Trends in Caspian Tern Nesting and Diet in San Francisco Bay: Conservation Implications for Terns and Salmonids

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Abstract.—Colony size, nesting ecology and diet of Caspian Terns (*Hydroprogne caspia*) were investigated in the San Francisco Bay area (SFBA) during 2003-2009 to assess the potential for conservation of the tern breeding population and possible negative effects of predation on survival of juvenile salmonids (*Oncorhynchus* spp.). Numbers of breeding Caspian Terns declined 36% from 2003 to 2009, mostly due to abandonment of the Knight Island colony and decline of the Brooks Island colony, the two largest colonies in the SFBA. Concurrently, nesting success declined 69% associated with colony site characteristics such as (a) quality and quantity of nesting substrate, (b) vulnerability to nest predators, (c) displacement by other colonial waterbirds and (d) human disturbance. Marine fishes were the predominant prey in tern diets from the SFBA; however, diet composition varied among colonies. Juvenile salmonids comprised 22.9% of the diet of terns nesting in the North Bay, 5.3% of diet of terns nesting in the Central Bay, and 0.1% in the South Bay. Construction or restoration of nesting islands in the South Bay may help maintain and restore breeding Caspian Terns without enhancing mortality of salmonid stocks of conservation concern. *Received 8 February 2011, accepted 18 October 2011.*

Key words.—Caspian Tern, colony restoration, colony size, diet composition, *Hydroprogne caspia,* limiting factors, productivity, *Oncorhynchus*, salmonids, San Francisco Bay.

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Over the past few decades, the numbers of Caspian Terns (*Hydroprogne caspia*) have increased in several areas of North America, including along the Pacific Coast (Wires and Cuthbert 2000; Suryan *et al.* 2004). The breeding population of Caspian Terns in the Pacific Coast region was previously centered in California, with an estimated 52% of the Pacific Coast population nesting in the San Francisco Bay Area (SFBA) in 1979 (Grinnell and Miller 1944; Shuford and Craig 2002). However, recently, the Pacific Coast population has shifted away from SFBA, in particular to one location in the Columbia River estuary where a large proportion (ca. 67%) of the Pacific Coast population of Caspian Terns now breeds (Wires and Cuthbert 2000; Roby *et al.* 2002).

The SFBA supports over one million waterbirds annually (Page *et al.* 1999; Takekawa *et al.* 2001). The history of Caspian Tern breeding colonies in the SFBA has been dynamic, with frequent changes in both the location and size of colonies. Published estimates indicate that Caspian Terns nested at 13 different colony locations in the SFBA during 1982-2002 (Strong *et al.* 2004). During the four years when all 13 colony sites were surveyed (1997, 2000-2002), Caspian Terns nested at 6-7 different colony sites in each year, with colony size ranging from 729 to 1,317 breeding pairs (Strong *et al.* 2004). However, low productivity of Caspian Terns during this period may have contributed to low colony site fidelity and low recruitment (Cuthbert 1988; Danchin *et al.* 1998; Strong *et al.* 2004). Similarly, Caspian Terns nesting in SFBA have been affected by habitat modification throughout the bay, including conversion of salt ponds to intertidal marshes (Warnock *et al.* 2002). Additional habitat modification in

SFBA has occurred since the last published report on nesting Caspian Terns in SFBA (Strong *et al.* 2004); however, no up-dated information has been published on the number, productivity or limiting factors for Caspian Terns nesting in the SFBA since 2002.

Impacts of Caspian Tern predation on Pacific salmonid (*Oncorhynchus* spp.) populations listed under the U.S. Endangered Species Act (ESA) have been well documented in the Columbia River basin for over a decade (Collis *et al.* 2002; Roby *et al.* 2002). However, impacts of avian predation on local fish populations vary by colony location (Collis *et al.* 2002). For instance, Roby *et al.* (2002) found large differences in diet composition of Caspian Terns after the breeding colony was relocated < 30 km from the original colony site in the Columbia River estuary. Despite documented differences in Caspian Tern diet and impacts to survival of ESA-listed salmonids by Caspian Tern colonies in the Columbia River basin (Collis *et al.* 2002; Roby *et al.* 2002; Antolos *et al.* 2005), little information is available regarding the diet of Caspian Terns nesting at various colonies throughout SFBA or their potential impact on ESA-listed salmonid populations in the SFBA (Evans *et al.* 2011).

