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Breeding Ecology of Caspian Terns at Colonies on the Columbia Plateau

Abstract

We investigated the breeding ecology and diet of Caspian terns on the Columbia Plateau in southeastern Washington and northeastern Oregon. We examined trends in colony size and area during 1996-2001, and estimated number of breeding pairs, nesting density, fledging success, and diet composition at selected colony sites in 2000 and 2001. We found six tern colonies totaling ~1,000 breeding pairs, ranging in size from < 50 to nearly 700 pairs. Predation by mink caused complete abandonment of one of these colonies in 2000 and 2001. The relocation of ~9,000 Caspian tern breeding pairs from Rice Island to East Sand Island in the Columbia River estuary did not result in an obvious increase in the number of tern breeding pairs on the Columbia Plateau during the study period. The majority of Caspian tern prey items at colonies on the mid-Columbia River consisted of juvenile salmonids. At a colony in Potholes Reservoir, Washington, Caspian terns commuted over 100 km round-trip to the Columbia River to forage on juvenile salmonids, suggesting that locally abundant food may be limiting. High nesting densities at other mid-Columbia River colonies suggest that availability of breeding habitat may limit colony size. The small size of Caspian tern colonies on the Columbia Plateau, and possible constraints on availability of suitable nesting habitat within the study area, suggest that the level of predation on ESA-listed juvenile salmonids in this region will likely remain well below that currently observed in the Columbia River estuary.

Introduction

The history of Caspian tern (*Sterna caspia*) breeding colonies on the Columbia Plateau in southeastern Washington and northeastern Oregon demonstrates their dynamic nature. The first nesting record for Caspian terns in this region was in 1929, when a single nest was found on an island in Moses Lake, Grant County, Washington (Kitchin 1930). In 1932, a colony of ~50 pairs was found on an island in the mid-Columbia River in Benton County, Washington (Decker and Bowles 1932). The Moses Lake colony disappeared in the mid-1950s, and was subsequently replaced by a colony in Potholes Reservoir, Washington, after the reservoir was created in the late 1950s (Penland 1982). Caspian terns nesting in Potholes Reservoir have fluctuated in number and changed nesting sites several times (Penland 1982); in 1997 three colonies existed on three islands totaling 259 breeding pairs (Finger and Tabor 1997). Five pairs of Caspian terns nested on Cabin Island in the mid-Columbia River in 1975, just above Priest Rapids Dam (Penland 1982). Thompson and Tabor (1981) thoroughly surveyed the Columbia River between Priest Rapids, Washington and Portland, Oregon in 1977 and 1978, and while no Caspian tern colony was found on Cabin Island, a colony of ~200 pairs was discovered on Three Mile Canyon Island, near Boardman, Oregon. Crescent Island, located in the Columbia River near Wallula, Washington, was created in 1985 from dredge-spoil as a nesting site for waterfowl, and was soon after colonized by Caspian terns (Ackerman 1994). Two small Caspian tern colonies (~20 pairs) in Banks Lake, Grant County, Washington, and Sprague Lake, Adams County, Washington, were first reported in 1997 (Shuford and Craig 2002).

In the Columbia River estuary, Caspian tern nesting was first documented in 1984, and by 1998, nearly 9,000 Caspian tern pairs were breeding in a single colony on Rice Island (Roby et al. 2002). This colony was of concern to fisheries managers because Caspian terns nesting on Rice Island consumed an estimated 13% (9.1-15.7 million) of juvenile salmonids (*Oncorhynchus* spp.) that reached the estuary during the 1998

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migration year (Roby et al. 2003), including those listed as Threatened or Endangered under the U.S. Endangered Species Act (National Marine Fisheries Service 1995). In an attempt to reduce the impact of Caspian tern predation on listed juvenile salmonids, terns were relocated 26 km down-river from Rice Island to a previously used breeding site on East Sand Island during 1999-2001 (United States Army Corps of Engineers 1999). Terns were expected to consume fewer salmonids at this site because of a greater availability of marine forage fishes (Roby et al. 2002). One concern in implementing this management plan was the possibility that displacing terns from the Rice Island colony would cause terns to disperse to up-river colonies, where impacts on survival of juvenile salmonids might be the same or greater (Collis et al. 2002).

