AN ABSTRACT OF THE THESIS OF

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Title: The Response of Caspian Terns to Managed Reductions in Nesting Habitat in the Columbia Plateau Region, Washington State, USA

Abstract approved: _____
Daniel D. Roby Donald E. Lyons

Declines in populations of anadromous salmonids (*Oncorhynchus* spp.) in the Columbia River drainage basin have resulted in extensive programs to annually release large numbers of hatchery-raised juvenile salmonids in an effort to support salmonid restoration. The Pacific Flyway population of Caspian terns (*Hydroprogne caspia*) has grown from around 3,500 nesting pairs in 1960 to around 13,000 nesting pairs in 2000, and the majority of breeding Caspian terns in the Pacific Flyway population were nesting in the Columbia River basin by 2000. This population growth is in part a result of the stabilization of nesting habitat due to human management of the Columbia River and nearby water bodies, plus the yearly release of over a hundred million hatchery-raised juvenile salmonids into the system. Research on the consumption of juvenile salmonids by piscivorous waterbirds resulted in the identification of Caspian tern predation as a factor limiting salmonid restoration in the basin. Caspian terns nesting in the Columbia Plateau region, which lies within the Columbia River drainage basin, were found to consume a much larger number of juvenile salmonids per capita than Caspian terns nesting elsewhere in the Columbia River basin. This finding resulted in the development of a management plan to reduce mortality of juvenile salmonids in the Columbia Plateau region by preventing nesting of Caspian terns at the two largest colonies in the region, in conjunction with the concurrent creation of alternative nesting habitat for Caspian terns elsewhere in the breeding range of the Pacific Flyway population.

I investigated the response of Caspian terns to the loss of available nesting habitat in the Columbia Plateau region. The management plan, developed by an interagency working group led by the U.S. Army Corps of Engineers, met its goal of preventing Caspian terns from nesting at the sites of the two largest colonies in the Columbia Plateau region, Goose Island in Potholes Reservoir and Crescent Island in McNary Reservoir, Washington State. The goal of lowering the region-wide number of breeding Caspian terns from about 875 nesting pairs to ≤ 200 nesting pairs, however, was not met within the first three years of management implementation. The majority of terns that previously nested at Goose or Crescent islands moved to nest on several low-lying gravel bars in the Blalock Islands, an archipelago downstream from Crescent Island in John Day Reservoir on the Columbia River. A new small tern colony also became established at Lenore Lake, north of Potholes Reservoir. While regional numbers of Caspian tern nesting pairs declined significantly in 2015 and 2016, the second and third years post-management, regional nesting success of terns did not decline. Instead, regional nesting success remained within the range estimated by Suryan et al. (2004) for a stable population of Caspian terns (average of 0.32 - 0.74 young raised per breeding pair per year). Analysis of banded terns that nested at either Goose Island or Crescent Island immediately prior to the initiation of management found that the proportion of terns that returned to breed in 2015 and 2016 declined significantly, while a significantly greater proportion of terns returned as non-breeding floaters in the Columbia Plateau region compared to pre-management. Also, the proportion of terns that went unobserved, either within the Columbia Plateau region or elsewhere in the Pacific Flyway, increased significantly in 2015 and 2016 compared to pre-management.

The management plan resulted in the loss of available nesting space for at least 90% of nesting Caspian terns in the Columbia Plateau region during 2004 - 2013. Despite the capacity of Caspian terns for long-distance breeding dispersal, the birds mostly took advantage of

previously active and potential nesting habitat within the region instead of emigrating from the region. My results suggest that, despite the regional drop in numbers of active nesting pairs, Caspian terns did not disperse from the Columbia Plateau region in large numbers. Instead, terns that were unable to successfully compete for nest sites within the region returned as non-breeding floaters. This philopatric response was likely reinforced by drought conditions at alternative nesting habitat in the southern Oregon and northeastern California region, which reduced the availability of suitable nest sites. Also, concurrent management to reduce available nesting habitat for Caspian terns at the large breeding colony in the Columbia River estuary caused a major reduction in space for nesting pairs at this location. Both of these factors apparently played a role in the choice of Caspian terns to remain in the Columbia Plateau region post-management. Following the implementation of management to reduce tern nesting habitat in the Columbia Plateau region, Caspian terns exhibited considerable flexibility and adaptability in their choice of nest site, and may have integrated information on the breeding success of conspecifics at other nesting locations within the region.

The Response of Caspian Terns to Managed Reductions in Nesting Habitat in the Columbia Plateau Region, Washington State, USA

by
Ethan Schniedermeyer

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APPROVED:

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Co-Major Professor, representing Wildlife Science

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Co-Major Professor, representing Wildlife Science

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Head of the Department of Fisheries and Wildlife

_____

Dean of the Graduate School

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Ethan Schniedermeyer, Author

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CONTRIBUTION OF AUTHORS

Dr. Daniel D. Roby acquired funding, assisted with study design, data analysis, interpretation of results, and provided extensive editorial comments for all chapters. Dr. Donald E. Lyons assisted with study design, data analysis, and provided editorial comments for all chapters. Dr. Yasuko Suzuki provided assistance with study design and interpretation of results.

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CHAPTER 1: GENERAL INTRODUCTION

Ethan Schniedermeyer

Caspian terns (*Hydroprogne caspia*) are the largest species of tern in the world and are nearly cosmopolitan in distribution, occurring on every continent except Antarctica (Roby et al. 2003a). Censuses of the Pacific Flyway population of Caspian terns since 1960 have documented a large increase in the number of nesting pairs. From 1960 to 1980, Gill and Mewaldt (1983) observed a 70% increase in the Pacific Flyway population, from about 3,500 breeding pairs to about 6,000 breeding pairs, in conjunction with northward expansion of large breeding colonies from California into Washington State. From 1981 to 2000, Suryan et al. (2004) found that the Pacific Flyway population had approximately doubled, from about 6,000 breeding pairs to about 13,000 breeding pairs. During these two decades, Caspian terns were found to nest in higher concentrations at a few larger colonies (Wires and Cuthbert 2000, Suryan et al. 2004) than during the 1960s and 1970s. A larger proportion of Caspian terns in the Pacific Flyway population were also breeding at anthropogenic sites (Suryan et al. 2004) compared to the 1960s and 1970s, and these anthropogenic colony sites, in conjunction with large releases of hatchery-raised fish, supported the continued growth of the Pacific Flyway population of Caspian terns.

Populations of anadromous salmonids (*Oncorhynchus* spp.) have been in decline in the Pacific Northwest since the early part of the 20th century due to a combination of anthropogenic factors (Lichatovich 1999, McClure et al. 2003). The decline in salmonid populations has led to the implementation of recovery processes that include the yearly release of over 100 million hatchery-raised salmonid smolts into the Columbia River basin to aid in restoration (Wiese et al. 2008). Out-migrating juvenile salmonids, both hatchery-raised and wild, are subjected to predation from a diversity of avian predators, piscivorous fishes, and mammalian predators (Antolos 2005, Wiese et al. 2008). Conflict between fisheries and piscivorous predators that

consume anadromous salmonids became more prominent following the listing under the U.S. Endangered Species Act of 13 of the 20 populations of salmonids in the Columbia River basin as threatened or endangered (Good et al. 2007). Investigations into predation on out-migrating juvenile salmonids have identified multiple species of predators as limiting factors for salmonid restoration in the Columbia River basin, including Caspian terns nesting in the Columbia River estuary (Steuber et al. 1995, Friesen and Ward 1999, Roby et al. 2002).

Caspian terns nesting at a large colony in the Columbia River estuary were estimated to have consumed 5.9-10.4 million juvenile salmonids in 1997 and 9.1-15.7 million juvenile salmonids in 1998 (Roby et al. 2003b). These findings resulted in the immediate implementation of management actions aimed at reducing the impact of predation by Caspian terns on survival of out-migrating juvenile salmonids in the Columbia River estuary (Roby et al. 2002). Until recently, most research and management of Caspian terns to benefit smolt survival has focused on Caspian terns nesting at the large colony in the Columbia River estuary (Evans et al. 2012). However, several smaller colonies of Caspian terns whose diet consists mostly of out-migrating juvenile salmonids also occur in the Columbia Plateau region of eastern Washington State (Adkins et al. 2014). This means that the survival of juvenile salmonids is negatively affected by piscivorous birds from multiple breeding colonies as they migrate from the upper Columbia River and Snake River and before reaching the Columbia River estuary (Evans et al. 2012). Caspian terns nesting at colonies in the Columbia Plateau region consume a much smaller number of juvenile salmonids than terns nesting at the large colony in the Columbia River estuary; however, the per capita consumption rate of juvenile salmonids by Caspian terns nesting at colonies in the Columbia Plateau region can be greater by an order of magnitude than that of Caspian terns nesting in the Columbia River estuary (Evans et al. 2012). In addition,

Caspian terns nesting on Goose Island in Potholes Reservoir in the Columbia Plateau region were found to commute as far from their colony as the Columbia River to forage, and a small proportion of Caspian terns fitted with GPS transmitters were found to commute 87-93 km to forage in the Snake River (Lyons et al., unpubl. data). This is the longest recorded commuting distance from a nest site to a foraging site for a breeding Caspian tern (Maranto et al. 2010, Roby et al. 2013).

The Inland Avian Predation Management Plan (IAPMP) was developed by the Inland Avian Predation Work Group, an interagency working group led by the U.S. Army Corps of Engineers (USACE), in order to reduce the losses of juvenile salmonids due to avian predation in the Columbia Plateau region. The IAPMP called for the elimination of Caspian tern nesting habitat at the two largest colony locations in the region, Crescent Island in the Columbia River near Pasco, Washington, and Goose Island in Potholes Reservoir, Washington, with the goal to reduce the number of tern nesting pairs in the region to ≤ 200, compared to the historical average during 2000-2013 of 878 nesting pairs. Management to reduce Caspian tern nesting habitat in the Columbia Plateau region was conducted in conjunction with development of new nesting habitat elsewhere in the breeding range of the Pacific Flyway population of Caspian terns, at Don Edwards National Wildlife Refuge in San Francisco Bay, with the intention that the new tern nesting habitat would compensate for the loss of nesting habitat in the Columbia Plateau region (USACE 2014).

Caspian terns have a high capacity for long-distance movements and breeding dispersal as demonstrated by previous management actions. It has been demonstrated that Caspian tern breeding colonies can be moved short distances using social attraction (i.e., decoys and audio playback systems) and that the terns can find and colonize newly formed nesting habitat in a

single season (Sirdevan and Quinn 1997, Roby et al. 2002, Suzuki 2012). Some banded individuals have exhibited long distance breeding dispersal (> 3,000 km), and there is high connectivity between colonies on the Pacific Coast and inland colonies in the Columbia Plateau region (Suzuki 2012).

While long-distance natal and breeding site dispersal has been documented for Caspian terns and other tern species, the rates of long distance dispersal have been low (Suzuki 2012). One objective of the IAPMP is to dissuade terns from nesting at Goose and Crescent islands, which had provided nesting habitat for nearly 90% of nesting terns in the Columbia Plateau region. With the nesting habitat formerly used by the majority of Caspian terns breeding in the region now made unavailable, however, there may not be sufficient nesting habitat available for all of the terns in the region, potentially resulting in increased rates of long-distance breeding dispersal and/or a shift to smaller colonies within the region that may be marginal nesting habitat that can only support low nesting success rates (Szostek et al. 2014).

Crescent Island, constructed of dredged material, and Goose Island, created by the construction of O'Sullivan Dam that formed Potholes Reservoir, were the sites of the two largest Caspian tern colonies in the Columbia Plateau region prior to the implementation of the IAPMP. Both anthropogenic islands are quite stable and not subject to inundation or land-bridging during normal seasonal fluctuations in reservoir levels. Historically, Caspian terns have nested mostly in ephemeral habitat (Wires and Cuthbert 2000, Collis et al. 2001), such as low-lying sandy islands subject to periodic erosion and accretion. While there is a history of Caspian tern nesting at a variety of sites within the region other than at Crescent and Goose islands (Antolos et al. 2004, Adkins et al. 2014), these other colony sites were also anthropogenic, and supported smaller colonies of less than 100 breeding pairs. Prior to the initiation of management under the

IAPMP, Caspian terns regularly nested in smaller numbers at three or four other sites scattered across the region (Adkins et al. 2014). Caspian terns displaced from the colony sites at Crescent and Goose islands might attempt to nest at these smaller colony locations in greater numbers, or resume nesting at former colony sites that have not supported breeding colonies for a number of years. If Caspian terns displaced from Crescent and Goose islands disperse to other prospective colony sites within the Columbia Plateau region, they may settle at locations where nesting habitat is ephemeral and nesting success limited, such as low-lying gravel-bars or sand-bars. Pressure for terns to find suitable nesting sites where the prospects for nesting successfully are greater may push them to search outside the Columbia Plateau region and find newly available nesting habitat outside the Columbia River Basin and far from its ESA-listed salmonid runs. If terns simply shift to other colony locations within the Columbia Plateau region, however, the goal of the IAPMP to reduce tern predation on juvenile salmonids may not be met, and anticipated benefits to survival of salmonid smolts may be limited. In order to determine to what extent, if any, Caspian terns disperse to locations outside the Columbia Plateau region after implementation of the IAPMP, it is necessary to monitor the response of Caspian terns to the loss of nesting habitat at both Crescent and Goose islands.

While effectiveness monitoring following implementation of the IAPMP is an opportunity to determine the success of this plan in achieving management objectives, this is also an opportunity to examine how Caspian terns respond to a major and abrupt loss of regional nesting habitat. Due to the ephemeral nature of historical Caspian tern nesting habitat, natural climatic events could suddenly alter the sites where terns formerly nested (i.e. sand-bars and gravel-bars) or disturbances by predators or anthropogenic factors could force terns to find new nesting locations (Vaisanen 1973, Penland 1982, Antolos et al. 2004). There are few

observed events such as this on record, and there is little known regarding long distance dispersal or “deserting flights” by entire tern colonies. Vaisanen (1973) observed that a Caspian tern colony in the Gulf of Bothnia moved from Sweden to Finland in 1947, a distance of around 800 km, apparently due to human disturbance. Implementation of the IAPMP is, in some respects, similar to a natural stochastic event that drastically reduces availability of nesting habitat for Caspian terns throughout a region. As such, this is a unique opportunity to observe the affinity and site faithfulness of Caspian terns for the Columbia Plateau region.

