

# Monitoring and Evaluation of Efforts to Reduce Predation on ESA-listed Salmonids by Caspian Terns Nesting at East Sand Island, Columbia River Estuary

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*2019 Final Annual Report*



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**Submitted By:** Oregon State University and Real Time Research, Inc.

**Monitoring and Evaluation of Efforts to Reduce Predation on  
ESA-listed Salmonids by Caspian Terns Nesting at East Sand Island,  
Columbia River Estuary**

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# TABLE OF CONTENTS

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EXECUTIVE SUMMARY .....	1
INTRODUCTION .....	3
STUDY AREA.....	5
CASPIAN TERN MONITORING & EVALUATION OF MANAGEMENT .....	6
Section 1. Habitat Preparation .....	6
Section 2. Colony Size, Nesting Distribution, Productivity, & Limiting Factors.....	7
Section 3. Inter-colony Movements, Dispersal Patterns & Aerial Surveys .....	11
Section 4. Tern Diet Composition & Consumption of Salmonid Smolts .....	13
Section 5. Other Piscivorous Waterbirds.....	15
LITERATURE CITED .....	17
MAPS .....	20
FIGURES .....	29
TABLES.....	46

## EXECUTIVE SUMMARY

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The objective of this study in 2019 was to monitor and evaluate management implemented by resource management agencies to reduce the number of Caspian terns (*Hydroprogne caspia*) nesting on East Sand Island in the Columbia River estuary as an approach to reducing tern predation rates on ESA-listed juvenile salmonids (*Oncorhynchus* spp.). During the 2019 Caspian tern breeding season on East Sand Island, we monitored tern nesting activity, assessed tern diet composition, and monitored factors that limited tern colony size and nesting success. In addition, we monitored inter-colony movements and dispersal patterns of banded Caspian terns to East Sand Island, and conducted an aerial reconnaissance flight to search for incipient tern colonies in lower Columbia River and/or estuaries on the outer coast of Washington. In 2019, the U.S. Army Corps of Engineers (USACE) prepared 1.0 acre of habitat for tern nesting on East Sand Island and installed passive nest dissuasion materials and hazed terns to prevent tern nesting outside of the designated 1.0-acre tern colony area both on East Sand Island and elsewhere in the Columbia River estuary (i.e. Rice Island) in 2019.

The management plan “*Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*” was first implemented in 2008, and implementation continued during the 2019 nesting season. The objective of this management plan is to reduce the size of the Caspian tern breeding colony on East Sand Island to 3,125-4,375 breeding pairs by reducing the amount of suitable nesting habitat on East Sand Island to 1.0 acre, while preventing Caspian terns from colonizing other sites in the Columbia River estuary (USACE 2015a). One acre of nesting habitat represents 20% of the area of habitat prepared for Caspian terns on East Sand Island prior to the initiation of implementation of the management plan in 2008. Caspian terns have been provided with just 1.0 acre of nesting habitat on East Sand Island since the 2015 nesting season; however, the location of the 1.0-acre colony area has shifted in most years due to erosion along the southern edge of the colony area during winter storms. Prior to the 2019 nesting season, USACE personnel delineated 1.0 acre of prospective nesting habitat for Caspian terns on East Sand Island and prepared the colony surface for tern nesting by removing existing vegetation. First, at the end of March, a USACE contractor used heavy equipment to prepare the colony surface for Caspian tern nesting by removing dense surface vegetation from about half of the 1.0-acre area, as well as an above-ground tunnel used to access an observation blind during the 2018 breeding season, and fence-rows of landscape fabric used to dissuade terns from nesting along the eastern edge of the designated colony area in 2018. Then, in early April, USACE personnel used a disking harrow on the entire 1.0-acre colony area to break up any shallow surface vegetation that remained on the colony following colony site preparation by heavy equipment.

Caspian terns arrived at the East Sand Island colony and initiated nesting around the same time as in recent years (i.e. early to mid-April), but high predation rates on tern eggs by gulls early in the breeding season resulted in delayed hatching of the first chick and a delayed chick-rearing period in 2019 compared to previous years. The tern colony slowly grew to peak size by mid-

June, when about 3,860 breeding pairs (95% c.i. = 3,667– 4,055 breeding pairs) were estimated to be nesting in the designated 1.0-acre colony area on East Sand Island. Subsequently, the number of breeding pairs on the tern colony slowly declined until the colony area was completely vacated by nesting terns in late September. The 2019 peak colony size estimate on the 1.0-acre colony area was significantly less than the 2018 peak colony size estimate (4,959 breeding pairs), and was within the range in colony size (i.e. 3,125-4,375 breeding pairs) stipulated in the management plan. In 2019, Caspian terns were displaced for nesting territories by glaucous-winged/western gulls (*Larus glaucescens* X *L. occidentalis*) on part of the eastern half of the prepared 1.0-acre colony area; consequently, Caspian terns nested on just 0.86 acres of the 1.0 acre provided. The portion of the 1.0-acre prepared tern colony area that was occupied by nesting gulls in 2019 was also used by nesting gulls in 2018.

Similar to the 2015 and 2016 breeding seasons, hundreds of pairs of Caspian terns attempted to nest on East Sand Island outside of the 1.0-acre colony area in 2019 with a sustained effort but were unsuccessful in raising any chicks to fledging. In 2015 and 2016, satellite colonies supported a total of about 810 breeding pairs and 700 breeding pairs, respectively. In 2019, Caspian terns were frequently observed in nest scrapes under passive dissuasion materials, apparently sitting on eggs. A total of about 550 breeding pairs of terns were counted in nest scrapes on several satellite colonies outside of the 1.0-acre prepared colony area at the peak of the 2019 nesting season.

At peak colony size, tern nesting density on the 1.0-acre designated colony area averaged 1.11 nests/m<sup>2</sup> (95% c.i. = 1.06–1.17 nests/m<sup>2</sup>), slightly lower than the nesting density of 1.23 nests/m<sup>2</sup> (95% c.i. = 1.16–1.29 nests/m<sup>2</sup>) observed in 2018, but higher than the nesting density of 0.97 nests/m<sup>2</sup> (95% c.i. = 0.87–1.06 nests/m<sup>2</sup>) observed in 2017. Tern productivity (average number of young raised/nesting pair) in 2019 was again much lower than the long-term average, but the colony did not fail to produce any young, as it did in 2017. During the last decade, two factors have emerged as causes of low productivity at the East Sand Island Caspian tern colony: (1) reduced availability of marine forage fish in the estuary associated with high Columbia River discharge and (2) frequent colony disturbances by bald eagles (*Haliaeetus leucocephalus*) and associated high predation rates on tern eggs and chicks by gulls. In 2019, eagle disturbances of the tern colony were frequent and northern anchovies (*Engraulis mordax*, a common marine forage fish in the Columbia River estuary) were a smaller proportion of the tern diet at East Sand Island compared to most previous years, despite below average Columbia River discharge that is usually associated with high abundance of anchovies in the estuary. Northern anchovy are generally a major prey type late in the breeding season for Caspian terns nesting at the East Sand Island colony, as this marine forage fish provides a high-energy food source for fledgling Caspian terns. In 2019, a large number of nearly fledged tern chicks were depredated by gulls, especially those gulls nesting in the designated 1.0-acre colony area. High gull predation rates on older Caspian tern chicks may have been a result of the relatively low availability of anchovy for Caspian terns raising young in 2019.

The average proportion of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island during the 2019 season was 33.5% (percent of identified prey items), lower than the

salmonid proportion in 2015, 2017, and 2018 (37.9%, 36.0%, and 40.1%, respectively); data on diet composition were not collected in 2016. During the 2019 tern nesting season, the average proportion of juvenile salmonids in the diet of terns nesting at East Sand Island was only slightly higher than the long-term average (31.7%), measured during the 2000-2015 nesting seasons. As in previous years, estuarine and marine forage fishes (e.g., anchovy [Engraulidae], surf perch [Embiotocidae], smelt [Osmeridae], and herring [Clupeidae]) were collectively most prevalent in the tern diet, together averaging 57% of all identified bill-loads in the diet of terns nesting on East Sand Island in 2019. Although the proportion of anchovy in the diet of Caspian terns nesting at East Sand Island was well below the long-term average, herring represented a much greater proportion of the tern diet in 2019, compared to the long-term average.

Bioenergetics calculations to estimate total smolt consumption by Caspian terns nesting at East Sand Island in 2019 are currently in progress and will be included in a subsequent version of this annual report. Predation rates on specific populations of anadromous salmonids (ESUs/DPSs) by Caspian terns nesting on East Sand Island in 2019 were again investigated by recovering smolt PIT tags from the surface of the tern colony after the breeding season. That study was performed separately by the U.S. Army Corps of Engineers – Portland District, however, and those results are not presented as part of this report.

Resightings of previously banded Caspian terns on East Sand Island during the 2019 nesting season indicated that there is strong natal and breeding philopatry to the East Sand Island colony, and some terns are immigrating to the East Sand Island colony from other colonies in the Pacific Flyway. Despite low resighting effort and small sample size, a few banded terns that were observed on East Sand Island during the 2018 breeding season were detected at the Blalock Islands in 2019, suggesting that some adult terns continue to disperse from the East Sand Island colony to other colony sites in the Columbia Plateau region. There was no effort to resight banded terns at other colony locations in the Pacific Flyway outside the Columbia River basin in 2019; as such the level of connectivity between the East Sand Island colony and other colonies throughout the region during the 2019 breeding season is unknown.

We recorded almost 400 Caspian terns at locations other than East Sand Island during the aerial survey of the lower Columbia River and estuaries on the outer coast of Washington in 2019. We observed about 135 Caspian terns loafing at four different sites on the lower Columbia River, and about 245 terns loafing at five different sites in Willapa Bay and Grays Harbor. However, we did not detect Caspian tern breeding activity at any of the sites where loafing terns were detected.

## INTRODUCTION

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Piscivorous colonial waterbirds (i.e. terns, cormorants, gulls, pelicans) are documented as having a substantial impact on survival of juvenile salmonids (*Oncorhynchus* spp.; salmon and steelhead) in the lower Columbia River (BRNW 2005-2019). Prior to management, Caspian terns

(*Hydroprogne caspia*) nesting 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 impact of avian predation on recovery of ESA-listed salmonids, in 1999 regional fish and wildlife managers called for immediate management action to reduce losses of juvenile salmonids to Caspian tern predation in the Columbia River estuary.

Management actions first implemented in 1999 sought to relocate the Caspian tern colony on Rice Island, the largest colony of its kind in the world, to a restored colony site on East Sand Island, 21 km closer to the ocean, where biologists believed terns would consume more marine forage fish and fewer juvenile salmonids. Over 94% of the Caspian terns nesting on Rice Island relocated to nest on East Sand Island in 2000, which resulted in a 48% reduction in the proportion of the tern diet that were salmonids (also see Roby et al. 2002). During 2001–2014, all Caspian terns nesting in the Columbia River estuary used East Sand Island, except for three nesting pairs that laid a total of four eggs on Rice Island in 2011 (BRNW 2012). During 2015–2018, terns attempted to re-establish a breeding colony on Rice Island, but dissuasion efforts at that island conducted by the Corps and its contractors effectively deterred terns from nesting successfully. During 2001–2015, estimated consumption of juvenile salmonids by Caspian terns nesting on East Sand Island averaged 5.1 million smolts per year (SD = 0.8 million, n = 15 years), an almost 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).

Beginning in 2008, additional management actions were implemented to reduce losses of juvenile salmonids to Caspian tern predation in the Columbia River estuary, while ensuring the long-term conservation of the Pacific Flyway population of Caspian terns. The Records of Decision (RODs) for the *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*, signed in November 2006 and updated in 2015, stipulated that enhancement of tern nesting habitat in the region and reduction of tern nesting habitat at East Sand Island be gradually phased in at a 2:1 ratio (area:area) with the aim of encouraging the redistribution of approximately 60% of the East Sand Island tern colony by creating alternative colony sites outside the Columbia River basin in Oregon and California (USFWS 2005, USFWS 2006, USACE 2006, USACE 2015a, USACE 2015b), thereby reducing tern predation on smolts in the Columbia River estuary. The nesting habitat component described in the management plan was completed, but the expected outcome in terms of shifting the distribution of nesting terns had not been achieved by the time monitoring at the alternative colony sites was concluded. By the beginning of the 2012 breeding season, the USACE – 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 southern San Francisco Bay at Don Edwards National Wildlife Refuge (NWR) was completed prior to the 2015 breeding season, and these sites were available to nesting Caspian terns for the first time during the 2015 nesting season. Concurrent with island construction outside the Columbia River basin, the USACE gradually reduced the area of suitable nesting

habitat for Caspian terns on East Sand Island from 5 acres in 2008 to 1.0 acre during the 2015–2019 breeding seasons, and implemented nest dissuasion measures to prevent Caspian terns from establishing new nesting colonies elsewhere in the Columbia River estuary.

In 2019, the USACE Fish Field Unit was responsible for delineating and preparing the designated 1.0-acre colony area for Caspian terns on East Sand Island and attempting to prevent nesting by terns outside that designated colony area. The objectives of this study in 2019 were to monitor and evaluate the outcome of tern management actions implemented on East Sand Island. First, we monitored tern nesting activity on the designated colony area on East Sand Island and evaluated tern diet composition and factors that limit tern colony size and nesting success. Second, we assessed inter-colony movements and dispersal patterns of banded Caspian terns at East Sand Island. These results along with those from other studies (i.e. on colony PIT tag recoveries to assess predation impacts of terns on ESA-listed juvenile salmonids) will be used to assess the efficacy of tern management in reaching targets in tern colony size on East Sand Island and reductions in tern predation on juvenile salmonids in the Columbia River estuary.

## STUDY AREA

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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*). In addition, this report provides limited information on roosting California brown pelicans (*Pelecanus occidentalis californicus*), nesting glaucous-winged/western gulls (*Larus glaucescens* X *L. occidentalis*), and nesting ring-billed gulls (*L. delawarensis*) on East Sand Island; data that were collected incidental to our monitoring and evaluation efforts for Caspian terns.

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, USFWS 2006, USACE 2006, USACE 2015a, USACE 2015b) and the *Inland Avian Predation Management Plan* (USACE 2014); both plans seek to reduce Caspian tern predation on ESA-listed juvenile salmonids from the Columbia River basin by reducing the availability of nesting habitat and dissuading Caspian terns from nesting at colonies within the basin where juvenile salmonids are particularly vulnerable to tern predation, while encouraging Caspian terns to nest at alternative colony sites outside the basin. Results from related studies funded by the U.S. Army Corps of Engineers (USACE) – Portland District, and the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee (PRCC) are provided in separate reports, with the latter being posted on the web at [www.birdresearchnw.org](http://www.birdresearchnw.org).

## CASPIAN TERN MONITORING & EVALUATION OF MANAGEMENT

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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, USFWS 2006, USACE 2006). Developed jointly by the U.S. Fish and Wildlife Service (USFWS; lead), the USACE – Portland District, and NOAA Fisheries, the management plan 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, while ensuring the long-term conservation of 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, whereas Caspian terns are protected under the Migratory Bird Treaty Act.

The specific objectives of the *Caspian Tern Management Plan* were to reduce the area of the East Sand Island Caspian tern colony to 1.0 acre of suitable nesting habitat, with an expected reduction in tern colony size to 3,125-4,375 breeding pairs, while providing new nesting habitat for Caspian terns at alternative colony sites outside the Columbia River basin. These objectives were identified as the preferred alternative in the Final Environmental Impact Statement released in early 2005 and updated in the Final Environmental Assessment and Finding of No Significant Impact, released in April 2015 (USFWS 2005, USACE 2015a, USACE 2015b). Caspian terns displaced by habitat reductions on East Sand Island were expected to relocate to 14 alternative colony sites: 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), plus five Corps-constructed tern islands in Don Edwards San Francisco Bay NWR in central California (*Map 2*). As alternative nesting habitat for terns was created or restored outside the Columbia River basin, the available nesting habitat for Caspian terns on East Sand Island was reduced from its initial size (approximately 5 acres in 2008) to 1.0 acre (*Map 3*).

### Section 1. Habitat Preparation

**Methods:** As part of the management plan for Caspian terns in the Columbia River estuary, the USACE Fish Field Unit delineated and prepared 1.0 acre of unvegetated nesting habitat for Caspian terns on East Sand Island just prior to the 2019 breeding season (*Map 4*). Storm surge during the winter of 2018-2019 caused substantial erosion along the southern edge of the former colony area, prompting a move of the colony northeast from the 2018 location and closer to the interior of the east end of the island (*Map 5*). The 1.0-acre colony area prepared in 2019 remained within the footprint of the original 6-acres of Caspian tern nesting habitat

prepared at East Sand Island in 2000; however, the eastern portion of the 1.0-acre colony area in 2019 had been occupied by breeding glaucous-winged/western gulls for several years previously (*Map 6*). In early March, a USACE contractor used heavy equipment to remove vegetation, tunnels, and old silt-fence materials from the eastern portion of the 2019 prepared colony area. In addition, they created a large berm along the southern edge of the delineated colony area using the surface materials removed by the heavy equipment in an attempt to provide a visual barrier between the 1.0-acre tern colony area and the southern shoreline of the island, where Caspian terns had attempted to nest in previous years. In early April, USACE Fish Field Unit personnel covered the narrow western-most portion of the 2018 colony area with passive dissuasion materials, and further prepared the bare ground nesting habitat for Caspian terns using a 4-wheel drive ATV pulling a disc harrow. The disc harrow was used to break-up established vegetation on the entire 1.0-acre designated colony area, including around the edges of the colony area to deter encroaching vegetation. Unlike prior to the 2018 nesting season, however, the edges of the colony area and newly rototilled nesting habitat were not sprayed with pre-emergent herbicide to help keep the colony clear of vegetation during the breeding season. The area of designated Caspian tern nesting habitat on East Sand Island during the 2015–2019 nesting seasons was approximately 1.0 acre, representing an 80% reduction in tern nesting habitat compared to pre-2008, before implementation of the tern management plan.

