Caspian Tern Research on the Lower Columbia River

FINAL 2002 Season Summary

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This Final 2002 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 This report is not for citation without permission of the authors.

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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 an expanding population of about 17,000 nesting Caspian terns in 1998. This colony was the largest known breeding colony of Caspian terns in the world, and supported 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% c.i. = 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. In 2001 and 2002, all Caspian terns nesting in the Columbia River estuary used East Sand Island, with approximately 9,000 and 9,900 pairs nesting at the site in 2001 and 2002, respectively.

Our results also indicate 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 (0.57–1.39 young raised per breeding pair on average during 1999-2002) was consistently higher than for terns nesting on Rice Island, both prior to tern management (1997–1998: 0.06–0.45 young raised per breeding pair) and post-management (1999–2000: 0.15–0.55 young raised per breeding pair). 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 between 31% and 47% salmonids during the years 1999-2002, compared to the diet of Rice Island terns, which consisted of 77% and 90% salmonids in 1999 and 2000, respectively. 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 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. This represents 53% and 48% reductions in estimates of smolt consumption compared to 1998. Caspian terns nesting on East Sand Island in 2002 still consumed an estimated 5.5 - 7.6 million smolts, with some ESA-listed stocks still suffering significant losses to tern predation (Ryan et al. 2001a, Ryan et al. 2001b). 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.

Caspian tern colonies on or near the mid-Columbia River show little promise as alternative nest sites for terns currently nesting in the estuary. Terns attempting to nest on Three Mile Canyon Island, which formerly consisted of 200-400 breeding pairs, completely failed in 2000 and 2001 due to mink predation; while in 2002 terns did not attempt to nest there. The tern colony on Crescent Island consisted of 550-700 breeding pairs in 2000-2002 and has experienced fair nesting success (0.67, 1.07, and 0.65 young raised per breeding pair in 2000, 2001, and 2002, respectively). But juvenile salmonids comprised 68% of identified prey items in 2001 and 2002, suggesting that adult terns shifting from the East Sand Island colony to the Crescent Island colony would have a greater impact on survival of juvenile salmonids. Also, the high density of tern nests on Crescent Island and the high nesting densities of gulls on the remainder of the island suggest that there is little opportunity for expansion of the tern colony. The Caspian tern colony that first became established on Miller Rocks in 2001 (15-20 pairs), was not reoccupied by terns in 2002. Tern colonies in Potholes Reservoir do not appear to be limited by nesting habitat, but terns from this colony are known to regularly commute over 50 km (30 miles) to the Columbia River to prey on juvenile salmonids. Terns from this colony have evidently been the subject of considerable lethal control at hydroelectric dams on the mid-Columbia River. The best prospects for restoration or augmentation of Caspian tern colonies seem to exist on the coast of the Pacific Northwest.

The welfare of other listed or beleaguered salmonid stocks has been a primary concern in coastal areas under consideration for restoration of Caspian tern colonies, yet for most former coastal 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 coast of the Pacific Northwest appears unlikely without empirical evidence that local salmonid stocks will not be at risk. In 2001, we tested the feasibility of attracting Caspian terns to nest on barges as temporary colony sites so that the suitability of alternative sites for tern colony restoration could be assessed. A small barge covered with sand and equipped with tern decoys and audio playback systems was anchored in Commencement Bay, Washington. Caspian terns began nesting on the barge within one month of deployment. Approximately 388 tern nests were initiated on the barge at a density of 1.5 nests/m^2, the highest Caspian tern nest density reported in the Pacific Northwest. Tern diets were 65% juvenile salmonids; a variety of marine forage fishes comprised the remainder of the diet. The barge was removed prior to hatching of

tern eggs because of a breakdown in inter-agency coordination on the project. Nevertheless, the study demonstrated that Caspian terns can rapidly colonize a suitable barge and that temporary colonies on barges can help assess prospective colony restoration sites along the coast of the Pacific Northwest. The rapid and overwhelming response of Caspian terns to the habitat provided on the barge in Commencement Bay is strong evidence for the acute shortage of suitable nesting habitat along the coast of the Pacific Northwest. Restoration of former colony sites or establishment of new sites for Caspian terns outside the Columbia River estuary would likely benefit both salmonid stocks from the Columbia Basin and Caspian terns. Currently, approximately two-thirds of all Caspian terns belonging to the Pacific Coast population nest on East Sand Island. The population is particularly vulnerable to local catastrophes, such as storms, disease outbreaks, oil spills, predation events, or human disturbance. Redistributing the tern population to a number of smaller colonies over a larger geographic area will reduce this risk.

Preparation and Modification of Nesting Habitat

Columbia River Estuary

On April 2, 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 and U.S. Fish and Wildlife Service). The signed agreement allowed habitat work to begin 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 (see Map 1). At East Sand Island, habitat improvements were accomplished by the USACE from April 6-8. Roughly 6.5 acres of suitable bare sand habitat was prepared on East Sand Island. Tern decoys (252) and sound systems (2) were deployed in the center of the colony area to attract nesting terns to the site. On April 8, a camp was set up on East Sand Island and was continuously occupied by two colony monitors throughout the 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 2002.

Work crews from NMFS, ODFW, and USACE flagged roughly 0.5 acres of bare sand habitat at the former Rice Island tern colony site on April 8. In addition, eagle decoys and eagle perches were deployed at the periphery of the former colony site. The remaining former colony area on Rice Island (roughly 7 acres) was completely vegetated and unsuitable for tern nesting. No hazing of terns to discourage nesting was conducted on Rice Island in 2002.

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 2002 (see Map 1) was estimated using aerial photographs of the colony taken near the end of the incubation period. The average of 2 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 2 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, all nesting by Caspian terns in the Columbia River estuary occurred on East Sand Island in 2002. We estimate that 9,933 breeding pairs (95% c.i. = 9,551 – 10,314 breeding pairs) attempted to nest at East Sand Island in 2002 (see Figure 1 for weekly counts of terns on the East Sand Island colony in 2002). This estimate is significantly greater than our estimate of colony size at East Sand Island in 2001 (8,982 breeding pairs, 95% c.i. = 8,427 – 9,538 breeding pairs). The increase in colony size at East Sand Island in 2002, as compared to the previous year, was likely due to a combination of recruitment of terns that formerly nested in Commencement Bay (and perhaps elsewhere) and first year breeders that were produced in the Columbia River estuary in 1999.

We estimate that 10,715 fledglings (95% c.i. = 10,271 – 11,158 fledglings) were produced at the East Sand Island colony in 2002. This corresponds to nesting success of 1.08 young raised per breeding pair (95% c.i. = 1.02 – 1.14 fledglings/breeding pair), which was significantly lower than the estimate of nesting success at the East Sand Island tern colony in 2001 (1.39 fledglings/breeding pair, 95% c.i. = 1.17 – 1.61 fledglings/breeding pair). The decrease in nesting success in 2002, as compared to the previous year, may have been due to lower availability of forage fishes. This is supported by an increase in average duration of tern foraging trips this year as compared to last. We also observed lower average fish delivery rates by terns to their nests in 2002 (0.450 fish/hour) than in 2001 (0.715 fish/hour). This comparison was confounded by smaller average brood size in 2002 (1.43 chicks) compared to 2001 (1.73 chicks). After accounting for different brood sizes using a simple linear regression model, fish delivery rates were still significantly lower in 2002 than in 2001 (difference of 0.203 fish/hour, 95% CI: 0.031 - 0.375 fish/hour, $p = 0.02$). Furthermore, a severe and unseasonable rain- and wind-storm in late June caused severe flooding on the colony and was likely a contributing factor in the lower productivity in 2002. Up to 1,000 chicks may have died as a direct result of this storm, and many more may have suffered delayed mortality (i.e., from exposure and adult-chick aggression associated with chicks wandering away from flooded areas and into the nesting territories of neighboring terns). Finally, it is possible that gull predation on tern eggs and chicks was higher this year as compared to 2001 due to a decline in food availability for nesting gulls.

On April 23, roughly 300 terns were observed loafing in an upland area on 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 had their personnel brought 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. No other aggregations of terns were observed at other dredge spoil disposal areas in the upper estuary (Rice Island, Miller Sands Spit, Puget Island) in 2002.

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 580 breeding pairs attempted to nest at the Crescent Island tern colony in 2002, about 12% fewer pairs than in 2001. We estimated that 375 young were fledged from that colony in 2001, or 0.65 young raised per breeding pair, lower nesting success than in 2001.

Caspian terns did not attempt to nest at either Three Mile Canyon Island or Miller Rocks in 2002. 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.

Commencement Bay and Other 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. Personnel from the WDFW surveyed potential nesting locations in Commencement Bay (see Map 3). Estimates of the number of nesting pairs at a site in Commencement Bay were based on ground counts of adult terns conducted late in the nesting season, multiplied by a factor of 0.62 (i.e., ratio of adults to nests for a number of sites along the Pacific Coast; D. Shuford, Point Reyes Bird Observatory, personal communication).

Results and Discussion: Although Caspian terns were commonly observed foraging and roosting in Willapa Bay and Grays Harbor throughout the 2002 breeding season, no

nesting attempts by terns were detected at either location in 2002. 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.