The purpose of this research was to determine the response of Caspian terns to managed reductions in nesting habitat in the Columbia Plateau region, and thereby ascertain the extent of potential benefits for the restoration of Columbia River basin salmonids, the primary prey type for Caspian terns nesting in the region. We surveyed historical and potential tern nesting habitat throughout the Columbia Plateau region to identify active colony locations, determine overall numbers of Caspian tern nests and their nesting success throughout the region, and determine the degree to which managed reductions in nesting habitat compelled terns that had previously nested in the Columbia Plateau region to emigrate. We predicted that the number of nesting pairs and nesting success of Caspian terns in the Columbia Plateau region would decrease as a result of the managed reduction of nesting habitat. We also predicted that terns that had previously nested at either Goose or Crescent island prior to the initiation of management would be more likely to transition to nesting or prospecting for a new nesting colony outside the Columbia Plateau region, elsewhere in the breeding range of the Pacific Flyway population.

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CHAPTER 2: CASPIAN TERN RESPONSE TO MANAGED REDUCTIONS IN NESTING HABITAT IN THE COLUMBIA PLATEAU REGION, WASHINGTON STATE, USA

Ethan Schniedermeyer, Daniel D. Roby, Donald E. Lyons, and Yasuko Suzuki

ABSTRACT

Predation on smolts by Caspian terns (*Hydroprogne caspia*) has been identified as a factor limiting the restoration of some populations of anadromous salmonids (*Oncorhynchus* spp.) from the Columbia River basin that are listed under the U.S. Endangered Species Act. Implementation of a management plan to reduce numbers of Caspian terns nesting at the two largest colonies in the Columbia Plateau region began in 2014 and has been ongoing since then. Following the initiation of management, we investigated the response of Caspian terns to reductions in nesting habitat by surveying previously used and potential Caspian tern nesting habitat across the Columbia Plateau region to identify all active tern colonies. Resightings of banded individuals were used to determine whether terns displaced by managed reductions in nesting habitat remained in the Columbia Plateau region or dispersed elsewhere. Terns were successfully prevented from nesting at the two largest colonies. The management objective of reducing numbers of nesting terns to ≤ 200 breeding pairs in the Plateau region was not achieved during the first two years of full implementation of the plan, but management did significantly reduce the number of nesting pairs in the region. Regional nesting success did not decline significantly post-management, and remained at levels considered sufficient to sustain the regional sub-population. Despite the capacity for long-distance breeding dispersal, the majority of displaced terns exhibited stronger than expected philopatry to the Columbia Plateau region. Resightings of banded terns indicated that most terns that nested in the Plateau region pre-management returned to the region in 2015 and 2016, but the proportion that returned as breeders decreased while the proportion that returned as non-breeding floaters increased compared to pre-management. The proportion of banded terns that were unobserved increased post-management, suggesting that more terns were either floaters in the Columbia Plateau

region or emigrated to locations where there was little or no monitoring. The unexpectedly high regional philopatry exhibited by terns post-management was likely a reflection of the low availability of suitable alternative nesting habitat outside the region. As a result, in the short term, most terns that remained in the region displayed considerable flexibility in nest site selection by taking advantage of one smaller previously successful breeding colony and one small colony where no nesting activity had previously been recorded.

INTRODUCTION

Conflict between fisheries and piscivorous wildlife that consume anadromous salmonids (*Oncorhynchus* spp.) in the Columbia River basin has persisted for decades (Ruggerone 1986, Steuber et al. 1995, York et al. 2000). This conflict became more prominent following the listing of 13 of the 20 populations of salmonids in the Columbia River basin as threatened or endangered under the U.S. Endangered Species Act (Good et al. 2007). Avian predators on juvenile salmonids have been identified as a limiting factor in the restoration process for Columbia River basin salmonids (Evans et al. 2012, USACE 2014). In particular, Caspian terns (*Hydroprogne caspia*) nesting at a large colony in the Columbia River estuary were estimated to have consumed an estimated 8.1 million juvenile salmonids in 1997 and an estimated 12.4 million juvenile salmonids in 1998 (Roby et al. 2003), which corresponded to a significant proportion of several listed populations (Collis et al. 2001). The Pacific Flyway population of Caspian terns has increased dramatically since 1960 (Suryan et al. 2004). While the Caspian tern colonies in the Columbia Plateau region of eastern Washington are far smaller than the large colony in the estuary, the estimated per capita consumption rate of juvenile salmonids by terns nesting at the largest colony in the Columbia Plateau region (Crescent Island) was far higher than that of terns nesting in the Columbia River estuary (Evans et al. 2012).

Caspian terns that nest in the Columbia Plateau region have been identified as a limiting factor for restoration of certain listed anadromous salmonid populations that originate from the Upper Columbia and Snake River basins. The Inland Avian Predation Management Plan (IAPMP) was developed by the Inland Avian Predation Work Group, an interagency working group led by the U.S. Army Corps of Engineers (USACE), in order to reduce the losses of juvenile salmonids due to avian predation. The IAPMP called for the elimination of Caspian tern nesting habitat at

the two largest colony locations in the Columbia Plateau region: Crescent Island in McNary Reservoir on the Columbia River near Pasco, Washington, and Goose Island in Potholes Reservoir near Moses Lake, Washington (USACE 2014).

It has been repeatedly demonstrated that Caspian terns can locate and colonize newly formed nesting habitat within a single nesting season (Sirdevan and Quinn 1997, Roby et al. 2002, Suzuki 2012). Caspian terns breeding in the Pacific Flyway of North America have exhibited high connectivity among colony sites (Suzuki 2012). Some individuals in the Pacific Flyway population have exhibited long distance breeding dispersal (> 3,000 km), and there is high connectivity between colonies on the Pacific Coast and inland colonies in the Columbia Plateau region (Suzuki 2012). While long-distance natal and breeding site dispersal has been documented for Caspian terns and other tern species, the rates of long distance dispersal have been consistently low, and most individuals display high breeding site fidelity (Suzuki 2012). Vaisanen (1973) documented a colony deserting flight, however, resulting in a Caspian tern colony in the Baltic Sea relocating 800 km away following regular human disturbance. Now that the nesting habitat formerly used by the majority of breeding Caspian terns in the Columbia Plateau region is unavailable, there may not be sufficient habitat for all terns that are motivated to nest in the region, potentially resulting in increasing rates of long-distance breeding dispersal, or a shift to marginal nesting habitat in the Plateau region that can only support low nesting success rates.

The numbers of Caspian terns nesting in the Columbia Plateau region more than doubled from 1980 to 2000 (Shuford and Craig 2002, Suryan et al. 2004). The increase in this sub-population occurred in conjunction with anthropogenic habitat alterations (Wires and Cuthbert 2000, Collis et al. 2001). Crescent Island in McNary Reservoir on the Columbia River

was constructed of dredged material in the mid-1980s, and Goose Island was created by the construction of O'Sullivan Dam, which formed Potholes Reservoir in 1951. Thus, the two islands that supported the two largest Caspian tern breeding colonies in the Columbia Plateau region were anthropogenic in origin. Both anthropogenic islands offered secure, un-vegetated nesting habitat for Caspian terns that was not subject to inundation resulting from wide fluctuations in reservoir levels, and not subject to vegetation encroachment due to rocky soils, arid regional climate, and isolation from the underlying water table. Historically, Caspian terns have nested mostly in highly ephemeral natural habitats (Wires and Cuthbert 2000, Collis et al. 2001), such as low-lying sandy islands subject to periodic erosion and accretion. In addition to the two main colonies at Crescent Island and Goose Island, Caspian terns regularly nested at 3 or 4 other sites scattered across the region, where small colonies (< 100 breeding pairs) existed prior to the initiation of management under the IAPMP (Adkins et al. 2014). If Caspian terns displaced from colonies on Crescent and Goose islands disperse to other prospective colony sites within the Columbia Plateau region, they may settle at more ephemeral locations, such as low-lying gravel-bars or sand-bars, where nesting habitat and nesting success would likely be limited. Alternatively, the motivation of terns to find suitable nesting sites and reproduce may drive them to search outside the Columbia Plateau region and find newly available habitat far from the Columbia River basin and its salmonid runs. The U.S. Army Corps of Engineers constructed alternative nesting habitat in San Francisco Bay (about 1,000 km from the Columbia Plateau region) to compensate for the loss of nesting habitat in the Columbia Plateau region.

Caspian terns displaced from the colony sites at Crescent and Goose islands might be expected to emigrate to either (1) other smaller extant colonies nearby, causing an increase in colony size, (2) reestablish colonies at former sites nearby that have not supported breeding

colonies for a number of years, (3) establish new colonies at sites nearby with no documented history of nesting, or (4) emigrate to colony sites outside the Columbia Plateau region. If displaced Caspian terns were to simply shift to other colony locations within the Columbia Plateau region, instead of dispersing outside the region, the goal of the IAPMP to reduce tern predation on juvenile salmonids might not be met, and the intended benefits to salmonid populations of reduced tern predation could be limited. In order to determine the extent to which the IAPMP was successful at reducing Caspian tern predation on juvenile salmonids in the Columbia Plateau region, it is necessary to determine the response of Caspian terns to the loss of nesting habitat at Crescent and Goose islands.

To determine the response of terns to managed reductions in nesting habitat, we tested the hypotheses that a managed reduction in Caspian tern nesting habitat will (1) reduce the number of Caspian terns breeding within the Columbia Plateau region, (2) reduce the productivity of Caspian terns breeding within the Columbia Plateau region, and (3) result in an increase in emigration of Caspian terns from the Columbia Plateau region to colonies outside of the region. We reasoned that if managed elimination of nesting habitat at the two largest breeding colonies for Caspian terns in the Columbia Plateau region were successful, breeding Caspian terns would be forced to find nesting habitat outside of the region, or utilize more ephemeral habitat that could significantly reduce their average productivity.

METHODS

Study Area

This study was conducted in the Columbia Plateau region of central Washington State and north-central Oregon (Figure 2.1). The study area included the reservoirs and free-flowing

reaches of the mid-Columbia River from Chief Joseph Dam (in Bridgeport, WA below the Grand Coulee Dam) downstream to The Dalles Dam (near The Dalles, Oregon), the lower Snake River from Lewiston, Idaho, to its confluence with the Columbia River, other large tributaries of the Columbia River (e.g., the Yakima River), Potholes Reservoir in Grant County, Washington, and multiple other lakes and reservoirs in central Washington. The region is semi-arid with little topographic relief, and dominated by sagebrush/steppe habitat and agricultural uses that are supported by irrigation. Prior to the initiation of management, the majority of breeding Caspian terns in the Columbia Plateau region nested on either Goose Island (46°59'08.67"N, 119°18'38.52"W) or Crescent Island (46°05'36.12"N, 118°55'52.14"W). Both of these islands were also home to much larger breeding colonies of gulls, both California gulls (*Larus californicus*) and ring-billed gulls (*L. delawarensis*).

Summary of Management at Goose and Crescent Islands

The primary objective of the IAPMP was to reduce the size of the Caspian tern breeding colonies at Goose Island and at Crescent Island to less than 40 breeding pairs each; management was implemented at Goose island beginning in 2014, and at Crescent Island beginning in 2015. Reduction in colony size was accomplished non-lethally by limiting the availability of suitable nesting habitat. Passive nest dissuasion materials, consisting of a dense network of stakes, ropes, and flagging, were deployed on all suitable tern nesting habitat at both Goose and Crescent islands. At Crescent Island only, fence rows of privacy fabric and brush piles of woody debris were also deployed in suitable habitat. Passive dissuasion materials were installed over formerly used tern nesting habitat, as well as marginal nesting habitat that terns might nest in on both islands. Efforts were also made to dissuade the large colonies of California and ring-billed gulls from nesting on the islands on the hypothesis that persistence of these

colonies would attract Caspian terns to continue to nest at these locations. Once terns and gulls began arriving to initiate nesting at Goose and Crescent islands, prospecting adults were actively hazed by personnel stationed on the islands for that purpose (Roby et al. 2014, 2015, 2016).

Regional Population Size and Nesting Success

Boat-based and ground-based surveys of historical Caspian tern colony sites and previously identified potential colony sites were conducted weekly throughout the Columbia Plateau region during the 2015 and 2016 breeding seasons. Surveys were further guided by periodic aerial surveys using fixed-wing aircraft that surveyed historical, current, and potential nesting habitat on a pre-determined flight path. The flight path included the Columbia River from Troutdale, Oregon, to Bridgeport, Washington, then south to Banks Lake and Potholes Reservoir, then east to Sprague Lake, and then south to the Snake River from its confluence with the Clearwater River near Lewiston, Idaho, to its confluence with the Columbia River near Pasco, Washington. Ground-based and boat-based surveys for active Caspian tern breeding colonies were also guided by the reported locations of Caspian terns that were tagged with PTS satellite transmitters prior to the 2014 and 2015 breeding seasons on either Goose Island or Crescent Island; most of these tagged terns were present in the region during the 2015 and 2016 breeding seasons (DEL, unpubl. data).

Active Caspian tern breeding colonies in the region were visited at least twice per week during the 2015 and 2016 breeding seasons, and observed from semi-permanent or pop-up blinds, when possible. Large, active Caspian tern colonies (> 100 nesting pairs) were visited at least three times per week during the breeding season, and observed from semi-permanent observation blinds near the colony. Data collection included colony attendance (number of adult terns present on-colony), numbers of active tern nests, and numbers of tern chicks present on-

colony. The numbers of adults, active nests, and chicks recorded during each visit to a colony were the average of two counts conducted simultaneously by two different observers. If the two simultaneous counts were not within 10% of each other, the counts were repeated.

Ground counts of colony size (number of nesting pairs) were supplemented with counts from aerial photography. For colonies that were presumed to be larger than 30 nesting pairs, high-resolution vertical aerial photography was taken late in the incubation period (late May) by Geoterra (Portland, Oregon). For small colonies (≤ 30 pairs), oblique photography was taken from a fixed-wing aircraft using a digital SLR camera equipped with an image-stabilizing zoom lens. The peak size of each Caspian tern breeding colony during each year of the study was taken to be the maximum number of incubating terns counted on-colony either during a ground visit or in aerial photography. The estimated total number of nesting pairs of Caspian terns in the Columbia Plateau region during each year of the study was the sum of the peak colony counts for all colonies in the region during that year.