Following the scarification and preparation of the 1.0-acre colony area, we constructed observation blinds, access tunnels to the blinds, installed a rope grid on the colony area, and delineated 20 6m x 6m square sample plots on the colony area. We were able to retain one observation blind from the previous field season for use at the colony during the 2019 breeding season. The observation blind that was located on the northern boundary of the colony in the middle during the 2018 nesting season was relocated to the western end of the colony in 2019 (*Map 6*). We constructed an additional two observation blinds along the northern boundary of the delineated colony area to monitor the Caspian tern colony during the 2019 breeding season (*Map 4*). The rope grid provided on-the-ground reference features to assist with our blind-based data collection efforts. We used the 6m x 6m rope plots as part of our methodology to estimate colony size (*see below*).

## Section 2. Colony Size, Nesting Distribution, 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 (21 June). In 2019, aerial imagery of the Caspian tern colony at peak colony size was acquired using an unmanned aerial vehicle (UAV) operated by a licensed UAV pilot, and orthophotos were generated using Pix4Dmapper software. We then used an ArcGIS desktop tool, ArcMap, to count adults in high-resolution vertical images of the Caspian tern colony. We used the average of three direct counts of all adult terns on the colony in aerial photography, corrected using concurrent ground counts of the ratio of incubating to non-incubating terns in 20 sample plots (each plot measured 6m x 6m) within the colony area, to estimate the peak number of breeding pairs on the designated

1.0-acre colony area. Confidence intervals for the number of breeding pairs on the designated 1.0-acre colony area were calculated using a Monte Carlo simulation procedure to incorporate the variance in the counts from aerial photography and the variance in the ratio of incubating to non-incubating adult terns among the 20 on-colony sample 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 in sample plots. Standard errors and confidence intervals for the number of breeding pairs were derived from the resulting distribution. We used the average of three direct counts of all adult terns on satellite colonies (i.e. in areas on East Sand Island outside the designated 1.0-acre colony area) in aerial photography to estimate the peak use of satellite colonies in 2019. However, lacking concurrent ground counts of the adult terns on the satellite colonies, we were unable to generate confidence intervals for our estimate of satellite colony use.

We used the count files generated in ArcMap of adult Caspian terns present on the colony near the end of the incubation period (21 June) to assess tern distribution on the designated 1.0-acre colony area and to calculate the amount of colony area used by nesting terns. We used a custom Python script to calculate the median Euclidean distance between individual points. Then, in ArcMap, we used the derived median Euclidean distance as a buffer radius around each individual to create a footprint of the area used by terns. We considered the outline of this footprint to represent the total area used by nesting terns at peak colony size. We calculated nesting density as a function of the estimated colony size (*see above*) divided by the colony area ( $m^2$ ) used by Caspian terns.

Productivity (average number of young raised per breeding pair) at the East Sand Island tern colony was estimated using aerial photography taken of the colony early in the fledging period (06 August). Similar to the aerial imagery of the Caspian tern colony at the peak of nesting, aerial photography early in the fledging period was acquired using an UAV operated by a licensed UAV pilot and generated using Pix4Dmapper software. The 2019 breeding season was only the second time that we obtained high-resolution imagery early in the fledging period using an UAV. In 2018, the first year, we found that ground counts and photo counts of late-stage chicks were nearly identical. As such, in 2019 we estimated the number of near-fledging age chicks on the colony at the time of the photography as the average of three direct counts of all tern chicks in the mid-size to black-capped stage of development on the colony in aerial photography taken on 06 August. Confidence intervals for the number of near-fledging age chicks were calculated using a Monte Carlo simulation procedure to incorporate the variance in the counts from the aerial photography. Estimates of productivity were calculated one thousand times using random draws from the sample distributions of the total number of tern chicks counted on-colony. Standard errors and confidence intervals for the number of tern chicks were derived from the resulting distribution. We used an ArcGIS desktop tool, ArcMap, to count near-fledging age chicks in the high-resolution vertical images of the Caspian tern colony to estimate productivity.

In order to monitor diet composition, re-sight banded terns, and evaluate limiting factors, the East Sand Island tern colony was monitored approximately every other day by field staff during the 2019 breeding season. Colony monitors did not live on-site and, from late April until the end of August, accessed the island by boat from the nearby harbor in Chinook, Washington. The 2019 breeding season marked the first year since monitoring of the tern colony began at East Sand Island (1999) that field crew members did not camp on the island and monitor the tern colony on a daily basis. Given the reduction in monitoring effort during the 2019 nesting season, it was not possible to compare disturbance rates to the colony directly with those measured in previous years, and we standardized the disturbance rates by the number of daily observation hours in an effort to correct for this difference.

**Results and Discussion:** In 2019, we first observed adult Caspian terns on the designated 1.0-acre colony area during a visit to the island on 11 April (*Figure 1*), but inclement weather prevented access to the island for the three days prior to our first detection of terns on-colony. As such, terns may have arrived on colony a few days earlier than was first observed by field staff. The arrival date of terns on the prepared colony area was consistent with the dates observed in 2016-2017, slightly earlier than observed in 2018, but one to two weeks later than documented in the years prior to 2016. Although the first arrival date in 2019 was relatively consistent with recent years, gulls heavily depredated tern nests that were initiated early in the nesting season on the designated 1.0-acre colony area and delayed the subsequent tern nesting chronology at East Sand Island in 2019 compared to the previous several years. Although we observed the first tern egg on 29 April, the latest occurrence recorded for the East Sand Island tern colony to date by only a few days, field staff did not observe the first chick for more than two weeks later than had been observed during all previous breeding seasons at East Sand Island. Following this long delay in successful egg hatching, the peak fledging date in 2019 was also delayed by several weeks compared to previous years (*Figure 1*).

Despite passive dissuasion materials and active hazing of terns prospecting outside the designated 1.0-acre colony area by the USACE Fish Field Unit, several satellite tern colonies formed on East Sand Island in 2019, as they had in previous years. Caspian terns attempted to establish satellite colonies on the beach south of the 1.0-acre colony area and on the southeastern tip of the island but failed to maintain active nests at those locations long enough to hatch young (*Map 7*). Using the UAV imagery, we counted over 1,400 adult Caspian terns on satellite colonies south of the 1.0-acre colony area at the peak of the 2019 breeding season (21 June; *Map 8*); nearly 550 of these adult terns were sitting in well-formed nest scrapes with some proportion of these terns likely attending nests with eggs. For the first time in 2019, we observed Caspian terns attempting to nest in large numbers beneath passive dissuasion materials at East Sand Island; however, with the exception of a single nest, successful breeding (i.e. fledging of young) by Caspian terns on East Sand Island in 2019 was limited to nesting on the designated 1.0-acre colony area.

Once nesting terns became established on the designated 1.0-acre colony area in mid-May, the colony slowly grew to its peak size by mid-June, and slowly declined until late September (*Figure 2*). The estimate of peak colony size in mid-June was 3,861 breeding pairs (95% c.i. =

3,667–4,055 breeding pairs), significantly less than last year’s estimate of 4,959 breeding pairs on the designated colony area. The estimated number of Caspian tern breeding pairs on the 1.0-acre colony area in 2019 was much less than during the 2000-2007 time period, prior to the initiation of management at the East Sand Island tern colony (*Figure 3; Table 1*). In 2019, the estimated size of the tern colony on the 1.0-acre area at East Sand Island was within the updated target colony size (3,125–4,375 breeding pairs) specified in the Final Environmental Assessment and Finding of No Significant Impact (USACE 2015a, USACE 2015b); marking the first year when the Caspian tern colony in the designated colony area on East Sand Island has been within the targeted range of colony sizes and also successfully fledged some young. The estimated size of the tern colony was also within this targeted range in 2017, but terns abandoned the colony in June of that year due to predator disturbances and lack of food, and no young terns were fledged. The reduced size of the tern colony on the designated 1.0-acre colony area in 2019 was due, at least in part, to the presence of established glaucous-winged/western gull breeding territories on the eastern portion of the prepared tern colony area that restricted tern use of this part of the colony area for nesting; only 0.86 acres of the 1.0 acre of provided colony area was used by nesting Caspian tern in 2019 (*Figure 4; Map 8*). The majority of the reduction in tern colony size at East Sand Island during 2008-2019, however, can be attributed to the managed reduction 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, USFWS 2006, USACE 2006, USACE 2015a, USACE 2015b).

During 2008-2012, the amount of nesting habitat prepared for terns on East Sand Island was incrementally reduced 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 during 2015-2019 the amount of nesting habitat prepared was reduced to the minimum colony area specified in the management plan (1.0 acre; *Map 3*). The decline in available nesting habitat for Caspian terns at the East Sand Island colony resulted in a near doubling in nesting density, from 0.72 nests/m<sup>2</sup> in 2008 to 1.36 nests/m<sup>2</sup> in 2016. In 2019, nesting density was 1.11 nests/m<sup>2</sup> (95% c.i. = 1.06–1.17 nests/m<sup>2</sup>), slightly lower than the nesting density of 1.23 nests/m<sup>2</sup> (95% c.i. = 1.16–1.29 nests/m<sup>2</sup>) in 2018, and higher than the nesting density of 0.97 nests/m<sup>2</sup> (95% c.i. = 0.87–1.06 nests/m<sup>2</sup>) in 2017 (*Figure 5; Table 1*).

Reduced marine forage fish availability in the estuary associated with high Columbia River discharge, combined with frequent colony disturbances by bald eagles and resulting nest predation by gulls, have been identified as key factors contributing to past breeding failures, lowered productivity, and colony abandonment by Caspian terns nesting at East Sand Island (Collar et al. 2017, BRNW 2018, Bailey 2018). In 2019, Columbia River discharge was lower than in 2018 and below the 2008-2018 average for nearly the entire breeding season (*Figure 6*). Once corrected for the difference in monitoring effort, however, the bald eagle disturbance rate to the tern colony was similar, if not slightly higher, in 2019 compared to the 2018 breeding season, despite lower river discharge (*Figure 7*). We also found that productivity (fledglings/breeding pair) was comparable between the two years. We estimated an average of 0.18 fledglings/breeding pair were raised in 2019 (95% c.i. = 0.17–0.19 fledglings/breeding pair).

compared to 0.17 fledglings/breeding pair raised during the 2018 breeding season (95% c.i. = 0.15–0.18 fledglings/breeding pair; *Figure 8*). Additionally, during the 2019 nesting season, active glaucous-winged/western gull territories nearly surrounded the tern colony (*Map 9*), and tern chicks near fledging age were vulnerable to predation by gulls even in the absence of colony disturbances from bald eagles which may have also influenced productivity rates in 2019.

Despite Columbia River discharge being below the 2008-2018 average, northern anchovies (*Engraulis mordax*; a marine forage fish) were underrepresented in the diet of terns breeding at East Sand Island compared to the average in previous years, especially late in the breeding season when anchovies are an important high-energy food source for fledgling Caspian terns (*Figures 9-10*). Other marine forage fishes, such as those in the family Clupeidae (i.e. herring, sardines, and shad), however, comprised a larger proportion of the diet in 2019 as compared to previous years, and the proportion of surfperch in the diet was also well above the long-term average during the peak fledging period in 2019 (*Figure 9*). In 2019, the diet of Caspian terns nesting at East Sand Island consisted of slightly more salmonid smolts (33.5% of prey items) compared to the average during 2000-2015 (31.8%; *Figure 9*). However, the above average proportion of salmonid smolts in the tern diet occurred mainly early in the 2019 breeding season (*Figure 11*).

### Section 3. Inter-colony Movements, Dispersal Patterns & Aerial Surveys

**Methods:** We continued to resight color-banded Caspian terns at the East Sand Island colony in 2019; however, the resighting effort was much reduced compared to previous years. Results presented here describe movements of banded Caspian terns to the East Sand Island colony, either within or between years, to better assess the consequences of management initiatives implemented as part of the Caspian Tern Management Plan for the Columbia River estuary. Because a limited number of aerial, ground, and boat-based surveys were conducted at locations away from East Sand Island to assess where Caspian terns emigrating from the East Sand Island colony were attempting to nest in 2019, most resightings of banded terns were at the frequently monitored colony on East Sand Island.

Caspian terns were banded with a federal numbered metal leg-band and two-colored plastic leg-bands on one leg and a colored plastic leg-band engraved with a unique alphanumeric code on the other leg during the 2005–2016 breeding seasons. This compliment of leg bands allowed us to individually identify each banded tern from a distance, such that the banding location (colony) and banding year were known. Banding was conducted at the colony on East Sand Island, as well as at other colonies both within the Columbia River basin and outside the basin, in previous years. In 2019, banded adult Caspian terns were resighted opportunistically on the East Sand Island tern colony by field personnel using binoculars and spotting scopes during 1-2 days per week throughout the breeding season. As part of related but separate studies, resighting of previously-banded Caspian terns was also conducted opportunistically at a limited sites in the Columbia Plateau region during the 2019 breeding season to evaluate movements of Caspian terns to and from the Columbia River estuary (*Map 1*).

Summaries of band resighting data collected at East Sand Island during the 2019 breeding season are presented in this report, along with information on where those individuals were originally banded. The summaries represent dispersal or site fidelity across years, between the time when each tern was banded and when it was observed again in 2019. This report also includes a summary of banded Caspian terns observed at East Sand Island in 2018 and locations where those terns were observed again in 2019. Although a few banded terns seen at East Sand Island in 2018 were detected outside of the Columbia River estuary in 2019, this summary is intended to mainly provide information on inter-annual fidelity to the tern colony on East Sand Island.

We conducted a single reconnaissance aerial survey from a manned fixed-wing aircraft to determine the distribution and detect any incipient colonies of Caspian terns along the lower Columbia River below Longview, Washington, and on islands in Willapa Bay and Grays Harbor on the outer Washington coast in 2019 (*Map 1*). The aerial survey was conducted on 04 June during the 2019 nesting season to allow for the detection of new colonies that may have formed during the 2019 Caspian tern breeding season in the region. Aerial surveys followed established methods, including reconnaissance surveys to search for new Caspian tern colonies and photographic surveys of sites where nesting Caspian terns were present. If Caspian terns were observed on the ground on substrate that was considered suitable for nesting, oblique aerial photographs were taken using a digital SLR camera with an image-stabilizing, zoom lens. When in-flight observations of Caspian terns or post-flight inspection of digital images suggested the presence of a Caspian tern breeding colony, ground- or boat-based surveys were conducted to assess breeding status and other colony metrics at the site.

**Results and Discussion:** During the 2019 field season, a total of 232 individual Caspian terns that were previously color-banded were resighted on East Sand Island. Of these resighted individuals, 90% were banded at East Sand Island (96 as adults and 112 as chicks), 5% were banded at Crescent Island in the mid-Columbia River (10 as adults and 2 as chicks), 3% were banded at Goose Island-Potholes Reservoir (7 as adults), 1% were banded at the Port of Bellingham in Washington (2 as chicks), 1% were banded at Brooks Island in San Francisco Bay (2 as chicks), and < 1% were banded at Sheepy Lake tern island in Lower Klamath NWR, California (one as a chick; *Table 2*). These resightings of banded Caspian terns at the East Sand Island colony indicate that there is high natal and breeding philopatry (site fidelity) among Caspian terns at this colony. Resightings of terns banded as adults on either Crescent Island or Goose Island in the Columbia Plateau region indicate that some terns displaced from these managed colonies in the Columbia Plateau region have immigrated to the East Sand Island colony. In addition, movement of banded Caspian terns from inland and coastal colonies throughout the breeding range of the Pacific Flyway population to the colony on East Sand Island continues to highlight the strong draw of the Columbia River estuary to terns prospecting for potential nesting habitat, despite management actions to reduce the availability of tern nesting habitat at East Sand Island.

Of the 377 color-banded Caspian terns seen on East Sand Island in 2018, 214 terns (57%) were

resighted again in 2019, either at East Sand Island or elsewhere; one of these individuals was resighted at two different locations in 2019. Of the 215 resighting records in 2019 of banded terns seen at East Sand Island in 2018, 99% were recorded at East Sand Island and 1% ( $n = 3$ ) were recorded at the Blalock Islands in the mid-Columbia River (*Table 3*). These resightings underscore the high breeding philopatry of Caspian terns for the East Sand Island colony, but also indicate that some adults continue to at least visit colony sites in the Columbia Plateau region. However, band resighting efforts outside of the Columbia River estuary during the 2019 nesting season were insufficient to determine the extent of movements of banded terns away from East Sand Island.

