Caspian Tern Nesting Ecology and Diet in San Francisco Bay and Interior Oregon

FINAL 2008 ANNUAL REPORT

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

In 2008, the U.S. Army Corps of Engineers (USACE) began implementing management actions for Caspian terns (*Hydroprogne caspia*) that were 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 USACE, the U.S. Fish and Wildlife Service, and NOAA Fisheries, seeks to redistribute a portion of the Caspian tern colony on East Sand Island in the Columbia River estuary to alternative colony sites in interior Oregon and the San Francisco Bay area by 2015. The goal of the plan is to reduce Caspian tern predation on out-migrating juvenile salmonids (*Oncorhynchus* spp.) in the Columbia River estuary, and thereby enhance recovery of salmonid stocks from throughout the Columbia River basin. Thirteen of 20 evolutionarily significant units (ESUs) of Columbia Basin salmonids are currently listed as either threatened or endangered under the U.S. Endangered Species Act (ESA).

As part of this management plan the USACE completed construction of two 1-acre islands specifically designed for tern nesting in interior Oregon prior to the 2008 breeding season: a 1-acre island on Fern Ridge Reservoir near Eugene, Oregon (completed February 2008) and a 1-acre island on Crump Lake in the Warner Valley, northeast of Lakeview, Oregon (completed March 2008). The constructed island in Crump Lake was at the site of a former island that supported colonial-nesting waterbirds, including Caspian terns. Following the construction of the islands and before the arrival of terns from their wintering grounds, Caspian tern decoys and audio playback systems that broadcast tern calls were deployed on both islands to attract terns to nest.

Video cameras were used to monitor the island in Fern Ridge Reservoir instead of direct observation by a field crew, and the island was visited periodically throughout the breeding season by project staff. Review of video footage and our site visits revealed that Caspian terns did not attempt to nest on the island in 2008, but visited the island after the breeding season. During the month of August the Fern Ridge tern island was visited by Caspian terns on 23 different days, with as many as nine terns observed on the island at one time.

There is a history of Caspian terns attempting to nest on the remnant island at Crump Lake in the Warner Valley, so a field crew monitored the island throughout the nesting season. During May, a Caspian tern breeding colony formed on the Crump Lake island and grew to about 150 breeding pairs. Concurrently, about 500 pairs of California gulls (*Larus californicus*), about 850 pairs of ring-billed gulls (*L. delawarensis*), and 10 pairs of double-crested cormorants (*Phalacrocorax auritus*) initiated nesting on the new island. In early June the Caspian tern colony dropped to a low of 23 nesting pairs due to egg predation by gulls. We selectively removed 10 gulls that were depredating tern eggs, once the required depredation permits had been issued. Subsequently, the Caspian tern colony expanded to 428 breeding pairs, and ultimately raised about 145 young terns to fledging age. Hundreds of pairs of nesting California and ring-billed gulls and one pair of cormorants also successfully raised young on the Crump Lake island.

The diet composition of Caspian terns nesting on Crump Lake consisted primarily of tui chub (*Gala bicolor*; 55.4% of the identifiable prey items), followed by bullhead catfish (*Ameiurus* sp.; 27.8%) and crappie (*Pomoxis* sp.; 15.0%). The remaining 1.8% of prey items consisted of rainbow trout (*Oncorhynchus mykiss*), lamprey (*Entosphenus* spp.), suckers (*Catostomus* spp.), bass (*Micropterus* spp.), and dace (*Rhinichthys* spp.). A total of 5 suckers (0.17% of identifiable prey items) were observed by researchers during the nesting season, one of which was positively identified as a Warner sucker (*C. warnerensis*). Warner suckers are listed as threatened under the ESA.

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

Although no management action was undertaken to enhance Caspian tern nesting habitat in the San Francisco Bay area in 2008, we monitored existing Caspian tern colonies in the Bay area to gain a better understanding of current colony status, diet composition, and factors limiting colony size and nesting success in preparation for potential colony expansion at Brooks Island in the central Bay and island construction/restoration in the south Bay. There were four known breeding colonies of Caspian terns in the San Francisco Bay area in 2008, where a total of approximately 1,000 breeding pairs nested. This represents a decline over the last 3-5 years in both total number of breeding colonies (formerly 5) and total number of breeding pairs (1,085-1,372) in the San Francisco Bay area. As was the case in 2003-2005, most breeding pairs of Caspian terns in the San Francisco Bay area (81%) nested at the Brooks Island colony in 2008, by far the largest tern colony in the Bay area (ca. 810 breeding pairs). Marine forage fishes, in particular anchovies, surfperch, and herring, were the predominant component of Caspian tern diets at Brooks Island in 2008. In 2008, the proportion of the diet that was juvenile salmonids increased to about 9%, raising concerns that relocation of Caspian terns from the Columbia River estuary to Brooks Island might reduce survival of ESA-listed salmonids from the Sacramento River basin. A radio telemetry study of Brooks Island terns, combined with recoveries of coded wire tags from smolts on the Brooks Island colony, revealed that the vast majority of salmonid smolts consumed by Caspian terns from this colony in 2008 were hatchery-reared, non-listed fall-run Chinook that were released from net pens in eastern San Pablo Bay.

Caspian terns also nested at Eden Landing, Stevens Creek, and Agua Vista Park, but only periodic colony monitoring was conducted at the tern colonies at Agua Vista Park and Stevens Creek, while weekly colony monitoring was conducted at Eden Landing. The Eden Landing colony was more intensively monitored because of its proximity to

Hayward Regional Shoreline and Don Edwards National Wildlife Refuge, two sites identified for future island construction/restoration for Caspian tern nesting in the FEIS and RODs. We estimated that 56 breeding pairs of Caspian terns nested at Eden Landing in 2008. In contrast to the diet of terns nesting on Brooks Island in 2008, terns nesting at Eden Landing had a much smaller percentage of juvenile salmonids in their diet (0.2% at Eden Landing versus 9% at Brooks Island). These and other previously reported results (Roby et al. 2003b, 2004, 2005) suggest that Caspian tern colonies located in the south Bay will likely have little impact on survival of juvenile salmonids compared to Caspian tern colonies in the north and central Bay.

Tern nesting success at Eden Landing (0.81 young fledged per breeding pair) was higher than at Brooks Island (0.42 young fledged per breeding pair). All four Caspian tern colonies in the San Francisco Bay area appeared to be primarily limited both in size and productivity by the availability of suitable nesting habitat and/or the quality of nesting substrate. Other factors limiting nesting success for at least some of the colonies were mammalian nest predators, displacement by other colonial waterbirds, and human disturbance. Food availability may be a limiting factor for nesting success in some years, but it did not appear to be a significant constraint on productivity in 2008.

The preliminary conclusions from this study of Caspian terns nesting in interior Oregon and the San Francisco Bay Area during 2008 are (1) Caspian terns can be recruited to new colony sites (i.e., Crump Lake) from existing breeding colonies (i.e., East Sand Island) over considerable distances, (2) Caspian terns are more easily recruited to nest at sites with a prior history of tern nesting (i.e., Crump Lake island), as compared to sites with no history of tern nesting (i.e., Fern Ridge island), (3) the diet of terns nesting at sites identified as alternative nesting locations in the FEIS (i.e., Brooks Island and Crump Lake) consisted mostly of forage fishes that are neither listed under the ESA nor of significant economic value for commercial, recreational, or subsistence fisheries, (4) availability of suitable sites for breeding colonies was the main factor limiting the number and size of tern colonies in both the San Francisco Bay area and interior Oregon, and (5) nesting success at existing colonies was limited by attributes of those colony sites as they influence (a) quality of nesting substrate, (b) vulnerability to mammalian and avian nest predators, (c) displacement by other colonial waterbirds, and (d) human disturbance.

INTRODUCTION

In 2008, the U.S. Army Corps of Engineers (USACE) began implementing the management actions for Caspian terns (*Hydroprogne caspia*) that were outlined in the January 2005 Final Environmental Impact Statement (FEIS) and November 2006 Records of Decision (RODs) for *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary* (USFWS 2005, 2006). This management plan, which was developed jointly by the USACE, the U.S. Fish and Wildlife Service, and NOAA Fisheries, seeks to redistribute a portion of the Caspian tern colony on East Sand Island in the Columbia River estuary to alternative colony sites in interior Oregon and the San Francisco Bay area by 2015. The goal of the plan is to reduce Caspian tern predation on out-migrating juvenile salmonids (*Oncorhynchus* spp.) in the Columbia River estuary, and thereby enhance recovery of salmonid stocks from throughout the Columbia River basin. Thirteen of 20 evolutionarily significant units (ESUs) of Columbia Basin salmonids are currently listed as either threatened or endangered under the U.S. Endangered Species Act (ESA).

The Caspian Tern Management Plan calls for the creation of approximately 7 acres of new or restored Caspian tern nesting habitat in interior Oregon (specifically Fern Ridge Reservoir, Crump Lake, and Summer Lake) and the San Francisco Bay area (specifically Don Edwards National Wildlife Refuge, Hayward Regional Shoreline, and Brooks Island) and to actively attract Caspian terns to nest at these sites. As alternative tern nesting habitat is created or restored, the available tern nesting habitat on East Sand Island will be reduced from its current size (approximately 5 acres) to 1.0 – 1.5 acres.

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

The potential for further reduction in Caspian tern nesting habitat at East Sand Island down to 1 acre is addressed in the RODs. Before nesting habitat on East Sand Island can be reduced below 1.5 acres, additional alternative sites for tern nesting would need to be developed. The criteria for selection of alternative sites are described in Appendix G of the FEIS. If potential new colony sites that have not already been analyzed in the FEIS are identified, an environmental assessment would be prepared for each site. A reduction

to 2,500 -3,125 pairs could be accomplished with development of alternative tern nesting habitat at two potential additional sites in northeastern California, Tule Lake National Wildlife Refuge and Lower Klamath National Wildlife Refuge, which are currently undergoing environmental assessments.

The USACE completed construction of a 1-acre island specifically designed for Caspian tern nesting at Fern Ridge Reservoir near Eugene, Oregon in February 2008. Construction of a 1-acre Caspian tern nesting island on Crump Lake in the Warner Valley, northeast of Lakeview, Oregon was completed in March 2008. The new island in Crump Lake is at the site of a former island that supported colonial-nesting waterbirds, including Caspian terns, prior to its destruction in the 1950s by hunters of Native American artifacts. Following island construction and before the arrival of terns from their wintering grounds, Caspian tern decoys and audio playback systems that broadcast tern calls were deployed on both islands to attract terns to nest (Kress 2000, Kress and Hall 2002).

The objectives of this study were to determine the diet composition, colony size, and nesting success of Caspian terns nesting at colonies in the San Francisco Bay area and at newly created/restored tern nesting islands in interior Oregon (i.e., Fern Ridge Reservoir and Crump Lake). This is a continuation of previously funded work (2003-2005) that investigated the food habits of Caspian terns at prospective alternative colony sites (i.e., San Francisco Bay area and interior Oregon) to assess the potential impacts of larger, permanent tern colonies on local stocks of forage fishes, particularly fish species of special concern (e.g., juvenile salmonids and Warner suckers [*Catostomus warnerensis*]; Roby et al. 2003b, 2004, 2005). This study will also investigate whether low food availability or locally abundant nest predators may render some former or prospective tern colony sites as population sinks (Penland 1982).

STUDY SITES

There were 6 different Caspian tern colony sites monitored in 2008, four active colonies in the San Francisco Bay area (see Map 1) and two new colony sites in interior Oregon (see Map 2). In the San Francisco Bay area, the study sites were: Brooks Island, Eden Landing, Agua Vista Park, and Stevens Creek (Map 1). The primary study sites in the San Francisco Bay area during the 2008 nesting season were Brooks Island in the central Bay, where ca. 950 pairs of terns nested in 2005, and Eden Landing (formerly known as "Baumberg Ponds") in the south Bay, where ca. 30 pairs of terns nested in 2003 and 2004. In interior Oregon, the primary study sites were two newly constructed/restored islands specifically designed for tern nesting and built prior to the 2008 breeding season; one at Crump Lake in the Warner Valley, northeast of Lakeview, and the other at Fern Ridge Reservoir near Eugene. Prior to island restoration in 2008, Crump Lake had a history of intermittent nesting by terns (Shuford and Craig 2002, Roby et al. 2003a, Roby et al. 2003b), reflecting annual variation in water levels and resultant changes in the availability of suitable nesting habitat and an adequate food supply. In drought years, the island formerly used by nesting terns became connected to the mainland, providing

mammalian predators with easy access to the colony site. Conversely, during high water years, the island became inundated, eliminating all suitable nesting habitat.

Although Caspian terns have been observed in the area, there is no prior history of Caspian terns nesting near Fern Ridge Reservoir, presumably due to the lack of suitable nesting habitat. We monitored the newly constructed islands in Crump Lake and Fern Ridge Reservoir to determine whether Caspian terns would use the sites for nesting and, if so, what factors limited the size and nesting success of the new Caspian tern colonies. We also conducted aerial, road-based, and boat-based surveys of sites in central Oregon, south-central Oregon, southeastern Oregon, and northeastern California searching for other active Caspian terns colonies in the region (Map 2).

METHODS

We constructed observation blinds at the periphery of some tern colonies (Brooks Island, Crump Lake island, and Fern Ridge island) to facilitate colony observations without disturbing nesting terns; other colonies (Eden Landing, Agua Vista Park, and Stevens Creek) were observed from a vehicle or mainland vantage point that was sufficiently distant from the colony so as not to have a noticeable effect on tern nesting behavior. Data on number of terns on the colony, diet composition, and causes of tern nesting failure were collected by observers 3-7 days per week at Brooks Island, Eden Landing, and Crump Lake island. Other colonies (Agua Vista Park and Stevens Creek) were visited on a less frequent basis (1 day per week) to determine colony status and to estimate the number of nesting pairs. Because there has been no prior history of Caspian terns nesting near Fern Ridge Reservoir or elsewhere in the Willamette Valley, we suspected that Caspian terns might not nest on the Fern Ridge tern island during the first breeding season following construction. Consequently, video cameras were used to monitor the island instead of direct observation by a field crew, and the island was visited periodically throughout the breeding season by project staff.

With the exception of the large Caspian tern colony on Brooks Island in San Francisco Bay, the number of Caspian terns breeding at colonies in San Francisco Bay and interior Oregon was estimated from ground counts of incubating adult terns near the end of the incubation period. At Brooks Island, colony size was estimated by counting the total number of Caspian terns in aerial photos taken of the colony late in incubation. These counts were then adjusted to reflect the total number of breeding pairs by determining the ratio of sitting terns to total terns on plots visible from an observation blind adjacent to the tern colony. Nesting success (number of young raised per breeding pair) at all colonies was estimated from ground counts of young at the colony just prior to the fledging period. Previously banded Caspian terns were re-sighted at all colonies, where feasible, to estimate survival rates, post-breeding dispersal, and movements among colonies of Caspian terns in the Pacific Coast population. Tern chicks near fledging age were banded at Brooks Island and Crump Lake island (the two largest nesting colonies). Each tern fledgling was banded with a federal numbered metal leg band and two plastic, colored leg bands on the left leg and a plastic leg band engraved with a unique

alphanumeric code on the right leg to allow for the identification of individual terns at a distance (i.e., at roosts or on colonies).

In addition, a sample of adult Caspian terns nesting at Brooks Island was radio-tagged in order to assess where terns from this colony foraged. Adult terns (n = 42) were captured on the Brooks Island colony using noose mats placed around active nests. Trapping of nesting terns on Brooks Island was conducted during late incubation to minimize nest abandonment due to disturbance (Sirdevan and Quinn 1997). Once captured, each adult was banded (see description above) and radio-tagged using a 3-g VHF radio transmitter affixed to the central tail feathers. These transmitters are shed by the terns when they molt their tail feathers after the nesting season. Radio-tagged terns were also marked on the back and upper wing coverts with rhodamine-B dye to aid in re-sighting radio-tagged individuals on-colony. Nesting status of radio-tagged adults was confirmed by observing their behavior while on-colony.

We conducted 11 aerial surveys from May 28 to June 20 to relocate radio-tagged terns while foraging off-colony during the chick-rearing period. Aerial surveys were conducted from a Cessna fixed-winged aircraft with a single dipole antenna mounted on each wing. Antennae were connected to a radio telemetry receiver through a switch box that allowed the tracker to listen to one antenna at a time (while tracking a single bird) or both simultaneously (while scanning for birds). Once in the vicinity of a radio-tagged tern, the pilot "boxed in" the signal by circling with one wing in the direction of the strongest signal, while the location was marked with a GPS receiver. Radio-tracking was also performed from the ground using a truck mounted dual antennae null peak system (used for additional off-colony detections), several fixed antennae sites around the bay, and a fixed antenna erected adjacent to the Brooks Island tern colony (used to monitor colony attendance). The aerial and road-based surveys were designed to identify key foraging areas for Caspian terns nesting at the Brooks Island colony.

Diet composition at selected study colonies (i.e., Brooks Island, Eden Landing, and Crump Lake island) was determined by visually identifying fish brought back to the colonies in the bills of nesting adults with the aid of binoculars and spotting scopes. Forage fishes were identified to the lowest taxonomic grouping possible from visual observation. Visual identifications were verified using voucher specimens whenever possible. In addition, fish tags (coded wire tags, PIT tags, and floy tags) were recovered on selected tern colonies to estimate tern predation rates on fish species of special concern to resource managers (i.e., juvenile salmonids in San Francisco Bay and Warner suckers at Crump Lake).

Coded wire tags (CWT) implanted in juvenile salmonids originating from the Sacramento River basin were recovered on the Brooks Island Caspian tern colony to evaluate impacts of tern predation on salmonids. This approach is possible because indigestible tags in fish caught by adult terns are deposited by the tern (or their chick) on-colony and can be recovered by researchers following the nesting season. Each year millions of juvenile salmonids, some of which are listed as threatened or endangered under the ESA, are coded wire tagged and released into the Sacramento River basin. Coded wire tags, which

are implanted into the nasal cartilage of the fish, provide data on the species, rear-type (hatchery or wild), run-type (fall, winter, spring), brood year, and release location of the fish. CWTs are made of 0.25-mm steel wire, range in length from 0.5 to 1.5 mm, and each specific release group is assigned a unique number.

CWTs were recovered by sifting through substrate (sand, shells, guano, bones, etc.) used by nesting Caspian terns on Brooks Island in 2008. This was accomplished by removing nesting substrate from several haphazardly selected 1-m^2 plots within the colony area in August and November 2008, after terns had abandoned the Brooks Island colony following the nesting season. Once removed, the substrate was ground (to breakup up guano), sifted (to remove shell, rocks, bones and other large material), and poured over a magnetized trough to recover the steel CWTs from the substrate. Tags collected in the trough were then cleaned with isopropyl alcohol and the tag's unique code read with a specially-designed MagniViewer (Northwest Marine Technology, Inc., Shaw Island, WA). Release information on CWT fish from the region were obtained by querying the Regional Mark Processing Center (RMISD 1977), a database of CWT salmonids from the Pacific Coast Region of North America.

The numbers of CWT fish released (by species, run-type, and release location) were compared to the number recovered on the Brooks Island tern colony to generate minimum estimates of predation rates (see Appendix 1). Our analysis focused on predation of ESA-listed fish tagged and released into the basin. We also investigated the link between fish release date and release location as a function of proportion consumed by Caspian terns. Data presented here are preliminary and incomplete, as we are still processing substrate samples collected from Brooks Island in 2008. A complete report of the 2008 Brooks Island coded wire tag data will be prepared after the remaining tags have been processed and after the data have been more thoroughly analyzed. We anticipate these final result will be available by August 2009.

At Crump Lake island, we estimated the total numbers of Warner suckers (an ESA-listed species) consumed by Caspian terns nesting on Crump Lake (see Appendix 2 for detailed description of methods) based upon the numbers of these fish observed in tern bill loads by researchers during the 2008 nesting season. In addition to suckers, we also estimated the number of introduced non-native, predatory fish (crappie [*Pomoxis* spp.], bullhead catfish [*Ameiurus* spp.], and bass [*Micropterus* spp.]) that were consumed by terns nesting on Crump Lake island. Estimates of tern consumption of predatory fish were generated under the premise that the terns' negative impact on Warner sucker survival may be off-set or mitigated by the terns' consumption of non-native piscivorous fishes, fish that are also presumably consuming juvenile Warner suckers.

Colony monitoring methodology followed standardized observational and data collection protocols described in Collis et al. (2002), Roby et al. (2002), and Roby et al. (2003c). Use of these protocols ensures that results from different colonies and across years are comparable and will provide managers with the information necessary to (1) assess the efficacy of implemented management initiatives and (2) make future management decisions.

RESULTS AND DISCUSSION

San Francisco Bay Area

Brooks Island

Background: Brooks Island is a natural island in central San Francisco Bay near the City of Richmond, and is owned by the City and managed under a long-term lease by the East Bay Regional Parks District. Brooks Island has been the site of the largest nesting colony of Caspian terns in the Bay area for the last decade. The tern colony is located on a sandy, low-lying spit that extends to the northwest of the island, built from material dredged from the adjacent shipping channel to the Port of Richmond. The Caspian tern colony was estimated at 950 breeding pairs in 2005. Caspian terns nest on the upper part of the beach on the leeward (northeast) shore of the spit. The size and productivity of the Brooks Island Caspian tern colony is currently limited by suitable nesting habitat, which has been declining due to shoreline erosion, spread of invasive vegetation, and expansion of a recently formed California gull colony. The terns nest in close proximity to two species of gulls, western gulls (*Larus occidentalis*) and California gulls (*L. californicus*); western gulls have traditionally nested on Brooks Island, but the California gull colony has recently become established on the spit and is expanding rapidly.

