Caspian Tern Research on the Lower Columbia River

FINAL 2003 Season Summary

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This Final 2003 Season Summary has been prepared for the Bonneville Power Administration and the Interagency Caspian Tern Working Group for the purpose of assessing project accomplishments. This report is not for citation without permission of the authors.

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TABLE OF CONTENTS

Executive Summary

We initiated a field study in 1997 to assess the impact of predation by Caspian terns (*Sterna caspia*) on the survival of juvenile salmonids in the lower Columbia River and estuary. Rice Island, a dredged material disposal island at river mile 21, supported a breeding colony of about 17,000 Caspian terns in 1998. This colony was the largest known breeding colony of Caspian terns in the world, and included about two-thirds of all the Caspian terns nesting along the Pacific Coast of North America. Diet analysis indicated that Caspian terns nesting on Rice Island consumed more juvenile salmonids than any other prey type (73% of prey items in 1997 and 1998). Using bioenergetics modeling, we estimated that in 1998 Caspian terns nesting on Rice Island consumed about 12.4 million juvenile salmonids (95% confidence interval = 9.1–15.7 million), or approximately 13% (95% c.i. = 9%–16%) of the estimated 97 million out-migrating smolts that reached the estuary during the 1998 migration year. Analysis of over 36,000 smolt PIT tags recovered from the Caspian tern breeding colony on Rice Island revealed that over 13.3% of all PIT-tagged steelhead smolts that reached the estuary were consumed by terns in 1998.

The magnitude of predation on juvenile salmonids by Rice Island terns led to management action in 1999. A pilot study was conducted to determine whether the Rice Island tern colony could be relocated 26 km (16 miles) closer to the ocean on East Sand Island (river mile 5), where it was hoped terns would consume fewer salmonids. Habitat restoration, social attraction (decoys and audio playback systems), and selective gull removal were used to encourage terns to nest on East Sand Island. About 1,400 pairs of Caspian terns nested at the new colony site on East Sand Island in 1999. In 2000, about 8,500 pairs of Caspian terns nested on East Sand Island, or 94% of all terns nesting in the estuary. During 2001–2003, all Caspian terns nesting in the Columbia River estuary used East Sand Island.

Our results indicated that relocating the tern colony to East Sand Island enhanced the productivity of Caspian terns nesting in the Columbia River estuary. Nesting success of Caspian terns on East Sand Island (1.06 young raised per breeding pair on average during 1999–2003) was consistently higher than for terns nesting on Rice Island, both prior to tern management (0.06 young raised per breeding pair in 1997, 0.45 young per breeding pair in 1998) and post-management (0.55 young per breeding pair in 1999, 0.15 young per breeding pair in 2000). The productivity measured at Rice Island was considerably lower than at other well-studied Caspian tern colonies in North America (range of 0.6–1.6 young raised per breeding pair; Cuthbert and Wires 1999).

Terns nesting on East Sand Island foraged more in marine and brackish water habitats than did the terns nesting on Rice Island. The diet of East Sand Island terns averaged from 31% to 47% salmonids during 1999–2002, compared to the diet of Rice Island terns, which averaged from 73% to 90% salmonids during 1997–2000. The relocation of all nesting terns from Rice Island to East Sand Island resulted in a sharp drop in consumption of juvenile salmonids by terns nesting in the Columbia River estuary. Total consumption of juvenile salmonids in 2000, when most terns nested on East Sand Island,

was estimated at 8.2 million (95% c.i. = 6.7–9.7 million), a reduction of about 4.2 million (34%) compared to 1998. Total smolt consumption by Caspian terns nesting on East Sand Island in 2001 and 2002, when all terns nested on East Sand Island, was approximately 5.8 million and 6.5 million, respectively, a 53% and 48% reduction in estimated smolt consumption compared to 1998.

In 2003 the estimated size of the Caspian tern colony on East Sand Island was 8,325 nesting pairs. This represents about a 16% decline in the size of the colony compared to the 2002 breeding season. Nesting success at the East Sand Island colony remained high, with an average productivity of 1.08 young raised per breeding pair in 2003. During the 2003 breeding season, the diet of East Sand Island terns averaged 24% salmonids, the lowest proportion of salmonids in the diet so far recorded for this tern colony. Consumption of juvenile salmonids by the East Sand Island tern colony in 2003 was approximately 4.2 million smolts (95% c.i. = 3.5–4.8 million), ca. 8.2 million fewer smolts consumed compared to 1998, when all terns nested on Rice Island. The factor(s) responsible for the decline in the size of the tern colony in 2003 are not known, but there was no evidence of significant increases in the size of other colonies or formation of sizable new colonies within the breeding range of the Pacific Coast population of Caspian terns. The area of quality nesting habitat prepared for Caspian terns on East Sand Island (6.5 acres) and the area of habitat used by nesting terns (4.5 acres) was very similar to 2002. Marine forage fishes were abundant in the Columbia River estuary and nesting success in 2003 was very similar to 2002, revealing no apparent incentive for Caspian terns to shift to alternative colony sites.

The only known Caspian tern breeding colony in the mid-Columbia River during 2003 was on Crescent Island, just below the confluence of the Snake and Columbia rivers. For the second year in a row, no terns attempted to nest at the former colony site on Three Mile Canyon Island, which formerly supported a colony of 200–400 breeding pairs. The tern colony on Crescent Island consisted of about 510 breeding pairs in 2003, a significant decline from the ca. 650 breeding pairs that nested on Crescent Island in 2001. Average nesting success of Caspian terns on Crescent Island in 2003 (0.55 young raised per breeding pair) was also less than in 2001 (1.1 young per breeding pair). The diet of Caspian terns nesting on Crescent Island in 2003 consisted of ca. 68% juvenile salmonids, similar to diets of Crescent Island terns during the 2000-2002 breeding seasons. The tern colony on Crescent Island is the second largest colony of Caspian terns in the Pacific Northwest, second only to the colony on East Sand Island. The trend of declining size at this colony over the last two years supports the hypothesis that Caspian terns that formerly nested on East Sand Island are not shifting to other colonies in the region. Also, the limited area of suitable tern nesting habitat on Crescent Island and the large colony of California gulls on the island suggest that there is little opportunity for expansion of the Crescent Island tern colony.

Caspian terns nesting on East Sand Island in 2003 still consumed an estimated 4.2 million smolts, including some ESA-listed stocks. To achieve further reductions in consumption of juvenile salmonids by Caspian terns in the estuary it will likely be necessary to relocate a portion of the East Sand Island colony to alternative sites outside the estuary. 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; Kress and Hall 2002). Food habits studies of terns at sites outside of the Columbia River basin 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. Studies have been initiated recently to develop a better understanding of Caspian tern colony status and diet composition at representative colonies in coastal and interior habitats outside the Columbia River basin. Information from these studies 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 while ensuring the protection and conservation of Caspian terns in the Pacific Coast/Western region.

Preliminary results from Caspian tern studies conducted in Commencement Bay, Washington, in 2001 and in the San Francisco Bay area and south-central Oregon in 2003 suggest: (1) Caspian terns breeding in the San Francisco Bay area and southcentral Oregon prey mostly on forage fish that are neither listed under the ESA nor of significant economic value for commercial, recreational, or subsistence fisheries, while Caspian terns breeding in Commencement Bay consumed mostly juvenile salmonids, at least early in the nesting season; (2) availability of suitable sites for breeding colonies was the main factor limiting the number and size of tern colonies in each study area, and (3) nesting success at existing colonies was limited by attributes of those colony sites as they influenced (a) quality of nesting substrate, (b) vulnerability to nest predators, (c) displacement by other colonial waterbirds, and (d) human disturbance (see Collis et al. 2002 and Roby et al. 2003*a*). Studies of Caspian tern colony status and diet composition in the Pacific Coast/Western region are ongoing and will be used to help develop management actions aimed at reducing predation on salmonids by Caspian terns nesting on East Sand Island, while ensuring the protection and conservation of Caspian terns in the Pacific Coast/Western region.

Preparation and Modification of Nesting Habitat

Columbia River Estuary

On 2 April 2002, Federal District Judge Barbara Rothstein signed a settlement agreement between the plaintiffs (National Audubon Society, Defenders of Wildlife, Seattle Audubon Society, and American Bird Conservancy) and defendants (U.S. Army Corps of Engineers [USACE] and U.S. Fish and Wildlife Service [USFWS]). The signed agreement allowed habitat work to resume on East Sand Island (to encourage tern nesting) and Rice Island (to discourage tern nesting), and allowed limited hazing of terns (i.e., prior to egg laying) attempting to nest in the upper estuary in 2002 and 2003 (see Map 1). At East Sand Island in 2003, habitat improvements were accomplished by the USACE from 1–4 April. Approximately 6.5 acres of suitable bare sand habitat was prepared on East Sand Island. Tern decoys (100) and sound systems (2) were deployed

in the center of the colony area to attract nesting terns to the site. On 9 April, a camp was set up on East Sand Island and was continuously occupied by two colony monitors throughout the tern breeding season. Limited gull control activities that were performed during the 1999 and 2000 breeding seasons to enhance prospects for tern colony restoration at East Sand Island were not conducted in 2003.

In previous years, work crews from NOAA Fisheries, Oregon Department of Fish and Wildlife, and USACE carried out various habitat modifications (e.g., fencing and flagging of the former colony area) on Rice Island prior to the breeding season to discourage terns from nesting there. This was not necessary in 2003 because the former colony area on Rice Island had become completely vegetated and was consequently unsuitable for tern nesting. No hazing of terns to discourage nesting was conducted on Rice Island in 2003.

Colony Size and Nesting Success

Columbia River Estuary

Methods: The number of Caspian terns breeding on East Sand Island in the Columbia River estuary in 2003 (see Map 1) was estimated using aerial photographs of the colony taken near the end of the incubation period. The average of 3 direct counts of adult terns in aerial photos was corrected to estimate the number of breeding pairs at the colony using ground counts of incubating and non-incubating terns on 12 different plots within the colony area. Nesting success (number of young raised per breeding pair) at the East Sand Island tern colony was estimated using aerial photos taken of the colony just prior to the fledging period. The average of 3 direct counts of all terns (adults and juveniles) in aerial photos was corrected to estimate the number of fledglings on the colony using ground counts of adults and fledglings on 12 different plots within the colony area. The confidence intervals for number of breeding pairs and nesting success were calculated using a Monte Carlo routine to incorporate the variance of the multiple counts from the aerial photos and the plot counts used to generate these estimates.

Results and Discussion: As was the case in 2001 and 2002, all nesting by Caspian terns in the Columbia River estuary occurred on East Sand Island in 2003. We estimate that 8,325 breeding pairs (95% c.i. = 7,837–8,812 breeding pairs) attempted to nest at East Sand Island in 2003 (see Figure 1 for weekly counts from the ground of terns on the East Sand Island colony in 2003). This estimate is 16% less than our estimate of colony size at East Sand Island in 2002 (9,933 breeding pairs, 95% c.i. = 9,551–10,314 breeding pairs). This significant decline in colony size at East Sand Island in 2003, as compared to the previous year, was likely due to lower than normal survival rates between the 2002 and 2003 breeding seasons. The cause(s) of this hypothesized lower survival are not known. No evidence was found for terns that previously nested on East Sand Island either emigrating to alternative breeding colonies or not attempting to nest at all.

We estimate that 8,977 fledglings (95% c.i. = 8,212–9,742 fledglings) were produced at the East Sand Island colony in 2003. This corresponds to nesting success of 1.08 young raised per breeding pair (95% c.i. = 0.96–1.19 fledglings/breeding pair), which was the same as the estimate of nesting success for the East Sand Island tern colony in 2002 (1.08 fledglings/breeding pair, 95% c.i. = 1.02–1.14 fledglings/breeding pair). Productivity at East Sand Island continues to be higher than was recorded at Rice Island both prior to and after management, and similar to other well-studied Caspian tern colonies along the Pacific Coast (Cuthbert and Wires 1999; see below).

On 23 April, over 1,000 terns were observed loafing on an upland area at the eastern end of Pillar Rock Sands, a dredged material disposal site in the upper estuary (river mile 27) above Rice Island (see Map 1). The site was investigated and no nest scrapes were observed; however, terns attending the site were copulating and bringing in fish as part of courtship. The USACE deployed their personnel to the island to discourage terns from nesting at the site. These activities (i.e., continuous day and night time monitoring of the site and hazing of any terns that settled in upland areas) were successful in dissuading terns from nesting on Pillar Rock Sands.

On 25 April, about 250 terns were observed loafing on an upland area at Miller Sands Spit, a dredged material disposal site in the upper estuary (river mile 24) above Rice Island (see Map 1). The site was investigated and no nest scrapes were observed; however, terns attending the site were copulating and bringing in fish as part of courtship. The USACE deployed their personnel to the island to discourage terns from nesting at the site. These activities (i.e., around the clock monitoring of the site and hazing of any terns that settled in upland areas) were successful in dissuading terns from nesting on Miller Sands Spit.