The aerial survey of the lower Columbia River and estuaries on the outer coast of Washington in 2019 during the incubation period (04 June) recorded almost 400 Caspian terns at locations other than East Sand Island. We observed about 135 Caspian terns loafing at four different sites on the lower Columbia River, and about 245 terns loafing at five different sites in Willapa Bay and Grays Harbor. We did not detect Caspian tern breeding activity at any of the sites where loafing terns were detected and, as such, no follow-up ground- or boat-based surveys were conducted. As was the case during 2013-2018, Caspian terns were observed at a dredged material disposal site at the downstream end of Rice Island in the upper Columbia River estuary. Data on nesting attempts by Caspian terns and nest dissuasion efforts in the upper Columbia River estuary were collected as part of a separate study funded by the USACE – Portland District.

#### Section 4. Tern Diet Composition & Consumption of Salmonid Smolts

*Methods:* Breeding Caspian terns transport single whole fish in their bills to feed their mates (courtship meals) and to feed their young (chick meals) at the breeding colony. Consequently, it is possible to determine the taxonomic composition of the diet 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. In 2019, the target sample size was 300 bill-load identifications per week; slightly lower than the targeted sample size of 350 bill-loads in previous years. Field staff conducted bill-load observations at the East Sand Island tern colony twice each day, with a minimum of a one-hour break between sessions. The timing of bill-load observations varied throughout the season but were not timed to coincide with high and low tide periods, as in previous years. We identified prey items to the taxonomic level of family, and although 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, 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. We based the diet composition of terns over the entire breeding season on the average of the percentages for the 2-week periods from 22 April through 22 July 2019.

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

Predation rates on specific populations of anadromous salmonids (ESUs/DPSs) by Caspian terns nesting on East Sand Island in 2019 were again investigated by recovering PIT tags from juvenile salmonids on the tern colony after the breeding season. The USACE – Portland District performed this work, however, and those data are not included as part of this report.

**Results and Discussion:** Of the bill-load fish identified at the East Sand Island Caspian tern colony during the 2019 nesting season (n = 4,050 bill-loads), marine forage fishes (e.g., anchovies [Engraulidae], surfperch [Embiotocidae], smelt [Osmeridae], and herring [Clupeidae]) were collectively more prevalent than salmonids in the tern diet, which has been the case since the Caspian tern colony was relocated from Rice island to East Sand Island in 2000. Together these marine forage fishes averaged 57% of all tern bill-loads identified on East Sand Island in 2019; in contrast, 33.5% of identifiable bill-loads were juvenile salmonids (*Figure 9*). The proportion of salmonids in the tern diet during the 2019 nesting season was lower than during the 2018 nesting season (40.1%), but slightly higher than the long-term average during 2000-2015 (31.7%; *Figure 12*), years when tern diet composition data were collected at East Sand Island while controlling for tide stage. In 2019, the proportion of salmonids in the diet of Caspian terns nesting at East Sand Island peaked in early May, similar timing to the peak in salmonids in previous years (*Figure 11*). The weekly proportion of salmonids in the tern diet was, however, substantially greater than the long-term average during late-April and early May in 2019 (*Figure 11*); this coincides with the peak in spring out-migration of juvenile salmonids.

A consistent trend in the proportion of marine forage fishes (e.g., anchovies, clupeids, smelt) in the tern diet during the 2019 nesting season was not apparent. The proportion of anchovy was considerably lower than the long-term average, and this difference was most pronounced at the end of the breeding season, a period when anchovies have historically comprised the largest proportion of the tern diet at East Sand Island (*Figure 10*). The proportion of clupeids, a taxon of marine forage fishes that includes herring, sardines, and shad, in the tern diet was well above the long-term average during much of the 2019 breeding season (*Figure 9*), especially in mid-July (*Figure 13*). The proportion of smelt in the diet was lower than the long-term average during April and May, but consistent with the long-term average for the remainder of the nesting season (*Figure 14*). Surfperch, an estuarine resident forage fish, were present in the tern diet above the long-term average throughout the entire nesting season (*Figure 15*). Around 10% of the Caspian tern diet at East Sand Island in 2019 consisted of a combination of other native and introduced taxa of marine, estuarine, and freshwater forage fishes, such as juvenile cod (Gadidae), sculpin (Cottidae), flatfish (Pleuronectidae), lamprey (Petromyzontidae), sand lance (*Ammodytes personatus*), northern pikeminnow (*Ptychocheilus oregonensis*), juvenile rockfish (Sebastidae), peamouth chub (*Mylocheilus caurinus*), snake prickleback (*Lumpenus*

*sagitta*), banded killifish (*Fundulus diaphanus*), weather loach (*Misgurnus anguillicaudatus*), and goby (Gobiidae).

Bioenergetics calculations to estimate total smolt consumption by Caspian terns nesting on East Sand Island in 2019 are currently in progress, and these results will be included in the Final Annual Report for 2019, which will be submitted to BPA by late March 2020.

## Section 5. Other Piscivorous Waterbirds

In addition to Caspian terns, we incidentally monitored the presence and nesting status of other waterbird species (i.e. glaucous-winged/western gulls, ring-billed gulls, and California brown pelicans) at the east end of East Sand Island. Because California brown pelicans have attempted to nest on East Sand Island in previous years, most recently in 2016 when three brown pelican nests with eggs were discovered, efforts were made to detect any nesting activity by brown pelicans during the 2019 breeding season. We monitored for potential brown pelican nesting activity from several vantage points on the east end of East Sand Island and by conducting island-wide boat-based surveys for brown pelicans once a month from mid-May through mid-September. These surveys were also used to estimate the peak number of California brown pelicans that roosted on East Sand Island during the 2019 field season. In addition to the effort by field personnel to detect brown pelican nesting activity using boat-based surveys and monitoring from the ground, we installed five remote sensing camera traps to monitor areas where brown pelicans had previously attempted to nest and are difficult to observe during ground-and boat-based surveys.

**Results and Discussion:** As in previous years, large numbers of both glaucous-winged/western gulls and ring-billed gulls nested at the east end of East Sand Island. In 2019, an unknown number of glaucous-winged/western gull nests were located above the heavy wrack line high on the upper beach and in vegetated upland areas (*Map 7*), and about 85 breeding pairs of glaucous-winged/western gulls nested in the 1.0-acre prepared colony area for Caspian tern nesting, and excluded nesting terns from the vicinity of their nests. As in 2018, a large ring-billed gull colony formed on the vegetated and driftwood-filled inlet and surrounding upland area on the northeast tip of East Sand Island (*Map 7*). Active gull nests were generally well removed (> 15 m) from the travel paths used by field personnel while walking the beach as part of Caspian tern monitoring activities and nesting gulls were apparently undisturbed by the presence of researchers. The glaucous-winged/western gull and ring-billed gull colonies on East Sand Island successfully fledged many young during the 2019 breeding season, but no estimate of nesting success was attempted.

East Sand Island is the largest known post-breeding roost site for California brown pelicans, and the only known night roost for this species in the Columbia River estuary (Wright 2005). In 2019, as in previous years, the east end of East Sand Island was used as a roost site by non-breeding and post-breeding California brown pelicans. However, the first California brown pelicans were not seen on East Sand Island until 12 May in 2019, the latest arrival date observed during the previous decade of monitoring at East Sand Island by about three weeks.

Counts of California brown pelicans on East Sand Island peaked in August at around 3,285 individuals (*Figure 16*), and although the peak occurred several weeks later in 2019 compared to 2018, the peak count of individuals was similar (3,011). The peak count of brown pelicans roosting at East Sand Island in 2019 was also similar to the peak count in 2017 (ca. 3,300 individuals), but appreciably lower than in 2016 (5,282 individuals), and well below the average peak count during the 19-year period of 2000-2018 (8,062 individuals; *Figure 17*). The reason for this decline is unknown, but may be related to concurrent declines in northern anchovy in the Columbia River estuary and nearby off-shore areas. Although a few individual brown pelicans were observed carrying sticks in flight, no nest structures, copulation, or other pelican breeding behaviors were observed, and no nesting activity by California brown pelicans was detected on East Sand Island during the 2019 breeding season.

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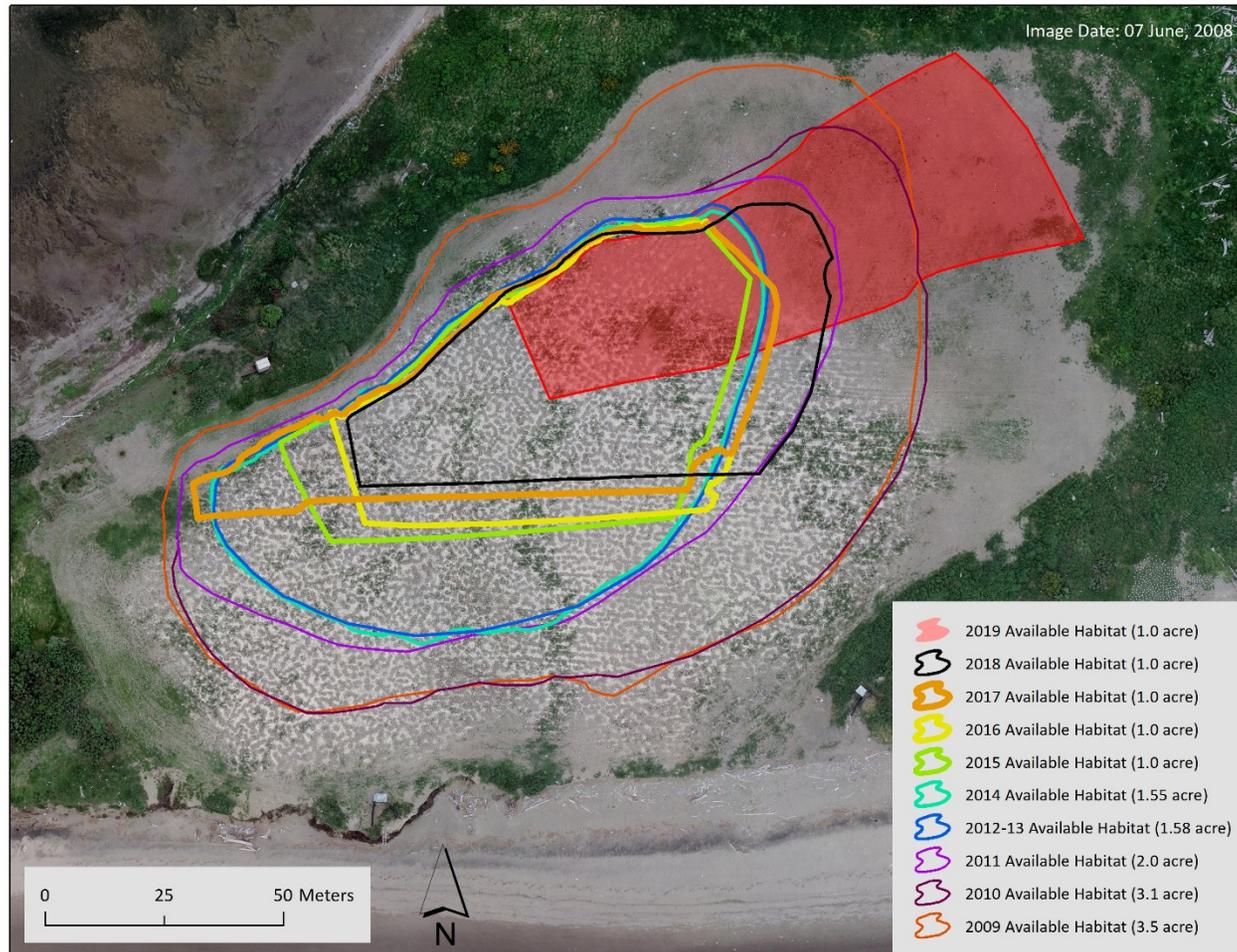
# MAPS



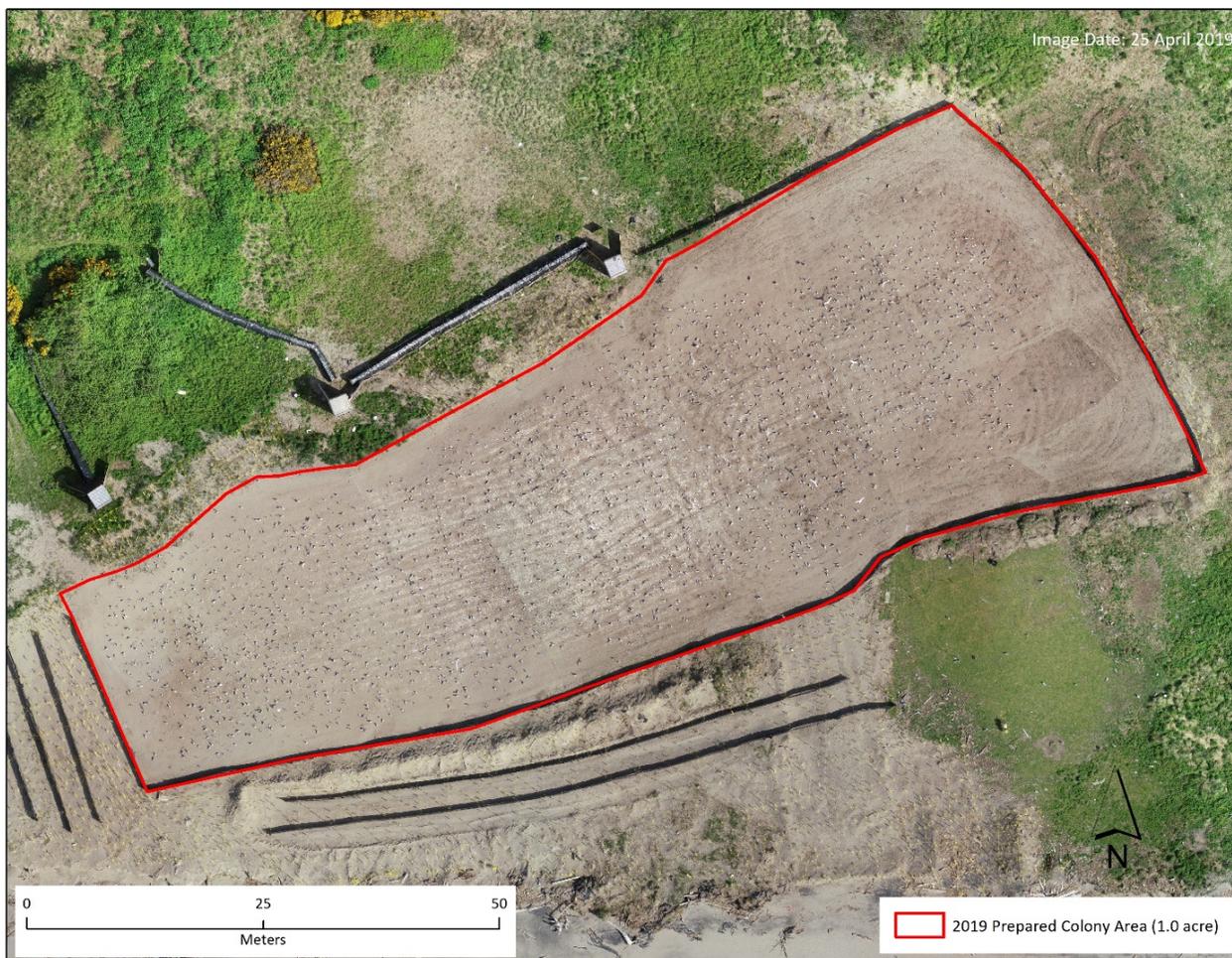
Map 1. Study area in the Columbia River basin showing the locations of active and former Caspian tern breeding colonies referenced in this report.