Caspian terns nested on the rooftop of a building near the mouth of the Hylebos Waterway in the Port of Tacoma (Commencement Bay; see Map 3). Michelle Tirhi of the Washington Department of Fish and Wildlife surveyed this colony on July 9. A total of 347 adult terns, 96 tern chicks, and 11 tern eggs were counted on the rooftop. The terns had apparently selected this rooftop because of some accumulation of dirt and debris, although nest scrapes were barely discernible due to a paucity of nesting substrate. A conservative estimate (i.e., some portion of the rooftop was not visible from the vantage used during the count) of the number of nesting pairs on the rooftop was 215. This represents the only known Caspian tern breeding colony along the coast of Washington in 2002. The Port of Tacoma plans to remove the dirt and debris from the roof prior to the tern nesting season next year.

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 once each 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 10 bill load fish each week at 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"). Salmonids were identified as 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. PIT tags placed in juvenile salmonids were also collected from the East Sand Island tern colony in 2002. Those data are being analyzed and will be available through NOAA Fisheries (Brad Ryan, *brad.ryan@noaa.gov*).

Estimates of annual smolt consumption for the East Sand Island tern colony were calculated using a bioenergetics modeling approach (see 1998 Annual Report 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 31% were juvenile salmonids (n = 5,661). 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 (69% of identified bill loads) in the diets of terns nesting on East Sand Island (Figure 2). The proportion of the diet that was salmonids peaked at ca. 65% during the first week in June (Figure 3), approximately three weeks later than the peak in salmonid consumption in 2001. We estimated that Caspian terns nesting on East Sand Island consumed 6.5 million juvenile salmonids in 2002 (95% confidence interval = 5.5 - 7.6 million). Of all the juvenile salmonids consumed, we estimate that 53% were coho salmon (best estimate = 3.5 million, 95% c.i. = 2.9 - 4.1 million), 35% were chinook salmon (best estimate = 2.3 million, 95% c.i. = 1.8 – 2.8 million), and 11% were steelhead (best estimate = 0.7 million, 95% c.i. = 0.6 - 0.9 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). 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 2002. Those data are being analyzed and will be available through NOAA Fisheries (Brad Ryan, *brad.ryan@noaa.gov*).

Results and Discussion: Juvenile salmonids were the most prevalent prey type for Caspian terns nesting on Crescent Island (67% of total identified bill loads), followed by centrarchids (bass and sunfish, 11%) and cyprinids (carp and minnows, 8%; n = 2,222). The proportion of the diet that was salmonids was higher and more variable over time than for terns nesting on East Sand Island. The salmonid portion of the diet peaked (over 80% of prey items) in early May, and again in late June (Figure 4); 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.

Dispersal and Survival

Methods: Juvenile terns were banded at several tern colonies throughout the Pacific Northwest in 2002 in order to continue efforts to measure survival, post-breeding dispersal, and movements among colonies. Each tern was banded with a federal numbered metal leg band and a unique combination of colored leg bands that allows for the identification of individual terns at a distance (i.e., at roosts or on colonies). Tern chicks that were near fledging were banded at the East Sand Island (n = 375) and Crescent Island (n = 72) colonies. Tern chicks were captured on-colony by herding the flightless birds 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 in captive chicks. Terns that were color-banded in previous years (2000-2001) were re-sighted on various breeding colonies by researchers throughout the 2002 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 2002, over 2,500 re-sightings of 436 color-banded Caspian terns had been reported as of 30 September. Resighted terns were all initially banded as adults in 2000 and 2001 at the Rice Island, East Sand Island, or ASARCO (Commencement Bay, WA) colonies. Thirteen of the 66 adults terns (20%) banded at the ASARCO Site in 2000 and 2001 were subsequently re-sighted at East Sand Island in 2002; four of these were confirmed to be breeding (i.e., attending chicks). None of the terns color-banded as chicks in 2000 or 2001 were re-sighted at any tern colony in 2002. This is not surprising because subadult terns normally do not return 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 eventually 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.

As was the case in 2001, most re-sightings of post-breeding terns were along the coasts of Oregon, Washington, and British Columbia (as far north as Vancouver, B.C.). Later re-sightings have been from along the Pacific Coast south to Sinoloa Mexico. These data suggest that terns may disperse northward along the coast before heading south to over-winter along the Pacific coast of Mexico and Central America.

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 (Figure 5). 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 6). Since 1997, the number of Caspian terns nesting in the estuary increased significantly from 1997 to 1998, remained relatively stable from 1998 to 2001, and once again increased significantly from 2001 to 2002 (Figure 5).

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 1, Figure 7). Caspian terns nesting on East Sand Island in 2002 had the lowest average percentage of salmonids in their diet (31%) and terns nesting on Rice Island in 2000 had the highest percentage of salmonids in their diet (90%; Figure 7). 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%, and 48% in 2000, 2001, and 2002, respectively (Figure 8). 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 2000-2002 compared to 1998 was primarily due to a reduction in the number of chinook salmon consumed (Figure 9). In 2001, we also observed a large decline (ca. 50%) in the consumption of steelhead, compared to 1999 and 2000 (Figure 9).

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 1 and Figure 7). 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. Nesting success of Caspian terns on East Sand Island (1.20, 0.57, 1.39, and 1.08 young raised per breeding pair in 1999, 2000, 2001, and 2002, respectively) 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 10). 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 11), 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 and 2002, 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 10). The relatively high nesting success of Caspian terns on East Sand Island in 2001 and 2002 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 2002 still consumed an estimated 5.5-7.6 million smolts, with 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 the only undisturbed Caspian tern breeding site 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 coast of the Pacific Northwest appears unlikely without empirical evidence that local salmonid stocks will not be at risk. Toward that end, we tested the feasibility of using small barges as temporary colony sites for Caspian terns as a means to assess diet composition of terns at potential colony restoration sites outside the Columbia River estuary. The success of the pilot study suggests that this approach holds promise for providing resource managers with the information needed for a science-based, long-term management plan.

The solution to the tern predation problem should not lie solely in management of the birds themselves. As part of research proposed for 2003-2005, we would look at differences in vulnerability to predation of various salmonid stocks and investigate the cause(s) for those differences. First, the research on smolt PIT tags recovered from piscivorous waterbird colonies that we have done previously (Collis et al. 2001a) and propose to do in future years would address the relative vulnerability of different groups of salmonids to predation. These results, coupled with information on fish origin, health,

and passage history, would be used to help identify the potential causes for differences in vulnerability to avian predation, including testing predictions of the delayed mortality hypothesis. Second, we would assess the condition, contaminant burdens, and health status of salmonid smolts consumed by piscivorous waterbirds to compare with the condition of smolts caught in river. These analyses would enable us to test hypotheses regarding the compensatory/additive nature of avian predation. Third, we are proposing to use genetic markers to identify the salmonid species and stocks, if feasible, in stomach content samples from piscivorous waterbirds. Fourth, we would test the feasibility of experiments using juvenile salmonids in net pens anchored near Caspian tern colonies to test hypotheses regarding the cause of differences in vulnerability among salmonids. Further, net pens offer the potential for providing terns with an alternative food source, thereby reducing their reliance on in-river migrants. 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.

Literature Cited

Cuthbert, F., and L. Wires. 1999. Caspian tern (*Sterna caspia*). in A. Poole and F. Gill, editors. The Birds of North America, no. 403. The Birds of North America, Inc., Philadelphia, Pennsylvania.

Ryan, B. A., J. H. Glabek, J. W. Ferguson, E. P. Nunnallee, and R. D. Ledgerwood. 2001a. Detection of passive integrated transponder (PIT) tags on piscivorous bird colonies in the Columbia River basin, 2000. Report of Research, Northwest Fisheries Science Center, NMFS/NOAA, Seattle, WA.

Ryan, B. A., E. P. Nunnallee, J. H. Glabek, and J. W. Ferguson. 2001b. Recovery of passive integrated transponder tag codes from piscivorous bird colonies in the Columbia River basin. 2001 Annual Research Review, Anadromous Fish Evaluation Program, U.S. Army Corps of Engineers, Portland, OR. (abstract only).

Quinn, J. S., and J. Sirdevan. 1998. Experimental measurement of nesting substrate preference in Caspian terns, *Sterna caspia*, and the successful colonization of human constructed islands. Biological Conservation 85:63-68.

Publications and Submitted Manuscripts

Most of the study results presented here are in the published literature or in manuscripts recently submitted for publication. Published literature from this study include:

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.

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

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

Collis, K., D.D. Roby, C.W. Thompson, D.E. Lyons, and M. Tirhi. 2002. Barges as temporary breeding sites for Caspian terns: Assessing potential sites for colony restoration. Wildlife Society Bulletin 30: 1140-1149.

Roby, D.D., K. Collis, D.E. Lyons, M. Antolos, and D.P. Craig. In press. Caspian Tern (*Sterna caspia*). Species account in Birds of Oregon: A General Reference (D. Marshall, M. Hunter, and A. Contreras, eds.), Oregon State Univ. Press, Corvallis (available at http://osu.orst.edu/pubs/birds/bogr/accounts.htm.).

