A REVIEW OF INTERIOR LEAST TERN AND PIPING PLOVER MANAGEMENT, CONSERVATION, AND RECOVERY ON THE LOWER PLATTE RIVER, NEBRASKA

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NONGAME BIRD PROGRAM

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SUMMARY

The Lower Platte River in eastern Nebraska provides many resources for wildlife and a variety of stakeholders. This river and its major tributaries contain important nesting habitat for two state and federally-listed bird species, the Interior Least Tern (endangered; *Sternula antillarum athalassos*) and the Northern Great Plains Piping Plover (threatened; *Charadrius melodus*). Both species nest on bare or sparsely-vegetated expanses of sand in natural and human-created habitat, which occur in and along river channels; the Lower Platte River system is critical for the survival and recovery of both species.

In contrast to other river systems in Nebraska, there is no programmatic agreement or framework that generates a comprehensive Interior Least Tern and Piping Plover policy on the Lower Platte River. The Nebraska Game and Parks Commission (NGPC) and the Tern and Plover Conservation Partnership (TPCP), in cooperation with the U.S. Fish and Wildlife Service (USFWS), are responsible for making and implementing management decisions in this region. Collectively, these decisions constitute a *de facto* tern and plover policy for the Lower Platte River. The fundamental challenge with regard to policy-making on the Lower Platte River is how to conserve terns and plovers while balancing the needs and concerns of stakeholders.

This document serves as a foundation for developing management strategies for Interior Least Terns and Piping Plovers on the Lower Platte River. To meet this end, we provide a summary of the area's geographic and political setting. Next, we provide detailed species descriptions for Interior Least Tern and Piping Plovers, including their ecology, population trends, and reasons for both species' declines. Finally, we describe current management activities by the Nebraska Game and Parks Commission and the Tern and Plover Conservation Partnership.

We hope that this document will facilitate meaningful discussion about the future of the Lower Platte River and the people and wildlife that depend on it.

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ABBREVIATIONS

CFS – Cubic feet per second
ESA – Endangered Species Act
IPCC – Intergovernmental Panel on Climate Change
KAF – Kilo-acre feet
LPPD – Loup Public Power District
LPR – Lower Platte River
NBP – Nongame Bird Program (Nebraska Game and Parks Commission)
NDNR – Nebraska Department of Natural Resources
NGPC – Nebraska Game and Parks Commission
NHCC – Nebraska Habitat Conservation Coalition
NRC – National Research Council
NRD – Natural Resource District
PVA – Population Viability Analysis
TPCP – Tern and Plover Conservation Partnership
USDOI – United States Department of the Interior
USFWS – United States Fish and Wildlife Service
USGS – United States Geological Survey

DEFINITIONS

For clarity we provide the definitions of some terms as we use them in this document, below:

Adult – terns: a second-year or older, rarely a first-year, bird, in adult plumage that is capable of breeding; plovers: a first-year or older plover in adult plumage that is capable of breeding

Alluvium – loose, unconsolidated sediments or soil that is eroded, deposited, and reshaped by the action of water

Altricial – the state of physical maturity of a hatchling and its dependence on parental care; chicks naked, blind, and helpless at hatching

Anabranch – a secondary channel that diverts from the main channel, rejoining it downstream (Joeckel and Henebry 2008)

Armor – various materials used to prevent erosion at specific locations on river and stream banks and islands

Bank full – stream flow that fills and forms the channel

Bank full flows – high flow events that occur relatively frequently (1.5 years) and responsible for subsequent breeding habitat conditions (Parham 2007)

Bed load – particles in flowing water that are transported along the stream bed

Belt width – the meandering stream channel; a channel with lateral movement

Bioaccumulation – process by which chemicals are taken up by an organism, either directly from exposure to a contaminated medium or by consumption of food containing the chemical (USEPA 2010)

Breeding habitat – set of physical and environmental components that a species uses for courtship, pairing, nest-site selection and construction, egg-laying, incubation, and chick-rearing

Channel – stream bed and bank

Channelization – the down-cutting and incising of the channel due to erosive processes in the river system.

Chick (hatchling) – life stage from hatching to when the bird is capable of flight

Chick habitat – set of physical and environmental variables that chicks use

Colonial (colony) – assemblages of largely unrelated individuals spatially restricted to particular breeding sites; individuals generally do not exhibit "helping" or cooperative breeding (Brown and Brown 1996)

Conservation - as defined by the 1973 Endangered Species Act (ESA):

> The terms ''conserve,'' ''conserving,'' and ''conservation'' mean to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary. Such methods and procedures include, but are not limited to, all activities associated with scientific resources management such as research, census, law enforcement, habitat acquisition and maintenance, propagation, live trapping, and transplantation, and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking.

Critical habitat – as defined by the ESA – habitat that is essential to the conservation of a threatened or endangered species, and that may require special management and protection; critical habitat may include areas not currently occupied by species but necessary for their recovery.

