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

2017 Final Annual Report

Submitted To: Bonneville Power Administration & Northwest Power and Conservation Council

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

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

Contract No. 60846
Project No. 1997-024-00
2/1/2017 – 1/31/2018

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
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
Telephone: 541-719-1652

Peter J. Loschl, Kirsten S. Bixler, Donald E. Lyons, Yasuko Suzuki,
Timothy J. Lawes, and Bristol Underwood
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

Final report submitted: May 10, 2018

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The primary objective of this study in 2017 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 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 evaluated 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 2017 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 breeding pairs or less, while preventing Caspian terns from colonizing other sites in the Columbia River estuary. As part of this plan, we delineated 1.0 acres of bare-ground nesting habitat for Caspian terns on East Sand Island prior to the 2017 nesting season; the same surface area of nesting habitat was provided for terns during the 2015 and 2016 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 later in 2017 than in previous years. The tern colony slowly grew to a peak size (numbers of breeding pairs) in early June, when about 3,500 breeding pairs (95% CI = 3,200 – 3,900 breeding pairs) were estimated to be nesting at the East Sand Island colony. This is a significantly smaller colony size than last year's estimate of peak colony size on the 1.0-acre colony area (5,200 breeding pairs), and approximately 12% greater than NOAA's management objective of 3,125 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 0.97 nests/m^2 (95% c.i. = 0.87 – 1.06 nests/m^2), significantly less than average nesting density in either 2015 (1.32 nests/m^2) or 2016 (1.36 nests/m^2), and the lowest nesting density observed at the East Sand Island tern colony since 2011.

By mid-June the size of the tern colony began to decline rapidly, however, and ultimately all active tern nesting attempts failed. The proximate cause of nest failure was disturbance by predators, primarily bald eagles (*Haliaeetus leucocephalus*), and associated secondary

predation on tern eggs and young chicks by gulls (*Larus* spp.). By 23 June the tern colony was completely abandoned and remained devoid of terns for 10 days, an unprecedented event at this colony. A second, much smaller wave of tern nesting activity at the East Sand Island colony began in early July and persisted until early September, with up to several hundred active tern nests with eggs present on the colony at one time. All nesting attempts in this second wave ultimately failed, however, and no Caspian tern young were raised at the East Sand Island colony in 2017.

Before and during the 2017 nesting season, we installed a total of 3.85 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 to further discourage nesting. This was the third 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 first year that those efforts were successful in preventing any Caspian terns from 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 2017 nesting season was 36% (percent of identified prey items), similar to the proportion (38%) in 2015 (the last year that tern diet composition was measured at East Sand Island), but higher than the average proportion of salmonids in the diet (29%) prior to the initiation of management to reduce colony size on East Sand Island (2000-2007). As in previous years, estuarine and marine forage fishes (e.g., anchovies [Engraulidae], surf perch [Embiotocidae], smelt [Osmeridae], and herring [Clupeidae]) were collectively most prevalent in the tern diet, together averaging 53% of all identified bill-loads in the diet of terns nesting on East Sand Island in 2017. Bioenergetics calculations to estimate total smolt consumption by Caspian terns nesting at East Sand Island in 2017 are currently in progress and will be included in a subsequent annual report. Predation rates on specific populations of anadromous salmonids (ESUs/DPSs) by Caspian terns nesting on East Sand Island in 2017 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 the funding agency.

Resightings of previously-banded Caspian terns on East Sand Island during the 2017 nesting season indicated that there is strong natal and breeding philopatry to the East Sand Island colony, but 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 2017 that were seen on East Sand Island during the 2016 breeding season indicate that some adults are dispersing from the East Sand Island colony to alternative colony sites in the Columbia Plateau region and the Puget Sound region. One tern banded as a fledgling on East Sand Island and resighted at

that colony in 2016 was resighted at the Corps-constructed tern islands in Don Edwards NWR in San Francisco Bay during the 2017 breeding season.

Although the proximate causes of nesting failure at the Caspian tern colony on East Sand Island in 2017 were eagle disturbance and associated gull nest predation, ultimate cause(s) of tern colony failure and abandonment are less certain. Unusually high river discharge and poor ocean conditions during much of the 2017 Caspian tern nesting season appear to have played a major role. In 2011, the only other year when the tern colony at East Sand Island failed to raise any fledglings, river discharge was also exceptionally high, and marine forage fishes were scarce in the Columbia River estuary. In 2017, the diet of terns nesting at East Sand Island consisted of more salmonid smolts and fewer marine forage fishes during much of the nesting season, compared to the average in previous years. Our results suggest that the failure of the tern colony on East Sand Island to produce any young in 2017 was due to the interaction of top-down effects (eagles, gulls) and bottom-up effects (river discharge, ocean conditions) as they influence availability of marine forage fishes. While these factors likely had a major impact on tern nesting success at East Sand Island in 2017, they also may have limited the size and nest density of the East Sand Island tern colony in 2017.

INTRODUCTION

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 2005-2017). 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). In 2015 and 2016, 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).

Further management of Caspian terns to reduce losses of juvenile salmonids in the Columbia River estuary is currently in progress; the Records of Decision (RODs) for *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*, signed in November 2006, stipulated the redistribution of approximately 60% of the East Sand Island tern colony to alternative colony sites outside the Columbia River basin in Oregon and California (USFWS 2005, 2006). This management action is intended to further reduce smolt losses to Caspian terns in the estuary, while 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 was 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 2015–2017 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 2017 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

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, 2006) 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 relocating nesting Caspian terns from colonies within the basin to alternative colonies 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 (posted on the web at www.birdresearchnw.org).

CASPIAN TERN MONITORING & EVALUATION OF MANAGEMENT

Beginning in 2008, the USACE – Portland District implemented management described in the January 2005 Final Environmental Impact Statement (FEIS) and November 2006 Records of Decision (RODs) for *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary* (USFWS 2005, 2006). This management plan, which was developed jointly by the U.S. Fish and Wildlife Service (USFWS; lead), the USACE – Portland District, and NOAA Fisheries, sought to redistribute the majority of Caspian terns nesting at the colony on East Sand Island in the Columbia River estuary to alternative colony sites (artificial islands) in interior Oregon, northeastern California, and in the San Francisco Bay area (*Map 2*). The goal of the plan is to reduce Caspian tern predation on out-migrating juvenile salmonids in the Columbia River estuary, and thereby enhance recovery of salmonid stocks from throughout the Columbia River basin, without negatively affecting the Pacific Flyway population of Caspian terns. Thirteen of 20 evolutionarily significant units (ESUs) of Columbia Basin salmonids are currently listed as either threatened or endangered under the U.S. Endangered Species Act.

The Caspian Tern Management Plan for the Columbia River estuary called for the creation of approximately 5 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 1.0 acres (*Map 3*).

The specific objectives of the Plan are to reduce the size of the East Sand Island Caspian tern colony to 3,125 breeding pairs or less by limiting the availability of suitable nesting habitat, while providing new nesting habitat for Caspian terns at alternative colony sites outside the Columbia River estuary. These objectives were identified as the preferred alternative in the Final Environmental Impact Statement released in early 2005 (USFWS 2005). Caspian terns

displaced by habitat reduction on East Sand Island are expected to relocate to 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 1.0 acres of unvegetated nesting habitat for Caspian terns on East Sand Island just prior to the 2017 breeding season (*Map 4*).

The Caspian Tern Adaptive Management Team (Tern AMT) provided two new instructions for the preparation of tern nesting habitat on East Sand Island in 2017: (1) the shape of the nesting habitat should be more elongated than in previous years to create more colony edge, and (2) tilling of the colony surface should be limited to just the vegetated portions of the designated 1.0-acre colony area. Increased edge and decreased pre-season disking of the colony surface were two deviations from the tern habitat preparation procedure used in previous years. The Tern AMT hoped these changes would reduce the high tern nesting densities observed on the East Sand Island colony during the 2015 and 2016 nesting seasons.

The boundaries of the designated tern nesting area were adjusted in 2017 through the placement of fabric fencing on the edge of the 1.0-acre 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 two feet, spaced 6-8 feet apart, with each length of fence securely anchored at both ends using a diagonal bracing system (Wedge-Loc®). Runs of taught, barbless wire were secured to the fence posts at ground level, 18 inches above ground level (AGL), and 36 inches AGL. Commercial grade knitted fabric material (PAK Unlimited Inc.; 90% privacy screen), constructed with finished and grommeted edges, was used on East Sand Island in 2017 for the second 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 onto adjacent nesting substrate covered with posts, rope, and flagging.

To prepare a more elongated colony area in 2017, the southern edge of the colony was moved about 4 meters north of the 2016 location and the western limit of the colony was moved 32 m west of the 2016 location. The southern edge of the colony included a 103-m fabric fence row installed from near the southeast observation blind to the western limit of the colony. A second fence row was installed along the southern edge of the colony, two meters north of the first fence, extending 82 meters from the southeast observation blind before connecting with the

longer fence row. A short 7-m fence was installed to delineate 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*), and the eastern edge of the colony area was defined by the above-ground access tunnel used by the field crew to access the southeast observation blind (*Map 4*).

Preparation of unvegetated nesting habitat for Caspian terns was accomplished using a 4-wheel drive ATV and disking a portion of the 1.0-acre designated colony area to break-up newly-established vegetation around the edges of the area. Disking was limited to specific parts of the designated colony area that were pre-approved by the Tern AMT in 2017; disking occurred to a depth of approximately six inches. As was the case during 2013-2016, the colony area was not sprayed with pre-emergent herbicide in 2017. The area of designated Caspian tern nesting habitat on East Sand Island during the 2015 – 2017 nesting seasons was 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: Provision of 1.0 acres of unvegetated nesting habitat for Caspian terns on East Sand Island was completed during 4–11 April. As instructed by the Tern AMT, 1.0 acres of tern nesting habitat was delineated in a more elongated shape in 2017, and tilling of the colony surface was restricted to areas where dense annual weed growth occurred in 2016 or where perennial grass encroachment was evident. While the equipment used to prepare the colony surface was not effective at removing well-established European beach grass, one to two meters of sparse new beach grass growth that was encroaching along the northern edge of the designated colony area was successfully disked under. In addition, 3 to 5 passes with the disk were used to scarify two other parts of the designated 1.0-acre colony area: (1) the western portion of the colony area where a combination of European beach grass and annual weeds grew between fence rows installed in 2016, and (2) the east side of the colony area where perennial grasses were sprouting within 10 m of the access tunnel to the southeast blind. Following disking, the substrate was smoothed by dragging a section of chain-link fence over the disked areas. Approximately 30-40% of the 1.0-acre designated colony area was disked in 2017; the remainder of the surface of the designated colony area was left undisturbed.

Although new vegetation growth and gully-washout occurred on portions of the designated colony area, tern nesting was initiated over the full extent of the prepared 1.0-acre colony area in 2017. 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 2017 tern nesting season.

Maps depicting the placement of passive nest dissuasion materials in 2016 were used as an initial guide for placement of materials in 2017, with adjustments made for changes in the location of suitable tern nesting habitat since the previous breeding season. Passive dissuasion was re-installed on 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 nesting habitat not present in 2016. 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 nest dissuasion materials were deployed during 27 March - 13 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 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 high tide line. Most areas covered by passive dissuasion on East Sand Island consisted of installing a grid of 4- to 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). Ropes were attached to posts using clove hitch knots that allowed for rapid installation, secure attachment, and easy removal. Each cell was crossed diagonally with rope and 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 dissuasion was needed on beach locations deemed likely to be inundated during spring tides series, 1- to 1.3-inch diameter bamboo posts and 0.25-inch manila rope were sometimes substituted to reduce the amount of synthetic material washed away or buried by tide action. More liberal deployments of passive dissuasion materials were installed directly adjacent to the designated 1.0-acre colony area and in the locations where satellite tern colonies formed in 2015 and 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 high tide line. Two fence rows oriented east/west and spaced 2 m apart were installed on a portion of the historical colony area to create visual barriers on highly suitable nesting substrate directly adjacent to the south edge of the 1.0-acre area designated for tern nesting in 2017 (*Map 4*). 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 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 15-27 March. 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 high tide line (*Map 5*).

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 was conducted on the east end of East Sand Island only. 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 29 June through 3 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 2017, 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 3.49 acres of passive dissuasion was deployed on East Sand Island prior to the initiation of nesting by Caspian terns in 2017 (*Map 5*). Installation of fence rows and double layers of passive nest dissuasion in areas of highest risk for tern nesting contributed to successful nest dissuasion directly adjacent to the designated 1.0-acre tern nesting habitat. Unlike 2015, when Caspian terns established a satellite colony directly south of the prepared 1.0-acre tern colony site, terns were excluded from nesting successfully adjacent to the designated colony in both 2016 and 2017. The primary factors that prevented terns from nesting directly adjacent to the 1.0-acre designated colony area in 2017 included dense beach grass to the north, an installed fence row to the west, the access tunnel and dense vegetation to the east, and a combination of installed fence rows, double-layered posts, rope, and flagging, a steep, eroded bank at the top of the beach, and a dense accumulation of driftwood to the south (*Map 4*). In 2017, up to 10 nesting attempts occurred just outside and directly adjacent to the designated 1.0-acre colony area, where terns laid eggs under a single layer of passive nest dissuasion that was installed over about 80 m^2 of sparsely vegetated ground east of the northeast observation blind. Tern eggs laid in this location were depredated by glaucous-winged/western gulls within 24 hours of being laid. In addition, after the tern eggs were laid in this area and depredated, a dense regrowth of beach grass excluded terns from most of this area later in the breeding season.

Field observations of Caspian tern breeding behaviors on the east end of East Sand Island, including egg-laying on upper beaches, resulted in consultations with the USACE COR and 18 subsequent installations of supplemental passive nest dissuasion materials covering 0.35 acres (*Map 5*). Supplemental dissuasion materials were deployed during 7 May - 7 July, adjacent to

existing passive dissuasion that was installed prior to the arrival of terns. On 7 May, 26 cells of supplemental nest dissuasion were installed on the south beach in response to nest prospecting by Caspian terns and confirmation of the first tern egg laid outside the designated 1.0-acre colony. From 4 to 32 cells of supplemental dissuasion were deployed during 12 additional installations in response to continued Caspian tern nest prospecting and egg-laying through 2 June. In June, however, a marked decline in tern nesting activity occurred; no nest-scraping or egg-laying was detected outside the 1.0-acre colony area after 11 June. Coupled with complete abandonment by terns of the 1.0-acre designated colony area on 23 June, the complete lack of nesting activity on East Sand Island for the rest of June led to the limited removal of supplemental passive nest dissuasion material that was considered most prone to destruction from spring tides. On 29 June, passive nest dissuasion materials near the high tide line were removed from the south beach (26 cells), southeast beach (7 cells), and east beach (38 cells), and materials were stored on the island. Following complete abandonment of the designated 1.0-acre colony area for 10 days, Caspian terns resumed using the area on 3 July, but there were very limited signs of renewed nest scraping behavior on the beaches. During July, a maximum count of 10 nest scrapes in a single location was observed on 6 July. In response, 16 cells of passive nest dissuasion material were deployed in five final installations during 5-7 July. The installation of 0.35 acres of supplemental passive dissuasion during the breeding season brought the total area of passive nest dissuasion deployed on East Sand Island to 3.85 acres in 2017.

During the 2015 and 2016 nesting seasons, sizeable satellite tern nesting colonies formed outside the prepared 1.0-acre designated colony area, including a few nests that were established within areas covered with either initial or supplemental passive dissuasion materials. In 2017, however, tern nest dissuasion efforts were effective at deterring satellite colony formation. Extensive deployment of passive nest dissuasion materials on the south beach and around the ring-billed gull colony on the northeast beach, areas where social attraction contributed to the formation of satellite colonies in prior years, was part of successful dissuasion in 2017. All tern egg-laying outside the designated 1.0-acre colony area on East Sand Island occurred over a relatively short period in 2017 (less than 4 weeks), from 7 May to 2 June, and only 26 tern eggs were discovered outside the 1.0-acre colony area during the entire nesting season.

While passive nest dissuasion played a vital role in preventing the formation of tern satellite colonies on East Sand Island in 2017, environmental factors likely contributed to the reduction in tern nesting activity outside the designated 1.0-acre colony area. The combined effects of high river discharge and reduced marine forage fish availability, coupled with predator pressure in the form of bald eagle disturbances and subsequent nest depredation by glaucous-winged/western gulls, resulted in poor nesting success and a complete failure to raise young by Caspian terns nesting on East Sand Island in 2017. At the same time, Caspian terns consistently prospected for nest sites on suitable habitat at Rice Island in the upper estuary in 2017 (J. Maenhout, Blue Leaf Environmental, pers. com.), an alternate nesting site rarely occupied by terns since 2001. The large numbers of terns regularly prospecting for nest sites at Rice Island likely resulted in fewer terns prospecting for nest sites outside the designated 1.0-acre colony

area on East Sand Island. Additionally, complete nest failure and temporary colony abandonment occurred on the designated 1.0-acre colony area in late June. Finally, the smaller size, temporary abandonment, and reproductive failure of the tern colony in the designated 1.0-acre colony area in 2017 may have resulted in fewer terns being attracted to nest at the East Sand Island colony. Thus, annual variability in environmental conditions for nesting at East Sand Island, plus the availability of alternative tern nesting habitat in the estuary are likely important factors influencing the effort required to prevent the formation of tern satellite colonies on East Sand Island.