The plan "*Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*," which seeks to redistribute a portion of the East Sand Island tern colony to alternative colony sites in Oregon and California, identifies Brooks Island as one of three sites in the San Francisco Bay Area where resource managers intend to create or enhance Caspian tern nesting habitat (USFWS 2005). No immediate plans are in place, however, to restore or increase the amount of Caspian tern nesting habitat on Brooks Island.

Nesting Chronology, Colony Size, and Nesting Success: Nesting chronology of Caspian terns at the Brooks Island colony in 2008 was somewhat advanced compared to previous years (2003-2005); the dates when the first tern arrived at the colony, the first egg was laid, and the first chick was hatched were the earliest we had observed at the Brooks Island tern colony (Figure 1). The nesting habitat near the observation blind was occupied first (hereafter referred to as the "Main Sub-colony"), and later a separate satellite colony formed further down the beach to the northwest (hereafter referred to as the "NW Satellite Sub-colony"), as was the case during 2003-2005. Most of the Main Sub-colony could be observed and numbers of adult terns counted from the observation blind, but some nesting adults were obscured by vegetation or topography. The NW Satellite Sub-colony could not be observed from the observation blind, and numbers of adult terns in attendance could only be estimated by observers in a skiff offshore. Consequently, counts of adult terns on-colony are minimums and generally less than the number of active nests in the Main and NW Satellite sub-colonies combined. Average weekly colony attendance at the Brooks Island Caspian tern colony in 2008 was higher throughout most of the breeding season compared to the average from previous years

(2003-2005; Figure 2). However, higher colony attendance did not translate into larger colony size in 2008 relative to 2003-2005 (Figure 3). Instead, the higher colony attendance may have reflected higher food availability in 2008 relative to previous years. Based on the aerial photography, corrected using ground counts of sitting terns, we estimated the size of the Main Sub-colony as ca. 515 breeding pairs and the size of the NW Satellite Sub-colony at ca. 295 breeding pairs, or a total of ca. 810 pairs of Caspian terns nesting on Brooks Island. As was the case in 2003-2005, Brooks Island was by far the largest Caspian tern colony in the Bay Area in 2008, with 81% of the entire San Francisco Bay breeding population nesting at this one site (Table 1). Colony size at the Brooks Island Caspian tern colony in 2008 was below the average colony size during 2003-2005 (Figure 3). The number of Caspian terns nesting on Brooks Island appears to be slowly declining since 2004 (Figure 3). The decline in colony size is apparently due to a reduction in the availability of suitable nesting habitat on Brooks Island, the increase in the breeding population of California gulls on Brooks Island, and increased competition with and nest predation from nesting gulls.

We estimated that approximately 341 young terns fledged from the Brooks Island colony in 2008, or 212 and 129 young terns fledged from the Main and NW Satellite sub-colonies, respectively. Productivity was 0.35 and 0.44 young raised per breeding pair for the Main and NW Satellite sub-colonies, respectively, or 0.42 fledglings per breeding pair for the entire Brooks Island tern colony. Productivity at the Brooks Island tern colony was roughly half the productivity of terns nesting at Eden Landing (Table 1). Nesting success at the Brooks Island Caspian tern colony was slightly higher in 2008 than in 2005, but below levels observed in 2003 and 2004 (Figure 4). On average, nesting success at the Brooks Island tern colony (ca. 0.5 young raised/breeding pair; Figure 4) is within the range observed at other Caspian tern colonies studied in the San Francisco Bay Area (range = 0.31 - 0.81 young raised/breeding pair).

Chick Banding and Re-sightings of Banded Adults: On June 26, 147 Caspian tern chicks near fledging age were banded at Brooks Island. Each fledgling was banded with a federal numbered metal leg band and two plastic, colored leg bands on the left leg and a plastic leg band engraved with a unique alphanumeric code on the right leg; an additional 35 tern chicks that were too young to be banded with alphanumeric bands were banded with just a federal numbered metal band.

In 2008, 19 previously-banded Caspian terns were re-sighted at the Brooks Island tern colony. All 19 re-sighted banded terns were identified to year banded, age class when banded (i.e., adult or chick), and banding location. Of these 19 banded individuals, 9 (47%) were banded at Brooks Island as chicks, 4 (21%) were banded at Knight Island in San Pablo Bay (northern San Francisco Bay area; Map 1) as chicks, and 6 (32%) were banded at East Sand Island in the Columbia River estuary as chicks.

The re-sighted terns that had been banded on East Sand Island were re-sighted in the San Francisco Bay area from May to July; therefore, is it unlikely that these six terns were only passing through the Bay area during migration. At least one of the six was confirmed breeding (incubating eggs) on Brooks Island.

Six of the banded terns re-sighted at Brooks Island were also re-sighted at Eden Landing in 2008, suggesting that there were movements of individuals between the two colonies. Possible explanations of this observation are (1) some terns were prospecting for breeding sites at both colonies, (2) some individuals breeding at one site in the Bay area were using the other site as a loafing area, (3) individuals that failed to nest at one site emigrated to the other colony for re-nesting.

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

Diet Composition: A large number of Caspian tern bill loads (N = 4,440) were identified at the Brooks Island colony in 2008. As was the case during 2003-2005, the diet of Caspian terns nesting at Brooks Island in 2008 consisted primarily of marine forage fishes, in particular anchovies (Engraulidae; 31.4% of identifiable prey items), surfperch (Embiotocidae; 19.4% of identifiable prey items), herring/sardines (Clupeidae; 13.1%), and gobies (Gobiidae; 10.8%; Figure 5). Additional fish taxa that represented more than 1% but less than 10% of the diet in 2008 included salmonids (Salmonidae; 8.9%), silversides (Atherinidae; 4.9%), sculpins (Cottidae; 4.6%), smelt (Osmeridae; 2.0%), and sunfish (Centrarchidae; 1.4%). Eight other prey taxa represented less than 1% of the diet.

During 2003-2005, small numbers of juvenile salmonids (primarily Chinook salmon smolts, *O. tshawytscha*) were identified in the diet of terns nesting on Brooks Island (ca. 3%; Figure 6). In 2008, the proportion of the diet that was juvenile salmonids increased to about 9% (Figure 6), raising concerns that relocation of Caspian terns from the Columbia River estuary to Brooks Island might reduce survival of ESA-listed salmonids from the Sacramento River basin. A radio telemetry study of Brooks Island terns (see below), combined with recoveries of smolt coded wire tags from the Brooks Island colony (see Appendix 1), revealed that nearly all salmonid smolts consumed by Caspian terns from this colony in 2008 were hatchery-reared, non-listed fall-run Chinook salmon smolts that had been released from net pens in eastern San Pablo Bay. In 2008, juvenile salmonids were released from net pens in eastern San Pablo Bay from early April through mid-June (see Appendix 1), which roughly corresponded with when juvenile salmonids peaked in the diet of Caspian terns nesting on Brooks Island (Figure 7).

Radio-Telemetry of Nesting Adults: A total of 86 off-colony detections for 20 nesting adult Caspian terns from Brooks Island were collected during aerial surveys in 2008. The areas with the highest density of relocations were western San Francisco Bay (around Angel Island and Sausalito), eastern San Pablo Bay (from Pt. San Pablo north to the mouth of Carquinez Strait), and a marine area just outside the Bay. Very few relocations were collected in the South Bay, although one tern captured and radio-tagged on Brooks

Island successfully nested at the colony on Eden Landing island (located in the South Bay; see Map 1). That bird was relocated off colony three times in the South Bay, and was not relocated in the North Bay. Relocations collected during road surveys indicated similar densities of radio-tagged terns compared to those collected during aerial surveys, with the South Bay providing very few relocations, and western San Francisco Bay and eastern San Pablo Bay showing high use by Caspian terns. Relocations of radio-tagged terns in San Pablo Bay appeared to be associated, at least in part, with the release of hatchery-reared fall Chinook salmon from net pens in that area. We plan to repeat this radio telemetry study in 2009; a much more in-depth analysis of these results will be made available once the second year of data collection is completed.

Factors Limiting Colony Size and Nesting Success: The primary factors limiting the size and productivity of the Brooks Island Caspian tern colony in 2008 appeared to be (1) availability of suitable nesting habitat, (2) displacement of nesting terns by other colonial waterbirds, and (3) human disturbance (Table 2). Nesting habitat for terns on Brooks Island is restricted to a narrow band of bare sand habitat between the vegetated areas that dominate the spit and the high tide line. The area of suitable habitat for tern nesting appears to vary from year to year based on expansion and contraction of the beaches and vegetated areas (primarily native pickleweed, exotic ice plant, and a non-native aster), depending on the number and intensity of winter and spring storms. Shoreline erosion removes nesting substrate from the seaward direction and annual dredging of the commercial shipping channel on the leeward side of the sand spit contributes to beach loss on the leeward side, where Caspian terns nest. These two processes appear to be responsible for the fragmentation of the Brooks Island tern colony into two sub-colonies. Although the mean high tide for this part of the bay is 5.4 feet, monthly high tides can reach 7.4 feet, further limiting the available beach area suitable for tern nesting and likely causing some tern nests in low-lying areas to fail. Thus the size of the Caspian tern colony on Brooks Island appeared to be largely limited by availability of suitable nesting habitat.

The expanding California gull colony on Brooks Island appears to be another major factor limiting the size and productivity of the Brooks Island Caspian tern colony. As was the case in previous years, the California gull colony on Brooks Island was in close proximity to the Caspian tern colony in 2008. Gull predation on Caspian tern eggs and chicks was observed daily at the Brooks Island tern colony and has increased considerably compared to previous years (i.e., 2003-2005), to the point where it is having a large impact on tern productivity.

Another constraint on nesting success of Caspian terns at Brooks Island appeared to be human disturbance. Gull predation on Caspian tern eggs and chicks was observed at the Brooks Island colony, but these events were uncommon except during disturbance events, especially human disturbance. We repeatedly observed that kayakers, other recreational boaters, and low-altitude aircraft caused nesting terns to flush from the NW Satellite Sub-colony which provided easy access to unattended nests and their contents by nest predators (i.e., gulls).

Eden Landing

Background: Eden Landing/Pond E10 (formerly Baumberg Ponds/Pond B10) is a former salt pond in southern San Francisco Bay, near the east end of the San Mateo Bridge. Eden Landing/Pond E10 was created for industrial salt production by building a levee around low-lying inter-tidal marsh, but is now owned and managed by the California Department of Fish and Game. In 1998, Caspian terns began nesting on a very small island in Pond E10 near the west levee and continued to nest there until 2004, when all of the active tern nests with eggs were depredated or abandoned early in the breeding season. Subsequently, a tide gate malfunction led to the draining of the salt pond, providing a land bridge to the surrounding levee where foxes, raccoons, and long-tailed weasels were seen. No terns attempted to nest at this site during 2005-2007.

Nesting Chronology, Colony Size, and Nesting Success: Caspian terns were first observed on the island at Eden Landing on April 29 (78 terns counted); we estimate that the first eggs were laid at the colony the following day (April 30; Figure 8), almost three weeks after the first tern eggs were laid at Brooks Island. The first tern chick was observed on May 23 and the first fledgling was observed on July 20 (Figure 8), nearly a month after the first young were fledged from Brooks Island. Weekly colony attendance at the Eden Landing Caspian tern colony in 2008 was higher throughout the breeding season compared to the average in 2003 and 2004 (Figure 9). In 2008, the Eden Landing Caspian tern colony (56 nesting pairs) was nearly twice the size that it was in 2003 and 2004 (Figure 10).

We estimated that approximately 48 young terns fledged from the Eden Landing colony in 2008. Nesting success at the Eden Landing Caspian tern colony in 2008 (0.8 young raised/breeding pair) was nearly twice what it was in 2003 (Figure 11). Although Caspian terns attempted to nest at Eden Landing in 2004, all tern nests failed prior to hatching, presumably due to nest predation by mammalian predators. In 2008, nesting success at the Eden Landing colony was nearly twice what it was at the Brooks Island tern colony.

Chick Banding and Re-sightings of Banded Adults: Tern chicks were not banded at the Eden Landing colony due to relatively small colony size and the potential impact to colony productivity associated with disturbance during banding activities.

In 2008, 6 previously-banded Caspian terns were re-sighted at the Eden Landing tern colony. All 6 re-sighted banded terns were identified to banding year, age class when banded (i.e., adult or chick), and banding location. Of the 6 banded individuals that were re-sighted at Eden Landing, 3 (50%) were banded at Knight Island in San Pablo Bay (northern San Francisco Bay area; Map 1) as chicks, 2 (33%) were banded at East Sand Island in the Columbia River estuary as chicks, and 1 (17%) was banded at Brooks Island as a chick.

All of the banded terns re-sighted at Eden Landing Island were also re-sighted at Brooks Island in 2008, suggesting that movements of individuals between these two colonies were frequent (see above for explanation).

Diet Composition: A total of 1,355 bill load fish were identified at the Eden Landing tern colony in 2008. The diet of Caspian terns nesting at Eden Landing was dominated by silversides (Atherinidae; 21.0% of identifiable prey items), surfperch (Embiotocidae; 20.1%), anchovies (Engraulidae; 14.1%), juvenile sharks (Carcharhinidae; 14.1%), and sculpins (Cottidae; 13.1%; Figure 12). Additional fish taxa that represented more than 1% but less than 10% of the identified prey items included gobies (Gobiidae; 2.4%), flatfish (Pleuronectidae; 3.2%), herring/sardine (Clupeidae; 2.8%), and smelt (Osmeridae; 2.4%). Three other prey taxa each represented less than 1% of the diet.

In 2008, three juvenile salmonids were identified among the 1,355 identifiable prey items, or 0.20% of all prey items identified at the Eden Landing colony (Figure 13). By comparison, juvenile salmonids comprised only 0.1% of the diet of terns nesting at Eden landing in 2003 (Figure 13). The general trend that has emerged from our research is that the further south Caspian terns nest in San Francisco Bay, the fewer juvenile salmonids they consume. Terns nesting at Eden Landing, a South Bay site, are less reliant on juvenile salmonids as a food source than terns nesting at Brooks Island, a Central Bay site (3 - 9% of prey items), which are less reliant on salmonids than terns that nested on the now abandoned colony site at Knight Island, a North Bay site (10 - 26% of prey items).

Factors Limiting Colony Size and Nesting Success: The primary factors limiting the size and productivity of the Caspian tern colony at Eden Landing are (1) availability of suitable nesting habitat, (2) the quality of nesting substrate, and (3) encroachment by roosting American white pelicans (*Pelecanus erythrorhynchos*) and double-crested cormorants (*Phalacrocorax auritus*; Table 2). The island is very small and much of it consists of fine-grained sediment that turns mucky after a rain, which negatively affects egg hatchability. We suspect that some of the active Caspian tern nests on the Eden Landing colony were destroyed this past season by American white pelicans and double-crested cormorants that used the small island as a roosting site.

Agua Vista Park

Background: This small Caspian tern colony near Agua Vista Park was discovered during the 2002 nesting season and was estimated to consist of 38 nesting pairs in 2004, although the size of the colony has declined recently. The colony formerly existed on two decaying fragments of a former wooden pier (Pier 63) on the San Francisco waterfront, just south of Pacific Bell Park (home of the SF Giants). The colony gets its name from a very small park of that name on the shores of the Bay adjacent to the collapsing pier. The section of pier nearest the shore has completely rotted away, leaving the outer sections unconnected to the mainland and thus free of mammalian predators. The Caspian terns currently nest on one remaining section of pier, digging nest scrapes in the dirt and debris on the surface. Several pairs of western gulls also nest in the vicinity, including on the section of pier where the terns nest. This pier fragment appears to be in imminent danger of collapsing. The owner of the property is the San Francisco Port Authority.

Colony Size and Nesting Success: Based on periodic visits to the Agua Vista Park tern colony throughout the breeding season, we estimate that 14 breeding pairs nested there, the smallest Caspian tern breeding colony in the San Francisco Bay area during 2008 (Table 3). This colony was roughly the same size as it was in more recent years (9-19 breeding pairs in 2005-2007; USFWS unpublished data). Although it is believe that some young were fledged from this colony in 2008, we were not able to quantify nesting success. Based on our research in 2003-2005, average nesting success (0.75 young per breeding pair) at this colony was considered fair to good compared to other well-studied colonies in the Pacific Region.

Chick Banding and Re-sightings of Banded Adults: Tern chicks were not banded at the Agua Vista Park colony due to the inaccessibility of the colony and the danger associated with attempting to access the colony on the decaying pier structure.

We were unable to determine if any banded adult terns frequented the Agua Vista Park tern colony in 2008 due to the distance between the colony and our observation site (> 300 m).

Diet Composition: Diet data were not collected at the Agua Vista tern colony in 2008. Based a small number of Caspian tern bill loads identified in 2003-2004, terns nesting at Agua Vista ate mostly schooling marine forage fish (i.e., surfperch, anchovies, silversides, and herring/sardines. Juvenile salmonids comprised between 0.1% and 1.4% of the diet during 2003-2004.

Factors Limiting Colony Size and Nesting Success: The primary factors limiting the size and productivity of the Agua Vista Caspian tern colony during 2003-2005 and in 2008 appeared to be the quality of nesting substrate and the availability of suitable nesting habitat (Table 2). Suitable nesting substrate is certainly the proximate factor limiting the size of the tern colony on the remaining pier fragment, but because terns are nesting at this site it is evident that the availability of suitable nesting habitat for Caspian terns is extremely limited in that part of San Francisco Bay.

Stevens Creek

Background: Stevens Creek (Pond B2) is in southern San Francisco Bay near the Town of Moffet (CA), and is part of the Don Edwards NWR. Caspian terns were first observed nesting at the site in 2007 (12 breeding pairs). Few data are currently available on this incipient Caspian tern colony.

Colony Size and Nesting Success: We estimate that ca. 120 breeding pairs of Caspian terns nested at Stevens Creek in 2008, the second largest Caspian tern colony in San Francisco Bay in 2008 (Table 3). Although it is believed that some young were fledged from this colony in 2008, we were unable to estimate Caspian tern nesting success due to infrequent visits to the colony and the distance between the colony and our observation site (> 300 m).

Chick Banding and Re-sightings of Banded Adults: Tern chicks were not banded at the Stevens Creek colony due to the relatively small colony size and concern over the potential impact of disturbance during banding activities on the productivity of this colony.

Re-sightings of previously banded adult Caspian terns were not conducted at the Stevens Creek colony in 2008.

Diet Composition: Diet data were not collected at the Stevens Creek tern colony in 2008 due to the distance between the colony and our observation site. The Stevens Creek tern colony is located in the extreme southern end of San Francisco Bay near the now abandoned tern colony at Alviso Ponds (A7). Due to their proximity, we suspect that the diet composition of terns nesting at these two locations is similar. Based on small sample sizes, the diet of Caspian terns nesting at Alviso Ponds in 2003-2004 consisted primarily of benthic forage fish (i.e., gobies [Gobiidae], toadfish [Batrachoididae], and sculpins [Cottidae]), suggesting that terns are foraging in shallow water habitats in that part of the Bay. Juvenile salmonids comprised between 0.0% (in 2003) and 3.5% (in 2004) of the diet of terns nesting at Alviso Ponds. The salmonids consumed by Caspian terns nesting at Alviso Ponds in 2004 consisted primarily, if not entirely, of rainbow trout stocked in local reservoirs. During visits to several of these reservoirs, where trout were stocked for recreational fishers (e.g., Lake Chabot), we commonly observed foraging Caspian terns.

Factors Limiting Colony Size and Nesting Success: The primary factors limiting the size and productivity of the Caspian tern colony at Stevens Creek appeared to be the availability of suitable nesting habitat and the quality of nesting substrate (Table 2). The island is small and much of it consists of fine-grained sediment that turns mucky after a rain, which negatively affects egg hatchability.

Interior Oregon and California

Crump Lake

Background: Crump Lake is located in the Warner Valley in south-central Oregon, near Adel (OR). All islands and seasonally inundated wetlands associated with the lake are owned and managed by the Oregon Division of State Lands. A low-lying rocky island that was used by a variety of colonial nesting waterbirds in years of low lake levels was located in the central portion of Crump Lake, north of the peninsula that nearly bisects the lake. In the early part of the 20th Century the island supported large numbers of colonial waterbirds each year, but in the 1950s, when the lake dried out, heavy equipment was used to scour the island for Native American artifacts, which resulted in a lower elevation island that was completely inundated in high water years. In the early 1990s, following another drought year, the Oregon Department of Fish and Wildlife attempted to restore the island so that it would offer perennial nesting habitat for colonial waterbirds, but subsequent wind and wave erosion again reduced island elevation so that it was inundated during high-water periods in spring and early summer, preventing nesting on the island. Caspian terns were observed nesting on Crump Lake island in 2000, when

approximately 150 breeding pairs nested in association with a larger colony of California gulls, but no Caspian terns nested on the island in 2001 and 2002 due to high water levels. In 2003, a temporary wooden nesting platform was constructed on the submerged island and equipped with Caspian tern decoys and audio systems to attract nesting terns (Kress 2000, Kress and Hall 2002); Caspian terns nested successfully on the platform (49 breeding pairs), and subsequently on the island (22 breeding pairs), once the lake level had dropped sufficiently to expose part of the island. In 2008, the U.S. Army Corps of Engineers began implementing the plan "*Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*" to redistribute a portion of the East Sand Island tern colony to alternative colony sites in Oregon and California (USFWS 2005). Crump Lake is one of three sites in interior Oregon where resource managers intended to create Caspian tern nesting habitat as part of this plan. In March 2008, the U.S. Army Corps of Engineers completed construction of a 1-acre island in Crump Lake at the location of the pre-existing island. The island was designed so as to resist erosion and remain well above lake levels, even at full pool, and the surface was covered with gravel and sand to provide nesting substrate for Caspian terns. Caspian tern decoys and audio systems that broadcast tern calls were installed on the island in April 2008 in order to attract terns to nest at the site (Kress 2000, Kress and Hall 2002).