Roby, D.D., K. Collis, and D.E. Lyons. 2003. Conservation and management for fish-eating birds and endangered salmon. Proceedings of the Third International Partners In Flight Conference, Asilomar, California.

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

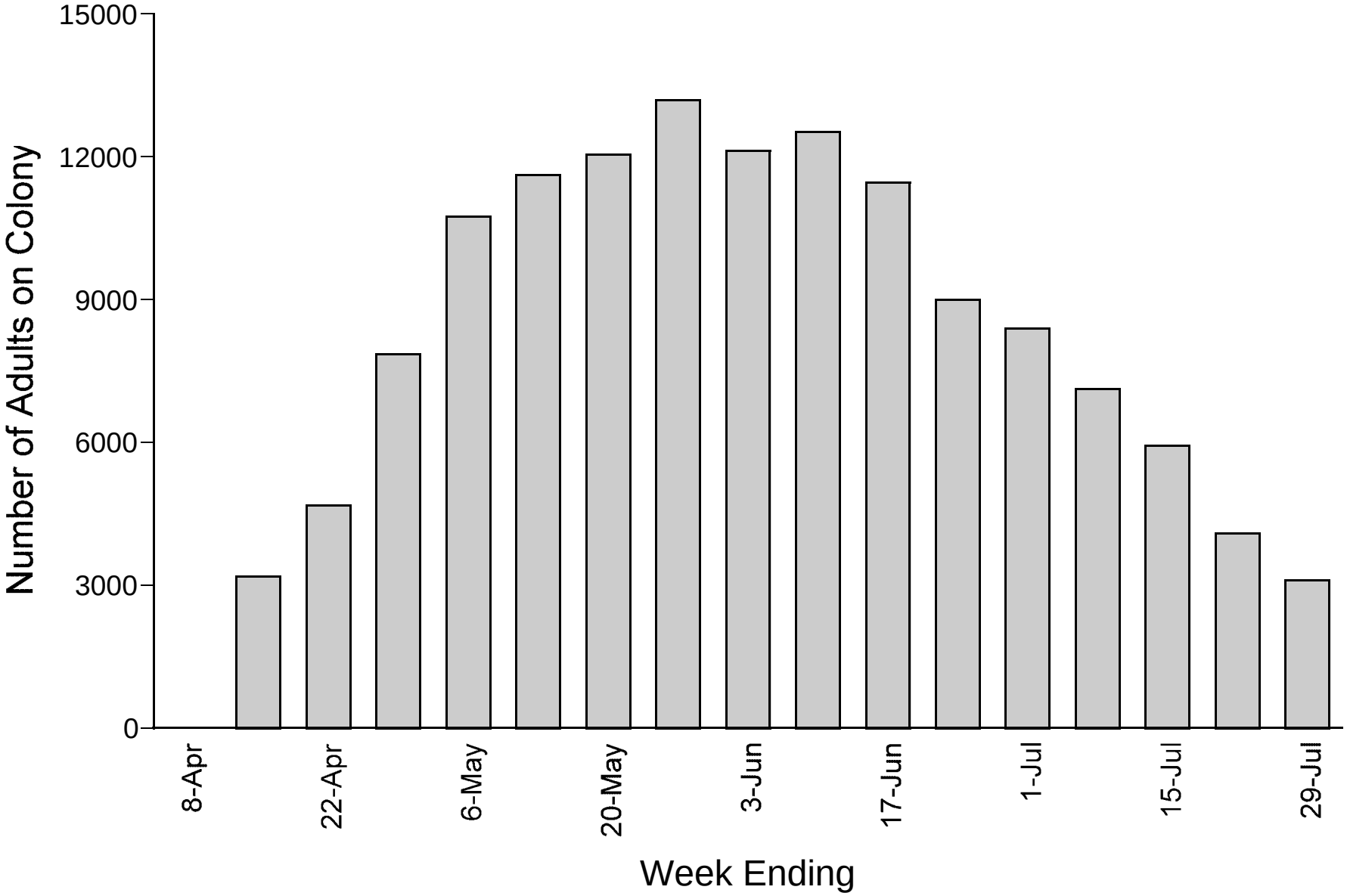


Figure 1. Visual estimates of the number of adult Caspian terns on the East Sand Island colony in 2002.

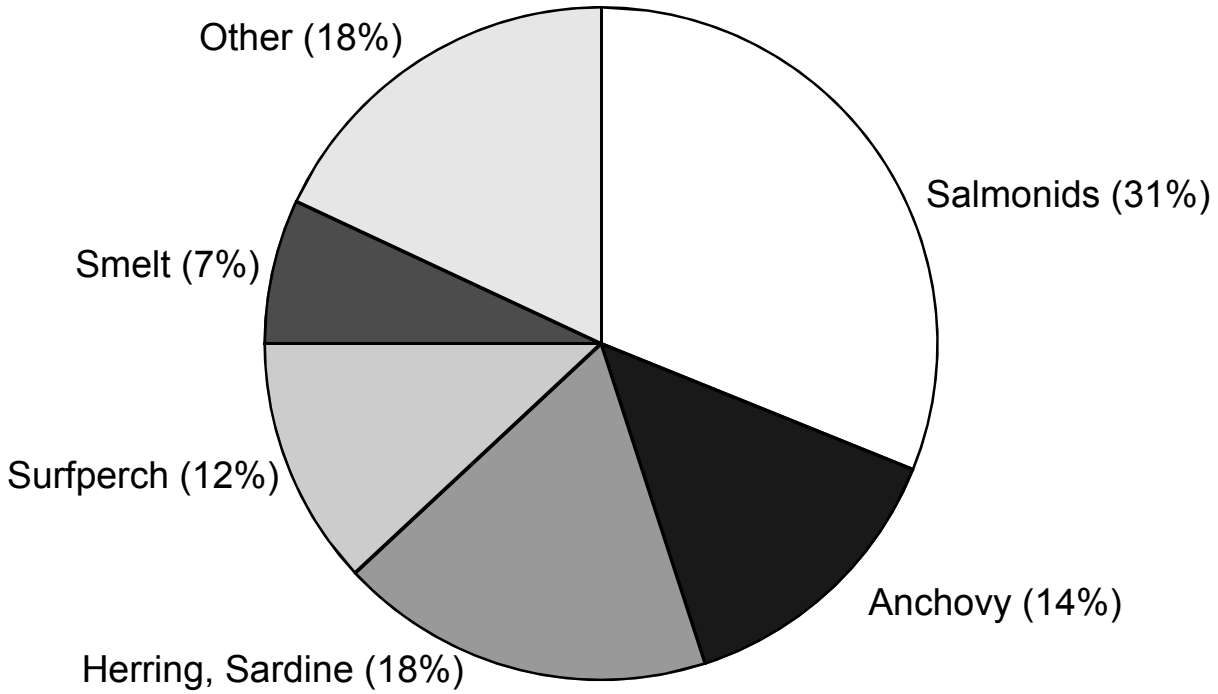


Figure 2. Diet composition of Caspian terns nesting on East Sand Island in 2002 (see text for methods of calculation).