No other aggregations of terns were observed at other dredge spoil disposal areas in the upper estuary (e.g., Rice Island, Puget Island) in 2003.

Mid-Columbia River (east of the Cascades)

Methods: The numbers of Caspian terns breeding at Crescent Island (see Map 2) were estimated as described above. The numbers of terns attempting to breed at other locations (i.e., Three Mile Canyon Island and Miller Rocks; see Map 2) were estimated using ground counts of incubating terns. Nesting success was estimated from ground counts of all fledglings on each colony just prior to fledging.

Results and Discussion: About 510 breeding pairs attempted to nest at the Crescent Island tern colony in 2003 (see Figure 2 for weekly counts of terns on the Crescent Island colony in 2003), about 12% fewer pairs than in 2002. We estimated that 278 young were fledged from that colony in 2003, or 0.55 young raised per breeding pair, lower nesting success than in 2002.

Caspian terns did not attempt to nest at either Three Mile Canyon Island or Miller Rocks in 2003. A mink disrupted tern nesting at Three Mile Canyon Island in 2000 and 2001,

causing the colony to fail in both years. Caspian terns were found nesting on Miller Rocks in the mid-Columbia River just upstream of the mouth of the Deschutes River for the first time in 2001; up to 20 breeding pairs attempted to nest on the edge of a large gull colony. We suspect that terns nesting on Miller Rocks in 2001 were failed breeders from the Three Mile Canyon Island colony.

Coastal Washington Sites

Methods: Aerial surveys along the southern Washington Coast, including Willapa Bay and Grays Harbor, (see Map 1) were conducted on a periodic basis throughout the breeding season in order to detect any new tern colonies outside the Columbia River estuary.

Results and Discussion: Although Caspian terns were commonly observed foraging and roosting in Willapa Bay and Grays Harbor throughout the 2003 breeding season, no nesting attempts by terns were detected at either location in 2003. This suggests that suitable tern nesting sites (i.e., upland island or mainland sites that are unvegetated, unoccupied by other colonial nesting birds, and free of mammalian predators) are not currently available in Willapa Bay or Grays Harbor.

Diet Composition and Estimates of Salmonid Consumption

Columbia River Estuary

Methods: Because terns transport whole fish in their bills to their mates (courtship meals) and young (chick meals), taxonomic composition of the diet can be determined by direct observation of adults as they return to the colony with fish (i.e., bill load observations). Observation blinds were set up at the periphery of the tern colony on East Sand Island so that prey items could be identified with the aid of binoculars and spotting scopes. The target sample size was 350 bill load identifications per week. Fish watches at the East Sand Island tern colony were conducted twice each day, at high and low tide, to control for potential tidal and time of day effects on diet. Prey items were identified to the taxonomic level of family. We were confident in our ability to distinguish salmonids from non-salmonids and to distinguish among most non-salmonid taxa based on direct observations from blinds, but we did not attempt to distinguish the various salmonid species. The percent of the identifiable prey items in tern diets was calculated for two-week periods throughout the nesting season. The diet composition of terns over the entire breeding season was based on the average of these two-week percentages.

To assess the relative proportion of the various salmonid species in tern diets, we collected bill load fish near the East Sand Island tern colony by shooting Caspian terns returning to the colony with whole fish carried in their bills (referred to hereafter as "collected bill loads"). Salmonid bill loads were identified as either chinook salmon, sockeye salmon, coho salmon, steelhead, or unknown based on soft tissue or

morphometric analysis. P. Bently of NOAA Fisheries provided verifications of salmonids collected as bill loads that were difficult to identify.

Estimates of annual smolt consumption for the East Sand Island tern colony were calculated using a bioenergetics modeling approach (see Roby et al. 2003*b* for detailed description of the model construction and input variables). We also used a Monte Carlo simulation procedure to calculate reliable 95% confidence intervals for estimates of smolt consumption by terns.

Results and Discussion: Of the bill load fish identified at the East Sand Island tern colony 24% were juvenile salmonids (n = 5,476). As in previous years, marine forage fishes (i.e., Pacific herring [*Clupea pallasi*], anchovies [Engraulidae], smelt [Osmeridae], surfperch [Embiotocidae], Pacific sand lance [*Ammodytes hexapterus*]) were prevalent (71% of identified bill loads) in the diets of terns nesting on East Sand Island (Figure 3). The proportion of the diet that was salmonids peaked at ca. 67% during the second week in May (Figure 4), approximately three weeks earlier than the peak in salmonid consumption in 2002. We estimated that Caspian terns nesting on East Sand Island consumed 4.2 million juvenile salmonids in 2003 (95% c.i. = 3.5–4.8 million). Of all the juvenile salmonids consumed, we estimate that 43% were coho salmon (best estimate = 1.8 million, 95% c.i. = 1.5–2.1 million), 26% were yearling chinook salmon (best estimate = 1.1 million, 95% c.i. = 0.1–1.3 million), 17% were sub-yearling chinook salmon (best estimate = 0.7 million, 95% c.i. = 0.5–0.9 million), and 14% were steelhead (best estimate = 0.6 million, 95% c.i. = 0.5–0.7 million).

Mid-Columbia River (east of Cascades)

Methods: The taxonomic composition of the diet of Caspian terns nesting on Crescent Island was determined by direct observation of adults as they returned to the colony with fish (i.e., bill load observations; described above). The target sample size was 150 bill load identifications per week at Crescent Island (see above for further details on the analysis of diet composition data). Prey items were identified to the taxonomic level of family. We were confident in our ability to distinguish salmonids from non-salmonids and to distinguish among most non-salmonid taxa based on direct observations from blinds, but we did not attempt to distinguish the various salmonid species. The percent of the identifiable prey items in tern diets was calculated for two-week periods throughout the nesting season. The diet composition of terns over the entire breeding season was based on the average of these two-week percentages.

Bill load fish were not collected at the Crescent Island tern colony due to the potential impact of lethal sampling on a small colony. Therefore, we were unable to assess the relative proportion of the various salmonid species in the diet of terns nesting on Crescent Island. PIT tags placed in juvenile salmonids were also collected from the Crescent Island tern colony in 2003. Those data are being analyzed and will be available through NOAA Fisheries (Brad Ryan, *brad.ryan@noaa.gov*).

A feasibility study was initiated to determine if Caspian terns would feed on fish held in a net pen. If so, this approach could be used to assess the relative vulnerability of various stocks of juvenile salmonids and other fish to Caspian tern predation in a controlled environment.

A 6-meter circular net pen was anchored in a Burbank Slough (see Map 3) off the Columbia River near Crescent Island from early May to early June. The net pen frame was fitted with wire spike strips to prevent avian predators from roosting on the net pen frame and to deter non-plunge diving avian predators (e.g., gulls, herons, pelicans, and cormorants) from foraging on fish in the net pen. A total of 2,000 juvenile rainbow trout (approximately 10-15 cm in length) were placed in the net pen. All fish were certified, disease-free triploids (sterile as adults) obtained from the Trout Lodge Hatchery, WA. The net pen and the surrounding slough were monitored opportunistically before (4 days of observation) and during (21 days of observation) the time when fish were in the net pen. Observation periods were roughly 4 hrs/day and 8 hrs/day before and during the time when fish were in the pen, respectively.

Results and Discussion: Juvenile salmonids were the most prevalent prey type for Caspian terns nesting on Crescent Island (68% of total identified bill loads), followed by cyprinids (carp and minnows, 17%) and centrarchids (bass and sunfish, 11%; n = 2,129; Figure 5). The proportion of salmonids in the diet was higher and more variable over time than for terns nesting on East Sand Island. The salmonid portion of the diet peaked at over 80% of prey items in mid-April, May, and again in early June (Figure 6); these changes in diet composition probably reflected changes in availability of hatchery-reared juvenile salmonids near the colony. Efforts to estimate juvenile salmonid consumption by terns nesting at Crescent Island using bioenergetics models are currently in progress.

In the days preceding the stocking of fish in the net pen, Caspian terns were often seen commuting past the net pen site, but did not forage in the slough where the net pen was located. Following the stocking of trout in the net pen on 7 May, terns were observed foraging on fish within the pen and in the surrounding slough (i.e., 2 and 20 days after for Forster's terns and Caspian terns, respectively). Spike strips placed on the net pen frame were successful in discouraging other piscivorous waterbirds from perching, roosting, and staging foraging activities from the net pen frame. Following our observation of the first foraging attempt by a Caspian tern at the net pen, Caspian terns were seen foraging on fish within the pen during every subsequent observation period (n = 9). As many as 7 Caspian terns were observed foraging in the vicinity of the net pen at one time and many more commuted past the site each day to other foraging areas. A total of 49 foraging attempts by Caspian terns were observed, 32 (65%) of which were successful (i.e., resulted in a fish being captured). The net pen feasibility study was concluded on 6 June. This study demonstrated conclusively that Caspian terns can learn to forage for fish confined to a net pen that is equipped with deterrents that prevent other avian predators from using the net pen.

Foraging Ecology

Methods: A total of 16 adult Caspian terns were captured on Crescent Island during late incubation using noose mats placed around active nests. Twelve adult terns were radio-tagged and marked for visual identification (i.e., banded with colored leg bands and partially dyed with rhodamine-B). Of the 12 radio-tagged terns, 10 terns were later confirmed to be nesting on Crescent Island based on direct observation, one tern left Crescent Island and subsequently attempted to nest on East Sand Island, and one tern was not resighted or detected after it was radio-tagged. The movements of radio-tagged adults were monitored using both fixed-winged aircraft (one flight/week) and road-based surveys (two surveys/week) from mid May through July. The area surveyed included: the lower Columbia River from one mile below McNary Dam to Richland, Washington; the lower Snake River from the Columbia River confluence to 10 miles above Ice Harbor Dam; the Walla Walla River from the Columbia River confluence to Touchet, Washington; Burbank Slough; and the Yakima River from the Columbia River confluence to river mile 7 (see Map 3).

Results and Discussion: Based on aerial surveys, off-colony detections of radio-tagged terns nesting on Crescent Island (n =29) were distributed as follows: 17 (59.0%) on the Columbia River downstream of Crescent, 4 (14.0%) on the Walla Walla River, 3 (10.0%) on the Snake River (not including Ice Harbor Dam), 3 (10.0%) on the Columbia River upstream of Crescent, and 2 (7.0%) at McNary Dam. Based on road surveys, off-colony detections of radio-tagged terns nesting on Crescent Island (n = 83) were distributed as follows: 34 (41.0%) on the tributaries of the Columbia River, 33 (39.8%) on the Columbia River downstream of Crescent (not including McNary Dam), 8 (9.6%) on the Columbia River upstream of Crescent, 5 (6.0%) at McNary Dam, 1 (1.2%) at Ice Harbor Dam, and 2 (2.4%) on the Snake River exclusive of Ice Harbor Dam (Table 1). Of those terns located on tributaries during road surveys, 19 (55.9%) were located on the Walla Walla River, while 15 (44.1%) were located in the vicinity of Burbank Slough. No radio-tagged terns were detected on the Yakima River during aerial or road-based surveys. Based on road surveys, there was a trend towards decreasing foraging activity on the Walla Walla River and Burbank Slough and increasing foraging activity on the Columbia River upstream from Crescent as the nesting season progressed (Table 1). It is important to note that these results are based on small sample sizes (29 and 83 detections for aerial surveys and road surveys, respectively).

Dispersal and Survival

Methods: Juvenile terns were banded at seven tern colonies throughout Oregon, Washington, and California in 2003 (see Roby et al. 2003*a* for banding results outside the Columbia River basin) in order to continue efforts to measure survival rates, post-breeding dispersal, 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). As part of this study, tern chicks that were near fledging were banded at East Sand Island, (n

= 450), Crescent Island (n = 100), and Solstice Island (in Potholes Reservoir; n = 21). Tern chicks were captured on-colony by herding flightless young into holding pens. Once captured, chicks were immediately transferred to holding crates until they were banded and released. Chick banding operations were conducted only during early morning and evening hours when moderate temperatures reduced the risk of heat stress for captive chicks. Terns that were color-banded in previous years (2000–2002) were re-sighted on various breeding colonies by researchers throughout the 2003 breeding season. Re-sightings of banded terns at other locations were reported to us through our project web page (www.columbiabirdresearch.org), by phone, or by e-mail.

