

# Implementation 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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*2018 Final Annual Report*



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**Submitted By:** U.S. Geological Survey – Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, & Real Time Research, Inc.

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ESA-listed Salmonids by Caspian Terns Nesting at East Sand Island,  
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Daniel D. Roby, Principal Investigator  
U.S. Geological Survey - Oregon Cooperative Fish and Wildlife Research Unit  
Department of Fisheries and Wildlife  
Oregon State University  
Corvallis, Oregon 97331-3803  
E-mail: [daniel.roby@oregonstate.edu](mailto:daniel.roby@oregonstate.edu)  
Telephone: 541-737-1955

Ken Collis, Co-Principal Investigator  
Real Time Research, Inc.  
1000 S.W. Emkay Drive  
Bend, Oregon 97702  
E-mail: [ken@realtimeresearch.com](mailto:ken@realtimeresearch.com)  
Telephone: 541-719-1652

Timothy J. Lawes, Kirsten S. Bixler, Donald E. Lyons, Yasuko Suzuki,  
and Jordan Scheibe  
Oregon Cooperative Fish and Wildlife Research Unit  
Department of Fisheries and Wildlife  
Oregon State University  
Corvallis, Oregon 97331-3803

Aaron Turecek and Mike Hawbecker  
Real Time Research, Inc.  
1000 S.W. Emkay Drive  
Bend, Oregon 97702

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## EXECUTIVE SUMMARY

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The primary objective of this study in 2018 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. The goal of these management actions is to reduce tern predation rates on ESA-listed juvenile salmonids (*Oncorhynchus* spp.) in the estuary. First, with guidance from the responsible resource management agencies, we delineated and prepared 1.0 acres of bare ground habitat for terns to nest on at East Sand Island. Then we attempted to prevent nesting by terns on East Sand Island outside that designated 1.0-acre nesting area, while monitoring for potential effects of tern management actions on other colonial waterbirds that nest and roost on the island. We also monitored tern nesting activity on East Sand Island throughout the tern nesting season and assessed tern diet composition and factors that limited tern colony size and nesting success. Lastly, we monitored inter-colony movements and dispersal patterns of Caspian terns from East Sand Island to evaluate the efficacy of management implemented to disperse nesting Caspian terns to alternative colony sites outside the Columbia River basin.

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 2018 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 habitat to 1.0 acres of suitable nesting habitat at East Sand Island, while preventing Caspian terns from colonizing other sites in the Columbia River estuary (USACE 2015a). As part of this plan, we delineated 1.0 acres of lightly vegetated habitat and, using disking and rototilling, created 1.0 acres of bare-ground nesting habitat for Caspian terns on East Sand Island prior to the 2018 nesting season; the same surface area of nesting habitat was provided for terns during the 2015-2017 nesting seasons. One acre of nesting habitat is 20% of the area of habitat prepared for terns on East Sand Island prior to the implementation of the management plan in 2008.

Caspian terns arrived on the East Sand Island colony and initiated nesting late in 2018 compared to previous years. The tern colony slowly grew to a peak size (number of breeding pairs) in mid-June, when about 4,959 breeding pairs (95% c.i. = 4,682 – 5,236 breeding pairs) were estimated to be nesting at the East Sand Island colony. The number of breeding pairs on the colony then slowly declined until the colony area was vacated for the season in early September. The 2018 colony size estimate is significantly larger than the 2017 estimate of peak colony size on the 1.0-acre colony area (3,500 breeding pairs), and 13-59% greater than the management objective of 3,125-4,375 breeding pairs for the tern colony on East Sand Island. At peak colony size, tern nesting density on the 1.0-acre designated colony area averaged 1.23 nests/m<sup>2</sup> (95% c.i. = 1.16 – 1.29 nests/m<sup>2</sup>), significantly greater than average nesting density in 2017 (0.97 nests/m<sup>2</sup>), but significantly lower than the average nesting density in 2016 (1.36 nests/m<sup>2</sup>). Although productivity (average number of fledglings raised/nesting pair) was much

lower than the long-term average, some Caspian tern young were raised at the East Sand Island colony in 2018 despite high Columbia River discharge, which negatively affects forage fish availability, and frequent disturbance of the tern colony by bald eagles (*Haliaeetus leucocephalus*) early in the breeding season.

Before and during the 2018 nesting season, we installed a total of 3.81 acres of passive tern nest dissuasion materials (posts, rope, and flagging) in a successful effort to limit tern nesting on East Sand Island to just the 1.0 acres of designated tern nesting habitat. Any Caspian terns that attempted to nest on the eastern half of East Sand Island outside the 1.0-acre designated colony site were actively hazed by members of our field crew to further discourage nesting. This was the fourth breeding season that we were tasked with Caspian tern nest dissuasion activities as part of BPA-funded monitoring and evaluation on East Sand Island, and the second year that those efforts were effective in preventing any Caspian terns from successfully nesting outside the 1.0-acre designated colony area. In 2015 and 2016, satellite tern colonies became established, at least briefly, outside the designated 1.0-acre colony area; those satellite colonies supported a total of 810 breeding pairs and 700 breeding pairs in 2015 and 2016, respectively.

The average proportion of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island during the 2018 nesting season was 40% (percent of identified prey items), somewhat higher than the salmonid proportion in 2017 (36%), and more similar to the proportion in 2015 (38%; no diet composition data were collected in 2016). During all three of these years, the average proportion of juvenile salmonids in the diet of terns nesting at East Sand Island has been higher than the long-term average (31%) measured during the 2000-2014 breeding 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 50% of all identified bill-loads in the diet of terns nesting on East Sand Island in 2018. 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 2018 compared to the long-term average.

Bioenergetics calculations to estimate total smolt consumption by Caspian terns nesting at East Sand Island in 2018 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 2018 were investigated by recovering smolt PIT tags from the surface of the tern colony after the breeding season. That study was funded separately by the U.S. Army Corps of Engineers – Portland District, and study results will be presented as part of a separate report to that funding agency.

Resightings of previously-banded Caspian terns on East Sand Island during the 2018 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 throughout the Pacific Flyway, especially the two managed colony sites in the Columbia Plateau region: Goose Island and Crescent Island. Resightings of banded terns in 2018 that were seen on East Sand Island during the 2017 breeding season indicate that some adults are dispersing from the East Sand Island colony to alternative 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 2018, however, so the level of connectivity between the East Sand Island colony and other colonies throughout the region during the 2018 breeding season is unknown.

## INTRODUCTION

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Piscivorous colonial waterbirds (i.e. terns, cormorants, gulls, pelicans) are documented as having a significant impact on survival of juvenile salmonids (*Oncorhynchus* spp.; salmon and steelhead) in the lower Columbia River (BRNW 2005-2018). 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.

A management plan 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 it was believed 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, except for three nesting pairs that laid a total of four eggs on Rice Island in 2011 (BRNW 2012). During 2015-2017, larger numbers of terns attempted to nest on Rice Island, but were unsuccessful in rearing any young (P. Schmidt, USACE, pers. comm.). 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), 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).

Additional management of Caspian terns to reduce losses of juvenile salmonids in the Columbia River estuary is now complete; the Records of Decision (RODs) for *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 in tern nesting habitat at East Sand Island be gradually phased in at a 2:1 ratio (area:area) with the expectation that there would be a redistribution of approximately 60% of the East Sand Island tern colony to alternative colony sites outside the Columbia River basin in Oregon and California (USFWS 2005, USFWS 2006, USACE 2006, USACE 2015a, USACE 2015b). This management action was intended to reduce smolt losses to Caspian terns in the estuary,

while 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 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 Corps has gradually reduced the area of suitable nesting habitat for Caspian terns on East Sand Island from 5 acres in 2008 to 1.0 acres during the 2015–2018 breeding seasons, and has implemented nest dissuasion measures to prevent Caspian terns from establishing new nesting colonies elsewhere in the Columbia River estuary.

The primary objectives of this study in 2018 were to monitor and evaluate management implemented to reduce the number of Caspian terns nesting on East Sand Island and, therefore, reduce tern predation on ESA-listed juvenile salmonids (*Oncorhynchus* spp.) in the Columbia River estuary. First, with guidance from resource management agencies, we delineated 1.0 acres of unvegetated nesting habitat for terns to use on East Sand Island, attempted to prevent nesting by terns outside that designated nesting area, and monitored the potential effects of management activities on the other colonial waterbirds that nest and roost on East Sand Island. Second, we monitored tern nesting activity on the designated East Sand Island colony and evaluated tern diet composition and factors that limit colony size and nesting success. Lastly, we assessed inter-colony movements and dispersal patterns of banded Caspian terns to evaluate the efficacy of management implemented to disperse nesting Caspian terns from the East Sand Island colony to alternative colony sites outside the basin.

## 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, 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) – Walla Walla District, 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 that are 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). 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, 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 Caspian Tern Management Plan for the Columbia River estuary called for the creation of approximately 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 River basin, the available nesting habitat for Caspian terns on East Sand Island would be reduced from its initial size (approximately 5 acres in 2008) to 1 acre (*Map 3*).

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, 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 reduction on East Sand Island are 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) and five Corps-constructed tern islands in Don Edwards San Francisco Bay NWR in central California (*Map 2*).

## Section 1. Habitat Preparation

**Methods:** As part of the plan entitled *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*, we delineated and prepared approximately 1.0 acres of unvegetated nesting habitat for Caspian terns on East Sand Island just prior to the 2018 breeding season (*Map 4*). Storm surge caused substantial erosion along the southern edge of the former colony area during the winter of 2017-2018. In response, the Caspian Tern Adaptive Management Team (Tern AMT) provided instructions to shift the prepared colony area to the northeast by covering the narrow western-most extent of the former colony area with passive dissuasion materials, removing the access tunnel and old dissuasion fence rows from the eastern edge of the former colony area, and roto-tilling and applying pre-emergent herbicide to prepare replacement habitat terns on East Sand Island in 2018. Pre-season tilling and disking of vegetated areas was limited to the newly prepared nesting habitat required to shift the 1-acre colony area to the northeast, and disking was used to remove encroaching vegetation along the northern edge of the delineated colony area (*Map 5*). Shifting the location of the 1 acre of Caspian tern nesting habitat in 2018 resulted in a more oval-shaped colony area that did not have the narrower, more elongated shape as in 2017. Because much of the access tunnel along the eastern edge of the former colony area was removed, the observation blind that had been situated on the southeastern edge of the colony was moved on the eastern edge of the colony and a new access tunnel to the blind was built in 2018.

The boundaries of the designated 1-acre tern nesting area were adjusted in 2018 through the placement of fabric fencing on the edge of the colony area to create a visual barrier for Caspian terns that might land on the ground outside the fences. Fences were constructed by driving 6-foot fence posts into the ground to depths of at least 2 feet, spaced 6-8 feet apart, with each length of fence securely anchored at both ends using a diagonal bracing system (Wedge-Loc®). Three strands of taught, barbless wire were secured to the fence posts at ground level, at 18 inches above ground level (AGL), and at 36 inches AGL. Commercial grade knitted fabric material (PAK Unlimited Inc.; 90% privacy screen), manufactured with finished and grommeted edges, was used on East Sand Island in 2018 for the third year, replacing woven fabric “silt” fence or “landscape fabric” material used in previous years. The knitted fabric material, which is more durable and not prone to fraying like woven silt fence material, was attached with heavy duty UV resistant zip ties to the top and bottom wire strands. Placement of fabric fences served to delineate the 1.0-acre designated colony area, dissuade Caspian terns from nesting between parallel fence rows, and prevent the expansion of tern nesting beyond the designated 1.0-acre colony area onto adjacent potential nesting substrate that was covered with additional passive dissuasion materials (posts, rope, and flagging).

To prepare the colony area in 2018, the southern edge of the colony area was moved about 2 meters north of the southern edge of the colony area in 2017, the western edge of the colony was moved about 30 meters east of the western edge in 2017, and about 0.2 acres of new bare

ground nesting habitat was created on the eastern edge of the former colony area. The southern edge of the colony was delimited by an 85-m row of fabric fence that extended from near the southeastern corner of the colony area to the southwestern corner. A short 17-m fabric fence was installed to delimit the western edge of the designated colony area. As in previous years, the northern edge of the 1.0-acre designated colony area was defined by well-established stands of European beach grass (*Ammophila arenaria*). The eastern edge of the colony area was delimited by the above-ground access tunnel used by the field crew to access the eastern observation blind, a newly installed 23-m length of knitted fabric fence, and a 20-m length of previously installed landscape fabric fencing (*Map 5*).

Preparation of unvegetated nesting habitat for Caspian terns was accomplished using a hand-driven rototiller and a 4-wheel drive ATV pulling a disc harrow, with oversight from the Tern AMT. The rototiller and disc harrow were used on the newly created portion of the 1.0-acre designated colony area to break-up established vegetation. The disc harrow was also used around the edges of the colony area to break-up any encroaching vegetation (*Map 5*). Rototilling and disking was limited to specific portions of the designated colony area that were pre-approved by the Tern AMT in 2018; rototilling occurred to a depth of approximately 12 inches and disking occurred to a depth of approximately six inches. Unlike the 2013-2017 nesting seasons, the edges of the colony and newly rototilled habitat were 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 2015–2018 nesting seasons was approximately 1.0 acres, representing an 80% reduction in tern nesting habitat compared to pre-2008, before implementation of the tern management plan.

**Results and Discussion:** Preparation of approximately 1.0 acres of unvegetated nesting habitat for Caspian terns on East Sand Island was completed on 18 April; field measurements using a Garmin Etrex 10 GPS unit returned an area of 1.0 acres, but subsequent ArcGIS measurements of ortho-rectified aerial images returned an area of 1.01 acres of prepared nesting substrate. (The 0.01-acre difference is equivalent to a 1-foot difference in the positioning of the southern fence-line border, which was beyond the accuracy level of the handheld GPS unit but within the range of variation about the designated colony sizes of past delineations.) As instructed by the Tern AMT, 1.0 acres of tern nesting habitat was delineated and tilling of the colony surface was restricted to the 0.2-acre area of newly created habitat on the east edge of the colony and the periphery of the colony (*Map 5*). Tilled areas were sprayed with pre-emergent herbicide retard or stop the regrowth of vegetation; spraying was conducted by a USACE contractor on 02 April under the supervision of a USACE employee. Access to the colony area by the field crew was restricted for several days following the herbicide application to allow for root absorption of the herbicide. The final step in colony preparation involved dragging a section of chain-link fence over the colony surface to remove debris deposited during the winter and smooth the tilled areas. Approximately 20-25% of the designated colony area was rototilled or disked prior to the nesting season in 2018.

Some regrowth of herbaceous vegetation was observed within the 0.2-acre tilled area at the eastern edge of the colony, but the pre-emergent herbicide was more effective at controlling

regrowth of beach grass at the periphery of the colony area. In addition, some soil creep of the herbicide along the northern edge of the prepared colony area may have also suppressed the growth of beach grass in areas near the observation blinds that were expected to quickly fill in with vegetation during the breeding season (*Map 6*). In 2018, terns initiated nesting over most of the prepared 1.0-acre colony area and expanded into sparsely vegetated areas of unprepared habitat along the northern edge of the colony. Fabric fencing that was installed in combination with adjacent passive dissuasion materials to delimit the boundaries of the prepared tern nesting area remained intact and effective over the entire tern nesting season.

## Section 2. Passive Nest Dissuasion

**Methods:** To restrict nesting by Caspian terns on East Sand Island to just the designated 1.0-acre colony area, we deployed passive tern nest dissuasion materials on potentially suitable nesting habitat prior to the initiation of the 2018 tern nesting season. Maps depicting the placement of passive nest dissuasion materials in 2017 were used as an initial guide for placement of materials in 2018, with adjustments made for changes in the location of suitable tern nesting habitat since the previous breeding season. Passive dissuasion was re-installed in areas where there was a possibility of Caspian terns nesting (i.e. little to no vegetation encroachment) and installed in new areas where annual accretion of shifting sand created potential tern nesting habitat not present in 2017. Prior to installation, areas where passive nest dissuasion materials were to be deployed on both the east and west ends of East Sand Island were approved by representatives of both the U.S. Army Corps of Engineers - Portland District and the Bonneville Power Administration.

On the east side of East Sand Island, passive tern nest dissuasion materials were deployed during 17 March - 18 April. The materials used consisted of a combination of posts, rope, and flagging installed over areas of bare ground and sparsely vegetated habitat, and between parallel rows of fabric fencing installed adjacent to the designated 1.0-acre tern nesting area. Passive dissuasion was placed on both upland areas near the 1.0-acre designated colony area and upper beach areas extending to, and sometimes below, the approximate high tide line. In most areas where passive dissuasion was installed on East Sand Island, installation consisted of a grid of 4-foot or 6-foot metal t-posts and u-posts (supplied by the USACE) connected with yellow twisted 0.25-inch polypropylene rope to form a 10' by 10' grid of squares (cells). Also, each cell was crossed diagonally with rope. Ropes were attached to posts using clove hitch knots that allowed for rapid installation, secure attachment, and easy removal. Then 4-foot lengths of industrial barricade tape (polyethylene flagging; hereafter "flagging") were inserted between strands of the rope at approximately 3-foot intervals, leaving 2-foot lengths to move freely with the wind. Where passive nest dissuasion was needed on beach locations deemed likely to be inundated during spring tides series, 1-inch to 1.3-inch diameter bamboo posts and 0.25-inch manila rope were substituted for metal posts and polypropylene rope to reduce the amount of synthetic material washed away or buried by tidal action. More liberal deployments of passive nest dissuasion materials were installed directly adjacent to the designated 1.0-acre colony area and in locations where satellite tern colonies had formed in 2015 or 2016. Liberal application of passive dissuasion materials included fabric

fences installed to create visual barriers, a double layer of ropes and flagging, and/or placement of passive dissuasion (posts, rope, and flagging) on areas below the high tide line. A fence row oriented east/west was installed on a portion of the historical colony area to create a visual barrier on highly suitable nesting substrate directly adjacent to the south edge of the 1.0-acre designated colony area in 2018 (*Map 7*). A layer of rope and flagging was suspended between the parallel fence rows as an additional nesting deterrent. Areas of suitable nesting substrate directly south and southeast of the main tern colony, where numerous tern nesting attempts occurred in previous years, were covered with a double layer of rope and flagging.

On the west side of East Sand Island, passive tern nest dissuasion materials were deployed during 28 March – 02 April. Dissuasion materials deployed on the west end of the island consisted of 10' x 10' arrays of posts with a single layer of rope and flagging (as described *above*) installed largely in upland areas down to the high tide line (*Map 8*).

Supplemental passive dissuasion materials were held in reserve, to be deployed as a response to Caspian tern nest prospecting on any areas without passive nest dissuasion and outside of the 1.0-acre designated colony area. Daily active hazing and on-island monitoring for Caspian tern nesting activity outside of the designated colony area were conducted only on the east end of East Sand Island. Observations of tern breeding behaviors elicited consultation with the USACE Contacting Officer's Representative (COR) regarding the potential for in-season installation of supplemental passive dissuasion materials.

Removal of passive nest dissuasion materials after the nesting season occurred in stages from 11 July through 06 November, based on observations of Caspian tern nest prospecting behavior and the breeding status of other nesting bird species on the island. Following the protracted breeding seasons of Caspian terns, double-crested cormorants, and Brandt's cormorants on East Sand Island in 2018, all posts, rope, flagging, and all fabric fences installed as passive tern nest dissuasion were disassembled and consolidated for storage. All used flagging, heavily worn or frayed rope, and a limited number of broken and bent posts were removed from the island and discarded at a waste disposal facility. Serviceable posts were stacked neatly and covered with tarps on the east and west ends of East Sand Island. Reusable rope was re-spooled for future use. Used spooled rope and remaining passive dissuasion materials, including the woven fabric fencing and unused flagging, were removed from the island and stored at the USACE warehouse on Liberty Lane in Astoria, OR.

*Results and Discussion:* A total of 2.73 acres of passive dissuasion was deployed on East Sand Island prior to the initiation of nesting by Caspian terns in 2018 (*Map 8*). Another 0.11 acres of double-row passive dissuasion was installed along the south beach adjacent to the 1.0-acre prepared colony area on 23 March and again on 15 April; however, each time this passive dissuasion was washed out by high tides that extended to the cut-bank along the edge of the main colony area, and passive dissuasion materials were not reinstalled along the southern edge of the colony until the end of May (*Map 9*). Despite the delay to the installation of passive dissuasion adjacent to the southern edge of the colony, an area of high risk for tern nesting outside of the 1.0-acre prepared colony area, no satellite tern colony formed in that area during

the 2018 nesting season. Similar to 2017, the primary factors that prevented terns from nesting immediately adjacent to the 1.0-acre designated colony area in 2018 included dense beach grass to the north, installed fabric fence rows and passive dissuasion to the west, an access tunnel, fence rows, and dense vegetation to the east, and a combination of installed fence rows, double-layered rope and flagging, a steep cut bank at the top of the beach, and a dense accumulation of driftwood to the south (*Map 7*). In 2018, terns avoided nesting near the fence rows along the western and southern edges of the delineated colony as well as directly in front of the eastern observation blind; however, approximately 50 nesting attempts by terns occurred just outside and directly adjacent to the designated 1.0-acre colony area, where terns laid eggs along the sparsely vegetated ground along the northern edge of the colony that had been sprayed with pre-emergent herbicide prior the start of the breeding season (*Map 10*). Given the pattern of edge avoidance by nesting terns on three sides of the colony and the slight expansion into beach grass substrate on the north side of the colony, Caspian terns nested over an area of 1.0 acres at the designated colony site.