We found no evidence of brown pelicans or other bird species becoming entangled in passive nest dissuasion materials during the 2017 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 discovered when dissuasion materials were later disassembled for storage.

Section 3. Active Nest Dissuasion

Methods: In addition to passive tern nest dissuasion methods, we used active dissuasion (human hazing) to prevent Caspian terns from initiating nests outside of the designated 1.0-acre colony area at the east side of East Sand Island. Surveys of the east end of East Sand Island for terns prospecting for nest sites were conducted daily from 13 April to 21 July, and then 3-4 days each week through August. The number of active dissuasion sessions, their timing and duration, and the spatial extent of active hazing conducted by field technicians was adjusted on a daily basis, depending on the number, location, and behaviors of Caspian terns present outside the 1.0-acre designated colony area. Additionally, we monitored the presence and nesting status of other species of nesting and roosting waterbirds, and adapted active hazing activities to avoid disturbance that might cause egg loss (incidental take) at Caspian tern, California brown pelican, or gull nests that were initiated on or outside the designated 1.0-acre tern colony.

The peak number of California brown pelicans using East Sand Island in 2017 was determined by conducting periodic boat-based surveys (approximately every two weeks) from mid-May through early November. Because California brown pelican attempted to nest on East Sand Island in previous years, most recently in 2016 when three pelican nests with eggs were discovered, an effort was made to detect any nesting activity by brown pelicans during the 2017 breeding season. In addition to the effort by field personnel to detect brown pelican nesting activity, six remote sensing camera traps were positioned to monitor areas where brown pelicans had previously attempted to nest.

We installed an above-ground tunnel (5 m in length) from the southeast blind to the upper beach to facilitate access to the south beach for active hazing of terns by the field crew (*Map 4*) and to minimize potential disturbance to nesting terns or other species on or near the designated 1.0-acre colony area.

The primary technique used for active dissuasion was human hazing to flush Caspian terns from potential nesting substrate outside the designated colony area. Surveys for prospecting Caspian terns were conducted on foot by field personnel. 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 search 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 and nest scrapes, covered empty scrapes, and left the area immediately to avoid causing nest failure (loss of eggs) due to abandonment or depredation by gulls. When Caspian tern behavior suggested the potential for satellite colony formation, field personnel notified project supervisory staff who then consulted with the Corps' COR regarding the need to install additional supplemental passive dissuasion at the site where terns were prospecting.

The eastern portion of East Sand Island was subdivided into eight sectors for the purpose of data collection during active hazing. The eight sectors were identified as the "north beach," "northeast beach," "east beach," "southeast beach," "south beach," "west inland," "east inland," and "below tide-line" (Map 6). Although the below tide-line sector could not support the formation of a satellite tern colony due to frequent inundation, we monitored Caspian tern numbers and activity below the tide line to document trends in the total numbers of Caspian terns located outside of the designated 1.0-acre colony area on the east side of the island.

Results and Discussion: Caspian tern numbers and observations of breeding activities varied among the 8 sectors monitored on the east side of East Sand Island in 2017 (*Table 1*). In general, areas that were the focus of intensive tern nest prospecting and egg-laying in 2016 were again the areas with the highest (albeit reduced) tern nesting activity in 2017. Although a total of 26 Caspian tern eggs were detected on 5 of the 8 sectors on the east end of the island, no satellite tern colonies formed in 2017.

The two inland sectors located near the designated 1.0-acre colony area (west inland and east inland) were not used by Caspian terns during the 2017 nesting season, similar to 2016 when only three terns were observed on the east inland sector in late July. Both inland sectors were heavily vegetated, however, providing limited bare ground where terns could establish nests. In addition, regular use of the two inland sectors, particularly the east inland sector, by nesting glaucous-winged/western gulls, an aggressive nest predator, provided a natural deterrent to Caspian tern nesting.

The north beach sector was used infrequently and intermittently by Caspian terns in 2017, with up to 308 Caspian terns counted in this sector during a single hazing session. While the high count of terns observed in the north beach sector in 2017 was greater than that of 2016, use of the area was very limited, with terns observed during only 11 hazing sessions and nest scrapes (n = 8) detected only once (on 21 May). No Caspian tern eggs were found in the north beach sector. While terns were regularly observed loafing in large numbers on the mud flats below

the high tide line of the north beach sector, infrequent use of the limited beach area above the high tide line usually occurred on rising tides.

Caspian tern use of the east beach sector was also intermittent, but considerably more extensive than in 2016, when tern activity on the east beach sector was largely restricted to two weeks in May. The field crew counted 1 - 568 adult terns during 41 hazing sessions and 1 - 25 tern nest scrapes during 13 hazing sessions from 18 May - 28 July 2017. Despite increased tern presence and nest scraping activity in this sector during 2017, only one Caspian tern egg was detected in the east beach sector (on 17 May); this egg was not in a nest scrape and was never observed being attended by an adult tern. Unlike the south beach sector and a large portion of the southeast beach sector, where shoreline erosion removed beach sand and lead to a narrowing of the beach above the high tide line, the east beach sector has been an area of sand deposition and accretion above the high tide line. Thus, observers reported a widening area of suitable nesting substrate in the east beach sector throughout the 2017 breeding season.

Similar to 2016, the southeast beach sector was an area of relatively high tern nest prospecting activity in 2017. Although counts of adult terns in the southeast beach sector were not particularly high (only 2 - 60 individuals during 24 hazing sessions), 1 - 33 tern nest scrapes were detected during 26 hazing sessions, and four Caspian tern eggs were detected in the southeast beach sector during the 2017 nesting season. This compares to 17 tern eggs detected on the southeast beach during the 2016 nesting season. While shoreline erosion along most of the southeast beach sector reduced the area of suitable nesting substrate to a narrow band between the high tide line and densely accumulated woody debris, sand deposition at the eastern end of this sector resulted in increased area for nest prospecting in 2017.

Although no satellite tern colonies became established on East Sand Island in 2017, the highest level of prospecting outside the designated 1.0-acre colony area occurred on the northeast beach and south beach sectors, areas where satellite colonies formed in 2016. In the northeast beach area, 1 - 325 adult Caspian terns were counted during 67 hazing sessions and 1 - 53 tern nest scrapes were counted during 42 hazing sessions, all before the last week of May. In addition, nine Caspian tern eggs were detected in nine separate nest scrapes during five hazing sessions over just four days (14 - 17 May; *Table 2*). Six Caspian tern eggs were detected near the boundary of the east beach sector, including the only tern egg found outside the designated 1.0-acre colony area that was not lost within 24 hours of being laid. A complete absence of terns in the northeast beach sector beginning in late May contrasted with tern activity in this sector during the 2016 nesting season, when formation of a satellite colony was first detected on 22 June.

The greatest amount of Caspian tern nest prospecting activity outside the designated 1.0-acre colony area during 2017, by far, was in the south beach sector. Large numbers of Caspian terns dug many nest scrapes in this sector, and tern presence in the sector occurred over an extended period of the 2017 breeding season (*Table 1*). From 19 April to 3 August, 1 - 490 adult Caspian terns were counted during 340 hazing sessions, and 1 - 43 tern nest scrapes were

counted during 225 hazing sessions from 21 April to 24 July. With the exception of two weeks when the designated 1.0-acre colony area was completely abandoned, and terns were only observed roosting below the high tide line on East Sand Island, the south beach sector was the only off-colony sector with nesting substrate on the east end of the island that was consistently used by terns. A total of 10 tern eggs were detected in the south beach sector during hazing sessions over a 3-week period, from 7 May to 1 June. While a few tern nest scrapes retained eggs between successive hazing sessions, no tern eggs detected in the south beach sector persisted for more than 24 hrs. Thus, as in 2016, the majority of Caspian tern nesting attempts that occurred outside the designated 1.0-acre colony area were facilitated by social attraction from the nesting activity on the main tern colony, but in 2017 fewer eggs were laid and all nests failed before a satellite colony could become established.

In addition to the 24 Caspian tern eggs detected in beach sectors above the high tide line, two tern eggs were detected below the high tide line near the south beach sector (*Table 2*). A tern egg laid in a shallow nest scrape late in the day on 9 May was inundated by a high tide overnight. The second tern egg found below the high tide line was not in a tern nest scrape and may have been "dumped;" it was gone within 90 min of when it was first detected, likely depredated by a gull.

Habituation to active hazing of Caspian terns on the beach by terns nesting on the 1.0-acre colony area varied both between and across the 2016 and 2017 breeding seasons. In 2016, after apparent habituation by terns early in the nesting season, sensitivity by terns to the presence of hazers on the beach restricted efforts to actively dissuade terns from nesting on the south beach beginning in mid-June. The consequent reduction in hazing of the south beach sector, in order to avoid tern egg loss on the designated 1.0-acre colony area, contributed to the formation of a satellite tern colony in the south beach sector in 2016 (BRNW 2017). Early in the 2017 nesting season, hazing activity by field personnel in the south beach sector resulted in flushes of 5-50% of the Caspian terns on the 1.0-acre colony area. Flushes of the main tern colony declined to 1-5% of adults by early May, however, as field personnel adjusted their paths, used slower movements during active hazing, and terns became more habituated to the daily presence of hazers. Because the Caspian terns establishing nests on the main colony habituated quickly to the presence of nearby hazers, personnel were relatively unconstrained while hazing terns early in the nesting season. Increased tern sensitivity to hazers occurred later in the nesting season in 2017, after terns reoccupied the main colony area in early July following a 10-day temporary abandonment. An increase in the incidence and magnitude of tern colony disturbances was reported over a 3-week period following recolonization of the 1.0-acre colony area in early July, including several 90-100% colony flushes attributed to hazer activity on the south beach. Due to the heightened sensitivity of terns during the late season re-nesting, and tern eggs surviving for multiple days by late July, active hazing on the south beach and southeast beach sectors was discontinued on 27 July. Also, any field crew activities that might disturb the tern colony on the 1.0-acre colony area, including use of the southeast blind for monitoring, were discontinued on 27 July.

Our monitoring of other 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 on the eastern part of East Sand Island, but neither of these species was at significant risk of egg loss due to tern hazing activities in 2017. Also as in previous years, the eastern end of East Sand Island was used as a large post-breeding roost by California brown pelicans.

Glaucous-winged/western gulls were confirmed nesting in all seven sectors above the high tide line on 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 glaucous-winged/western gull nests were generally well removed (> 15 m) from the travel paths used by field personnel for daily monitoring and hazing of Caspian terns.

As in 2016, a large ring-billed gull colony formed on the vegetated and driftwood filled inlet and surrounding upland area adjacent to the northeast beach sector during the 2017 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 sector were restricted to more open habitat, well removed from the ring-billed gull colony, that remained accessible to field personnel for hazing and deployment of supplemental 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 2017, the first California brown pelicans seen on East Sand Island were observed roosting above the high tide line on the east beach on 19 April. Bi-weekly counts of California brown pelicans on East Sand Island peaked in early August at about 3,300 individuals (*Figure 14*), appreciably lower than the peak count in either 2016 (5,076 individuals) or 2015 (9,285 individuals), and well below the 18-year average peak count (8,342 individuals; *Figure 15*). No nesting activity by California brown pelicans was observed on East Sand Island during the 2017 breeding season. Aside from a few individual brown pelicans carrying sticks, no copulations, nest structures, or other pelican breeding behaviors were detected in 2017.

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 (5 June). Aerial imagery acquisition and orthophoto generation for East Sand Island was completed by GeoTerra, Inc. in conjunction with another project contracted by USACE – Portland District, but with coordinated flight timing to ensure capture and availability of island images when the Caspian tern breeding colony was at peak size in 2017. The average of three direct counts of all adult terns on the colony in aerial photography taken on 5 June, corrected using concurrent ground counts of the ratio of incubating to non-incubating terns on 12 plots within the colony area, was used to estimate the

number of breeding pairs on the colony at the time of the photography. Confidence intervals for the number of breeding pairs were calculated using a Monte Carlo simulation procedure to incorporate the variance in the counts from the aerial photography and the variance in the ratios of incubating to non-incubating adult terns among the 12 plots. Estimates of the number of breeding pairs were calculated one thousand times using random draws from the sample distributions of the total number of terns on-colony and the ratio of incubating to non-incubating adult terns on plots. Standard errors and confidence intervals for the number of breeding pairs were derived from the resulting distribution. The ArcGIS desktop tool, ArcMap, was used to count adults in the high-resolution vertical images of the Caspian tern colony to estimate colony size.

Historically, 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. Because no young terns were fledged from the East Sand Island colony during the 2017 nesting season (see *below*), this was not necessary.

Results and Discussion: Caspian tern nesting on East Sand Island in 2017 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 2017. Terns arrived on the main colony and initiated nesting later in 2017 than in previous years (*Figure 1*). The tern colony slowly grew to a peak size in early June, before declining rapidly due to the proximate cause of predator disturbance (primarily bald eagles) and associated secondary predation by gulls on tern eggs and young chicks. By 23 June, the designated 1.0-acre tern colony area was completely abandoned and it remained devoid of terns for 10 days (*Figure 2*), an unprecedented occurrence for the middle of the nesting season. The estimate of peak colony size in early June was 3,500 breeding pairs (95% CI = 3,200 – 3,900 breeding pairs), significantly less than last year's estimate of 5,200 breeding pairs on the designated colony area. A second, smaller wave of tern nesting at East Sand Island was initiated in early July, with several hundred active nests present on the 1.0-acre designated colony area at times and tern nesting attempts persisting until early September.

Efforts to limit tern nesting on East Sand Island to the 1.0-acre designated colony area using passive dissuasion (posts, ropes, and flagging) and active dissuasion (human hazing) were successful in 2017; in both 2015 and 2016 tern satellite colonies formed outside the 1.0-acre colony area on East Sand Island despite nest dissuasion efforts, supporting an additional 810 breeding pairs and 700 breeding pairs, respectively. Thus, the total number of Caspian terns that attempted to nest on East Sand Island in 2017 (3,500 pairs) represented a 41% decline in colony size compared to the total number of terns that nested on both the 1.0-acre designated colony area and nearby satellite colonies in 2016 (5,915 pairs; 95% c.i. = 5,410 – 6,425 pairs). This is the largest one-year decline in the number of breeding pairs of Caspian tern on East Sand Island since all terns nesting in the estuary relocated from Rice Island to East Sand Island in 2001 (Figure 3 and Table 3). Nevertheless, tern colony size on East Sand Island in 2017 was still slightly larger (12%) than the target colony size specified in the Caspian Tern Management Plan for the Columbia River estuary (3,125 breeding pairs; USFWS 2005, 2006).

The overall decline in tern colony size at East Sand Island during 2008-2017 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, 2006). 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 2015-2017 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 2008 (0.72 nests/m^2) to 2016 (1.36 nests/m^2). In 2017, however, nesting density declined to 0.97 nests/m^2 (95% c.i. = 0.87 – 1.06 nests/m^2), the lowest point estimate for nesting density observed at the East Sand Island tern colony since 2011 (*Figure 4*; *Table 3*).

Caspian terns failed to raise any young to fledging at the East Sand Island colony in 2017 (*Figure 5*). Although the proximate causes of nesting failure at the colony in 2017 were eagle disturbance and associated gull nest predation, ultimate cause(s) of tern colony failure and abandonment are less certain. Unusually high river discharge (*Figure 16*) and poor ocean conditions during much of the 2017 Caspian tern nesting season (L. Weitkamp, pers. comm.) appear to have played a major role. In 2011, the only other year when the tern colony at East Sand Island failed to raise any fledglings, river discharge was also exceptionally high (*Figure 16*), and marine forage fishes were scarce in the Columbia River estuary (Weitkamp et al. 2012, Collar et al. 2017). In 2017, the diet of terns nesting at East Sand Island consisted of more salmonid smolts and fewer marine forage fishes during much of the nesting season, compared to the average in previous years (Figures 8-12). In addition, the average size of one type of marine forage fish prey for terns, clupeids (herring, sardines, shad), was significantly smaller during most of the 2017 nesting season than in previous years (*Figure 13*). Together, these results suggest that the failure of the tern colony on East Sand Island to produce any young in 2017 was due to the interaction of top-down effects (eagles, gulls) and bottom-up effects (river discharge, ocean conditions) as they influence availability and quality of marine forage fishes (Collar et al. 2017; L. Weitkamp, pers. comm.). While these factors likely had a major impact on Caspian tern nesting success at East Sand Island in 2017, they also may have limited the size and nest density of the East Sand Island tern colony in 2017. Consequently, the relatively small colony size (3,500 pairs), and low nesting density (0.97 nests/m^2) of the tern colony in 2017 may not represent a trend that can be expected to continue in 2018.

As was the case during 2013-2016, 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 2017 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. DT03).

Section 5. Inter-colony Movements & Dispersal Patterns

Methods: In 2017, we continued to resight color-banded Caspian terns at the East Sand Island colony as part of our on-going efforts to develop a demographic model for Caspian terns in the Pacific Flyway population (*Appendix A*). 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 in 2017 to assess where Caspian terns emigrating from the East Sand Island colony were attempting to nest, 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 2017, 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 various sites in the Pacific Flyway during the 2017 breeding season to evaluate movements of Caspian terns to and from the Columbia River estuary (*Maps 1 and 2*).

