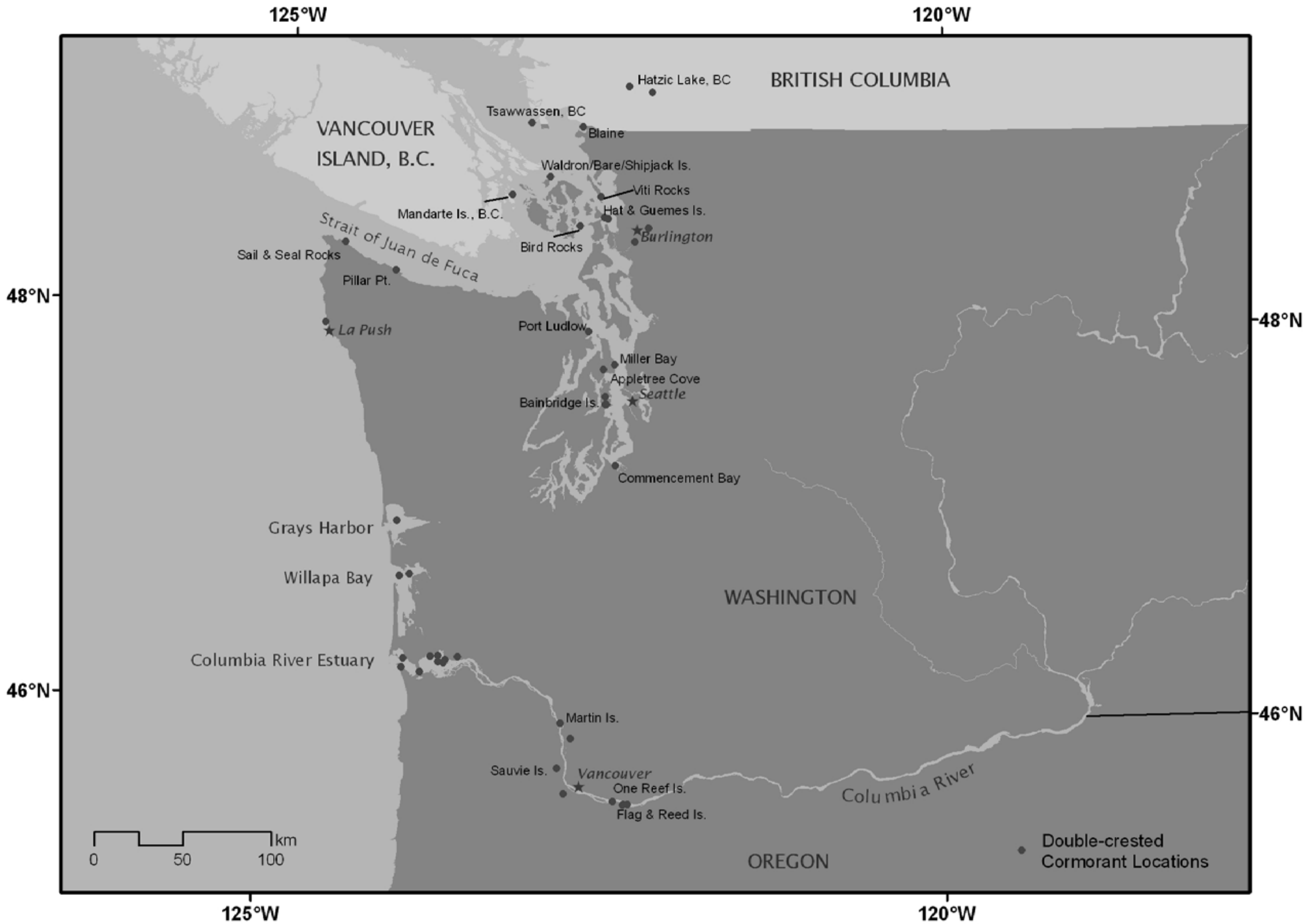

Map 2. Study area along the Columbia River and the locations of active and historical bird colonies mentioned in this report.



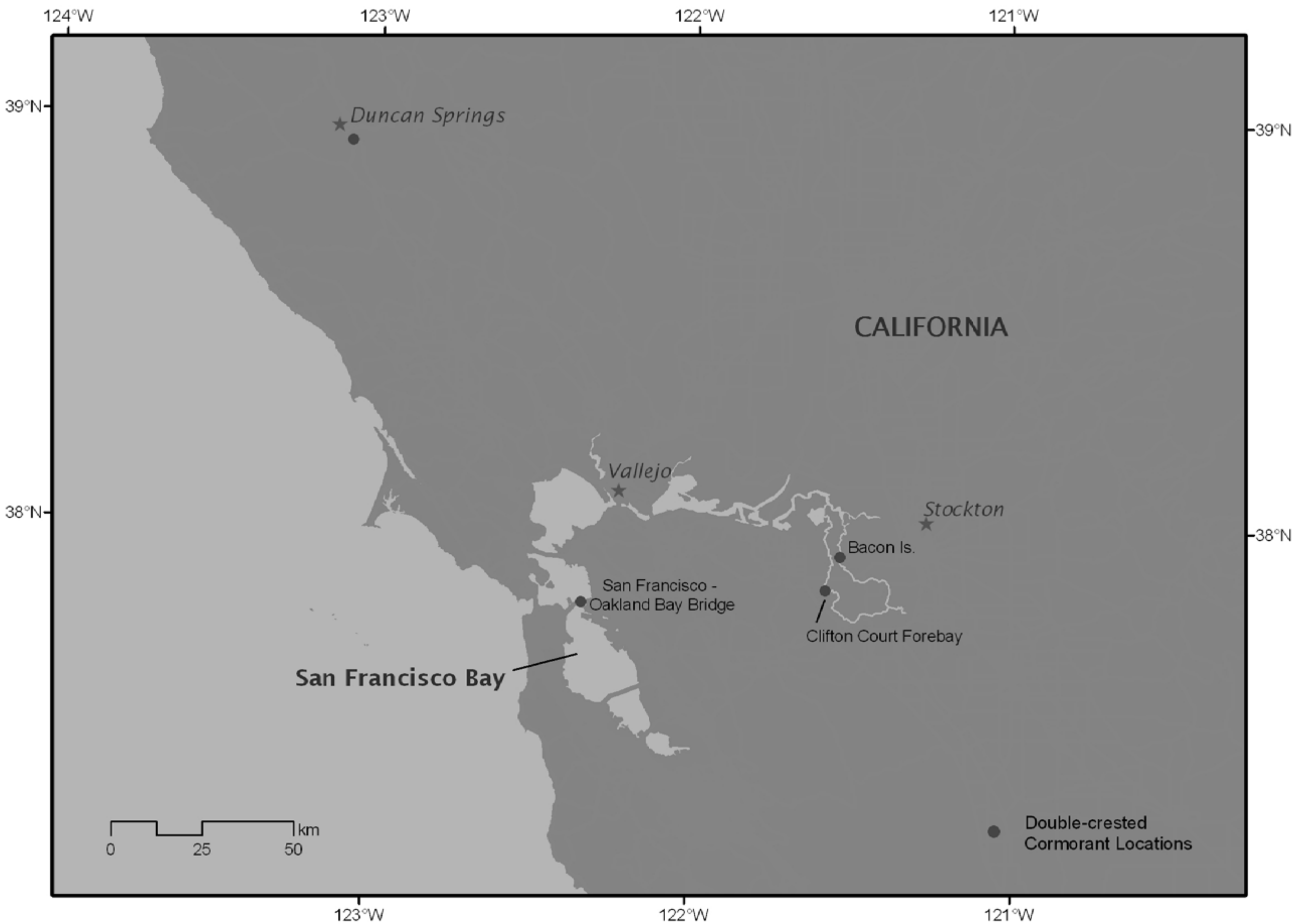

Map 3. Study area on the mid-Columbia River.




Map 4. Distribution of double-crested cormorant nests (shown in black) on East Sand Island in 2008 and the location of the experimental nesting platforms (shown in red), observations blinds (shown in gray), and blind access and experimental disturbance tunnels (see text for details). Cormorants only nested on the western half of East Sand Island (shown here) and did not nest elsewhere on the island in 2008.




Map 5. Roosting locations of 28 satellite-tagged double-crested cormorants during June through December, 2008. Cormorants were satellite-tagged as breeders at East Sand Island, OR during June and July, 2008.




Map 6. Roosting locations of three satellite-tagged double-crested cormorants in California during November and December, 2008. Cormorants were satellite-tagged as breeders at East Sand Island, OR during June and July, 2008.

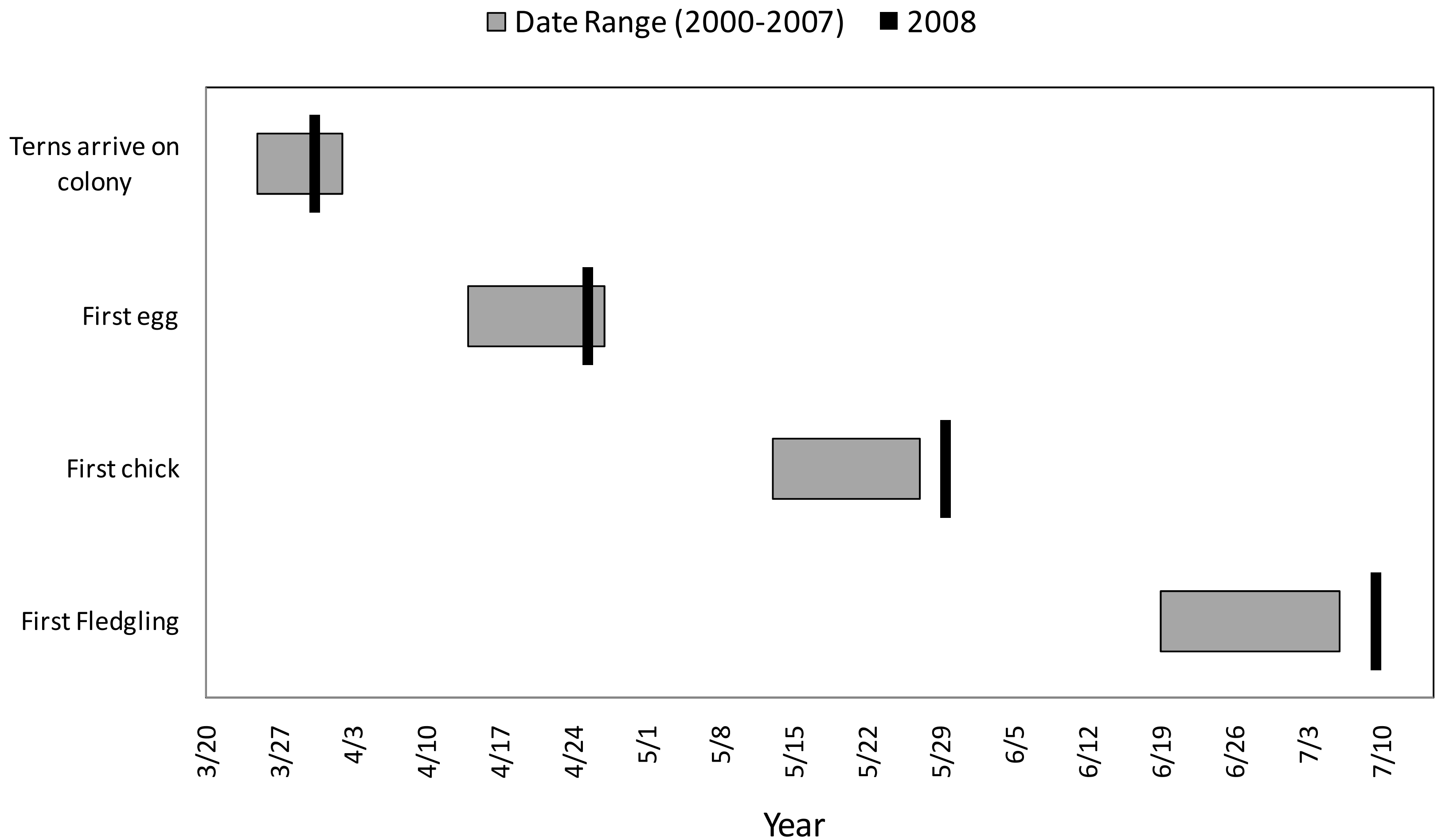



Figure 1. Nesting chronology at the East Sand Island Caspian tern colony during 2008.

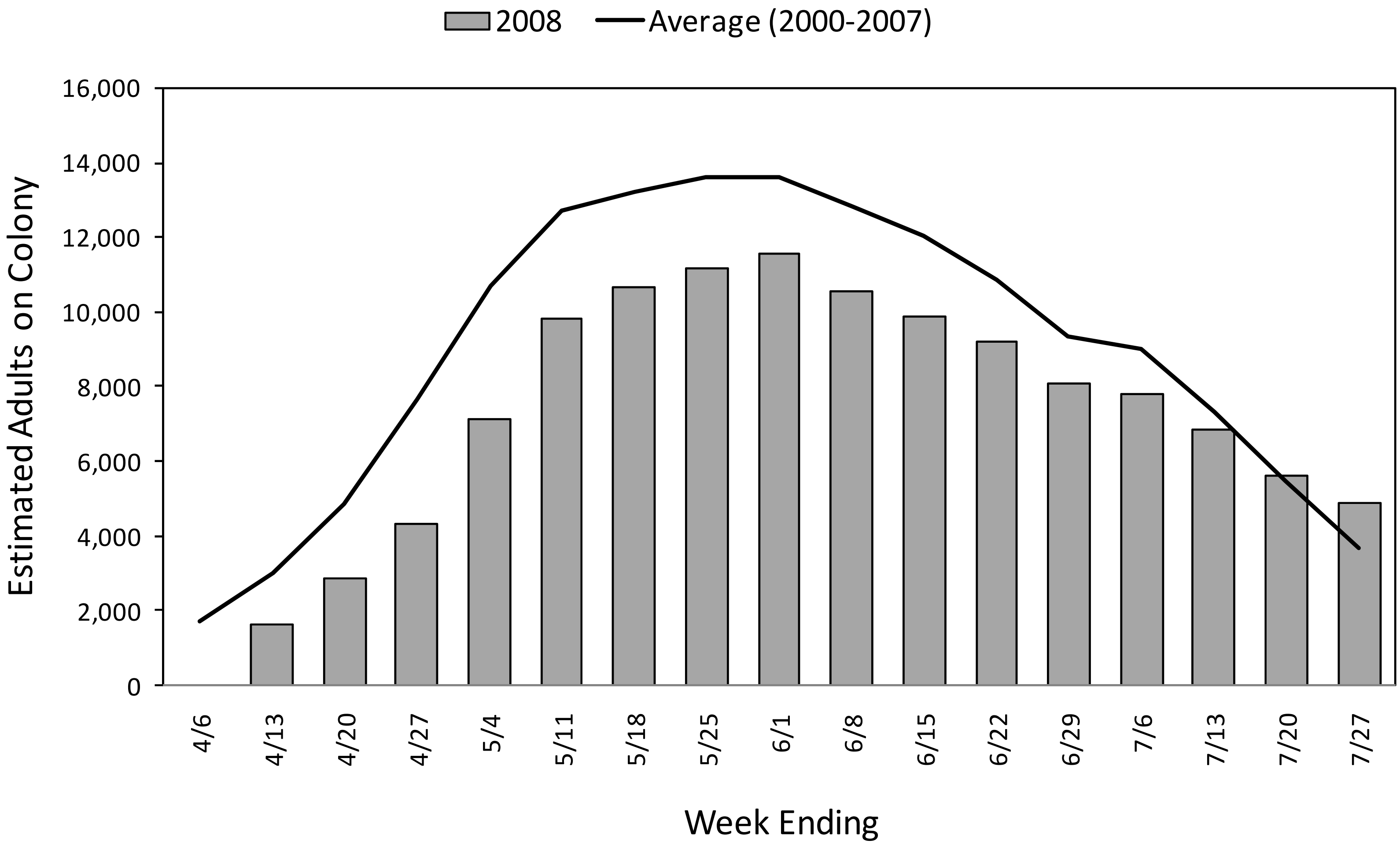



Figure 2. Weekly estimates from the ground of the number of adult Caspian terns on the East Sand Island colony during the 2008 nesting season.

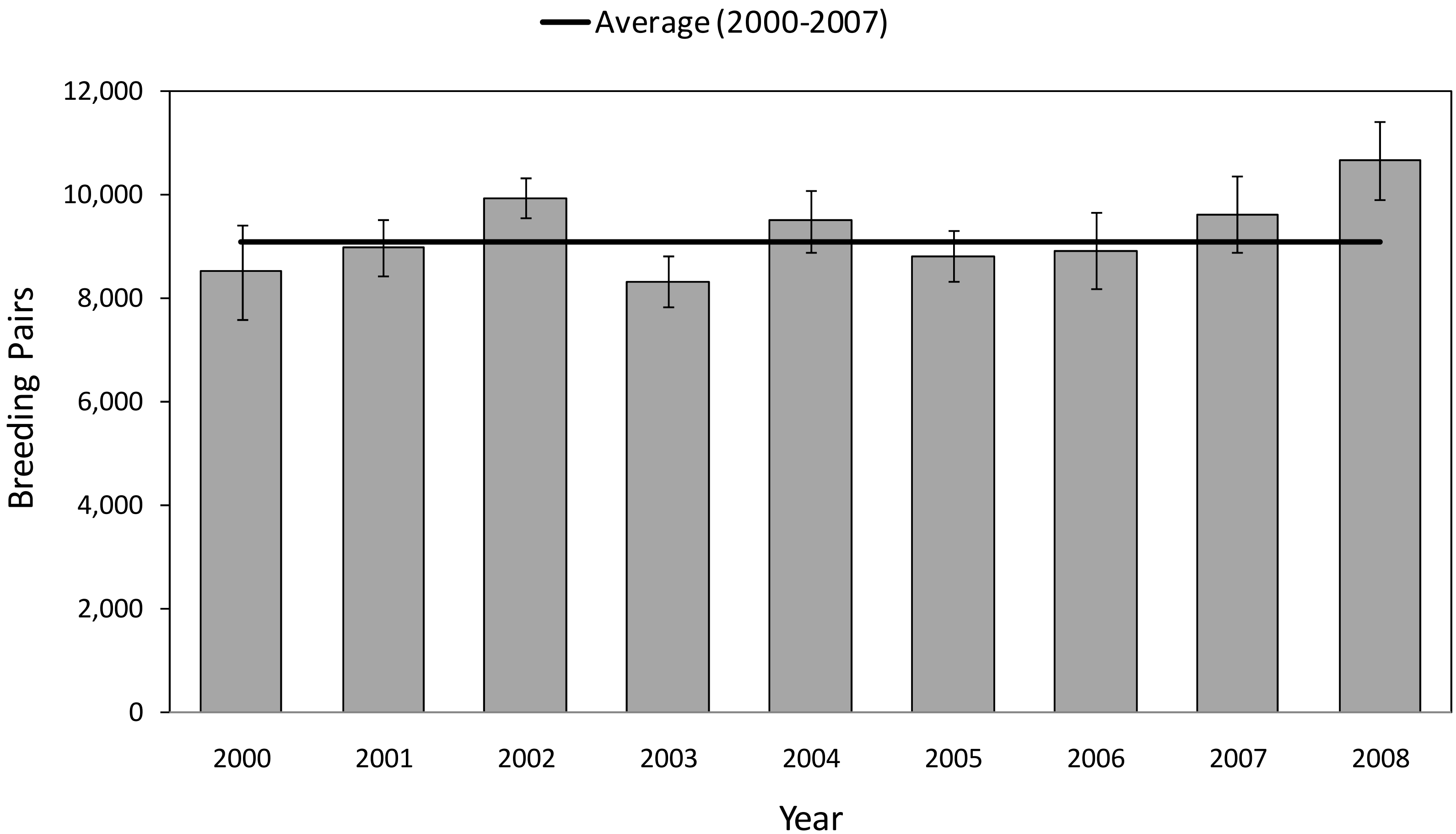



Figure 3. Caspian tern colony size on East Sand Island during 2000-2008. Error bars represent 95% confidence intervals for the number of breeding pairs.

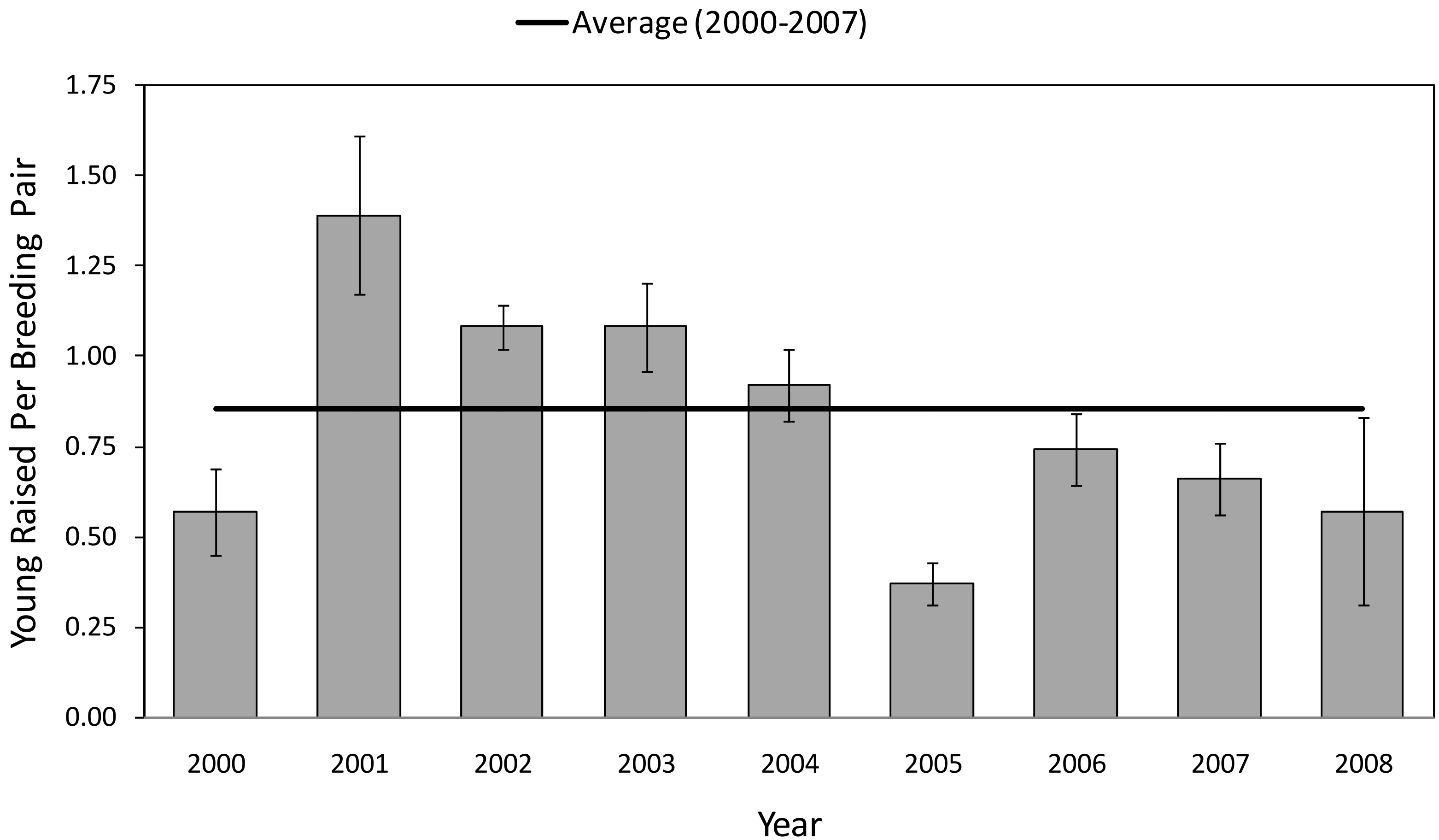



Figure 4. Caspian tern nesting success on East Sand Island during 2000-2008. Error bars represent 95% confidence intervals for the average number of young raised per breeding pair.

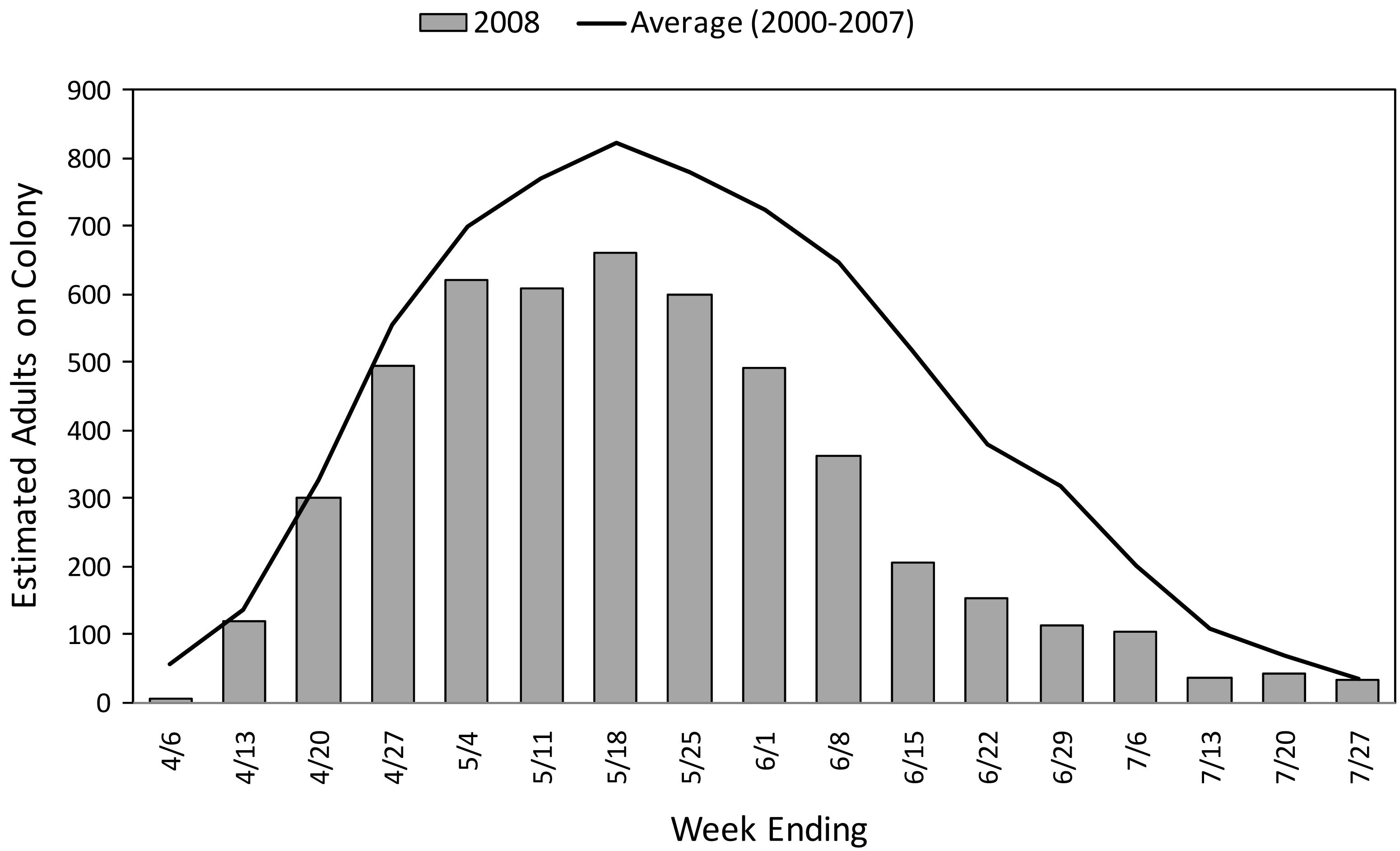



Figure 5. Weekly estimates from the ground of the number of adult Caspian terns on the Crescent Island colony during the 2008 nesting season.