Nesting Chronology, Colony Size, and Nesting Success: In 2008, the first Caspian terns were observed at the new tern island in Crump Lake on 5 May and within two weeks the first tern egg was laid on the island (Figure 14). Due to intense nest predation by gulls in early June, most of the early tern nesting attempts failed. Following the implementation of selective gull control, many new tern nests were initiated in mid- to late June, which resulted in a protracted chick-rearing period (Figure 14). The first fledgling was observed on the Crump Lake tern colony on 20 July, nearly a month later than at other well studied tern colonies at interior sites (e.g., Crescent Island).

Caspian terns were quick to colonize the new tern nesting island in Crump Lake following island construction and the deployment of tern decoys and audio playback systems on the island. Over the next month tern colony size on the Crump Lake island quickly grew to nearly 150 breeding pairs before nest predation by neighboring gulls (primarily, California gulls) caused almost complete failure of the tern colony (Figure 15). Once the necessary permits were obtained, we began selective lethal removal of gulls that had been observed to specialize on feeding on tern eggs. A total of 7 California gulls and 3 ring-billed gulls were removed from the colony between 30 May and 25 June, allowing the tern colony to rebound from a low of 23 nesting pairs in early June to a high of 428 nesting pairs in late June. This is the largest Caspian tern colony ever recorded at Crump Lake.

We estimated that approximately 144 young terns fledged from the Crump Lake tern colony in 2008, or an average of 0.34 young fledged per breeding pair (Figure 17). This is less than the productivity measured at the Crump Lake tern colony in 2003 (ca. 0.63 young fledged per breeding pair; Figure 17), and is considered low compared to other well-studied colonies in the Pacific Region.

Chick Banding and Re-sightings of Banded Adults: On August 26, 132 Caspian tern chicks near fledging age were banded at Crump Lake island with a federal numbered metal leg band and two plastic, colored leg bands on the left leg and a plastic leg band engraved with a unique alphanumeric code on the right leg; an additional 12 tern chicks that were too young to band with alphanumeric bands were banded only with federal numbered metal bands.

In 2008, 30 previously-banded Caspian terns were re-sighted at the newly constructed tern nesting island on Crump Lake. Twenty-eight of the re-sighted banded terns had been banded by our team and were identified to banding year, age class when banded (i.e., adult or chick), and banding location; the other two banded adults had been banded in 1999 in Nevada, one as a chick at a colony in Still Water, by another field crew. Of the 28 individuals banded by our crew, 18 (64%) were banded at Crescent Island on the mid-Columbia River near Pasco, WA (3 as adults and 15 as chicks), 5 (18%) were banded at East Sand Island in the Columbia River estuary (1 as an adult and 4 as chicks), 2 (7%) were banded as chicks at Goose Island in Pothole Reservoir near Moses Lake, WA, 2 (7%) were banded as chicks at Solstice Island in Pothole Reservoir, and 1 (4%) was banded at Crump Lake as a chick.

Based on the re-sighting of Caspian terns on the Crump Lake colony that had been banded on East Sand Island, the Crump Lake tern colony currently serves as an alternative nesting site for terns dispersing from the large colony on East Sand Island, over 500 km away. Further reductions in the available Caspian tern nesting habitat on East Sand Island are imminent as part of the Caspian Tern Management Plan (USFWS 2005), suggesting that more Caspian terns nesting on East Sand Island will emigrate to Crump Lake island. The proportion of color-banded terns at East Sand Island is very small relative to total numbers of terns present at East Sand Island (e.g., about 5% of fledglings were banded in 2003), whereas the proportion of color-banded terns at some other sites is significantly higher (e.g., about 67% of fledglings at Crescent Island were banded in 2004; Table 3). Consequently, it is likely that approximately half of the Caspian terns that colonized Crump Lake island in 2008 originated from the colony on East Sand Island (Table 3).

Diet Composition: A large number of Caspian tern bill loads (N = 2,915) were identified at the Crump Lake colony in 2008. As was the case in 2003, the diet composition of Caspian terns nesting on Crump Lake consisted primarily of tui chub (*Gala bicolor*; 55.4% of the identifiable prey items), followed by bullhead catfish (Ictaluridae; 27.8%), and crappie (Centrarchidae; 15.0%; Figure 18). The remaining 1.8% of prey items consisted of rainbow trout (*Oncorhynchus mykiss*), lamprey (*Entosphenus* spp.), suckers (*Catostomus* spp.), bass (*Micropterus* spp.), and dace (*Rhinichthys* spp.). A total of 5 suckers (0.17% of identifiable prey items) were observed by researchers during the nesting season, one of which was positively identified as an ESA-listed Warner sucker (*C. warnerensis*) because of its orange floy tag. In 2008, our rough best estimate of the total number of Warner suckers consumed by Caspian terns nesting on Crump Lake was ca. 93 (see Appendix 2 for further details, including methods of calculation). In 2009, we plan to improve the methodology used to estimate consumption of Warner suckers by

terns nesting on Crump Lake, until then this "best estimate" should be viewed with considerable skepticism.

Factors Limiting Colony Size and Nesting Success: Prior to 2008, the main factor limiting nesting success of Caspian terns at Crump Lake was fluctuating water levels that either inundated the available nesting habitat or caused the nesting island to be connected to the mainland, allowing access by mammalian nest predators. In 2008, gull predation was the most significant factor limiting the size and nesting success of the Crump Lake tern colony (Table 2).

Fern Ridge Reservoir

Background: Fern Ridge Reservoir is a shallow and expansive flood control reservoir in the southern Willamette Valley near the City of Eugene (OR), owned and managed by the U.S. Army Corps of Engineers. Although Caspian terns have been observed to use the lake during migration, terns have not previously nested in the area. In 2008, the U.S. Army Corps of Engineers began implementing the plan "*Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary*" described in the Final Environmental Impact Statement (FEIS) and Records of Decision (RODs) signed in November 2006 (USFWS 2005, 2006). Fern Ridge Reservoir is one of three sites in interior Oregon where resource managers intended to create nesting habitat for Caspian terns as part of this plan. In February 2008, the U.S. Army Corps of Engineers completed construction of a 1-acre island in Fern Ridge Reservoir near the Fern Ridge Wildlife Area, which is managed jointly by the Oregon Department of Fish and Wildlife and the Corps of Engineers. The island was revetted with rip-rap to prevent erosion and topped with pea gravel as a nesting substrate for Caspian terns. Caspian tern decoys and audio systems that broadcast Caspian tern calls were installed on the island in April 2008 in an effort to attract terns to nest at the site (Kress 2000, Kress and Hall 2002).

Results in 2008: Caspian terns apparently did not attempt to nest on the island in Fern Ridge Reservoir in 2008. Review of video footage revealed that Caspian terns visited the island after the breeding season, presumably once post-breeding terns dispersed from other nesting colonies. During the month of August the Fern Ridge tern island was visited by Caspian terns on 23 different days, with as many as nine Caspian terns observed on the island at one time. We will attempt to attract Caspian terns to nest at Fern Ridge island again in 2009, and we are hopeful that some terns will attempt to breed on this new island in years to come.

Other Interior Oregon and California Sites

Aerial, road-based, and boat-based surveys for Caspian terns were conducted at potential nesting locations in central Oregon (i.e., Fern Ridge Reservoir, Wickiup Reservoir, Crane Prairie Reservoir, Davis Lake, Agency Lake, Swan Lake, Spring Lake, Whiteline Reservoir, and Upper Klamath Lake), south-central Oregon (i.e., Summer Lake, Willow Valley Reservoir, Lake Abert, Gerber Reservoir, Drews Reservoir, Greaser Reservoir, Pelican Lake, Crump Lake, Hart Lake, Anderson Lake, Flagstaff Lake, Mugwump Lake,

Swamp Lake, Upper Campbell Lake, Campbell Lake, Stone Coral Lake, Turpin Lake, Bluejoint Lake, and Goose Lake), south-eastern Oregon (i.e., Malheur Lake, Mud Lake, Harney Lake, Baca Lake, Knox Pond, Krumbo Lake, Warm Springs Valley, Antelope Reservoir, Lower Cow Lake, and Upper Cow Lake), and north-eastern California (i.e., Meiss Lake, Big Sage Reservoir, Clear Lake Reservoir, Tule Lake, and Raker and Thomas reservoirs) in 2008 (see Map 2). Based on an aerial survey conducted in 11-12 June, nesting activity was evident at two sites; on an island near the western shore of Goose Lake, where 397 Caspian terns were counted, and on two islands in Clear Lake Reservoir within Clear Lake NWR where 124 Caspian terns were counted. Subsequent visits to both sites in late June revealed that all three colonies had been abandoned, apparently due to receding lake levels that connected the islands to the mainland. The failure of these two Caspian tern nesting colonies likely contributed substantially to the unexpectedly high number of Caspian terns nesting on Crump Lake island in Warner Valley, Oregon. No other Caspian tern nesting activity was observed in interior Oregon or northeastern California in 2008.

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LITERATURE CITED

Collis, K., D.D. Roby, D.P. Craig, S. Adamany, J.Y. Adkins, and D.E. Lyons. 2002. Colony size and diet composition of piscivorous waterbirds on the lower Columbia River: Implications for losses of juvenile salmonids to avian predators. Transactions of the American Fisheries Society 131:537-550.

Kress, S.W. 2000. Colony site management techniques. Issue Report in the Managers Toolbox, North American Waterbird Conservation Plan. Available through the Internet at http//www.nawcp.org/plan/toolbox.html

Kress, S.W., and C.S. Hall. 2002. Tern management handbook: Coastal Northeastern United States and Atlantic Canada. Draft Report submitted to U.S. Fish and Wildlife Service, Migratory Bird Division, Hadley, MA.

Penland, S. 1982. Distribution and status of the Caspian tern in Washington State. Murrelet 63: 73–79.

Regional Mark Information System Database [online database]. Continuously since 1977. Portland (OR): Regional Mark Processing Center, Pacific States Marine Fisheries Commission. URL:<http://www.rmpc.org>.

Roby, D.D., K. Collis, D.E. Lyons, D.P. Craig, J.Y. 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., K. Collis, D.E. Lyons, D.P. Craig, and M. Antolos. 2003a. Caspian Tern *Sterna caspia*. Pp. 277-279 *in* Birds of Oregon: A General Reference. D.B. Marshall, M.G. Hunter, and A.L. Contreras (eds.). Oregon State University Press, Corvallis. 752 pp.

Roby, D.D., K. Collis, S.K. Nelson, K. Larson, C. Couch, and P. Klavon. 2003b. Caspian tern nesting ecology and diet in San Francisco Bay and Interior Oregon. 2003 Annual Report submitted to the U.S. Fish and Wildlife Service, Region 1, Migratory Birds and Habitat Programs, Portland, OR.

Roby, D.D., D.E. Lyons, D.P. Craig,, K. Collis, and G.H. Visser. 2003c. 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.

Roby, D.D., K. Collis, S.K. Nelson, K. Larson, and K. Bixler. 2004. Caspian tern nesting ecology and diet in San Francisco Bay and Dungeness National Wildlife Refuge. 2004 Annual Report submitted to the U.S. Fish and Wildlife Service, Region 1, Migratory Birds and Habitat Programs, Portland, OR.

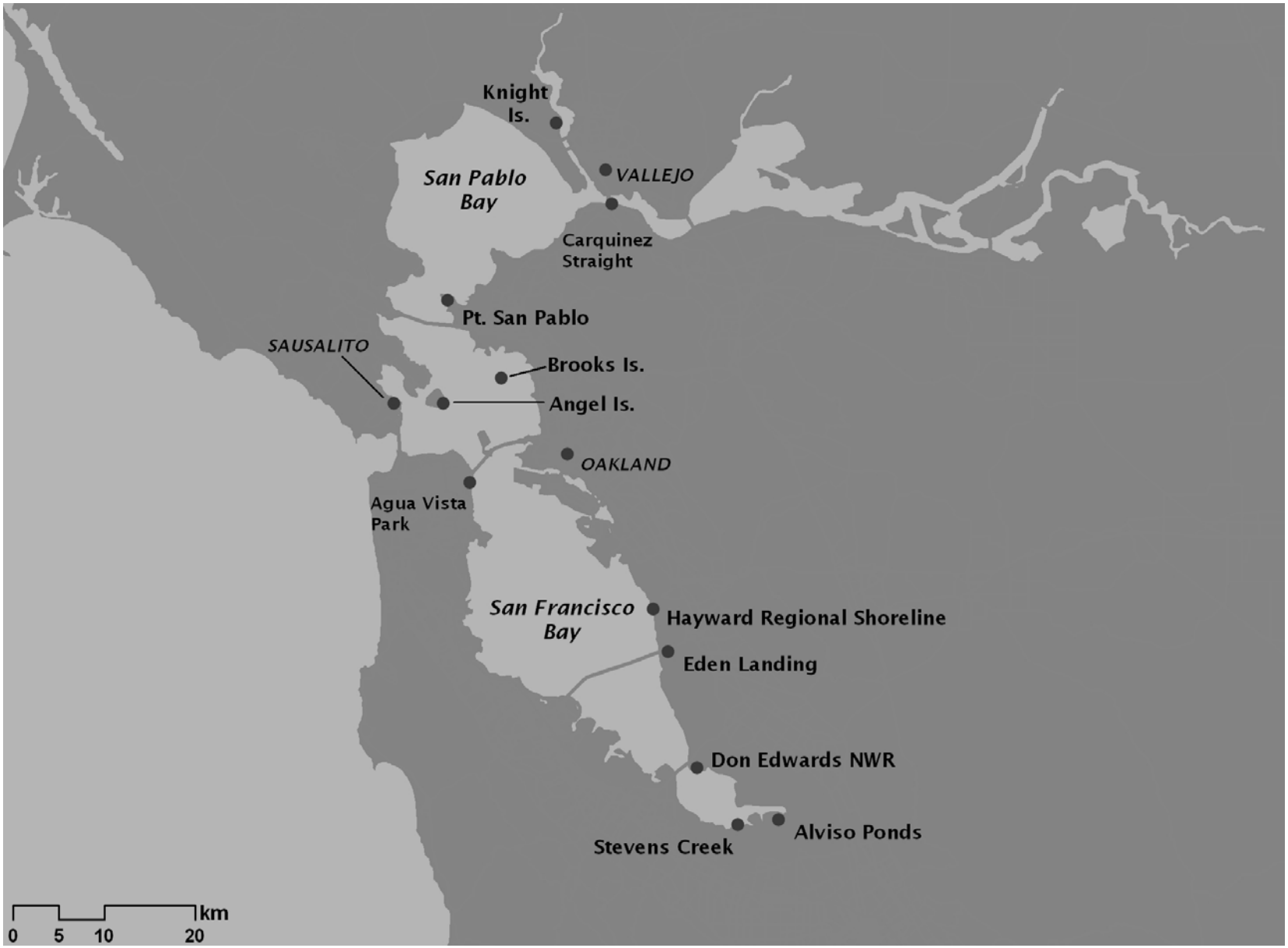
Roby, D.D., K. Collis, A. Evans, S.K. Nelson, and K. Bixler. 2005. Caspian Tern Nesting Ecology and Diet at Colony Sites on the Olympic Peninsula. 2005 Annual Report submitted to the U.S. Fish and Wildlife Service, Region 1, Migratory Birds and Habitat Programs and the U.S. Army Corps of Engineers, Portland District, Portland, OR.

Shuford, W.D., and D.P. Craig. 2002. Status assessment and conservation recommendations for the Caspian tern (*Sterna caspia*) in North America. U.S. Department of the Interior, Fish and Wildlife Service, Portland, OR.

Sirdevan, J.E., Quinn, J.S., 1997. Foraging patterns of Caspian terns (*Sterna caspia*) determined using radio-telemetry. Colonial Waterbirds 20, 429-435.

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 OR.

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.



Map 1. Study area in the San Francisco Bay area during 2008.

Map 2. Study area in interior Oregon and northeastern California and locations of piscivorous waterbird colonies mentioned in this report.

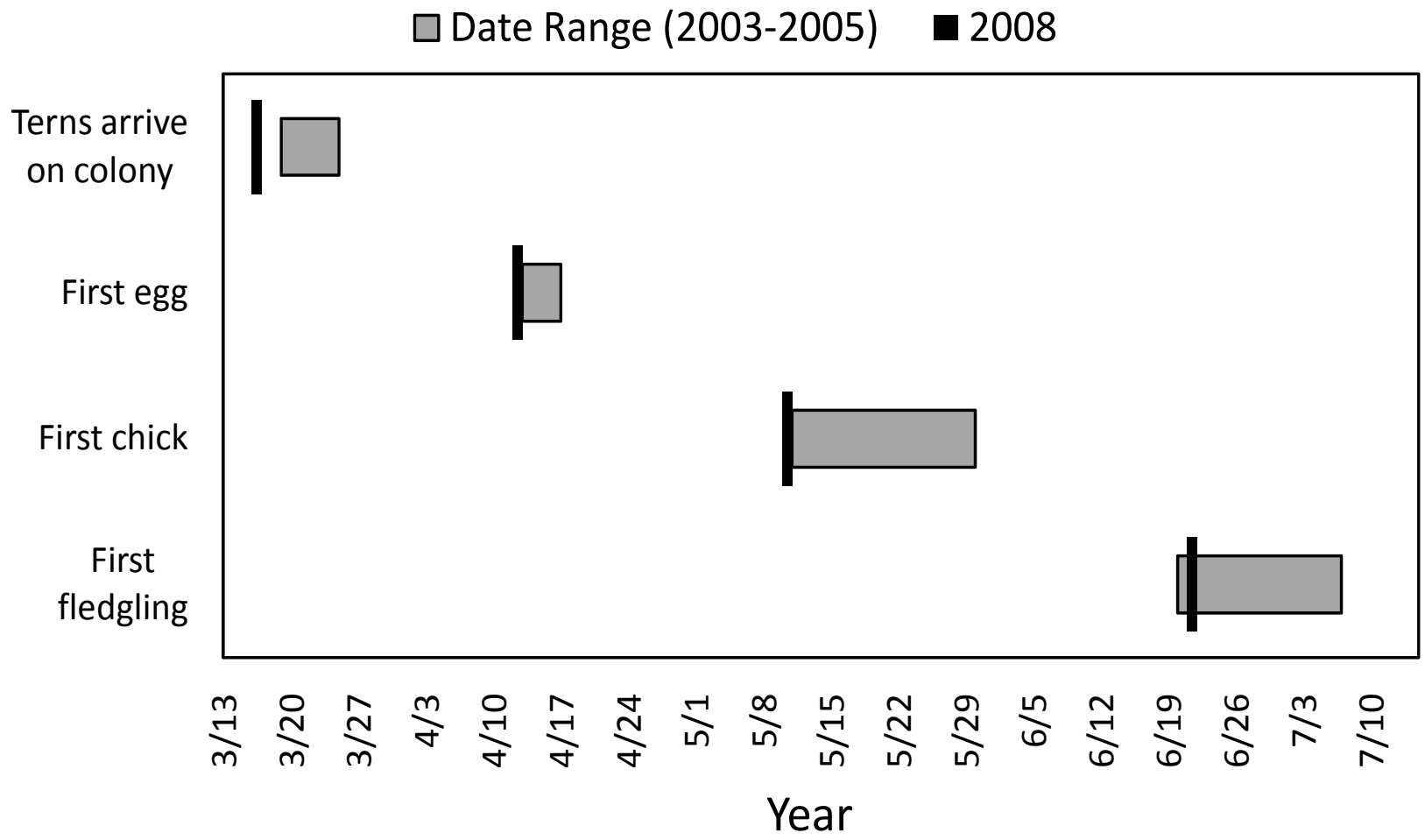


Figure 1. Nesting chronology at the Brooks Island Caspian tern colony in 2008.

