Evaluating Colony Displacement as a Method to Reduce Caspian Tern Predation on Juvenile Salmonids in the Columbia Plateau Region

This Draft Report has been prepared for the Grant County Public Utility District and Priest Rapids Coordinating Committee. This report is not for citation without permission from the authors.

Daniel D. Roby[1], Principal Investigator
E-mail: daniel.roby@oregonstate.edu
Telephone: 541-737-1955

Donald E. Lyons[1,2], Co-Principal Investigator
E-mail: don.lyons@oregonstate.edu
Telephone: 541-207-2062

Ken Collis[3], Co-Principal Investigator
E-mail: ken@realtimeresearch.com
Telephone: 541-719-1652

Report Prepared by:
Timothy J. Lawes[1]
E-mail: timothy.lawes@oregonstate.edu
Telephone: 541-737-5895

[1] Department of Fisheries and Wildlife
104 Nash Hall, Oregon State University
Corvallis, Oregon 97331

[2] National Audubon Society Seabird Restoration Program
10 Audubon Road
Bremen, Maine 04551

[3] Real Time Research, Inc.
1000 SW Emkay Drive
Bend, Oregon 97702

EXECUTIVE SUMMARY

The *Inland Avian Predation Management Plan* (IAPMP) was developed to reduce the mortality of ESA-listed anadromous salmonid smolts, especially steelhead trout, due to predation by piscivorous colonial waterbirds nesting in the Columbia Plateau region. Implementation of the IAPMP was successful in preventing Caspian terns from nesting at the two largest breeding colonies of terns in the Columbia Plateau region: Goose Island in Potholes Reservoir and Crescent Island in McNary Reservoir on the Columbia River. Our study was designed to track the movements and habitat use of adult Caspian terns that formerly nested at these two colonies as part of a comprehensive effort to assess the efficacy of the IAPMP in reducing the numbers of Caspian terns nesting and foraging in the Columbia Plateau region. We captured adult Caspian terns prior to the 2014 and 2015 breeding season at the Goose Island and Crescent Island colonies, tagged them with Platform Transmitting Terminal (PTT) tags, and tracked their subsequent movements using the ARGOS satellite telemetry system. Terns were tagged immediately before or shortly after the initiation of management to prevent Caspian terns from nesting at the two managed colonies. In total, 76 adult terns were tagged and tracked for an average of 705 days post-release, with tracking of some tagged terns continuing for more than four breeding season following tag deployment. Data on tagged tern locations during the steelhead smolt out-migration period (April-June) were analyzed using Kernel Density Estimation (KDE) in order to identify sites and areas where tagged terns concentrated for foraging and nesting in the Columbia Plateau region. We also used Akaike Information Criterion (AIC_c) model selection to identify those factors that best explained variation in tern foraging habitat use, nest site use, and dispersal of tagged individuals. The *a priori* explanatory variables used in model selection were: (1) colony where tern captured, (2) year when tern captured, (3) sex, (4) number of years since management initiated, (5) starting date of the steelhead smolt out-migration period, (6) duration of the steelhead smolt out-migration period, and (7) the interaction between starting date and duration of the steelhead smolt out-migration period.

PTT-tagged Caspian terns exhibited stronger philopatry (foraging and nest site fidelity) to the Columbia Plateau region than anticipated for a species that is known to engage in long-distance dispersal from breeding sites. The majority of terns with actively transmitting tags were detected in the Columbia Plateau region during the peak of the steelhead smolt out-migration, even in the fourth breeding season following initiation of management that successfully prevented nesting at the Goose Island and Crescent Island colonies. During the fourth breeding season after initiation of management under IAPMP, 68.1% of detected locations of tagged terns were still in the Columbia Plateau region, and 36.3% of detected locations on the Plateau were at former or existing breeding colonies for the species. Of the 16 tagged terns that were tracked during their fourth nesting season after tagging, 14 (87.5%) spent most of the season in the Columbia Plateau region.

AIC_c model selection indicated that there was differential use of foraging areas by tagged terns depending on whether the tern was tagged at the Goose Island or Crescent Island colony; terns tagged at Goose Island foraged mainly along the Columbia River above the confluence with the Snake River, and terns tagged at Crescent Island foraged mainly below the confluence. However, the KDE analyses indicated that, overall, tagged terns concentrated at many of the same foraging, loafing, and nesting sites in the Columbia Plateau region throughout the 5-year study (2014-2018). Nevertheless, the proportion of terns tagged at the Goose Island colony that subsequently foraged along the Columbia River above the confluence with the Snake River declined steadily and significantly following

implementation of the IAPMP, supporting the conclusion that successfully dissuading terns from nesting at Goose Island provided benefits to smolt survival in that stretch of the Columbia River. On the other hand, the proportion of tagged terns that foraged along the Columbia River below the confluence with the Snake River did not decline significantly during the management period (2015-2018), because many Caspian terns that formerly nested at the Crescent Island colony in McNary Reservoir (Rkm 510) shifted to the colony at the Blalock Islands in John Day Reservoir (Rkm 440) and continued to forage along that stretch of the Columbia River. Following successful elimination of the Crescent Island tern colony, there was little foraging use of the lower Snake River by tagged Caspian terns.

The above-mentioned slow pace of dispersal from the Columbia Plateau region by tagged Caspian terns that formerly nested at the two largest colonies in the region indicates that most displaced terns persisted in prospecting for alternative nest sites within the region. Although tagged terns made many apparent exploratory trips both within and outside the Columbia Plateau region, most terns that ventured away from the region during the nesting season returned to the region instead of permanently emigrating. This behavior has two implications: (1) tagged terns were unsuccessful in locating suitable alternative nesting habitat outside the Columbia Plateau region and/or (2) available alternative nesting habitat in the Columbia Plateau region, although less suitable than the former colony sites on Goose and Crescent islands, offered more favorable conditions for nesting and foraging than sites outside the region. Our results suggest that to achieve the IAPMP goal of no more than 200 breeding pairs of Caspian terns nesting throughout the Columbia Plateau region, (1) more than four years will be required for terns that formerly nested at the Crescent Island and Goose Island colonies to identify and disperse to alternative breeding colonies outside the region, (2) additional quality nesting habitat for terns may need to be provided outside the Columbia Plateau region, perhaps at or near former colony sites along the Washington coast, and (3) adaptive management will be needed to dissuade Caspian terns from nesting at colony sites in the Columbia Plateau region where more than 40 breeding pairs currently nest and predation rates on some stocks of juvenile salmonids are above the 2% threshold identified in the IAPMP, in particular at the Caspian tern colony in the Blalock Islands in John Day Reservoir.

INTRODUCTION

Caspian terns (*Hydroprogne caspia*) are a plunge-diving, piscivorous, colonial waterbird with nearly a global distribution. In western North America, Caspian terns have historically nested on naturally occurring islands along coastlines, in estuaries, and at inland sites on major rivers, lakes, and marshes (Cuthbert and Wires 1999). More recently, colonies have occurred on dredge spoil islands, on salt pond levees, on rooftops of waterfront buildings in major metropolitan areas, on moored barges, and on the ground at abandoned commercial sites near water (Shugart and Tirhi 2001, Collis et al. 2002, BRNW 2011, 2012, 2013, 2014a, 2015a, 2016a, 2017a). Within the Pacific Flyway in particular, many Caspian terns no longer nest in relatively small colonies in ephemeral natural habitats that frequently relocate because nesting habitat has become unsuitable or disturbed by predators (Suryan et al. 2004). Instead, in the past several decades large breeding colonies have formed in the Columbia River estuary, the Columbia Plateau region, and elsewhere on more stable anthropogenic habitats; these colonies have often persisted for decades regardless of predator disturbances (BRNW 2012, 2017a). The lack of alternative suitable nesting habitats near reliable food sources within much of the Pacific Flyway region, as well as an abundance of high-quality forage fish near fewer, but larger colony sites associated with the Columbia River, has likely contributed to the recent pattern of greater nest site fidelity among Caspian terns throughout much of the Pacific Flyway.

In the Columbia Plateau region, a small number of Caspian terns were documented nesting at Moses Lake, Washington, as far back as 1929 (Kitchin 1930); however, the number of Caspian tern breeding colonies in the region increased to around five, and the average number of breeding pairs throughout the region increased to about 860 by 2005-2010 (Adkins et al. 2014). In 2013, the year prior to the initiation of management actions to enhance salmonid smolt survival by reducing the number of breeding pairs using the Columbia Plateau, about 775 breeding pairs nested at five colony sites throughout the Plateau region, the largest of which were located at Goose Island in Potholes Reservoir and at Crescent Island in McNary Reservoir on the Columbia River (BRNW 2014b). Antolos et al. (2004) found that over 60% of the diet of Caspian terns nesting at Crescent Island consisted of salmonid smolts (*Oncorhynchus* spp.). Caspian terns breeding at the Goose Island colony have been documented to fly over 60 km round-trip to the Columbia River (Maranto et al. 2010) and make 180-km round trip flights to the lower Snake River in order to forage on anadromous salmonid smolts (BRNW 2014). Estimates of Caspian tern predation rates on ESA-listed steelhead smolts (*O. mykiss*) from the Upper Columbia River population have been as high as 20% in some years, based on smolt PIT tags recovered at these colonies (Evans et al. 2012; Evans et al. 2016; Evans et al., In press). Predation on anadromous juvenile salmonids by Caspian terns nesting at Goose and Crescent islands on the Columbia Plateau, combined with predation by Caspian terns nesting at sites near the mouth of the Columbia River, has been identified as a contributing factor limiting the recovery of threatened and endangered ESUs/DPSs within the Columbia River basin (Collis et al. 2002; USACE 2006; Lyons et al. 2011; Evans et al. 2012), especially steelhead populations (Evans et al., In press).

In an effort to reduce predation on ESA-listed salmonid smolts out-migrating through the Columbia River system, management actions to dissuade nesting activity and displace Caspian terns from the two historically largest breeding colonies in the Columbia Plateau region (Goose Island and Crescent Island colonies) were implemented by the U.S. Army Corps of Engineers – Walla Walla District (USACE) as part of the *Inland Avian Predation Management Plan* (IAPMP; USACE 2014). Recognizing that alternative nesting habitat was available in the Columbia Plateau region, the management objectives of the IAPMP were to reduce the size of Caspian tern breeding colonies throughout the Plateau region to fewer than 40 breeding pairs at each colony site, and fewer than a total of 200 breeding pairs throughout the Columbia Plateau. The ultimate goal was to reduce predation on ESA-listed salmonid populations by Caspian terns nesting in the Plateau region to less than 2% per breeding colony and 5% overall (USACE 2014). Management actions were undertaken by resource management agencies (i.e. USACE and U.S. Bureau of Reclamation [BOR]) at the Goose Island colony beginning in 2014, and similar actions were undertaken at Crescent Island in McNary Reservoir on the Columbia River beginning in 2015. Management actions and Action Effectiveness Monitoring at Goose and Crescent islands continued through the 2019 breeding season in an effort to redistribute Caspian terns from these two breeding colony sites in the Columbia Plateau region to colony sites elsewhere within the Pacific Flyway (USFWS 2005). Concurrently, research was conducted to identify hotspots of Caspian tern predation on smolts along the mid-Columbia River in order to adaptively manage those sites and protect out-migrating smolts.

As one component of Action Effectiveness Monitoring, and with the support of the Grant County Public Utility District (GPUD) and the Priest Rapids Coordinating Committee (PRCC), we conducted a satellite tracking study to monitor the response of Caspian terns displaced from breeding colonies on Goose and

Crescent islands during implementation of the IAPMP. Prior to the initiation of management at these two tern colonies in 2014 and 2015, we deployed solar-recharging tracking devices on adult Caspian terns using a long-duration tag attachment method that allowed us to monitor the dispersal, foraging site use, and colony connectivity of displaced individuals through the 2018 breeding season. Previous annual reports on this study have described several broad categories of response to management by the satellite-tagged sample of Caspian terns: (1) some individuals returned to the Columbia Plateau for the breeding season and continued to be associated with colonies and foraging sites in the Plateau region; (2) some other individuals returned to the Columbia Plateau region briefly at the beginning of the breeding season, but then traveled widely throughout the Pacific Flyway visiting other tern colonies and possibly returned to the Plateau region after prospecting in other regions; (3) some individuals relocated to relatively nearby colony sites outside the Columbia Plateau region, possibly making short visits back to the Plateau region; and (4) a small number of individuals abandoned the Columbia Plateau region altogether and engaged in long distance dispersal away from the Columbia Plateau region (BRNW 2016b, 2017b). Here we analyze the Caspian tern tracking data collected during 2014-2018 to assess factors potentially affecting the use of the Columbia River and Snake River basins, philopatry (or lack thereof) to the Columbia Plateau region, and associations with breeding colonies throughout the Pacific Flyway. These analyses synthesize the outcome of five years of tracking Caspian terns that were displaced from their nesting colony by management actions in the Columbia Plateau region.

METHODS

Study Area – Our study area consisted of the Columbia Plateau region, which includes portions of the states of Washington, Oregon, and Idaho (Figure 1), and is part of the Pacific Flyway of North America north of the US/Mexico border and south of the US/Canada border (Figure 2). Within the Columbia Plateau region, we included colony sites managed to reduce nesting by Caspian terns, historical Caspian tern colony sites identified by the IAPMP as at-risk for recolonization or increased use by nesting Caspian terns in response to management (USACE 2014), and the sites of new Caspian tern colonies that formed following the implementation of the IAPMP. Within the Pacific Flyway, we included well-established historical Caspian tern colony sites and tern colonies active for multiple years during the study period; this included the colony sites in the Columbia River estuary that are actively managed to limit or prevent Caspian terns from nesting, as well as islands constructed by the USACE to provide alternative Caspian tern nesting habitat as part of the plan *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary* (USACE 2006) and the IAPMP (USACE 2014).

Capture and Tagging – We used a Netblaster compressed air-powered net launcher (Wildlife Control Supplies, East Granby, CT) to capture Caspian terns at their colony sites on Goose Island in Potholes Reservoir and on Crescent Island in McNary Reservoir; both of these Caspian tern colonies were located in the State of Washington (Figure 1). We used social attraction (i.e. decoys and audio playback) to attract pre-breeding adult Caspian terns to land within the capture footprint of the net launcher as they returned to the colony site from their wintering range in March and April. Once captured, terns were temporarily held in crates prior to applying leg-bands and/or attaching satellite tags. Captured adult terns that had not previously been banded were fitted with an U.S. Geological Survey metal leg-band and two small plastic colored bands on the left leg, and a uniquely coded plastic field readable alphanumeric color band on the right leg. When a Caspian tern was captured that had been previously banded as part of a long-term demographic study in the region, we checked the condition of existing bands and replaced them as needed (see Appendix). To track captured individuals, we selected Platform Transmitting Terminal (PTT) tags that transmit to the ARGOS satellite network and use the Doppler Effect to estimate location, with precision varying from several 10s of meters to a km or more, depending on satellite position during location fixes. We attached the PTT tags to healthy adult terns weighing ≥ 550 g using either a leg-loop or backpack harness of 0.2-inch tubular Teflon tape (Bally Ribbon Mills, Bally, PA). Tags (model: PTT-100-12g solar; Microwave Telemetry Inc., Columbia, MD) were factory-programmed to operate on a 32-hour duty cycle, with 6 hours "on" and 26 hours "off," transmitting at a 60-second repetition rate during the "on" period of each cycle. Each tag included a small solar panel to recharge the battery, which allowed for extended tag life and transmission of location data during daylight or nighttime hours. Tags weighed 12.4 – 12.9 g, not including harness materials, and were ≤ 2.3% of body mass for all individual tagged terns (body mass of tagged terns ranged from 560 g to 720 g). We collected breast feathers from each captured tern to allow DNA-based determination of sex; feather samples were sent to Animal Genetics, Inc. (Tallahassee, FL) for testing.