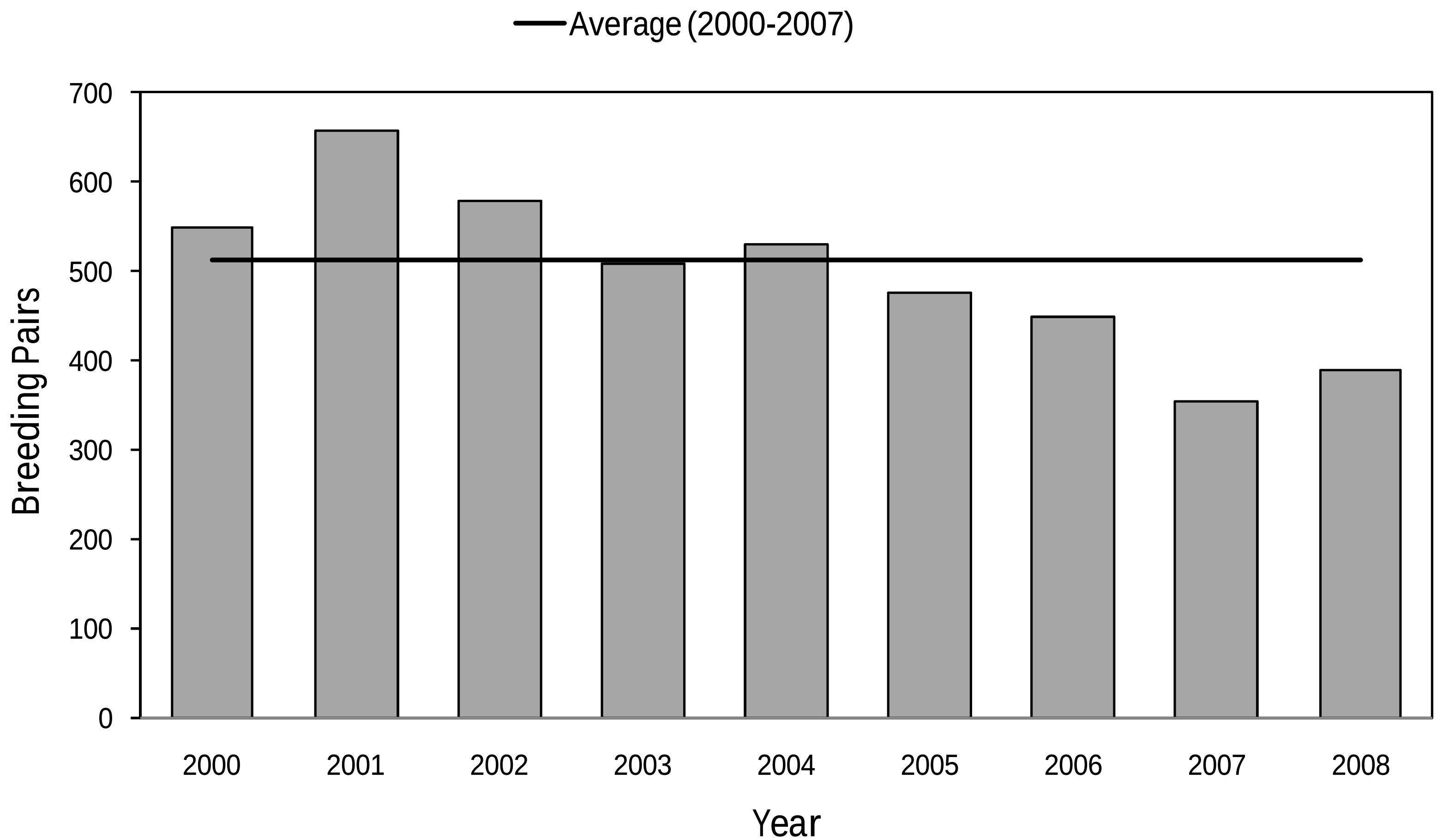



Figure 6. Caspian tern colony size on Crescent Island during 2000-2008.

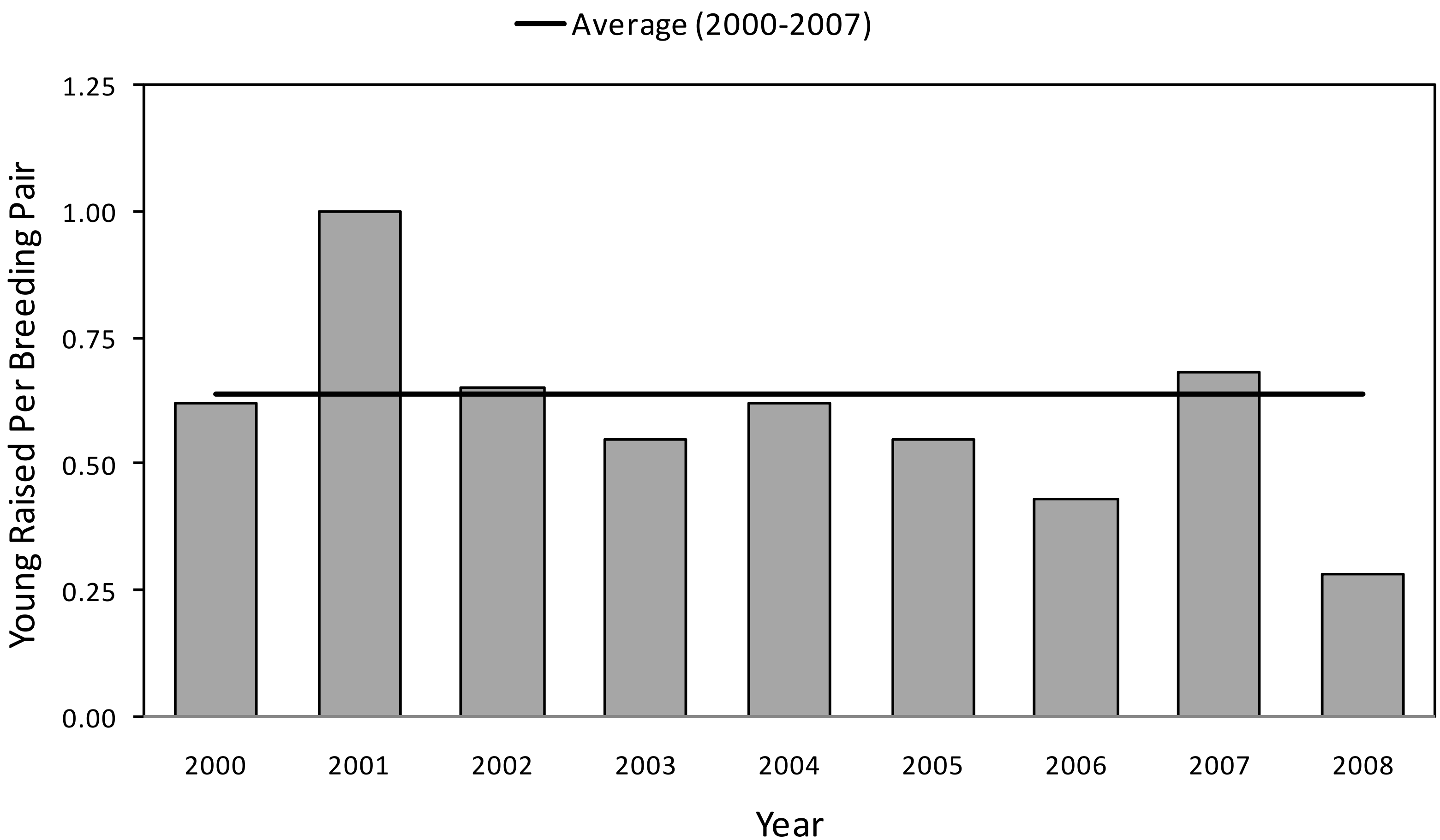



Figure 7. Caspian tern nesting success at the Crescent Island nesting colony during 2000-2008.

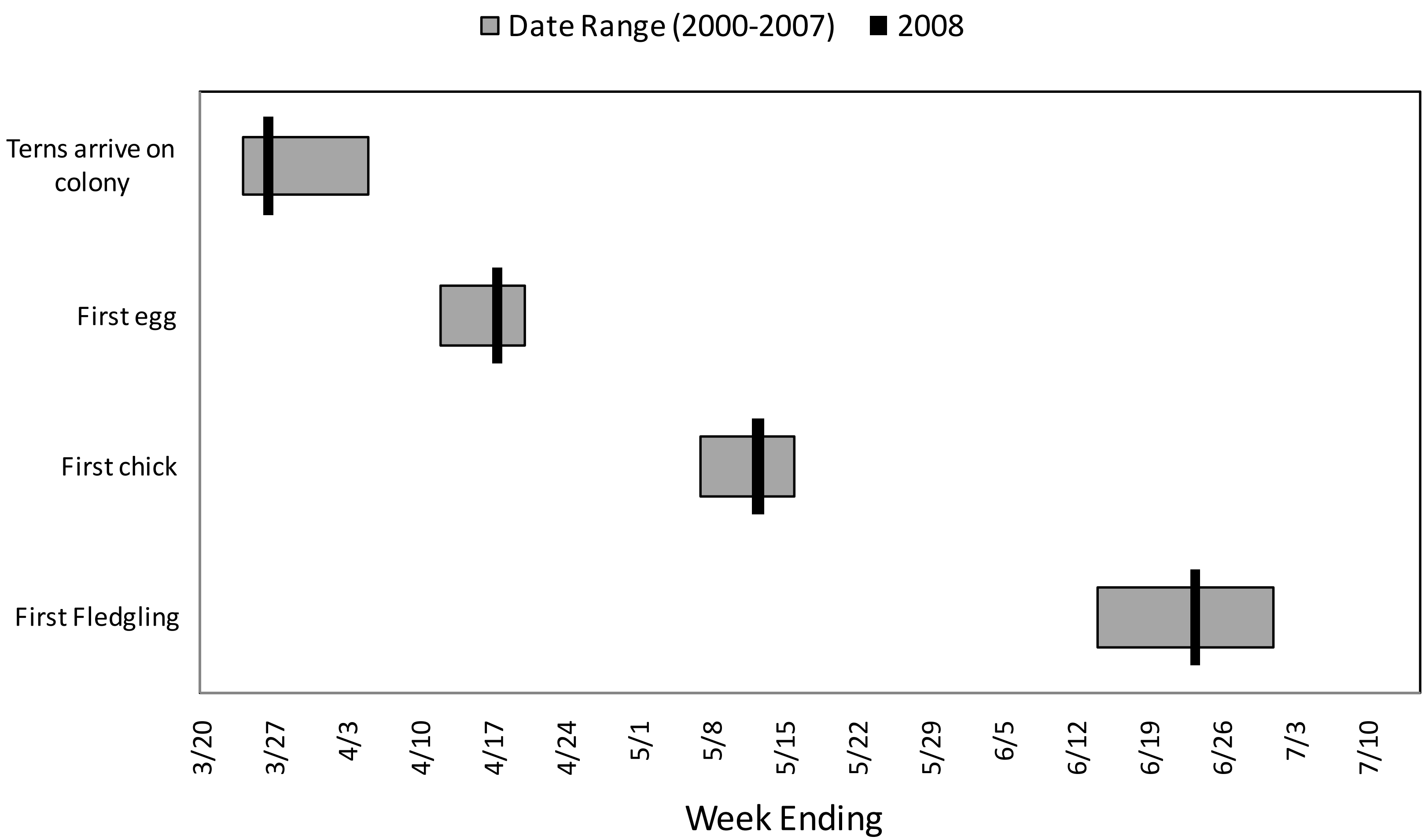



Figure 8. Nesting chronology at the Crescent Island Caspian tern colony during 2008.

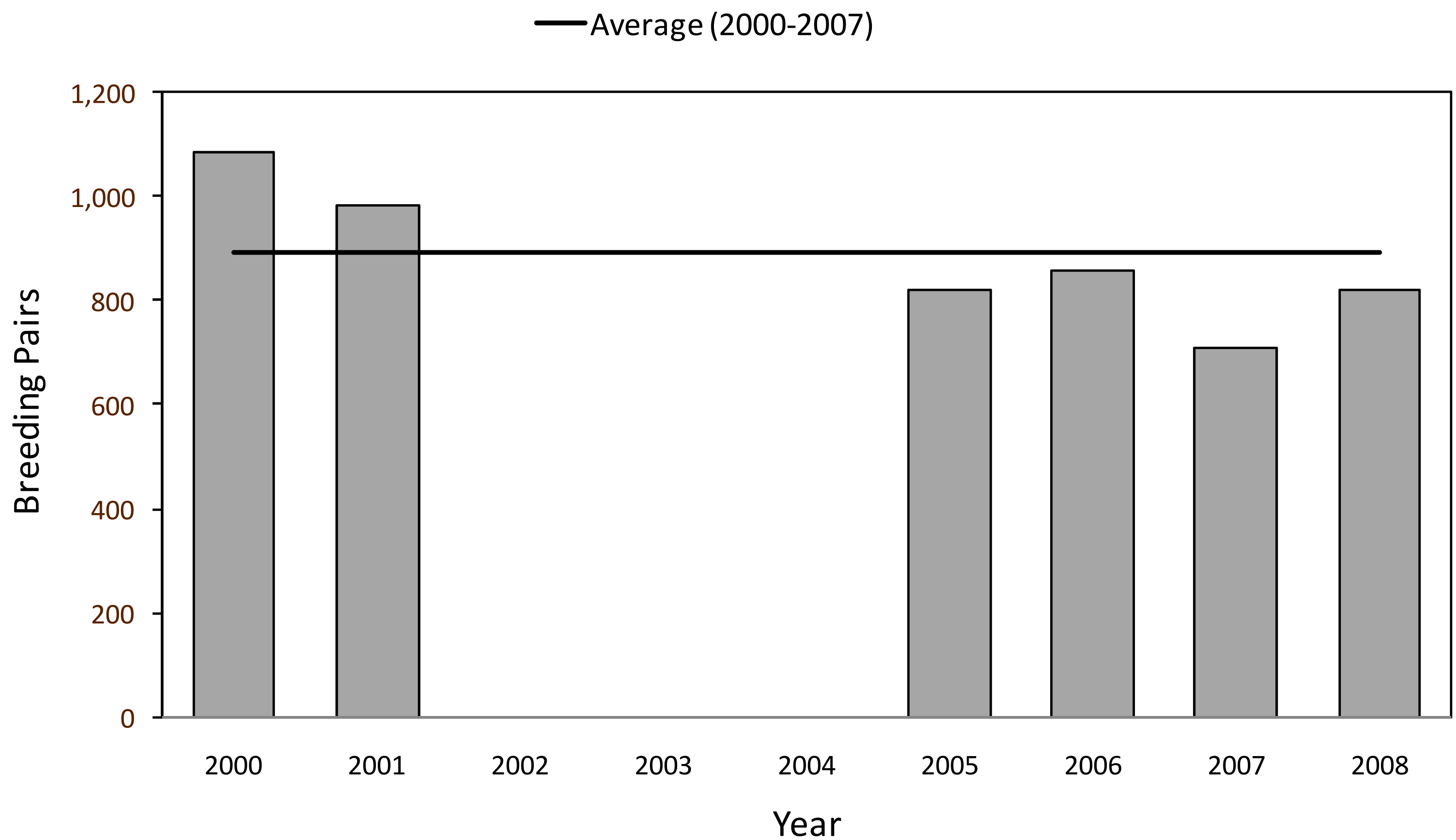



Figure 9. Population estimates for Caspian terns nesting on the Columbia Plateau during 2000-2008. Estimates of the number of breeding pairs were not available for all Caspian tern colonies on the Columbia Plateau during 2002-2004.

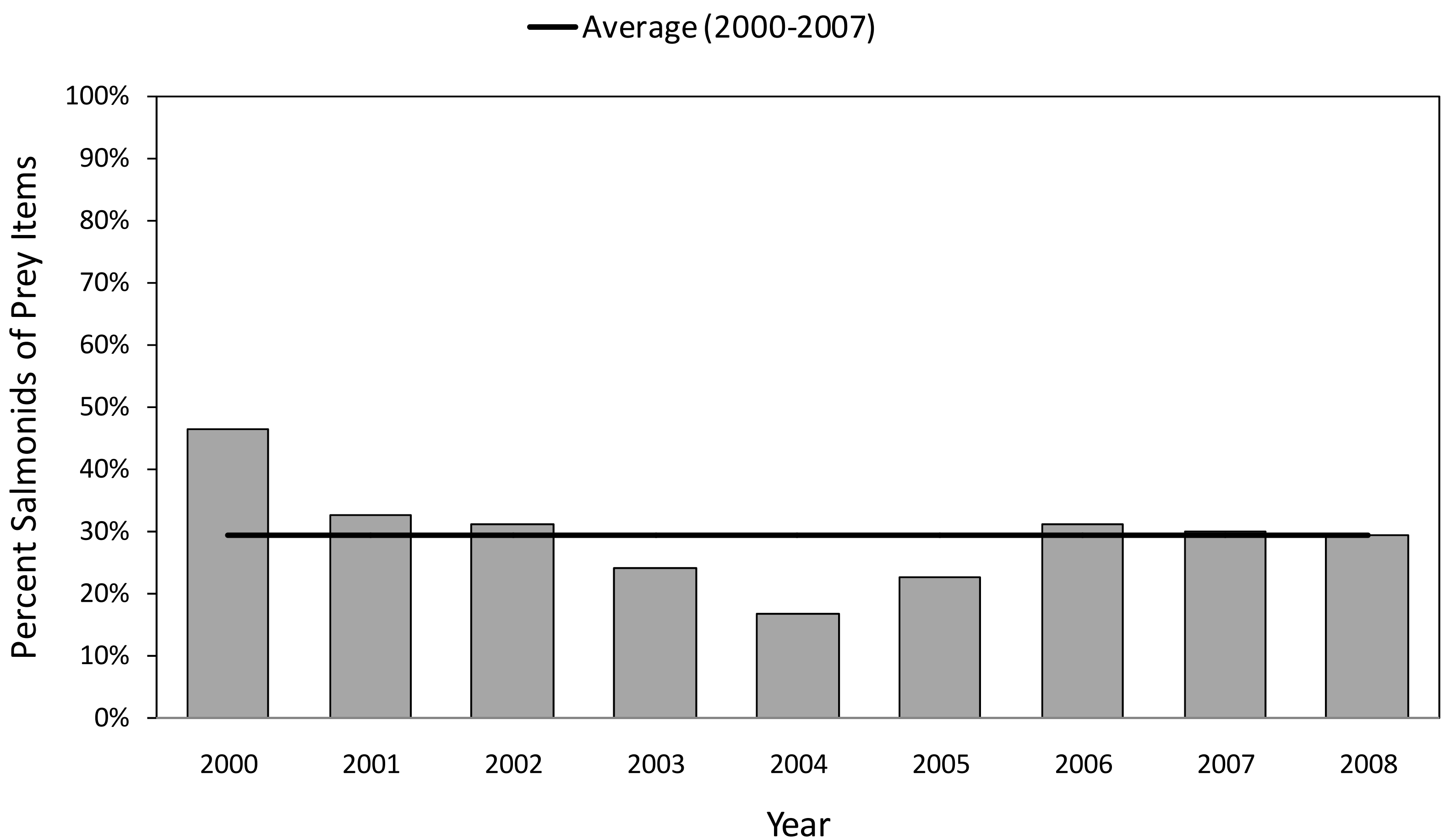



Figure 10. Average proportion of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island during 2000-2008.

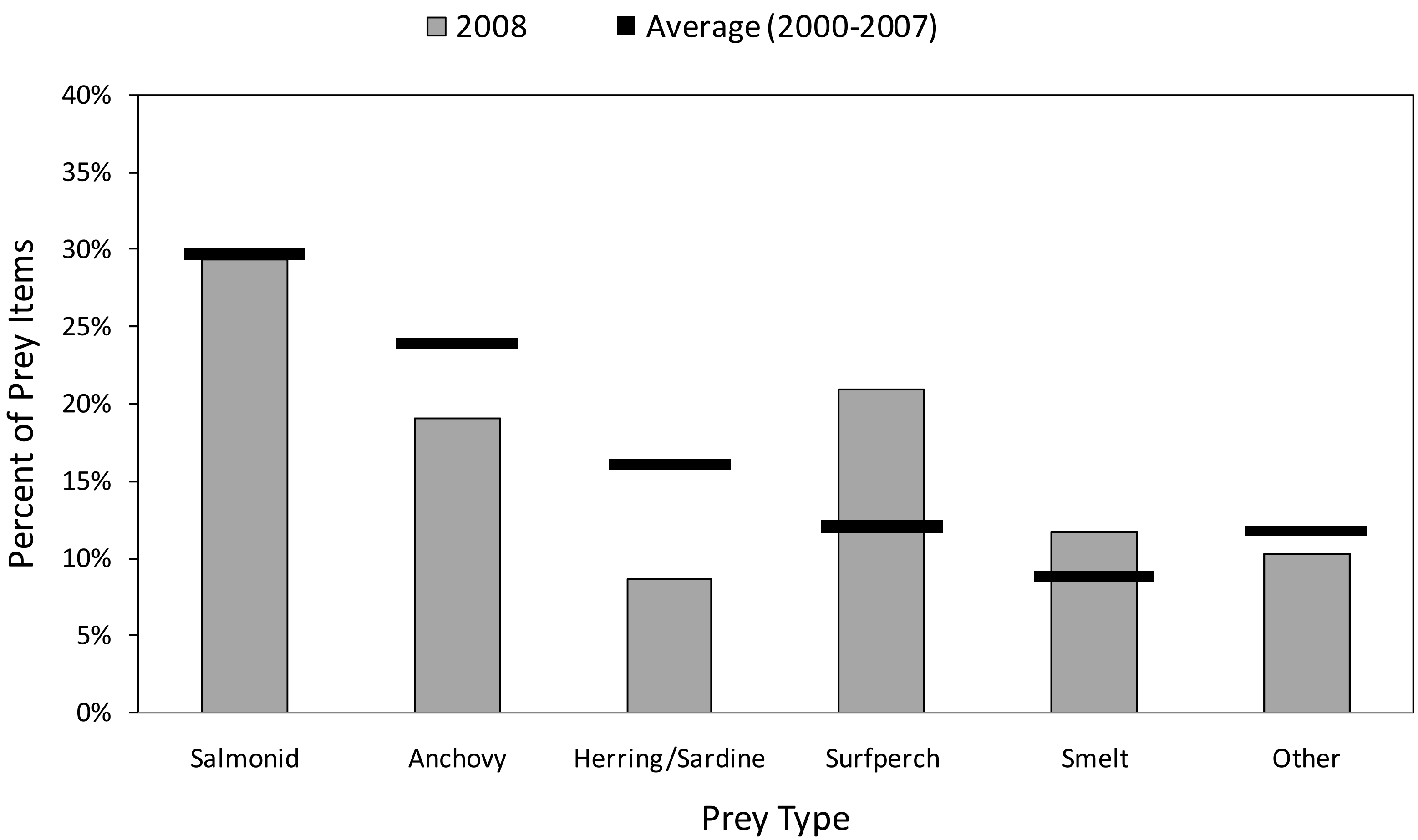



Figure 11. Diet composition of Caspian terns nesting on East Sand Island during 2008.

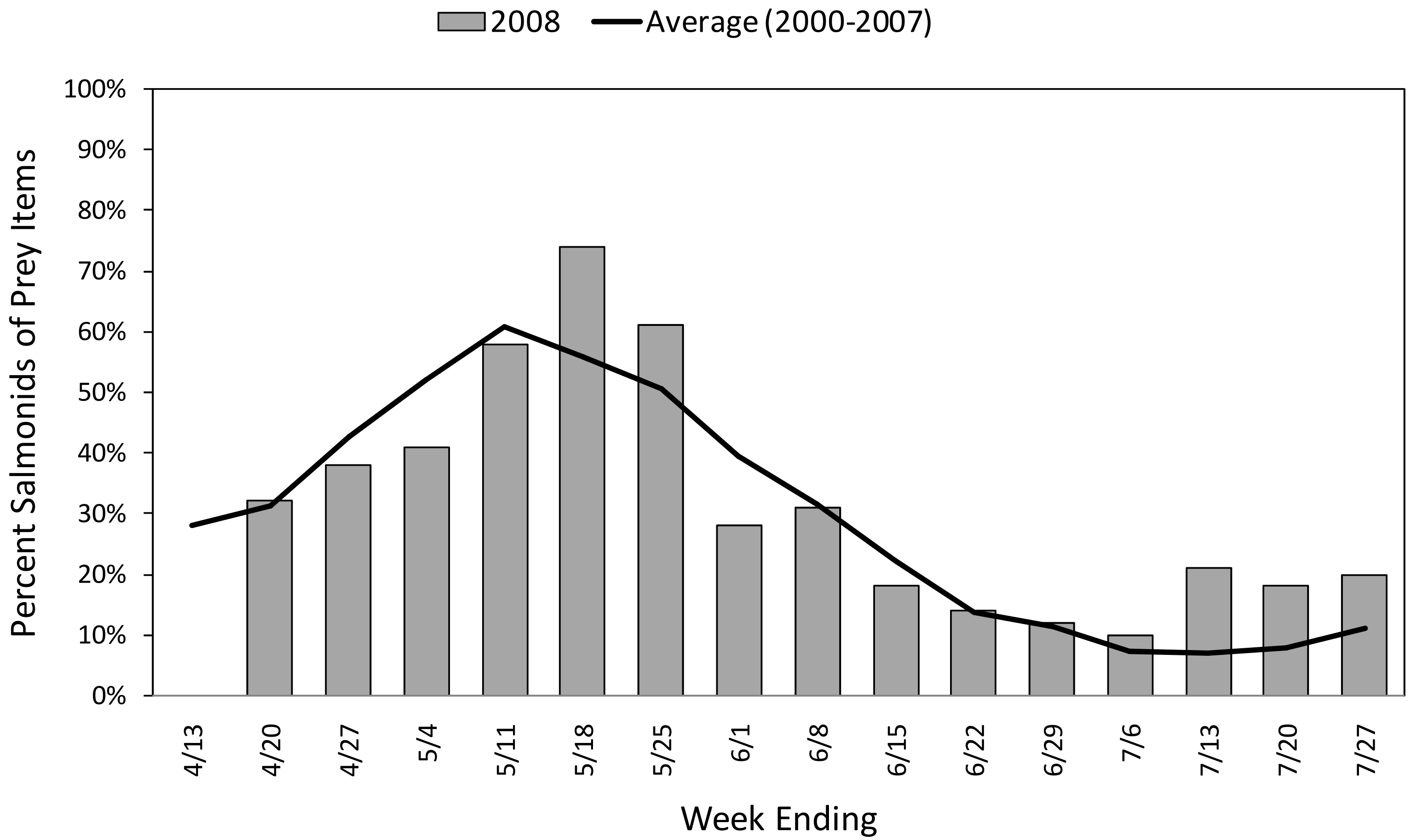



Figure 12. Weekly proportions of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island during the 2008 nesting season.