As river discharge and tidal amplitudes decreased during the breeding season, additional tern nesting habitat was exposed on areas of accreted sand, and field observations of Caspian tern breeding behaviors on the east end of East Sand Island, including egg-laying, resulted in consultations with the USACE's COR. A total of 13 different installations of supplemental passive nest dissuasion materials covering 1.08 acres (*Map 8*) occurred following these consultations. Supplemental tern nest dissuasion materials were deployed during 4 May - 8 June, adjacent to existing passive dissuasion that was installed prior to the arrival of terns. On 4 May, 70 cells of supplemental nest dissuasion were installed on the southeast beach in response to nest prospecting by Caspian terns; similar to the south beach adjacent to the colony, this area had been subject to inundation during high tides until the first week of May and was not available as suitable nesting habitat for terns until then. An additional 158 cells of supplemental passive dissuasion were deployed during five installations in response to continued Caspian tern nest prospecting and egg-laying through 31 May. In June, another 197 cells of supplemental dissuasion were deployed during seven additional installations. The installation of 1.08 acres of supplemental passive dissuasion during the breeding season brought the total area of passive nest dissuasion deployed on East Sand Island during the 2018 nesting season to 3.81 acres. By 11 July, nest scraping and egg laying attempts had abated on the east beach, and removal of passive dissuasion materials began in that area. Removal of all passive dissuasion materials from the beaches on the east end of East Sand Island was completed on 14 September. Removal of all passive dissuasion from the beaches on the west end of East Sand Island was completed on 06 November.

During the 2015 and 2016 nesting seasons, sizeable satellite nesting colonies of Caspian terns formed outside the prepared 1.0-acre designated colony area at East Sand Island. In 2017, however, tern nest dissuasion efforts were more effective at deterring satellite colony formation due to extensive deployment of passive nest dissuasion materials on areas where social attraction had previously contributed to the formation of satellite colonies. Also, in 2017 the main Caspian tern colony on East sand Island completely failed to raise any young, and the colony site was temporarily abandoned for a 10-day period. The nesting failure on the

designated 1.0-acre colony area was associated with a combination of high river discharge and reduced marine forage fish availability, which was coupled with intense predation pressure in the form of bald eagle disturbances and subsequent nest depredation by glaucous-winged/western gulls. In 2018, extensive pre-arrival deployment of passive dissuasion in areas that proved successful in 2017, along with frequent monitoring and rapid deployment of supplemental dissuasion in areas of interest to prospecting terns, again aided in preventing the formation of satellite colonies outside of the 1.0-acre prepared colony area. This was despite the large number of tern eggs laid on the south beach adjacent to the main colony area in 2018 (see Active Nest Dissuasion section below for details).

Installation of passive nest dissuasion materials along the south beaches of East Sand Island prior to the arrival of Caspian terns was hindered by changes in beach elevation and erosion caused by estuary currents and storm surges during the previous winter, combined with high river discharge that amplified the reach of high tides during spring tide series in 2018. Several efforts were made to install passive dissuasion materials on the upper beach along the southern shoreline prior to the arrival of the terns, only to have them washed out by high tide events. The field crew was unable to install permanent passive dissuasion adjacent to the main tern colony until 31 May, at which time a 0.05-acre strip of passive dissuasion (11 cells of double layer and 11 cells of single layer) was installed to about the mid-point of the south edge of the main colony. Field crew access further west was not possible without causing a major disturbance to the main tern colony. Subsequently, there was about 40-m of potential tern nesting habitat on the south beach adjacent to the prepared colony area that had been covered with passive dissuasion in 2017, but remained uncovered in 2018. Later, this area became inaccessible to active hazing walk-throughs by the field crew as well, and terns prospecting on this section of beach could only be hazed using a green laser from a distance due to the sensitivity of the tern colony to human activity in that area (see Active Nest Dissuasion section below for details).

We found no evidence that brown pelicans or other bird species became entangled in passive nest dissuasion materials during the 2018 field season. Not only were no bird entanglements in passive dissuasion materials detected by field personnel during the breeding season, there was no evidence of entanglements when dissuasion materials were later disassembled and removed for storage.

### Section 3. Active Nest Dissuasion

*Methods:* In addition to passive nest dissuasion methods, we used active dissuasion (i.e. hazing) to prevent Caspian terns from initiating nests outside of the designated 1.0-acre prepared colony area at the east end of East Sand Island. We surveyed the east end of East Sand Island for terns prospecting for nest sites daily from 20 April to 30 July, and then 2-5 days per week throughout August. The number of active dissuasion sessions, their timing and duration, and the spatial extent of active hazing conducted by field technicians were adjusted on a daily basis depending on the number, location(s), and behaviors of Caspian terns present outside the 1.0-acre designated colony area.

In addition to Caspian terns, we monitored the presence and nesting status of other waterbird species at the east end of East Sand Island. Our active hazing efforts were adapted to avoid disturbances that might cause egg loss (i.e. incidental take) at any Caspian tern, gull, or California brown pelican nests initiated on or outside the designated 1.0-acre tern colony. 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 2018 breeding season. We monitored for potential brown pelican nesting activity from several vantage points on the east side of East Sand Island and by conducting island-wide boat-based surveys for brown pelicans periodically (approximately every two weeks) from mid-May through early September. These surveys were also used to estimate the peak number of California brown pelicans that roosted on East Sand Island during the 2018 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.

We used human hazing (i.e. “walk-throughs”) as our primary method of active dissuasion. Surveys for prospecting Caspian terns were conducted on foot by field personnel, and hazing was used to flush Caspian terns from potential nesting substrate outside the designated colony area. If prospecting Caspian terns were discovered during a survey, field staff first attempted to determine if tern eggs had been laid in the area. If it was determined that no tern eggs had been laid, field personnel hazed terns by approaching slowly to flush the birds and then searched the area for evidence of nest scraping. If nest scrapes were found, they were counted and covered over (i.e. smoothed over or filled with sand). If tern eggs were discovered, field personnel counted the number of eggs, documented location, and left the area immediately to avoid causing nest failure (loss of tern eggs) due to abandonment or depredation by gulls. Field personnel would then observe the egg from a safe distance in an attempt to document nest fate. When Caspian tern behavior suggested the potential for formation of a satellite tern colony, field personnel notified project supervisory staff who then consulted with the Corps’ COR regarding the need to install supplemental passive dissuasion at the site where terns were prospecting. We used a green laser as a secondary method of active dissuasion when terns were present in areas that were not accessible by foot without causing disturbances to the main tern colony. However, the green laser was only effective as a dissuasion technique during periods of low ambient light (i.e. dawn and dusk).

In order to facilitate data collection during active hazing sessions, we subdivided the east end of East Sand Island into eight survey zones. The survey zones were identified as the “North Beach,” “Northeast Beach,” “East Beach,” “Southeast Beach,” “South Beach,” “West Inland,” “East Inland,” and “Below Tide-line” (*Map 11*). Although the potential tern nesting habitat below the high tide-line would not have been suitable for the formation of a satellite tern colony because of inundation, we monitored Caspian tern numbers and activity in that area to document trends in the total numbers of Caspian terns present at the east end of the island outside of the designated 1.0-acre colony area.

*Results and Discussion:* Caspian tern numbers and observations of tern breeding behavior varied among the eight zones monitored on the east end of East Sand Island in 2018 (*Figure 1*). In general, areas that were the focus of intensive tern nest prospecting and egg-laying in 2017 were again the areas where the highest tern nesting activity was observed in 2018. A total of 84 Caspian tern eggs were discovered outside the 1.0-acre designated colony area on the east end of the island, distributed among four of the eight survey zones, but no satellite tern colonies formed in 2018.

The two inland survey zones (West Inland and East Inland; *Map 11*) located near the designated 1.0-acre colony area were not used by Caspian terns during the 2018 nesting season; this was also the case during the 2017 breeding season. The inland survey zones were heavily vegetated during both years and have limited bare ground habitat suitable for terns to dig nest scrapes. In addition, the heavy use of the two inland zones by nesting glaucous-winged/western gulls, an aggressive nest predator, provided another natural deterrent to Caspian tern nesting in those zones.

Similar to the 2017 breeding season, the use of the North Beach survey zone by prospecting Caspian terns was very limited during the 2018 breeding season. Technicians only observed adult terns on the ground in the North Beach zone during two hazing sessions in 2018, once on 28 April, when a maximum of 20 adult terns were counted, and again on 12 July when 4 adult terns were counted (*Table 1*). Pre-nesting or nesting behaviors were not exhibited by the terns observed in the North Beach survey zone on either of these dates, however, and no Caspian tern nest scrapes or eggs were found in the North Beach survey zone in 2018 (*Table 2*; *Figure 3*). Although the North Beach zone included little nesting habitat for Caspian terns above the high tide line, adult Caspian terns were regularly observed loafing in large numbers on the mud flats exposed during low tide.

In 2018, Caspian tern prospecting in the Northeast Beach zone was infrequent and less extensive compared to the 2017 breeding season, but adult Caspian terns were observed prospecting for nest sites in the upland portion of the Northeast Beach zone from late April to early June. Supplemental passive dissuasion materials were installed in-season to discourage the formation of a satellite colony in this zone. In mid-July, a small number of adult terns ( $n = 31$ ) were observed on the ground near where prospecting behavior had been observed earlier, but no nesting behaviors by Caspian terns or tern nest scrapes were observed after 14 June. During the week of highest nest tern prospecting activity in this zone (28 May to 3 June), on average about 24 individuals were present during hazing sessions (*Figure 1*). A maximum of 125 individual terns were counted in this survey zone on 29 May (*Table 1*), substantially fewer than the maximum of 325 adult terns counted in this zone in 2017. The proportion of tern nest scrapes found in the Northeast Beach zone during the 2018 breeding season accounted for approximately 4% ( $n = 297$ ) of the total nest scrapes ( $n = 6,969$ ) found outside of the 1.0-acre prepared colony area in 2018 (*Table 2*).

The East Beach survey zone was used frequently by prospecting Caspian terns during the 2018 breeding season, but less extensively compared to the 2017 breeding season. In addition, fewer Caspian terns prospecting for nest sites in the East Beach survey zone than in the South Beach and Southeast Beach zones during 2018, and the prospecting behaviors that were observed were predominantly during May and July (*Figure 1*). Nest prospecting by terns in the East Beach zone during 2018 first peaked in May, with a weekly average of 31 individuals counted in that zone during the week beginning 14 May, and spiked again in July with an average of 34 adult terns counted in the week beginning 30 July (*Figure 1*). The maximum count of adult Caspian terns during a hazing session in the East Beach survey zone was 226 individuals in 2018, a decrease from the maximum count of 568 individuals in 2017. In 2018, 6% ( $n = 413$ ) of all tern nest scrapes found and removed were located in the east beach survey zone (*Table 2*). Unlike the South Beach zone and western part of the Southeast Beach zone, where winter currents had eroded the shoreline each year, the East Beach survey zone was an area of sand deposition and accretion during the spring and summer. This pattern of erosion and deposition at East Sand Island resulted in an area of suitable tern nesting habitat that gradually expanded throughout the 2018 breeding season in the East Beach survey zone. Additional passive dissuasion materials were deployed in-season as suitable tern nesting habitat became more available to Caspian terns prospecting in the East Beach survey zone.

Within the Southeast Beach survey zone, Caspian terns prospecting for nest sites at a higher frequency and for a more extended period of time during the 2018 breeding season compared to the 2017 breeding season. Field technicians counted an average of between 1 and 67 individual terns per week in the Southeast Beach zone throughout the 2018 breeding season; however, highest use of the area was recorded in July. The maximum individual count of adult terns in the Southeast Beach zone was over four times greater in 2018 than was observed in 2017; up to 259 individuals were observed in 2018 compared to 60 individuals in 2017. The number of Caspian tern nest scrapes discovered in the Southeast Beach zone accounted for approximately 26% ( $n = 1,828$ ) of all the nest scrapes discovered outside of the 1.0-acre prepared colony area in 2018 (*Table 2*). There was some shoreline erosion along the western part of the Southeast Beach zone during the winter of 2017-2018, which reduced the area of suitable nesting substrate at the beginning of the breeding season to a narrow band between the high tide line and densely accumulated woody debris. There was subsequent sand deposition in the eastern part of this zone, which continued to accrete throughout the breeding season and resulted in an increased area of habitat suitable for tern nest prospecting. We installed additional passive dissuasion materials in-season to cover this potential nesting habitat as it became available due to declining river flows and changes in high tide levels.

As was the case during the 2017 breeding season, the highest incidence of Caspian tern nest prospecting activity outside the designated 1.0-acre colony area during 2018 was within the South Beach survey zone, which abuts the main tern colony. Caspian tern prospecting activity in the South Beach zone was highest at the beginning and the near the end of the 2018 breeding season. During the period from 23 April to 13 May, an average of 132 adult terns were counted in the South Beach survey zone during hazing sessions; from 16 July to 12

August, an average of 120 adult terns were counted in the South Beach survey zone (*Figure 1*). A maximum of 441 adult Caspian terns were counted in the South Beach zone on 3 May (*Table 1*), similar to the maximum count of 490 adult terns in the South Beach zone during the 2017 breeding season. In 2018, 62% ( $n = 4,323$ ) of all tern nest scrapes discovered outside the 1.0-acre designated colony area were in the South Beach zone (*Table 2*); however, that number of tern nest scrapes underestimates the extent of tern nest scraping activity within the South Beach zone. The main tern colony adjacent to this survey zone was highly sensitive to human presence in the South Beach zone and would flush with little provocation. In order to avoid disturbing Caspian terns that were nesting on the designated 1.0-acre colony area, the field crew had limited access to the South Beach zone from mid-July until the end of the breeding season, which hampered their ability to find, count, and remove nest scrapes from the South Beach survey zone. With limited access to conduct hazing walk-throughs, secondary active dissuasion of this zone was conducted using a green laser at dawn and dusk. As was the case in 2017, the majority of Caspian tern nesting attempts by Caspian terns outside the designated 1.0-acre colony area were facilitated by social attraction from the nesting activity on the main tern colony. In 2018, however, the South Beach zone consisted of a narrow band of marginal tern nesting habitat that was subject to tidal inundation early in the breeding season (*Map 9*), and all nesting attempts eventually failed before a satellite tern colony could become established.

In addition to monitoring the zones with suitable nesting habitat on the east end of East Sand Island, we also recorded the total number of Caspian terns present on the exposed sandflats below the high-tide line during each dissuasion walk-through (see *Map 11* for location of each zone). We observed the largest number of terns in the Below Tide-line zone early in the breeding season, whereas the numbers of terns using the sandflats below the high-tide line declined during the peak period of breeding in June, and then increased again as the breeding season progressed (*Figure 2*). Terns observed in the Below Tide-line zone were likely composed of mainly pre-breeding individuals staging on the island early in the breeding season, off-duty adults paired with on-colony mates during the peak of the breeding season, and failed breeders or post-breeding birds later in the season; some unknown proportion of the terns counted in the Below-Tide-line zone were non-breeders that may have been present throughout the breeding season. As in previous years, however, it was not possible to estimate the number of non-breeding Caspian terns present on East Sand Island based on the data collected in 2018. The largest numbers of Caspian terns were typically counted in the Below Tide-line zone during low tide, when a greater area of beach was exposed; the maximum number of terns counted in the Below Tide-line zone during each week of the breeding season is provided in *Table 1*. During high tides, the majority of terns nesting on the colony at East Sand Island were presumably on the 1.0-acre colony area, in one of the above tide-line beach zones, or foraging away from the 1.0-acre colony area.

A total of 6,969 Caspian tern nest scrapes were discovered by field crew members on the beaches outside the 1.0-acre designated colony area on the east end of East Sand Island during the 2018 nesting season. This was a substantial increase from the 2,339 nest scrapes reported in 2017; however, the increased count of nest scrapes in 2018 was due in part to a

protocol modification that resulted in the counting of even the most rudimentary and undeveloped of tern nest scrapes, scrapes that might not have been counted during the 2017 breeding season. In 2018, of the 6,969 nest scrapes that were found and covered over, 21 nest scrapes were located below the most recent high tide line and would likely have been inundated during the next high tide event. The majority of tern nest scrapes found outside of the 1.0-acre designated colony area were discovered during the months of May and June. In May, a daily average of 142 adult terns (range = 23-352) were observed on the upper beaches (above the high tide line) outside of the 1.0-acre designated colony area, and the field crew covered over 4,364 tern nest scrapes on the beaches at the east end of East Sand Island (63% of the total number of tern nest scrapes covered over in 2018). In June, a daily average of 54 adult terns (range = 4-267) were observed on the beaches outside of the 1.0-acre designated colony area, and the field crew covered over 1,600 tern nest scrapes (23% of the total number of nest scrapes covered over in 2018). A total of 1,005 Caspian tern nest scrapes (14% of the total) were discovered and covered over in April, July, and August combined (*Table 2*). Although a large number of tern nest scrapes were covered over on the upper beaches at the east end of East Sand Island during the 2018 breeding season, this was due to the frequent covering over of nest scrapes that were repeatedly dug by a relatively small number of terns that persistently prospected for nest sites on the upper beach, rather than attempts by a large number of Caspian terns to nest outside of the 1.0-acre colony area.

Although no satellite tern colonies formed on East Sand Island during the 2018 breeding season, 84 Caspian tern eggs were discovered on the beaches at the east end of the island outside of the 1.0-acre designated colony area. In comparison, 26 Caspian tern eggs were found on the beaches at the east end of East Sand Island in 2017 (BRNW 2018b). Similar to 2017, the highest proportion of tern eggs discovered outside the main colony in 2018 were found in the South Beach survey zone adjacent to the main colony area (58% of all tern eggs found; n = 49). A total of 21 Caspian tern eggs were discovered in the Southeast Beach zone (25% of total eggs found) and 12 tern eggs were found in the East Beach zone (14% of total eggs found). Two tern eggs (2% of total eggs found) were discovered in scrapes in the Northeast Beach zone and no tern eggs were seen in the North Beach survey zone during the 2018 breeding season (*Figure 3*). The majority of tern eggs discovered outside of the main colony area were discovered in May (49% of all eggs) and June (46% of all eggs), and the remaining 5% of eggs were laid in July (*Figure 4*). Although Caspian terns laid 84 eggs on the beaches at the east end of East Sand Island in 2018, a Caspian tern egg deposited outside the 1.0-acre designated area persisted, on average, for only about 7 hours after it was discovered by a field crew member. Of the tern eggs found on the beaches of East Sand Island in 2018, 74 eggs (88%) persisted less than 24 hours, and 10 eggs (12%) persisted for longer than 24 hours (*Figure 5*). The 10 Caspian tern eggs that persisted longer than 24 hours remained intact on average for about 34 hours, whereas those that did not persist longer than 24 hours remained intact on average for about 4 hours. Throughout the breeding season, Caspian tern eggs that were laid and discovered outside the 1.0-acre designated colony area persisted the longest during May and July, on average (*Figure 5*).

All Caspian tern eggs discovered outside the main colony area were monitored closely by field personnel in an attempt to document their fates. Out of the 84 total eggs discovered, 4% (n = 3 eggs) had been inundated by the tide or were partially buried in sand at the time of their discovery. About 8% of discovered eggs (n = 7 eggs) were depredated by western/glaucous-winged gulls due to unintentional researcher-induced disturbance to the attending adult tern. Another 21% (n = 18 eggs) were confirmed depredated by gulls as the result of active predation events in the absence of human disturbance. The remaining 67% of discovered eggs (n = 56 eggs) were confirmed missing during a subsequent hazing session; while the actual fate of these eggs was not determined we presumed that most, if not all, were depredated by western/glaucous-winged gulls.

As with previous years, hazing efforts outside of the 1.0-acre designated colony area were commensurate with the intensity of nest prospecting by Caspian terns on suitable nesting substrate. Whereas the main tern colony was abandoned for 10 days and failed to produce young in 2017, the Caspian tern nesting effort on the main colony at East Sand Island persisted uninterrupted and produced some young in 2018. Along with the sustained breeding effort on the main colony, nest prospecting on the beach was also persistent throughout the 2018 breeding season. As such, the number of hours spent conducting dissuasion surveys and actively hazing prospecting Caspian terns outside of the main colony area was higher in 2018 than in 2017. In 2018, field technicians spent a total of 675 hours conducting dissuasion sessions, of which 324 hours were spent actively hazing terns (*Table 1*). In 2017 by comparison, 352 hours were spent conducting active dissuasion sessions and 124 hours were spent actively hazing Caspian terns.

Habituation to active hazing of Caspian terns on the beach by terns nesting on the 1.0-acre designated colony area differed between and across the 2017 and 2018 breeding seasons. In 2017, after apparent habituation by terns early in the nesting season, the sensitivity of terns to the presence of hazers on the beach restricted efforts to actively dissuade terns from nesting in the South Beach zone beginning in early-July, once terns reoccupied the main colony area following a 10-day temporary abandonment of the colony. The consequent reduction in hazing of the South Beach zone in order to avoid tern egg loss on the 1.0-acre designated colony area contributed to tern eggs surviving for up to several days by late July. Active hazing was discontinued in the South Beach and Southeast Beach zones on 27 July (BRNW 2018b). Early in the 2018 nesting season, attempts to haze terns from the South Beach survey zone tended to result in some nesting Caspian terns flushing from the 1.0-acre colony area. By early May, field personnel had learned to adjust their travel paths, use slower movements during active hazing, and the terns had become more habituated to the daily presence of hazers. At this point, any flushes on the main tern colony related to attempted hazing on the south beach was reduced to the few terns loafing on the periphery of the colony.

