Bonneville Power Administration

Avian Predation on Juvenile Salmonids: Evaluation of the Caspian Tern Management Plan in the Columbia River Estuary

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2015 Final Annual Report

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The primary objective of this study in 2015 was to monitor and evaluate management initiatives implemented to reduce predation on juvenile salmonids (*Oncorhynchus* spp.) by Caspian terns (*Hydroprogne caspia*) nesting on East Sand Island in the Columbia River estuary. Specifically, we monitored and evaluated the managed reduction of tern nesting habitat on East Sand Island, which is designed to reduce the size of the Caspian tern breeding colony and, as a consequence, reduce tern predation on ESA-listed juvenile salmonids in the Columbia River estuary.

The management plan entitled, *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary* was first implemented in 2008, and implementation continued in 2015. As part of this plan, the U.S. Army Corps of Engineers – Portland District (Corps) provided 1.0 acre of suitable nesting habitat for Caspian terns on East Sand Island prior to the 2015 nesting season, a reduction in the area of nesting habitat provided in 2014 (1.55 acres), and a 80% reduction in what was provided for terns on East Sand Island prior to implementation of the management plan. The estimate of Caspian tern colony size on the 1.0-acre core colony area in 2015 was 5,430 breeding pairs (95% c.i. = 5,200 – 5,660 pairs), about 13% smaller than in 2014 (6,270 breeding pairs; 95% c.i. = 5,860 – 6,680 pairs), and nearly a 50% reduction from the peak size of the tern colony on East Sand Island (ca. 10,670 pairs), which occurred in 2008. Despite efforts to limit tern nesting on East Sand Island to the 1.0-acre core colony area using passive dissuasion (stakes, rope, and flagging) and active dissuasion (human hazing), two satellite colonies formed adjacent to the core colony area and supported an additional 810 breeding pairs. As a result, the total number of Caspian terns nesting on East Sand Island in 2015 (6,240 pairs; 95% c.i. = 6,000 – 6,460 pairs) was about the same as the colony size in 2014 (6,270 pairs), despite the reduction in amount of nesting habitat prepared for terns in 2015 relative to the previous year. Additionally, some Caspian terns attempted to nest on Rice Island in 2015, a dredged material disposal island in the upper Columbia River estuary, where Caspian terns nested prior to relocating the colony to East Sand Island in 2001.

In 2015, the average nesting density of Caspian terns in the 1-acre core colony area on East Sand Island was 1.32 nests/m^2, an increase from the average nesting density of terns on East Sand Island in 2014 (1.06 nests/m^2), and the highest nesting density ever recorded for Caspian terns nesting on East Sand Island. Given the more than 30-year history of Caspian terns nesting in the Columbia River estuary, it is expected that some, perhaps most, terns will initially adapt to reductions in the amount of suitable nesting habitat on East Sand Island by nesting at higher densities and/or attempting to nest in other, sometimes marginal, nesting habitat on East Sand Island (e.g., upland beaches) and elsewhere in the Columbia River estuary (e.g., Rice Island). Efforts to reduce Caspian tern predation on juvenile salmonids to levels stipulated in the management plan will likely require that all Caspian terns nesting in the Columbia River estuary be restricted to just the 1-acre core colony area on East Sand Island, thereby forcing terns displaced from East Sand Island to relocate to alternative colony sites outside the Columbia River Basin.

Caspian terns nesting on East Sand Island in 2015 were relatively resilient to disturbances by bald eagles (*Haliaeetus leucocephalus*) and associated gull (*Larus* spp.) depredation of tern eggs and chicks, even more so than was the case during 2013-2014. These limiting factors caused the Caspian tern colony on East Sand Island to fail or nearly fail during 2010-2012. In 2015, the East Sand Island Caspian tern colony produced about 3,700 fledglings (average of 0.59 young raised/breeding pair), an increase compared to 2014 (0.28 young raised/breeding pair), and similar to the average productivity during 2000-2014 (0.57 young raised/breeding pair).

To assess the efficacy of management implemented to disperse Caspian terns from nest sites within the Columbia River Basin to alternative colony sites outside the Basin, we monitored Caspian tern movements by re-sighting terns previously banded with field-readable leg bands at colonies both inside and outside the Basin. The majority of resighted Caspian terns exhibited site fidelity to the colony on East Sand Island in 2015. There was little movement of Caspian terns banded as adults on East Sand Island to the Corps-constructed alternative colony sites in interior Oregon and northeastern California in 2015; nevertheless, Caspian terns banded as chicks at East Sand Island were observed at all four of the monitored alternative colony sites in 2015. Estimated numbers of Caspian terns that moved from the alternative colony sites to the Columbia River estuary and to the Columbia Plateau region in 2015 were greater than those that moved in the opposite directions, probably due to the severe drought that has negatively affected tern nesting and foraging habitat in interior Oregon and northeastern California during 2014-2015.

The average proportion of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island during the 2015 nesting season was 38% (percent of identified prey items), higher than the average during the previous 15 years (31%), and corresponding to a somewhat lower than average proportion of northern anchovy (*Engraulis mordax*) in the tern diet. The estimated total smolt consumption by Caspian terns nesting at East Sand Island in 2015 was 5.2 million smolts (95% c.i. = 4.6 – 5.9 million smolts), not significantly different from the average annual smolt consumption during 2000–2014, but significantly lower than annual smolt consumption when the Caspian tern colony was located on Rice Island in the upper estuary. Consumption of sub-yearling Chinook salmon by East Sand Island Caspian terns in June and July was significantly higher in 2015 than in 2014, presumably due to reduced availability of alternative prey such as northern anchovy.

To further reduce predation rates by Caspian terns nesting at East Sand Island on salmonid smolts in the Columbia River estuary, more Caspian terns will need to be relocated to colonies outside the estuary. Based on the size of the East Sand Island colony in 2015 (6,240 breeding pairs) relative to the target colony size stipulated in the Management Plan (3,125 - 4,375 breeding pairs), an additional 1,900-3,100 breeding pairs will need to be relocated outside the estuary. This will likely require an increased effort to prevent Caspian terns from nesting outside the designated 1-acre core colony area on East Sand Island. In addition, either nesting density within the 1-acre core colony area on East Sand Island will need to decline from the record density observed in 2015 or the core colony area will need to be reduced to less than 1

acre of nesting habitat, or both, in order to meet the management goal for colony size stipulated in the Plan.

INTRODUCTION

Piscivorous colonial waterbirds (i.e., terns, cormorants, gulls, pelicans) are having a significant impact on survival of juvenile salmonids (*Oncorhynchus* spp.; salmon and steelhead) in the lower Columbia River (BRNW 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013a, 2014a, 2015a). Prior to management, Caspian terns (*Hydroprogne caspia*) at the nesting colony on Rice Island, an artificial dredged material disposal island in the Columbia River estuary, consumed an estimated 5.4 - 14.2 million juvenile salmonids in both 1997 and 1998. This represents about 5 - 15% of all salmonid smolts reaching the estuary during those two migration years. Due to growing concern regarding the impacts of avian predation on recovery of ESA-listed salmonids, regional fish and wildlife managers in 1999 called for immediate management action to reduce losses of juvenile salmonids to Caspian tern predation in the Columbia River estuary.

A management plan first implemented in 1999 sought to relocate the Caspian tern colony on Rice Island, the largest of its kind in the world, to a restored colony site on East Sand Island, 21 km closer to the ocean, where it was hoped terns would consume significantly fewer juvenile salmonids. Over 94% of the nesting Caspian terns shifted from Rice Island to East Sand Island in 2000, where juvenile salmonids comprised 47% of tern prey items, compared to 90% of prey items at Rice Island (Roby et al. 2002). During 2001–2014, all Caspian terns nesting in the Columbia River estuary used East Sand Island, with the exception of three nesting pairs that laid a total of four eggs on Rice Island in 2011 (BRNW 2012). During 2001-2014, estimated consumption of juvenile salmonids by Caspian terns nesting on East Sand Island averaged 5.1 million smolts per year (SD = 0.9 million, n = 14 years), a ca. 59% reduction in annual consumption of salmonid smolts compared to when the Caspian tern colony was on Rice Island (12.4 million smolts consumed in 1998; Roby et al. 2003).

Further management of Caspian terns to reduce losses of juvenile salmonids in the Columbia River estuary is currently in progress; the Records of Decision (RODs) for *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*, signed in November 2006, stipulated the redistribution of approximately 60% of the East Sand Island tern colony to alternative colony sites outside the Columbia Basin in Oregon and California (USFWS 2005, 2006). This management action is intended to further reduce smolt losses to Caspian terns in the estuary, while still maintaining the long-term viability of the Pacific Flyway population of Caspian terns. By the beginning of the 2012 breeding season, the U.S. Army Corps of Engineers – Portland District had constructed nine islands, six in interior Oregon and three in northeastern California, as alternative nesting habitat for Caspian terns nesting on East Sand Island. Construction of additional Caspian tern colony sites in the southern portion of San Francisco Bay at Don Edwards National Wildlife Refuge was completed prior to the 2015 breeding season, and was available to nesting Caspian terns for the first time during the 2015 nesting season. Concurrent with island construction outside the Columbia Basin, the Corps has been gradually reducing the area of suitable nesting habitat for Caspian terns on East Sand

Island from 5 acres in 2008 to 1 acre in 2015, and hazing Caspian terns that attempt to establish new nesting colonies elsewhere in the Columbia River estuary.

The primary objective of this study is to monitor and evaluate the managed reduction of tern nesting habitat on East Sand Island in 2015, designed to reduce the size of the Caspian tern breeding colony and, consequently, the predation rates on juvenile salmonids in the estuary. Specifically, we measured nesting chronology, colony attendance (adults on colony/week), colony size (peak number of breeding pairs), colony area (area [m^2] used by nesting terns), nesting density (nests/m^2), nesting success (young fledged/breeding pair), and factors limiting colony size and nesting success for Caspian terns on East Sand Island. We also used tern bill load identifications to assess the percentage of juvenile salmonids in the tern diet and employed a bioenergetics modeling approach to quantify the numbers of juvenile salmonids consumed by Caspian terns nesting on East Sand Island. We evaluated movement rates of previously color-banded Caspian terns to and from the East Sand Island to assess the efficacy of management initiatives implemented to relocate nesting terns to sites outside the Columbia River Basin. We also monitored the effects of Caspian tern management actions implemented on East Sand Island on the other colonial waterbirds that nest and roost on the island. Finally, we provided technical assistance to BPA and other regional fish and wildlife management agencies in developing short- and long-term management plans to reduce avian predation on juvenile salmonids in the lower Columbia River.

STUDY AREA

This study, funded by the Bonneville Power Administration, focused on the nesting activities of Caspian terns at East Sand Island in the Columbia River estuary (Map 1). Additionally, this report provides information on roosting California brown pelicans (*Pelecanus occidentalis californicus*), nesting glaucous-winged/western gulls (*Larus glaucescens/occidentalis*), and nesting ring-billed gulls (*L. delawarensis*) on East Sand Island.

This work is part of a comprehensive program to monitor and evaluate the management plans entitled, *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary* (USFWS 2005, 2006) and the *Inland Avian Predation Management Plan* (USACE 2014; BRNW 2014b, 2015b); both plans seek to reduce Caspian tern predation on ESA-listed juvenile salmonids from the Columbia River Basin by relocating nesting Caspian terns from colonies within the Basin to alternative colonies outside the Basin. Results from other related studies are provided in separate reports, work funded by the U.S. Army Corps of Engineers (USACE) – Walla Walla District (BRNW 2015b), the USACE – Portland District (BRNW 2015c, 2015e), and the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee (BRNW 2015d).

SECTION 1: CASPIAN TERNS

Beginning in 2008, the USACE – Portland District implemented management described in the January 2005 Final Environmental Impact Statement (FEIS) and November 2006 Records of

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

The Caspian Tern Management Plan for the Columbia River estuary called for the creation of approximately 7 – 8 acres of new or restored Caspian tern nesting habitat (islands) and to actively attract Caspian terns to nest at these sites. As alternative tern nesting habitat is created or restored outside the Columbia Basin, the available nesting habitat for Caspian terns on East Sand Island would be reduced from its initial size (approximately 5 acres in 2007) to 1.0 – 1.5 acres.

