U.S Fish & Wildlife Service

Caspian Tern Nesting Ecology and Diet in San Francisco Bay and Dungeness National Wildlife Refuge

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November 2004

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San Francisco Bay and Dungeness National Wildlife Refuge

2004 Final Annual Report

[Not for citation or publication without prior permission from the authors]

Submitted to:

U.S. Fish and Wildlife Service, Region 1
Migratory Birds and Habitat Programs
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November 15, 2004

EXECUTIVE SUMMARY

The goal of this 2-year study was to develop a better understanding of Caspian tern (*Sterna caspia*) colony status and diet composition at representative colonies in coastal and interior habitats of California, Oregon, and Washington. Information from this study will be used in the development of a Caspian Tern Management Plan and Environmental Impact Statement (EIS) by the U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, and NOAA Fisheries. The Caspian Tern Management Plan and EIS are mandated by a court-mediated settlement agreement with the goal of reducing predation on salmonids by Caspian terns nesting on East Sand Island in the Columbia River estuary.

This annual report on the second year of the study summarizes data collected on nesting Caspian terns during the 2004 breeding season at five different colonies in the San Francisco Bay area (Brooks Island, Knight Island [South Colony], Baumberg Ponds [B-10], Alviso Ponds [A-7], and Agua Vista Park) and one colony in coastal Washington (Dungeness Spit, Dungeness National Wildlife Refuge). The purpose of this report is to present results to the funding agency, resource management agencies, and other stakeholders. This report addresses diet composition, colony size, nesting success, and factors limiting colony size and nesting success at these six colonies. The findings presented in this report may change with further review and analysis; results have not yet undergone peer-review. Consequently, these data are not for citation or publication without prior permission from the authors.

There were five known breeding colonies of Caspian terns in the San Francisco Bay area in 2004, where approximately 1,350 breeding pairs nested. As was the case in 2003, most breeding pairs in the San Francisco Bay area in 2004 (> 75%) nested at the Brooks Island colony, by far the largest tern colony in the Bay area. Marine forage fishes, in particular anchovies (Engraulidae), surfperch (Embiotocidae), herring (Clupeidae), and silversides (Atherinidae), were the predominant prey types for terns nesting at both the Brooks Island and Agua Vista colonies. At the Knight Island tern colony, however, salmon smolts were the most prevalent prey type (26.1% of prey items), consisting mostly or entirely of Central Valley fall-run chinook salmon (not ESA-listed). In general, juvenile salmonids were more prevalent in tern diets in the San Francisco Bay area in 2004 compared to the previous year, but remained a relatively minor proportion of the diet (< 4% of prey items) at four of the five colonies. The higher prevalence of salmonids in 2004 tern diets was apparently not a result of higher availability of salmonids, but instead a lower availability of marine forage fishes, particularly northern anchovy and surfperch. These two marine prey types were less prevalent in the diet at all Caspian tern colonies in the Bay area in 2004 compared to 2003.

Nesting success at Caspian tern colonies in the San Francisco Bay area ranged from 0.00 to 0.82 young fledged/breeding pair, and was lower in 2004 (0.42 young fledged/breeding pair) compared to 2003 (0.59 young fledged/breeding pair). The level of productivity observed at colonies in the San Francisco Bay area over the past two

years is considered fair to poor compared to other well-studied Caspian tern colonies in the region. In 2004, the size of the five Caspian tern colonies in the San Francisco Bay area appeared to be primarily limited by the availability of suitable nesting habitat above the high high tide line. Productivity at these colonies was primarily limited by mammalian nest predators (Brooks Island, B-10), tidal inundation of active nests (Knight Island, Brooks Island), human disturbance (Brooks Island), and nest predation by gulls during mammalian nest predator and human disturbance events. The lower overall nesting success in 2004 compared to 2003 was primarily due to higher disturbance and nest predation by mammalian predators (Brooks Island) and a higher incidence of nest inundation during spring tide series (Knight Island). Lower availability of marine forage fishes, particularly northern anchovy and surfperch, may also have been a contributing factor in lower nesting success in 2004.

We also studied Caspian tern nesting ecology and diet composition at a colony on the Washington coast in 2004. This Caspian tern colony on Dungeness Spit in Dungeness National Wildlife Refuge evidently formed for the first time during the 2003 nesting season, and was located on sandy substrate amongst driftwood approximately one mile southwest of the Dungeness Lighthouse National Historic Site. We estimated that there were 233 – 293 breeding pairs at the site, and that 211 – 295 young were fledged or 0.80 – 1.12 young fledged/breeding pair in 2004. Nesting success at Dungeness Spit, considered good compared to other well-studied Caspian tern colonies in the region, was surprisingly high considering that most early nesting attempts at the site failed due to frequent visits to the colony by a coyote. In addition, raccoon, opossum, weasel, and river otter tracks were seen near the colony and a river otter was observed on the colony site during the day. Mammalian predators, and to a lesser extent gull predation and human disturbance, were the primary limiting factors for colony size and nesting success at Dungeness Spit. The diet of terns nesting at Dungeness NWR consisted mostly of surfperch (Embiotocidae; 36%) and salmonids (Salmonidae; 29%). Presumably, some of the salmonid smolts consumed by this tern colony were released from the Dungeness Hatchery, located on the Dungeness River approximately 9 miles upstream from the mouth.

We conclude from studies during the 2004 nesting season that (1) juvenile salmonids were a minor component of Caspian tern diets at Brooks Island, B-10, A-7, and Agua Vista, but a major component of the diet at Knight Island and Dungeness Spit, (2) availability of suitable nesting habitat at sites free of mammalian predators was the main factor limiting the number and size of tern colonies in both the San Francisco Bay area and coastal Washington, and (3) nesting success at existing colonies was limited by attributes of those colony sites as they influence (a) vulnerability to mammalian nest predators, (b) vulnerability to inundation during spring tide series, and (c) vulnerability to nest predation from gulls during disturbances caused by human and other mammalian nest predators.

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INTRODUCTION

Caspian terns (*Sterna caspia*) nesting at the colony on East Sand Island in the Columbia River estuary continue to consume about 3 - 6 million juvenile salmonids from the Columbia Basin annually. This despite the reduction in smolt consumption associated with relocation of the tern colony from Rice Island to East Sand Island (Roby et al. 2002, CBR 2003). Approximately two-thirds of all breeding age adults from the Pacific Coast population of Caspian terns are now nesting at East Sand Island (Wires and Cuthbert 2000, Suryan et al. 2004), the sole remaining Caspian tern colony along the outer coast of Oregon and Washington (Shuford and Craig 2002, Suryan et al. 2004). The U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, and NOAA Fisheries are preparing an Environmental Impact Statement (EIS) for management of Caspian terns in the Columbia River estuary. The EIS will explore options to reduce the level of tern predation on Columbia River salmon while ensuring the protection and conservation of Caspian terns in the Pacific Coast/Western region. Some of these management options include the potential for relocating some of the East Sand Island colony to a number of smaller tern colonies outside the Columbia River estuary.

In 2000, Seattle Audubon, National Audubon, American Bird Conservancy, and Defenders of Wildlife filed a lawsuit against the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service on the basis that compliance with NEPA for the proposed management actions to relocate terns from Rice Island to East Sand Island was insufficient, and in objection to the potential take of eggs as a means to prevent tern nesting on Rice Island. In April 2002, all parties reached a settlement agreement mediated through the Ninth Circuit Court of Appeals. Terms of the settlement agreement stipulate federal agencies will (1) complete specific management actions in the estuary in 2002-2004, (2) prepare three technical reports addressing tern and salmon conservation, and (3) comply with a court stipulated timeline for completing an Environmental Impact Statement and Caspian Tern Management Plan to address smolt predation and tern management in the Columbia River estuary. The diet studies included in this report are a critical component in the development of management options for the EIS. Results of diet and food habits studies at potential alternative colony sites will be a major factor in determining which sites along the Pacific coast, if any, are selected for potential new, restored, or enhanced Caspian tern colonies.

Management of island sites for nesting terns has proven to be an effective method to assure adequate distribution of nesting colonies for several tern species, as well as restore colonies that have been abandoned (Kress 2000). Food habit studies of terns at sites outside of the Columbia River estuary are especially crucial because these data are necessary to assess the potential impacts of larger, permanent tern colonies in a variety of interior and coastal areas. This study was also designed to investigate whether low food availability or locally abundant nest predators may render some former or prospective tern colony sites as population sinks (Penland 1982). Studies at historical nesting locations in the San Francisco Bay area (in 2003 and 2004), interior Oregon (in 2003), and coastal Washington (in 2004) were conducted as part of a comprehensive effort to evaluate the suitability of alternative colony sites along the west coast of the U.S.

The objectives of this study were to determine the diet composition, colony size, and nesting success of Caspian terns nesting at these historic colonies. Our primary objective was to determine the fish species comprising the primary prey for terns nesting at selected colonies outside of the Columbia River estuary. Secondary objectives were to determine (1) the size of each tern colony (number of breeding pairs), (2) nesting success at each colony (average number of young fledged per breeding pair), and (3) those factors limiting the size and productivity of each colony, to the extent possible. In this study we evaluated the following potential factors limiting size and productivity of tern colonies outside the Columbia River estuary: (1) availability of suitable bare-sand nesting habitat, (2) competition for available nesting habitat with other colonial waterbirds (i.e., gulls, cormorants), (3) nest predation, (4) disturbance to nesting adults by potential predators (including humans), (5) forage fish availability, and (6) severe weather. Presented here are the results from our studies in the San Francisco Bay area and at the Dungeness National Wildlife Refuge, Olympic Peninsula, Washington in 2004.

STUDY AREAS

The Caspian tern colonies under study in 2004 were in the San Francisco Bay area and at Dungeness National Wildlife Refuge, Washington (Figure 1). In the San Francisco Bay area, the study sites were five existing colonies (Figure 2): Brooks Island (Figure 3),

Brooks Island Caspian tern colony, 2004. Photo taken from the blind of the NW sub-colony.

Knight Island (South Colony; Figure 4), Baumberg Ponds (B-10), Alviso Ponds (A-7), and Agua Vista Park (Figure 2). The primary study site in the San Francisco Bay area was on Brooks Island in central San Francisco Bay, where over 800 pairs of terns nested in 2003. The other study colonies are smaller (Knight Island in the northern San Francisco Bay area, Agua Vista Park in the central San Francisco Bay, and Baumberg Ponds and Alviso Ponds in the southern San Francisco Bay area).

Dungeness Spit Caspian tern colony, 2004. Tern colony is beyond the blind at the water's edge.

An existing tern colony on Dungeness Spit was also investigated in 2004. Dungeness Spit is a natural sand spit approximately 5 miles in length located on the Olympic Peninsula in the Strait of Juan De Fuca near the city of Sequim, Washington (Figure 5). Dungeness Spit is a low-lying peninsula that is connected to the mainland, and is owned and managed by the U.S. Fish and Wildlife Service as part of Dungeness National Wildlife Refuge. The Caspian tern colony evidently formed on Dungeness Spit for the first time during the 2003 nesting season, and was located on sandy substrate amongst driftwood approximately one mile southwest of the Dungeness Lighthouse National Historic Site (Figure 5). With the exception of some small ephemeral tern colonies located on waterfront rooftops, this was the only known Caspian tern breeding colony on the coast of Washington during the last two years.

METHODS

We constructed observation blinds at the periphery of most tern colonies (Brooks Island, Knight Island, Baumberg Ponds, and Dungeness NWR) to facilitate colony observations without disturbing nesting terns; other colonies (Alviso Ponds and Agua Vista Park) were observed from a 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 (adult and juvenile), diet composition, and causes of tern nesting failure were collected on a weekly basis at each colony.

The number of Caspian tern breeding pairs nesting at each colony was estimated using aerial photos taken from fixed-wing aircraft and helicopters (Brooks Island, Knight Island, and Dungeness NWR) or ground counts (Baumberg Ponds, Alviso Ponds, and Agua Vista Park) of incubating terns near the end of the incubation period. Counts of all adult terns in aerial photos were corrected to estimate the number of breeding pairs at the colony using ground counts of incubating and non-incubating terns on several study plots within the colony area. Nesting success (number of young fledged per breeding pair) was

estimated using ground counts of young at the colony just prior to the fledging period. Diet composition at all study colonies was determined by visually identifying fish brought back to the colonies in the bills of nesting adults ("bill-loads") with the aid of binoculars, spotting scopes, and digital photography. Forage fishes were identified to the lowest taxonomic grouping possible from visual observation. Visual identifications were verified using voucher specimens whenever possible. Tern chicks near fledging age were banded at Brooks Island to measure subsequent survival rates and movements among colonies. Each tern was banded with a federal numbered metal leg band and a unique color combination of plastic leg bands that allows for the identification of individual terns at a distance (i.e., at roosts or on colonies). Colony monitoring methodology followed standardized observational and data collection protocols described in Collis et al. (2002), Roby et al. (2002), and Roby et al. (2003). Use of these protocols ensures that results are comparable and will provide managers with specific information necessary for decision-making and selection of sites to manage as permanent tern colony sites beginning in the 2005 nesting season.