Data filtering and analysis – Raw position fixes of tagged terns were reported daily by the Argos System (CLS America, Inc., Largo, MD). We used the Douglas Argos-Filter Algorithm (Douglas et al. 2012) to remove spurious locations from the raw data, using criteria similar to other seabird telemetry studies (e.g., Courtot et al. 2012). Location precision of tags using the ARGOS satellite network can range from ≤ 150 m (Class 3) to > 1 km (Class 0); however, we removed any location with > 1 km estimated accuracy from the data set used for analyses following the filtering process. Consistent with the management objective of minimizing Caspian tern predation on out-migrating steelhead smolts, we focused our data analyses on the steelhead smolt out-migration period (i.e. the 95% runtime, as measured at Bonneville Dam; FPC 2014, 2015, 2016, 2017, 2018) during each year (Table 1). In addition, we limited our data set to those individuals that had actively transmitting tags for ≥ 75% of the duration of each yearly runtime. We censored 2018 data from individuals tagged at Goose Island because only three individuals tagged at Goose Island were still providing location fixes in 2018 (i.e. the fifth breeding season following initiation of management actions at that colony site), which was considered an inadequately small sample size. In addition, because we were interested in potential response differences based on the sex of the individual, we did not use the telemetry data from one individual that was captured late in the 2014 breeding season and not sexed following banding and tagging.

First, we investigated the effects of management actions on the foraging behavior of satellite-tagged Caspian terns in the Columbia Plateau region by dividing the river into three separate reaches of interest: (1) the Columbia River from Chief Joseph Dam downstream to the confluence with the Snake River; (2) the Snake River from Steamboat Island to the confluence with the Columbia River; and (3) the Columbia River from the confluence with the Snake River downstream to The Dalles, Oregon (Figure 1). Then, using ArcMap geographical information systems (GIS) software (ESRI, Redlands, CA), we created a 1-km buffer on either side of each river reach of interest and calculated the proportion of high quality locations for each individual that fell within each buffered reach as a measure of foraging use. Using this measure of foraging behavior as the response, we then applied linear mixed-effects models in the R statistical software package (R Core Team 2018; LME4 package [Bates et al. 2015]), with the individual as a random effect. We selected seven *a priori* explanatory variables that we believed might influence Caspian tern use of each river reach for foraging and evaluated candidate models that included a combination of those variables as fixed effects. The explanatory variables that we tested included (1) the colony site where an individual tern was captured (Capture Location), (2) the sex of the individual (Sex), (3) the year when the individual was captured (Capture Year), (4) the number of years since management was initiated to dissuade terns from nesting at either Goose Island or Crescent Island (Year Post-Mgmt), (5) the ordinal date of the start of the steelhead smolt out-migration (Start of Steelhead Run), (6) the duration in days of the steelhead smolt out-migration (Duration of Steelhead Run), and (7) the interaction between the ordinal start date and duration of the steelhead out-migration (Interaction between Start and Duration of Steelhead Run). To choose between candidate models, we used model selection based on the Akaike Information Criterion corrected for small sample sizes (AIC_c), and we considered any model with a $\Delta AIC_c \leq 2$ to be a supported candidate model. We used model averaging of the supported candidate models to calculate parameter estimates (Burnham and Anderson 2002).

Second, we investigated the effects of management actions on the displacement of tagged Caspian terns from the Columbia Plateau region by compiling the proportion of ARGOS satellite telemetry locations for each individual tern during each annual steelhead smolt out-migration period that was within the geographic boundaries of the Columbia Plateau region using ArcMap GIS software (Figure 1). Using this measure of tern use of the Columbia Plateau region as the response, we then applied linear mixed-effects models in the R statistical software package (R Core Team 2018; LME4 package [Bates et al. 2015]), with the individual as a random effect. We selected seven *a priori* explanatory variables that we believed might influence philopatry to the Columbia Plateau region during the peak of the steelhead smolt out-migration period, the same seven explanatory variables that were selected to investigate the effects of management on tern foraging behavior, and evaluated candidate models that included a combination of those variables as fixed effects. To choose between candidate models, we again used model selection based on the Akaike Information Criterion corrected for small sample sizes (AIC_c), and we considered any model with a $\Delta AIC_c \leq 2$ to be a supported candidate model; we used model averaging of the supported candidate models to calculate parameter estimates (Burnham and Anderson 2002). In addition, we used kernel density estimates (KDE) in ArcMap and Geospatial Modeling Environment software (Spatial Ecology LLC) to graphically represent the utilization distribution of tagged individuals within the Columbia Plateau region during each year of the study.

Third, we examined the effects of IAPMP management actions on Caspian tern use of colony sites in the Columbia Plateau region (Figure 1) by creating a circular buffer with a 1-km radius around each Caspian tern colony of interest in the Plateau region using ArcMap GIS software. We then calculated the proportion of high-quality locations for each individual that fell within the buffered area around colonies each year during steelhead smolt out-migration. Using this measure of colony use as a response, we then applied linear mixed-effects models in the R statistical software package (R Core Team 2018; LME4 package [Bates et al. 2015]), with the individual as a random effect. We selected seven *a priori* explanatory variables that we believed might influence philopatry to nesting sites in the Columbia Plateau region during the peak of the steelhead smolt out-migration period, the same seven explanatory variables that were selected to investigate the effects of management on foraging behavior and displacement from the Columbia Plateau region, and evaluated candidate models that included a combination of those variables as fixed effects. As before, we used model selection based on the Akaike Information Criterion corrected for small sample sizes (AIC_c) to choose among candidate models, and considered any model with a $\Delta AIC_c \leq 2$ to be a supported candidate model; we used model averaging of the supported candidate models to calculate parameter estimates (Burnham and Anderson 2002).

Finally, we examined the effects of IAPMP management actions on Caspian tern use of colony sites outside of the Columbia Plateau region (Figure 2). Using ArcMap GIS software, we created a circular buffer with a 1-km radius around the Caspian tern colonies within the Pacific Flyway that were located outside of the Columbia Plateau region. Next, we calculated the proportion of high-quality locations for each individual that fell within any of the buffered colonies each year during the steelhead smolt out-migration. Using this measure of colony use as a response, we then applied linear mixed-effects models in the R statistical software package (R Core Team 2018; LME4 package [Bates et al. 2015]), with the individual as a random effect. We selected seven *a priori* explanatory variables that we believed might influence use of nesting sites outside of the Columbia Plateau region during the peak of the steelhead smolt out-migration period, the same seven explanatory variables that were selected to investigate the effects of management on foraging behavior, displacement from the Columbia Plateau region, and use of colony sites within the Columbia Plateau region; we evaluated candidate models that included a combination of those variables as fixed effects. As before, we used model selection based on the Akaike Information Criterion corrected for small sample sizes (AIC_c) to choose among candidate models, and considered any model with a $\Delta AIC_c \leq 2$ to be a supported candidate model; we again used model averaging of the supported candidate models to calculate parameter estimates (Burnham and Anderson 2002).

RESULTS

In 2014, we attached PTT tags to 30 adult Caspian terns that were captured at the colony site on Goose Island in Potholes Reservoir prior to the onset of nesting. In 2015, prior to the breeding season, we deployed an additional 18 PTT tags on terns captured at Goose Island and deployed another 28 PTT tags on terns captured at Crescent Island in McNary Reservoir on the Columbia River (Table 2). We tracked each of these 76 tagged Caspian terns for an average of 705 days (SD = 406, range = 1 day – 4.26 years). Considering terns that were tagged at either colony site, we tracked the movements of 56 tagged Caspian terns during the steelhead smolt out-migration period in the initial year of management (Year 0; 2014 for Goose Island terns, 2015 for Crescent Island terns), 53 tagged terns during the steelhead out-migration in the second breeding season following the initiation of management (Year 1), 36 tagged terns during the steelhead out-migration in the third breeding season following the initiation of management (Year 2), and 16 tagged terns during the steelhead out-migration in the fourth breeding season following the initiation of management (Year 3; 2017 for Goose Island terns, 2018 for Crescent Island terns; Table 3). Of the 76 Caspian terns fitted with tags, 36 were female (47.4%), 39 were male (51.3%), and the sex of one individual was undetermined. Of the 76 individuals that were captured and fitted with PTT tags, 24 had been banded prior to being captured for PTT tagging and had a history of previous resightings; one of these previously banded individuals was banded as early as 2003 (see attached Supplemental Data spreadsheets).

Model selection analyses of factors influencing the use of the Columbia River from Chief Joseph Dam to the confluence with the Snake River by foraging Caspian terns indicated that there were five competing candidate models (Table 4), given the data. Of these competitive models, the explanatory variable “Colony Location” was present in all five, and the explanatory variable “Year Post-Mgmt” was present in four of the five competitive models. The model containing both of these explanatory variables had an AIC_c weight of 0.36 (Table 4). In addition, using the conditional model averaging of the top candidate models, the parameter estimates of these two explanatory variables were the only variables whose effects on the response variable were significant; “Colony Location” had a very strong effect on whether the tagged tern foraged in this reach of the Columbia River ($p < 0.0001$), plus there was support for a decline in the use of this river reach over time following the initiation of management ($p = 0.03$; Table 5). On average, Caspian terns that had been captured and tagged at Goose Island in Potholes Reservoir were detected much more frequently along this river reach ($\bar{x}$ = 10.3% ± 1.0% SE of telemetry locations) compared to Caspian terns that were captured and tagged at Crescent Island in McNary Reservoir ($\bar{x}$ = 0.9% ± 0.3% SE of telemetry locations; Figure 3). There was also a trend of declining detections of foraging terns from either colony along the Columbia River from Chief Joseph Dam to the confluence with the Snake River as time elapsed since the initiation of management at Goose Island and Crescent Island (Figure 4). The decline in the proportion of tern detections in this river reach with time was much more pronounced for terns that were captured and tagged at Goose Island in Potholes Reservoir compared to those tagged at Crescent Island in McNary Reservoir. The percentage of telemetry locations detected along this river reach for terns tagged at Goose Island declined from a mean of 13.4% (± 1.6% SE) of telemetry locations during the year when management was first implemented to a mean of 5.8% (± 1.6% SE) of telemetry locations four years after implementation of management to eliminate the Goose Island colony of Caspian terns (Figure 5).

Similarly, the explanatory variable "Colony Location" was the factor most significantly associated with foraging use of the Columbia River from the confluence with the Snake River downstream to The Dalles, Oregon (Table 6); terns captured and tagged at the Crescent Island colony were detected much more frequently along this river reach ($\bar{x}$ = 64.3% ± 4.4 SE) than terns captured and tagged at Goose Island in Potholes Reservoir ($\bar{x}$ = 19.1% ± 2.8 SE; Figure 6). Model selection indicated that there were four competing candidate models that best described foraging use by tagged terns of the Columbia River from the confluence with the Snake River to The Dalles, given the data (Table 6); the explanatory variable "Colony Location" was included in all four competitive models. In addition, using the conditional model averaging of the top candidate models, the parameter estimate for the explanatory variable "Colony Location" was the only variable whose effect on the response variable was significant, and had a very strong effect on whether the tagged tern foraged along this reach of the Columbia River (p < 0.0001; Table 7). The model containing only "Colony Location" (Goose Island vs. Crescent Island) had an AIC_c weight of 0.42. In the fourth year after management was initiated at the Crescent Island colony, the median percentage of telemetry locations along the Columbia River between the confluence with the Snake River and The Dalles for terns that were tagged at that colony was lower than during the previous three years (Figure 7); however, we did not detect a statistically significant decline in use of this river reach by tagged terns after the initiation of management to prevent terns from nesting at Crescent Island (p = 0.3; Kruskal-Wallace rank sum test).

We found relatively little use by tagged Caspian terns of the lower Snake River for foraging, as measured by the proportion of telemetry locations detected along the Snake River between Steamboat Island and the confluence with the Columbia River (ca. 2.3% of all telemetry location on average each year). Model selection indicated that there were eight competitive candidate models, given the data, that explained variation in foraging use by tagged terns of the lower Snake River; "Sex" was an explanatory variable that was present in six of the eight models (Table 8). The model containing only "Sex" had an AIC_c weight of only 0.22, however. Also, the Null model was included in the set of eight competitive models (ΔAIC_c = 0.94) with an AIC_c weight of 0.14 (Table 9). Although there was some suggestion that female tagged terns were more likely to use the lower Snake River for foraging than male tagged terns (p = 0.054), the Null model also received support from the data, indicating that none of the explanatory variables explained much of the variation in the propensity of tagged terns to forage along the lower Snake River (Figure 8; Table 9).

Based on the results from linear mixed modelling, there was support for decreased use of the Columbia Plateau region by tagged Caspian terns following management to prevent terns from nesting at the colony sites on Goose and Crescent islands. The proportion of tagged tern telemetry locations that were within the Columbia Plateau region declined from 83.7% (± 3.9% SE) during the first steelhead out-migration period after the initiation of management to 68.1% (± 9.2% SE) during the fourth steelhead out-migration period after the initiation of management (Figure 9). Model selection indicated that there were five competitive candidate models for describing variation in the use by tagged terns of the Columbia Plateau region following management; the explanatory variable "Year Post-Mgmt" was included in all five competitive models (Table 10). The model containing only the variable "Year Post-Mgmt" had an AIC_c weight of 0.26. Although the top model included the explanatory variable "Start of Steelhead Run," parameter estimation using conditional model averaging of the top candidate models provided little support for an effect of this variable on the propensity of tagged terns to remain in the Columbia Plateau region ($p = 0.11$; Table 11). Although model selection indicated a decline in the use of the Columbia Plateau region by tagged terns following management at the Crescent Island and Goose Island colony sites, the KDE analysis indicted that tagged terns that remained in the Plateau region continued to use many of the same foraging, roosting, and nesting locations during the first four steelhead outmigration periods after the initiation of management (Figure 10). The KDE analysis indicated that terns captured and tagged at Goose Island began using the Blalock Islands in John Day Reservoir on the Columbia River during the first steelhead out-migration period after the initiation of management to prevent tern nesting at Goose Island (2014), and the Blalock Islands remained a hotspot of tern activity, especially after terns were prevented from nesting on Crescent Island starting in 2015 (Figure 10). By the 2018 breeding season, nearly all of the tags deployed at Goose Island, Potholes Reservoir had stopped transmitting (only three PTT tags deployed at Goose Island were still transmitting); consequently, the KDE analysis indicated that Caspian tern use was highly concentrated at nesting, foraging, and loafing sites along McNary and John Day reservoirs on the Columbia River by terns that had been tagged at Crescent Island more than three years earlier.

Along with decreased use by tagged terns of the Columbia Plateau region as a whole, there was also strong support for decreased use of the available colony sites in the Plateau region following management actions to prevent tern nesting at Goose and Crescent islands (Table 12). Model selection indicated that there were seven competitive candidate models for describing variation in the use of colony sites in the Columbia Plateau region by tagged terns following management; the explanatory variable "Year Post-Mgmt" was included in all seven competitive models (Table 13). The model containing only the variable "Year Post-Mgmt" had an AIC_c weight of 0.25. There was a decline in the proportion of telemetry locations from tagged terns that were detected at colony sites in the Columbia Plateau region from 50.7% (± 3.3% SE) during the first steelhead out-migration period after initiation of management to 36.3% (± 5.9% SE) during the fourth steelhead out-migration period after management (Figure 11).