The specific objectives of the Plan are to reduce the size of the East Sand Island Caspian tern colony to 3,125 – 4,375 breeding pairs by limiting the availability of suitable nesting habitat, while providing new nesting habitat for Caspian terns at alternative colony sites outside the Columbia River estuary. These objectives were identified as the preferred alternative in the Final Environmental Impact Statement released in early 2005 (USFWS 2005). Caspian terns displaced by habitat reduction on East Sand Island are expected to relocate to alternative colony sites, including the nine Corps-constructed tern islands in interior Oregon and northeastern California (i.e., Fern Ridge Reservoir, Crump Lake, Summer Lake Wildlife Area [3 separate islands], Tule Lake NWR, Lower Klamath NWR [2 separate islands], and Malheur NWR) and the five Corps-constructed tern islands in the southern portion of San Francisco Bay at Don Edwards National Wildlife Refuge.

1.1. Habitat Preparations & Nest Dissuasion Activities

As part of the plan entitled *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*, the USACE – Portland District prepared 1.0 acre of suitable bare-sand nesting habitat for Caspian terns on East Sand Island in 2015 (Map 3). A limited amount of European beach grass (*Ammophila arenaria*) along the northern edge of the managed colony area was successfully removed by disking and the sand smoothed by dragging a section of chain-link fence over the 1-acre area. As was the case in 2013 and 2014, the colony area was not sprayed with pre-emergent herbicide during the spring of 2015. In addition, a 310-ft., single line of silt fencing was installed along the south edge of the colony area (running east to west) and along the west edge of the colony area (running north to south). Two additional 75 ft. lengths of silt fencing were installed 20-25 ft. apart behind row of fencing on the west edge of the colony. Posts, ropes, and flagging were erected behind (to the south) of the row of silt

fencing along the south edge to dissuade terns from nesting on the exposed sand of the former colony area. The disking and placement of passive dissuasion materials resulted in a 0.55-acre reduction in area of nesting habitat compared to the 1.55 acres of habitat prepared the previous year. The area of Caspian tern nesting habitat prepared on East Sand Island in 2015 represented an 80% reduction from what had been provided prior to implementation of the management plan in 2008.

Under separate contracts with the Corps and as stipulated in the Caspian Tern Management Plan, the Corps endeavored to prevent Caspian terns from nesting outside the prepared 1-acre colony area on East Sand Island and elsewhere in the Columbia River estuary. This work was conducted by other contractors and the results were provided to the Corps in separate reports and are outside the scope of this report.

1.2. Nesting Distribution, Colony Size, Productivity, & Limiting Factors

Methods: The number of Caspian terns breeding on East Sand Island in the Columbia River estuary was estimated using low-altitude, high-resolution, vertical aerial photography of the colony taken near the end of the incubation period (7 June). The average of 3 direct counts of all adult terns on the colony in aerial photography, corrected using ground counts of the ratio of incubating to non-incubating terns on 12 different plots within the colony area, was used to estimate the number of breeding pairs on the colony at the time of the photography. Confidence intervals for the number of breeding pairs were calculated using a Monte Carlo simulation procedure to incorporate the variance in the multiple counts from the aerial photography and the variance in the ratios of incubating to non-incubating adult terns among the 12 plots. Estimates of the number of breeding pairs were calculated one thousand times using random draws from the sample distributions of the total number of terns on-colony and the ratio of incubating to non-incubating adult terns on plots. Standard errors and confidence intervals for the number of breeding pairs were derived from the resulting distribution.

Nesting success (average number of young raised per breeding pair) at the East Sand Island tern colony was estimated using aerial photography taken of the colony just prior to the fledging period (9 July). The average of 3 direct counts of all terns (adults and juveniles) on the colony in aerial photography, corrected using ground counts of the ratio of fledglings to adults on 12 different plots within the colony area, was used to estimate the number of fledglings on the colony at the time of the photography. To estimate nesting success, the total number of fledglings counted on-colony was divided by the number of breeding pairs estimated during late incubation (see above). Confidence intervals for nesting success were calculated using a Monte Carlo simulation procedure to incorporate the variance in the multiple counts from the aerial photography and the variance in the ratios of fledglings to adults on the plots. Monte Carlo calculations were performed using Visual Basic within Microsoft Excel (Microsoft Corp., Redmond, WA); 1000 iterations were performed and 95% bootstrap percentile limits were used for confidence intervals.

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

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

Results and Discussion: We estimate that 5,430 breeding pairs of Caspian terns (95% c.i. = 5,200 – 5,660 pairs) were nesting on the 1-acre core colony area on East Sand Island at the peak of nesting activity (late May – early June) in 2015 (Figure 1). This is about 13% fewer nesting Caspian terns than in 2014 (6,270 pairs; 95% c.i. = 5,860 – 6,680 pairs; Table 1). Despite efforts to limit tern nesting on East Sand Island to the 1-acre core colony area using passive dissuasion (stakes, ropes, and flagging) and active dissuasion (human hazing), efforts that were conducted by the Corps' contractor (LKE), satellite Caspian tern colonies formed adjacent to the core colony area and supported an additional 810 breeding pairs. As a result, the total number of Caspian terns nesting on East Sand Island in 2015 (6,240 pairs; 95% c.i. = 6,000 – 6,460 pairs) was similar to the colony size in 2014 (6,270 pairs). Nevertheless, 6,240 breeding pairs is the smallest point estimate for colony size recorded at East Sand Island since the reduction in tern nesting habitat was first implemented on the island in 2008. The number of terns nesting in the 1-acre core colony area (5,430 breeding pairs) represents nearly a 50% decline from the peak Caspian tern colony size on East Sand Island, which was observed in 2008 (ca. 10,670 pairs; Figure 2; Table 1), but is still larger than the target colony size specified in the Caspian Tern Management Plan for the Columbia River estuary (3,125 – 4,375 breeding pairs; USFWS 2005, 2006).

The overall decline in colony size at the East Sand Island tern colony during 2008-2015 can be attributed to the planned reductions in area of tern nesting habitat provided on East Sand Island as part of the Caspian Tern Management Plan for the Columbia River estuary (USFWS 2005, 2006; see above). During 2008-2012, the amount of nesting habitat prepared for terns on East Sand Island was incrementally reduced in each year, from approximately 5 acres in 2008 to 1.58 acres in 2012 and 2013. In 2014, the amount of nesting habitat prepared for Caspian terns on East Sand Island was reduced slightly (1.55 acres) from what was prepared the previous two years, and in 2015 the amount of nesting habitat prepared was reduced to the target colony area stated in the management plan (1 acre). In response to the gradual decline in available nesting habitat for Caspian terns on East Sand Island, there has been a gradual increase in nesting density, from 0.72 nests/m^2 in 2008 to 1.32 nests/m^2 in 2015, the highest nesting density ever recorded at the East Sand Island Caspian tern colony (Figure 3; Table 1). Nesting densities for Caspian terns on East Sand island in recent years are now well above the nesting densities used to establish the colony size and colony area targets in the Caspian Tern Management Plan for the Columbia River estuary (0.55 – 0.78 nests/m^2; USFWS 2005, 2006). Based on these nesting densities, the area of Caspian tern nesting habitat provided on East Sand Island will likely need to be reduced to less than 1 acre to realize the goal of reducing the

size of the East Sand Island tern colony to 3,125 – 4,375 breeding pairs, as prescribed in the Caspian Tern Management Plan (USFWS 2005, 2006).

Using the 9 July aerial photography of the Caspian tern colony, we estimate that ca. 3,700 fledglings were produced at the core and satellite colonies on East Sand Island in 2015. This corresponds to an average nesting success of 0.59 young raised per breeding pair (95% c.i. = 0.48 – 0.70 fledglings/breeding pair). Compared to Caspian tern nesting success at East Sand Island in previous years and at other Caspian tern colonies in the region, this is considered average productivity, but higher than the average productivity observed at this colony during the previous five years (0.12 fledglings/breeding pair; Figure 4). Nesting success at the East Sand Island Caspian tern colony peaked in 2001 and has trended downward since then (Figure 4). At least two factors have contributed to the decline in productivity of the Caspian tern colony at East Sand Island: (1) ocean conditions and/or high river flows as they influence the availability of marine forage fishes in the estuary and (2) predation on tern eggs and chicks by gulls, especially during tern colony disturbance events caused by bald eagles (*Haliaeetus leucocephalus*; Collar 2013).

As was the case prior to 2013-2014, Caspian terns were observed prospecting for nest sites at dredged material disposal sites on Rice Island in the upper Columbia River estuary during 2015. Up to 4,000 Caspian terns were observed loafing on Rice Island during the month of May. Active and passive dissuasion measures used by the Corps' contractor (LKE) to dissuade Caspian terns from nesting on Rice Island were not fully successful; a total of 189 tern eggs were laid at a site near the former colony area on Rice Island. Once laid, these tern eggs were collected under permit. Egg collection and continuous human hazing caused Caspian terns to finally abandon Rice Island by the end of June. Caspian terns did not attempt to nest at any other dredged material disposal site or other sites (e.g., Tongue Point piers) in the upper estuary during 2015.

1.3. Diet Composition & Salmonid Consumption

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

The diet composition of terns over the entire breeding season was based on the average of the percentages for the 2-week periods.

To assess the relative proportion of the various salmonid species in tern diets, we collected fish near the East Sand Island tern colony from Caspian terns returning to the colony with whole fish carried in their bills (referred to hereafter as "collected bill loads"). We employed a non-lethal sampling technique developed in 2011 that utilizes hazing shells to startle terns into dropping their fish; collection of a total of 282 bill load fish was conducted from 19 April to 29 July 2015. No lethal sampling of Caspian terns to determine diet composition was conducted during 2012-2015. Salmonid bill loads were identified as either Chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), or unknown based on analyses of morphometrics, diagnostic bones, and molecular genetics[1].

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

Results and Discussion: Of the bill load fish identified at the East Sand Island Caspian tern colony during the 2015 nesting season (n = 4,803 bill loads), on average of 38% were juvenile salmonids. This proportion was higher than the average over the previous 15 years (31%; Figure 5). As in previous years, marine forage fishes (e.g., anchovies [Engraulidae], surf perch [Embiotocidae], smelt [Osmeridae], and herring [Clupeidae]) were most prevalent in the tern diet, together averaging 58% of all identified bill loads in the diet of terns nesting on East Sand Island in 2015 (Figures 6). In 2015, the peak in the proportion of salmonids in the diet of Caspian terns nesting on East Sand Island occurred in mid-May, a week later than the average timing of the peak in salmonids in the tern diet during the previous 15 years (Figure 7). The proportion of salmonids in the tern diet during the 2015 nesting season was higher than average from mid-May through August (Figure 7).

Genetic stock identification of salmonid bill load fish collected from East Sand Island Caspian terns during 2011-15 indicated that terns consumed smolts from many of the uniquely identifiable stocks from across the Columbia Basin. For Chinook salmon, the most common genetic stocks of origin for smolts depredated by terns during April and May were the Middle Columbia River, Upper Columbia River, and Snake River spring run stocks (combined 69 of 119,

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

or 58%; Figure 8, Table 2). During June and July, most depredated Chinook salmon smolts (45 of 86, or 52%) originated from the lower Columbia River (Spring Creek Group fall run, West Cascades Tributary fall run, and the introduced Rogue River fall run). The remaining Chinook salmon in tern diets during this period was dominated by smolts belonging to the Snake River populations were 35 of 86, or 41%). Depredated steelhead trout originated from seven stocks, fall run and Upper Columbia River summer/fall run stocks (combined, smolts from these with steelhead from the Snake River consisting of almost half of the identified samples (74 of 161 samples, or 46%; Figure 9, Table 3). Genetic stock identification was performed for 81 coho salmon smolts collected from terns. Over half of identified coho salmon originated from the Columbia River stock (49 of 81 samples, or 60%; Figure 10, Table 4).

Our best estimate of total smolt consumption by Caspian terns nesting on East Sand Island in 2015 was 5.2 million smolts (95% c.i. = 4.6 – 5.9 million smolts), very similar to the average for the previous 14 years (Figure 10). This is less than half the annual consumption of juvenile salmonids by Caspian terns nesting in the Columbia River estuary prior to 2000, when the breeding colony was located on Rice Island in the upper Columbia River estuary. Further reductions in smolt consumption by Caspian terns in the Columbia River estuary will be realized once the management goals associated with reductions in colony size and colony area on East Sand Island and elsewhere in the estuary are met.

Of the juvenile salmonids consumed by East Sand Island Caspian terns in 2015, we estimate that 1.8 million or 35% were coho salmon (95% c.i. = 1.6 – 2.1 million smolts), 1.7 million or 32% were sub-yearling Chinook salmon (95% c.i. = 1.4 – 2.0 million smolts), 0.8 million or 16% were steelhead (95% c.i. = 0.7 – 1.0 million smolts), 0.8 million or 16% were yearling Chinook salmon (95% c.i. = 0.7 – 1.0 million smolts), and 0.02 million or < 1% were sockeye salmon (95% c.i. = 0.00 – 0.04 million smolts; Figure 11). Consumption of sub-yearling Chinook was significantly higher than in 2014 (0.8 million smolts; 95% c.i. = 0.8 – 1.1 million smolts), presumably due to less anchovy in the tern diet during June and July of 2015.