RESULTS AND DISCUSSION

SAN FRANCISCO BAY AREA

Brooks Island

Background: Brooks Island is in Central San Francisco Bay near the city of Richmond, and is owned and managed 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 in the last decade. The tern colony is located on a sandy, low-lying spit that extends to the northwest of the main part of the island, and was estimated at over 850 breeding pairs in 2003. Caspian terns nest on the upper part of the beach on the leeward (northeast) shore of the spit. The terns nest in close proximity to gull colonies that also use the spit; a colony of western gulls (*Larus occidentalis*) that has traditionally used Brooks Island, and a newly formed colony of California gulls (*L. californicus*) that is evidently still expanding. Brooks Island is a popular destination for recreational boaters, and is located beneath the flight path of recreational and commercial aircraft. Rats were inadvertently introduced to Brooks Island, and other mammalian predators such as raccoons and red foxes have made it on to the island.

Colony Size and Nesting Success: Brooks Island was the first site in the San Francisco Bay area where Caspian tern nesting activity was recorded in 2004. The first Caspian tern egg was laid on the Brooks Island colony on 15 April (two days earlier than in 2003), and chicks began hatching on 30 May (17 days later than in 2003). The first fledgling (young capable of flight) was observed on 7 July (17 days later than in 2003). See Table 1 for a complete timeline of research activities and Caspian tern nesting chronology at Brooks Island in 2004.

Caspian tern chick on Brooks Island, 2004. Migrant elegant terns in background.

Early nesting attempts by Caspian terns at Brooks Island mostly failed because of the activities of predators on the colony. Beginning 9 April, adult terns attending the colony site appeared to be agitated; nesting terns were extremely sensitive to disturbance and we observed long periods when virtually no terns were at the colony site. About the same time, fresh mammal tracks were seen in the vicinity of the tern colony, and on 15 April a red fox was seen near the colony. During the previous week, the island caretakers had reported seeing a pair of great horned owls (*Bubo virginianus*) on the island within 400 m of the tern colony. In addition, fresh raccoon tracks were also discovered, verifying that the raccoon that was reported on Brooks Island in 2003 was still resident. Attempts by resource managers to remove the mammalian predators were successful; with the assistance of East Bay Parks and USDA-Wildlife Services, the raccoon and red fox were removed from the island on 9 May and 13 May, respectively. The owls were not seen on Brooks Island after the middle of April. After removal of the mammalian predators from the island, tern behavior and colony attendance patterns returned to normal.

The nesting habitat near the observation blind was occupied first (Main Colony), and later a separate satellite colony was formed further down the beach to the northwest (NW Satellite), as was the case in 2003. After removal of the fox and raccoon from the island, colony attendance by terns increased and the NW Satellite colony split into two disjunct nesting aggregations that were separated by about 50 m. Delays in nesting and re-nesting by failed breeders, presumably caused by the presence of mammalian predators earlier in the season, resulted in less synchrony in tern nesting activity at Brooks Island in 2004, compared to the previous year.

As was the case in 2003, most of the Main Colony could be observed and numbers of adult terns counted from the observation blind (Table 7), but some nesting adults were obscured by vegetation or topography. The NW Satellites could not be observed from the observation blind, and numbers of adults on colony were instead estimated by observers in a skiff on the water. To estimate the number of nesting pairs on Brooks Island, three

sets of aerial photographs were taken from fixed-wing aircraft and helicopters, two by the East Bay Parks District on 24 May and 11 June, and one by the USFWS on 25 May.

We estimated the size of the Main Colony at 695 breeding pairs (251 more pairs than in 2003) and the size of the NW Satellite at 415 breeding pairs (70 fewer pairs than in 2003), or a total of 1,040 pairs (181 more pairs than in 2003) of Caspian terns nesting on Brooks Island in 2004 (Table 15). This represents over 75% of the estimated total number of pairs nesting in the San Francisco Bay area during 2004 (1,350 pairs).

We estimated that approximately 504 young terns fledged from the Brooks Island colony in 2004, or 353 and 151 young terns fledged from the Main and NW Satellite sub-colonies, respectively (Table 15). Productivity was 0.51 and 0.44 young fledged per breeding pair for the Main and NW Satellite sub-colonies, respectively, or 0.48 fledglings per breeding pair for the entire Brooks Island tern colony (Table 15). This level of productivity is considered low compared to other well-studied colonies in the Pacific Region, and is below what was observed at Brooks Island in 2003 (0.62 young fledged per breeding pair).

Chick Banding and Resightings of Banded Adults: On 20-21 July, 53 Caspian tern chicks near fledging age were banded with USGS numbered metal leg bands and a unique color combination of plastic leg bands; an additional 25 tern chicks that were too young to hold plastic leg bands were banded with numbered metal bands only.

From late March to early August, there were 30 different sightings of banded adult terns at the Brooks Island colony site. Of these, 12 banded birds were identified such that the banding date and location were known. All 12 banded birds were banded as chicks at colonies in South San Francisco Bay (3 birds banded in 1984), southern California at Bolsa Chica (3 birds in 1995), the Columbia River estuary at Rice Island (2 birds in 2001), coastal Washington in Grays Harbor (2 birds in 1984 and 1980, respectively), interior Oregon at Malheur National Wildlife Refuge (1 bird in 1984), and in southern California at the Salton Sea (1 bird in 1999). Three of these birds were confirmed breeding on the main Brooks Island colony (one each from South San Francisco Bay, Malheur National Wildlife Refuge, and Bolsa Chica).

Diet Composition: A large number of Caspian tern bill loads were identified at the Brooks Island colony (N = 5,766; Table 8). As was the case in 2003, the diet of Caspian terns nesting at Brooks Island in 2004 consisted primarily of schooling marine forage fishes, in particular anchovies (Engraulidae), herring (Clupeidae), surfperch (Embiotocidae), and silversides (Atherinidae), in that order (Table 8). These four taxa each made up greater than 10% of identified prey items. Additional fish taxa that represented more than 1% but less than 10% of the diet included salmonids (Salmonidae), toadfish (Batrachoididae), gobies (Gobiidae), and sculpins (Cottidae), in that order (Table 8). Nine other prey taxa represented less than 1% of the diet (Table 8).

The salmonid portion of the diet in 2004 (3.3% of prey items; Table 8) consisted primarily of juvenile Central Valley fall-run chinook salmon (*Oncorhynchus*

tshawytscha); this evolutionarily significant unit (ESU) is not listed under the U.S. Endangered Species Act (see below), nor is it listed by the State of California, nor is it a candidate for listing. In 2004, over 1 million hatchery-raised smolts belonging to this ESU were released at 5 sites near the mouth of the Sacramento River, 18-32 km from the Brooks Island tern colony. The percentage of salmonids in the diet during 2004 nearly doubled compared to 2003 (1.9% of prey items). The higher proportion of juvenile salmonids in the diet in 2004 may reflect a relative decline in the availability of some marine forage fishes, such as northern anchovy and surfperch, in 2004 compared to 2003 (Kathy Hieb, CDFG, pers. comm.). The trout portion of the diet (0.1% of prey items; Table 8) consisted of rainbow trout (*Salmo gairdneri*), evidently caught at nearby reservoirs (> 11 km distant), where trout are stocked for recreational fisheries.

Factors Limiting Colony Size and Nesting Success: Several factors were apparently responsible for limiting the size and productivity of the Brooks Island Caspian tern colony in 2004: (1) the availability of suitable nesting habitat, (2) nest predators, (3) human disturbance, and, possibly, (4) availability of marine forage fish (Table 14).

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. In 2003, we noted that the area of suitable habitat for tern nesting might be declining, as vegetation (pickleweed and ice plant) appeared to be encroaching from the landward direction and shoreline erosion was removing nesting substrate from the seaward direction. These two processes appeared to be responsible for the fragmentation of the Brooks Island tern colony into two sub-colonies. Thus the size of the Caspian tern colony on Brooks Island appeared to be primarily limited by availability of suitable nesting habitat. In 2004, vegetation and debris were manually removed (using hand pulling and shovels) from an area of approximately 150 m^2 adjacent to the 2003 tern colony site; approximately 70 pairs of terns nested on this newly created habitat.

In 2004 nesting success appeared to be mostly limited by mammalian predators (see above). Also, in association with the recent expansion of the California gull colony on Brooks Island, gull predation on Caspian tern eggs and chicks was often associated with colony disturbances due to kayakers, other recreational boaters, and low-altitude aircraft. When terns were caused

Kayaker causing disturbance at the Brooks Island tern colony.

to take flight due to these disturbances, gulls waiting nearby quickly depredated eggs and chicks. Disturbance and subsequent gull predation increased to the point where this factor now appears to have had a significant impact on tern productivity (Table 16).

Plunge diving Caspian tern near the Brooks Island tern colony.

Availability of marine forage fish may have been a factor contributing to lower productivity at the Brooks Island tern colony in 2004. The proportion of northern anchovies and surfperch in the diet was less in 2004 compared to 2003. Also, fisheries biologists from the California Department of Fish and Game reported fewer northern anchovies in trawls conducted in 2004 throughout the San Francisco Bay Basin. The average estimated total length of bill-loads identified at the Brooks Island colony in 2004 was significantly less than in 2003 ($t = 4.53$, $P = 0.00001$). Finally, the average body mass of Caspian tern fledglings, corrected for variation in stage of development, was lower in 2004 compared to 2003, suggesting that tern chicks were provisioned better by their parents in 2003. All of these observations support the hypothesis that prey availability limited nesting success at Brooks Island in 2004.

Knight Island

Background: Knight Island is in San Pablo Bay (northern San Francisco Bay area) near the mouth of the Napa River and the city of Vallejo. Knight Island is actually a low-lying island of inter-tidal marsh that was converted into a salt pond. The area is owned and managed by the California Department of Fish and Game. In recent years Caspian terns have nested on small islands in the Knight Island salt pond. In particular, one island in the northeast portion of the salt pond (North Colony) and two islands near the levee on the

south side of the salt pond (South Colony, Figure 4) together supported over 300 nesting pairs of Caspian terns in 2003.

In September 2002, the levee surrounding the Knight Island salt pond was intentionally and illegally breached, restoring the former salt pond to tidal wetland (I. Woo, pers. comm.). This change caused flooding of low-lying nests and provided mammalian predators with easier access to nesting islands during spring tide series in the 2003 breeding season (i.e., all active tern nests on the South Colony were destroyed early last season by an unidentified mammalian predator). Foxes, raccoons, and other mammalian predators are known to frequent the levee surrounding the former salt pond on Knight Island. Expanding double-crested cormorant colonies on islands in the Knight Island salt pond also appeared to limit the number of nesting Caspian terns. Human disturbance is

Knight Island (South Colony), 2004. Photo taken from the levee in a northern direction.

evidently infrequent, although the slough surrounding Knight Island sees daily use by recreational fishers and boaters and there is evidence of recreational use of the levee. During the 2003 breeding season, boaters were seen on several occasions using the levee to stretch their legs and walk dogs.

Colony Size and Nesting Success: The first terns (23) were seen roosting on the southern island at the South Colony on 6 April. The first egg was laid at the South Colony on 2 May, one day earlier than was observed in 2003. During a high tide event on 8 May, all

the nests on the southern island of the South Colony were inundated, resulting in failure of all active tern nests. Caspian terns began re-laying at the South Colony on 14 May. The first Caspian tern chick was observed on 8 June (nine days earlier than in 2003) and the first fledgling (young capable of flight) was observed on 7 July (20 days earlier than in 2003). Terns did not nest on the Northeast Colony in 2004 because that colony site was lower in elevation than the South Colony site and was underwater during most high tides. To estimate the number of tern nesting pairs at the South Colony, aerial photographs were taken by the USFWS on 26 May. See Table 2 for a complete timeline of research activities and Caspian tern nesting chronology at Knight Island in 2004.

We estimated the size of the South Colony on Knight Island at 238 breeding pairs (35 more pairs than in 2003), with 100 pairs nesting on the north island of the South Colony and 138 pairs nesting on the south island of the South Colony. The slightly larger size of the South Colony at Knight Island in 2004 compared to 2003 is likely due the complete lack of Caspian tern nesting at the North Colony on Knight Island in 2004. The Knight Island colony represented the second largest breeding colony of Caspian terns in the San Francisco Bay area during 2004 (Table 15).

We estimated that a minimum of 76 young terns fledged from the South Colony on Knight Island, or 0.32 young fledged per breeding pair (Table 15). Three separate spring tide series in 2004 caused flooding on the colony that resulted in no successful nesting on the south island of the South Colony and reduced nesting success on the north island of the South Colony at Knight Island in 2004 (Table 15). This level of productivity was below that recorded the previous year (0.62 young fledged per breeding pair), and is considered low compared to other well-studied colonies in the Pacific Region.