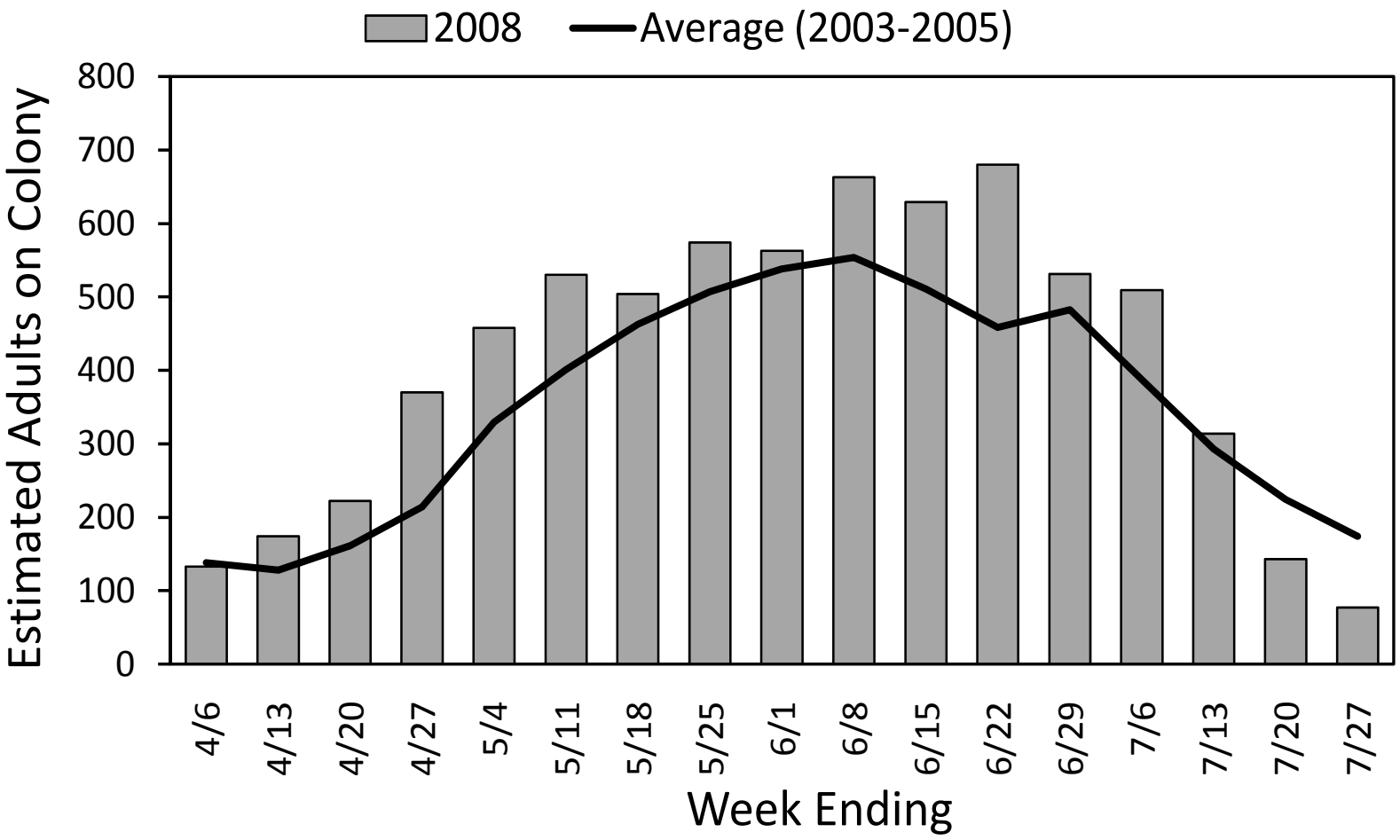


Figure 2. Weekly estimates from the ground of the number of adult Caspian terns on the Brooks Island colony during the 2008 nesting season.

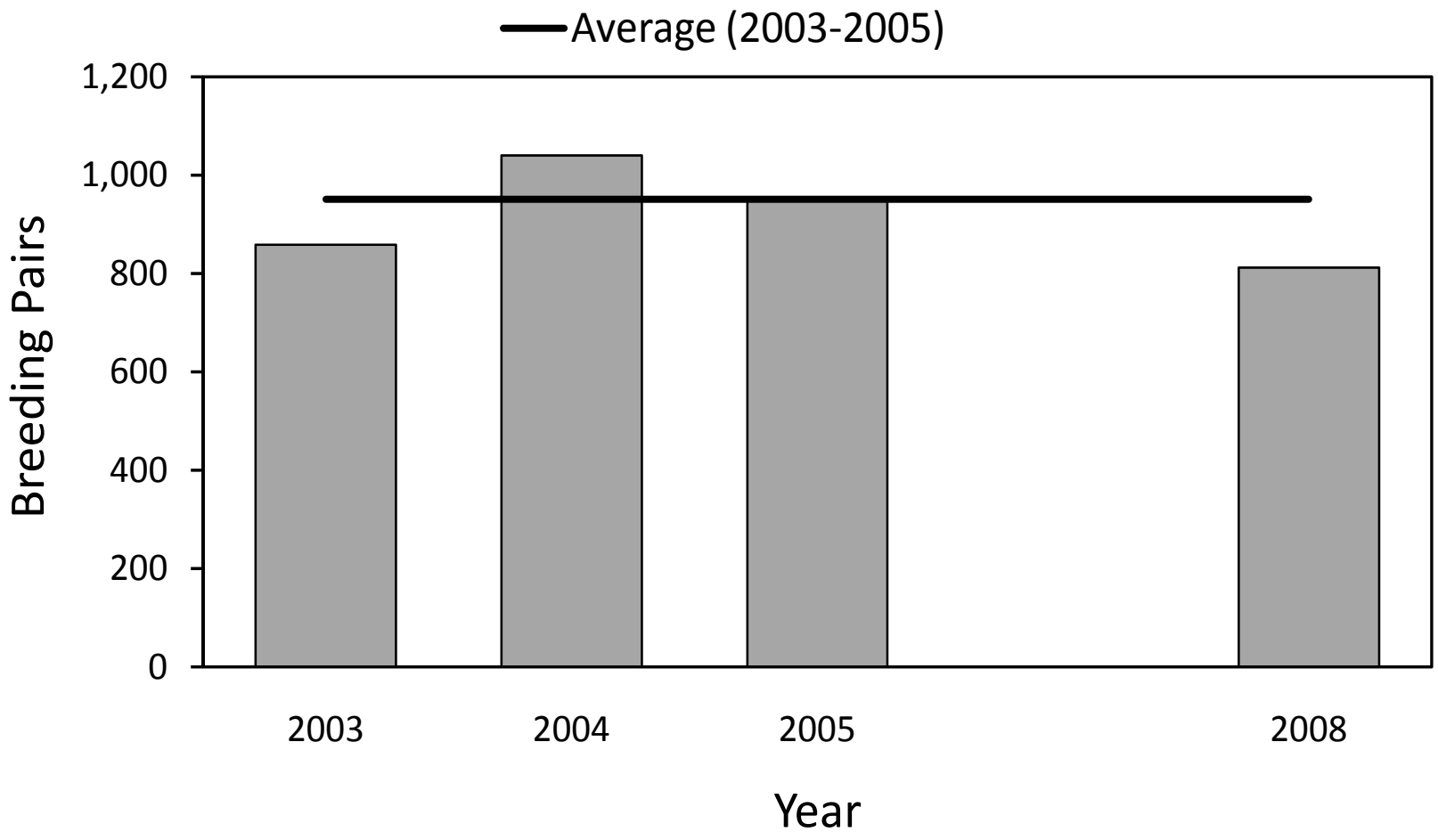


Figure 3. Caspian tern colony size on Brooks Island in 2008 compared to 2003-2005.

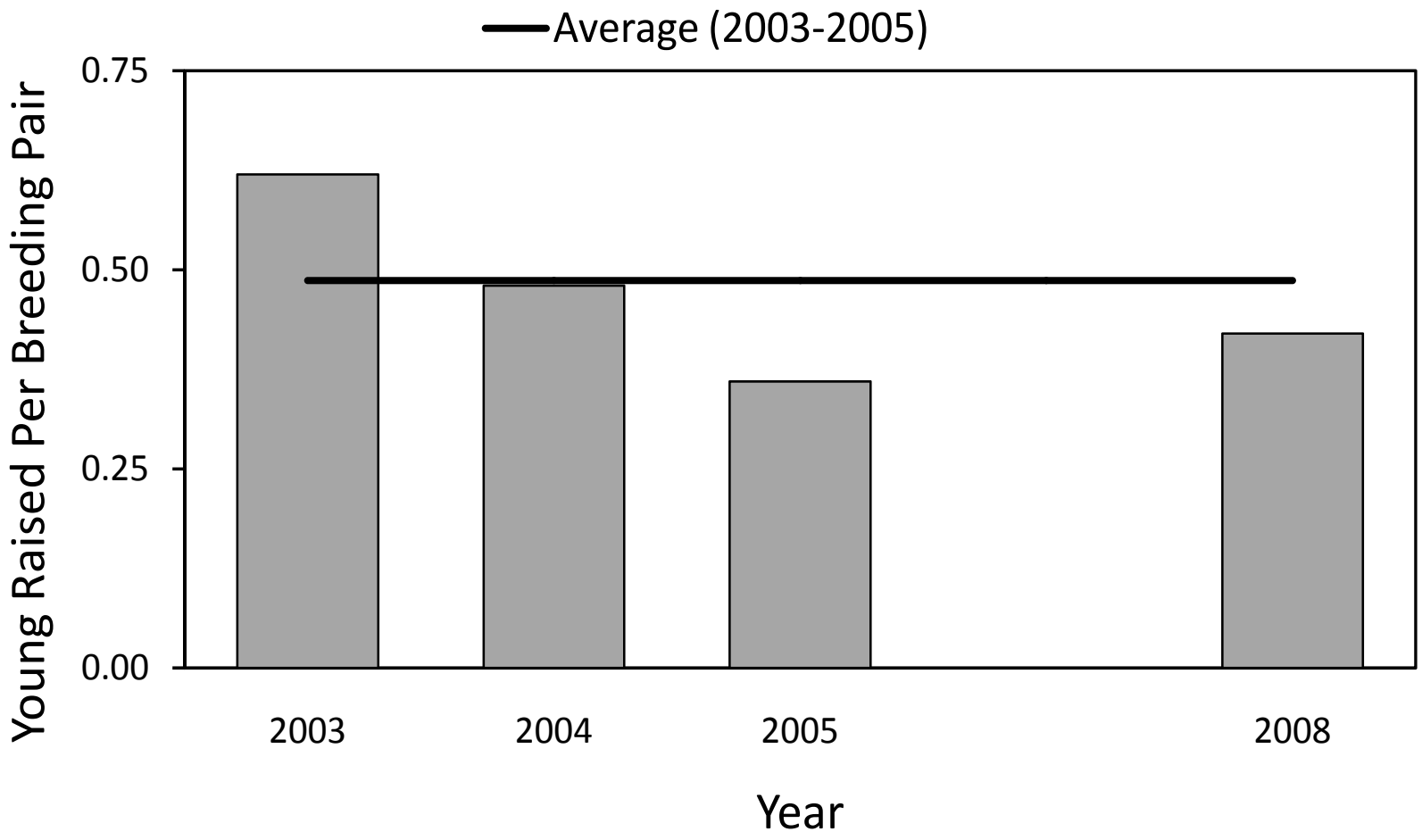


Figure 4. Caspian tern nesting success on Brooks Island in 2008 compared to 2003-2005.

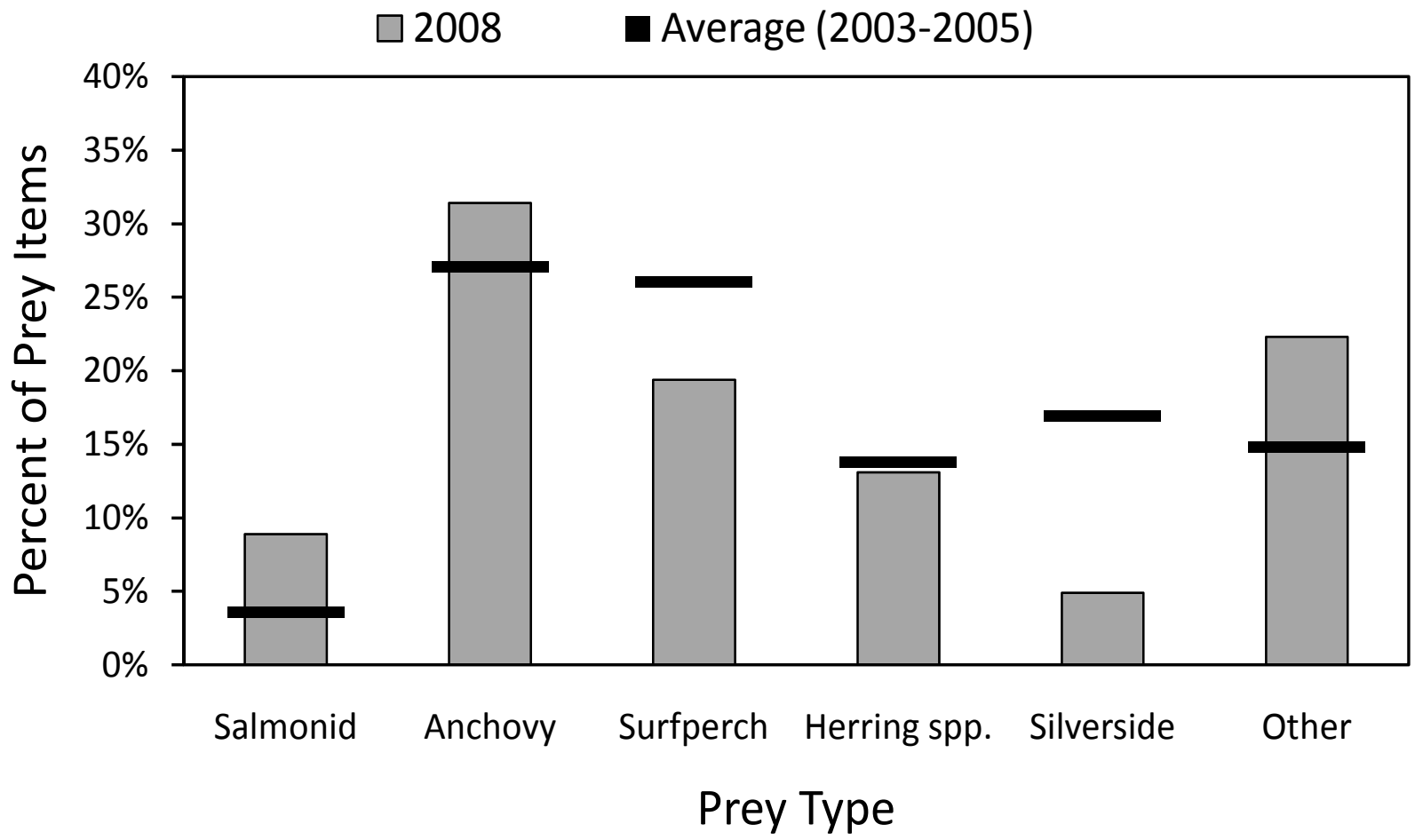


Figure 5. Diet composition of Caspian terns nesting on Brooks Island in 2008.

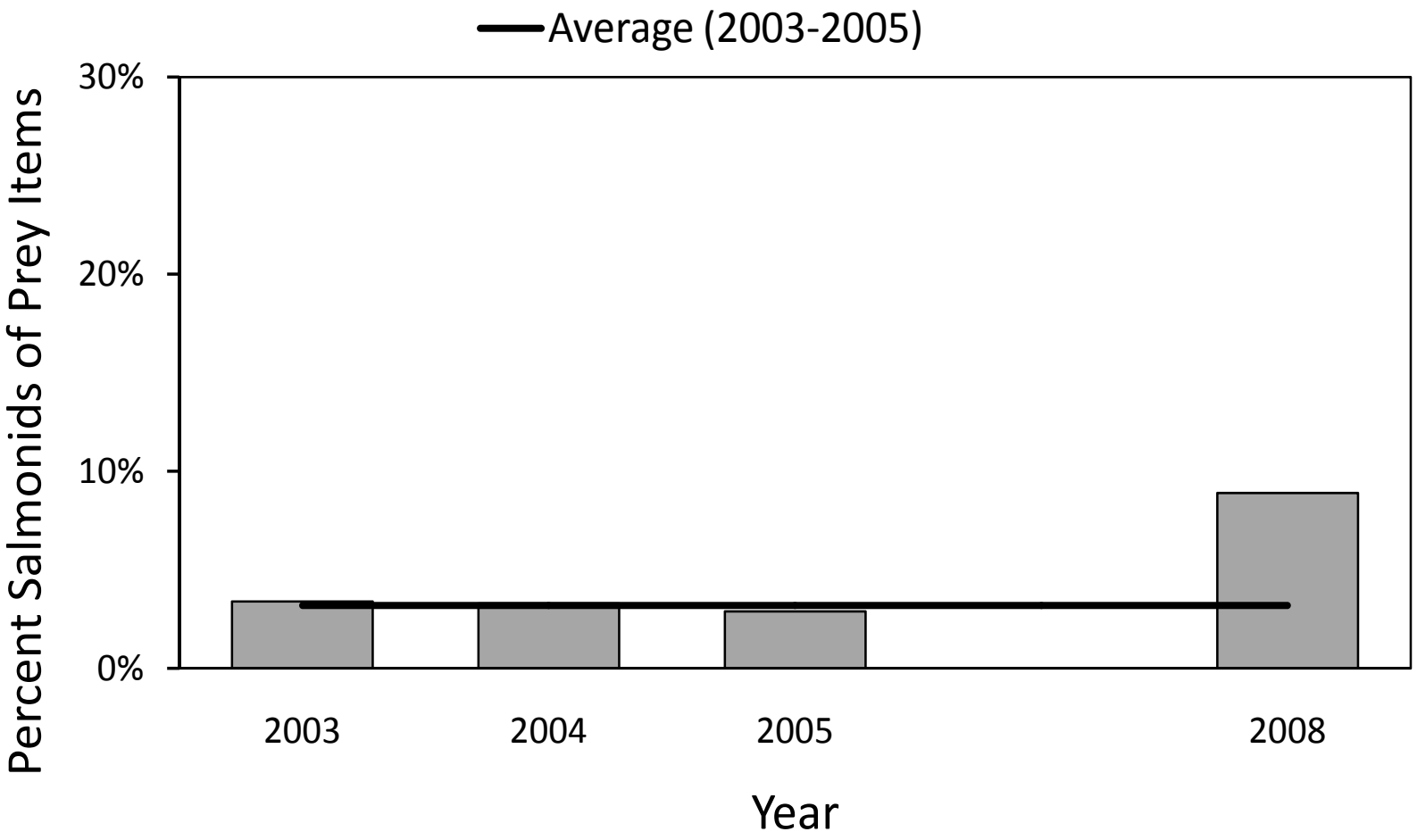


Figure 6. Proportion of juvenile salmonids in the diet of Caspian terns nesting on Brooks Island in 2008 compared to 2003-2005.

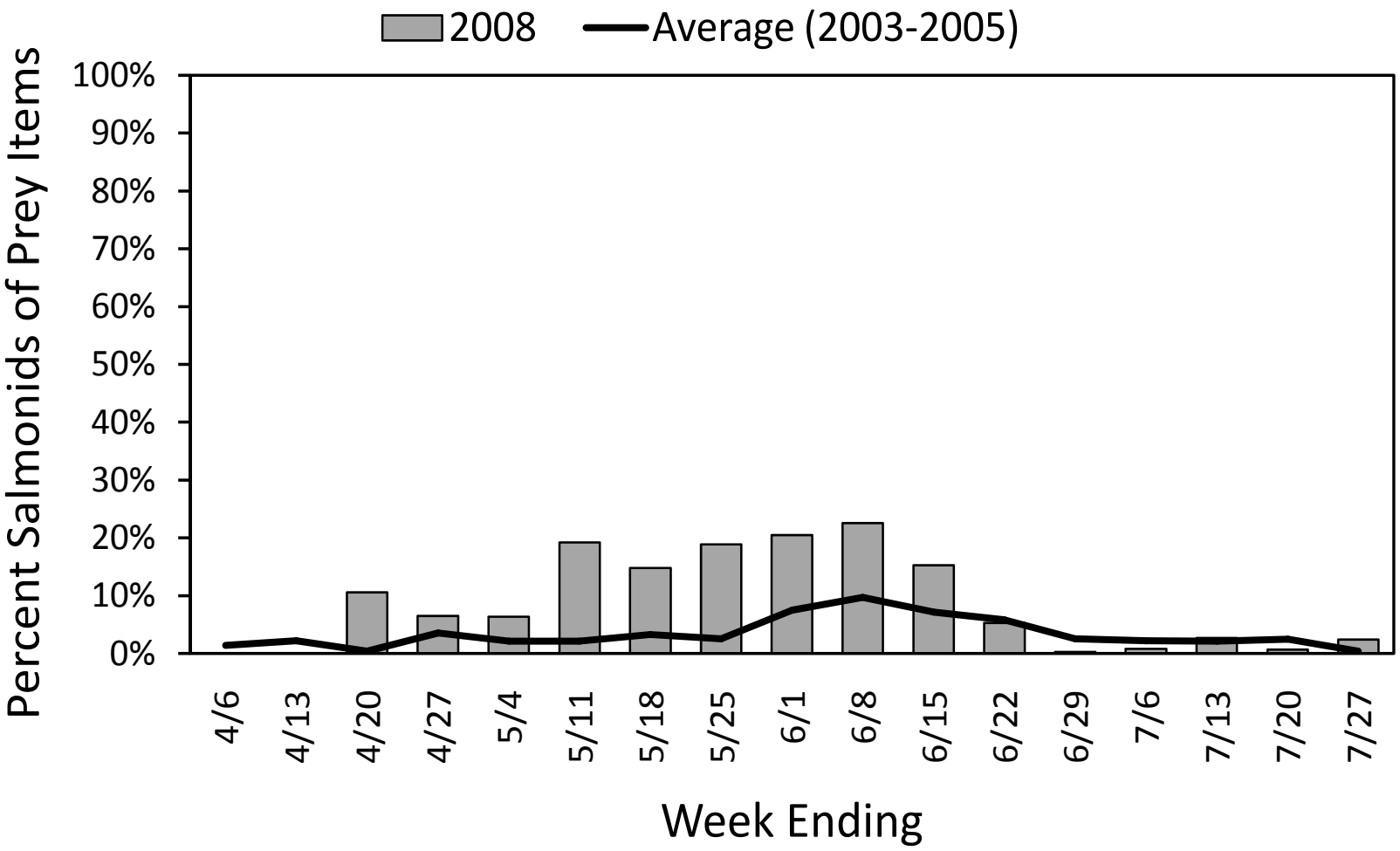


Figure 7. Weekly proportions of juvenile salmonids in the diet of Caspian terns nesting on Brooks Island in 2008.