Caspian terns with established nests on the main colony did habituate to the presence of hazers in the South Beach zone, and personnel were able to conduct some hazing efforts early in nesting season in this zone. However, the tern colony became more sensitive to human

presence in the South Beach zone later in the 2018 nesting season. Access to the South Beach zone to conduct hazing was reduced once terns on the main colony began flushing in response to alarm calls made by western/glaucous-winged gulls nesting on the outskirts of the tern colony; alarm calls became more frequent and intense as more gulls attending nests hatched their chicks. Early in July, the field crew started using a combination of dissuasion walk-throughs at low tide and hazing (from a distance) using a green laser during periods of high nest-scraping activity by terns in the South Beach zone. Tern hazing sessions using the laser were conducted during low-light conditions at dawn (beginning at 05:30) and at dusk (until 21:45). Near the end of July, a small number of ephemeral nesting attempts by Caspian terns were observed in the heavy wrack-line of the upper South Beach zone. These nest scrapes were not regularly attended and were no longer present by early August. The South Beach zone was completely inaccessible to hazers by the end of July and remained that way until all terns had vacated the main colony. Despite limited access to the South Beach zone, no satellite tern colony was able to form in that zone, or anywhere else outside of the 1.0-acre designated colony area.

Our monitoring of other nesting waterbird species during active tern hazing sessions confirmed that, 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, but neither of these species appeared to be at significant risk of egg loss due to tern hazing activities in 2018. Also as in previous years, the east end of East Sand Island was used as a large post-breeding roost site by California brown pelicans.

Glaucous-winged/western gulls were confirmed nesting above the high tide line in all seven survey zones at the east end of East Sand Island, but typically their nests were above the heavy wrack line high on the upper beach and in vegetated upland areas. Active nests of glaucous-winged/western gulls were generally well removed (> 15 m) from the travel paths used by field personnel for daily monitoring and hazing of Caspian terns on the beach.

As in 2017, a large ring-billed gull colony formed on the vegetated and driftwood-filled inlet and surrounding upland area adjacent to the Northeast Beach survey zone during the 2018 nesting season, and this gull colony attracted Caspian terns prospecting for nest sites. Liberal deployment of passive nest dissuasion materials on and around the ring-billed gull nesting area, however, resulted in a greater separation between the ring-billed gull colony and nesting substrate suitable for Caspian terns. Thus, tern nesting attempts in the Northeast Beach zone were restricted to more open habitat, well removed from the ring-billed gull colony, which remained accessible to field personnel for tern hazing and deployment of supplemental nest dissuasion materials.

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 2018, the first California brown pelican was seen on East Sand Island on 17 April, loafing in the Southeast Beach zone. Counts of California brown pelicans on East Sand Island peaked in early July at 3,011 individuals (*Figure 6*), similar to the peak count in 2017 (ca. 3,300 individuals) but

appreciably lower than in 2016 (5,282 individuals), and well below the previous 18-year average peak count of 8,342 individuals (*Figure 7*). No nesting activity by California brown pelicans was observed on East Sand Island during the 2018 breeding season. Aside from a few individuals in breeding plumage during late May (a maximum of 6 individuals with red gular pouches were observed at one time), no brown pelicans were observed carrying sticks (i.e. nest building) and no nest structures, copulation, or other pelican breeding behaviors were witnessed on East Sand Island in 2018.

#### Section 4. 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 (13 June). In 2018, 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. The average of three direct counts of all adult terns on the colony in aerial photography taken on 13 June, corrected using concurrent ground counts of the ratio of incubating to non-incubating terns on 20 plots (each plot measured 6m x 6m) 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 counts from the aerial photography and the variance in the ratios of incubating to non-incubating adult terns among the 20 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. An ArcGIS desktop tool, ArcMap, was used to count adults in the high-resolution vertical images of the Caspian tern colony to estimate colony size.

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 early in the fledging period (27 July). Similar to the aerial imagery of the Caspian tern colony at the peak of breeding, aerial photography during the peak fledgling period was acquired using an UAV operated by a licensed UAV pilot. Orthophotos were generated, however, using the web-based DroneDeploy image processing service. 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 27 June, corrected using concurrent ground counts of the number of tern chicks present on 11 plots within the colony area, was used to estimate the number of near-fledging age chicks on the colony at the time of the photography. 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 and the variance in the number of Caspian tern chicks among the 11 plots. Estimates of nesting success were calculated one thousand times using random draws from the sample distributions of the total number of tern chicks counted on-colony and the number of tern chicks on plots. Standard errors and confidence

intervals for the number of tern chicks were derived from the resulting distribution. An ArcGIS desktop tool, ArcMap, was used to count near-fledging age chicks in the high-resolution vertical images of the Caspian tern colony to estimate nesting success.

**Results and Discussion:** Caspian tern nesting on East Sand Island in 2018 was limited to the designated 1.0-acre colony area by installing passive dissuasion materials and actively hazing terns that attempted to nest outside the 1.0-acre area (see *above*); no satellite tern colonies formed on East Sand Island in 2018. Terns were first observed on the main colony later in 2018 than in any previous year (*Figure 8*); however, inclement weather prevented access to the island for the four days prior to the first detection of terns on-colony and terns likely arrived on colony a few days earlier than when they were first detected by field staff. The timing of nest initiation and subsequent breeding chronology at East Sand Island in 2018 was similar to that of the last several years. The tern colony slowly grew to a peak size in mid-June, and slowly declined until early September (*Figure 9*). The estimate of peak colony size in mid-June was 4,959 breeding pairs (95% c.i. = 4,682 – 5,236 breeding pairs), significantly more than last year's estimate of 3,500 breeding pairs on the designated colony area. With the exception of 2017, a year when the colony was abandoned in June due to predator disturbances, the estimated number of Caspian tern breeding pairs at East Sand Island in 2018 was significantly lower than the estimated number of breeding pairs at East Sand Island since 2001, when all terns nesting in the estuary relocated from Rice Island to East Sand Island (*Figure 10; Table 3*). Nevertheless, the estimated size of the tern colony on East Sand Island in 2018 was still substantially larger (13-59% greater) than 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).

The overall decline in tern colony size at East Sand Island during 2008-2018 can be attributed in large part 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 2015-2018 the amount of nesting habitat prepared was reduced to the minimum colony area specified in the management plan (1.0 acres). In response to the decline in available nesting habitat for Caspian terns on East Sand Island, there was 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 2018, nesting density was 1.23 nests/m<sup>2</sup> (95% c.i. = 1.16 – 1.29 nests/m<sup>2</sup>), significantly 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, but significantly lower than the nesting density of 1.36 nests/m<sup>2</sup> (95% c.i. = 1.31 – 1.41 nests/m<sup>2</sup>) in 2016 (*Figure 11; Table 3*).

Although Columbia River discharge throughout May 2018 was comparable to flows in 2011 and 2017 (*Figure 12*), two years when Caspian terns at the East Sand Island colony failed to raise any fledglings, an average of 0.17 fledglings/breeding pair were raised in 2018 (95% c.i. = 0.15 –

0.18 fledglings/breeding pair; *Figure 13*). In 2011 and 2017, suppressed marine forage fish availability associated with high river discharge combined with frequent colony disturbances by bald eagles were thought to be contributing factors for breeding failures and colony abandonment by terns nesting at East Sand Island (Collar et al. 2017, BRNW 2018b). During the period of high river discharge early in the 2018 nesting season, the average number of bald eagle disturbances to the colony per day was generally higher than in 2017; however, the frequency of eagle-caused disturbances tapered off in June of 2018, when river discharge declined and the tern colony was at peak size. In June 2017, by contrast, there was a spike in the number of bald eagle disturbances to the tern colony up to the date when the colony was abandoned by all terns (*Figure 14*).

In 2018, the diet of Caspian terns nesting at East Sand Island consisted of more salmonid smolts (40.1% of prey items) compared to the average during 2000-2015 (31.7%; *Figure 15, Figure 16*); the increased proportion of salmonid smolts in the tern diet was distributed throughout the 2018 breeding season (*Figure 17*). In contrast, northern anchovies (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 (*Figure 16, Figure 18*). Other marine forage fish, such as those in the family Clupeidae (i.e. herring, sardines, and shad), comprised a larger proportion of the diet in 2018 than in previous years (*Figure 16*), whereas the proportion of surfperch in the diet was consistent with the long-term average. Decreased river flows accompanied by decreased colony disturbances caused by bald eagles during the latter half of the breeding season may have contributed to the ability of some tern breeding pairs to successfully fledge a small number of young in 2018, despite unfavorable early season conditions and a low proportion of anchovies in the diet.

As was the case during 2013-2017, Caspian terns were observed prospecting for nest sites at a dredged material disposal site at the downstream end of Rice Island in the upper Columbia River estuary during the 2018 nesting season. Data on nesting attempts by Caspian terns in the upper Columbia River estuary were collected as part of a separate study and may be available by contacting the funding agency (USACE – Portland District; Contract No. W912EF-14-D-0004, Order No. W9127N18F0096).

## Section 5. Inter-colony Movements & Dispersal Patterns

**Methods:** In 2018, we continued to resight color-banded Caspian terns at the East Sand Island colony. Results presented here describe movements of banded Caspian terns to and from 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 2018, most resightings of banded terns were from the continuously 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 2018, banded adult Caspian terns were resighted on the East Sand Island tern colony by field personnel using binoculars and spotting scopes during 5-7 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 few sites in the Columbia Plateau region during the 2018 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 2018 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 2018. This report also includes a summary of banded Caspian terns observed at East Sand Island in 2017 and locations where those terns were observed again in 2018. The summary provides information on inter-annual dispersal from, or fidelity to, the tern colony on East Sand Island.

Reconnaissance aerial surveys were conducted from a manned fixed-wing aircraft to determine the distribution and detect 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 (*Map 1*). Aerial surveys were conducted on 20 May and 21 June during the 2018 nesting season to allow for the detection of new colonies that may have formed early or late in the 2018 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 potential 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 2018 field season, a total of 377 individual Caspian terns that were previously color-banded were resighted on East Sand Island. Of these resighted individuals, 89% were banded at East Sand Island (147 as adults and 188 as chicks), 7% were banded at Crescent Island in the mid-Columbia River (16 as adults and 10 as chicks), 3% were banded at Goose Island-Potholes Reservoir (10 as adults), 1% were banded at the Port of Bellingham (3 as chicks) in Washington, 1% were banded at Sheepy Lake tern island in Lower Klamath NWR, California, and < 1% were banded as chicks at Brooks Island in San Francisco Bay (*Table 4*). 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 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 the management actions to reduce the availability of tern nesting habitat at East Sand Island.

Of a total of 433 color-banded Caspian terns seen on East Sand Island in 2017, 295 terns (68%) were resighted again in 2018, either at East Sand Island or elsewhere; two of these individuals were resighted at two different locations in 2018. Of a total of 297 resighting records of these banded birds in 2018, 96% were resighted at East Sand Island, 3% were resighted at the Blalock Islands in the mid-Columbia River, 1% were resighted at Potholes Reservoir, Washington (either at Goose Island or at islands in northern Potholes Reservoir) (*Table 5*). These resightings underscore the high breeding philopatry of Caspian terns for the East Sand Island colony, but they also indicate that some adults have dispersed from the East Sand Island colony to alternative colony sites in the Columbia Plateau region.

Results of aerial surveys of the lower Columbia River and estuaries on the outer coast of Washington in 2018 indicated that about 300 Caspian terns were present at locations other than East Sand Island during the mid-May survey, and about 600 Caspian terns were present at locations other than East Sand Island during the mid-June survey. On 20 May, about 140 Caspian terns were observed loafing at four different sites on the lower Columbia River, and about 150 terns were observed loafing at six different sites in Willapa Bay and Grays Harbor. During the 21 June aerial survey of the lower Columbia River, two Caspian terns were observed loafing at Miller Sands Spit and approximately 500 terns were photographed at Rice Island, of which over 200 appeared to be in sitting in nest scrapes in an incubation posture. No ground-based follow-up was conducted, however, because Caspian tern monitoring and active management (hazing) were being implemented at Rice Island under a separate contract with the USACE - Portland District. During the 21 June aerial survey of Willapa Bay and Grays Harbor, nearly 110 terns were observed loafing at three different sites, the bulk of which were seen on No Name Island in Grays Harbor. Although Caspian terns were seen in higher numbers at potential colony sites other than East Sand Island in the lower Columbia River and nearby estuaries on the outer Washington coast in 2018 compared to 2017, Caspian terns appeared to have only attempted to nest at Rice Island in 2018.

## Section 6. 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, 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 from 17 April to 23 July, 2018.

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 2018 were investigated by recovering PIT tags from juvenile salmonids on the tern colony after the breeding season. This work was funded by the U.S. Army Corps of Engineers – Portland District (Contract No. W912EF-14-D-0004, Order No. W9127N18F0120), and the study results will be made available in a separate report to the funding agency.

**Results and Discussion:** Of the bill-load fish identified at the East Sand Island Caspian tern colony during the 2018 nesting season ( $n = 4,643$  bill-loads), on average 40.1% were juvenile salmonids. This proportion was slightly higher than the proportion of salmonids in 2017 (36%), when the estimate was somewhat confounded by a 10-day period of colony abandonment in late June/early July and a modification to diet data collection methods (i.e. no control for tide stage) due to a paucity of bill-load observations after 16 June. The proportion of salmonids in the diet in 2018 was, however, similar to that of 2015 (38%), the most recent year when tern diet composition data were collected throughout the season and controlling for tide stage at East Sand Island. The proportion of salmonids in the diet in 2018 was higher than the long-term average from 2000 through 2014 (31%; *Figure 15*). As in previous years, marine forage fishes (e.g., anchovies [Engraulidae], surfperch [Embiotocidae], smelt [Osmeridae], and herring [Clupeidae]) were collectively most prevalent in the tern diet, together averaging 50% of all tern bill-loads identified on East Sand Island in 2018 (*Figure 16*). In 2018, the peak in the proportion of salmonids in the diet of Caspian terns nesting on East Sand Island occurred in early May, similar timing to the peak in salmonids in previous years (*Figure 17*). However, the weekly proportion of salmonids in the tern diet was higher in late-April and most of May in 2018, during spring smolt outmigration, as compared with the weekly averages during previous years (*Figure 17*). This period of heavy reliance on juvenile salmonids as a food source coincided with unusually high river discharge in the Columbia River estuary (*Figure 12*).

The proportion of some marine forage fishes, such as anchovies and smelt, in the tern diet during the 2018 nesting season was considerably lower than the long-term average (*Figure 18* and *Figure 19*, respectively), and for anchovies this difference was most pronounced at the end of the breeding season, a time period when anchovies have historically comprised the largest proportion of the tern diet at East Sand Island. Although no forage fish surveys were conducted by NOAA Fisheries in the Columbia River estuary during the 2018 nesting season, the impression of fisheries biologists was that few anchovies entered the estuary in 2018 compared to normal (L. Weitkamp, NOAA Fisheries, pers. comm.). The proportion of clupeids, another taxon of marine forage fishes that includes herring, sardines and shad, in the tern diet was well above the long-term average during the 2018 breeding season (*Figure 16*), especially after Columbia River discharge in the estuary decreased below the average observed during 2008-2017 (*Figure 20*). This agrees with the large catches of herring by NOAA Fisheries along the Willapa Bay line to the north of the Columbia River mouth (L. Weitkamp, NOAA Fisheries, pers. comm.). Surfperch, an estuarine resident forage fish, were present in the tern diet at a level similar to the long-term average (*Figure 21*). Around 10% of the Caspian tern diet at East Sand Island in 2018 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* spp.), 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 2018 are currently in progress, and these results will be included in the Final Annual Report for 2018, which will be submitted to BPA by late March 2019.

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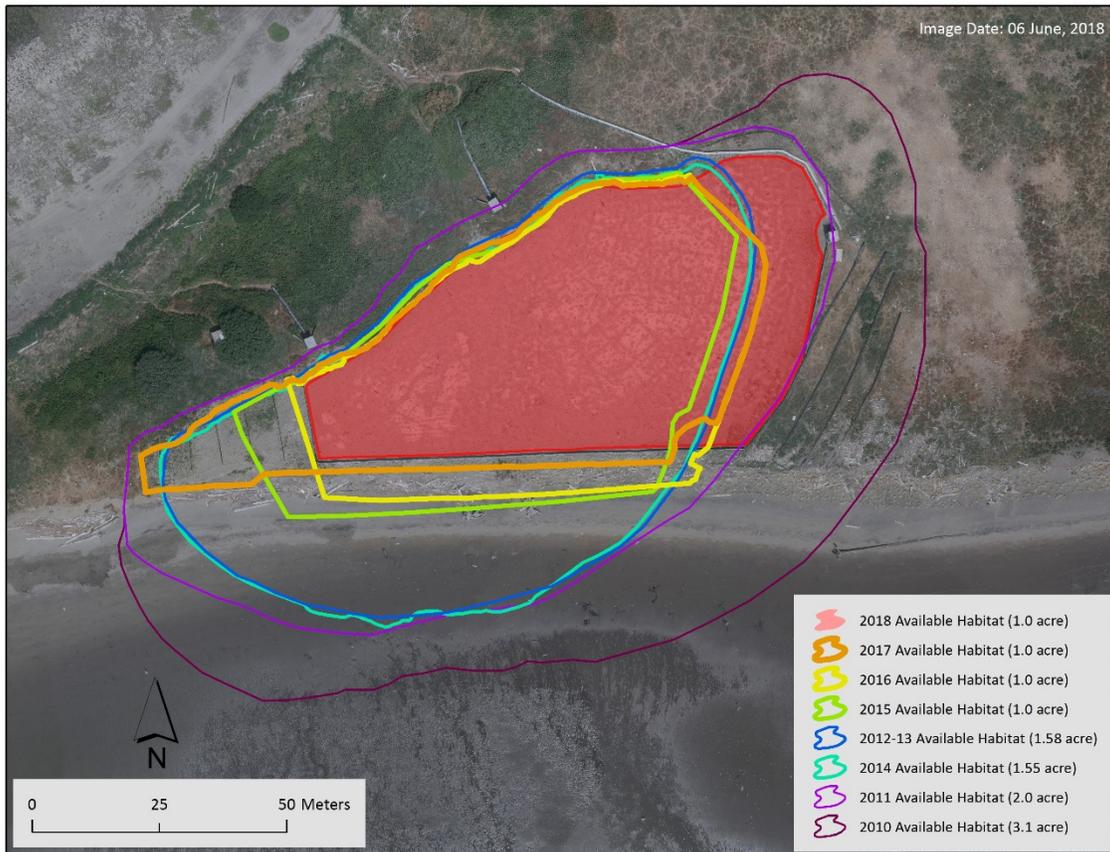
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## MAPS





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



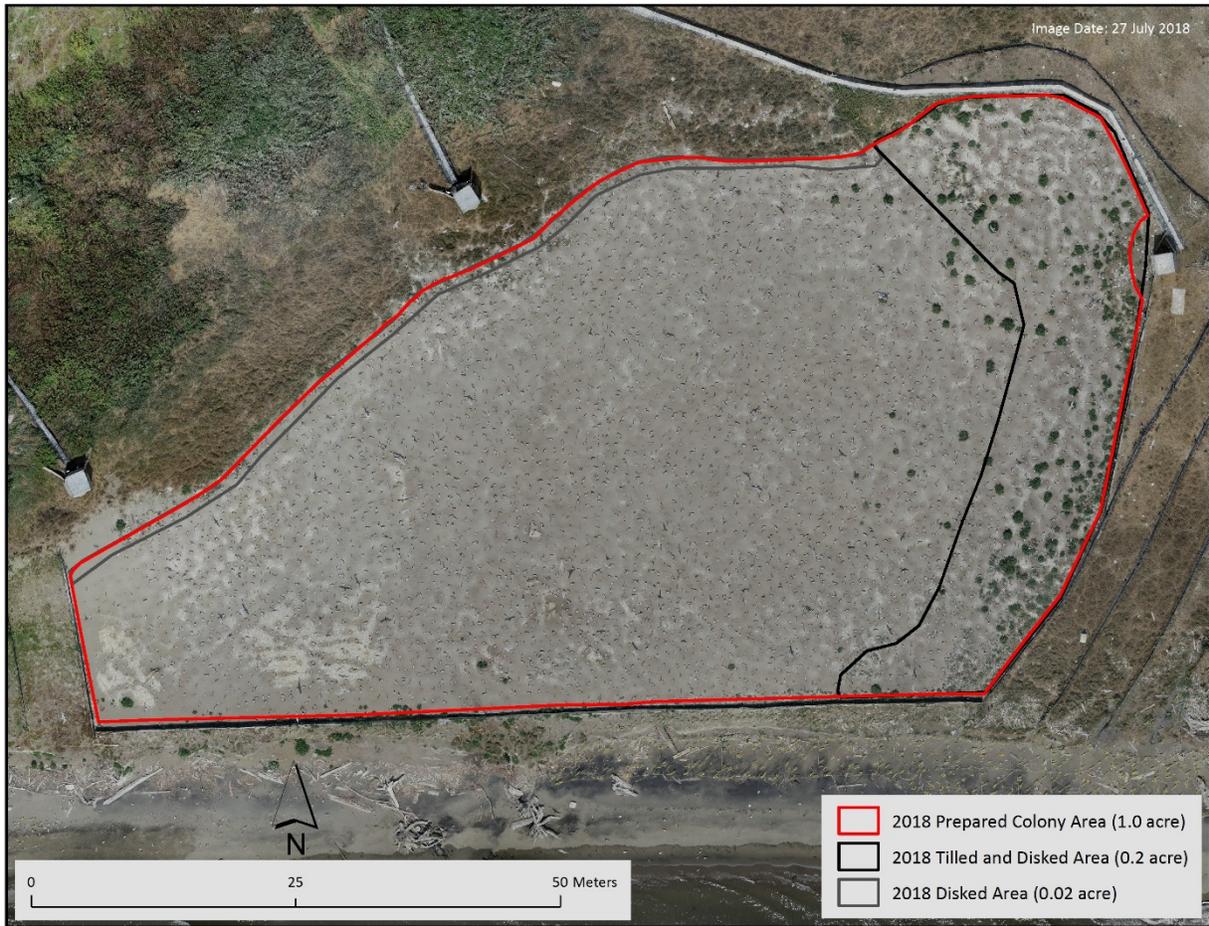
Map 3. Nesting habitat prepared for Caspian terns on the eastern end of East Sand Island in the Columbia River estuary during 2010-2018. Colony delineations depict the area of nesting habitat available to terns each breeding season during 2010-2018 and were overlaid on 2018 aerial photography. The southern shoreline of East Sand Island has gradually eroded during each winter, encroaching on the area of available tern nesting habitat in most years during 2010-2018. 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).