Model selection indicated that there were six competitive candidate models for describing variation in the proportion of telemetry locations for tagged terns that were detected at Caspian tern colony sites outside of the Columbia Plateau region; the explanatory variable "Duration of Steelhead Run" was included in all six competitive models. The model containing only the variable "Duration of Steelhead Run" had an AIC_c weight of 0.31 (Table 14). Although the median proportion of telemetry locations for tagged terns detected at colony sites outside of the Columbia Plateau region was greater in 2018, when the duration of the steelhead out-migration (period when 95% of the steelhead run passed) was 43 days (Figure 12), model averaging of parameter estimates in our analysis did not provide support for a significant effect of any of the explanatory variables on the proportion of tagged terns using colony sites outside the Columbia Plateau region (Table 15).

DISCUSSION

We were able to examine the movements of PTT-tagged Caspian terns following the initiation of management to prevent terns from nesting at their historical breeding colonies on Goose and Crescent islands. Sixteen of the 76 PTT-tagged terns (21%) were still transmitting their location during the fourth breeding season after they were tagged. Our results indicate that fewer tagged Caspian terns were associated with the managed colonies and the Columbia Plateau region as a whole following the implementation of management. Colony monitoring during the same time period detected a 44% decrease in the number of Caspian tern breeding pairs that nested in the Columbia Plateau region in 2018 compared the pre-management average (BRNW 2019), while the Pacific Flyway breeding population of Caspian terns remained stable during the same period (2015-2018; Peck-Richardson et al. 2019). Despite this finding, results from this study indicate that terns displaced from the colonies on Goose and Crescent islands exhibited greater than expected fidelity to foraging areas and nesting sites in the Columbia Plateau region during the management period. Also, the detected locations of the sample of PTT-tagged terns in this study were early predictors of the use of alternative colony sites and nesting habitats and provided much valuable information for an adaptive monitoring and management approach.

In 2014, the first year of management to reduce the size of the Caspian tern colony on Goose Island in Potholes Reservoir, 159 Caspian tern breeding pairs (53% of the estimated size of the Goose Island colony in 2013) that were dissuaded from nesting at the historical colony site on Goose Island moved to a small nearby islet (BRNW 2015b) where Caspian terns had not previously nested. Attempts at preventing Caspian terns from nesting at Goose Island were not completely successful until 2017 (BRNW 2018). Efforts to prevent Caspian terns from nesting at Crescent Island in McNary Reservoir were completely successful in 2015, the first year of management at that colony (BRNW 2016c). As indicated by subsequent tracking of Crescent Island terns, however, many individuals from this colony relocated about 70 Rkm downstream and recruited to a breeding colony at the Blalock Islands in John Day Reservoir on the Columbia River, where Caspian terns had a history of nesting in small numbers (6 - 136 breeding pairs) with limited nesting success (BRNW 2016c). Although there were increases in the number of breeding pairs at some of the historical colony sites in the Columbia Plateau region following the initiation of management at Goose and Crescent islands, the largest post-management incease in colony size was at the Blalock Islands (BRNW 2019). Based on the movements and distribution of PTT-tagged terns from the Crescent Island and Goose Island colonies, there does not appear to be sufficient suitable nesting habitat to support the number of Caspian tern breeding pairs that nested in the Columbia Plateau region before management to prevent nesting at these two colonies. There is, however, sufficient available nesting habitat to support more than the target number of 200 breeding pairs of Caspian terns stipulated by the IAPMP.

Overall, we found considerable differences in the response of PTT-tagged terns to colony management depending on whether the tern was captured and tagged at the Goose Island colony or the Crescent Island colony. Caspian terns tagged at Goose Island were detected with greater frequency along the Columbia River above the confluence with the Snake River, while terns tagged at Crescent Island were detected mostly along the Columbia River below the confluence with the Snake River. Nevertheless, terns tagged at Goose Island used the reach of Columbia River below the confluence with the Snake River more than terns tagged at Crescent Island used the Columbia River reach above the confluence with the Snake River. Our interpretation of the greater foraging use by tagged terns of the Columbia River below the confluence of the Snake River was somewhat confounded by the use of the Blalock Islands as a breeding and loafing site by a number of tagged terns from Crescent Island. Nevertheless, our results strongly suggest that management actions to prevent Caspian terns from nesting at Potholes Reservoir have substantially reduced foraging activity by Caspian terns along the Columbia River above the confluence with the Snake River during the study period. Lastly, our ARGOS satellite telemetry data suggested relatively low foraging use by Caspian terns of the lower Snake River in all years of the study, and provided marginal support for the hypothesis that female tagged terns in our sample foraged more along the lower Snake River than did their male counterparts. This gender difference in use of the lower Snake River for foraging may be related to known gender differences in brooding rates and provisioning rates of young (Quinn 1990; Cuthbert and Wires 1999; Anderson et al. 2005).

We detected a small increase in the median proportion of telemetry locations reported at colony sites outside of the Columbia Plateau in 2018, suggesting that after 3-4 years of management to prevent nesting at the Goose Island and Crescent Island colonies some displaced terns were recruiting to colonies outside the Plateau region; however, model selection was not able to detect a statistically significant difference among years. Although model selection highlighted the explanatory variable “Duration of Steelhead Run” as a potential factor influencing the increasing level of colony use outside of the Columbia Plateau region, the pattern of use was the opposite of what was expected. The proportion of tagged terns that were detected outside the region was slightly higher in 2018, compared to 2014-2017, and yet 2018 was the year when the duration of the steelhead smolt out-migration was greater than in any other year during the study period. Serendipitously, the explanatory variable “Duration of Steelhead Run” increased during the five years of our study, suggesting that the positive association between Duration of Steelhead Run and proportion of tagged tern detections at colonies outside the Columbia Plateau region was spurious, and instead a reflection of the gradual emigration of terns from the region following management.

Drivers of tern colony use in regions outside of the Columbia Plateau region were unique to each outside region and were not reflected in the set of *a priori* explanatory variables used in our modelling. For example, concurrent with our study, Caspian tern nesting habitat in the Columbia River estuary was managed in an attempt to limit the number of terns nesting at the large colony on East Sand Island and prevent terns from nesting elsewhere in the Columbia River estuary (USFWS 2005). Also, drought conditions that negatively affected the availability of nesting habitat and forage fish for Caspian terns in the Southern Oregon/Northeastern California (SONEC) region persisted throughout the study period (BRNW 2014a, 2015a, 2016a). Similarly, Caspian tern use of colony sites in the vicinity of the Salton Sea, California, declined dramatically in recent years as salinity and alkalinity levels have increased to the point where forage fish can no longer survive (Molina 2015, 2018; Lyons et al. 2018). Caspian tern breeding colonies in the Puget Sound/Salish Sea region of Washington are now mostly on warehouse rooftops and other urban sites where nesting success is low, colony failures are frequent, and most colonies are actively hazed to disperse nesting birds (BRNW 2017a). Finally, despite the addition of Caspian tern nesting habitat that has recently been constructed at the Don Edwards San Francisco Bay National Wildlife Refuge, the number of Caspian terns nesting throughout the Bay area has remained fairly stable, with no large influxes of Caspian terns from regions to the north where management and lack of suitable nesting habitat have displaced terns (Peterson et al. 2017; Peck-Richardson et al. 2019).

As indicated by this study, Caspian terns have shown greater than expected philopatry to the Columbia Plateau region during the first four breeding season after initiation of management to prevent nesting at the two largest breeding colonies in the region. The faithfulness of tagged terns to the region was especially surprising considering the species' capacity for long-distance breeding dispersal (Schniedermeyer 2018, Suzuki et al. 2019). Management to reduce the number of Caspian terns nesting at colonies in the Columbia Plateau region to substantially less than pre-management levels, and thus reduce predation rates on threatened and endangered Columbia Basin salmonid populations, will require a sustained effort over a longer period than four years. Although many Caspian terns in the Pacific Flyway population have exploited more stable nesting habitats within foraging distance of high-quality prey over the past several decades, there are a number of recent examples of Caspian terns displaying the behavioral plasticity that has historically allowed them to colonize new nesting sites when ephemeral nesting habitat is lost. Caspian terns are a long-lived species, and previous results from this and other tagging studies, in addition to resighting of banded birds (BRNW 2014, 2015a, 2016a, 2017a, Suzuki 2012, Patterson 2012, Lyons et al. 2018, Bailey 2018), have shown that individual terns are familiar with a network of available nesting sites and foraging habitats within the Pacific Flyway. The reluctance of many Caspian terns from the Crescent Island and Goose Island colonies to emigrate to alternative colony sites, however, suggests that the overall reduction in fitness associated with repeated breeding failure and/or competition for limited nest sites at colonies in the Columbia Plateau region might still be less than elsewhere in the Pacific Flyway, or that foraging conditions are better in the Columbia Plateau region than in other regions of the Pacific Flyway. We frequently observed that tagged Caspian terns left the Columbia Plateau region and visited other active tern breeding colonies within the Pacific Flyway, only to return to the Columbia Plateau soon thereafter, suggesting that the conditions these emigrants encountered at prospective colony sites outside the region were unfavorable. As such, it may require providing additional suitable nesting habitat within commuting distance of foraging habitat with equal or greater availability of forage fish, or improvement in nesting and/or foraging conditions at currently available colony sites, in order to encourage emigration from the Columbia Plateau region by the majority of Caspian terns that have historically nested there.

LITERATURE CITED

Adkins, J.Y., D.E. Lyons, P.J. Loschl, D.D. Roby, K. Collis, A.F. Evans, & N.J. Hostetter. 2014). Demographics of piscivorous colonial waterbirds and management implications for ESA-listed salmonids on the Columbia Plateau. Northwest Science 88:344-359.

Anderson, S.K., D.D. Roby, D.E. Lyons, and K. Collis. 2005. Factors affecting chick provisioning by Caspian Terns nesting in the Columbia River estuary. Waterbirds 28:95-105.

Antolos, M., D.D. Roby, and K. Collis. 2004. Breeding ecology of Caspian terns at colonies on the Columbia Plateau. Northwest Science 78:303-312.

Bailey, O. 2018. Extrinsic and intrinsic factors associated with reproductive success of Caspian terns (*Hydroprogne caspia*) at East Sand Island, Columbia River estuary. Unpubl. M.Sc. thesis, Oregon State University, Corvallis, OR.

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67: 1-48.

BRNW (Bird Research Northwest). 2011. Research, monitoring, and evaluation of avian predation on salmonid smolts in the lower and mid-Columbia River, 2010 Final Annual Report. Submitted to the Bonneville Power Administration, the U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2012. Research, monitoring, and evaluation of avian predation on salmonid smolts in the lower and mid-Columbia River, 2011 Final Annual Report. Submitted to the Bonneville Power Administration, the U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2013. Research, monitoring, and evaluation of avian predation on salmonid smolts in the lower and mid-Columbia River, 2012 Final Annual Report. Submitted to the Bonneville Power Administration, the U.S. Army Corps of Engineers – Walla Walla District, and the U.S Army Corps of Engineers – Portland District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2014. Research, monitoring, and evaluation of avian predation on salmonid smolts in the lower and mid-Columbia River, 2013 Final Annual Report. Submitted to the Bonneville Power Administration, the U.S. Army Corps of Engineers – Walla Walla District, the U.S Army Corps of Engineers – Portland District, and the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2015a. Research, monitoring, and evaluation of avian predation on salmonid smolts in the lower and mid-Columbia River, 2014 Final Annual Report. Submitted to the Bonneville Power Administration, the U.S. Army Corps of Engineers – Walla Walla District, the U.S Army Corps of Engineers – Portland District, and the Grant County Public Utility District (GPUD)/Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2015b. Implementation of the Inland Avian Predation Management Plan, 2014 Final Annual Report. Submitted to the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2016a. Avian predation on juvenile salmonids: Evaluation of the Caspian Tern Management Plan in the Columbia River Estuary, 2015 Final Annual Report. Submitted to the Bonneville Power Administration. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2016b. Evaluation of foraging behavior, dispersal, and predation on ESA-listed salmonids by Caspian terns displaced from managed colonies in the Columbia Plateau region. 2015 Final Annual Report. Submitted to the Grant County Public Utility District and the Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2016c. Implementation of the Inland Avian Predation Management Plan, 2015 Final Annual Report. Submitted to the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2017a. Avian predation on juvenile salmonids: Evaluation of the Caspian Tern Management Plan in the Columbia River Estuary, 2016 Final Annual Report. Submitted to the Bonneville Power Administration. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2017b. Evaluation of foraging behavior, dispersal, and predation on ESA-listed salmonids by Caspian terns displaced from managed colonies in the Columbia Plateau region. 2016 Final Annual Report. Submitted to the Grant County Public Utility District and the Priest Rapids Coordinating Committee. Available on-line at www.birdresearchnw.org.

BRNW (Bird Research Northwest). 2019. Implementation of the Inland Avian Predation Management Plan, 2018. Submitted to the U.S. Army Corps of Engineers – Walla Walla District. Available on-line at www.birdresearchnw.org.

Burnham, K.P., and D.R. Anderson. 2002. Model selection and multimodel inference: A practical information-theoretic approach, 2nd ed. Springer, Berlin.

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

Courtot, K.N., D.D. Roby, J.Y. Adkins, D.E. Lyons, D.T. King, and R.S. Larsen. 2012. Colony connectivity of Pacific Coast double-crested cormorants based on post-breeding dispersal from the region's largest colony. Journal of Wildlife Management 76:1462-1471.

Cuthbert, F.J., and L.R. Wires. 1999. Caspian Tern (*Hydroprogne caspia*). The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online:http://bna.birds.cornell.edu/bna/species/403

Douglas, D.C., R. Weinzierl, S.C. Davidson, R. Kays, M. Wikelski, and G. Bohrer. 2012. Moderating Argos location errors in animal tracking data. Methods in Ecology and Evolution 3:999-1007.

Evans, A.F., N.J. Hostetter, D.D. Roby, K. Collis, D.E. Lyons, B.P. Sandford, R.D. Ledgerwood, and S. Sebring. 2012. Systemwide evaluation of avian predation on juvenile salmonids from the Columbia River based on recoveries of passive integrated transponder tags. Transactions of American Fisheries Society 141:975-989.

Evans, A.F., Q. Payton, A. Turecek, B.M. Cramer, K. Collis, D.D. Roby, P.J. Loschl, L. Sullivan, J. Skalski, M. Weiland, and C. Dotson. 2016. Avian predation on juvenile salmonids: Spatial and temporal analysis based on acoustic and Passive Integrated Transponder tags. Transactions of the American Fisheries Society 145:860-877.

Evans, A., Q. Payton, B. Cramer, K. Collis, N. Hostetter, D. Roby, and C. Dotson. In press. Cumulative effects of avian predation on Upper Columbia River steelhead. Transactions of the American Fisheries Society 000:000-000.

FPC (Fish Passage Center). 2014. Fish Passage Center smolt passage index. Available on-line at www.fpc.org.

FPC (Fish Passage Center). 2015. Fish Passage Center smolt passage index. Available on-line at www.fpc.org.

FPC (Fish Passage Center). 2016. Fish Passage Center smolt passage index. Available on-line at www.fpc.org.

FPC (Fish Passage Center). 2017. Fish Passage Center smolt passage index. Available on-line at www.fpc.org.

FPC (Fish Passage Center). 2018. Fish Passage Center smolt passage index. Available on-line at www.fpc.org.

Kitchin, E.A. 1930. Nesting observations at Moses Lake in May. Murrelet 11:55-59.

Lyons, D.E., D.D. Roby, A.F. Evans, N.J. Hostetter, and K. Collis. 2011. Benefits to Columbia River anadromous salmonids from potential reductions in avian predation on the Columbia Plateau: A report to the U.S. Army Corps of Engineers - Walla Walla District. Bird Research Northwest. Available on-line at www.birdresearchnw.org.