The purpose of this study was to assess diet composition, colony size, productivity, and factors limiting colony size and productivity for Caspian Terns nesting in the San Francisco Bay area during 2003-2009. Data on the nesting ecology and diet of Caspian Tern in SFBA are of particular importance as current management plans to recover ESA-listed salmonids in the Columbia River basin involve relocating a portion of Caspian Terns nesting in the Columbia River estuary to other locations, including SFBA (USFWS 2006). Data are therefore needed to assess the suitability of sites chosen for future and on-going Caspian Tern colony restoration efforts in the SFBA to maximize potential success of bird colonies, while minimizing potential impacts to ESA-listed Chinook Salmon (*O. tshawytscha*) and Steelhead Trout (*O. mykiss*) from the Sacramento-San Joaquin Basin.

METHODS

Study Area

For the purposes of this study, the SFBA was divided into three sectors: the North Bay was defined as the area north of the Richmond-San Rafael Bridge to Carquinez Strait; the Central Bay was defined as the area south of the Richmond-San Rafael Bridge to Hunters Point on the west bank and San Leandro Channel on the east bank; the South Bay was defined as the area south of Hunters Point and San Leandro Channel (Fig. 1). During this study, Caspian Tern breeding colonies were located in the North Bay at Knight Island; in the Central Bay at Brooks Island and Agua Vista Park; and in the South Bay at Alviso Ponds A-7, Eden Landing E-10, Coyote Hills, Ravenswood, Stevens Creek B-2, and Redwood Shores (Table 1; see Shuford and Craig 2002 and BRNW 2009 for colony site descriptions). Project personnel collected all data presented for 2003-2005 and 2008-2009, while comparable data on colony status and size during 2006-2007 were provided by the San Francisco Bay Bird Observatory (C. Strong, SFBBO, personal communication) for the Agua Vista colony and all South Bay tern colonies, and by U.S. Fish and Wildlife Service (G. McChesney, USFWS, personal communication) and Humboldt State University (P. Capitolo, HSU, personal communication) for the Brooks Island and Knight Island colonies.

Colony Size

Colony monitoring was conducted during the Caspian Tern breeding season, which occurred from late March through late July/early August. Nesting pairs on colonies were counted from observation blinds (Brooks Island, Knight Island, Eden Landing E-10, and Stevens Creek B-2) or from vantage points that were a sufficient distance from the colony to conduct counts while avoid-

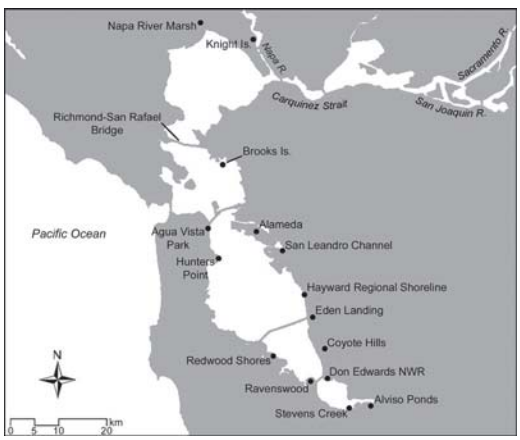

Figure 1. San Francisco Bay study area showing locations of past, present, and future (planned) Caspian Tern nesting colonies and other locations mentioned in the text.

Table 1. Caspian Tern nesting in the San Francisco Bay area during 2003-2009.