Chick Banding and Resightings of Banded Adults: Tern chicks were not banded at the Knight Island colony due to flooding that resulted in too few chicks on the colony to band.

Throughout the season we saw one partial color-banded adult tern breeding on the colony. Two other metal-banded birds were spotted on the colony in June and July. Due to the great distances, we were unable to read the band numbers.

Diet Composition: A moderate number of Caspian tern bill loads were successfully identified at the South Colony on Knight Island (N = 1,720; Table 9). The diet of Caspian terns nesting at Knight Island was dominated by salmonids (Salmonidae) and silversides (Atherinidae), followed by sunfish (Centrarchidae) and gobies (Gobiidae), in that order (Table 9). Each of these four prey types represented greater than 10% of identified prey items. Additional fish taxa that represented more than 1% but less than 10% of the identified prey items were surfperch (Embiotocidae), herring (Clupeidae), anchovies (Engraulidae), croakers (Sciaenidae), and toadfish (Batrachoididae), in that order (Table 9). Four other prey taxa represented less than 1% of the diet (Table 9).

As was the case in 2003, the Knight Island Caspian tern colony had the highest proportion of salmonids in the diet of the five tern colonies studied in the San Francisco Bay area during 2004. The salmonid portion of the diet consisted primarily of juvenile

Central Valley fall-run chinook salmon, an evolutionarily significant unit (ESU) that is not listed under the U.S. Endangered Species Act. Chinook salmon smolts represented approximately 26% of the forage fish that were delivered to the Knight Island tern colony (Table 9), compared to less than 9% juvenile chinook salmon in the diet of Knight Island terns in 2003. The large increase in the proportion of salmonids in the diet of Knight Island terns in 2004 compared to 2003, was apparently not a reflection of higher availability of juvenile salmonids; abundance estimates for fall-run chinook salmon smolts near the mouth of the Sacramento River were higher in 2003 than in 2004. Furthermore, more hatchery-reared spring- and fall-run chinook salmon were released into the North Bay in 2003 than in 2004 (PSMFC 2004). This is further support for the hypothesis that a decline in availability of marine forage fishes, especially northern anchovy and surfperch, in the San Francisco Bay area was responsible for the increased prevalence of salmonids in the diet of Caspian terns in 2004.

Caspian tern with a juvenile salmon in its bill.

Six ESUs of salmonids are known to occur in the San Francisco Bay Basin, four of which are listed under the U.S. Endangered Species Act: (1) Sacramento River winter-run chinook salmon (endangered), (2) Central Valley fall-run chinook salmon (not listed), (3) Central Valley late fall-run chinook salmon (not listed), (4) Central Valley spring-run chinook salmon (threatened), (5) Central Valley steelhead (threatened), and (6) Central California Coast coho (threatened) (http://www.nwr.noaa.gov/1salmon/salmesa/). An additional steelhead ESU (Coastal California steelhead) is considered extirpated from the Basin. The U.S. Fish and Wildlife Service, NOAA Fisheries, and California Department of Fish and Game use timing of out-migration and fork length to distinguish species and ESUs of salmonids (Pat Brandes, USFWS, pers. comm., Fisher 1994, Johnson 1992). Based on the dates when juvenile salmonids were identified in Caspian tern bill-loads, the proximity of tern colonies to the mouth of the Sacramento River, and the length of juvenile salmonid bill-loads (estimated during bill-load identifications from observation blinds), Central Valley fall-run chinook salmon smolts (not listed) represented most, if not all, of the salmonid bill-loads.

Central Valley fall-run chinook salmon are the most abundant salmonid run from the Sacramento River basin, and the great majority are hatchery-reared. The timing of the juvenile out-migration for this ESU (January – July) coincides with much of the Caspian tern nesting season. Between mid-March and late July, the vast majority of juvenile salmonids caught in trawls in the Sacramento River delta are Central Valley fall-run chinook salmon (Paul Cadrett, USFWS, pers. comm.). Large numbers of hatchery-raised smolts belonging to this ESU (> 1 million) are released at 5 different sites near the mouth of the Sacramento River (PSMFC 2004), 6-20 km from the Knight Island tern colony.

The Sacramento River winter-run chinook salmon ESU is listed as endangered, and juveniles out-migrate during January – April, with the peak out-migration occurring in February and early March (Larry Hansen, USFWS, pers. comm.). Thus the bulk of the out-migration for this ESU occurs before the arrival of Caspian terns to the San Francisco Bay area for the nesting season, so it is unlikely that an appreciable number of this or any other ESA-listed salmonid ESU in the San Francisco Bay area is taken by Caspian terns nesting at Knight Island or Brooks Island.

Factors Limiting Colony Size and Nesting Success: The primary factors limiting the size and productivity of the Knight Island Caspian tern colony in 2004 appeared to be the availability of nesting habitat, quality of the nesting substrate, flooding of tern nests during extreme high tide events, predation, and encroachment by other colonial waterbirds. In 2004, all the active Caspian tern nests on the south island (South Colony) were destroyed as a result of a high high tide event on 8 May, but the small island that supports the South Colony was quickly re-occupied. Two subsequent high high tide events caused further nest failure. The breaching of the salt pond levee at Knight Island may also pose a problem to nesting terns during low low tides by providing mainland mammalian predators with easy access to the island.

Gulls consuming a tern egg.

Increasing numbers of double-crested cormorants are using the small islands in the Knight Island salt pond for nesting sites, and competition for nest sites appeared to be limiting the number of Caspian tern nesting pairs. Competition for nest sites with cormorants also appeared to cause terns to nest in low lying areas, areas that were susceptible to flooding during high high tides. Cormorant nesting colonies also attracted avian predators, primarily western and California gulls, which seemed to be having a greater impact on tern productivity than in 2003.

Baumberg Ponds (B-10)

Background: Baumberg Ponds (B-10) is a former salt pond in South San Francisco Bay near the east end of the San Mateo Bridge. Baumberg Ponds (B-10) was created for industrial salt production by building a levee around low-lying inter-tidal marsh, and is now owned and managed by the California Department of Fish and Game. In recent years several dozen pairs of Caspian terns have nested on a very small island in B-10 near the west levee. Foxes, raccoons, and other mammalian predators (e.g., long-tailed weasels and black rats) are known to frequent the levees surrounding B-10. Human disturbance is evidently infrequent, and the area is currently closed to the public. Plans to convert Baumberg Ponds B-10 into a muted tidal basin were implemented late in the 2004 breeding season (i.e., mid-July).

Colony Size and Nesting Success: Caspian terns were observed on the island in Baumberg Ponds as early as 27 March (28 terns counted), and the first tern egg was laid on the island about 13 April, 18 days earlier than in 2003. The Baumberg Ponds (B-10) colony was

Baumberg Ponds (B-10) Caspian tern colony before it was abandoned, 2004.

completely abandoned on 3 May, presumably due to predation by a grey fox that was seen repeatedly on the levee adjacent to the colony island. We suspect that a fox swam across to the island from the levee; evidenced by numerous fox tracks observed on the levee (throughout the season) and on the island (in early May). No Caspian terns nested on the island after 3 May. Interestingly, a nearby Forster's tern colony did not appear to be disturbed by the fox. We suspect that this was because the water surrounding the Forster's tern colony provided them with more protection from mammalian predators (i.e., a wide area of deep water immediately surrounding the island) than the water surrounding the Caspian tern colony.

Prior to colony abandonment, the size of the B-10 colony was estimated at 28 breeding pairs (Table 15). No young were raised at the B-10 colony in 2004 (Table 15). See Table 3 for a complete timeline for research activities and Caspian tern nesting chronology at B-10 in 2004.

Chick Banding and Resightings of Banded Adults: Because no tern chicks were produced, no banding took place at the Baumberg Ponds (B-10) colony in 2004. One metal-banded adult tern was observed at the Baumberg Ponds tern colony in 2004.

Caspian tern flipping surfperch in its bill. Photo courtesy of Gary Shaffer.

Diet Composition: Very few Caspian tern bill-loads were identified at the Baumberg Ponds (B-10) colony (N = 31; Table 10). Based on this limited sample of fish identified during the four weeks prior to colony abandonment, the diet of Caspian terns nesting at Baumberg Ponds (B-10) was dominated by surfperch (embiotocids), followed by gobies (gobiids; Table 10). Each of these prey types represented at least 25% of the diet. Additional fish taxa that represented more than 10% of the identified prey items included silversides (atherinids), juvenile sharks (carcharhinids), flatfish (pleuronectids), and unidentified non-salmonids, in that order (Table 10). No juvenile salmonids were detected in the diet of terns nesting at Baumberg Ponds (B-10) in 2004 (Table 10).

Factors Limiting Colony Size and Nesting Success: In 2004, the primary factors limiting the size and productivity of the Caspian tern colony at Baumberg Ponds (B-10) were (1) mammalian nest predators, (2) availability of suitable nesting habitat, and (3) the quality of nesting substrate (Table 14). The island is very small and much of it consists of fine-grained sediment that turns mucky after a rain, which affected the ability of breeding terns to successfully incubate their eggs in 2003 (i.e., eggs became stuck in the mud). In 2004, all of the active tern nests with eggs on the B-10 colony were depredated or abandoned early in the 2004 breeding season; no terns attempted to nest at the colony site after it was abandoned on 3 May.

Alviso Ponds (A-7)

Background: Alviso Ponds (A-7) is a former salt pond in South San Francisco Bay near the southern tip of the Bay. Alviso Ponds was created by a levee surrounding low-lying inter-tidal marsh, and is owned and managed by the U.S. Fish and Wildlife Service as part of the Don Edwards San Francisco Bay National Wildlife Refuge Complex. In recent years several dozen pairs of Caspian terns have nested on several very small islands near the middle of A-7. Foxes, raccoons, and other mammalian predators are known to frequent the levee surrounding A-7. Human disturbance is evidently infrequent, and the area is closed to the public.

Colony Size and Nesting Success: Caspian terns were not observed in the vicinity of A-7 until 13 April, and adult terns (21) were first observed on the nesting islands on 16 April.

The first tern egg was observed at the A-7 colony on 9 May, nine days earlier than in 2003. As was the case last year, nesting chronology at the A-7 colony was later than at any other known Caspian tern colony in the San Francisco Bay area. Tern chicks began hatching at the A-7 colony on 30 May and the first fledging was observed on 11 July. See Table 4 for a complete timeline of research activities and Caspian tern nesting chronology at A-7 in 2004.

Alviso Ponds (A-7) Caspian tern colony, 2004.

The size of the A-7 colony was estimated at 28 breeding pairs in 2004 (Table 15), 22 fewer pairs than in 2003. We estimated that a minimum of 14 young terns fledged from the A-7 colony, or 0.50 young fledged per breeding pair (Table 15). This level of productivity was much higher than in 2003 (0.08 young fledged per breeding pair), but is still considered low compared to other well-studied colonies in the Pacific Region.

Chick Banding and Resightings of Banded Adults: Tern chicks were not banded at the A-7 colony due to the relatively small colony size and concern over the potential impact of disturbance during banding activities on the already low productivity of this colony.

No banded adult terns were observed at the A-7 tern colony in 2004.

Diet Composition: A small number of Caspian tern bill-loads (N = 164) were successfully identified at the A-7 colony due to the distance between the levee and the colony (> 300

m). Based on this small sample size, the diet of Caspian terns nesting at A-7 consisted primarily of gobies (Gobiidae; Table 11). This prey type represented more than 50% of prey items. Additional fish taxa that represented more than 1% but less than 10% of the identified prey items included sculpins (Cottidae), salmonids (Salmonidae), silversides (Atherinidae), herring (Clupeidae), anchovies (Engraulidae), and sunfish (Centrarchidae), in that order (Table 11).

Salmonids represented 3.5% of the identified prey items at the A-7 colony in 2004 (Table 11). These salmonids likely consisted primarily or entirely of rainbow trout stocked in local reservoirs. During visits to several of these reservoirs where trout are stocked for recreational fishers (e.g., Lake Chabot) we commonly observed foraging Caspian terns. Last year no tern bill-loads at the A-7 colony were identified as juvenile salmonids.

Factors Limiting Colony Size and Nesting Success: The primary factors limiting the size and productivity of the A-7 Caspian tern colony in 2004 appeared to be availability of suitable nesting habitat and the quality of nesting substrate (Table 14). The islands in A-7 are very small and mostly consist of fine-grained material that turns mucky after a rain. In addition, although we did not witness any kleptoparasitism or depredation of tern nests at A-7, a colony of over 6,500 pairs of California gulls was located less than two kilometers away (C. Strong, SFBBO, pers comm.) and may pose problems for nesting terns in the future.