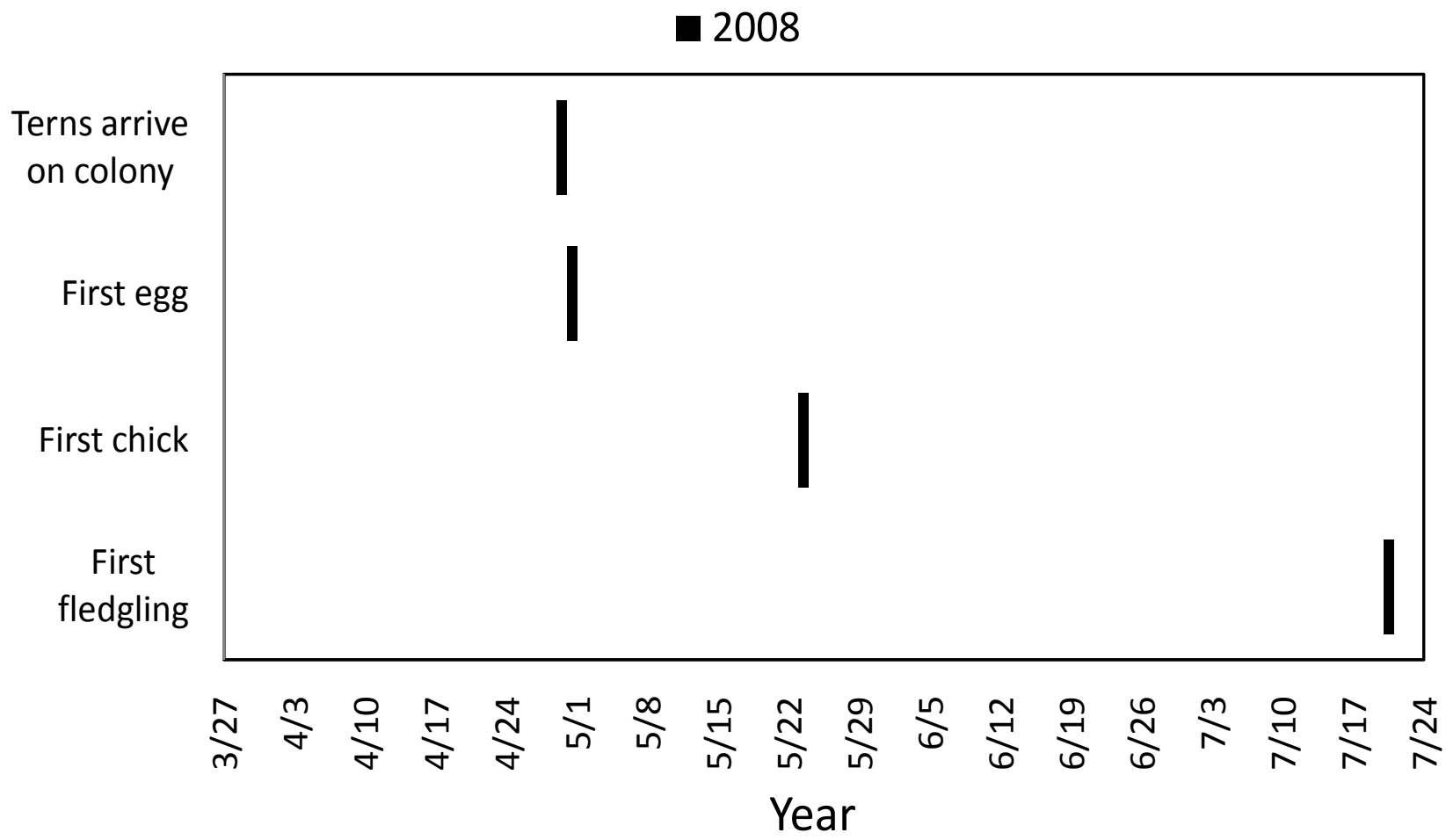


Figure 8. Nesting chronology at the Eden Landing Caspian tern colony in 2008.

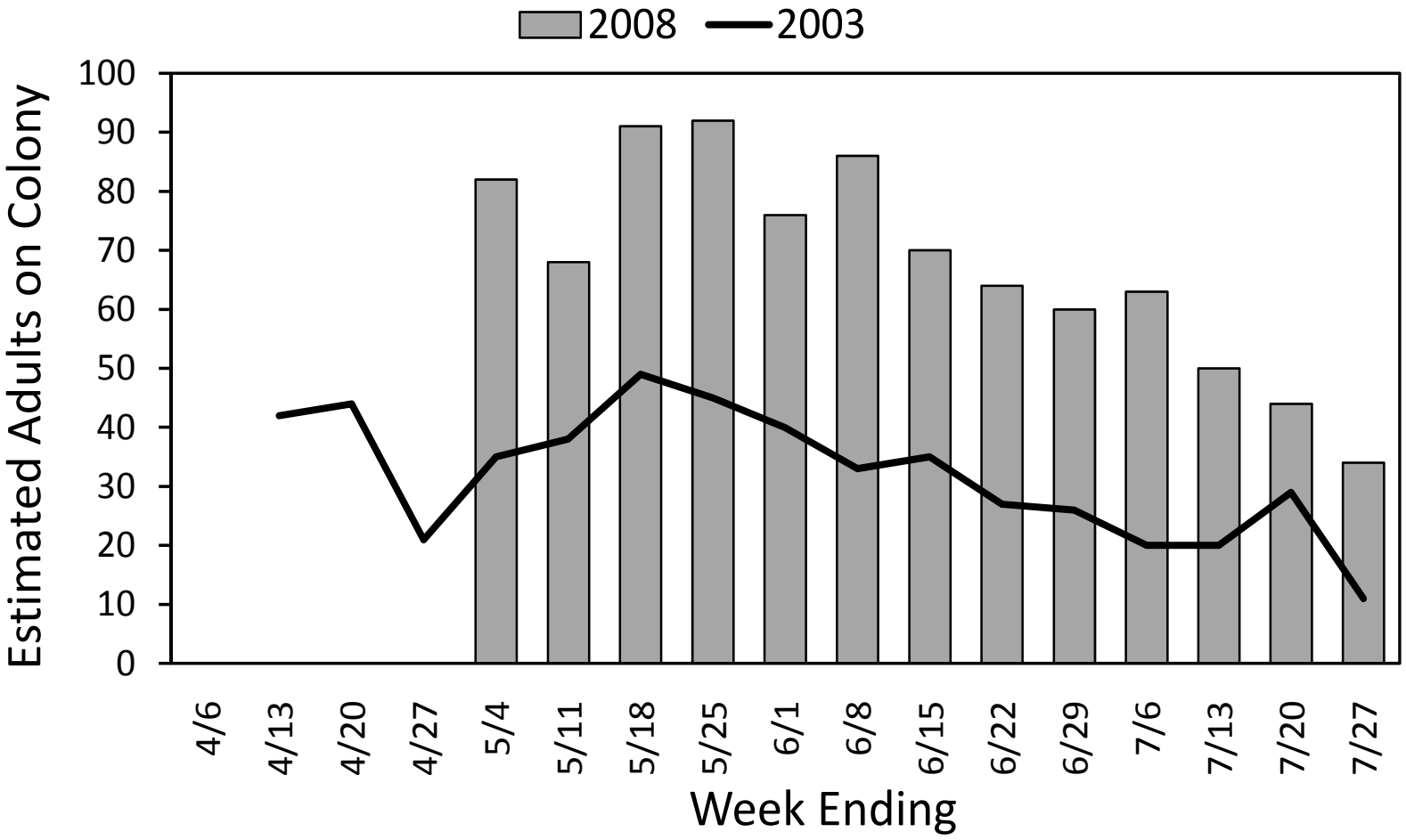


Figure 9. Weekly estimates from the ground of the number of adult Caspian terns on the Eden Landing colony during the 2008 nesting season.

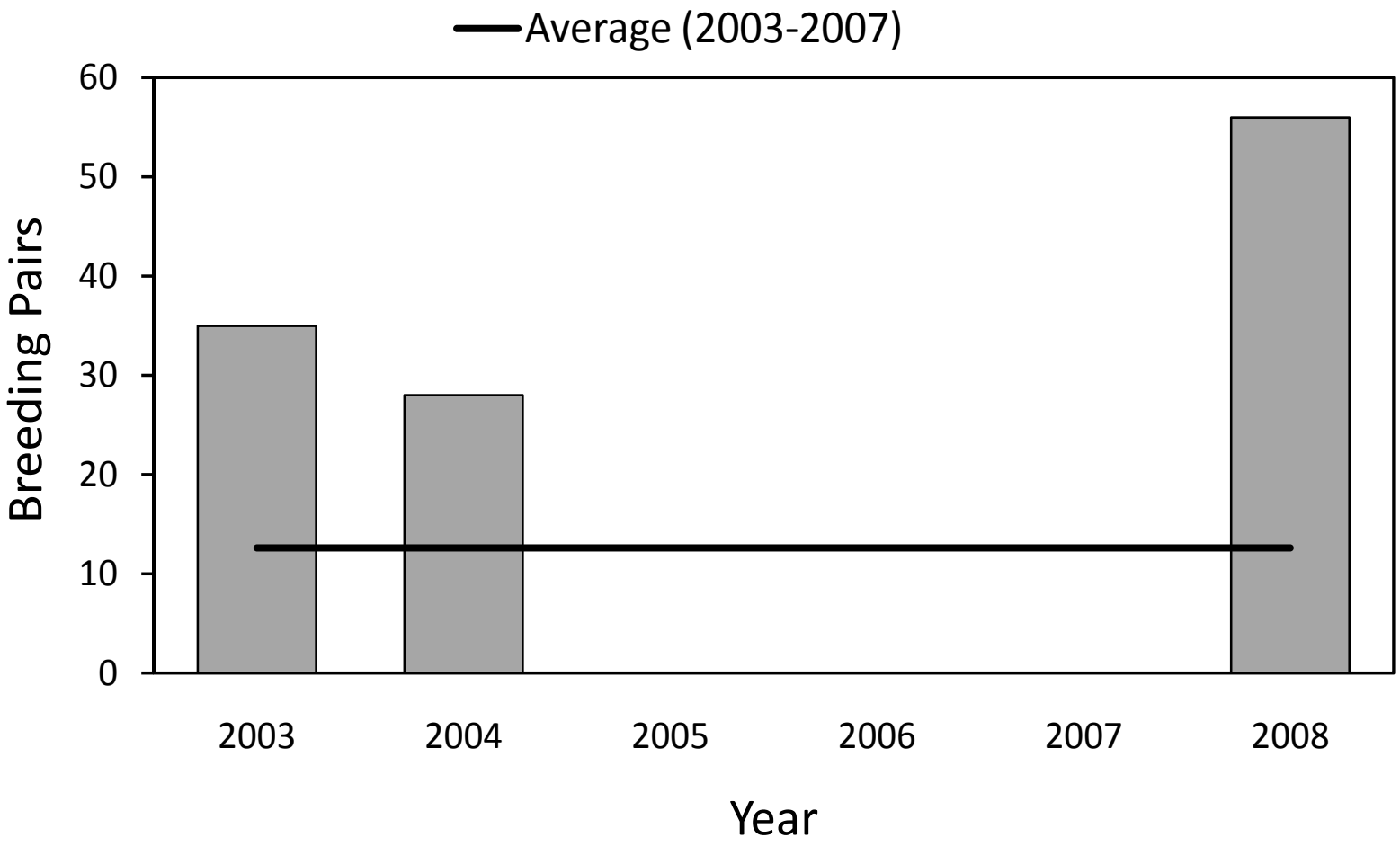


Figure 10. Caspian tern colony size at Eden Landing in 2008 compared to 2003-2007. Terns did not nest at Eden Landing during 2005-2007.

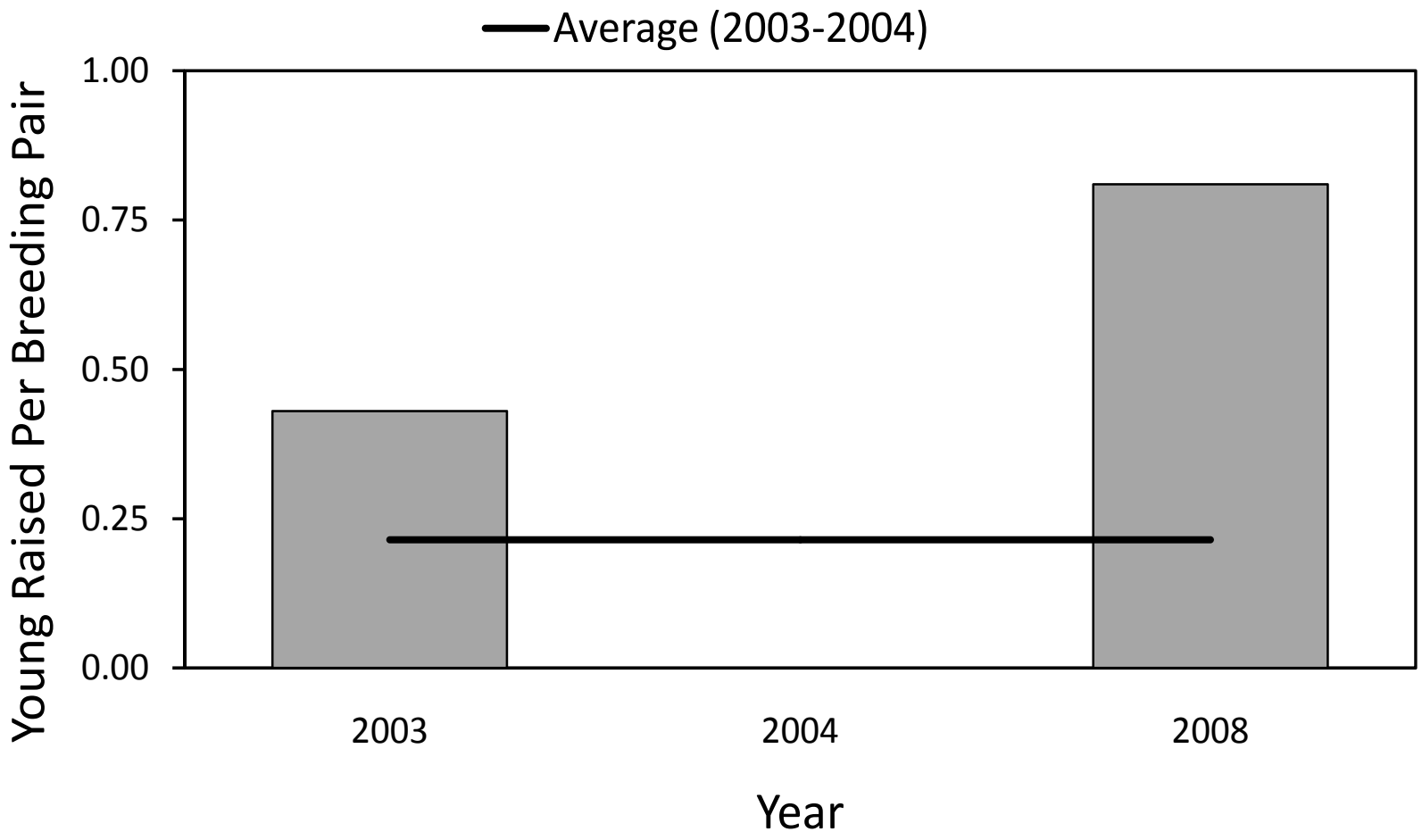


Figure 11. Caspian tern nesting success at Eden Landing in 2008 compared to 2003-2004. Terns nested at Eden Landing in 2004 but were unsuccessful in fledging any young during that year. Terns did not nest at Eden Landing during 2005-2007.

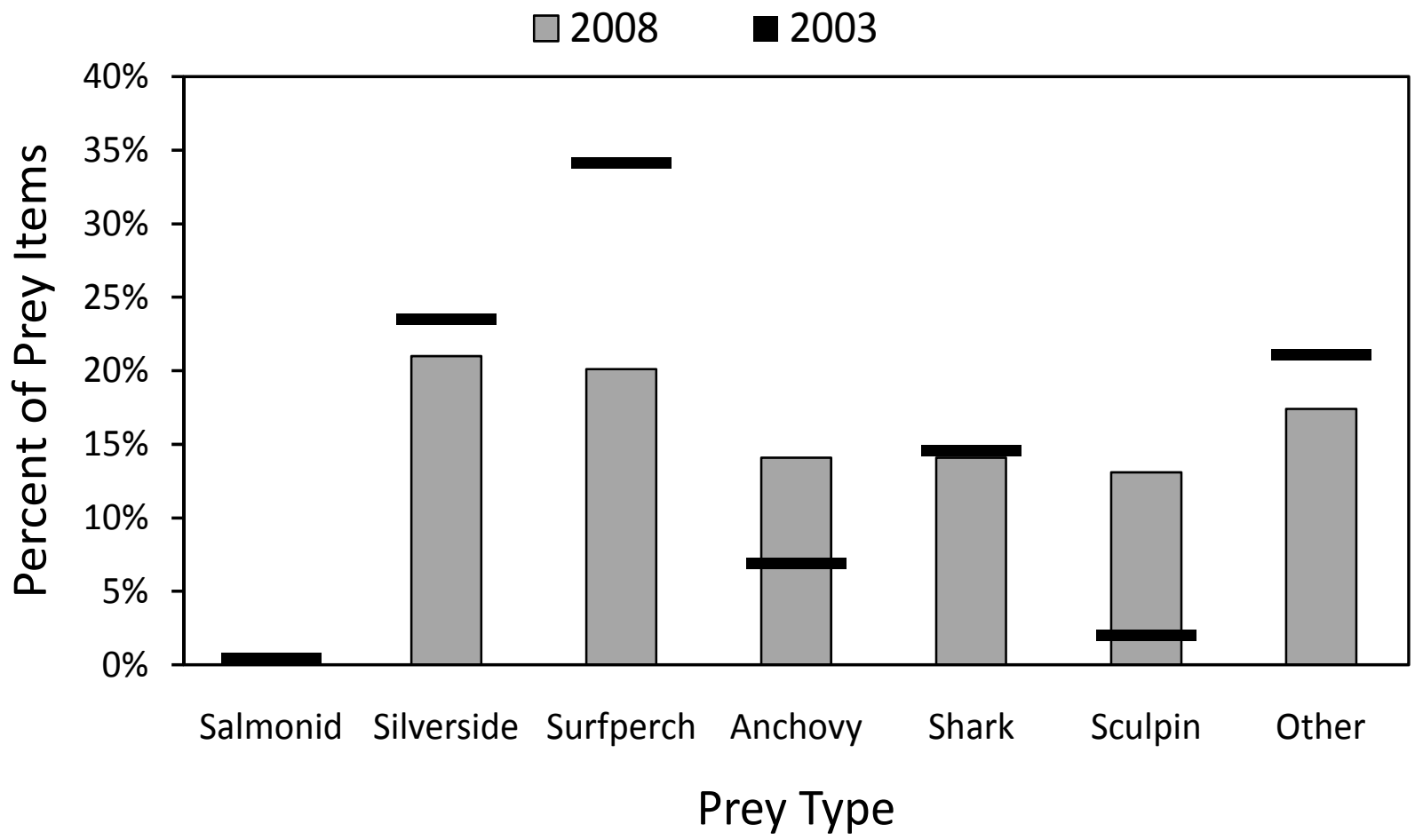


Figure 12. Diet composition of Caspian terns nesting at Eden Landing in 2008.

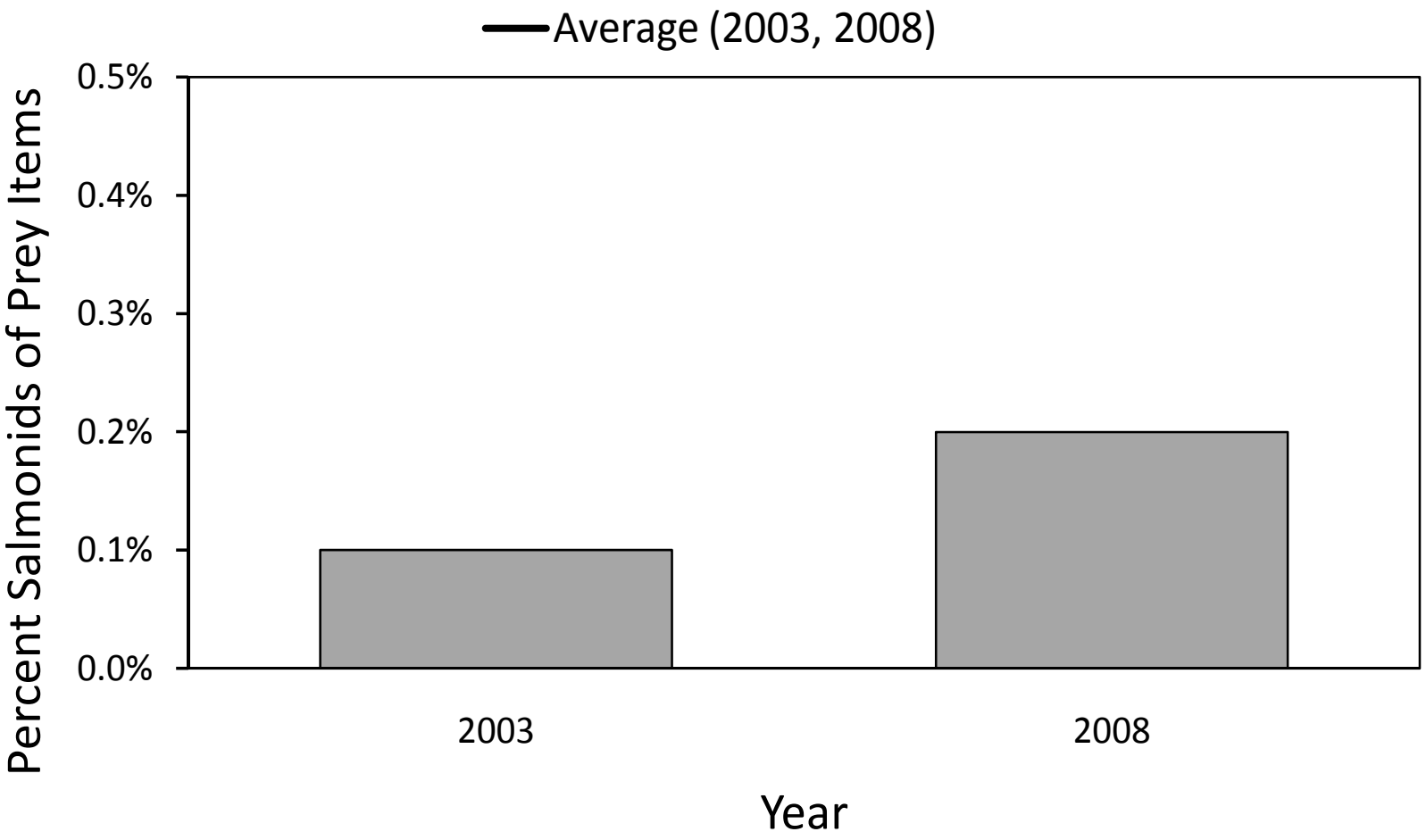


Figure 13. Proportion of juvenile salmonids in the diet of Caspian terns nesting at Eden Landing in 2008 compared to 2003.