Caspian tern nesting success (average number of young raised per breeding pair) was estimated as the maximum number of chicks counted on each colony 7 - 10 days after the first fledgling was observed, divided by the estimated peak colony size (Patterson 2012). The total number of fledglings estimated to have been produced at all breeding colonies in the Columbia Plateau region was then divided by the total number of nesting pairs in the region during that year to obtain an estimate of regional nesting success.

The total numbers of Caspian tern nesting pairs in the Columbia Plateau region during 2015 and 2016 were each compared to the historical average during 2000-2013, prior to implementation of the IAPMP. Region-wide Caspian tern nesting success in 2015 and 2016 were also each compared to the historical average during 2000-2013. The number of nesting pairs

and nesting success in the Columbia Plateau region during 2014 were not included in these analyses because tern management had been initiated on Goose Island, but not on Crescent Island, so there was little net change in numbers of nesting pairs, nesting success, or consumption of juvenile salmonids in the region during 2014, compared to pre-management (Roby et al. 2014). Also, management intended to eliminate tern nesting habitat on Goose Island in 2014 was not fully effective and about 156 pairs of terns nested on a small rocky islet immediately adjacent to Goose Island.

Pre-management numbers of Caspian terns nesting throughout the Columbia Plateau region were first determined in 2000, when comprehensive monitoring was initiated, and last measured in 2013, the last season prior to the initiation of management under the IAPMP. Historical data on number of nesting pairs and nesting success of Caspian terns in the Columbia Plateau region were acquired from Antolos et al. (2004), Adkins et al. (2014), unpublished annual reports during 2000-2014 (http://www.birdresearchnw.org), and C.J. Maranto (Univ. Washington, pers. comm.). For some early years during this pre-management period there was limited information collected regarding the number of fledglings produced at some smaller tern breeding colonies. In those years, colony sizes for colonies without nesting success data were not included in the calculation of overall nest success for the Columbia Plateau region. However, the colonies with limited information on nesting success were included in the estimate of total number of Caspian tern nesting pairs in the Plateau region.

Total numbers of Caspian tern nesting pairs and average tern nesting success in the Columbia Plateau region after the initiation of management (2015 and 2016) were compared to the historical average (2000-2013) using one-sample t-tests. The 2014 breeding season was

omitted from analysis of post-management effects because it was a transition year when management was taking place on Goose Island, but not on Crescent Island.

Factors Limiting Nest Success

During tern colony monitoring visits and surveys of potential tern nesting habitat, factors that may have contributed to limiting the nesting success of Caspian terns at each colony, if any, were observed and recorded. Potential factors limiting nesting success included fluctuating water levels (e.g., evidence of inundation or land-bridging of nesting islands), terrestrial predators (e.g., coyotes [*Canis latrans*], American mink [*Neovison vison*]), avian predators (e.g., bald eagles [*Haliaeetus leucocephalus*]), competition with gulls for nesting habitat (e.g., California and ring-billed gulls), and human disturbance.

Dispersal

During 2005-2011, large numbers of adult Caspian terns (n = 775) and fledgling Caspian terns (n = 3,344) were captured and banded with unique, field-readable leg bands at breeding colonies within the study area and at other colony locations throughout the Pacific Flyway, including colonies in California, Oregon, Washington, and Alaska (YS, unpubl. data). Of these, 146 adults and 667 chicks were banded at Crescent Island and 110 adults and 288 chicks were banded at Goose Island. Banded individuals have subsequently been resighted, providing data on philopatry and dispersal from the breeding colony where each tern was banded. Resighting data for banded Caspian terns were collected during the 2014-2016 breeding seasons throughout the Columbia Plateau region during each survey or monitoring session, where feasible. Any adult Caspian tern banded with a field-readable leg band that was observed at a given colony site was recorded and its breeding status assessed. The unique alphanumeric code for each banded tern was determined using spotting scopes or, occasionally, binoculars. All band

resighting observations were made within 60 m of the edge of a colony. Larger colonies were searched for banded individuals more intensively than smaller colonies.

The large dataset of resightings of banded Caspian terns in the Pacific Flyway (YS, unpubl. data) was used to identify a subset of banded terns that exhibited a history of nesting (colony attendance) at either the Goose Island colony or the Crescent Island colony, prior to the initiation of management under the IAPMP. Banded terns were defined as Breeders at one of these colonies pre-management if the individual was resighted at least 5 times over a period of at least 3 weeks and/or breeding status was confirmed because the banded individual was observed either incubating eggs, brooding nestlings, or feeding chicks. Five resightings was at the lower end of the number of resightings for banded Caspian terns that were confirmed to be breeding at a particular colony; 5 resightings was therefore chosen to be the threshold for designation as a Breeder to include as many prospective breeding terns as possible in the analysis. Designating as Breeders only those banded individuals that were observed five times over at least a three-week period avoided including terns that were only resighted at a colony during short time period. By comparing the nesting behavior and movements of these banded Breeders before the initiation of management (2014 at Goose Island and 2015 at Crescent Island) to the behavior and movements of these same individuals after management, we sought to understand how the implementation of the IAPMP affected the behavior of individuals that formerly nested at the two managed colonies.

We were interested in whether managed reductions in nesting habitat would compel Caspian terns with previous breeding experience in the Columbia Plateau region to leave the region and attempt to nest at active colonies outside the region. To accomplish this we used band resighting data during the 2011-2016 breeding seasons and applied set criteria (≥ 5

resightings at a colony over a period ≥ 3 weeks and/or confirmed breeding status) to define whether an individual bird resighted at a colony during a particular breeding season was a "Breeder" or not during that season. Birds that were resighted at a colony during a breeding season, but did not meet the criteria for a Breeder were classified as "Non-breeders" during that season. Furthermore, banded birds that were resighted within the Columbia Plateau region during a breeding season were classified as either a "Plateau Breeder" or a "Plateau Non-breeder" during that season. Banded birds that were observed at colonies outside of the Columbia Plateau region were defined as either an "Off-Plateau Breeder" or an "Off-Plateau Non-breeder" during that season, based on the same criteria used in the Columbia Plateau region. Finally, banded birds that were not resighted anywhere during a given breeding season were considered as having "Unknown" status for that season.

We used these definitions to investigate transitions between consecutive breeding seasons in the breeding status of banded individuals. The high degree of connectivity among Caspian tern colonies in the Pacific Flyway (Suzuki 2012; YS, unpubl. data) is reflected in movement of banded individuals among colonies and regional sub-populations, as well as banded birds that may shift between breeding and non-breeding status, depending on an individual's physiological condition or opportunities for breeding (Dobson and Jouventin 2010, Giudici et al. 2010). Therefore, we used data collected on changes in the breeding status of banded individuals between consecutive years to determine whether these background rates of inter-colony movement and shifts in breeding status changed significantly following implementation of the IAPMP (Figure 2.2).

Individual banded terns were included in this analysis based on whether they were classified as Plateau Breeders at either the Goose Island colony in 2013 or the Crescent Island

colony in 2014, the last years before implementation of management at each respective colony. Transitions between consecutive years in breeding status for this sample of banded terns were compiled from 2011 to 2016. We were particularly interested in whether implementation of the IAPMP resulted in elevated dispersal away from the Columbia Plateau region or shifts from Breeder status to Non-breeder status within the region. Hence, we focused on whether transitions from Plateau Breeder to either Plateau Non-breeder, Off-Plateau Breeder, Off-Plateau Non-breeder, or Unknown increased following the implementation of management (Figure 2.3). Because the implementation of management could induce terns to transition to non-breeder status before emigrating from the Columbia Plateau region, we also focused on whether transitions from Plateau Non-breeder to either Off-Plateau Breeder, Off-Plateau Non-breeder, or Unknown increased following the implementation of management (Figure 2.4).

Fisher's Exact test was used to test the hypothesis that the change in proportions for each transition type between consecutive years post-management (2014-2015 and 2015-2016) were different from combined transitions pre-management (2011-2012, 2012-2013). This was followed by a post-hoc comparison of each transition type within each statistically significant post-management transition year. Within each significant post-management transition year, the proportion of each transition type was compared to the combined proportion of that same transition type pre-management (2011-2012, 2012-2013). This technique was used in order to identify statistically significant changes in the proportion of each transition type within each statistically significant post-management transition year. A significant result would identify whether there was a significant increase or decrease in that transition type following management. Because there are five different transition types within each year of the post-hoc analysis, we utilized a Bonferroni correction of 0.01 (α level of 0.05/5 comparisons) as the

significance threshold. The 2013-2014 transition was excluded from the analysis because management was implemented only at Goose Island in 2014, plus the individual banded terns included in the analysis were selected based on their breeding status at Goose Island in 2013 or at Crescent Island in 2014, potentially confounding the 2013-2014 transition results.

RESULTS

In 2013, the year prior to the initiation of management as part of the IAPMP, 95% of the 773 breeding pairs of Caspian terns that nested in the Columbia Plateau region did so on either Goose Island or Crescent Island (Table 2.1, Figure 2.5). Consequently, the average nesting success of Caspian terns in the Columbia Plateau region in 2013 (0.39 young fledged per breeding pair) largely reflected the average nesting success at these two colonies (Table 2.2). Management to reduce the size of the Caspian tern colony on Goose Island was initiated in 2014, and was successful at reducing the size of the colony to 156 breeding pairs from 340 breeding pairs the year before. Despite the reduction in the numbers of Caspian terns nesting on Goose Island, no major shifts in the numbers of nesting pairs or their distribution occurred within the Columbia Plateau region during 2014 (Table 2.1, Figure 2.6); however, two pairs of Caspian terns attempted to nest for the first time on a small island in Lenore Lake (47°28’48.38”N, 119°31’26.13”W) just south of Banks Lake, where a small mixed breeding colony of double-crested cormorants (*Phalacrocorax auritus*), ring-billed gulls, and California gulls had recently become established.

In 2015, management to reduce Caspian tern nesting habitat expanded to include Crescent Island, and management was successful in preventing any Caspian terns from nesting on Crescent Island. Management at Goose Island was also successful in meeting the

management objective of reducing colony size to less than 40 nesting pairs, and only two pairs of Caspian terns managed to fledge chicks from Goose Island in 2015. Concurrently, one of the smaller Caspian tern colonies in the Columbia Plateau region increased substantially in size. The colony in the Blalock Islands (45°53'43.06"N, 119°38'51.46"W) in John Day Reservoir on the Columbia River (just upstream from Boardman, Oregon) became the largest Caspian tern colony in the region in 2015. The Blalock Islands colony grew from 45 nesting pairs in 2014 to 677 nesting pairs in 2015. The newly formed, small colony at Lenore Lake grew from 2 breeding pairs in 2014 to 16 breeding pairs in 2015. Nesting success at this location grew from an average of 0.0 fledglings per breeding pair in 2014 to 0.38 fledglings per breeding pair in 2015. (Table 2.2). The numbers of breeding pairs at other small colonies in the region remained similar to historical averages (Table 2.1, Figure 2.7).

In 2015, small numbers of Caspian terns briefly attempted to nest at two other previously unoccupied locations. Terns were often observed loafing at a pair of vegetated gravel bar islands, dubbed the Finley Islands (46°08'35.97"N, 118°59'35.97"W), just upstream of Crescent Island near the community of Finley, Washington. A Caspian tern egg was discovered on one of the islands on April 18, but the site was abandoned shortly thereafter. Caspian terns were also discovered loafing on a mud bar in an impoundment (46°57'17.21"N, 119°15'43.06"W) within the Columbia National Wildlife Refuge, about 5 km south of Goose Island. Two active tern nests with eggs were observed in early May, but failed shortly thereafter. Neither of these locations was occupied by nesting terns in 2016.

In 2016, management was successful at completely preventing Caspian terns from nesting at both Goose and Crescent islands (Table 2.1, Figure 2.8). The colony at the Blalock Islands continued to be the largest in the region; however, colony size declined from 677

breeding pairs in 2015 to 483 breeding pairs in 2016. The small colony at Lenore Lake continued to grow in 2016, reaching 39 breeding pairs. Average nesting success at Lenore Lake in 2016 also increased to 0.59 fledglings per breeding pair (Table 2.2). Terns also formed a colony of 144 breeding pairs on a small sandy island in the northeastern part of Potholes Reservoir (47°02'03.50"N, 119°19'37.16"W). Terns had historically nested in the northern part of the reservoir until 2003, but on a different sandy island about 1 km to the west, dubbed Solstice Island. The island used by terns in 2016 had not previously been used by breeding terns, and this nesting attempt failed to fledge any young before the colony was abandoned in early June.

Regional Population Size and Nesting Success

The mean number of Caspian terns breeding in the Columbia Plateau region during the pre-management period (2000-2013) was $\overline{x}$ = 878 pairs (SD = 111.2, n = 14; Figure 2.9). Linear regression analysis indicated no significant trend in the number of breeding pairs as a function of year during the pre-management period (p = 0.94). The estimated total number of breeding pairs in the Columbia Plateau region in 2015 was 769 pairs, significantly less than the pre-management average (one sample t-test, t = -3.67, p < 0.005). The estimated total number of breeding pairs in the Columbia Plateau region in 2016 was 675 pairs, also significantly less than the pre-management average (one sample t-test, t = -6.84, p < 0.001; Figure 2.9). However, in neither 2015 nor in 2016 did the size of the Columbia Plateau sub-population of Caspian terns come close to achieving the management goal under the IAPMP of no more than 200 breeding pairs (USACE 2014).

The average annual nesting success for Caspian terns breeding in the Columbia Plateau region during the pre-management period was $\overline{x}$ = 0.40 fledglings raised per breeding pair (SD = 0.18, n = 14; Figure 2.10). Linear regression analysis, however, indicated there was a significant

downward trend in the average number of fledglings/pair as a function of year across the pre-management period (2000-2013; $p = 0.01$; Figure 2.10). Estimated average nesting success for Caspian terns in the Columbia Plateau region during 2015 was 0.33 fledglings/breeding pair, not significantly different from average annual nesting success during the pre-management period (one sample *t*-test, $t = -1.45$, $p = 0.08$). Estimated average nesting success in the Columbia Plateau region during 2016 was 0.34 fledglings/breeding pair, also not significantly different from average annual nesting success during the pre-management period (one sample *t*-test, $t = -1.21$, $p = 0.12$; Figure 2.10).