Lyons, D.E., A.G.L. Patterson, J. Tennyson, T.J. Lawes, and D.D. Roby. 2018. The Salton Sea: critical migratory stopover habitat for Caspian Terns (*Hydroprogne caspia*) in the North America Pacific Flyway. Waterbirds 41:154-165.

Maranto, C.J., T.P. Good, F.K. Wiese, and J.K. Parrish. 2010. Impact of the Potholes Reservoir Caspian tern breeding colony on out-migrating juvenile salmonids in the mid-Columbia River. Transactions of the American Fisheries Society 139:362-381.

Molina, K.C., 2015. The breeding of Caspian terns at the Salton Sea, California, 2015. Final Annual Report. Submitted to the Oregon State University Department of Fisheries and Wildlife.

Molina, K.C., 2018. The breeding of Caspian terns at the Salton Sea, California, 2018. Final Annual Report. Submitted to the Oregon State University Department of Fisheries and Wildlife.

Peck-Richardson, A.G., D.E. Lyons, D.D. Roby, and T.L. Lawes. 2019. Draft Annual Report: 2018 Pacific Flyway Caspian tern population monitoring. Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Peterson, R.C., D.E. Lyons, D.D. Roby, and Y. Suzuki. 2017. Final Annual Report: 2015 Pacific Flyway Caspian tern population monitoring. Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Quinn, J.S. 1990. Sexual size dimorphism and parental care patterns in a monomorphic and a dimorphic larid. Auk 107:260-274.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Schniedermeyer, E., 2018. The response of Caspian terns to managed reductions in nesting habitat in the Columbia Plateau region, Washington State, USA. Unpubl. M.Sc. thesis, Oregon State University, Corvallis, OR.

Shugart, G.W., and M. Tirhi. 2001. Nesting Caspian Terns in lower Puget Sound, Washington during 1999. Northwestern Naturalist 82:32-35.

Suzuki, Y. 2012. Piscivorous colonial waterbirds in the Columbia River estuary: demography, dietary contaminants, and management. Unpubl. Ph.D. dissertation, Oregon State University, Corvallis, OR.

Suzuki, Y., M.A. Bishop, D.D. Roby, and K.S. Bixler. 2019. Colony connectivity and the rapid growth of a Caspian Tern (*Hydroprogne caspia*) colony on Alaska's Copper River Delta, USA. Waterbirds 42:1-7.

Suryan, R.M., D.P. Craig, D.D. Roby, N.D. Chelgren, K. Collis, W.D. Shuford, and D.E. Lyons. 2004. Redistribution and growth of the Caspian Tern population in the Pacific Coast region of North America, 1981-2000. Condor 106:777-790.

USFWS (U.S. Fish and Wildlife Service). 2005. Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary: Final Environmental Impact Statement, January 2005. Migratory Birds and Habitat Programs, Portland, Oregon.

USACE (U.S. Army Corps of Engineers). 2006. Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary: Record of Decision, November 2006. U.S. Army Corps of Engineers, Portland District, Northwestern Division, Portland, Oregon.

USACE (U.S. Army Corps of Engineers). 2014. Inland Avian Predation Management Plan Environmental Assessment. U.S. Army Corps of Engineers, Walla Walla District, Northwestern Division, Walla Walla, Washington. January 2014. Available online at http://www.nww.usace.army.mil/Missions/Projects/InlandAvianPredationManagementPlan.aspx.

FIGURES

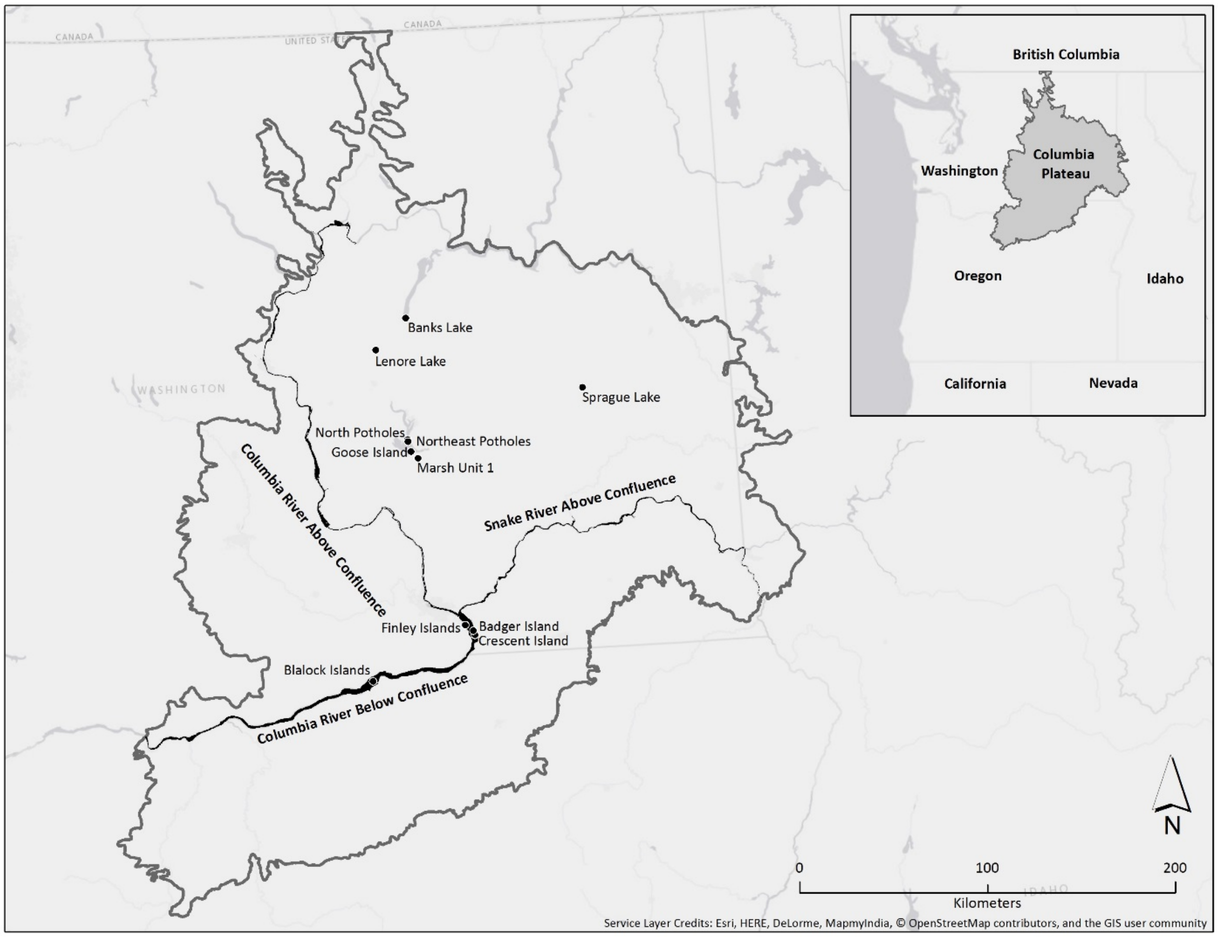

Figure 1. The Columbia Plateau region of Washington, Oregon, and Idaho, showing river reaches of interest and the location of Caspian tern breeding colonies. Those river reaches included: (1) the Columbia River from Chief Joseph Dam downstream to the confluence with the Snake River; (2) the Snake River from Steamboat Island (located approximately 15 river kilometers upstream of the confluence with the Grande Ronde River) and the confluence with the Columbia River; and (3) the Columbia River from the confluence with the Snake River downstream to The Dalles, Oregon.

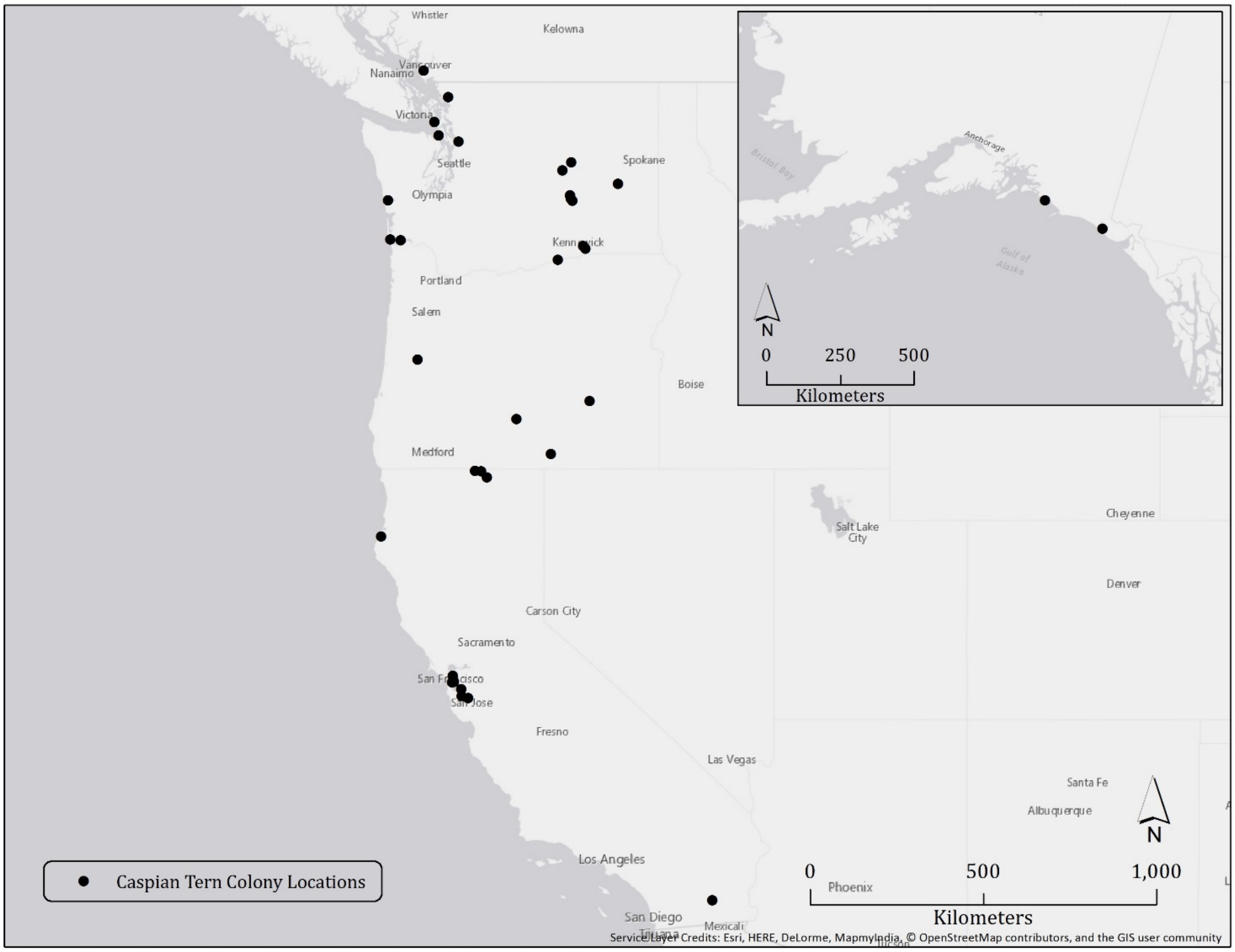

Figure 2. Locations of Caspian tern breeding colonies in the Pacific Flyway of North America north of the US/Mexico border. Colonies include those managed to prevent or reduce Caspian tern nesting activity in the Columbia Plateau region and in the Columbia River estuary, locations of historical Caspian tern colonies, new Caspian tern colonies that formed in the Columbia Plateau region following the initiation of the Inland Avian Predation Management Plan (IAPMP), Caspian tern colonies active for multiple years during the study period, and islands constructed to provide Caspian tern nesting habitat as part of the plan *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary* (USACE 2006) and the Inland Avian Predation Management Plan (USACE 2014).

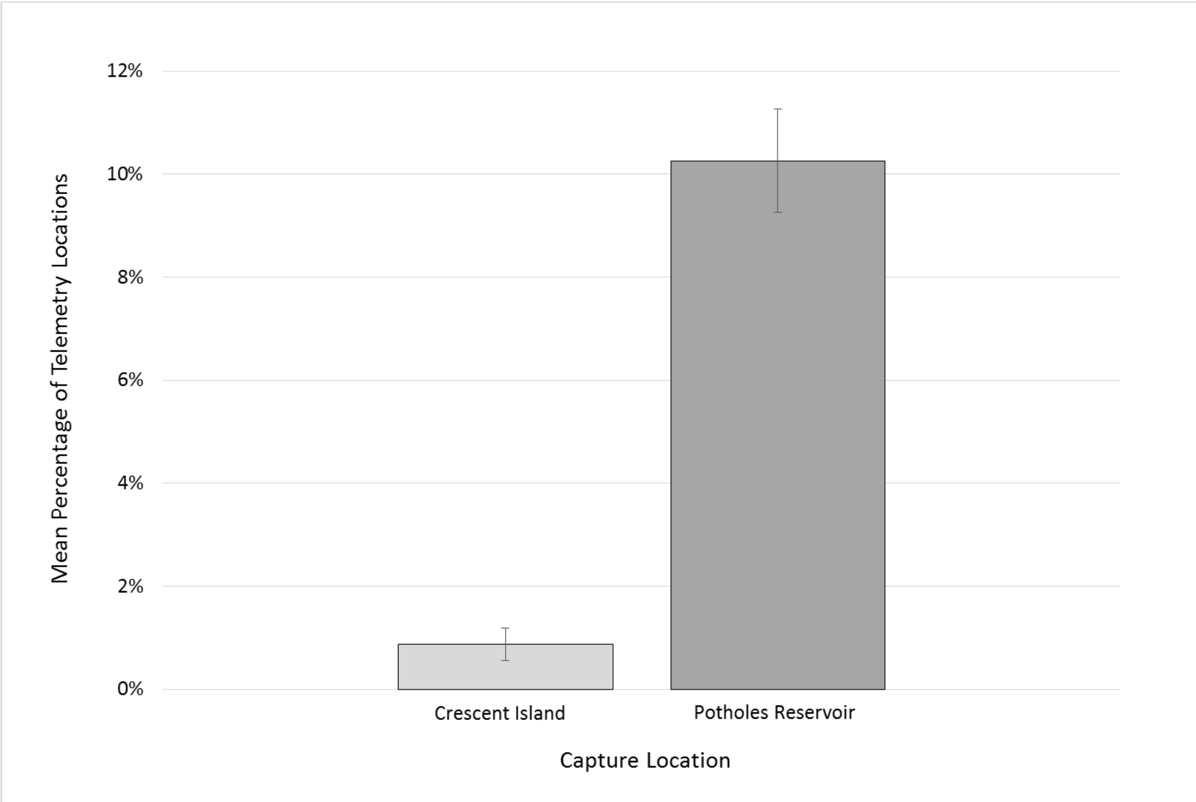

Figure 3. Mean percentage of Caspian tern telemetry locations detected along the Columbia River between the confluence with the Snake River and Chief Joseph Dam during the peak of the steelhead smolt out-migration, 2014-2018 (error bars are ± 1 SE). Percentages are depicted separately for terns captured and tagged at Crescent Island on the Columbia River and at Goose Island in Potholes Reservoir.

