Caspian Tern Research on the Lower Columbia River

FINAL 2001 Summary

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This Final 2001 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 This report is not for citation without permission of the authors.

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Columbia Bird Research Update

FINAL 2001 CASPIAN TERN RESEARCH SUMMARY

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Executive Summary

We initiated a field study in 1997 to assess the impacts of Caspian terns (*Sterna caspia*) on the survival of juvenile salmonids in the lower Columbia River. Rice Island, a dredged material disposal site at river mile 21, supported an expanding colony of about 17,000 nesting terns in 1998. This colony was the largest known Caspian tern breeding colony 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 ate mostly juvenile salmonids (73% of prey items in 1998). Using bioenergetics modeling, we estimated that in 1998 this tern colony consumed about 11.2 million juvenile salmonids (95% c.i. = 8.5 – 14.1 million), or approximately 12% (95% c.i. = 8% - 15%) of the estimated 95 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 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 in 1999, where nesting success was considerably higher than on Rice Island. In 2000, about 8,500 pairs of Caspian terns nested on East Sand Island, or 94% of all terns nesting in the estuary, and nesting success was again much higher than at Rice Island.

During 1999 and 2000, the 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 consisted of 46% and 47% salmonids in 1999 and 2000, respectively, compared to the diet of Rice Island terns, which consisted of 77% and 90% salmonids, respectively. The relocation of nearly all the nesting terns from Rice Island to East Sand Island in 2000 resulted in a sharp drop in consumption of juvenile salmonids by terns nesting in the Columbia River estuary; total consumption was estimated at 7.3 million smolts (95% c.i. = 6.1 – 8.6 million smolts), a reduction in smolt consumption of about 4.4 million (38%) compared to 1999.

In 2001, all Caspian terns nesting in the Columbia River estuary used 3.9 acres of the restored habitat on East Sand Island. The estimated size of the East Sand Island colony (8,900 pairs) was not significantly different from 2000. Tern nesting success at the East Sand Island colony in 2001 (1.4 young raised per nesting pair) was the highest ever recorded for Caspian terns nesting in the Columbia River estuary, apparently a reflection of high forage fish availability. The proportion of juvenile salmonids in the diet (33%) was the lowest ever recorded for terns nesting in the estuary. This resulted in another decline in consumption of juvenile salmonids by terns in the Columbia River estuary; consumption in 2001 was estimated at 5.9 million smolts (95% c.i. = 4.8 – 7.0 million

smolts). This represents a reduction in smolt consumption by terns of about 5.9 million (50%) compared to the 1999 consumption estimate.

To achieve further reductions in annual consumption of juvenile salmonids by Caspian terns in the Columbia River estuary, regional resource managers are considering the restoration of tern colonies outside the estuary and the relocation of a portion of the East Sand Island colony to these alternative sites. Caspian tern colonies on or near the mid-Columbia River show little promise as alternative nest sites for terns currently nesting in the estuary. The tern colony on Three Mile Canyon Island, which formerly consisted of 200-400 breeding pairs, completely failed for the second year in a row due to mink predation. The tern colony on Crescent Island (ca. 720 breeding pairs) increased 26% compared to 2000 and experienced good nesting success (0.84 young raised per breeding pair). But juvenile salmonids comprised 68% of prey items, 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 on Miller Rocks was new in 2001, but is very small (15-20 pairs) and also appears to be strongly limited by nest site competition with gulls. The Solstice Island tern colony in Potholes Reservoir does not appear to be limited by nesting habitat, but terns from this colony are known to regularly commute over 30 miles to the Columbia River to prey on juvenile salmonids and have been the subject of considerable lethal control at the mid-Columbia River dams. 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 can 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.

Preparation and Modification of Nesting Habitat

Columbia River Estuary

Vegetation continued to encroach on the former Rice Island Caspian tern colony site (see Map 1) during 2001. The Oregon Department of Fish and Wildlife (ODFW) repaired silt fences and placed streamers to preclude nesting by terns on the previous Rice Island colony site. No hazing of terns to discourage nesting was conducted on Rice Island in 2001.

On East Sand Island (see Map 1), the U.S. Army Corps of Engineers (USACE) treated vegetation encroaching on the tern colony site with herbicides (Rodeo) in mid March, prior to the tillage and hand removal of up-rooted plants later that month. USACE and ODFW prepared about 1.5 hectares of bare sand as Caspian tern nesting habitat on East Sand Island in 2001. In addition, a 20-30 meter wide buffer was prepared on the west and east sides of the colony area of bare sand. These buffers were scraped clear of vegetation, but no work was done to remove below ground parts of scarified plants. The buffers were intended to provide nesting terns with additional protection from glaucous-winged/western gulls that previously used these vegetated areas for nesting. Two audio playback systems and 253 tern decoys were deployed on the middle of the East Sand Island colony site on March 31st. Gull control activities that were performed during the 1999 and 2000 breeding seasons to enhance tern colony restoration were not conducted in 2001.

Commencement Bay, Washington

Commencement Bay, Washington was selected as the site to test the feasibility of using barges as temporary colony sites for Caspian terns. The primary objective of this study was to develop a method for assessing the suitability of alternative sites for tern colony restoration along the coast of the Pacific Northwest.

The first confirmed nesting by Caspian terns on the shores of Commencement Bay was in 1999 on the former copper smelter site owned by the American Smelting and Refining Company (ASARCO). The terns dug nest scrapes in sand that had leaked from sandbags used to weigh down tarpaulins covering mounds of contaminated soil (Shugart and Tirhi 2001). The entire ASARCO Industrial Site was previously designated a “Superfund Site” by the U.S. Environmental Protection Agency (EPA) and contaminated soil was scheduled for removal early in 2001. Thus nesting habitat for terns was no longer available at the ASARCO site after the 2000 breeding season. This colony was of particular conservation interest because it was the only Caspian tern colony anywhere along the coast of the State of Washington, and no potential alternative colony sites were known. In 2000, up to 1,000 pairs of Caspian terns nested at the ASARCO site and raised several hundred young terns. Local conservation groups expressed interest in providing a safer and more permanent site for a Caspian tern colony on the shores of Commencement Bay, but no specific site had yet been identified.

The tern barge was anchored about 100 m offshore in Commencement Bay, Washington near Browns Point on 13 April, 2001. The barge was located about 7 km east of the former Caspian tern colony on the ASARCO Site (see Map 2). The shoreline of Commencement Bay is entirely within the city limits of Tacoma, Washington, a major shipping port. The anchorage site for the barge was chosen so as to minimize navigational hazards and disturbance from commercial and recreational watercraft. The timing of deployment of the tern nesting barge was designed to coincide with arrival of Caspian terns from the wintering grounds.

Logs were secured to the perimeter of the barge deck and sand was spread over the deck within the retainer logs to a depth of 20 - 30 cm. The total area of sand-covered deck was 259.4 m^2. Ninety-nine Caspian tern decoys and four solar-powered audio playback speakers that broadcast digital recordings of Caspian tern calls were placed on the deck of the barge to provide social attraction and encourage prospecting terns to settle and nest on the barge.

Colony Size and Nesting Success

Columbia River Estuary

Methods: The numbers of Caspian terns breeding in the Columbia River estuary (East Sand Island, see Map 1) were estimated using aerial photographs of the colony taken near the end of the incubation period. An average of 2 direct counts of adult terns in aerial photos were corrected to estimate the number of breeding pairs at the colony using ground counts of incubating and non-incubating terns on plots. 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. An average of 2 direct counts of all terns (adults and juveniles) in aerial photos were corrected to estimate the number of fledglings on the colony using ground counts of adults and fledglings on plots.

Results and Discussion: In 2001, all nesting by Caspian terns in the Columbia River estuary occurred on East Sand Island. We estimate that 8,900 breeding pairs attempted to nest at East Sand Island in 2001 (see Figure 1 for weekly counts of terns on the East Sand Island colony in 2001). This estimate is not significantly different from the estimate of colony size at East Sand Island in 2000. We estimated that roughly 12,500 young terns were fledged from the East Sand Island colony. This corresponds to nesting success of 1.40 young raised per breeding pair, or about twice the productivity of the colony in 2000.

Early in the 2001 breeding season (April and May), terns were occasionally seen roosting on bare sand dredge spoil directly east of the old colony site on Rice Island. One Caspian tern egg was laid in this area, but was depredated by gulls the following day. No other tern nesting attempts were detected on Rice Island or any other island in the upper estuary in 2001.

Mid-Columbia River (east of the Cascades)

Methods: The numbers of Caspian terns breeding at Crescent Island (see Map 3) were estimated as described above. The numbers of terns attempting to breed at Three Mile Canyon Island and Miller Rocks (see Map 3) 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 720 breeding pairs attempted to nest at the Crescent Island tern colony in 2001, about 26% more pairs than in 2000. We estimated that 600 young were fledged from that colony in 2001, or 0.84 young raised per breeding pair, higher nesting success than in 2000.

The Caspian tern colony at Three Mile Canyon Island was disrupted by a mink early in the 2001 breeding season and was soon abandoned, but at least two pairs laid eggs prior to colony abandonment. As in 2000, Caspian terns were unsuccessful in raising any young on Three Mile Canyon Island in 2001.

For the first time Caspian terns were found nesting on Miller Rocks in the mid-Columbia River just upstream of the mouth of the Deschutes River. As many as 20 breeding pairs attempted to nest on the edge of a large gull colony there. We suspect that terns nesting on Miller Rocks were failed breeders from the Three Mile Canyon Island colony. Up to six young may have been raised at the Miller Rocks colony in 2001.

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 weekly basis throughout the breeding season in order to detect any new tern colonies outside the Columbia River estuary. The number of terns attempting to nest on the tern barge in Commencement Bay (see Map 2) was estimated by direct counts of nest scrapes containing eggs on 31 May (see below). Aerial, boat, and ground-based surveys were conducted along the northern Washington Coast (i.e., Puget Sound) in June and early July to locate other Caspian tern nesting colonies.

Results and Discussion: Although terns were commonly observed foraging and roosting in Willapa Bay and Grays Harbor throughout the 2001 breeding season, terns did not attempt to breed at either location in 2001. 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 were observed circling the barge in Commencement Bay soon after it was deployed. Terns did not utilize the barge for roosting, however, until 14 days after the barge was anchored in Commencement Bay, when two terns landed briefly on the barge.

For the next two weeks small numbers of Caspian terns (<10 individuals) occasionally landed on the tern barge, but did not remain for extended periods (see Table 1 for chronology of tern use at the barge in 2001). Some of the adult terns that landed on the barge were carrying courtship meals (whole fish) in their bills.

Meanwhile, adult terns were periodically disturbed and flushed by workers and equipment at ASARCO, 7 km to the west, which discouraged Caspian terns from nesting at any of several roost sites there. Also, the mounds where Caspian terns had nested in 1999 and 2000 were covered with new plastic tarps so that terns no longer had access to suitable nesting substrate. Nevertheless, terns showed strong fidelity to the ASARCO site through mid-May, with up to 400 terns settling on any of several mounds within the ASARCO Site, despite periodic disturbance.