Agua Vista Park

Background: This small Caspian tern colony was first noted during the 2002 nesting season, and was estimated to consist of 43 nesting pairs in 2003. This colony formed on two fragments of a wooden pier on the San Francisco waterfront, just south of SBC Yahoo Park (home of the SF Giants). The colony got its name from a very small city park of that name on the shores of the Bay adjacent to the tern colony. The section of the pier

Agua Vista Park Caspian tern colony, 2004.

nearest the shore has completely rotted away, leaving the outer sections unconnected to the mainland and thus free of mammalian predators. The Caspian terns are nesting on the decaying wooden pier covered with crumbling asphalt, and dug nest scrapes in the dirt and debris on the surface. Several pairs of western gulls nest in the vicinity, including on the pier fragments where the terns are nesting. The two sections of pier that support the

tern colony appear in imminent danger of collapsing. The property is owned by the Port of San Francisco.

Colony Size and Nesting Success: The first terns (15) were seen roosting at the Agua Vista Park colony on 26 March. The first tern egg was laid on 16 April, approximately two weeks earlier than in 2003. Tern chicks began hatching at the Agua Vista Park colony on 15 May and the first fledgling was observed 23 June, 10 days and 23 days earlier than in 2003, respectively. See Table 5 for a complete timeline of research activities and Caspian tern nesting chronology at Agua Vista Park in 2004.

The size of the Agua Vista Park tern colony was estimated at 38 breeding pairs in 2004 (Table 15), five fewer pairs than in 2003. The minimum estimate of number of young fledged from the Agua Vista Park colony was 31, or 0.82 young fledged per breeding pair (Table 15). This is the minimum productivity for this colony in 2004 because not all fledglings on the colony could be seen from shore, and the colony is not accessible for closer inspection. Productivity at the Agua Vista Park colony was the highest of all known colonies of Caspian terns in the San Francisco Bay area in 2004. This minimum level of productivity was higher than was recorded there the previous year (0.42 young fledged per breeding pair) and is considered fair to good compared to other well-studied colonies in the Pacific Region.

Chick Banding and Resightings 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 sighted one adult Caspian tern that had a metal band at Agua Vista Park tern colony in 2004; however, we were unable to read the band combination due to the great distance between the colony and our observation site (> 300 m).

Diet Composition: A moderate number of Caspian tern bill loads were identified at the Agua Vista Park colony (N = 817; Table 12). Based on the data collected, the diet of Caspian terns nesting at the Agua Vista Park colony was dominated by silversides (Atherinidae), herring (Clupeidae), surfperch (Embiotocidae), and anchovies (Engraulidae), in that order (Table 12). Each of these prey types represented at least 10% of the identified prey items. Additional fish taxa that represented more than 1% but less than 10% of the identified diet included toadfish (Batrachoididae), sand lance (Ammodytidae), and salmon (Salmonidae), in that order (Table 12). Five additional prey taxa each represented less than 1% of the diet (Table 12).

Salmonids represented 1.4% of the identified prey items at the Agua Vista Park colony (Table 12), compared to 0.1% of prey items in 2003. The ESU(s) of salmonids in the diet of this tern colony is not known, but are likely Central Valley fall-run chinook salmon, given the time of year, size of fish, and abundance of this ESU relative to all others.

Factors Limiting Colony Size and Nesting Success: As was the case last year, the primary factors limiting the size and productivity of the Agua Vista Caspian tern colony in 2004 appeared to be the quality of nesting substrate and the availability of suitable nesting

habitat. Nesting substrate was certainly extremely limited and the availability of suitable nesting substrate was a proximate factor limiting the size of the tern colony on the pier fragments. The presence of terns nesting at this site is strong evidence that the availability of suitable nesting habitat for Caspian terns in this part of San Francisco Bay was very limited. The eastern most pier fragment was collapsing into the bay and offered less nesting habitat for terns in 2004 compared to 2003.

DUNGENESS NATIONAL WILDLIFE REFUGE, WASHINGTON

Dungeness Spit

Background: Dungeness Spit is a natural sand spit approximately 5 miles in length located on the Olympic Peninsula, on the shores of the Strait of Juan De Fuca near the city of Sequim, Washington. Dungeness Spit is a low-lying peninsula that is connected to the mainland, and is owned and managed by the U.S. Fish and Wildlife Service as part of Dungeness National Wildlife Refuge. The Caspian tern colony evidently formed on Dungeness Spit for the first time during the 2003 nesting season, and was located on sandy substrate amongst driftwood approximately one mile southwest of the Dungeness Lighthouse National Historic Site. Skunks, river otters, opossums, raccoons, foxes, coyotes, and other mammalian predators are known to frequent the spit. Although the colony is located in an area that is closed to the public, human disturbance may potentially affect the colony because a beach adjacent to the colony is open to the public and is commonly used by hikers and recreational boaters.

Coyote spotted near the Dungeness Spit tern colony, 2004.

Colony Size and Nesting Success: Caspian terns were first observed in the vicinity of the Dungeness Spit nesting colony on 23 March, but terns were not observed on-colony until nearly a month later (19 April). The first tern egg was laid at the Dungeness Spit colony on about 10 May. Most of the early nesting attempts by terns at Dungeness Spit failed due to frequent visits to the colony by a coyote, which was first observed on 29 May. Beginning on 29 May, no adult terns attended the colony overnight for at least eight of 12 nights when observers were present, including six consecutive nights. Approximately 63 (69%) of the 93 tern nests visible from the blind were depredated or abandoned during this time. On 7 June, USDA-Wildlife Services commenced harassment of the coyote using a paintball gun for three consecutive nights. Hazing of the coyote may have been successful, as fresh coyote

tracks were not seen at the colony after 9 June. In addition to coyote tracks, raccoon, opossum, and river otter tracks were seen in the vicinity of the colony and a river otter was observed at the colony site during the day.

Despite the severe disturbance of the Dungeness Spit Caspian tern colony by the coyote and other mammalian nest predators, at least 13 chicks hatched during the week of 13 June, and a total of at least 18 chicks ultimately hatched from nests initiated before the repeated visits by the coyote. The successful hatching of a few of the tern eggs not depredated by mammalian predators is conclusive proof that Caspian tern eggs are remarkably tolerant of considerable neglect by incubating adults, including extended periods of cool, inclement weather. See Table 6 for a complete timeline of research activities and Caspian tern nesting chronology at Dungeness Spit in 2004.

The size of the Dungeness Spit tern colony was estimated to be between 233 and 293 breeding pairs in 2004 (Table 15). The uncertainty in the size of this breeding colony was due to (1) the extreme asynchrony of nesting attempts at this colony in 2004, (2) the apparent recruitment of additional breeding pairs to the colony throughout the nesting season, and (3) the concealment of a number of tern nests amongst the driftwood that littered the colony site. The estimate of number of young fledged from the Dungeness Spit colony was between 211 and 295, or 0.80 – 1.12 young fledged per breeding pair (Table 15). The uncertainty in the number of young fledged from this colony in 2004 was due to concealment of fledglings amongst the driftwood that littered the colony site. Productivity at the Dungeness Spit colony in 2004 was surprisingly high given the magnitude of mammalian predator activity and nest predation. Estimated productivity at the Dungeness Spit colony was as high or higher than at any of the other Caspian tern colonies monitored in 2004, including the East Sand Island colony, and is considered fair to good compared to other well-studied colonies in the Pacific Region.

Chick Banding and Resightings of Banded Adults: Tern chicks were not banded at the Dungeness Spit colony in order to minimize potential impacts from disturbance following repeated predation events at the colony early in the season.

Between late April and late August, there were 76 different sightings of banded terns on the Dungeness Spit colony site. Some of these banded birds probably passed through the site early in the season on their way to small colonies farther north (e.g., rooftop colonies near Puget Sound). Later in the season, it is likely that banded terns stopped at the colony after experiencing nest failure at these sites or in the Columbia River estuary. There was one banded tern that was confirmed nesting at the Dungeness Spit colony site. Of the 76 resightings of banded terns at the Dungeness Spit colony site, 19 banded birds were identified such that the banding year, age class (i.e., adult or chick), and location were known. Seven of the banded birds that were resighted at the Dungeness Spit tern colony were banded as adults; 3 were banded at Rice Island (in 2000), 3 were banded in Commencement Bay at the ASARCO Industrial Site (1 in 2000 and 2 in 2001), and 1 was banded at East Sand Island (in 2004). Thirteen of the banded birds that were resighted at the Dungeness Spit tern colony were banded as chicks; all were banded at East Sand Island (6 in 2000, 5 in 2001, and 2 in 2002).

Caspian tern at Dungeness Spit colony with steelhead in its bill. Photo courtesy of Gary Shaffer.

Diet Composition: A large number of Caspian tern bill loads were successfully identified at the Dungeness Spit colony (N = 5,265; Table 13). The diet of Caspian terns nesting at Dungeness Spit was dominated by surfperch (Embiotocidae) and salmonids (*Oncorhynchus* spp.), in that order (Table 13). Both of these prey types represented more than 25% of the identified prey items. Additional fish taxa that represented more than 1% but less than 10% of the identified prey items included sculpins (Cottidae), herring (Clupeidae), pricklebacks (Stichaeidae), smelt (Osmeridae), and anchovies (Engraulidae), in that order (Table 13). Seven additional prey taxa each represented less than 1% of the diet (Table 13).

The proportion of juvenile salmonids in the diet averaged 29% of identified prey items (this percentage is the average of the weekly percentages; Table 13). A variety of salmonid species and evolutionarily significant units (ESUs) are potentially susceptible to predation from Caspian terns nesting at Dungeness Spit. At least nine different salmonid ESUs have been documented in Dungeness Bay or in the nearby Strait of Juan de Fuca (Beamish 1998; Sweeting et al. 2003): (1) Puget Sound chinook salmon *(O. tshawytscha*), (2) Even-year pink salmon (*O. gorbuscha*), (3) Odd-year pink salmon, (4) Hood Canal chum salmon (*O. keta*), (5) Puget Sound/Strait of Georgia chum salmon, (6) Puget Sound/Strait of Georgia coho salmon (*O. kisutch*), (7) Puget Sound steelhead (*O. mykiss*), (8) Puget Sound bull trout/dolly varden (*Salvelinus* spp.), and (9) Puget Sound sea-run cutthroat trout (*O. clarki*). Sockeye salmon (*O. nerka*) are also present in the Strait of Juan de Fuca, but are not currently identified with a particular ESU. Three of these nine ESUs are currently listed under the U.S. Endangered Species Act: (1) Puget Sound spring/summer-run chinook salmon (threatened), (2) Hood Canal summer-run chum salmon (threatened), and (3) Puget Sound bull trout/dolly varden (threatened), (NOAA Fisheries, 2004).

The salmonid portion of the diet of Dungeness Spit Caspian terns likely included smolts released from the Dungeness Hatchery, located on the Dungeness River approximately 14 km upstream from the mouth. We observed Caspian terns foraging at the river mouth on multiple occasions, at several tide levels, and at various times of day. Chinook salmon, coho salmon, and steelhead are the most likely salmonid prey types for Caspian terns foraging at the mouth of the Dungeness River due to the large size of these smolts during out-migration (range ~100 – 200 mm). Although pink salmon (and to lesser extent chum salmon) are also relatively abundant in the Dungeness River, these species migrate to the bay immediately following emergence and may be too small (range ~20 – 40 mm) to

attract foraging Caspian terns. The Dungeness River does support a relatively large number of ESA-listed bull trout, but these fish primarily reside in the deep pools of the upper Dungeness River (WDFW 2000), presumably outside the foraging range of the Dungeness Spit Caspian tern colony. Terns foraging within the Strait of Juan de Fuca, however, are likely to encounter a more diverse assemblage of salmonid species, including large numbers of chum and pink salmon that are known to rear in the near-shore habitat of Puget Sound before migrating to the open North Pacific (Groot and Margolis 1991, Beamish 1998).

The large system of inlets, bays, and canals within Puget Sound provide a diversity of rearing habitats for young salmon. For example, Beamish et al. (1998) and Sweeting et al. (2003) have documented that large numbers of coho, chinook, and chum salmon are still present in Puget Sound throughout the summer, fall, and early winter months. Conversely, very few juvenile salmonids are believed to rear in the Columbia River estuary during this period, as populations of steelhead, coho salmon, and chinook salmon more readily enter the open reaches of the North Pacific following smoltification.

Factors Limiting Colony Size and Nesting Success: The main factors limiting colony size and nesting success of Caspian terns on Dungeness Spit were (1) mammalian nest predators (see above), (2) avian nest predators (especially gulls exploiting colony disturbances caused by bald eagles; Table 16), and (3) human disturbance (Table 14). In 2004, the level of human disturbance was lower than reported in 2003, perhaps as a result of (1) posting of area closure signs in the vicinity of the colony, (2) frequent presence of researchers in a blind located near the colony, and (3) relatively low numbers of visitors to the spit through June due to inclement weather. We observed two human disturbance events during 2004: two recreational boaters on 20 May and a hiker on 4 June each walked through the tern colony, potentially trampling nests and causing nest abandonment, and likely causing some nest failures.