Factors Limiting Nesting Success

Caspian terns have nested in small numbers (maximum of 136 pairs in 2010) in the Blalock Islands since 2005 (Adkins et al. 2014). After management was initiated to eliminate Caspian tern nesting habitat on Crescent Island, the size of the Blalock Islands tern colony increased dramatically. Caspian terns nested at the Blalock Islands on a group of three low-lying gravel-bars (45°53'43.06"N, 119°38'51.46"W) adjacent to a large vegetated island that supported a large California gull colony (45°53’52.12”N, 119°38’47.96”W). This Caspian tern colony was highly susceptible to flooding due to fluctuating water levels in John Day Reservoir. In 2015, high reservoir levels resulted in nest-loss around the edges of the tern colony, particularly on the most low-lying of the three gravel-bars. Despite this nest loss, terns at the Blalock Islands were able to fledge an average of 0.36 young per breeding pair (Table 2.2). In 2016, several larger fluctuations in reservoir water levels (Roby et al. 2016) prevented the colony from reaching a size similar to that observed in 2015. Despite increased nest-loss due to fluctuating reservoir levels, terns were able to fledge an average of 0.43 young per breeding pair (Table 2.2). Despite nesting near a large gull colony, no gull predation on tern eggs or chicks was

observed at the Blalock Islands colony; kleptoparasitism by gulls of nesting Caspian terns was apparently the only pressure that this tern colony experienced from gulls. Prior to the implementation of management under the IAPMP, the factors limiting nesting success at the Blalock Islands colony were fluctuating reservoir levels and mammalian or avian predation pressure (Roby et al. 2013).

The small rocky island in Lenore Lake where terns began nesting in 2014 after the initiation of management on Goose Island had been previously colonized by nesting gulls and cormorants. We did not observe any nest predation or kleptoparasitism of nesting Caspian terns by gulls at this small colony. Interspecific competition for limited nesting space appeared to be a significant limiting factor for the size of this tern colony. The island in Lenore Lake where tern nesting occurred is relatively small and the double-crested cormorants and ring-billed gulls that share the island initiate nesting earlier in the breeding season than do Caspian terns. The cormorant colony (ca. ~ 30 breeding pairs) was not large, but nests less densely than do ring-billed gulls (≥ 200 breeding pairs), and these two nesting species combined occupy most of the area of the island. Additionally, forage fish availability might be a limiting factor, as Lenore Lake is a small (680 ha) lake that is 46 km from the nearest stretch of the Columbia River. Recoveries of smolt PIT tags at the tern colony on Lenore Lake indicate that some terns nesting there are commuting to the Columbia River to forage for salmonid smolts, much like terns that previously nested at Goose Island (Lyons et al., unpubl. data; Roby et al. 2015, 2016)

Caspian terns have nested on islands at the south end of Banks Lake since comprehensive monitoring began in 2000 (Collis et al. 2001). Twinning Island (47°37'29.86"N, 119°18'11.35"W) in southern Banks Lake has been a nesting colony site for Caspian terns since 2005, and small numbers of Caspian terns have nested there regularly; however, only a few

young Caspian terns are known to have fledged from this colony site (Adkins et al. 2014). Nesting attempts on Twinning Island by small numbers of Caspian terns continued after the initiation of tern management on Goose and Crescent islands; however, this tern colony failed before any young were hatched in both 2015 and 2016 (Table 2.2). Surveys of the island after colony abandonment in 2015 yielded evidence of the presence of mustelids, likely American mink and owls, likely great-horned owl (*Bubo virginianus*). Mustelid scat, owl pellets, and depredated gulls were all observed on Twinning Island. Diurnal raptors were also observed nearby, suggesting that the tern colony at Twinning Island has experienced chronic pressure from both terrestrial and avian predators.

Caspian terns have attempted to nest at Harper Island (47°14'52.08"N, 118°05'05.19"W) in Sprague Lake in small numbers since the late 1990's (Roby et al. 2016). The tern colony at Harper Island was difficult to observe because the island is privately owned and the landowner did not grant permission to land on the island. Consequently, observations of nesting Caspian terns on Harper Island were made entirely from a boat or during aerial surveys. The tern colony on Harper Island persisted after the initiation of tern management at Goose and Crescent islands, but this small colony apparently failed prior to chick-hatching in 2014, 2015, and 2016. No tern eggs were confirmed on Harper Island during either the 2015 or 2016 breeding seasons due to the difficulty of viewing the colony from the water. Nesting Caspian terns on Harper Island may experience intense predation pressure from the large gull colony on the island. Pressure from gulls may be more intense if food availability is low. Also, several diurnal raptors, including bald eagles, red-tailed hawks (*Buteo jamaicensis*), peregrine falcons (*Falco peregrinus*), and northern harriers (*Circus cyaneus*) were frequently observed on or near the island. This suggests that the tern colony on Harper Island may be limited by disturbance from avian

predators and gull predation on tern eggs. Sprague Lake is a small lake and is more isolated from the Columbia and Snake rivers than other tern colonies in the Columbia Plateau region. Consequently, foraging opportunities and forage fish availability may be limited for terns nesting at Sprague Lake. Recovery of smolt PIT tags on the tern nesting area on Harper Island, however, indicate that at least some terns nesting at this colony commute over 67 km to the Snake River to prey on salmonid smolts (A. Evans, Real Time Research, unpubl. data).

The northern end of Potholes Reservoir is a maze of shallow channels and small sandy islets that are subject to inundation during high winds and high reservoir levels. Prior to 2004, the first year when Caspian terns were recorded nesting on Goose Island, terns had nested on a small, sandy islet, dubbed "Solstice Island," to the northwest of Goose Island (Adkins et al. 2014). In 2016, once the tern breeding colony on Goose Island was no longer active, Caspian terns colonized a different small, low-lying sandy islet in Potholes Reservoir (47°02'03.50"N, 119°19'37.16"W), northeast of Goose Island. This colony reached a size of 144 breeding pairs and succeeded at hatching a few chicks before it failed in early June 2016. The colony was abandoned after a mink depredated a number of Caspian tern adults and chicks on the island.

Dispersal

A total of 184 banded Caspian terns were classified as Breeders at either Goose Island in 2013 or Crescent Island in 2014. For this sample of banded terns, the distribution of transition proportions from Plateau Breeder to other status categories pre-management (2011-2012 and 2012-2013 combined) compared with post-management transition distributions (2014-2015 and 2015-2016) indicated that the 2014-2015 and 2015-2016 post-management transitions were significantly different from pre-management transitions (2014-2015 transition: $p < 0.001$; 2015-2016 transition: $p < 0.001$; Table 2.3). Based on post-hoc analysis of statistically significant post-

management transitions, the proportion of terns that remained Plateau Breeders between years significantly declined from 0.910 during pre-management transitions to 0.609 during the 2014-2015 transition ($p < 0.001$) and to 0.602 during the 2015-2016 transition ($p < 0.001$). The proportion of terns that transitioned from Plateau Breeder to Plateau Non-breeder significantly increased from 0.042 during pre-management transitions to 0.205 during the 2014-2015 transition ($p < 0.001$) and to 0.243 during the 2015-2016 transition ($p < 0.001$). The proportion of terns that transitioned from Plateau Breeder to Unknown significantly increased from 0.014 during pre-management years to 0.124 for the 2014-2015 transition ($p < 0.001$) and to 0.155 for the 2015-2016 transition ($p < 0.001$). Thus despite fewer terns remaining as Plateau Breeders post-management, the available band resighting data did not support the prediction that more terns would emigrate to other regions and breed there. Finally, the proportions of terns that transitioned from Plateau Breeder to either Off-Plateau Breeder (2014-2015: $p = 0.99$; 2015-2016: $p = 0.18$) or to Off-Plateau Non-breeder (2014-2015: $p = 0.04$; 2015-2016: $p = 0.99$) were not significantly different between either post-management transition year and the pre-management transition years (Table 2.3).

The distribution of transition proportions from Plateau Non-breeder to other status categories during pre-management transitions (2011-2012 and 2012-2013 combined) compared with post-management transition (2014-2015 and 2015-2016) indicated that the distribution of transitions post-management were significantly different from those pre-management only for the 2015-2016 transition year (2014-2015 transition: $p = 0.73$; 2015-2016 transition: $p = 0.02$; Table 2.4). Based on post-hoc analysis, the proportion of terns that remained Plateau Non-breeders in consecutive years significantly increased from 0.081 during pre-management to

0.351 for the 2015-2016 transition (p = 0.01). Transition proportions from Plateau Non-breeder to all other breeding states post-management remained similar to the pre-management period.

DISCUSSION

Despite the demonstrated capacity of Caspian terns for long-distance breeding dispersal and quick establishment of new breeding colonies (e.g., Roby et al. 2002, Suzuki 2012), the number of nesting pairs in the Columbia Plateau region remained far higher in the first three years following implementation of management under the IAPMP than the plan's goal of ≤ 200 breeding pairs. Caspian terns had nested concurrently at Crescent Island and Goose Island for a decade prior to the initiation of management in 2014 to prevent nesting at Goose Island. During that decade, those two colony sites provided nesting habitat for an average of 89% of all of the Caspian terns nesting in the Columbia Plateau region. Following implementation of the IAPMP, Caspian terns tended to shift to sites where small colonies were previously active, although one new, small, reproductively-successful colony also became established within the region (Lenore Lake). Terns also laid eggs at two other incipient colony sites in the region where there were no previous nesting records, but abandoned them shortly thereafter. Beginning in 2015, after the initiation of management to eliminate tern nesting habitat at both Goose Island and Crescent Island, the majority of Caspian terns within the Columbia Plateau region chose to nest on low-lying gravel bars in the Blalock Islands on the Columbia River. During the 2015 and 2016 breeding seasons, 88% and 72%, respectively, of all the Caspian terns nesting within the Columbia Plateau region did so at the Blalock Islands.

Caspian terns have historically attempted to nest at 11 different sites in the Columbia Plateau region, including Goose and Crescent islands (Appendix A). Following the

implementation of management, individuals with a strong drive to nest in the region were able to use alternative nesting habitat that was likely marginal (i.e. incapable of supporting consistent reproductive success) or that presents more challenges for raising young to fledging age than either the Goose Island or Crescent Island sites. Existing colonies at Twinning Island in Banks Lake and Harper Island in Sprague Lake, plus the new colony in northeastern Potholes Reservoir, all failed, either directly due to predation or indirectly due to the presence of predators that may have been a direct threat to adult survival (Conover 1979). Some terns nesting in the Blalock Islands experienced nesting failure due to fluctuating reservoir levels, but flooding was never so severe that it resulted in complete colony failure. Despite the threat of nest inundation, the majority of terns nesting in the Columbia Plateau region chose to breed at this somewhat marginal site.

Terns that established a new breeding colony at Lenore Lake experienced space constraints because they had to share the island with much larger colonies of ring-billed gulls and double-crested cormorants. Although the new Lenore Lake tern colony did not immediately grow into a large colony, such as at the Blalock Islands, the number of nesting pairs increased annually and those individuals experienced good reproductive success. The Blalock Islands colony and the Lenore Lake colony were the only alternative tern colony sites where chicks were successfully fledged during both 2015 and 2016, following full implementation of the IAPMP (Table 2.2). Given the perennial difficulties that terns have encountered in raising young at other colonies in the region, and the consistent nesting success of at least some breeding pairs at the Blalock Islands and Lenore Lake colonies, these two sites may be the only locations in the region where Caspian terns can nest successfully in the future.

While most terns that previously nested at Crescent Island exhibited low site fidelity, many terns that previously nested on Goose Island exhibited strong fidelity towards the Potholes Reservoir area (Roby et al. 2015, 2016). This suggests that Goose Island is the only colony site near the Potholes Reservoir that is conducive of reproductive success, especially considering that the incipient tern colony in northeastern Potholes Reservoir did not appear until the second year of full implementation of the IAPMP, and the colony completely failed well before any young fledged. In addition, productive alternative colonies (i.e. the Blalock Islands and Lenore Lake) likely did not provide enough space to accommodate all terns that previously nested at Goose and Crescent islands.

Despite the majority of Caspian terns that nested in the Columbia Plateau region shifting to more marginal nesting habitat, and the complete failure to raise young at some smaller tern colonies, regional reproductive success did not decline significantly compared to the pre-management average. In addition, nesting success in 2015 and 2016 stayed at the low end of the range sufficient to maintain a stable population (0.32-0.74 young fledged per breeding pair), as determined by Suryan et al. (2004). If environmental conditions at active Caspian tern colonies in the Columbia Plateau region remain similar, reproductive success may be high enough that breeding adults lose the incentive to disperse outside the region.

Our analyses of resighting data from banded terns indicated that, following the implementation of the IAPMP, a smaller proportion of breeding adults from the Crescent Island and Goose Island colonies returned to the region as breeders, compared to the pre-management period. Concurrently, a larger proportion of breeding adults from the two managed colonies returned to the region as non-breeding floaters. These two changes in the breeding status of adults in the region were expected. These results indicate that far more

breeding adult terns from the former Crescent Island and Goose Island colonies returned to the Columbia Plateau region post-management either as breeders or as non-breeders, than dispersed outside the region.

Following implementation of the IAPMP, a larger proportion of breeding adults from the two managed colonies went unobserved during the post-management transitions. These results indicate that more breeding adult terns from the two managed colonies either traveled outside of the Columbia Plateau region to locations where little or no monitoring was taking place, or remained within the Columbia Plateau region as non-breeding floaters and visiting sites where regular surveys were not conducted. The larger proportion of unobserved terns post-management may reflect a small increase in emigration rates of Caspian terns from the Columbia Plateau region that went undetected.

Contrary to our prediction that emigration by breeding terns from the Columbia Plateau region would increase dramatically in the aftermath of management, analysis of resightings of banded terns failed to support increased emigration rates. These results were likely a reflection of the concurrent management to reduce available nesting habitat at the largest Caspian tern breeding colony in the Pacific Flyway: East Sand Island in the Columbia River estuary. In addition, drought conditions substantially impacted alternative colony locations throughout the southern Oregon and northeastern California (SONEC) region (Roby et al. 2015, 2016). These additional pressures on tern nesting habitat outside of the Columbia Plateau region may have rendered these locations unattractive to terns that previously nested at Goose Island or Crescent Island, and compelled terns to remain within the Columbia Plateau region and compete for nesting space at smaller active colonies or newly colonized nesting habitat. Analyses of resightings of Caspian terns banded as adults in the SONEC region revealed a large increase in net movement

rates away from colonies in the SONEC region to colonies in other regions of the Pacific Flyway, including the Columbia Plateau region, coincident with implementation of the IAPMP (YS, unpubl. data). This finding, in conjunction with unfavorable environmental conditions for tern nesting in the SONEC region and ongoing management in the Columbia River estuary, may explain the higher than expected regional philopatry exhibited by terns that previously nested at Goose Island or Crescent Island.

