DECLINE OF THE BLACK TERN (*CHLIDONIAS NIGER*) POPULATION IN THE KLAMATH BASIN, OREGON, 2001–2010

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ABSTRACT—We monitored the Black Tern (*Chlidonias niger*) population at Agency and Upper Klamath Lakes, in the Klamath Basin, Oregon, from 2001–2010. We estimated that the population of adult Black Terns declined at these 2 joined waterbodies by 8.4% annually. In contrast, our analysis of Breeding Bird Survey data for the Bird Conservation Region 9/Great Basin during the same period did not detect a trend. Knowledge of local short-term trends in the Klamath Basin can contribute to understanding regional and continental population declines of this species. Water levels, which may affect both habitat availability and suitability, were relatively stable from 2001–2009, but dropped in 2010 and remained depressed from 2010–2014. The direct effect of water-level fluctuations on habitat availability (hectares of habitat loss) is not well understood. Water allocation is a management challenge in this region and has been exacerbated by recent drought conditions. In combination, understanding trends and causal factors can inform water management, restoration, and habitat protection, all of which may contribute to reversing the decline of breeding terns.

Key words: Bird Conservation Region 9/Great Basin, Black Tern, Breeding Bird Survey, *Chlidonias niger*, Klamath Basin, land management, Oregon, population trends, volunteer monitoring, wetland

Black Terns *(Chlidonias niger)* are migratory birds that breed throughout the northern United States and southern Canada and winter on the north coast of South America (Dunn and Agro 2009). The Klamath Basin in southern Oregon and northern California contains a number of wetlands that are important individually and cumulatively for breeding waterbirds, including terns (Shuford and others 2006). Black Terns nest semi-colonially in freshwater wetlands and typically forage in flocks (Dunn and Agro 2009). Their behaviors make estimating abundance and population size challenging. Their site tenacity is low and they will regularly shift colony locations (Dunn and Agro 2009). Generally, Black Terns return to their breeding grounds in the Klamath Basin in early to mid-May and spend one to several weeks at communal foraging grounds where pair bonds are established (Stern 2003; Dunn and Agro 2009). In late May they disperse to their nest sites, but continue to forage in flocks (Stern 2003); however, the timing of the peak of nesting can vary considerably both annually and among sites in a given year (Shuford 2014).

Black Tern populations declined in North America by about 3.4% per year from 1966–2010 (Sauer and others 2011). The steepest declines occurred prior to 1980. These declines suggest that the current population is roughly one-third of what it was in the late 1960s. The North American Waterbird Conservation Plan estimated the population at 100,000–500,000 (Kushlan and others 2002). This is consistent with the estimate of low hundreds of thousands suggested by Shuford (1999). Population declines have been primarily attributed to loss of wetlands, but reduced foraging opportunities as a result of agricultural pest control as well as overfishing in wintering areas have also been documented (Dunn and Agro 2009). Because of continental population declines, it is desirable to understand regional and local population dynamics.

Local Black Tern population trends derived from surveys will improve our understanding of continental population dynamics (for example, Matteson and others 2012). Most published information on Black Tern populations is based on Breeding Bird Survey data that provide a large and long-term data set despite the fact that terns are not well monitored by this method (Peterjohn and Sauer 1997; Shuford 1999). Estimates of population size for Black Terns in Oregon are undocumented (Stern 2003; Ivey and Herzigor 2006), or unreliable at best (Sauer and others 2011). To fill this gap in information at the local level, field technicians and volunteers monitored the number of Black Tern adults during the breeding season at Agency and Upper Klamath Lakes in the Klamath Basin, Oregon, from 2001–2010. We present local population trends over this 10-y period.