Colony	Nesting habitat	Management Authority	Number of years colony active	Extant in 2009 (Y/N)
North Bay				
Knight Is.	Island in salt pond	California Dept. of Fish and Game	3	N
Central Bay				
Brooks Is.	Sandy spit adjacent to natural island	East Bay Parks District	7	Y
Agua Vista Park	Old wooden pier fragment	San Francisco Port Authority	7	Y
South Bay				
Eden Landing E-10	Island in salt pond	California Dept. of Fish and Game	4	Y
Coyote Hills	Salt pond levee	U.S. Fish and Wildlife Service[a]	2	N
Alviso Ponds A-7	Island in salt pond	U.S. Fish and Wildlife Service[a]	4	N
Stevens Creek B-2	Island in salt pond	U.S. Fish and Wildlife Service[a]	3	Y
Ravenswood	Island in salt pond	U.S. Fish and Wildlife Service[a]	3	Y
Redwood Shores	Sewage treatment lagoon levee	South Bayside System Authority	1	Y

[a]Part of Don Edwards San Francisco Bay National Wildlife Refuge.

ing disturbance to nesting birds. Data were collected 2-7 days per week at Brooks Island, Knight Island, and Eden Landing E-10 and 1-2 days per week at other colonies. The number of Caspian Terns nesting at colonies in SFBA was estimated from ground counts of incubating adult Caspian Terns near the end of the incubation period, when maximum colony attendance has been observed (Roby *et al.* 2003; Antolos *et al.* 2005). However, at the Brooks Island colony, size was estimated by counting the total number of nesting Caspian Terns in low-altitude, high-resolution aerial photography taken near the end of the incubation period. Colony size is reported as the number of breeding pairs, hereafter referred to as "pairs".

Productivity

Productivity (average number of young raised per breeding pair) was determined by counting the total number of chicks on colony about one week prior to the median fledging date (~ one week after the first chick fledged) and dividing by the estimated number of pairs attempting to nest at the colony (Roby *et al.* 2002; Roby *et al.* 2003). Productivity for each sector (North, Central, and South bays) was determined by summing the total number of chicks at all colonies in that sector one week prior to the median fledging date and dividing by the estimated number of pairs attempting to nest at colonies in that sector.

Diet Composition

Diet composition was evaluated at three Caspian Tern colonies: Brooks Island in the Central Bay, Knight Island in the North Bay, and Eden Landing E-10 in the South Bay. Diet composition data were not available for all colonies in all years due to funding and logistical constraints. Years when diet composition was evaluated included: 2003-2005 and 2008-2009 at Brooks Island, 2003-2005 at Knight Island, and 2003 and 2008-2009 at Eden Landing E-10.

Caspian Terns transport single whole fish in their bills back to the colony to feed to their mates or young, allowing taxonomic composition of the diet to be determined with the aid of binoculars and spotting scopes. Bill load observations were conducted at both high tide and low tide to control for potential tidal and time of day effects on diet composition. Bill loads were identified to the lowest taxonomic grouping possible, usually to family. We were confident in our ability to distinguish salmonids from non-salmonids and to distinguish among most non-salmonid taxa based on direct observations from blinds. The accuracy of visual identifications was verified using voucher specimens and photographs. We assumed that prey items brought back to the colony by breeding adults were representative of the overall diet of Caspian Terns at that particular colony (Collis *et al.* 2002; Roby *et al* 2003).

A minimum of 200 tern bill loads per week were identified at the Brooks Island colony and 50 bill loads per week were identified at the Knight Island and Eden Landing E-10 colonies. The percent of each prey type in

tern diets was calculated for each two-week period during the breeding season (April through July). The diet composition of Caspian Terns at each colony over the entire breeding season was based on the average across all two-week periods. Further details on the methodology used in this study are presented in Collis *et al.* (2002) and Roby *et al.* (2003).

Limiting Factors

Factors limiting Caspian Tern colony size or productivity were recorded for each colony in each year. Limiting factors evaluated included availability and quality of nesting habitat, nest predation, displacement by other waterbirds and human disturbance. The observational nature of these data provides a qualitative comparison of limited factors at each colony and does not consider some additional factors that may limit Caspian Terns in SFBA (i.e. prey fish availability, contaminants or disease).