Summaries of band resighting data collected at East Sand Island during the 2017 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 2017. This report also includes a summary of banded Caspian terns observed at East Sand Island in 2016 and locations where those terns were observed again in 2017. 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 17 May and 17 June during the 2017 nesting season to allow for the detection of new colonies that may have formed early or late during the Caspian tern nesting 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 the breeding status and other colony metrics at the site.

Additionally, site visits were conducted at 10 locations in the Puget Sound/Salish Sea region with known or suspected Caspian tern nesting activity to determine Caspian tern occupancy and breeding status during the period when the East Sand Island colony was completely abandoned in late June 2017. During 26-30 June, field observers conducted monitoring from land, boat, or commercial building vantages to monitor for nesting at eight sites with historical records of tern nesting and at two additional sites where new colonies were suspected. Depending on the conditions at each site, field observers used pop-up blinds or other natural or manmade objects to conceal themselves when monitoring terns at occupied sites. Sites confirmed to be occupied by Caspian terns were monitored to determine numbers of adult terns present, nesting status, breeding success (numbers of young present), and to resight banded terns, when possible.

Results and Discussion: During the 2017 field season, a total of 427 individual Caspian terns that were previously color-banded were resighted on East Sand Island. Of these resighted individuals, 85% were banded at East Sand Island (163 as adults and 200 as chicks), 7% were banded at Crescent Island in the mid-Columbia River (17 as adults and 14 as chicks), 3% were banded each at Goose Island-Potholes Reservoir (11 as adults and 1 as a chick) and at the Port of Bellingham (13 as chicks) in Washington, and < 1% were banded as chicks each at Brooks Island in San Francisco Bay, Crump Lake tern island in the Warner Valley, Oregon, Sheepy Lake tern island in Lower Klamath NWR, California, Malheur new tern island in Malheur NWR, Oregon, and Kokinhenik Bar in the Copper River Delta, Alaska (*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. Also, some banded Caspian terns are moving from both inland and coastal colonies throughout the breeding range of the Pacific Flyway population to the colony on East Sand Island in the Columbia River estuary, reflecting the continued status of the East Sand Island colony as the largest for the species within the Pacific Flyway.

Of a total of 595 color-banded Caspian terns seen on East Sand Island in 2016, 357 terns (60%) were resighted again in 2017, either at East Sand Island or elsewhere; three of these individuals were resighted at two different locations in 2017. Of a total of 360 resighting records of these banded birds in 2017, 82% were resighted at East Sand Island, 9% were resighted at the Blalock Islands in the mid-Columbia River, 5% were resighted at an active colony in Everett, Washington, 4% were resighted at Potholes Reservoir, Washington (either at Goose Island or islands in northern Potholes Reservoir), and < 1% were resighted at an active breeding colony in Pond A16 in Don Edwards South San Francisco Bay NWR, California (*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 are dispersing from the East Sand Island colony to

alternative colony sites in the Columbia Plateau region and the Puget Sound region. One tern banded as a fledgling on East Sand Island and resighted at that colony in 2016 was resighted at the Corps-constructed tern islands in Don Edwards NWR in San Francisco Bay during the 2017 breeding season (A. Hartman, U.S. Geological Survey, pers. comm.).

Results of aerial surveys of the lower Columbia River and outer Washington coast estuaries in 2017 indicated low numbers of Caspian terns were present at locations other than East Sand Island during the mid-May survey. On 17 May, 24 to 200 Caspian terns were observed loafing at three different sites on the lower Columbia River, and no terns were observed in Willapa Bay or Grays Harbor. During the 17 June aerial survey, 5 to 197 terns were observed loafing at two sites on the lower Columbia River and nine sites in Willapa Bay and Grays Harbor. Also during the 17 June survey, 107 Caspian terns were counted on the downstream end of Rice Island, including 15-20 individuals that were photographed in incubation posture. Inspection of oblique aerial photos revealed additional unoccupied nest scrapes near apparently incubating terns on Rice Island. The area where terns were apparently nesting lacked a whitewash stain, however, suggesting that the tern nesting attempt was recently initiated. No ground-based follow-up was conducted because Caspian tern monitoring and active management (hazing) were being implemented at Rice Island by Blue Leaf Environmental under contract with USACE - Portland District.

Following the complete abandonment of the designated 1.0-acre colony area on East Sand Island, a boat-based survey of the lower Columbia River estuary was conducted on 24 June in an effort to determine if significant numbers of Caspian terns were roosting at sites other than East Sand Island. Field personnel surveyed East Sand Island and five sites in the lower estuary where significant numbers of Caspian terns have been observed in the past: Desdemona Sands near the Astoria-Megler Bridge, Tongue Point Piers, Rice Island, Miller Sands Spit, and Pillar Rock Sands (*Map 1*). A total of about 1,600 Caspian terns were counted during the survey, with most (969 individuals) seen on the beaches at East Sand Island. About 467 individual terns were counted on Rice Island, about 131 individuals on Pillar Rock Sands, and about 25 individuals on the Tongue Point piers. It appeared that at least 5,000 Caspian terns that had attempted to nest on East Sand Island in early June had dispersed outside the Columbia River estuary, presumably in search of food.

During the period when the East Sand Island tern colony was completely vacant, site visits were conducted at 10 locations in the Puget Sound region (*Map 1*), Washington, where Caspian terns had formerly nested or were suspected of nesting in an attempt to discover where many of the terns from the East Sand Island colony had dispersed. These site visits during 26-30 June, confirmed the presence of active Caspian tern breeding colonies at two sites: the Kimberly-Clark industrial site on the waterfront in Everett, Washington, and the rooftop of the Seattle Tunnel Partners warehouse in South Seattle. Caspian tern nests with eggs and young were confirmed at the historical tern colony at the Kimberly-Clark industrial site and a newly discovered colony site on the Seattle Tunnel Partners warehouse. At three other sites in the Puget Sound region where Caspian terns have nested previously, terns were present, but there were no indications of nesting activity: Northwest Industries warehouse in NW Seattle,

unnamed islands in Padilla Bay near Anacortes, and the warehouse rooftop at 1000 F Street in Bellingham. Four other historical Caspian tern breeding colony sites that were visited were unoccupied: the Sea-Pac warehouse in West Seattle, the Trident Seafood warehouse in NW Seattle, Rat Island southeast of Port Townsend, and Dungeness Spit near Sequim. Finally, one site that was visited based on repeated location fixes from satellite-tagged Caspian terns was a large, active construction zone in Tacoma, on a mill site at Portland Avenue East and east 11th Street, where Caspian terns were loafing on a large gravel pad, but there was no evidence of nesting.

At the Kimberly-Clark property in Everett, Caspian terns were nesting on barges tied up at a dock and on a warehouse rooftop. Nesting on the docked barges was first discovered at this site in 2016, when 242 active Caspian tern nests were counted on two of three docked barges and 179 tern nests were counted on the warehouse rooftop, all from aerial photography taken on 15 June. On 29 June 2017, field personnel counted 1,902 adult Caspian terns, 508 active tern nests, and 365 tern chicks scattered over all three of the docked barges. On the same date, there were 311 adults, 98 active nests, and 35 chicks counted on the warehouse rooftop. Thus, based on a single site visit in 2017 conducted from more restricted vantage points, the number of terns nesting at the Kimberly-Clark industrial site was about 30% greater in 2017 compared to the estimated colony size in 2016. Nineteen banded Caspian terns resighted at Kimberly-Clark during the 29 June visit were seen on East Sand Island during the 2016 nesting season, including 6 that were also observed at East Sand Island earlier in the 2017 nesting season. One of the banded terns resighted at the Kimberly-Clark colony was confirmed nesting at the East Sand Island colony earlier in the 2017 nesting season. While we did not monitor the Kimberly-Clark colony over the nesting season to track seasonal attendance of adults at the site, the observation, based on a single visit, of a substantially larger colony in 2017 compared to 2016, and resighting of banded terns formerly seen on East Sand Island, suggests that some terns that left the Columbia River estuary in late June dispersed to the Kimberly-Clark colony.

The new tern colony located on the Seattle Tunnel Partners warehouse was discovered on 30 June, while observers were monitoring the formerly occupied Sea-Pac colony site. During that survey, commuting terns were observed from the West Seattle Bridge, flying southward along the Duwamish Waterway past the vacant Sea-Pac warehouse. With permission from a local business, observations of the new rooftop colony were made from a rooftop across the street, and 286 adult Caspian terns, 117 active tern nests, and 20 small chicks were counted. Several adult terns on the newly discovered colony were color-banded, but resighting data indicated that they were not previously banded or resighted at the East Sand Island colony, and unlikely to have dispersed from there.

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.

In mid-June, the Caspian tern colony on East Sand Island began to decline rapidly, and during a 10-day period in late June and the beginning of July there were no terns present on the colony. Immediately before, during, and after this period of colony abandonment, few if any bill-load observations were possible. After Caspian terns resumed nesting attempts in early July, the rate of collecting bill-load observations remained low due to the small number of actively breeding tern pairs on-colony. Because of the scarcity of bill-load observations after 16 June, any bill-load observations, regardless of the tide stage when they were collected, were included in the data set for diet composition.

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 2017 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. W9127N17F0014), 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 2017 nesting season (n = 3,385 bill-loads), on average 36% were juvenile salmonids. This proportion was similar to the proportion (38%) in 2015 (the last year that tern diet composition was measured at East Sand Island), but higher than the average proportion prior to the initiation of management on East Sand Island in 2008 (29%; *Figure 6*). 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 53% of all identified bill-loads in the diet of terns nesting on East Sand Island in 2017 (*Figure 7*). In 2017, 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 8*). However, the weekly proportion of salmonids in the tern diet was higher in April and early May of 2017, during spring smolt outmigration, as compared with the weekly averages during previous years (*Figure 8*). This period of heavy reliance on juvenile salmonids as a food source coincided with unusually high discharge in the Columbia River (*Figure 16*).

The proportion of some marine forage fishes, such as anchovies and smelt, in the tern diet during the 2017 nesting season was considerably lower than the long-term average (*Figures 9 and 10*). Surfperches, an estuarine resident, seemed to take the place of both marine forage fishes and juvenile salmonids in the tern diet (*Figure 11*), after the proportion of salmonids in the diet declined to normal seasonal levels in late May. The proportion of clupeids in the tern diet during the 2017 nesting season was not appreciably different from the long-term average (*Figure 12*), but the average size of clupeid prey items delivered as bill-loads to the tern colony was considerably smaller compared to the long-term average (*Figure 13*).

Taken together, these seasonal changes in tern diet composition during the 2017 nesting season, coupled with how these seasonal changes compared with the long-term average of tern diet composition at East Sand Island, indicate how food availability may have contributed to the collapse of the tern colony in mid-June, followed by the abandonment of the colony site for 10 days before some terns attempted to re-nest in July. By mid-June, juvenile salmonids, anchovies, and smelt were all smaller proportions of the diet in 2017 than the long-term average, and surfperches, a lower quality forage fish replaced these high-quality forage fishes in the diet (Roby et al. 2003). These trends suggest that once spring migrant juvenile salmonids left the estuary and were no longer readily available as a food source for terns, high-quality marine forage fishes (e.g., anchovies, smelt) were also not available near East Sand Island, presumably due to the high river discharge earlier in the season (*Figure 16*). This may have forced terns to switch to a less profitable food source, surfperch, which is well-adapted to the vagaries of salinity in estuary habitats. When this lower energy content prey could not meet the terns' food requirements, they abandoned their nests and the East Sand Island colony in search of schools of high-quality marine forage fishes. Once anchovies became available in the estuary during July, terns returned to the East Sand Island colony, and some attempted to re-nested.

Bioenergetics calculations to estimate total smolt consumption by Caspian terns nesting on East Sand Island in 2017 are currently in progress, and these data will be presented in the annual report for 2018, which will be finalized by late March 2019.

LITERATURE CITED

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

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

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

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

BRNW (Bird Research Northwest). 2009. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2008 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2010. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2009 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2011. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2010 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2012. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2011 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2013. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2012 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2014. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2013 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, the U.S Army Corps of Engineers – Portland District, and the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2015. Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River, 2014 Final Report. Submitted to the Bonneville Power Administration, U.S. Army Corps of Engineers – Walla Walla District, the U.S Army Corps of Engineers – Portland District, and the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2016. Avian Predation on Juvenile Salmonids: Evaluation of the Caspian Tern Management Plan in the Columbia River Estuary, 2015 Final Report. Submitted to the Bonneville Power Administration. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2017. Avian Predation on Juvenile Salmonids: Evaluation of the Caspian Tern Management Plan in the Columbia River Estuary, 2016 Final Report. Submitted to the Bonneville Power Administration. Available on-line at www.birdresearchnw.org.

Brownie, C., J.E. Hines, J.D. Nichols, K.H. Pollock, and J.B. Hestbeck. 1993. Capture-recapture studies for multiple strata including non-Markovian transitions. Biometrics 49: 1173-1187.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multi-model inference: a practical information-theoretic approach, 2nd ed. Springer. New York, USA.

Collar, S., D.D. Roby, and D.E. Lyons. 2017. Top-down and bottom-up interactions influence fledging success at North America's largest colony of Caspian terns (*Hydroprogne caspia*). Estuaries and Coasts, DOI 10.1007/s12237-017-0238-x

Hestbeck, J.B., J.D. Nichols, and R.A. Malecki. 1991. Estimates of movement and site fidelity using mark-resight data of wintering Canada geese. Ecology 72:523-533.

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

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

USACE (U.S. Army Corps of Engineers). 2014. Inland Avian Predation Management Plan Environmental Assessment. U.S. Army Corps of Engineers, Walla Walla District, Northwestern Division. January 2014. Available online at http://www.nww.usace.army.mil/Missions/Projects/InlandAvianPredationManagementPlan.aspx.

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

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

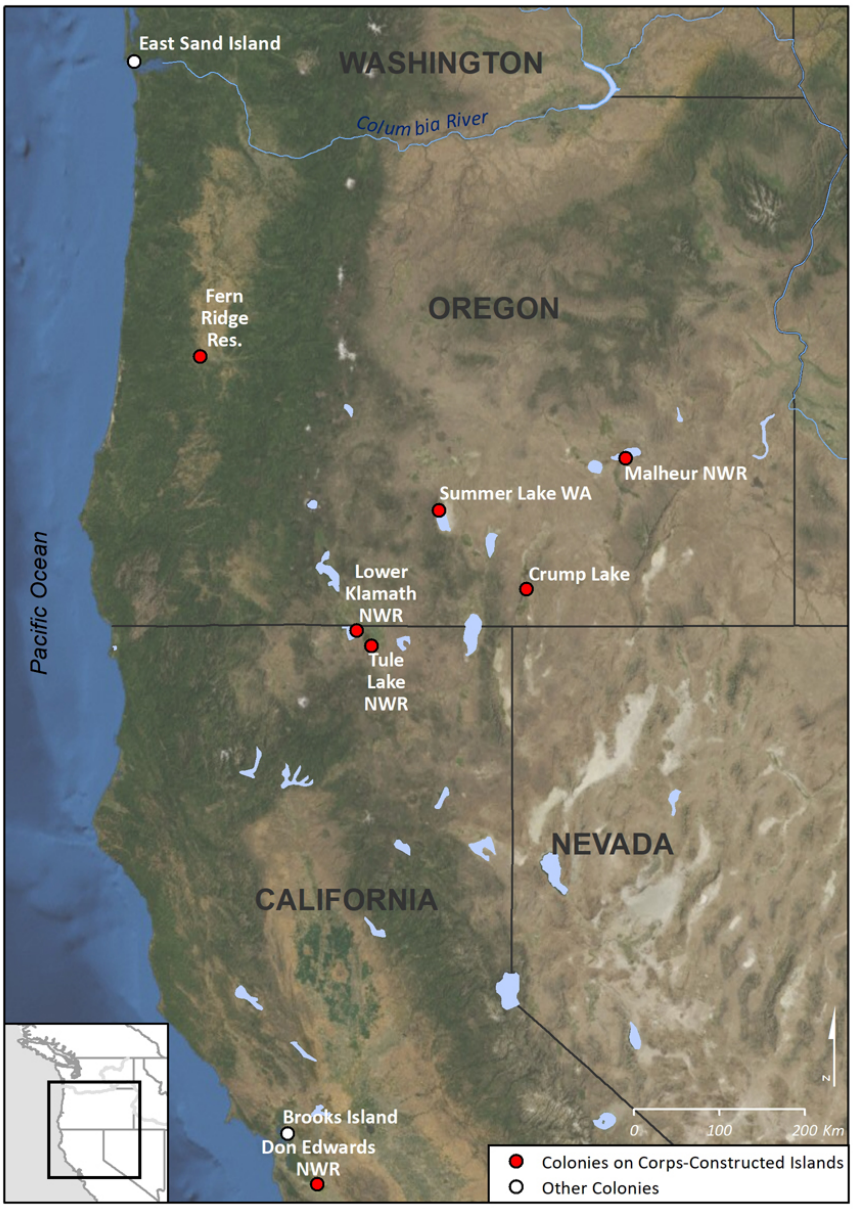
Weitkamp, L.A., P.J. Bentley, and M.N.C. Litz. 2012. Seasonal and interannual variation in juvenile salmonids and associated fish assemblage in open waters of the lower Columbia River Estuary. Fishery Bulletin 110:426–450.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:120-139.