To address concerns about changes in the number and size of up-river tern colonies following tern management in the estuary, we investigated the status, size, and breeding ecology of Caspian tern colonies on the mid-Columbia River during 1996-2001. In addition, we made detailed observations of Caspian tern diet at these colonies to gauge the magnitude of tern predation on juvenile salmonids. The tern colonies at Crescent and Three Mile Canyon islands were of particular interest because data collected in 1997 and 1998 suggested that terns nesting on islands in the mid-Columbia River foraged primarily on juvenile salmonids (Collis et al. 2002). We initiated collection of diet data at the Solstice Island colony in 2001 because we found direct evidence during the 2000 breeding season that terns nesting at this site were commuting long distances to the Columbia River to forage on juvenile salmonids (see Discussion). Diet data can be used to estimate total salmonid consumption by terns, and help inform decisions on management of terns at these colonies by state, federal, and tribal resource managers.

Our objectives in this study were (1) to identify factors limiting the number, size, and productivity of Caspian tern colonies in the Columbia Plateau region, (2) to determine if displacement of the Caspian tern colony on Rice Island resulted in increased numbers of Caspian terns nesting at colonies in southeastern Washington and northeastern Oregon, and (3) to estimate the proportion of juvenile salmonids in the diet of Caspian terns nesting at mid-Columbia River colonies.

Study Area

This study was conducted at Caspian tern colonies located on the Columbia Plateau in Washington and Oregon (Figure 1). Historical and suspected Caspian tern nesting sites were checked throughout the study area in 2000 and 2001, and sporadically during 1996-1999. Research was focused on colonies at Crescent Island, Three Mile Canyon Island, and Solstice Island, with limited investigations at Goose Island, Harper Island, and Miller Rocks (Figure 1); these were the only active tern colonies found during the study period (see Shuford and Craig 2002 for site characteristics).

Crescent Island is a 3.2 ha dredge-spoil island located on the Columbia River within the McNary Dam impoundment. During the study period, California gulls (*Larus californicus*), Caspian terns, and ring-billed gulls (*L. delawarensis*), (in order of decreasing abundance) nested in the sparsely vegetated areas of the island. Nesting California gulls nearly surrounded the Caspian tern colony on the northeastern side of the island.

Three Mile Canyon Island is 7.2 ha and is located in the John Day Dam impoundment of the Columbia River. California and ring-billed gulls nested in large numbers throughout the island. The Caspian tern colony was located on the northeastern end of the island, in a sandy clearing, where a small number of California gulls nested on the edge of the tern colony.

Solstice Island is a 1.6 ha sand dune island located at the north end of Potholes Reservoir. The Caspian tern colony was located on the eastern edge of the island, partially bordering a mixed colony of California and ring-billed gulls. While Caspian terns have been recorded nesting at other islands in the Potholes Reservoir in the past (Penland 1982, Finger and Tabor 1997), the first year that Caspian terns were recorded nesting at this particular site was during the 2000 breeding season.

Goose Island is ~0.2 ha and is located in Banks Lake, Washington. It is the northernmost of a small group of basalt rock islands at the south end of the lake. Caspian terns nested among California and ring-billed gulls on the southern portion of the island.

Harper Island, in Sprague Lake, Washington, is a 13 ha basalt rock island. California and ring-billed gulls nested in large numbers on this island