On 14 May, two terns settled on the barge and dug a nest scrape. Early the next day, an egg was laid in the scrape, and the pair began incubating. On 17 May, that nesting pair was joined by 15 more terns prospecting for nest sites, after which terns rapidly initiated nests on the barge in the following two weeks (Figure 2 and Table 1). During this period, 13 of 54 Caspian terns that had been captured and banded at the ASARCO site earlier that season (24%) were re-sighted on the tern barge. During the first week after nesting was initiated, predation by glaucous-winged gulls on tern eggs at the barge was intense, and it was not clear if the colony would persist. By 24 May, however, nesting and roosting terns were densely packed on the barge and gull predation on tern eggs declined dramatically.

During the last week of May, large numbers of Caspian terns were attracted to the vicinity of the tern barge by the nesting activity. On 25 May, 400-500 adult terns were observed roosting on a large barge moored about 500 m from the tern barge. By the end of the day the terns had left the large barge, abandoning at least 14 eggs that had been laid on the metal deck of the barge; gulls soon removed all tern eggs. Two days later (27 May), about 690 terns were counted on an adjacent large barge; as many as 50 appeared to be incubating eggs on the barge deck. Two days later a disturbance that flushed all the terns revealed that 22 eggs had been laid on this second large barge. These nesting attempts ultimately failed.

On May 31, the Washington Department of Fish and Wildlife (WDFW), in consultation with other resource management agencies, collected all tern eggs on the barge and removed the tern barge from Commencement Bay (for further details contact the WDFW, Wildlife Program at *wildthing@dfw.wa.gov*). A total of 980 tern eggs were collected from the barge, at least 235 of which had apparently been abandoned because they were found outside of nest scrapes. We counted 388 nest scrapes that contained eggs and these nest scrapes contained an average of 1.9 eggs. Although some of these nests may have been abandoned at the time eggs were collected from the barge, the best estimate of the number of tern nests initiated on the barge was 388. This corresponds to an average nesting density on the barge of 1.5 nests/m^2, higher than has previously been recorded at any other Caspian tern colony in the Pacific Northwest.

The day after the barge was removed from Commencement Bay, the large numbers of terns that had been roosting and dumping eggs on the decks of large barges about half a kilometer away from the tern barge disappeared. Only 175 adult Caspian terns were counted in the Commencement Bay area, compared to bay-wide counts ranging from 675 – 900 adult terns prior to barge removal. Counts of terns in the Commencement Bay area in June and early July never exceeded 200 adults. In late July, up to 700 post-breeding terns, presumably from the Columbia River estuary, were observed at various locations in Commencement Bay. Subsequent to barge removal, we did not find any new nesting aggregations in surveys conducted in south Puget Sound from Orcas Island in the north to Nisqually National Wildlife Refuge in the south and along the southwest Washington Coast from Grays Harbor in the north to the Columbia River estuary in the south.

Two of 13 color-banded terns (15%) that were sighted at the tern barge in Commencement Bay were re-sighted at the large Caspian tern colony on East Sand Island in the Columbia River estuary after the barge was removed, suggesting that at least some of the terns that left Commencement Bay following barge removal joined the breeding population of Caspian terns in the Columbia River estuary.

Inland Sites (off the Columbia River)

Methods: Several inland Caspian tern colony sites off the Columbia River in Washington State were visited in 2001. These surveys were conducted to determine the current status of Caspian tern colonies at inland locations where terns have nested in recent years. These sites were visited on 1-5 occasions during the breeding season. Counts of the number of adult and young terns were conducted at each colony site. Reliable estimates of the number of breeding pairs and their nesting success are not available for these colonies.

In 2001, we did not visit sites of former Caspian tern colonies off the Columbia River in Oregon. The information provided here on Caspian tern nesting at inland sites in Oregon are from (1) the literature, (2) contacts with regional biologists, and (3) our visits to inland Oregon tern nesting sites in 2000.

Results and Discussion: We identified three inland Caspian tern colonies off the Columbia River in eastern Washington in 2001 (see Map 3). All three of these sites are located east of the mid-Columbia River and north of the Snake River. Solstice Island, located in Potholes Reservoir, was visited on five separate occasions from early May through early July. We estimate that 200-300 breeding pairs attempted to nest on Solstice Island in 2001. Tern nesting success at Solstice Island in 2001 was 0.87 – 1.30 young raised per breeding pair.

On 27 June, 31 adult terns and 17 chicks were counted on Goose Island, located in Banks Lake just above Dry Falls Dam near Coulee City. On 2 July, 33 adult terns and 18 chicks were observed on Harper Island in Sprague Lake. Our surveys of inland Washington suggest that these three locations were the only active Caspian tern colonies in eastern Washington off the Columbia River in 2001.

Nesting at inland sites off the Columbia River in Oregon has occurred at only a few sites in southcentral Oregon in recent years: islands in Malheur/Harney, Crump, Pelican, and Summer lakes (M. St. Louis, ODFW, pers. comm.; M. Laws, USFWS, pers. comm.). Breeding at each of these lakes has been sporadic. There is a long history of nesting at Malheur/Harney Lake (Willett 1919), but colony sizes and locations are variable; breeding ceased in 1961 due to drought; resumed in 1983 (Littlefield 1990), and continued until drought returned in the early 1990s; 600 pairs returned in 1994 following flood (D.P. Craig, Willamette University, pers. comm.); 200-300 pairs nested on two separate islands at the north end of the lake in 2000; less than 100 pairs nested at only one site in 2001, a drought year (R. Roy and M. Laws, USFWS, pers. comm.). In 2000, ca. 150 pairs nested on Crump Lake and no nesting colonies were found elsewhere in the Warner Valley. Summer Lake in recent years has supported less than 50 nesting pairs (M. St. Louis, ODFW, pers. comm.). Formerly as many as 500 pairs nested on Upper Klamath Lake (Finley 1907), but no recent breeding records in the Upper Klamath Basin exist. Small numbers of nesting Caspian terns have previously been reported on islands on the Oregon side of the Snake River near Ontario and Nyssa, but there have been no confirmed nesting records in recent years (Contreras and Kindschy 1996).

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 lowest discernible taxon. 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.

To assess the relative proportion of the various salmonid species in tern diets, we collected 10 - 15 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 (NMFS) provided verifications of intact dropped salmonids that were difficult to identify. PIT tags placed in juvenile salmonids were also collected from the East Sand Island tern colony in 2001. Those data are currently being

collected and analyzed and will be available through the National Marine Fisheries Service (Brad Ryan, NMFS, 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 model construction and input variables). We also used a Monte Carlo simulation procedure to calculate reliable and narrower 95% confidence intervals for estimates of smolt consumption by terns.

To improve the estimates generated by the bioenergetics modeling approach, 20 tern chicks were removed from the East Sand Island colony at ages 3-5 days and raised in captivity to assess energy requirements of developing terns. One half of the chicks were fed as much fish as they chose to eat (*ad libidum*); the other half was fed a moderately restricted diet. Body mass and size were measured daily to assess growth rates of chicks fed each diet.

Results and Discussion: Of the bill load fish identified at the East Sand Island tern colony 33% were juvenile salmonids (n = 6,007). As in previous years, marine forage fishes (i.e., Pacific herring [*Clupea pallasi*], Pacific sardine [*Sardinops sagax*], anchovies [Engraulidae], smelt [Osmeridae], surfperch [Embiotocidae], Pacific sand lance [*Ammodytes hexapterus*]) were prevalent (67% 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. 60% during the first three weeks in May, and averaged ca. 25% of the diet for the remainder of the season (Figure 4). We estimated that Caspian terns nesting on East Sand Island consumed 5.9 million juvenile salmonids in 2001 (95% confidence interval = 4.8 – 7.0 million). Of all the juvenile salmonids consumed, we estimate that 46% were coho salmon (best estimate = 2.7 million, 95% c.i. = 2.2 – 3.1 million), 22% were yearling chinook salmon (best estimate = 1.3 million, 95% c.i. = 1.0 – 1.6 million), 20% were sub-yearling chinook salmon (best estimate = 1.2 million, 95% c.i. = 0.8 – 1.6 million), and 12% were steelhead (best estimate = 0.7 million, 95% c.i. = 0.6 – 0.9 million).

All 20 Caspian tern chicks removed from the East Sand Island colony as nestlings were raised successfully to fledging age. Six of the 20 were transferred to the Oregon Coast Aquarium in Newport, OR. The remaining birds were euthanized for body composition analysis. Results from the captive-rearing experiment will be used in future revisions of the bioenergetics model to improve the estimates of how many fish tern chicks consume at tern colonies in the estuary. In addition, morphometrics of the captive-reared chicks will be compared to similar measurements from wild chicks (chicks caught just prior to fledging during banding operations) to assess nutritional status of chicks reared at various tern colony locations in various years.

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 return 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. 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 diets of terns nesting on Crescent Island. PIT tags placed in juvenile salmonids were also collected from the Crescent Island and Three Mile Canyon Island tern colonies in 2001. Those data are currently being collected and analyzed and are available through the National Marine Fisheries Service (Brad Ryan, NMFS, brad.ryan@noaa.gov). Bill loads were not identified at Three Mile Canyon Island due to the early abandonment of the colony.

Results and Discussion: Juvenile salmonids were the most prevalent prey type for terns nesting on Crescent Island (68% of total identified bill loads), followed by centrarchids (bass and sunfish, 12%) and cyprinids (carp and minnows, 10%; n = 2,164). 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 and late May, and again in early and late June; these changes in diet composition probably reflected changes in availability of hatchery-reared juvenile salmonids. Efforts to estimate juvenile salmonid consumption by terns nesting at Crescent Island using bioenergetics models are currently in progress.

Commencement Bay, Washington

Methods: Visual identification of bill loads (see above) was also used to determine diet composition at the tern barge in Commencement Bay between 14 and 31 May. Bill load fish were not collected from terns using the barge; therefore we were unable to assess the relative proportion of the various salmonid species in diets of terns nesting on the tern barge.

Results and Discussion: We identified 1,097 bill load fish at the tern barge between 14 and 31 May. Overall, juvenile salmonids were the most prevalent prey type for terns nesting on the barge (65% of identified bill loads), followed by unidentified non-salmonids (13%), clupeids (herring and sardines, 10%), and embiotocids (surfperch, 8%). The percentage of salmonids in tern diets at the barge was consistent over the 18-day observation period, ranging from 64% to 66% for the three consecutive 6-day periods when diet data were collected.

Inland Sites (off the Columbia River)

Methods: Some data on diet composition (bill load identifications) were collected at Solstice Island in Potholes Reservoir. Also, the National Marine Fisheries Service, with help from biologists with the WDFW and the Mid-Columbia Public Utility Districts, recovered PIT tags placed in juvenile salmonids from the Solstice Island tern colony after the nesting season.

Results and Discussion: Overall, centrarchids (bass and sunfish) were the most prevalent prey type for terns nesting on Solstice Island (37% of identified bill loads), followed by salmonids (30%; n = 255).