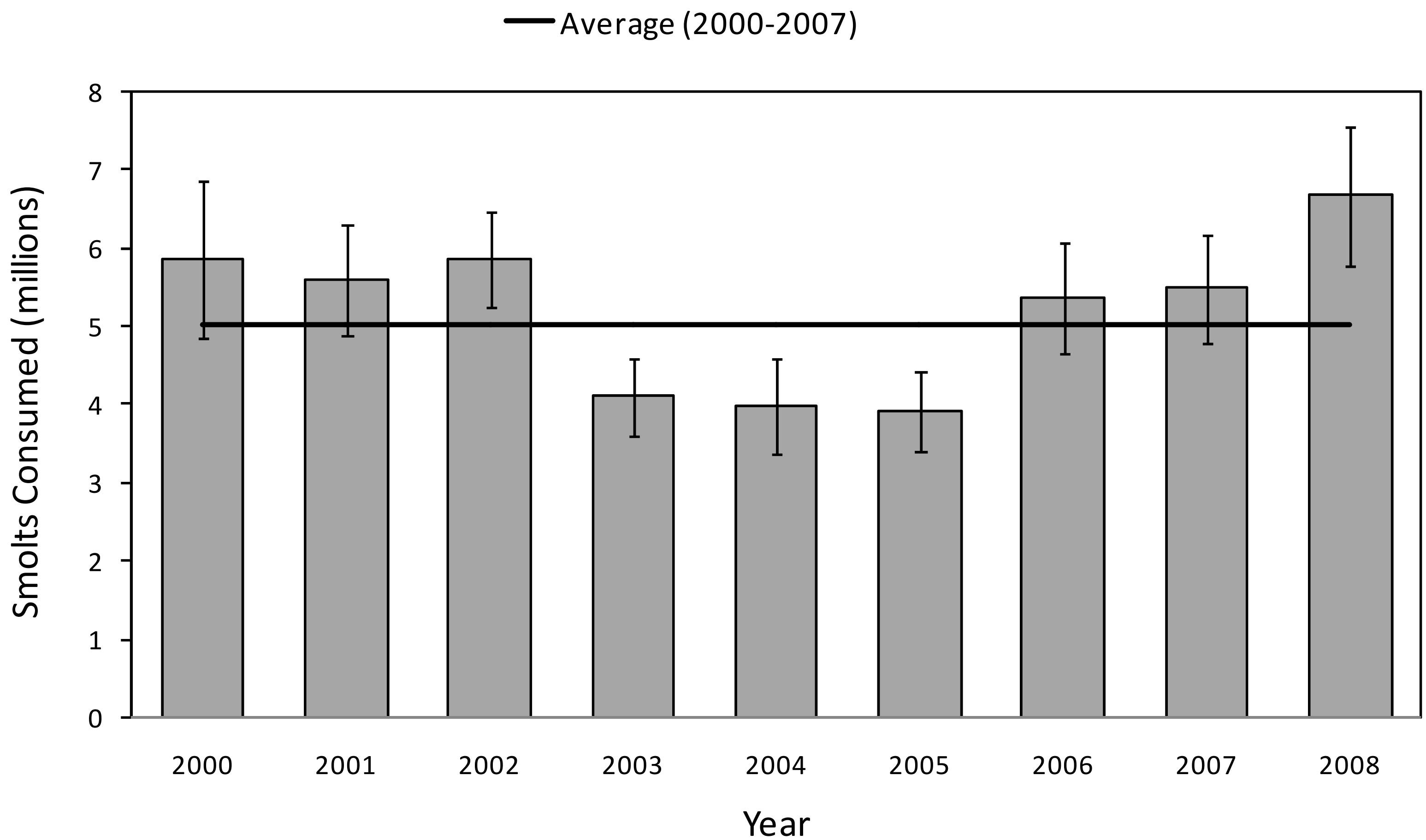



Figure 13. Total annual consumption of juvenile salmonids by Caspian terns nesting on East Sand Island during 2000-2008. Error bars represent 95% confidence intervals for the number of smolts consumed.

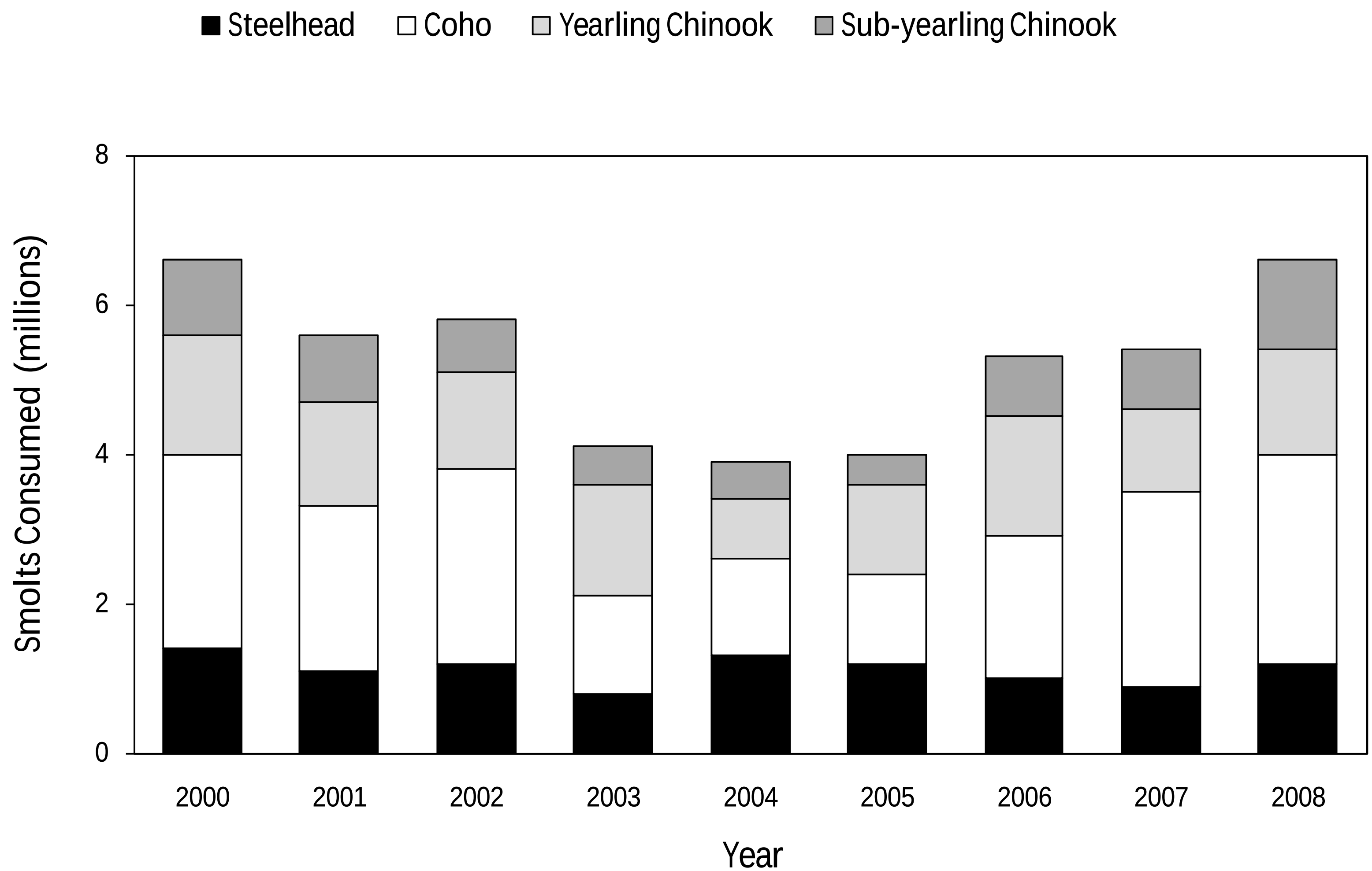



Figure 14. Total annual consumption of four species of juvenile salmonids by Caspian terns nesting on East Sand Island during 2000-2008.

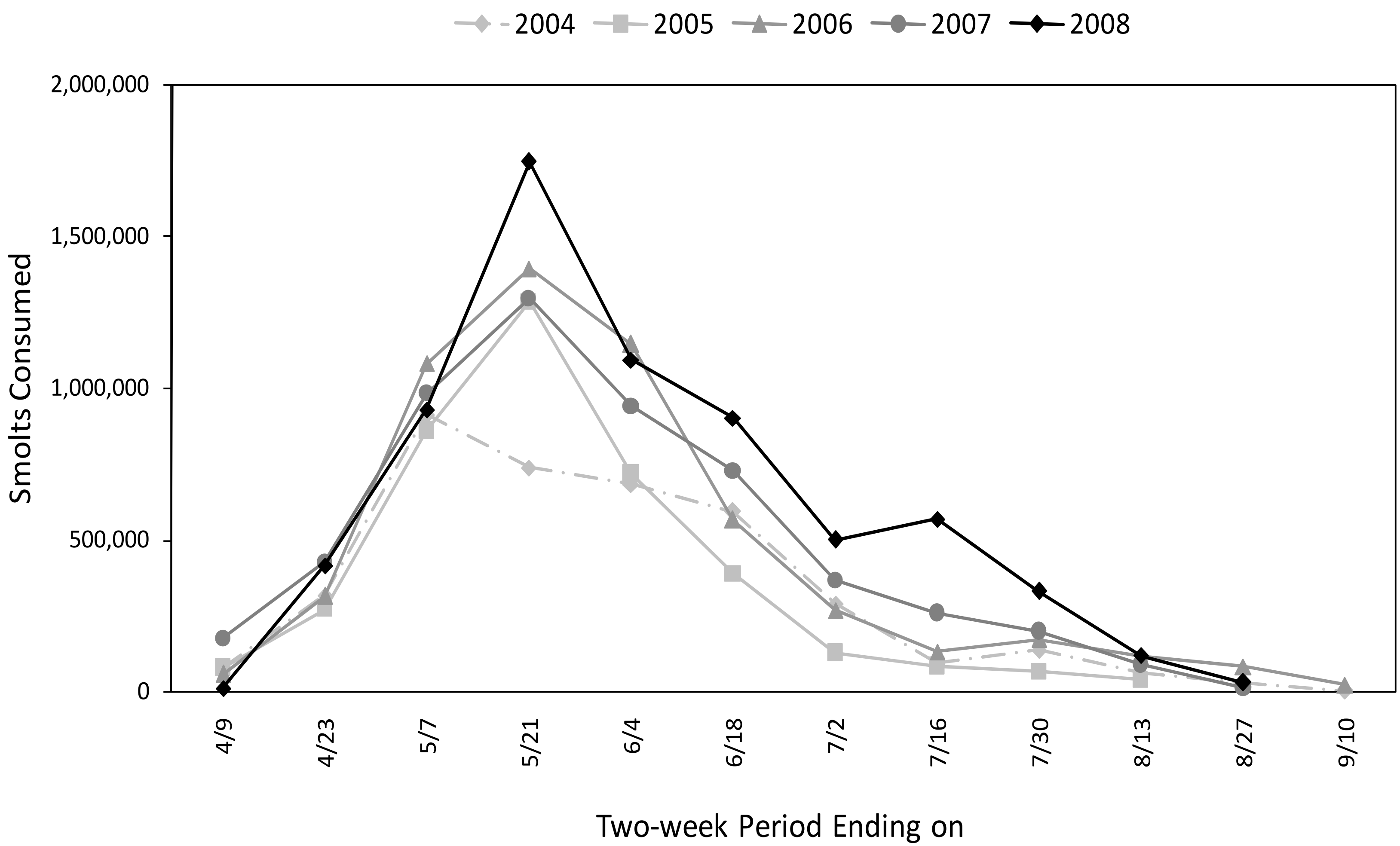



Figure 15. Seasonal trend in consumption of juvenile salmonids by Caspian terns nesting on East Sand Island during the 2004-2008 breeding seasons. Each data point includes steelhead, coho salmon, sockeye salmon, and yearling and sub-yearling Chinook salmon.

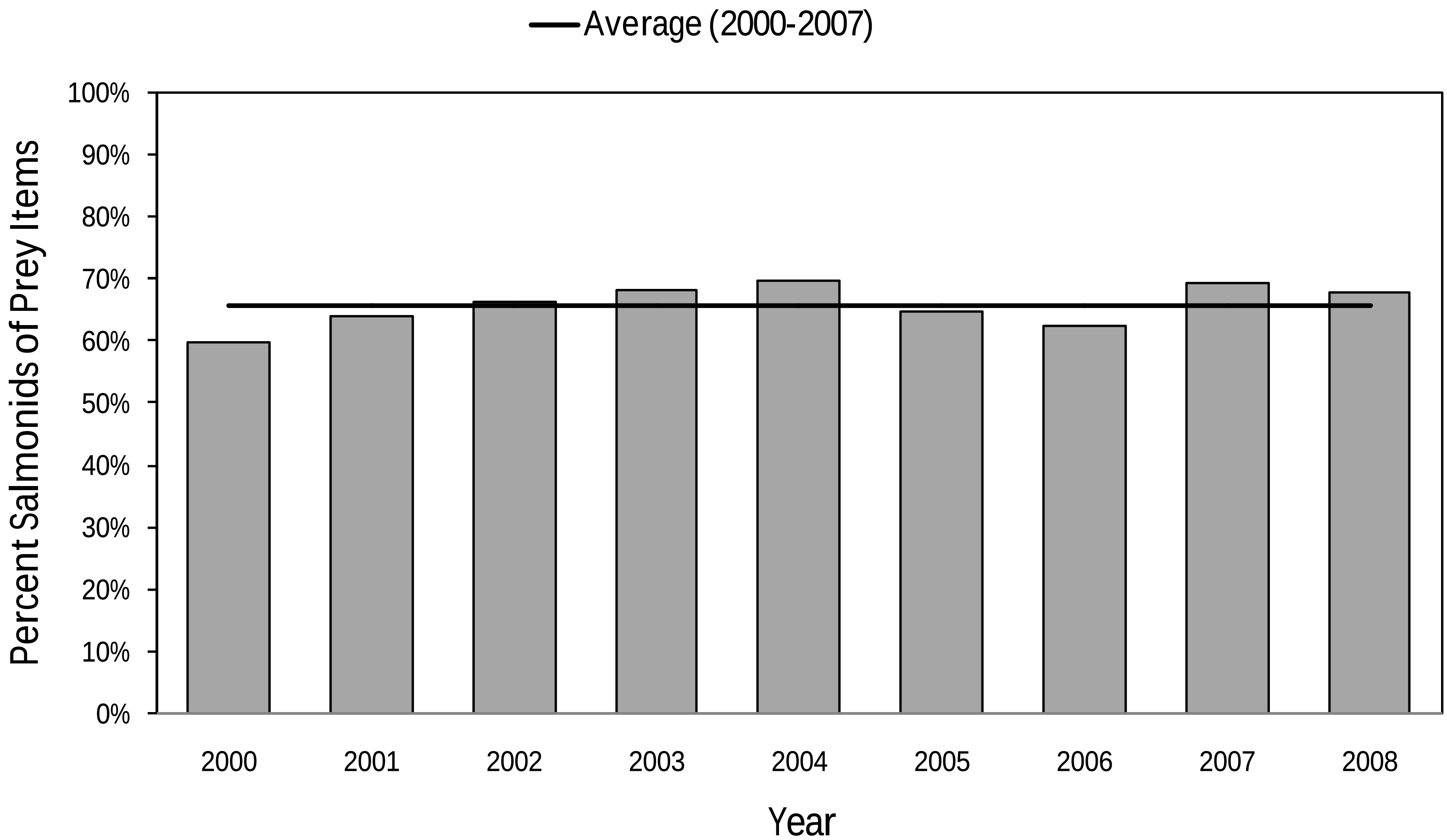



Figure 16. Proportion of juvenile salmonids in the diet of Caspian terns nesting on Crescent Island during 2000-2008.

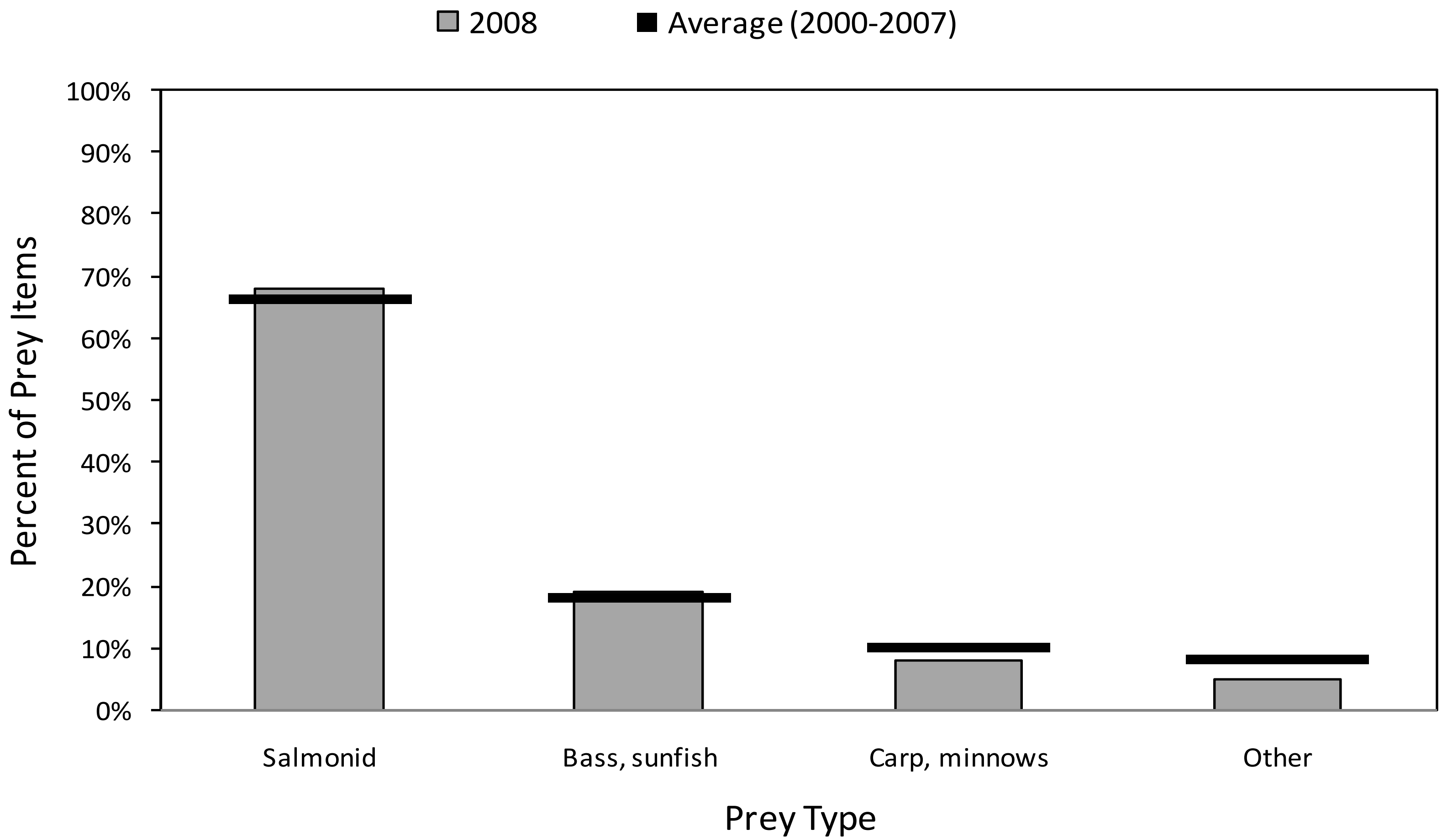



Figure 17. Diet composition of Caspian terns nesting on Crescent Island during 2008.

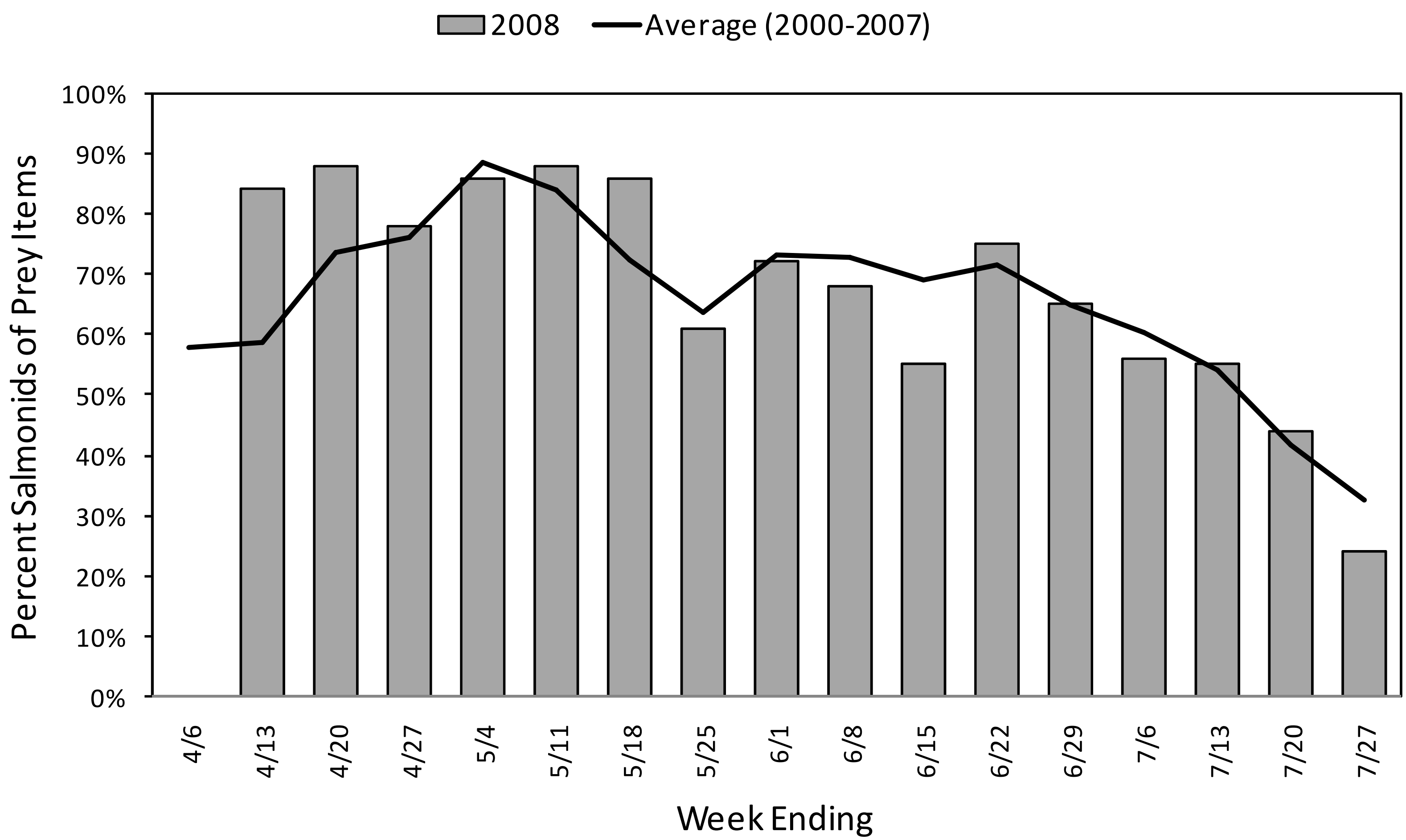



Figure 18. Weekly proportions of juvenile salmonids in the diet of Caspian terns nesting on Crescent Island during 2008.

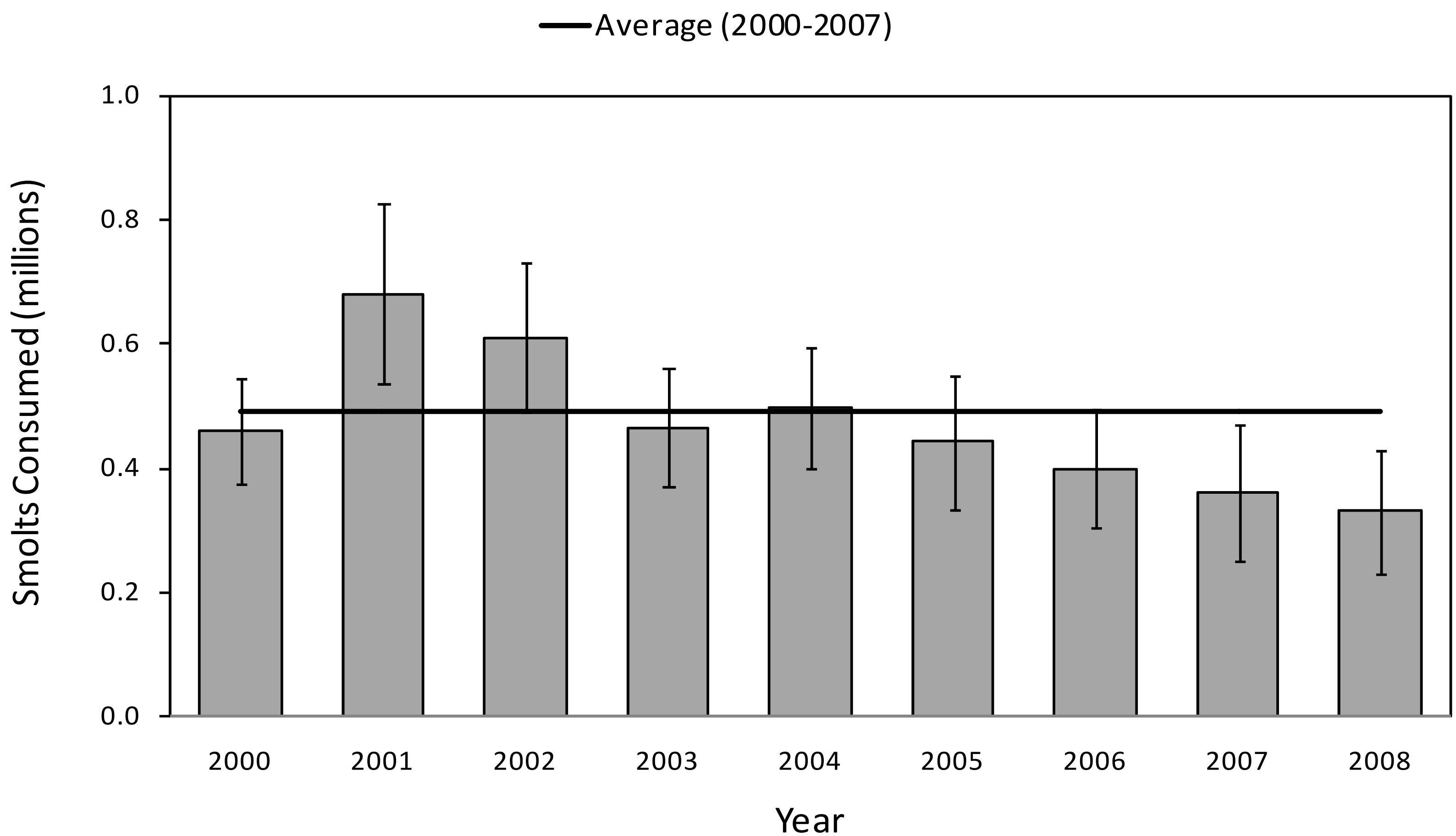



Figure 19. Total annual consumption of juvenile salmonids by Caspian terns nesting on Crescent Island during 2000-2008. Error bars represent 95% confidence intervals for the number of smolts consumed.