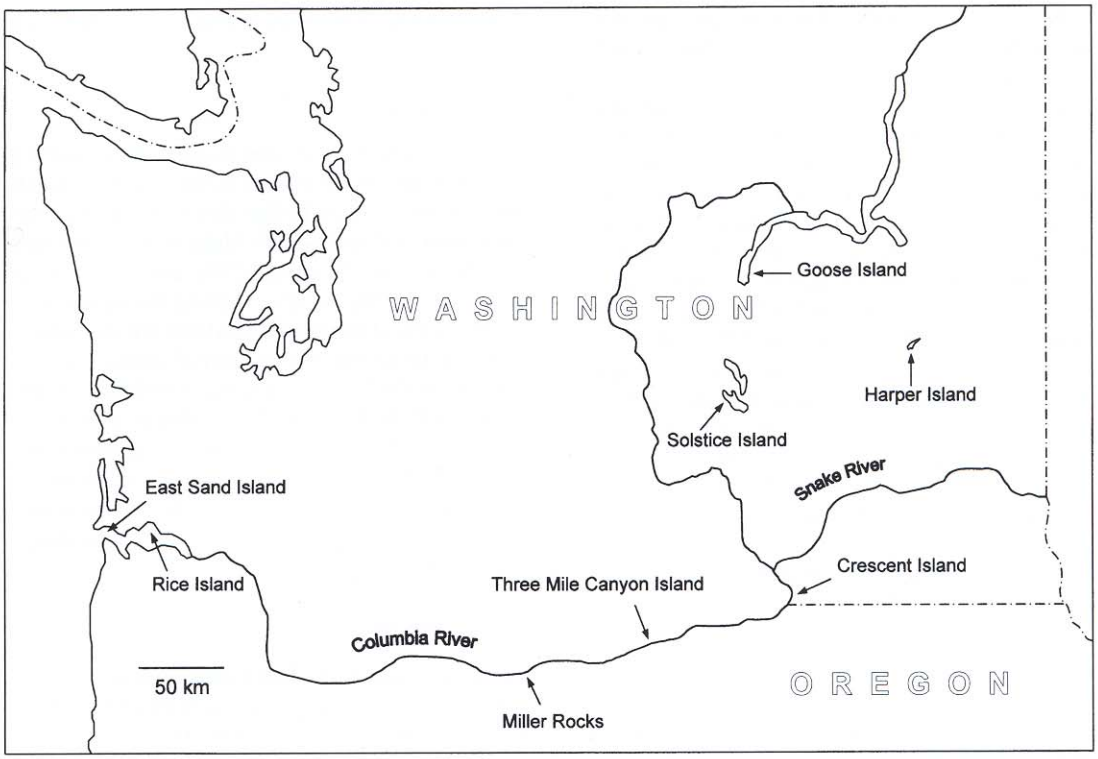

Figure 1. Locations of known Caspian tern colonies in the Columbia Plateau region of southeastern Washington and northeastern Oregon during 2000-2001. Caspian tern colonies located in the Columbia River estuary during the study period are also shown.

and bordered the Caspian tern colony, located on the northwestern edge of the island.

Miller Rocks, a cluster of basalt rock islets, is located in the reservoir formed by The Dalles Dam in the Columbia River, east of Miller Island, Washington. Caspian terns nested among California and ring-billed gulls on the westernmost of the two main islets, which has an area of ~0.4 ha. The first record of Caspian tern nesting on Miller Rocks was in 2001 (David P. Craig, Willamette University, personal communication).

Methods

Colony Size

Colony sizes were estimated using several methods. Aerial photographs were taken with a high resolution (1:1200), large format camera (Zeiss RMK Top 300) at Crescent Island and Three Mile Canyon Island during 1996-2001, and at Solstice Island in 2001. Photographs were timed to coincide with late incubation, when maximum colony attendance was assumed (Bullock and Gomersal 1981, Gaston and Smith 1984). Direct counts of total numbers of Caspian terns and gulls were made from these photographs by the Survey, Mapping, and Photogrammetry Department of the Bonneville Power Administration, Portland, Oregon (see Collis et al. 2002 for details). Gulls could not be identified to species from the aerial photos. These data were then used to assess trends in colony size across years for terns and gulls at Crescent and Three Mile Canyon islands. We also used these data to compare the combined number of terns counted on Crescent and Three Mile Canyon islands before (1996-1998) and during (1999-2001) tern management in the Columbia River estuary. This analysis was limited to these two colonies because they were the only sites where count data were available for six years. Estimates of tern colony size at Solstice Island in 2000, Miller Rocks in 2001, and Goose and Harper islands in 2000 and 2001 were based on ground counts from a vantage outside the colony.

On Crescent, Three Mile Canyon, and Solstice islands, we converted aerial photo counts to estimate the number of tern breeding pairs at these colonies. We used the ratio of the number of incubating terns to the total number of terns in sampled areas of the colony to estimate the total number of incubating birds from the aerial photo counts. These ratios were determined on the day of aerial photography by counting birds in 5 m x 5 m plots from observation blinds at Crescent Island (16 plots in 2000 and 2001) and at Three Mile Canyon Island (5 plots in 2000). Because we did not have an observation blind or sample plots on the colony at Solstice Island, we used an average of the ratios of incubating/total birds collected at the other two colonies to convert the aerial photo count at Solstice Island in 2001 to the number of breeding pairs. We assumed all other colonies in our study area were less than 50 breeding pairs, due to the small numbers counted late in the season (Table 1).