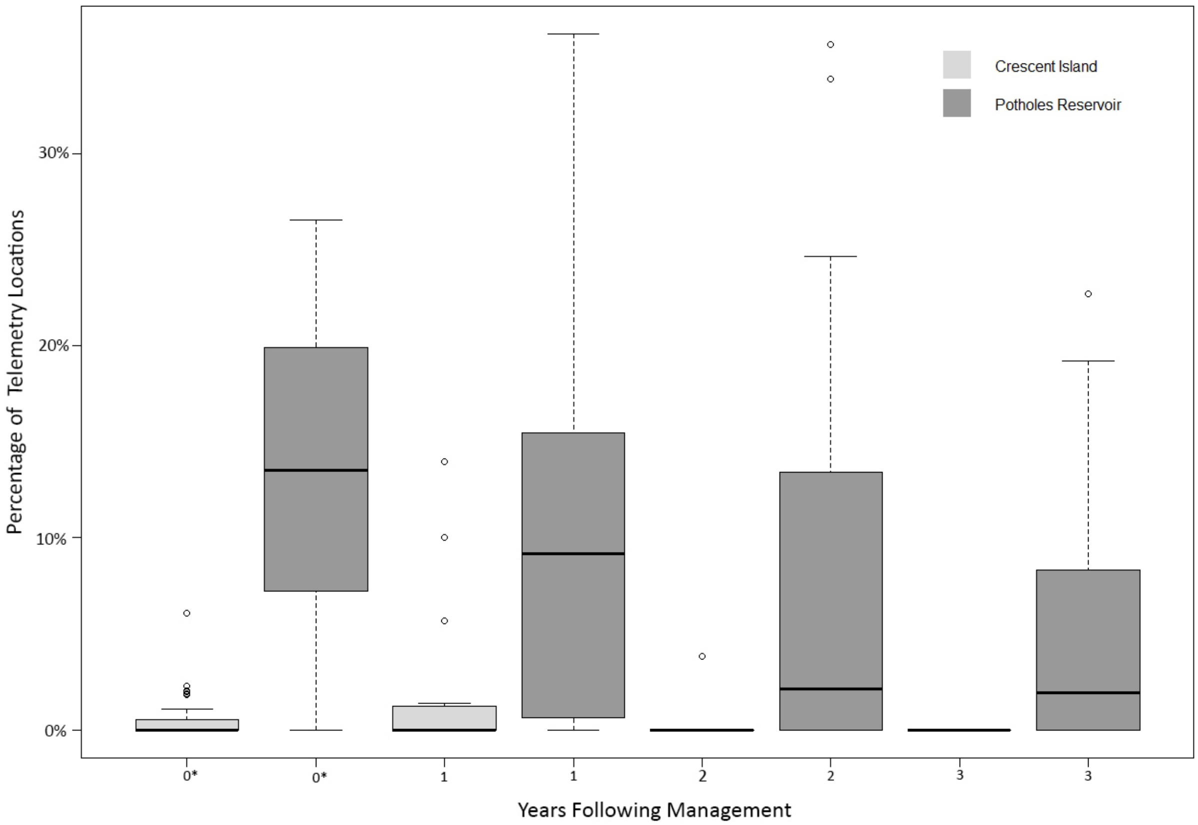

Figure 4. Foraging use of the Columbia River from Chief Joseph Dam downstream to the confluence with the Snake River by Caspian terns tagged at the colony at Goose Island in Potholes Reservoir and the colony at Crescent Island in McNary Reservoir on the Columbia River. Median, 25% percentile, 75th percentile, and range are presented during the peak of the steelhead smolt out-migration in each year following the initiation of management to prevent terns from nesting at those two colony sites.
*Year “0” was the year when management was initiated.

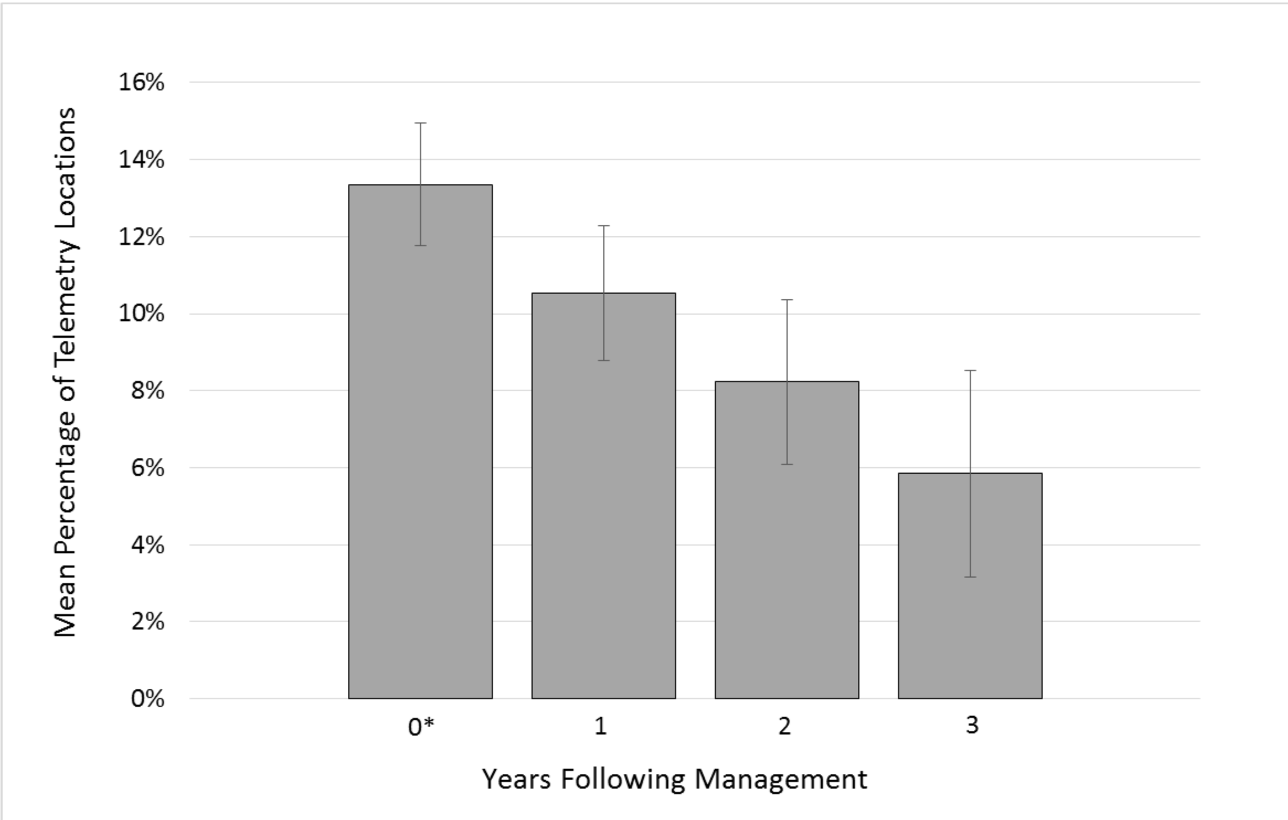

Figure 5. Mean percentage of telemetry locations for PTT-tagged Caspian terns during the peak of the steelhead smolt out-migration detected along the Columbia River from Chief Joseph Dam downstream to the confluence with the Snake River for terns tagged at Goose Island in Potholes Reservoir in each of the first four breeding seasons following the initiation of management to prevent terns from nesting at this colony site (error bars are ± 1 SE).
*Year "0" was the year when management was initiated.

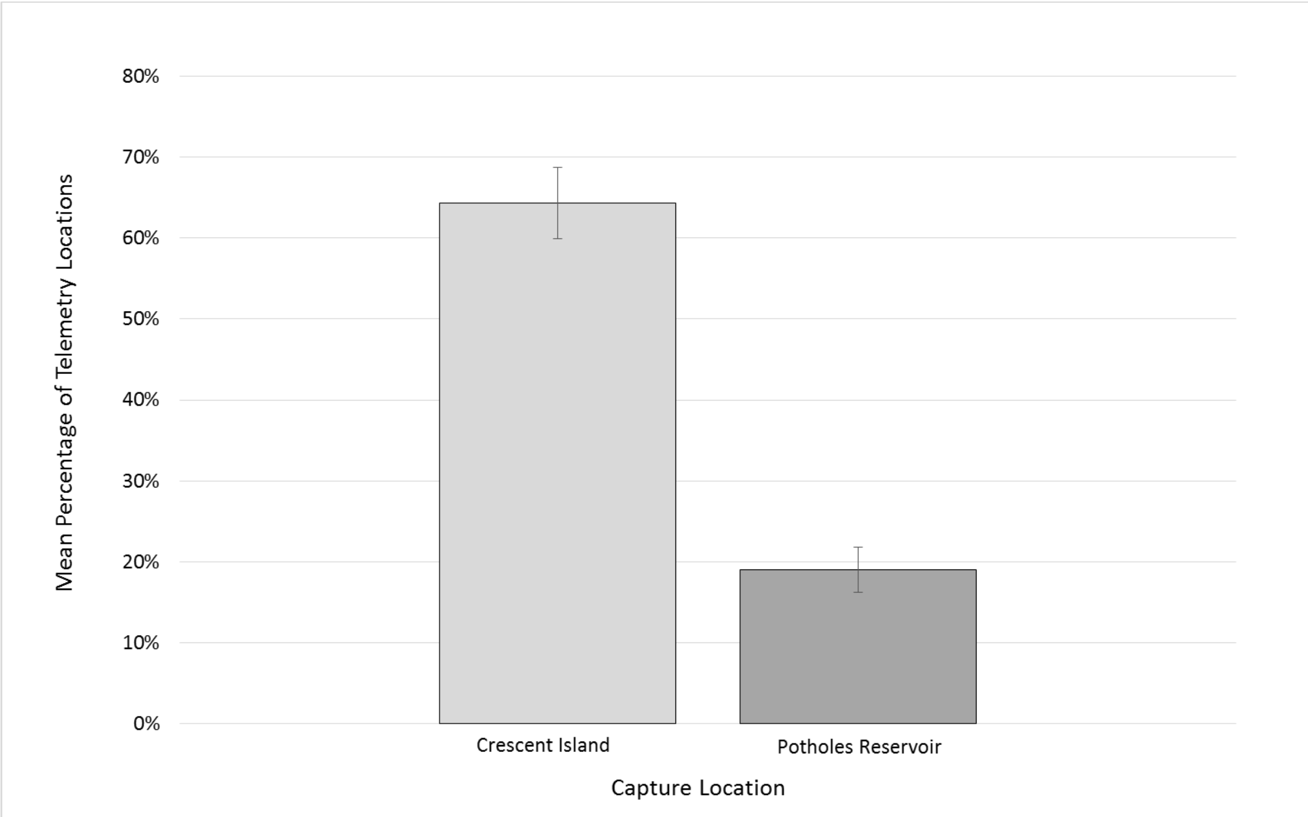

Figure 6. Mean percentage of Caspian tern telemetry locations detected along the Columbia River between the confluence with the Snake River and The Dalles, Oregon, during the peak of the steelhead smolt out-migration, 2014-2018 (error bars are ± 1 SE). Percentages are depicted separately for terns captured and tagged at Crescent Island in McNary Reservoir on the Columbia River and at Goose Island in Potholes Reservoir.

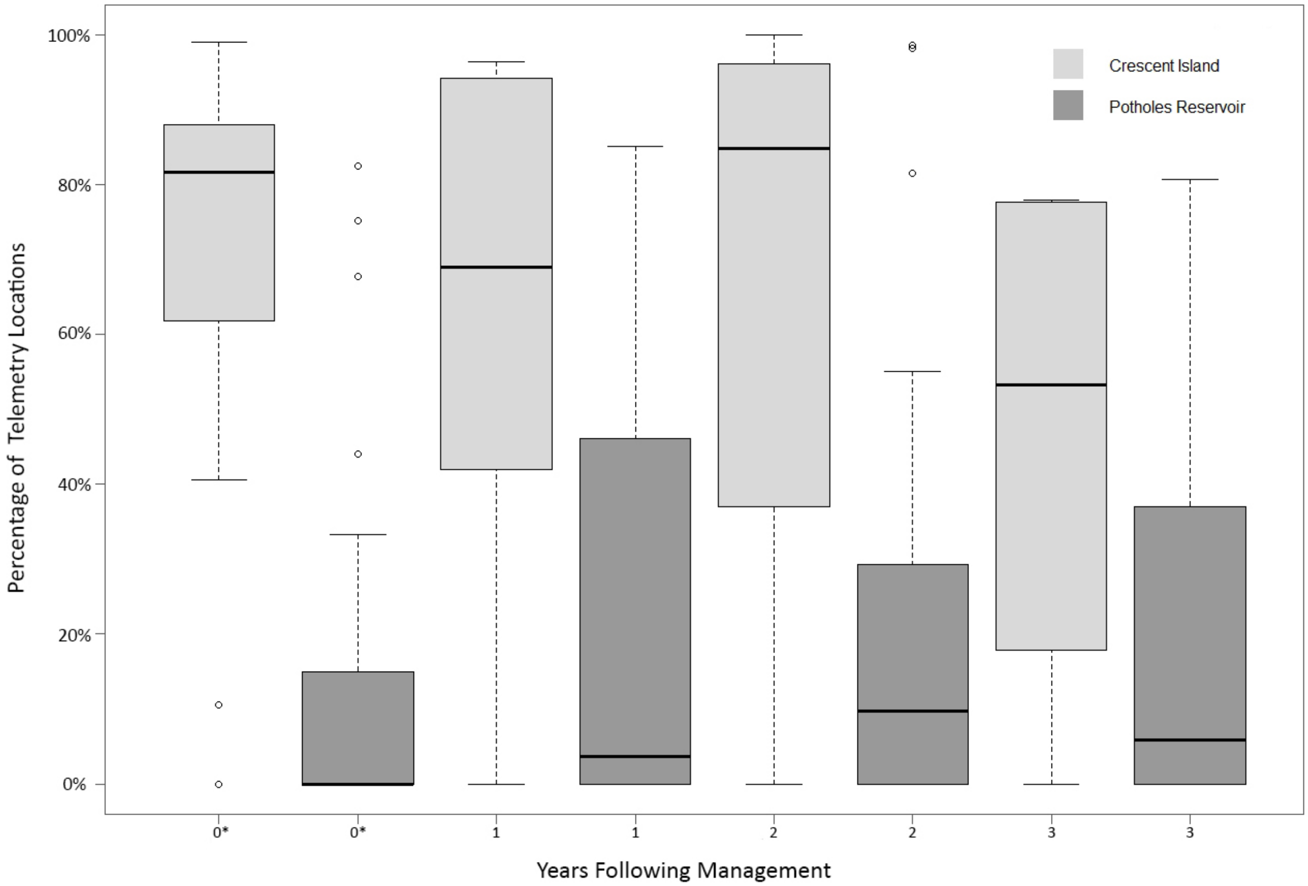

Figure 7. Use of the Columbia River between the confluence with the Snake River and The Dalles, Oregon, by Caspian terns tagged at the colony sites at Goose Island in Potholes Reservoir and at Crescent Island in McNary Reservoir on the Columbia River. Median, 25% percentile, 75th percentile, and range are presented during the peak of the steelhead smolt out-migration in the first four breeding seasons following the initiation of management to prevent terns from nesting at those two colony sites. *Year “0” was the year when management was initiated.