1.4. Inter-colony Movements & Dispersal Patterns

Methods: In 2015, we continued our efforts to resight color-banded Caspian terns for on-going demographic studies and to evaluate movement probabilities by adult Caspian terns among breeding colonies. Results presented here track the movements of banded Caspian terns among colonies, either within or between years, to better assess the consequences of various management initiatives implemented as part of the Caspian Tern Management Plan for the Columbia River estuary.

Caspian terns were banded with a federal numbered metal leg-band and two colored plastic leg-bands on one leg and a colored plastic leg-band engraved with a unique alphanumeric code on the other leg during 2005 – 2014. Banded adult Caspian terns were resighted on the East Sand Island tern colony by researchers using binoculars and spotting scopes during 5-7 days per week throughout the 2015 breeding season. Numbers of banded Caspian terns resighted with a

complete set of color bands, thus identifying banding location and year, are presented in this report.

Multi-state analysis (Hestbeck et al. 1991, Brownie et al. 1993) in Program MARK (White and Burnham 1999) was used to estimate inter-regional movement probabilities of Caspian terns banded as adults during 2005-2014. Movement probabilities were estimated between three regions; the Columbia River estuary (including East Sand Island, Rice Island, Tongue Point Piers [a loafing site]), the Columbia Plateau (including the Blalock Islands, Goose Island, and other smaller colonies and loafing sites), and the alternative Corps-constructed colony sites (all the Corps-constructed tern islands in interior Oregon and northeastern California). *A priori* models were constructed to evaluate effects of transitions from one region to another and effects of year on movement probabilities. Models that incorporate locations and year effects on resighting probabilities were included in this analysis, which allowed us to calculate unbiased probabilities of inter-regional movement rates despite resighting efforts that may vary among locations and years. Akaike's Information Criterion adjusted for small samples (AICc) was used to select the best model (Burnham and Anderson 2002) for estimating inter-regional movements. Based on movement probabilities between 2014 and 2015 from the best model, and the numbers of Caspian terns present at the colony of origin in 2014, the numbers of terns that moved between colonies from 2014 to 2015 were estimated.

In 2015, a total of 482 previously color-banded Caspian terns were resighted on East Sand Island. Of these resighted terns, 83% were banded at East Sand Island (214 as adults and 186 as chicks), 6% were banded at Crescent Island (20 as adults and 11 as chicks), 5% were banded at Goose Island-Potholes Reservoir (19 as adults and 6 as chicks), 4% were banded as chicks at the Port of Bellingham, Washington, 1% were banded at Sheepy Lake tern island in Lower Klamath NWR, California (1 as an adult and 2 as chicks), < 1% were banded as chicks each at Malheur Lake tern island in Malheur NWR, Brooks Island in San Francisco Bay, California, and Kokinhenik Bar in the Copper River Delta, Alaska (Table 5). Resightings of banded Caspian terns at the East Sand Island colony indicate that some Caspian terns are moving from both inland and coastal colonies to the East Sand Island colony.

Of a total of 470 color-banded Caspian terns seen on East Sand Island in 2014, 386 terns were resighted again at East Sand Island or elsewhere in 2015; some of these individuals were resighted at multiple locations in 2015. Of a total of 433 resighting records of these birds in 2015, 82% were resighted at East Sand Island, 4% were resighted at Rice Island in the upper Columbia River estuary, 3% were resighted at the Blalock Islands in the mid-Columbia River, 3% were resighted at Tule Lake tern island in Tule Lake NWR, California, 2% were resighted at an active colony on Rat Island in the Puget Sound area, Washington, 2% were resighted at Tongue Point Piers (loafing site) in the upper Columbia River estuary, 1% were resighted at an active colony in Everett, Washington, 1% were resighted at Goose Island in Potholes Reservoir. Also, < 1% were resighted each at East Link tern island at Summer Lake Wildlife Area, Malheur Lake tern island in Malheur NWR, Twinning Island in Banks Lake, Washington, and Kokinhenik Bar in the Copper River Delta during 2015 (Table 6).

Out of 11 *a priori* models constructed in 2015, a model with transition (from one region to another) and year effects on inter-regional movement probabilities was selected based on the smallest value of AICc. This model included an interaction term between transition and year effects, which allows movement probabilities to vary over years regardless of trends observed in other transitions. There was little movement (< 0.01%) of Caspian terns banded as adults from the Columbia River estuary to Columbia Plateau prior to 2010. During 2010-2015, there were limited movements from the estuary to the Columbia Plateau region, < 2% in most years, with the exception of a 2.1% movement rate in 2012. Estimated net movement of adult Caspian terns (the estimated number of terns that moved from one region to another, subtracted from the number of terns that moved in the opposite direction) from the Columbia River estuary to the Columbia Plateau in 2015 was 105 individuals (Table 7). Movement probabilities of Caspian terns banded as adults from the Columbia River estuary to the alternative colony sites on the Corps-constructed tern islands in interior Oregon and northeastern California ranged from < 0.01% to 1.7% during 2008-2015, with the highest movement probability recorded in 2012. Movement probability from the estuary to the alternative colony sites was below detectable levels in 2015; interior Oregon and northeastern California experienced severe drought in both 2014 and 2015, negatively affecting both tern nesting and foraging habitat throughout the region.

Some adult Caspian terns present at East Sand Island in 2014, where management reduced the area of tern nesting habitat before the 2015 nesting season, moved to the Columbia Plateau region in 2015, although the number was small. This could have partially off-set benefits to salmonids of tern management in the estuary because per bird impacts on smolt survival are higher for terns nesting in the Columbia Plateau region compared to those nesting in the estuary, where marine forage fishes (e.g., anchovy, smelt, surfperch, etc.) tend to dominate the diet. Although few movements of Caspian terns banded as adults from the Columbia River estuary to the alternative colony sites were observed between 2014 and 2015 based on the analysis using Program MARK, Caspian terns banded at East Sand Island (mostly as chicks) were resighted at four different Corps-constructed tern islands in 2015; all of these recently built tern islands are more than 400 km from the Caspian tern colony on East Sand Island in the Columbia River estuary. If those alternative colony sites had not been available, those terns banded at East Sand Island and subsequently resighted at the alternative colony sites likely would have moved back to their natal colony. Therefore, the Corps-constructed islands continue to serve as important nesting habitat for Caspian terns dispersed from the managed colony at East Sand Island. Movements of banded Caspian terns among the Corps-constructed alternative nesting islands were also documented, which suggests a network of nesting habitat within the region has been developed to some extent. This network should provide opportunities for some Caspian terns to remain within the region despite some of the alternative colony sites becoming unsuitable for nesting due to severe drought.

Based on the best model selected to estimate inter-colony movements (see above), movement probabilities of Caspian terns banded as adults from alternative colony sites on the Corps-constructed tern islands in interior Oregon and northeastern California to the Columbia River estuary ranged from < 0.01% to 12% per year during 2008-2014, with the highest movement

rate observed in 2014, when interior Oregon and northeastern California entered a severe drought. The movement probability from the Corps-constructed islands to the estuary in 2015 was estimated at 5%. This translates into an estimated net movement of 79 Caspian terns from the Corps-constructed islands to the Columbia River estuary in 2015 (Table 7). Movement probabilities from colonies on the Corps-constructed islands to the Columbia Plateau region ranged from < 0.01% to 20% during 2009-2014, with the highest rate observed in 2014. The movement probability from the alternative colony sites to the Columbia Plateau remained high again in 2015 at 19%, despite management actions to reduce colony size at both Crescent Island and Goose Island. Estimated net movement of adult Caspian terns from the Corps-constructed alternative colony sites to the Columbia Plateau region in 2015 was 282 individuals. The drought in 2014 and 2015 not only made some of the Corps-constructed islands more accessible to terrestrial predators (e.g., raccoons), but also limited foraging habitat and prey availability within commuting distance of Caspian tern colonies on Corps-constructed islands. The sustained high movement probability from the alternative colony sites to the Columbia Plateau region in 2015 might have been partly due to available nesting habitat at the Blalock Islands in the mid-Columbia River and the terns' strong fidelity to Goose Island in Potholes Reservoir.

SECTION 2: GULLS AND PELICANS

Methods: Counts of the number of adults on-colony at East Sand Island were conducted for glaucous-winged/western gulls and for ring-billed gulls in 2015, based on one count of all adults on-colony in aerial photography (see Section 1.1.2 for a description of methods); these counts were used as an index to breeding colony size. The peak number of California brown pelicans using East Sand Island as a nighttime roost in 2015 was determined by conducting periodic boat-based surveys (approximately every two weeks) in the evenings from mid-May through mid-September. Because three California brown pelican nests containing eggs were discovered on East Sand Island in 2013 and eleven nests were also initiated in 2014 (although no egg-laying was confirmed), an effort was made to detect any nesting activity by brown pelicans during the 2015 breeding season. In addition to increased direct effort by field researchers, six remote sensing camera traps were positioned to cover the area of failed nesting attempts by pelicans in 2013 and 2014, an area where we suspected brown pelicans might attempt to nest again.

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

Gulls − Based on one count of aerial photography taken of East Sand Island on 7 June, we estimate that ca. 4,123 glaucous-winged/western gulls and ca. 1,924 ring-billed gulls were on their respective colonies. This represents a 15% increase and 16% decline in the index counts of glaucous-winged/western gulls and ring-billed gulls, respectively, on East Sand Island in 2015 compared to 2014. Nesting ring-billed gulls were again restricted to a small area at the northeastern tip of the island, while nesting glaucous-winged/western gulls were more evenly

distributed across the island, but with a large gap with no nesting gulls in the central, densely-vegetated portion of the island.

There were no marked differences in the distribution of glaucous-winged/western gulls on the western end of East Sand Island between 2013, when cormorant nest dissuasion trials were being conducted, 2014, when dissuasion trials were no longer being conducted, and 2015, the first year of lethal management at the double-crested cormorant colony on East Sand Island. In 2015, 1,187 individuals or 29% of the total were counted west of the western privacy fence (compared to 29% in 2014 and 24% in 2013); 2,356 individuals or 57% were counted east of the eastern privacy fence (compared to 55% in 2014 and 62% in 2013); and 598 individuals or 14% were counted between the fences (compared to 16% in 2014 and 14% in 2013).

California Brown Pelicans − East Sand Island is the largest known post-breeding nighttime roost site for California brown pelicans, and the only known night roost for this species in the Columbia River estuary (Wright 2005). In 2015, the first California brown pelicans were observed roosting on East Sand Island on 11 April. These first pelicans were roosting on the southeast beach above the high water line, not far from where the nests were discovered in 2013 and 2014. The weekly counts of California brown pelicans roosting on East Sand Island peaked in late June at 9,285 individuals (Figure 55), slightly lower than the peak count in 2014 (10,835 individuals), but still significantly higher than the peak count in 2013 (ca. 3,850) and less than the peak count in 2011 (ca. 14,225 individuals; Figure 56).

As was the case in 2009, 2010, 2012, 2013, and 2014, we observed some breeding behavior by brown pelicans on East Sand Island (i.e. courtship displays, collecting nest-material, and attempted copulations) in 2015. Unlike 2013 and 2014, however, no California brown pelican nests were discovered in 2015. Roosting and breeding behaviors were captured in digital images collected on 3 of the 6 cameras. The distribution of roosting California brown pelicans in 2015 shifted to a greater use of the south beaches and a small upland area west of the Caspian tern colony, compared to the more extensive use of inland habitat east of the tern colony that was observed in 2013 and 2014. New areas of pelican use that were located away from camera view, including the upper beach, were observable from observation blinds and in aerial photography, but there were still no indications of nesting.

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All work with live vertebrates conducted as part of this study followed protocols approved by the Institutional Animal Care and Use Committee (IACUC) at Oregon State University.