Nesting Density

The nesting density of Caspian terns was determined for colonies and years for which aerial photographs were taken and estimates of breeding pairs were made. The estimate of breeding pairs was divided by area of the colony, as determined from aerial photographs using Plus3 TerraModel software (Trimble Navigation Limited, Sunnyvale, California). Colony areas from aerial photography were also used to examine trends in tern colony area, and thus nesting habitat, at Crescent and Three Mile Canyon islands between 1996 and 2001.

Fledging Success

Nesting success was determined by counting the total number of chicks in the colony 1 week prior to the median fledge date (~1 wk after the first chick fledged) and dividing by the estimated number of breeding pairs. We assumed that at this stage of the fledging period the number of young that had already fledged and left the colony would approximate the number of chicks counted on-colony that would not survive to fledge (Roby et al. 2002, Roby et al. 2003). Because Solstice Island was checked infrequently, we assumed that breeding chronology at this site was the same as at Crescent Island, where we made regular visits, in order to calculate the number of fledglings produced at this colony.

Diet Composition

Percent composition of prey items was determined for Caspian terns nesting at Crescent, Three Mile Canyon, and Solstice islands. Prey items were assigned to the lowest distinguishable taxa by visually identifying bill loads of adult terns (fish held crosswise in the bill) (Collis et al. 2002). We assumed that prey items brought back to the colony by breeding adults represented the overall diet of Caspian terns. This assumption was supported by observations in the Columbia River estuary that prey composition in gut contents did not differ

TABLE 1. Total numbers of Caspian terns and California and ring-billed gulls counted on islands in the Columbia Plateau region of southeast Washington and northeast Oregon. Unless noted otherwise, these numbers were determined from aerial photography taken during late incubation. ND = no data.

SITES	1996	1997	1998	1999	2000	2001
Caspian terns						
Crescent Island	347	941	636	677	870	904
Three Mile Canyon Island	436	526	349	418	431	1
Solstice Island	ND	ND	ND	ND	199[1]	368
Goose Island	ND	ND	ND	ND	30[2]	29[3]
Harper Island	ND	ND	ND	ND	32[4]	33[5]
Miller Rocks	0	0	0	ND	ND	13[6]
California and ring-billed gulls						
Crescent Island	3,334	5,76	4,597	4,929	4,262	2,690
Three Mile Canyon Island	8,828	13,305	11,102	9,338	9,573	8,836
Solstice Island	ND	ND	ND	ND	ND	4,297

Determined from ground counts on: [1]20 June, [2]29 June, [3]27 June, [4]8 July, [5]2 July, [6]17 June; 32 adults were counted on 7 June (David P. Craig, Willamette University, personal communication).

significantly from prey composition of bill loads (Collis et al. 2002).

Observations were made at the colony from blinds or from a boat on the water at distances of 10-40 m. We identified between 100 and 200 tern bill loads each week at Crescent Island in 2000 and 2001, while at Three Mile Canyon Island in 2000 and Solstice Island in 2001 between 250 and 350 bill loads were identified over the entire breeding season. Overall diet composition was calculated for each colony-year by averaging the weekly percentages of each prey type. This method was used to avoid a bias toward weeks with high sample sizes; sample sizes varied among weeks due to seasonal fluctuations in the number of terns on-colony and hence the number of prey items brought into the colony.

Whenever possible, diet data from the entire breeding season (April-late July) were used for comparisons. At the Three Mile Canyon Island colony, diet data were collected from the beginning of May until mid-June, when Caspian terns abandoned the site. In order to compare diet data from Three Mile Canyon Island to other colonies, we restricted our analysis of diet data from other colonies to similar periods.

Statistical Analysis

We used simple linear regression to examine trends in the number of terns and gulls nesting at Crescent and Three Mile Canyon islands, as well as trends in tern colony area, over time. We used a nonparametric Wilcoxon rank-sum test to compare numbers of Crescent and Three Mile Canyon terns before (1996-1998) and during (1999-2001) tern management in the Columbia River estuary. We tested for differences in diet composition using Chi-square tests for independence. All P-values are two-tailed, and the level of significance was set at $P = 0.05$.

Results

Colony Size and Area

We found six tern colonies ranging in size from < 50 to nearly 700 breeding pairs, totaling approximately 1,000 pairs (Table 1, 2). We calculated a ratio of incubating/total terns of 0.63 ± 0.01 (Mean ± SE) for Crescent Island in 2000, 0.73 ± 0.01 for Crescent Island in 2001, 0.64 ± 0.001 for Three Mile Canyon Island in 2000. Crescent Island was the largest known Caspian tern colony in the study area, followed by Three Mile Canyon and Solstice islands, with smaller numbers nesting at Goose Island, Harper Island, and Miller Rocks (Table 1).