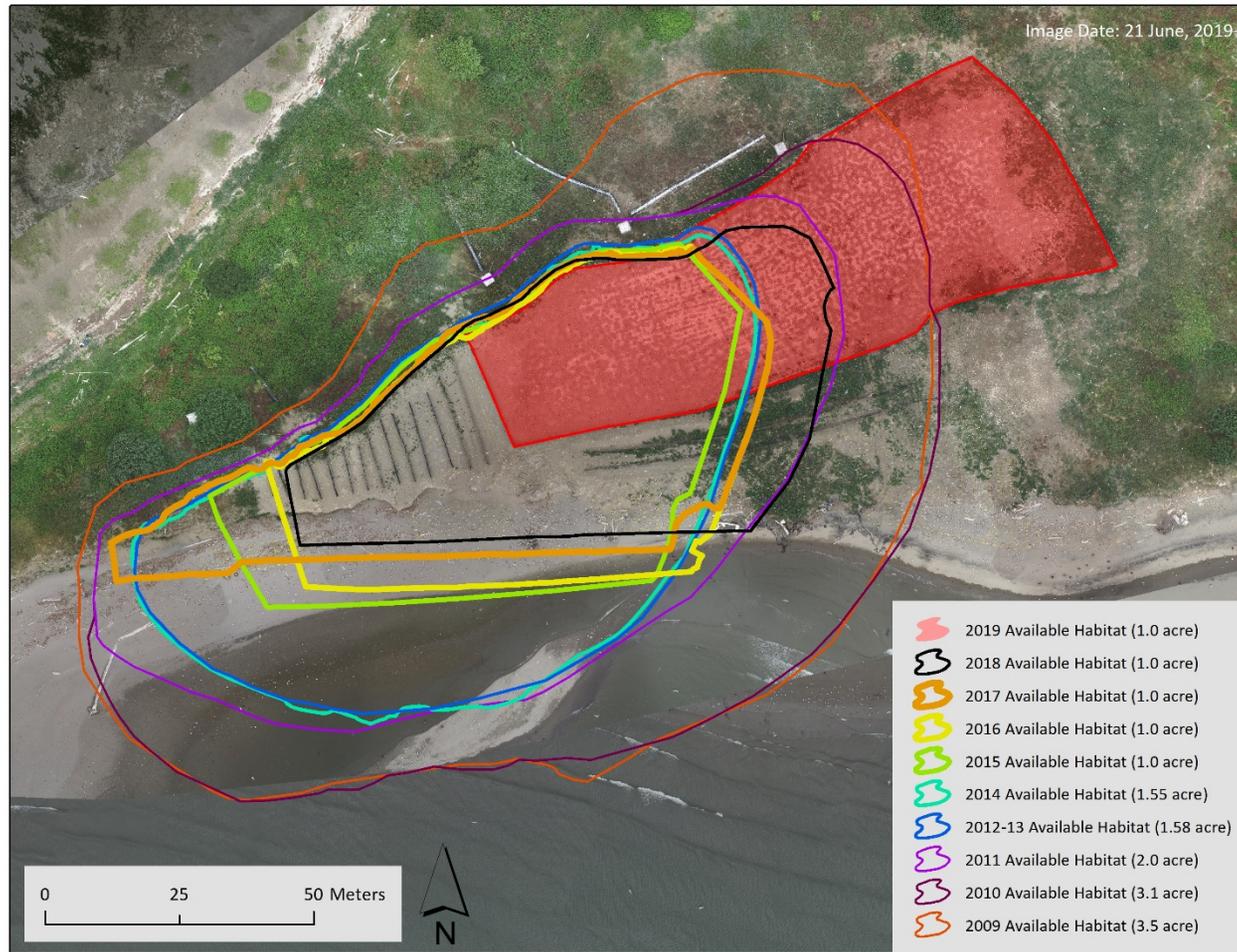
Map 2. East Sand Island and out-of-basin Caspian tern colony sites referred to in this report, including Corps-constructed Caspian tern islands.



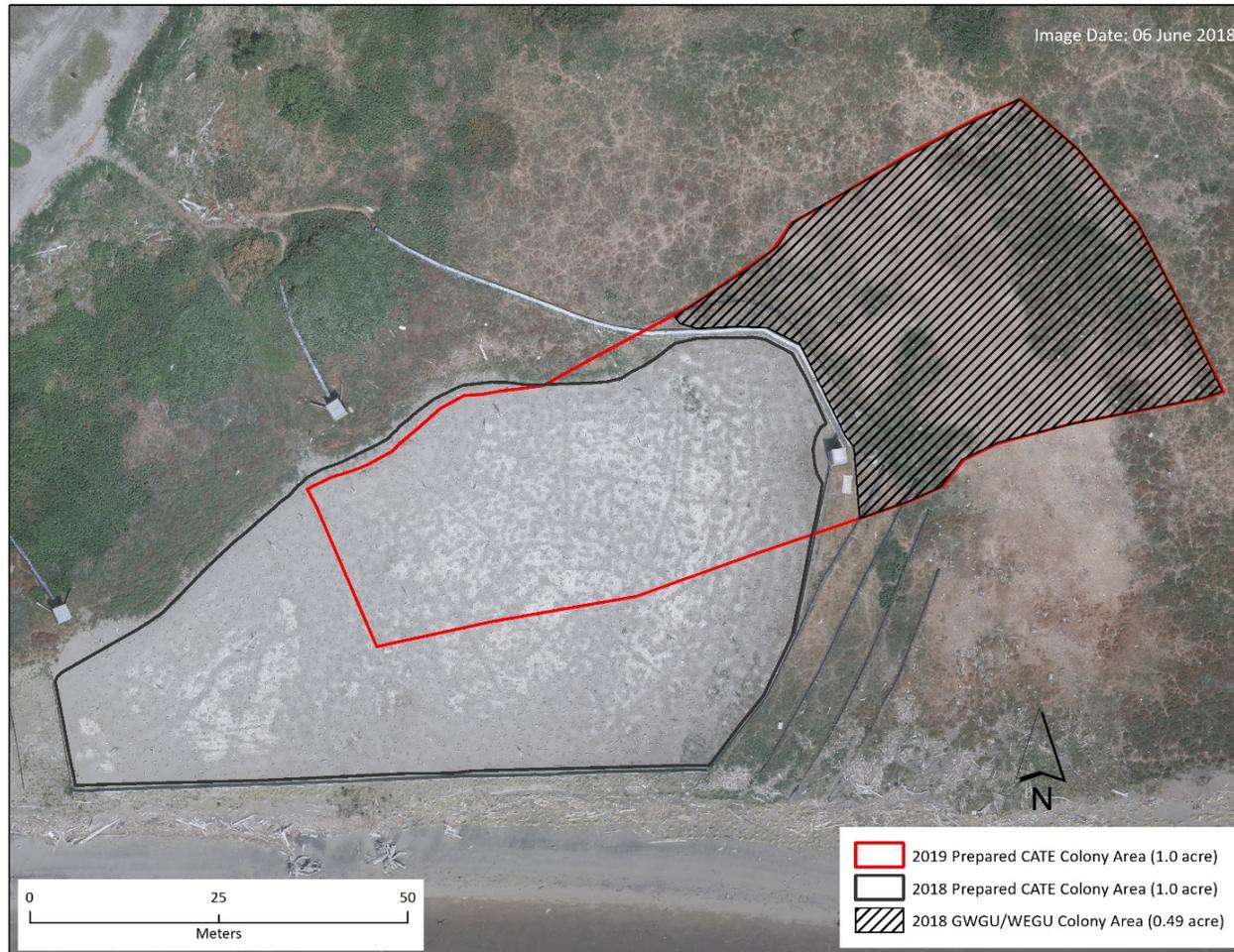
Map 3. Nesting habitat prepared for Caspian terns on the eastern end of East Sand Island in the Columbia River estuary during 2008-2019. Colony delineations depict the area of nesting habitat available to terns each breeding season during 2009-2019 overlaid on aerial photography taken in 2008 when approximately 5 acres of nesting habitat was provided. Passive nest dissuasion materials (i.e. fabric fencing, posts, ropes, and flagging), invasive vegetation, and island erosion have all served to limit tern nesting habitat to the acreage specified by resource managers (see *legend* and *text* for details).



Map 4. Aerial photography of the designated 1.0-acre colony area for Caspian terns on East Sand Island in 2019. Three observation blinds and their respective access tunnels were located on the northern edge of the colony area in 2019.



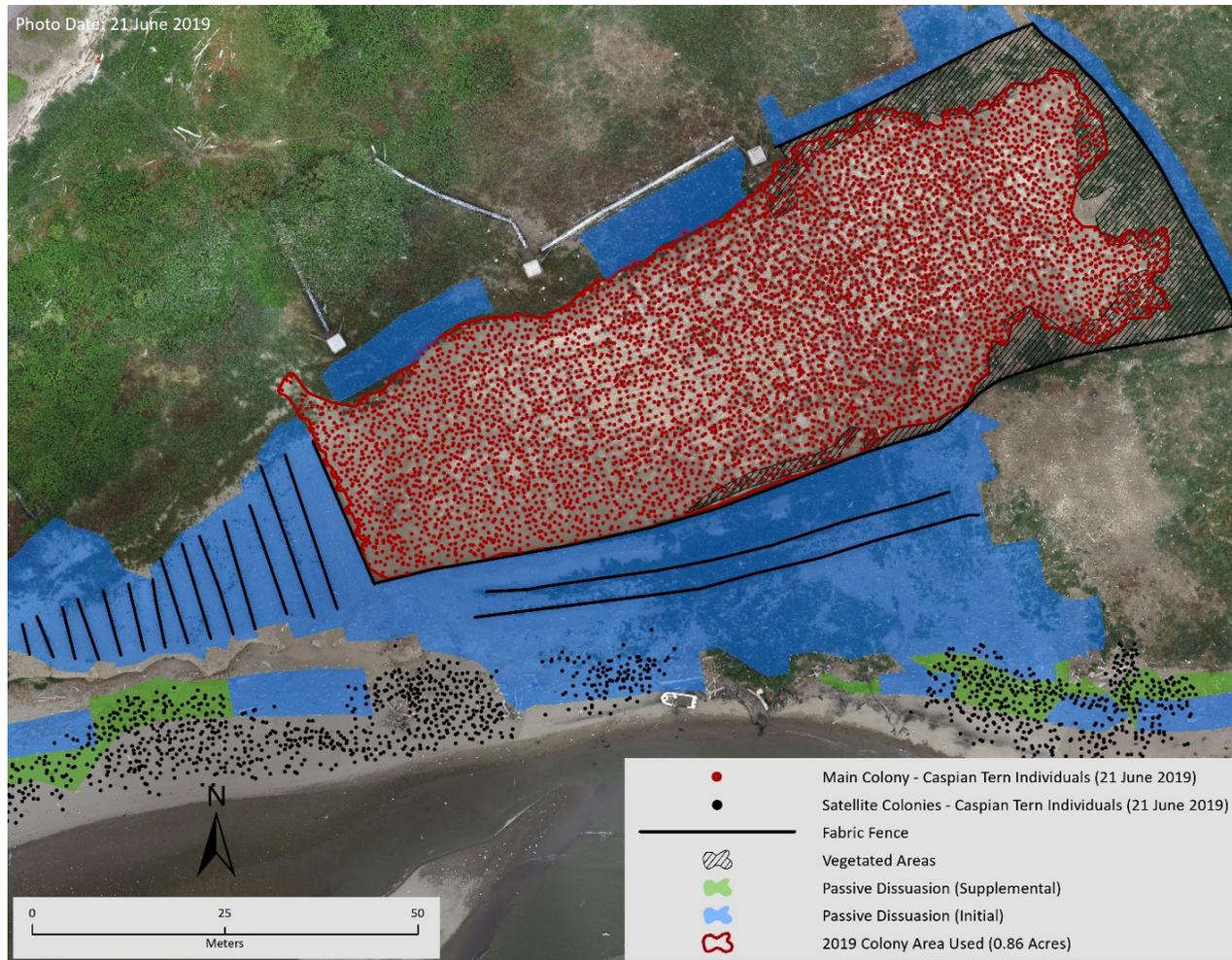
Map 5. Nesting habitat prepared for Caspian terns on the eastern end of East Sand Island in the Columbia River estuary during 2009-2019. Colony delineations depict the area of nesting habitat available to terns each breeding season during 2009-2019 overlaid on aerial photography taken in 2019. The southern shoreline of East Sand Island has gradually eroded during each winter, encroaching on the area of available tern nesting habitat in most years during 2009-2019. Passive nest dissuasion materials (i.e. fabric fencing, posts, ropes, and flagging), invasive vegetation, and island erosion have all served to limit tern nesting habitat to the acreage specified by resource managers (see *legend* and *text* for details).



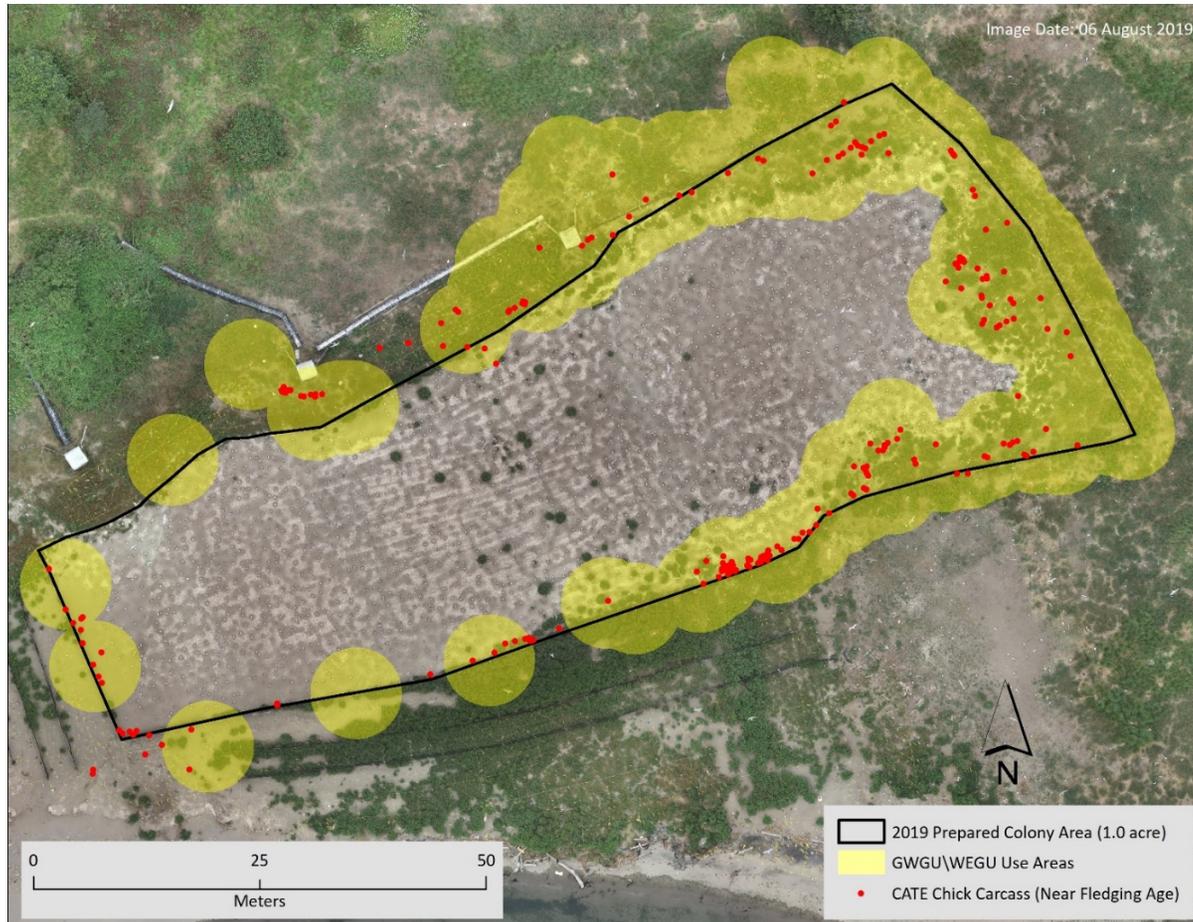
Map 6. Aerial photography of the prepared area of unvegetated substrate designated as nesting habitat for Caspian terns on East Sand Island in 2019, overlaid on the boundaries of the 1.0-acre colony area in 2018. Hatched area was occupied by nesting glaucous-winged/western gulls (GWGU/WEGU) in 2018 and required removal of dense vegetation in order to shift the tern colony area in 2019 to the northeast of the 2018 colony area. Over half of the 1.0-acre tern colony area in 2019 was not Caspian tern nesting habitat in 2018, and most of the newly created tern habitat was occupied by nesting glaucous-wing/western gulls in 2018.



Map 7. Aerial photography of the eastern end of East Sand Island, showing locations of piscivorous waterbird nesting colonies during the 2019 breeding season. CATE = Caspian tern; RBGU = ring-billed gull; GWGU/WEGU = glaucous-winged/western gull.



Map 8. Aerial photography of the designated 1.0-acre colony area for Caspian terns on East Sand Island in 2019. Map shows the peak use of the designated colony area and satellite colonies by Caspian terns and the extent of vegetation regrowth at the eastern end during the 2019 breeding season on East Sand Island.



Map 9. Aerial photography of the 1.0-acre of tern nesting habitat for Caspian terns on East Sand Island in 2019, showing glaucous-winged/western gull (GWGU/WEGU) territories and locations of carcasses of Caspian tern (CATE) chicks late in the nesting season.