All of the PIT tags detected on the Solstice Island colony by NMFS and its collaborators were from juvenile salmonids tagged and released in the Columbia River Basin. In total, 1,759 PIT tags from juvenile salmonids released in 2001 were detected on colony. These PIT tags were from fish released in the Columbia River Basin (1,743 or 99%) and Snake River Basin (16 or 1%). Most of the PIT tags (1,519 or 86%) were from juvenile salmonids tagged and released at Mid-Columbia River dams (i.e., Wells, Rock Island, and Rocky Reach dams). See Table 2 for species and release site information for all PIT tags recovered on Solstice Island in 2001. The Solstice Island tern colony is 30 miles from the Columbia River at its closest point, indicating that Caspian terns nesting at this off-river colony are commuting considerable distances to forage on juvenile salmonids in the Columbia River.

Foraging Ecology

Methods: Prior to the initiation of egg-laying, 30 adult Caspian terns were captured at the former Rice Island colony site using rocket nets and radio-tagged. In addition, another 24 adult terns were captured on East Sand Island during incubation using noose mats and radio-tagged. The movements of these radio-tagged adults were monitored using both fixed receiving stations located on East Sand Island and mobile tracking from fixed-winged aircraft. Of the 54 radio-tagged terns, 30 were confirmed to be nesting on East Sand Island based on direct observation of nesting behavior and another 16 radio-tagged terns were assumed to be nesting on East Sand Island based on nighttime attendance recorded by the fixed receiving stations (a total of 46 radio-tagged terns nesting on East Sand Island). The foraging distributions of radio-tagged terns nesting on East Sand Island were monitored using fixed-winged aircraft each week from late April through July. We flew 23 times to relocate radio-tagged terns over the 12-week nesting period, an average of 1.9 flights/week. Off-colony locations of radio-tagged terns were categorized as one of the following: (1) the Columbia River between the Astoria Bridge and Kelso/Longview, (2) the Columbia River between the Astoria Bridge and the mouth, (3) Willapa Bay and the Washington Coast between the mouth of the Columbia River and Willapa Bay, (4) Grays Harbor and the Washington Coast between Willapa Bay and Grays Harbor, and (5) the Oregon Coast (see Map 1).

Results and Discussion: All off-colony detections of radio-tagged terns nesting on East Sand Island (n = 140) were distributed as follows: 63 (45.0%) on the Columbia River above the Astoria Bridge, 43 (30.7%) on the Columbia River below the Astoria Bridge, 23 (16.4%) in Willapa Bay and vicinity, 2 (1.4%) in Grays Harbor and vicinity, and 9 (6.5%) in Oregon coastal areas. A disproportionate number of detections above the Astoria Bridge occurred in April and May (see Figure 5; late July time period removed from figure because of small sample size [N = 5]), early in the nesting season when the proportion of salmonids in the diet was highest. Also, 2001 was a drought year of low

flows in the Columbia River, and the extent of salt water intrusion in the estuary was likely greater than normal, allowing marine fishes to venture further into the estuary. Together these factors help explain the higher than expected frequency of detections of radio-tagged terns above the Astoria Bridge, despite the preponderance of marine forage fish in the diet of terns throughout the brood-rearing period.

Dispersal and Survival

Methods: Adult and juvenile terns were banded at several tern colonies throughout the Pacific Northwest in 2001 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). Adult terns were banded at the former Rice Island colony (n = 48), the East Sand Island colony (n = 24), and the former ASARCO colony (n = 54; G. Shugart and C Thompson, unpubl. data). Adult terns were captured for banding prior to the initiation of egg-laying using rocket nets (Rice Island) and cannon nets (ASARCO), and during incubation using noose mats placed over active nests (East Sand Island). Tern chicks that were near fledging were banded at the East Sand Island (n = 350), Crescent Island (n = 87), and Solstice Island (n = 88) 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. Color-banded terns were re-sighted on various breeding colonies by researchers throughout the 2001 breeding season. Re-sightings of banded terns at other locations were reported to us through this web page, by phone, or by e-mail.

Results and Discussion: In 2001, over 3,100 re-sightings of color-banded Caspian terns had been reported as of 30 September. Approximately 520 of 619 adult terns (84%) banded at East Sand and Rice islands in 2000 returned or relocated to East Sand Island in 2001. Three of the 12 adults terns (25%) banded at the ASARCO Site in Commencement Bay, Washington in 2000 were subsequently re-sighted at East Sand Island in 2001. Also, about 10 of the 54 adults (19%) banded at ASARCO in 2001 had been re-sighted at East Sand Island by the end of June; three of the 54 banded adults (6%) were known to have successfully raised chicks at the East Sand Island colony. None of the terns color-banded as chicks in 2000 were re-sighted at any tern colony in 2001 (see Map 3). 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). Interestingly, a tern that was banded as a chick at Rice Island in 1997 was observed successfully rearing two chicks on East Sand Island in 2001. 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 inter- and intra-annual movements of breeding adult terns we can better assess the consequences of various management strategies.

As was the case in 2000, 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 Manzanillo 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 nesting Caspian terns shifted from the colony site on Rice Island to the restored site on East Sand Island during the three-year period 1999-2001, when Caspian terns were actively managed in the Columbia River estuary (Figure 6). 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 7). The number of Caspian terns nesting on Rice Island increased in 1998, while numbers of nesting terns in the Columbia River estuary remained approximately stable during 1999-2001 (Figure 6).

The successful restoration of the East Sand Island Caspian tern colony 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*], Pacific sardine [*Sardinops sagax*], 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 3). Caspian terns nesting on East Sand Island had the lowest percentage of salmonids in their diet (33%) in 2001 and terns nesting on Rice Island had the highest percentage of salmonids in their diet (90%) in 2000 (Figure 8). In general, juvenile salmonids were most prevalent in the diets of Caspian terns during April and May, and salmonids declined in the diet in June and July. The one exception to this trend was at Rice Island in 2000, when the salmonid portion of the diet remained high (over 80%) for the entire breeding season.

The estimated total consumption of juvenile salmonids by Caspian terns nesting in the Columbia River estuary declined by 4.4 million smolts (down 38%) from 1999 to 2000 and declined again by 1.5 million smolts (down 20%) from 2000 to 2001 (Figure 9 and Figure 10), coincident with the shift of breeding terns from Rice Island to East Sand Island. The large reduction in the estimated number of juvenile salmonids consumed by terns in 2001 compared to 1999 (down a total of 50%) was primarily due to a reduction in the number of 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 (Figure 8 and Table 3). The differences in the proportion of salmonids in the diets of Caspian terns nesting on Rice and East Sand islands are also consistent with the significant inter-colony differences in the diets of other piscivorous waterbirds (i.e., cormorants, 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 close 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, and 1.40 young raised per breeding pair in 1999, 2000, and 2001, respectively) was consistently higher than for terns 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), and suggests that nesting success at Rice Island during 1997-2000 may not have been adequate to compensate for annual adult and sub-adult mortality. Nesting 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, 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, when there was no gull control on the East Sand Island tern colony, tern nesting success was the highest ever recorded in the Columbia River estuary (Figure 12). The high nesting success of Caspian terns on East Sand Island in

2001 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 in 2001 (R. Emmett, NMFS, 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

Despite progress toward developing and implementing a management plan for Caspian terns that reduces predation on juvenile salmonids in the Columbia River estuary, there remain several impediments to implementation. Several bird conservation groups have sued to block efforts to manage terns in the Columbia River estuary until an Environmental Impact Statement is completed. A recent U.S. District Court ruling concurred with the plaintiffs claim that current scientific knowledge does not prove that tern management will aid salmon recovery efforts in the Columbia River Basin, nor does it prove that tern colony relocation will not harm the tern population in the long term. Research is needed to determine if reductions in Caspian tern predation on juvenile salmonids in the Columbia River estuary result in increased adult escapement, and if colony relocation results in poor productivity and population declines in Caspian terns over the long term.

The short-term advantages to both juvenile salmonids and Caspian terns associated with the relocation of 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). Large proportions of the Pacific Coast population (ca. 70%), 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 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.

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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.

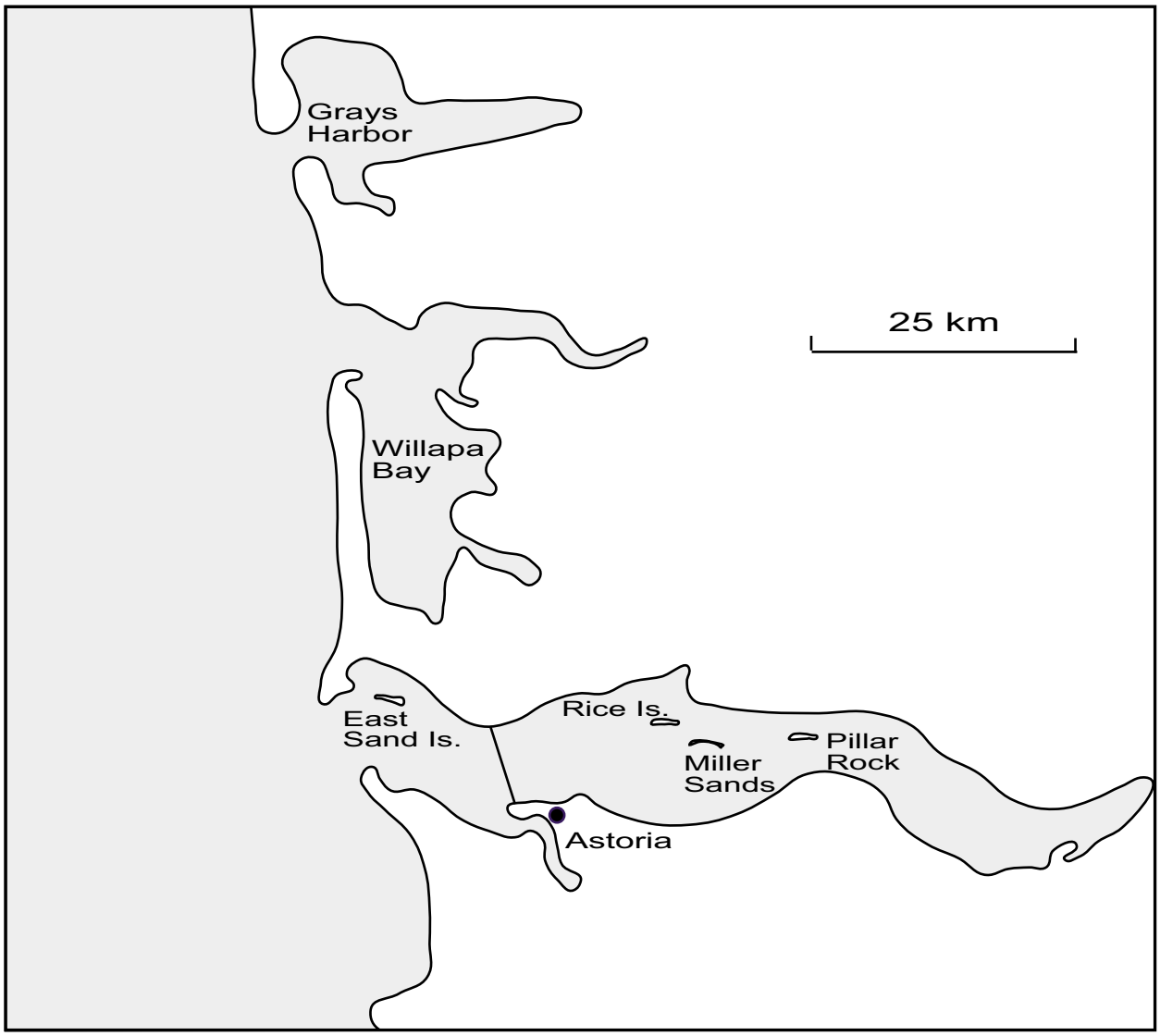
Collis, K., D.D. Roby, C.W. Thompson, D.E. Lyons, and M. Tirhi. 2002. Barges as temporary breeding sites for Caspian terns: Assessing potential sites for colony restoration. Submitted to Wildlife Society Bulletin 30: in press.