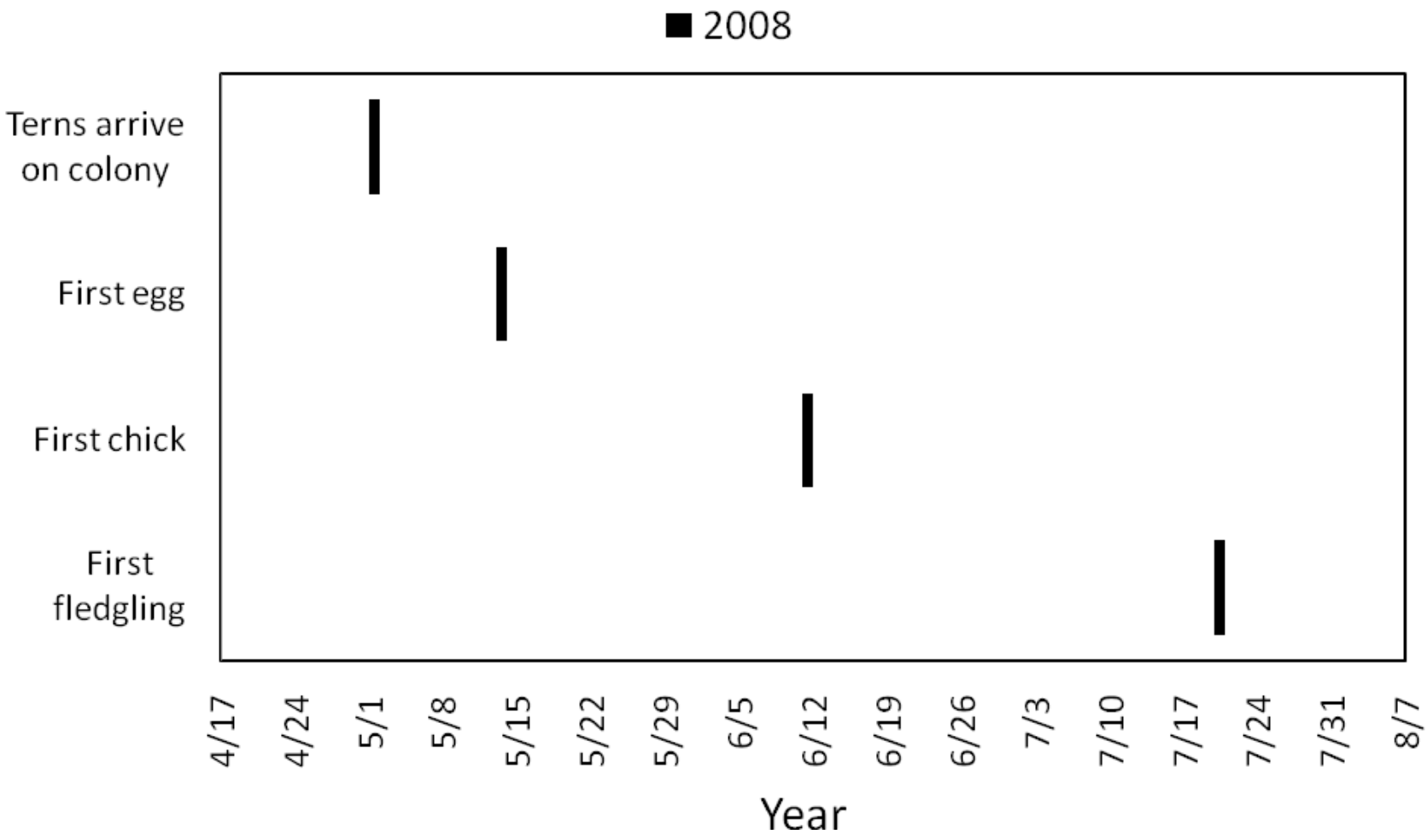


Figure 14. Nesting chronology at the Crump Lake Caspian tern colony in 2008.

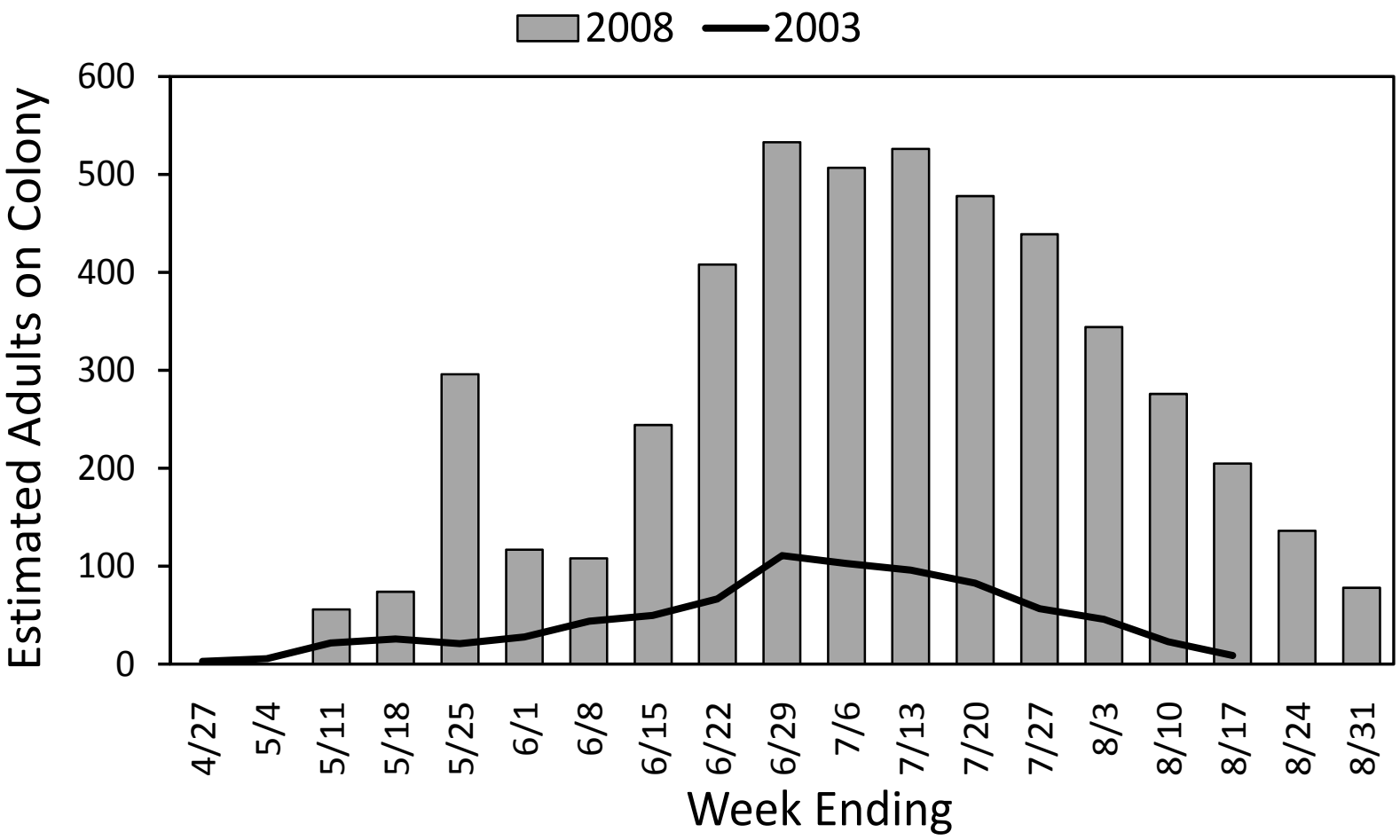


Figure 15. Weekly estimates from the ground of the number of adult Caspian terns at the Crump Lake colony during the 2008 nesting season.

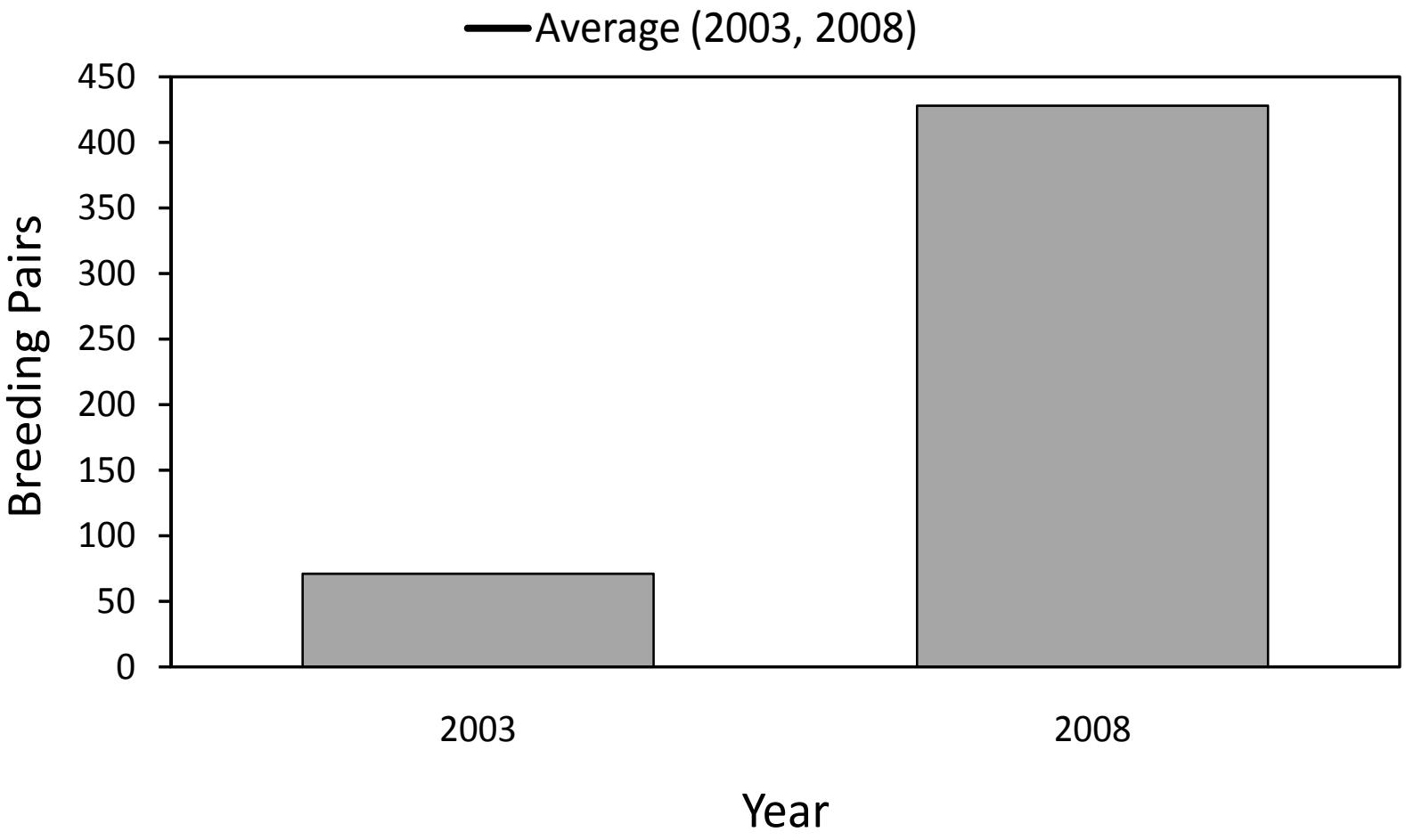


Figure 16. Caspian tern colony size at Crump Lake in 2008 compared to 2003.

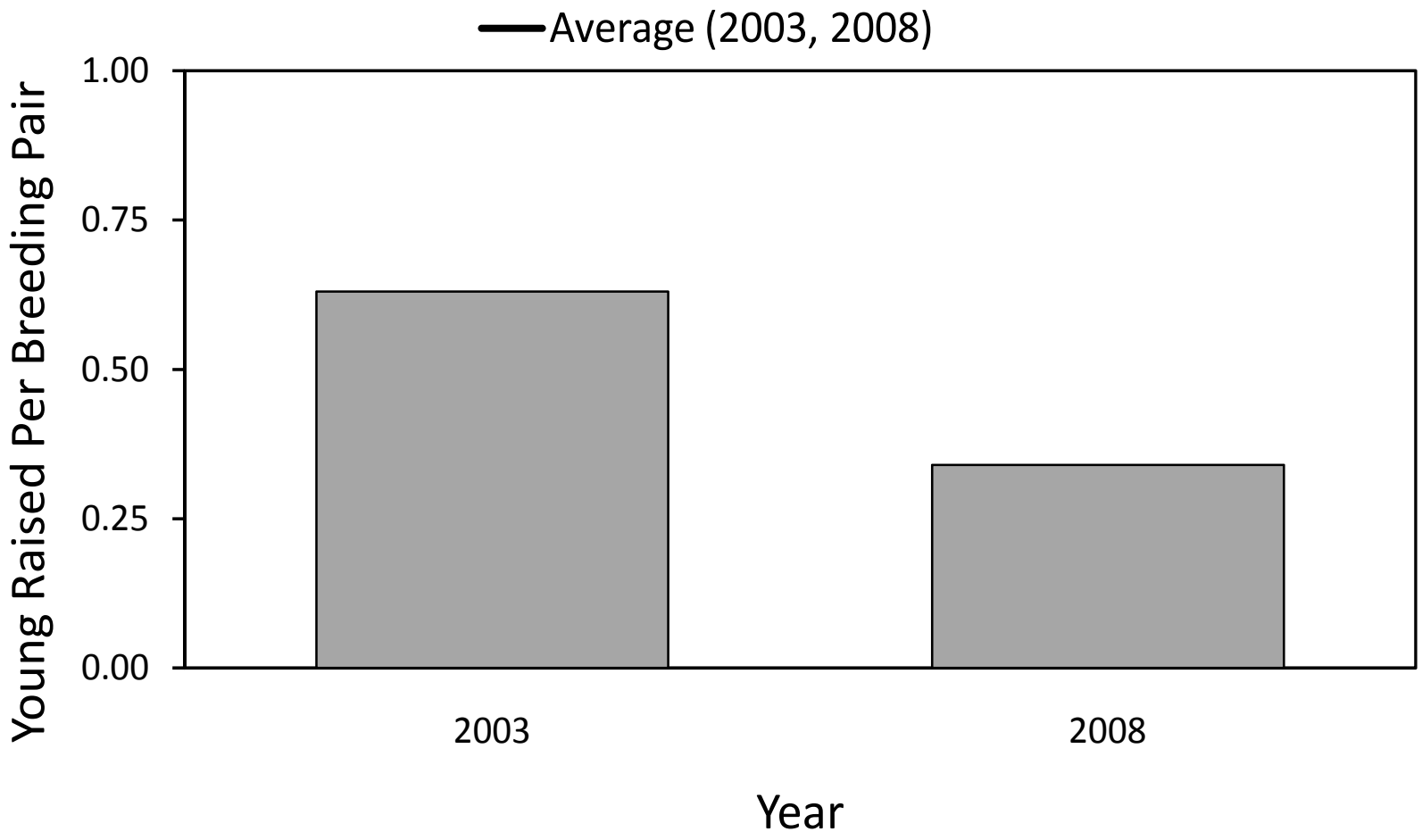


Figure 17. Caspian tern nesting success at Crump Lake in 2008 compared to 2003.

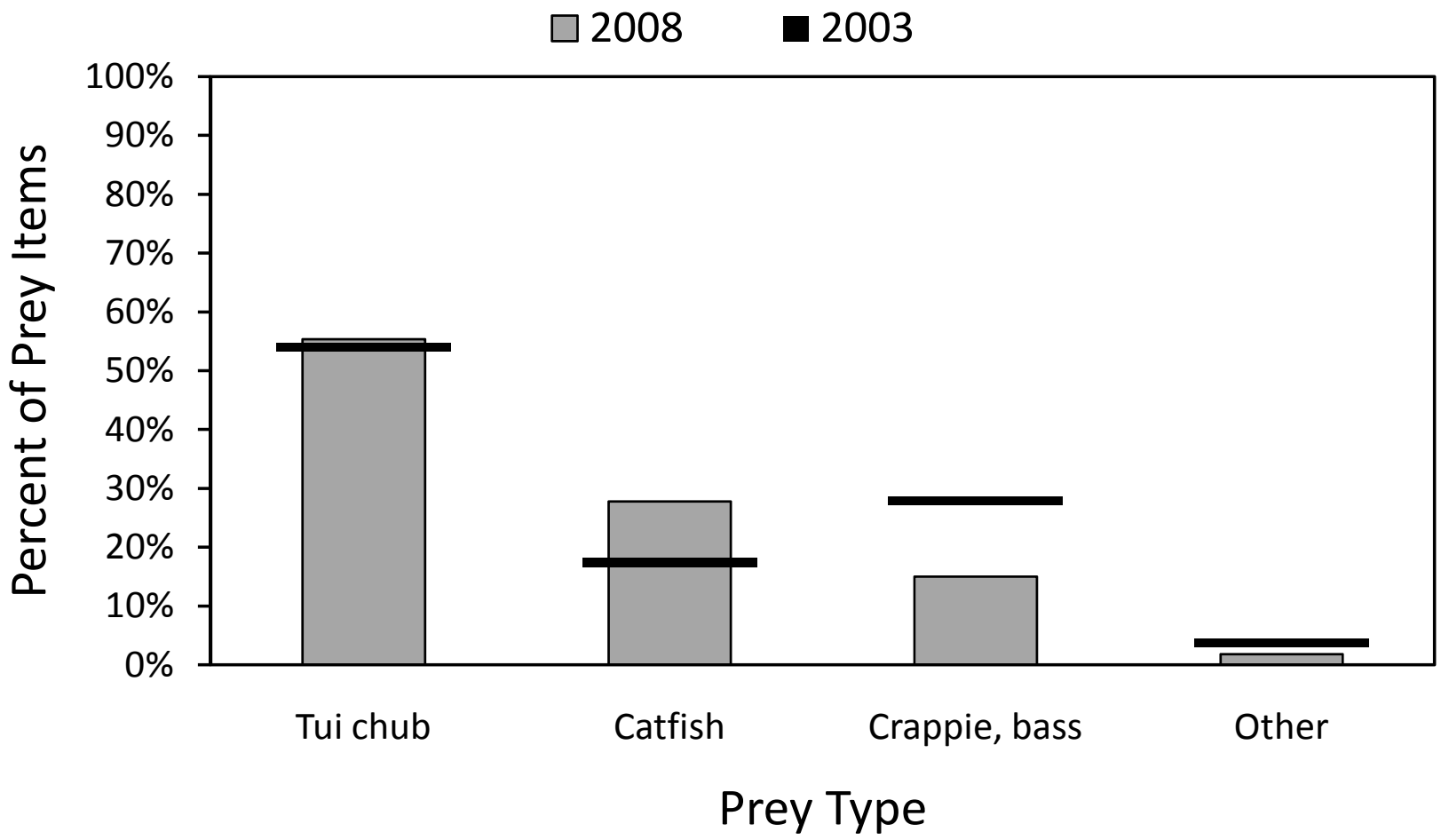


Figure 18. Diet composition of Caspian terns nesting at Crump Lake in 2008.

Table 1. Data collected in 2008 for piscivorous waterbirds nesting at colonies in San Francisco Bay and Interior Oregon. Species include Caspian tern (CATE), double-crested cormorant (DCCO), California gull (CAGU), ring-billed gull (RBGU), and western gull (WEGU).