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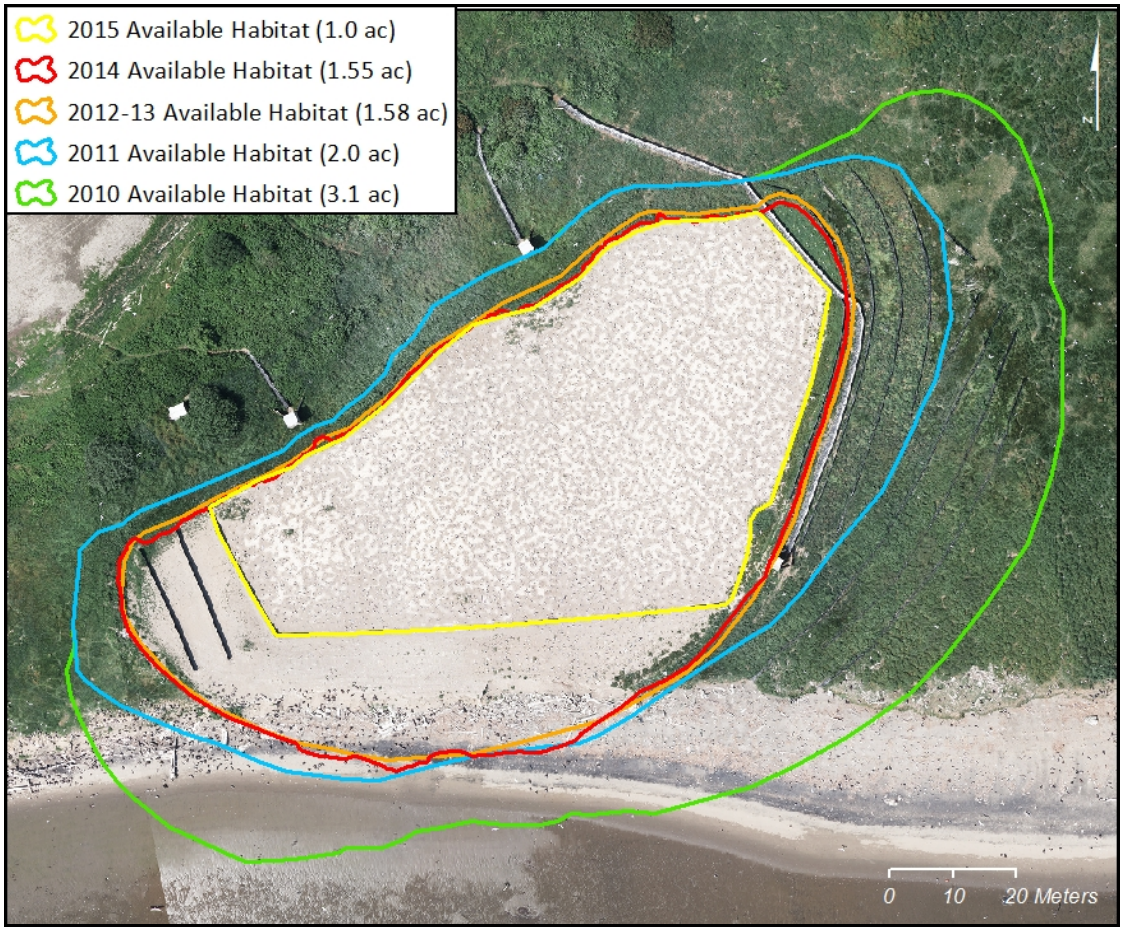
Map 1. Study area in the Columbia River basin showing the locations of active and former breeding colonies of piscivorous colonial waterbirds mentioned in this report.

Map 2. East Sand Island and out of basin sites mentioned in this report, including Corps-constructed tern islands.



Map 3. Nesting habitat prepared for Caspian terns on the eastern end of East Sand Island in the Columbia River estuary during 2010-2015. Aerial photography was taken on 28 May 2015. Colony delineations depict the area of nesting habitat available to terns each breeding season during 2010-2015 and were overlaid on the 2015 photography. The southern shoreline of East Sand Island has been gradually eroding during each winter since 2010, as indicated by the colony delineations in 2010-2014. Passive nest dissuasion materials (i.e. silt fencing, stakes, ropes, and flagging), invasive vegetation, and island erosion have all served to limit nesting habitat to the acreage specified by resource managers (see map legend and text for details).

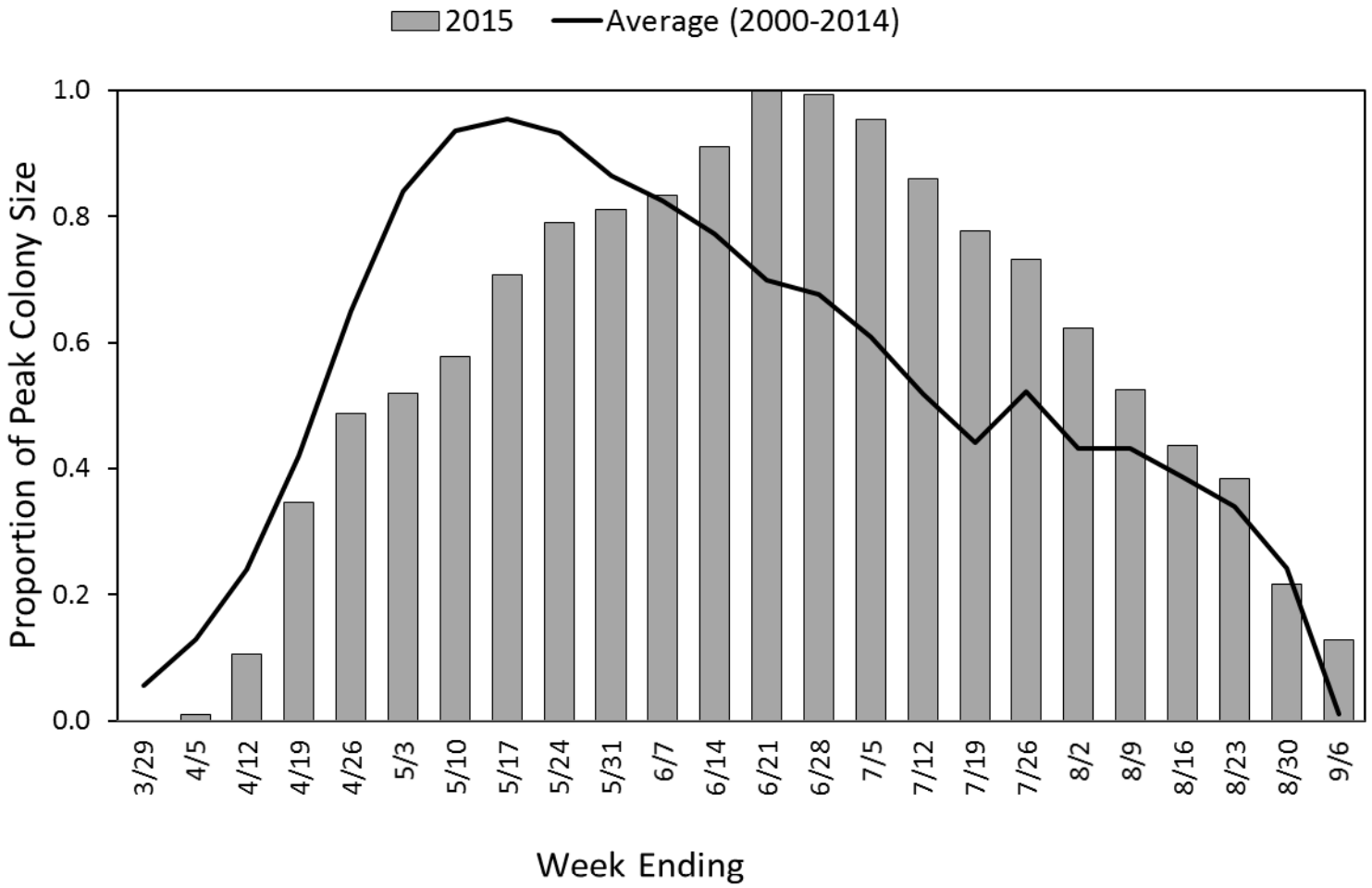


Figure 1. Weekly estimates from the ground of the number of adult Caspian terns on the 1-acre core colony a East Sand Island during the 2015 breeding season, normalized to peak colony attendance during the week en 21 June as determined from counts of aerial photography of the colony taken during that week (late in the incubation period).

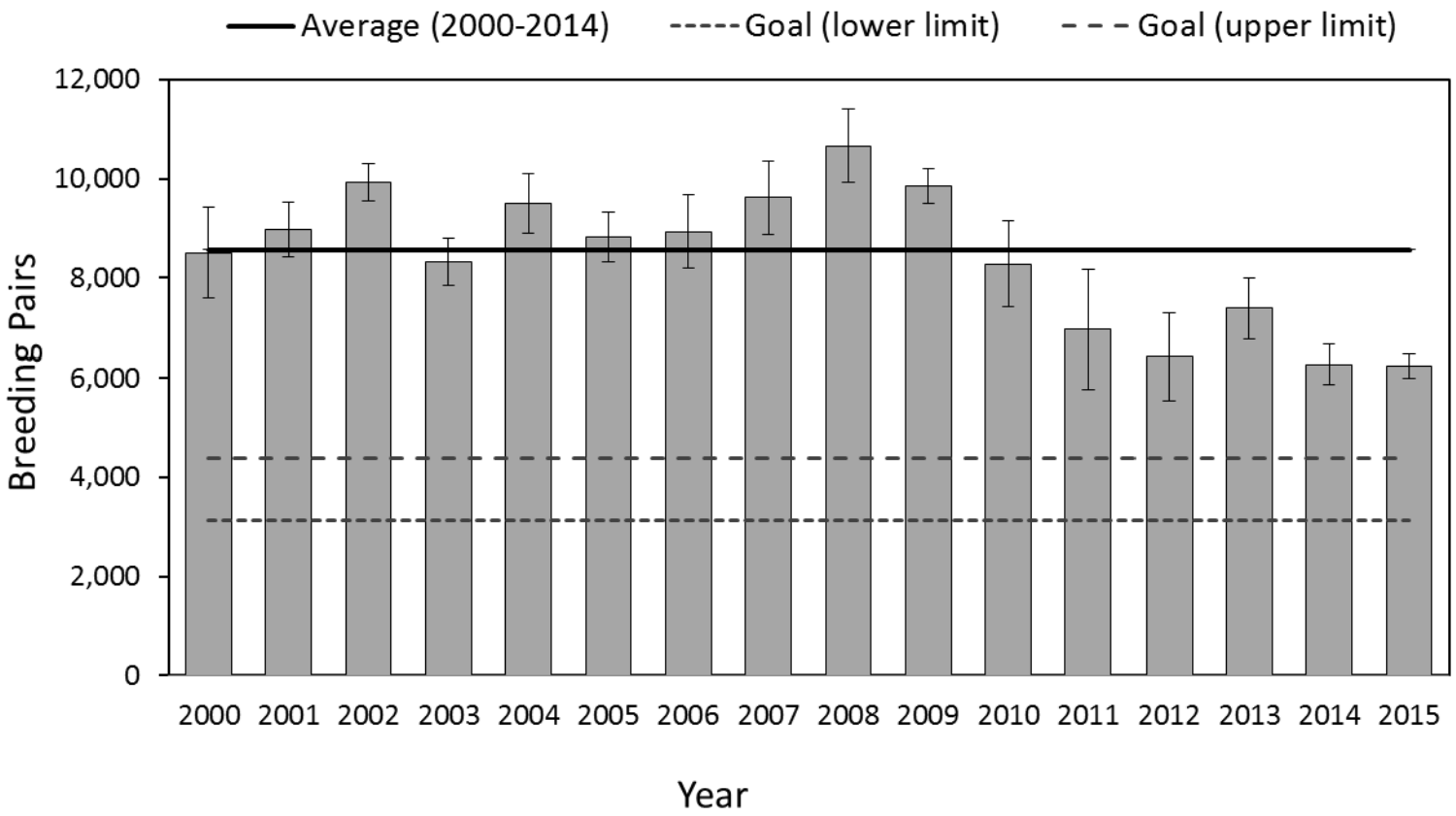


Figure 2. Caspian tern colony size (number of breeding pairs) on East Sand Island in the Columbia River estuary during 2000-2015. The colony size estimate for 2015 includes breeding pairs that nested outside the 1-acre core colony area in two satellite colonies. The error bars represent 95% confidence intervals for the estimate of the number of breeding pairs. The upper and lower limits of the target colony size from the Management Plan (goal) for East Sand Island are also provided for comparison.