ACKNOWLEDGMENTS

This study was funded by the U.S. Fish and Wildlife Service, Pacific Region, Migratory Birds and Habitat Programs; we thank Nanette Seto, Tara Zimmerman, Brad Bortner, and Dave Wesley, without whose support and assistance this project would not have been possible. We also thank the Don Edwards San Francisco Bay National Wildlife Refuge, Dungeness National Wildlife Refuge, East Bay Regional State Parks, and the California Department of Fish and Game for allowing access to the study sites. We very much appreciate the hard work and dedication of the field technicians, interns, and volunteers whose contribution to this research was invaluable: Chris Couch, Brendan Courtot, Annette de Knijf, Karen Fischer, Christy Hand, Dylan Horvath, Samantha Lantz, Don Lyons, Michelle Melby, Sarah Moculeski, Anne Mary Myers, Kelly Redman, Anja Schiller, Joel Shinn, and Kari Vandenburgh. Allen Evans and Mike Hawbecker provided important assistance at critical times during this project. Aerial photographs of Caspian Tern colonies at Brook's Island (25 May 2004), Knight Island (27 May 2004), and Sand Island (2 June 2004) were provided by G. J. McChesney (USFWS, San Francisco Bay

NWRC, Fremont, CA). Photographs were taken by McChesney and P. A. Capitolo (Humboldt State University) from a Califoria Department of Fish and Game Partenavia aircraft.

We are very grateful for the assistance, advice, and in-kind support from the following individuals: Ellen Holsberry, Department of Fisheries and Wildlife, Oregon State University; Terry Adelsbach, Sacramento Field Office, U.S. Fish and Wildlife Service; Janet Hansen, Heather Klausmeyer, Ellie Loomis, Amy Scarpignato, Rachel Strickman, Cheryl Strong, Ian Walsh, and staff, San Francisco Bay Bird Observatory; Lisa Eigner, Nate Jones, Gerry McChesney, Clyde Morris, Mike Parker, Travis Poitras, and Karen Vickers, Don Edwards San Francisco Bay National Wildlife Refuge, U.S. Fish and Wildlife Service; Steve Bobzien, Ron Russo, Mark Taylor, and Kevin Takei, East Bay Regional Parks District; Josh Ackerman, Scott Demers, Dan Gaube, Kate Goodenough, Christina Kereki, Hanna Mounce, Shannon Page, Catalina Reyes, John Takekawa, Kelley Turner, Susan Wainwright-De La Cruz, Alex Westhoff, and Isa Woo, San Francisco Bay Estuary Field Station, Western Ecological Research Center, Biological Resources Division, U.S. Geological Survey; Andrea Claassen, Robin Hunnewell, Jessica Griffiths, and Mark Fogg, Big Sur Ornithology Lab; Jackson Gentry, Karen Peluso, Kate Schafer, Marilou Seiff, and Andrea Swensrud, Marine Science Institute; Roy and Heather Tedder, resident caretakers on Brooks Island; Christy Smith and Giselle Downard, San Pablo Bay National Wildlife Refuge, U.S. Fish and Wildlife Service; Esther Burkett, Tom Huffman, John Krause, Carl Wilcox, and Larry Wyckoff, California Department of Fish and Game; Tiffany Brown, Tom Greiner, Kent Hespeler, Kathy Hieb, Dennis Riley, Steven Slater, Gary Webb, Central Valley Bay-Delta Branch, California Department of Fish and Game; Dave Shuford, PRBO Conservation Science; Dave Craig, Willamette University; Kevin Ryan, Pam Sanguinetti, Annette de Knijf, and staff, U.S. Fish and Wildlife Service Washington Maritime National Wildlife Refuge Complex; Kolleen Irvine and Cathy Wagoner, Dungeness National Wildlife Refuge Rangers; Amber Cox, Resident Caretaker on Dungeness National Wildlife Refuge; John Pease, Manager of Dungeness Recreation Area, the Friends of Dungeness National Wildlife Refuge, and Sarah Stieg, volunteer; Office of Law Enforcement, Sacramento, CA; Office of Law Enforcement, Redmond, WA; and the Oregon Coast National Wildlife Refuge.

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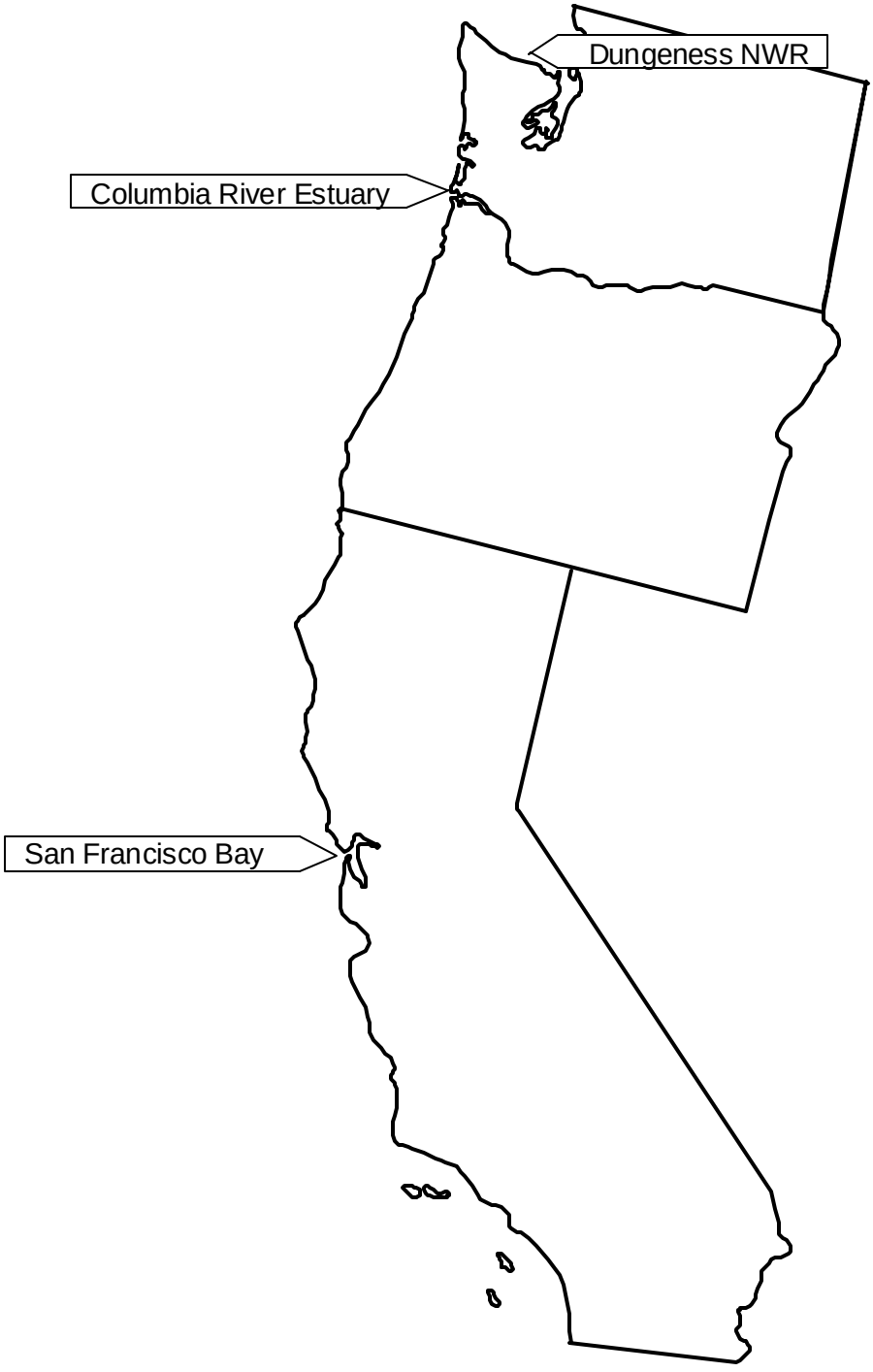

Figure 1. Caspian tern nesting areas mentioned in this report.

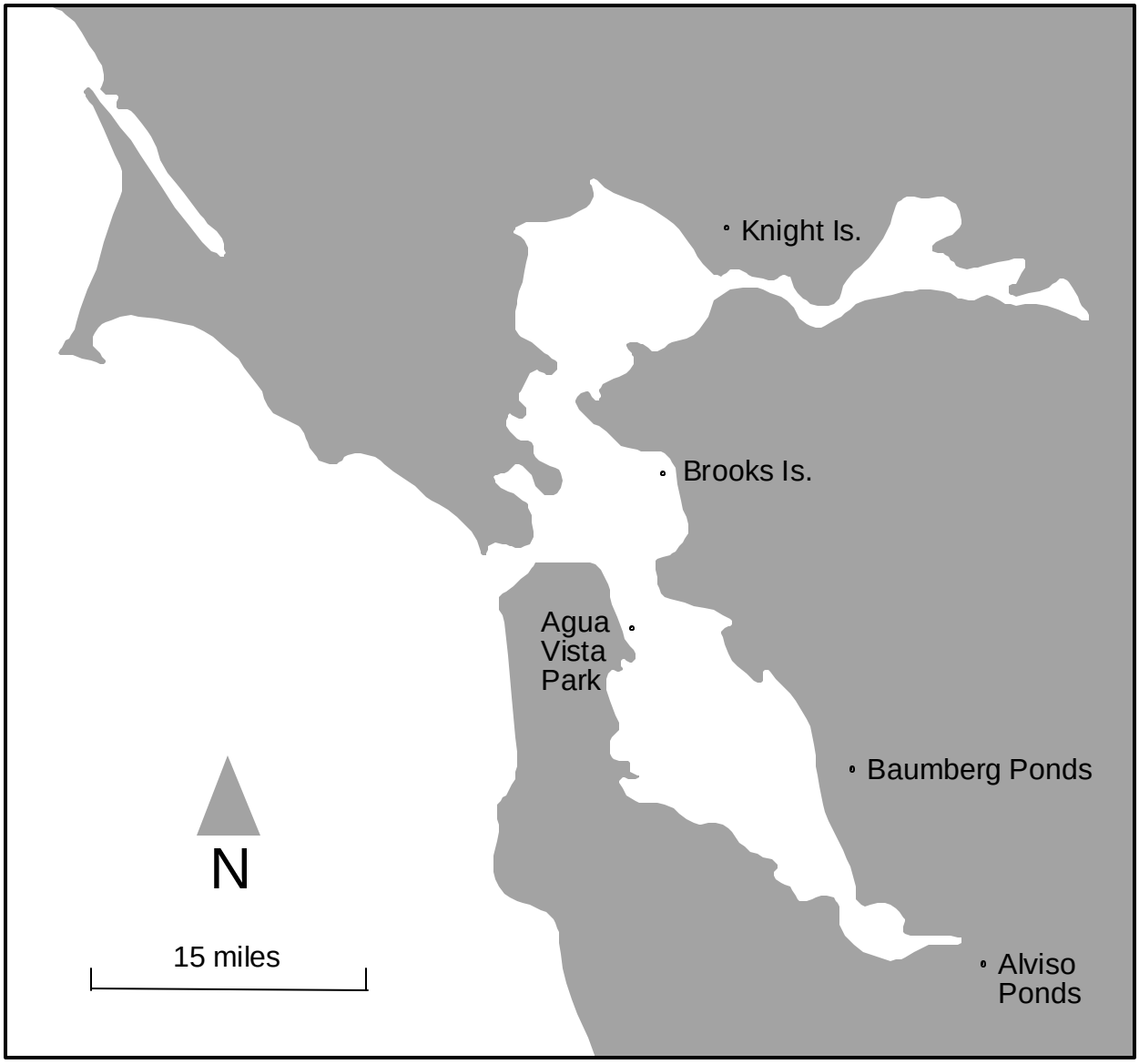

Figure 2. Map of the San Francisco Bay area showing the locations of known active breeding colonies of Caspian terns in 2004.

Figure 3. Map of the Brooks Island tern colony areas in 2004.