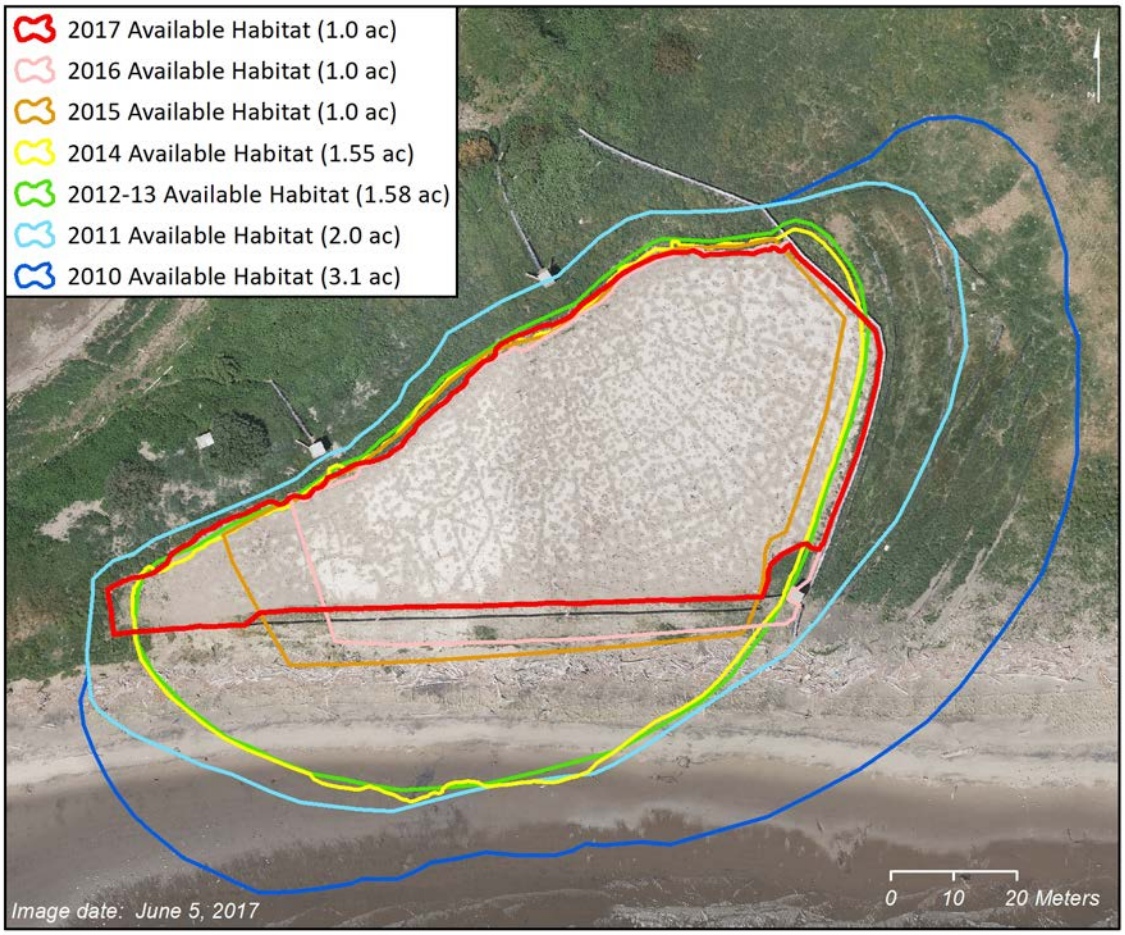
Wright, S.K. 2005. Disturbance and roosting ecology of California brown pelicans (*Pelecanus occidentalis californicus*) on East Sand Island in the Columbia River estuary. Unpublished M.Sc. Thesis, Oregon State University, Corvallis, Oregon. 106 pp.

MAPS

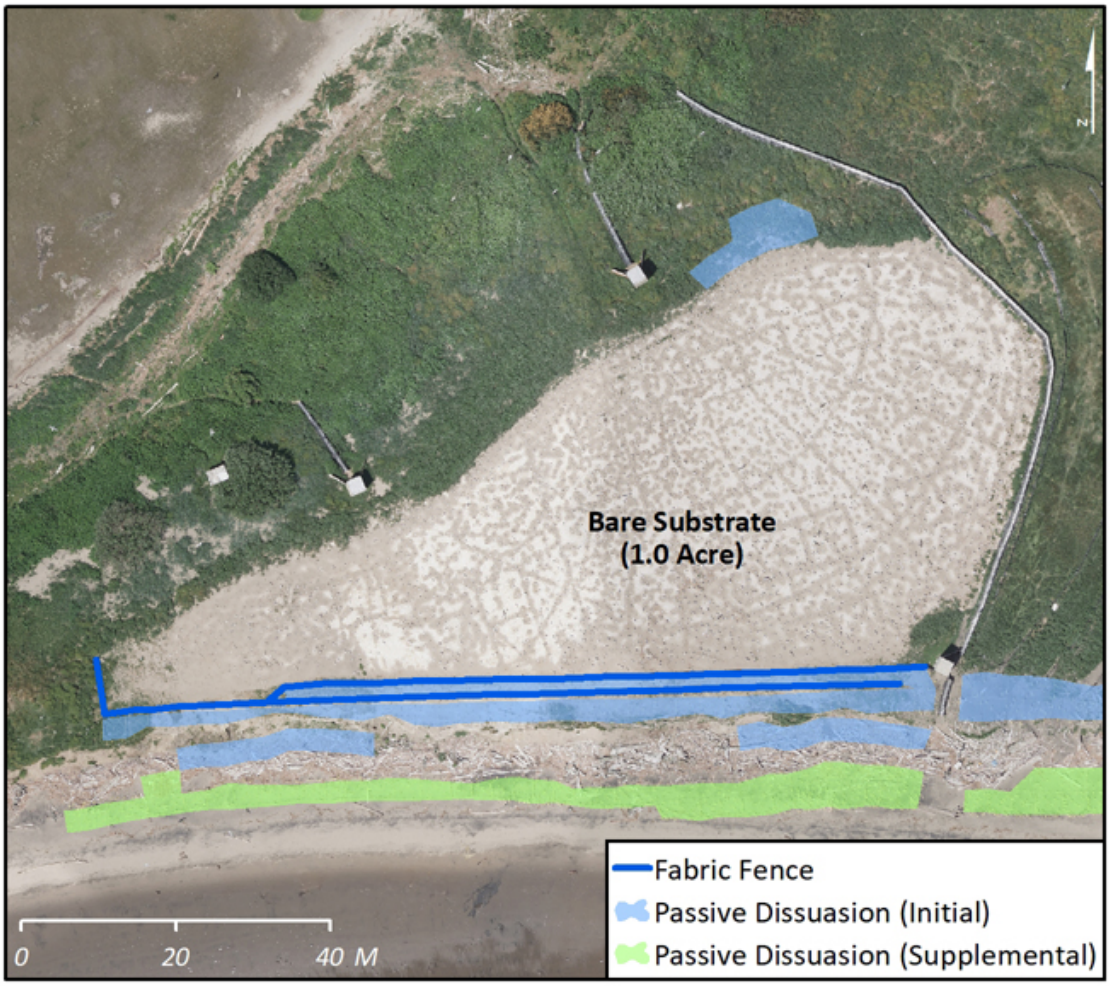
Map 1. Study area in the Columbia River basin showing the locations of active and former Caspian tern breeding colonies referenced in this report.



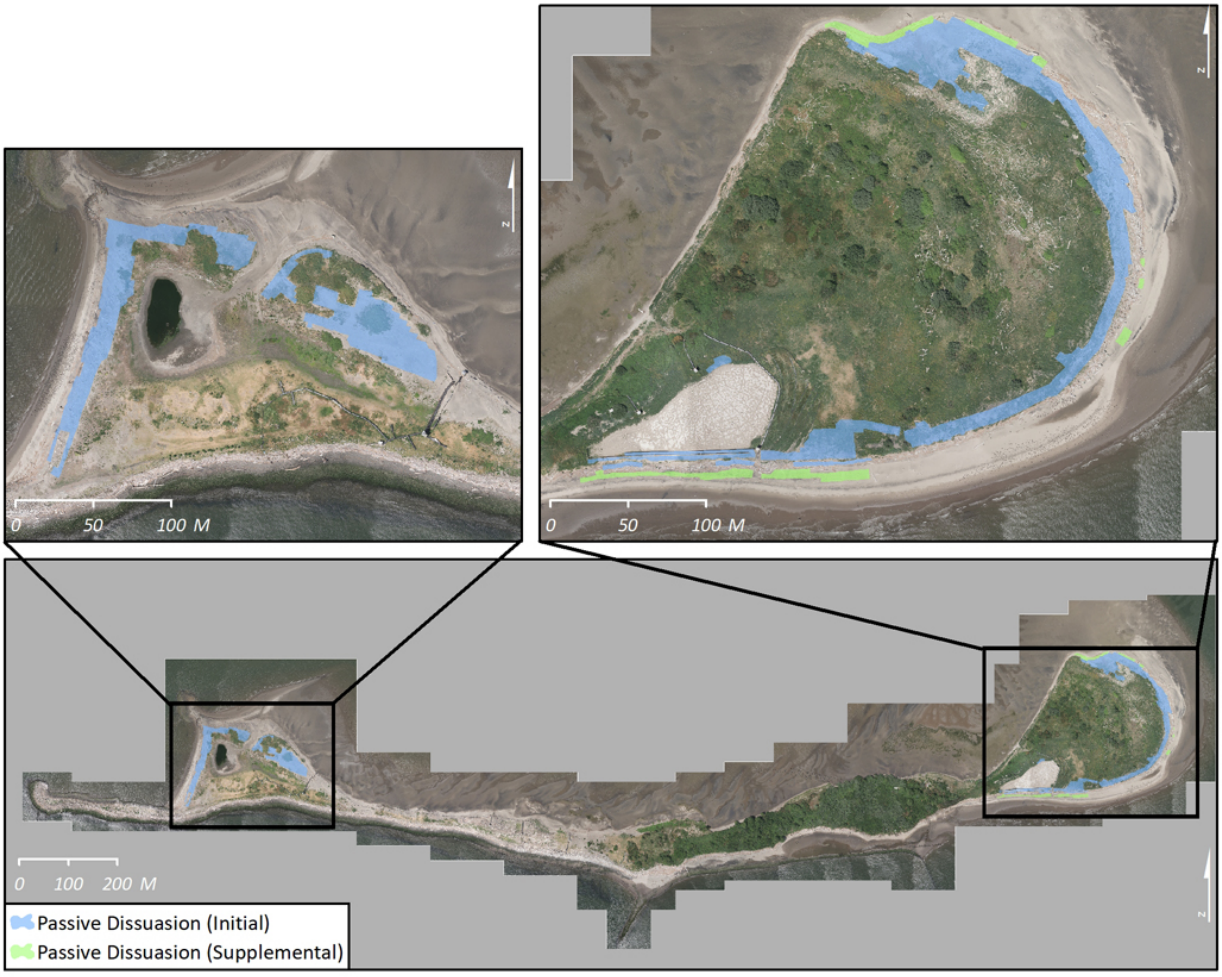
Map 2. East Sand Island and out of basin colony sites referred to in this report, including Corps-constructed Caspian tern islands.



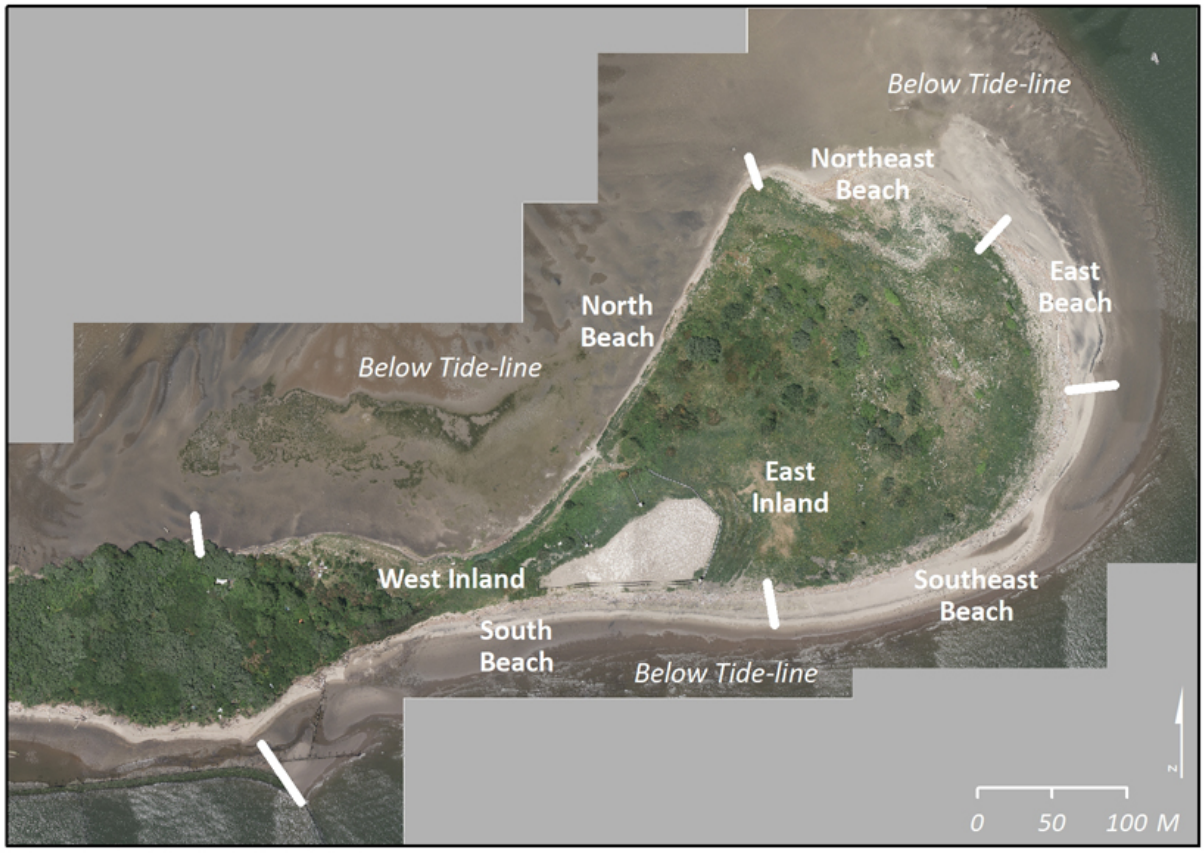
Map 3. Nesting habitat prepared for Caspian terns on the eastern end of East Sand Island in the Columbia River estuary during 2010-2017. Colony delineations depict the area of nesting habitat available to terns each breeding season during 2010-2017 and were overlaid on 2017 aerial photography. The southern shoreline of East Sand Island has gradually eroded during each winter, influencing the area of available habitat in most years during 2010-2017. Passive nest dissuasion materials (i.e. fabric fencing, posts, ropes, and flagging), invasive vegetation, and island erosion have all served to limit nesting habitat to the acreage specified by resource managers (see *legend* and *text* for details).



Map 4. Aerial photography of the 1.0 acres of unvegetated substrate designated as nesting habitat for Caspian terns on East Sand Island in 2017, 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 5. Locations of passive tern nest dissuasion materials installed to prevent Caspian terns from nesting outside of the 1.0-acre designated colony area on East Sand Island in 2017.



Map 6. Eight sectors identified for data collection on the eastern portion of East Sand Island during monitoring and active hazing of Caspian terns outside the designated 1.0-acre colony area.

FIGURES

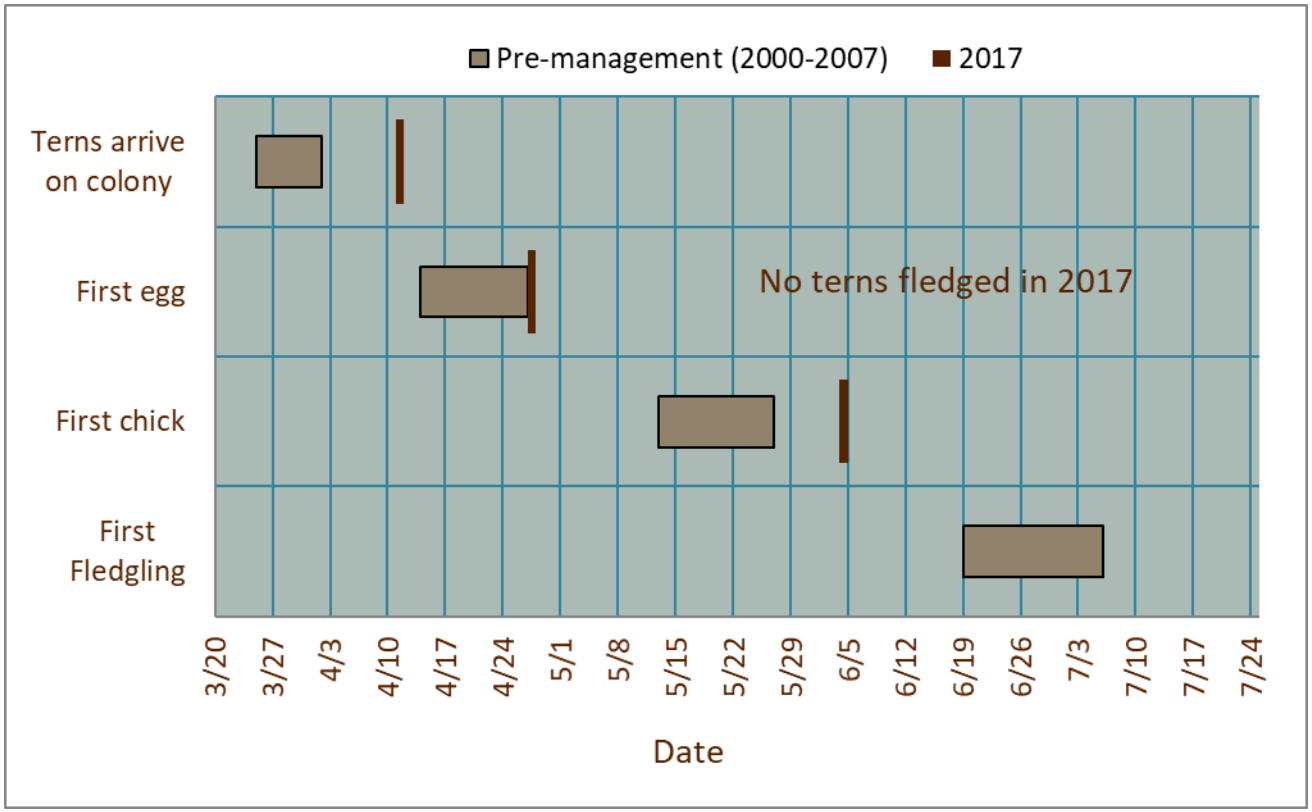


Figure 1. Nesting chronology for Caspian terns on the 1.0-acre designated colony area at East Sand Island during the 2017 breeding season.