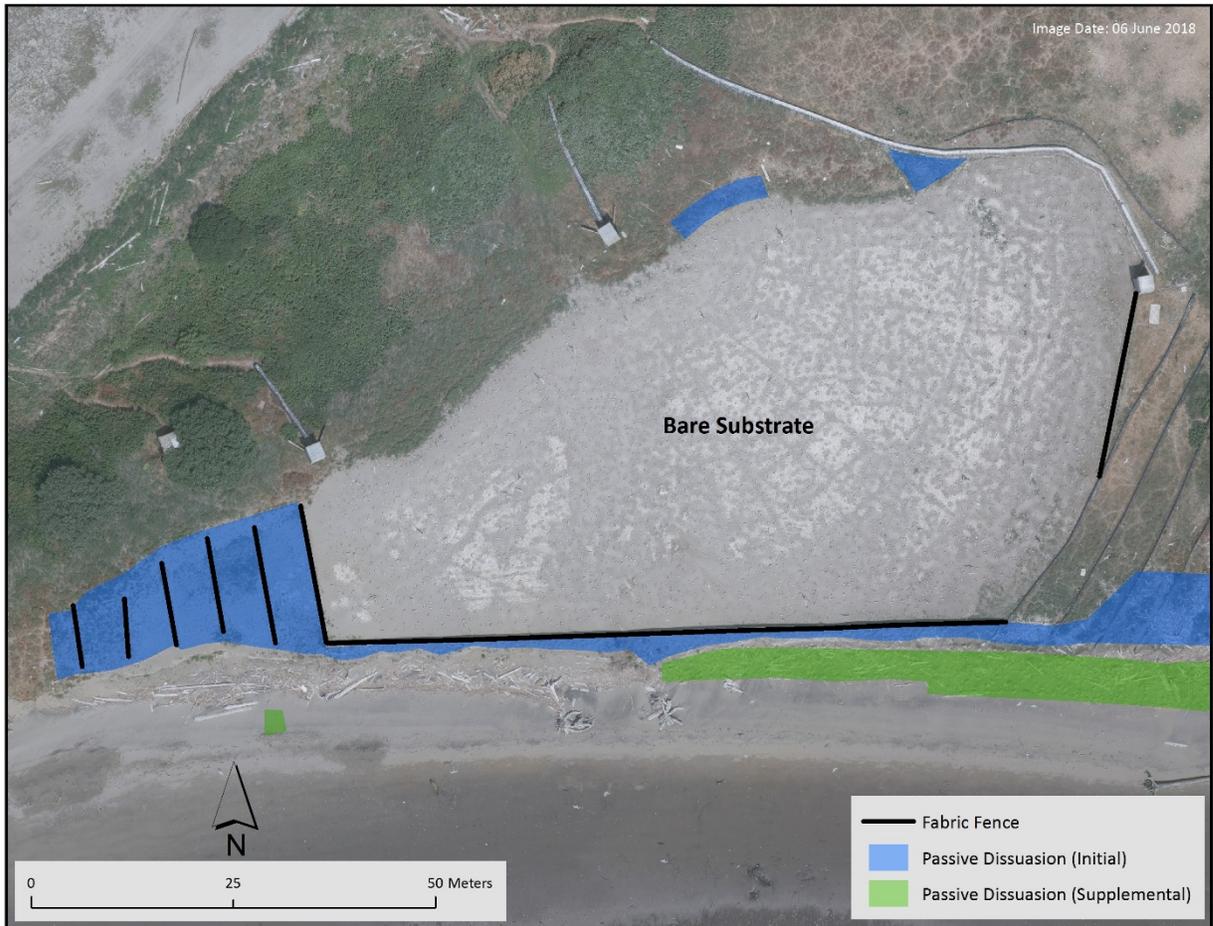
Map 4. Aerial photography of the prepared 1.0-acres of unvegetated substrate designated as nesting habitat for Caspian terns on East Sand Island in 2018.



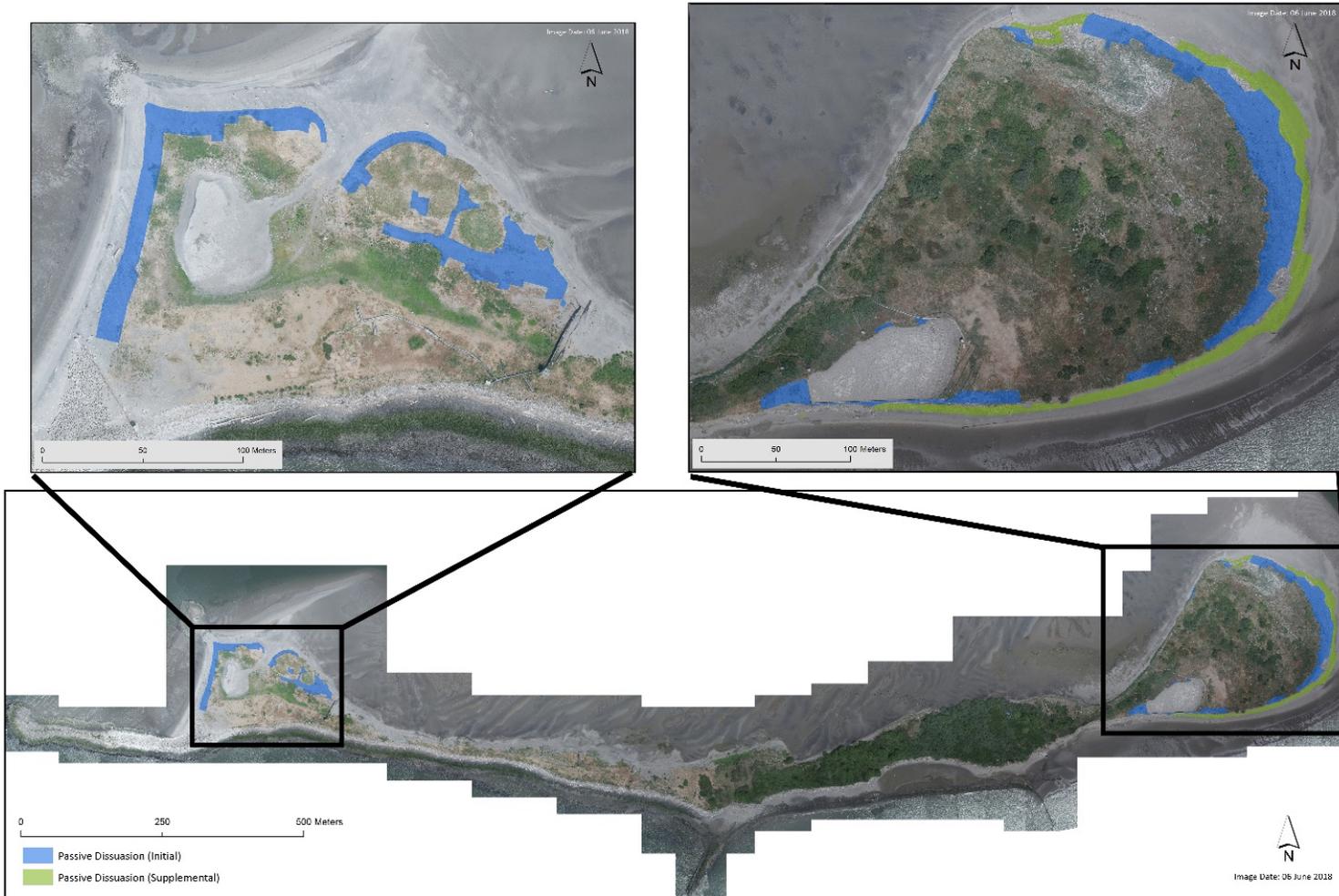
Map 5. Aerial photography of the prepared area of unvegetated substrate designated as nesting habitat for Caspian terns on East Sand Island in 2017, overlaid with the boundaries of the 1.0-acres of designated tern nesting habitat in 2018 and showing areas that required rototilling and disking to remove dense vegetation in order to shift the colony area to the northeast of the 2017 location.



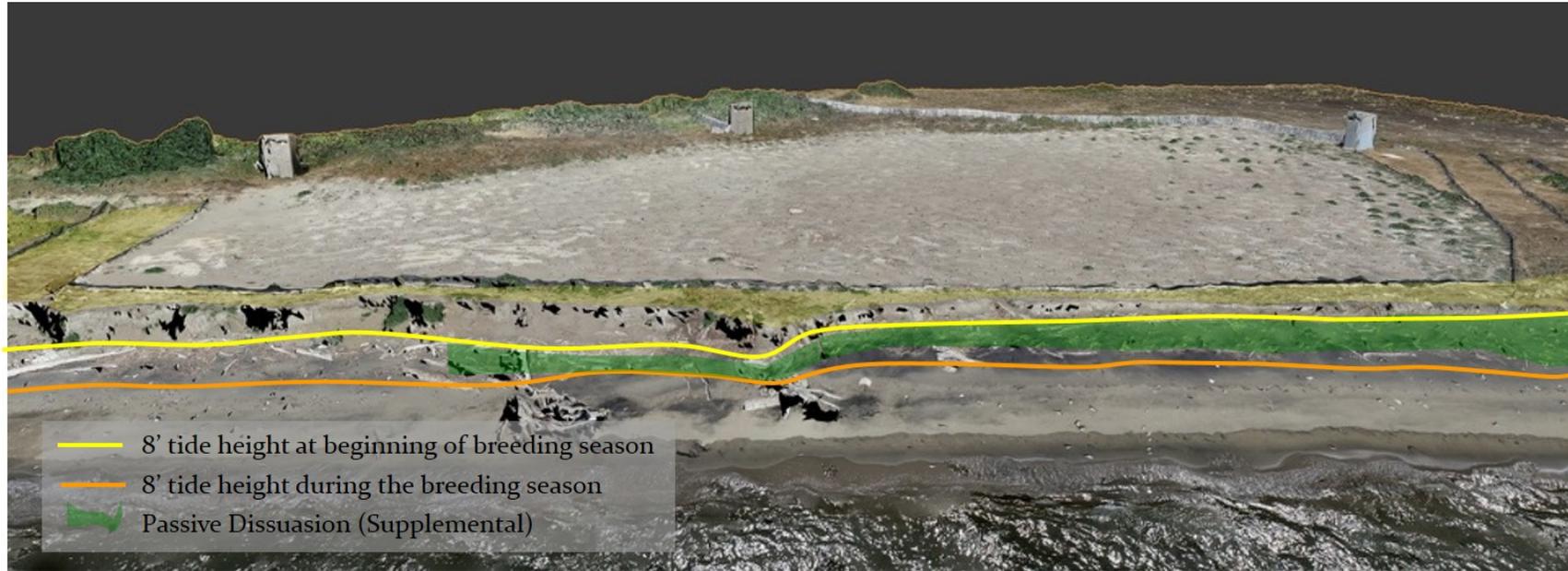
Map 6. Aerial photography of the 1.0-acres of prepared tern nesting habitat designated as the colony area for Caspian terns on East Sand Island in 2018, showing the extent of the vegetation regrowth in the rototilled and disked areas during the 2018 breeding season.



Map 7. Aerial photography of the 1.0-acres of unvegetated substrate designated as nesting habitat for Caspian terns on East Sand Island in 2018, showing locations of installed fabric fences and other passive dissuasion materials (posts, rope, and flagging) used to discourage terns from nesting on potentially suitable habitat immediately adjacent to the designated colony area.



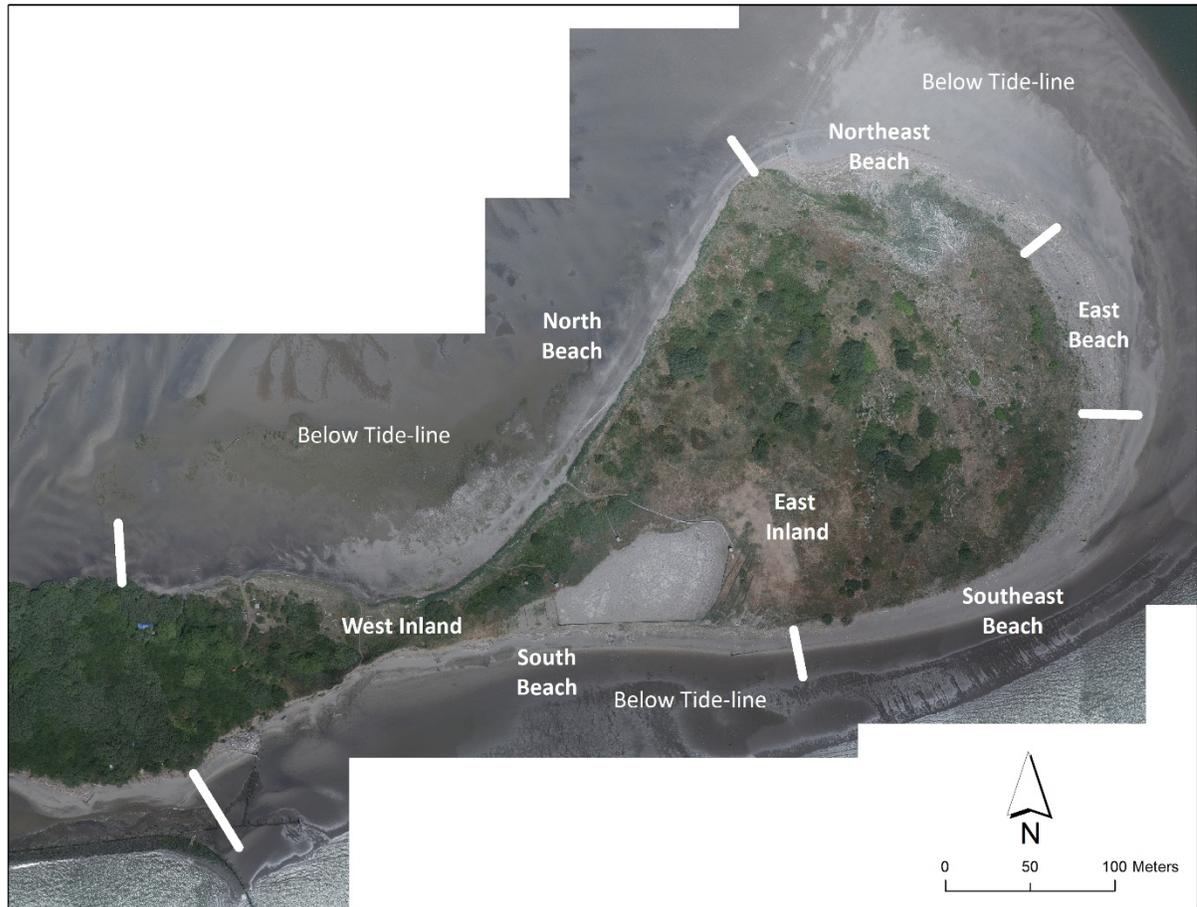
Map 8. Locations of passive tern nest dissuasion materials (stakes, ropes, and flagging) installed to prevent Caspian terns from nesting outside of the 1-acre designated colony area on East Sand Island in 2018.



Map 9. 3-D model of the Caspian tern colony at East Sand Island in 2018 showing the extent of inundation at high tide during the beginning and the middle of the breeding season and the extent of the supplemental passive dissuasion installed along the south beach adjacent to the prepared 1-acre tern colony area. Installation of passive dissuasion along the southern beaches of East Sand Island prior to the arrival of Caspian terns was complicated by high tides and late-season winter storms in 2018.



Map 10. Aerial photography of the 1.0-acres of unvegetated substrate designated as nesting habitat for Caspian terns on East Sand Island in 2018, showing the outline of area used by nesting terns during the peak of the 2018 breeding season in relation to installed fabric fencing and other passive dissuasion materials (posts, rope, and flagging) used to discourage terns from nesting on potentially suitable habitat immediately adjacent to the designated colony area. Red dots represent individual adult terns present on the 1.0-acre colony area.



Map 11. Eight survey zones designated for data collection on prospecting Caspian terns at the eastern end of East Sand Island during monitoring and active hazing of prospecting Caspian terns outside the designated 1.0-acres colony area. Suitable Caspian tern nesting habitat was located on each of the beach zones above the high-tide line. The Below Tide-line zone encompassed all of the area below the high-tide line that was unsuitable as Caspian tern nesting habitat due to frequent tidal inundation.

## FIGURES

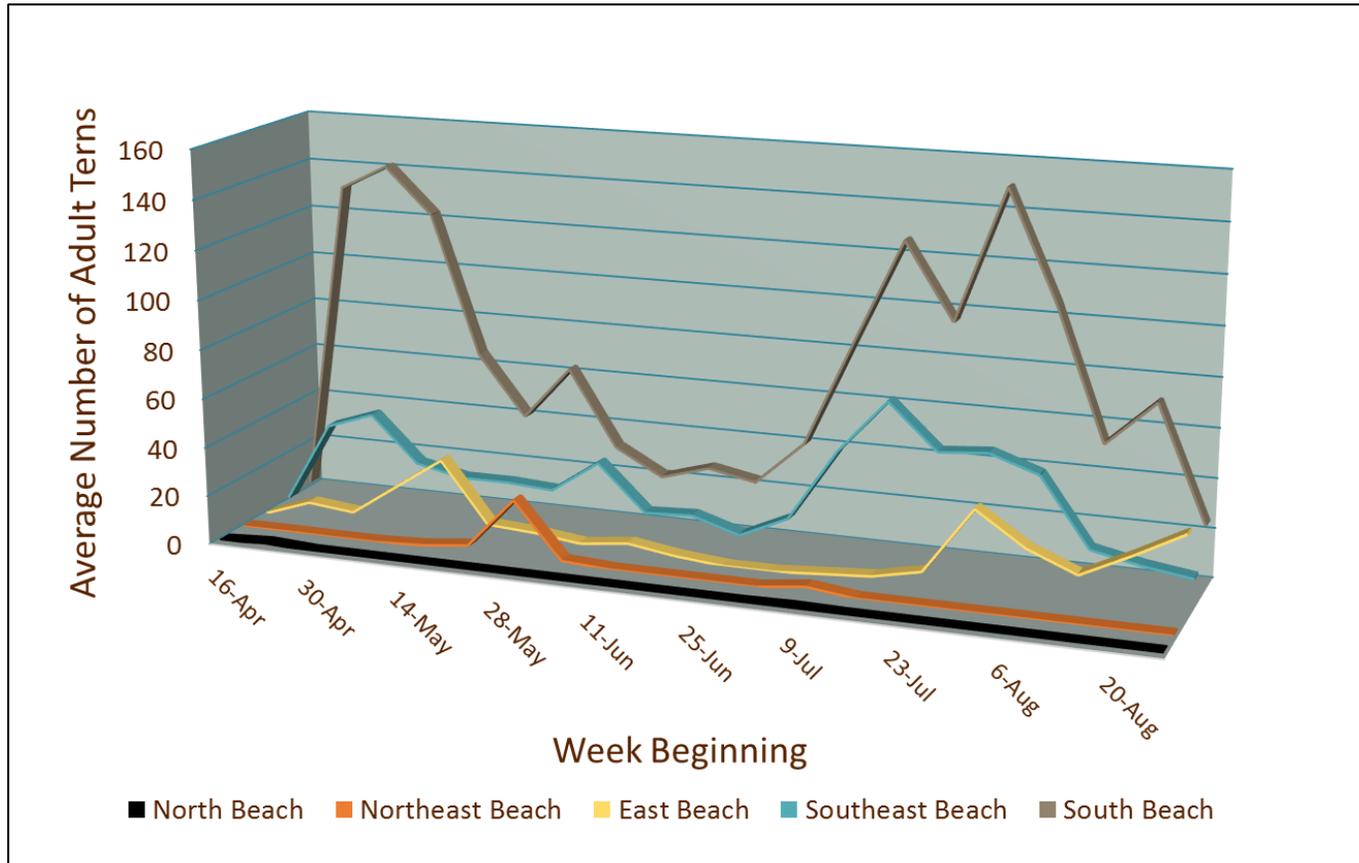


Figure 1. Average of the daily number of Caspian terns present each week in survey zones with suitable beach nesting habitat outside of the 1.0-acre prepared colony area on the eastern half of East Sand Island in 2018. Counts were performed by field staff during active nest dissuasion sessions. Not included in this figure are the “West Inland”, “East Inland”, and “Below Tide-line” survey zones. Caspian terns were not observed using the inland zones and no nesting habitat was available below the high-tide line. Refer to Map 11 for the location of each of the 2018 survey zones at East Sand Island.