RESULTS

Colony Size

The number of Caspian Terns breeding in SFBA during 2003-2009 ranged from 1,372 pairs in 2004 to 830 pairs in 2009. A total of nine islands were occupied by nesting Caspian Terns during the seven-year study period. Six colony sites were located in the South Bay, two in the Central Bay, and one in the North Bay (Table 2). The total number of Caspian Terns nesting in SFBA declined during the study period by 35.5%, from 1,287 pairs in 2003 to 830 pairs in 2009 (Table 2).

The majority of nesting Caspian Terns in SFBA were located in the Central Bay (Table 2). The number of Caspian Terns nesting in the Central Bay (Brooks Island and Agua Vista Park) declined throughout the study, from 1,078 pairs in 2004 to 689 pairs in 2009 (Table 2). Knight Island was the second largest Caspian Tern colony in SFBA when the study began in 2003 (300 pairs), but was abandoned in 2005 (Table 2). Caspian Terns were not observed nesting anywhere in the North Bay after abandonment of Knight Island in 2005 (Table 2). The South Bay contained the smallest number of nesting Caspian Terns during 2003-2005 (85-174 pairs). However, Caspian Terns nesting in the South Bay increased both in number of pairs and number of colonies used during 2003 - 2009. In 2003, there were two colonies in the South Bay with a total of 85 Caspian Tern pairs, but by 2009 there were four colonies in the South Bay with a total of 141 pairs (Table 2).

Brooks Island was the largest Caspian Tern colony in SFBA throughout this study, where on average 83% of SFBA Caspian Terns nested. The number of Caspian Terns nesting on Brooks Island steadily declined after 2004 (1,040 pairs), and by 2009 consisted of 681 pairs (Table 2).

Only two Caspian Tern colonies in SFBA were active throughout the entire seven-year study period (Brooks Island and Agua Vista Park; Table 1). Caspian Tern nesting at the remaining colonies ranged from one year (Redwood Shores) to four years (Eden Landing and Alviso Ponds; Table 1). In any given year, four-six colonies were active (Table 2).

Productivity

Productivity of Caspian Terns breeding at colonies in SFBA declined from a high of 0.55 young raised per breeding pair in 2003 to a low of 0.17 young raised per breeding pair in 2009 (Table 3). The decline was due to declines in productivity for Caspian Terns nesting at colonies in the North Bay and in the Central Bay (Table 3). In the South Bay, tern productivity was generally lower, averaging 0.23 young raised per breeding pair (range = 0-0.81; Table 3).

Limiting Factors

Availability and/or suitability of nesting habitat was documented as a limiting factor at all nine colony sites used by Caspian Terns in SFBA (Table 4) primarily associated with changing water levels, encroaching vegetation and/or displacement by other colonial waterbirds. Quality of nesting habitat was the next most prevalent documented limiting factor (eight colonies; Table 4). Poor quality nesting habitat was most often associated with salt ponds (seven colonies; Table 1), where the nesting substrate consisted of hard-packed material that became sticky when wet, making it difficult for terns to dig nest scrapes and causing eggs to become cemented to the substrate after rain. The one

Table 2. Number of breeding pairs of Caspian Terns nesting in the San Francisco Bay area during 2003-2009.

Colony	2003	2004	2005	2006	2007	2008	2009
North Bay							
Knight Is.	300	238[a]	45[b]	0[c]	0[c]	0	0
Central Bay							
Brooks Is.	859	1,040[a]	954[d]	931[c]	888[c]	812	681
Agua Vista Park	43	38	18	19[e]	9[e]	14	8
South Bay							
Eden Landing E-10	35	28[b]	0	0[e]	0[e]	56	75
Coyote Hills	0	0	49[e]	42[e]	0[e]	0	0
Alviso Ponds A-7	50	28	18	35[e]	0[e]	0	0
Stevens Creek B-2	0	0	0	0[e]	12[e]	118[f]	64[f]
Ravenswood	0	0	0	1[e]	1[e]	0	1
Redwood Shores	0	0	0	0[e]	0[e]	0	1
Totals							
San Francisco Bay	1,287	1,372	1,084	1,028	910	1,000	830
Sector Sub-totals							
North Bay	300	238	45	0	0	0	0
Central Bay	902	1,078	972	950	897	826	689
South Bay	85	56	67	78	13	174	141