Results and Discussion: In 2003, over 2,500 re-sightings of at least 430 individual color-banded Caspian terns had been reported as of 30 September. All but three of the re-sighted terns were initially banded as adults in previous years at either the Rice Island, East Sand Island, or ASARCO (Commencement Bay, WA) colonies. The other three were banded as chicks at East Sand Island. At least seventeen of the 66 adults terns (26%) banded at the ASARCO Site in 2000 and 2001 were subsequently re-sighted at East Sand Island in 2002; three of these were confirmed to be breeding (i.e., attending chicks). Three of the terns color-banded as chicks in 2000 or 2001 were re-sighted at East Sand Island in 2003. Such a low number of sightings is not surprising because subadult terns normally do not begin returning to their natal colony until they are 2–3 years old (Cuthbert and Wires 1999). The analysis of the band re-sighting data is on-going and will allow us to estimate adult survival, juvenile survival, age at first breeding, colony site fidelity, and other factors important in determining the status of the population and whether current nesting success is likely to result in an increasing, stable, or declining population. Moreover, by tracking movements of breeding adult terns between colonies, either within or between years, we can better assess the consequences of various management strategies.

The newly renovated web page reporting form received a total of 102 postings of color-banded Caspian terns this season. Ninety-eight of the sightings were from outside Oregon and included approximately 55 different individuals. As was the case in previous years, most re-sightings of post-breeding terns away from their breeding colonies were from the coasts of California (n = 6), Oregon (n = 4), Washington (n = 23), and British Columbia (n = 68, as far north as Vancouver, B.C.). Many terns, including fledglings, from the Columbia River initially fly north to British Columbia in July and August, but by September have migrated south.

Monitoring and Evaluation of Management

Nesting Distribution

All Caspian terns that nested at the former colony site on Rice Island shifted to the restored site on East Sand Island during the three-year period 1999–2001. Because of active management, all Caspian terns nesting in the Columbia River estuary remained on East Sand Island in 2002 and 2003 (Figure 7). Habitat restoration, social attraction, and

gull control at the East Sand Island colony site were successful in attracting terns to breed there and provided suitable nesting habitat for terns that formerly nested on Rice Island. Efforts to reduce available nesting habitat on Rice Island were successful in gradually reducing the area used by nesting terns (Figure 8). The number of Caspian terns nesting in the estuary increased significantly from 1997 to 1998, remained relatively stable from 1998 to 2001, increased significantly from 2001 to 2002, and decreased significantly from 2002 to 2003 (Figure 7).

The successful restoration of the Caspian tern colony on East Sand Island is partly a reflection of the species' nesting ecology. Caspian terns prefer to nest on patches of open habitat covered with sand (Quinn and Sirdevan 1998), at a safe elevation above the high tide line, and on islands that are devoid of mammalian predators (Cuthbert and Wires 1999). These habitats are typically ephemeral, particularly in coastal environments, and can be created or destroyed during winter storm events. Breeding Caspian terns must be able to adapt to these changes in available nesting habitat. Consequently, Caspian terns are in a sense pre-adapted to shifting their nesting activities from one site to another more so than most other colonial seabirds.

Diet and Salmonid Consumption

Juvenile salmonids were less prevalent and marine forage fishes (i.e., Pacific herring [*Clupea pallasi*], anchovies [Engraulidae], smelt [Osmeridae], surf perch [Embiotocidae], Pacific sand lance [*Ammodytes hexapterus*]) were more prevalent in the diets of Caspian terns nesting on East Sand Island, compared to terns nesting on Rice Island (Table 2, Figure 9). Caspian terns nesting on East Sand Island in 2003 had the lowest average percentage of salmonids in their diet (24%) and terns nesting on Rice Island in 2000 had the highest percentage of salmonids in their diet (90%; Table 2). In general, juvenile salmonids were more prevalent in the diets of Caspian terns during April and May, and salmonids declined in the diet during June and July. The one exception to this trend was at Rice Island in 2000, when the proportion of salmonids in the diet remained high (over 80%) for the entire breeding season.

Compared to the estimate of total consumption of juvenile salmonids in 1998 (12.4 million), when all Caspian terns nested on Rice Island, consumption of juvenile salmonids by all Caspian terns nesting in the Columbia River estuary was lower by approximately 34%, 53%, 48%, and 66% in 2000, 2001, 2002, and 2003, respectively (Figure 10). This decline in losses of juvenile salmonids to Caspian tern predation coincided with the shift of breeding terns from Rice Island to East Sand Island. This large reduction in the estimated number of juvenile salmonids consumed by terns in 2000–2003 compared to 1998 was primarily due to a reduction in the number of sub-yearling chinook salmon consumed (Figure 11).

The diet composition of Caspian terns nesting on Rice and East Sand islands suggests that relocating the tern colony to East Sand Island significantly enhanced survival of juvenile salmonids in the estuary. As predicted, juvenile salmonids were less prevalent and marine forage fishes more prevalent in the diets of Caspian terns nesting on East

Sand Island compared to terns nesting on Rice Island (Table 2 and Figure 9). The differences in the proportion of salmonids in the diets of Caspian terns nesting on Rice and East Sand islands are also consistent with significant inter-colony differences in the diets of other piscivorous waterbirds (i.e., double-crested cormorants, glaucous-winged/western gulls) nesting on the two islands. Birds nesting on Rice Island were consistently more reliant on juvenile salmonids and consumed a less diverse fish diet than birds nesting on East Sand Island. The major difference in diets of Caspian terns nesting at colonies separated by only 26 km suggests that the terns foraged primarily in proximity to their nesting colonies in the estuary, instead of commuting longer distances to favored or traditional foraging sites. The success of tern colony relocation as a means to reduce consumption of juvenile salmonids was contingent on the terns foraging opportunistically and adapting their foraging behavior to local conditions near the colony.

Nesting Success

Our results indicate that relocating the tern colony from Rice Island to East Sand Island enhanced the nesting success of Caspian terns nesting in the Columbia River estuary. Average nesting success of Caspian terns on East Sand Island in 1999–2003 (1.06 young raised per breeding pair) was consistently higher than for terns nesting on Rice Island, both prior to tern management (0.06 and 0.45 young raised per breeding pair in 1997 and 1998, respectively) and post-management (0.55 and 0.15 young raised per breeding pair in 1999 and 2000, respectively; Figure 12). Nesting success at the Rice Island colony was also considerably 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), suggesting that nesting success at Rice Island during 1997–2000 may not have been adequate to compensate for annual adult and sub-adult mortality. Average nest density, which ranged from 0.25 to 0.78 nests/m^2 on Rice Island, and from 0.26 to 0.62 nests/m^2 on East Sand Island (Figure 13), was not apparently related to nesting success at either colony.

Gull control on the East Sand Island tern colony may have been largely responsible for differences in nesting success between the Rice Island and East Sand Island colonies in 1999 and 2000; however, in 2001–2003, when there was no gull control on the East Sand Island tern colony, tern nesting success was still significantly higher than was ever recorded at Rice Island (Figure 12). The relatively high nesting success of Caspian terns on East Sand Island in 2001–2003 was reflected in similarly high nesting success among double-crested cormorants and glaucous-winged/western gulls nesting on East Sand Island. These piscivorous colonial waterbirds all benefited from strong coastal up-welling and associated high primary and secondary productivity along the coast of the Pacific Northwest, particularly in 2001 (R. Emmett, NOAA Fisheries, pers. comm.). The favorable ocean conditions have been linked to the regime shift associated with the Pacific Decadal Oscillation (PDO) and may ensure relatively high availability of marine forage fishes near the mouth of the Columbia River for several years to come.

Future Research Needs

The short-term advantages to both juvenile salmonids and Caspian terns associated with the relocation of the breeding colony from Rice Island to East Sand Island are evident. There may be risks, however, associated with the continued concentration of such a large proportion of the breeding population of Caspian terns at a single colony site (currently East Sand Island). Caspian terns nesting on East Sand Island in 2003 still consumed an estimated 3.5–4.8 million smolts, with presumably some ESA-listed stocks still suffering significant losses to tern predation (Ryan et al. 2001a, Ryan et al. 2001b). Furthermore, large proportions of the Pacific Coast population (ca. 67%), the continent-wide metapopulation (ca. 25%), and the worldwide numbers of Caspian terns (ca. 10%) continue to nest at one location in the Columbia River estuary (Cuthbert and Wires 1999). Under current conditions, the risks from disease, storms, predators, human disturbance, oil spills, or other local events are substantially greater than if the breeding population was more widely distributed at a number of smaller colonies. A potential return to poor ocean conditions and reduced availability of marine forage fish could lead to an increase in the reliance of East Sand Island terns on juvenile salmonids as a food source. Close monitoring is needed to assess the long-term effects of the relocation of the Caspian tern colony on survival of juvenile salmonids, as well as the productivity and demography of Caspian terns in the Columbia River estuary.

To minimize risks to Columbia Basin salmonids and the Pacific Coast population of Caspian terns, long-term management could include attracting a portion of the East Sand Island tern colony to nest at several new and/or restored colony sites outside the Columbia River estuary. The East Sand Island colony is currently one of the only undisturbed Caspian tern breeding sites anywhere along the coast of the Pacific Northwest. Caspian terns formerly nested in large colonies (> 1,000 pairs) on islands in Willapa Bay and Grays Harbor, estuaries that no longer support nesting Caspian terns. Caspian tern colonies were also located along the coast of Puget Sound near Everett and Tacoma, Washington, but these colonies have been intentionally eliminated. The welfare of other listed or beleaguered salmonid stocks has been a primary concern in areas considered for restoration of Caspian tern colonies, yet for most former colony sites there is little or no evidence that juvenile salmonids were a significant component of tern diets. Restoration of permanent colony sites for Caspian terns along the Pacific Coast and elsewhere appears unlikely without empirical evidence that local salmonid stocks and other fish species of special concern will not be at risk. Toward that end, studies have been initiated to assess Caspian Tern colony status and diet composition at coastal and inland sites outside the Columbia River basin. These studies are ongoing and will gather important information needed to develop a Caspian Tern Management Plan and Environmental Impact Statement (EIS). The Caspian Tern Management Plan and EIS are being prepared by the U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, and NOAA Fisheries with the goal of reducing predation on salmonids by Caspian terns nesting on East Sand Island, while ensuring the protection and conservation of Caspian terns in the Pacific Coast/Western region.

Future research will also focus on (1) measuring the differences in predation vulnerability among various groups of salmonids (e.g., stocks, rearing types, transported versus run-of-the river fish) from the Columbia River basin, and (2) investigating ways to reduce predation impacts through management of the fish themselves. As was done previously (Collis et al. 2001, Ryan et al. 2003), smolt PIT tags recovered from piscivorous waterbird colonies will be used to assess the relative vulnerability of different groups of salmonids to predation. These results, coupled with information on fish origin, health, and passage history, will be used to help identify the potential causes for differences in vulnerability to avian predation, including testing predictions of the delayed mortality hypothesis. Second, by comparing the condition, contaminant burdens, and health status of salmonid smolts consumed by piscivorous waterbirds to smolts caught in river, hypotheses regarding the compensatory/additive nature of avian predation can be tested. Third, genetic markers will be used to identify the different salmonid species and stocks found in the diet of piscivorous waterbirds, improving assessments of stock specific predation rates. Fourth, controlled experiments using fish confined to net pens anchored near existing waterbird colonies will be used to test hypotheses regarding the cause(s) for differences in predation vulnerability among salmonids. With this information, fisheries managers would be able to modify fish management practices to reduce the impacts of Caspian terns and other avian predators on the survival of juvenile salmonids from the Columbia River basin, as warranted.

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Publications and Submitted Manuscripts

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Collis, K., D.D. Roby, D.P. Craig, B.A. Ryan, and R.D. Ledgerwood. 2001. Colonial waterbird predation on juvenile salmonids tagged with Passive Integrated Transponders in the Columbia River Estuary: Vulnerability of different species, stocks, and rearing types. Transactions of the American Fisheries Society 130: 385–396.

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Submitted and in prep manuscripts from this study include:

Anderson, C.D., D.D. Roby, and K. Collis. In review. Conservation implications of the large colony of double-crested cormorants on East Sand Island, Columbia River estuary, Oregon, USA. Submitted to Waterbirds.

Anderson, C.D., D.D. Roby, and K. Collis. In review. Foraging patterns of male and female double-crested cormorants nesting in the Columbia River estuary. Submitted to Canadian Journal of Zoology.

Antolos, M., D.D. Roby, and K. Collis. In review. Breeding ecology of Caspian terns at colonies on the Columbia Plateau. Submitted to Northwest Science.

Antolos, M., D.D. Roby, D.E. Lyons, S.K. Anderson, and K. Collis. In review. Effects of nest density, location, and timing on breeding success of Caspian terns. Submitted to Condor.