Roby, D.D., K. Collis, D.E. Lyons, M. Antolos, and D.P. Craig. 2002. Caspian Tern (*Sterna caspia*). Species account submitted to 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.).

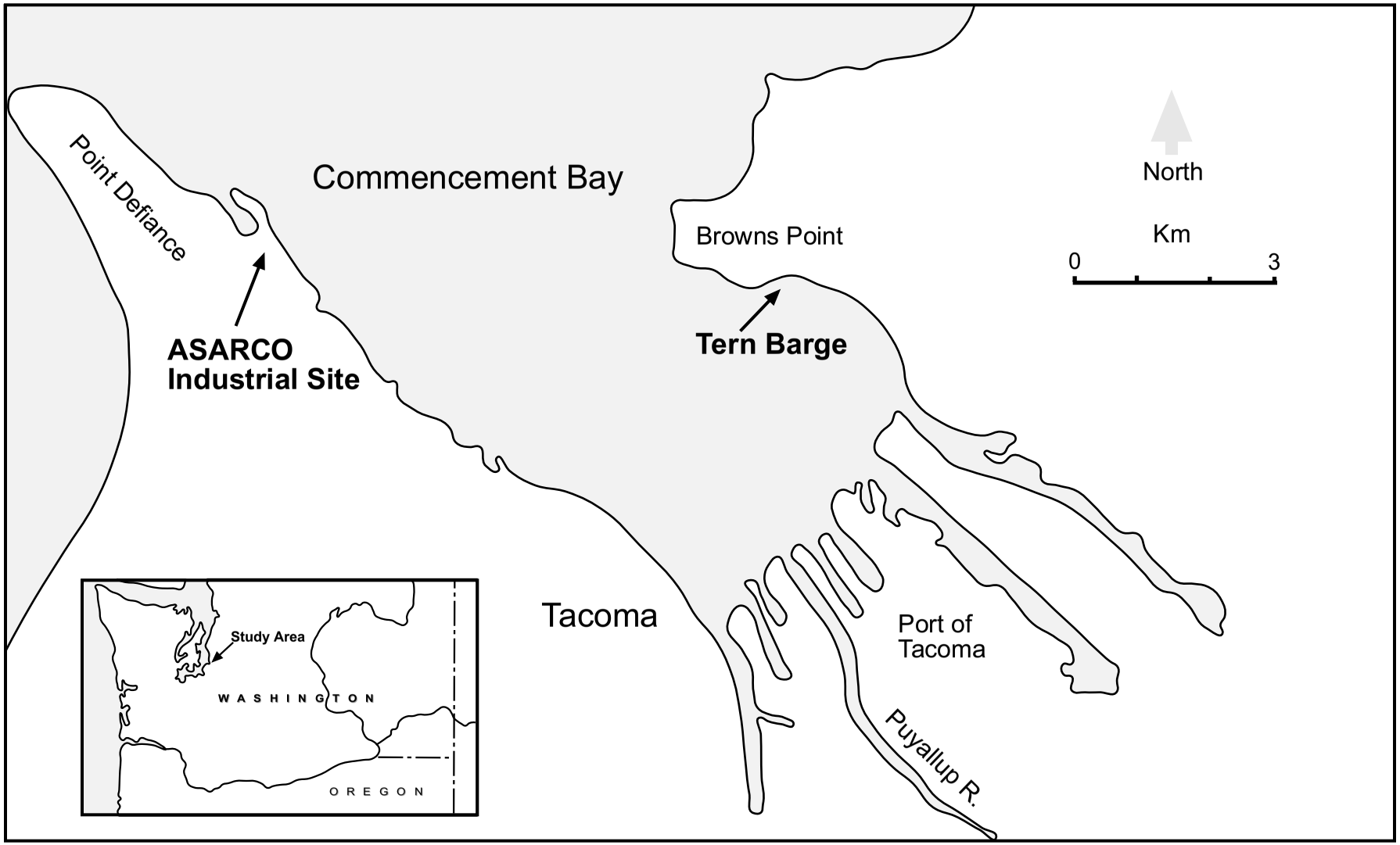
Submitted manuscripts from this study include:

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

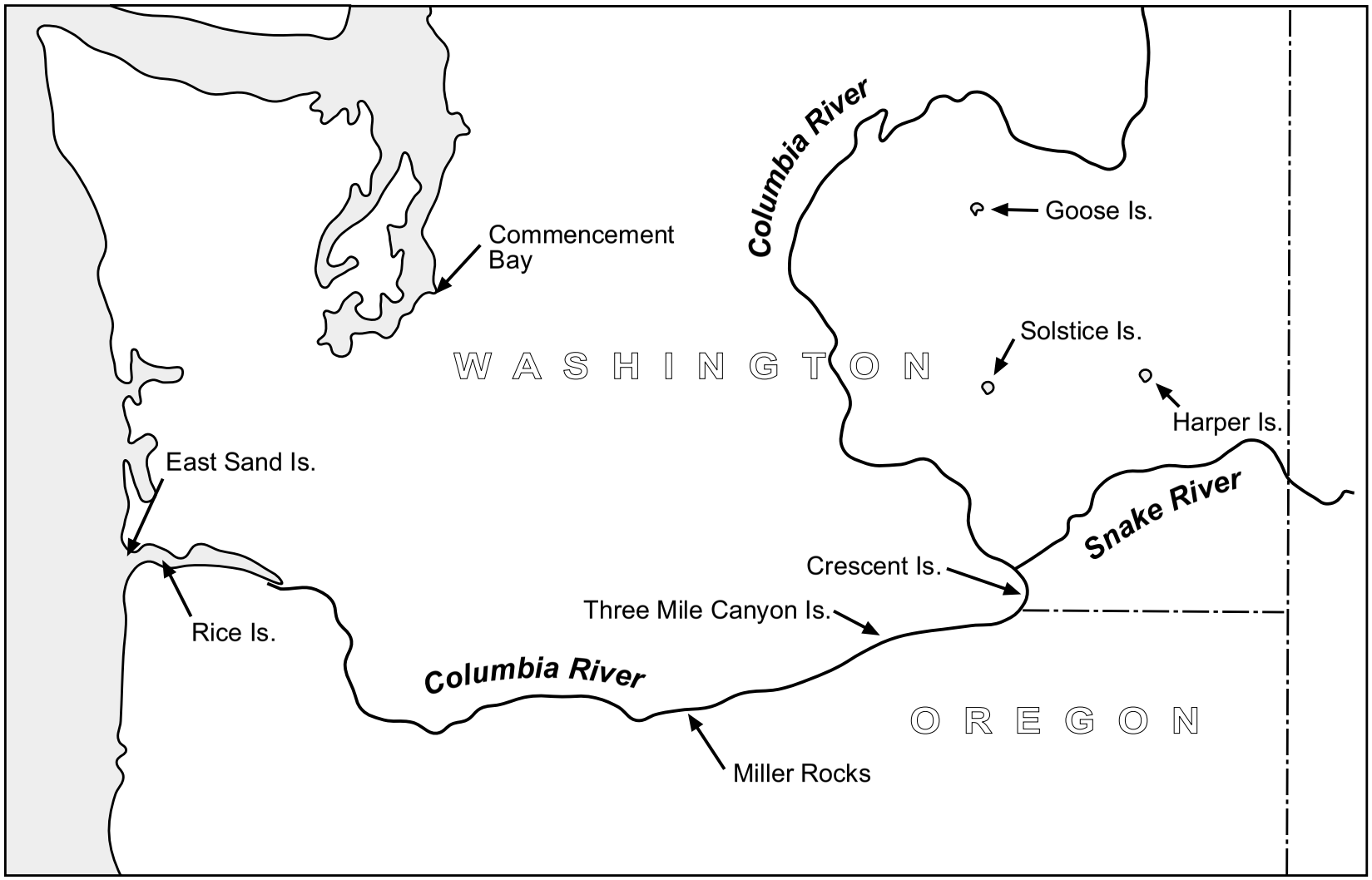
Roby, D.D., K. Collis, D.E. Lyons. In review. Conservation and management for fish-eating birds and endangered salmon. Third International Partners In Flight Conference. Asilomar, California. March 2002.



Map 1. Columbia River estuary and coastal Washington study area, 2001.



Map 2. Commencement Bay study area with the locations of the ASARCO Industrial Site and the tern nesting barge.



Map 3. Caspian tern colony locations on the lower Columbia River and eastern Washington, 2001.