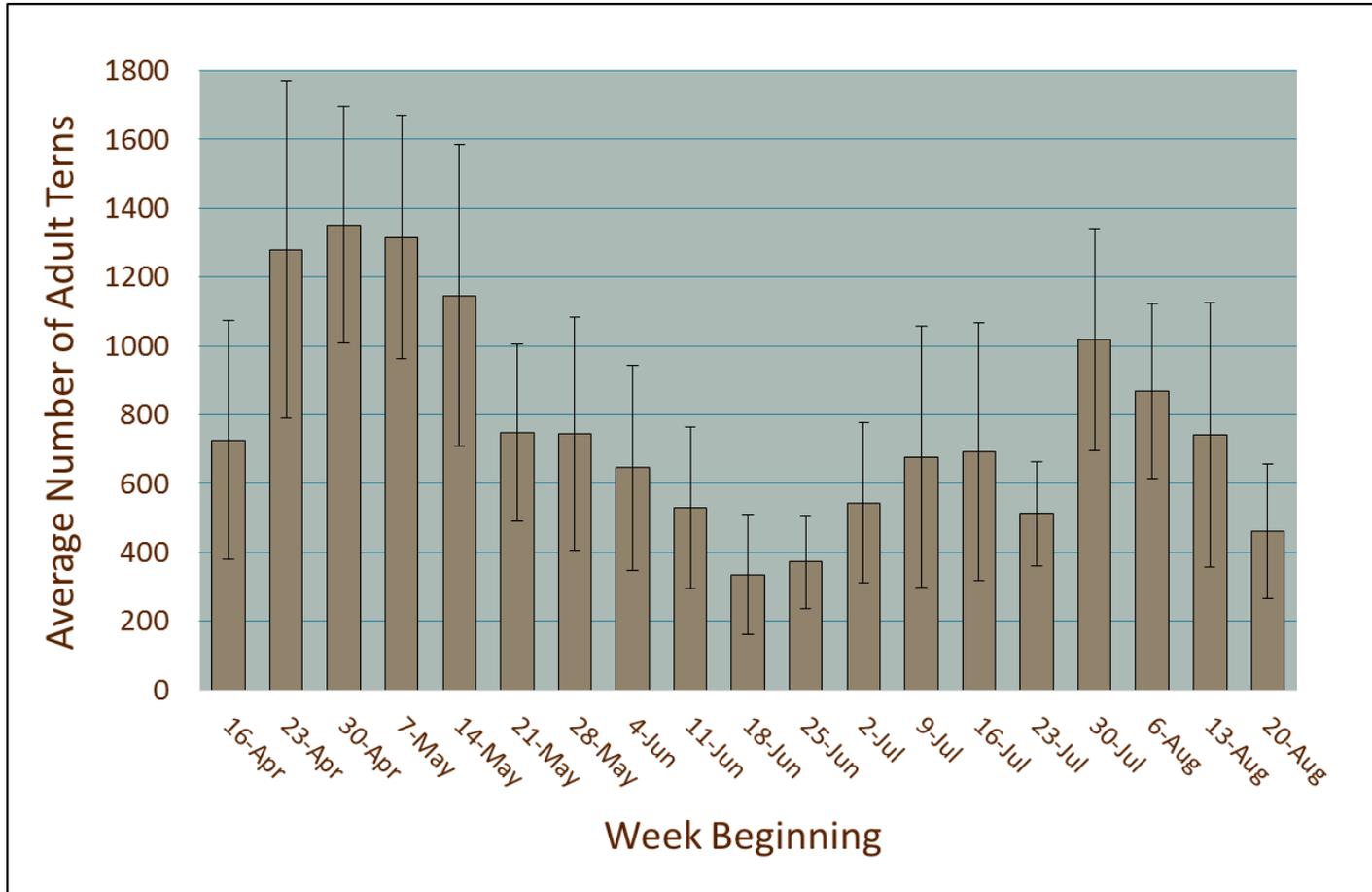


Figure 2. Weekly average of the daily number of Caspian terns counted in the Below Tide-line survey zone outside of the 1.0-acre prepared colony area on the eastern half of East Sand Island in 2018. The error bars represent one Standard Deviation of the mean number of adult terns counted each week. No suitable nesting habitat was available in this zone due to frequent inundation. Caspian terns using the Below Tide-line zone consisted of “off-duty” breeding adults with nests on the main colony, terns prospecting for nest sites, non-breeding adults, and failed breeders. Counts were performed by field staff during active nest dissuasion sessions. Refer to Map 11 for the location of the 2018 survey zones at East Sand Island.

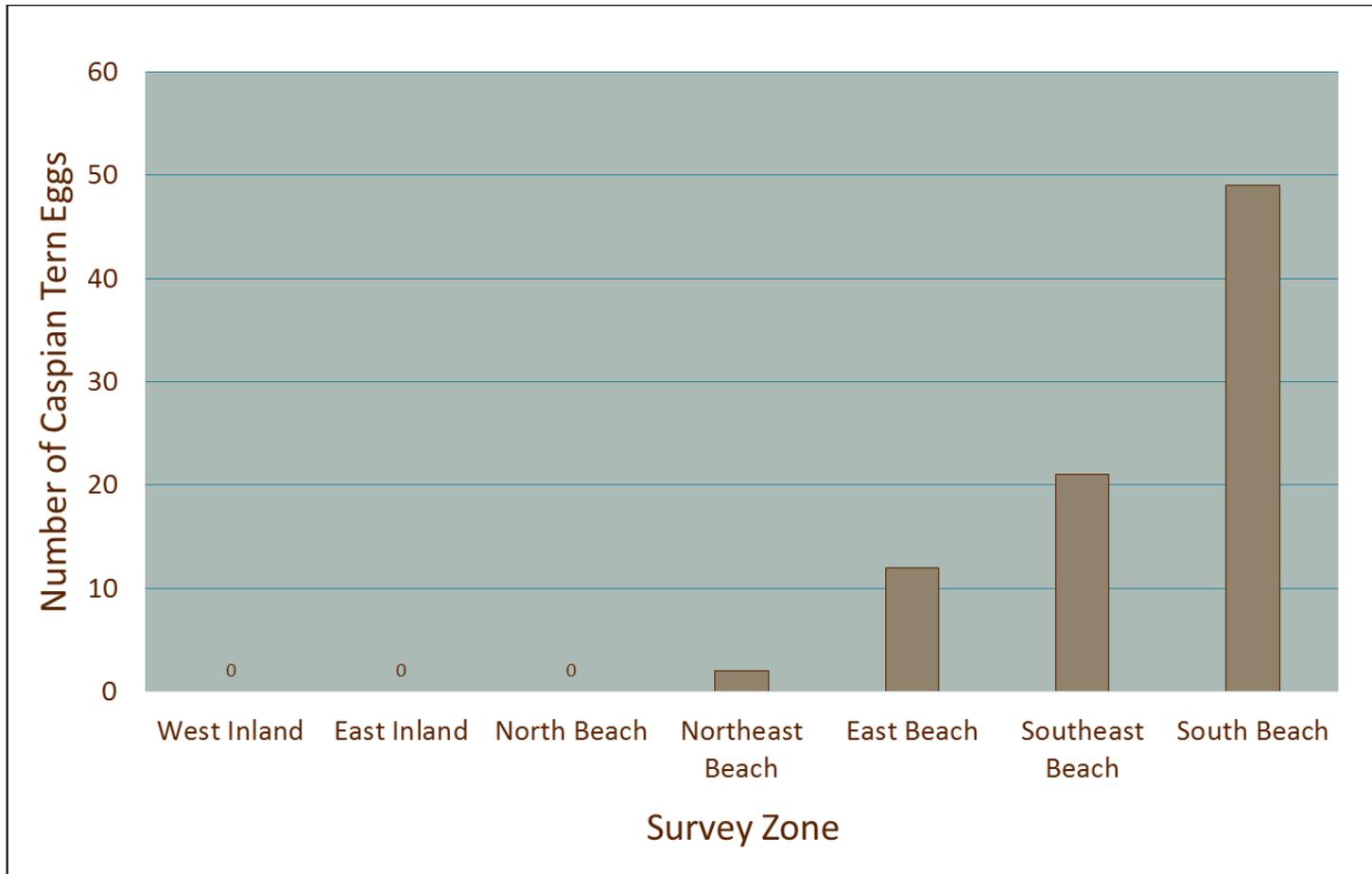


Figure 3. Number of intact Caspian tern eggs discovered outside of the 1.0-acres prepared colony area in each survey zone with suitable beach nesting habitat on the eastern half of East Sand Island during the 2018 breeding season. Caspian tern eggs laid outside of the 1.0-acres prepared colony area were found during daily monitoring and active nest dissuasion sessions on the eastern half of East Sand Island. Not included in this figure are “Below Tide-line” survey zones where suitable beach nesting habitat for Caspian terns was absent. Refer to Map 11 for the location of each of the 2018 survey zones at East Sand Island.

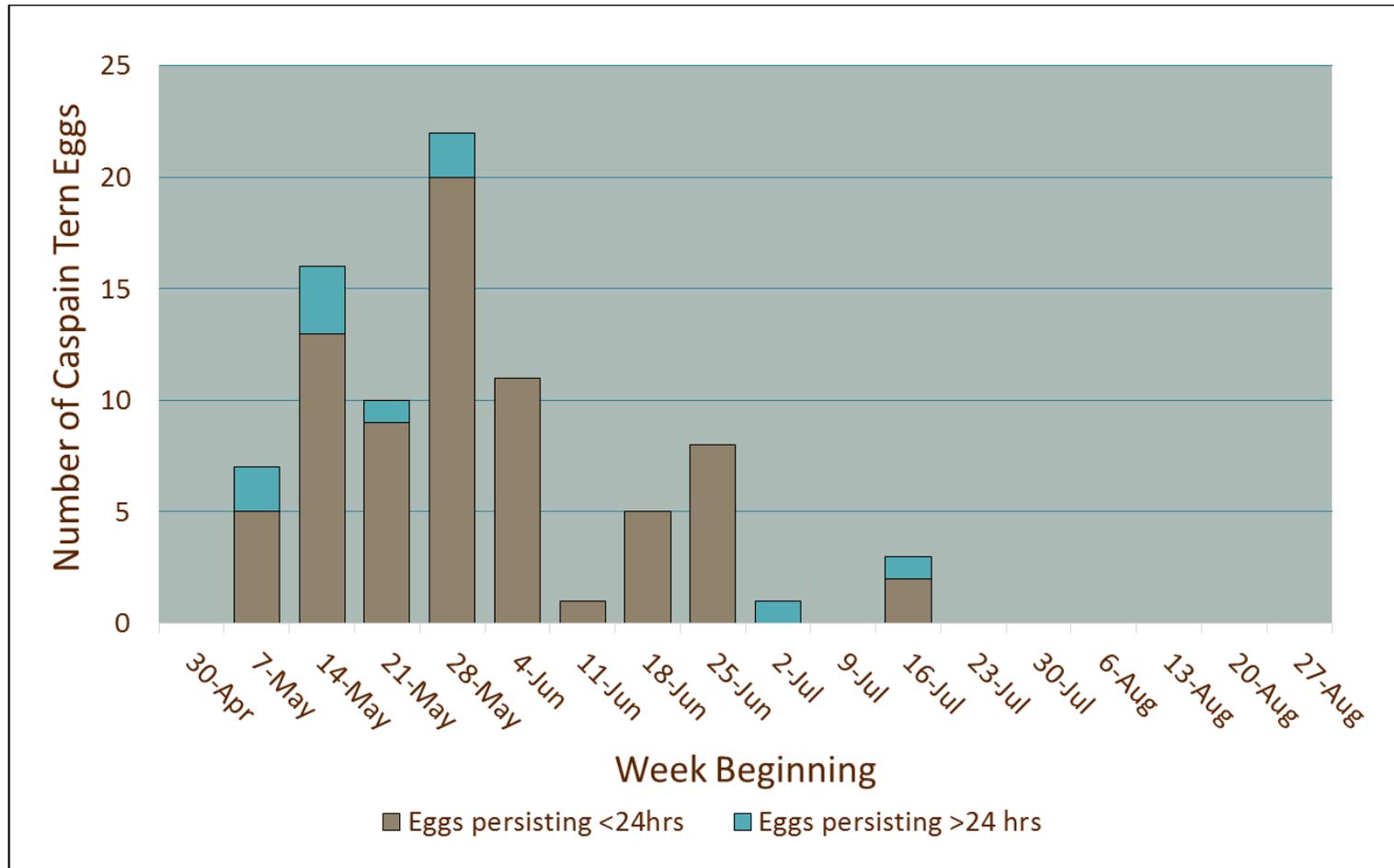


Figure 4. Number of intact Caspian tern eggs discovered outside of the 1.0-acres prepared colony area during monitoring and active nest dissuasion sessions on the eastern half of East Sand Island in 2018 by week. Tern eggs were categorized as persisting either less than or greater than 24 hours.

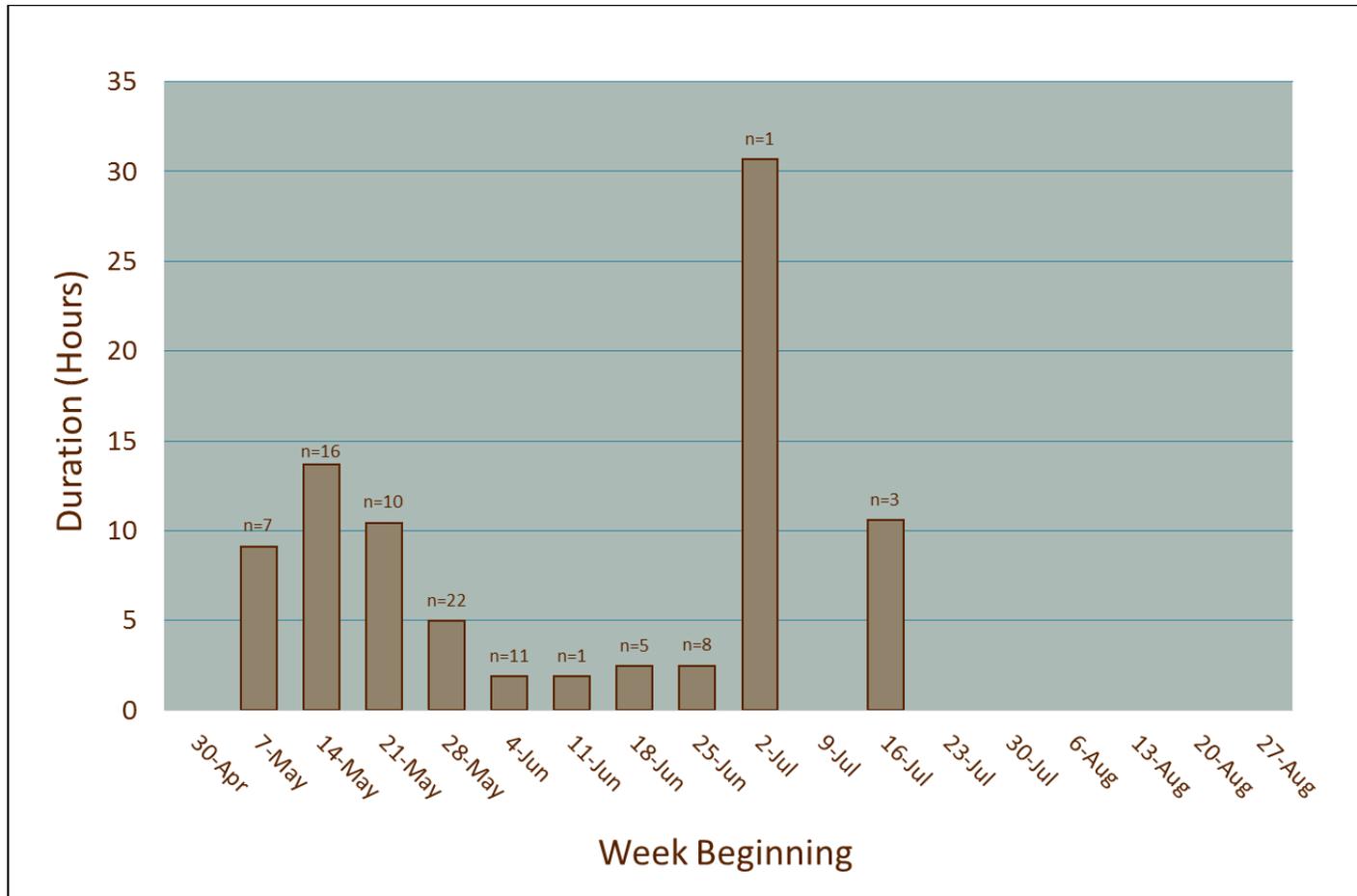


Figure 5. Average duration (hours) that intact Caspian tern eggs discovered outside the 1.0-acre prepared colony area persisted before a fate was observed or the egg was confirmed no longer present during a subsequent hazing session. Tern eggs were discovered during monitoring and active nest dissuasion sessions on the eastern half of East Sand Island in 2018. Note: During the week beginning 2 July, only one tern egg was discovered on the beach and it persisted for approximately 31 hours, resulting in a disproportionately high average for that week. No tern eggs were discovered outside of the main colony area during 10 of the 20 weeks when active dissuasion was implemented. Sample size of Caspian tern eggs used to calculate the average persistence each week is listed above the corresponding bar.

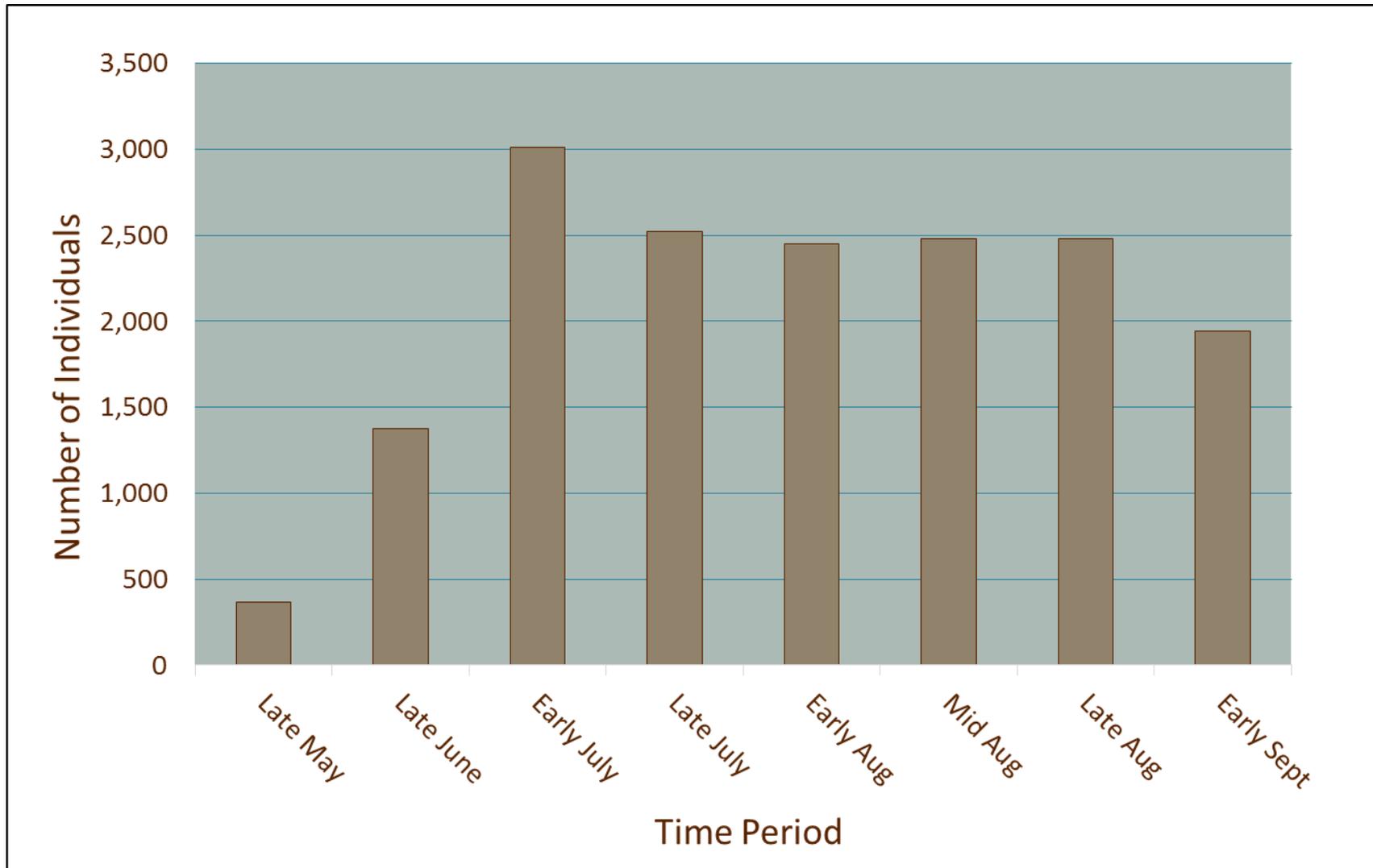


Figure 6. Estimates from boat-based surveys of the number of roosting California brown pelicans on East Sand Island in the Columbia River estuary, during the 2018 field season.