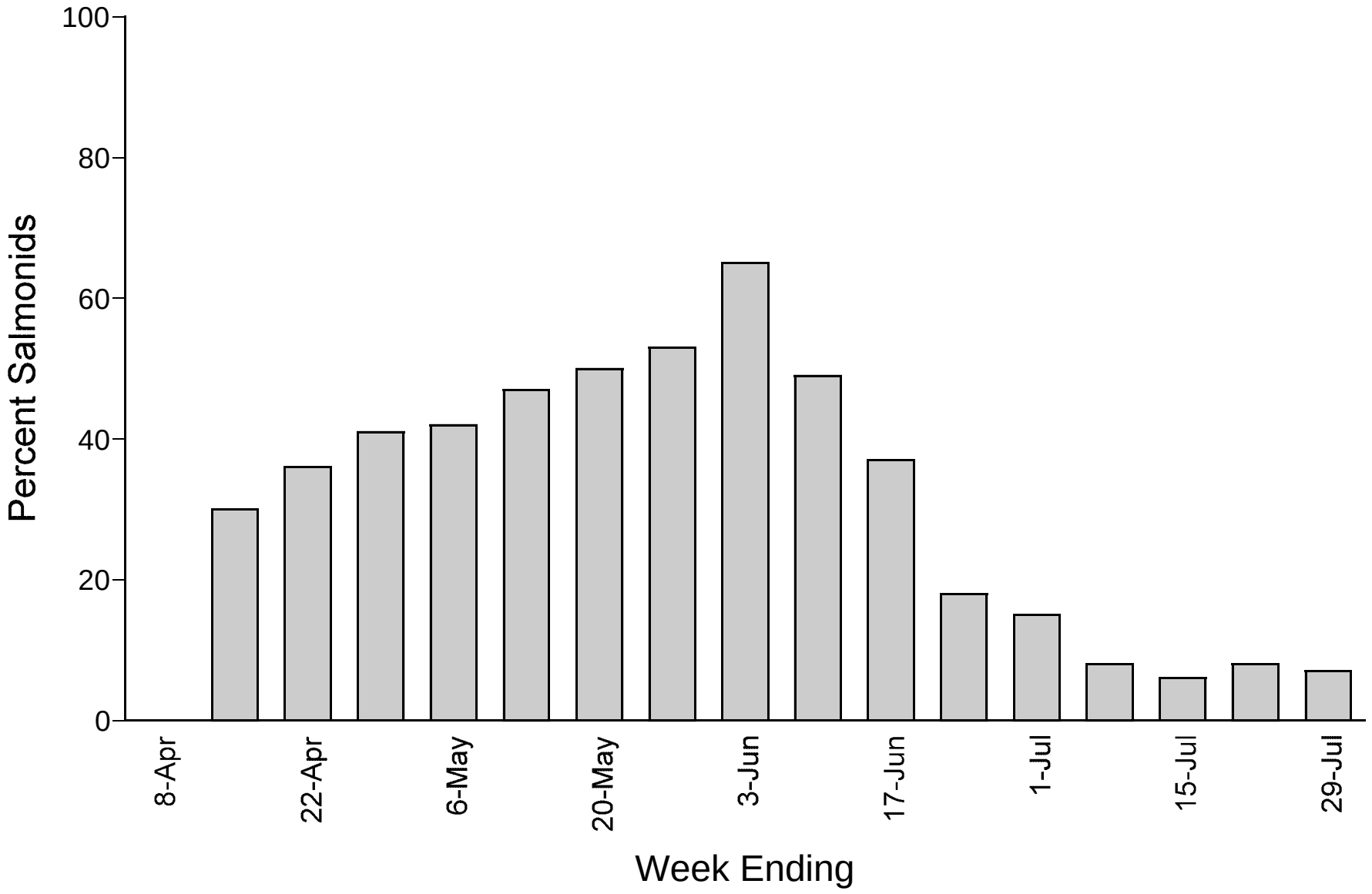


Figure 3. Proportion of juvenile salmonids in the diet of Caspian terns nesting on East Sand Island in 2002.

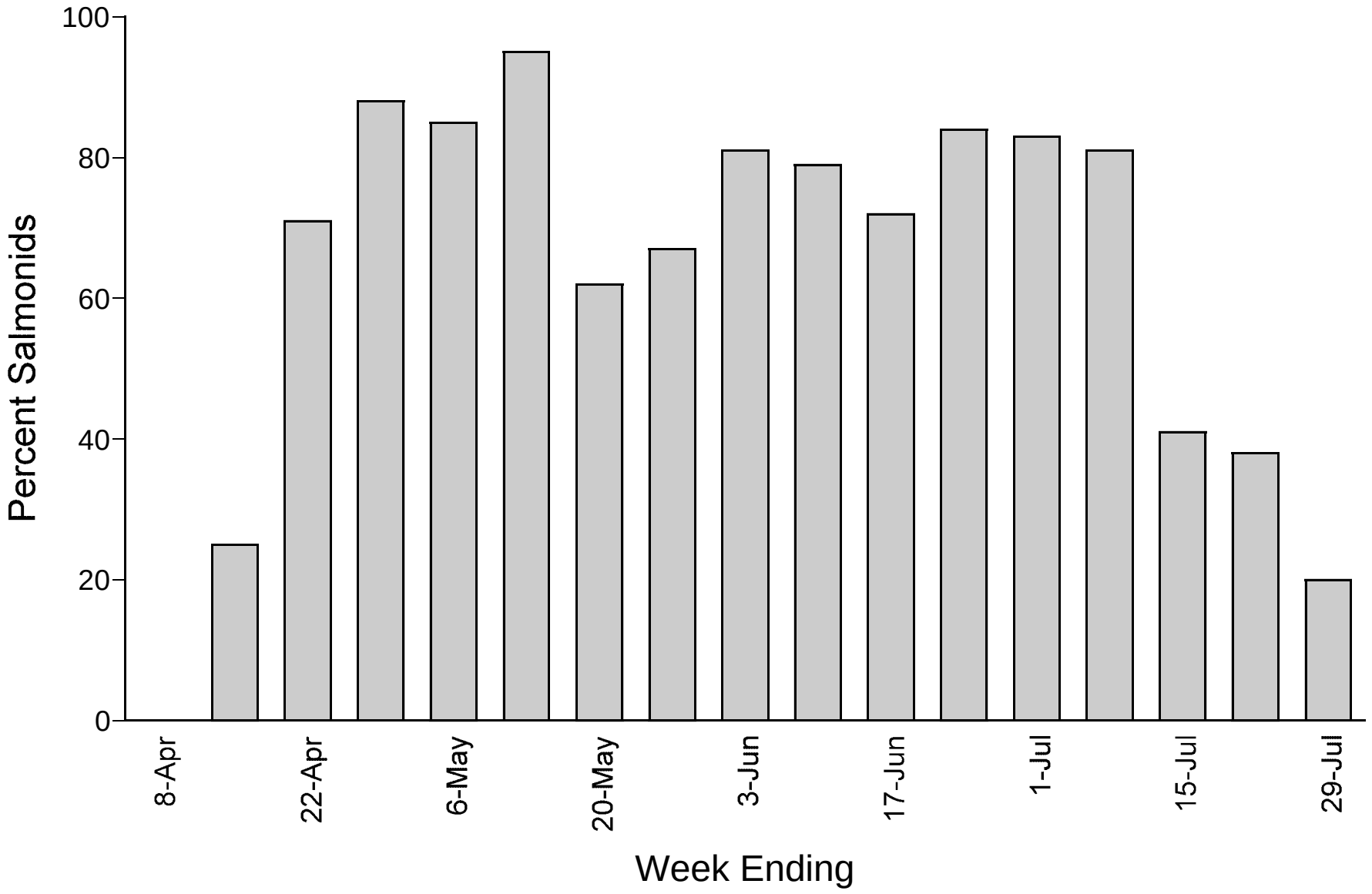


Figure 4. Proportion of juvenile salmonids in the diet of Caspian terns nesting on Crescent Island in 2002.

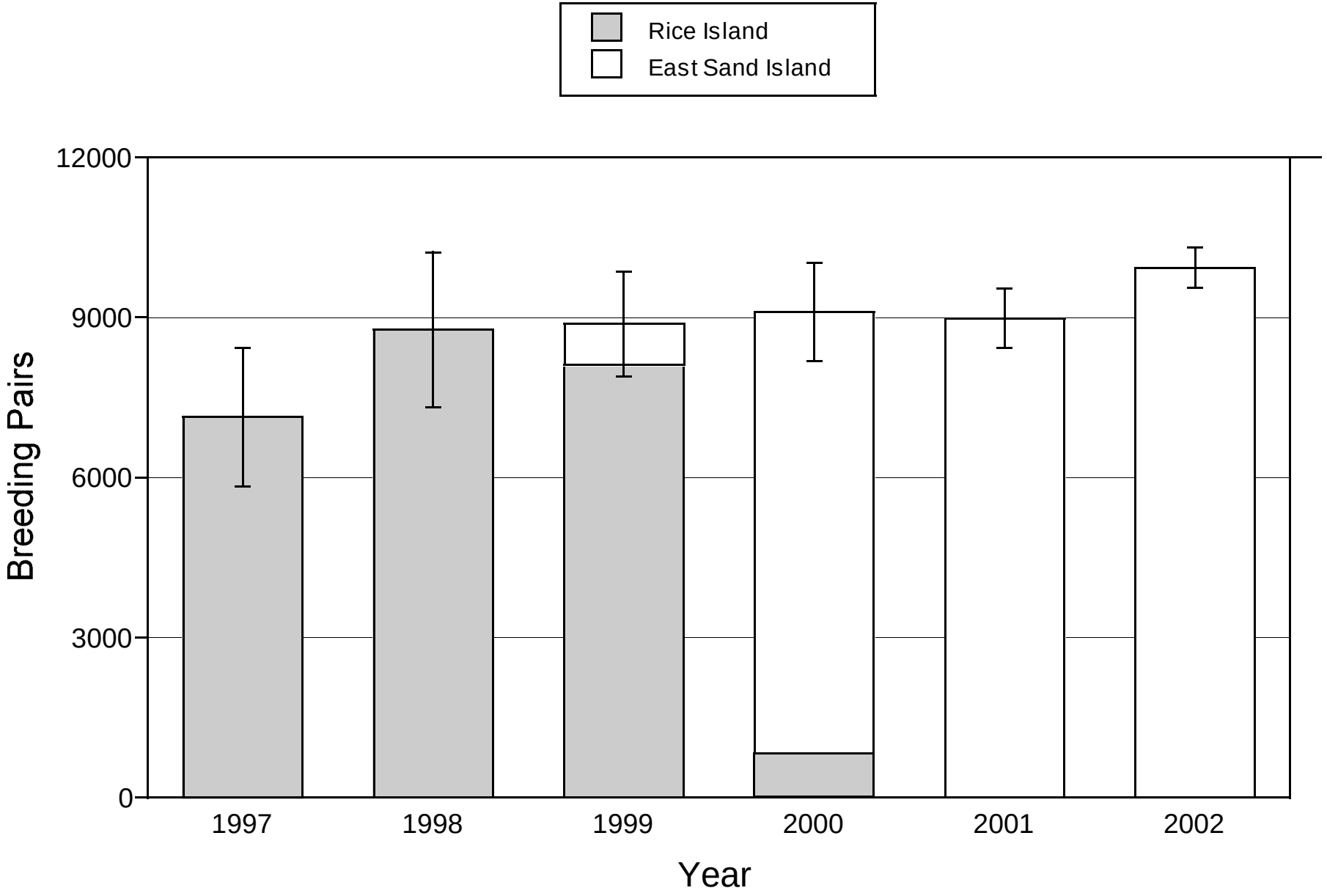


Figure 5. Caspian tern colony size in the Columbia River Estuary, 1997 - 2002.