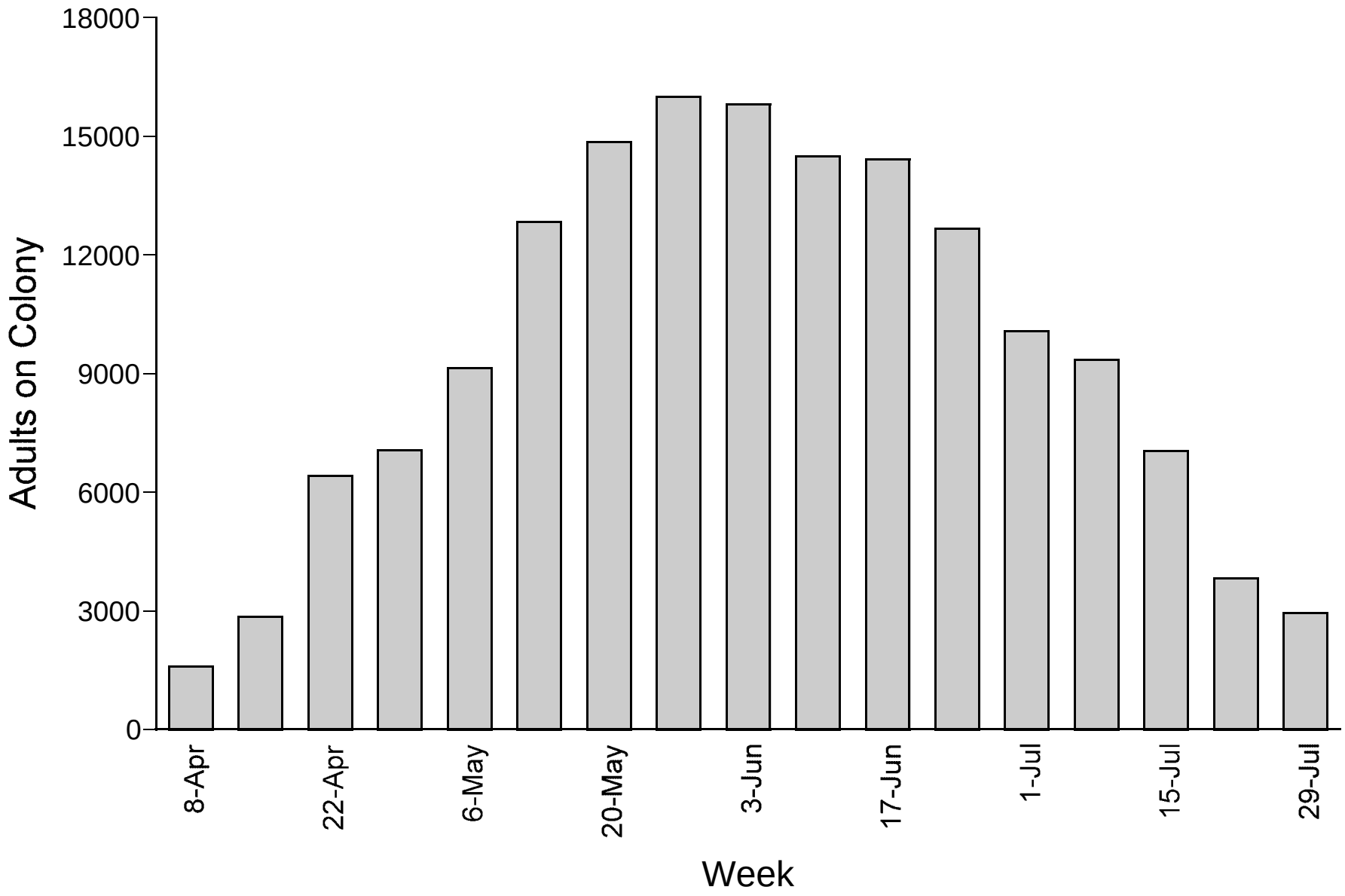


Figure 1. Caspian tern colony counts on East Sand Island, 2001.

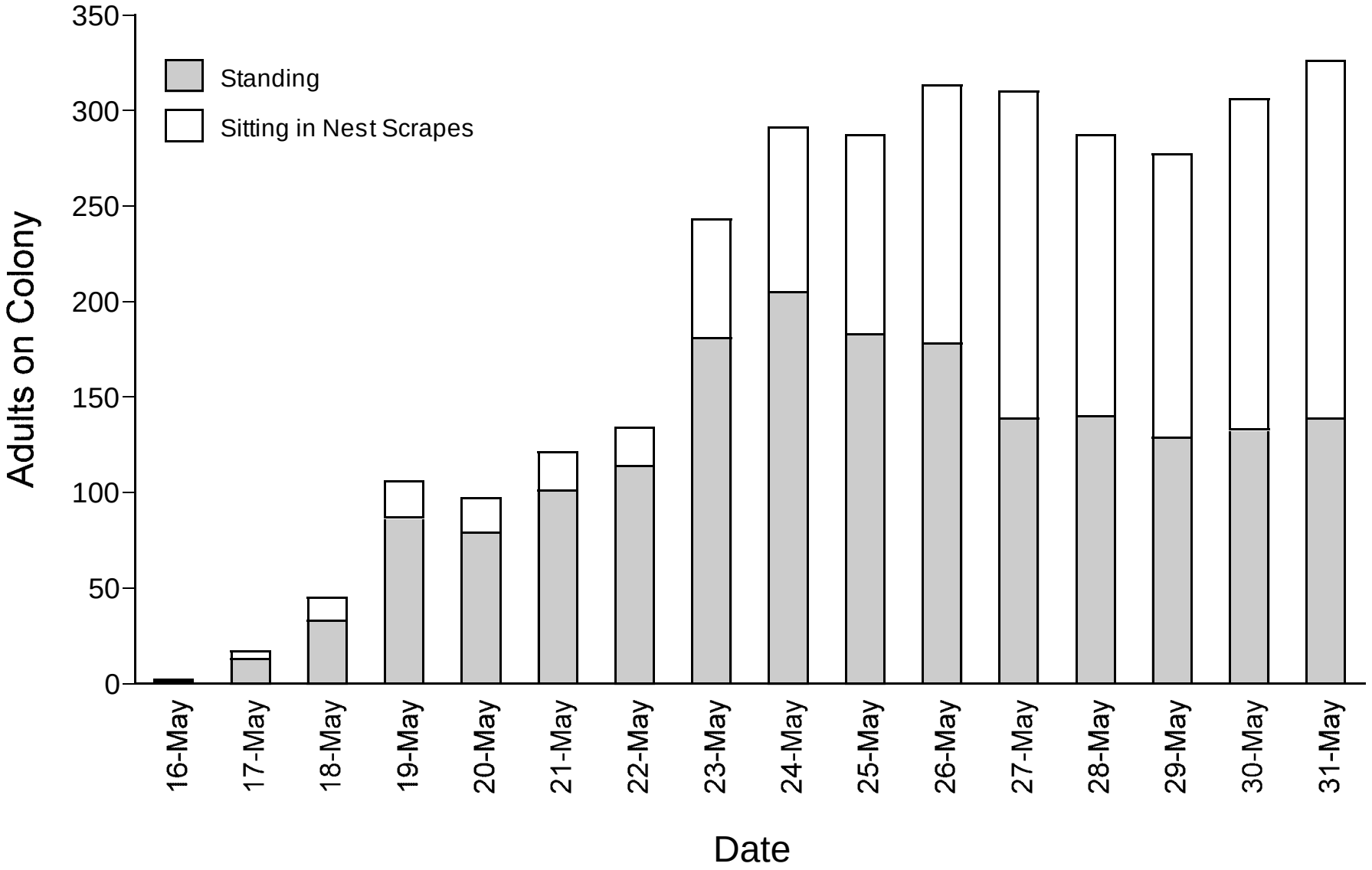
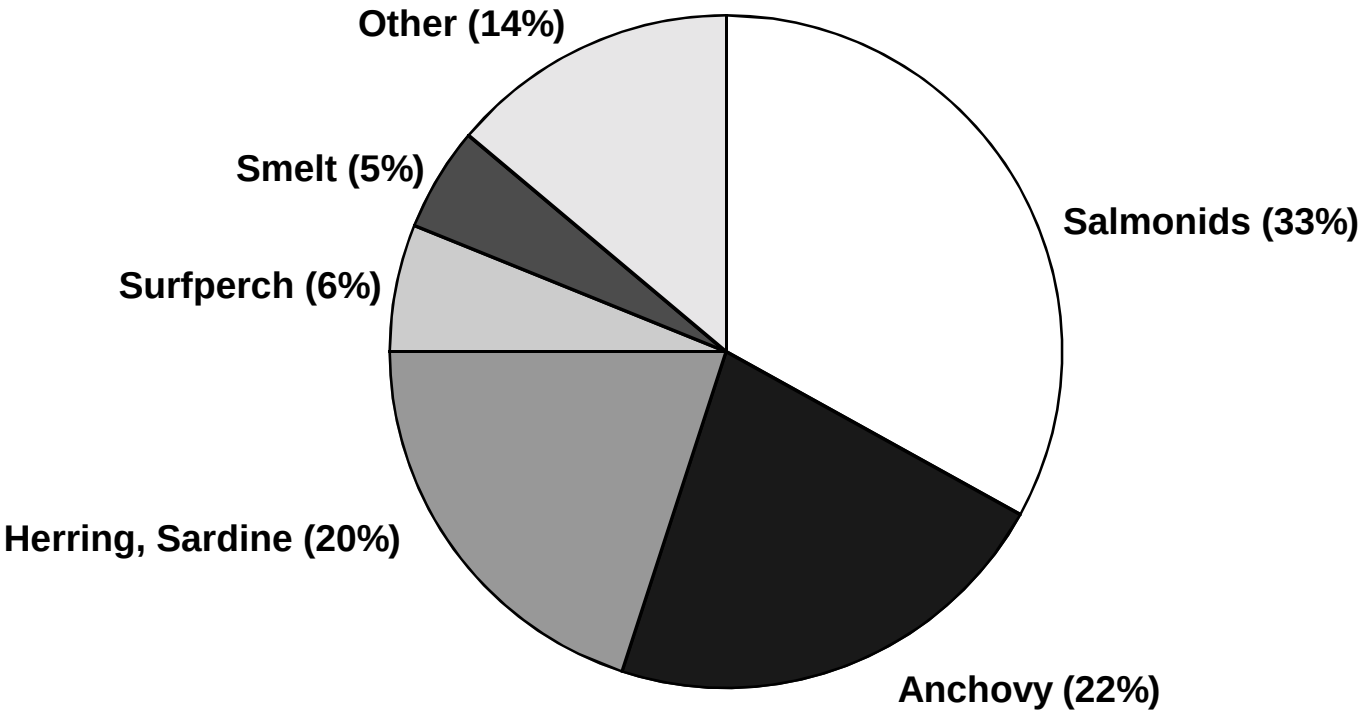


Figure 2. Caspian tern colony counts on barge in Commencement Bay, 2001.



N = 6,007 bill load fish

Figure 3. Caspian tern diet composition on East Sand Island, 2001.