## FIGURES

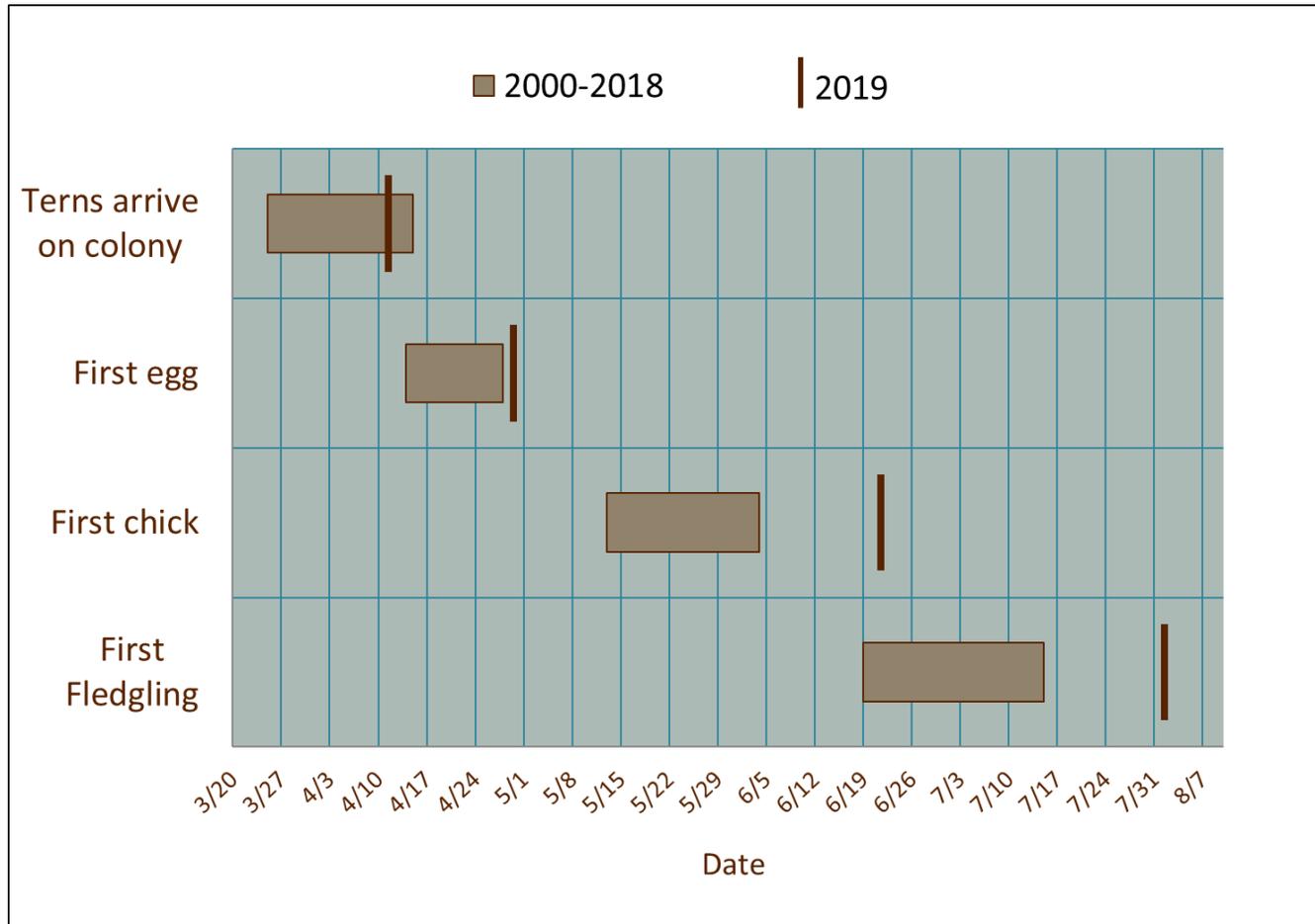


Figure 1. Nesting chronology for Caspian terns on the designated 1.0-acre colony area at East Sand Island during the 2019 breeding season. *Note:* In 2019, the island was not accessible to the field crew due to inclement weather on 4/8-4/10 and terns may have landed on the colony during those dates and before 4/11.

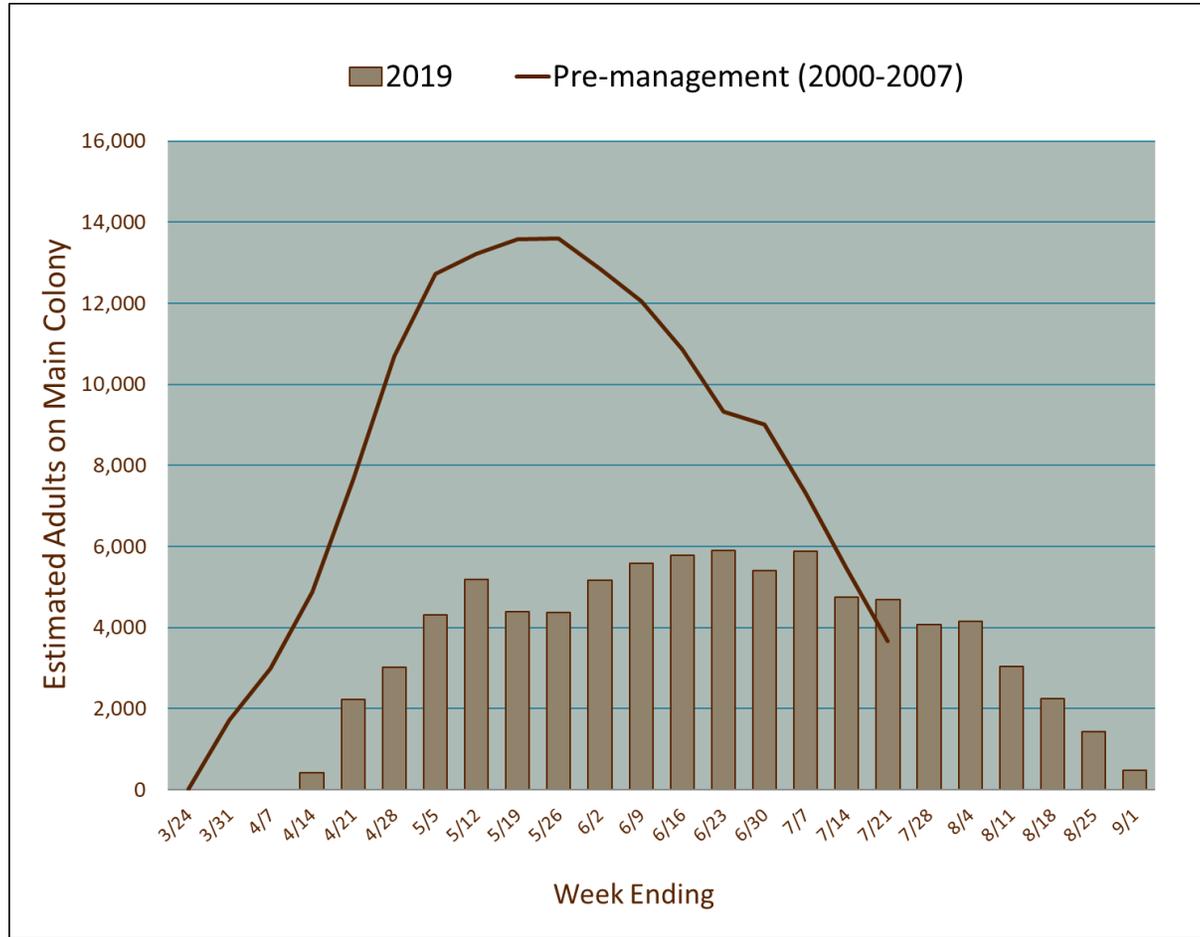


Figure 2. Weekly estimates from the ground of the number of adult Caspian terns on the designated 1.0-acre designated colony area at East Sand Island during the 2019 breeding season.

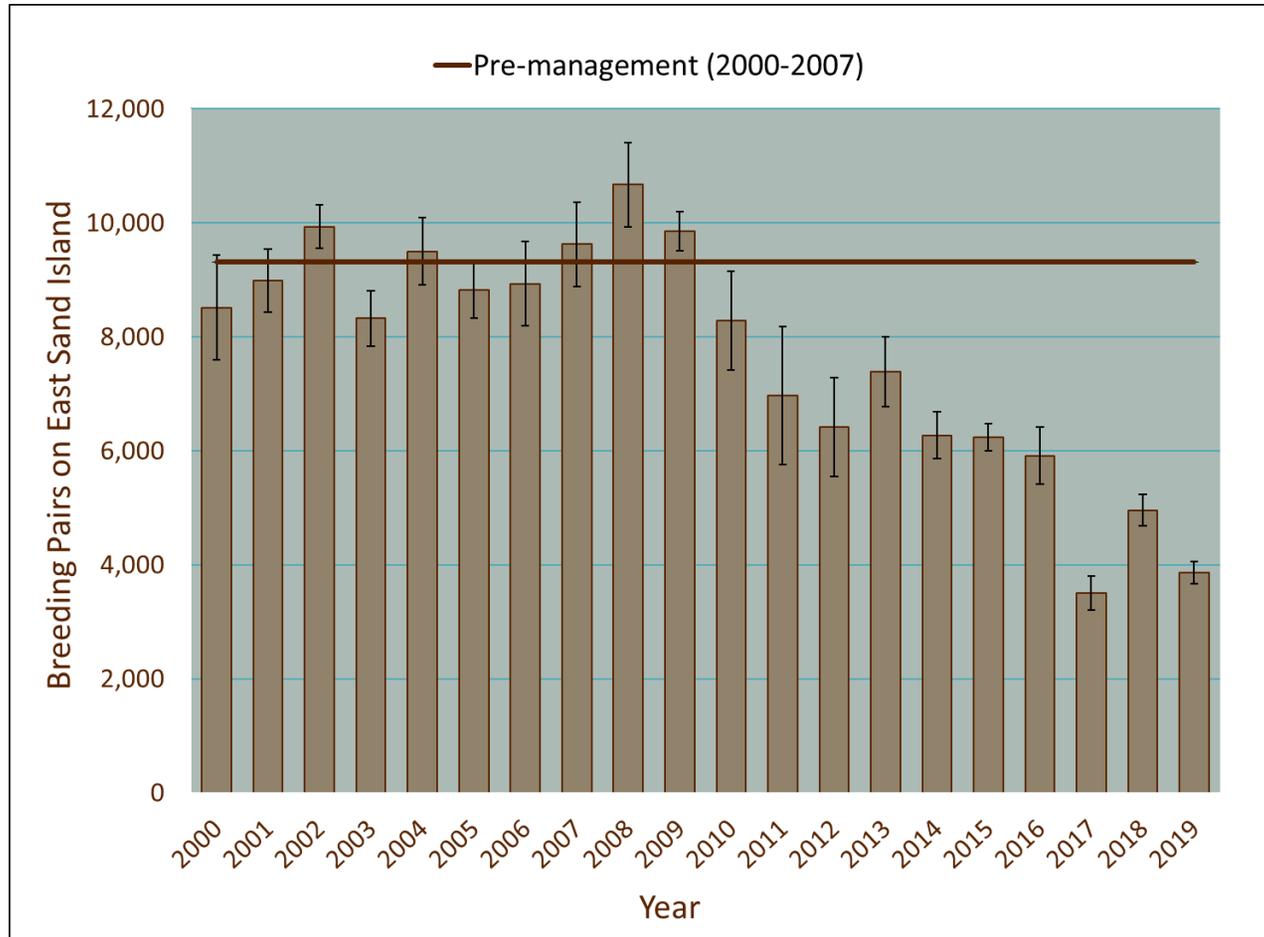


Figure 3. Caspian tern colony size (number of breeding pairs) on East Sand Island in the Columbia River estuary during 2000-2019. The error bars represent the 95% confidence intervals. *Note:* the estimated number of breeding pairs in 2019 represents terns nesting on the designated 1.0-acre colony area only, whereas estimates for 2012, 2013, 2015, and 2016 include Caspian terns nesting outside of the provided habitat in those years (i.e. “satellite” tern colonies).

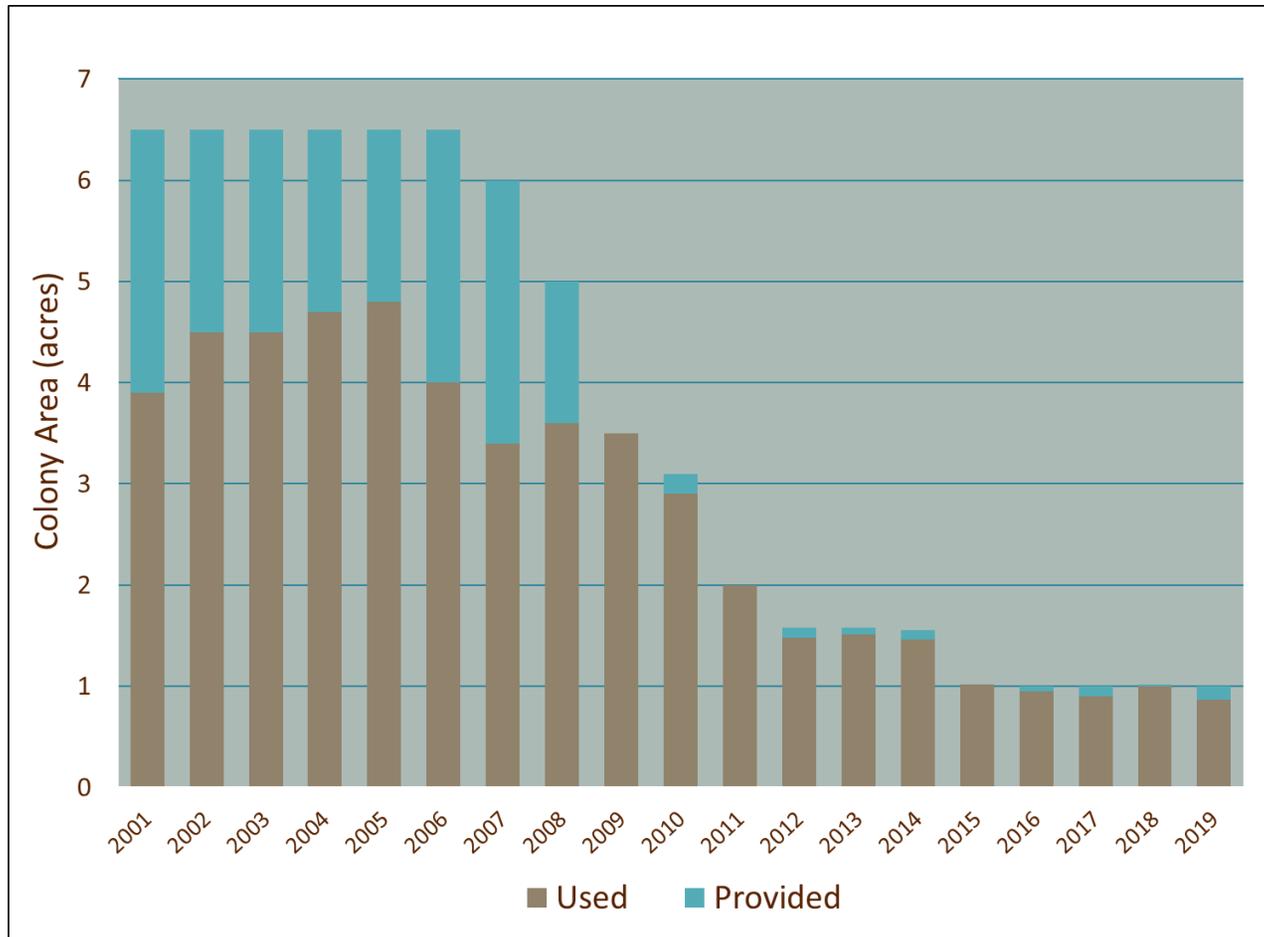


Figure 4. Caspian tern use of available nesting habitat at the breeding colony on East Sand Island in the Columbia River estuary during 2001-2019.

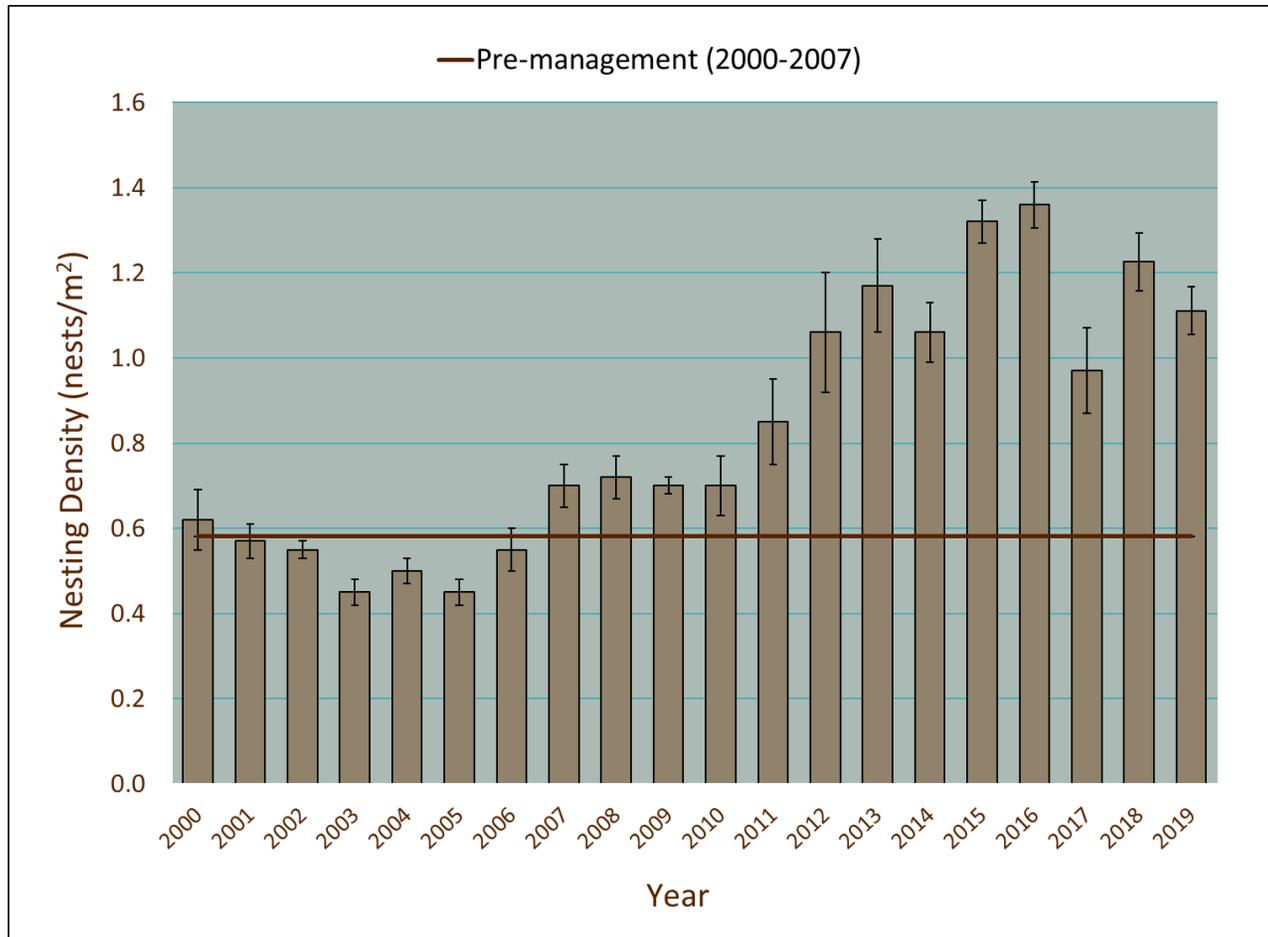


Figure 5. Caspian tern nesting density at the breeding colony on East Sand Island in the Columbia River estuary during 2000-2019. The error bars represent 95% confidence intervals (confidence interval not available for 2011 and based on confidence interval for 2012).