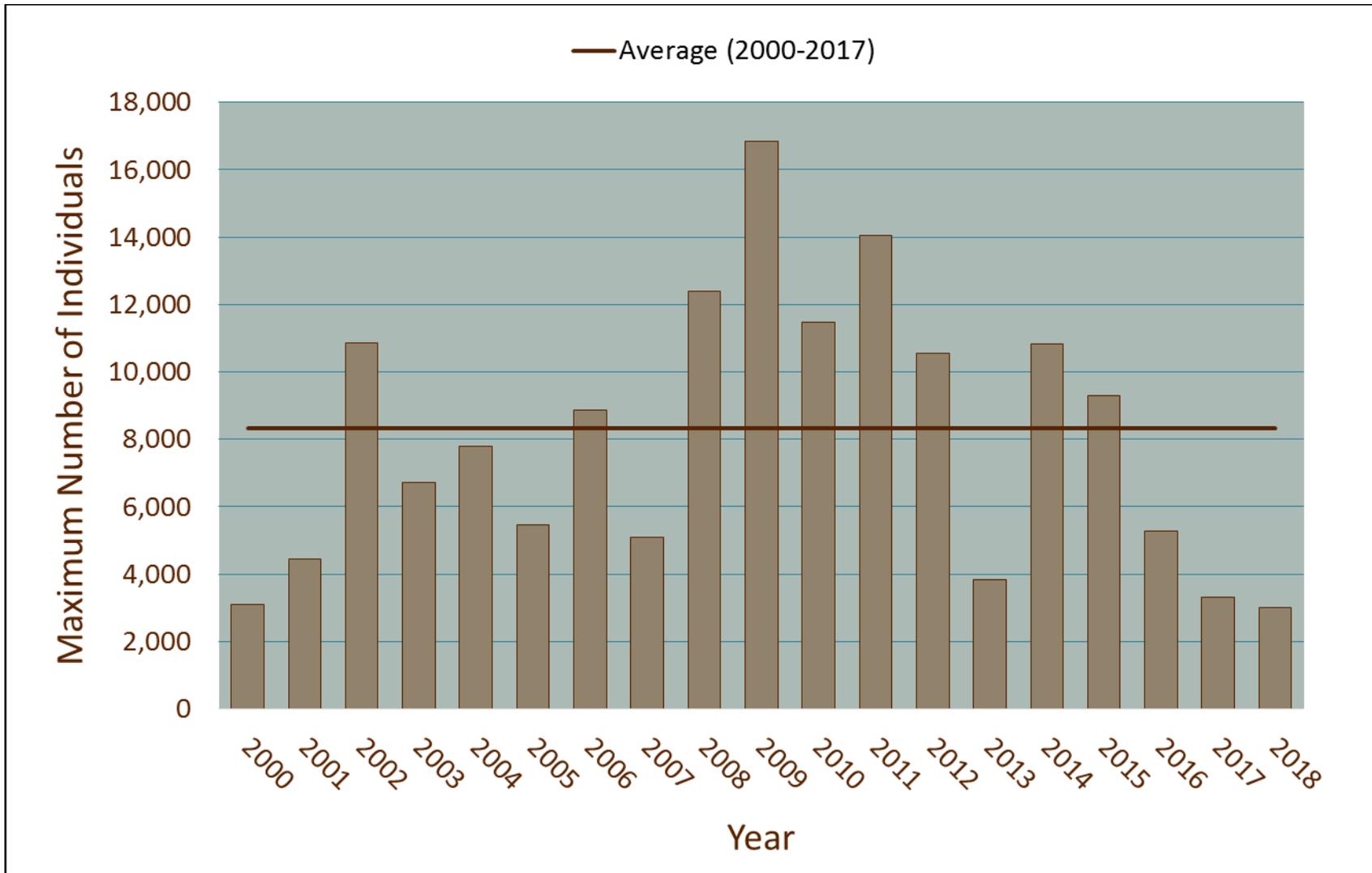


Figure 7. Maximum number of roosting California brown pelicans counted during boat-based surveys at East Sand Island in the Columbia River estuary during the 2000-2018 field seasons.

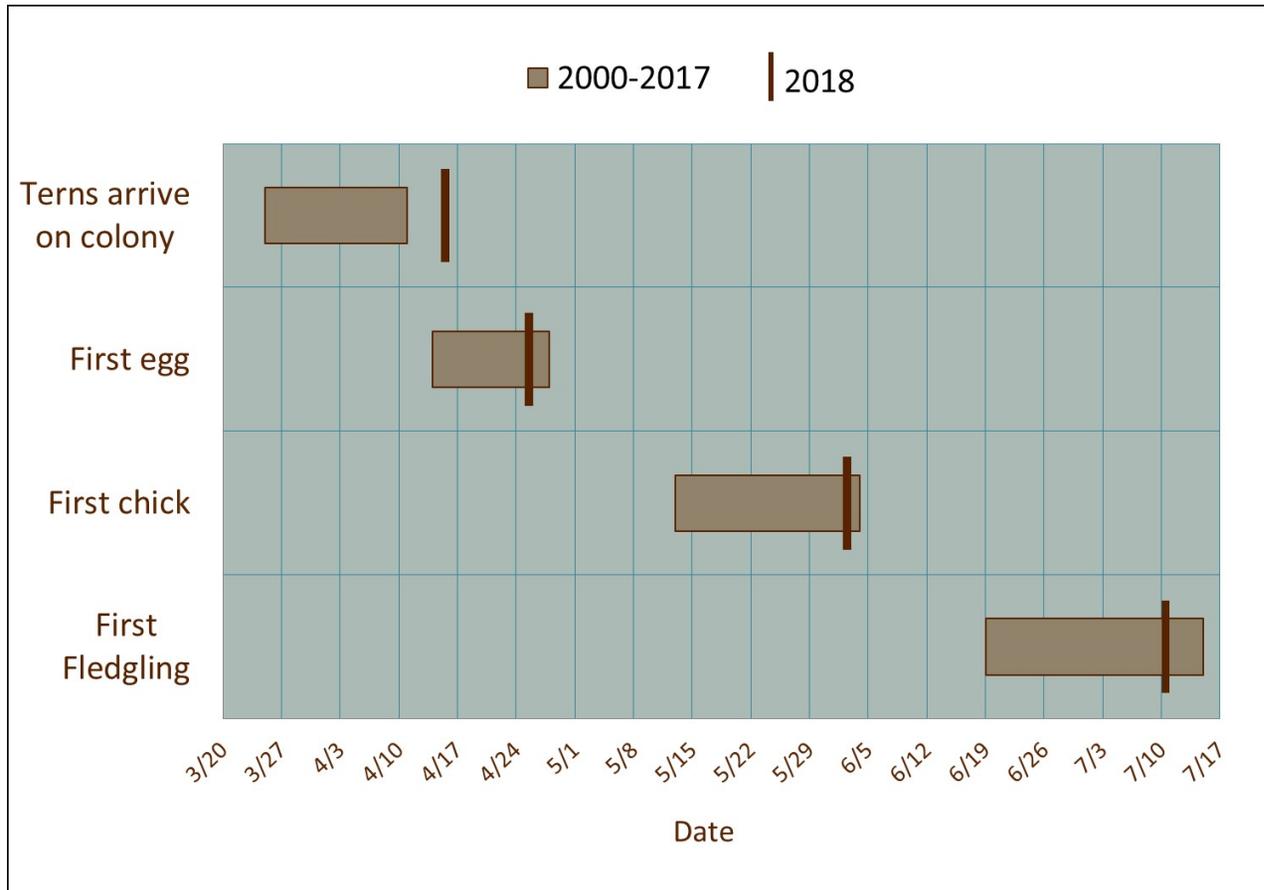


Figure 8. Nesting chronology for Caspian terns on the 1-acre designated colony area at East Sand Island during the 2018 breeding season. Note: In 2018, the island wasn't accessible due to inclement weather on 4/10-4/14 and terns may have landed on the colony during those dates.

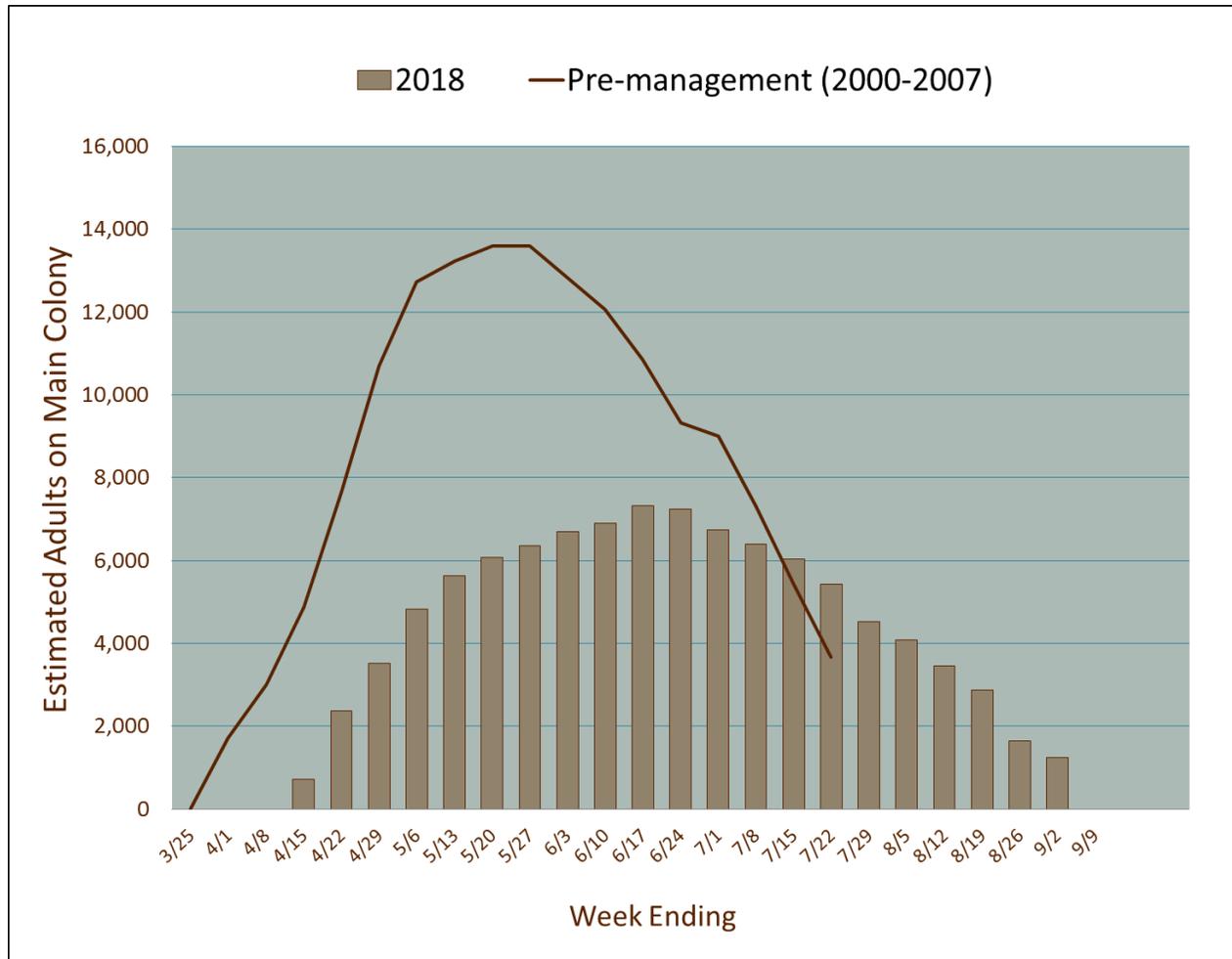


Figure 9. Weekly estimates from the ground of the number of adult Caspian terns on the 1-acre designated colony area at East Sand Island during the 2018 breeding season.

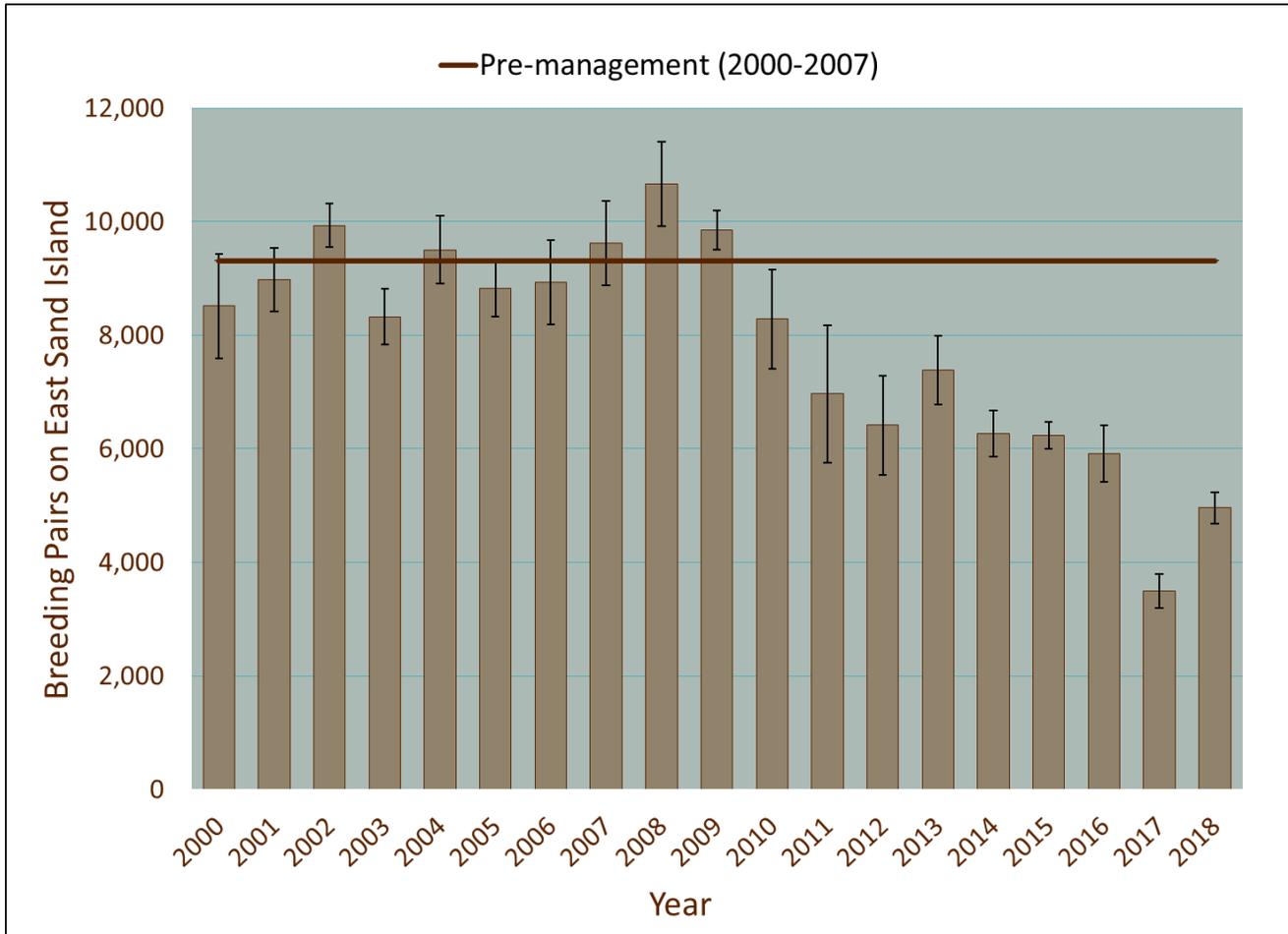


Figure 10. Caspian tern colony size (number of breeding pairs) on East Sand Island in the Columbia River estuary during 2000-2018. The error bars represent 95% confidence intervals for the estimate of the number of breeding pairs.

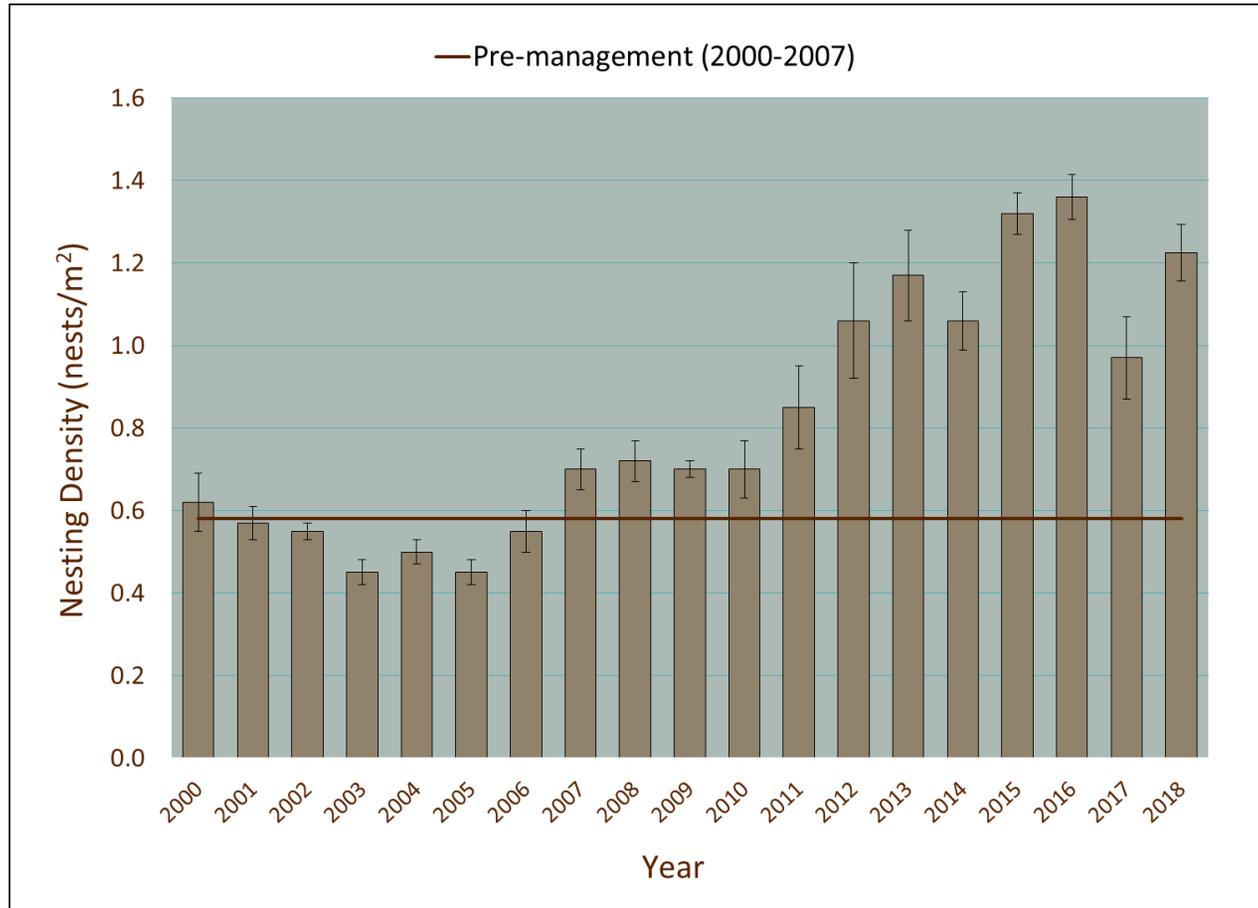


Figure 11. Caspian tern nesting density at the breeding colony on East Sand Island in the Columbia River estuary during 2000-2018. The error bars represent 95% confidence intervals for the estimate of nesting density (confidence interval not available for 2011 and based on confidence interval for 2012).

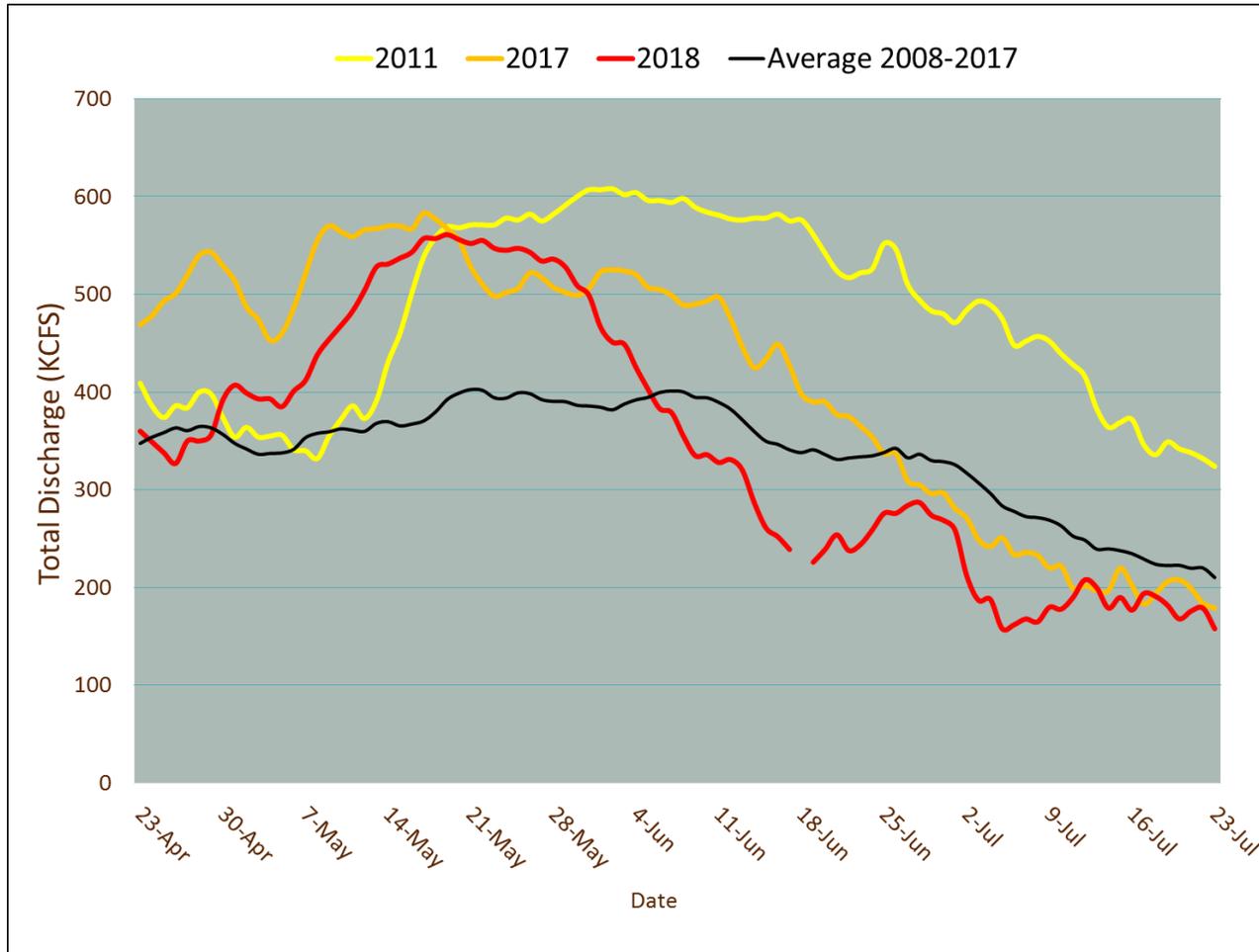


Figure 12. Total Columbia River discharge in thousands of cubic feet per second (kcfs) from 23 April to 23 July, 2008 – 2018 at USGS hydrological gage number 14246900 near Clatskanie, OR. Discharge in 2011 and 2017, the two years when the Caspian tern colony on East Sand Island failed to produce any young, is shown as yellow and orange lines, respectively.