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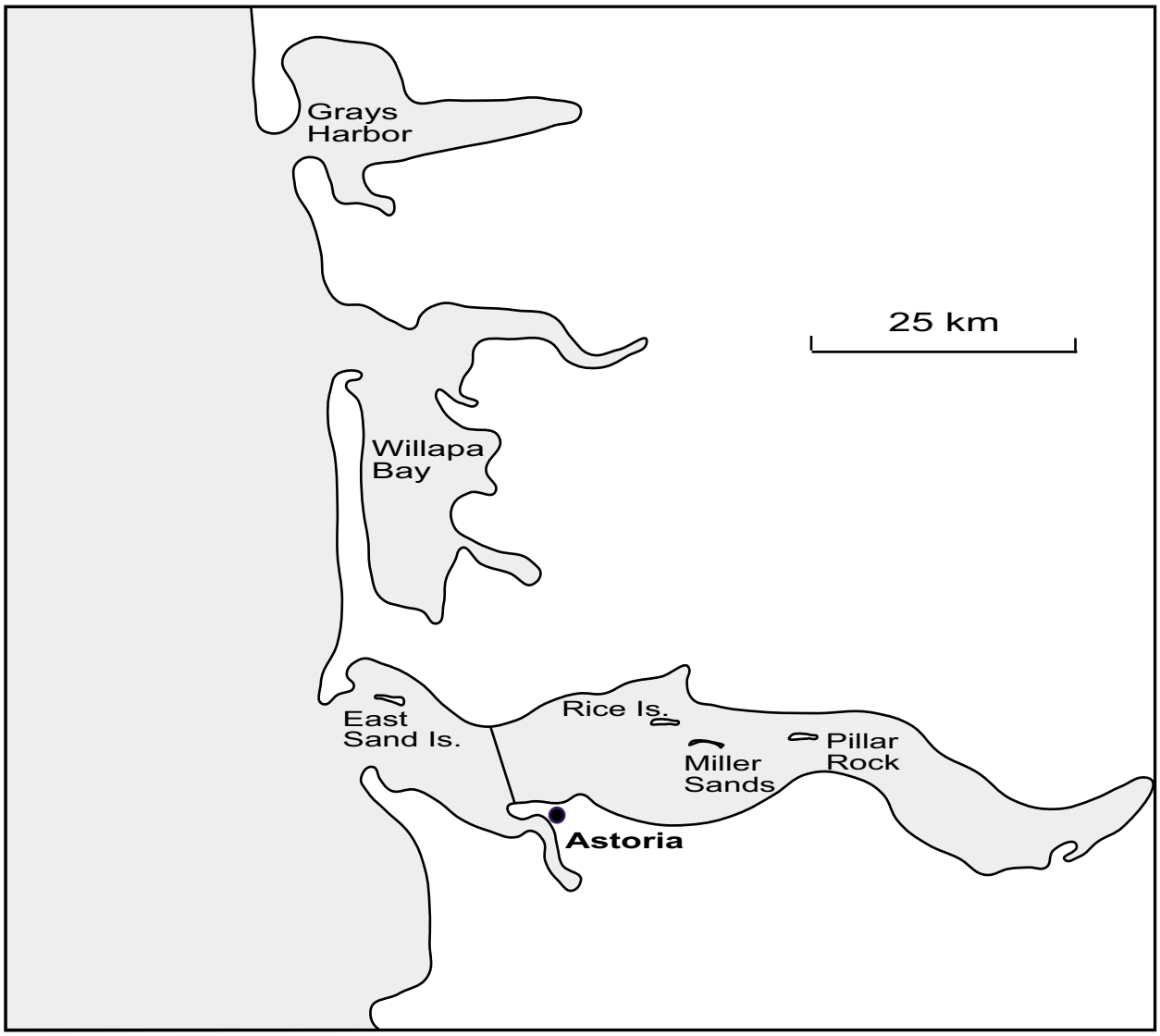
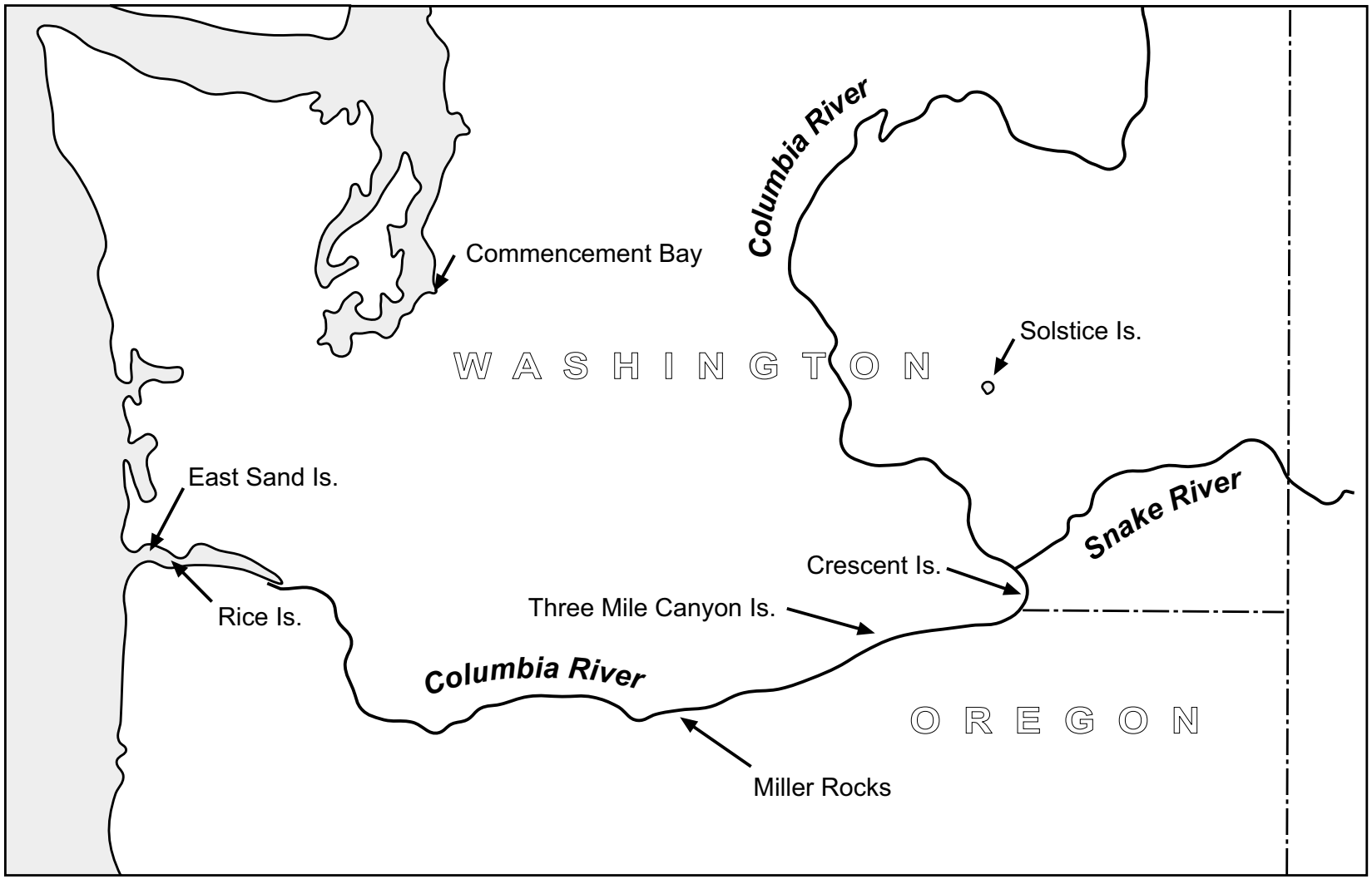
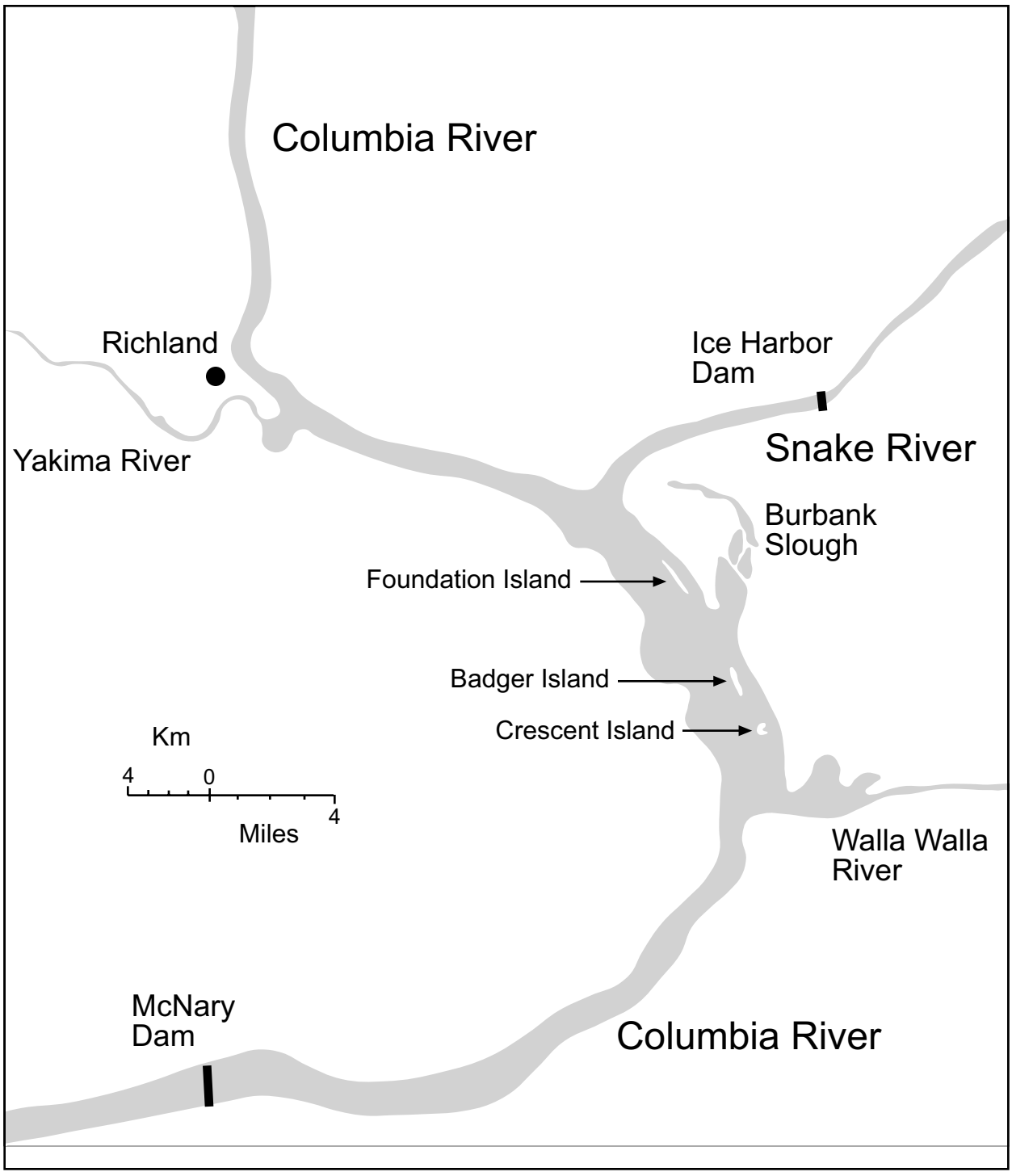
Suryan, R.M., D.P. Craig, D.D. Roby, N.D. Chelgren, K. Collis, W.D. Shuford, and D.E. Lyons. In review. Redistribution and growth of the Caspian tern population in the Pacific coast region of North America, 1981-2000. Submitted to Condor.



Map 1. Study area in the Columbia River Estuary and along the Washington Coast in 2003.



Map 2. Locations of active and historic Caspian tern colonies discussed in this report.



Map 3. Mid-Columbia River study area.