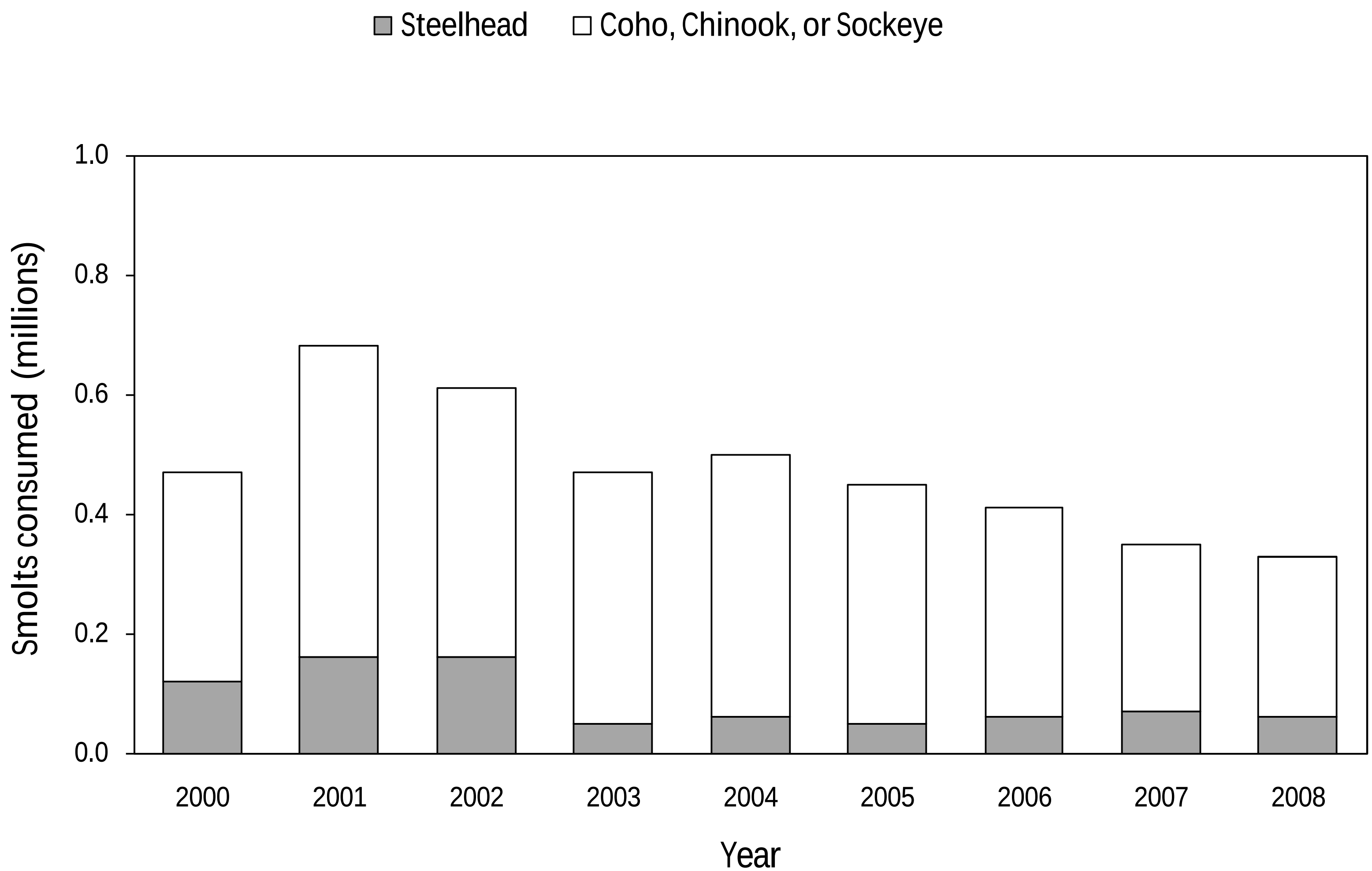



Figure 20. Total annual consumption of steelhead and other salmonids by Caspian terns nesting on Crescent Island during 2000-2008.

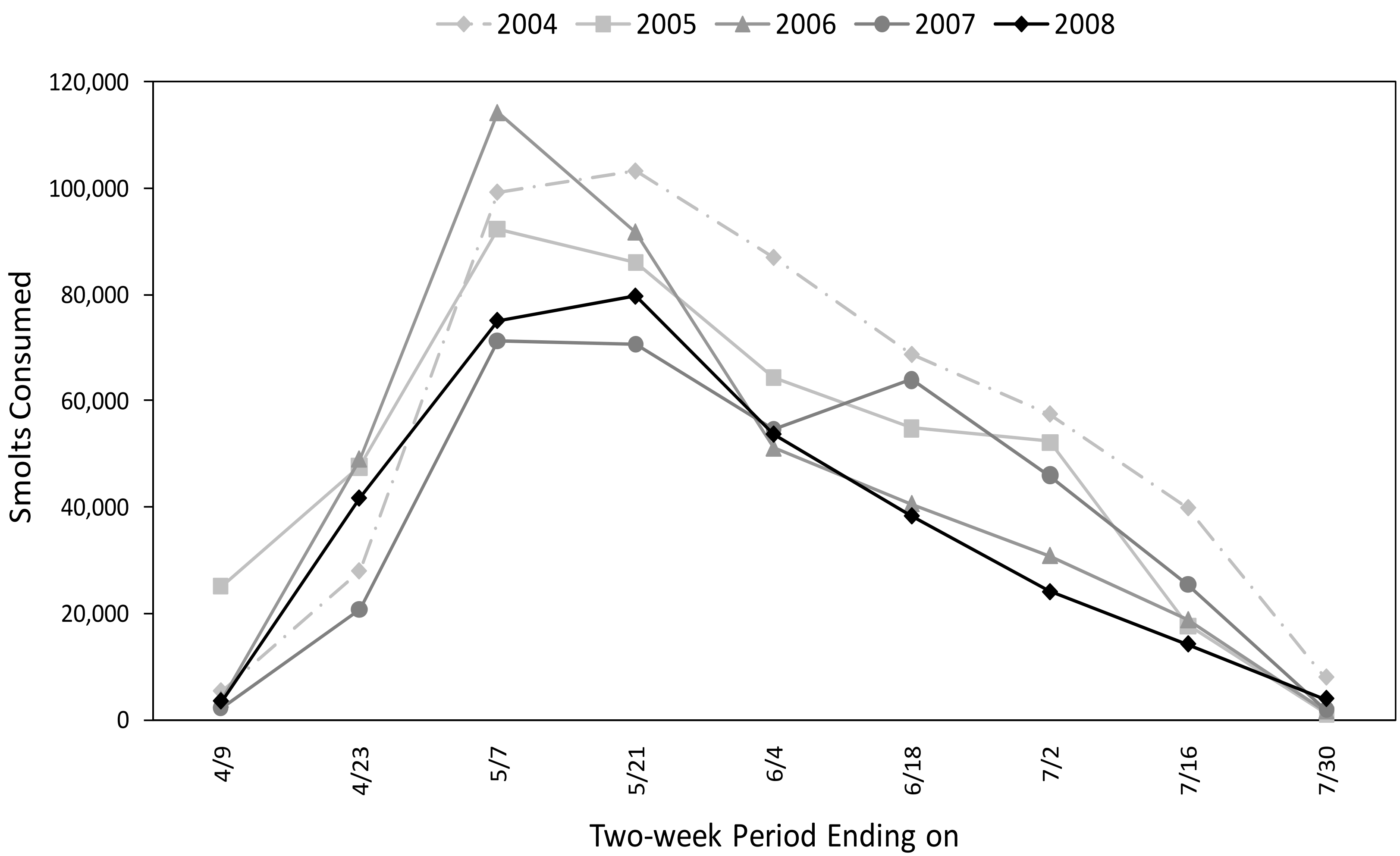
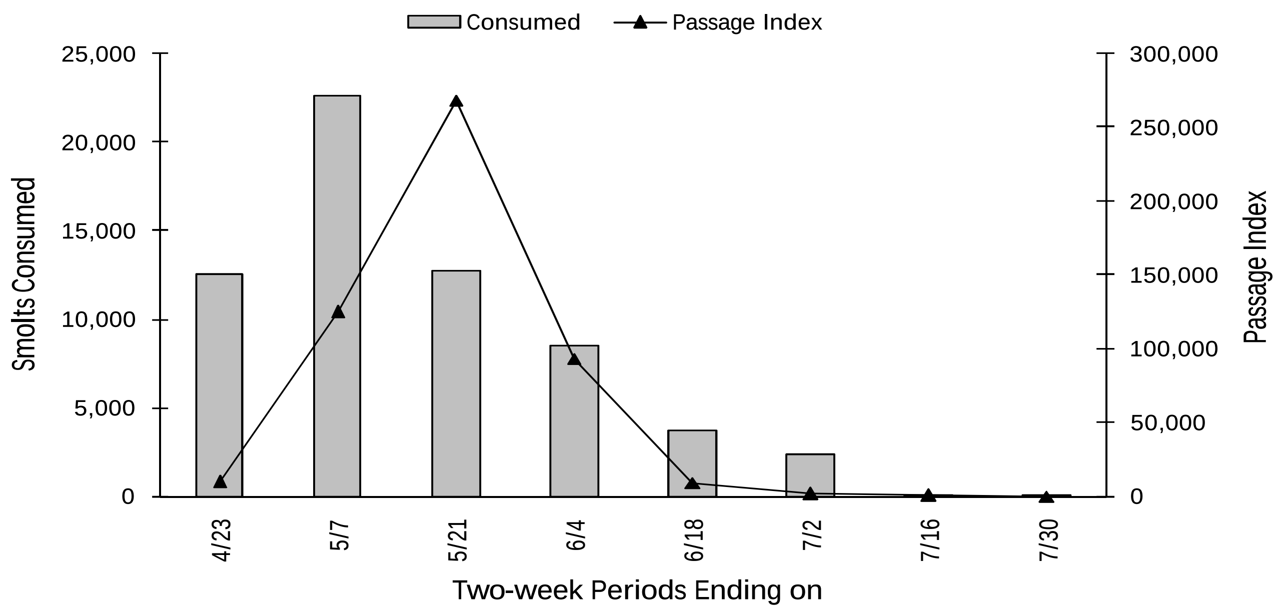



Figure 21. Seasonal trend in consumption of juvenile salmonids by Caspian terns nesting on Crescent Island during the 2004-2008 breeding seasons. Each data point includes steelhead, coho salmon, sockeye salmon, and yearling and sub-yearling Chinook salmon.

a) Steelhead




b) Coho, Chinook, and Sockeye

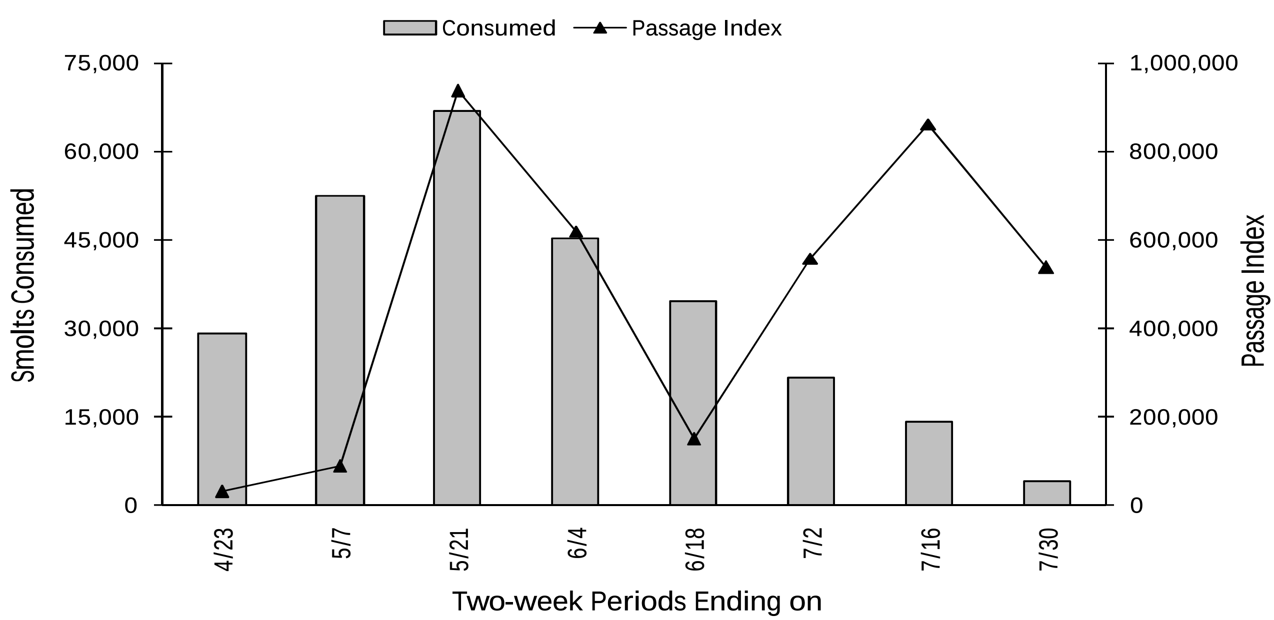



Figure 22. Consumption of steelhead and other salmonids by Caspian terns nesting on Crescent Island during 2008, by two-week periods. Passage index is for steelhead and other salmonids passing McNary Dam on the mid-Columbia River (FPC 2008).

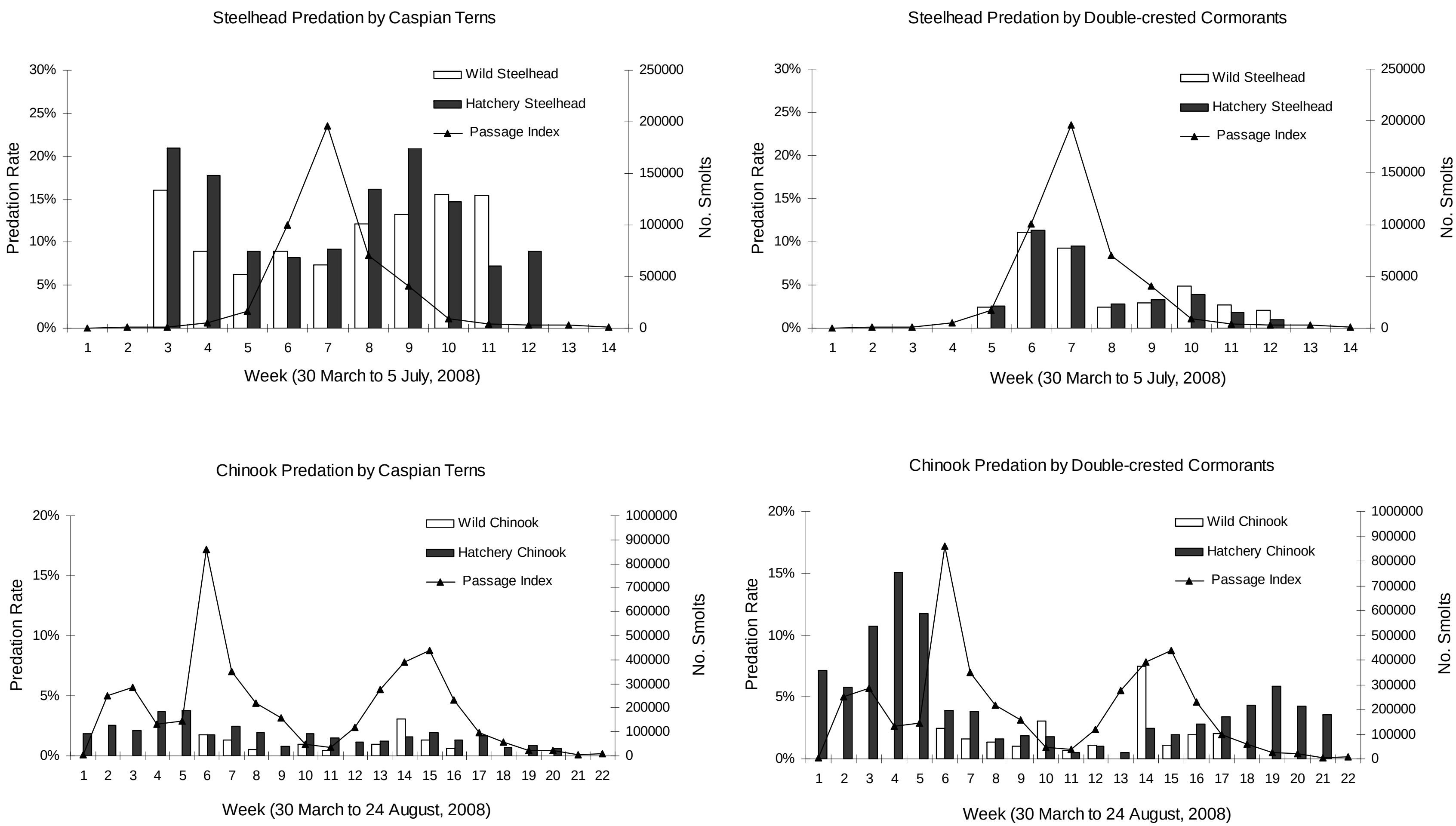



Figure 23. Estimated weekly predation rates on hatchery-reared and wild steelhead and Chinook salmon smolts by Caspian terns and double-crested cormorants nesting on East Sand Island in 2008. Predation rates are based on the proportion of PIT-tagged fish interrogated passing Bonneville Dam that was subsequently recovered on the tern or cormorant colony. Passage index is for steelhead and Chinook salmon passing Bonneville Dam. Predation rates are corrected for on-colony PIT tag detection efficiency, but not for deposition rates, and are therefore minimum estimates.

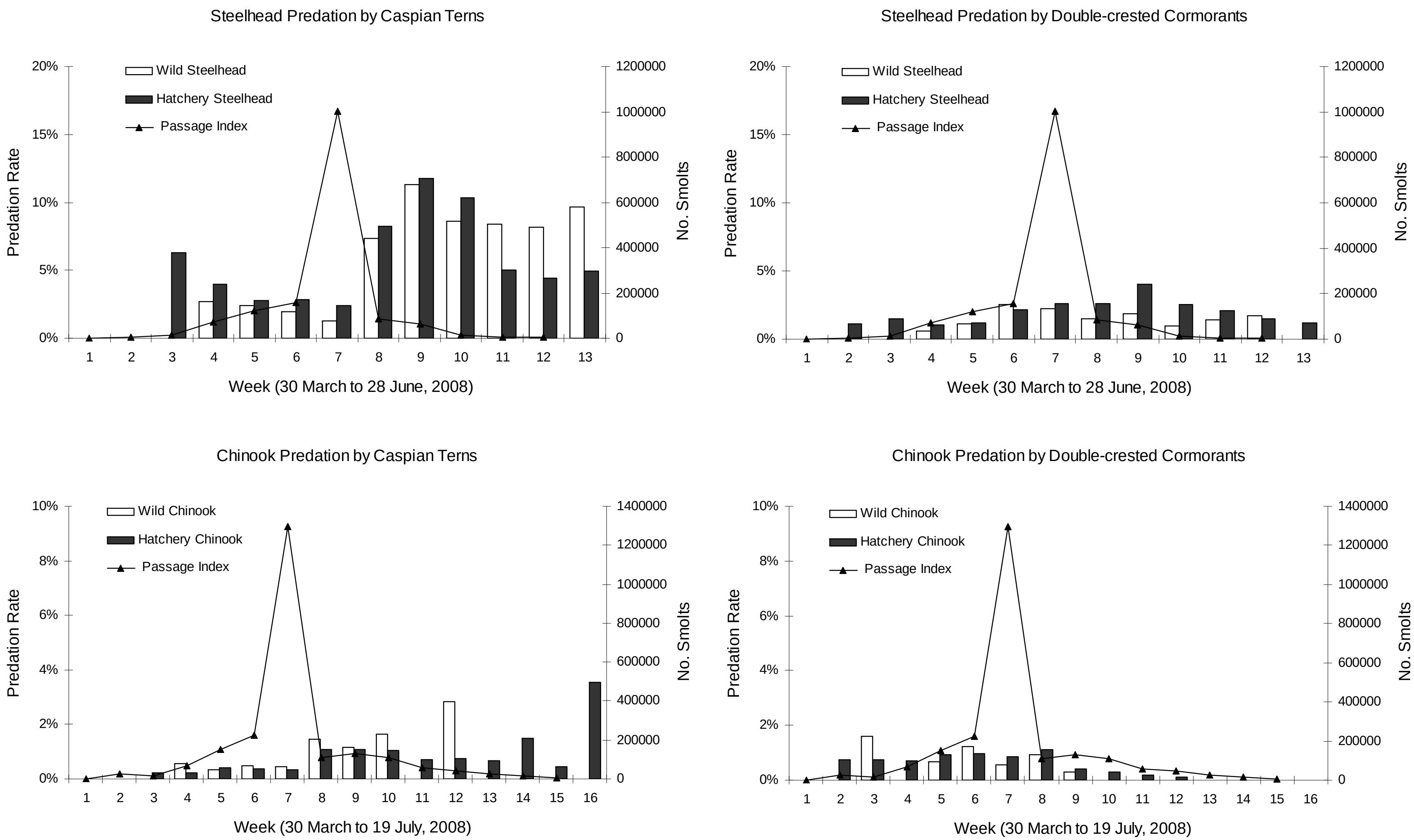



Figure 24. Estimated weekly predation rates on hatchery-reared and wild steelhead and Chinook salmon smolts by Caspian terns and double-crested cormorants nesting on Crescent Island and Foundation Island, respectively, during 2008. Predation rates are based on the proportion of PIT-tagged fish interrogated passing Lower Monumental Dam that was subsequently recovered on the tern or cormorant colony. Passage index is for steelhead and Chinook salmon passing Lower Monumental Dam. Predation rates are corrected for on-colony PIT tag detection efficiency but not for deposition rates and are therefore minimum estimates.

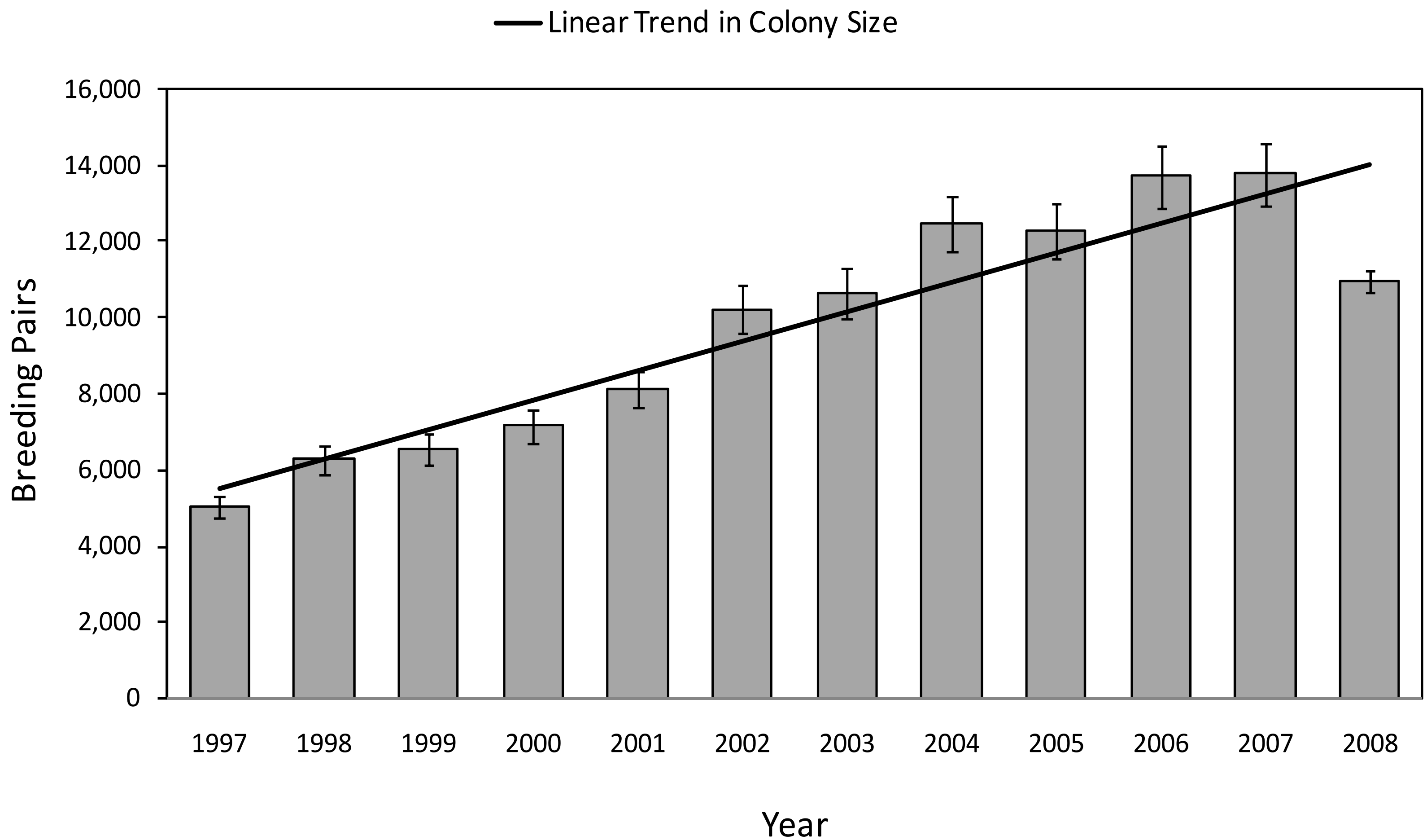



Figure 25. Double-crested cormorant colony size on East Sand Island during 1997-2008. Error bars represent 95% confidence intervals for the number of breeding pairs.

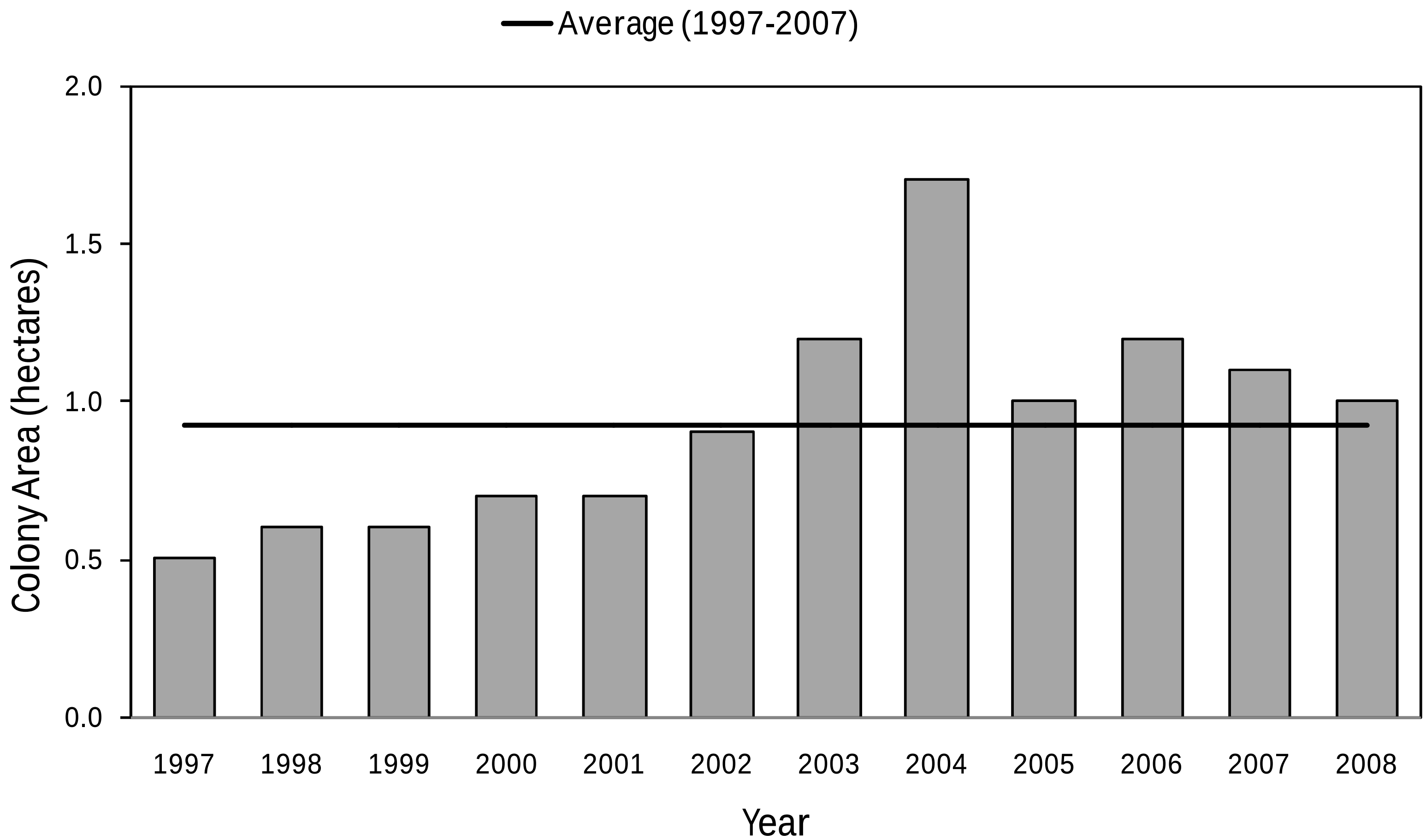



Figure 26.  Area occupied by nesting double-crested cormorants on East Sand Island during 1997-2008.