METHODS

Study Area

Our study area included Klamath Lake and the smaller adjoining Agency Lake (Fig. 1). These lakes are located in the Klamath Basin, an area of approximately 20,000 km^2, in a large valley of southern Oregon and northern California on the east-slope of the Cascade Range, within Bird Conservation Region 9/Great Basin (Rich and others 2004). The Klamath Basin contains extensive emergent wetlands, most of which have managed water levels, ranging from temporarily to permanently flooded wetlands and deepwater habitats in Palustrine and Riverine Systems (Cowardin and others 1979). In the early 1900s, significant amounts of wetland were converted to agriculture, and today less than 25% of historic wetlands remain (Ivey 2001). Vegetation in the Klamath Basin marshes is primarily composed of sedge-reed communities, with components of bulrush (*Cyperaceae* spp.), cattails (*Typhaceae* spp.), and Wocus Lily (*Nuphar luteum*) (Johnson and others 1985).

Upper Klamath Lake and the smaller adjoining Agency Lake form a 28,000-ha shallow waterbody, making them the largest freshwater lake system in Oregon (Johnson and others 1985). The water level is regulated by the Link River Dam constructed in 1921 (Pedery 2004), with managed water levels fluctuating seasonally and annually (USGS 2015). Most of the wetlands surrounding the lake have been drained for agriculture, but several areas have recently been reclaimed by forming dikes to isolate them from the lakes and managing them for lower water levels (Snider and Morace 1997; Ivey 2001). Our study did not evaluate whether restoration actions could affect tern populations, but it should be noted that a number of management actions including dam removal (Agency Creek), breaching of dikes (Caledonia and Williamson Rivers), and habitat restoration (wetlands near Wood River) occurred during the study period (BLM 1996; David Evans and Associates, Inc. 2010; Burdick 2012).

Surveys

As a component of Klamath Bird Observatory's student volunteer intern program, volunteers are based in the Klamath Basin each summer. The primary responsibility of volunteers includes mist-netting and banding passerines during early morning hours to determine population trends. In the afternoons, volunteers were given the opportunity to conduct Black Tern surveys from 2001–2008 (Alexander and others 2004). In 2010, Klamath Bird Observatory contributed to the US Fish and Wildlife Service western colonial waterbird survey and conducted surveys throughout Oregon (Cavitt and others 2014). As a component of that work, field technicians monitored Black Terns at Agency and Upper Klamath Lakes in 2010 following the volunteer-based method described below.

Survey routes were established in suitable habitat, the study design was not random, and all areas of the water body were not covered. Surveys were completed between 25 May and 7 July each year. This time period aligns with the Black Tern breeding season in the Klamath Basin as described in the literature (Shuford and others 2001; Stern 2003) and according to our own observations (no terns were recorded exhibiting nesting behaviors before late May; Alexander and others, unpubl. data).

We completed a total of 320 surveys along 39 routes at Agency and Upper Klamath Lakes.