[a]Minimum estimate due to re-nesting that occurred after the aerial survey was conducted.
[b]Colony was abandoned during the breeding season; some of these terns may have re-nested at other colonies in the Bay area.
[c]Data provided by U.S. Fish and Wildlife Service (G. McChesney, personal communication) and Humboldt State University (P. Capitolo, personal communication).
[d]Includes influx of late nesting terns, some of which may have come from abandoned tern colony at Knight Island.
[e]Data provided by San Francisco Bay Bird Observatory (C. Strong, personal communication).
[f]Minimum estimate because entire colony area not visible from the observation blind.

Table 3. Productivity (average number of young raised per breeding pair) at Caspian Tern colonies in the San Francisco Bay area during 2003-2009. Blanks indicate that no tern nesting occurred. Zeros indicate that tern nesting occurred but no young were fledged. Dashes indicate that tern nesting occurred but no counts of fledgling terns were conducted.

Colony	2003	2004	2005	2006	2007	2008	2009
North Bay							
Knight Is.	0.46[a]	0.32[b]	0.0				
Central Bay							
Brooks Is.	0.62	0.48[b]	0.31[c]	—	—	0.42	0.14
Agua Vista Park	0.42[b]	0.82[b]	1.00[b]	—	—	—	—
South Bay							
Eden Landing E-10	0.43	0.0				0.81	0.41
Coyote Hills			0.02[b]	—			
Alviso Ponds A-7	0.08[a]	0.50[b]	0.61[b]	—			
Stevens Creek B-2					—	—	0.16[b]
Ravenswood				—	—		0.00
Redwood Shores							0.00
Totals							
San Francisco Bay	0.55	0.46	0.30	—	—	—	0.17[d]
Sector Sub-totals							
North Bay	0.46	0.32	0.00				
Central Bay	0.61	0.50	0.32	—	—	—	0.14[d]
South Bay	0.22	0.25	0.18	—	—	—	0.29

[a]Maximum estimate because estimate includes smaller chicks that may not have survived to fledging.
[b]Minimum estimate because entire colony area not visible from the observation blind.
[c]Minimum estimate due to exclusion of small chicks produced by late nesting terns that remained on the colony at the end of the field season.
[d]Minimum estimate due to exclusion of chicks produced at Agua Vista Park.

Table 4. Limiting factors for colony size and productivity at Caspian Tern colonies in San Francisco Bay area documented during 2003-2005 and 2008-2009 (see Results for additional detail).

	North Bay	Central Bay		South Bay					
	Knight Is.	Brooks Is.	Agua Vista	Eden Landing	Coyote Hills	Alviso Ponds	Stevens Creek	Ravenswood	Redwood Shores
Availability of nesting habitat	X	X	X	X	X	X	X	X	X
Quality of nesting habit	X		X	X	X	X	X	X	X
Mammalian predators	X			X					
Gull kleptoparasitism	X	X							
Gull nest predation	X	X							
Other avian predators	X	X							
Human disturbance		X							
Aircraft		X				X			

exception was the Agua Vista colony that was located on a dilapidated pier that was gradually collapsing into the bay. Other factors documented to limit colony size or productivity of Caspian Terns at SFBA colonies included: mammalian nest predators (two colonies); kleptoparasitism and nest predation by Western Gulls (*Larus occidentalis*) and California Gulls (*L. californicus*; two colonies); disturbance by other avian predators (two colonies); and human disturbance, including from aircraft (two colonies; Table 4).