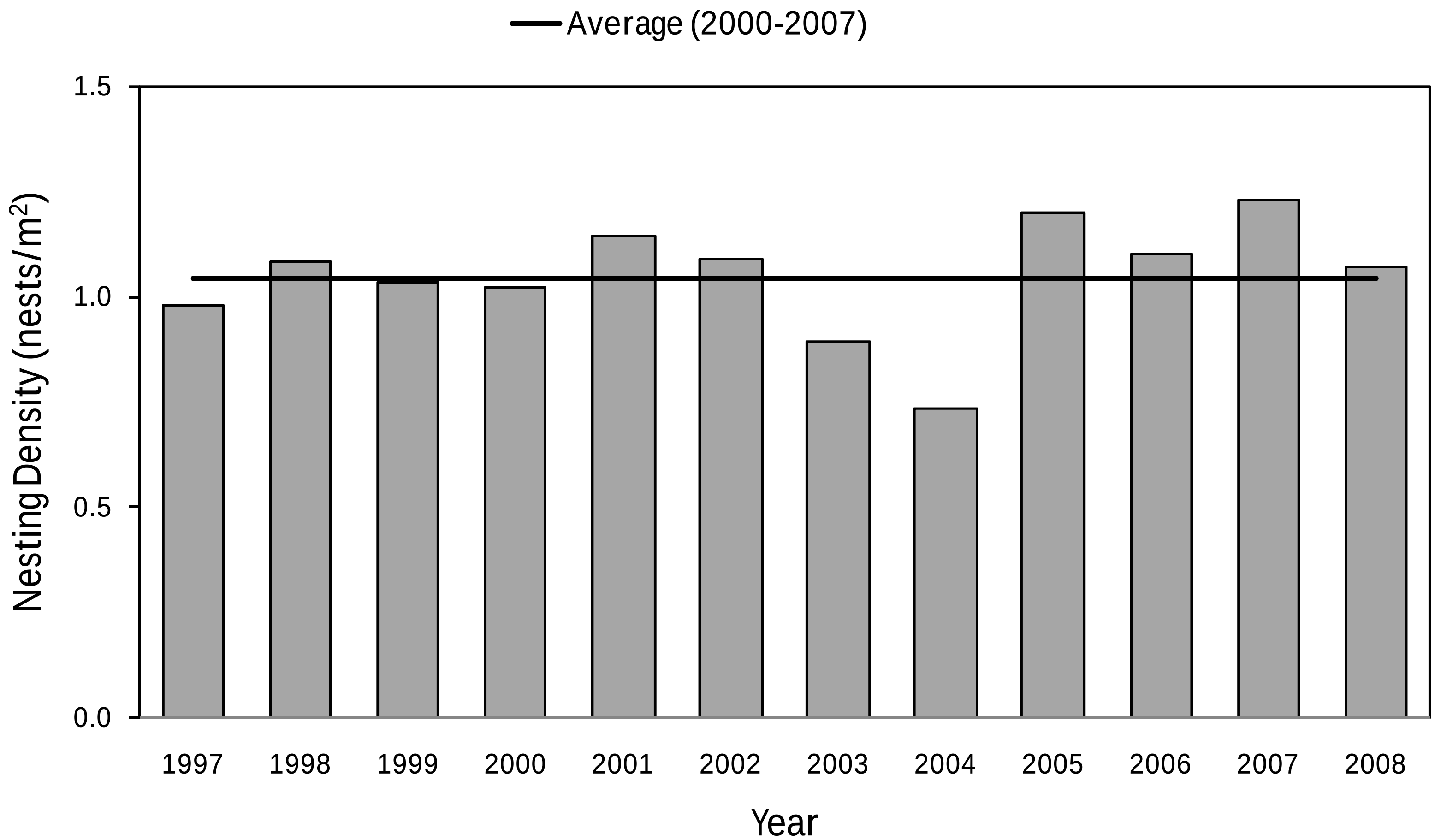



Figure 27. Average nesting density for double-crested cormorants nesting on East Sand Island during 1997-2008.

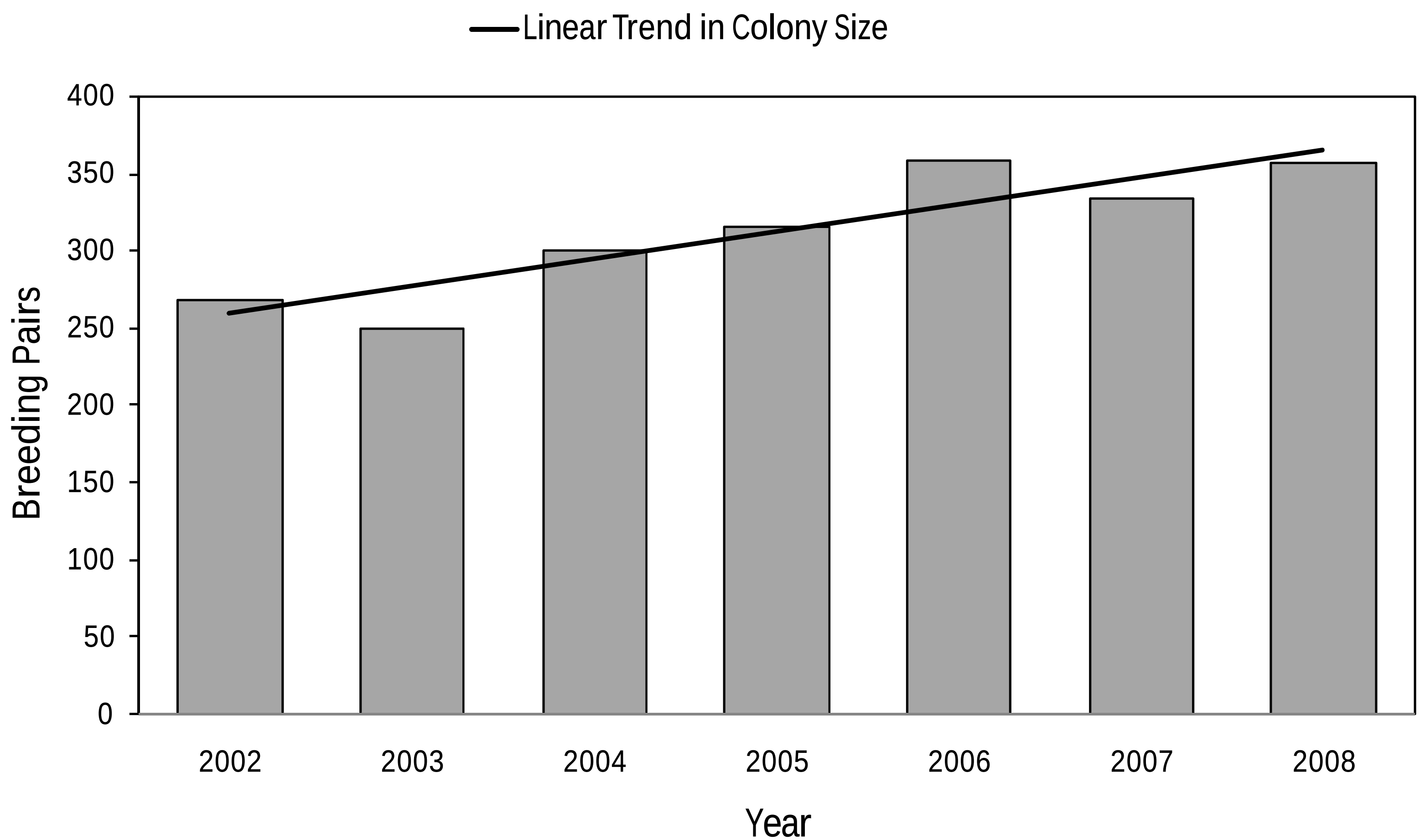



Figure 28. Double-crested cormorant colony size on Foundation Island during 2002-2008.

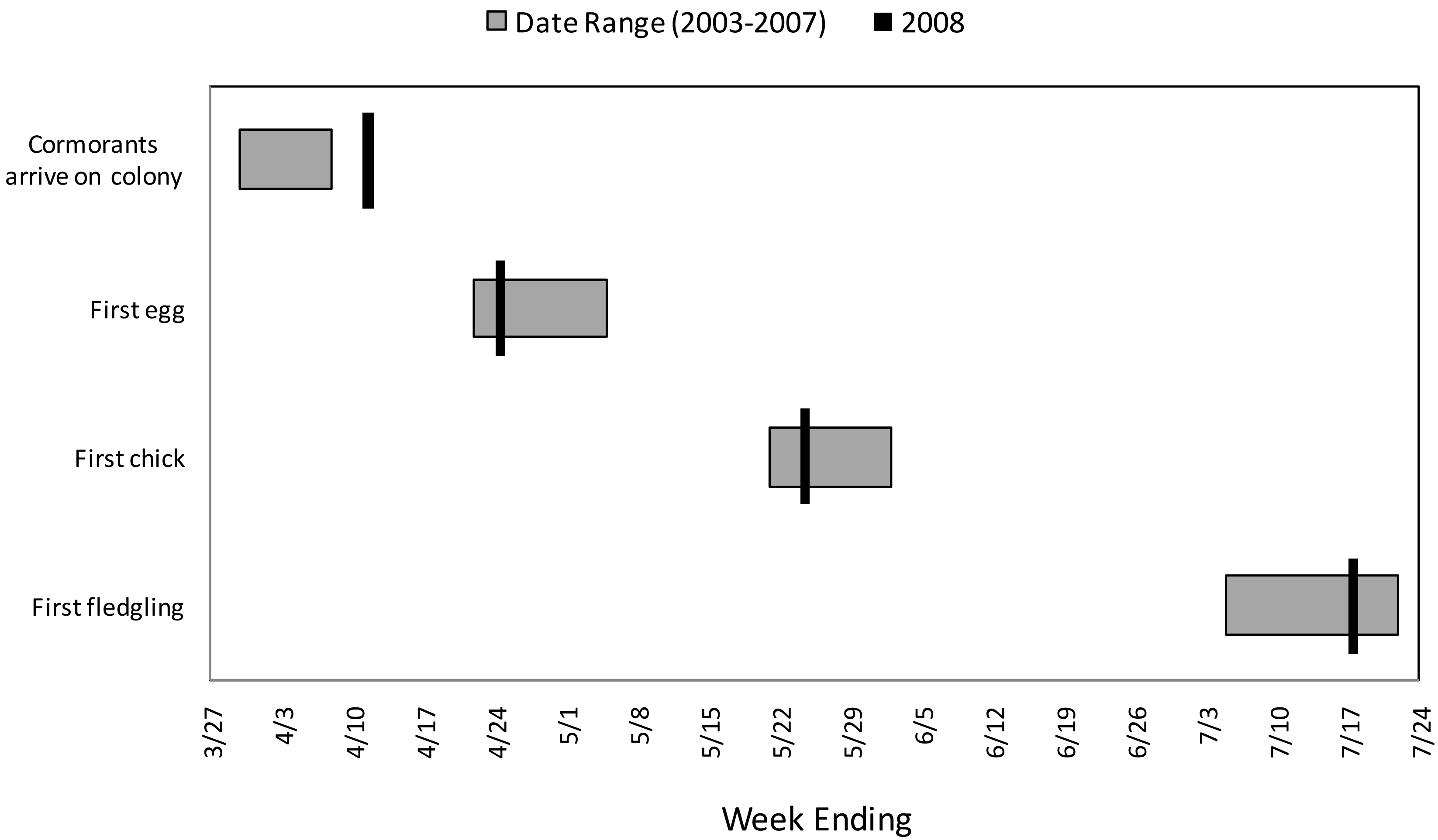



Figure 29. Nesting chronology at the East Sand Island double-crested cormorant colony during 2008.

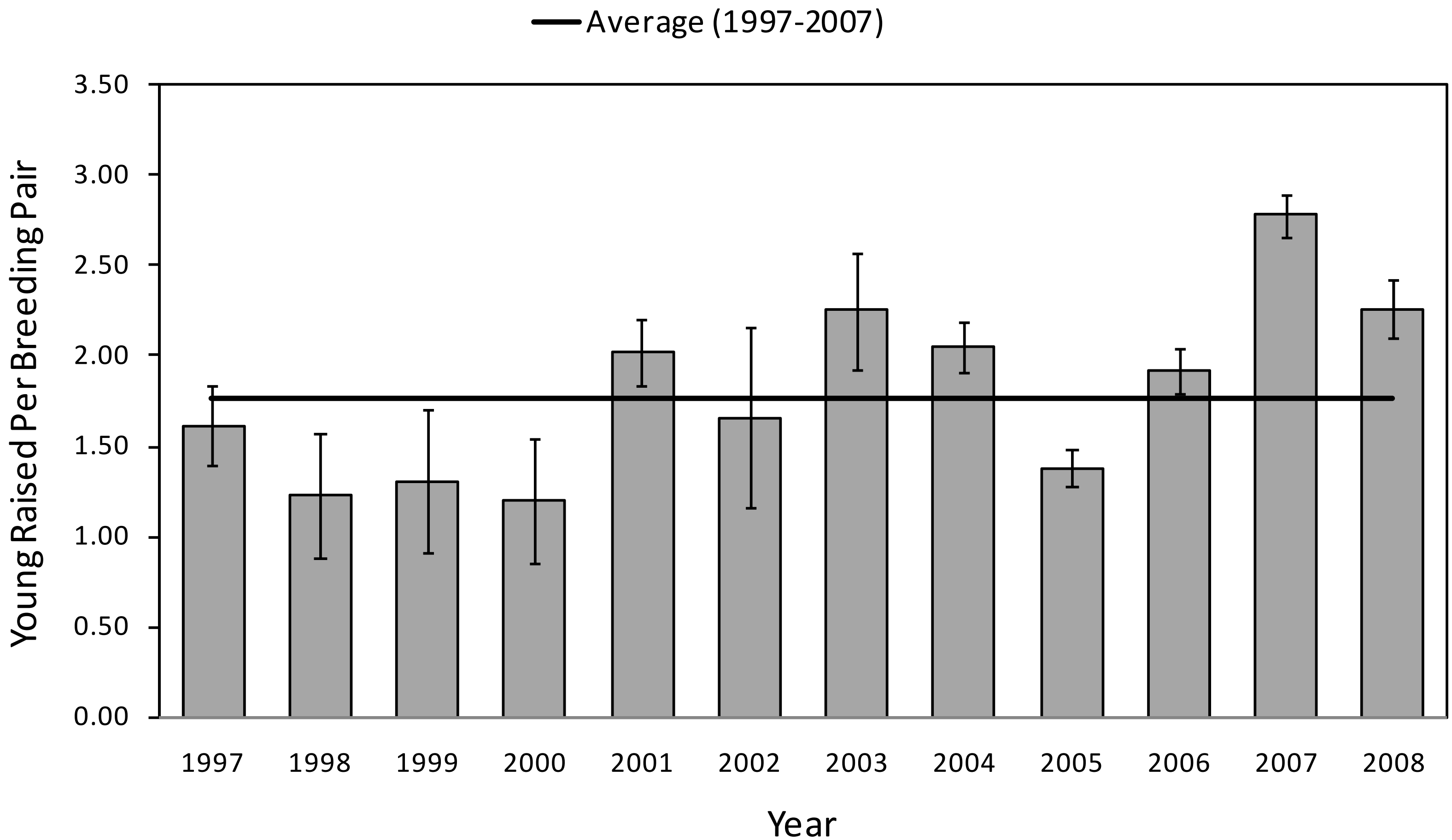



Figure 30. Double-crested cormorant nesting success on East Sand Island during 1997-2008. Error bars represent 95% confidence intervals for the average number young raised per breeding pair.

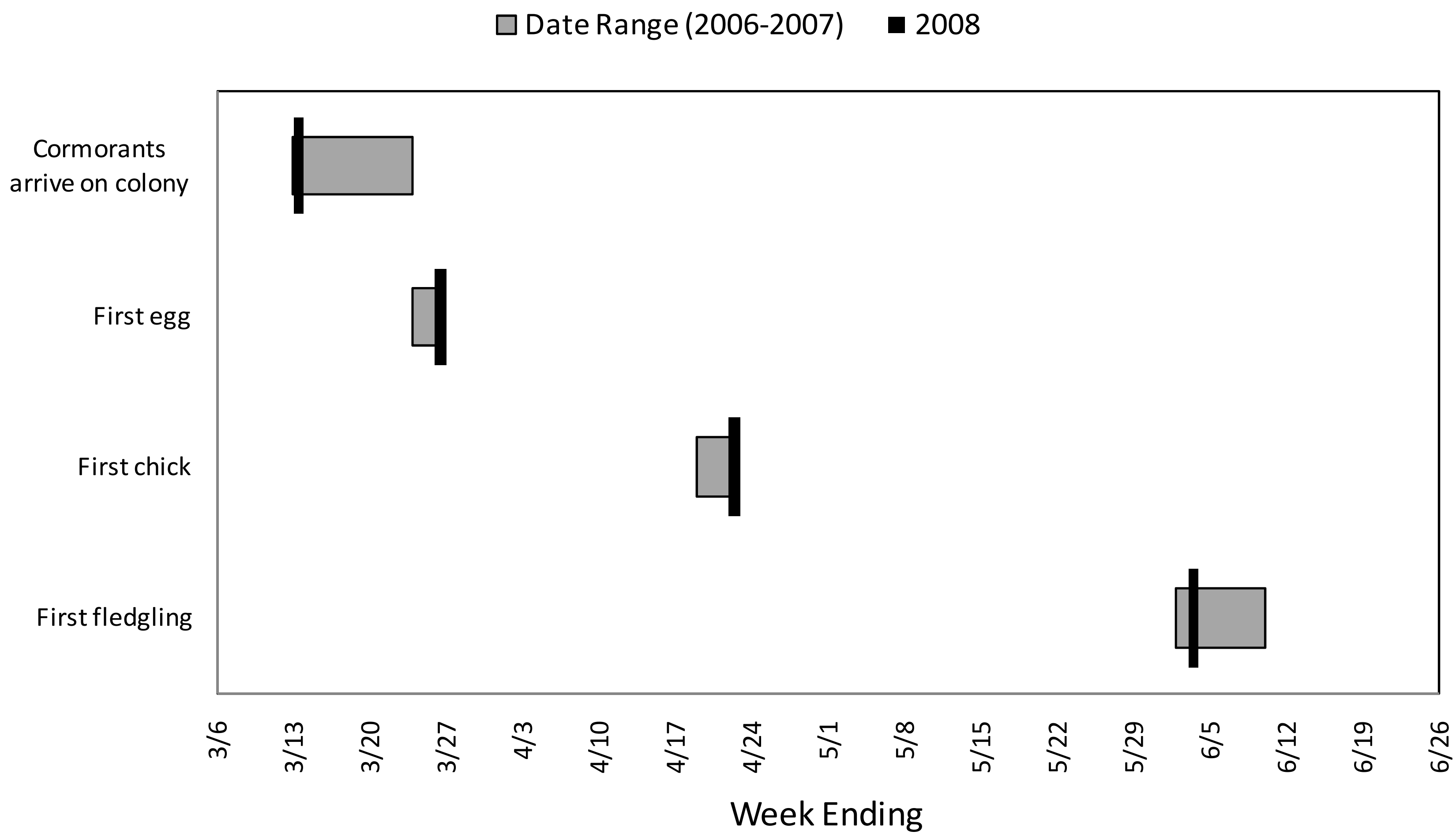



Figure 31. Nesting chronology at the Foundation Island double-crested cormorant colony during 2008.

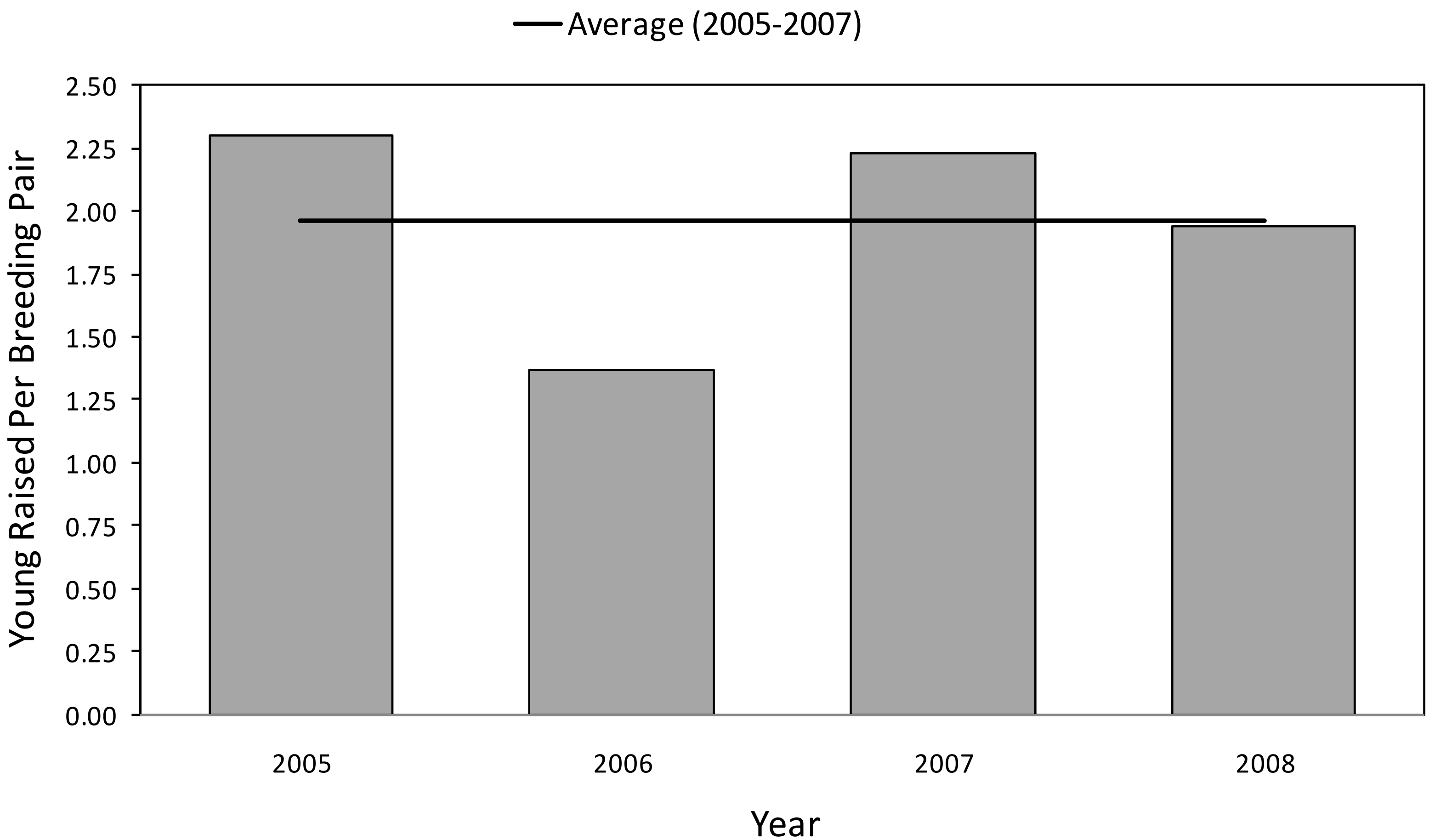



Figure 32. Double-crested cormorant nesting success at the Foundation Island colony during 2005-2008.

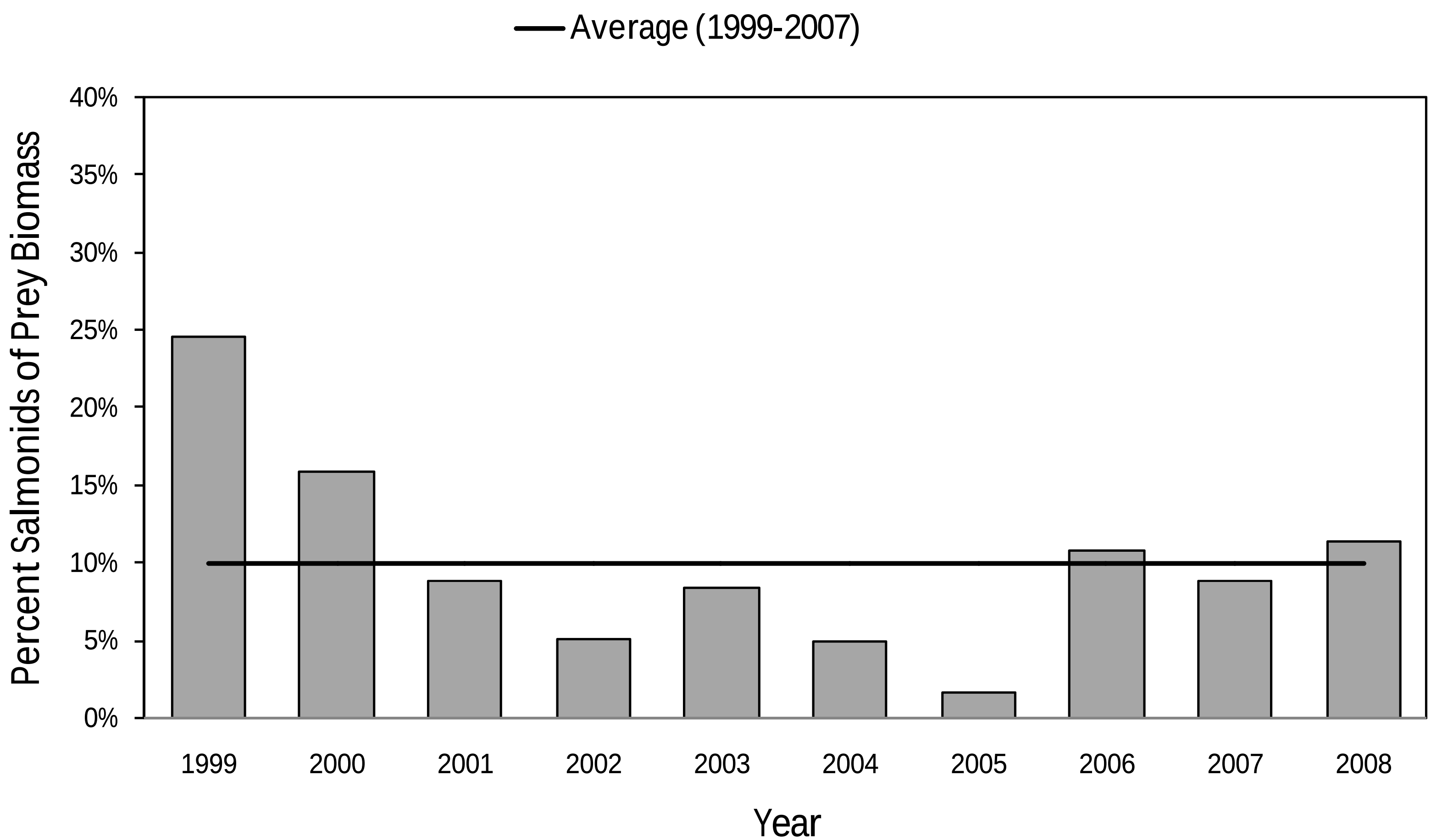



Figure 33. Proportion of juvenile salmonids in the diet of double-crested cormorants nesting on East Sand Island during 1999-2008.