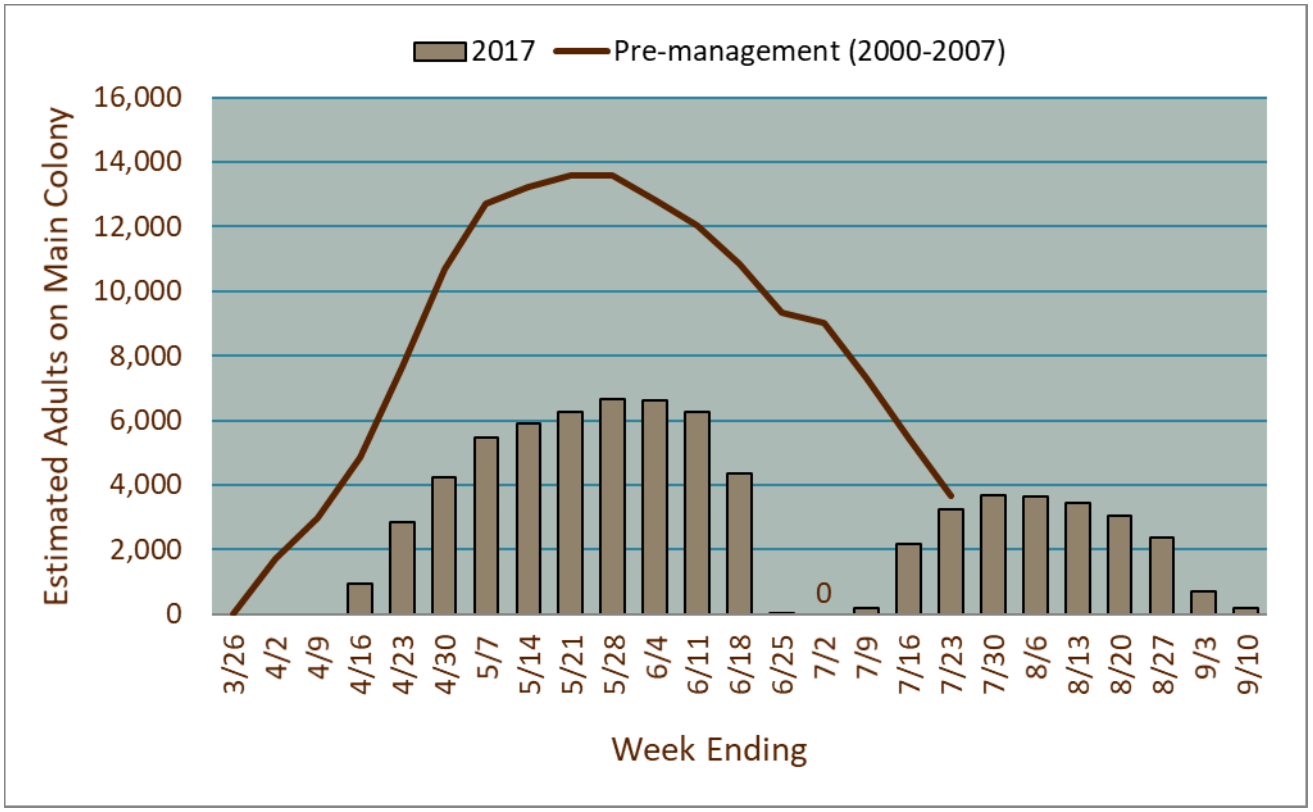


Figure 2. Weekly estimates from the ground of the number of adult Caspian terns on the 1.0-acre designated colony area at East Sand Island during the 2017 breeding season.

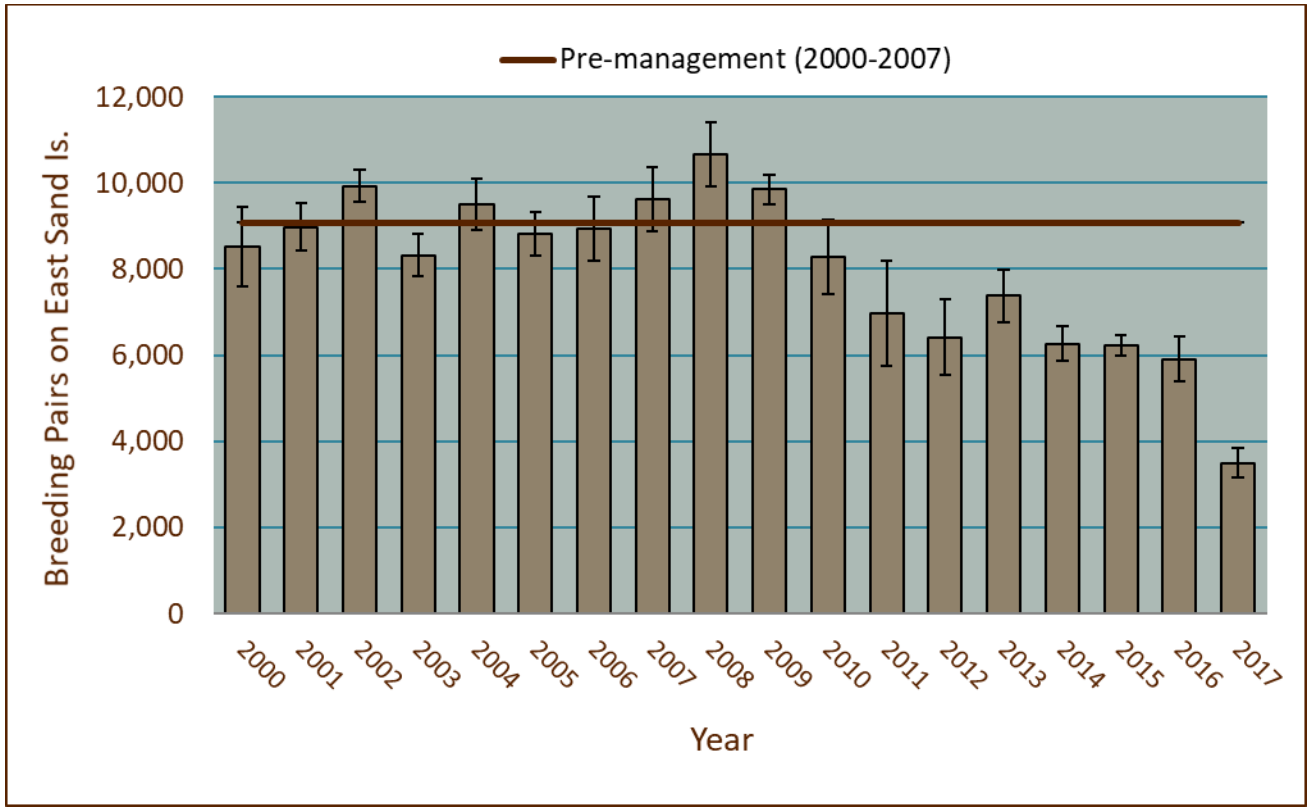


Figure 3. Caspian tern colony size (number of breeding pairs) on East Sand Island in the Columbia River estuary during 2000-2017. The error bars represent 95% confidence intervals for the estimate of the number of breeding pairs.

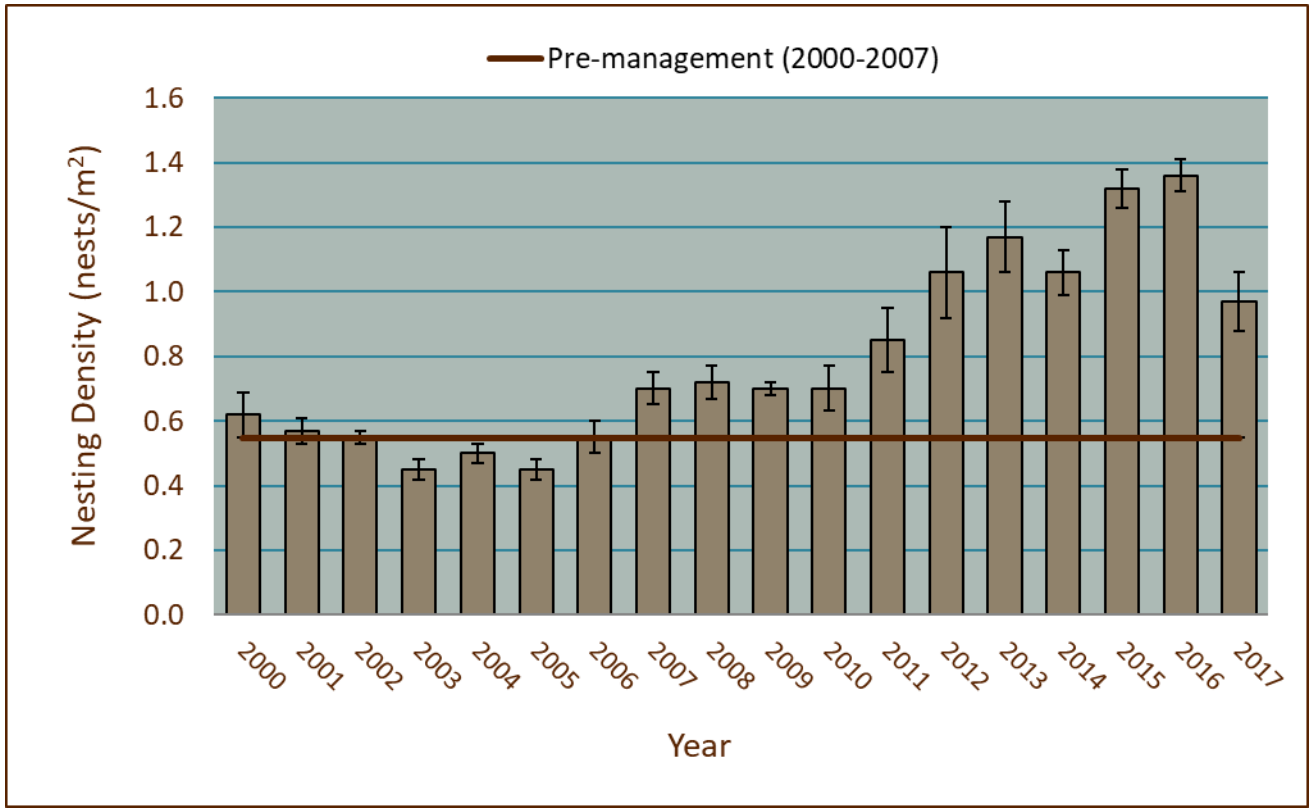


Figure 4. Caspian tern nesting density at the breeding colony on East Sand Island in the Columbia River estuary during 2000-2017. The error bars represent 95% confidence intervals for the estimate of nesting density (confidence interval not available for 2011 and based on confidence interval for 2012).

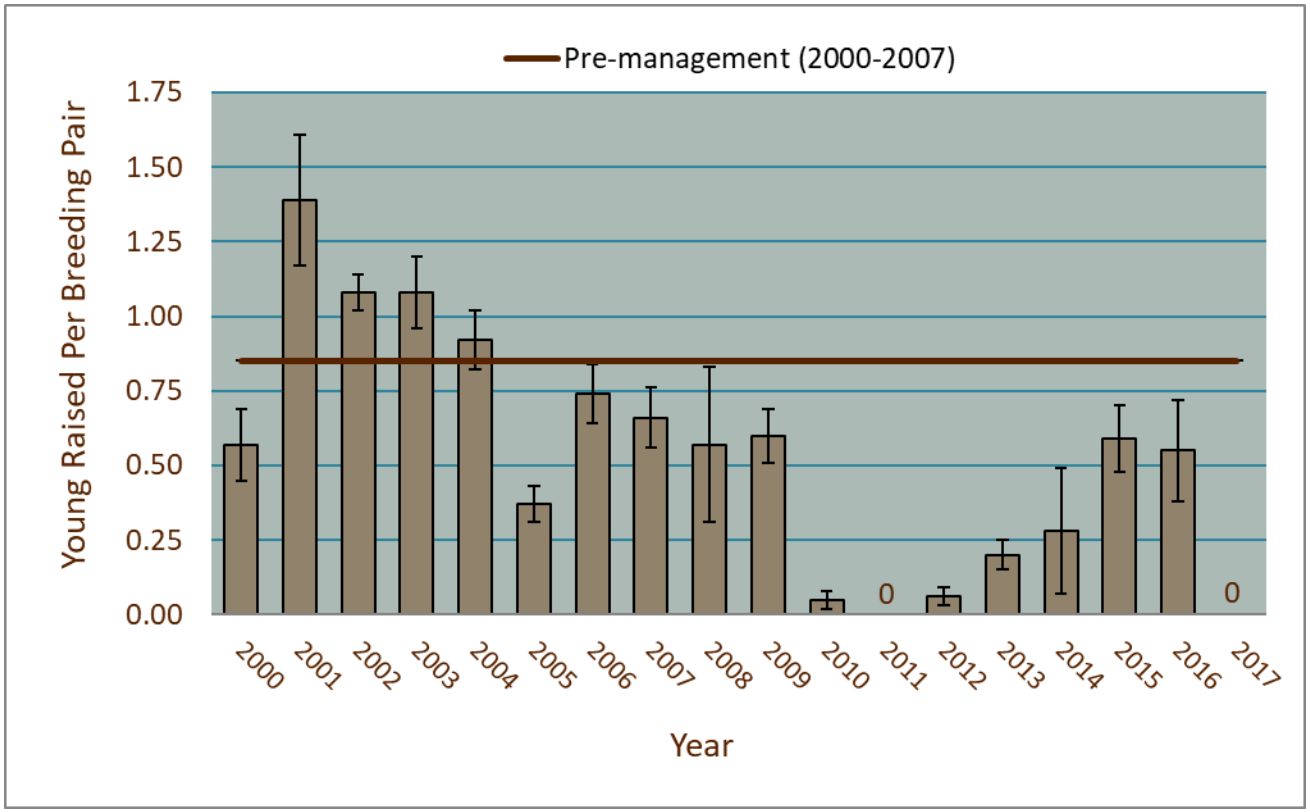


Figure 5. Caspian tern nesting success (average number of young raised per breeding pair) on East Sand Island in the Columbia River estuary during 2000-2017. The error bars represent 95% confidence intervals. No young were raised at the East Sand Island breeding colony in 2011 or 2017.

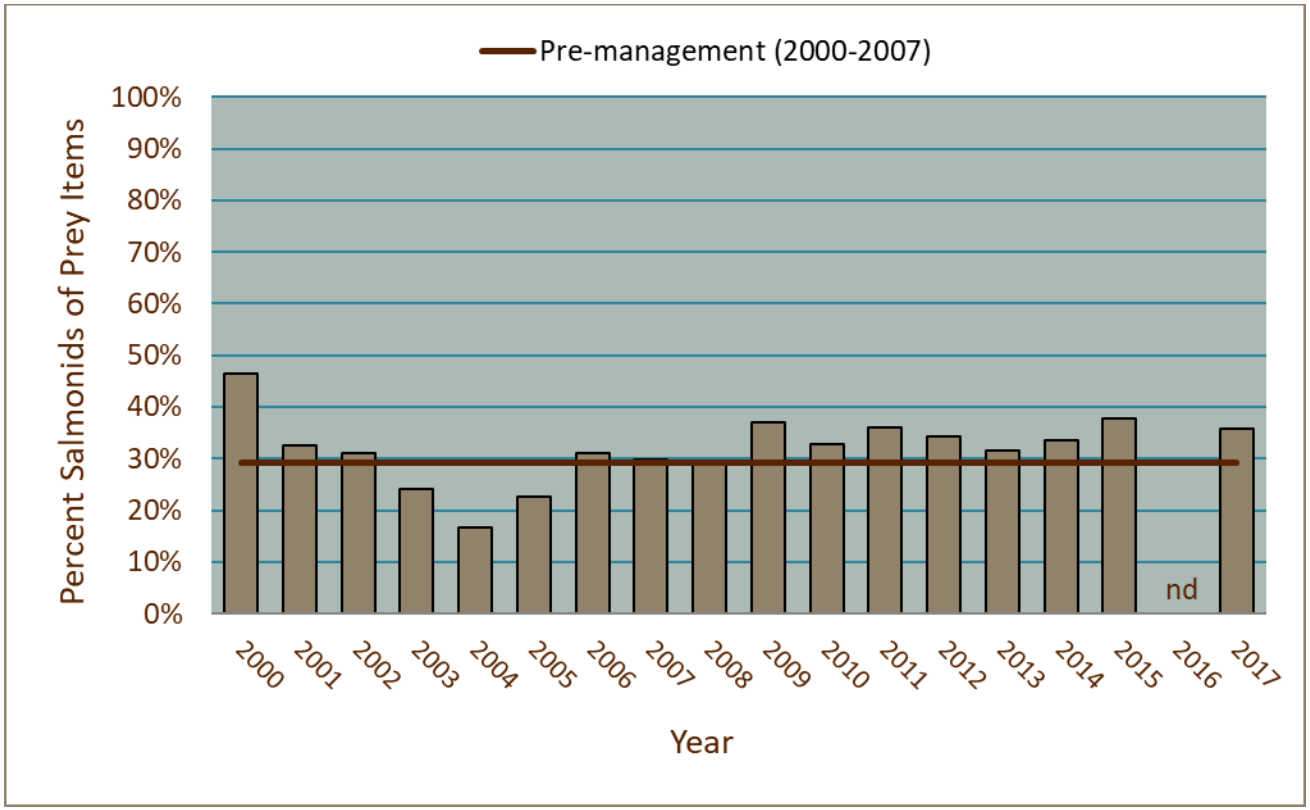


Figure 6. Average annual proportion of juvenile salmonids in the diet (percent of prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2000-2017 breeding seasons. Each annual value represents the average of the proportions during the 2-week periods encompassing the entire nesting season.