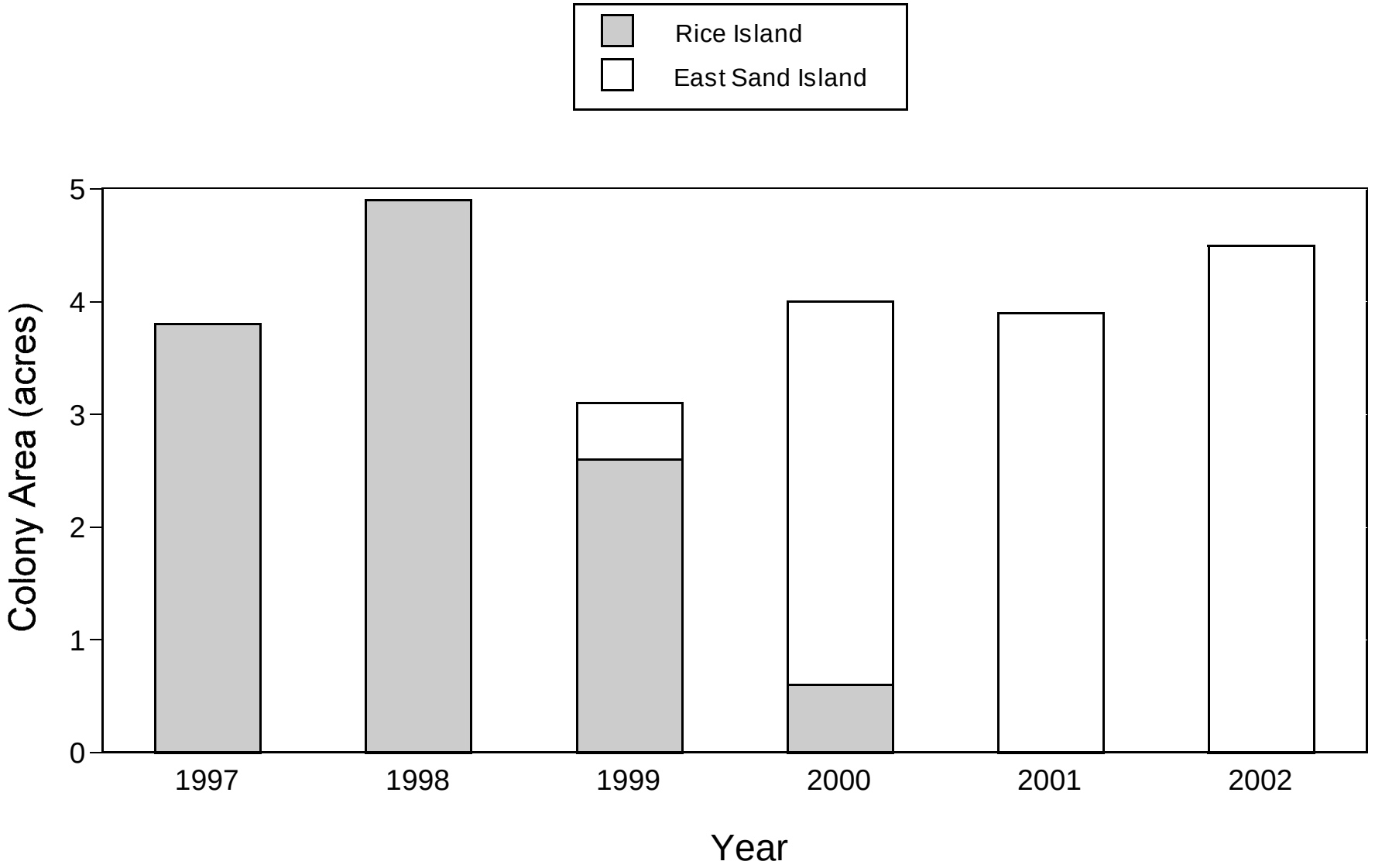


Figure 6. Caspian tern colony area in the Columbia River Estuary, 1997 - 2002.

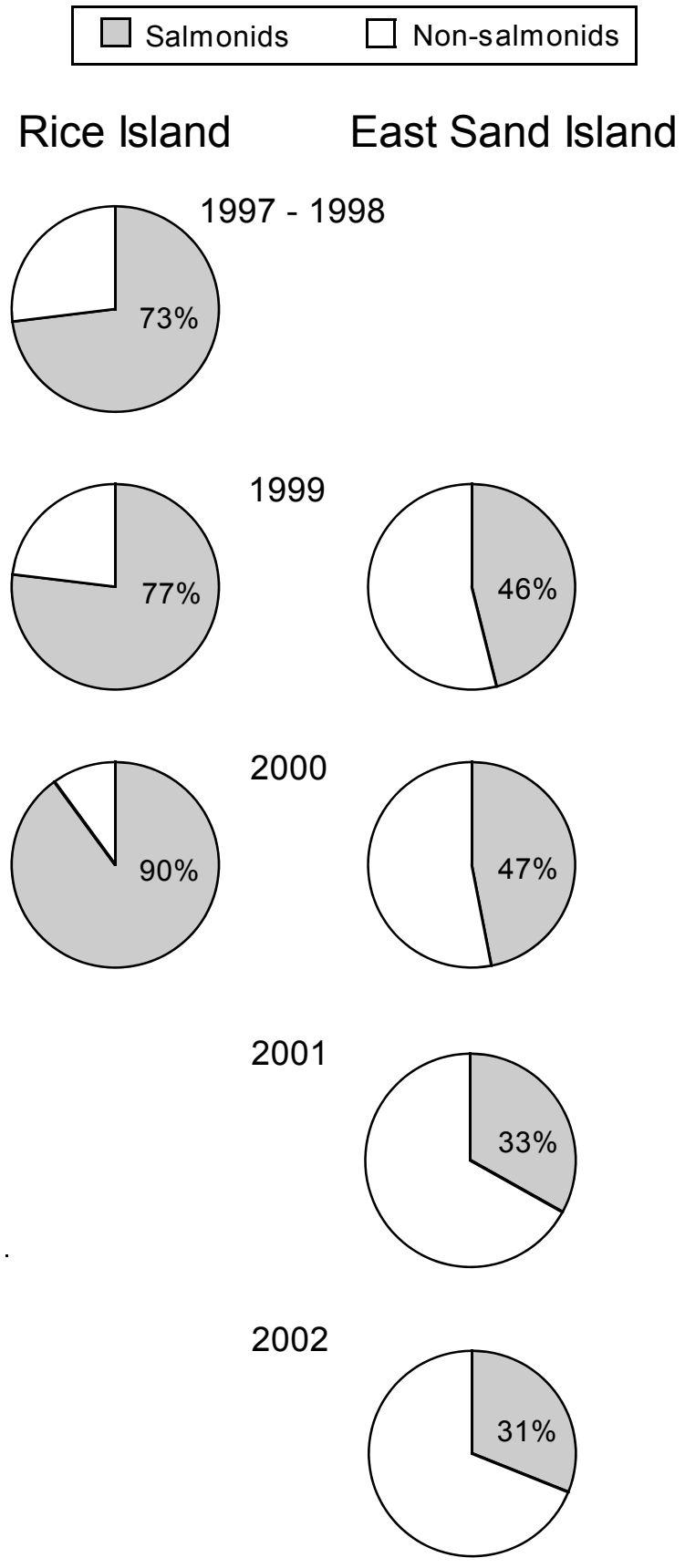


Figure 7. Overall proportion of juvenile salmonids in the diet of Caspian terns nesting on two colonies in the Columbia River Estuary, 1997 - 2002.