Location/Colony	Species	2008 Data: Colony Size (breeding pairs)	2008 Data: Nesting success (fledglings/breeding pair)	2008 Data: Salmonids in diet (percent of prey items)	Notes
San Francisco Bay					
Brooks Is.	CATE	810	0.42	8.9	
	WEGU				Colony present, size unknown
	CAGU				Colony present, size unknown
Eden Landing	CATE	56	0.81	0.2	
Stevens Creek	CATE	120			
	CAGU	<10			
Agua Vista Park	CATE	14			
	WEGU				Colony present, size unknown
Interior Oregon					
Crump Lake	CATE	428	0.34		
	DCCO	10			
	RBGU	≈850			
	CAGU	≈500			

Table 2. Potential limiting factors for colony size and nesting success at Caspian tern colonies in the San Francisco Bay area and interior Oregon in 2008. "X" denotes an observed factor of significance, "x" denotes an observed factor of minor importance, and "?" denotes a suspected factor. Contaminants are also a possible limiting factor at some colonies in San Francisco Bay, but this study does not address that issue directly.

	San Francisco Bay				Interior Oregon
	Brooks Is.	Eden Landing	Stevens Creek	Agua Vista	Crump Lake
Availability of nesting habitat	**X**[1]	**X**[4]	x[9]	**X**[11]	
Quality of nesting substrate		**X**[5]	?[5]	**X**[12]	
Prey fish availability					?[13]
Mammalian predators		x[6]			
Displacement by other colonial waterbirds	**X**[2]	**X**[7]			?[14]
Avian predators (other than gulls)	x	x			
Gull kleptoparasitism	x		?[10]	?[10]	x[14]
Gull nest predation	x		?[10]	?[10]	**X**[14]
Human disturbance	**X**[3]	?[8]	?[8]		
Commercial aircraft					
Recreational aircraft					

[1] encroaching pickleweed and other vegetation; high spring tides associated with extreme weather
[2] expanding California gull colony
[3] disturbance mostly from recreational kayakers, boaters, and wind surfers
[4] changing water levels flooding low lying nests and encroaching pickle weed
[5] sticky when wet and terns have difficulty digging scrapes
[6] two red foxes, and a domestic cat are using adjacent dikes
[7] tern eggs and nests trampled by roosting white pelicans and double-crested cormorants
[8] island in close proximity to nearby levees frequented by researchers and land mangers
[9] encroaching vegetation limits available nesting habitat
[10] nesting and loafing gulls may impact tern nesting success
[11] Pier birds are nesting on is slowly collapsing into the bay
[12] nesting on pier deck where there is little or no nesting substrate
[13] scarcity of prey fish in draught years
[14] California and Ring-billed gulls nesting in large numbers may limit success of Caspian tern

Table 3. The estimated number of Caspian terns that emigrated from other colonies to the Crump Lake tern colony in 2008. These data assume (1) that banded fledglings and adults are representative of all fledglings and adults at the colony and (2) that differences in how long ago a tern was banded did not influence its chances of being re-sighted at Crump Lake in 2008.

Location banded	Year banded	Age	No. of terns resighted at Crump in 2008	Total no.of terns banded	Best estimate of no. of terns (unbanded + banded) at site/year	No. of terns (unbanded + banded) potentially present at Crump Lake in 2008, from other tern colonies.	Total no. of terns (all year and age class; unbanded + banded) potentially present at Crump Lake in 2008
East Sand	2001	Chick	1	347	12477	36	502
	2002	Chick	1	372	10715	29	
	2003	Chick	2	450	8977	40	
	2006	Adult	1	45	17858	397	
Crescent	2003	Chick	4	100	280	11	96
	2004	Adult	1	28	1060	38	
	2004	Chick	8	223	329	12	
	2005	Chick	3	164	262	5	
	2006	Adult	2	59	896	30	
Goose	2006	Chick	2	60	60	2	2
Solstice	2001	Chick	2	101	101	2	2
Crump Lake	2003	Chick	1	45	45	1	1
Nevada[1]	1999	Chick	1	N/A	N/A	N/A	N/A
	1999	NA	1	N/A	N/A	N/A	N/A
TOTAL			30	1994	53060	603	603

Appendix 1:

Recovery of Smolt Coded Wire Tags on the Brooks Island Caspian Tern Colony to Assess the Impact on Salmonid Survival in San Francisco Bay

INTRODUCTION

We conducted a pilot study to determine if coded wire tags (CWT) implanted in juvenile salmonids could be recovered from the Brooks Island Caspian tern colony following the tern nesting season. Coded wire tags are small (0.5 to 1.1 mm in length), stainless steel tags that are implanted in the nasal cartilage of fish. The code imbedded on each tag provides data on the species, rear-type (hatchery or wild), run-type (fall, winter, spring), release date, and release location of juvenile salmonids in the Sacramento and San Joaquin river basins. If recovered on colony, coded wire tags could be used to evaluate the impact of the Brooks Island Caspian tern colony on ESA-listed salmonid species that migrate through San Francisco Bay.

METHODS

We searched for coded wire tags by sifting through the nesting substrate (sand, shells, guano, bones, etc) of Caspian terns on Brooks Island after terns had left the colony site following the 2008 breeding season. This was accomplished by removing substrate samples (~ 3 to 5 cm deep) within several 1 m^2 plots located within the area used by nesting terns. Once removed, the substrate samples were grinded (to break up guano), sifted (to remove shells, rocks, bones and other large material), and poured over a magnetized trough in order to collect the tiny, coded wire tags. Tags collect in the trough were then cleaned with isopropyl alcohol and the tag's code read using a microscope. In order to quantify the efficiency of our extraction techniques, we intentionally spread coded wire tags with known tag codes (n = 100) onto several discrete 1 m^2 plots on the tern colony prior to and after the nesting season. Tags were also sown directly into the substrate samples (n = 140) after they had been removed from the island to further measure detection efficiency. These intentional releases were done under the premise that not all of the tags deposited by terns on Brooks Island were subsequently recovered (i.e., tags could be blown off the colony, buried deeper than 3 to 5 cm, or otherwise damaged or lost) and that not all of the tags collected in the substrate samples were recovered using our extraction technique. Detection efficiency estimates (percentage of sown tags subsequently recovered) were analyzed relative to the release location (on-colony versus in substrate sample) and release date (pre-season or post-season) to describe spatial and temporal variation.

Release information on CWT salmonid smolts in the region was obtained by querying the Regional Mark Information Systems Database (RMISD 1977) on 10 March 2009. Data on coded wire tagged fish released but not posted on the RMISD website were obtained directly from the U.S. Fish and Wildlife Service (POC: Kevin Neimela) or the California Department of Fish and Game (POC: Armando Quinones). The numbers of juvenile CWT salmonids released (by species, run-type, rear-type, ESA-status, and release location) were compared to the number recovered on the Brooks Island tern colony. Salmonid release locations were characterized in one of three ways, based on the distance from Brooks Island and the release strategy employed: (1) releases directly into the Sacramento River or a tributary of the Sacramento River, (2) trucked to and released into the Sacramento and San Joaquin river delta, or (3) trucked to and released directly into San Pablo Bay. The vast majority (> 95%) of the fish trucked to and released into San Pablo Bay were released from net pens; specifically, fish were trucked from the hatchery, placed in a net pen for salt water acclimation, and then towed out to a central release point in the bay (FFC 2008).

RESULTS AND DISCUSSION

We removed a total of 83 m^2 of nesting top soil or substrate from the Caspian tern colony on Brooks Island following the 2008 nesting season. Substrate samples represented an estimated 38.9% of the available nesting habitat utilized by terns on the main colony (where 514 pairs nested) and 4.2% of the available nesting habitat utilized by terns on a smaller satellite colony (where 296 pairs nested) on Brooks Island. Over-all (both sub-colonies combined), tags were removed from 26.2% of the nesting habitat used by Caspian terns on Brooks Island in 2008 (810 pairs). From the 83 m^2 of nesting material, a total of 2,340 salmonid coded wire tags were recovered. Of these, the majority (2,079 or 88.8%) were from tagged fish released during the 2008 migration year (fish released and presumably available to terns nesting on Brooks Island in 2008). The remaining 261 tags were from fish released prior to July 2007 and were presumably consumed by Caspian terns or other waterbirds that nested on Brooks Island in previous years. The oldest coded wire tag recovered was from a Sacramento steelhead smolt that was released in December of 2002.

The vast majority (99.9%) of the tags recovered were undamaged, with tag's complete or full binary code still identifiable. This finding demonstrates the tags are not damaged during tern digestion of the tagged fish and remain intact after being deposited on land. Detection efficiency of tags intentionally sown on the colony prior to and after the nesting season averaged 40.0% (n = 100). A large difference between pre-season (ca. 20%) and post-season (ca. 60%) detection efficiency was observed. Detection efficiency of tags placed into the soil samples during processing was much higher, with 91.4% (n = 140) of sown tags being recovered. More research is needed to determine if on-colony tag loss was a result of environmental conditions (e.g., erosion or other factor that displaced tags off of the tern colony) or a result of on-colony substrate extraction methods (e.g., the removal of just the top 3 to 5 cm of nesting material). Regardless of the cause(s) of tag loss, detection efficiency results suggest that we did not recover all of

the tags deposited by terns within substrate samples and thus data presented here represents minimum estimates of predation on groups of tagged fish.

In total, 12.3 million juvenile Chinook salmon originating from the Sacramento and San Joaquin rivers were coded wire tagged and released in 2008 (Table 1). The vast majority of tagged fish were of hatchery stock (11.8 million or 95.8% of all tagged fish). Of these hatchery fish, the majority were fall-run Chinook (8.3 million; a non-listed species). Late-fall Chinook salmon (0.9 million; a non-listed species), spring Chinook salmon (2.9 million; ESA-listed fish produced from the Feather River Hatchery, with some wild fish from Butte Creek) and winter Chinook salmon (0.1 million; ESA-listed fish produced from Coleman National Fish Hatchery) were also tagged and released in 2008 (Table 1). A relatively small number (0.2 million) of wild-origin fall Chinook were also tagged and released in 2008. Nearly all or 100% of the spring, winter, and late-fall hatchery Chinook salmon released in 2008 were implanted with coded wire tags. An estimated 23.6 million non-tagged hatchery fall Chinook salmon and 2.0 million non-tagged hatchery steelhead (0.9 million ESA-listed fish from the Feather and Coleman hatcheries and 1.1 million non-listed fish from the Nimbus and Mokelumne hatcheries), however, were also released in 2008. Unfortunately, the lack of coded wire tagged steelhead eliminates the possibility of using tag recoveries on the Brooks Island Caspian tern colony to evaluate impacts on this threatened evolutionarily significant unit (ESU) of steelhead.

Table 1. Coded wire tagged juvenile Chinook salmon from the Sacramento and San Joaquin rivers that were released and subsequently recovered on the Brooks Island Caspian tern colony in 2008. In-river fish were released directly into the Sacramento or a tributary of the Sacramento River between 160 and 640 river kilometers (Rkm) upstream of Brooks Island. Delta fish were released into sloughs below the confluence of the Sacramento and San Joaquin rivers between 105 and 115 Rkm upstream of Brooks Island. Bay fish were released directly into San Pablo Bay between 25 and 35 Rkm upstream of Brooks Island. Asterisks denote ESA-listed fish.

Release Location	Run-type	Rear-type	Release Period	No. Released	Recovered on Tern Colony
In-river	Winter*	Hatchery	January	69,144	0
	Spring*	Hatchery	April	1,378,941	1
		Wild	January - March	311,061	0
	Fall	Hatchery	April - June	2,987,604	4
		Wild	January - March	206,998	0
	Late-Fall	Hatchery	January	725,650	1
	Sub-total			*5,679,398*	*6*
Delta	Fall	Hatchery	April - June	101,458	0
	Late-Fall	Hatchery	Dec.- January	209,523	0
	Sub-total			*310,981*	*0*
Bay	Spring*	Hatchery	April	1,242,388	40
	Fall	Hatchery	April - June	5,029,315	2,033
	Sub-total			*6,271,698*	*2,073*
TOTALS				**12,262,077**	**2,079**

Of the 2,079 coded wire tags recovered from fish released in 2008, 2,037 or 98.0% were hatchery fall Chinook salmon (Table 1). A total of 41 (2.0%) hatchery spring Chinook salmon and one (< 0.1%) hatchery late-fall Chinook salmon were recovered on the tern colony (Table 1). No tags from hatchery winter run Chinook or from wild spring or wild fall run Chinook salmon were found on the tern colony. The large discrepancies in vulnerability to tern predation between hatchery fall Chinook salmon and the other Chinook salmon run and rear-types can be explained, in part, by where and when the salmon were released in the basin relative to the nesting season of the Brooks Island Caspian tern colony. Of the 2,079 tags recovered on Brooks Island, 2,073 or 99.7% were from fish trucked to and released into San Pablo Bay (Table 1). Conversely, only six fish with in-river life histories were recovered on the Brooks Island Caspian tern colony, despite in-river releases of over 5 million Chinook salmon in 2008 (Table 1). An examination of net pen release times in San Pablo Bay indicates that Brooks Island Caspian terns were consuming fall Chinook throughout the entire release period of early April to mid-June, 2008 (Figure 1). A positive association between fish release numbers and consumption by terns was also observed, with increasing numbers of fall Chinook consumed in concert with increasing numbers of released fish ($R^2 = 0.7005$, based on a simple linear regression; $p < 0.001$).

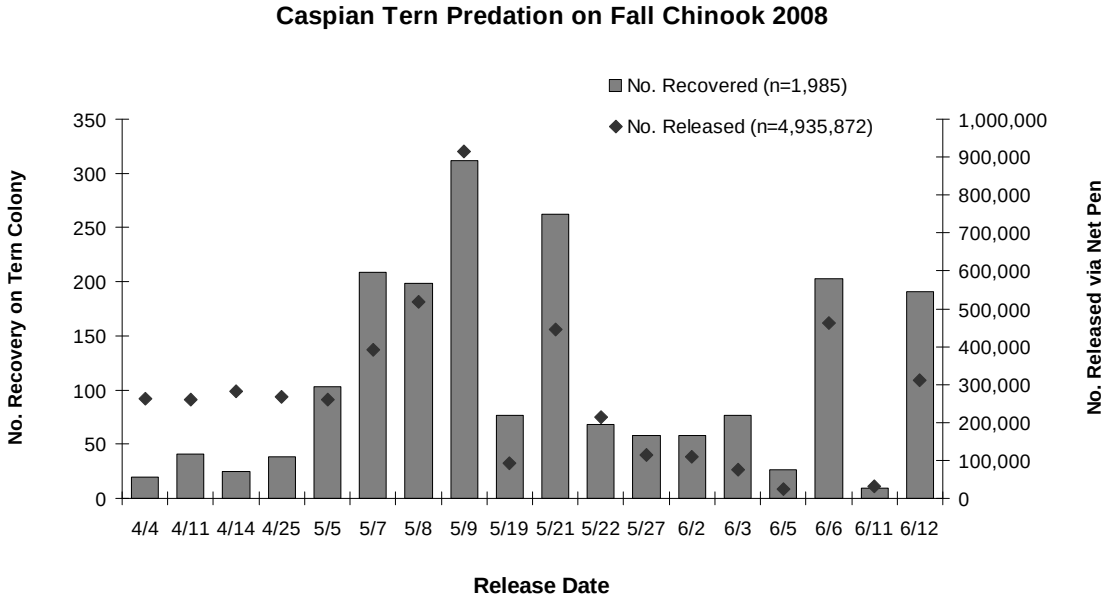


Figure 1. Predation on coded wire tagged hatchery fall Chinook salmon by Caspian terns nesting on Brooks Island in San Francisco Bay. Fall Chinook salmon were released from net pens directly into San Pablo Bay from early April to mid June, 2008. Release date represents the first day of several possible consecutive days that batches of tagged fish were released, thus release numbers on a given date are approximate values. The number of fall Chinook salmon tags recovered on the tern colony were from a sub-sample of the substrate used by nesting terns on Brooks Island in 2008.

Based on the total amount of available nesting substrate searched for CWTs (ca. 26.2%), average on-colony (ca. 40.0%) and processing (ca. 91.4%) CWT detection efficiency, and the total number of 2008 migration year salmonid tags recovered (n=2,079), a minimum estimate of 19,150 juvenile salmonids with coded wire tags were deposited by Caspian terns on Brooks Island in 2008. This value is weighted to account for differences in nesting density and sampling effort between the main and satellite tern nesting colonies on Brooks Island. This value, however, is still a minimum value because is assumes that all CWT tagged fish consumed by terns were subsequently deposited on the tern colony (as apposed to tags deposited by nesting terns at off-colony loafing sites). This finding suggests that over-all, only a small percentage (< 0.2% or 19,150/12,262,077) of the tagged Chinook salmon from Sacramento and San Joaquin rivers were deposited on and subsequently recovered from the Brooks Island Caspian tern colony in 2008.

The proportion of salmonid smolts in the Brooks Island Caspian tern diet in 2008 (ca. 8.9%) was substantially higher relative to the 2003-2005 average (ca. 3.2%; the colony was not monitored in 2006 and 2007). This finding raises concern that the tern colony's impact on juvenile salmonids may be increasing, an alarming trend given the dramatic decline in adult salmon returns to the Sacramento River basin in recent years. One theory that explains this recent and unexpected increase in salmon consumption by Caspian terns relates to the increasing numbers of hatchery fall Chinook salmon that are being trucked to and released into San Pablo Bay. For example, in 2008, approximately 19.9 million hatchery fall Chinook smolts were released into the bay compared to an average of 8.4 million from 2003 to 2005 (Table 2). The size (numbers of fish per release) and duration of releases were also greater in 2008 relative to released in 2003 to 2005.

Table 2. Caspian tern colony size (nesting pairs) and diet composition (% salmonids) relative to the number of juvenile fall Chinook released (both tagged and untagged) into San Pablo Bay in 2003-2005 and in 2008.

Year	Colony Size	Salmonids in Diet	No. Released in San Pablo Bay
2003	859	3.4%	5.5 million
2004	1040	3.4%	7.9 million
2005	954	2.9%	11.9 million
2008	812	8.9%	19.9 million

Based on the finding that smolt predation by Caspian terns nesting on Brooks Island was highly skewed towards fish released via net pens into San Pablo Bay, we conclude that impacts on wild or naturally produced salmonids smolts by terns are minimal and have not been increasing over the course of our study. Only one ESA-listed hatchery spring Chinook salmon was recovered on-colony from fish with an in-river migration history. More conclusively, we did not find any of the approximately 518,000 wild spring and wild fall-run Chinook smolts that were tagged and released in-river on the tern colony in 2008. Unfortunately, we can not evaluate the relative vulnerability of juvenile Chinook salmon compared to juvenile steelhead because steelhead were not coded wire tagged in

2008. Data from tern colonies in the Columbia River basin suggest that steelhead smolts are particularly vulnerable to Caspian tern predation (Collis et al. 2001; Ryan et al. 2003; Antolos et al. 2005). Bill load observations at the Brooks Island Caspian tern colony in 2008 (see above) indicated that only a small percentage of the salmonids delivered to the colony were steelhead (ca. 2.4% of all salmonids and 0.7% of all prey items). Whether these steelhead were part of the threatened Central Valley or Central California Coast ESU or several other non-listed steelhead stocks in the region is unknown, but the over-all tern impact on steelhead survival in 2008 was likely minimal.

The results of this pilot study demonstrate that coded wire tags can be recovered from Caspian tern colonies and used to evaluate salmonid impacts for those runs that are coded wire tagged. Results presented here provide over-whelming evidence that terns on Brooks Island are consuming primarily non-listed, hatchery fall Chinook salmon that are being released in mass into San Pablo Bay. Of the 41 listed hatchery spring Chinook salmon recovered on the tern colony, 40 were from Bay releases and just one fish was an in-river migrant. The lack of wild-origin Chinook tag codes found on the tern colony in 2008 supports the notion that impacts to naturally produced, ESA-listed salmonids smolts by Caspian terns on Brooks Island are minimal. Finally, we will continue to refine our CWT recovery techniques, utilize detection efficiency data to better address or correct for biases in tag loss, and collect coded wire tags from tern colonies in San Francisco Bay in 2009.

REFERENCES

Antolos, M., D.D. Roby, D.E. Lyons, K. Collis, A.F. Evans, M. Hawbecker, and Brad A. Ryan. 2005. Caspian tern predation on juvenile salmonids in the Mid-Columbia River. Transactions of the American Fisheries Society 134:466-480.

Collis, K., D.D. Roby, D.P. Craig, B.A. Ryan, and R.D. Ledgerwood. 2001. Colonial waterbird predation on juvenile salmonids tagged with passive integrated transponders in the Columbia River estuary: vulnerability of different salmonid species, stocks, and rearing types. Transactions of the American Fisheries Society 130:385-396.

Fisheries Foundation of California. 2008 Final Report. San Francisco Bay Estuary Acclimation of Central Valley Hatchery Raised Chinook Salmon Project. Available from the Fishery Foundation of California MB 330, Elk Grove, CA.

Regional Mark Information System Database [online database]. Continuously since 1977. Portland (OR): Regional Mark Processing Center, Pacific States Marine Fisheries Commission. URL:<http://www.rmpc.org>.

Ryan, B.A., S.G. Smith, J.M. Butzerin, and J.W. Ferguson. 2003. Relative vulnerability to avian predation of juvenile salmonids tagged with Passive Integrated Transponders in the Columbia River estuary, 1998-2000. Transactions of the American Fisheries Society 132:275-288.

Appendix 2:

Consumption of Fish by Caspian Terns Nesting on Crump Lake in 2008

INTRODUCTION

Presented here is an estimate of the total number of Warner suckers (*Catostomus warnerensis*; an ESA-listed species) consumed by Caspian terns (*Hydroprogne caspia)* nesting on a recently constructed island in Crump Lake, Oregon during 2008. In addition to sucker consumption, we have also estimated the numbers of predatory non-native fishes (crappie, bullhead catfish, and bass) consumed by Caspian terns nesting on Crump Lake. Predatory fish consumption estimates were generated under the premise that the terns' negative impact on Warner sucker survival may be off-set or mitigated by the birds' consumption of exotic piscivorous fishes, fish that are also presumably consuming Warner suckers.