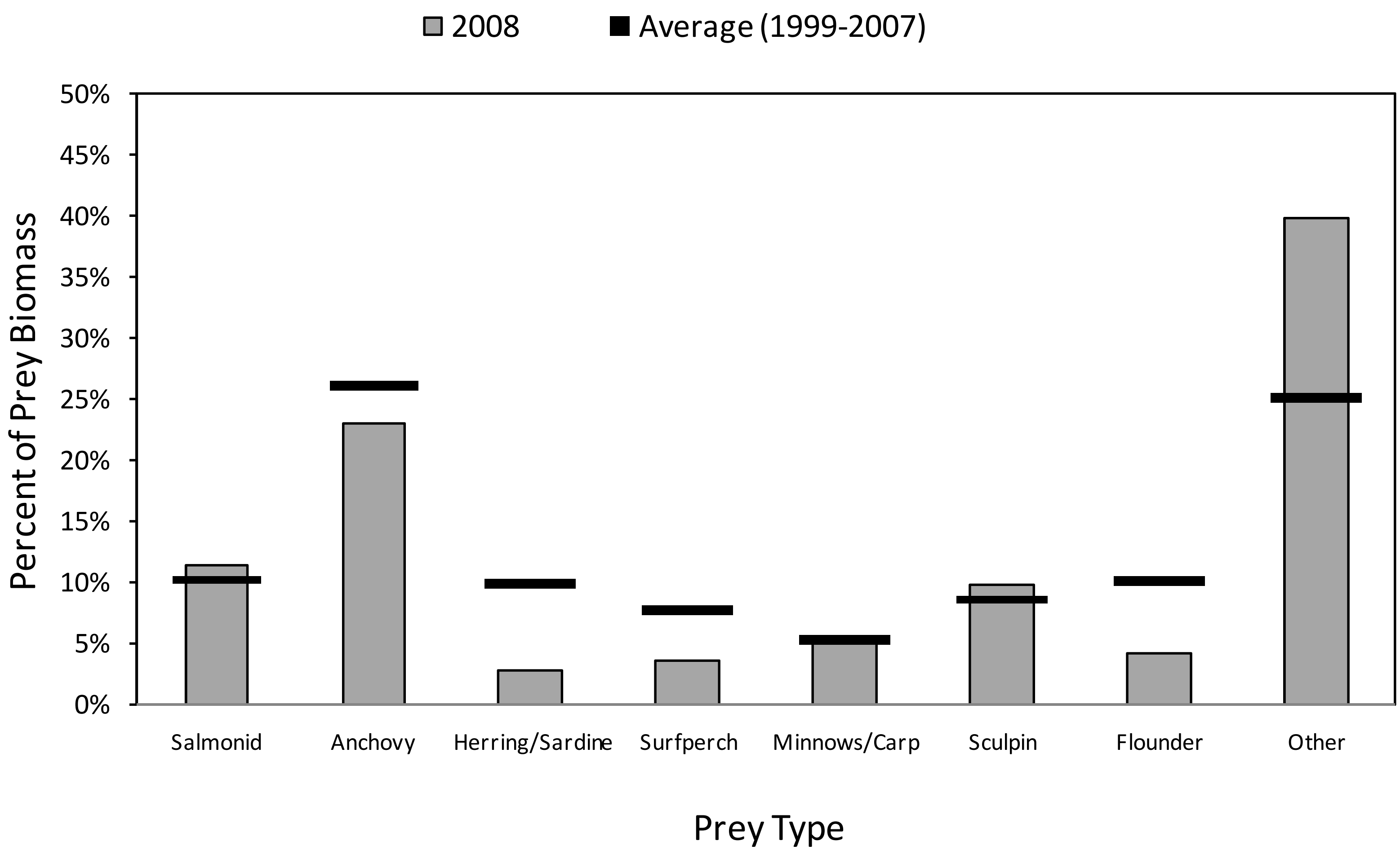



Figure 34. Diet composition of double-crested cormorants nesting on East Sand Island during 2008.

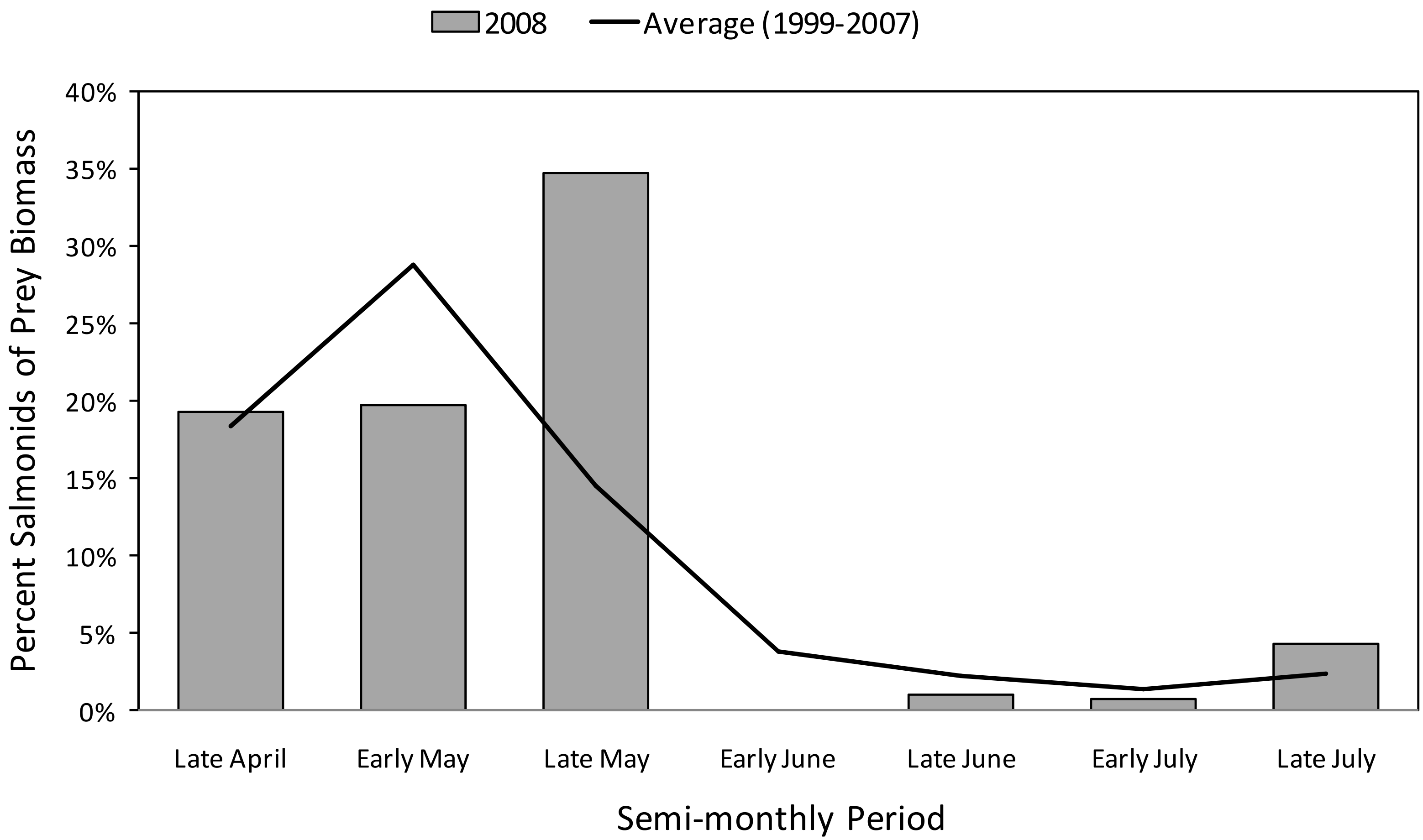



Figure 35. Semi-monthly proportions of juvenile salmonids in the diet of double-crested cormorants nesting on East Sand Island during 2008.

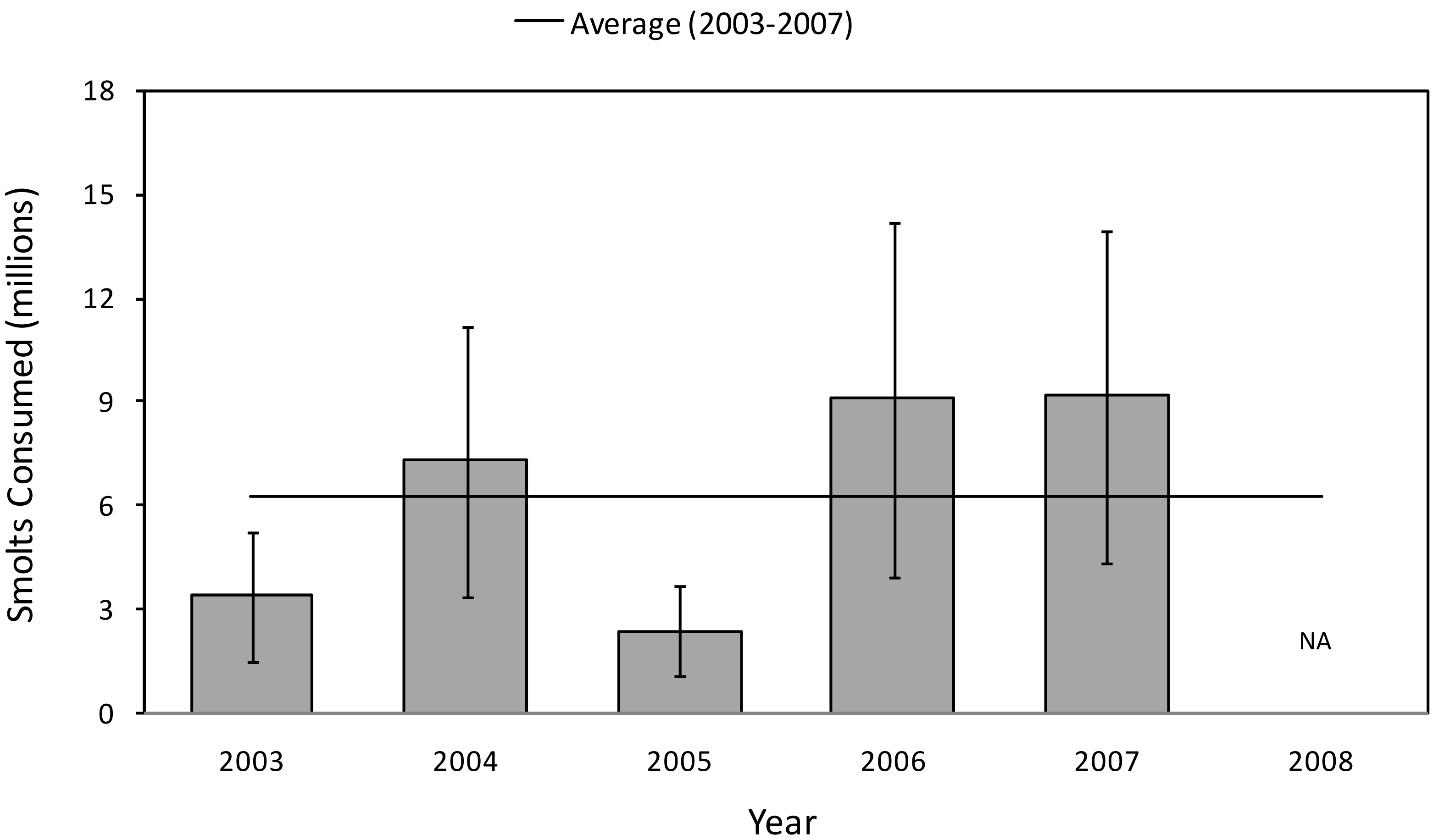



Figure 36. Total annual consumption of juvenile salmonids by double-crested cormorants nesting on East Sand Island during 2003-2007. Error bars represent 95% confidence intervals for the number of smolts consumed.

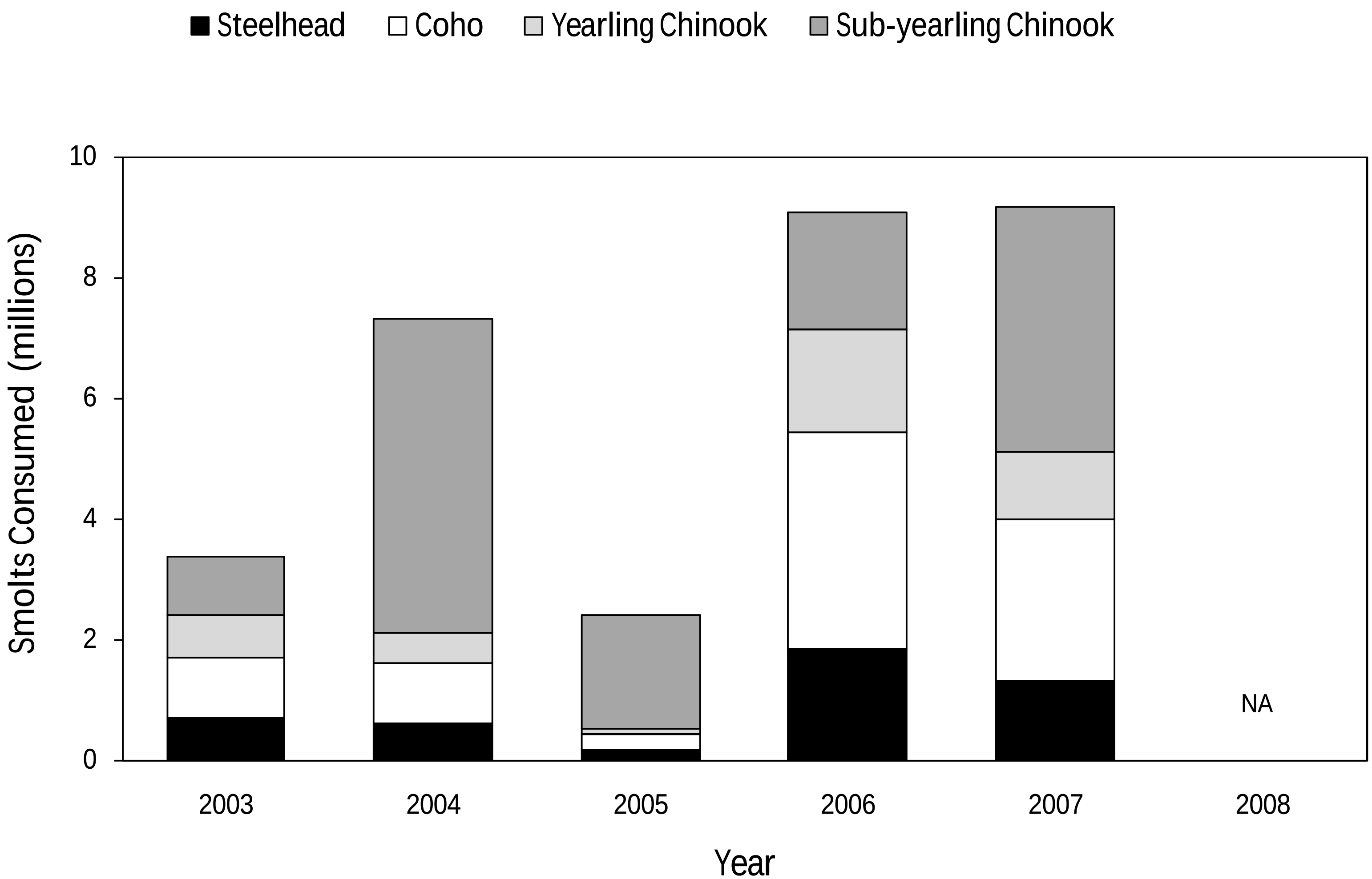



Figure 37. Total annual consumption of four species of juvenile salmonids by double-crested cormorants nesting on East Sand Island during 2003-2007.

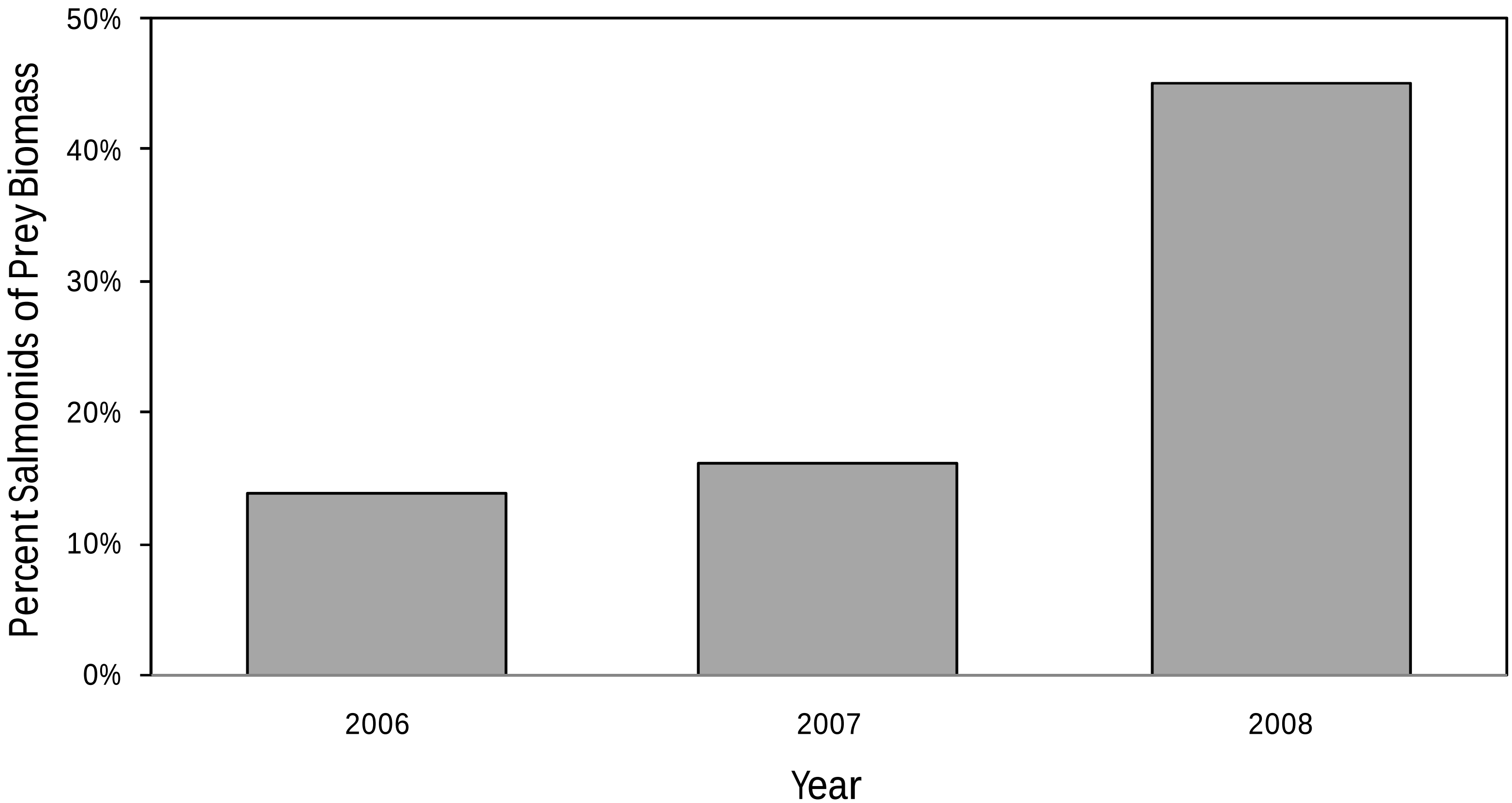



Figure 38. Proportion of juvenile salmonids in the diet of double-crested cormorants nesting on Foundation Island during 2006-2008.

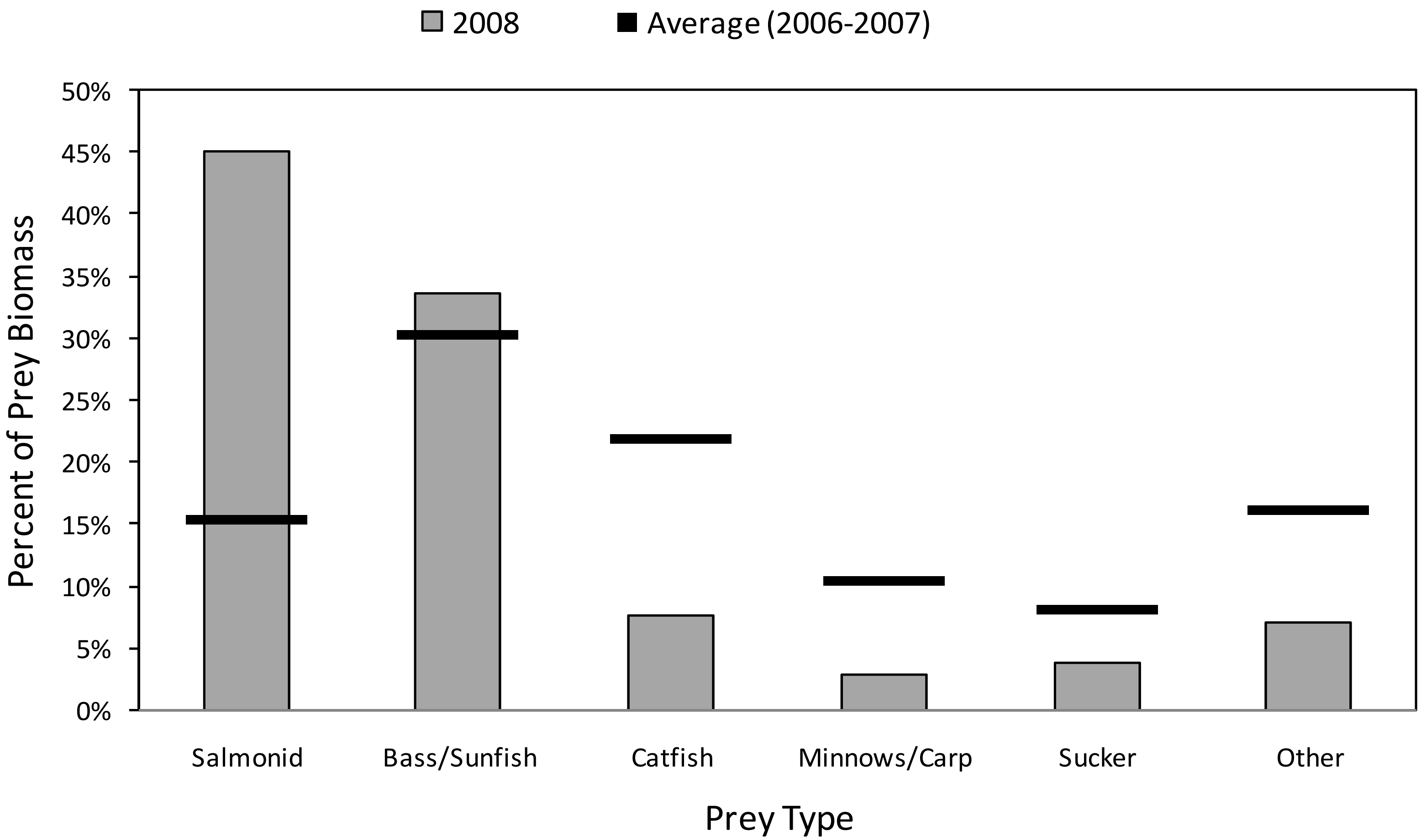



Figure 39. Diet composition of double-crested cormorants nesting on Foundation Island during 2008.

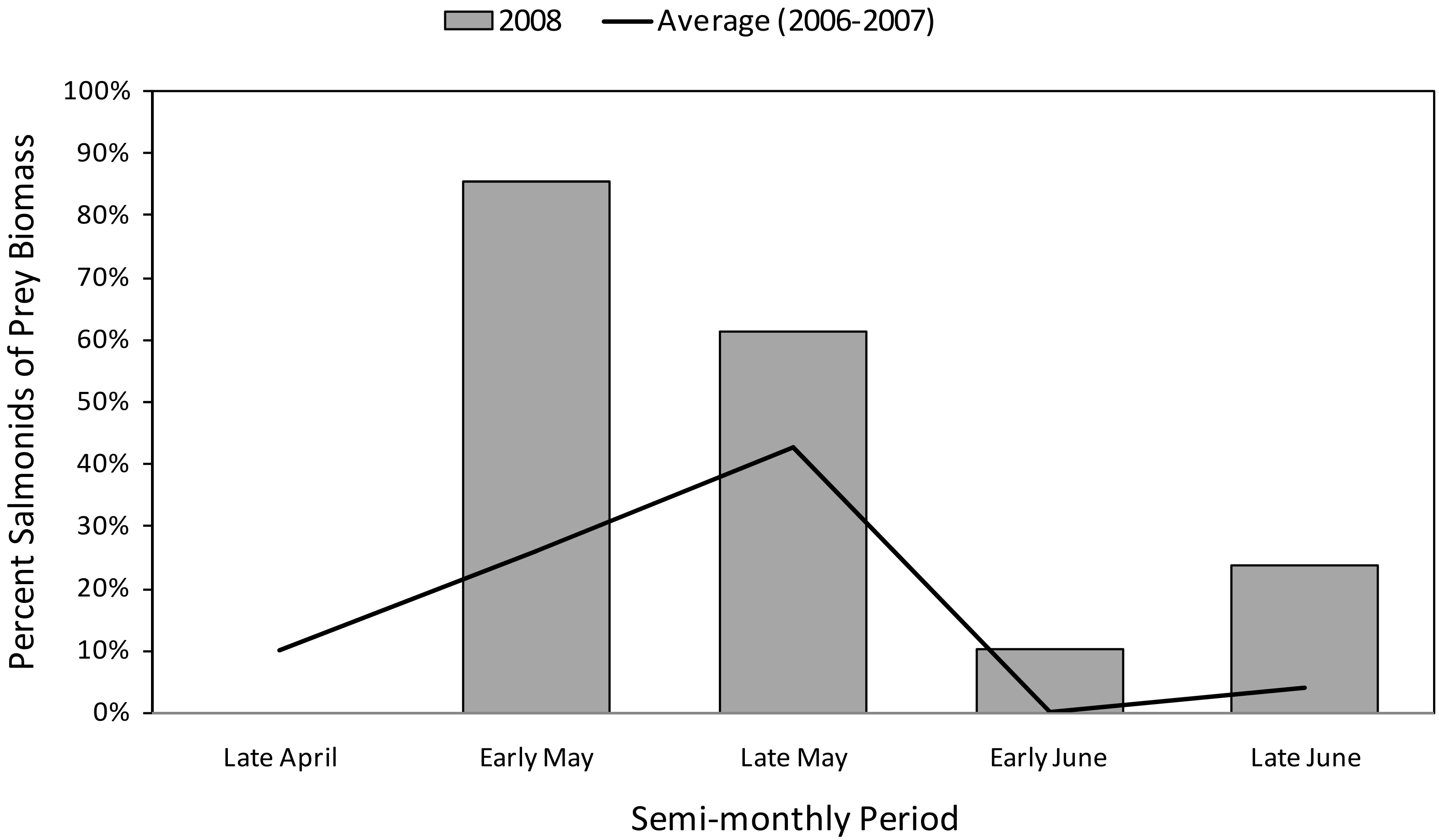



Figure 40. Semi-monthly proportions of juvenile salmonids in the diet of double-crested cormorants nesting on Foundation Island during 2008.