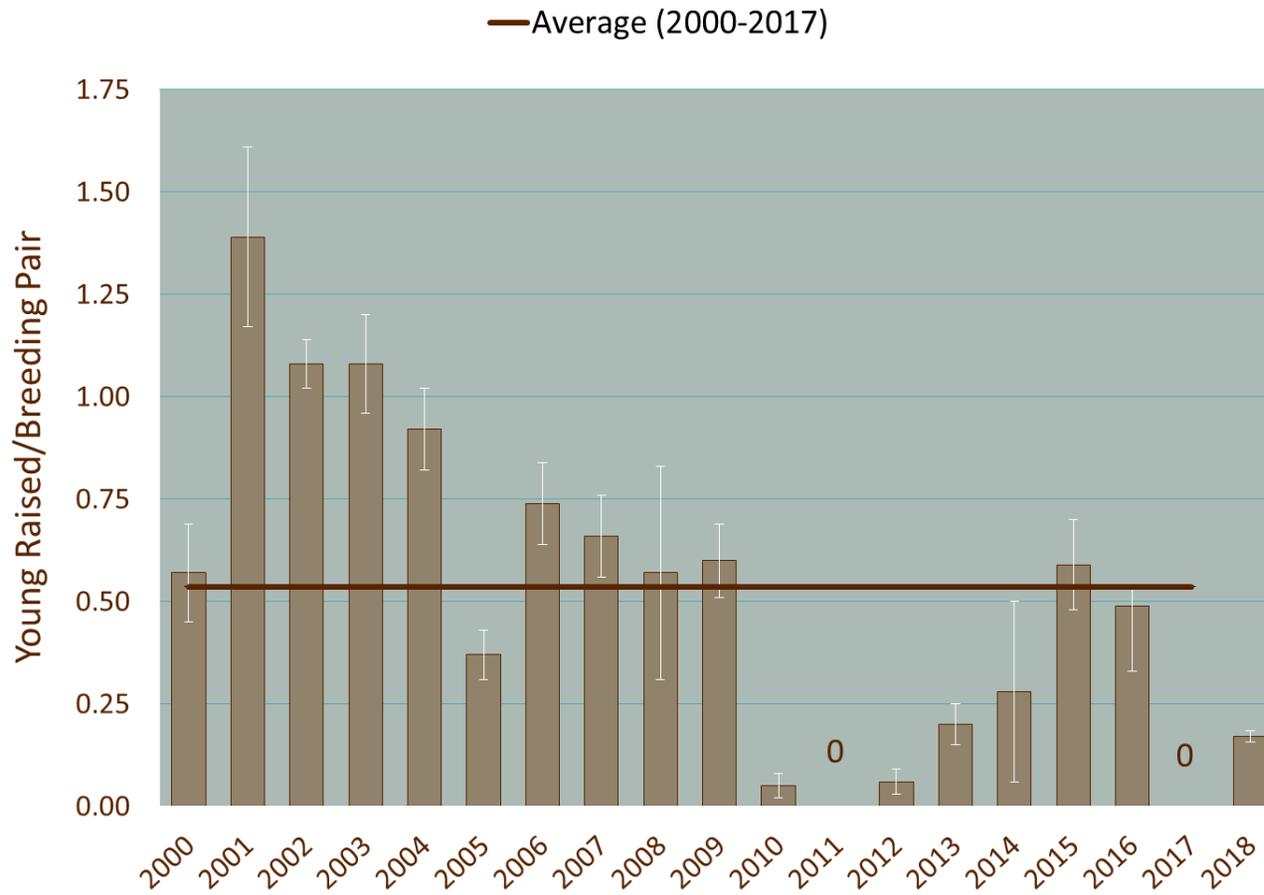


Figure 13. Caspian tern nesting success (average number of young raised per breeding pair) on East Sand Island in the Columbia River estuary during 2000-2018. The error bars represent 95% confidence intervals. No young were raised at the East Sand Island breeding colony in 2011 or 2017.

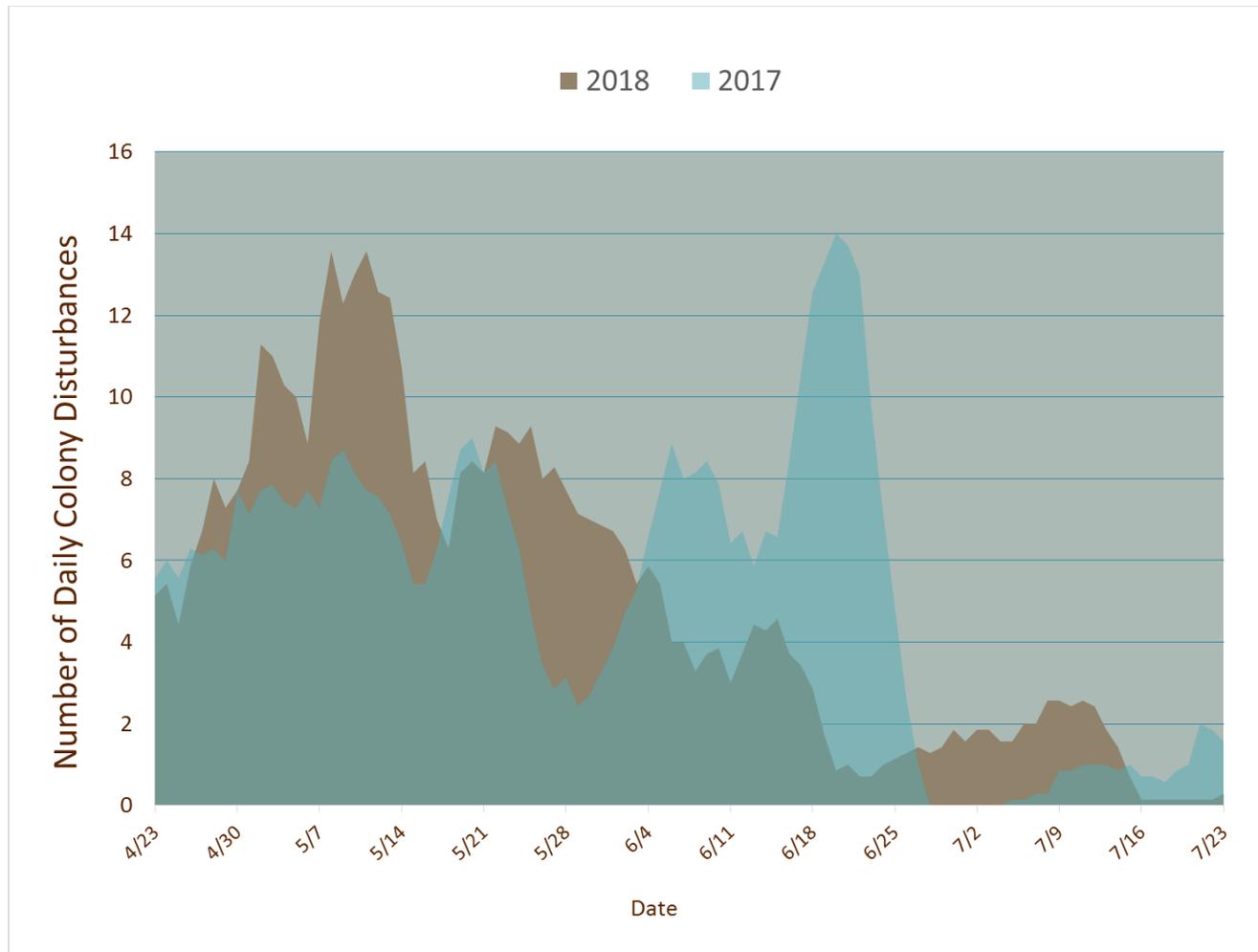


Figure 14. Number of daily Caspian tern colony flushes caused by bald eagles in 2017 and 2018 at the 1.0-acres prepared colony area on East Sand Island. Eagle disturbances were more frequent at the beginning of the 2018 breeding season compared to the 2017 breeding season, but tapered off by mid-June. In 2017, there was a large increase in the frequency of bald eagle disturbances in mid-June, immediately before a 10-day period when the tern colony was abandoned by the Caspian terns nesting on the prepared colony area at East Sand Island. In 2018, no extended periods of colony abandonment were observed and Caspian terns were able to fledge some young.

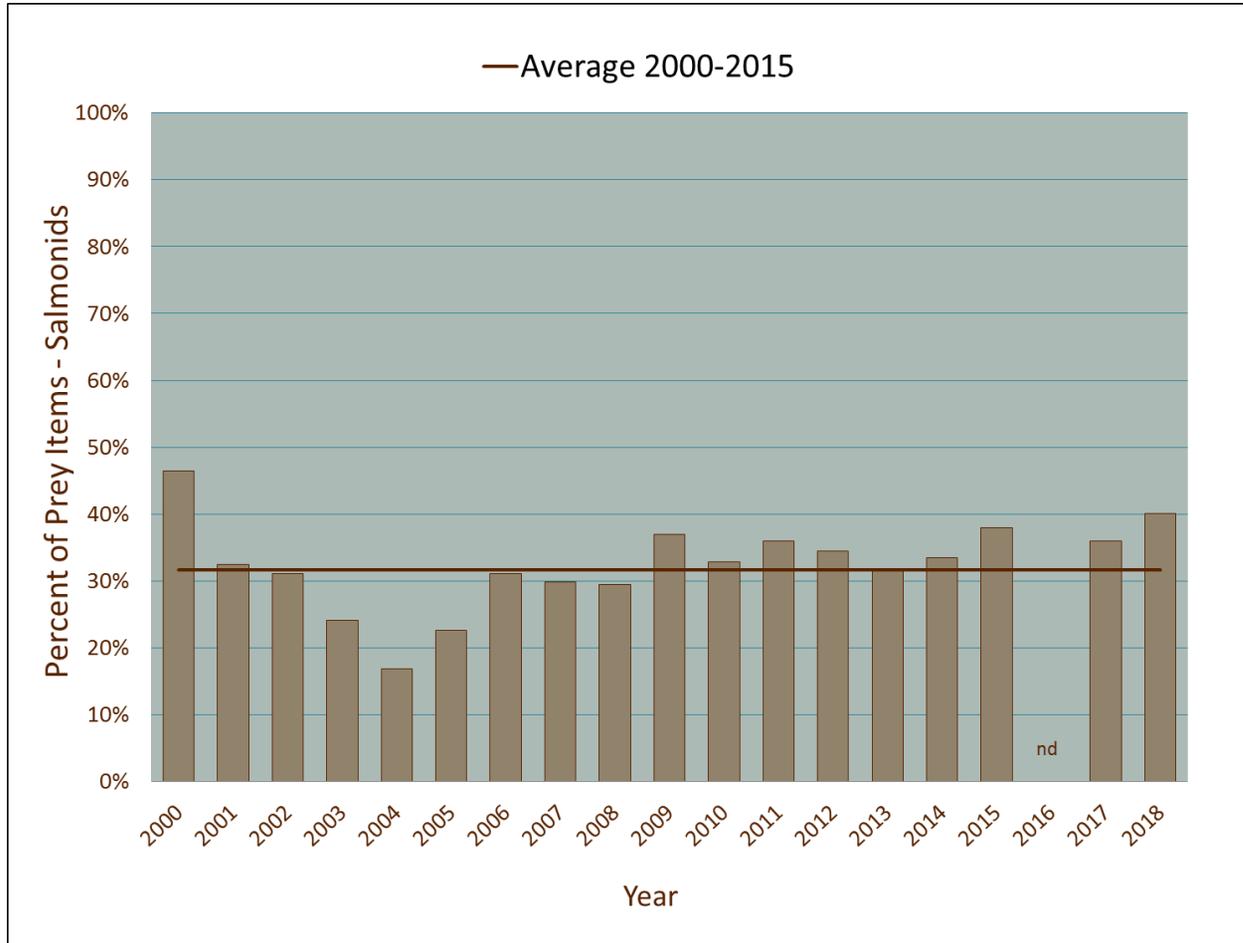


Figure 15. Average annual proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2018 breeding seasons. Each annual value represents the average of the proportions during the 2-week periods encompassing the entire nesting season.

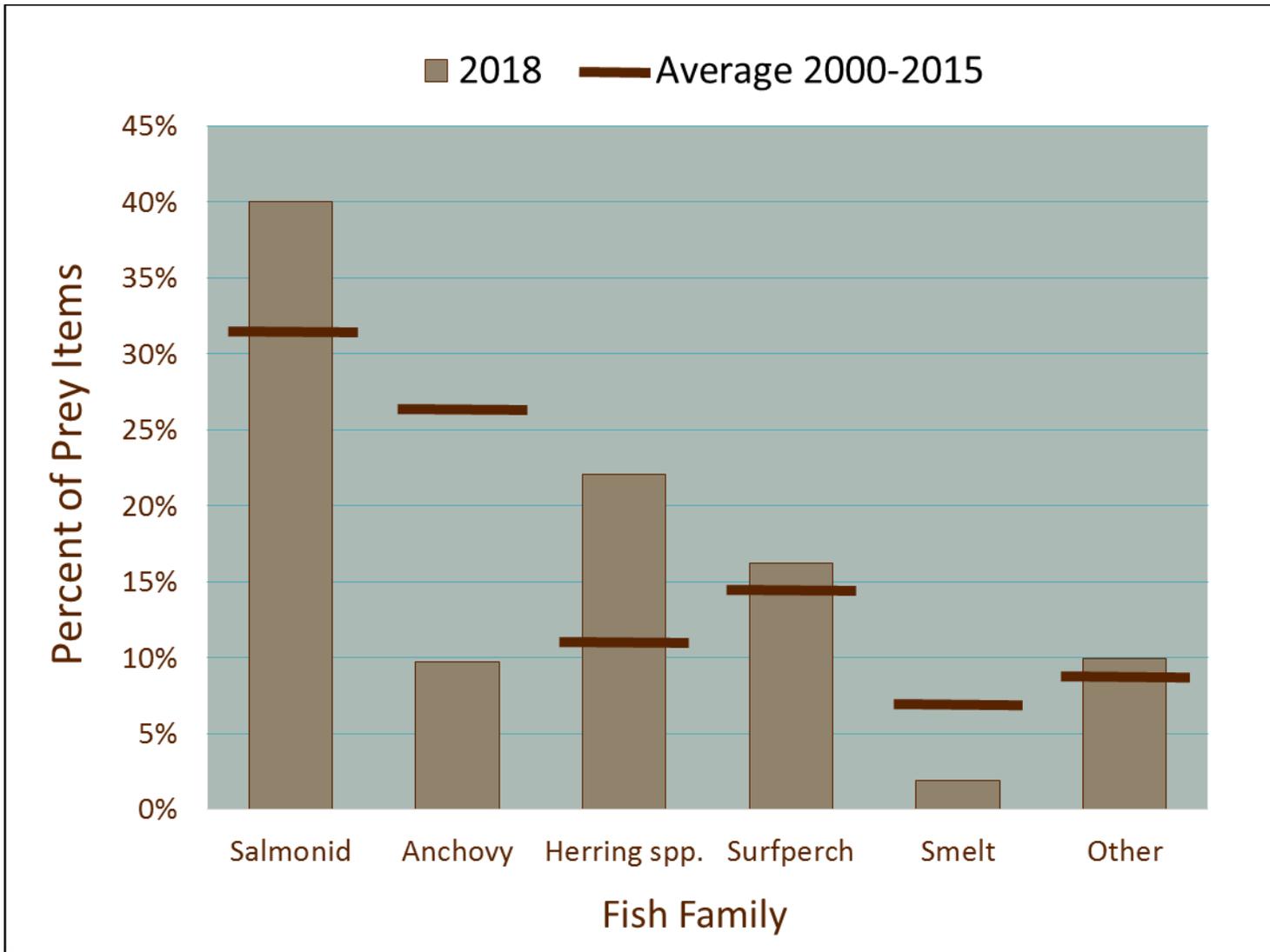


Figure 16. Diet composition (percent of identified prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2018 breeding season. Diet composition was based on fish visually identified on-colony in Caspian tern bill-loads.

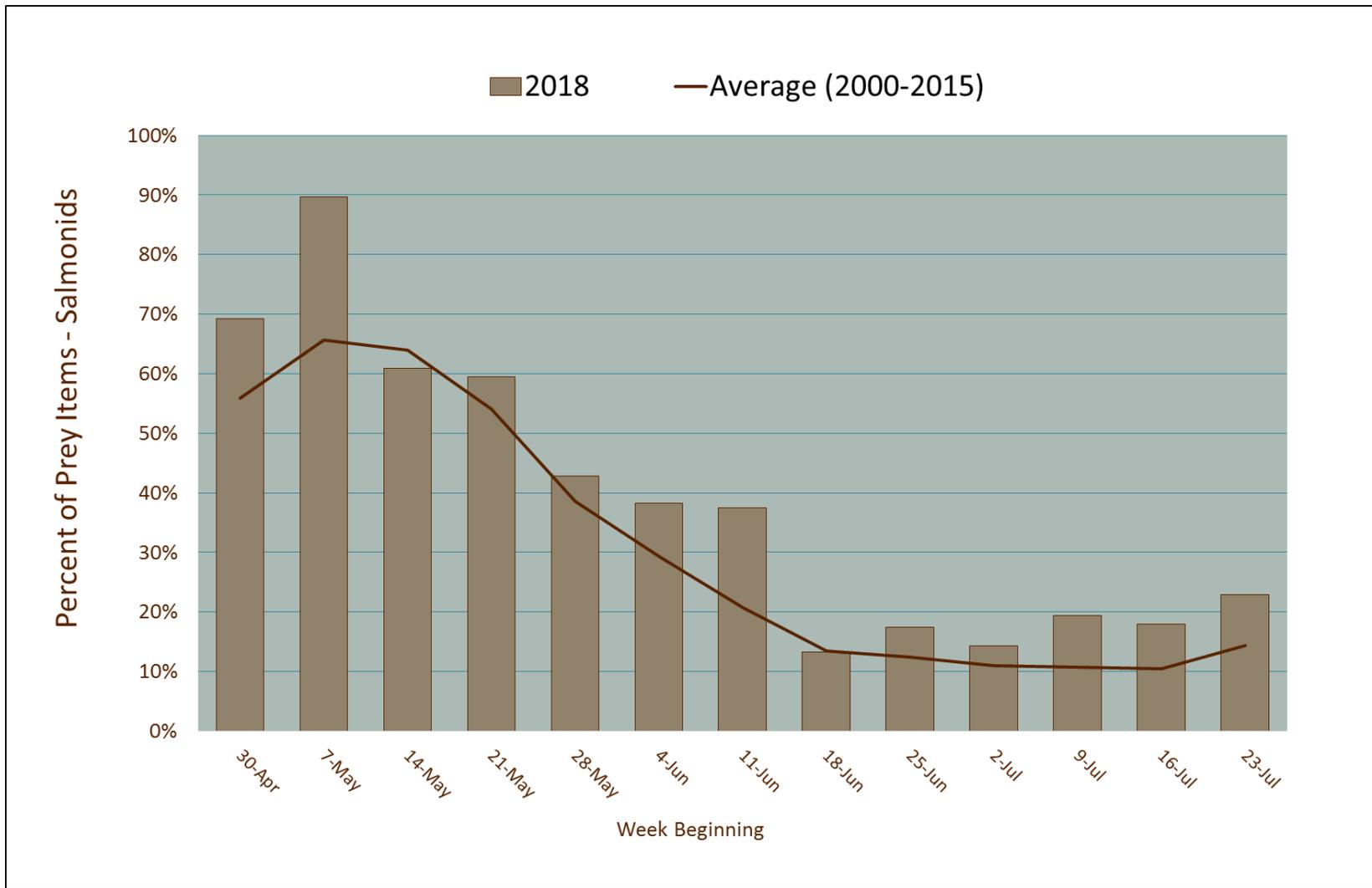


Figure 17. Proportion of juvenile salmonids (*Oncorhynchus* spp.) in the diet (percent of prey items) for Caspian terns nesting on East Sand Island in the Columbia River estuary, by week during the 2018 breeding season. Juvenile salmonids comprised a greater proportion of the tern diet compared to the long-term average in 11 of 13 one-week periods during the nesting season.