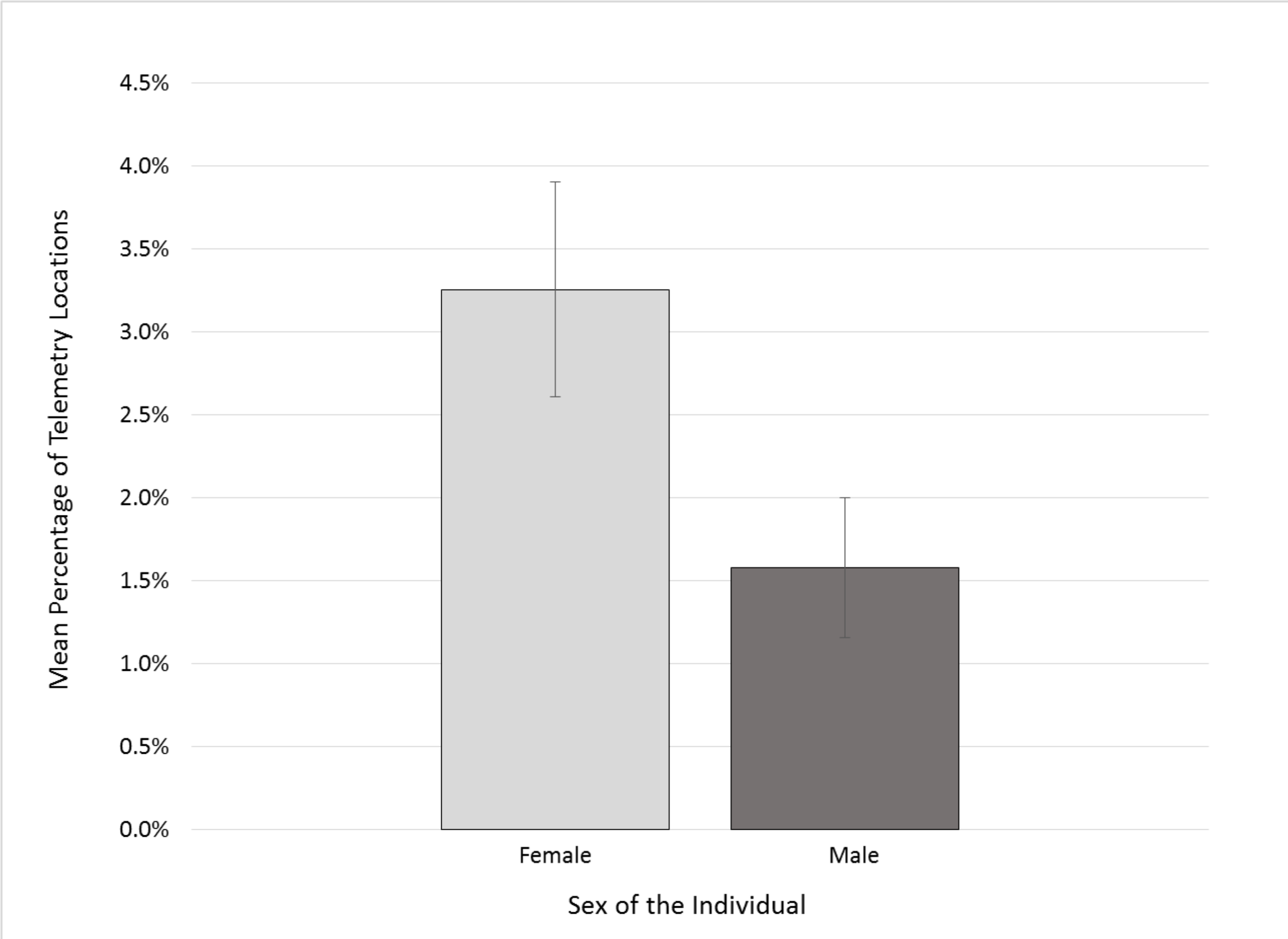

Figure 8. Mean percentage of telemetry locations of Caspian terns detected during the peak of the steelhead smolt out-migration (2014-2018) along the Snake River between Steamboat Island and the confluence with the Columbia River for terns tagged at Goose Island in Potholes Reservoir and at Crescent Island in McNary Reservoir on the Columbia River as a function of gender (error bars are ± 1 SE).

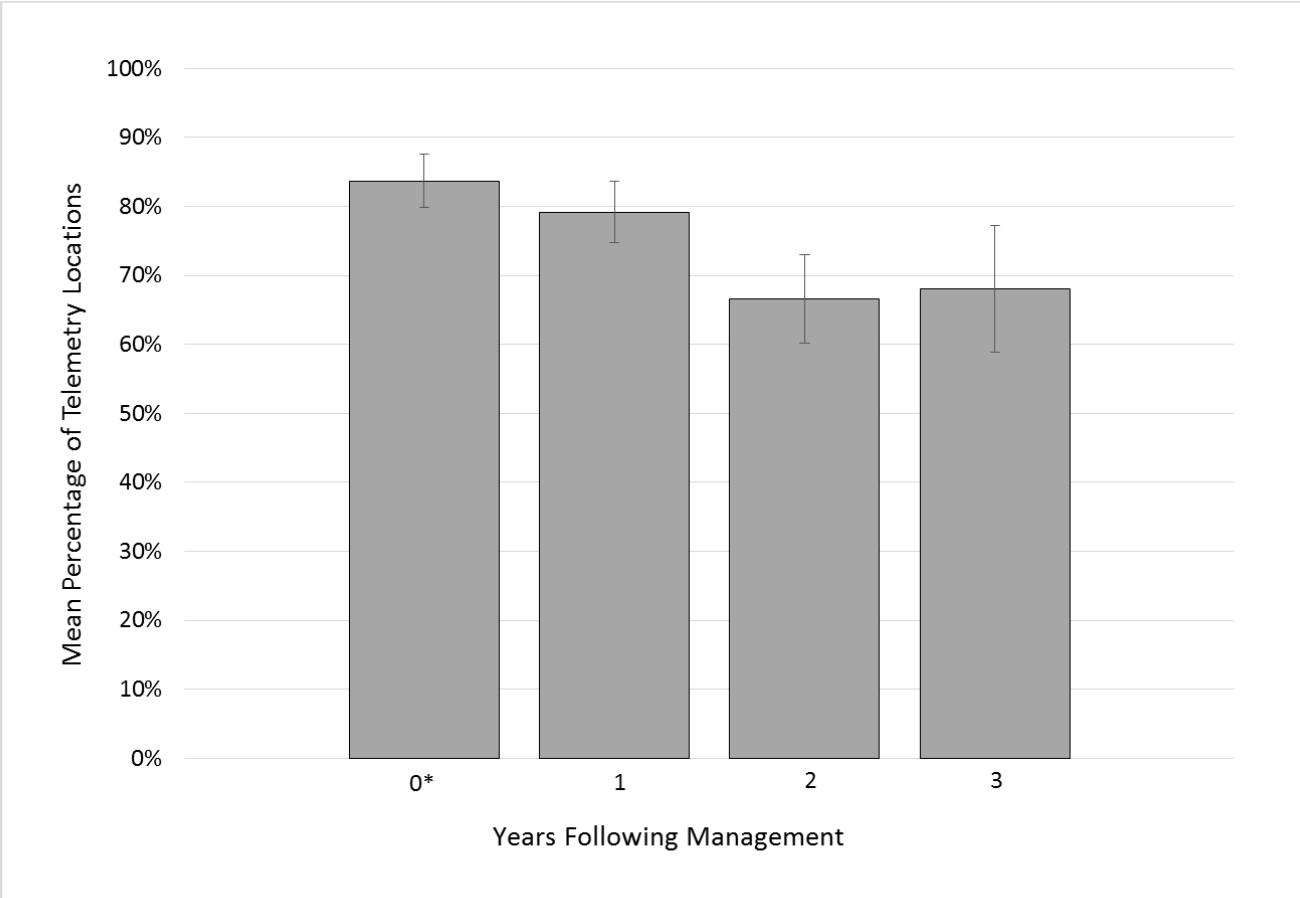

Figure 9. Mean percentage of Caspian tern telemetry locations detected in the Columbia Plateau region during the peak of the steelhead smolt out-migration for terns tagged either at Goose Island in Potholes Reservoir or at Crescent Island in McNary Reservoir on the Columbia River for the first four breeding seasons following the initiation of management to prevent terns from nesting at those two colony sites (error bars are ± 1 SE).
*Year "0" was the year when management was initiated.

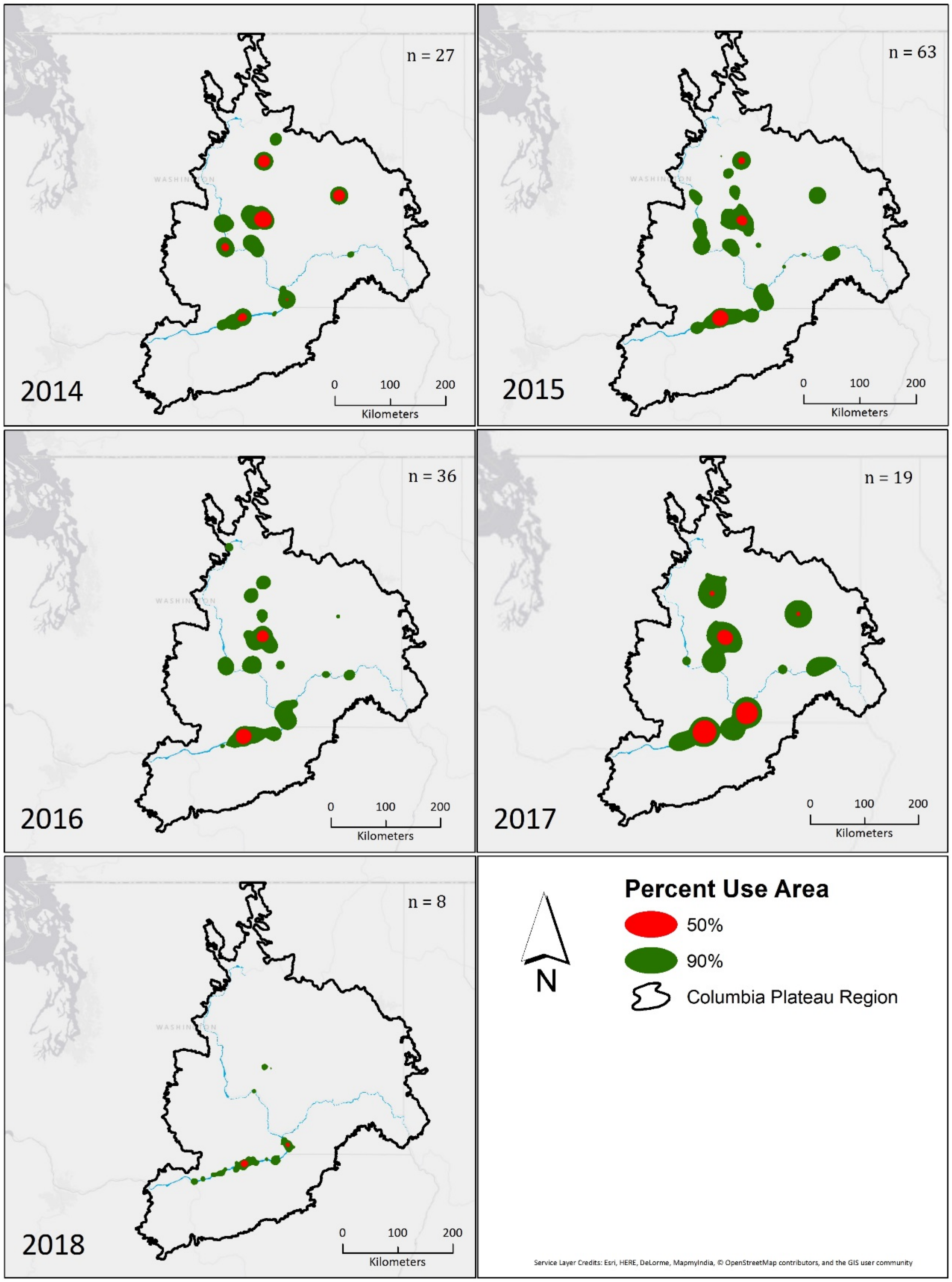

Figure 10. Utilization distributions of tagged Caspian terns across the Columbia Plateau region during the peak of steelhead smolt out-migration in 2014-2018. Red indicates the area where the probability of detecting an individual tagged tern was 50% and green indicates the area where the probability of detecting a tagged tern was 90% (note: areas of higher percentage use include the areas of lower percentage use that are contained within). Only locations within the Columbia Plateau were used.

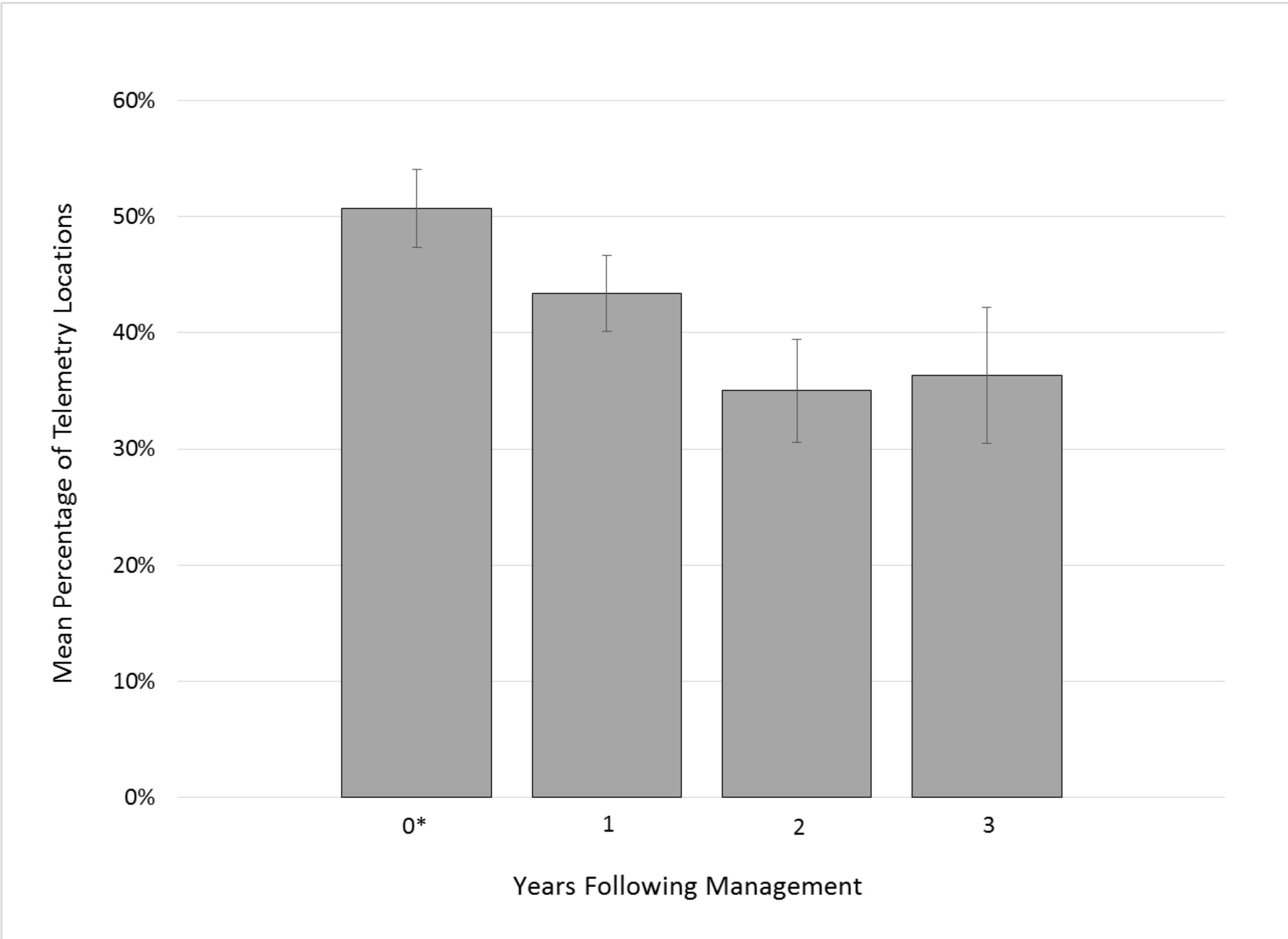

Figure 11. Mean percentage of Caspian tern telemetry locations that were detected at tern colonies in the Columbia Plateau region during the peak of the steelhead smolt out-migration for terns tagged either at Goose Island in Potholes Reservoir or at Crescent Island in McNary Reservoir on the Columbia River for the first four breeding seasons after the initiation of management to prevent terns from nesting at those two colony sites (error bars are ± 1 SE).
*Year "0" was the year when management was initiated.