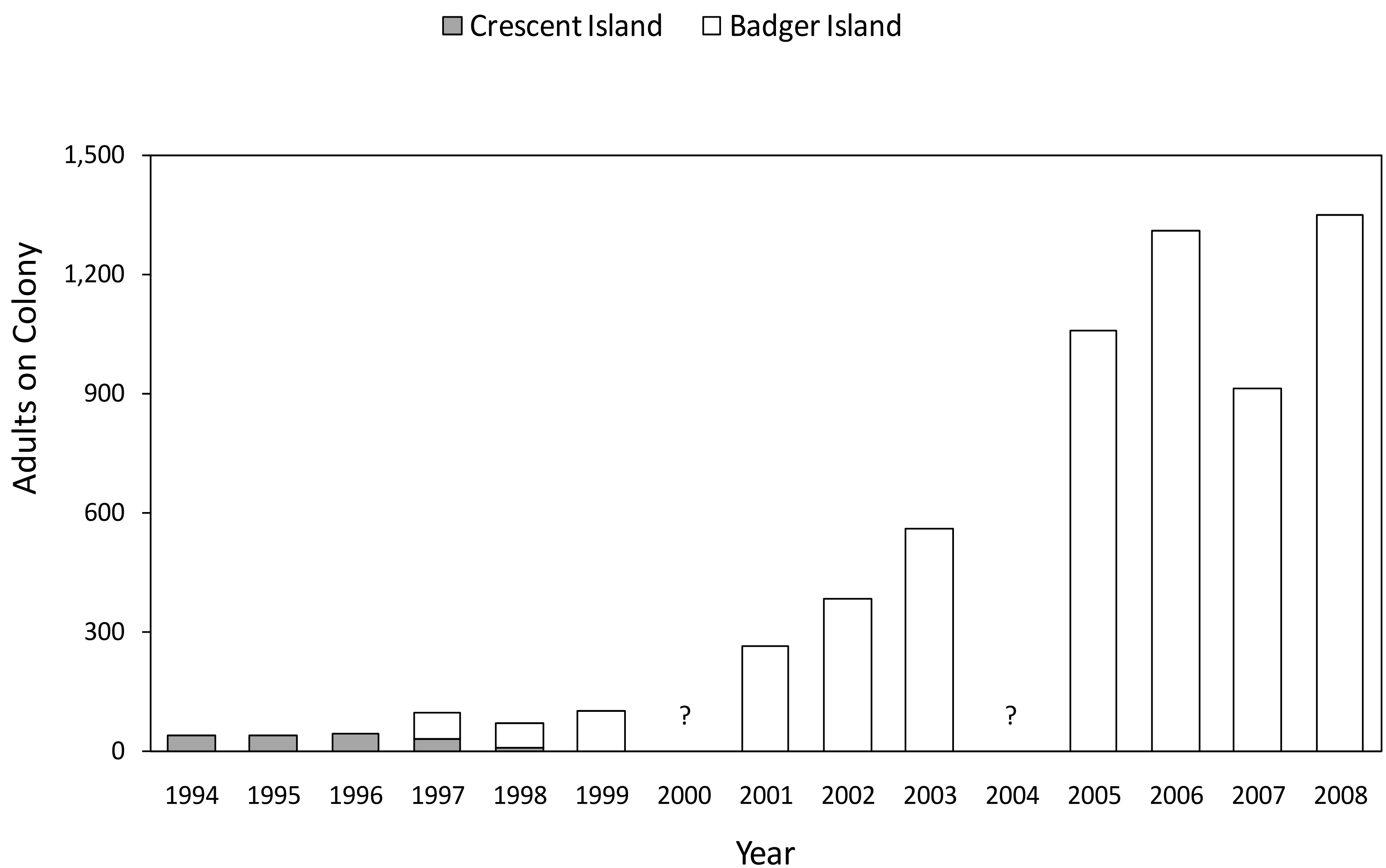



Figure 41. Population trends for American white pelicans nesting on two islands in the mid-Columbia River during 1994-2008. Missing bars indicate that no colony counts were conducted during that year.

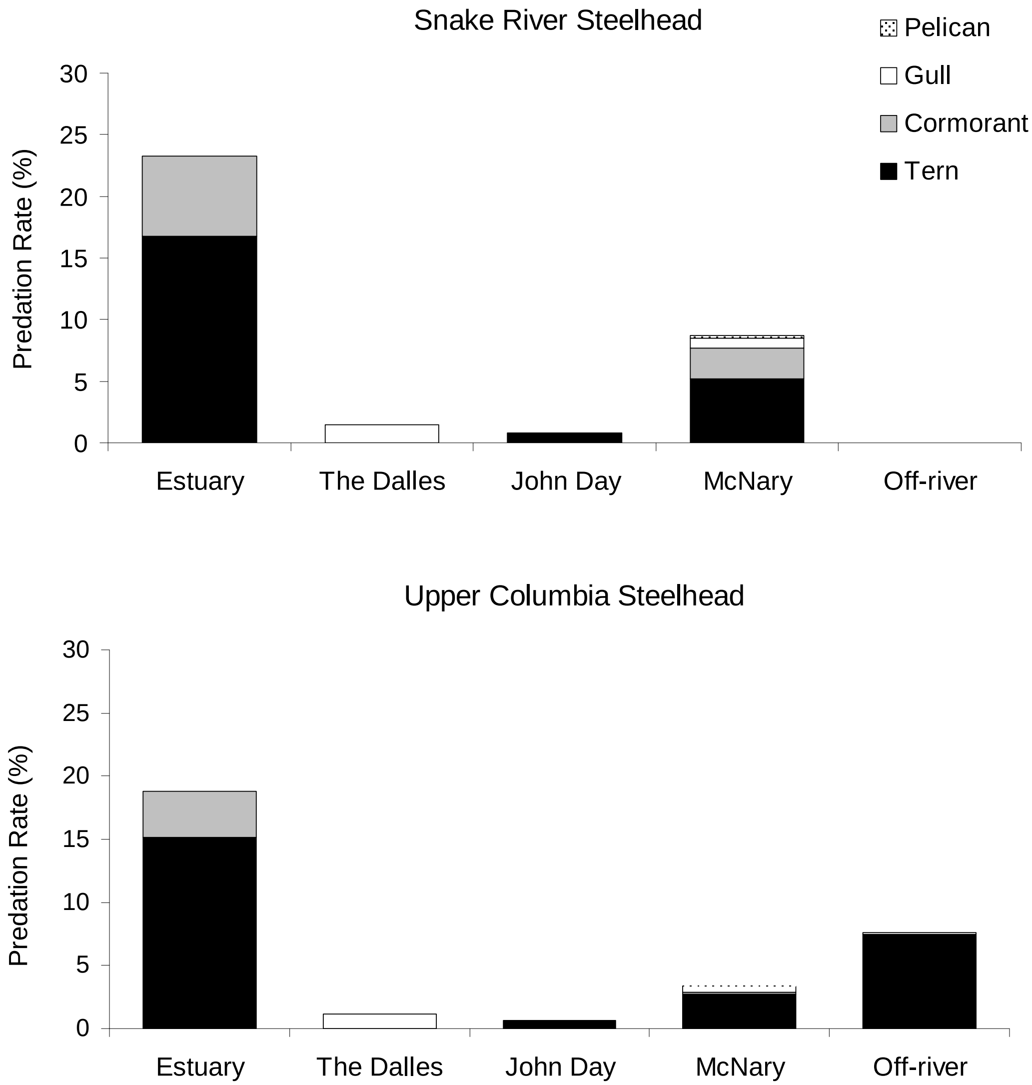



Figure 42. Estimated reach-specific predation rates on steelhead tagged and released at Lower Monumental and Ice Harbor dams (n = 9,180; Snake River ESU) and Rock Island Dam (n = 7,271; Upper Columbia River ESU) by avian predators nesting on islands in the Columbia River basin in 2008. Estimates represent the number of released fish that survived to each river reach that were subsequently consumed by avian predators nesting in that reach. Predation rates were corrected for bias due to on-colony PIT tag detection efficiency (see Table 3), but not for deposition rates, and therefore are minimum estimates.

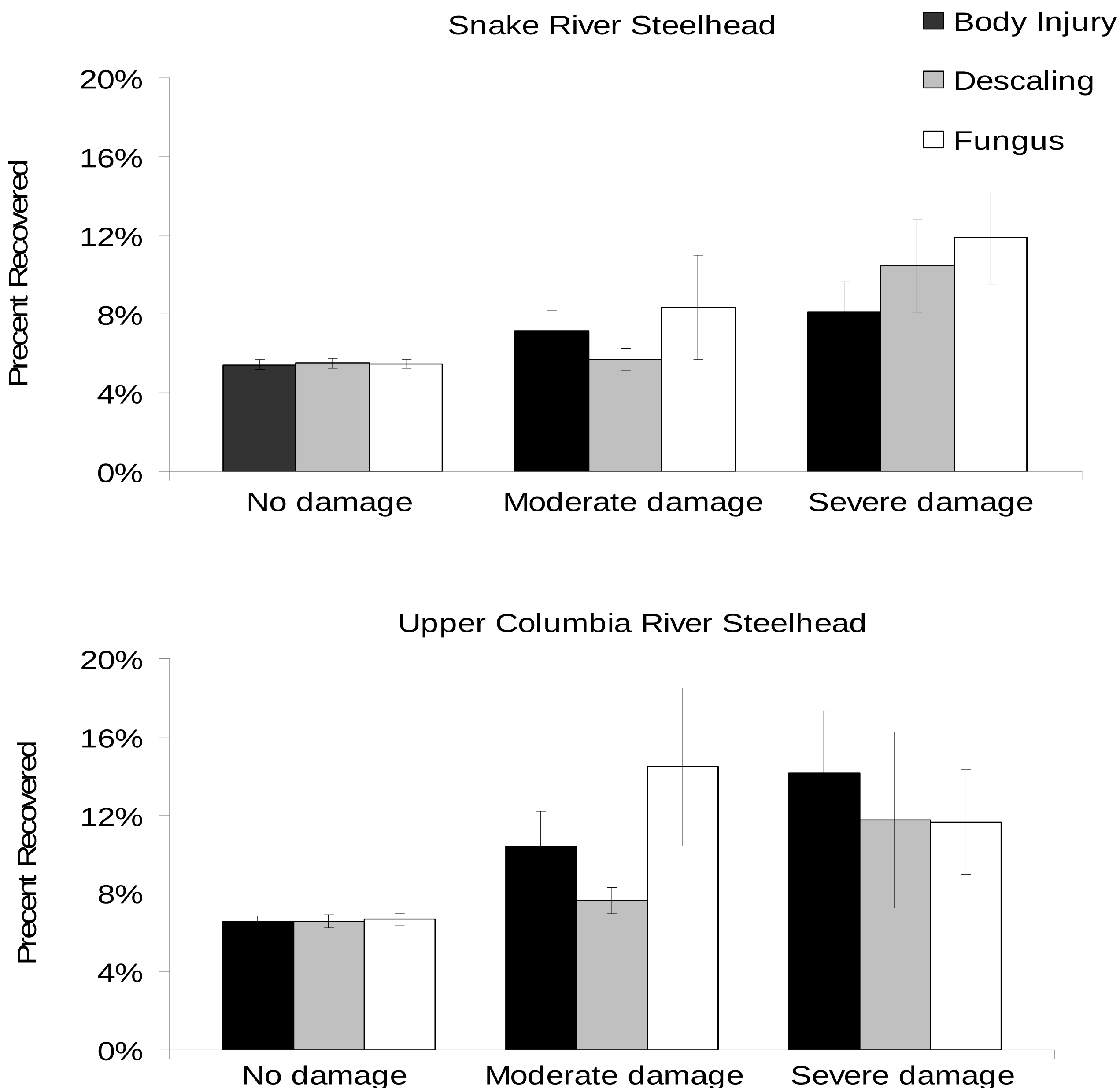



Figure 43. The percentage of steelhead tagged and released at Lower Monumental and Ice Harbor dams (n = 9,180; Snake River ESU) and Rock Island Dam (n = 7,271; Upper Columbia River ESU) that were subsequently recovered on a piscivorous waterbird colony in McNary pool as a function of the severity of external damage to the fish at the time of release. Damages include body injuries, de-scaling, and fungal infections. Error bars represent one standard error for the percentage of PIT tags recovered.

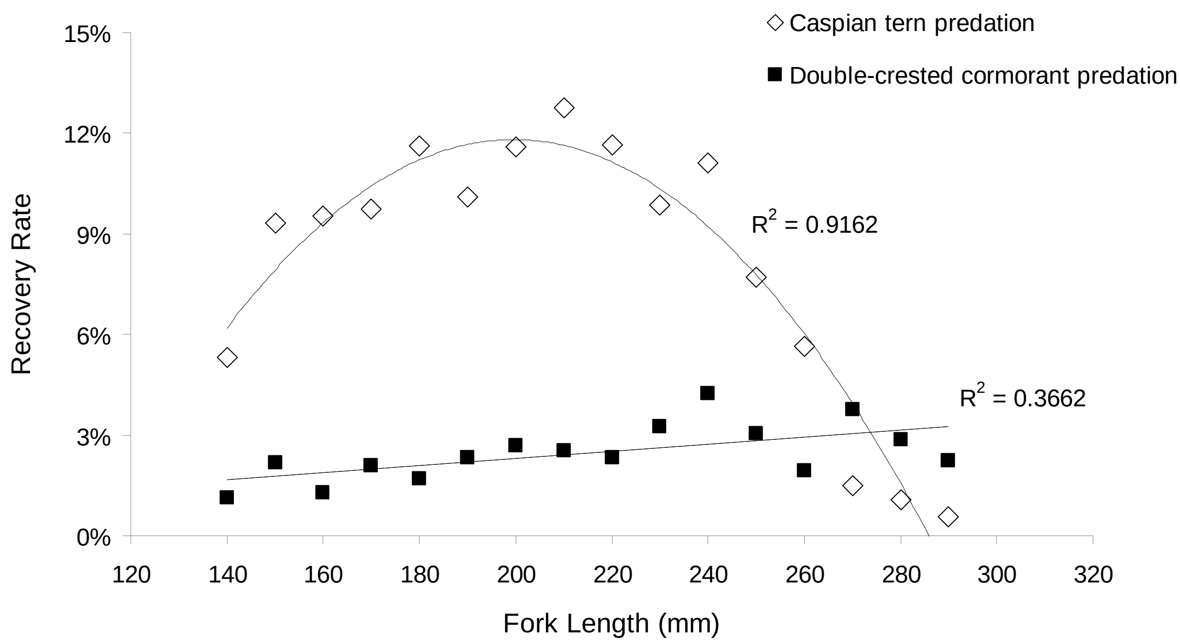



Figure 44. Predation rates on steelhead smolts by Caspian terns and double-crested cormorants as a function of fish length. Each data point represents the proportion of released PIT-tagged steelhead from Snake River and Upper Columbia River ESUs (n = 16,451) in that size range that was subsequently recovered on a tern or cormorant colony in the Columbia River basin during 2008.

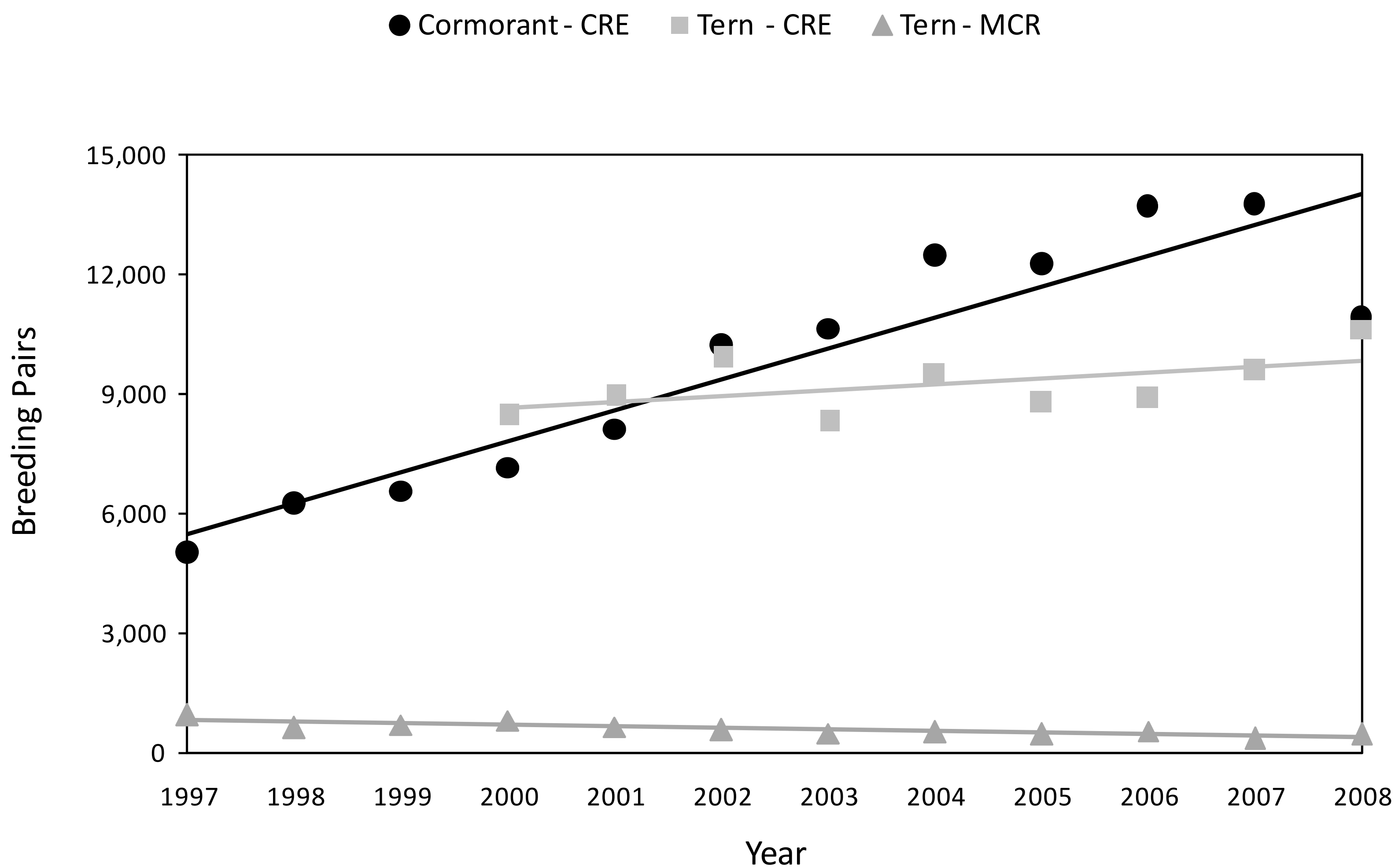



Figure 45. Trends in the size of double-crested cormorant and Caspian tern colonies in the Columbia River estuary (CRE) compared with Caspian tern colonies on the mid-Columbia River (MCR) during 1997-2008.

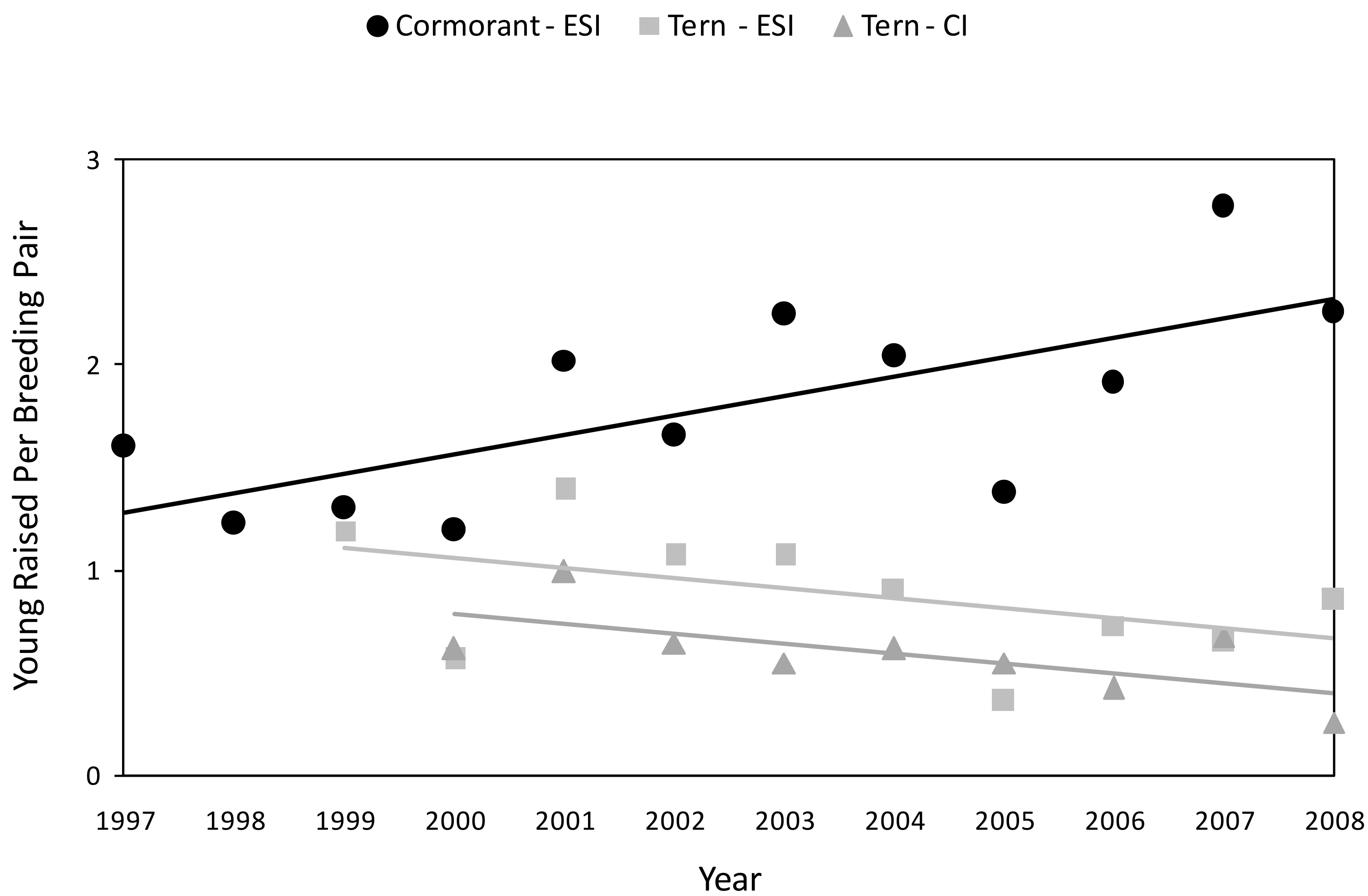



Figure 46. Trends in nesting success of double-crested cormorants and Caspian terns nesting on East Sand Island (ESI) in the Columbia River estuary compared with Caspian terns nesting on Crescent Island (CI) on the mid-Columbia River during 1997-2008.

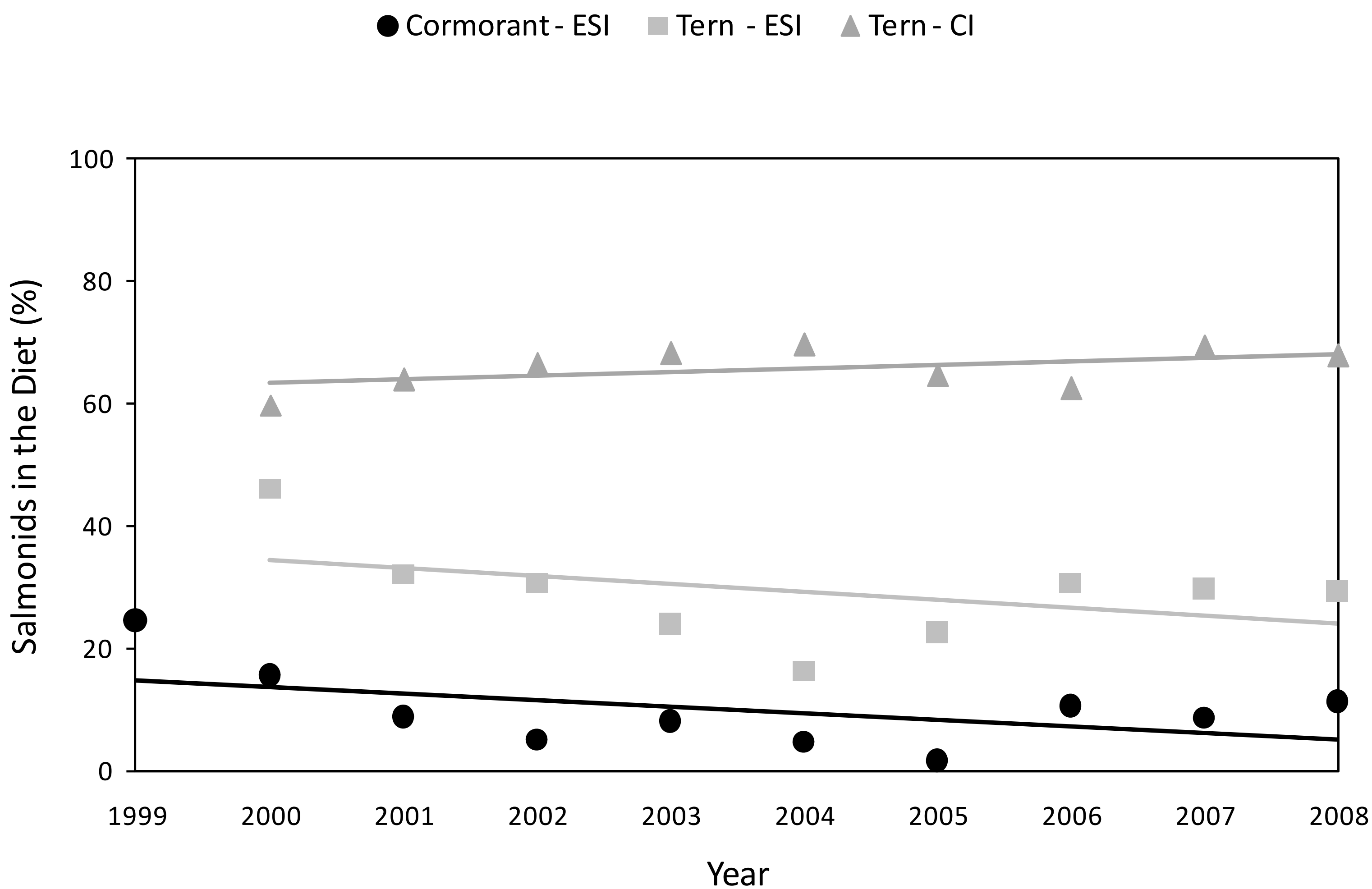



Figure 47. Trends in the proportion of juvenile salmonids in the diet of double-crested cormorants and Caspian terns nesting on East Sand Island (ESI) in the Columbia River estuary compared with Caspian terns nesting on Crescent Island (CI) on the mid-Columbia River during 1999-2008. Salmonids in the diet are expressed as percent of prey items for terns and percent or prey biomass for cormorants.