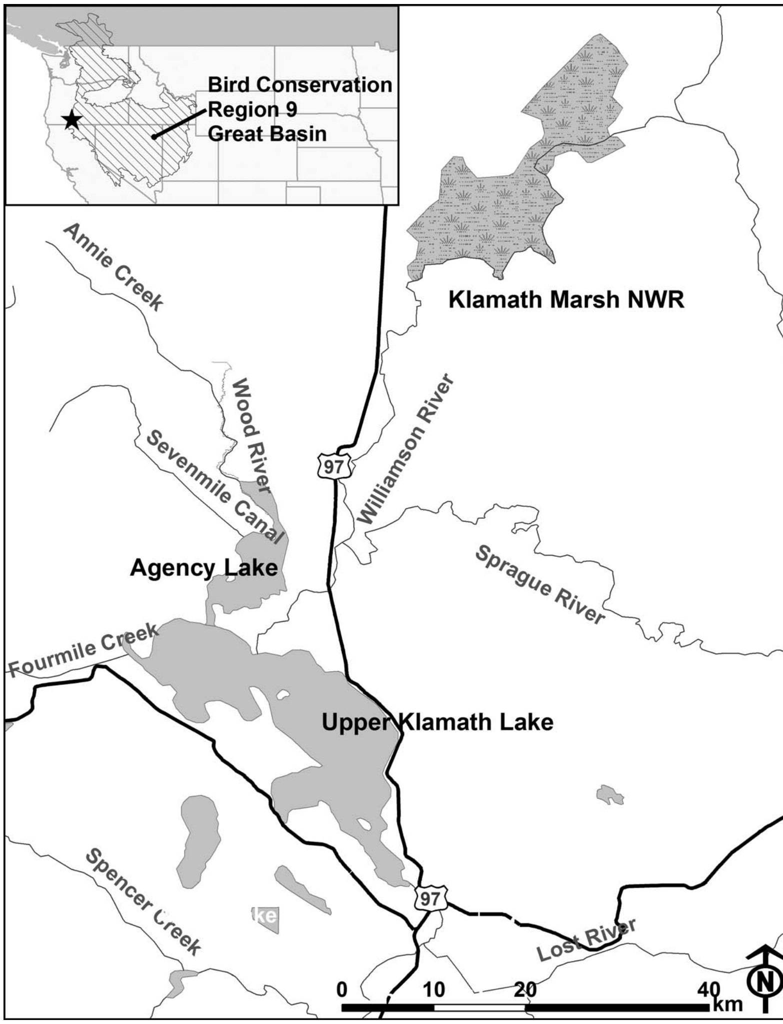


FIGURE 1. Black Tern surveys were completed at Agency and Upper Klamath Lakes, in the Klamath Basin, Oregon. The star on the inset map shows where the study area is located in relation to Bird Conservation Region 9/Great Basin.

Survey effort (how many routes were surveyed and of those, how many were surveyed multiple times within a year) varied by year. Counts from multiple surveys of a route in the same year were averaged, resulting in 237 data points (2001, n = 39; 2002, n = 13; 2003, n = 34; 2004, n = 21; 2005, n = 26; 2006, n = 19; 2007, n = 15; 2008, n = 31; 2009, n = 0; 2010, n = 39), approximately 25% of which represent means of routes that were surveyed multiple times in a given year. Of these, 41 are the mean of 2 surveys, 15 are the mean of 3 surveys, and 4 are the mean of 4 surveys. All routes were surveyed in 3 or more years.

Routes were surveyed by boat and were approximately 2 km in length, with count stations 150 to 200 m apart. Count time at stations ranged from 3 to 5 min, but generally, if no terns were detected in 3 min, observers resumed travel along the route. All adult Black Terns detected along the route to an unlimited distance from the boat in all directions were recorded. Visibility varied by route based on the amount of emergent vegetation present, but was generally consistent within routes among years. Observers took care to not double-count individuals along a survey route. A total of 34 to 95 km was surveyed annually (mean = 52 km ± 20 standard deviation, hereafter sd); no surveys were conducted in 2009.

Analysis

Because routes varied in length, we divided the total number of adults detected by the length of the route to generate a relative abundance measure of adults km^{-1}. In instances where routes were visited more than once in a given year, counts of total adults per route were averaged. We used linear mixed models, with the natural log of adults km^{-1} as the dependent variable, year as a fixed effect, and route as a random effect to estimate trends for the study area. Our models allowed each survey route to have a unique intercept. Natural logarithm transformed data approximated normal distributions, and results were back-transformed onto the original scale for presentation. Analyses were conducted in R using package nlme (R Development Core Team 2012).

We obtained Black Tern population trends from Breeding Bird Survey data for the Bird Conservation Region 9/Great Basin (hereafter Great Basin) for 2 time periods, 1968–2010 and 2001–2010. Results were generated from online analysis tools (www.mbr-pwrc.usgs.gov/bbs/bbs2010.html) and are based on a hierarchical model for population change, as described in Link and Sauer (2002).