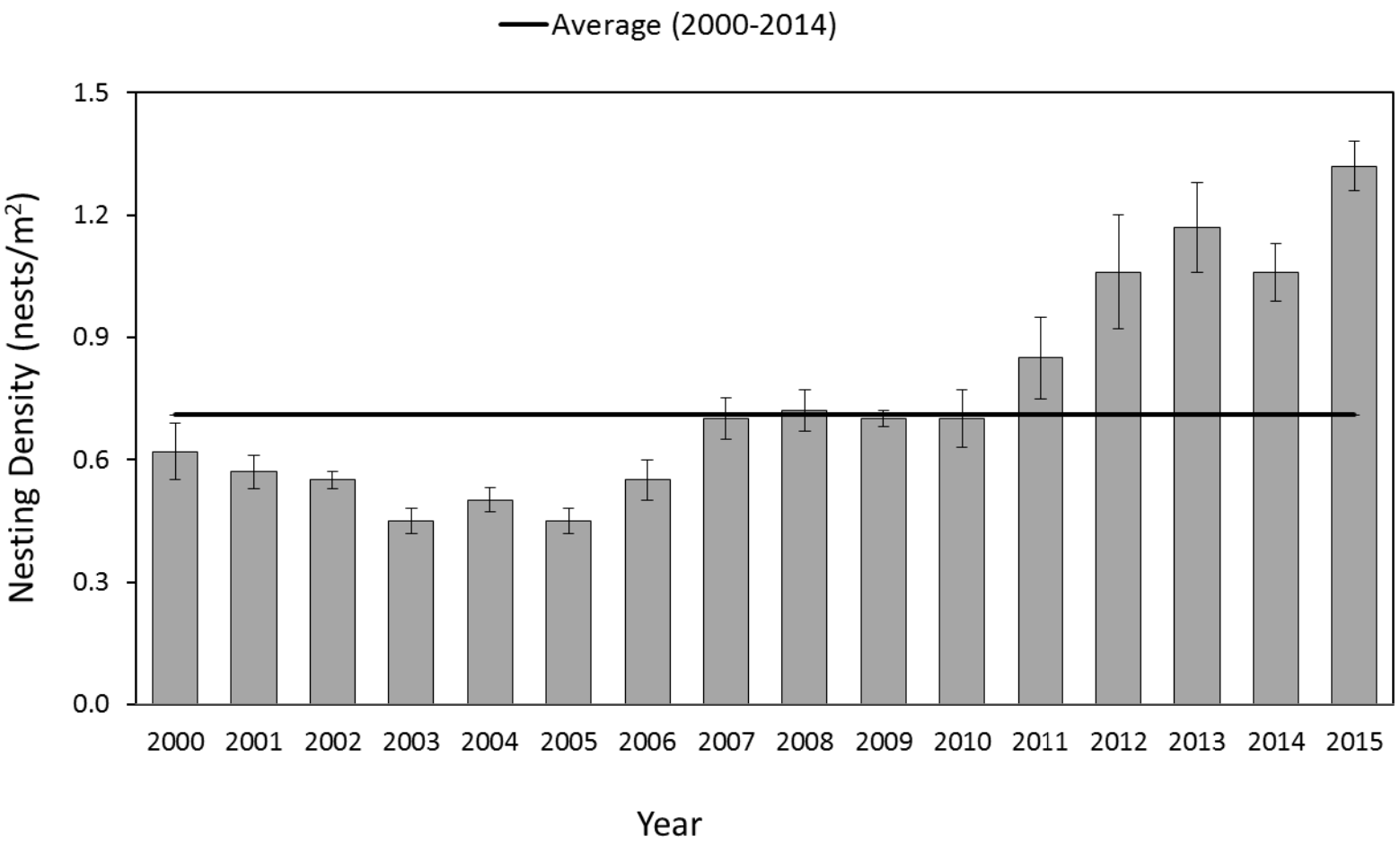


Figure 3. Caspian tern nesting density at the breeding colony on East Sand Island in the Columbia River estuary during 2000-2015. Nesting density in 2015 was measured only in the 1-acre core colony area. The error bars represent 95% confidence intervals for the estimate of nesting density (confidence interval not available for 2011 and based on confidence interval for 2012).

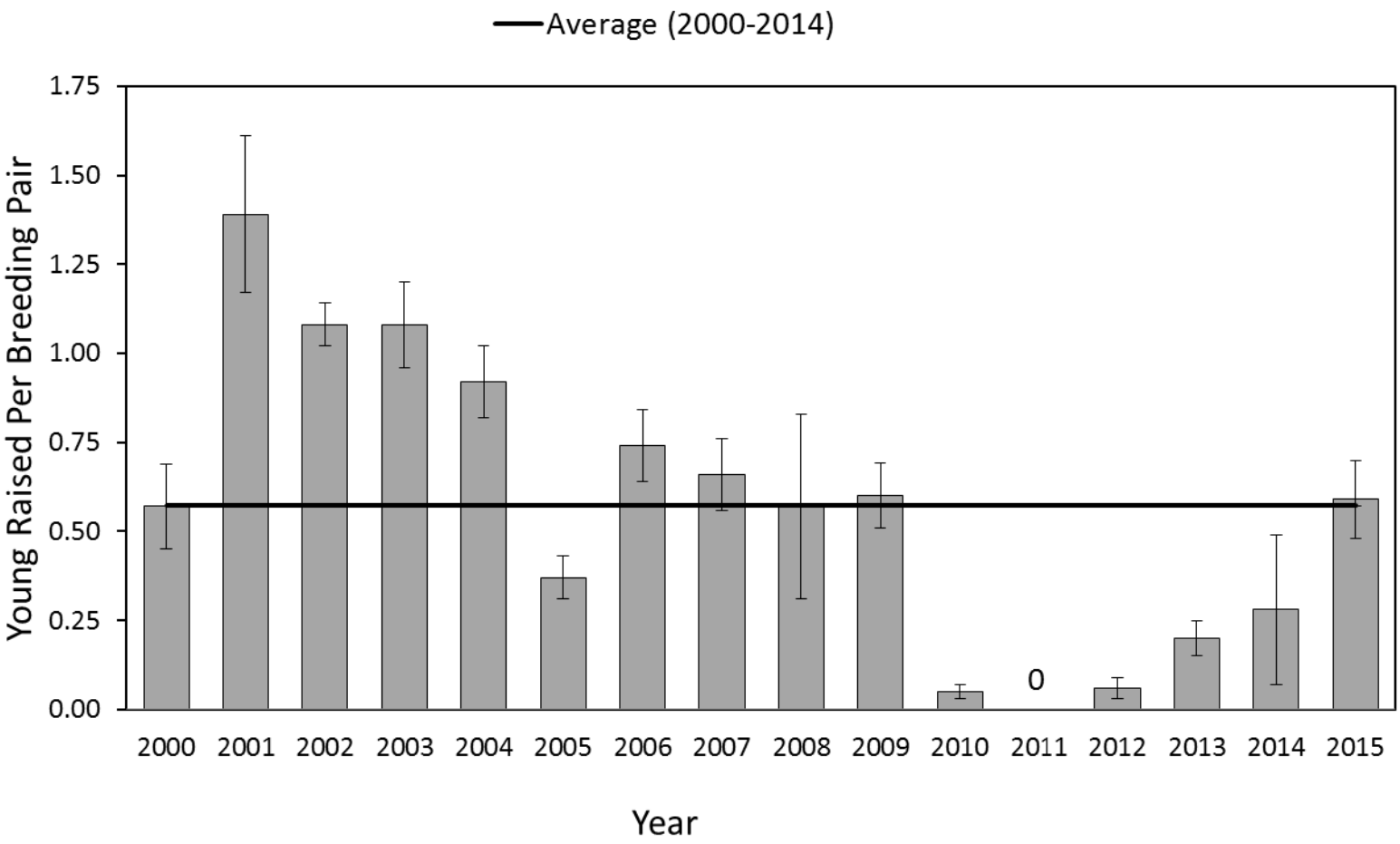


Figure 4. Caspian tern nesting success (average number of young raised per breeding pair) at the breeding colony on East Sand Island in the Columbia River estuary during 2000-2015. The nesting success estimate for 2015 includes breeding pairs that nested outside the 1-acre core colony area in two satellite colonies. The error bars represent 95% confidence intervals. No young were raised at the East Sand Island breeding colony in 2011.

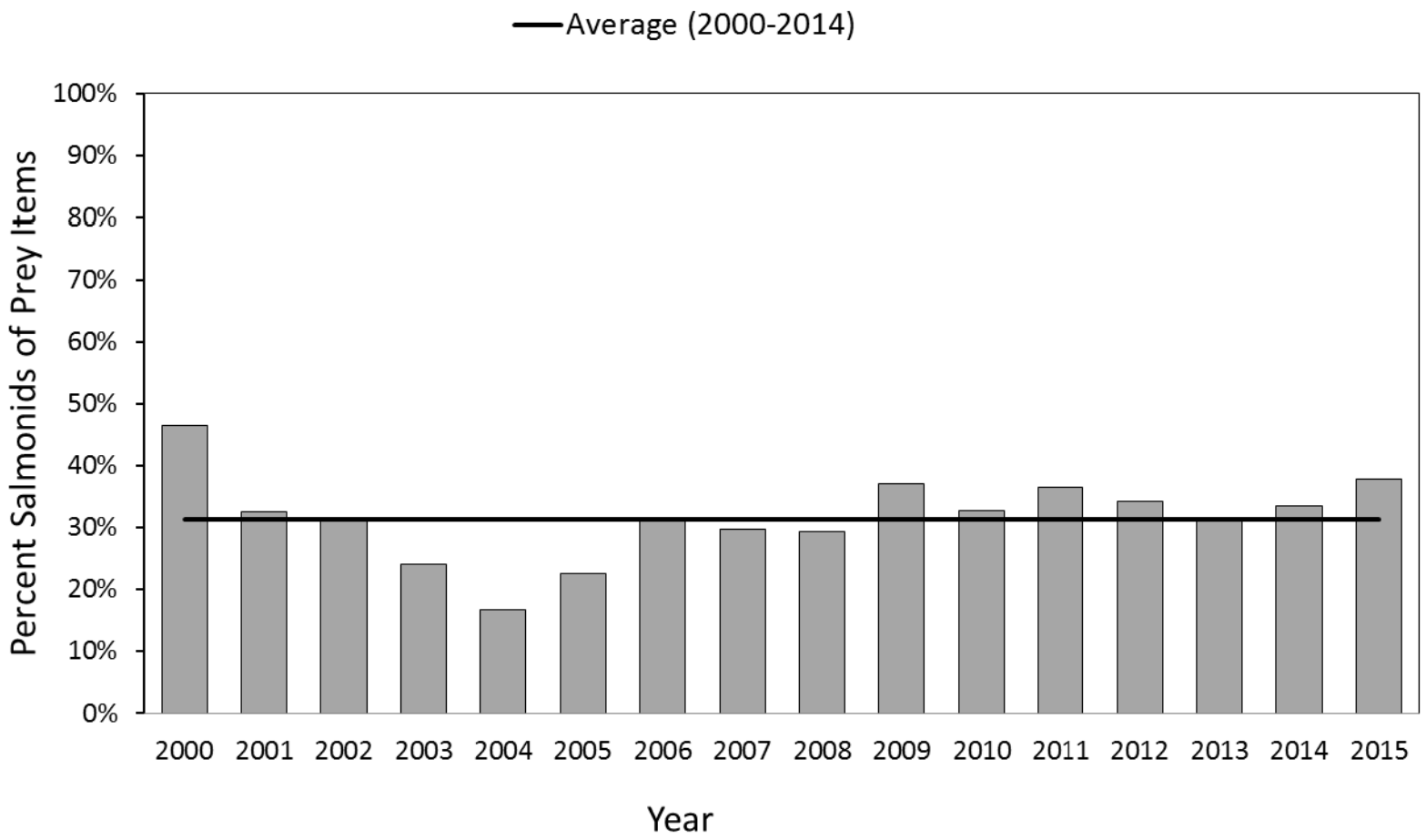


Figure 5. Average annual proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2015 breeding seasons. Each annual value represents the average of the proportions during the 2-week periods encompassing the entire nesting season.