METHODS

Because Caspian terns transport whole fish in their bills to their mates (courtship meals) and young (chick meals), 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). Bill loads were identified from an observation blind located at the periphery of the tern colony with the aid of binoculars and spotting scopes. We were confident in our ability to identify fish to the genus level but we did not attempt to distinguish the various fish species. Identification to the species level was not possible because diagnostic morphological characteristics – those readily viewable from a distance – are lacking among many of the closely related freshwater fish species found in southeastern Oregon. The length of fish prey was also estimated using the length of the adult tern's bill (exposed culmen; ~7 cm) as a reference point for approximate fish length (cm).

We estimated the total numbers of suckers, crappie, bullhead catfish, and bass consumed by Caspian terns based the numbers of these fish observed as bill loads by researchers. We then developed several expansion factors to account for the number of fish consumed when researchers were not present to identify bill loads and to account for fish captured and consumed away from the colony. Uncertainty was incorporated into our consumption calculations by generating estimates based on three different scenarios (a minimum, best, and maximum estimate) for each fish genus of interest. The values associated with each scenario were derived by using slightly different expansion parameters, ranging from the minimum or most conservative value (generally the smallest number or proportion of fish consumed) to the maximum or most liberal value (generally the largest number or proportion of fish consumed).

Finally, because Warner suckers could not be distinguished from other sucker species in the region (e.g., the Sacramento sucker [*Catostomus occidentalis*], which is found in nearby Goose

Lake), we had to estimate what proportion of suckers captured by terns were from the Warner Valley relative to other regions. Empirical data regarding the proportion of ESA-listed suckers relative to non-listed suckers consumed by Caspian terns nesting on Crump Lake are lacking. The proportion of listed to non-listed suckers used here was based on the finding that (1) at least one of the suckers captured by a tern in 2008 was a Warner sucker (based on the recovery of a PIT-tagged sucker that was initially captured and released into Crump Lake by the ODFW) and the finding that (2) Crump Lake terns were consistently capturing and delivering lamprey to the colony, a species not found in the Warner Basin, but native to nearby Goose Lake. In addition to lamprey, Goose Lake also has a relatively healthy population of Sacramento suckers, a non-listed species.

The following expansion factors were used to estimate fish consumption:

(1) Number of foraging hours monitored by researchers / total number of foraging hours available to terns (defined as 30 minutes before sunrise to 30 minutes after sunset).
(2) The proportion of incoming bill load fish identified by researchers while monitoring the colony. This proportion was based on the size of the tern colony and ranged from an identification percentage of 100% (when the colony was small and all birds could be watched simultaneously) to 50% (when the colony was larger and all birds could not be watched simultaneously).
(3) The number of fish consumed off-colony for each fish delivered to the colony. This value ranged from a minimum of 1 fish to a maximum of 3 fish for each fish delivered to the colony as a bill load.
(4) The percentage of ESA-listed suckers relative to non-listed suckers consumed by terns. This percentage ranged from a minimum of 25% to a maximum of 100%.

The following assumptions apply to consumption estimates:

(1) Fish were correctly identified to the genus level
(2) All ESA-listed suckers were Warner suckers
(3) The proportions or rates used as expansion factors were representative of the actual consumption rates and foraging behaviors exhibited by terns nesting on Crump Lake Island in 2008

RESULTS

Colony Size and Productivity: A total of 428 breeding pairs of Caspian terns attempted to nest at the Crump Lake colony in 2008 (Figure 1), about 350 more pairs than in 2003 (the last year monitoring was conducted). We estimated that 145 young were fledged from that colony in 2008, or 0.34 young raised per breeding pair. The number of terns on-colony peaked in July but adults were observed on-colony as late as 15 September 2008. In addition to Caspian terns, approximately 850 pairs of ring-billed gulls (*Larus delawarensis),* 500 pairs of California gulls (*L. californicus),* and 10 pairs of double-crested cormorants (*Phalacrocorax auritus)* nested on Crump Island in 2008.

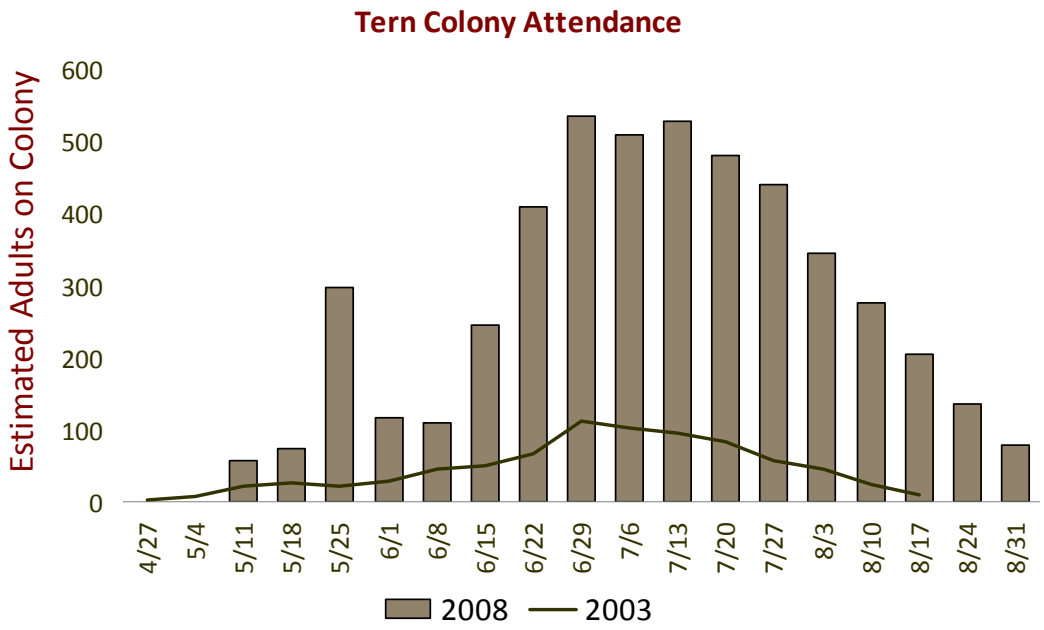


Figure 1. The estimated number of adult Caspian terns nesting on the new island in Crump Lake in 2008 (bar) and 2003 (line).

Diet Composition: A total of 2,909 fish were identified as bill loads at the Crump Lake tern colony from 5 May to 30 August 2008. The majority (55.4% of prey items) were tui chub (Table 1), followed by bullhead catfish (27.8%) and crappie (15.0%) (Table 1). The remaining 1.8% of prey items consisted of rainbow trout, lamprey, suckers, bass, and dace (Table 1). A total of 5 suckers (0.17% of prey items) were observed by researchers during the nesting season (Figure 2). On average, bill load fish were 12.6 cm in length, but this varied considerably both within and among the different fish genera observed (Table 1). The longest sucker observed on-colony was an estimated 27 cm and the smallest was 13 cm (Table 1).

Table 1. Diet composition of Caspian terns nesting on Crump Lake island from May to August, 2008. The genus of fish and length of fish (cm; total length) were determined by researchers monitoring the colony from an observation blind.

Common Name (*Genus*)	**Percent of Prey Items**	**Mean Length (cm)**	**Length Range (cm)**
Tui Chub (*Gila*)	55.4%	12.1	4 to 26
Bullhead catfish (*Ameiurus*)	27.8%	11.0	4 to 22
Crappie (*Pomoxi*)	15.0%	10.9	5 to 21
Rainbow Trout (*Oncorhynchus*)	< 1%	13.0	9 to 19
Lamprey (*Entosphenus*)	< 1%	22.5	20 to 28
Sucker (*Catostomus*)	< 1%	19.6	13 to 27
Bass (*Micropterus*)	< 1%	13.6	9 to 16
Speckled Dace (*Rhinichthys*)	< 1%	9.0	-
Unidentified Fish	< 1%	4.0	3 to 6

Consumption Estimates: Our best-guess estimate was that Caspian terns consumed 93 Warner suckers during the 2008 nesting season, with a minimum estimate of 14 and a maximum estimate of 606 suckers (Table 2). Our best estimates for the consumption of non-native predatory fishes by Caspian terns nesting at Crump Lake in 2008 was approximately 16,000 crappie, 23,500 bullhead, and 200 bass (Table 2). Based on these estimates, we predict that for every Warner sucker consumed by a Caspian tern, approximately 400 non-native predatory fish are also consumed.

At the Corps' request, we have also attempted to extrapolate our estimates of sucker, crappie, catfish, and bass consumption in the event that the Crump Lake tern colony expanded from 428 pairs in 2008 to either 500 nesting pairs or 1,000 nesting pairs in future years (Table 3). Our best-guess estimate of Warner sucker consumption for a Caspian tern colony of 500 pairs is 109 suckers, and our best-guess estimate for a tern colony of 1,000 pairs is 217 suckers (Table 3). Our maximum or worst-case estimates are 708 Warner suckers for a 500-pair tern colony and 1,416 Warner suckers for a 1,000-pair tern colony (Table 3). These maximum estimates assume that all suckers consumed by Caspian terns nesting on Crump Lake are from the ESA-listed Warner Valley population, and none from sucker populations elsewhere. Our estimates for non-native predatory fishes ranged substantially (96 to 102,054) depending on the species of fish and the size of the tern colony (Table 3). All predictive estimates (for suckers and predatory fish) assume that Caspian tern foraging behavior and diet composition at the Crump Lake colony will remain as in 2008, which is highly unlikely given the variability in these parameters typically observed at other tern colonies in the region.

Table 2. Estimated consumption of Warner suckers and non-native predatory fishes by Caspian terns nesting on Crump Lake, OR in 2008.

	Estimated Consumption		
	Minimum	**Best**	**Maximum**
Warner sucker	14	93	606
Crappie	7,450	15,964	29,799
Bullhead catfish	10,920	23,399	43,679
Bass	82	176	329

Table 3. Estimated consumption of Warner suckers and non-native predatory fishes by hypothetical Caspian tern colonies of 500 and 1,000 breeding pairs at Crump Lake, OR.

	Estimated Consumption					
	500 Pairs			**1,000 Pairs**		
	Minimum	**Best**	**Maximum**	**Minimum**	**Best**	**Maximum**
Warner sucker	16	109	708	33	217	1416
Crappie	8,703	18,650	34,812	17,407	37,299	69,624
Bullhead catfish	12,757	27,335	51,027	25,514	54,671	102,054
Bass	96	206	384	192	411	769

Temporal trends in fish consumption: The following graphs depict the number of fish, by species and week, observed being delivered to the Caspian tern colony nesting on Crump Lake in 2008; suckers (Figure 2), tui chub (Figure 3), bullhead catfish (Figure 4), and crappie (Figure 5).

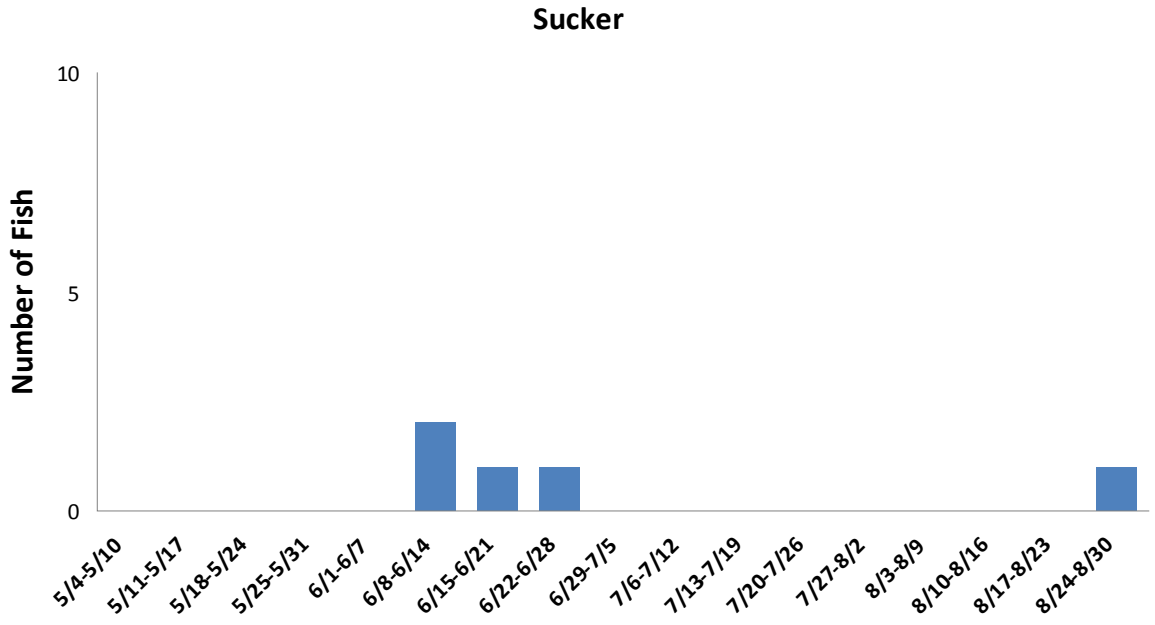


Figure 2. Weekly numbers of sucker (*Catostomus* spp.) observed on the Crump Lake Caspian tern colony by researchers in 2008.

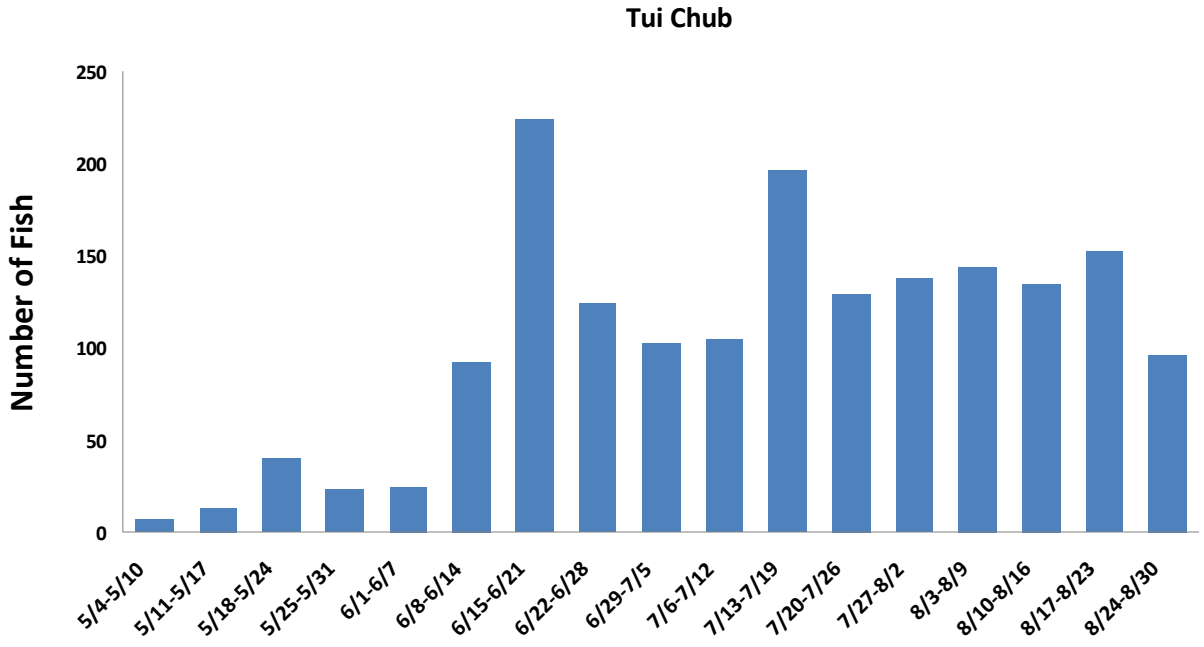


Figure 3. Weekly numbers of tui chub (*Gala bicolor*) observed on the Crump Lake Caspian tern colony by researchers in 2008.

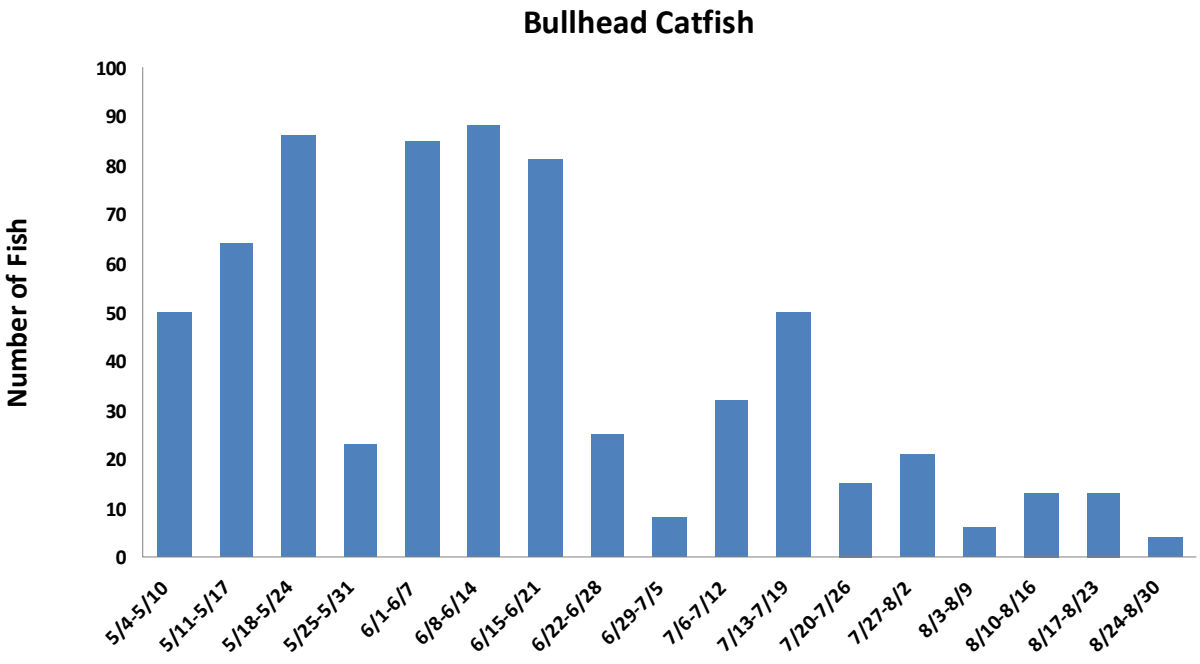


Figure 4. Weekly numbers of bullhead catfish (*Ameiurus* spp.) observed on the Crump Lake Caspian tern colony by researchers in 2008.

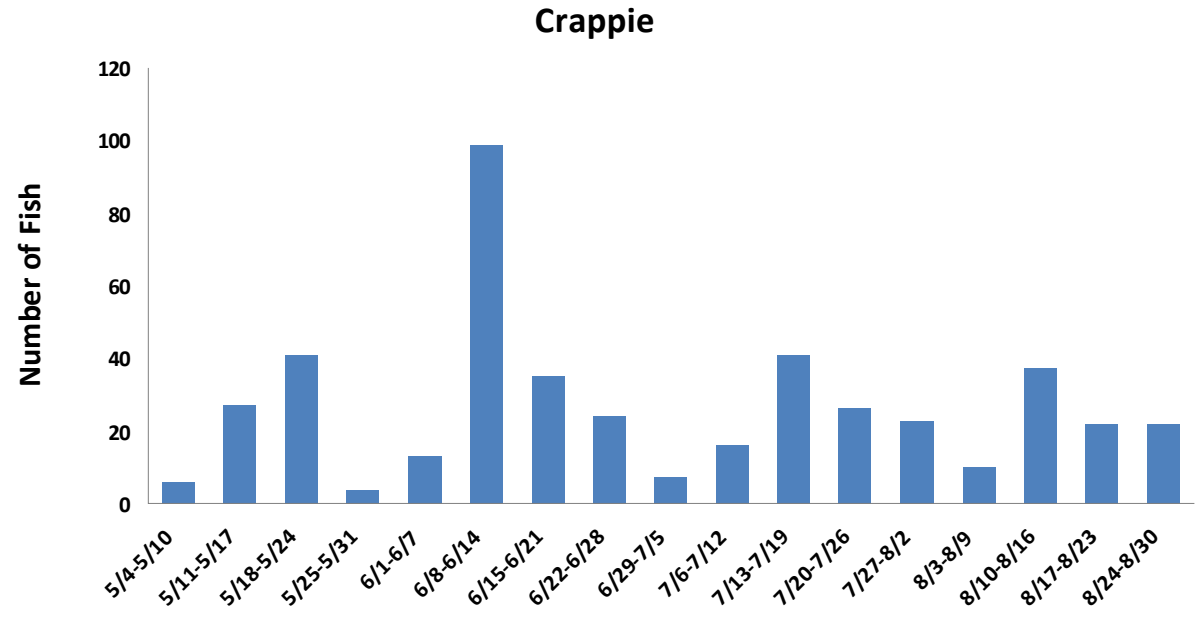


Figure 5. Weekly numbers of crappie (*Pomoxis* spp.) observed on the Crump Lake Caspian tern colony by researchers in 2008.

DISCUSSION

This approach allowed for a very rough estimate of total fish consumption by Caspian terns nesting on Crump Lake in 2008. We caution that the actual number of fish consumed may differ substantially from the estimates because the method does not take into consideration the colony's energetic demands or the energy content of their prey. Additional research is needed to develop a more accurate estimate of total fish consumption by Caspian terns nesting on Crump Lake using a bioenergetics calculation approach. This approach will yield more reliable estimates of numbers of prey consumed for each prey type in the diet.