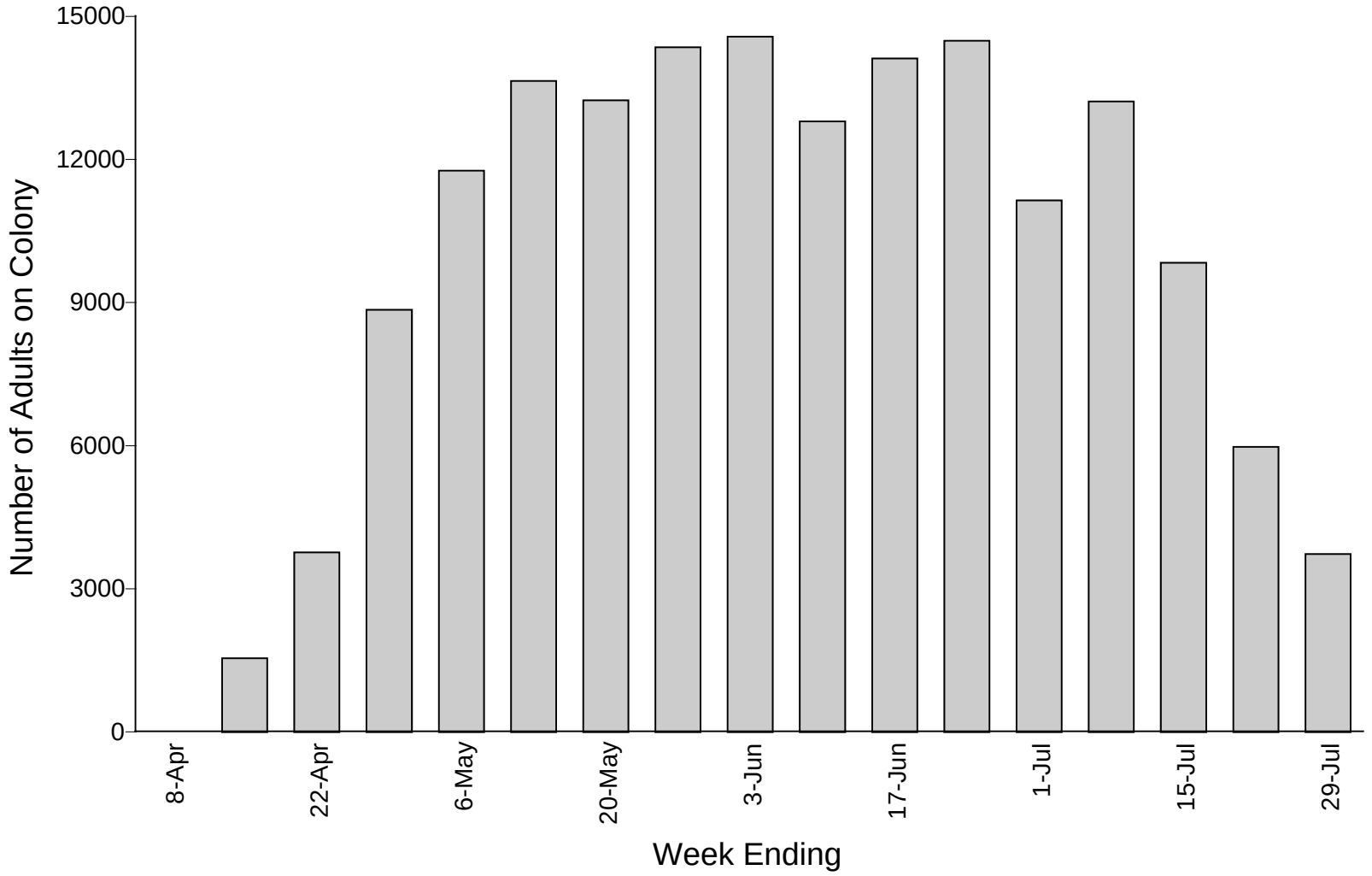


Figure 1. Visual estimates of the number of adult Caspian terns on the East Sand Island colony in 2003.

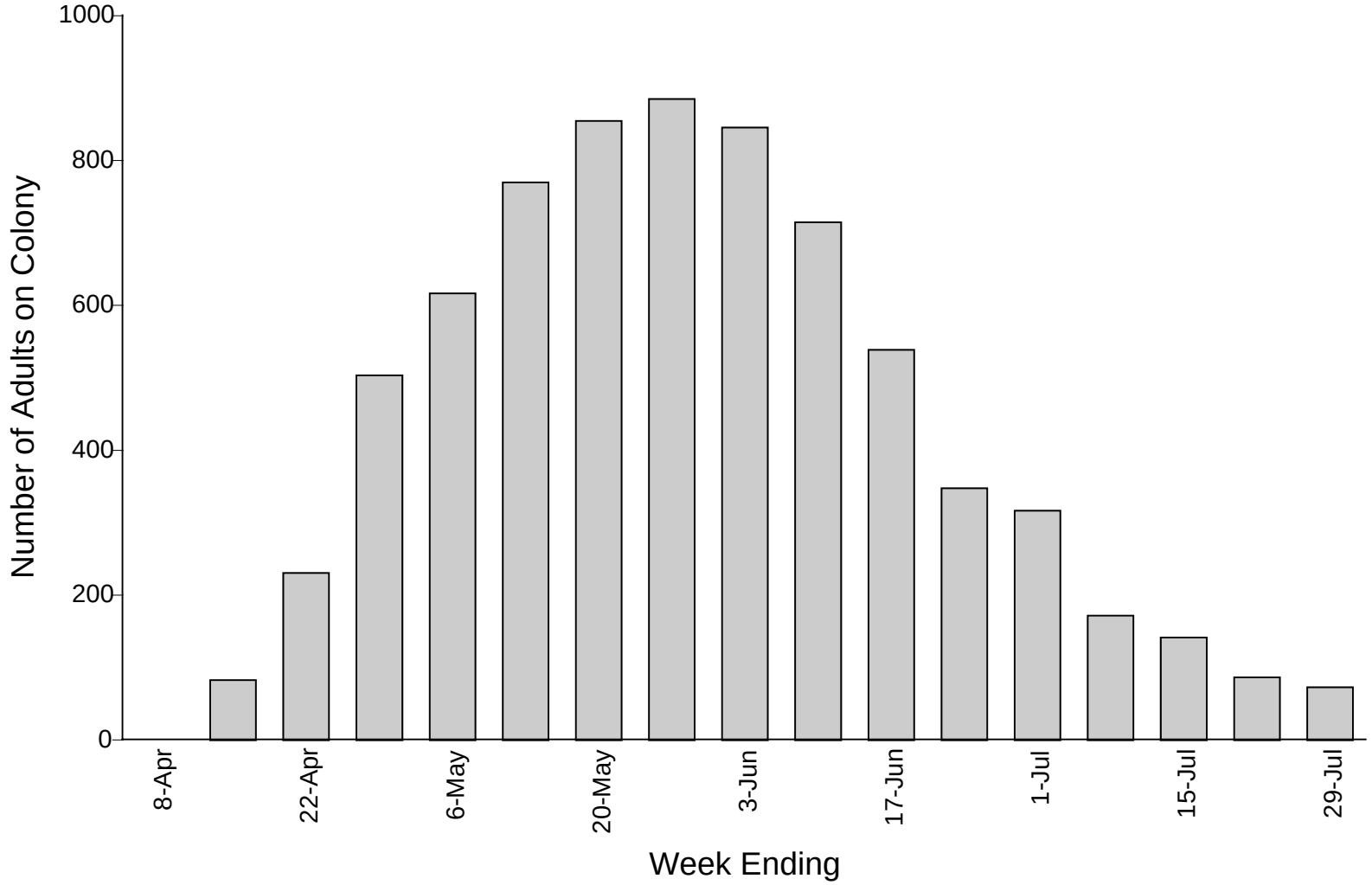
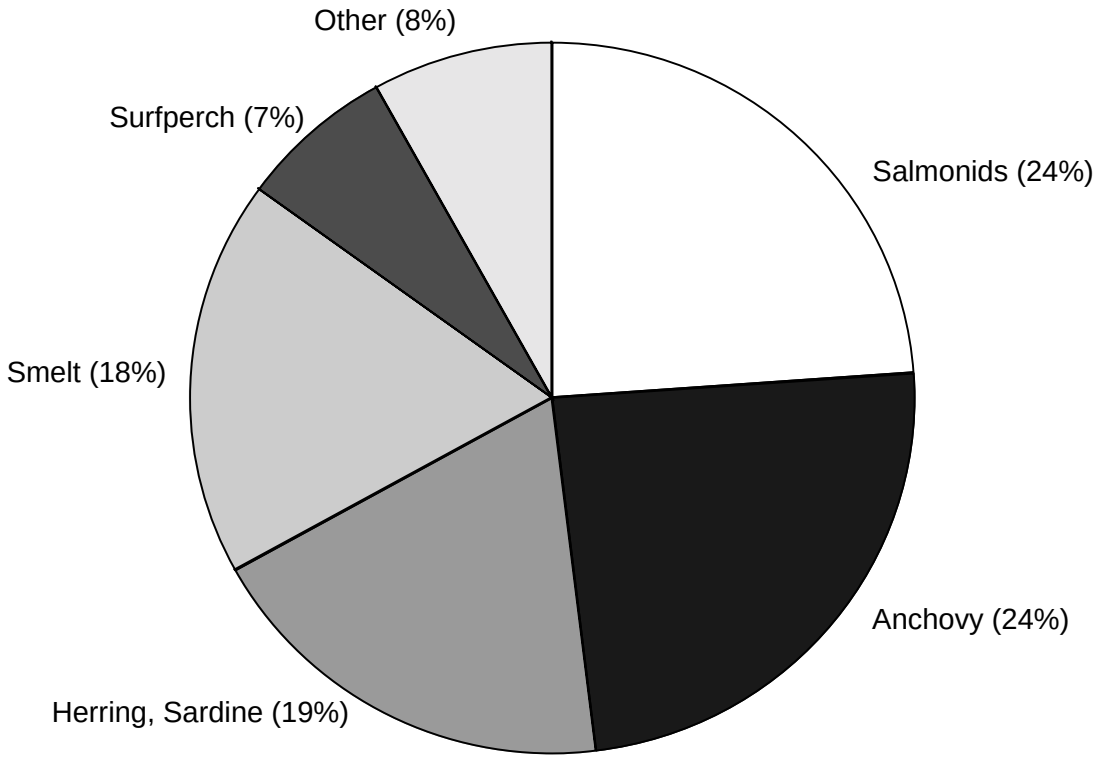


Figure 2. Visual estimates of the number of adult Caspian terns on the Crescent Island colony in 2003.



N = 5,476 bill load fish

Figure 3. Diet composition of Caspian terns nesting on East Sand Island in 2003 (see text for methods of calculation).

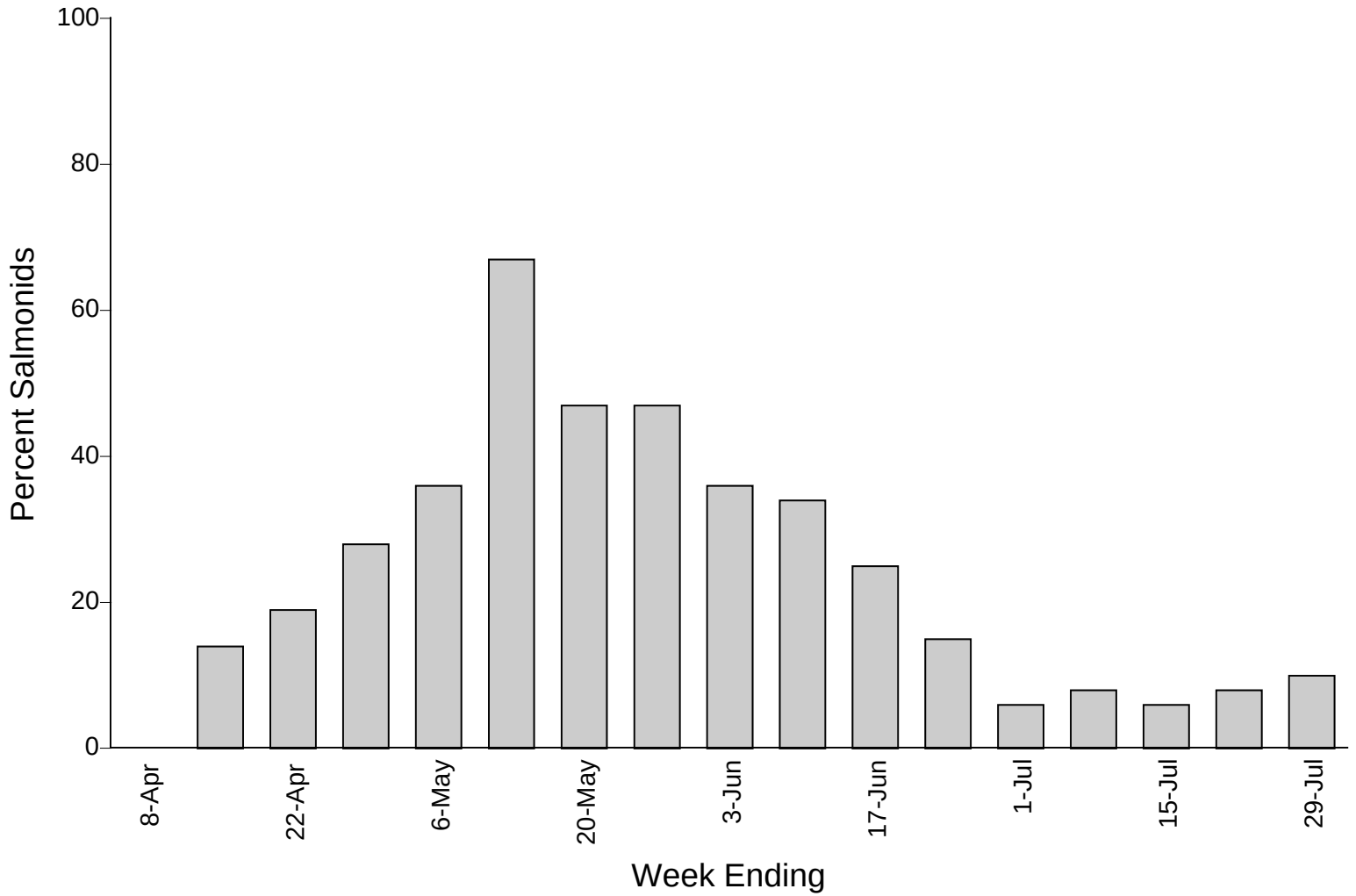


Figure 4. Proportion of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island in 2003.