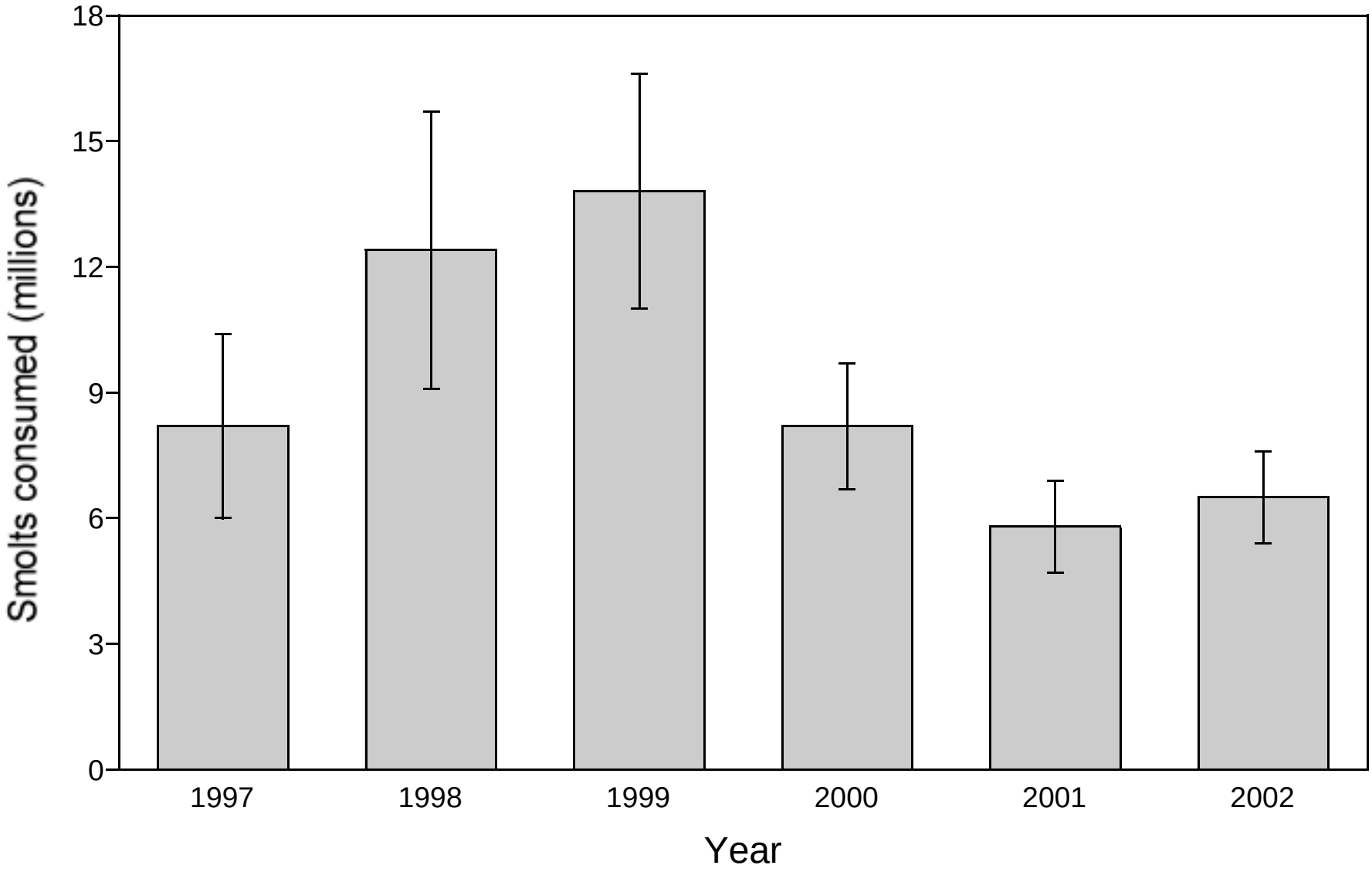


Figure 8. Total estimated consumption of juvenile salmonids by Caspian terns nesting in the Columbia River Estuary, 1997 - 2002.

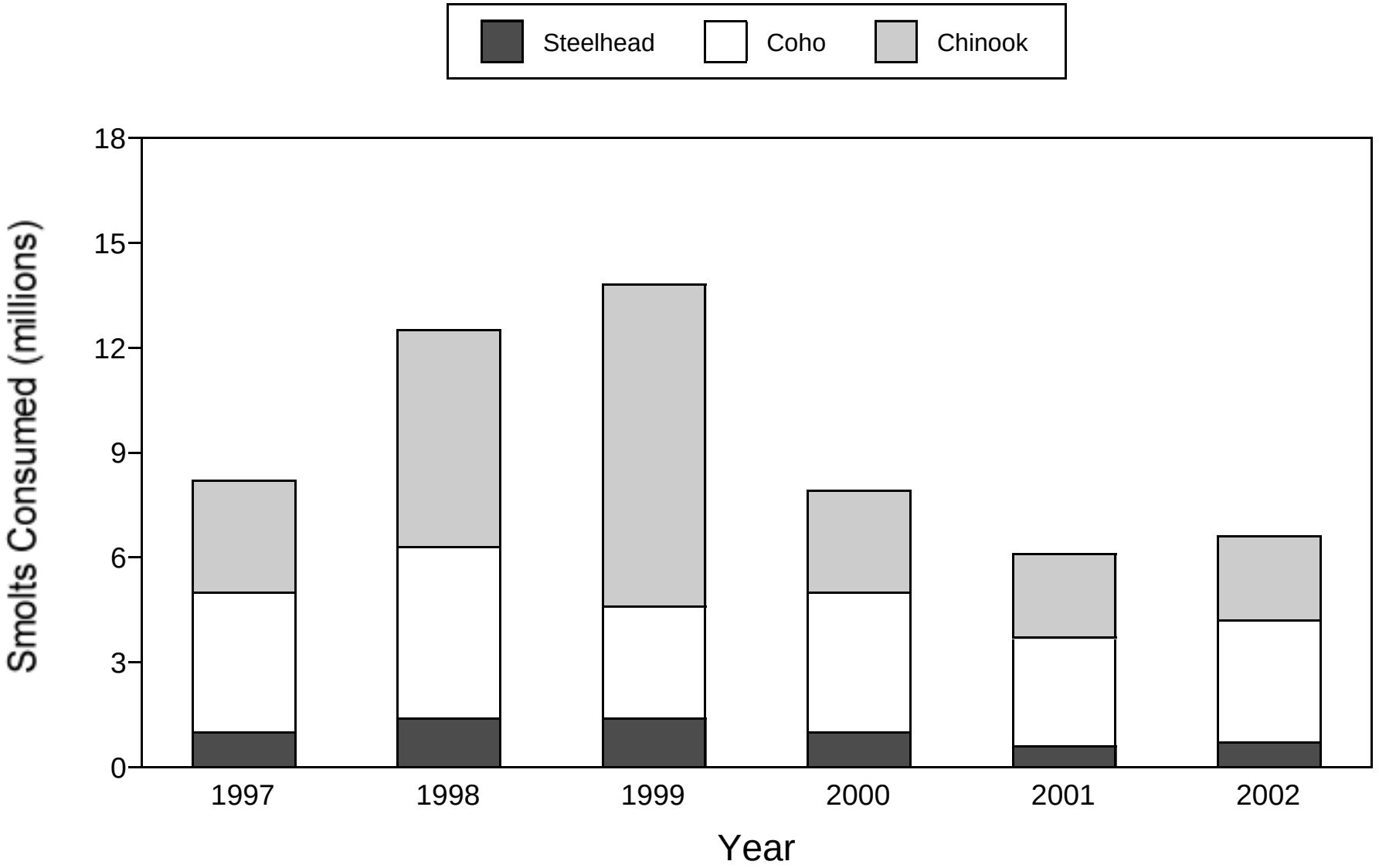


Figure 9. Total estimated consumption of three species of juvenile salmonids by Caspian terns nesting in the Columbia River Estuary, 1997-2002.