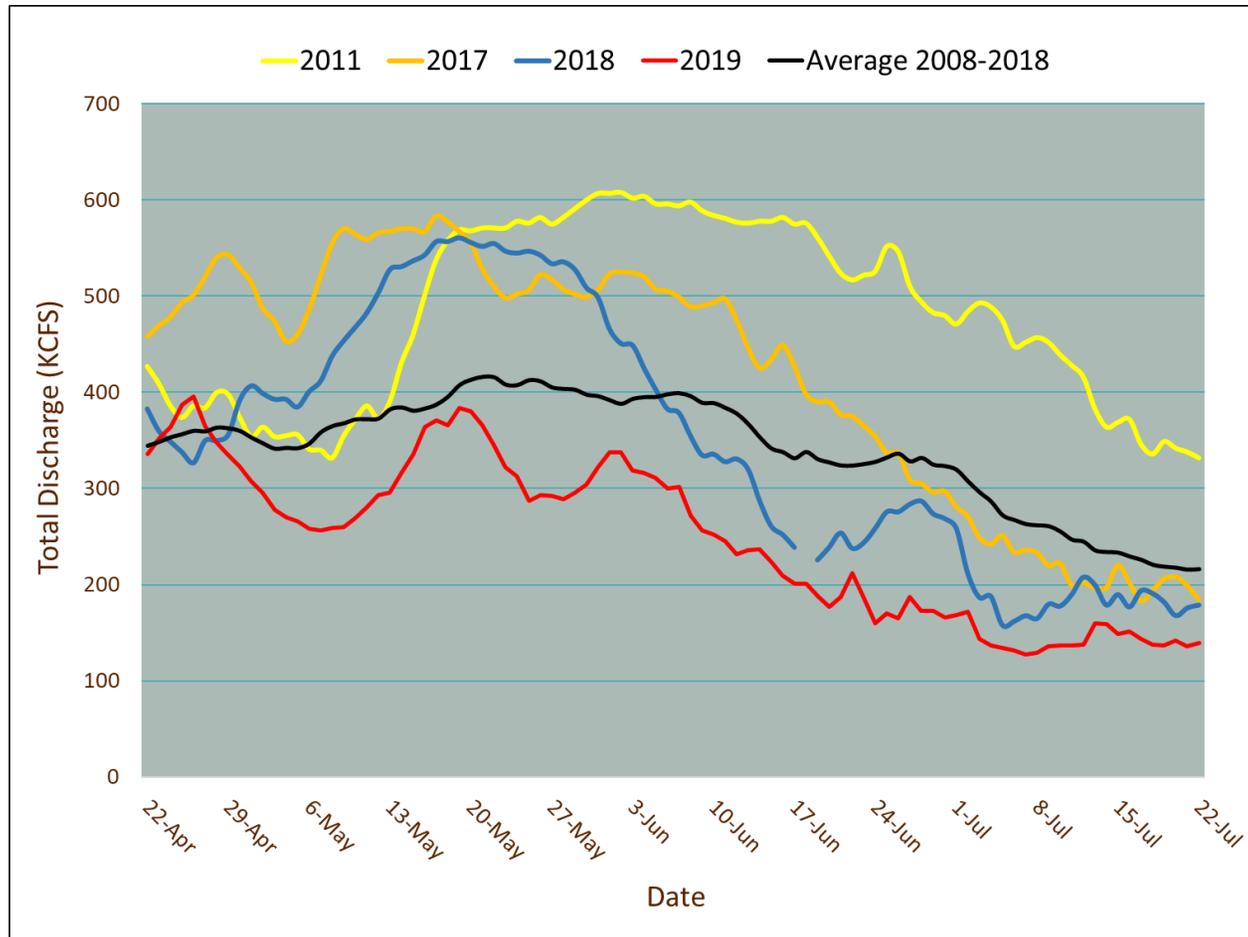


Figure 6. Total Columbia River discharge in thousands of cubic feet per second (kcfs) from 22 April to 22 July during 2008–2019 at USGS hydrological gage number 14246900 near Clatskanie, Oregon. Discharge in 2011 and 2017, the two years when the Caspian tern colony on East Sand Island failed to produce any young, is shown as yellow and orange lines, respectively.

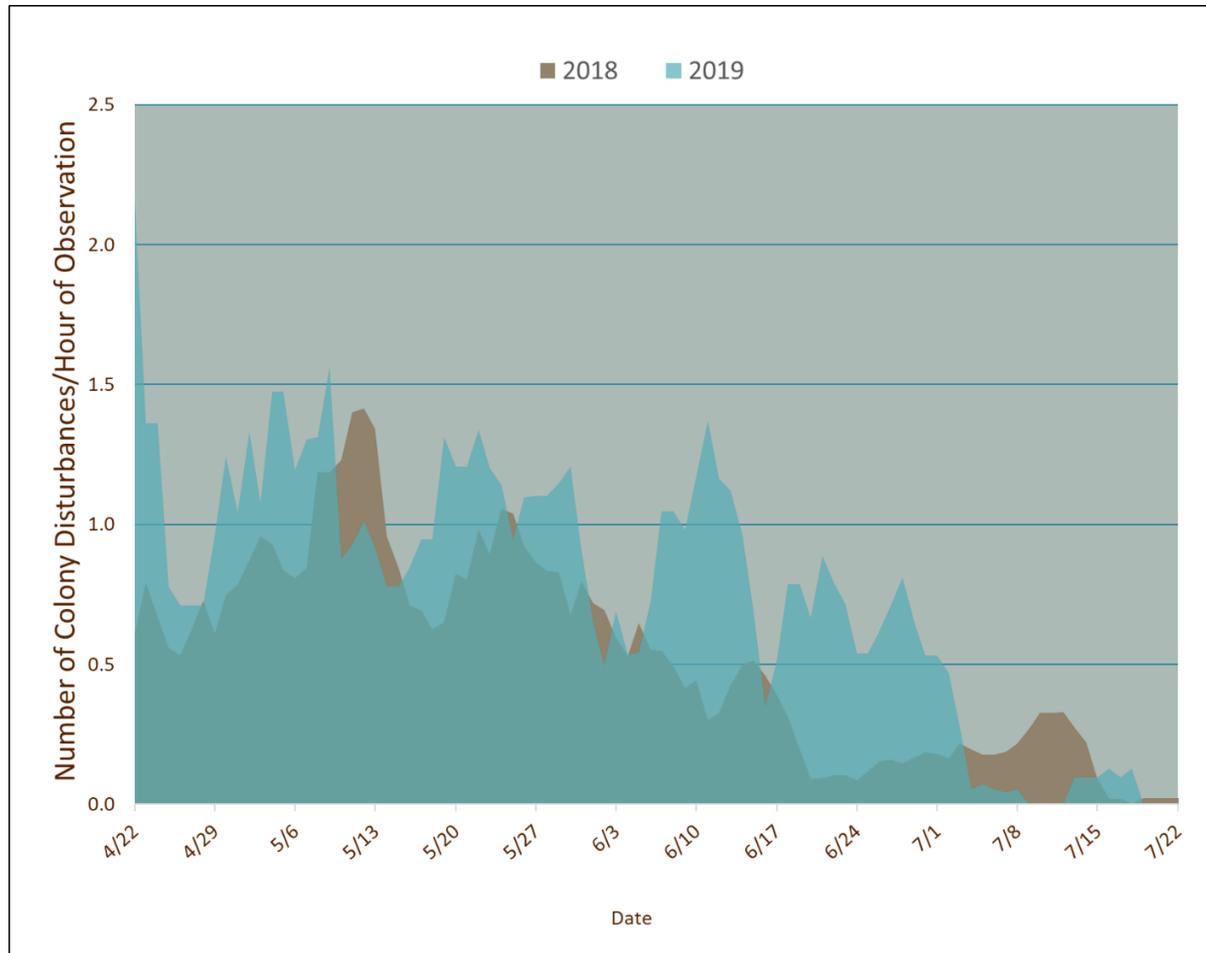


Figure 7. Number of daily Caspian tern colony flushes caused by bald eagles at the designated 1.0-acre colony area on East Sand Island per hour of observation in 2018 and 2019. After adjusting for differences in monitoring effort, eagle disturbances were generally more frequent during the 2019 breeding season compared to the 2018 breeding season.

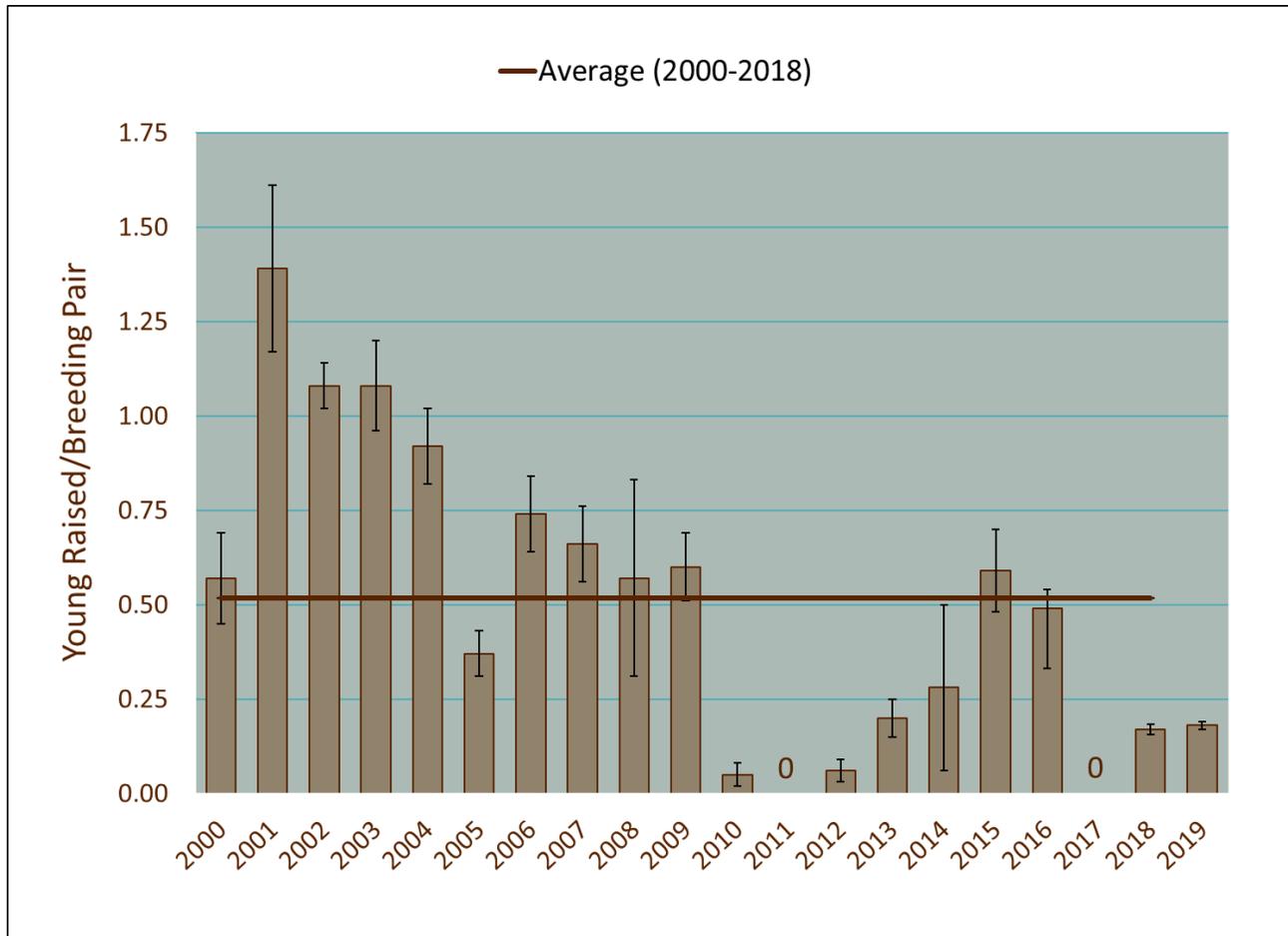


Figure 8. Caspian tern nesting success (average number of young raised per breeding pair) on East Sand Island in the Columbia River estuary during 2000-2019. The error bars represent 95% confidence intervals. No young were raised at the East Sand Island breeding colony in 2011 or in 2017.

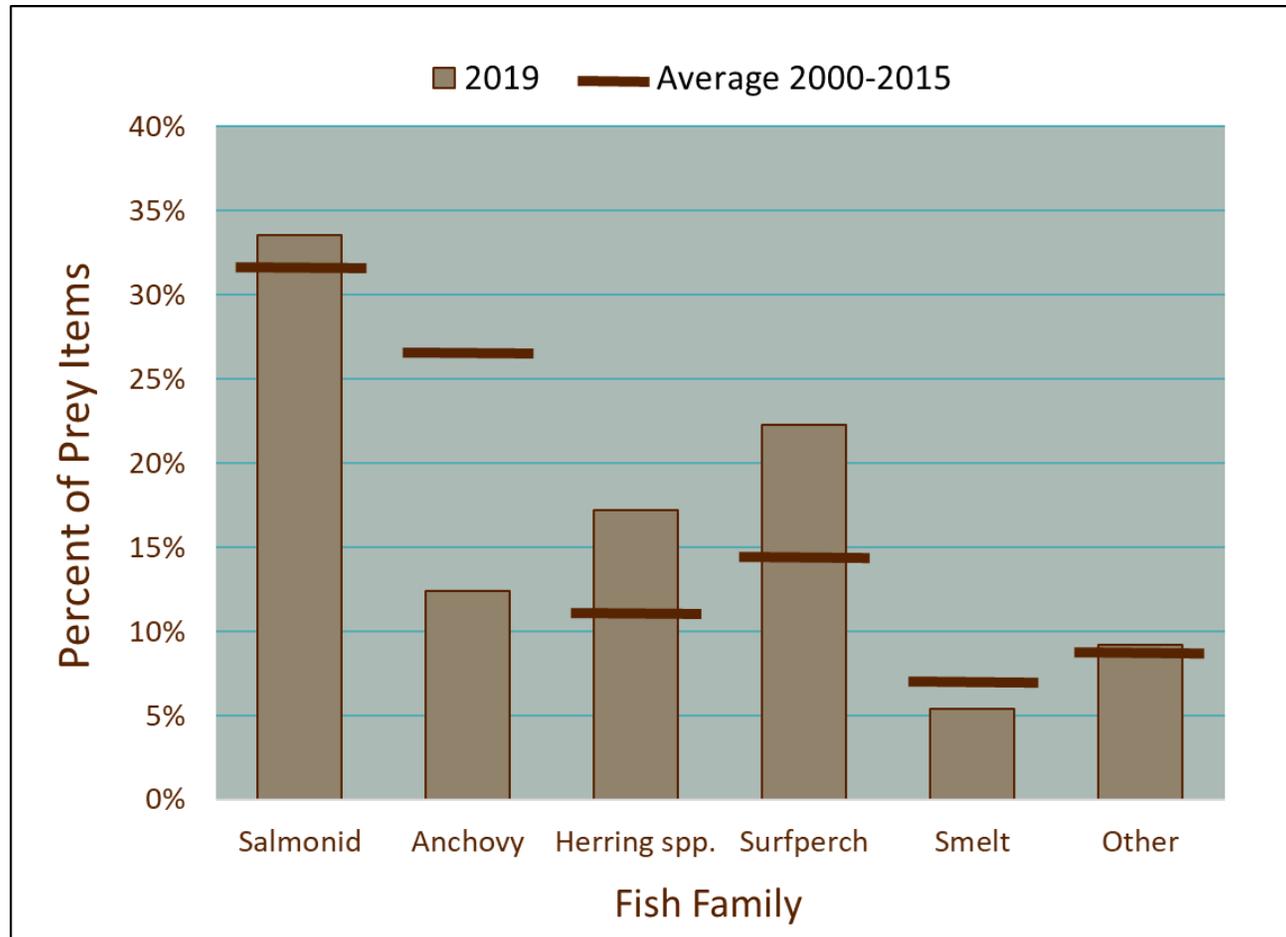


Figure 9. Diet composition (percent of identified prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2019 breeding season. Diet composition is based on fish visually identified on-colony in Caspian tern bill-loads.