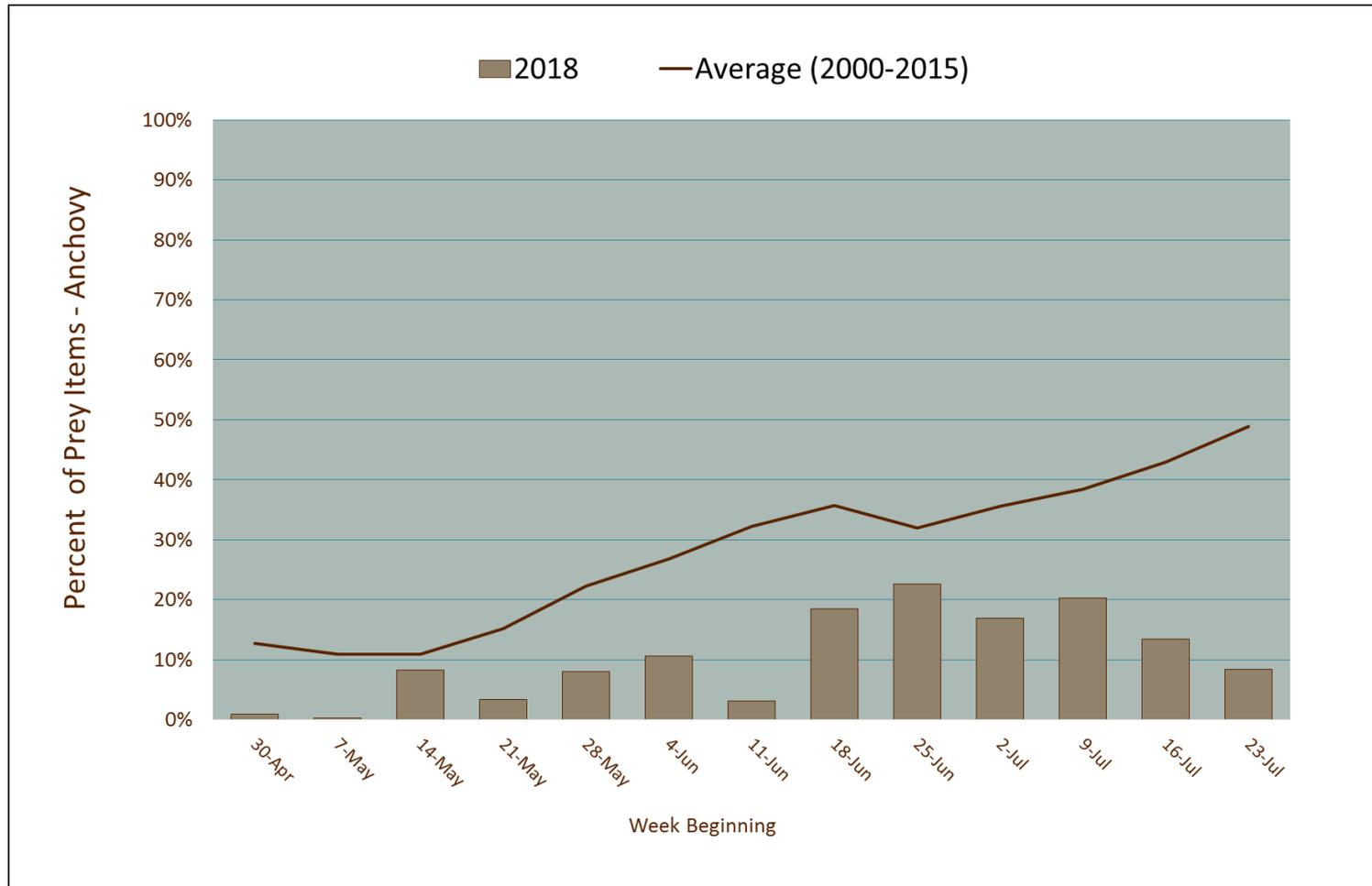


Figure 18. Weekly percentage of northern anchovy (*Engraulis mordax*) observed in the diet of Caspian terns (proportion of identified bill-loads) nesting at the East Sand Island colony during the 2018 breeding season. Anchovy comprised a smaller proportion of the tern diet throughout the 2018 nesting season compared to the long-term average.

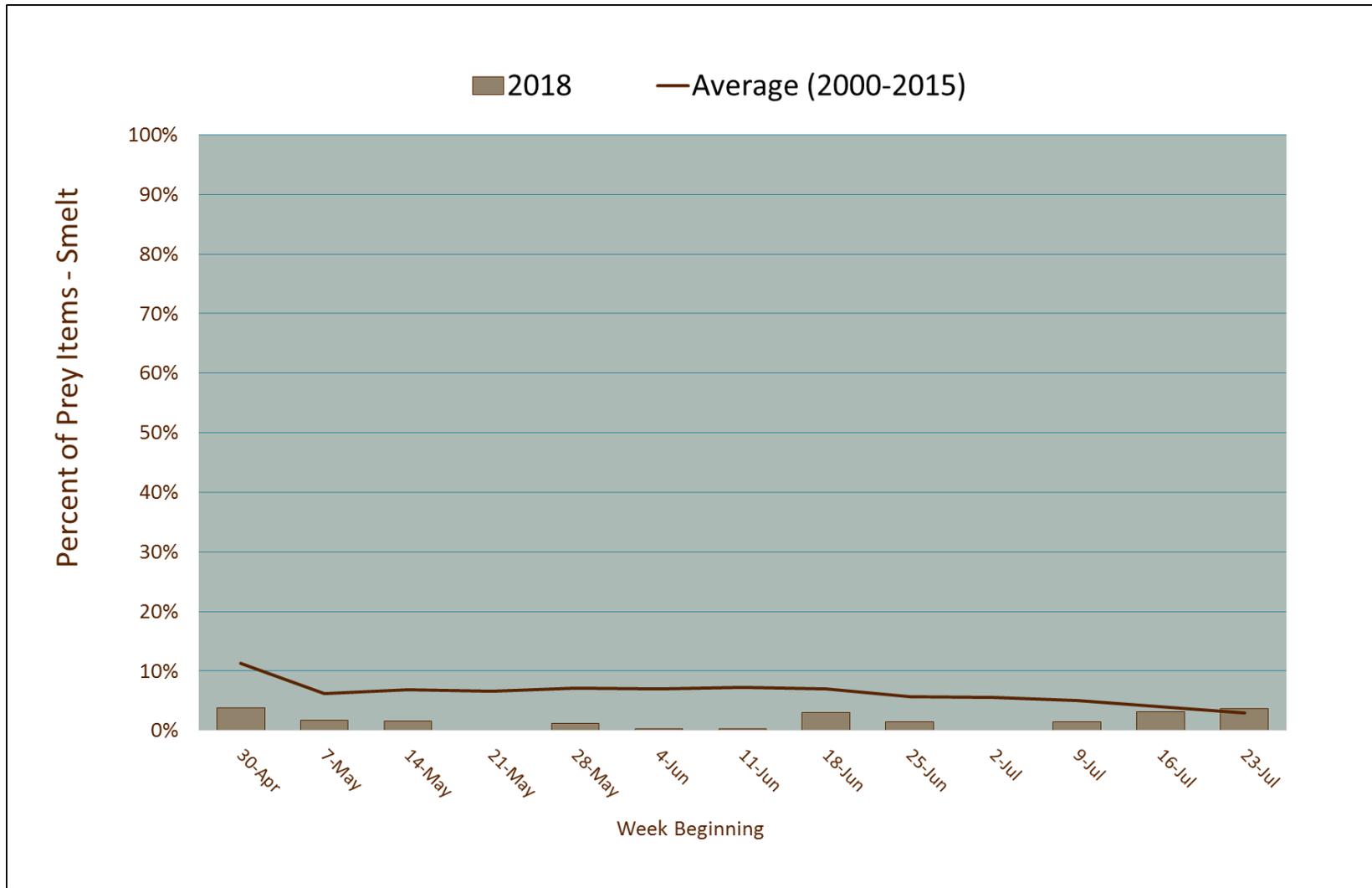


Figure 19. Weekly percentage of smelts (*Osmeridae*) observed in the diet of Caspian terns (proportion of identified bill-loads) nesting at the East Sand Island colony during the 2018 breeding season. Smelt comprised a smaller proportion of the tern diet throughout the 2018 nesting season compared to the long-term average, except for the last sampling week.

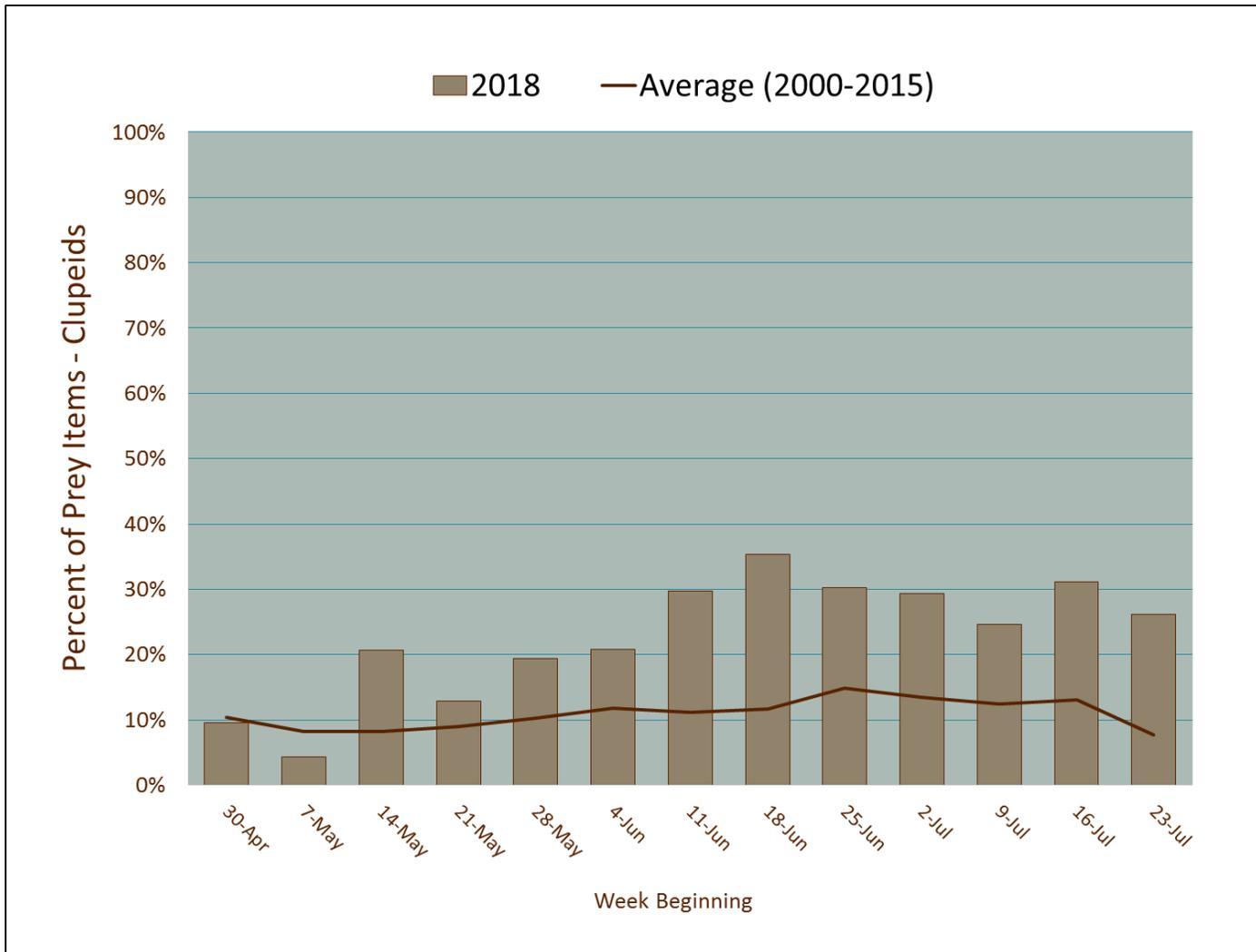


Figure 20. Weekly percentage of clupeids (Clupeidae: herring, sardines, and shad) in the diet of Caspian terns (proportion of identified bill-loads) nesting at the East Sand Island colony during the 2018 breeding season. Clupeids comprised a greater proportion of the tern diet compared to the long-term average in 11 of 13 one-week periods during the nesting season; the exceptions were the first two weeks when the diet was sampled.

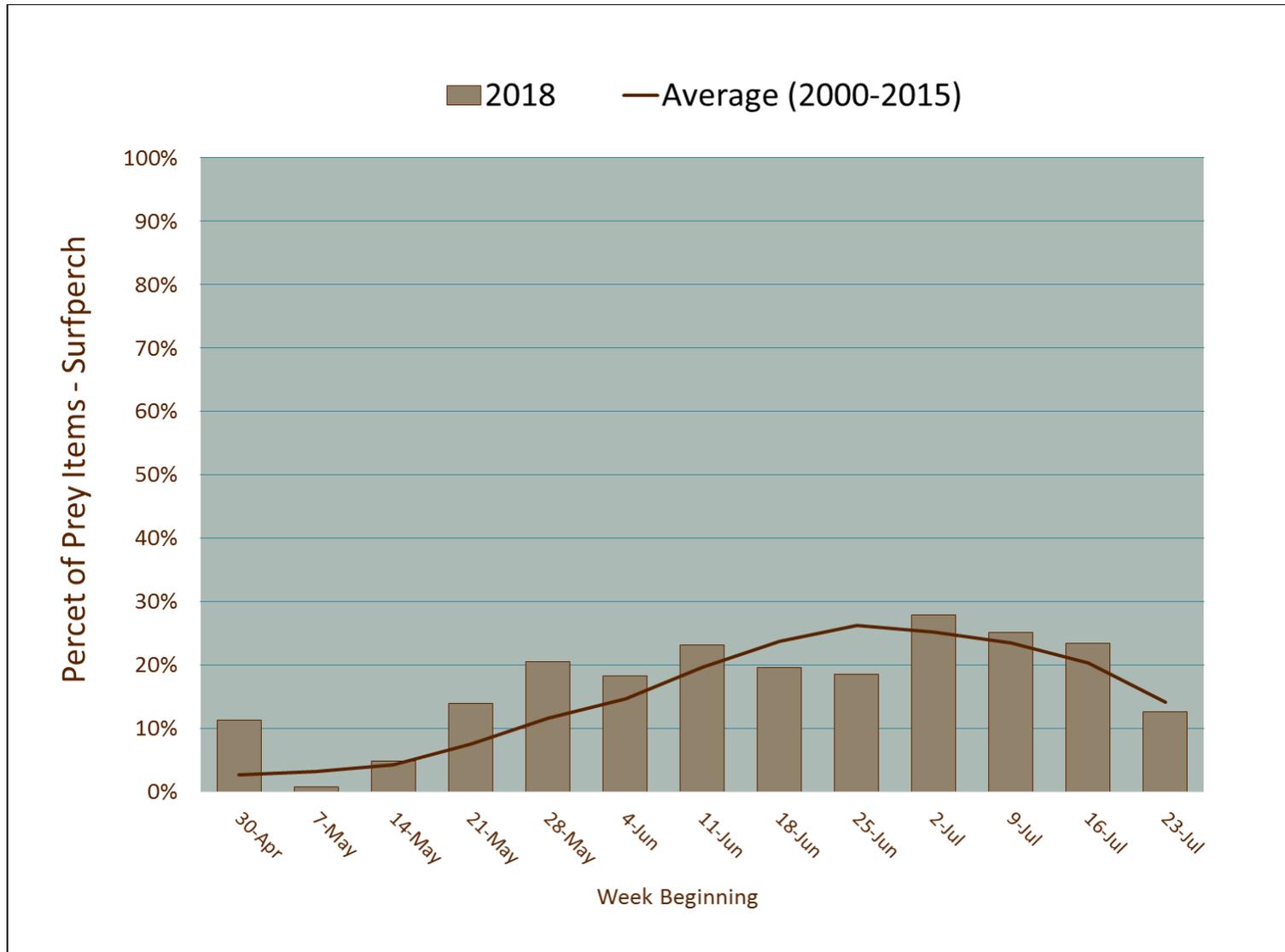


Figure 21. Weekly percentage of surfperch (Embiotocidae) in the diet of Caspian terns (proportion of identified bill-loads) nesting at the East Sand Island colony during the 2018 breeding season.

## TABLES

Table 1. Weekly duration (minutes) and maximum number of Caspian terns counted in each zone during monitoring and active nest dissuasion sessions on the eastern half of East Sand Island in 2018. Dissuasion effort is the time required to monitor for nesting behaviors and nest contents. Active hazing effort reflects the amount of human presence and disturbance needed to prevent Caspian tern nesting activity outside of the 1-acre colony area in 2018. See Map 11 for locations of survey zones.

| Week      | Average Daily Dissuasion Effort (min.) | Average Daily Active Hazing Effort (min.) | Maximum Number of Caspian Terns Counted |                 |            |                 |             |             |             |                 |
|-----------|--|---|---|-----------------|------------|-----------------|-------------|-------------|-------------|-----------------|
|           |  |   | North Beach                             | Northeast Beach | East Beach | Southeast Beach | South Beach | East Inland | West Inland | Below Tide-line |
| 4/16-4/22 | 57                                     | 1   | 0                                       | 0               | 0          | 2               | 7           | 0           | 0           | 1189            |
| 4/23-4/29 | 121                                    | 33  | 20                                      | 2               | 56         | 152             | 372         | 0           | 0           | 2505            |
| 4/30-5/6  | 93                                     | 39  | 0                                       | 0               | 47         | 192             | 441         | 0           | 0           | 2268            |
| 5/7-5/13  | 200                                    | 225                                       | 0                                       | 2               | 85         | 156             | 341         | 0           | 0           | 2017            |
| 5/14-5/20 | 755                                    | 438                                       | 0                                       | 19              | 226        | 84              | 311         | 0           | 0           | 2157            |
| 5/21-5/27 | 891                                    | 427                                       | 0                                       | 54              | 67         | 127             | 174         | 0           | 0           | 1275            |
| 5/28-6/3  | 823                                    | 412                                       | 0                                       | 125             | 48         | 117             | 212         | 0           | 0           | 1731            |
| 6/4-6/10  | 905                                    | 435                                       | 0                                       | 12              | 29         | 166             | 171         | 0           | 0           | 1396            |
| 6/11-6/17 | 527                                    | 220                                       | 0                                       | 2               | 83         | 74              | 106         | 0           | 0           | 1115            |
| 6/18-6/24 | 322                                    | 136                                       | 0                                       | 0               | 50         | 91              | 83          | 0           | 0           | 831             |
| 6/25-7/1  | 432                                    | 177                                       | 0                                       | 0               | 0          | 79              | 121         | 0           | 0           | 647             |
| 7/2-7/8   | 167                                    | 62  | 0                                       | 0               | 0          | 95              | 107         | 0           | 0           | 977             |
| 7/9-7/15  | 126                                    | 74  | 4                                       | 31              | 18         | 259             | 253         | 0           | 0           | 1469            |
| 7/16-7/22 | 100                                    | 57  | 0                                       | 0               | 23         | 130             | 286         | 0           | 0           | 1373            |
| 7/23-7/29 | 114                                    | 33  | 0                                       | 0               | 58         | 109             | 215         | 0           | 0           | 980             |
| 7/30-8/5  | 39                                     | 3   | 0                                       | 0               | 95         | 94              | 303         | 0           | 0           | 1402            |
| 8/6-8/12  | 47                                     | 4   | 0                                       | 0               | 48         | 95              | 168         | 0           | 0           | 1240            |
| 8/13-8/19 | 32                                     | 3   | 0                                       | 0               | 30         | 23              | 111         | 0           | 0           | 1105            |
| 8/20-8/26 | 22                                     | 2   | 0                                       | 0               | 52         | 33              | 97          | 0           | 0           | 660             |
| 8/27-9/2  | 16                                     | 1   | 0                                       | 0               | 64         | 19              | 37          | 0           | 0           | 565             |

Table 2. Total number of Caspian tern nest scrapes found and smoothed over each month in the eight survey zones during active nest dissuasion sessions on the eastern half of East Sand Island in 2018. No Caspian tern nest scrapes were discovered in the north beach, east inland, and west inland zones; nest scrapes below the high tide-line (n = 21) were likely inundated by the first high tide following discovery. See Map 11 for locations of survey zones.

|   | Survey Zone |             |             |                 |            |                 |             |                 |                    |                                     |
|---|-------------|-------------|-------------|-----------------|------------|-----------------|-------------|-----------------|--------------------|-------------------------------------|
|   | West Inland | East Inland | North Beach | Northeast Beach | East Beach | Southeast Beach | South Beach | Below Tide-line | All Zones Combined | All Zones (% of Total Nest Scrapes) |
| April                                       | 0           | 0           | 0           | 5               | 12         | 47              | 88          | 0               | 152                | 2%                                  |
| May   | 0           | 0           | 0           | 135             | 267        | 793             | 3,169       | 0               | 4,364              | 63%                                 |
| June  | 0           | 0           | 0           | 157             | 9          | 437             | 985         | 12              | 1,600              | 23%                                 |
| July  | 0           | 0           | 0           | 0               | 7          | 332             | 83          | 6               | 428                | 6%                                  |
| August                                      | 0           | 0           | 0           | 0               | 160        | 262             | 0           | 3               | 425                | 6%                                  |
| <b>All Months Combined</b>                  | 0           | 0           | 0           | 297             | 413        | 1,828           | 4,323       | 21              | <b>6,969</b>       |                                     |
| <b>All Months (% of Total Nest Scrapes)</b> | 0%          | 0%          | 0%          | 4%              | 6%         | 26%             | 62%         | 0%              |                    |                                     |

Table 3. 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 2000-2018. 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           |
| 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           |
| Average (2000-2017) | 8,007       | 7,395          | 8,620          | 0.79            | 0.73           | 0.85           |

Table 4. Numbers of banded Caspian terns resighted at East Sand Island in 2018 and the colony locations where they were originally marked 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 | 147              | 188              | 335   |
| Crescent Island, mid-Columbia River, WA      | 16               | 10               | 26    |
| Goose Island – Potholes Reservoir, WA        | 10               | 0                | 10    |
| Sheepy Lake, Lower Klamath NWR, CA           | 0                | 2                | 2     |
| Port of Bellingham, WA                       | 0                | 3                | 3     |
| Brooks Island, San Francisco Bay, CA         | 0                | 1                | 1     |
| Total  | 173              | 204              | 377   |

Table 5. Numbers of color-banded Caspian terns seen at East Sand Island in 2017 and resighted during the 2018 breeding season at nesting or roosting sites. Terns were banded during 2005-2016 with colored leg-bands engraved with unique alphanumeric codes. A total of 295 banded terns that were seen on East Sand Island in 2017 were resighted in 2018; two of these banded terns were resighted at two separate locations in 2018.

| Location where resighted in 2018             | Banded as adults | Banded as chicks | Total      |   |
|--|------------------|------------------|------------|---|
| East Sand Island, Columbia River estuary, OR | 142              | 144              | 286        |   |
| Blalock Islands, mid-Columbia River, OR      | 6                | 2                | 8          |   |
| Potholes Reservoir, WA*                      | 3                | 0                | 3          |   |
| <b>Total</b>                                 | <b>151</b>       | <b>146</b>       | <b>297</b> | * Potholes Reservoir includes<br>Goose Island and islands in northern Potholes Reservoir. |