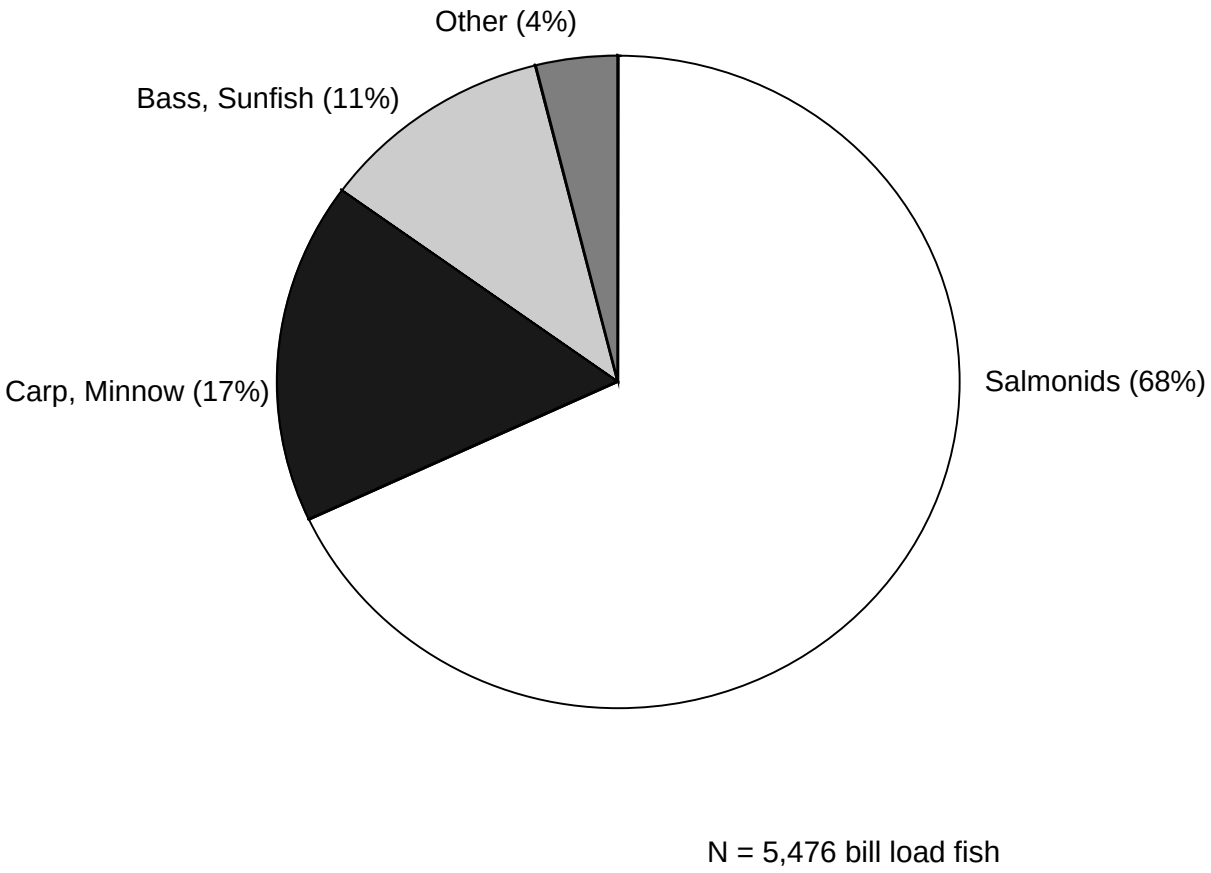


Figure 5. Diet composition of Caspian terns nesting on Crescent Island in 2003 (see text for methods of calculation).

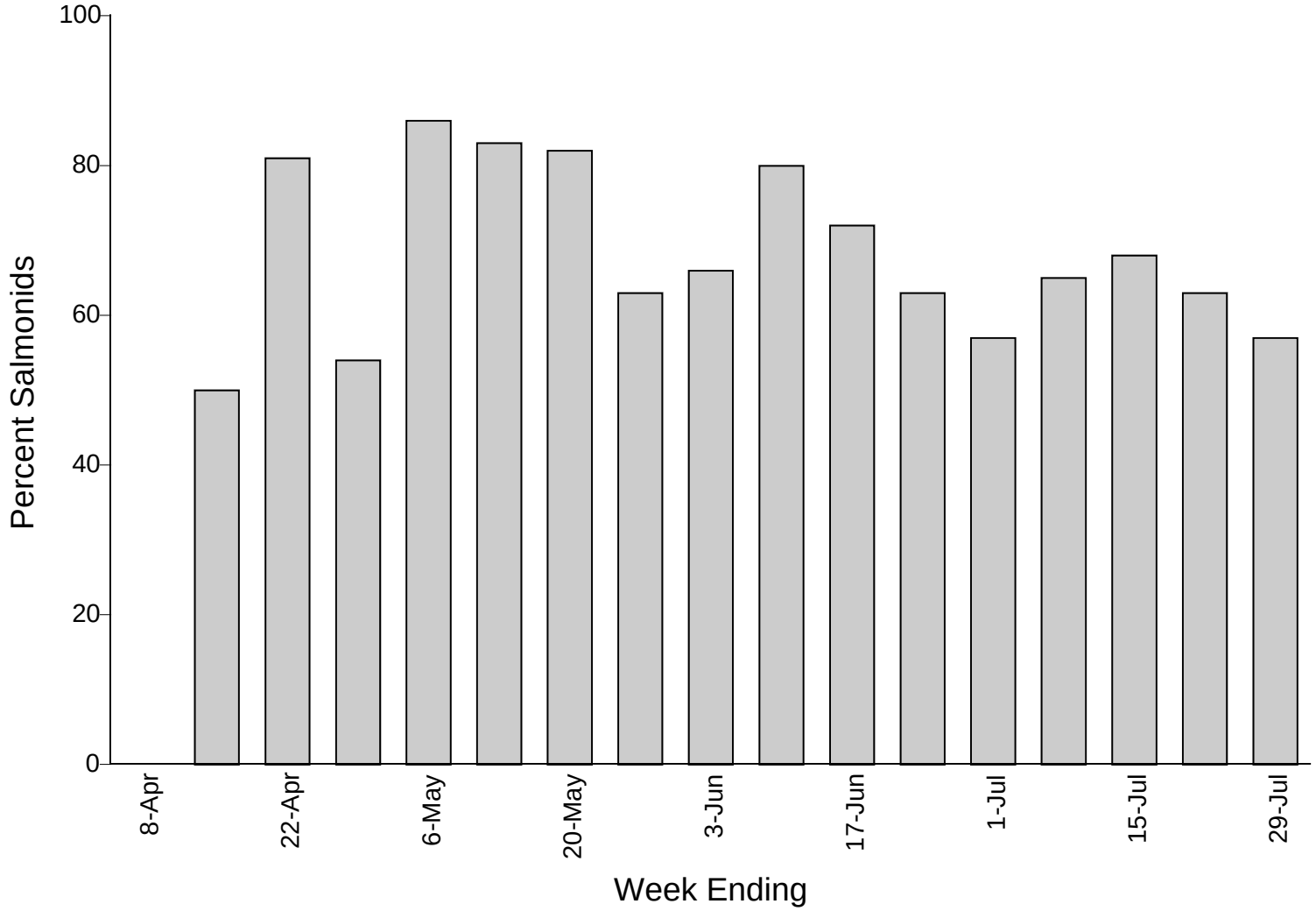


Figure 6. Proportion of juvenile salmonids in the diet of Caspian terns nesting on Crescent Island in 2003.

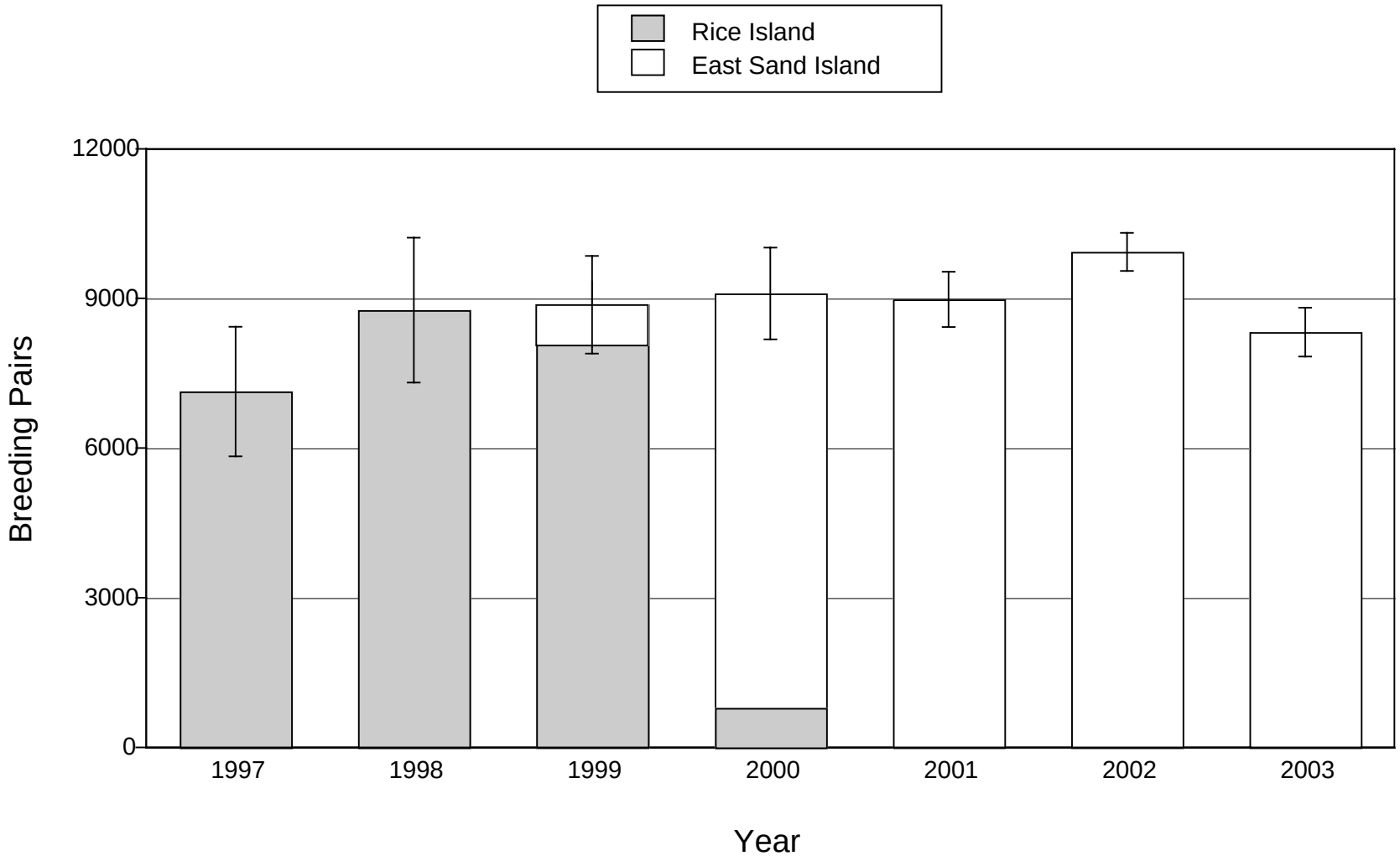


Figure 7. Caspian tern colony size in the Columbia River Estuary, 1997 - 2003.