Terns that remain in the Columbia Plateau region as non-breeders could at least temporarily offset some of the potential management benefits for survival of salmonid smolts by continuing to forage in the region during a sabbatical from nesting. As non-breeders, these adults could still target juvenile salmonids during the out-migration because they are not bound by central place foraging around a particular nesting site. Data on the movements of satellite-tagged terns during 2014 - 2016, the first three years of management under the IAPMP, found that the elimination of the tern colonies at Goose and Crescent islands only resulted in limited dispersal of terns away from the Columbia Plateau region (Lyons et al., unpubl. data), consistent with the analysis of banded tern movements presented here. Measures of predation on juvenile salmonids by terns from the Potholes Reservoir were reduced, but this benefit was offset by increased predation by terns nesting at the Blalock Islands (Roby et al. 2015, 2016).

It seems unlikely that terns that became non-breeding floaters in the Columbia Plateau region as a result of the implementation of the IAPMP would remain so indefinitely. Non-breeders have the option to (1) stay and compete for limited nesting space at existing colonies in the Plateau region, (2) stay and establish new colonies in the Plateau region, or (3) to disperse and prospect/compete for nesting space elsewhere within the breeding range of the Pacific Flyway population. Given these three options, most terns displaced by the elimination of the

Goose and Crescent island colonies appear to have chosen options 1 and 2, and remained in the Columbia Plateau region, at least for the first two years following full implementation of the IAPMP. Remaining a non-breeder while competing for nesting space in familiar habitat is a strategy that may enhance an individual's reproductive value by enhancing the prospects for breeding in quality habitat (Zack and Stutchbury 1992, Naves et al. 2006). This potential strategy was supported by the increase in the proportion of non-breeders in the Plateau region, and little to no corresponding increase in the proportion of emigrants from the Plateau region. Terns employing this strategy could enhance their fitness by remaining non-breeders while competing for nesting space at active colonies, replacing failed breeders, or establishing new colonies.

The two new colony locations established by terns post-management suggest that all suitable nesting habitat may not be occupied. For example, the newly-formed colony in northeastern Potholes Reservoir did not appear until two years after the initiation of management at the Goose island colony. With fewer nesting pairs counted post-management, it would be expected that in the future a higher proportion of terns will emigrate from the Columbia Plateau region if they are unable to raise young successfully in the Columbia Plateau region. Naves et al. (2006) suggested that long-lived seabirds might integrate information from a number of consecutive breeding failures before making a decision to immigrate to a new region to breed. Adult Caspian terns with a history of regular nesting in the Columbia Plateau region that have not yet emigrated still might do so, especially if environmental conditions improve at potential nesting locations outside the Columbia Plateau region. For example, if drought conditions ease in the SONEC region, terns that have expended energy competing for nesting space in marginal habitat in the Plateau region during the early years of management might be more motivated to emigrate to these alternative colony locations.

Staav (1979) and Cuthbert (1988) described Caspian tern nesting systems that consisted of a network of islands, some of which terns were able to utilize for nesting during periods when other sites within the system were unsuitable or unavailable. While these studies did not describe extensive losses of nesting habitat formerly used by the majority of nesting terns in their respective study areas, they highlight the flexibility of Caspian terns for changing nesting locations quickly in response to changes in availability of nesting habitat. Familiarity with potential alternative nesting habitat and other smaller active colonies within the region could facilitate the establishment of new or larger colonies locally, and lead to minimal emigration outside the region in search of prospective breeding sites (McNicholl 1975).

Prior knowledge of good alternative nesting habitat may inform displaced terns where they can potentially breed successfully. The management action to relocate the Rice Island Caspian tern colony in the Columbia River estuary to East Sand Island, closer to the Columbia River mouth, was completely successful within three breeding seasons, and the majority of nesting terns relocated within the second breeding season. This was facilitated by the familiarity of at least some of the terns nesting on Rice Island with the East Sand Island colony site. Also, the straight-line distance between the two colony sites is only about 20 km. The Blalock Islands are about 60 km straight line distance from Crescent Island, and it is very likely that at least some terns that formerly nested at Crescent Island encountered the Blalock Islands during foraging trips or migration prior to the onset of management, as the Blalock Islands and Crescent Island are both located on the Columbia River.

Disturbance to Caspian tern colonies in the Baltic Sea during the 1940s and 1950s pushed terns first to a location a few hundred kilometers away, and then to another location 800 kilometers further away in the Gulf of Bothnia, with no apparent suitable nesting habitat in

between (Vaisanen 1973). Like the Caspian terns dispersed from the Crescent Island colony, terns nesting in the Baltic Sea and in the Columbia River estuary moved to what was apparently the nearest suitable alternative breeding habitat. With presumably acceptable nesting habitat available within the Columbia Plateau region, terns may not have been compelled to disperse to locations outside of the Columbia Plateau region to locate nesting habitat. In the two years prior to the implementation of the IAPMP, 2012 and 2013, the Blalock Islands were the site of the only active Caspian tern colony other than Goose Island and Crescent Island where young were successfully fledged. As the next most productive breeding location immediately prior to the initiation of management, prior knowledge of the Blalock Islands colony may have informed terns that this site could be productive nesting habitat in a region already familiar to them (Danchin et al. 1998, Naves et al. 2006).

In conclusion, despite this capacity for dispersal, terns nesting in the Columbia Plateau region have exhibited regional fidelity, at least in the short term, in response to drastic changes in availability of nesting habitat. In response to the loss of the majority of quality nesting habitat available within the region due to management, most terns were able to take advantage of other active, former, or prospective nesting habitat within the Columbia Plateau region that is potentially less conducive of nesting success than the former colony sites on Crescent and Goose islands. While there was a significant drop in numbers of regional nesting pairs, the analysis of resightings of banded terns indicates that a higher proportion of terns that formerly bred in the region returned as non-breeding floaters, instead of immigrating to other colony sites within the Pacific Flyway. This suggests that some of the potential benefits to survival of salmonid smolts from the implementation of the IAPMP have been offset in the short term by an increase in the numbers of non-breeding terns that continue to consume juvenile salmonids

in the region, but whose movements and foraging behavior are difficult to monitor. The marginal nature of nesting habitat chosen by terns after the implementation of the IAPMP may eventually act to more severely restrict the numbers of nesting pairs within the Columbia Plateau region. If environmental conditions remain similar in the future, we would expect that the number of Caspian tern nesting pairs in the Columbia Plateau region will continue to gradually decline as existing colony locations experience partial breeding failures (e.g., the Blalock Islands) or complete breeding failures (e.g., northeastern Potholes Reservoir). Indeed, the analysis of resightings of banded terns suggests that terns may be slowly trickling away from the Columbia Plateau region. If conditions remain unfavorable at alternative colony sites outside of the Columbia Plateau region, however, the majority of terns may continue to prospect and compete for limited nesting space within the region.

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Table 2.1. Active Caspian tern breeding colonies in the Columbia Plateau region and numbers of nesting pairs at each colony during the 2013-2016 study period.

	Year			
	2013	**2014**	**2015**	**2016**
Location				
Crescent Island, McNary Reservoir	393	474	0	0
Goose Island, Potholes Reservoir	340	156	2	0
Blalock Islands, John Day Reservoir	26	45	677	483
Twinning Island, Banks Lake	13	67	64	6
Harper Island, Sprague Lake	1	8	10	3
Lenore Lake	0	2	16	39
Northeastern Potholes Reservoir	0	0	0	144
Totals	773	752	769	675

Table 2.2. Nesting success (average number of young fledged per breeding pair) at each active Caspian tern breeding colony in the Columbia Plateau region during the 2013-2016 study period. "----" indicates that no Caspian terns nested at that colony site in that year.

	Year			
	2013	**2014**	**2015**	**2016**
Location				
Crescent Island, McNary Reservoir	0.43	0.33	----	----
Goose Island, Potholes Reservoir	0.38	0.29	1.00	----
Blalock Islands, John Day Reservoir	0.12	0.33	0.36	0.43
Twinning Island, Banks Lake	0.00	0.00	0.00	0.00
Harper Island, Sprague Lake	0.00	0.00	0.00	0.00
Lenore Lake	----	0.00	0.38	0.59
Northeastern Potholes Reservoir	----	----	----	0.00
Regional Average	0.39	0.29	0.33	0.34

Table 2.3. Proportions of individual marked Caspian terns classified as Plateau Breeders in one year that transitioned to the same or alternative breeding status in the subsequent year. Transition proportions are separated into the pre-management period (2011-2013) and the two post-management transition years when management was ongoing at both Goose and Crescent islands. Significant differences in the distribution of transition proportions between the pre-management period and the post-management period were observed for both the 2014-2015 and 2015-2016 transition years ($p < 0.001$ for both transitions). Post-management transition proportions that were significantly different from pre-management transition proportions ($p < 0.01$, the Bonferroni-adjusted significance threshold) are shown in bold.

	Pre-Management	**Post-Management**	
	2011-2013	2014-2015	2015-2016
	n = 212	n = 161	n = 103
Year 2 Status			
Plateau Breeder	0.910	**0.609**	**0.602**
Plateau Non-breeder	0.042	**0.205**	**0.243**
Off-Plateau Breeder	0.024	0.018	0.0
Off-Plateau Non-breeder	0.009	0.043	0.0
Unknown	0.014	**0.124**	**0.155**

Table 2.4. Proportions of individual marked Caspian terns classified as Plateau Prospectors in one year that transitioned to the same or alternative breeding status in the subsequent year. Transition proportions are separated into the pre-management period (2011-2013) and two post-management transition years when management was ongoing at both Goose and Crescent islands. A significant difference in the distribution of transition proportions between the pre-management period and the post-management period was observed for only the 2015-2016 transition ($p = 0.02$). Post-management transition proportions that were significantly different from pre-management transition proportions ($p < 0.01$, the Bonferroni-adjusted significance threshold) are shown in bold.

	Pre-Management	**Post-Management**	
	2011-2013	2014-2015	2015-2016
	n = 37	n = 10	n = 37
Year 2 Status			
Plateau Non-breeder	0.081	0.20	**0.351**
Plateau Breeder	0.595	0.50	0.432
Off-Plateau Breeder	0.054	0.0	0.0
Off-Plateau Non-breeder	0.027	0.0	0.0
Unknown	0.243	0.30	0.216

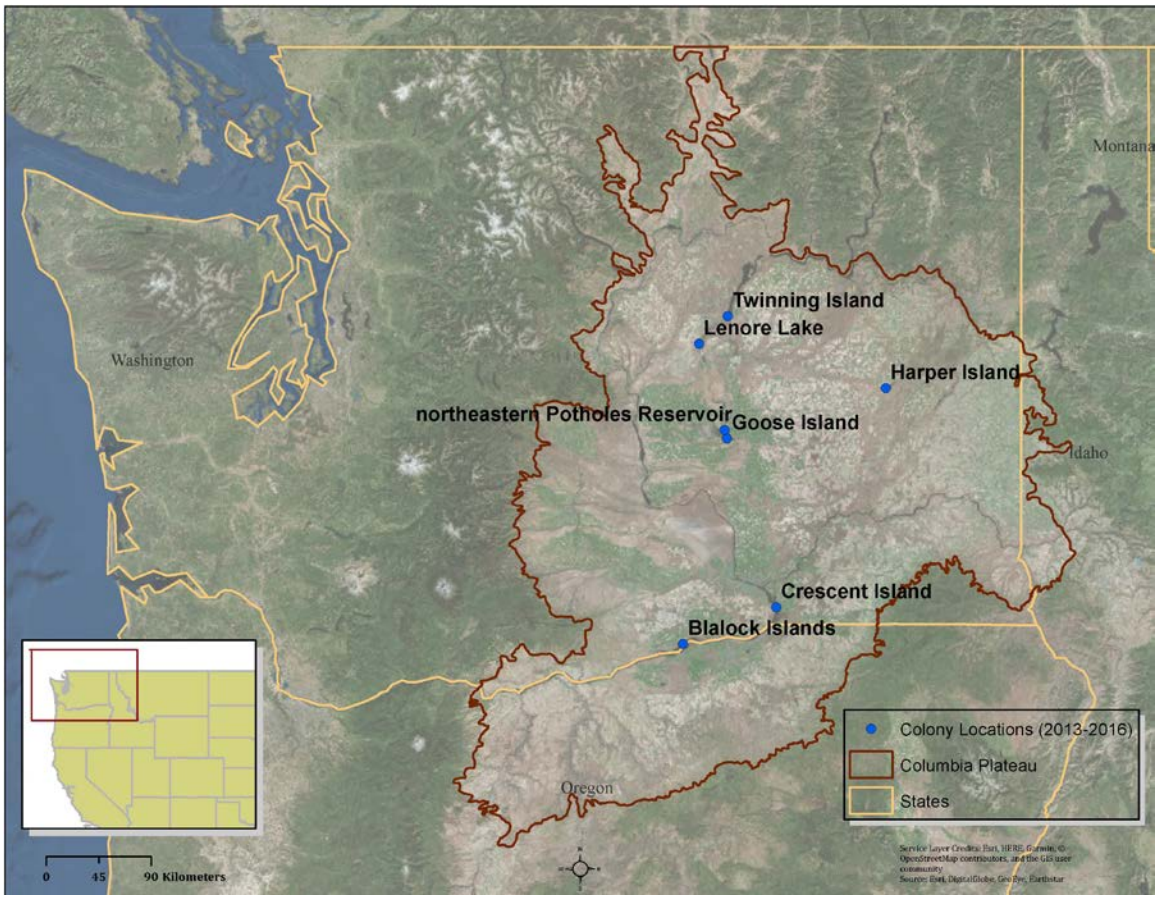

Figure 2.1. Map of the Columbia Plateau region, showing the location of Goose Island in Potholes Reservoir and Crescent Island in McNary Reservoir, as well as the location of other Caspian tern breeding colonies in the Columbia Plateau region following management at Goose and Crescent islands.