Several Caspian Tern colonies were completely abandoned during this study (Table 2). In 2005 the Knight Island colony was abandoned due to tidal inundation of the salt pond where the nesting island was located, after the surrounding levee was breached, and by high nest predation from Western Gulls. Eden Landing E-10 was abandoned in 2004 due to mammalian nest predation. Coyote Hills was abandoned in 2006 due to encroachment and high nest predation rates by an expanding California Gull colony (C. Strong, SFBBO, personal communication). Alviso Ponds A-7 was abandoned in 2006 apparently due to variable water levels after the former salt pond was converted to a muted tidal wetland, allowing mammalian predators access to the colony (C. Strong, SFBBO, personal communication).

Diet Composition

Marine forage fishes, in particular silversides (Atheridae), surfperch (Embiotocidae), anchovies (Engraulidae) and herring/sardines (Clupeidae; in that order), were the predominant component of Caspian Tern diets in SFBA (Table 5). However, diet composition varied among colonies. Terns nesting in the Central Bay (Brooks Island) were the most reliant on schooling marine forage fishes (76.7% of prey items), followed by terns nesting in the South Bay (Eden Landing; 61.4% of prey items), and terns nesting in the North Bay (Knight Island; 49.1% of prey items; Table 5). Freshwater fish species, such as sunfish and bass (Centrarchidae), were most prevalent in the diet of terns nesting in the North Bay (7.4%) and least

Table 5. Average diet composition (percentage of identifiable prey items in bill loads) of Caspian Terns nesting on Knight Island (North Bay), Brooks Island (Central Bay) and Eden Landing (South Bay) in the San Francisco Bay area during 2003-2005 and 2008-2009. Only prey types comprising more than 5% of the tern diet from at least one colony are listed in the table. Prey types comprising less than 5% of the tern diet at each of the three colonies are listed in the footnotes.

Prey type	North Bay (Knight Island colony) 2003-2005	Central Bay (Brooks Island colony) 2003-2005, 2008-2009	South Bay (Eden Landing colony) 2003, 2008-2009
Silversides (Atherinidae)	25.9	13.6	26.2
Surfperches (Embiotocidae)	7.3	26.3	20.6
Anchovies (Engraulidae)	3.1	24.4	10.3
Herring, sardines (Clupeidae)	12.8	12.4	4.3
Salmon, trout (Salmonidae)	22.9	5.3	0.1
Gobies (Gobiidae)	11.3	5.2	4.8
Sharks (Carcharhinidae)	0.0	0.1	11.1
Sculpins (Cottidae)	1.2	3.1	6.6
Sunfish, bass (Centrarchidae)	7.4	1.4	0.9
Flatfish (Pleuronectidae)	0.1	0.3	7.5
Other	8.1[a]	7.8[a]	7.6[a]
No. of identified prey items	3,043	24,287	3,687

[a]Butterfish (Stromateidae), Catfish (Ictaluridae), Cod/Haddock (Gadidae), Croaker (Sciaenidae), Kelpfish (Clinidae), Lamprey (Petromyzontidae), Minnow/Carp (Cyprinidae), Needlefish (Belonidae), Pacific Sand lance (Ammodytidae), Pacific Saury (Scomberesocidae), Pipefish (Syngnathidae), Sablefish (Anoplopomatidae), Shrimp (Crangonidae), Smelt (Osmeridae), Striped Bass (Moronidae), Sucker (Catostomidae), Toadfish (Batrachoididae), unidentified non-salmonid

prevalent in the diet of terns nesting in the South Bay (0.9%). Diets of terns nesting in the South Bay contained the highest proportions of juvenile sharks (Carcharhinidae; 11.1%) and flatfishes (Pleuronectidae; 7.5%) compared to Caspian Terns nesting in the North or Central sectors of the Bay (Table 5). Pooled diet composition data included multiple years at each colony; nevertheless, all of the regional differences in diet composition described above hold true when the comparisons were restricted to diet data available in 2003, the only year when diet data were collected at all three colonies.