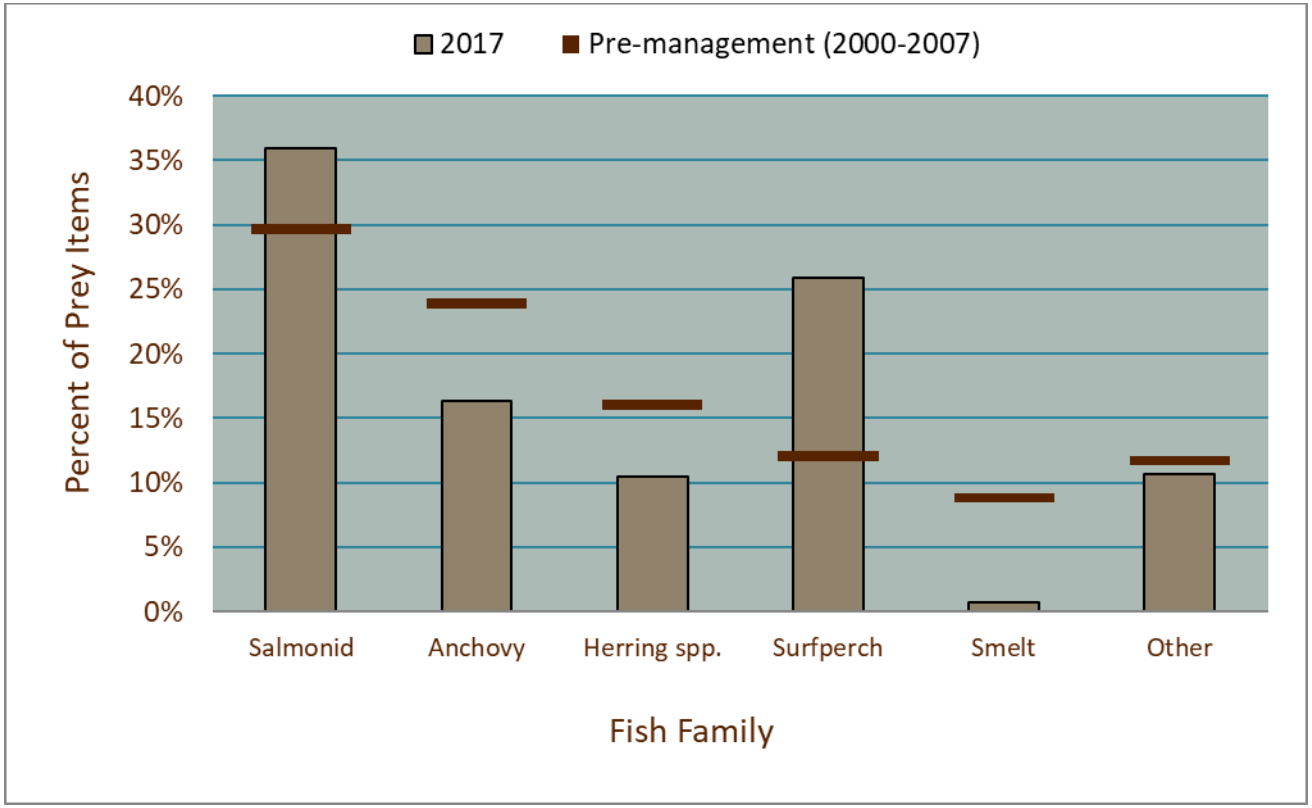


Figure 7. Diet composition (percent of identified prey items) of Caspian terns nesting on East Sand Island in the Columbia River estuary during the 2017 breeding season. Diet composition was based on fish visually identified on-colony in Caspian tern bill-loads.

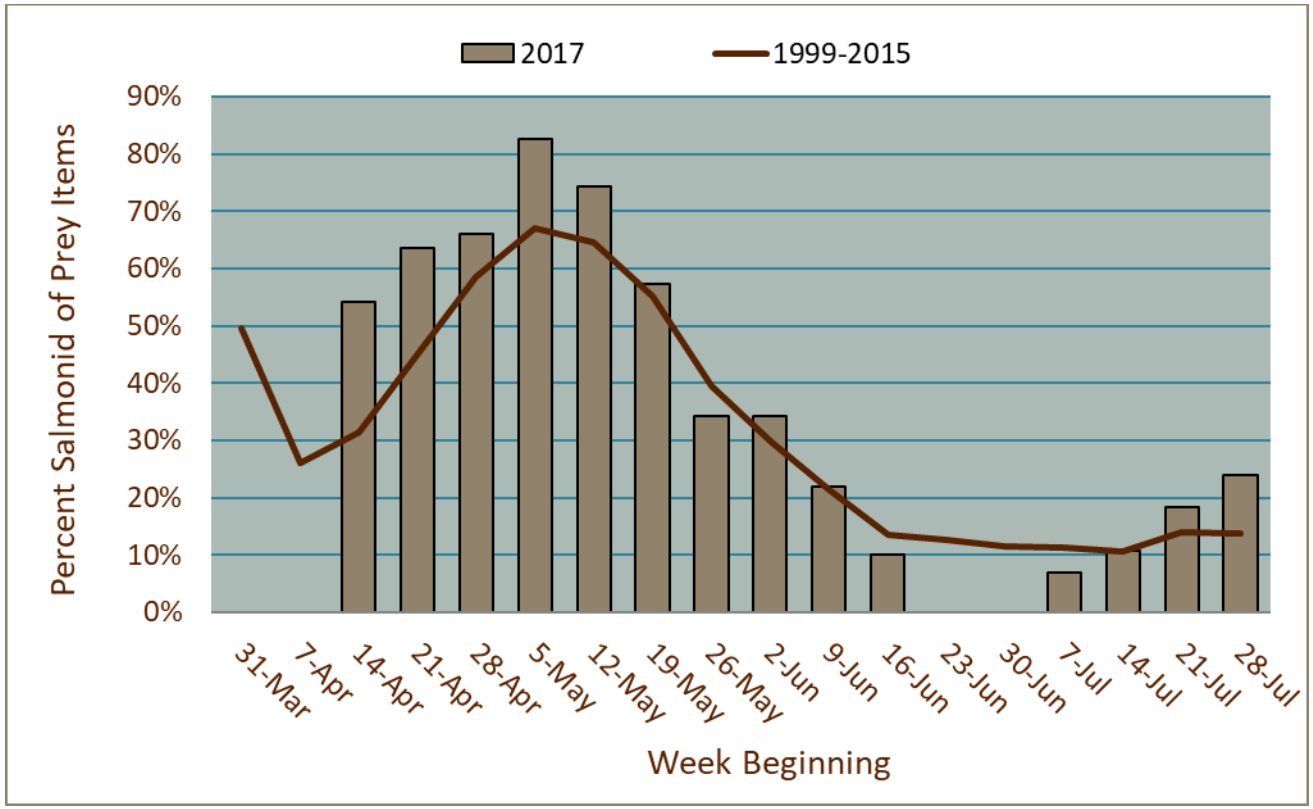


Figure 8. Proportion of juvenile salmonids (*Oncorhynchus* spp.) in the diet (percent of prey items) for Caspian terns nesting on East Sand Island in the Columbia River estuary, by week during the 2017 breeding season. No diet composition data were collected during the weeks beginning 23 June and 30 June in 2017.

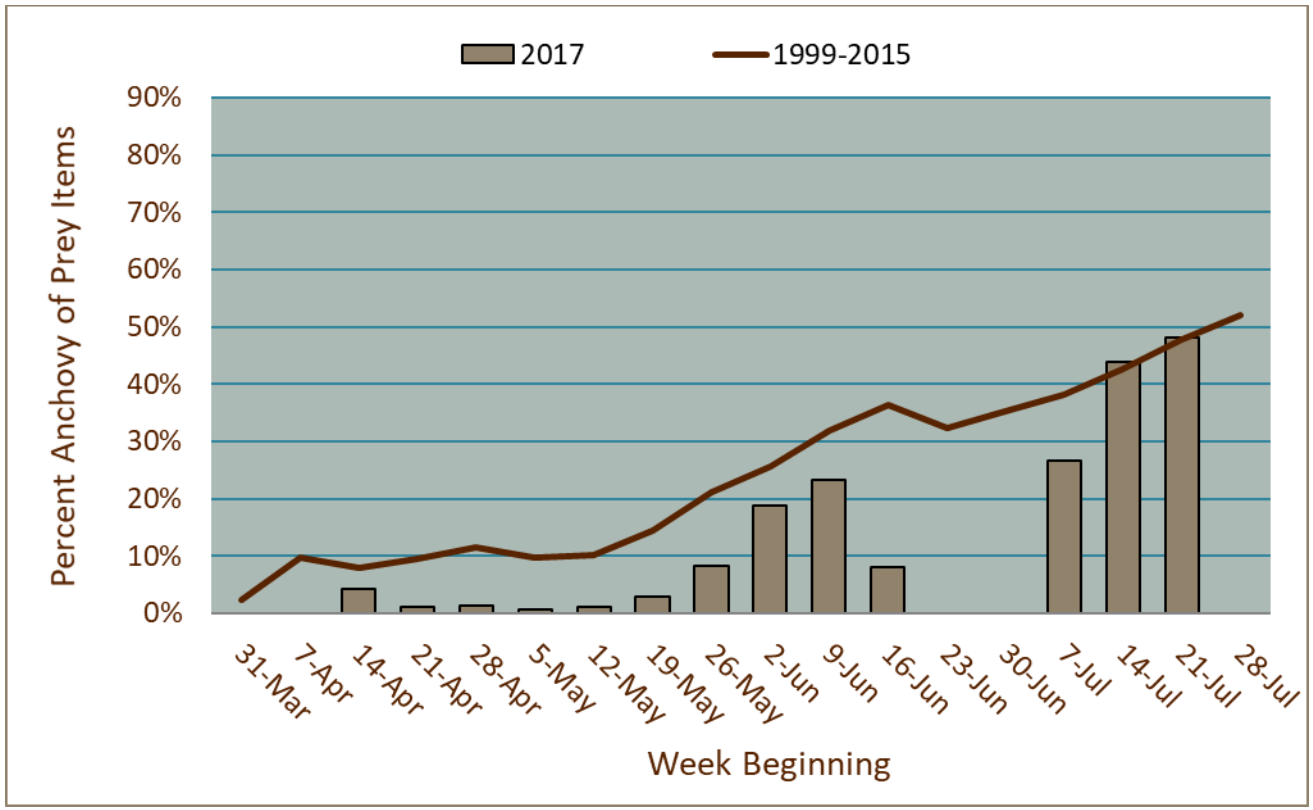


Figure 9. Weekly percentage of northern anchovy (*Engraulis mordax*) observed as Caspian tern bill-loads that were delivered to the East Sand Island colony, 2017. No diet composition data were collected during the weeks beginning 23 June and 30 June in 2017.

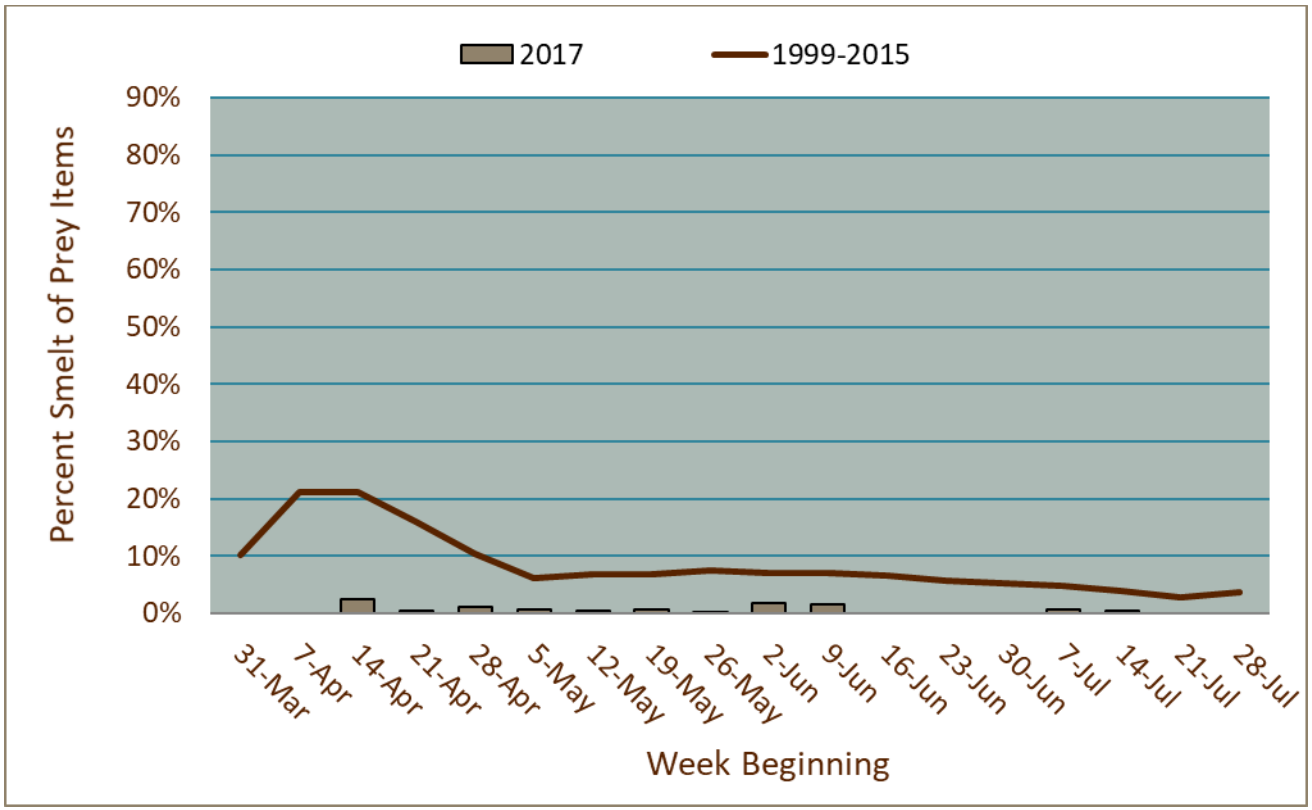


Figure 10. Weekly percentage of smelt (Osmeridae) observed as Caspian tern bill-loads that were delivered to the East Sand Island colony, 2017. No diet composition data were collected during the weeks beginning 23 June and 30 June in 2017.