There was no significant trend in the size of the Crescent Island tern colony between 1996 and 2001, although the number of terns ranged between 347 and 941 adults (Table 1). At Three Mile Canyon Island, there was no significant trend in the size of the tern colony between 1996 and the initial stages of the 2000 breeding season, but by early chick-rearing in 2000, all Caspian terns nesting on Three Mile Canyon Island had abandoned this site (Table 1). In addition, there was no significant difference between the combined number of terns counted on Crescent and Three Mile Canyon islands in the period before (1,078 ± 203) (Mean ± SE) and during (1,100 ± 114) tern management in the Columbia River estuary.

There was no significant trend in the number of gulls nesting on Crescent Island, or Three Mile Canyon Island between 1996 and 2001 (Table 1). There was an increase in tern colony area on Crescent Island of 150 m^2 (28.5%) between 1996

TABLE 2. Number of breeding pairs, nesting density, and fledging success of Caspian terns at colonies in the Columbia Plateau region and the Columbia River estuary.

	Columbia Plateau					Columbia River estuary					
	Crescent Island		Three Mile Canyon Island		Solstice Island	Rice Island[1]			East Sand Island[1]		
	2000	2001	2000	2001	2001	1999	2000	2001	1999	2000	2001
Breeding pairs	548	657	275	0	248	8,300	590	0	550	8,500	8,900
Nesting density (pairs/m^2)	0.87	0.97	0.95	--	0.74	0.78	0.25	--	0.26	0.62	0.57
Fledging success (fledglings/pair)	0.62	1.00	0.00	--	0.88	0.55	0.15	--	1.20	0.57	1.40

[1]From Roby et al. 2002

and 2001; however, there was not a significant linear increase over time (Figure 2). The area of the tern colony at Three Mile Canyon Island decreased significantly between 1996 and 2000 ($P = 0.02$), before the abandonment of the colony in June of 2000 (Figure 2).

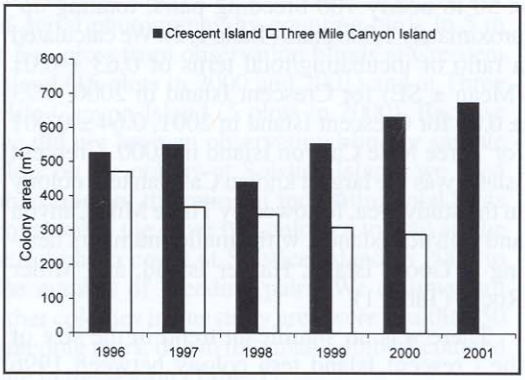

Figure 2. Area (m^2) of Caspian tern colonies on Crescent and Three Mile Canyon islands during late incubation, 1996-2001.

Nesting Density

Densities of tern nests at colonies on Crescent and Three Mile Canyon islands were similar, and higher than tern nesting density at Solstice Island (Table 2). Nest density increased (11.5%) in association with an increase in colony size at Crescent Island from 2000-2001 (Table 2).

Fledging Success

At Crescent Island, we estimated that 342 chicks fledged in 2000 and 657 chicks fledged in 2001; at Solstice Island, we estimated that 217 chicks fledged in 2001. Overall fledging success was therefore 0.62 fledglings/nesting pair at Crescent Island in 2000, 1.00 fledglings/nesting pair at Crescent Island in 2001, and 0.88 fledglings/nesting pair at Solstice Island in 2001 (Table 2). No young terns were fledged from the Three Mile Canyon Island colony in either 2000 or 2001 likely due to predation and disturbance by American mink (*Mustela vison*; see Discussion).