Salmonids were detected in the diets of Caspian Terns nesting at colonies in all three sectors of the Bay; however, the proportion of the diet that consisted of salmonids varied among the colonies in the three sectors. In the North Bay, salmonids comprised 22.9% of the diet at the Knight Island colony, followed by Brooks Island in the Central Bay where 5.3% of the diet was salmonids, and finally by Eden Landing E10 in the South Bay where 0.1% of the diet was salmonids (Table 5).

DISCUSSION

Colony size, colony location, and productivity of Caspian Terns nesting in SFBA were variable during 2003-2009. These results are consistent with previous studies of Caspian Terns nesting in SFBA (Strong *et al.* 2004). Over the course of this study, there was a decline in the number of Caspian Terns nesting in SFBA. The decline was primarily due to the abandonment of the Knight Island colony and the decline in size of the Brooks Island colony, the two largest Caspian Tern colonies in SFBA at the beginning of the study.

Low colony-site fidelity and frequent shifts among colony locations by Caspian Terns are associated with two primary factors: (1) the quality and quantity of nesting habitat and (2) disturbance and nest predation (Penland 1982; Shugart *et al.* 1979; Cuthbert 1981; Gill and Mewaldt 1983; Antolos *et al.* 2004). Inadequate nesting substrate or disturbance by various causes were documented at the majority of colony sites in SFBA, likely leading to the frequent shifts of nesting terns among colony locations, particularly in the South Bay.

Caspian tern productivity in SFBA was, on average, lower than at other well-studied Caspian Tern colonies along the Pacific Coast (average of 1.1 young raised per breeding pair; Cuthbert and Wires 1999). Over the course of this study, productivity at Caspian Tern colonies in SFBA declined

69%, largely driven by the decline in productivity at the Brooks Island colony (77%). In general, factors limiting productivity varied by colony site, but were most frequently related to (a) quality of nesting substrate, (b) vulnerability to mammalian and avian nest predators, (c) displacement by other colonial waterbirds and (d) human disturbance.

Diet composition varied according to where a Caspian tern colony was located in SFBA, despite the fact that the distances between colony locations (27-59 km) were within the reported maximum foraging range of nesting Caspian Terns (62-70 km; Soikkeli 1973; Gill 1976). In general, the proportion of marine forage fishes in the diet of Caspian Terns was higher at colonies closer to marine environments. These results suggest that Caspian Terns nesting in the San Francisco Bay area tend to forage on fish that are locally abundant and available near their nesting colony, as was shown for Caspian Terns nesting in the Columbia River estuary (Roby *et al.* 2002; Lyons *et al.* 2005; Lyons *et al.* 2007).

Caspian Terns nesting in the North Bay had the highest percentage of juvenile salmonids in their diet compared to terns nesting in the Central Bay or South Bay. Caspian Terns nesting in the North Bay were located closest to the Sacramento-San Joaquin Delta (Fig. 1), where out-migrating anadromous salmonids from the Central Valley are likely more abundant relative to elsewhere in the Bay. Estimates of the number of juvenile salmonids consumed by Caspian Terns nesting in SFBA have yet to be published; therefore, it is unknown to what extent Caspian Tern predation might limit the recovery of ESA-listed salmonid stocks in the region. Evans *et al.* (2011) suggest, however, that the vast majority of the juvenile salmonids consumed by Caspian Terns nesting on Brooks Island (the largest colony in SFBA) were hatchery-reared smolts not listed under the U.S. Endangered Species Act.

Three sites within San Francisco Bay have been identified as potential alternative nesting sites for Caspian Terns displaced from East Sand Island in the Columbia River estuary (USFWS 2005; USFWS 2006): two sites in the South Bay (at Hayward Regional Shoreline and Don Edwards National Wildlife Refuge) and one site in the Central Bay (Brooks Island). Results from our study suggest that locating new and improved colony sites for Caspian Terns in the South Bay, relative to sites in the North Bay and Central Bay, would have little to no impact on salmonid stocks. Restoration of suitable nesting habitat for Caspian Terns in San Francisco Bay would ensure that there is a network of suitable colony sites available for species on a regional scale, which would benefit both the local breeding population of Caspian Terns in SFBA and the Pacific Coast population as a whole.

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