RESULTS

Klamath Basin

For a given route and year (hereafter route-year), we observed a minimum of 0 and a maximum of 331 adult Black Terns ($\bar{x}$ adults counted/route = 30 ± 41 sd), or a range of 0–154 adults counted km^{-1} ($\bar{x}$ = 16 ± 21 sd). There were 28 instances of a 0 count for an entire route-year, 17 of which occurred during 2010. The mean number of adult Black Terns surveyed per km was highest in 2006 ($\bar{x}$ = 32 ± 22 sd) and lowest in 2010 ($\bar{x}$ = 9 ± 25 sd). Results from the linear mixed model suggest that the Black Tern population (mean adults km^{-1}) at Agency and Upper Klamath Lakes declined significantly over the period 2001–2010 at a rate of –8.4% annually (t = –4.07, n = 237, P = 0.0001; Fig. 2).

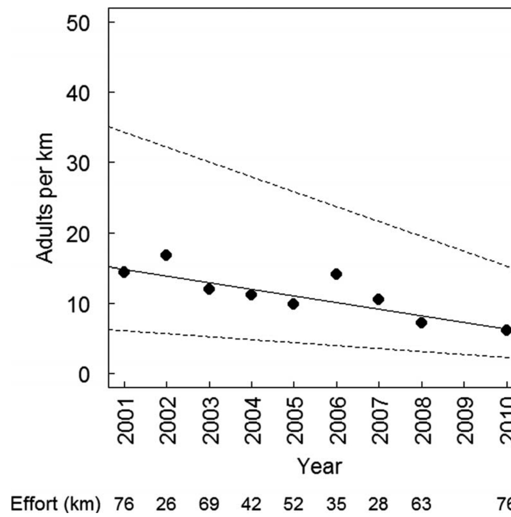


FIGURE 2. Relative abundance of Black Terns from 2001–2010 in the Klamath Basin, Oregon. Results are from a linear mixed model with year as a fixed effect and route as a random effect. Data points are mean back-transformed fitted values on the original scale, with a 95% confidence interval shown in dotted lines. Annual effort is summarized by the total km surveyed of all routes combined.

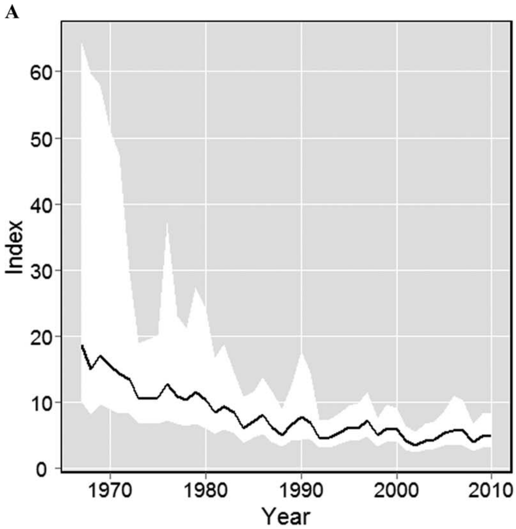
Great Basin

From 1968–2010, Great Basin populations (mean adults km^{-1}) declined at a rate of –4.4% annually (95% CI = –8.67, –0.37) based on Breeding Bird Survey data (Link and Sauer 2002; Sauer and others 2011) (Fig. 3A). During our 2001–2010 study period, however, populations in the Great Basin showed no significant trend (–3.12%, 95% CI = –12.63, 5.47) (Link and Sauer 2002; Sauer and others 2011) (Fig. 3B).