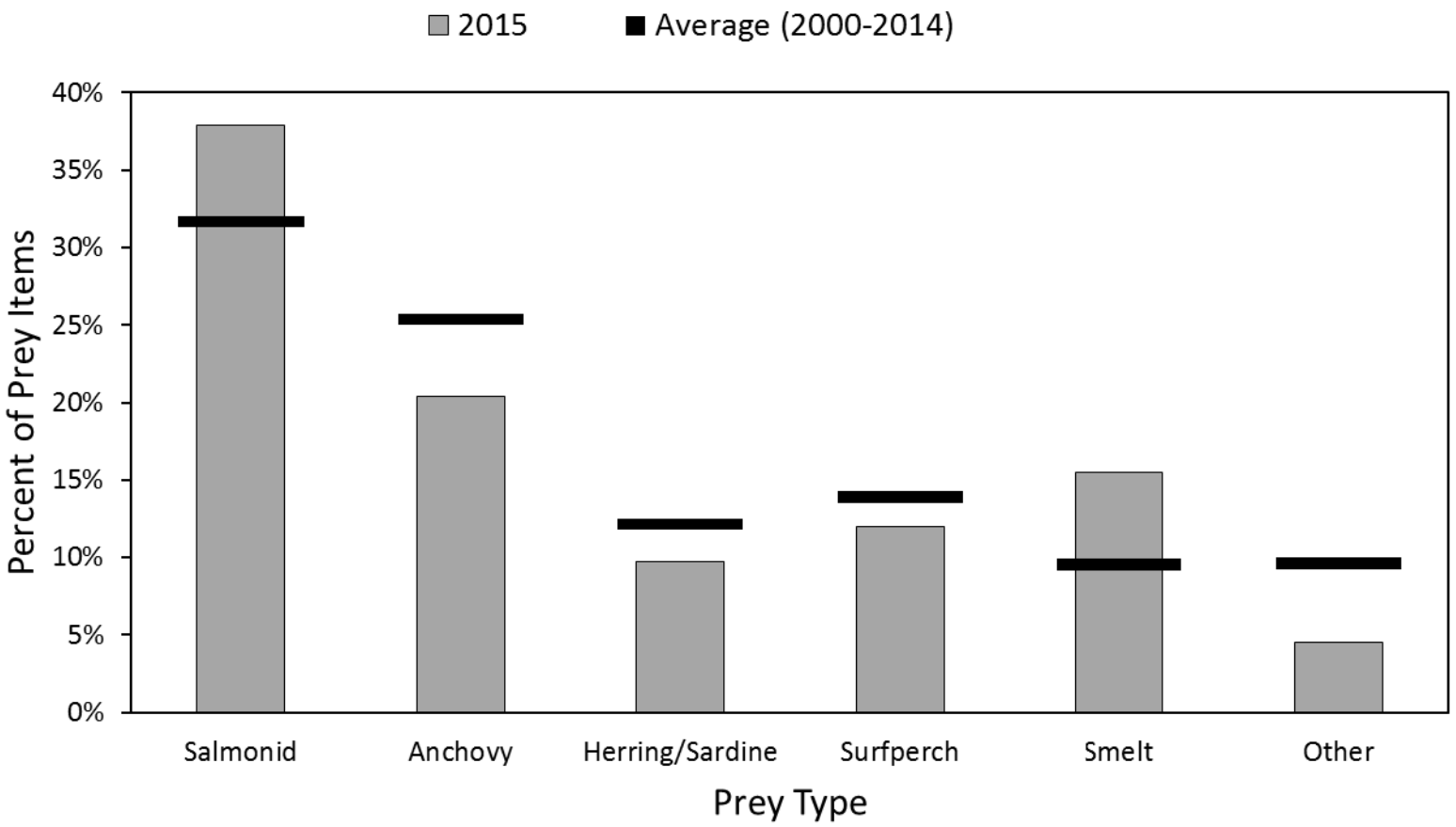


Figure 6. Diet composition (percent of identified prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2015 breeding season. Diet composition was based on fish visually identified on-colony in Caspian tern bill-loads.

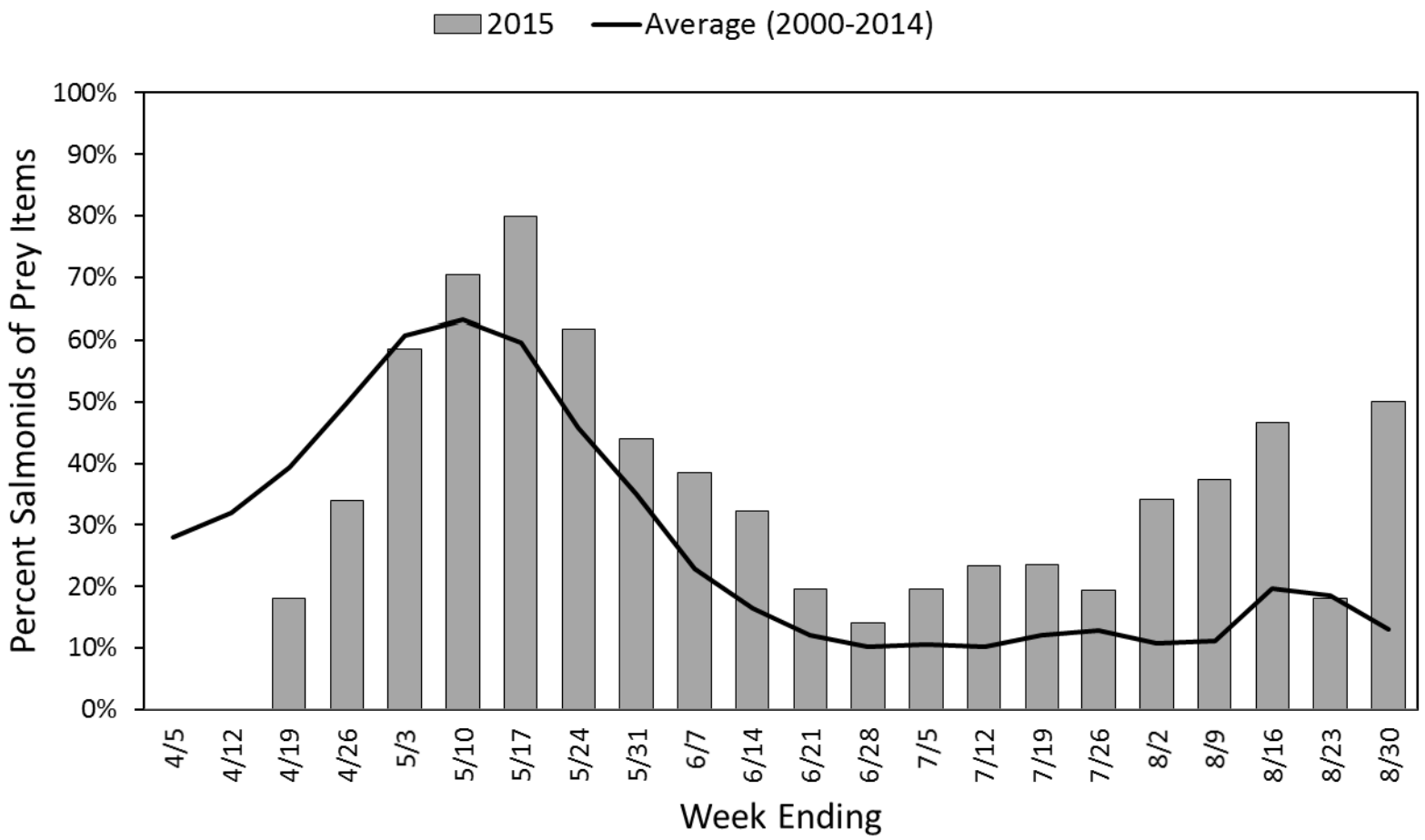


Figure 7. Proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary, by week during the 2015 breeding season.

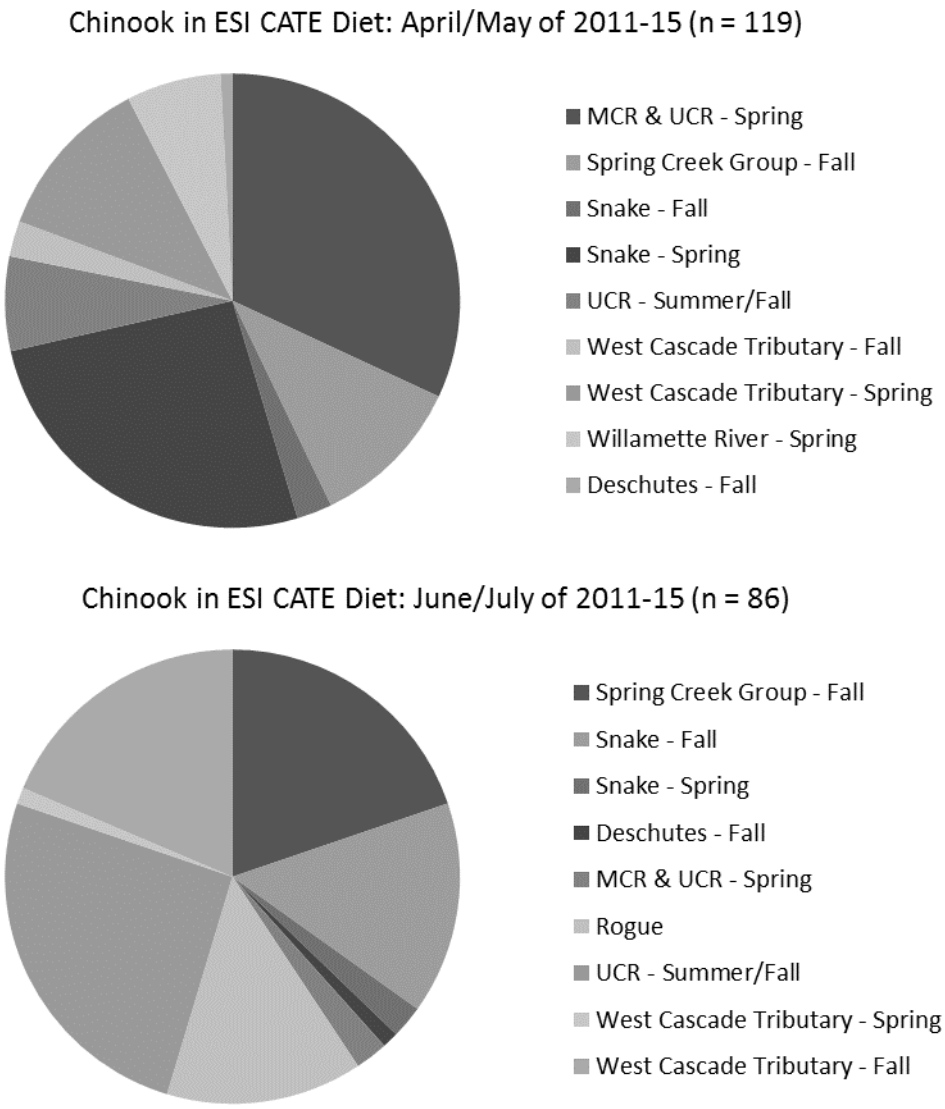


Figure 8. Genetic stock of origin for Chinook salmon in the diet of Caspian terns (CATE) nesting at East Sand Island (ESI) in the Columbia River estuary. Genetic stock identification of salmonids was performed by D. Kuligowski, NOAA Fisheries, on bill-load fish obtained from Caspian terns returning to the East Sand Island colony during the 2011-2015 breeding seasons. The Rogue River fall run stock was introduced to the lower Columbia River as part of a select area fishery enhancement project (North et al. 2006).