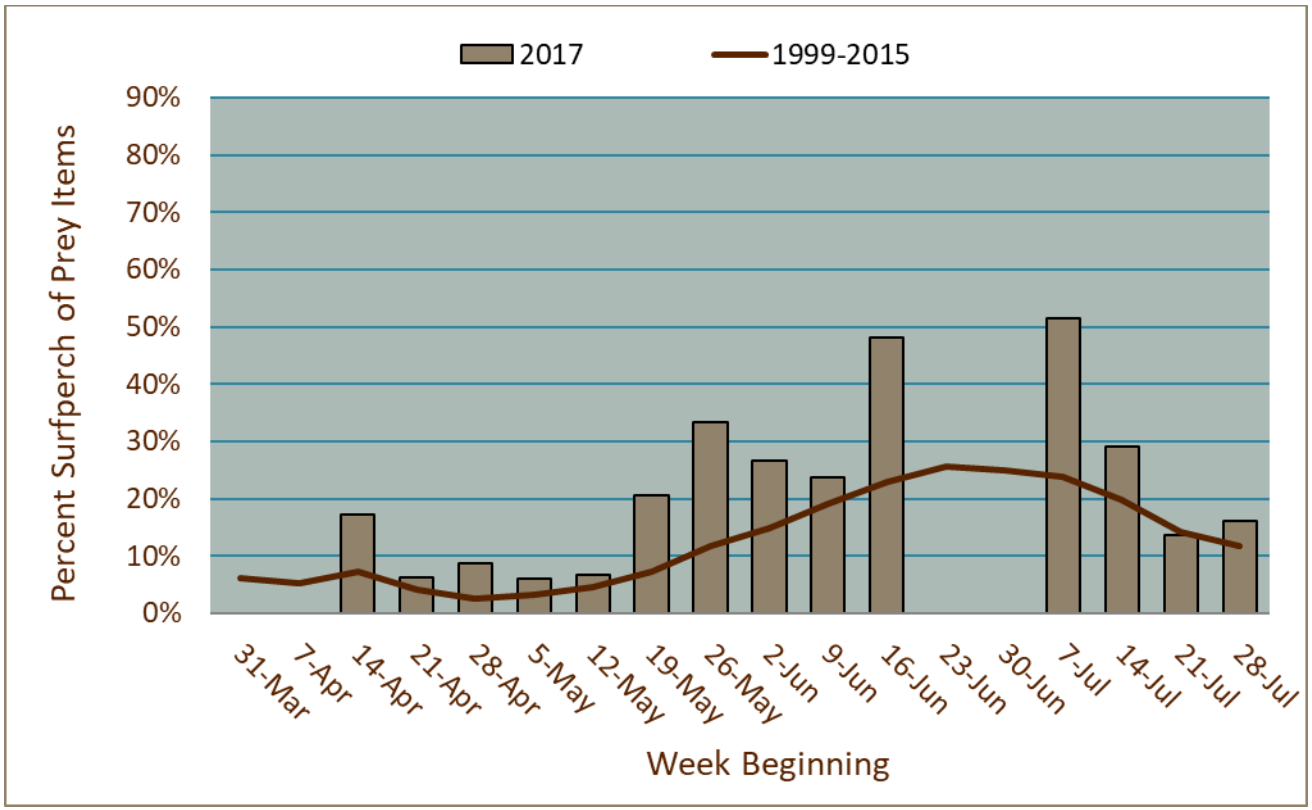


Figure 11. Weekly percentage of surfperch (Embiotocidae) observed as Caspian tern bill-loads that were delivered to the East Sand Island colony, 2017. No diet composition data were collected during the weeks beginning 23 June and 30 June in 2017.

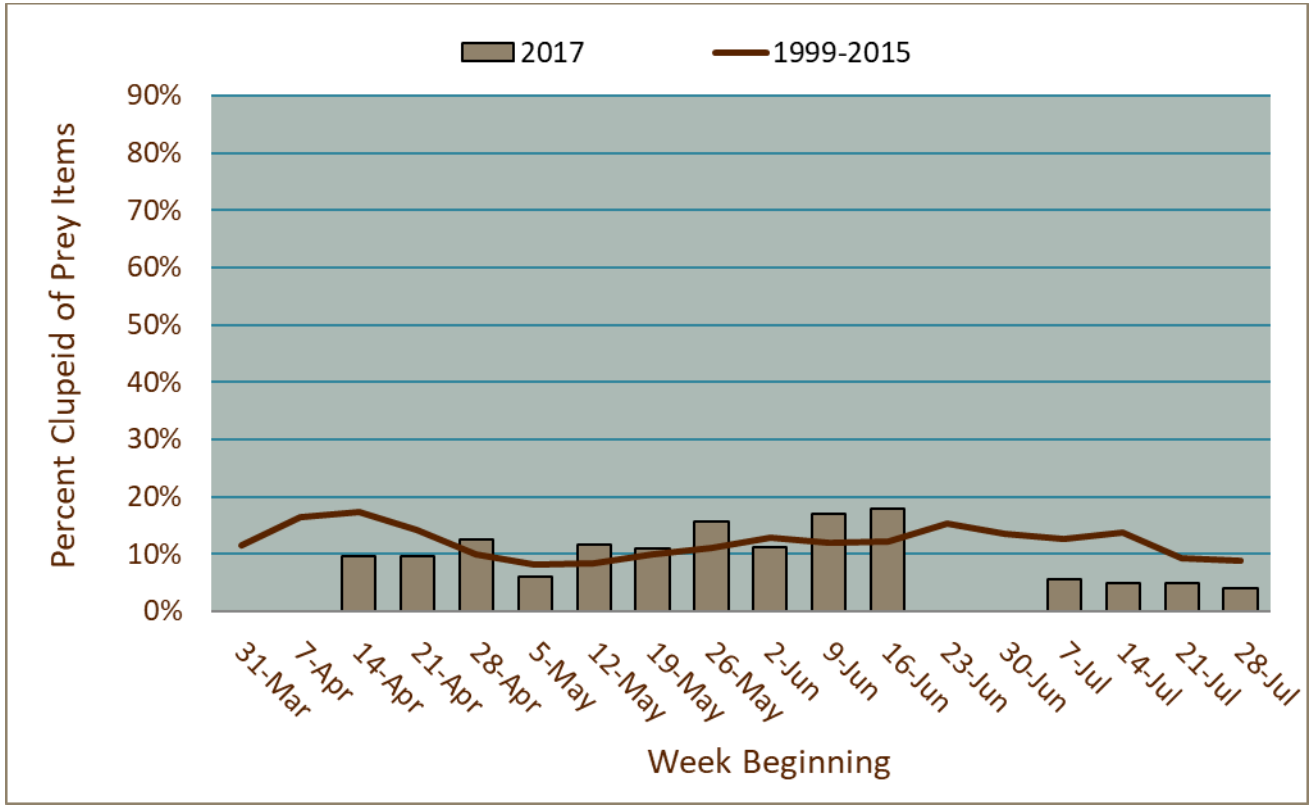


Figure 12. Weekly percentage of clupeids (Clupeidae: herring, sardines, shad) observed as Caspian tern bill-loads that were delivered to the East Sand Island colony, 2017. No diet composition data were collected during the weeks beginning 23 June and 30 June in 2017.

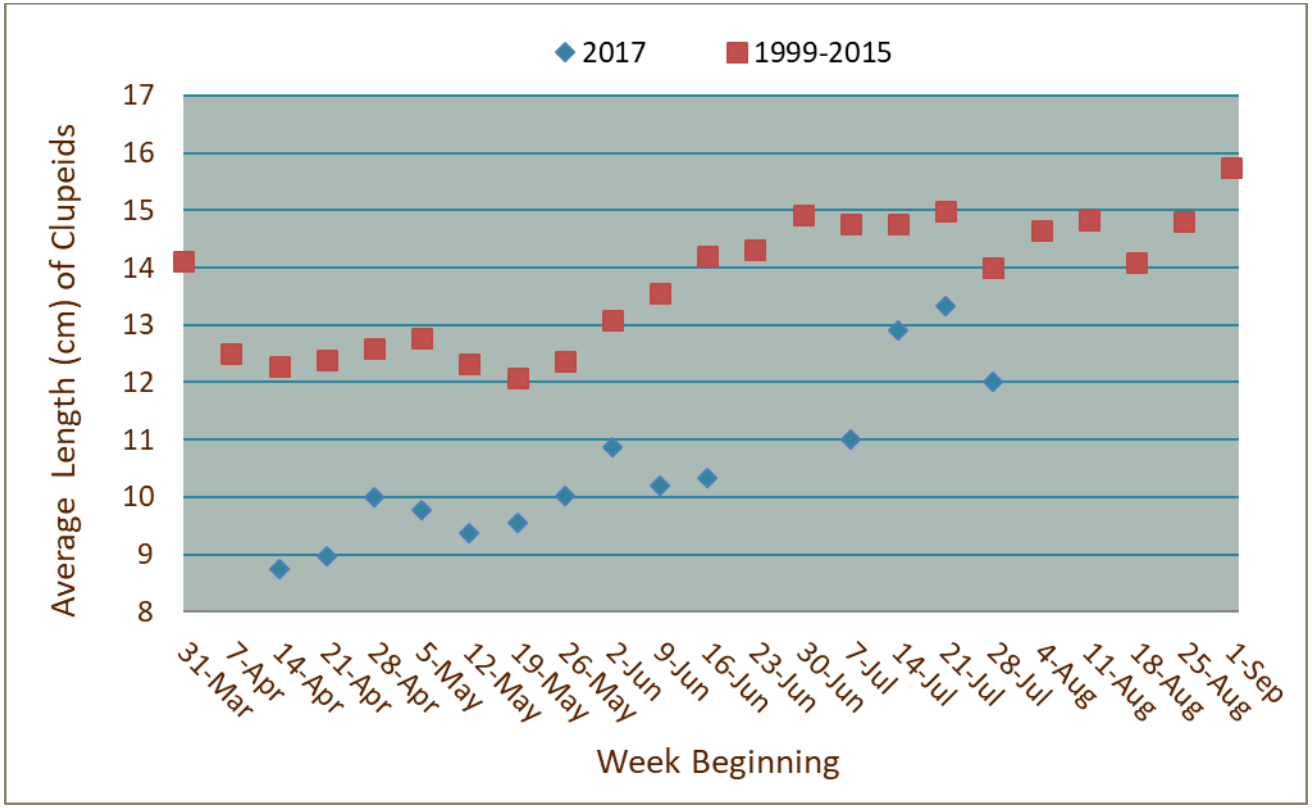


Figure 13. Weekly average length of clupeids (Clupeidae) observed as Caspian tern bill-loads that were delivered to the East Sand Island colony, 2017. No diet composition data were collected during the weeks beginning 23 June and 30 June in 2017.

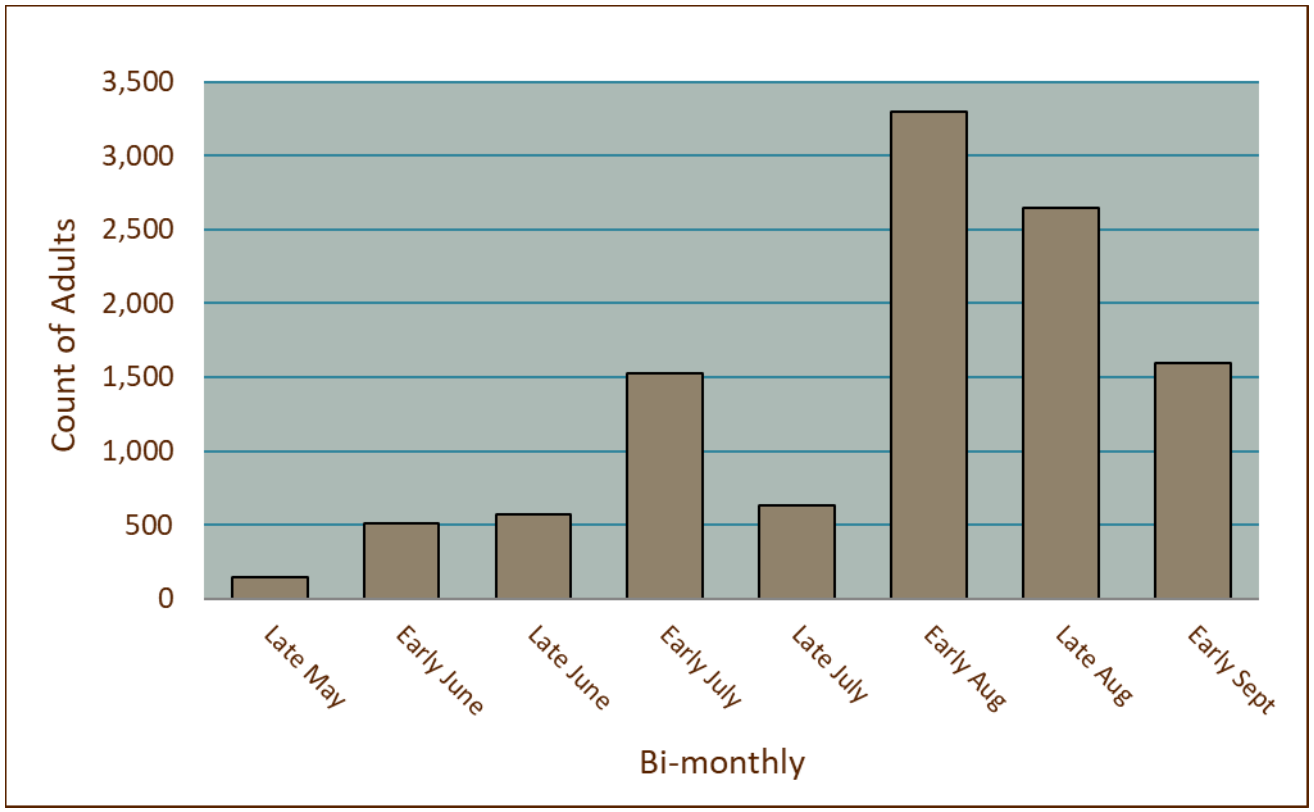


Figure 14. Estimates from boat-based surveys of the number of roosting California brown pelicans on East Sand Island, by 2-week period during the 2017 field season.

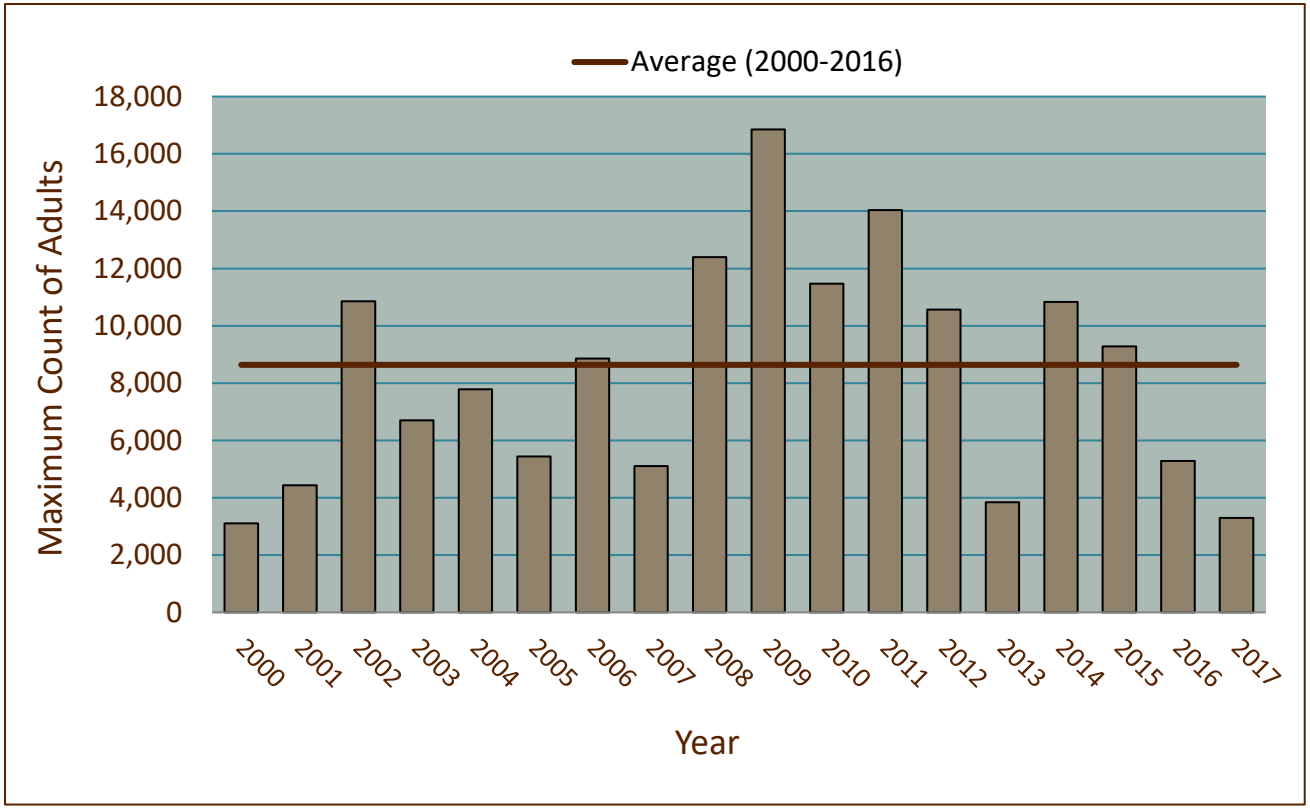


Figure 15. Maximum number of roosting California brown pelicans counted during boat-based surveys at East Sand Island in the Columbia River estuary during the 2000-2017 field seasons.