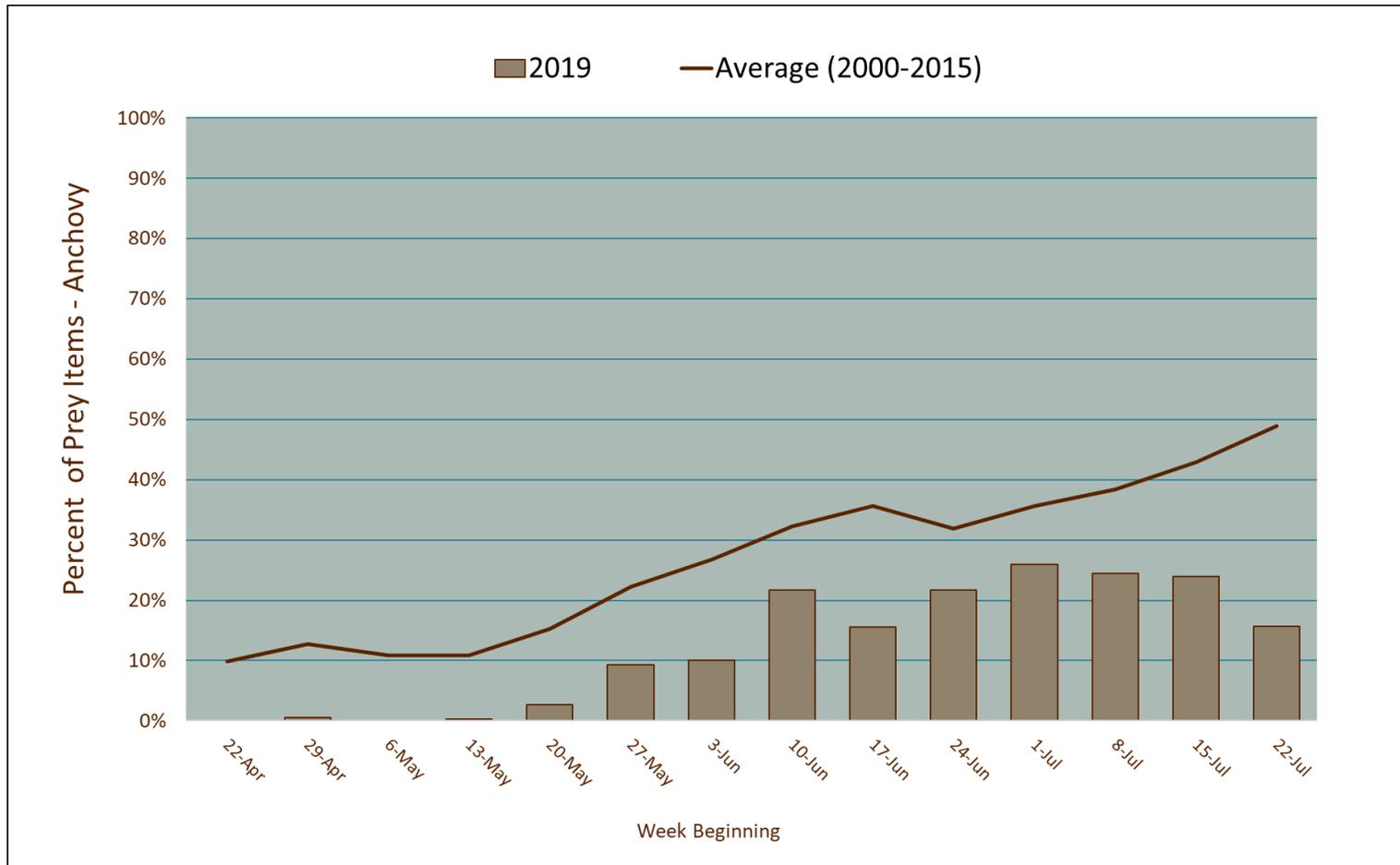


Figure 10. Weekly percentage of northern anchovy (*Engraulis mordax*) observed in the diet (percent of identified bill-loads) of Caspian terns nesting at the East Sand Island colony in the Columbia River estuary during the 2019 breeding season. Anchovy comprised a smaller proportion of the tern diet throughout the 2019 nesting season compared to the long-term average.

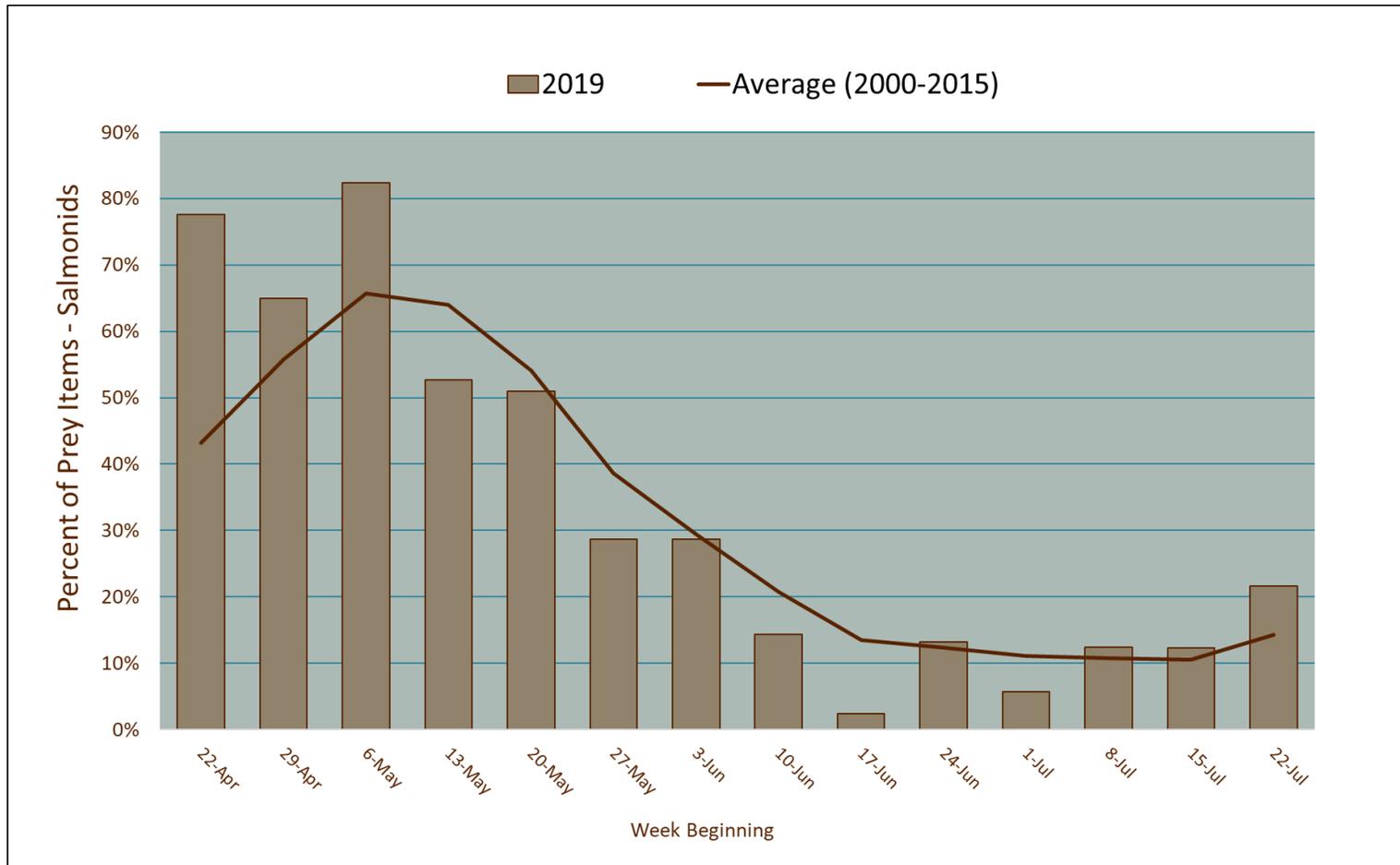


Figure 11. Proportion of juvenile salmonids (*Oncorhynchus* spp.) in the diet (percent of identified prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2019 breeding season. Juvenile salmonids comprised a notably greater proportion of the tern diet compared to the long-term average in four of 14 one-week periods during the nesting season, in particular during late April and early May.

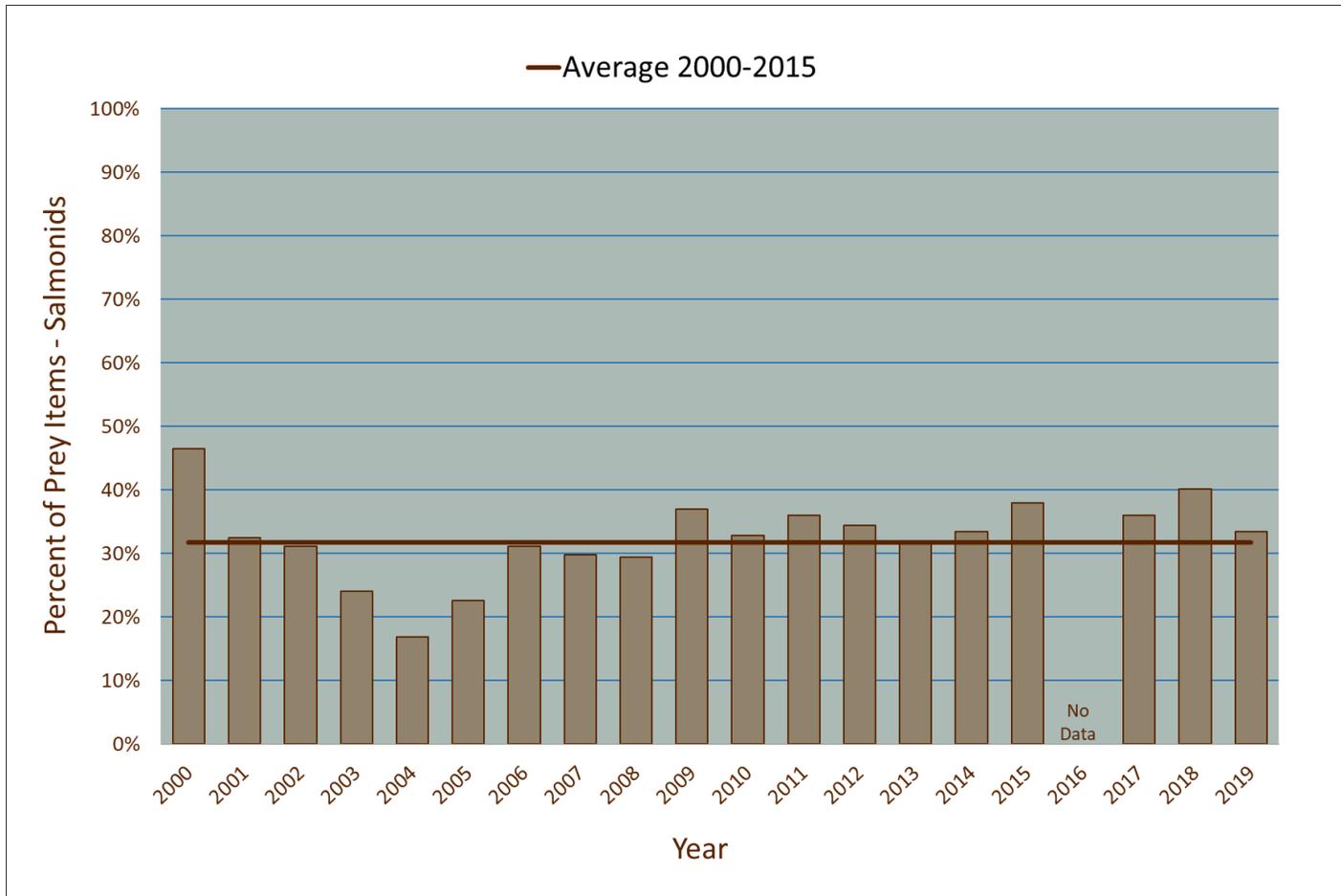


Figure 12. Average annual proportion of juvenile salmonids in the diet (percent of identified prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2019 breeding seasons. Each annual value represents the average of the proportions during the 2-week periods encompassing the entire nesting season.

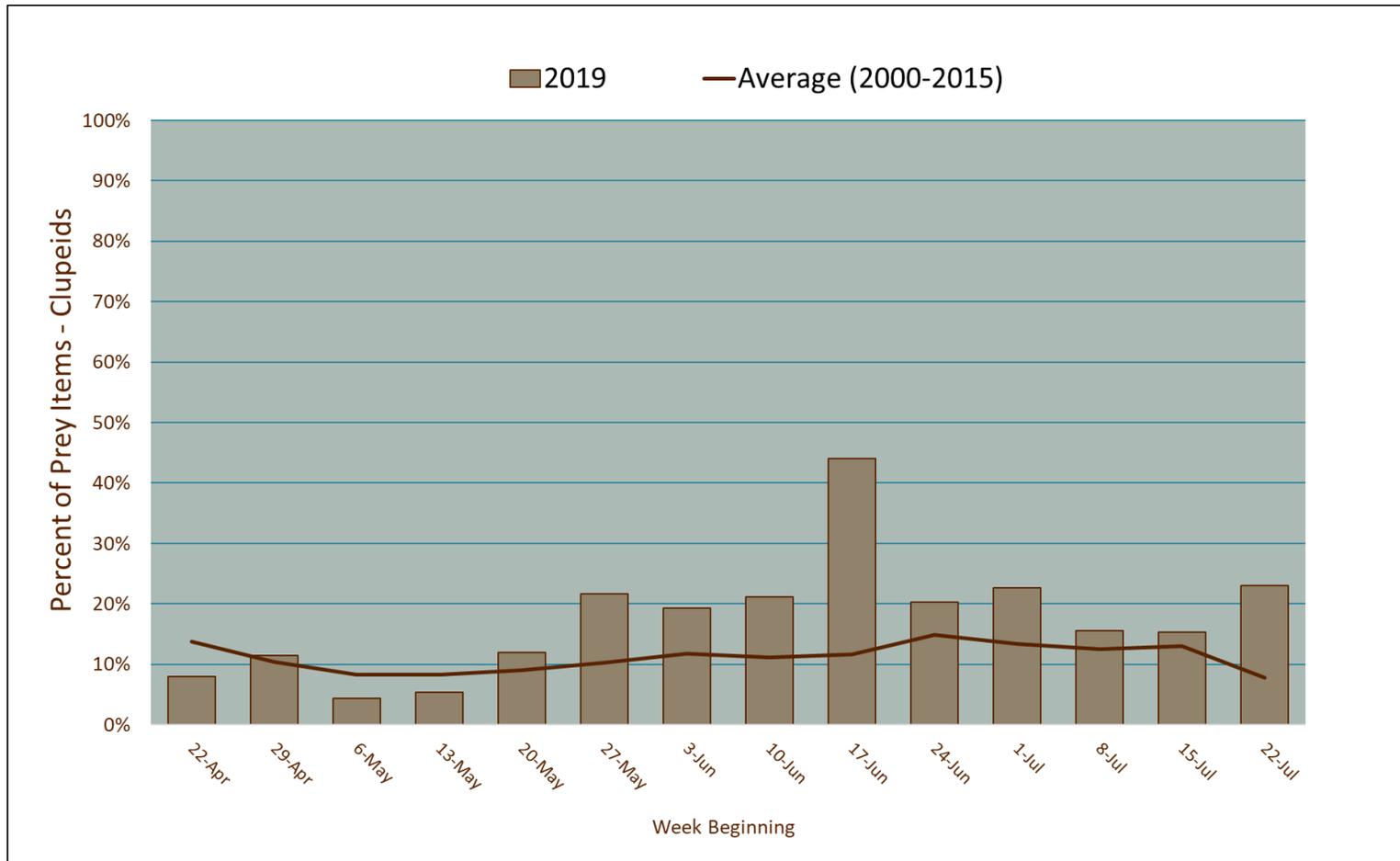


Figure 13. Weekly percentage of clupeids (Clupeidae: herring, sardines, and shad) in the diet of Caspian terns (percent of identified bill-loads) nesting at the East Sand Island colony in the Columbia River estuary during the 2019 breeding season. Clupeids comprised a greater proportion of the tern diet compared to the long-term average in 10 of 13 one-week periods during the nesting season, beginning in mid-May.