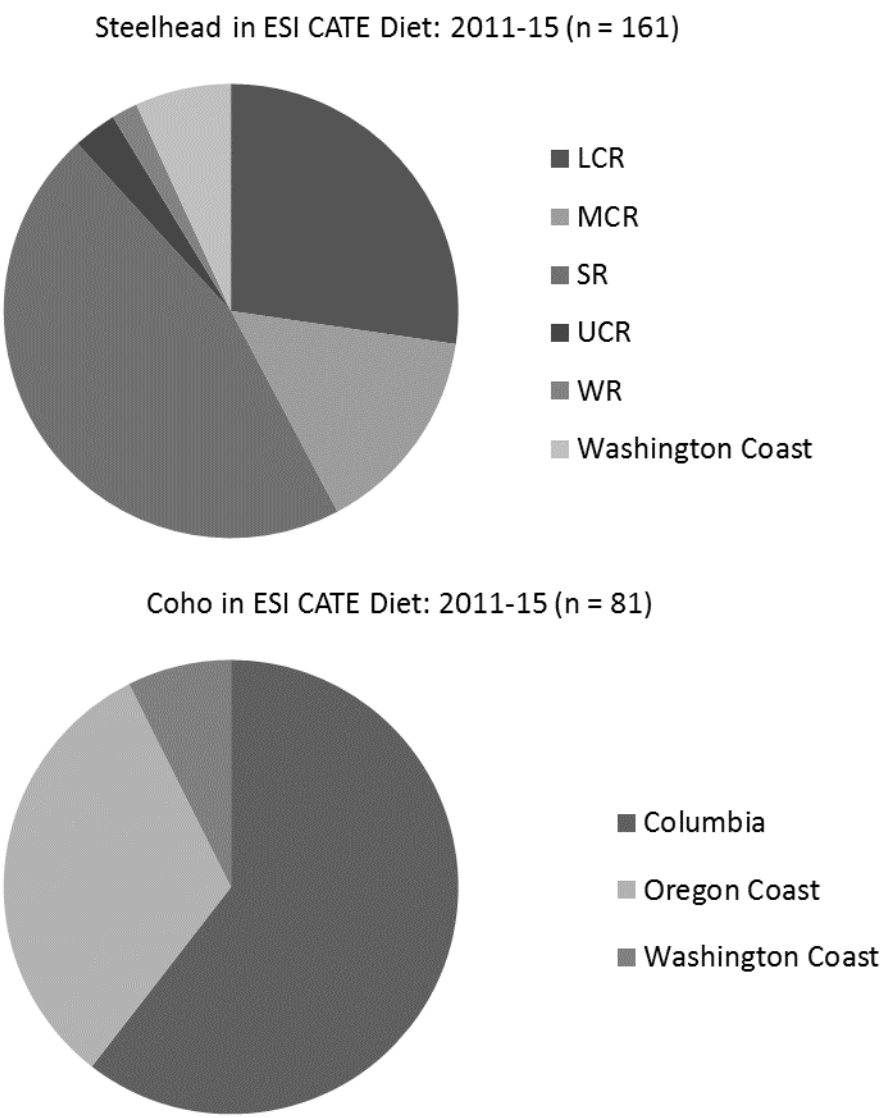


Figure 9. Genetic stock of origin for steelhead trout and coho salmon in the diet of Caspian terns (CATE) nesting on East Sand Island (ESI) in the Columbia River estuary. Genetic stock identification of salmonids was performed by D. Kuligowski, NOAA Fisheries, on bill-load fish obtained from Caspian terns returning to the East Sand Island colony during the 2011-2015 breeding seasons.

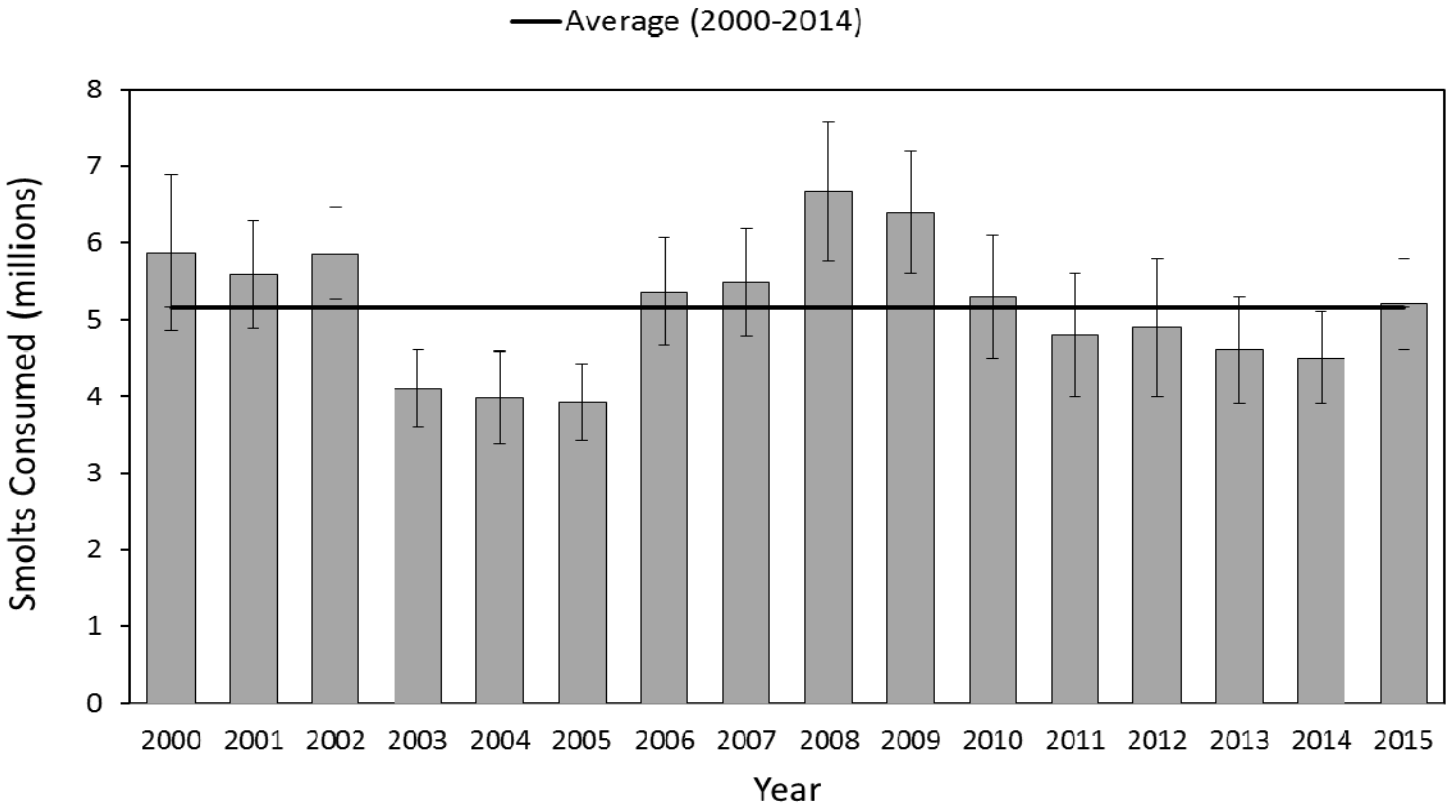


Figure 10. Estimated total annual consumption of juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2015 breeding seasons. The smolt consumption estimate for 2015 includes breeding pairs that nested outside the 1-acre core colony area in two satellite colonies. Estimates are based on fish identified in tern bill-loads on-colony and bioenergetics calculations. Error bars represent 95% confidence intervals for the number of smolts consumed.

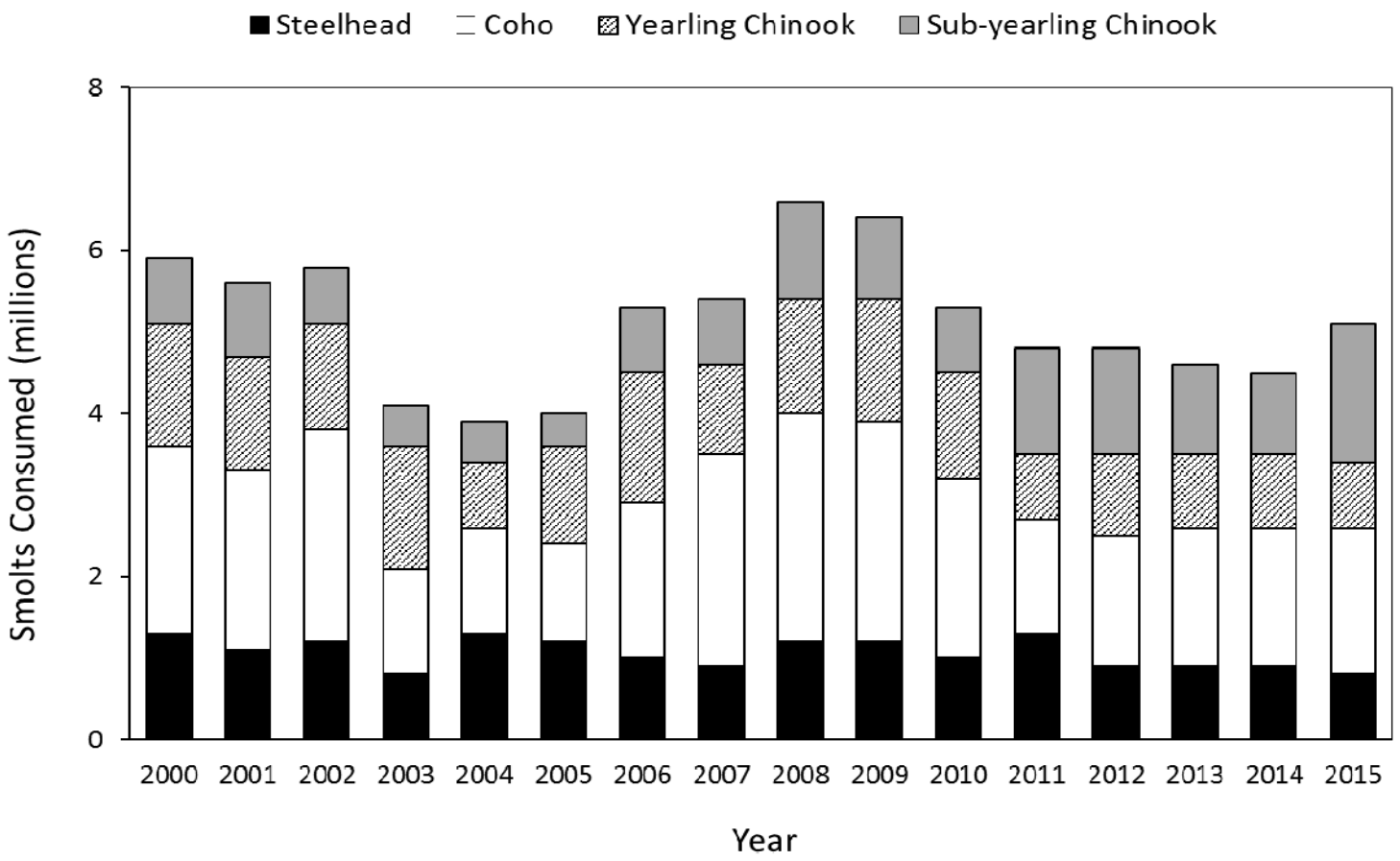


Figure 11. Estimated total annual consumption of four species/run types of juvenile salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2015 breeding seasons. Estimates are based on fish collected from tern bill-loads near the colony and bioenergetics calculations.

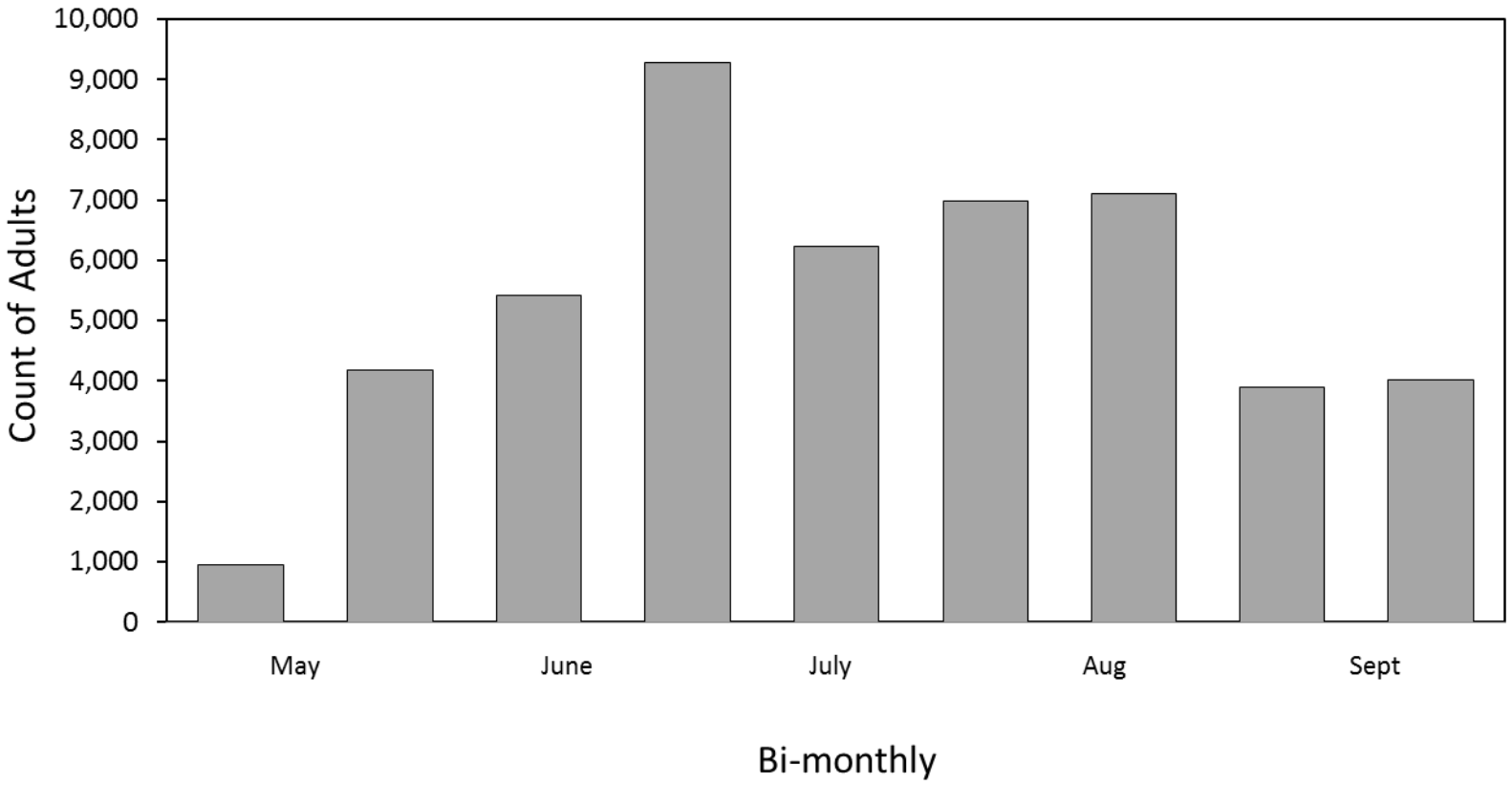


Figure 12. Estimates from boat-based surveys of the number of roosting California brown pelicans on East Sand Island, by 2-week period during the 2015 field season.