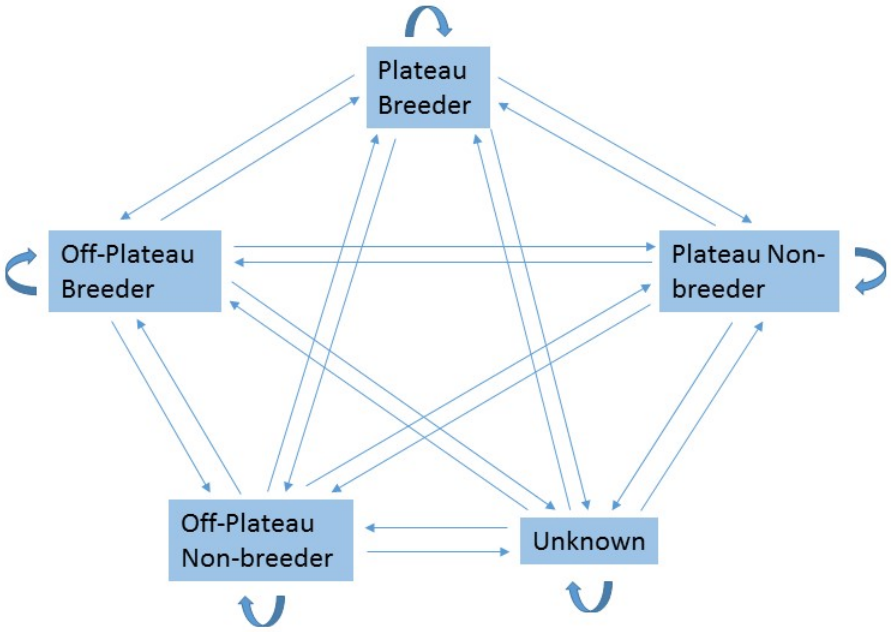

Figure 2.2. Diagram illustrating all possible breeding status transitions used for analysis of resightings of banded Caspian terns that nested on Goose or Crescent islands pre-management.

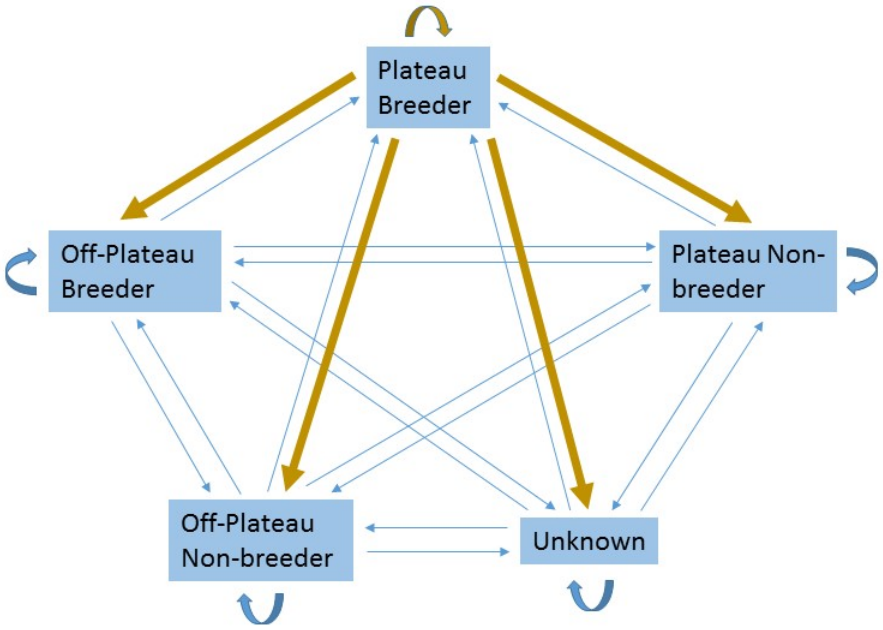

Figure 2.3. Diagram illustrating all possible breeding status transitions from Plateau Breeder to all other breeding statuses used for analysis of resightings of banded Caspian terns.

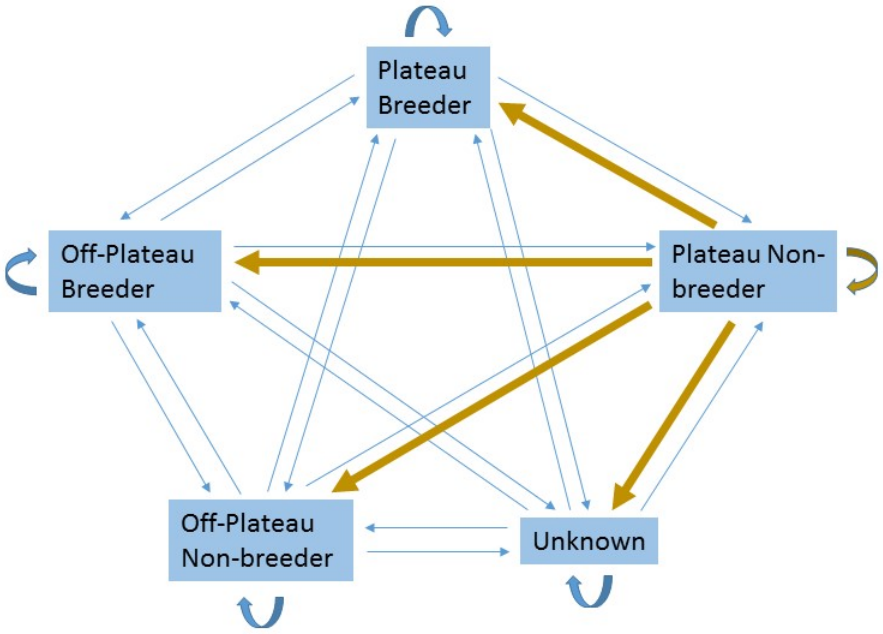

Figure 2.4. Diagram illustrating all possible breeding status transitions from Plateau Non-breeder to all other breeding statuses used for analysis of resightings of banded Caspian terns.

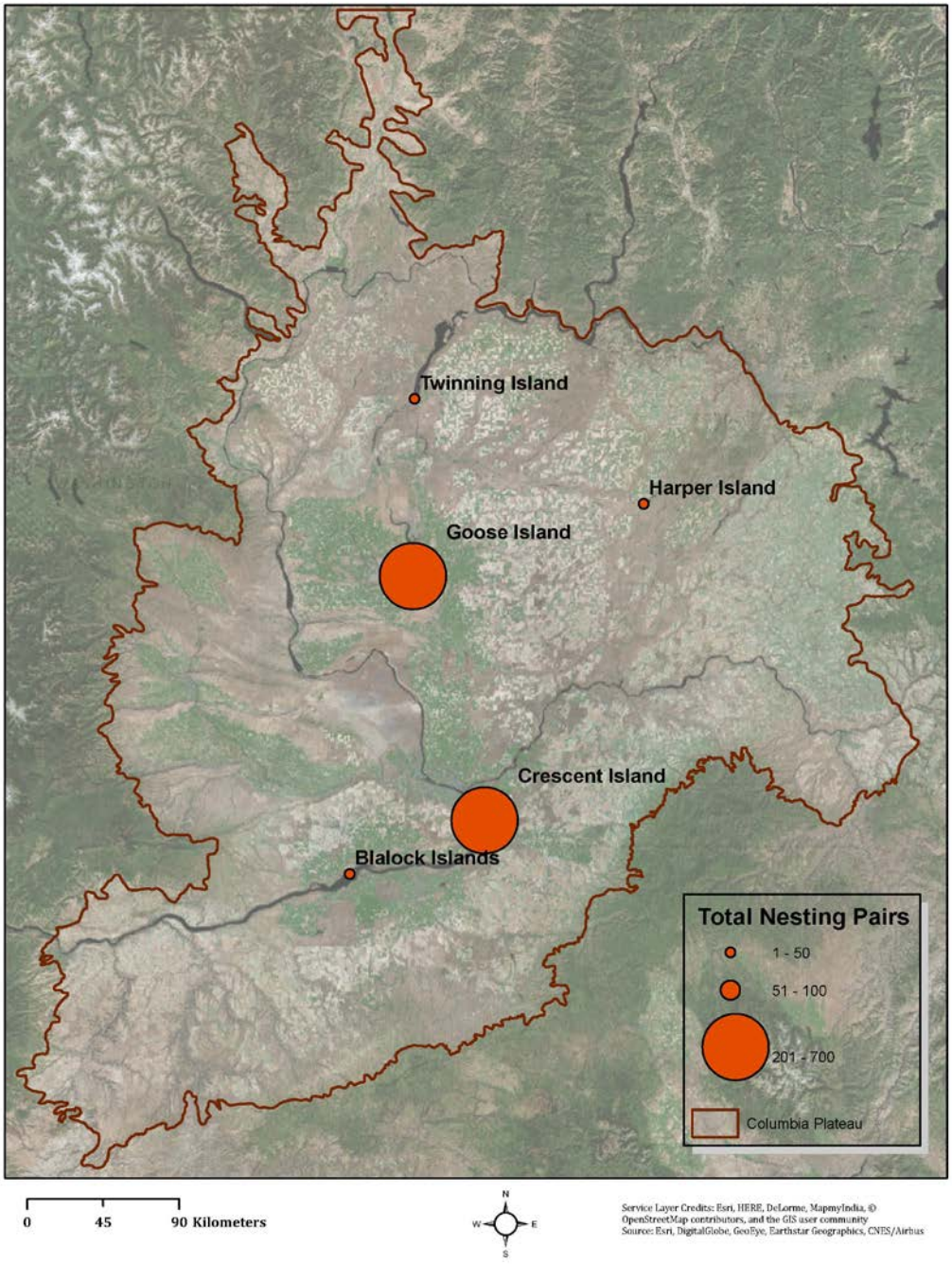

Figure 2.5. Map of the distribution and relative size of active Caspian tern nesting colonies in the Columbia Plateau region in 2013, immediately prior to the initiation of management to reduce Caspian tern nesting habitat under the Inland Avian Predation Management Plan.

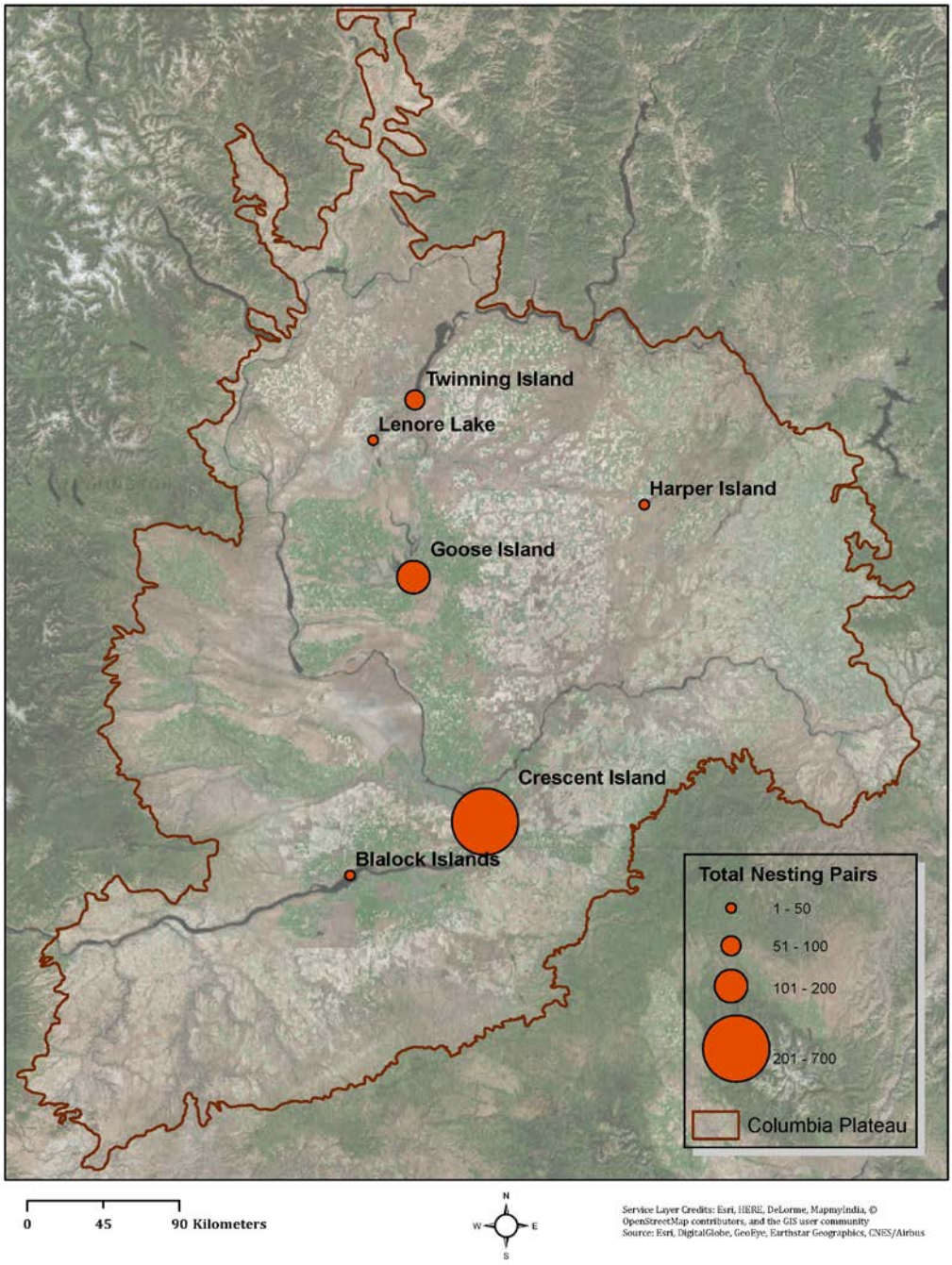

Figure 2.6. Map of the distribution and relative size of active Caspian tern nesting colonies in the Columbia Plateau region in 2014, the first year of implementation of the Inland Avian Predation Management Plan, when management to reduce nesting habitat occurred only at Goose Island, Potholes Reservoir.