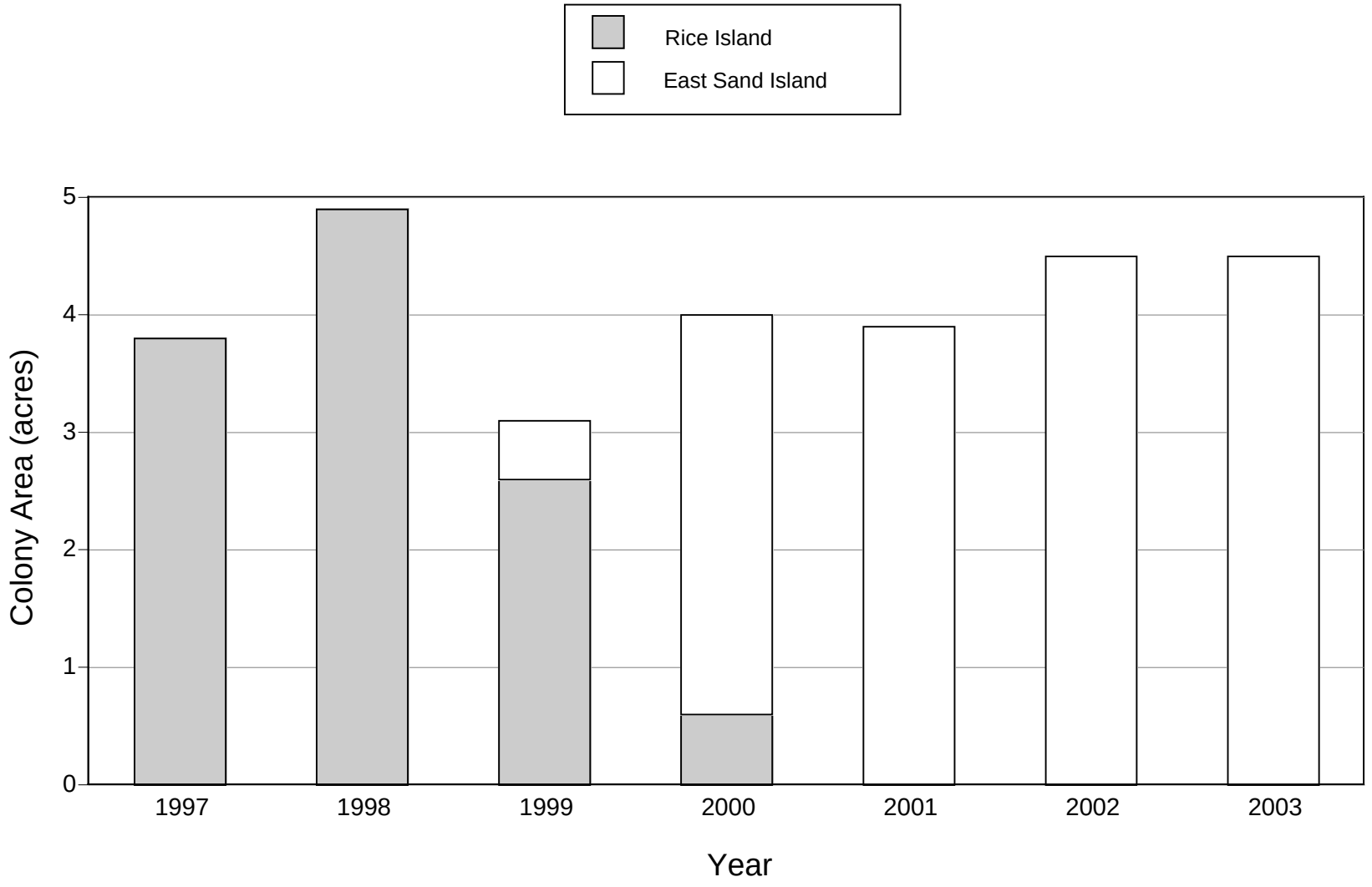


Figure 8. Caspian tern colony area in the Columbia River Estuary, 1997 - 2003.

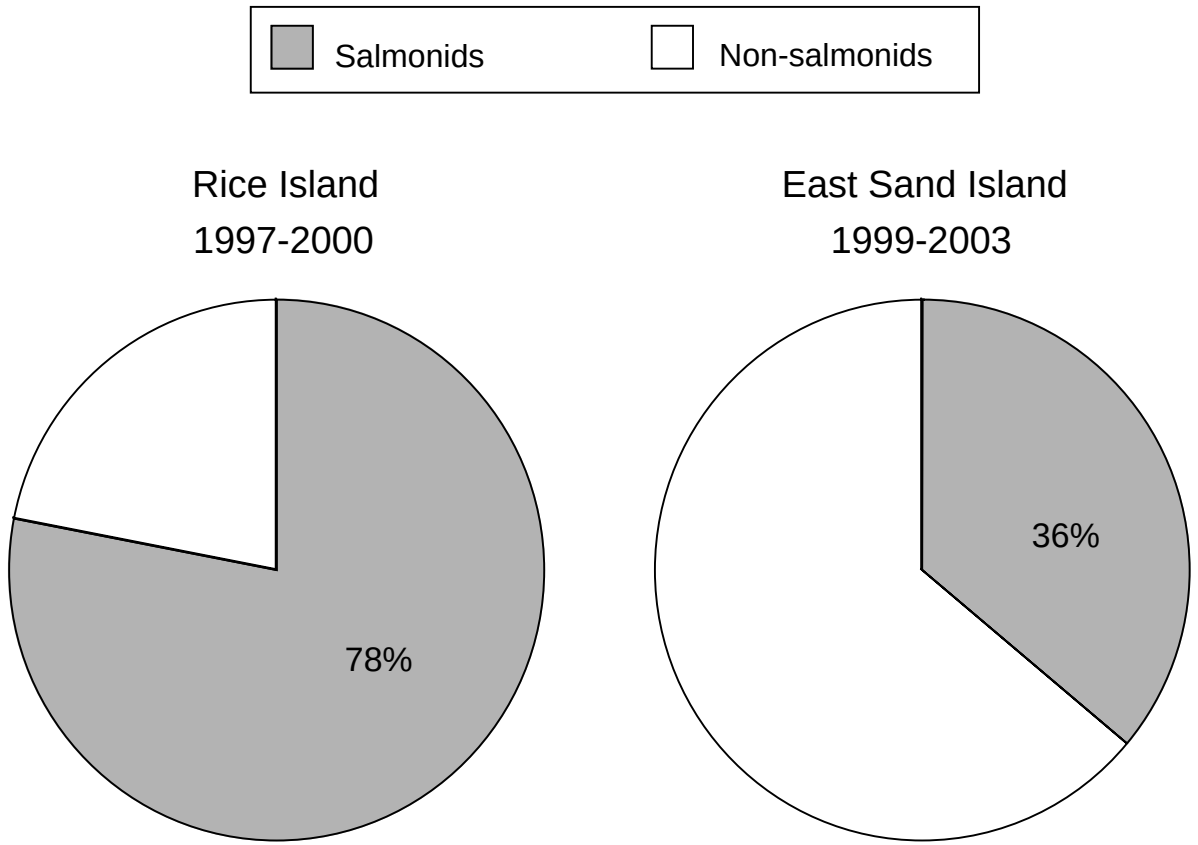


Figure 9. Mean proportion of juvenile salmonids in the diet of Caspian terns nesting on two colonies in the Columbia River Estuary, 1997-2003.

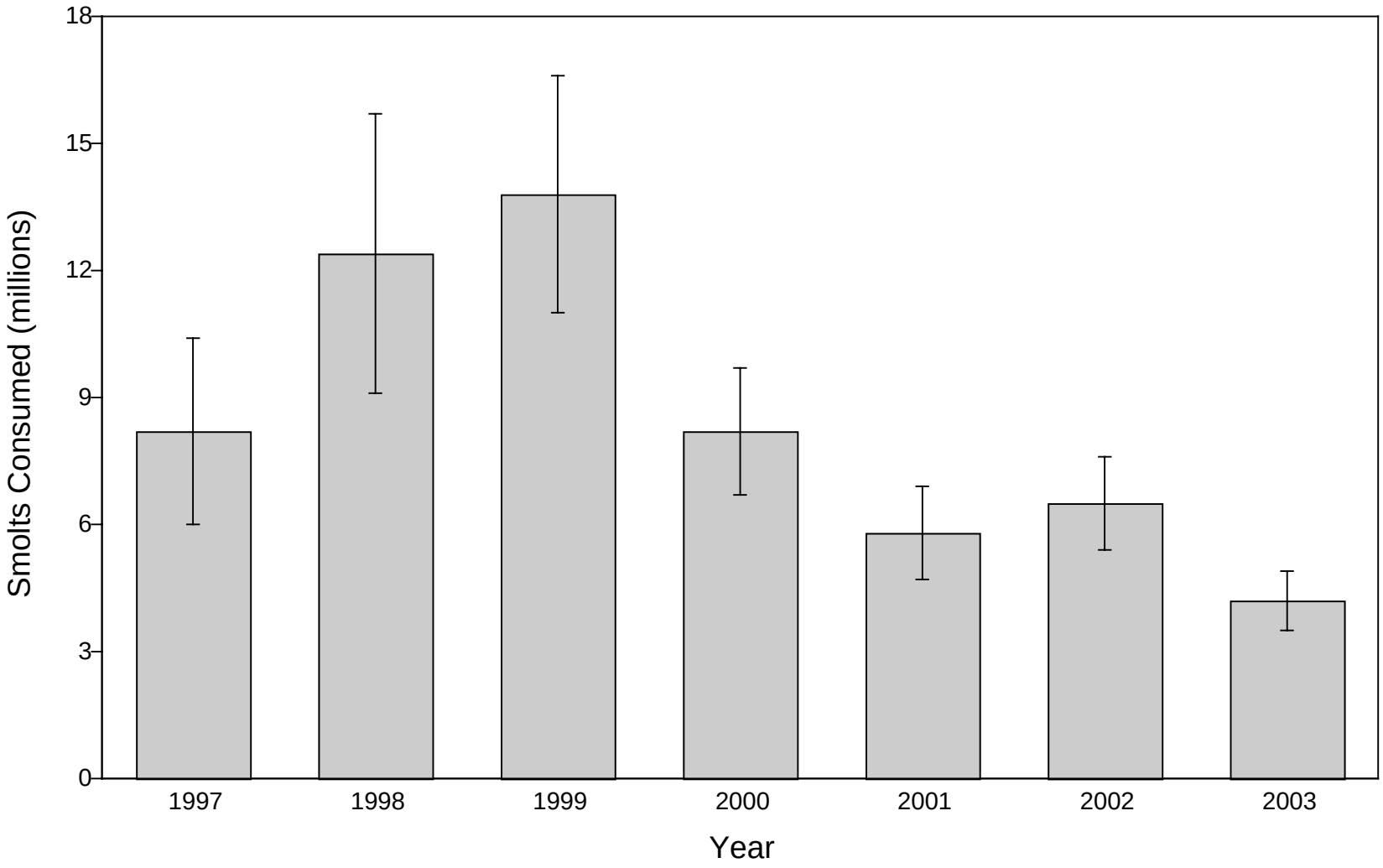


Figure 10. Total estimated consumption of juvenile salmonids by Caspian terns nesting in the Columbia River Estuary, 1997 - 2003.