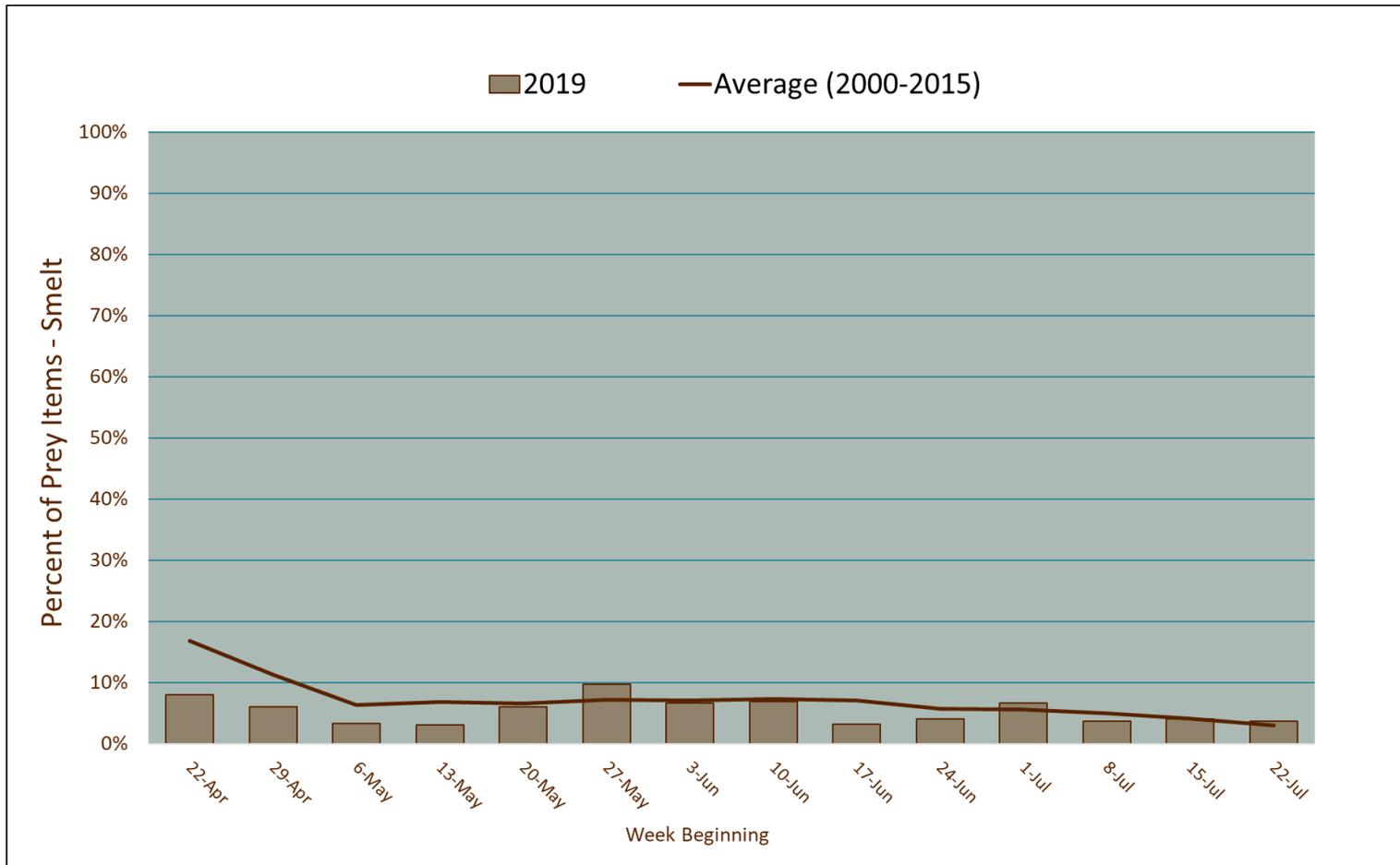


Figure 14. Weekly percentage of smelts (*Osmeridae*) observed in the diet (percentage of identified bill-loads) of Caspian terns nesting at the East Sand Island colony in the Columbia River estuary during the 2019 breeding season. During most of the 2019 nesting season smelt comprised a proportion of the tern diet similar to the long-term average, with the exception of the first four weeks of the nesting season, when smelt were a smaller proportion of the diet.

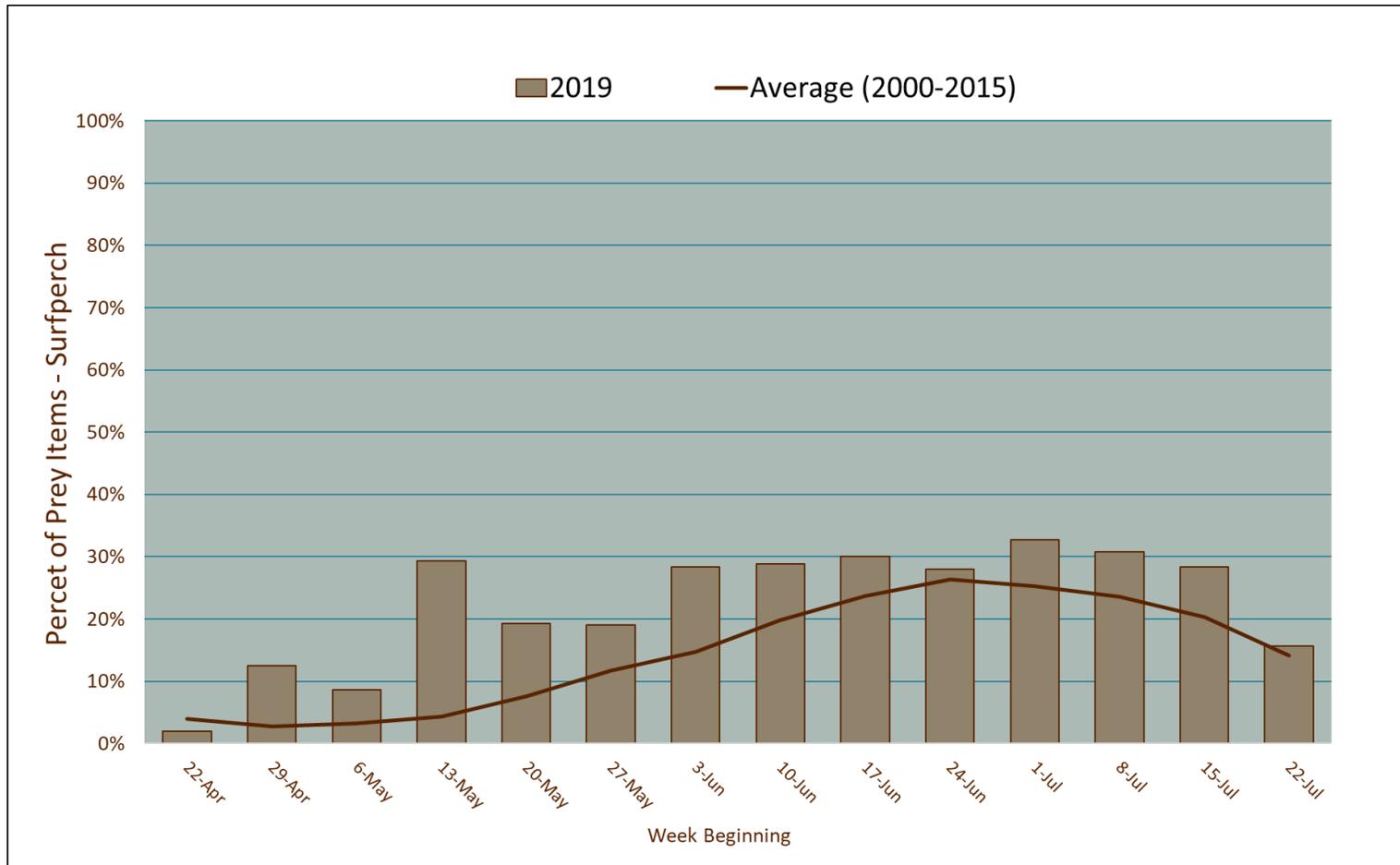


Figure 15. Weekly percentage of surfperch (*Embiotocidae*) in the diet (percent of identified bill-loads) of Caspian terns nesting at the East Sand Island colony in the Columbia River estuary during the 2019 breeding season. Surfperch comprised a greater proportion of the tern diet nearly throughout the 2019 nesting season compared to the long-term average, with the exception of the first week of the nesting season.

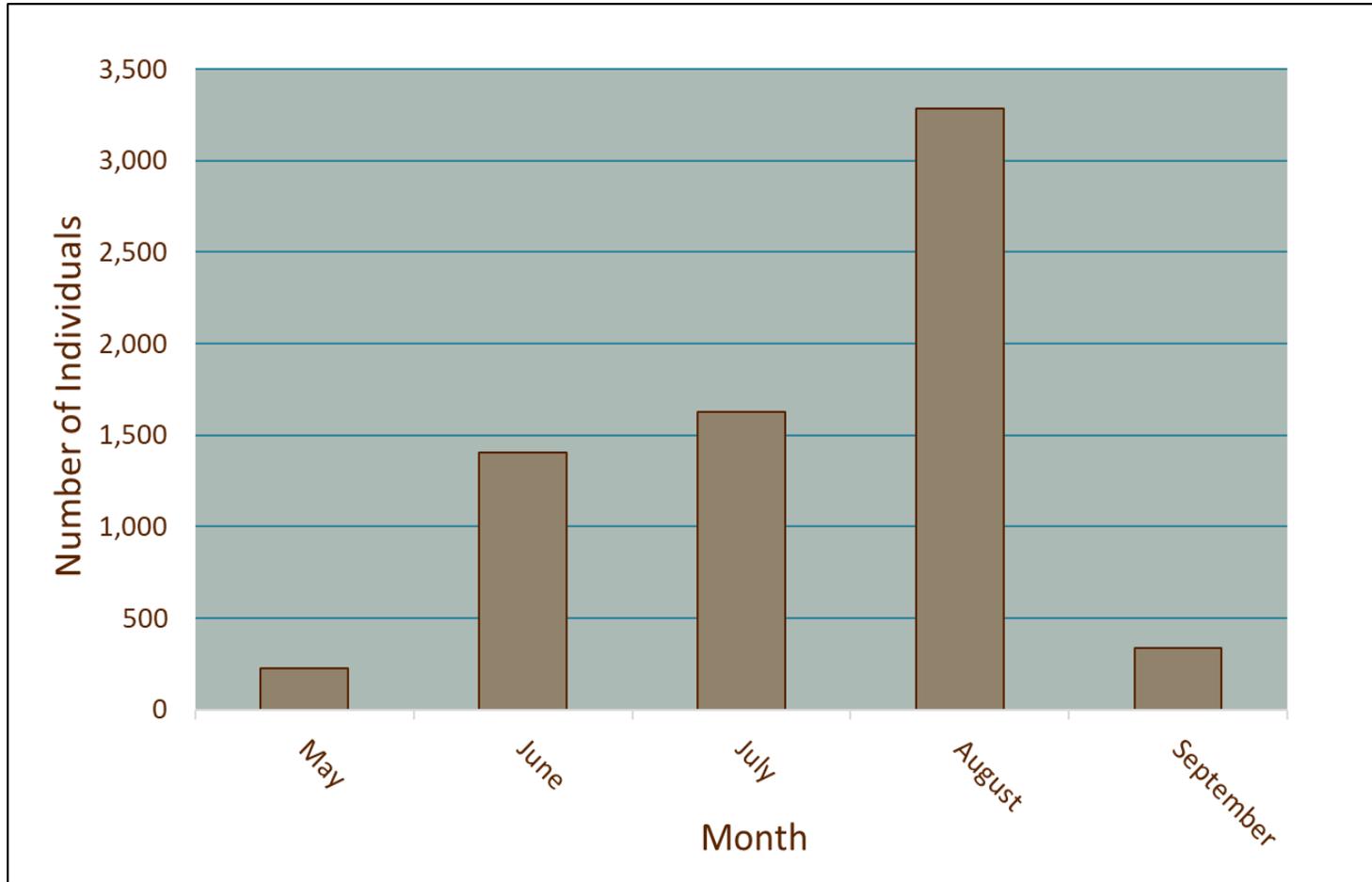


Figure 16. Estimates from monthly boat-based surveys of the number of roosting California brown pelicans on East Sand Island in the Columbia River estuary during the 2019 field season.

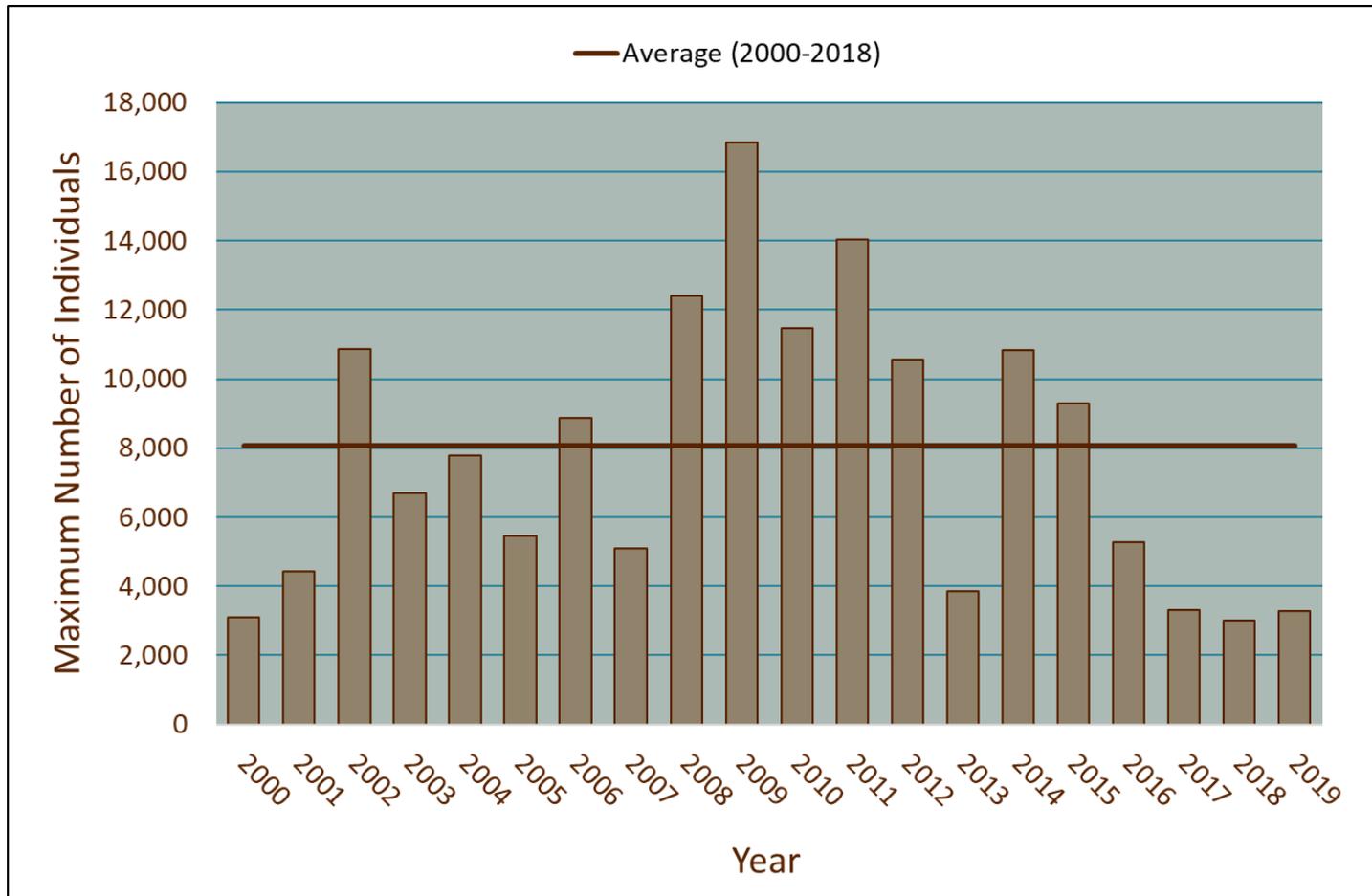


Figure 17. The annual maximum number of roosting California brown pelicans counted during boat-based surveys at East Sand Island in the Columbia River estuary during the 2000-2019 field seasons as compared to the average for 2000-2018.

## TABLES

Table 1. Estimated colony size (number of breeding pairs) and nesting density (nests/m<sup>2</sup>) for Caspian terns nesting on East Sand Island in the Columbia River estuary during 2000-2019. Potential error of the estimates is expressed as the 95% confidence interval (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
2016	5,915	5,410	6,425	1.36	1.31	1.41
2017	3,500	3,200	3,900	0.97	0.87	1.06
2018	4,959	4,682	5,236	1.23	1.16	1.29
2019	3,861	3,667	4,055	1.11	1.06	1.17
Average (2000-2018)	7,847	7,252	8,447	0.82	0.76	0.88

Table 2. Numbers of banded Caspian terns resighted at East Sand Island in 2019 and the colony locations where they were originally banded with unique alphanumeric, colored leg-bands during the 2005-2016 breeding seasons.

Colony where banded	Banded as adults	Banded as chicks	Total
East Sand Island, Columbia River estuary, OR	96	112	208
Crescent Island, mid-Columbia River, WA	10	2	12
Goose Island – Potholes Reservoir, WA	7	0	7
Port of Bellingham, WA	0	2	2
Brooks Island, San Francisco Bay, CA	0	2	2
Sheepy Lake, Lower Klamath NWR, CA	0	1	1
Total	113	119	232

Table 3. Numbers of color-banded Caspian terns seen at East Sand Island in 2018 and resighted during the 2019 breeding season at nesting or roosting sites. Terns were banded during the 2005-2016 breeding seasons with colored leg-bands engraved with unique alphanumeric codes. A total of 214 banded terns that were seen on East Sand Island in 2018 were resighted in 2019; one of these banded terns was resighted at two separate locations in 2019.

Location where resighted in 2019	Banded as adults	Banded as chicks	Total
East Sand Island, Columbia River estuary, OR	109	103	212
Blalock Islands, mid-Columbia River, OR	3	0	3
Total	112	103	215