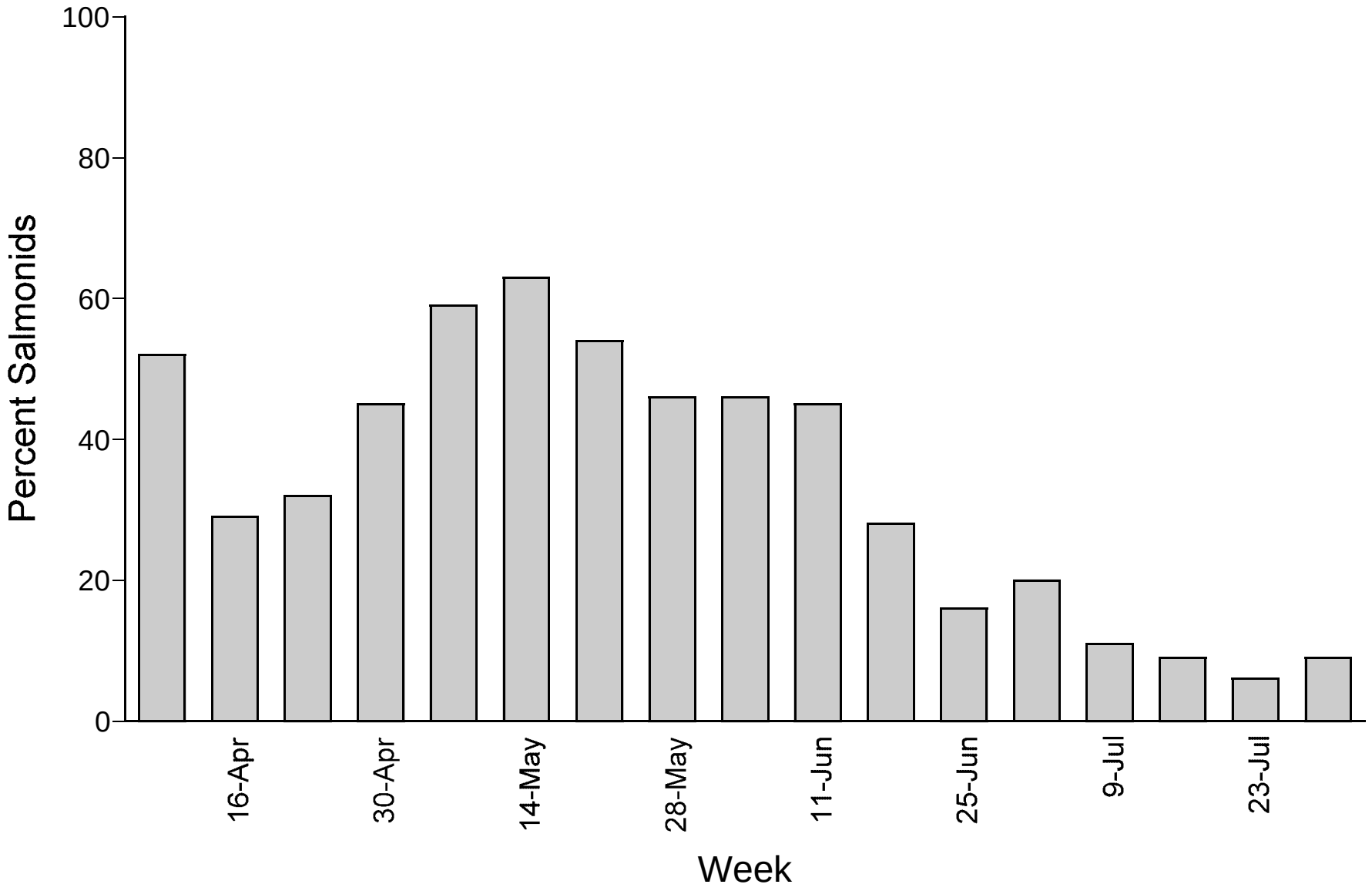


Figure 4. Caspian tern diet composition on East Sand Island, 2001.

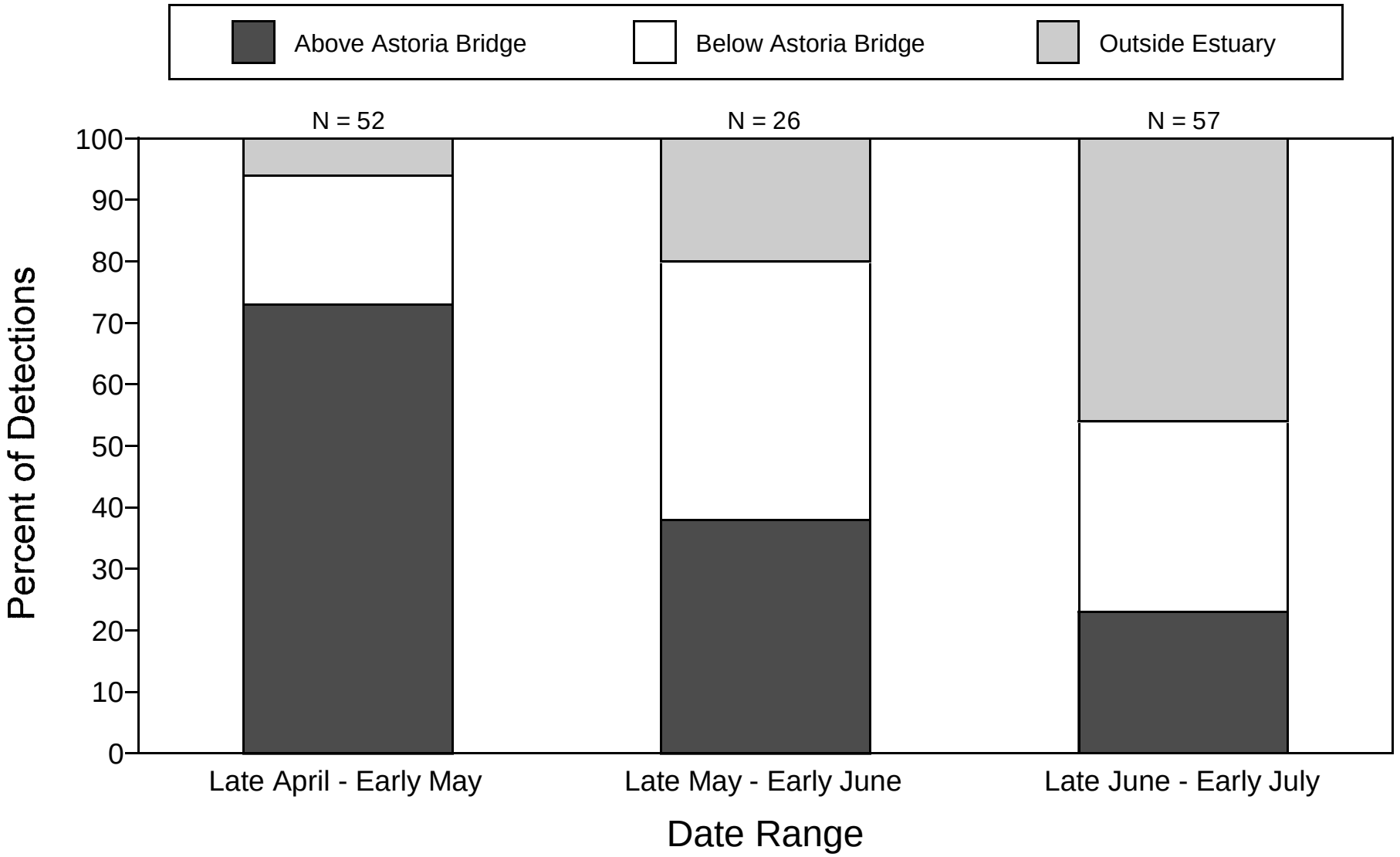


Figure 5. Off-colony detections of radio-tagged Caspian terns breeding on East Sand Island, 2001.

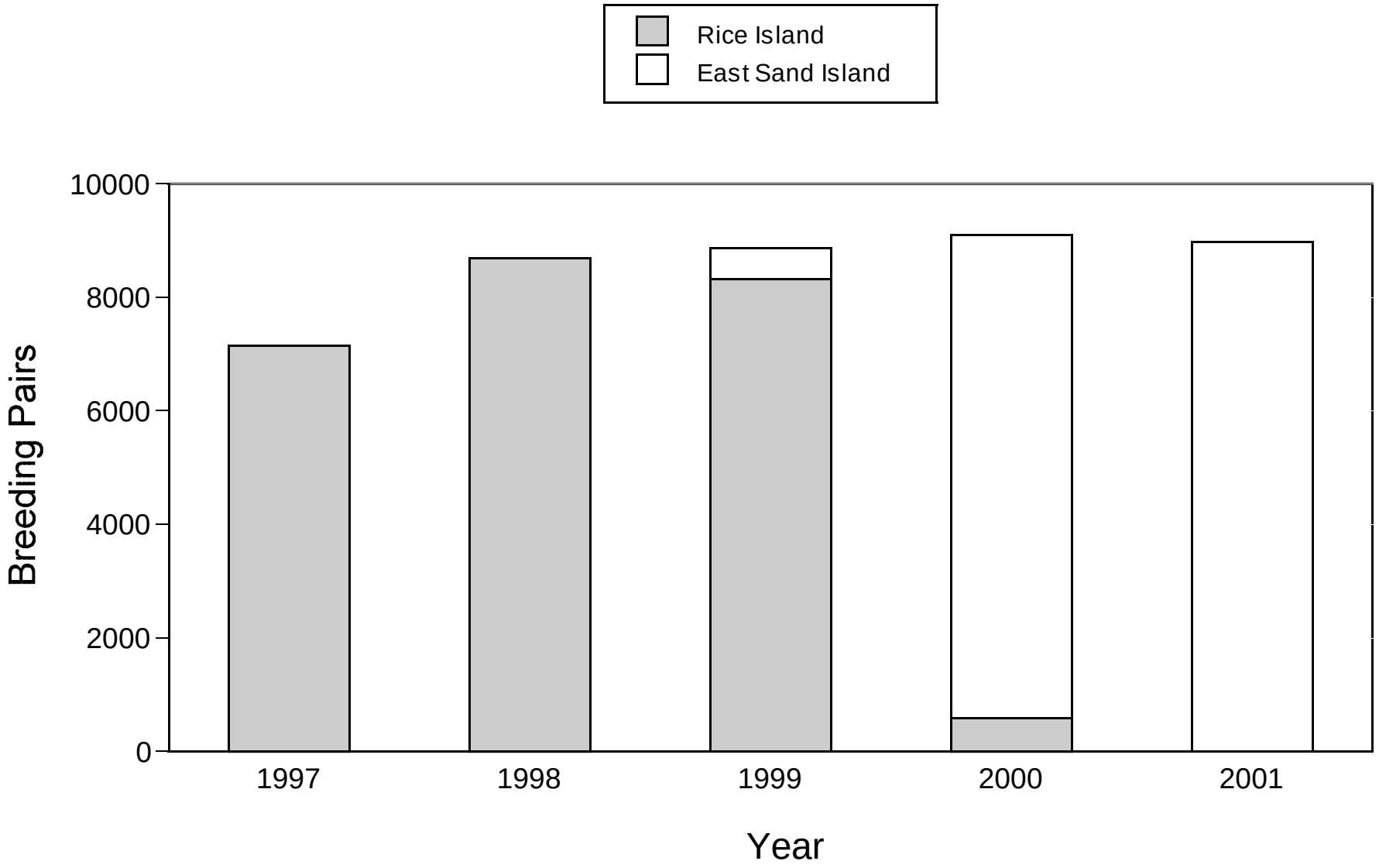


Figure 6. Caspian tern colony size in the Columbia River Estuary, 1997 - 2001.