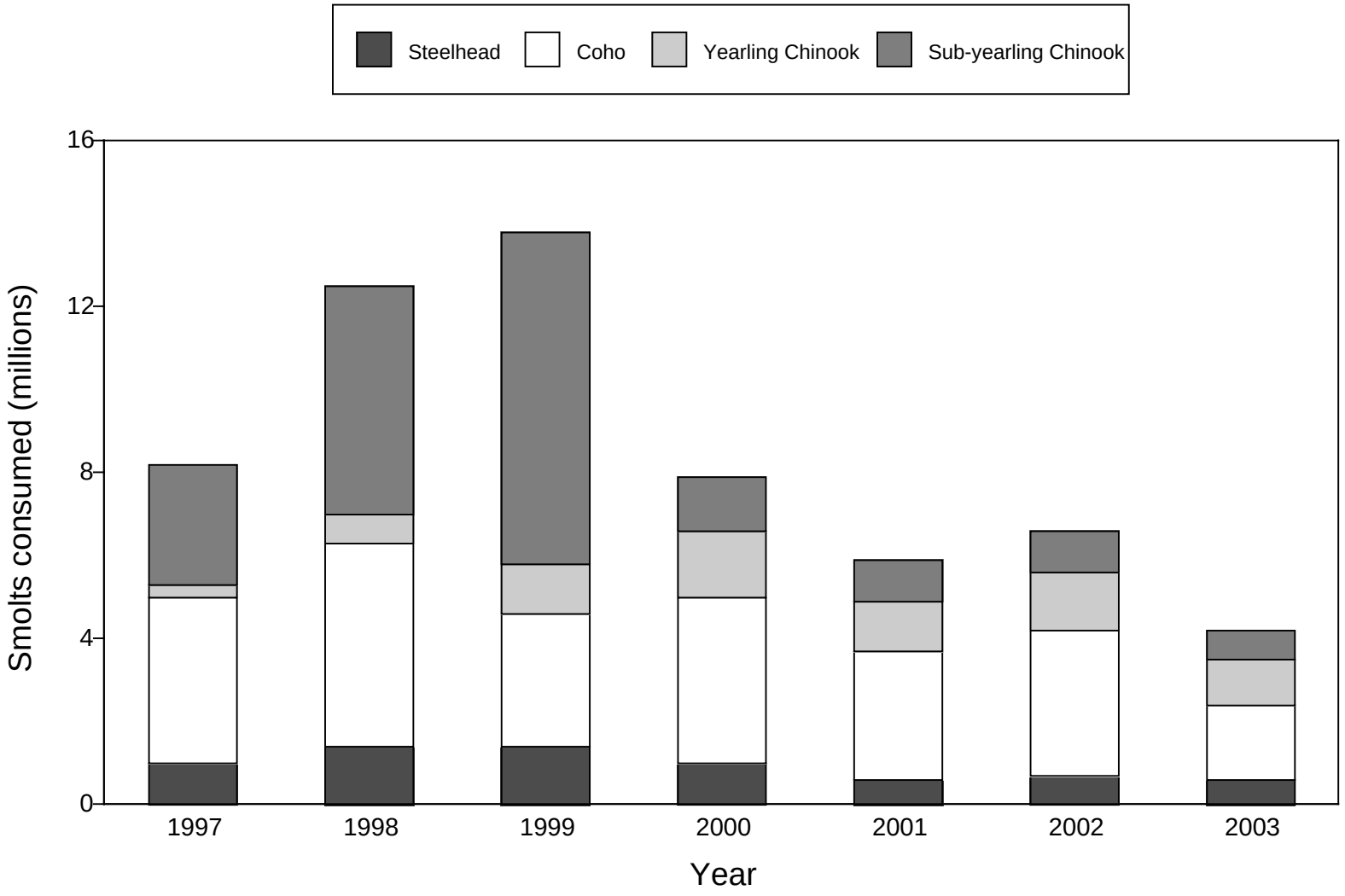


Figure 11. Total estimated consumption of three species of juvenile salmonids by Caspian terns nesting in the Columbia River Estuary, 1997-2003.

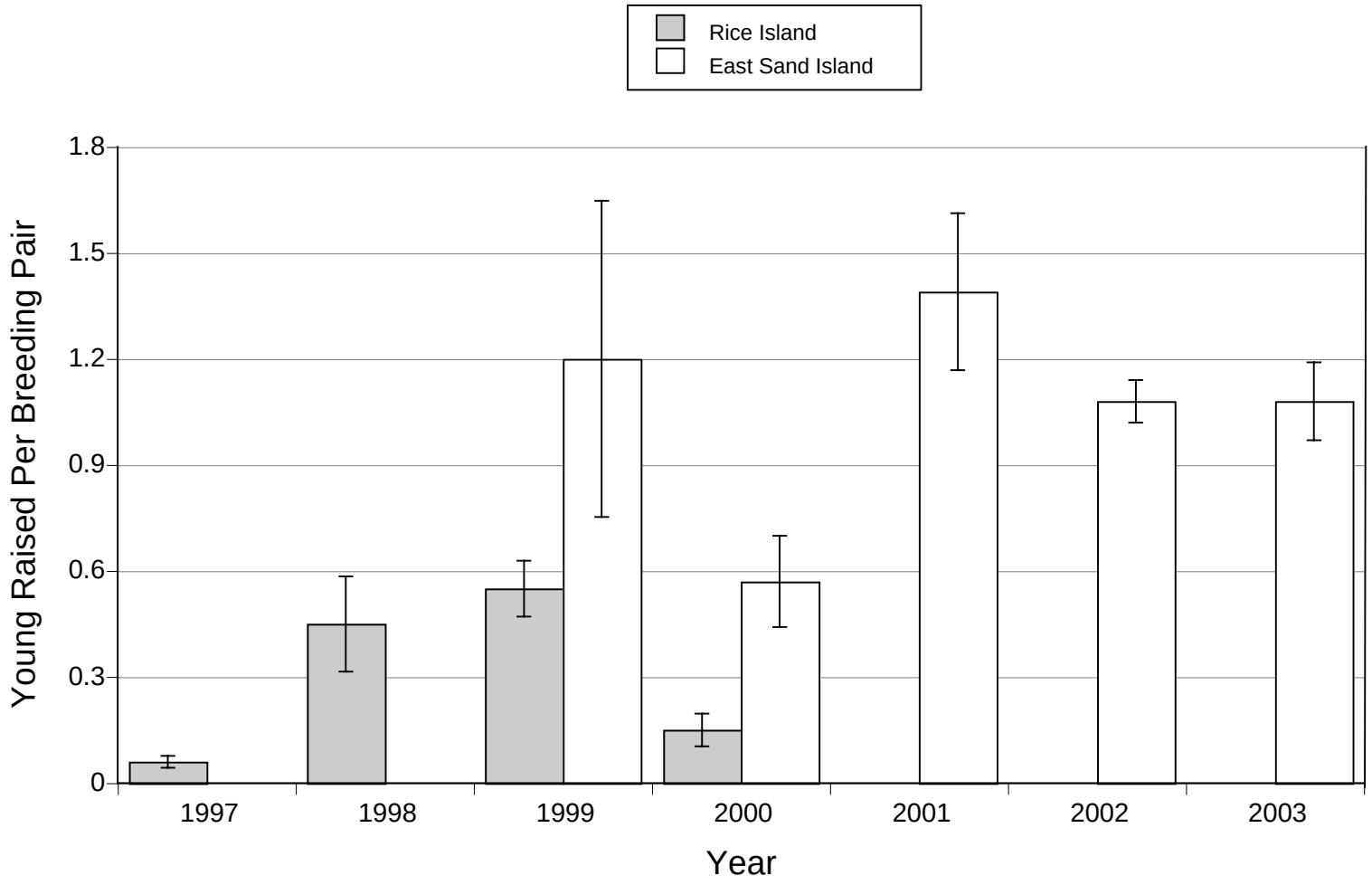


Figure 12. Caspian tern nesting success at two colonies in the Columbia River Estuary, 1997 - 2003.

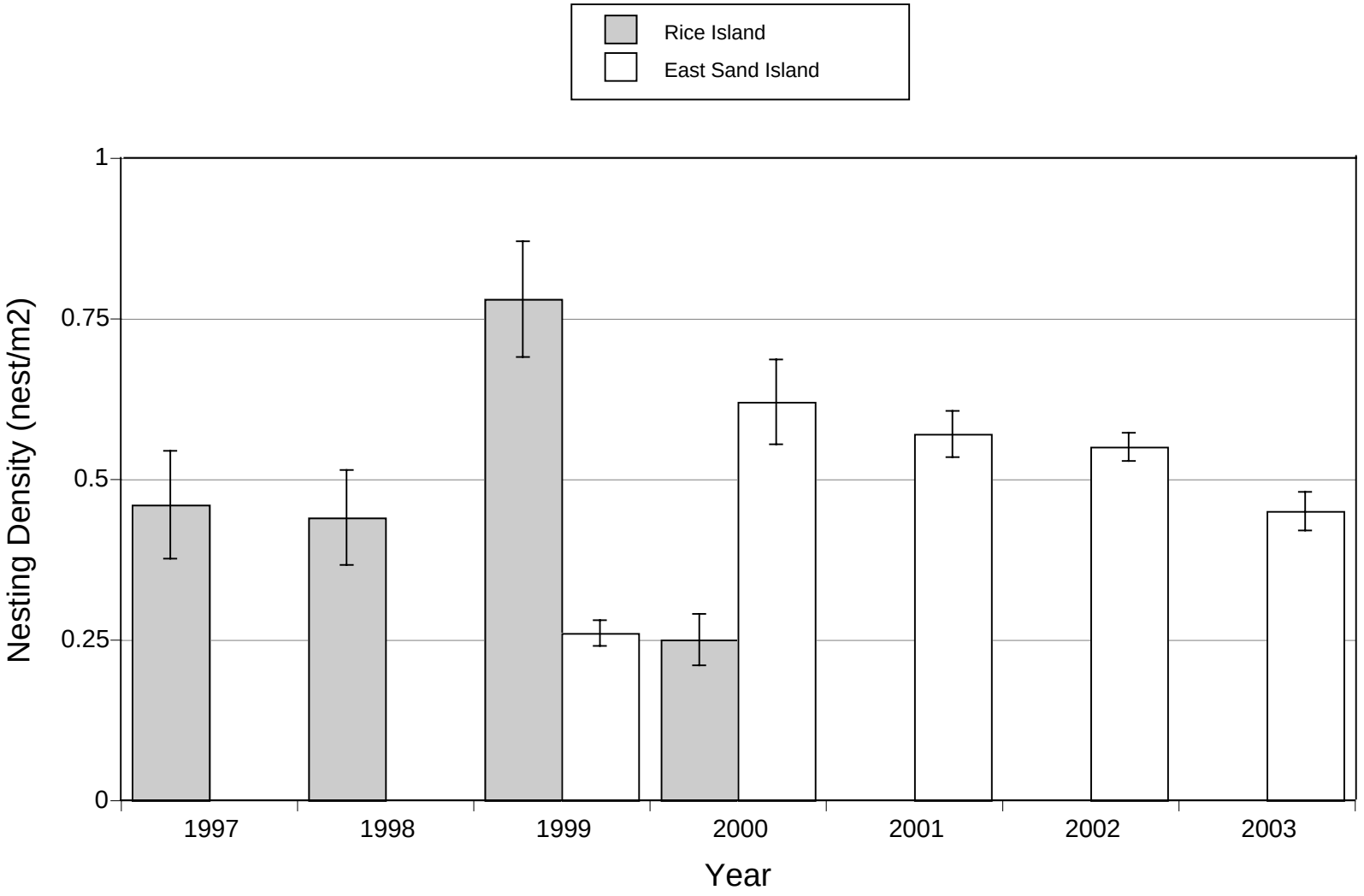


Figure 13. Caspian tern nesting density at two colonies in the Columbia River Estuary, 1997 - 2003.

Table 1. Off-colony detections (% of total) of radio-tagged Caspian terns nesting on Crescent Island in 2003. The area surveyed by road included: the lower Columbia River from one mile below McNary Dam to Richland, Washington; the lower Snake River from the Columbia River confluence to 10 miles above Ice Harbor Dam; the Walla Walla River from the Columbia River confluence to Touchet, Washington; Burbank Slough; and the Yakima River from the Columbia River confluence to river mile 7.

		Columbia River			**Snake River**		**Other Tributaries**		
	# of detections	Downstream of Crescent Is.	Upstream of Crescent Is.	McNary Dam	Confluence to above Ice Harbor Dam	Ice Harbor Dam	Walla Walla River	Burbank Slough	Yakima River
Late May	20	25.0	0.0	0.0	5.0	0.0	35.0	35.0	0.0
Early June	19	36.8	5.3	0.0	0.0	5.3	36.8	15.8	0.0
Late June	16	50.0	12.5	12.5	0.0	0.0	18.8	6.3	0.0
Early July	18	44.4	11.1	16.7	5.6	0.0	5.6	16.7	0.0
Late July	10	50.0	30.0	0.0	0.0	0.0	10.0	10.0	0.0
Total	83	39.8	9.6	6.0	2.4	1.2	22.9	18.1	0.0

Table 2. Diet composition (% identifiable prey items) of Caspian terns nesting on Rice Island and East Sand Island, 1997-2003.

	1997-1998	1999		2000		2001	2002	2003
Prey Type	Rice Is.	Rice Is.	East Sand Is.	Rice Is.	East Sand Is.	East Sand Is.	East Sand Is.	East Sand Is.
Herring, sardine, shad	10.7	1.8	8.2	1.7	10.1	20.3	18.4	18.5
Anchovy	0.0	6.5	15.9	0.5	11.6	22.4	14.1	23.7
Peamouth, pike minnow	2.0	1.0	0.5	0.9	0.8	0.6	0.5	0.1
Smelt	6.2	0.9	3.8	0.7	5.6	5.1	7.3	17.6
Salmonid	**72.7**	**76.5**	**45.6**	**89.6**	**46.5**	**32.5**	**31.1**	**24.1**
Cod	0.0	0.0	0.0	0.0	0.0	2.2	0.1	0.3
Sculpin	1.2	1.3	3.3	1.9	5.1	3.6	2.4	3.0
Surfperch	5.5	2.8	10.7	1.2	10.0	5.9	11.6	6.7
Pacific sand lance	0.1	0.1	5.9	0.1	5.6	3.1	2.5	4.5
Flounder	0.2	0.3	0.2	1.8	0.6	0.2	0.1	0.0
Other	1.4	8.7	5.8	1.6	3.9	3.9	11.9	1.5
Total no. of prey	1,448	5,305	5,486	5,023	5,387	6,007	5,661	5,476