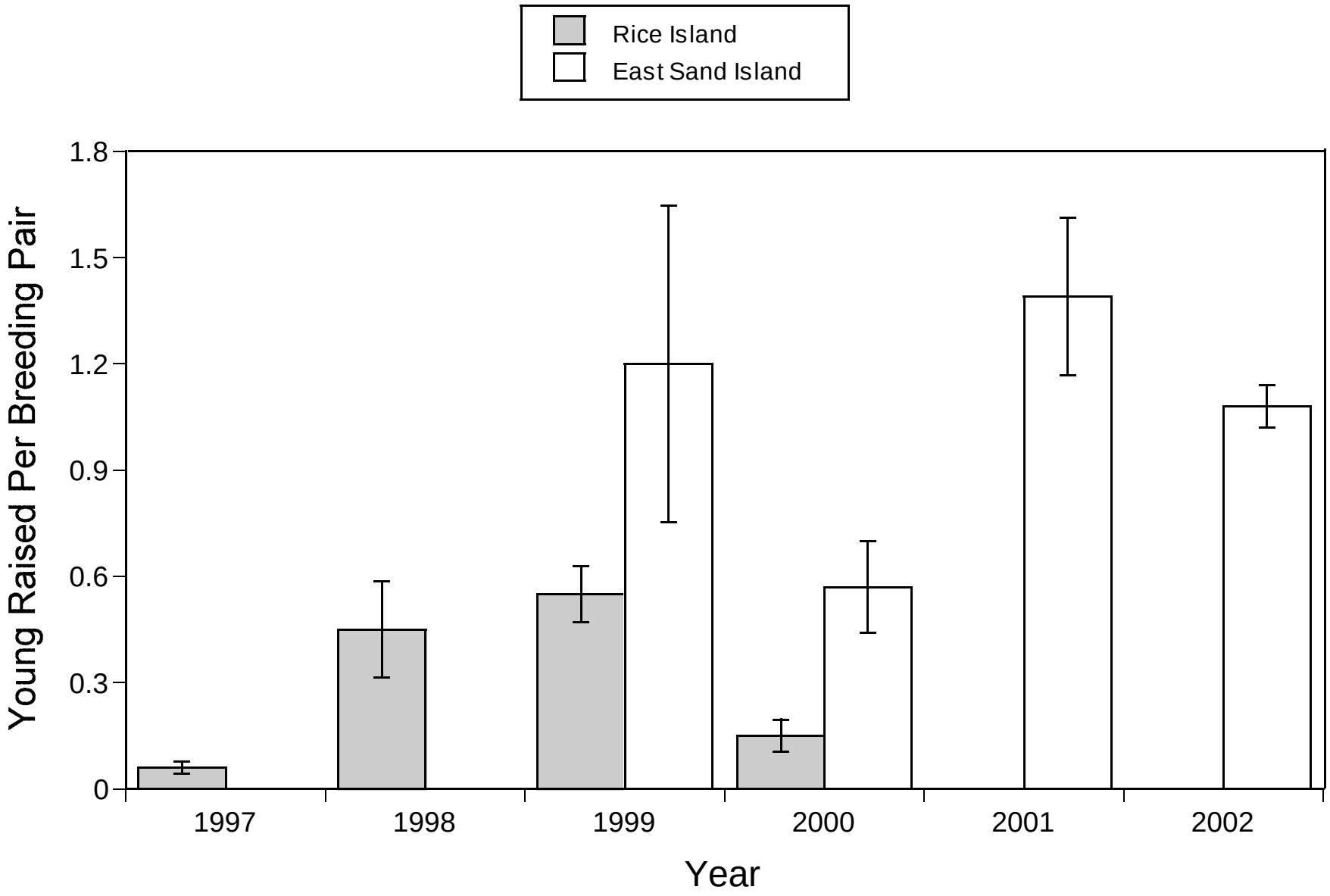


Figure 10. Caspian tern nesting success at two colonies in the Columbia River Estuary, 1997 - 2002.

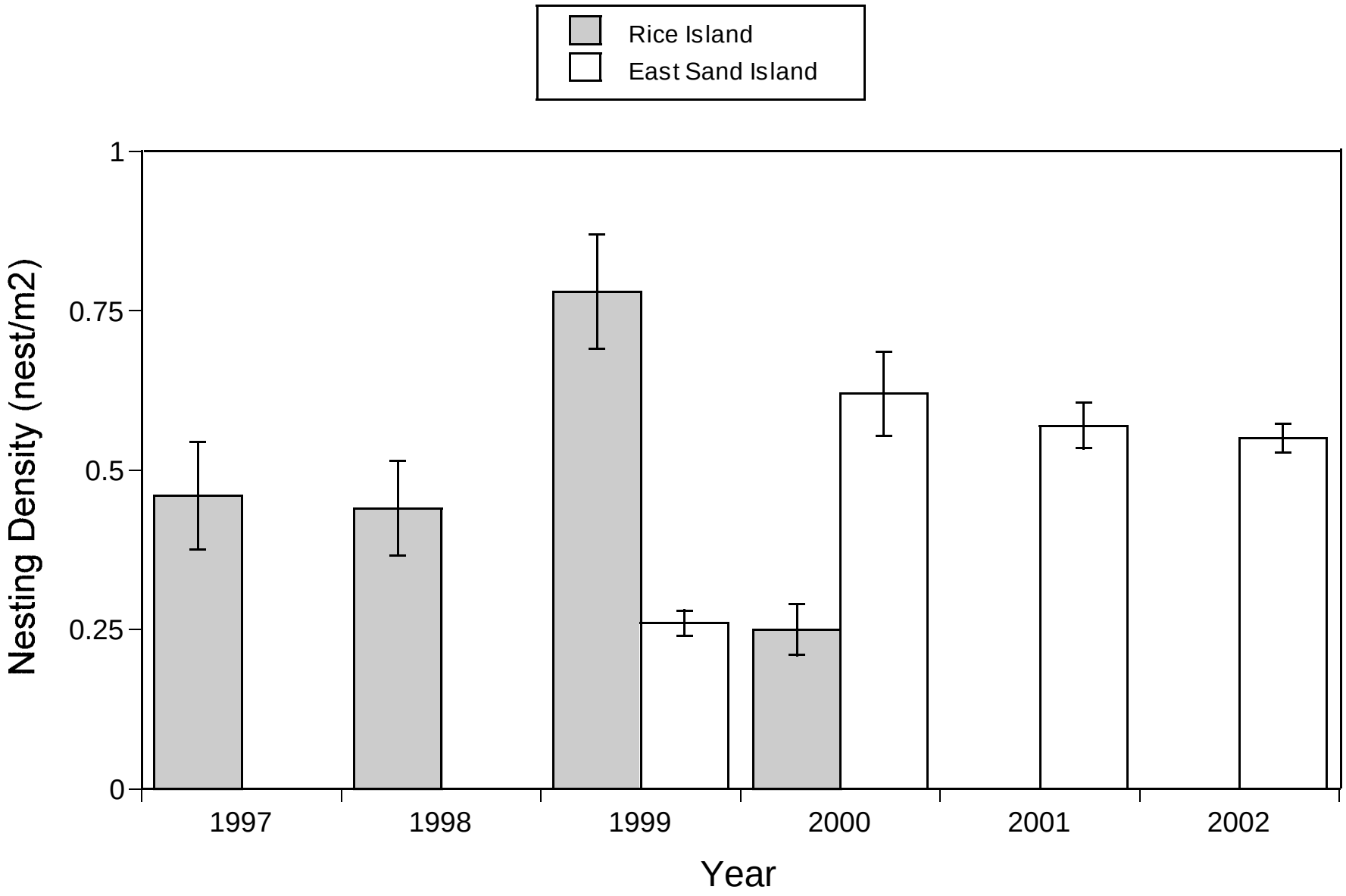
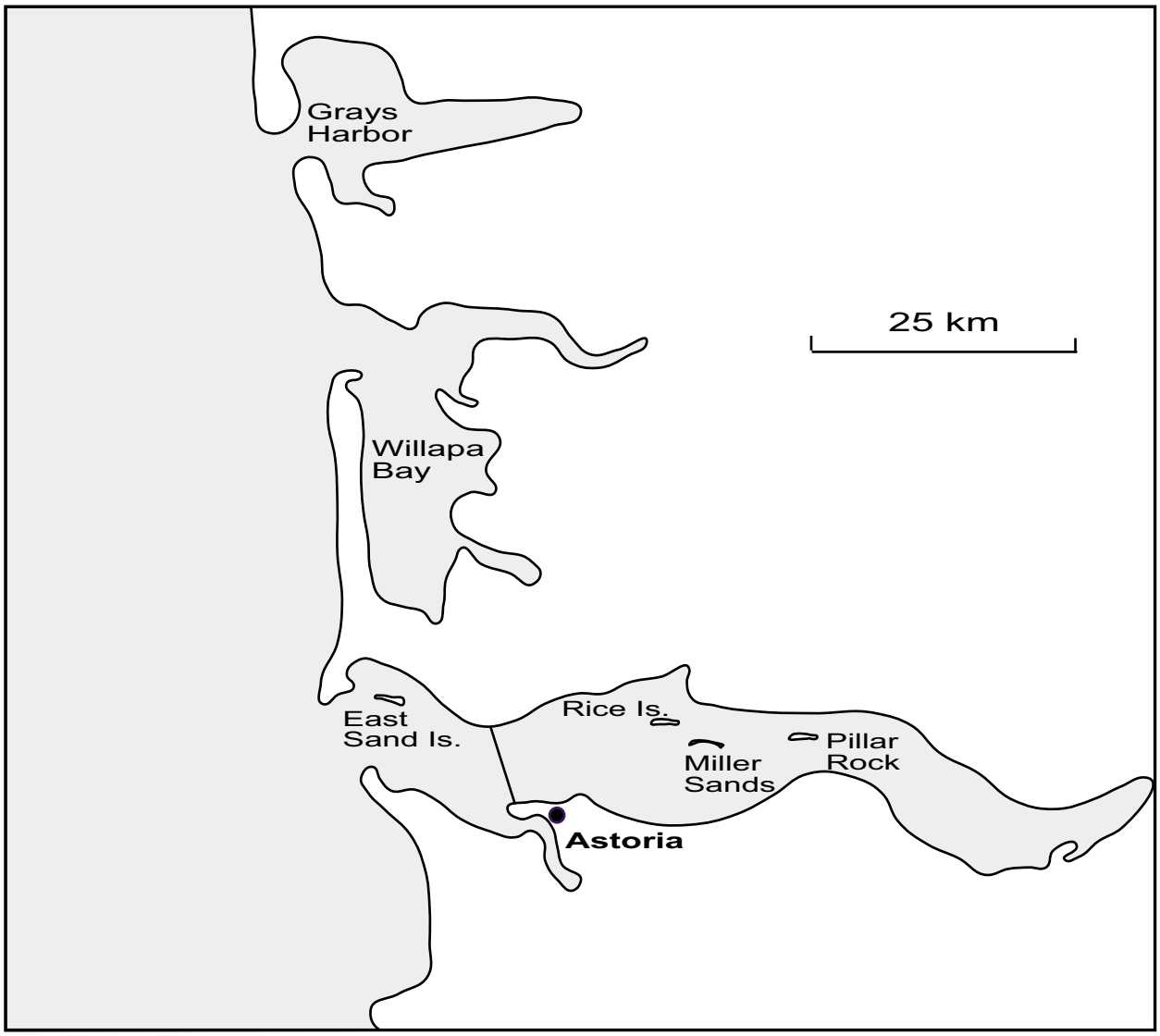
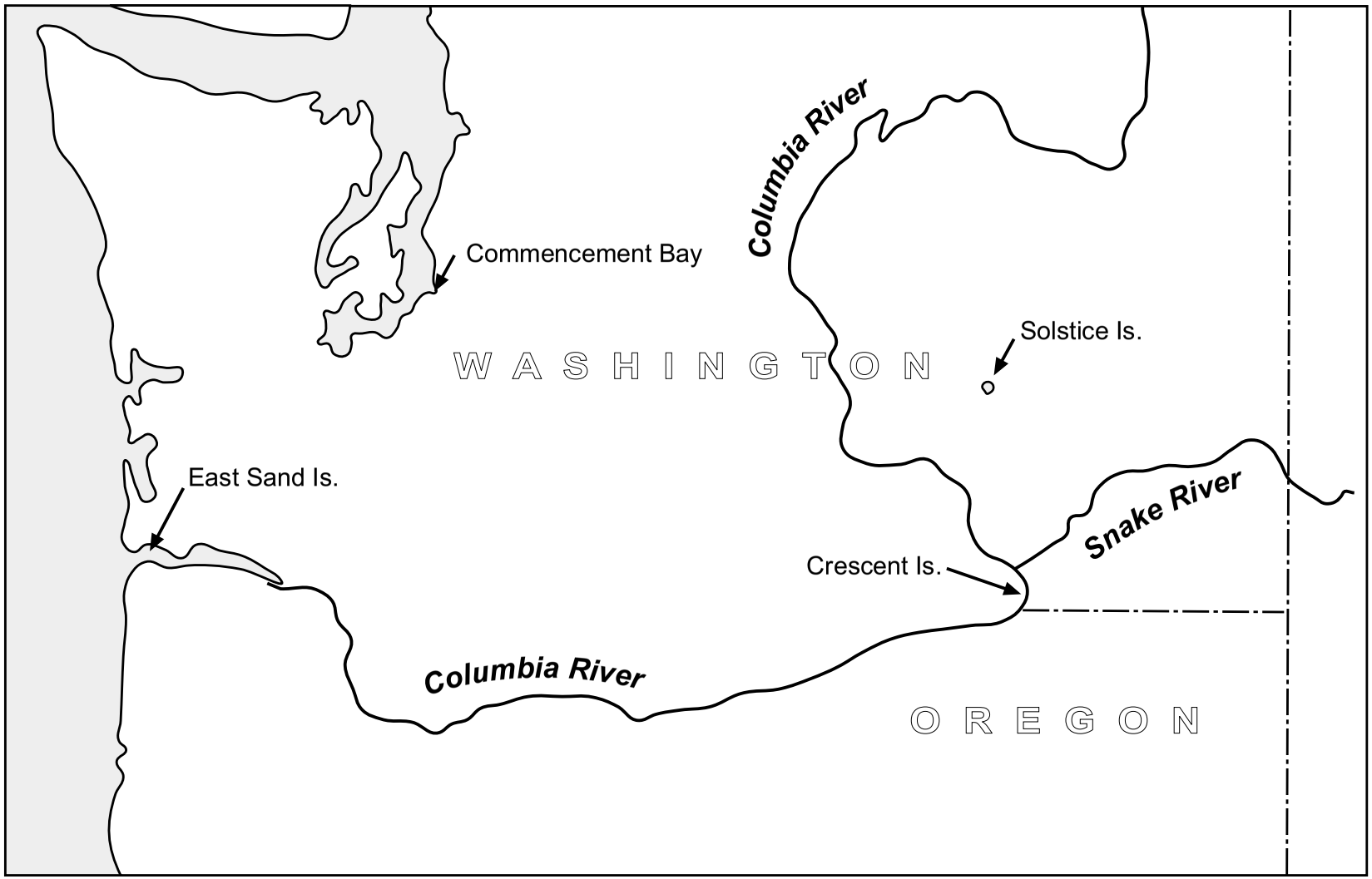