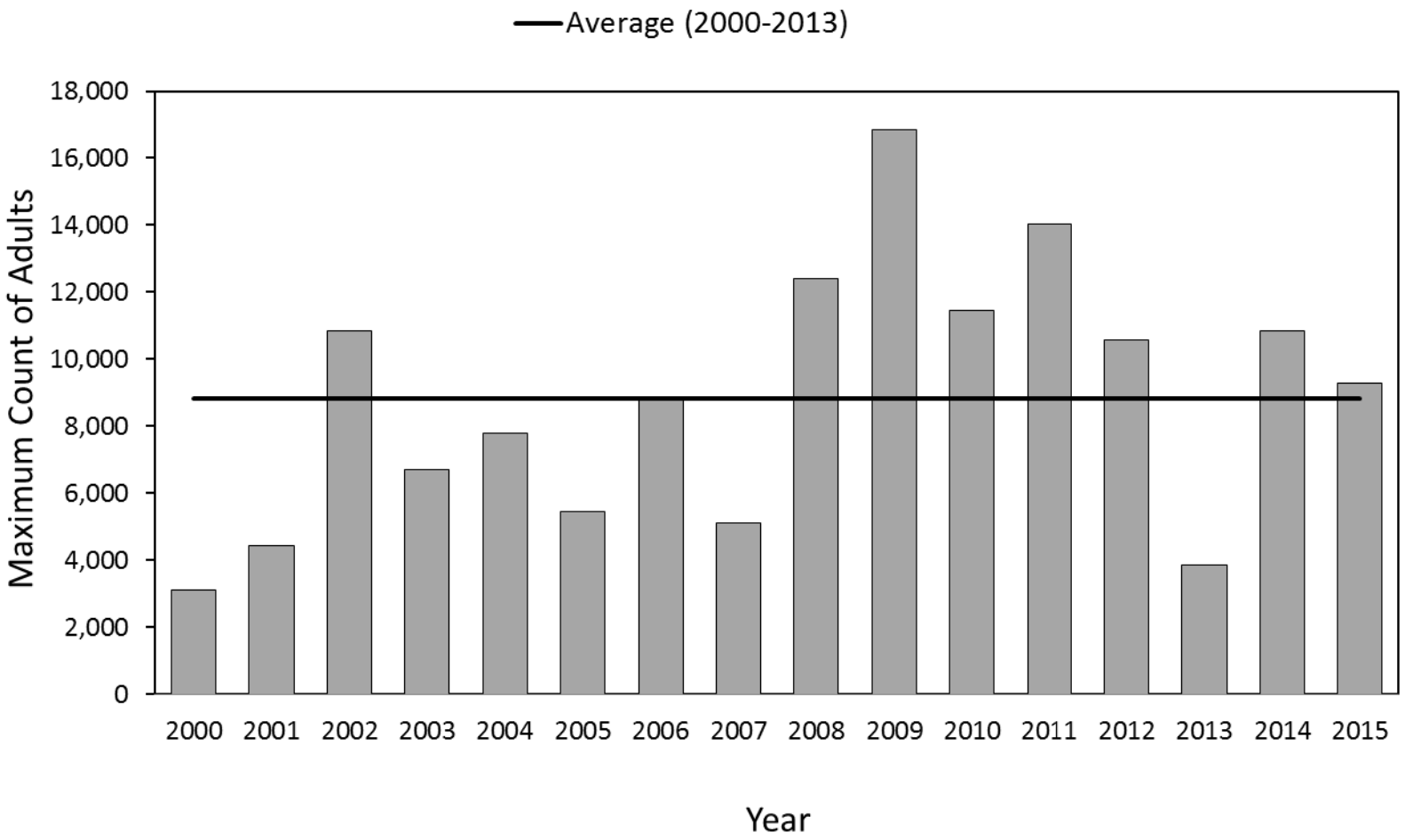


Figure 13. Maximum number of roosting California brown pelicans counted during boat-based surveys at East Sand Island in the Columbia River estuary during the 2000-2015 field seasons.

Table 1. Estimated colony size (number of breeding pairs) and nesting density (nests/m^2) for Caspian terns nesting on East Sand Island in the Columbia River estuary during 2000-2015. The colony size estimate for 2015 includes breeding pairs that nested outside the 1-acre core colony area in two satellite colonies, whereas nesting density in 2015 was measured only in the 1-acre core colony area. Potential error of the estimates is expressed as the 95% confidence limits (c.i.).

Year	Colony Size	Lower 95% c.i	Upper 95% c.i.	Nesting Density	Lower 95% c.i.	Upper 95% c.i.
2000	8,513	7,597	9,429	0.62	0.55	0.69
2001	8,982	8,427	9,537	0.57	0.53	0.61
2002	9,933	9,552	10,314	0.55	0.53	0.57
2003	8,325	7,838	8,812	0.45	0.42	0.48
2004	9,502	8,905	10,099	0.50	0.47	0.53
2005	8,822	8,325	9,319	0.45	0.42	0.48
2006	8,929	8,188	9,670	0.55	0.50	0.60
2007	9,623	8,880	10,366	0.70	0.65	0.75
2008	10,668	9,923	11,413	0.72	0.67	0.77
2009	9,854	9,509	10,199	0.70	0.68	0.72
2010	8,283	7,412	9,154	0.70	0.63	0.77
2011	6,969	5,759	8,179	0.85	0.75	0.95
2012	6,416	5,545	7,287	1.06	0.92	1.20
2013	7,387	6,776	7,998	1.17	1.06	1.28
2014	6,269	5,858	6,680	1.06	0.99	1.13
2015	6,240	6,000	6,480	1.32	1.26	1.37
Average (2000-2014)	8,565	7,900	9,230	0.71	0.65	0.77

Table 2. Estimated proportional stock composition and lower and upper 95% confidence limits (c.i.) for Chinook salmon consumed by Caspian terns nesting at East Sand Island in the Columbia River estuary during 2011- 2015. Data are separated into the early (April/May; n = 120) and late (June/July; n = 81) smolt outmigration periods. Confidence intervals are derived from 100 bootstrap resampling iterations of baseline and mixture genotypes.

	Early (April/May)			Late (June/July)		
	Estimate	Lower 95% c.i.	Upper 95% c.i.	Estimate	Lower 95% c.i.	Upper 95% c.i.
Deschutes River – Fall	0.8%	0.0%	2.8%	0.0%	0.0%	7.6%
West Cascades Tributary - Fall	0.0%	0.0%	5.1%	15.4%	7.4%	26.5%
West Cascades Tributary - Spring	9.7%	3.8%	15.1%	1.2%	0.0%	5.1%
MCR & UCR – Spring[1]	31.6%	20.6%	38.9%	2.4%	0.0%	6.2%
Spring Creek Group - Fall	12.4%	6.1%	17.5%	19.7%	8.1%	26.6%
Snake River - Fall	2.7%	0.0%	7.9%	16.0%	6.4%	26.0%
Snake River - Spring	27.7%	19.4%	37.9%	2.5%	0.0%	6.2%
UCR - Summer/Fall[1]	7.4%	1.6%	10.9%	29.5%	16.7%	39.9%
Willamette River - Spring	7.7%	3.4%	11.7%	0.0%	0.0%	0.0%
Rogue River	0.0%	0.0%	0.0%	13.4%	6.9%	19.9%

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

Table 3. Estimated proportional stock composition and lower and upper 95% confidence limits (c.i.) for steelhead trout (n = 161) consumed by Caspian terns at East Sand Island in the Columbia River estuary during 2011- 2015. Confidence intervals are derived from 100 bootstrap resampling iterations of baseline and mixture genotypes.

	Estimate	Lower 95% c.i.	Upper 95% c.i.
Lower Columbia River	29.2%	20.6%	35.2%
Middle Columbia River	10.8%	6.5%	19.7%
Snake River	47.1%	37.9%	54.4%
Upper Columbia River	4.5%	0.0%	9.5%
Willamette River	8.3%	3.6%	13.5%
Washington Coast	0.0%	0.0%	2.1%

Table 4. Estimated proportional stock composition and upper and lower 95% confidence limits (c.i.) for coho salmon (n = 87) consumed by Caspian terns at East Sand Island in the Columbia River estuary during 2011-2015. Confidence intervals are derived from 100 bootstrap resampling iterations of baseline and mixture genotypes.

	Estimate	Lower 95% c.i.	Upper 95% c.i.
Washington Coast	9.2%	2.3%	21.2%
Columbia River	64.2%	49.1%	71.4%
North Oregon Coast	26.7%	15.0%	40.6%

Table 5. Numbers of banded Caspian terns resighted at East Sand Island in 2015 and the colony locations where they were originally marked with unique alphanumeric color leg-bands during 2006-2015.

Colony where banded	Banded as adults	Banded as chicks	Total
East Sand Island, Columbia River estuary, OR	214	186	400
Crescent Island, mid-Columbia River, WA	20	11	31
Goose Island – Potholes Reservoir, WA	19	6	25
Port of Bellingham, WA	0	20	20
Sheepy Lake, Lower Klamath NWR, CA	1	2	3
Malheur Lake, Malheur NWR, OR	0	1	1
Brooks Island, San Francisco Bay, CA	0	1	1
Kokinhenik Bar, Copper River Delta, AK	0	1	1
Total	254	228	482

Table 6. Numbers of color-banded Caspian terns seen at East Sand Island in 2014 and resighted during the 2015 breeding season at nesting or roosting sites. Terns were banded during 2006-2014 with colored leg-bands engraved with unique alphanumeric codes. A total of 386 banded terns that were seen on East Sand Island in 2014 were resighted in 2015 elsewhere; some of these banded terns were resighted at more than one location in 2015.

Location where resighted in 2015	Banded as adults	Banded as chicks	Total
East Sand Island, Columbia River estuary, OR	207	147	354
Rice Island, Columbia River estuary, OR	5	14	19
Blalock Islands, mid-Columbia River, OR	9	6	15
Tule Lake, Tule Lake NWR, CA	2	12	14
Rat Island, Puget Sound, WA	4	4	8
Tongue Point Piers, Columbia River estuary, OR	7	1	8
Everett, WA	1	4	5
Goose Island – Potholes Reservoir, WA	2	2	4
Summer Lake Wildlife Area (East Link), OR	0	2	2
Kokinhenik Bar, Copper River Delta, AK	0	2	2
Twinning Island, Banks Lake, WA	0	1	1
Malheur Lake, Malheur NWR, OR	0	1	1
Total	229	112	341

Table 7. Inter-colony movement probabilities for banded Caspian terns between 2014 and 2015. Data used in movement probability estimates were from terns banded as adults during 2005-2014 and re-sighted during 2006-2015. The numbers of individuals that moved between 2014 and 2015 were estimated from movement probabilities between those two years multiplied by the estimated numbers of adult terns present in the source regions during the 2014 nesting season.

Source colony	Receiving colony	Movement probabilities (%)	Estimated number of individuals that moved
Columbia River estuary	Columbia Plateau region	1.4	172
Columbia River estuary	Corps-constructed islands	<0.0001	Below detectable limits
Columbia Plateau region	Columbia River estuary	4.4	67
Columbia Plateau region	Corps-constructed islands	0.7	11
Corps-constructed islands	Columbia River estuary	5.0	79
Corps-constructed islands	Columbia Plateau region	18.7	293