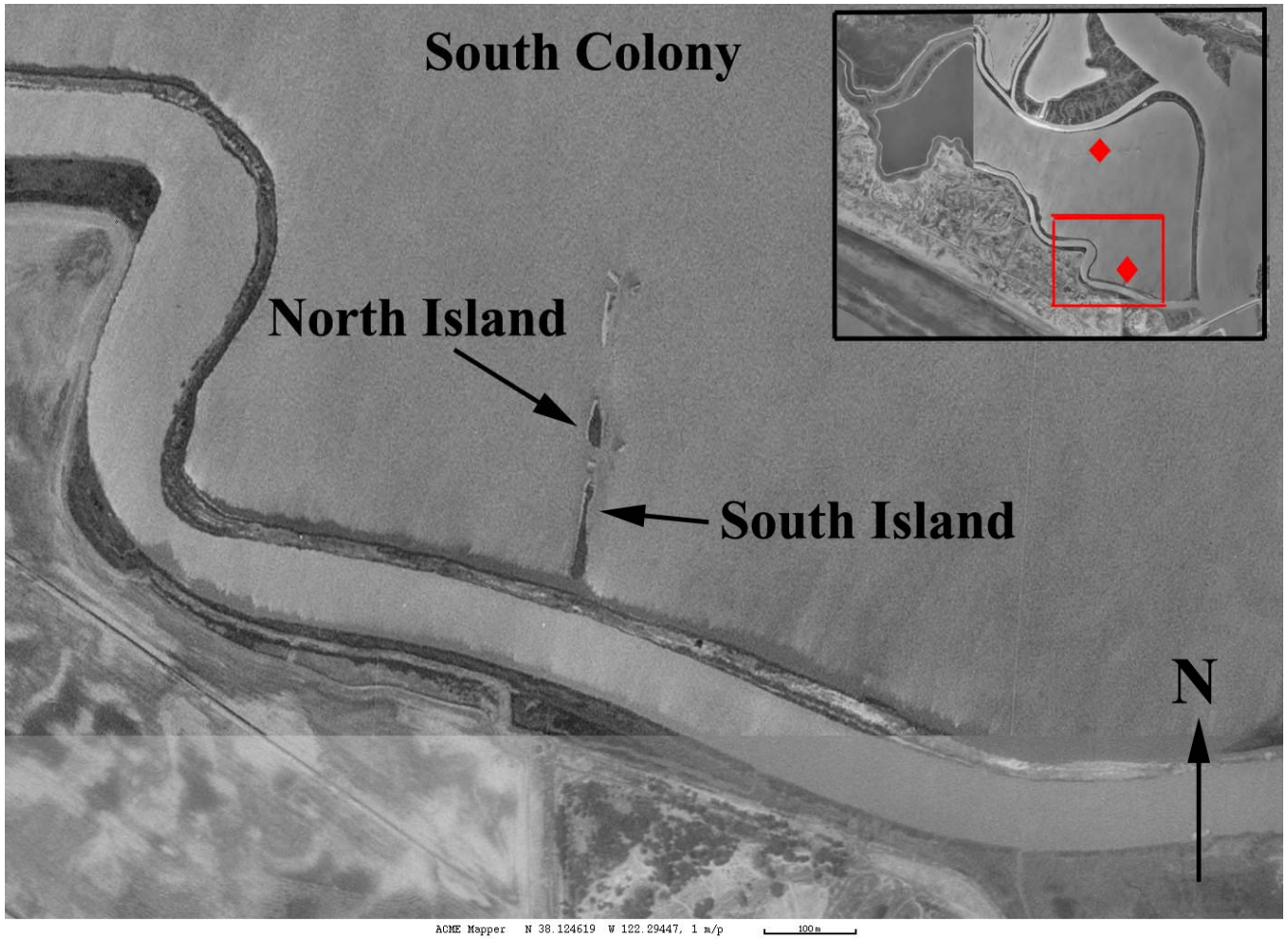

Figure 4. Map of the Knight Island tern colony (South Colony) in 2004. The location of the North Colony at Knight Island is also shown (inset) but terns did not attempt to nest there in 2004 due to tidal inundation and island erosion.

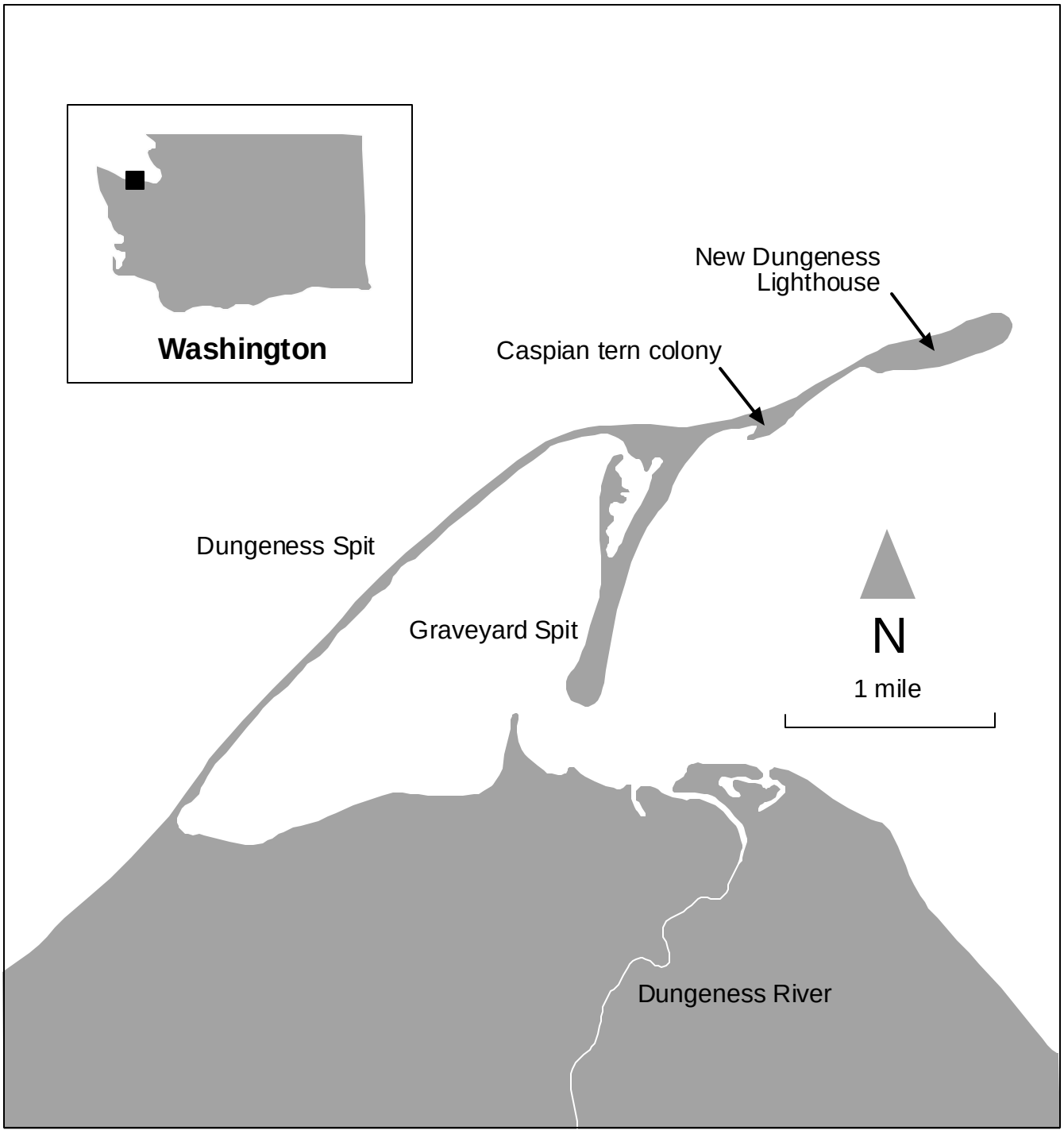

Figure 5. Map of Dungeness National Wildlife Refuge showing the location of the active breeding colony of Caspian terns in 2004.

Table 1. Timeline for research activities and Caspian tern nesting chronology at Brooks Island, San Francisco Bay, California in 2004.

Date	Colony	Note
03/07/04	Brooks Is.	First adult terns (3) observed near colony
03/08/04	Brooks Is.	First crew visit to colony site
03/19/04	Brooks Is.	First adult terns (35) observed on-colony
04/02/04	Brooks Is.	Diet data collection begins
04/13/04	Brooks Is.	First sighting of fox tracks on island
04/15/04	Brooks Is.	First tern egg observed (main colony)
04/15/04	Brooks Is.	First sighting of red fox on island
04/15/04	Brooks Is.	First sighting of racoon tracks on island
04/28/04	Brooks Is.	First tern egg observed (NW satellite)
05/08/04	Brooks Is.	High high tide event caused some nest failure
05/09/04	Brooks Is.	Raccoon removed from island
05/13/04	Brooks Is.	Second distinct satellite colony formed (ca. 50 meters NW from NW satellite colony)
05/13/04	Brooks Is.	Red fox removed from island
05/24/04	Brooks Is.	First aerial photo census of colony conducted (East Bay Parks)
05/25/04	Brooks Is.	Second aerial photo census of colony conducted (USFWS)
05/30/04	Brooks Is.	First tern chick observed (main colony)
06/06/04	Brooks Is.	High high tide event caused some nest failure
07/05/04	Brooks Is.	High high tide event caused some nest failure
07/07/04	Brooks Is.	First tern chick fledged (main colony)
07/20/04	Brooks Is.	Chick banding (18 metal banded, 33 color banded)
07/21/04	Brooks Is.	Chick banding (7 metal banded, 20 color banded)
08/07/04	Brooks Is.	Last day of colony observations
08/13/04	Brooks Is.	Observation blind winterized

Table 2. Timeline for research activities and Caspian tern nesting chronology at Knight Island (South Colony), San Pablo Bay, California, 2004.

Date	Colony	Note
03/30/04	Knight Is.	First crew visit to colony site
04/06/04	Knight Is.	First adult terns (23) observed on-colony
04/06/04	Knight Is.	Diet data collection begins
05/02/04	Knight Is.	First tern egg observed
05/04/04	Knight Is.	Spring tide series began; some tern nests flooded
05/08/04	Knight Is.	Spring tide series ended; all active tern nests on south island of colony failed due to inundation
05/14/04	Knight Is.	Re-laying by terns begins
05/27/04	Knight Is.	Aerial photo census of colony conducted (USFWS)
05/30/04	Knight Is.	Spring tide series began; some tern nests inundated
06/06/04	Knight Is.	Spring tide series ended; > 130 nests failed on south island of colony due to inundation
06/08/04	Knight Is.	First tern chick observed
06/28/04	Knight Is.	Spring tide series began
07/05/04	Knight Is.	Spring tide series ended; no new tern nests flooded
07/07/04	Knight Is.	First tern fledgling observed
07/30/04	Knight Is.	Last day of colony observations
08/12/04	Knight Is.	Observation blind removed

Table 3. Timeline for research activities and Caspian tern nesting chronology at Baumberg Ponds (B-10), San Francisco Bay, California in 2004.

Date	Colony	Note
03/27/04	Baumberg Ponds (B10)	First crew visit to colony site
03/27/04	Baumberg Ponds (B10)	First adult terns (28) observed on-colony
03/27/04	Baumberg Ponds (B10)	Diet data collection begins
04/11/04	Baumberg Ponds (B10)	First sighting of grey fox on levee adjacent to island
04/13/04	Baumberg Ponds (B10)	First tern egg observed
04/16/04	Baumberg Ponds (B10)	Colony mostly abandoned; fox predation suspected cause
05/01/04	Baumberg Ponds (B10)	Tide gate opened permanently; salt pond converted to muted tidal basin
05/03/04	Baumberg Ponds (B10)	Colony completely abandoned; fox tracks observed on island
06/06/04	Baumberg Ponds (B10)	Last sighting of a Caspian tern on the colony island
07/14/04	Baumberg Ponds (B10)	Pond inadvertently drained when temporary tide gate stuck in open position
07/30/04	Baumberg Ponds (B10)	Last day of colony observations
08/13/04	Baumberg Ponds (B10)	Observation blind removed

Table 4. Timeline for research activities and Caspian tern nesting chronology at Alviso Ponds (A-7), San Francisco Bay, California in 2004.

Date	Colony	Note
04/01/04	Alviso Ponds (A7)	First crew visit to colony site
04/13/04	Alviso Ponds (A7)	First adult terns observed near colony
04/16/04	Alviso Ponds (A7)	First adult terns (21) observed on-colony
04/16/04	Alviso Ponds (A7)	Diet data collection begins
05/09/04	Alviso Ponds (A7)	First tern egg observed
05/30/04	Alviso Ponds (A7)	First tern chick observed
07/04/11	Alviso Ponds (A7)	First tern chick fledged (suspected)
07/11/04	Alviso Ponds (A7)	First tern fledgling observed
08/03/04	Alviso Ponds (A7)	Last day of colony observations

Table 5. Timeline for research activities and Caspian tern nesting chronology at Agua Vista Park, San Francisco Bay, California in 2004.