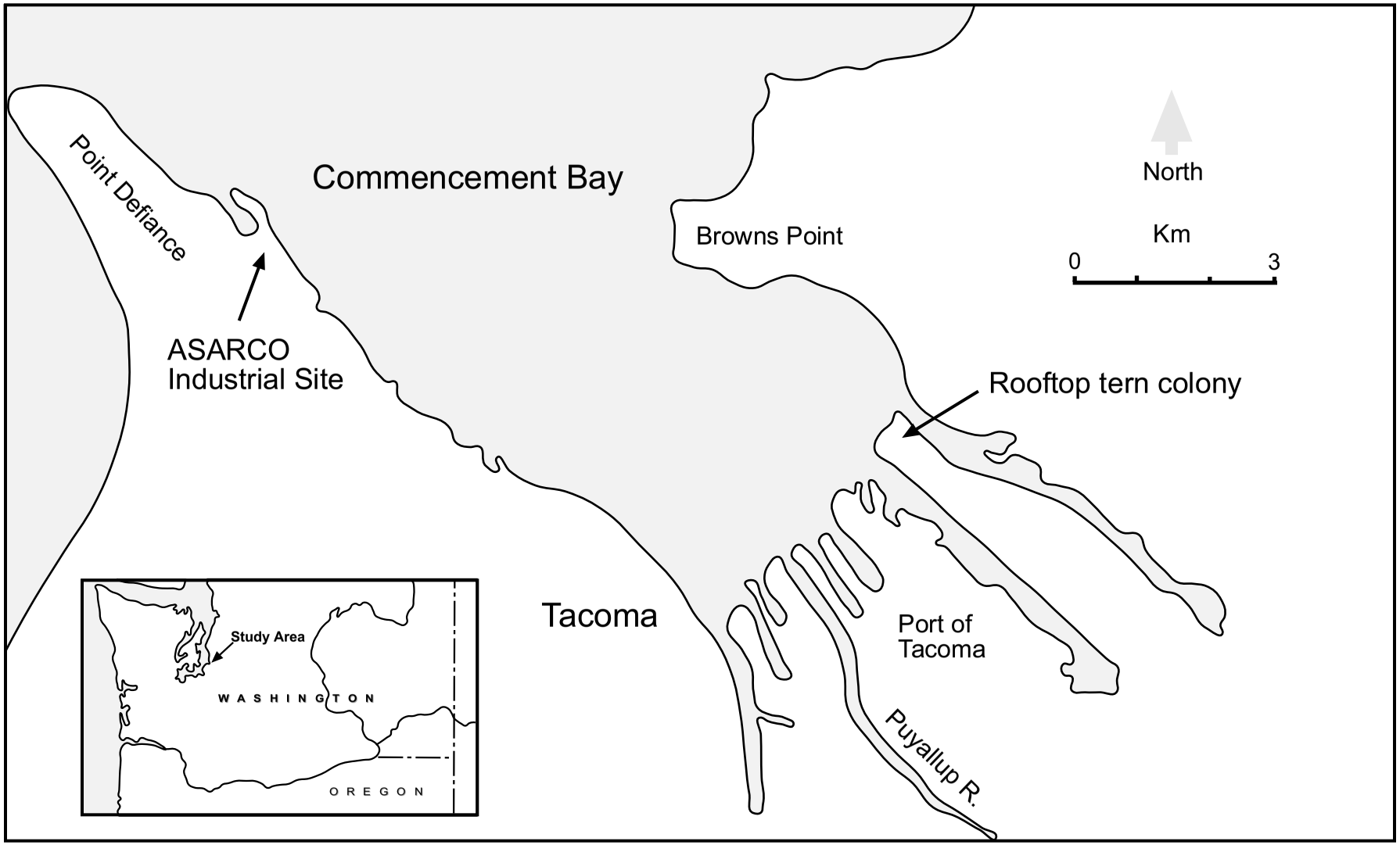
Figure 11. Caspian tern nesting density at two colonies in the Columbia River Estuary, 1997 - 2002.



Map 1. Study area in the Columbia River Estuary and coastal Washington in 2002.



Map 2. Locations of active Caspian tern colonies in 2002 that were discussed in this report.



Map 3. Commencement Bay study area with the locations of the ASARCO Industrial Site and the rooftop tern colony.

Table 1. Diet composition (% identifiable prey items) of Caspian terns nesting on Rice Island and East Sand Island, 1999-2002.

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