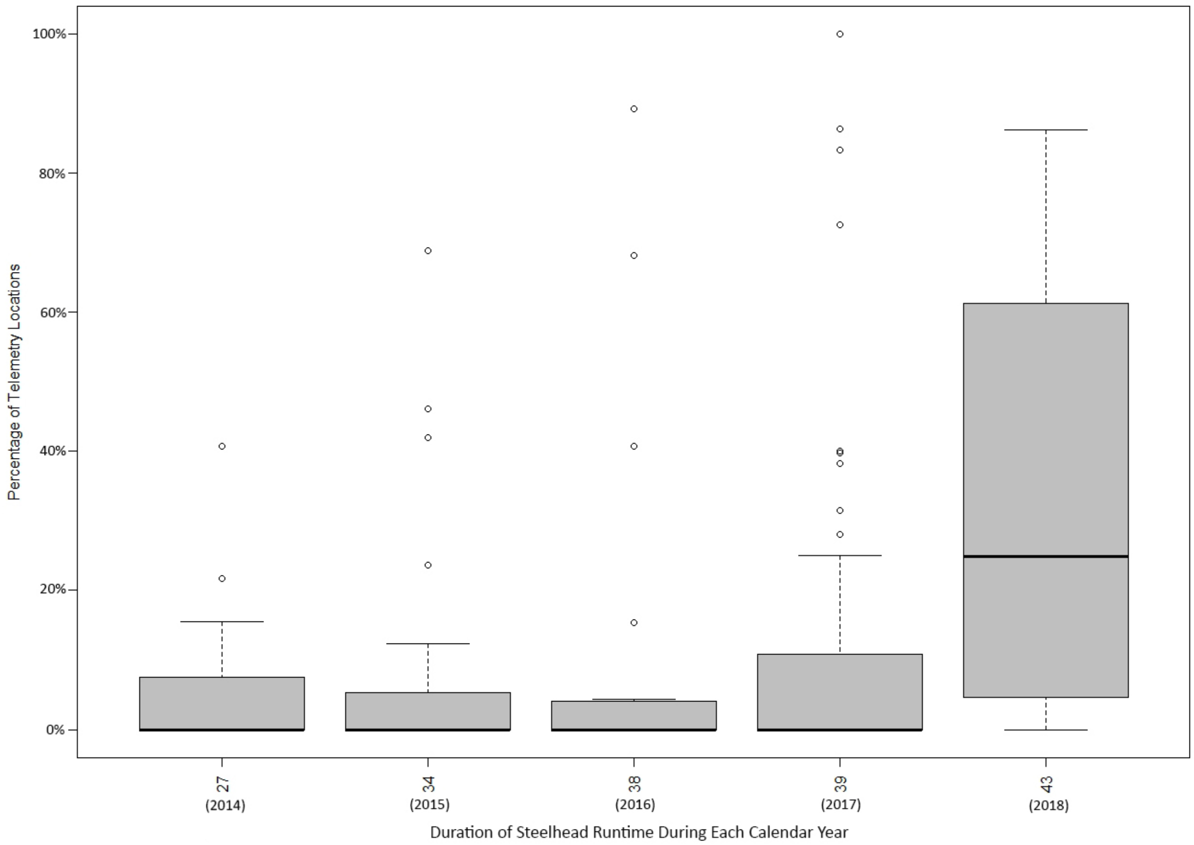

Figure 12. Use by Caspian terns of breeding colonies outside the Columbia Plateau region during the peak of the steelhead smolt out-migration by terns tagged either at Goose Island in Potholes Reservoir or at Crescent Island in McNary Reservoir on the Columbia River following management to eliminate tern nesting at those two colony sites. Median, 25% percentile, 75th percentile, and range are shown as a function of the duration of the peak of the smolt out-migration during the five-year study period (2014-2018).

TABLES

Table 1. Start date and duration of the peak of steelhead smolt out-migration as measured at Bonneville Dam on the Columbia River during 2014-2018. Peak timing was based on the 95% Passage Index for each year (FPC 2014, 2015, 2016, 2017, 2018).

	Steelhead Runtime				
Year	2014	2015	2016	2017	2018
Start Date	5-May	29-Apr	23-Apr	3-May	28-Apr
Duration (Days)	27	34	38	39	43

Table 2. Number of Caspian terns fitted with solar-powered PTT tags at Goose Island in Potholes Reservoir and at Crescent Island in McNary Reservoir on the Columbia River in 2014 and 2015.

	Tagging Year	
Tagging Site	2014	2015
Potholes Reservoir	30	18
Crescent Island	-	28

Table 3. Number of adult Caspian terns fitted with solar-powered PTT tags at Goose Island in Potholes Reservoir and at Crescent Island in McNary Reservoir on the Columbia River that transmitted location data beginning the year management was initiated (Year 0) and each subsequent year.

	Year Post-Management			
Tagging Site	Year 0 (n = 56)	Year 1 (n = 53)	Year 2 (n = 36)	Year 3 (n = 16)
Potholes Reservoir	28	36	26	10
Crescent Island	28	17	10	6

Table 4. Model selection results describing the foraging use of the Columbia River between Chief Joseph Dam downstream to the confluence with the Snake River by tagged Caspian terns during 2014-2018.

Model	df	logLik	AIC_c	ΔAIC_c	Weight
Capture Location, Year Post-Mgmt	5	180.91	-351.43	0	0.36
Capture Location, Duration of Steelhead Run, Year Post-Mgmt	6	181.4	-350.26	1.18	0.2
Capture Location, Sex, Year Post-Mgmt	6	181.11	-349.67	1.77	0.15
Capture Location, Start of Steelhead Run, Year Post-Mgmt	6	181.05	-349.55	1.89	0.14
Capture Location, Duration of Steelhead Run	5	179.96	-349.53	1.91	0.14
Full	10	182.14	-342.81	8.62	0
Null (Intercept Only)	3	159.24	-312.32	39.11	0

Table 5. Model averaged parameter estimates describing the foraging use of the Columbia River between Chief Joseph Dam downstream to the confluence with the Snake River by tagged Caspian terns during 2014-2018.

Parameter	Estimate	SE	Adjusted SE	Z value	Pr(>|z|)
(Intercept)	0.0335	0.1046	0.1052	0.318	0.7505
Capture Location (Goose Island, Potholes Reservoir*)	0.0943	0.0145	0.0146	6.445	<0.0001
Year Post-Mgmt	-0.0145	0.0068	0.0068	2.125	0.0336
Duration of Steelhead Run	-0.0021	0.0017	0.0017	1.264	0.2061
Sex (Male*)	-0.0080	0.0127	0.0128	0.622	0.5339
Start of Steelhead Run	0.0009	0.0017	0.0018	0.515	0.6066

*= reference variable

Table 6. Model selection results describing the foraging use of the Columbia River between the confluence with the Snake River and The Dalles, Oregon by tagged Caspian terns during 2014-2018.

Model	df	logLik	AIC_c	ΔAIC_c	Weight
Capture Location	4	-22.35	52.96	0	0.42
Capture Location, Duration of Steelhead Run	5	-21.98	54.34	1.38	0.21
Capture Location, Sex	5	-21.99	54.36	1.4	0.21
Capture Location, Capture Year	5	-22.28	54.94	1.98	0.16
Full	10	-20.02	61.5	8.53	0
Null (Intercept Only)	3	-46.91	99.98	47.01	0

Table 7. Model averaged parameter estimates describing the foraging use of the Columbia River between the confluence with the Snake River and The Dalles, Oregon, by tagged Caspian terns during 2014-2018.

Parameter	Estimate	SE	Adjusted SE	Z Value	Pr(>|z|)
(Intercept)	0.6210	0.1152	0.1159	5.36	<0.0001
Capture Location (Potholes Reservoir*)	-0.4784	0.0642	0.0647	7.392	<0.0001
Duration of Steelhead Run	0.0040	0.0046	0.0046	0.863	0.388
Sex (Male*)	0.0507	0.0588	0.0593	0.855	0.393
Capture Year (2015*)	0.0298	0.0765	0.0771	0.387	0.699

*= reference variable

Table 8. Model selection results describing the foraging use of the Snake River between Steamboat Island the confluence of with the Columbia River by tagged Caspian terns during 2014-2018.

Model	df	logLik	AIC_c	ΔAIC_c	Weight
Sex	4	259.29	-510.33	0	0.22
Sex, Year of Capture	5	260.03	-509.67	0.66	0.16
Null (Intercept Only)	3	257.77	-509.39	0.94	0.14
Sex, Year of Capture, Capture Location	6	260.82	-509.1	1.23	0.12
Sex, Year of Capture, Duration of Steelhead Run	6	260.82	-509.09	1.24	0.12
Sex, Duration of Steelhead Run	5	259.42	-508.45	1.89	0.09
Year of Capture	4	258.31	-508.37	1.96	0.08
Sex, Year of Capture, Duration of Steelhead Run, Capture Location	7	261.54	-508.36	1.97	0.08
Full	10	262.41	-503.34	6.99	0

Table 9. Model averaged parameter estimates describing the foraging use of the Snake River between Steamboat Island and the confluence of with the Columbia River by tagged Caspian terns during 2014-2018.

Parameter	Estimate	Std. Error	Adjusted SE	Z Value	Pr(>|z|)
(Intercept)	0.0277	0.0235	0.0236	1.17	0.2419
Sex (Male*)	-0.0162	0.0083	0.0084	1.931	0.0535
Year of Capture (2015*)	-0.0154	0.0110	0.0111	1.39	0.1646
Capture Location (Potholes Reservoir*)	-0.0136	0.0110	0.0111	1.233	0.2175
Duration of Steelhead Run	0.0009	0.0010	0.0010	0.961	0.3364

*= reference variable

Table 10. Model selection results describing the use of the Columbia Plateau region by tagged Caspian terns during 2014-2018.

Model	df	logLik	AIC_c	ΔAIC_c	Weight
Year Post-Mgmt, Start of Steelhead Run	5	-24.78	59.95	0	0.3
Year Post-Mgmt	4	-26.01	60.28	0.32	0.26
Year Post-Mgmt, Capture Year, Start of Steelhead Run	6	-24.14	60.82	0.87	0.2
Year Post-Mgmt, Start of Steelhead Run, Sex	6	-24.59	61.72	1.77	0.12
Year Post-Mgmt, Capture Year	5	-25.71	61.8	1.85	0.12
Full	10	-23.79	69.04	9.09	0
Null (Intercept Only)	3	-31.8	69.76	9.81	0

Table 11. Model averaged parameter estimates describing the use of the Columbia Plateau region by tagged Caspian terns during 2014-2018.

Parameter	Estimate	Std. Error	Adjusted SE	Z Value	Pr(>|z|)
(Intercept)	0.2304	0.6819	0.6846	0.337	0.7365
Start of Steelhead Run	0.0082	0.0050	0.0051	1.613	0.1068
Year Post-Mgmt	-0.0641	0.0212	0.0214	3.00	0.0027
Year of Capture (2015*)	0.0690	0.0699	0.0704	0.98	0.3271
Sex (Male*)	-0.0415	0.0661	0.0666	0.622	0.5337

*= reference variable

Table 12. Model selection results describing the use of colony locations in the Columbia Plateau Region by tagged Caspian terns from 2014-2018.

Model	df	logLik	AIC_c	ΔAIC_c	Weight
Year Post-Mgmt	4	11.82	-15.39	0	0.25
Year Post-Mgmt, Capture Year	5	12.74	-15.1	0.29	0.22
Year Post-Mgmt, Capture Location	5	12.14	-13.9	1.49	0.12
Year Post-Mgmt, Duration of Steelhead Run	5	12.06	-13.74	1.65	0.11
Year Post-Mgmt, Sex	5	12.01	-13.63	1.76	0.1
Year Post-Mgmt, Capture Year, Start of Steelhead Run	6	13.03	-13.52	1.87	0.1
Year Post-Mgmt, Start of Steelhead Run	5	11.91	-13.44	1.95	0.1
Full	10	13.88	-6.28	9.1	0
Null (Intercept Only)	3	3.83	-1.5	13.88	0

Table 13. Model averaged parameter estimates describing the use of colony locations in the Columbia Plateau Region by tagged Caspian terns from 2014-2018.

Parameter	Estimate	SE	Adjusted SE	Z Value	Pr(>|z|)
(Intercept)	0.4330	0.2676	0.2692	1.609	0.108
Year Post-Mgmt	-0.0685	0.0168	0.0170	4.033	0.000055
Year of Capture (2015*)	0.0710	0.0505	0.0509	1.394	0.163
Capture Location (Potholes Reservoir*)	-0.0408	0.0508	0.0512	0.798	0.425
Duration of Steelhead Run	0.0026	0.0038	0.0038	0.689	0.491
Sex (Male*)	-0.0298	0.0491	0.0494	0.603	0.546
Start of Steelhead Run	0.0025	0.0043	0.0043	0.586	0.558

*= reference variable

Table 14. Model selection results describing the use of colony locations outside of the Columbia Plateau Region by tagged Caspian terns from 2014-2018.

Model	df	logLik	AIC_c	ΔAIC_c	Weight
Duration of Steelhead Run	4	57.86	-107.46	0	0.31
Duration of Steelhead Run, Start of Steelhead Run	5	58.37	-106.36	1.09	0.18
Duration of Steelhead Run, Sex	5	58.11	-105.83	1.63	0.14
Duration of Steelhead Run, Year of Capture	5	58.04	-105.68	1.77	0.13
Duration of Steelhead Run, Year Post-Mgmt	5	57.94	-105.5	1.95	0.12
Duration of SH Run, Start of SH Run, Interaction between Start/Duration	6	59	-105.46	2	0.12
Null (Intercept Only)	3	53.94	-101.74	5.72	0.01
Full	10	59.67	-97.88	9.57	0

SH = steelhead

Table 15. Model averaged parameter estimates describing the use of colony locations outside of the Columbia Plateau Region by tagged Caspian terns from 2014-2018.