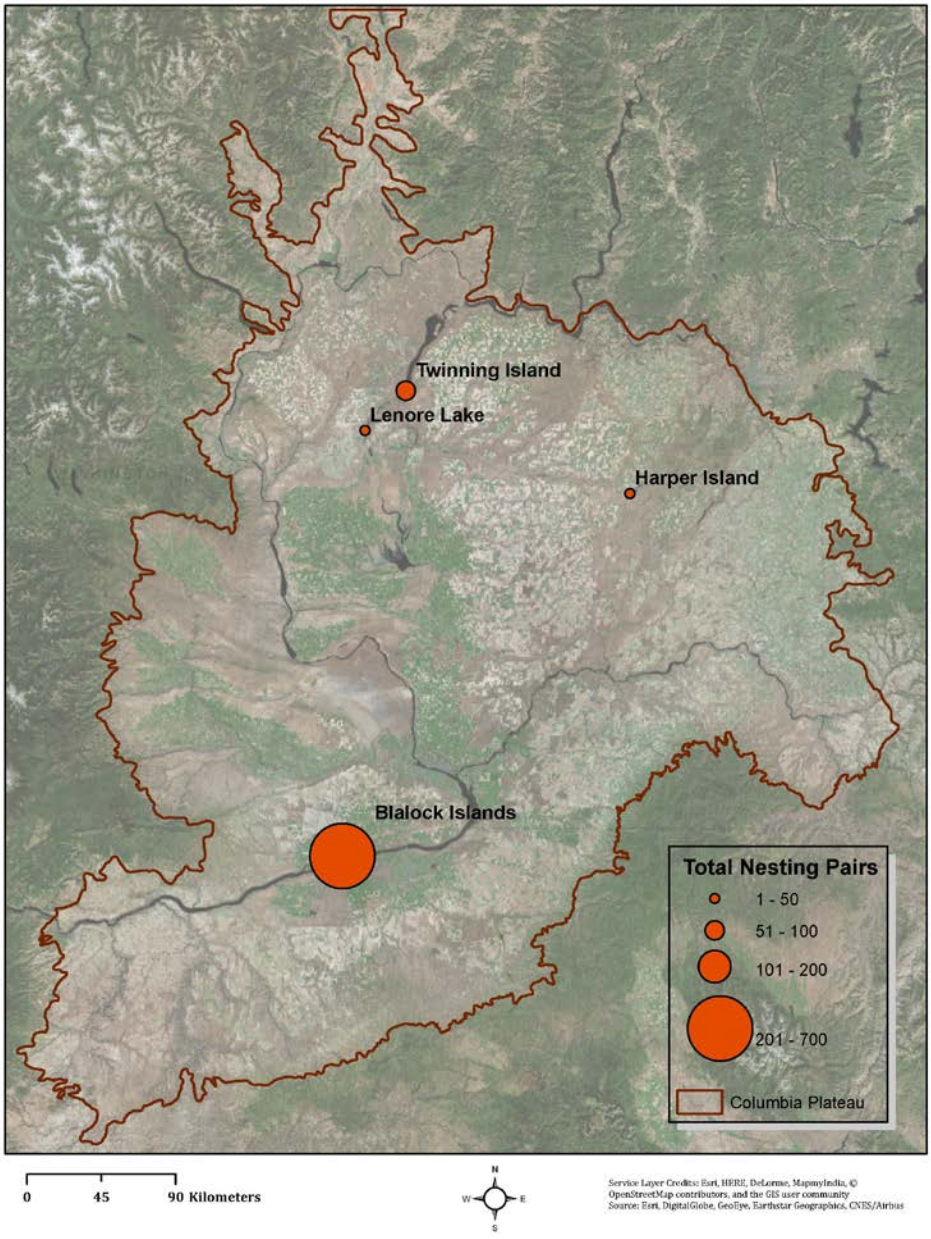

Figure 2.7. Map of the distribution and relative size of active Caspian tern nesting colonies in the Columbia Plateau region during 2015, the second year of implementation of the Inland Avian Predation Management Plan and the first year of management to prevent nesting by Caspian terns at both Goose Island, Potholes Reservoir, and Crescent Island, McNary Reservoir.

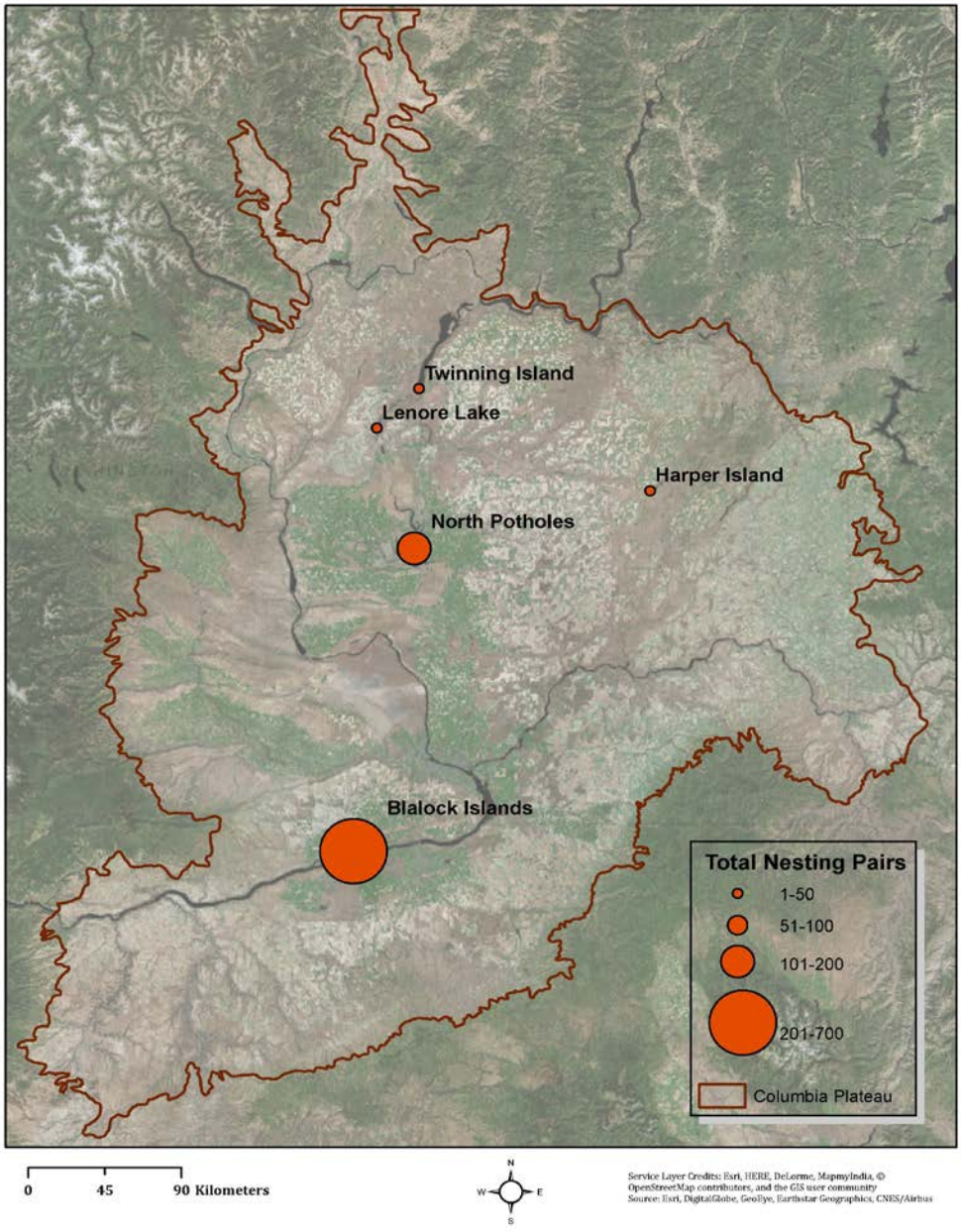

Figure 2.8. Map of the distribution and relative size of active Caspian tern nesting colonies in the Columbia Plateau region during 2016, the third year of implementation of the Inland Avian Predation Management Plan and the second year of management to prevent nesting by Caspian terns at both Goose Island, Potholes Reservoir and Crescent Island, McNary Reservoir.

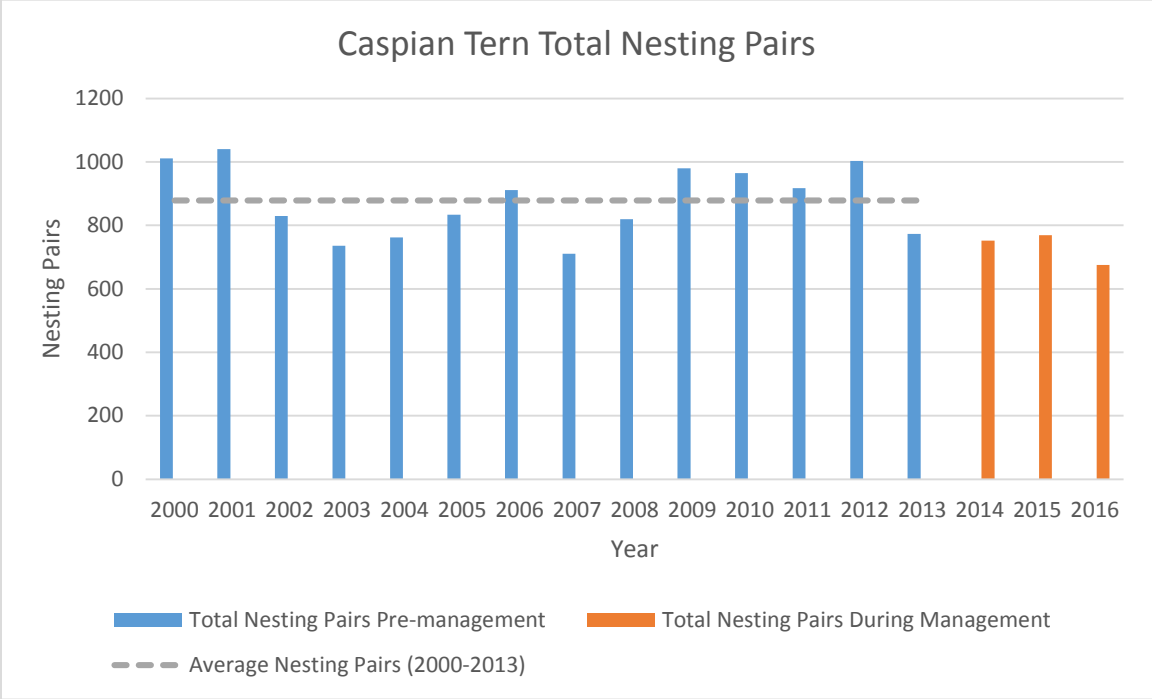

Figure 2.9. Total numbers of nesting pairs of Caspian terns at breeding colonies in the Columbia Plateau region before implementation of management under the Inland Avian Predation Management Plan and in the first three years after implementation of the plan. There was no significant trend in total number of nesting pairs in the region prior to the implementation of management (2000-2013; $p = 0.94$).

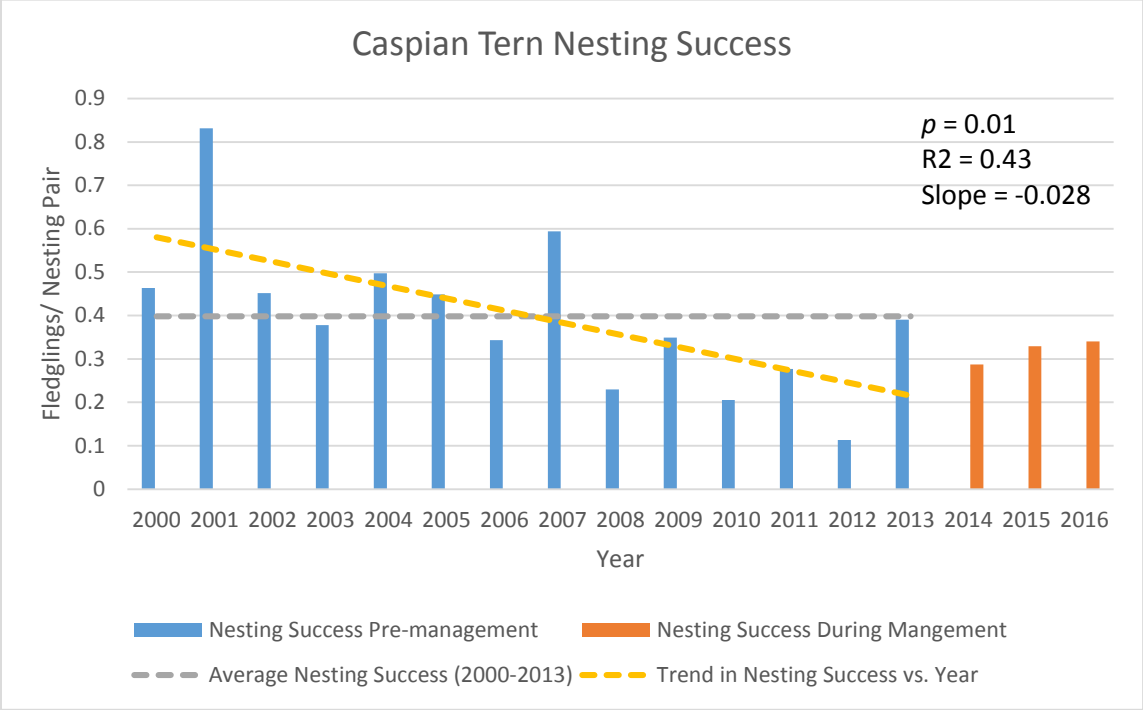

Figure 2.10. Average nesting success of Caspian terns at breeding colonies in the Columbia Plateau region before implementation of management under the Inland Avian Predation Management Plan and during the first three years after implementation of the plan. During the pre-management period (2000-2013) there was a significant decline in region-wide nesting success as a function of year; the least squares regression is indicated by the dashed yellow line.

APPENDIX

Appendix A: All known Caspian tern breeding colony sites in the Columbia Plateau region (latitude, longitude) and years when the colony site was occupied. No comprehensive surveys of Caspian tern colonies in the Columbia Plateau region occurred prior to 2000, so records are likely incomplete prior to that year. All coordinates are in the WGS84 datum.