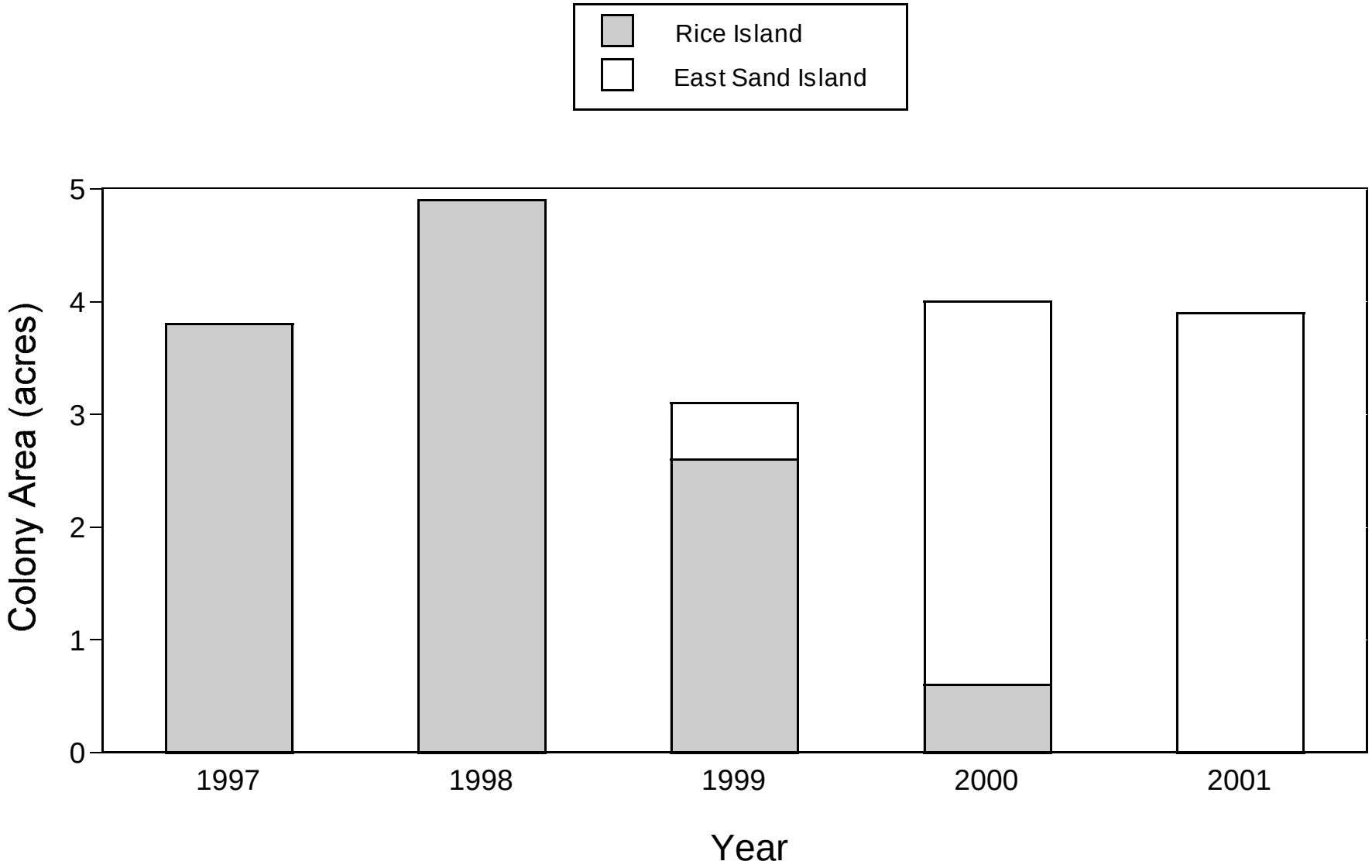


Figure 7. Caspian tern colony area in the Columbia River Estuary, 1997 - 2001.

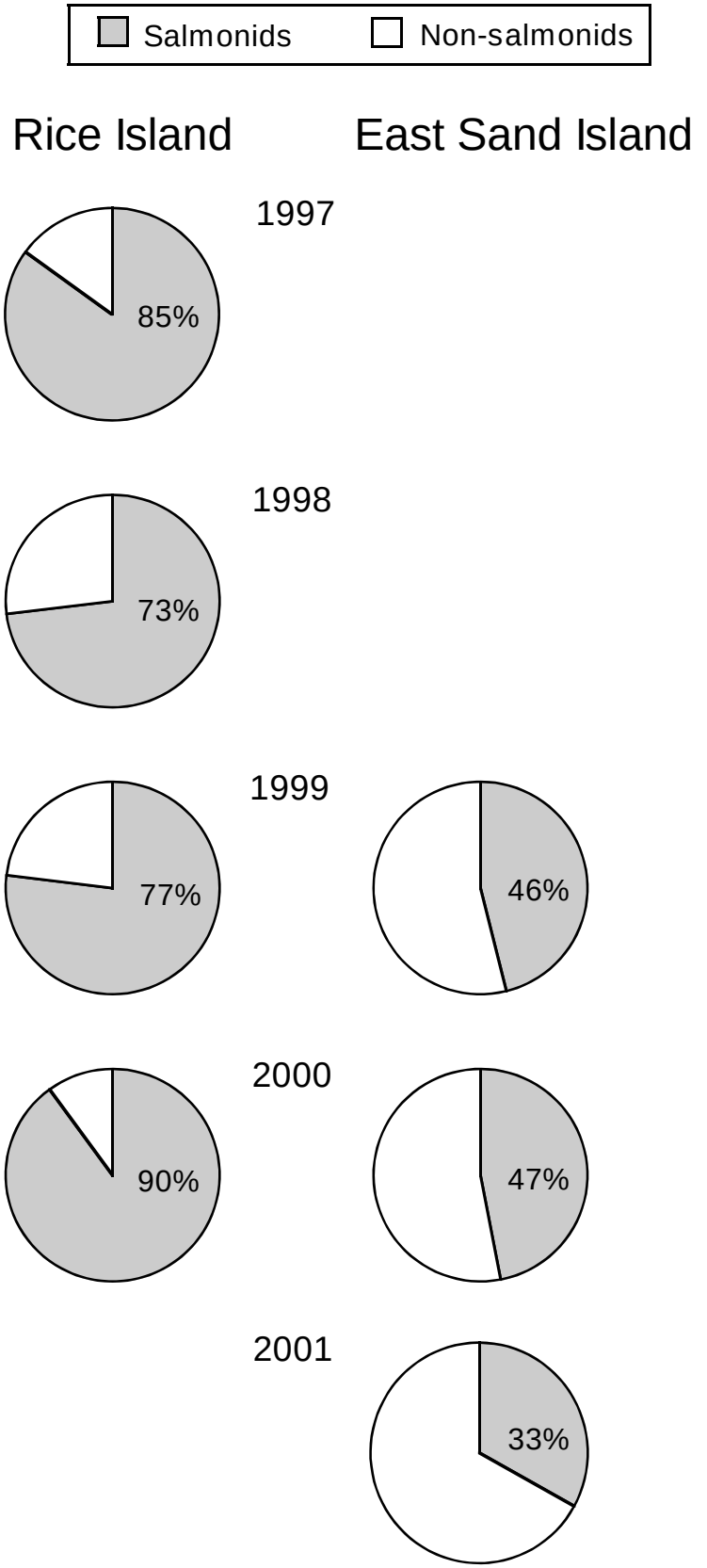


Figure 8. Caspian tern diet composition in the Columbia River Estuary, 1997 - 2001.

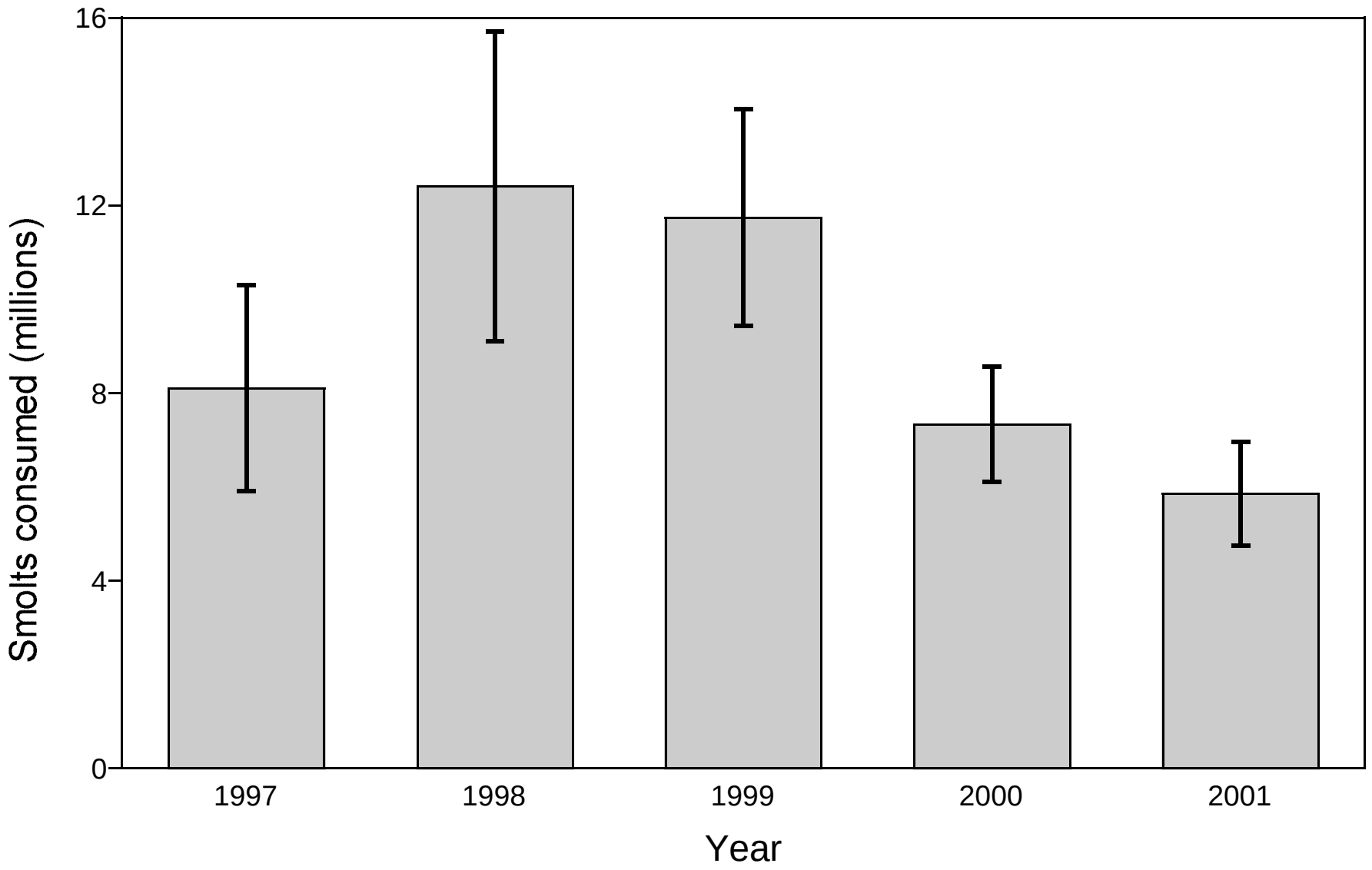


Figure 9. Salmonid consumption by Caspian terns in the Columbia River Estuary, 1997 - 2001.