Parameter	Estimate	SE	Adjusted SE	Z Value	Pr(>|z|)
(Intercept)	-0.9111	2.4096	2.4182	0.377	0.706
Duration of Steelhead Run	0.0262	0.0706	0.0709	0.37	0.711
Start of Steelhead Run	0.0198	0.0321	0.0322	0.615	0.538
Sex (Male*)	0.0274	0.0385	0.0388	0.706	0.48
Year of Capture (2015*)	-0.0256	0.0427	0.0431	0.596	0.551
Year Post-Mgmt	-0.0055	0.0129	0.0130	0.42	0.674
Interaction between Start/Duration of SH Run	-0.0013	0.0012	0.0012	1.114	0.265

*= reference variable
SH = steelheadd

APPENDIX

Capture Location	Leg Band ID	Color	Top	Middle	Bottom	USGSBandNumber	Sex	Satellite Tag Model	Tag Platform ID	GroundTrack Freq	Harness Type	Date Tagged	Last Transmission Date	Deployement Duration (Days)	Breeding Activty Confirmed	Where	When
Potholes	A018	Yellow/Black	DG	DG	M	875-96173	Male	Microwave-PTT-12g Solar	135829	412.400	Backpack	4/6/2014	8/24/16	872	N	N/A	N/A
Crescent	A271	Yellow/Black	O	DG	M	875-97098	Male	Microwave-PTT-12g Solar	146641	412.075	Leg	4/2/2015	9/17/16	535	N	N/A	N/A
Potholes	A366	Red/White	DB	LB	M	1135-02553	Male	Microwave-PTT-12g Solar	135824	412.275	Backpack	4/2/2014	6/5/14	65	N	N/A	N/A
Potholes	A367	Red/White	DB	LB	M	1135-02554	Male	Microwave-PTT-12g Solar	135826	412.325	Backpack	4/2/2014	6/15/16	806	N	N/A	N/A
Potholes	A368	Red/White	DB	LB	M	1135-02555	Female	Microwave-PTT-12g Solar	135832	412.475	Backpack	4/2/2014	6/30/14	90	N	N/A	N/A
Potholes	A369	Red/White	DB	LB	M	1135-02557	Female	Microwave-PTT-12g Solar	135813	412.000	Backpack	4/6/2014	6/15/14	71	N	N/A	N/A
Potholes	A370	Red/White	DB	LB	M	875-87276	Male	Microwave-PTT-12g Solar	135840	412.675	Backpack	4/6/2014	8/31/16	879	N	N/A	N/A
Potholes	A372	Red/White	DB	LB	M	1135-02559	Male	Microwave-PTT-12g Solar	135825	412.300	Backpack	4/6/2014	9/21/16	900	N	N/A	N/A
Potholes	A378	Red/White	DB	LB	M	1135-02565	Male	Microwave-PTT-12g Solar	135819	412.150	Leg	4/8/2014	1/27/18	1391	Yes	Goose Island	2014
Potholes	A380	Red/White	DB	LB	M	1135-02566	Female	Microwave-PTT-12g Solar	135817	412.100	Leg	4/8/2014	5/1/15	389	N	N/A	N/A
Potholes	A381	Red/White	DB	LB	M	1135-02567	Female	Microwave-PTT-12g Solar	135823	412.250	Leg	4/8/2014	5/8/15	396	N	N/A	N/A
Potholes	A382	Red/White	DB	LB	M	1135-02568	Female	Microwave-PTT-12g Solar	135820	412.175	Leg	4/9/2014	1/3/17	1001	N	N/A	N/A
Potholes	A383	Red/White	DB	LB	M	1135-02569	Female	Microwave-PTT-12g Solar	135830	412.425	Leg	4/9/2014	3/21/16	713	N	N/A	N/A
Potholes	A384	Red/White	DB	LB	M	1135-02570	Female	Microwave-PTT-12g Solar	135835	412.550	Leg	4/9/2014	4/30/18	1483	N	N/A	N/A
Potholes	A386	Red/White	DB	LB	M	1135-02574	Female	Microwave-PTT-12g Solar	135828	412.375	Leg	4/10/2014	8/5/16	849	N	N/A	N/A
Potholes	A387	Red/White	DB	LB	M	875-96032	Male	Microwave-PTT-12g Solar	135837	412.600	Leg	4/10/2014	9/16/15	525	N	N/A	N/A
Potholes	A389	Red/White	DB	LB	M	1135-02576	Male	Microwave-PTT-12g Solar	135838	412.625	Leg	4/10/2014	5/10/17	1127	Yes	Goose Island	2014
Potholes	A391	Red/White	DB	LB	M	1135-02578	Female	Microwave-PTT-12g Solar	135818	412.125	Leg	4/10/2014	5/21/17	1138	Yes	Goose Island/Blalocks	2014/2015
Potholes	A394	Red/White	DB	LB	M	1135-02581	Male	Microwave-PTT-12g Solar	135821	412.200	Leg	4/10/2014	4/11/16	733	N	N/A	
Potholes	A398	Red/White	DB	LB	M	1135-02585	Male	Microwave-PTT-12g Solar	135833	412.500	Leg	4/10/2014	5/27/16	779	Yes	Goose Island/Blalocks	2014/2016
Potholes	A399	Red/White	DB	LB	M	1135-02586	Female	Microwave-PTT-12g Solar	135831	412.450	Leg	4/11/2014	7/13/18	1555	Yes	Crescent Island	2014
Potholes	A428	Red/White	DB	LB	M	1135-02590	Unknown	Microwave-PTT-12g Solar	135824	412.275	Leg	6/25/2014	9/4/16	803	N	N/A	N/A
Crescent	A751	Red/White	W	DG	M	1135-04401	Female	Microwave-PTT-12g Solar	146626	412.700	Leg	3/30/2015	12/1/16	613	N	N/A	N/A
Crescent	A752	Red/White	W	DG	M	1135-04402	Male	Microwave-PTT-12g Solar	146627	412.725	Leg	3/30/2015	11/18/17	965	Yes	Tule Lake/Blalocks	2015/2016
Crescent	A753	Red/White	W	DG	M	1135-04403	Male	Microwave-PTT-12g Solar	146628	412.750	Leg	3/30/2015	3/23/16	360	N	N/A	N/A
Crescent	A754	Red/White	W	DG	M	1135-04404	Male	Microwave-PTT-12g Solar	146630	412.800	Leg	3/30/2015	6/16/16	445	N	N/A	N/A
Crescent	A755	Red/White	W	DG	M	875-94541	Male	Microwave-PTT-12g Solar	146633	412.875	Leg	4/1/2015	9/19/15	172	N	N/A	N/A
Crescent	A756	Red/White	W	DG	M	1135-04406	Male	Microwave-PTT-12g Solar	146635	412.925	Leg	4/1/2015	11/10/16	590	N	N/A	N/A
Crescent	A757	Red/White	W	DG	M	1135-04407	Male	Microwave-PTT-12g Solar	146636	412.950	Leg	4/1/2015	6/3/18	1160	Yes	Blalocks	2015
Crescent	A758	Red/White	W	DG	M	1135-04408	Male	Microwave-PTT-12g Solar	146637	412.975	Leg	4/1/2015	5/14/16	410	N	N/A	N/A
Crescent	A759	Red/White	W	DG	M	1135-04409	Male	Microwave-PTT-12g Solar	146638	412.000	Leg	4/1/2015	4/29/19	1490	Yes	Blalocks	2015/2016/2018?
Crescent	A760	Red/White	W	DG	M	1135-04410	Male	Microwave-PTT-12g Solar	146639	412.025	Leg	4/1/2015	4/17/16	383	Yes	Blalocks	2015
Crescent	A762	Red/White	W	DG	M	1135-04412	Female	Microwave-PTT-12g Solar	146640	412.050	Leg	4/1/2015	2/21/17	693	N	N/A	N/A
Crescent	A763	Red/White	W	DG	M	1135-01017	Male	Microwave-PTT-12g Solar	146645	412.175	Leg	4/2/2015	11/28/16	607	Yes	Blalocks	2015
Crescent	A764	Red/White	W	DG	M	875-96561	Male	Microwave-PTT-12g Solar	146652	412.350	Leg	4/2/2015	11/1/18	1310	Yes	Blalocks	2015/2016
Crescent	A765	Red/White	W	DG	M	1135-04413	Male	Microwave-PTT-12g Solar	146644	412.150	Leg	4/2/2015	1/29/17	669	Yes	ESI	2015
Crescent	A767	Red/White	W	DG	M	1135-04415	Female	Microwave-PTT-12g Solar	146651	412.325	Leg	4/2/2015	9/15/15	167	N	N/A	N/A
Crescent	A768	Red/White	W	DG	M	1135-04416	Male	Microwave-PTT-12g Solar	146653	412.375	Leg	4/2/2015	9/26/18	1274	Yes	ESI	2015/2016/2017/2018
Crescent	A769	Red/White	W	DG	M	1135-04417	Female	Microwave-PTT-12g Solar	146648	412.250	Leg	4/2/2015	5/4/16	399	N	N/A	N/A
Crescent	A770	Red/White	W	DG	M	1135-04418	Female	Microwave-PTT-12g Solar	146647	412.225	Leg	4/2/2015	7/5/15	95	Yes	ESI	2018
Potholes	A777	Red/White	W	LB	M	1135-04423	Female	Microwave-PTT-12g Solar	146670	412.800	Leg	4/10/2015	3/19/16	345	N	N/A	N/A
Potholes	A779	Red/White	W	LB	M	1135-04424	Male	Microwave-PTT-12g Solar	146660	412.550	Leg	4/15/2015	3/3/17	689	N	N/A	N/A
Potholes	A780	Red/White	W	LB	M	1135-04425	Female	Microwave-PTT-12g Solar	146667	412.725	Leg	4/15/2015	9/27/17	897	N	N/A	N/A
Potholes	A781	Red/White	W	LB	M	1135-04426	Female	Microwave-PTT-12g Solar	146664	412.650	Leg	4/15/2015	2/4/16	296	N	N/A	N/A
Potholes	A782	Red/White	W	LB	M	1135-04427	Female	Microwave-PTT-12g Solar	146673	412.875	Leg	4/15/2015	6/6/16	419	N	N/A	N/A
Potholes	A783	Red/White	W	LB	M	1135-04428	Female	Microwave-PTT-12g Solar	146669	412.775	Leg	4/15/2015	8/19/18	1223	N	N/A	N/A
Potholes	A784	Red/White	W	LB	M	875-97158	Female	Microwave-PTT-12g Solar	146663	412.625	Leg	4/16/2015	5/21/15	36	N	N/A	N/A
Potholes	A785	Red/White	W	LB	M	1135-04429	Female	Microwave-PTT-12g Solar	146659	412.525	Leg	4/16/2015	12/1/17	961	N	N/A	N/A
Potholes	A786	Red/White	W	LB	M	1135-04430	Female	Microwave-PTT-12g Solar	146649	412.275	Leg	4/16/2015	9/20/17	889	N	N/A	N/A
Potholes	A788	Red/White	W	LB	M	1135-04432	Male	Microwave-PTT-12g Solar	146666	412.700	Leg	4/16/2015	9/5/16	509	N	N/A	N/A
Potholes	A789	Red/White	W	LB	M	1135-04433	Female	Microwave-PTT-12g Solar	146662	412.600	Leg	4/16/2015	7/30/16	472	N	N/A	N/A
Potholes	A790	Red/White	W	LB	M	1135-04434	Male	Microwave-PTT-12g Solar	146665	412.675	Leg	4/16/2015	9/18/16	522	N	N/A	N/A
Potholes	A792	Red/White	W	LB	M	1135-04436	Female	Microwave-PTT-12g Solar	146672	412.850	Leg	4/18/2015	1/22/17	646	N	N/A	N/A
Potholes	A793	Red/White	W	LB	M	1135-04437	Female	Microwave-PTT-12g Solar	146655	412.425	Leg	4/18/2015	5/13/18	1122	N	N/A	N/A
Potholes	A794	Red/White	W	LB	M	1135-04438	Male	Microwave-PTT-12g Solar	146654	412.400	Leg	4/18/2015	10/7/15	173	N	N/A	N/A
Potholes	A795	Red/White	W	LB	M	1135-04439	Female	Microwave-PTT-12g Solar	146657	412.475	Leg	4/18/2015	11/12/16	575	N	N/A	N/A
Crescent	E604	Yellow/Black	DB	LB	M	1905-23593	Female	Microwave-PTT-12g Solar	146642	412.100	Leg	4/2/2015	6/29/18	1185	Yes	Blalocks	2015/2017
Crescent	F367	Yellow/Black	DG	LB	M	1135-01086	Female	Microwave-PTT-12g Solar	146646	412.200	Leg	4/2/2015	7/11/18	1197	Yes	ESI	2015/2018
Potholes	F369	Yellow/Black	DG	LB	M	1135-01087	Male	Microwave-PTT-12g Solar	135839	412.650	Leg	4/11/2014	10/20/16	924	N	N/A	N/A
Potholes	J201	Yellow/Black	O	LB	M	1905-24287	Male	Microwave-PTT-12g Solar	135827	412.350	Leg	4/11/2014	11/18/14	222	N	N/A	N/A
Potholes	J224	Yellow/Black	O	LB	M	1905-24310	Male	Microwave-PTT-12g Solar	135831	412.450	Backpack	4/6/2014	4/6/14	1	N	N/A	N/A
Potholes	J233	Yellow/Black	O	LB	M	1905-24319	Female	Microwave-PTT-12g Solar	135816	412.075	Leg	4/9/2014	6/2/15	420	N	N/A	N/A
Crescent	J878	Yellow/Black	W	DG	M	1135-00390	Female	Microwave-PTT-12g Solar	135815	412.050	Leg	3/29/2015	8/8/16	499	Yes	Twinning Island	2015
Crescent	J879	Yellow/Black	W	DG	M	1135-00521	Female	Microwave-PTT-12g Solar	146631	412.825	Leg	4/1/2015	8/23/16	511	N	N/A	N/A
Crescent	J892	Yellow/Black	W	DG	M	1135-00534	Male	Microwave-PTT-12g Solar	146629	412.775	Leg	4/1/2015	4/15/18	1111	N	N/A	N/A
Potholes	K019	Yellow/Black	W	LB	M	1135-00566	Male	Microwave-PTT-12g Solar	135834	412.525	Backpack	4/6/2014	2/22/16	688	N	N/A	N/A
Potholes	K023	Yellow/Black	W	LB	M	1135-00570	Male	Microwave-PTT-12g Solar	135815	412.050	Leg	4/9/2014	8/30/14	144	Yes	Goose Island -NW Rocks	2014
Potholes	K027	Yellow/Black	W	LB	M	875-94945	Male	Microwave-PTT-12g Solar	135814	412.025	Backpack	4/4/2014	7/23/16	842	N	N/A	N/A
Potholes	K032	Yellow/Black	W	LB	M	1135-00578	Female	Microwave-PTT-12g Solar	135822	412.225	Leg	4/10/2014	10/1/16	906	Yes	Blalocks	2015/2016
Potholes	K036	Yellow/Black	W	LB	M	1135-00583	Male	Microwave-PTT-12g Solar	146671	412.825	Leg	4/16/2015	4/19/18	1100	N	N/A	N/A
Potholes	K047	Yellow/Black	W	LB	M	1135-00592	Male	Microwave-PTT-12g Solar	146668	412.750	Leg	4/21/2015	1/9/19	1360	N	N/A	N/A
Crescent	K463	Yellow/Black	R	DG	M	1135-01703	Male	Microwave-PTT-12g Solar	146634	412.900	Leg	4/1/2015	4/22/19	1483	Yes	ESI	2015/2018
Crescent	K486	Yellow/Black	R	DG	M	1135-01725	Female	Microwave-PTT-12g Solar	146632	412.850	Leg	4/1/2015	12/5/16	615	N	N/A	N/A
Crescent	K501	Yellow/Black	R	DG	M	1135-01740	Male	Microwave-PTT-12g Solar	146643	412.125	Leg	4/2/2015	1/14/17	654	N	N/A	N/A
Crescent	K507	Yellow/Black	R	LB	M	1135-01747	Female	Microwave-PTT-12g Solar	146650	412.300	Leg	4/2/2015	12/26/17	1000	N	N/A	N/A
Potholes	K518	Yellow/Black	R	LB	M	1135-1757	Female	Microwave-PTT-12g Solar	135836	412.575	Leg	4/8/2014	5/31/14	54	N	N/A	N/A