DISCUSSION

Our local results suggest steep Black Tern population declines of 8.4% annually from 2001–2010, whereas regional Breeding Bird Survey data from that same time period did not yield a trend. Results from our study should be interpreted with caution; although robust in covering a 10-y time frame, the data set had other limitations, as routes were not randomly established and survey effort of both number of routes and visits to a given route varied between years. We believe, however, that the declining trends detected here are real and not an artifact of sampling design because they are strongly

A



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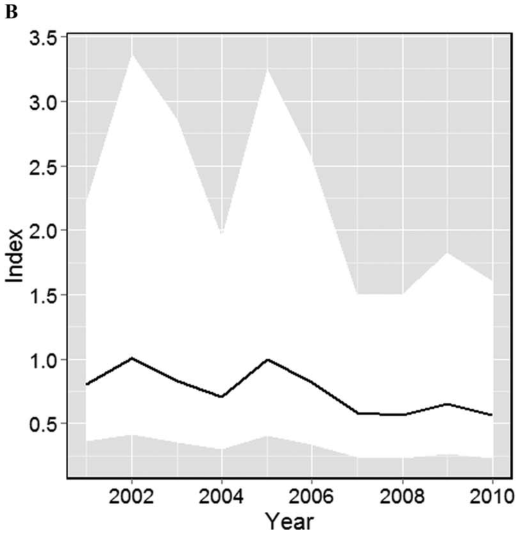

FIGURE 3. Black Tern Great Basin population trend and 95% confidence interval shown over (A) 43 y of Breeding Bird Survey (BBS) data from 1968–2010, and (B) the 10 y of BBS data from 2001–2010 matching our study period (Sauer and others 2011). Index (Y-axis label) is the annual abundance index produced by a hierarchical model on the BBS trend analysis website (http://www.mbr-pwrc.usgs.gov/bbs/trend/tf12.html) for the Great Basin region.

supported by abundance measures (mean adults surveyed km^{-1}) in years with the most comprehensive surveys, including the first and final years (2001 and 2010). Local Black Tern population trends such as these are an important component of understanding continent-wide population dynamics and can be used to identify opportunities for conservation that can aid in reversing local declines. Additionally, this study demonstrates the value of volunteer survey efforts in gathering meaningful data.

The Intermountain West Waterbird Conservation Plan (Ivey and Herziger 2006) set a desired population objective of just under 10,000 Black Terns for the Great Basin. The current population for this region is estimated at nearly 8000 (Ivey and Herziger 2006), roughly 3% of the North American population, with an estimate of 2089 terns in the Klamath Basin alone (Shuford and others 2004). Reversing declining trends at Agency and Upper Klamath Lakes would contribute to attaining regional population goals.

Degradation and loss of wetlands is potentially the greatest threat to Black Tern populations across their range (Dunn and Agro 2009). Periods of wetland loss, specifically loss of suitable habitat as opposed to numbers of wetlands, has been correlated with regional population declines (Peterjohn and Sauer 1997). Continentally, periods in which the species experienced the most dramatic declines overlap with periods of wetland loss (Dunn and Agro 2009). It is likely that degradation and loss of wetlands was historically the greatest threat to local populations as well. Wetland loss in the Klamath Basin is more pronounced than the national average, with more than 75% loss of historic wetlands (Ivey 2001) compared with 53% loss in the coterminous United States as of 1980 (Dahl 1990). However, we are unaware of direct habitat loss during our study period.

In addition to habitat availability, recent studies in the eastern and midwestern United States have focused on habitat suitability, including water levels, nest site selection and nest success, food resources, and predation to better understand population dynamics (for example, Naugle and others 2000; Maxson and others 2007; Heath and Servello 2008). All of these factors have the potential to affect tern populations in the Klamath Basin; for example, water level and water quality have undergone substantial changes in our study area over the last century. Upper Klamath Lake is naturally hypereutrophic and currently has a significant water quality problem largely attributed to runoff into the tributaries of the degraded watershed that feeds the lake (Johnson and others 1985). It is unknown how, or if, water quality may affect tern reproduction.