Date	Colony	Note
03/26/04	Agua Vista	First crew visit to colony site
03/26/04	Agua Vista	First adult terns (15) observed on-colony
04/06/04	Agua Vista	Diet data collection begins
04/16/04	Agua Vista	First tern egg observed
05/15/04	Agua Vista	First tern chick observed
06/23/04	Agua Vista	First tern fledgling observed
08/03/04	Agua Vista	Last day of colony observations

Table 6. Timeline for research activities and Caspian tern nesting chronology at Dungeness NWR, Washington in 2004.

Date	Colony	Note
03/23/04	Dungeness Spit	First adult tern observed near colony
04/05/04	Dungeness Spit	First crew visit to colony site
04/19/04	Dungeness Spit	First adult tern (1) observed on-colony
04/24/04	Dungeness Spit	Diet data collection begins
05/07/04	Dungeness Spit	Observation blind constructed
05/10/04	Dungeness Spit	First tern egg observed
05/29/04	Dungeness Spit	Tern nest predation discovered (roughly a third of the active nests depredated)
05/29/04	Dungeness Spit	First sighting of coyote within the tern colony eating eggs (coyote visited the colony nightly for more than a week)
05/29/04	Dungeness Spit	Adult terns discontinued night-time colony attendance (remaining eggs were not incubated at night for more than a week)
06/07/04	Dungeness Spit	USDA-Wildlife Services begins hazing coyote
06/15/04	Dungeness Spit	First tern chicks observed on colony
06/30/04	Dungeness Spit	Aerial photo census of colony conducted (USFWS)
07/10/04	Dungeness Spit	First tern fledgling observed
08/02/04	Dungeness Spit	Colony walk-through conducted to estimate total number of tern chicks and eggs on colony
08/30/04	Dungeness Spit	Last day of colony observations; observation blind removed

Table 7. Average number of adult Caspian terns counted each week at five nesting colonies in the San Francisco Bay area (Brooks Island [Main Colony], Brooks Island [NW Satellite Colony], Knight Island [South Colony], Baumberg Ponds [B-10], Alviso Ponds [A-7], Agua Vista Park) and one colony on the Olympic Peninsula, Washington (Dungeness Spit NWR) in 2004.

	San Francisco Bay area						
Week ending	Brooks Is. (main colony)	Brooks Is. (NW satelitte)	Knight Is. (South colony)	Baumberg Ponds (B-10)	Alviso Ponds (A-7)	Agua Vista Park	Dungeness Spit
14-Mar	0	0	no data	no data	no data	no data	no data
21-Mar	**35**	0	no data	no data	no data	no data	no data
28-Mar	**113**	0	no data	**28**	no data	**15**	no data
4-Apr	**275**	**35**	0	**46**	0	**38**	no data
11-Apr	112	43	14	14	0	35	0
18-Apr	197	74	37	10	21	41	0
25-Apr	293	45	63	8	4	56	2
2-May	340	48	59	3	41	68	66
9-May	502	123	145	0	23	55	82
16-May	520	270	208	0	28	48	158
23-May	548	275	238	0	28	50	215
30-May	503	228	243	0	26	40	181
6-Jun	616	199	254	0	29	44	195
13-Jun	522	no data	193	0	25	53	303
20-Jun	601	202	218	0	20	59	367
27-Jun	608	224	176	0	18	68	336
4-Jul	489	180	181	0	no data	72	311
11-Jul	304	141	130	0	13	64	314
18-Jul	280	145	80	0	no data	54	384
25-Jul	238	no data	65	0	14	47	392
1-Aug	159	no data	46	0	15	35	389
8-Aug	59	no data	13	0	20	31	261
15-Aug	no data	no data	no data	no data	no data	no data	314
22-Aug	no data	no data	no data	no data	no data	no data	213
29-Aug	no data	no data	no data	no data	no data	no data	140

Table 8. Caspian tern diet composition at Brooks Island (Main Colony), San Francisco Bay, based on percent of identifiable prey items delivered as bill-loads to the colony in 2004. TOTAL percentages are averages of the weekly percentages.

Week ending	N	Anchovy	Butterfish	Centrarchid	Clupeid	Croaker	Flatfish	Goby	Kelpfish	Trout	Salmon	Sand lance	Sculpin	Shark	Silverside	Surfperch	Toadfish	Tomcod	UNID
11-Apr	244	26.2	0	0	12.7	0.4	0.4	6.5	0	0.4	0	0	0	0	21.4	25.4	2	0	4.5
18-Apr	136	30.1	0	0	16.9	0.7	0.7	4.4	0	0.7	0	0	0	0.7	16.9	22.1	4.4	0	2.2
25-Apr	243	36.6	0	0.4	14.8	0	0	3.7	0	0.4	0	0	0	0	21.8	16.9	0.8	0.4	4.1
2-May	433	34.4	0	0.2	13.2	0.2	0	3.7	0.5	0.2	0	0	1.2	0.5	28.7	13.6	0.7	0	3
9-May	615	22.3	0	0.7	21	0	0	2	0	0.2	0	0	0.5	0.7	19.9	26.7	0.2	0	6.2
16-May	443	13.1	0	1.1	17.4	0	0	4.8	0	0.2	0.2	0	1.1	0.2	23	29.3	0.5	0	9
23-May	287	12.5	0	1	28.2	1	0	1.7	0	0	3.4	0	0.6	0	22.3	23	0.7	0.3	4.9
30-May	417	13.9	0.2	0.9	18	0.7	0	2.2	0	0	5.3	0	1.2	0	16.8	33.1	0.5	0.5	6.7
6-Jun	411	25.3	0	0	23.8	0.7	0	0.9	0	0	18.5	0.5	2	0	10.9	7.8	1	0	8.5
13-Jun	365	26.6	0.8	0	23.3	0.5	0	1.9	0	0	9.3	0	1.6	0	7.6	17.8	0.5	0	9.9
20-Jun	340	27.6	0	0	30.9	0	0	1.8	0	0	10	0.3	0.6	0	13.2	4.4	1.5	0	9.7
27-Jun	453	13.5	0	0	21.4	0.2	0	2.4	0	0	4.9	0	0.4	0	9.3	37.7	4.4	0	5.7
4-Jul	378	14.6	0.3	0	26.7	0	0	1.9	0	0	4	0	3.2	0	16.4	8.7	4.8	0.3	19.3
11-Jul	287	11.1	0.3	0.3	18.5	0.3	0	1.7	0	0.3	0.7	0	3.8	1	8	32.7	12.5	4.2	4.2
18-Jul	475	20.4	0.2	0.4	16.6	0	0	1.9	0	0.2	3	0	4.6	0	11.2	16.6	5.9	1.5	17.5
25-Jul	90	42.2	0	0	22.2	1.1	1.1	1.1	0	0	0	0	0	0	11.1	5.6	3.3	7.8	4.4
1-Aug	60	35	1.7	3.4	33.3	3.3	0	0	0	0	0	1.7	3.3	0	0	11.7	3.3	1.7	1.7
8-Aug	89	33.7	1.1	0	20.2	0	0	2.2	0	0	0	0	1.1	0	24.7	11.2	3.4	0	2.2
TOTAL	5766	24.4	0.3	0.5	21.1	0.5	0.1	2.5	0.0	0.1	3.3	0.1	1.4	0.2	15.7	19.1	2.8	0.9	6.9

NOTE: The "Salmon" category consisted primarily or entirely of juvenile Sacramento River fall run chinook salmon (not ESA-listed).

NOTE: The "Trout" category consisted of stocked rainbow trout from nearby reservoirs.

NOTE: The "UNID" category consisted of unidentified non-salmonids.

Table 9. Caspian tern diet composition at Knight Island (South Colony), San Pablo Bay, California, based on percent of identifiable prey items delivered as bill-loads to the colony in 2004. TOTAL percentages are averages of the weekly percentages.

Week ending	N	Anchovy	Butterfish	Centrarchid	Clupeid	Croaker	Goby	Trout	Salmon	Sculpin	Silverside	Surfperch	Toadfish	Tomcod	UNID
11-Apr	20	5	0	0	5	0	35	0	0	0	0	35	10	0	10
18-Apr	31	0	0	3.2	6.5	0	35.5	0	0	0	41.9	6.5	3.2	0	3.2
25-Apr	31	3.2	0	19.4	0	0	51.6	0	0	0	16.1	9.7	0	0	0
2-May	103	7.8	0	15.6	16.5	0	12.6	0	1.9	0	26.2	6.8	1	0	11.7
9-May	204	0.5	0	24.1	9.8	2.5	13.8	0	0	0	38.2	3.5	0.5	0	7.4
16-May	127	3.9	0	6.3	42.5	1.6	5.5	0	11.8	0	9.4	4	0	0	15
23-May	199	4	0	6	6.5	8.5	2	0.5	41.2	0	15.1	3	0	0	13.1
30-May	111	1.8	0	0.9	7.2	6.3	0.9	0	60.4	0	11.7	0.9	0	0	9.9
6-Jun	167	1.2	1.2	4.8	8.4	4.2	0	0	49.1	1.8	21	1.8	0.6	0	6
13-Jun	99	4	1	11.2	8.1	6.1	0	0	47.5	0	9.1	4	2	0	7.1
20-Jun	113	0	0	1.8	0.9	0.9	2.7	0	86.7	0.9	2.7	3.6	0	0	0
27-Jun	171	1.8	0	4.7	5.8	2.3	0.6	0	72.6	0	4.1	2.4	0.6	0	5.3
4-Jul	177	0	1.1	10.8	4.5	0.6	1.1	1.7	14.1	0.6	46.3	13.6	1.7	0.6	3.4
11-Jul	56	5.4	0	9	1.8	5.4	7.1	0	12.5	1.8	16.1	16	10.7	0	14.3
18-Jul	98	8.2	1	16.3	11.2	1	5.1	0	20.4	1	4.1	9.2	6.1	1	15.3
25-Jul 1-Aug 8-Aug	13	0	0	46.2	0	7.7	0	0	0	0	7.7	15.4	0	0	23.1
TOTAL	1720	2.9	0.3	11.3	8.4	2.9	10.8	0.1	26.1	0.4	16.9	8.5	2.3	0.1	9.1

NOTE: The "Salmon" category consisted primarily or entirely of juvenile Sacramento River fall run chinook salmon (not ESA-listed).

NOTE: The "Trout" category consisted of stocked rainbow trout from nearby reservoirs.

NOTE: The "UNID" category consisted of unidentified non-salmonids.

Table 10. Caspian tern diet composition at Baumberg Ponds (B-10), San Francisco Bay, California, based on percent of identifiable prey items delivered as bill-loads to the colony in 2004. All of the prey categories listed were found in the diet of terns nesting at Baumberg Ponds (B-10) in 2003. TOTAL percentages are averages of the weekly percentages.

Week ending	N	Anchovy	Butterfish	Centrarchid	Clupeid	Flatfish	Goby	Salmon	Sculpin	Shark	Silverside	Surfperch	Toadfish	UNID
11-Apr	20	0	0	0	0	0	5	0	0	20	10	60	0	5
18-Apr	5	0	0	0	0	0	20	0	0	20	60	0	0	0
25-Apr	4	0	0	0	0	0	25	0	0	25	0	50	0	0
2-May	2	0	0	0	0	50	50	0	0	0	0	0	0	0
9-May														
16-May														
23-May														
30-May														
6-Jun														
13-Jun														
20-Jun														
27-Jun														
4-Jul														
11-Jul														
18-Jul														
25-Jul														
1-Aug														
8-Aug														
TOTAL	31	0.0	0.0	0.0	0.0	12.5	25.0	0.0	0.0	16.3	17.5	27.5	0.0	1.3

NOTE: Caspian terns abandoned the Baumberg Pond colony on 3 May, presumably due to fox predation on active tern nests.

NOTE: The "UNID" category consisted of unidentified non-salmonids.

Table 11. Caspian tern diet composition at Alviso Ponds (A-7), San Francisco Bay, California, based on percent of identifiable prey items delivered as bill-loads to the colony in 2004. TOTAL percentages are averages of the weekly percentages.

Week ending	N	Anchovy	Centrarchid	Clupeid	Flatfish	Goby	Trout	Sculpin	Silverside	Surfperch	UNID
11-Apr											
18-Apr											
25-Apr											
2-May	47	0	0	2.1	0	91.5	0	0	0	0	6.4
9-May	21	0	0	0	0	95.3	0	0	0	0	4.8
16-May	15	0	0	0	0	73.4	0	0	13.3	0	13.3
23-May	5	0	20	20	0	20	0	0	0	0	40
30-May	4	25	0	0	0	25	0	0	25	0	25
6-Jun	12	0	0	8.3	0	33.3	8.3	8.3	0	0	41.7
13-Jun	16	0	0	0	0	37.5	37.5	0	0	0	25
20-Jun	8	0	0	0	0	37.5	0	0	0	12.5	50
27-Jun	9	0	0	0	0	88.9	0	0	0	0	11.1
4-Jul											
11-Jul	9	0	0	0	0	100	0	0	0	0	0
18-Jul											
25-Jul	1	0	0	0	0	100	0	0	0	0	0
1-Aug	15	0	0	0	0	0	0	40	0	0	60
8-Aug	2	0	0	0	0	0	0	0	0	0	100
TOTAL	164	1.9	1.5	2.3	0.0	54.0	3.5	3.7	2.9	1.0	29.0

NOTE: The "Trout" category consisted of stocked rainbow trout from nearby reservoirs.