Diet Composition

During the sampling periods, salmonids comprised most of the diet of Caspian terns nesting at Crescent and Three Mile Canyon islands, but not at Solstice Island (Table 3). At Crescent Island, the proportion of salmonids in the diet was significantly greater in 2001 compared to 2000 ($P < 0.001$) (Table 3). Other prevalent prey items in the diet of Caspian terns nesting on Crescent, Three Mile Canyon, and Solstice islands were bass (*Micropterus* spp.), bluegill (*Lepomis macrochirus*), peamouth (*Mylcheilus caurinus*), yellow perch (*Perca flavescens*), and suckers (*Catostomus* spp.) (Table 3). During May through mid-June, Caspian terns nesting at the Three Mile Canyon Island colony in 2000 had a higher proportion of juvenile salmonids in the diet (85.8%) compared to the Crescent Island colony in 2000 (74.9%) ($P = 0.02$) and the Solstice

TABLE 3. Diet composition (average of weekly percentages of identified prey items in bill loads) of Caspian terns nesting at colonies in the Columbia Plateau region.

	Crescent Island (April to July)		Three Mile Canyon Island (May to mid-June)	Solstice Island (April to July)
Prey Type	2000	2001	2000	2001
Salmonid	61.4%	68.1%	85.8%	26.9%
Bass, bluegill	12.2	11.6	5.6	36.5
Peamouth, pikeminnow, chiselmouth	6.1	10.0	0.3	2.0
Sucker	0.5	2.5	0.0	0.0
Sculpin	0.6	1.4	0.0	0.0
Yellow perch	1.2	1.3	0.4	9.9
Catfish	1.3	1.2	0.0	0.0
Sandroller	0.0	0.8	0.0	0.0
Lamprey	0.6	0.6	0.0	0.0
Unidentified non-salmonids	16.1	2.5	7.9	24.7

Island colony in 2001 (32.8%) ($P < 0.001$), but was not significantly different from the Crescent Island colony in 2001 (78.4%) (Table 3).

Discussion

One of the main objectives of this study was to identify factors limiting the number, size, and productivity of Caspian tern colonies in the Columbia Plateau region. Crescent and Three Mile Canyon islands had higher nest densities than did colonies in the Columbia River estuary (Table 2), suggesting that these colonies may have been constrained by the availability of nesting habitat. At Crescent Island, nesting density increased with an increase in colony size from 2000 to 2001; thus nest densities may vary in accordance with availability of breeding habitat. The presence of three small tern colonies on basalt rock islands (Goose Island, Harper Island, and Miller Rocks), which provide little nesting substrate (i.e., sand) for terns to dig nest scrapes, provides further evidence that suitable tern nesting habitat may be limited within the study area.

At Solstice Island, estimated nest density was lower than that at Crescent and Three Mile Canyon islands, and similar to that observed at some colonies in the Columbia River estuary (Roby et al. 2002) (Table 2). We suggest that during the study period, Caspian terns at this site were not constrained by nesting habitat, but instead, by food availability. This is supported by evidence that terns nesting at Solstice Island regularly commuted over 100 km round-trip to the mid-Columbia River to forage on juvenile salmonids. Our discovery of this evidence was prompted by the suggestion that Caspian terns observed foraging at mid-Columbia River dams in 2000 may have been nesting > 50 km away in Potholes Reservoir (Christopher W. Thompson, Washington Department of Fish and Wildlife, personal communication). While foraging trips in excess of 60 km have been recorded for Caspian terns (Soikkeli 1973, Gill 1976), average foraging distances are typically much smaller. In the Columbia River estuary, for example, radio-tagged Caspian terns foraged on average ≤ 20 km from the colony site (Anderson 2003).

During and immediately following the 2000 breeding season, we found numerous passive integrated transponder (PIT) tags, radio tags, and acoustic tags from juvenile salmonids on the Solstice Island tern colony. This provided direct evidence that Caspian terns nesting in Potholes Reservoir commuted > 100 km round-trip to the mid-Columbia River to forage on juvenile salmonids. These tags were first discovered during banding of tern chicks on 7 July 2000 (55 PIT tags, 6 radio tags), and then after the breeding season (26 July 2000), when 1,640 PIT tags, 52 radio tags, and 9 acoustic tags were collected as part of a cooperative recovery effort with the Douglas County Public Utilities District (Columbia Bird Research 2003a). All of the recovered tags were confirmed to be from fish tagged and released in the Columbia River Basin, primarily from locations on the mid-Columbia River. For example, 1,218 PIT tags were from juvenile steelhead tagged as part of a survival study at Wells Dam, Washington, representing 2% of all PIT-tagged smolts released in the study (Bickford et al. 2001). In addition, all tags recovered in 2000 were from that same salmonid migration year, suggesting that Caspian terns nesting in Potholes Reservoir colonized a new site at Solstice Island in 2000.