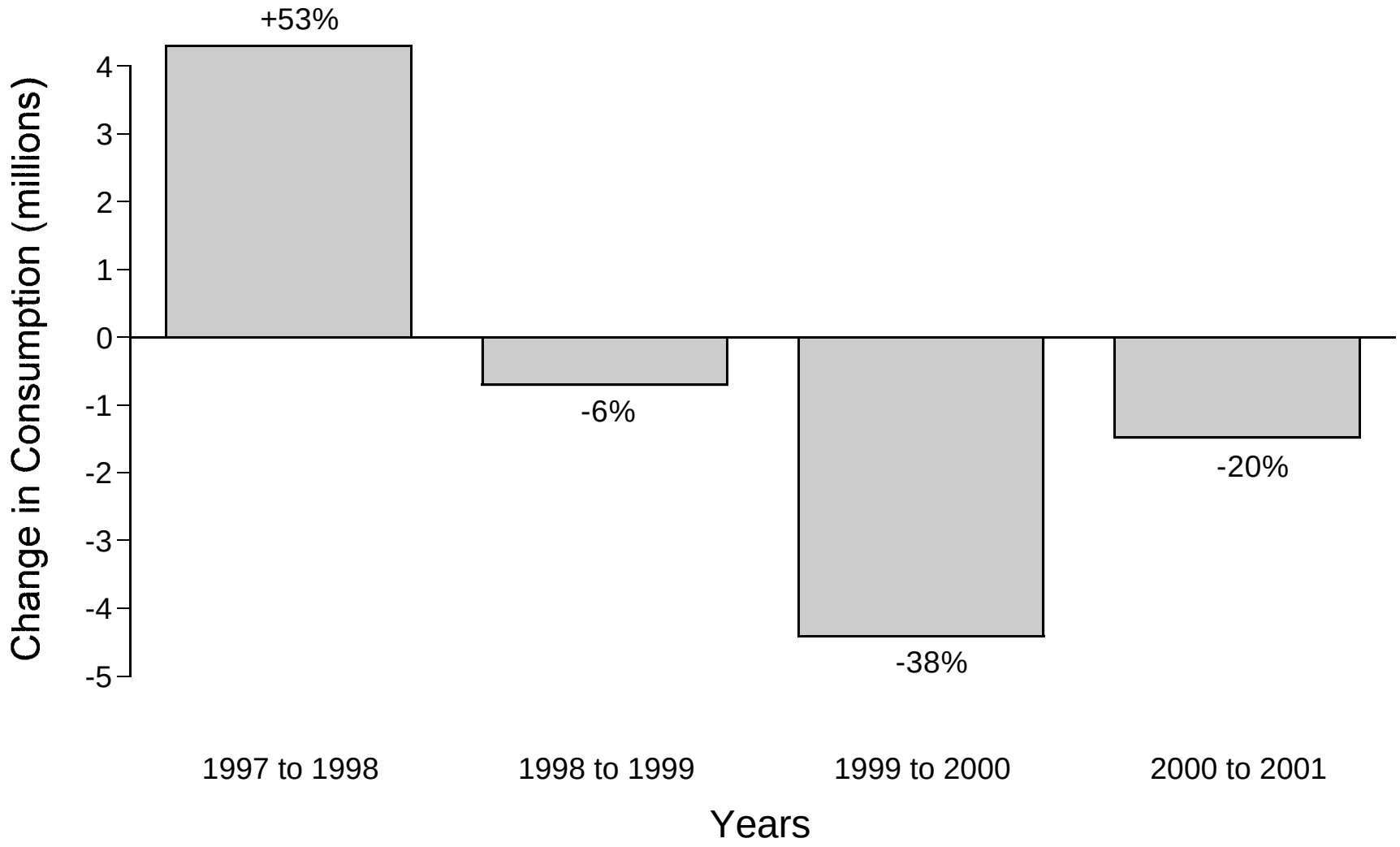


Figure 10. Change in salmonid consumption by Caspian terns in the Columbia River Estuary, 1998 - 2001.

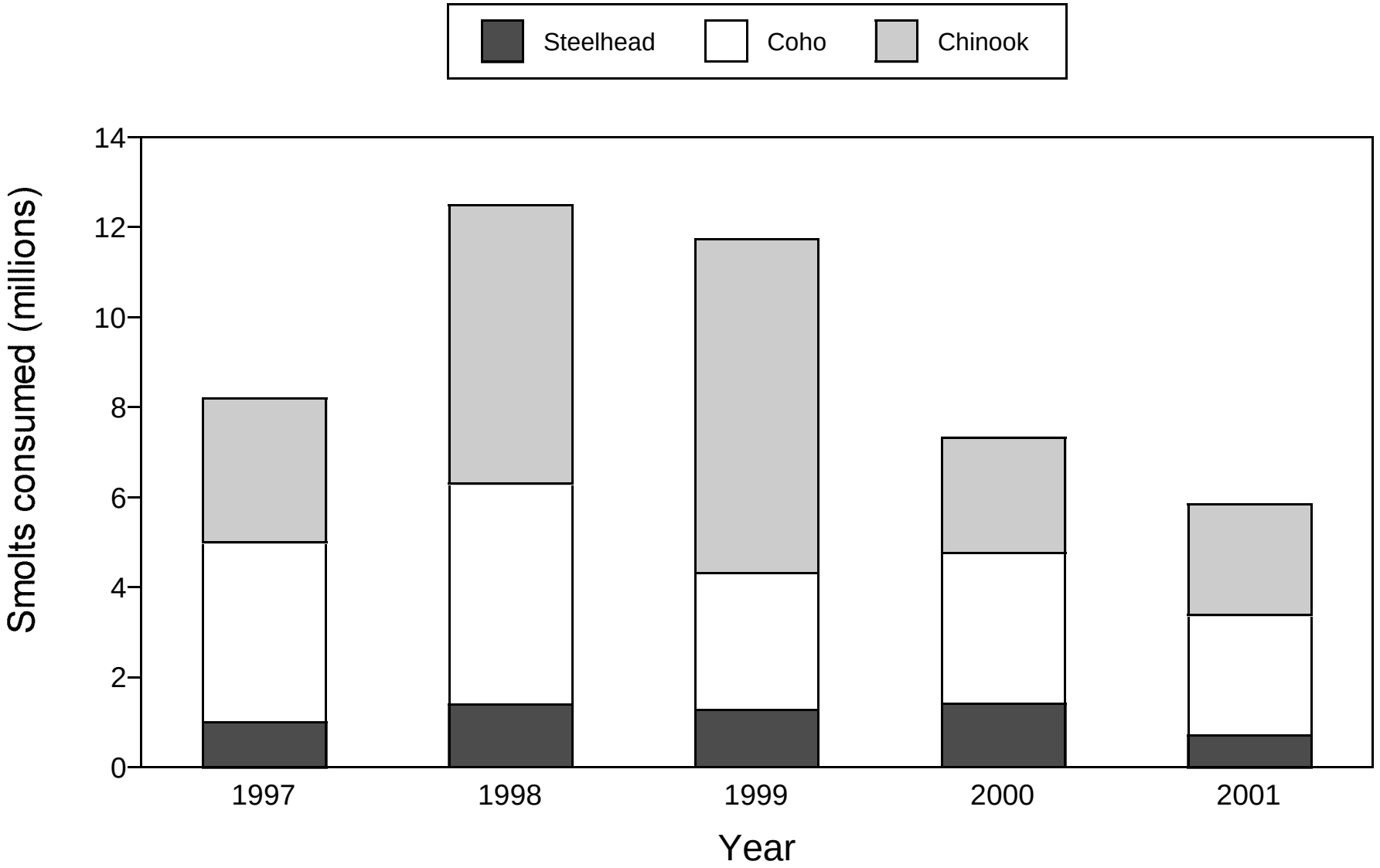


Figure 11. Salmonid consumption by Caspian terns in the Columbia River Estuary, 1997 - 2001.

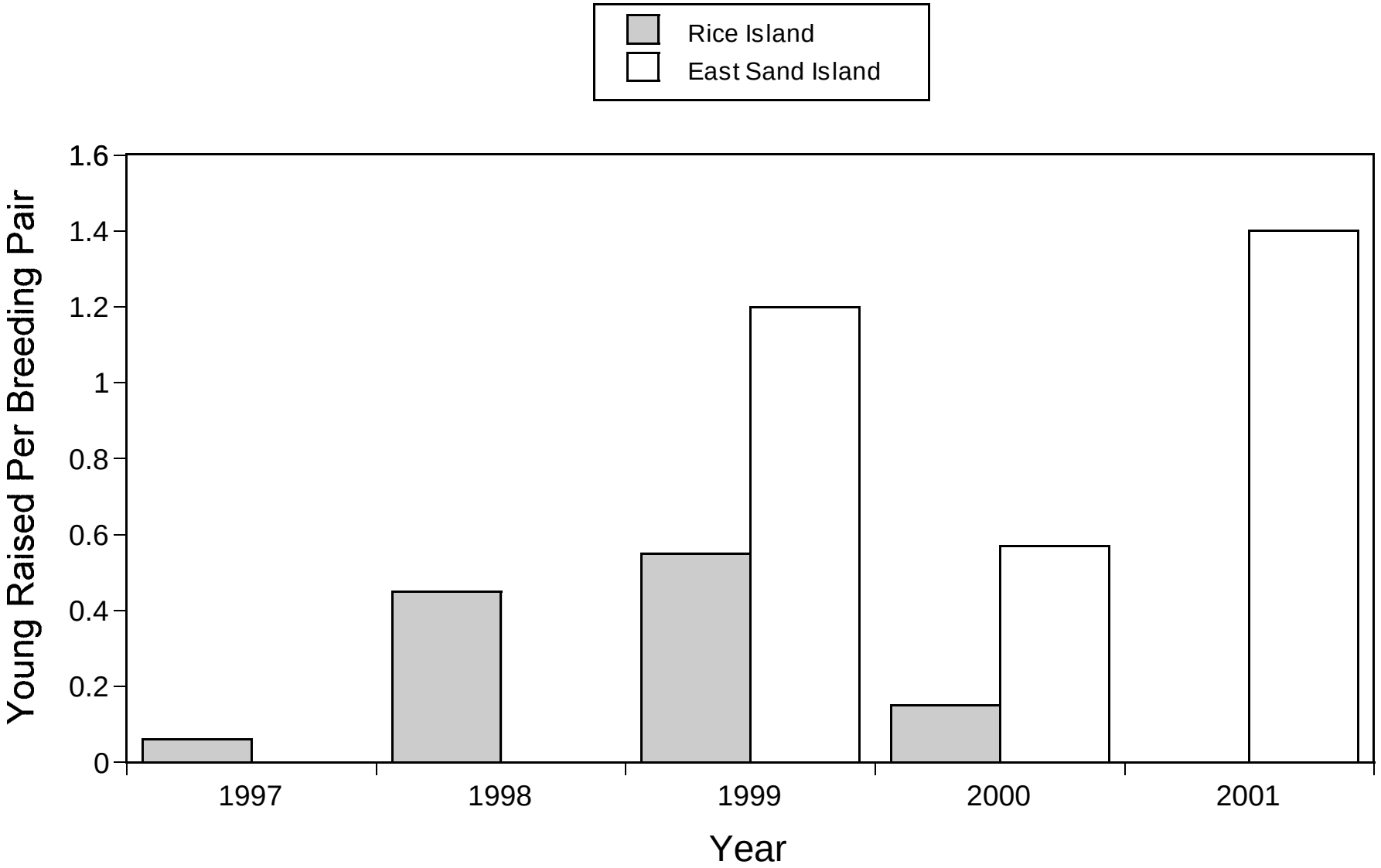


Figure 12. Caspian tern nesting success in the Columbia River Estuary, 1997 - 2001.