NOTE: The "UNID" category consisted of unidentified non-salmonids.

NOTE: Unable to count terns or conduct diet fish ID due to presence of American white pelicans on the island during the week ending 4 July.

NOTE: Colony not visited the week ending 18 July due to construction work on adjacent levees

Table 12. Caspian tern diet composition at the Agua Vista Park colony, San Francisco Bay, California, based on percent of identifiable prey items delivered as bill-loads to the colony in 2004. TOTAL percentages are averages of the weekly percentages.

Week ending	N	Anchovy	Butterfish	Centrarchid	Clupeid	Flatfish	Goby	Salmon	Sand lance	Sculpin	Silverside	Surfperch	Toadfish	UNID
11-Apr	36	27.8	0	0	2.8	0	0	0	0	0	55.6	8.4	0	5.6
18-Apr	6	33.3	0	0	0	0	0	0	16.7	0	50	0	0	0
25-Apr	30	13.3	0	0	13.3	0	0	0	3.3	0	53.3	6.6	0	10
2-May	31	12.9	0	0	16.1	0	0	0	0	0	48.4	3.2	0	19.4
9-May	19	10.5	0	0	26.3	5.3	0	0	0	0	15.8	42.1	0	0
16-May	30	10	0	0	56.7	0	0	0	0	0	26.6	3.3	0	3.3
23-May	28	14.3	0	0	50	0	0	3.6	0	0	7.1	14.3	0	10.7
30-May	41	4.9	0	2.4	9.8	0	2.4	0	0	0	14.6	51.2	0	14.6
6-Jun	37	10.8	0	0	27	0	0	2.7	0	0	27	0	0	32.4
13-Jun	120	6.7	0	0.8	17.5	0	3.3	0.8	0	1.6	32.5	11.6	1.7	23.3
20-Jun	64	20.3	0	0	23.4	0	0	4.7	1.6	0	21.9	9.4	0	18.8
27-Jun	100	13	1	0	16	0	2	3	0	0	14	27	7	17
4-Jul	61	11.5	0	0	19.7	0	1.6	1.6	0	0	19.7	22.9	11.5	11.5
11-Jul	137	9.5	0	0	15.3	0	3.6	1.5	0	2.9	18.2	10.9	19.7	18.2
18-Jul	40	25	0	0	2.5	0	0	0	0	0	5	40	12.5	15
25-Jul	32	12.5	0	0	28.1	0	3.1	6.3	0	3.1	21.9	15.6	6.3	3.1
1-Aug														
8-Aug	5	20	0	0	20	0	0	0	0	0	40	0	0	20
TOTAL	817	15.1	0.1	0.2	20.3	0.3	0.9	1.4	1.3	0.4	27.7	15.7	3.5	13.1

NOTE: The "Salmon" category consisted of unidentified salmonids.

NOTE: The "UNID" category consisted of unidentified non-salmonids.

Table 13. Caspian tern diet composition at the Dungeness NWR colony, Washington, based on percent of identifiable prey items delivered as bill-loads to the colony in 2004. TOTAL percentages are averages of the weekly percentages.

Week ending	N	Anchovy	Clupeid	Cod	Flatfish	Gunnel	Pipefish	Prickleback	Salmonid	Sand lance	Sculpin	Smelt	Stickleback	Surfperch	Toadfish	UNID
11-Apr																
18-Apr																
25-Apr	5	0	0	0	0	0	0	0	40	0	0	0	0	20	0	40
2-May	157	0	4.5	0	0	0	0	0	18.5	0	0	7.6	0	55.4	0	14
9-May	141	0	19.1	0	0	0	0	0	5	0	1.4	5	0	67.4	0.7	1.4
16-May	571	0	7.4	0	0	0	0.2	0	29.1	0.7	1.1	7.5	0.2	52.2	0.2	1.6
23-May	603	0	10.1	0	0	0	0	2.5	35.5	1.3	1.7	3	0	43.8	0	2.2
30-May	410	0	6.8	0	0.2	0	0.2	5.6	57.1	0	1.7	2	0	23.7	0	2.7
6-Jun	183	0	15.3	0	0	0	0	3.3	43.2	0	1.1	9.3	0	22.9	0	4.9
13-Jun	531	0.4	6.6	0	0	0	0	2.3	49.9	1.3	2.4	7.2	0.4	28.1	0	1.5
20-Jun	421	0	14.3	0	0.2	0	0	5.7	21.6	1.4	4.7	5.7	0	43.2	0	3.1
27-Jun	299	0	7.7	0	0	0	0	7.4	16.1	0.7	7	4	0	53.5	0	3.7
4-Jul	359	0	7.8	0	0.3	0	0	15.6	12.5	0	11.4	8.9	0	41.5	0	1.9
11-Jul	326	0.3	3.7	0	0	2.1	0	5.2	22.4	1.2	18.7	8.3	0	35.2	0	2.8
18-Jul	392	0	3.8	0.3	1	1.3	0	26.8	14.3	0.3	19.4	3.4	0.3	27.3	0	2
25-Jul	251	0	5.2	0	0	0	0	6.4	31.9	0	17.9	4	0	33.9	0	0.8
1-Aug	305	0	3.6	0	0.3	0.3	0	10.8	49.2	0	17	9.6	0	7.6	0	1.6
8-Aug	311	14.5	0.3	0	0.6	0.3	0	4.8	24.1	0	33.4	8	0	12.5	0	1.3
15-Aug	420	0	2.1	0	0.5	0	0	4	53.1	0	26.6	4.3	0	8.3	0	1
22-Aug	329	0.3	2.7	0.3	0.3	3	0	5.8	50.5	0	22.2	4.9	0	10	0	0
29-Aug	194	0	2.1	0	0	1.5	0	2.1	20.6	0	43.8	7.2	0	22.7	0	0
TOTAL	6208	0.8	6.5	0.0	0.2	0.4	0.0	5.7	31.3	0.4	12.2	5.8	0.0	32.1	0.0	4.6

NOTE: The "UNID" category consisted of unidentified non-salmonids.

Table 14. Potential limiting factors for colony size and nesting success at Caspian tern colonies in the San Francisco Bay area and on Dungeness Spit, Washington in 2004**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, particularly at some colonies in southern San Francisco Bay, but this study does not address that issue directly.

	San Francisco Bay					
	Brooks Is.	Knight Is.	Baumberg Ponds (B10)	Alviso Ponds (A7)	Agua Vista	Dungeness Spit
Availability of nesting habitat	**X**[1]	**X**[8]	**X**[12]	**X**[12]	**X**[21]	
Quality of nesting substrate		x	**X**[13]	**X**[13]	**X**[22]	
Prey fish availability	?	?		?		
Mammalian predators	**X**[2]	?[9]	**X**[14]	x[17]		**X**[23]
Encroachment by other colonial waterbirds	x[3]	**X**[10]	?[15]	?[18]		
Avian predators (other than gulls)	x	x	?[16]	?[16]		x[24]
Avian disturbances (other than gulls)						x[24]
Gull kleptoparasitism	x[4]	x[11]	?	?[19]	?	
Gull nest predation	**X**[4]	**X**[11]	?	?[19]	?	x[25]
Human disturbance	**X**[5]	x	?	x		x[26]
Recreational boats (including canoes and kayaks)	x[6]	?			?	
Commerical shipping (including dredges)	?				?	
Commercial, military, or enforcement aircraft	x[7]			x[20]		
Recreational aircraft	x					

[1] encroaching pickleweed, grasses, and non-native plants; spring/summer high-high tidal events
[2] one raccoon present on the island (removed 9 May); one red fox present on the island (removed 13 May); rats present on the island
[3] expanding California gull colony
[4] by California and western gulls
[5] by kite boarders, wind surfers, sport fisherman, kayakers, and sail boaters
[6] individual or non-organized group kayakers continue to land on the beaches of Brooks Island in close proximity to both colonies, especially NW Brooks
[7] primarily low flying US Coast Guard and law enforcement helicopters; massive colony disturbances caused during air show on 4 July
[8] tidally influenced since dike was breached in 2003; during high tide nesting habitat reduced, during low tide land bridges provide access to predators; vegetation encroachment on colony due to reduced salinity in pond
[9] previous problems with mammalian predators (2003); not observed in 2004
[10] expanding double-crested cormorant colony
[11] expanding double-crested cormorant colony is attracting gulls to island, in addition to displacement of terns by high tide events exposing eggs and chicks to depredation
[12] changing water levels due to mitigation for hyper-saline conditions in adjacent salt ponds; water control structure opened in July 2004
[13] substrate sticky when wet and terns have difficulty digging scrapes
[14] grey fox sighted on levee (11 April) and tracks found on colony that was depredated (3 May); pond unintentially drained on 14 July providing easier access to the island by mammalian predators
[15] white pelicans and double-crested cormorants using island as roost; eggs and nests on Baumberg Ponds (B10) trampled by these birds in previous year
[16] raven nests on nearby power poles; ravens not observed preying on tern eggs or chicks
[17] grey fox tracks sighted on levee road
[18] white pelicans using island as roost
[19] over 6,500 nesting pairs of California Gulls are within 1 km of tern colony
[20] massive colony disturbances caused during air show on 30 May
[21] habitat shrinking due to continued slow collapse of pier into bay
[22] nesting on pier deck where there is little or no nesting substrate, one of the two pier fragments is calving into bay and appeared to have less available area for nesting in 2004
[23] coyote repeatedly observed at colony site eating eggs and causing nesting terns to leave their nests unattended at night; evidence of other mammailian predators in the vacinity of the colony
[24] bald eagles and peregrine falcons caused frequent disturbance to the tern colony
[25] gull predation on terns eggs and chicks was an increasing factor as the season progressed
[26] public access beach adjacent to the colony site; human disturbance to the colony has been reported in previous years and twice in 2004

Table 15. Size and productivity of Caspian tern nesting colonies in the San Francisco Bay area and at Dungeness Spit, Olympic Peninsula, Washington during 2004.

	Colony Size (# breeding pairs)	# Fledglings Produced	Productivity (fledglings/pair)
San Francisco Bay			
Brooks Island	1,040[1]	504	0.48
Main Sub-colony	695	353	0.51
NW Satellite Sub-colony	345	151[5]	0.44
Knight Island (South Colony)	238[1]	76[5]	0.32
North Island	100[1]	76[5]	0.76
South Island	138[2]	0	0.00
Baumberg Ponds (B-10)	28[3]	0	0.00
Alviso Ponds (A-7)	28	14[5]	0.50
Agua Vista Park	38	31[5]	0.82
Olympic Peninsula			
Dungeness Spit NWR	233 – 293[4]	211 – 295[6]	0.80 – 1.12

[1] Minimum estimate of the number of breeding pairs due to re-nesting that occurred after the aerial survey was conducted

[2] These pairs may have been included in subsequent censuses at other colonies in the Bay Area (see text).

[3] Estimated number of breeding pairs based on maximum counts of adult terns sitting in nests (both incubating and non-incubating) prior to colony abandonment (these pairs may have been included in subsequent censuses at other colonies in the Bay area)

[4] Uncertainty in the number of breeding pairs due to obstructed view of the colony from the blind and re-nesting by some pairs after the aerial photo census

[5] Minimum estimate of the number of fledglings due to observation distance and visual obstructions

[6] Uncertainty in the number of fledglings due to obstructed view of the colony from the blind

Table 16. Disturbance and nest predation rates at five nesting colonies in the San Francisco Bay area (Brooks Island [Main Colony], Knight Island [South Colony], Baumberg Ponds [B-10], Alviso Ponds [A-7], Agua Vista Park) and one colony on the Olympic Peninsula, Washington (Dungeness Spit NWR) in 2004.

		Colony Disturbance[1]		Nest Predation[2]	
	Hrs of observation	#	Disturbances/hr	#	Predation events/hr
San Francisco Bay					
Brooks Is.	320.2	27	0.084	31	0.097
Knight Is.	180.1	7	0.039	10	0.056
Alviso Ponds (A-7)	32.9	0	0.000	0	0.000
Baumberg Ponds (B-10)	7.9	2	0.253	0	0.000
Agua Vista Park	143.5	5	0.035	1	0.007
Olympic Peninsula					
Dungeness Spit	234.3	195	0.832	15	0.064

[1] A colony disturbance is defined as an event which causes terns to be alarmed and take flight from the colony location.
[2] Nest predation is defined as either a tern egg or tern chick being taken from a active nest by a predator.