Water level may affect both habitat availability and suitability. Black Terns depend on emergent vegetation, the available extent of which is directly related to water level. High water levels result in less exposed emergent vegetation, whereas low levels cause the vegetation to dry out. Mean breeding-season water levels during our study period were relatively stable from 2001–2009 (1262.54 ± 0.08 m sd above sea level), but dropped in 2010 (1262.22 m above sea level) (USGS 2015). Our study predated the current drought which began in 2012 and is being compared in significance with 3 extreme drought cycles over the last century, the most recent ending in 1992 (State of California and California Natural Resources Agency 2015). Water levels from 2012–2014 dropped from 1262.39 to 1262.16 m above sea level (USGS 2015). The direct effect of such water level fluctuations on habitat availability (hectares of habitat loss) is not well understood.

Water allocation in the Klamath Basin is a management challenge that has been exacerbated by recent drought conditions. During our study period, lake levels were affected by water rights as well as habitat needs for endangered suckers (Shortnose Sucker [*Chasmistes brevirostris*], Lost River Sucker [*Deltistes luxatus*]) in the lake, and downstream of the lake for salmon and other species of concern (Coho Salmon [*Oncorhynchus kisutch*], Chinook Salmon [*Oncorhynchus tshawytscha*], steelhead trout [anadromous Rainbow Trout, *Oncorhynchus mykiss*], and Green Sturgeon [*Acipenser medirostris*]) (Goodman and others 2011; NMFS and USFWS 2013). In the future, water allocation will likely be guided by the Upper Klamath Basin Comprehensive Agreement (KBRA 2010; UKBA 2014). While increased certainty of water allocation is likely, the potential impact on Black Terns is unclear.

In addition to current drought conditions and water management challenges, climate change will likely affect Black Tern habitat availability and suitability in the future. Three climate models in Barr and others (2010; CSIRO, MIROC, and HADCM) for the Klamath Basin project an increase in annual average temperatures (2.1 to 3.6°F by mid-century and 4.6 to 7.2°F by late century), with summer warming greater than that of other seasons. Projections for annual average precipitation were variable, ranging from an 11% decrease to a 24% increase. However, all models agreed that summers are likely to be drier. In addition, snowpack is projected to decrease 37 to 65% by mid-century and 73 to 90% by late century. In combination, warmer temperatures, drier summers, and reduced snowpack suggest stream flows may increase in the winter and decrease during the rest of the year, reaching particularly low levels in late summer. Many streams with current low flows could become dry in some years, and shallow lakes will have more variable water levels and could go dry more frequently (Barr and others 2010). If climate change results in lower water levels, available habitat will likely be reduced.

In addition to the potential future direct loss of habitat, cumulative effects on wetland landscapes may also be a concern (Naugle and others 2000; Niemuth and Solberg 2003). Black Tern habitat suitability may relate to broad-scale landscape structure (for example, hectares of suitable habitat across multiple waterbodies) more than vegetation conditions within a single wetland (Naugle and others 2000). Because much of the suitable habitat in the Klamath Basin exists in managed wetlands, and water supply is a serious concern locally, more study is needed to understand what wetland characteristics at the site scale create suitable habitat across the broader landscape (such as distance to nearest wetland). Results from such work have the potential to inform future management decisions, such as water allocation and release schedules, as well as identify priorities for restoration and land acquisition programs (Shuford and others 2006; Shuford and Gardali 2008).

In response to these results, continued monitoring with expanded geographic coverage and additional research is warranted. Future study should focus on potential causal factors of population decline, including habitat availability and suitability, water levels and water quality, food resources, and predation. The most urgent need is to improve our understanding of how water levels affect wetland size and isolation in the Klamath Basin. This will improve our understanding of how future water allocation might affect

Black Tern populations. Securing adequate long-term water supply for Agency and Upper Klamath Lakes, as well as refuges throughout the Klamath Basin, will be needed to effectively manage for breeding terns (Shuford and Gardali 2008). Additional study of restoration actions and how they relate to breeding terns would help determine whether future restoration could be beneficial. Improved understanding of local trends and causal factors is needed to inform water management, restoration, and habitat protection. It is likely that in combination, these management techniques have the potential to reverse population declines.

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