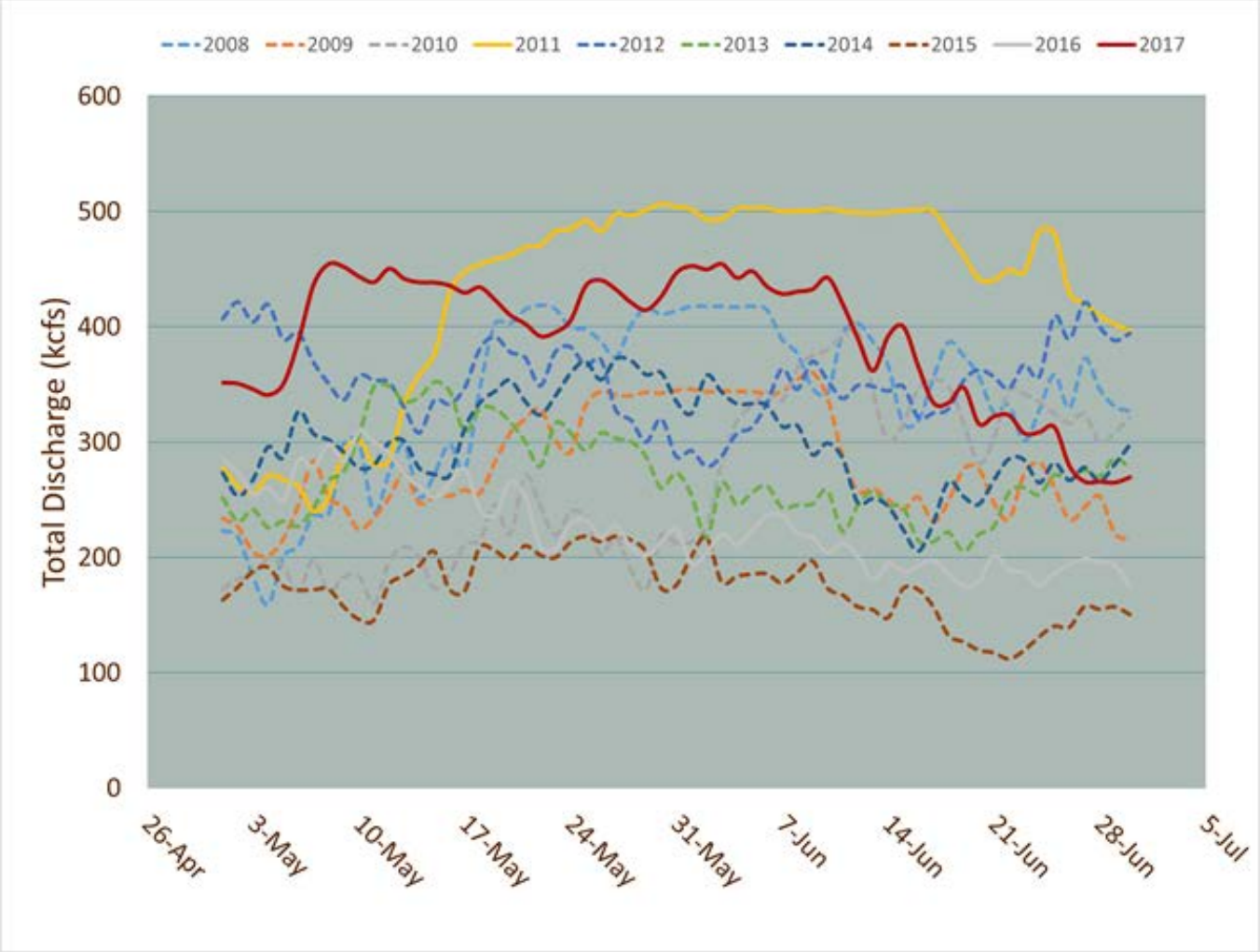


Figure 16. Total Columbia River discharge at Bonneville Dam in thousands of cubic feet per second (kcfs) for the months of May and June, 2008 – 2017. Discharge in 2011 and 2017, the two years when the Caspian tern colony on East Sand Island failed to produce any young, is shown as solid yellow and solid red lines, respectively.

TABLES

Table 1. Weekly estimates of duration (minutes) and maximum number of Caspian terns counted in each sector during monitoring and active nest dissuasion sessions on the eastern half of East Sand Island in 2017. Estimates of active hazing effort are minutes when Caspian terns were present and field personnel were intentionally hazing Caspian terns to prevent potential nesting activity. Map 6 indicates the locations where daily counts of Caspian terns were conducted. The last date of active dissuasion effort was 8/28. Exceptions were the Southeast Beach (7/28), South Beach (8/3), East Inland (8/1), and West Inland (8/1) sectors.

Week	Average Daily Dissuasion Effort	Average Daily Active Hazing Effort	Maximum Number of Caspian Terns Counted							
			North Beach	Northeast Beach	East Beach	Southeast Beach	South Beach	East Inland	West Inland	Below Tide-line
4/10-4/16	66	0	0	0	0	0	0	0	0	1377
4/17-4/23	105	6	0	4	205	0	250	0	0	1422
4/24-4/30	170	45	44	325	568	26	490	0	0	2106
5/1-5/7	295	149	2	167	45	3	210	0	0	2694
5/8-5/14	383	209	0	142	18	5	175	0	0	2470
5/15-5/21	458	308	20	133	75	45	130	0	0	2269
5/22-5/28	288	114	0	0	0	9	70	0	0	2290
5/29-6/4	289	155	308	0	280	10	284	0	0	1325
6/5-6/11	197	56	8	0	0	0	103	0	0	1408
6/12-6/18	91	2	66	0	0	0	12	0	0	1051
6/19-6/25	71	0	0	0	0	0	0	0	0	1875
6/26-7/2	71	0	0	0	0	0	0	0	0	1842
7/3-7/9	103	5	50	0	10	60	55	0	0	2008
7/10-7/16	123	6	0	0	10	42	65	0	0	2028
7/17-7/23	110	6	0	0	22	0	87	0	0	1106
7/24-7/30	59	2	38	0	55	0	88	0	0	1490
7/31-8/6	34	0	0	0	0	-	55	0	0	975
8/7-8/13	26	0	0	0	0	-	-	-	-	659
8/14-8/20	33	0	0	0	0	-	-	-	-	503
8/21-8/27	24	0	0	0	0	-	-	-	-	493
8/28/-9/3	20	0	0	0	0	-	-	-	-	222

Table 2. Caspian tern eggs located outside of the designated 1.0 acres of Caspian tern colony area on East Sand Island in 2017 and the final fate of each egg.

Date	Time	Number of Eggs	Sector	Fate of Egg(s)*	Final Fate - Date and Time	Notes
5/6	19:36	1	S Beach	Unknown	5/7 by 07:01	In shallow scrape 2 m west of south tunnel
5/9	20:50	1	Below Tide Line	Inundated	5/10 by 06:50	In shallow scrape 20 m west of dissuasion installed 5/7
5/10	8:50	1	Below Tide Line	Unknown	5/10 by 10:20	Not in scrape, dump egg or dropped by gull
5/14	19:58	1	NE Beach	Unknown	5/15 by 06:39	3 m below dissuasion, 15 m east of the RBGU colony
5/15	16:52	1	S Beach	Unknown	5/15 by 17:35	20 m west of supplemental dissuasion, 15 m below colony
5/16	7:17	2	NE Beach	1 Gull take/ researcher flush 1 Unnkown	5/16 at 07:21	In scrapes outside and behind supplemental dissuasion 1.5 m from dissuasion, 10 m from RBGU colony
5/16	10:31	1	NE Beach	Unknown	5/16 by 21:25	In a scrape 1 m from dissuasion
5/16	19:41	2	NE Beach	1 Gull take 1 Unnkown	5/17 at 09:36	Both in scrapes, 1 and 2 m from dissuasion
5/17	6:33	1	S Beach	Gull take/ researcher flush	5/17 at 06:35	40 m east of southeast blind, 2 m below dissuasion
5/17	6:48	1	E Beach	Unknown	5/17 by 19:36	Not in a scrape, 15 m below dissuasion, unattended
5/17	16:09	1	S Beach	Gull take/ researcher flush	5/17 at 16:12	In scrape 3m west of eastern edge of dissuasion
5/17	19:44	3	NE Beach	1 Unknown 2 Gull take	5/18 by 09:10	In scrapes, all within 10 ft of eggs located on 5/16 @ 19:41
5/18	9:25	1	SE Beach	Unknown	5/18 by 17:20	15 m below dissuasion
5/21	19:36	1	S Beach	Unknown	5/21 by 21:04	In a scrape 30 m east of SE blind, 15 m below dissuasion
5/22	6:33	2	SE Beach	Unknown	5/22 by 10:19	In scrapes, 5 m east of SE beach supplemental dissuasion, unattended
5/24	12:45	1	S Beach	Unknown	5/24 by 14:43	In a scrape, 30m east of SE blind, 2m below dissuasion
5/29	20:01	1	S Beach	Gull take/ researcher flush	5/29 at 20:03	Just south of supplemental dissuasion that is installed east of SE blind
5/30	6:45	1	S Beach	Unknown	5/30 by 16:13	In a scrape, 1.5 m west of west end of supplemental dissuasion
6/1	7:09	1	S Beach	Gull take	6/1 at 07:12	In a scrape, 0.5 m west of the west end of the S Beach supplemental dissuasion
6/1	7:11	1	S Beach	Unknown	6/1 by 07:34	In a scrape 2 m west and 1 m south of the east end of S beach dissuasion
6/2	9:24	1	SE Beach	Unknown	6/2 by 12:11	In a scrape, located 5 m south of the East sector, common raven seen in area

*Although unconfirmed, most eggs with fate listed as “unknown” were likely depredated by gulls between dissuasion sessions.

Table 3. Estimated colony size (number of breeding pairs) and nesting density (nests/m^2) for Caspian terns nesting on East Sand Island in the Columbia River estuary during 2000-2017. 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
Average (2000-2016)	8,272	7,641	8,903	0.78	0.73	0.84

Table 4. Numbers of banded Caspian terns resighted at East Sand Island in 2017 and the colony locations where they were originally marked with unique alphanumeric colored leg-bands during 2005-2016.

Colony where banded	Banded as adults	Banded as chicks	Total (%)
East Sand Island, Columbia River estuary, OR	163	200	363 (85%)
Crescent Island, mid-Columbia River, WA	17	14	31 (7%)
Port of Bellingham, WA	0	13	13 (3%)
Goose Island – Potholes Reservoir, WA	11	1	12 (3%)
Brooks Island, San Francisco Bay, CA	0	2	2 (<1%)
Crump Lake, Warner Valley, OR	0	2	2 (<1%)
Sheepy Lake, Lower Klamath NWR, CA	0	2	2 (<1%)
Malheur Lake, Malheur NWR, OR	0	1	1 (<1%)
Kokinhenik Bar, Copper River Delta, AK	0	1	1 (<1%)
Total	191	236	427 (100%)

Table 5. Numbers of color-banded Caspian terns seen at East Sand Island in 2016 and resighted during the 2017 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 357 banded terns that were seen on East Sand Island in 2016 were resighted in 2017; three of these banded terns were resighted at two separate locations in 2017.

Location where resighted in 2017	Banded as adults	Banded as chicks	Total (%)
East Sand Island, Columbia River estuary, OR	155	140	295 (82%)
Blalock Islands, mid-Columbia River, OR	16	16	32 (9%)
Everett, WA	3	16	19 (5%)
Potholes Reservoir, WA*	10	3	13 (4%)
Pond A16, Don Edwards NWR, CA	0	1	1 (<1%)
Total	184	176	360 (100%)

* Potholes Reservoir includes Goose Island and islands in northern Potholes Reservoir.

APPENDIX A: CASPIAN TERN POPULATION MODELING

In order to evaluate the effects of potential management options on future trends in the Pacific Flyway population of Caspian terns (*Hydroprogne caspia*), we developed a comprehensive and data-rich demographic population model. The model is structured in HexSim, a population simulator software package where individual terns are simulated to move through key life events (e.g., producing young, recruiting into the adult breeding population, natal and breeding dispersal) based on parameter inputs of empirically-derived vital rates and movement rates. This modeling framework was used to forecast how the population would change over a 30-year time period in five regions that encompass the entire breeding range of the Pacific Flyway population. The model was designed to estimate both the breeding and the non-breeding portions of the population. Caspian terns are characterized by delayed maturity and, when habitat is limited or conditions unfavorable, will skip or minimally invest in breeding in a given year; these two life history traits can result in a significant non-breeding portion of the population, which is especially difficult to census.

Using current demographic parameter estimates, model simulations assuming status quo management in the Columbia River basin (baseline) projected an increasing population trajectory for Pacific Flyway Caspian terns. The breeding portion of the Flyway-wide population exhibited a slight upward trajectory, with a more pronounced increase in the number of non-breeders over the simulation period. Current rates of survival and fledgling production, *if sustained*, appear sufficient to allow population persistence even with the currently achieved reductions in nesting habitat availability in the Columbia River estuary and Columbia Plateau region.

Seven additional scenarios were simulated to evaluate the potential effects on population trajectory of prospective tern management actions in the Flyway. In those scenarios, the carrying capacity for terns in three of the five regions of the breeding range (Columbia River estuary, Columbia Plateau, southern Oregon and northeastern California [SONEC]) were reduced to reflect a managed reduction in available nesting habitat. Management scenarios involving reductions in tern nesting habitat in only one of these three regions resulted in increases in the Flyway-wide population, but at a lower rate than in the baseline management scenario. Management scenarios with simultaneous reductions in carrying capacity for two of three regions revealed the synergetic effects of habitat reduction, but the Flyway-wide population continued to increase, albeit at a lower rate. The management scenario involving reduction in tern nesting habitat in all three regions resulted in the smallest Flyway-wide population at the end of the 30-year model run, but still did not result in declines in the Flyway-wide population. Population trajectories under the baseline scenario and the seven prospective management scenarios depended on the quantity and quality of available nesting habitat for Caspian terns in the Pacific Flyway, the predominant limiting factor for this population. Importantly, all projections assume reductions in available nesting habitat have no impact on rates of fledgling production and adult survival.

Additional refinements of the version of the population model described here are currently underway in order to more accurately reflect the complexities of tern responses to the changing landscape of available nesting habitat in the Pacific Flyway. The present preliminary version of the model, however, indicates considerable resiliency of the Pacific Flyway population of Caspian terns to prospective management options to reduce nesting habitat within the Columbia River basin (Figure A1; Suzuki et al. 2017).

Literature Cited

Suzuki, Y., J. Heinrichs, D.E. Lyons, D.D. Roby, and N. Schumaker. 2017. Modeling the Pacific Flyway population of Caspian terns to evaluate future management options. Phase 2: preliminary model results. Report to Bonneville Power Administration, Portland, Oregon. 66 pp.

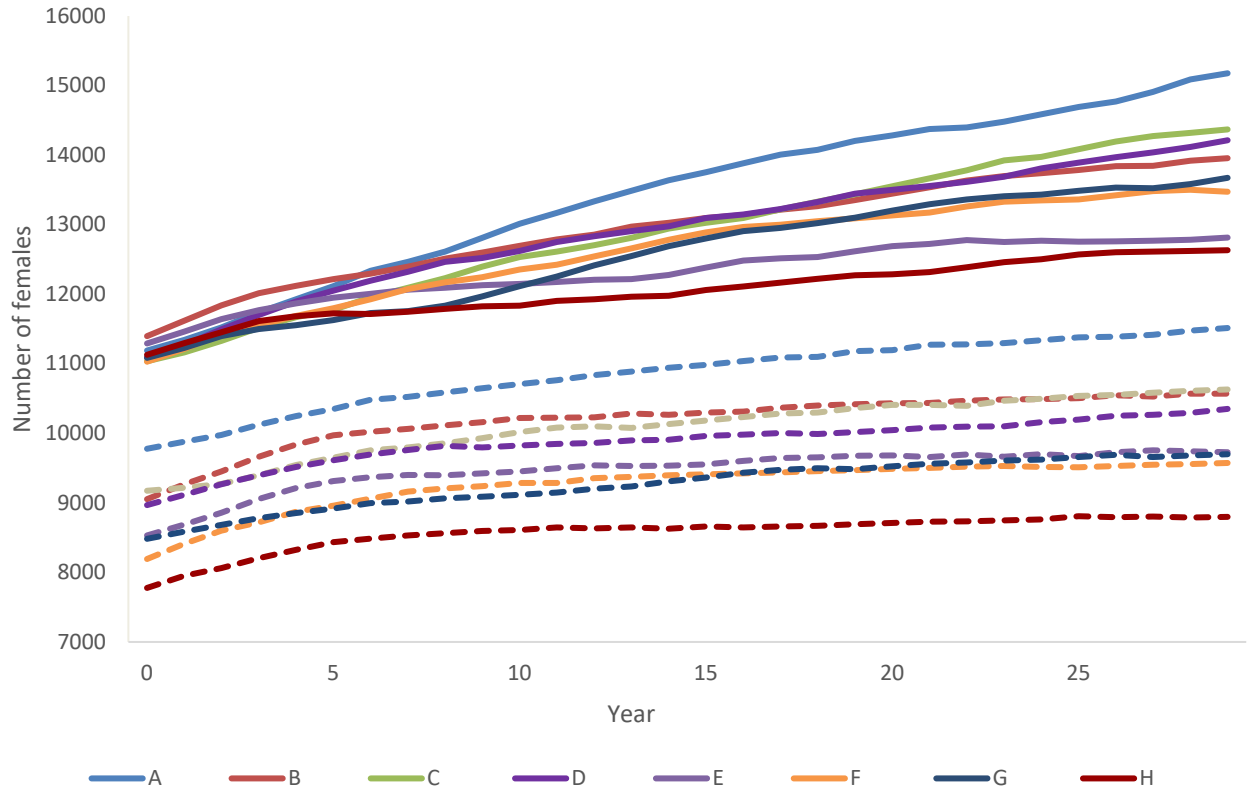


Figure A1. Preliminary projections of the total numbers of female Caspian terns in the Pacific Flyway population under the baseline (status quo) management scenario (A) and seven prospective management scenarios (B-H) that result in reductions in available nesting habitat in one to three of the five regions of the breeding range of the population. Solid lines represent the total number of female Caspian terns within the breeding range of the Pacific Flyway population (including sub-adults and non-colony attenders) and dashed lines are the total number of female colony attenders in the Flyway.