Data on the composition of Caspian tern diets also demonstrated the importance of juvenile salmonids as a food source for terns nesting at Three Mile Canyon and Crescent islands. Juvenile salmonids are a locally abundant and reliable food source for terns nesting in the mid-Columbia River, as millions of juvenile hatchery fish are released into the Columbia River basin each year (Fish Passage Center 2001, 2002). Thus food availability likely did not limit the number of Caspian terns to initiate nests at Crescent or Three Mile Canyon islands.

Other studies have suggested that gull encroachment on tern nesting habitat can cause the decline or abandonment of tern colonies (Crowell and Crowell 1946, Morris and Hunter 1976, Smith and Mudd 1978). While tern colony area declined significantly at Three Mile Canyon Island during 1996-2000, it is unlikely that the decline was caused by gull encroachment on available tern nesting habitat. This is supported by the fact that we did not find an increase in the number of gulls at Three Mile Canyon Island, and by the fact that the colony was only partially bordered by nesting gulls; in addition, we found evidence that mink predation was the ultimate cause of tern colony abandonment in 2000 and 2001 (see below). At Crescent Island, we did not find a significant change in tern colony area. Therefore, there is no evidence that gull nesting activities have reduced the amount

of nesting habitat available for Crescent Island terns. However, the presence of large numbers of nesting gulls on Crescent Island (Table 1) may be related to high tern nesting densities at this site. This is supported by the observation that tern nesting density increased with an increase in tern breeding pairs between 2000 and 2001.

Factors affecting overall breeding success appear to vary by colony site, but were often related to the presence of nest predators. The lowest fledging success observed was at Three Mile Canyon Island, where the colony completely failed likely due to predation and disturbance by mink. We observed a mink in the colony during the night of 5 June 2000, which caused adult terns to abandon their nests until sunrise. Young tern chicks often cannot survive exposure to cold temperatures caused by prolonged abandonment by adults (Cuthbert and Wires 1999). A combination of such predator induced abandonment and predation on eggs and chicks likely caused the total nesting failure in 2000 (see Burness and Morris 1993). Additional evidence of mink activity was found during the 2001 breeding season, when only two Caspian tern nests were known to have been initiated; the contents were quickly depredated by California gulls. After these initial nesting attempts, Caspian terns did not continue to nest on Three Mile Canyon Island in 2001, presumably because of mink activity.

Higher fledging success at Crescent and Solstice islands in 2001 (Table 2) may have been related to lower nest predation rates. During this year of study, we observed only one instance of nest predation at Crescent Island (Antolos 2003), and no nest predation at Solstice Island. Conversely, the extremely low fledging success at Rice Island in 2000 (Table 2) was associated with high nest predation rates by glaucous-winged/western gulls (*L. glaucescens* x *L. occidentalis*) nesting adjacent to the Rice Island tern colony (Roby et al. 1998). At tern colonies on the Columbia Plateau, nest predation is by the smaller California and ring-billed gulls, which may explain the observed differences in nest predation rates (Ryder 1993, Winkler 1996).

Another main objective of our study was to determine if management of Caspian terns in the Columbia River estuary caused immigration to Columbia Plateau colonies. Our study provided no evidence that tern colonies in the mid-Columbia River increased in size as a result of the displacement of terns from Rice Island during 1999-2001. During the period of tern management in the Columbia River estuary, nearly 700 adult Caspian terns were color-banded on Rice and East Sand islands (Columbia Bird Research 2003a, 2003b). Only four of these color-banded terns were resighted at Columbia Plateau colonies (at Three Mile Canyon and Crescent islands) in 2000 and 2001. While this represents 0.6% of the banded sample, only one of these terns was observed actively breeding. Thus while terns from the Columbia River estuary may have prospected in this area during the period of tern management, we did not find any evidence of substantial immigration into the breeding population on the Columbia Plateau.

The total number of Caspian tern breeding pairs on the Columbia Plateau during the study period remained nearly stable at ~1,000 breeding pairs at 4-6 colony sites. All colonies in the Columbia Plateau region were <10% the size of the Columbia River estuary breeding population during the same time period (Roby et al. 2002; Table 2). While the majority of Caspian terns nesting at colonies on the Columbia Plateau exploit juvenile salmonids as a food source, the apparent stability of this sub-population and its relatively low numbers will likely keep the level of predation on juvenile salmonids well below that currently observed in the Columbia River estuary.

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