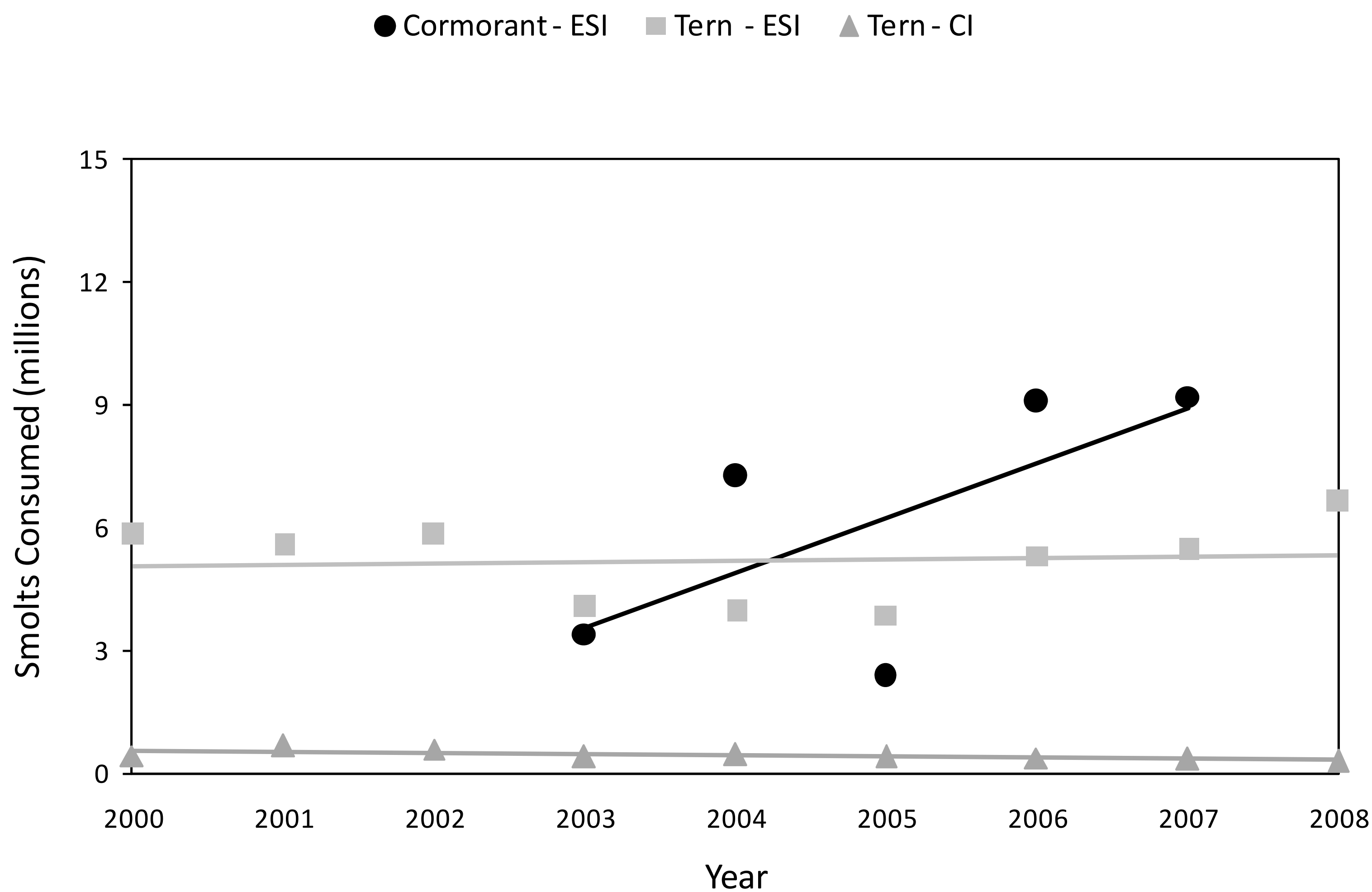



Figure 48. Trends in the total annual consumption of juvenile salmonids by double-crested cormorants and Caspian terns nesting on East Sand Island (ESI) in the Columbia River estuary compared with Caspian terns nesting on Crescent Island (CI) on the mid-Columbia River during 2000-2008.

Table 1. Recent estimates of numbers of piscivorous waterbirds at breeding colonies in the Columbia River basin and along the southwest Washington coast. Species include American white pelican (AWPE), brown pelican (BRPE), Caspian tern (CATE), double-crested cormorant (DCCO), Brandt's cormorant (BRAC), California gull (CAGU), ring-billed gull (RBGU), and glaucous-winged/western gull (GWGU/WEGU). Counts of terns and cormorants are the number of breeding pairs; the count of brown pelicans is the peak number of roosting individuals; all other counts are of the number of adults on colony.

| Location/Colony | Species | Year | Most Recent Data: Colony Size | Nesting success (fledglings/breeding pair) | Salmonids in diet (percent of prey items) | Smolt PIT tags recovered on colony in 2008[1] | Smolts consumed (millions) | Notes |
|---|---|---|---|---|---|---|---|---|
| **Columbia River Basin** | | | | | | | | |
| East Sand Is. | CATE | 2008 | 10,700 | 0.57 | 29.4 | 45,527 | 6.70 | |
| | DCCO | 2008 | 10,950 | 2.26 | 11.4 | 32,305 | | 2008 consumption estimate forthcoming |
| | BRAC | 2008 | 510 | | | | | |
| | RBGU | 2006 | 1,400 | | | | | |
| | GWGU/WEGU | 2006 | 8,600 | | | | | Minimum counts due to obscured view |
| | BRPE | 2008 | 12,400 | | | | | Peak number of roosting individuals |
| Rice Is. | GWGU/WEGU | 2006 | 1,730 | | | | | |
| Miller Sands Spit | GWGU/WEGU | 2006 | 700 | | | | | |
| Miller Rocks | RBGU/CAGU | 2008 | 4,510 | | | 4,186 | | |
| Three Mile Canyon Is. | RBGU/CAGU | 1998 | 11,100 | | | | | |
| Rock Is. | CATE | 2008 | 100 | 0.03 | | 1,365 | | |
| | RBGU | 2008 | | | | | | Colony present, size unknown |
| Crescent Is. | CATE | 2008 | 388 | 0.28 | 67.9 | 11,344 | 0.33 | |
| | RBGU/CAGU | 1998 | 4,597 | | | 1,965 | | |
| Badger Is. | AWPE | 2008 | 1,350 | | | 2,176 | | Minimum counts due to obscured view |
| Foundation Is. | DCCO | 2008 | 360 | | 45.1 | 9,763 | | Minimum counts due to obscured view |
| Island 20 | CAGU | 2008 | ~21,000 | | | 140 | | |
| Okanogan | DCCO | 2008 | 33 | | | | | |
| Potholes Reservoir | CATE | 2008 | 290 | | | 3,183 | | |
| | DCCO | 2008 | ~1,000 | | | | | |
| | RBGU/CAGU | 2008 | | | | 104 | | Colony present, size unknown |
| Sprague Lake | CATE | 2008 | 11 | | | | | |
| | DCCO | 2008 | 38 | | | | | |
| | RBGU/CAGU | 2008 | | | | | | Colony present, size unknown |
| Banks Lake | CATE | 2008 | 27 | 0.33 | | 98 | | |
| | RBGU/CAGU | 2008 | | | | | | Colony present, size unknown |
| **Coastal Washington** | | | | | | | | |
| Dungenesss Spit | CATE | 2008 | 883 | | | | | |
| | GWGU/WEGU | 2008 | | | | | | Colony present, size unknown |

[1] The number of smolt PIT tags recovered on colony is adjusted for detection efficiency at each colony.

Table 2: Numbers of 2008 migration year salmonid PIT tags recovered on piscivorous waterbird colonies in the Columbia River basin. PIT tags were recovered from the entire colony or from a sub-sample of the colony (denoted by an asterisk). Colonies include American white pelicans (AWPE), Caspian terns (CATE), double-crested cormorants (DCCO), and California, ring-billed, and glaucous-winged/western gulls (GULL). The total number of tags deposited on-colony was estimated based on a correction for PIT tag detection efficiency (see Table 3).

| River Segment | Location | Colony | No. Recovered | No. Deposited |
|---|---|---|---|---|
| Off-river | Banks Lake | CATE | 52 | 98 |
| | Potholes Reservoir | CATE | 2,021 | 3,183 |
| | | GULL | 66 | NA |
| McNary Pool | Island 20 | GULL | 140 | NA |
| | Foundation Island | DCCO | 7,250 | 9,764 |
| | Badger Island | AWPE | 1,429 | 2,101 |
| | Crescent Island | CATE | 7,191 | 11,432 |
| | | GULL | 1,444 | 1,965 |
| John Day Pool | Rock Island | CATE | 1,266 | 1,361 |
| The Dalles Pool | Miller Rocks | GULL | 3,474 | 4,211 |
| Estuary | Rice Island | GULL* | 16 | 19 |
| | East Sand Island | CATE | 42,340 | 45,674 |
| | | GULL* | 2 | 3 |
| | | DCCO | 21,320 | 37,449 |
| ALL | | | 87,991 | 117,466 |

Table 3. Average detection efficiency (DE) of test PIT tags sown on piscivorous waterbird colonies in the Columbia River basin during 2008. PIT tags were distributed haphazardly throughout the entire colony or within experimental plots (denoted by an asterisk). Colonies include American white pelicans (AWPE), Caspian terns (CATE), double-crested cormorants (DCCO), and California, ring-billed, and glaucous-winged/western gulls (GULL). NR is the number of discrete release events when tags were sown on-colony and SE is the standard error of the mean.

| Location | Colony | Sample | NR | DE (SE) |
|---|---|---|---|---|
| Banks Lake | CATE | 100 | 2 | 53.0 (44.4) |
| Potholes Reservoir | CATE | 400 | 4 | 63.5 (6.8) |
| Foundation Island | DCCO | 400 | 4 | 74.3 (2.9) |
| Badger Island | AWPE | 200 | 2 | 68.0 (5.7) |
| Crescent Island | CATE | 800 | 4 | 62.0 (9.3) |
| | GULL | 200 | 2 | 73.5 (12.0) |
| Rock Island | CATE | 200 | 2 | 93.0 (7.0) |
| Miller Rocks | GULL | 200 | 2 | 82.5 (3.7) |
| Rice Island | GULL* | 200 | 2 | 84.0 (2.8) |
| East Sand Island | CATE | 600 | 4 | 92.7 (2.9) |
| | GULL* | 200 | 2 | 68.0 (5.4) |
| | DCCO | 400 | 2 | 66.0 (7.9) |
| | DCCO* | 600 | 2 | 87.0 (3.5) |

Table 4. Estimated predation rates on PIT-tagged salmonid smolts by Caspian terns (CATE) and double-crested cormorants (DCCO) nesting on East Sand Island in 2008. Predation rates are based on the number of PIT-tagged fish interrogated (I) passing Bonneville Dam (In-river) or released (Rel) from transportation barges directly below Bonneville Dam (Transport). Rearing-types are for hatchery-reared (H), wild (W), and unknown (U) smolts and run-types are for summer, spring/summer (Spr/Sum), fall, and unknown. Sample sizes < 100 interrogated/released fish were not included in the analysis. Predation rates are corrected for bias due to on-colony PIT tag detection efficiency (Table 3), but not deposition rates, and are therefore minimum estimates.

| | In-river | | | Transport | | |
|---|---|---|---|---|---|---|
| **Species / Run Type** | **No. I** | **CATE** | **DCCO** | **No. Rel** | **CATE** | **DCCO** |
| W Summer Steelhead | 3,307 | 9.7% | 6.4% | 1,996 | 6.9% | 4.8% |
| H Summer Steelhead | 21,313 | 10.3% | 7.5% | 37,898 | 11.1% | 4.7% |
| W Spr/Sum Chinook | 2,871 | 1.1% | 1.8% | 4,306 | 0.9% | 1.5% |
| H Spr/Sum Chinook | 19,479 | 2.6% | 2.4% | 89,746 | 3.1% | 2.0% |
| W Fall Chinook | 308 | 1.1% | 1.7% | --- | --- | --- |
| H Fall Chinook | 47,184 | 1.6% | 5.8% | 63,708 | 1.1% | 3.0% |
| U Fall Chinook | 1,023 | 2.1% | 2.9% | --- | --- | --- |
| W U Run Chinook | 1,097 | 0.6% | 1.1% | 2,988 | 1.0% | 1.9% |
| H U Run Chinook | 12,202 | 2.3% | 2.1% | 351 | 2.8% | 1.0% |
| H Coho | 2,767 | 4.1% | 2.5% | --- | --- | --- |
| W Sockeye | 299 | 0.7% | 2.3% | --- | --- | --- |
| H Sockeye | 173 | 1.3% | 3.0% | --- | --- | --- |

Table 5. Estimated per-capita consumption of 2008 migration year PIT-tagged salmonid smolts by Caspian terns (CATE), double-crested cormorants (DCCO), American white pelicans (AWPE), and California, ring-billed, and glaucous-winged/western gulls (GULL) nesting at various locations in the Columbia River basin. Tagged juvenile salmonids include steelhead, Chinook salmon, coho salmon, and sockeye salmon. Values for per capita consumption are corrected for PIT tag detection efficiency, but not deposition rates, and are therefore minimum estimates. PIT tags were recovered from nesting locations using two different approaches: recoveries from the entire colony (C) or from plots within the colony (P). Estimates of per capita PIT tag consumption were calculated by dividing the total number of tags recovered (R; corrected for detection efficiency) by the number of breeding adults on the colony or in the plots.

| **River Segment / Avian Colony** (est. number of breeding adults) | **Approach** | **R** | **Steelhead** | **Chinook** | **Coho** | **Sockeye** | **Total** |
|---|---|---|---|---|---|---|---|
| **Inland Reservoirs and Lakes** | | | | | | | |
| Potholes Reservoir CATE (580) | C | 3,183 | 3.9 | 1.2 | 0.4 | <0.1 | 5.5 |
| Banks Lake CATE (54) | C | 98 | 0.8 | 0.6 | 0.4 | 0.0 | 1.8 |
| **McNary Pool** | | | | | | | |
| Island 20 GULL (21,000) | C | 140 | <0.1 | <0.1 | 0.0 | 0.0 | <0.1 |
| Badger Island AWPE (1,350) | C | 2,101 | 0.4 | 1.1 | 0.1 | 0.0 | 1.6 |
| Foundation Island DCCO (720) | C | 9,764 | 5.5 | 7.9 | 0.1 | <0.1 | 13.6 |
| Crescent Island CATE (776) | C | 11,432 | 5.9 | 8.2 | 0.6 | <0.1 | 14.7 |
| Crescent Island GULL (4,600) | C | 1,965 | 0.3 | 0.2 | <0.1 | <0.1 | 0.4 |
| **John Day Pool** | | | | | | | |
| Rock Island CATE (200) | C | 1,361 | 4.5 | 2.0 | 0.3 | 0.0 | 6.8 |
| **The Dallas Pool** | | | | | | | |
| Miller Rocks GULL (4,500) | C | 4,211 | 0.4 | 0.5 | <0.1 | <0.1 | 0.9 |
| **Columbia River Estuary** | | | | | | | |
| Rice Island GULL (28) | P | 19 | 0.6 | 0.1 | 0.0 | 0.0 | 0.7 |
| East Sand Island GULL (30) | P | 3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| East Sand Island CATE (21,400) | C | 45,674 | 1.4 | 0.7 | 0.1 | <0.1 | 2.1 |
| East Sand Island DCCO (610) | P | 1,043 | 0.6 | 1.1 | <0.1 | <0.1 | 1.7 |

Table 6. Estimated predation rates on PIT-tagged salmonid smolts last detected in the vicinity of McNary Pool by avian predators nesting at colonies in McNary Pool during 2008. Colonies included American white pelicans (AWPE) on Badger Island, Caspian terns (CATE) on Crescent Island, double-crested cormorants (DCCO) on Foundation Island, and California and ring-billed gulls (GULL) on Crescent Island. Predation rates are based on the proportions of fish interrogated/tagged at Lower Monumental Dam (LMO), Rock Island Dam (RIS), or in the McNary Pool (McP; fish tagged and released below Priest Rapids and Ice Harbor dams but upstream of McNary Dam) that were subsequently detected on-colony. Predation rates on hatchery-reared (H), wild (W), and unknown (U) rear-type smolts are listed separately. Chinook salmon are designated by run-type as spring/summer (Spr/Sum), Fall, and Unknown. Sample sizes < 100 interrogated/released fish were not included in the analysis. Predation rates were corrected for bias due to on-colony PIT tag detection efficiency (see Table 3), but not deposition, and are therefore minimum estimates.

| | | | | Predation Rate | | | | |
|---|---|---|---|---|---|---|---|---|
| **Location** | **Species/Run-type** | **Origin** | **N** | **CATE** | **DCCO** | **GULL** | **AWPE** | **All** |
| LMO | Steelhead | Hatchery | 25,712 | 4.6% | 2.3% | 0.8% | 0.2% | 7.9% |
| | | Wild | 7,962 | 6.0% | 1.7% | 0.4% | 0.1% | 8.2% |
| | Spr/Sum Chinook | Hatchery | 26,076 | 0.6% | 1.0% | 0.2% | 0.1% | 1.8% |
| | | Wild | 4,648 | 0.7% | 0.6% | 0.1% | <0.1% | 1.4% |
| | Fall Chinook | Hatchery | 22,028 | 1.2% | 0.4% | 0.1% | 0.1% | 1.8% |
| | | Unknown | 2,864 | 3.0% | 0.9% | 0.2% | 0.1% | 4.2% |
| | Unknown Chinook | Unknown | 24,051 | 0.5% | 1.0% | 0.2% | <0.1% | 1.7% |
| | Sockeye | Hatchery | 628 | 0.8% | 1.3% | 0.2% | <0.1% | 2.3% |
| | | Wild | 127 | 2.5% | <0.1% | <0.1% | <0.1% | 2.5% |
| RIS | Steelhead | Hatchery | 5,737 | 2.3% | 0.2% | 0.5% | 0.1% | 3.0% |
| | | Wild | 2,005 | 1.5% | 0.1% | <0.1% | 0.1% | 1.7% |
| | Spr/Sum Chinook | Unknown | 4,520 | 0.3% | 0.1% | <0.1% | <0.1% | 0.4% |
| | Sockeye | Wild | 1,917 | <0.1% | <0.1% | 0.1% | <0.1% | 0.1% |
| | Coho | Hatchery | 547 | 2.7% | <0.1% | <0.1% | <0.1% | 2.7% |
| McP | Steelhead | Hatchery | 16,647 | 1.7% | 5.7% | 0.2% | 0.2% | 7.8% |
| | | Wild | 5,080 | 1.7% | 2.9% | 0.1% | 0.1% | 4.7% |
| | Spr/Sum Chinook | Hatchery | 59,129 | 0.3% | 1.3% | <0.1% | 0.5% | 2.2% |
| | | Wild | 5,133 | 0.1% | 0.1% | 0.1% | 0.3% | 0.6% |
| | Fall Chinook | Hatchery | 56,533 | 0.4% | 0.5% | <0.1% | 1.0% | 1.9% |
| | | Wild | 1,140 | 0.3% | 0.4% | <0.1% | 3.8% | 4.5% |
| | Coho | Hatchery | 5,4175 | 0.5% | 0.1% | 0.1% | 0.3% | 1.0% |

Table 7. Stock-specific predation rates on in-river PIT-tagged salmonid smolts by Crescent Island Caspian terns (CATE), Foundation Island double-crested cormorants (DCCO), Badger Island American white pelicans (AWPE), and Crescent Island California and ring-billed gulls (GULL) during 2008. Assignment of each stock to an Evolutionarily Significant Unit (ESU) is based on genetic and geographic criteria developed by NOAA Fisheries. Only fish of known rearing type, origin, and release locations are included. Sample sizes and predation rates are listed separately for hatchery-reared (H) and wild (W) fish. Predation rates are corrected for bias due to PIT tag detection efficiency on-colony, but not deposition rates, and therefore are minimum estimates. Smolt mortality from the individual stock's release site to the vicinity of McNary Pool is not accounted for (see Table 6 for reach-specific estimates).

| **Species** | **ESU** | **Stock** | **Number Released** | | **Hatchery Predation Rate** | | | | **Wild Predation Rate** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | H | W | CATE | DCCO | AWPE | GULL | CATE | DCCO | AWPE | GULL |
| Steelhead | SR | Imnaha River | 9,410 | 2,497 | 1.0% | 1.3% | 0.1% | 0.2% | 1.9% | 1.8% | 0.1% | 0.3% |
| | | Grande Ronde River | 6,515 | 3,127 | 0.8% | 1.2% | 0.3% | 0.6% | 0.5% | 1.1% | 0.1% | 0.1% |
| | | Clearwater River | 41,542 | 6,005 | 1.5% | 1.1% | 0.2% | 0.7% | 0.8% | 0.5% | <0.1% | 0.1% |
| | | Salmon River | 49,725 | 16,111 | 1.2% | 1.4% | 0.2% | 0.4% | 0.2% | 0.1% | <0.1% | <0.1% |
| | | Lower Snake | 14,402 | 1,046 | 1.0% | 1.1% | 0.2% | 0.6% | 0.8% | 0.5% | <0.1% | 0.4% |
| | UCR | | | | | | | | | | | |
| | | Okanogan River | 6,985 | --- | 0.2% | <0.1% | <0.1% | <0.1% | --- | --- | --- | --- |
| | | Methow River | 7,995 | 1,195 | 0.9% | 0.1% | 0.1% | 0.6% | 0.3% | <0.1% | 0.1% | 0.2% |
| | | Entiat River | 4,192 | 5,168 | 2.3% | 0.2% | <0.1% | 0.6% | 0.7% | 0.1% | 0.1% | 0.1% |
| | | Wenatchee River | 30,686 | 4,137 | 0.9% | 0.2% | 0.1% | 0.3% | <0.1% | <0.1% | <0.1% | <0.1% |
| | MCR | | | | | | | | | | | |
| | | Walla Walla/Touchet | 15,445 | 3,364 | 1.9% | 6.2% | 0.2% | 0.2% | 2.5% | 4.3% | 0.1% | <0.1% |
| | | Yakima River | --- | 4,223 | --- | --- | --- | --- | 0.1% | 0.1% | <0.1% | <0.1% |
| Chinook | SR Fall | Mainstem Snake River | 591,278 | 1,118 | 0.7% | 0.2% | <0.1% | 0.1% | <0.1% | <0.1% | <0.1% | <0.1% |
| | SR S/S | Salmon River | 148,795 | 39,100 | 0.2% | 0.5% | <0.1% | 0.1% | 0.1% | 0.1% | <0.1% | <0.1% |
| | | Grande Ronde/Imnaha | 35,416 | 16,807 | 0.2% | 0.4% | <0.1% | 0.1% | 0.1% | 0.2% | <0.1% | <0.1% |
| | | Clearwater River | 131,238 | 5,435 | 0.3% | 0.5% | <0.1% | 0.1% | 0.4% | 0.3% | <0.1% | <0.1% |
| | | Lower Snake River | 11,078 | 1,557 | 0.5% | 1.3% | 0.1% | 0.2% | 0.1% | 0.7% | <0.1% | 0.2% |
| | UCR S | | | | | | | | | | | |
| | | Methow River | 5,674 | 3169 | 0.1% | 0.1% | <0.1% | <0.1% | 0.2% | 0.1% | 0.1% | <0.1% |
| | | Entiat River | --- | 6987 | --- | --- | --- | --- | 0.02% | 0.19% | 0.00% | 0.00% |
| | | Wenatchee River | 25,923 | 13158 | 0.1% | 0.2% | <0.1% | <0.1% | 0.1% | 0.1% | <0.1% | <0.1% |
| Sockeye | SR | Redfish Lake | 5,918 | 941 | 0.4% | 0.5% | <0.1% | 0.1% | 0.5% | 0.1% | <0.1% | <0.1% |

[a] SR = Snake River; UCR = Upper Columbia River; MCR = Middle Columbia River

Table 8. Average number of double-crested cormorants observed on the lower Snake River during five surveys conducted from October 2008 to February 2009. River reaches were from the mouth of the Snake River (SR) to Ice Harbor Dam (IHR), Ice Harbor Dam to Lower Monumental Dam (LMN), Lower Monumental Dam to Little Goose Dam (LGS), Little Goose Dam to Lower Granite Dam (LWG), and Lower Granite Dam to the mouth of the Clearwater River (CR).

| | **Survey Month** | | | | |
|---|---|---|---|---|---|
| River Reach (Rkm Distance) | October | November | December | January | February |
| SR to IHR (16) | 36 | 82 | 87 | 19 | 14 |
| IHR to LMN (51) | 101 | 63 | 91 | 29 | 19 |
| LMN to LGS (46) | 48 | 85 | 22 | 27 | 9 |
| LGS to LWG (60) | 113 | 116 | 65 | 75 | 74 |
| LWR to CR (51) | 53 | 49 | 55 | 30 | 45 |
| TOTAL (224) | 351 | 395 | 320 | 180 | 161 |

Table 9. Proportions of total counts of double-crested cormorants along the lower Snake River that were observed at dams (i.e., Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, or Lower Granite Dam). Proportions are based on counts of cormorants recorded during five river surveys conducted from October 2008 to February 2009.

| | **Distribution of Double-crested Cormorants** | |
|---|---|---|
| Survey Month (total count) | At Dams | Away from Dams |
| October (351) | 32% | 68% |
| November (395) | 31% | 69% |
| December (320) | 36% | 64% |
| January (180) | 12% | 88% |
| February (161) | 10% | 90% |
| AVERAGE | 24% | 76% |

Table 10. Average number of California and ring-billed gulls (Gulls), double-crested cormorants (Cormorants), western and Clark's grebes (Grebes), common mergansers (Mergansers), and American white pelicans (Pelicans) observed on the lower Snake River during five river surveys conducted from October 2008 to February 2009.

| | **Bird spp.** | | | | |
|---|---|---|---|---|---|
| Survey Month | Gulls | Cormorants | Grebes | Mergansers | Pelicans |
| October | 576 | 351 | 471 | 0 | 17 |
| November | 686 | 395 | 498 | 45 | 17 |
| December | 436 | 320 | 194 | 107 | 26 |
| January | 240 | 180 | 119 | 51 | 59 |
| February | 88 | 161 | 90 | 21 | 5 |
| AVERAGE | 405 | 281 | 274 | 45 | 25 |

Table 11. Diet composition (% identifiable prey biomass) of double-crested cormorants over-wintering on the lower Snake River. Cormorants were collected between Lower Monumental and Lower Granite dams during four 2-day collection periods from November 2008 to February 2009.

| Date [a] | N | Salmonid | Shad | Minnows and Carp | Sunfish and Bass | Suckers | Perch | Catfish | Unid. Non-salmonid | Other [b] |
|---|---|---|---|---|---|---|---|---|---|---|
| 11/03/08 | 14 | 37.8 | 0.0 | 5.6 | 31.3 | 0.0 | 0.0 | 10.0 | 15.3 | 0.1 |
| 12/16/08 | 10 | 0.0 | 39.9 | 10.0 | 28.7 | 0.0 | 0.0 | 10.0 | 11.4 | 0.0 |
| 1/13/09 | 16 | 12.0 | 0.0 | 5.3 | 31.8 | 0.0 | 9.4 | 20.0 | 19.3 | 1.3 |
| 2/12/09 | 17 | 0.0 | 0.0 | 32.5 | 23.3 | 23.6 | 11.8 | 6.3 | 2.5 | 0.0 |
| AVERAGE | 57 | 12.5 | 10.0 | 13.4 | 28.8 | 5.9 | 5.3 | 11.6 | 12.1 | 0.4 |

[a] Date listed is the first day of each of four monthly two-day collection periods.
[b] Several eyed salmon eggs were found in the stomach of one cormorant, an unique prey item for double-crested cormorants.

Table 12. Percentages of steelhead tagged and released at Rock Island Dam (n = 7,271; Columbia River) and Lower Monumental and Ice Harbor dams (n = 9,180; Snake River) recovered on avian colonies in the Columbia River basin in 2008. Percentages are listed separately for wild and hatchery steelhead. Recovery percentages were corrected for bias due to on-colony PIT tag detection efficiency (see Table 3), but not for steelhead survival to the vicinity of the avian colony or for off-colony deposition, and therefore are minimum estimates.

| | | | Columbia River | | Snake River | |
|---|---|---|---|---|---|---|
| **Location** | **Island** | **Avian Colony** | **Hatchery** | **Wild** | **Hatchery** | **Wild** |
| Banks Lake | Dry Falls Dam | Caspian tern | 0.2% | 0.1% | 0.0% | 0.0% |
| Potholes Reservoir | Goose Island | Caspian tern | 8.2% | 5.9% | 0.0% | 0.0% |
| | | California/ring-billed gulls | 0.1% | 0.1% | 0.0% | 0.0% |
| McNary Pool | Crescent Island | Caspian terns | 2.3% | 1.6% | 4.7% | 6.1% |
| | | California/ring-billed gulls | 0.6% | 0.1% | 0.8% | 0.3% |
| | Foundation Island | Double-crested cormorant | 0.2% | 0.1% | 2.8% | 1.8% |
| | Badger Island | American white pelican | 0.1% | 0.2% | 0.2% | 0.1% |
| John Day Pool | Rock Island | Caspian tern | 0.5% | 0.2% | 0.5% | 0.4% |
| The Dalles Pool | Miller Rocks | California/ring-billed gulls | 0.8% | 0.5% | 1.0% | 0.8% |
| Estuary | East Sand Island | Caspian tern | 6.9% | 4.5% | 6.4% | 6.6% |
| | | Double-crested cormorant | 1.3% | 2.3% | 2.7% | 1.9% |
| **ALL** | | | **21.3%** | **15.5%** | **19.1%** | **18.0%** |