Location Name	*Coordinates*	*Known Years Active*	*References*
Crescent Island, McNary Reservoir	46°05'36.12"N, 118°55'52.14"W	1986-2014	Antolos et al. 2004, Adkins et al. 2014
Goose Island, Potholes Reservoir	46°59'08.67"N, 119°18'38.52"W	2004-2013	
Moses Lake/Potholes Reservoir area (including Solstice Island and northeastern Potholes Reservoir)	47°01'41.11"N, 119°21'52.77"W	1930's, 1950's, 1972-1975, 2000-2003, 2016	Kitchin 1930, Penland 1982, Antolos et al. 2004
Three-Mile Canyon Island, John Day Reservoir	45°48'58.78"N, 119°57'55.89"W	1977-2001	Thompson & Tabor 1981, Antolos et al. 2004
Blalock Islands, John Day Reservoir	45°53'43.06"N, 119°38'51.46"W	2005-2016	Adkins et al. 2014
Twinning Island, Banks Lake	47°37'29.86"N, 119°18'11.35"W	2004-2016	Adkins et al. 2014, BRNW Reports
Goose Island, Banks Lake	47°38'49.84"N, 119°17'28.53"W	2000-2005	Adkins et al. 2014
Harper Island, Sprague Lake	47°14'52.08"N, 118°05'05.19"W	1999-2016	C. Maranto pers. comm., Adkins et al. 2014
Cabin Island, Priest Rapids Reservoir	46°39'37.42"N, 119°54'57.53"W	1975	Thompson & Tabor 1981
Badger Island, McNary Reservoir	46°06'36.81"N, 118°56'17.20"W	2011-2012	BRNW Reports

Miller Rocks, The Dalles Reservoir	45°39’41.90”N, 120°52’31.14”W	2001	Antolos et al. 2004, BRNW Reports
Lenore Lake	47°28’48.38”N, 119°31’26.13”W	2014-2016	
Finley Islands, McNary Reservoir	46°08’35.97”N, 118°59’35.97”W	2015	
Marsh Unit 1, Columbia National Wildlife Refuge	46°57’17.21”N, 119°15’43.06”W	2015	

CHAPTER 3: SYNOPSIS AND CONCLUSIONS

Ethan Schniedermeyer

The primary objectives for this study were to 1) observe the response of Caspian terns to managed reductions in nesting habitat at the two largest breeding colony locations within the Columbia Plateau region, 2) describe changes in the distribution and success of nesting Caspian terns within the region following implementation of management, and 3) determine the extent to which Caspian terns that previously nested at either of the managed colony sites emigrated from the Columbia Plateau region following management. Here I discuss my results relative to those of other studies of nest site selection in long-lived, colonial-nesting seabirds and discuss possible next steps for research and monitoring of this sub-population of Caspian terns.

Caspian terns nesting in the Columbia Plateau region exhibited high philopatry to the region during management. In the short term, implementation of the Inland Avian Predation Management Plan (IAPMP; USACE 2014) resulted largely in a redistribution of the majority of nesting Caspian terns within the Columbia Plateau region after the elimination of nesting at Goose and Crescent island. The numbers of nesting pairs in the region dropped during the first three years post-management as a result of management, but not nearly to the level of ≤ 200 nesting pairs, the goal of the management plan. In combination with the analysis of banded birds, my results indicated that terns were not leaving the Plateau region in search of nesting opportunities. In fact, my analysis strongly suggested that terns that were unable to breed as a result of management to reduce available nesting habitat remained in the Plateau region as non-breeding floaters, shifting among colony sites in search of nesting opportunities. Terns that were able to compete successfully for nesting space apparently did so by exhibiting flexibility in nest site selection.

There are multiple factors involved in nest site selection for long-lived seabirds, including life history, nesting success of conspecifics, availability of nesting habitat, risk of predation, and food availability (Cuthbert 1988, Dobson and Jouventin 2010). The

implementation of the IAPMP resulted in the loss of the most stable and consistently used nesting habitat for Caspian terns in the Columbia Plateau region. As a result, terns had to decide whether to stay in the region and compete for nest sites in habitat that may be less suitable and less conducive of fledging success, or emigrate to other regions to prospect for nest sites. Integrating knowledge on one or a combination of these factors may assist terns in making this decision. “Public information,” such as knowledge of conspecific reproductive success, availability of food, and suitability of nesting habitat combines many of these factors into a single cue for environmental quality (Doligez et al. 2003).

Prospecting behavior, which is often displayed by pre-breeders, non-breeders, or failed breeders, is a mechanism that connects colonies and allows individuals to collect information on conspecific reproductive success (Ponchon et al. 2015). Public information has been shown to be a strong factor in nest site selection by colonial seabirds (Boulinier and Danchin 1997, Danchin et al. 1998, Naves et al. 2006, Boulinier et al. 2008). Prospecting and gathering information on conspecific breeding success and the locations of other waterbird breeding colonies probably informed terns of quality alternative nesting locations within the Columbia Plateau region. This may explain why the majority of terns previously nesting in the Columbia Plateau region moved to the Blalock Islands, which was the only other colony, other than those at Goose and Crescent islands, to fledge chicks immediately prior to the implementation of the IAPMP.

Consistent with the high level of connectivity seen previously among Caspian tern colony sites in the Columbia Plateau region, as well as throughout the breeding range of the Pacific Flyway population as a whole (Suzuki 2012), individual terns displaced from both Goose and Crescent islands were able to recruit at existing colonies or collectively colonize new locations in the first year after implementation of management. Caspian terns nesting at Goose Island and, especially, Crescent Island likely visited and foraged around the Blalock Islands prior

to the initiation of management under the IAPMP. This kind of public information may have informed breeding terns as to the best opportunities for nesting in the Columbia Plateau region following the implementation of management (Doligez et al. 2003). Additionally, the nesting success of other terns post-management may be a factor in the choice by non-breeding terns to remain in the Columbia Plateau region and compete for the available nesting space.

Despite limitations in available nesting habitat experienced by Caspian terns in the Columbia Plateau region post-management, nesting success did not drop significantly and, in 2015 and 2016, was within the range found by Suryan et al. (2004) to support a stable population. Despite limitations like spatial restrictions and nesting failures due to flooding at locations that managed to fledge young, other potential limiting factors may have been less severe. At the Blalock Islands, where flooding was an issue for the tern colony, this is likely due to a combination of higher quality food resources, less competition from gulls as they were not nesting adjacent to terns, and lower apparent predation rates on tern nests. At Lenore Lake, where spatial constraints were an issue, there were low apparent predation rates on tern nests. In these instances the balance of factors that were negatively limiting reproductive success, such as flooding, may have been outweighed by factors positively influencing reproductive success in the Columbia Plateau region, such as familiarity with foraging locations.

The Blalock Islands are situated within the John Day Reservoir on the Columbia River, where the availability of out-migrating juvenile salmonids as a food source is high during the nesting season. In previous years, per capita consumption of juvenile salmonids by Caspian terns nesting at the Blalock Islands was similar to that of terns nesting at Goose Island prior to the implementation of the IAPMP (Evans et al. 2012). While outside the scope of this study, it seems reasonable that a fairly stable food source such as the yearly release of hatchery-raised juvenile

salmonids might be an important factor in terns' decision to remain in the Plateau region during the nesting season.

Exhibiting philopatry to predictable habitats where terns have previous breeding experience can reduce risk of breeding failure or mortality by allowing terns to familiarize themselves with potential predation risks, areas of high forage fish availability, and other factors influencing nesting success (McNicholl 1975). While the IAPMP removed the most stable and consistent nesting habitat for Caspian terns in the Columbia Plateau region, other nesting habitat was still available. Familiarity with other recently active colony locations could allow displaced individuals to avoid the energetic costs of long-distance breeding dispersal. Re-settling at colonies within the Columbia Plateau region that are within commuting distance of known foraging locations presumably has a lower energetic cost than dispersing over long distances to unknown or less known prospective nesting locations. While long-distance breeding dispersal has been shown to occur at low rates in Caspian terns from the Pacific Flyway population (Suzuki 2012), large-scale colonization of new nesting habitat, such as has been documented in coastal Washington and the Columbia River estuary, has occurred over shorter distances and relatively infrequently in the Pacific Flyway (Gill and Mewadt 1983, Suryan et al. 2004).

The dissuasion of Caspian terns nesting on Rice Island in the Columbia River estuary and the concurrent attraction of terns to nest on East Sand Island, closer to the mouth of the river, occurred across a distance of only 20 km. Terns nesting at Rice Island were likely familiar with the East Sand Island colony site prior to being dissuaded from nesting on Rice Island and re-establishing a colony on East Sand Island. The greatest distance between islands in the network of colony sites used by Caspian terns in Cuthbert's (1985) study was 39 km. In a study of 11 Caspian tern colonies in Sweden, Staav (1979) found that more than half of terns within his study area nested within 10 km of their natal colony, and only 3% dispersed to colonies greater

than 500 km from their natal colony. This suggests that long-distance dispersal, while possible in this species, might only occur when enough negative factors act together to compel terns to emigrate long distances to another region to find nesting opportunities. This situation appears not to have applied to the Caspian tern sub-population in the Columbia Plateau region during the first two years following full implementation of the IAPMP, because there were enough factors negatively affecting the availability and suitability of nesting habitat in other regions of the Pacific Flyway during this period, which compelled terns to continue to try and compete for nesting space in the Plateau region.

Drought conditions in the southern Oregon and northeastern California (SONEC) region beginning in 2014 apparently limited forage fish availability throughout much of the region, and reduced the insularity of potential nesting islands (Roby et al. 2014, 2015a, 2016a). Concurrent with drought conditions south of the Columbia Plateau region, management to reduce available Caspian tern nesting habitat by a third at the large colony on East Sand Island in the Columbia River estuary occurred in 2015 (Roby et al. 2015b, 2016b). Implementation of management to reduce nesting habitat for Caspian terns in the Columbia River estuary resulted in the displacement of a number of terns from their former nest sites at this large colony, forcing them to compete for limited nesting space. Space constraints at colony sites in both of these potential alternative breeding regions likely made these regions less attractive as breeding habitat for Caspian terns displaced from colony sites in the Columbia Plateau region, compared to more familiar colony sites within the region. Factors that negatively affected reproductive success in other parts of the breeding range off Caspian terns in the Pacific Flyway population, plus the energetic costs and risks associated with long distance dispersal, were probably outweighed by the breeding experience and familiarity with foraging habitat within the Columbia Plateau region of terns that previously nested at Goose and Crescent islands.

A small portion of the Caspian terns that were satellite-tagged on Goose or Crescent island prior to implementation of the IAPMP were observed associating with a colony in the Salish Sea region of coastal northwestern Washington State in 2015 and 2016 (Lyons et al., unpubl. data). However, there was very limited evidence that satellite-tagged terns recruited to or visited Caspian tern colonies that had formed on islands constructed in Don Edwards San Francisco Bay National Wildlife Refuge as alternative nesting habitat for terns displaced by management under the IAPMP (Lyons et al., unpubl. data). If terns that previously nested at Goose or Crescent island began to emigrate in larger numbers from the Columbia Plateau region to other regions in the Pacific Flyway, then the Salish Sea/Puget Sound region of coastal Washington could hold potential based on satellite telemetry data. Based on the distance of the new colony sites in south San Francisco Bay from Goose and Crescent islands (> 1,000 km) it seems unlikely that large numbers of terns displaced from Goose and Crescent islands would recruit there.

Caspian terns might be expected to display low breeding site tenacity due to the ephemeral nature of their natural nesting habitats (Cuthbert 1988). The species has been found to exhibit high site tenacity, however, in situations where birds were able to utilize environmentally predictable nesting habitat. Collar (2013) found that Caspian terns displaced from their nest sites at the large colony on East Sand Island in the Columbia River estuary showed high colony site tenacity during years of managed reductions in nesting habitat. Caspian terns nesting in the Columbia Plateau region appeared to exhibit high philopatry towards the region in general and, in particular, towards Goose Island in Potholes Reservoir. Data from banded terns re-sighted at the Blalock Islands showed that the majority of breeding terns that relocated to the Blalock Islands colony did so from Crescent Island colony; however, a small portion of the terns displaced from Goose Island did immigrate to the Blalock Islands (Roby et al.

2015a, 2016a). This suggests that the Blalock Islands may have been a location frequented by terns that nested at Crescent Island for foraging or a migration stopover on the way to Crescent Island prior to the initiation of management. This also suggests that at least some terns from Goose Island were familiar with the location of the Blalock Islands colony, possibly from passing it or stopping over during migration. Despite this connectivity among colony sites in the region, there does appear to be some local nest site fidelity.

Analysis of the movements of banded terns in the Columbia Plateau region did not take into account the age of the birds, detection probability, survival rates, or the specific location where banding took place. It would be interesting to differentiate the response to management between terns banded as adults and those banded as fledglings. Caspian terns banded as adults are not only older and more experienced, but presumably also have more investment in the region than those banded as fledglings, and thus may respond differently to changes in nesting habitat availability (Heidinger et al. 2006, Mauck et al. 2012).

Two breeding seasons of observations may not be sufficient to adequately assess the effectiveness of the IAPMP at dispersing breeding Caspian terns from the Columbia Plateau region. As long-lived seabirds that exhibited philopatry to the Columbia Plateau region, Caspian terns may choose to remain in the Plateau region for a number of years and compete for nesting space before eventually choosing to disperse to a different region to breed (Naves et al. 2006). If environmental conditions improve outside of the Columbia Plateau region, in combination with repeated breeding failures at marginal nesting habitat in the region, then more terns may emigrate from the Plateau region to other regions within the Pacific Flyway. It is difficult to predict the long-term response to management of a long-lived species without long-term monitoring.

Examining the behavior of non-breeding Caspian terns would be an additional valuable step in understanding the response of the species to the loss of stable nesting habitat in the Columbia Plateau region. The behavior of non-breeding Caspian terns and other larids during a "sabbatical" year is a poorly studied topic (Kazama et al. 2013). Because non-breeding Caspian terns are not easily observable, it is difficult to know to what degree they retain an attachment to the Columbia Plateau region and, consequently, sustain their impact on the survival of out-migrating juvenile salmonids within the region. Considering the observed response to management by Caspian terns, and the suboptimal conditions at alternative colony locations within the region, it is difficult to predict how much more time, if any, terns will spend attempting to compete for nesting space within the region before prospecting further afield in greater numbers.

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