Discharge – the rate of streamflow or the volume of water flowing at a location within a specified time interval (Annear et al. 2004)

Exceedance - the amount by which something exceeds a standard or permissible measurement

Fledge-ratio – the number of fledglings per adult pair (or nest) over a defined spatial or temporal area

Floodplain – the area on either side of the bank full that carries flow greater than the bank full flow; an abandoned floodplain may no longer function because of channelization

Foraging habitat – set of physical and environmental variables that a species uses to find food

Geomorphology - the evolution and configuration of landforms

Habitat –set of physical and environmental components that individuals and/or species use for survival and reproduction (Block and Brennan 1993)

Habitat quality – environment's relative ability to provide conditions appropriate for the persistence of individuals and populations

Habitat selection – the behavioral responses that results in the disproportionate use of habitats to include survival and fitness of individuals (Jones 2001)

Habitat use – the way in which an individual or species uses habitats to meet its life history needs (Jones 2001); habitat use is the result of habitat selection

Hydrograph – a graph showing in river discharge over time

Hydro-peaking – the deliberate release of short-duration or pulsing high flows from water impoundments

Immature – terns: a second-year bird that is neither a juvenile nor an adult; includes birds in first-alternate plumage, sometimes referred to as the *portlandica* plumage

Instream flows – any quantity of water flowing in a natural stream at any time of year; this quantity may or may not be adequate to sustain natural ecological processes, and may or may not be protected or administered under a permit, water right, or other legally recognized means (Annear et al. 2004)

Intra-seasonal high-flow pulses – flows that are the result of localized heavy precipitation events and which occur during the Interior Least Tern and Piping Plover breeding season

Juvenile – the life stage from the pre-juvenal molt to the post-juvenal molt when the bird is capable of flight (within the first year of life)

Loess – wind-deposited sediment consisting of accumulated silt with smaller amounts of sand and clay, loosely held together with calcium carbonate; highly porous and forms vertical bluffs

Macro-form sandbars – relatively large sandbars that are the predominant feature used as nesting and breeding by Interior Least Terns and Piping Plovers.

Meta-population – a population of interacting populations

Nest-site selection – subset of habitat selection that focuses solely on nest sites

Nesting habitat –set of physical and environmental conditions that a species uses for nesting; area where nest(s) are created and eggs are laid

Nesting habitat use – the way in which an individual or population uses habitats to initiate and tend nests; nesting habitat use is the result of nesting habitat selection

Off-river features – the set of physical and environmental variables away from the active river channel; for terns and plovers off-river features are synonymous with human-created features that result from mining and dredging operations or housing developments

Piscivorous - feeding on fishes

Population – a group of organisms of the same species occupying a particular space at a particular time (Williams et al. 2001)

Precocial - refers to the state of physical maturity of a hatchling and its dependence on parental care; chicks capable of body temperature regulation; chicks mobile and leave the nest immediately

Recovery – attainment of a species' population and habitat goals (as expressed in an Endangered Species Act recovery plan)

Recruitment – addition of new individuals to a population by reproduction; usually restricted to addition of breeding individuals

Reproductive success – combination of the rates of reproduction [i.e., hatch success and fledge success] and annual survival of individual birds; reproductive success of all individuals in a population define the dynamics of that population's increase or decrease

Revetment – see ***Armor***

River features – the set of physical and environmental variables within the active river channel; river features include macro-form sandbars, transverse bars, channel width, sediment, and anabranches

River mile – a measure of distance along a river from its mouth; river miles begin at zero and increase further upstream

Riverine - located on or inhabiting the banks of a river

Semiprecocial - refers to the state of physical maturity of a hatchling and its dependence on parental care; chicks capable of body temperature regulation; chicks mobile but stay in the nest for a period of time

Streamway – land near the stream that may become flooded (i.e., active floodplain)

Stream geomorphology – formation of land by streams

Take – as defined by the ESA – to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct

Thalweg – the line of maximum depth in a stream or river; nearly always the line of fastest flow

Washover – area created by the flow of water through a primary dune line with deposition of sand on barrier flats, marsh, or lagoon

Water appropriations (water allocation) – determining the quantity of water from a given source that can or should be ascribed to various instream or out-of-stream uses (Annear et al. 2004)

INTRODUCTION

The Lower Platte River in Nebraska is an important resource for a variety of stakeholders. The river has been, and will continue to be, modified to meet the needs of these stakeholders. The modifications take two general forms, 1) use of the river's water and 2) control of the annual hydrological variation in the river system. Examples of the first include water diversion for agricultural or industrial purposes and of the second include levee construction for flood control. Balancing the needs for natural resource use by people and conservation of imperiled species in the ecosystem presents a challenge for decision-makers, resource agencies, and stakeholders. Currently, the river retains the capacity to create and maintain habitat for wildlife that depend on the river. However, as demands on the river's resources accumulate, the river system may reach a threshold beyond which the river will lose much of its natural function and become unable to create and maintain habitat for wildlife. This has occurred on the nearby Central Platte and Missouri rivers, and massive efforts are underway to restore the components of the former ecosystem so the wildlife and economies that rely on these rivers are able to survive.

The Lower Platte River differs from the Central Platte and Missouri Rivers in that there is no omnibus agreement in place that controls the management of the river. Management of the Missouri River is dictated by congressional mandate (e.g., Flood Control Act of 1944 and USFWS Biological Opinion of 2003) and is carried out by the U.S. Army Corps of Engineers. Management of the Central Platte River is influenced by local water use policy and by a three-state cooperative agreement (Platte River Recovery Implementation Program, http://www.platteriverprogram.org) that implements actions to provide habitat for imperiled wildlife.

The Lower Platte River system provides habitat for two state and federally-listed bird species, the Interior Least Tern (*Sternula antillarum athalassos*) and the Northern Great Plains Piping Plover (*Charadrius melodus*). Terns and plovers breed along the river during late spring and summer and spend the remainder of year in migration or on their wintering areas. Both species nest in aggregations on bare or sparsely-vegetated expanses of sand in natural and human-created habitat. Natural habitat consists of sandbars within the river channel, which are created and maintained by geomorphological processes. Human-created habitat occurs outside the river channel and is created by industrial or commercial activities (i.e., sand and gravel mining, dredging and construction). The Interior Least Tern is state and federally listed as endangered (50 Federal Register 21784–21792), and the Great Plains Piping Plover is state and federally listed as threatened (50 Federal Register 50726–50734). Federal listing is under authority of the Endangered Species Act (1973), and state listing is under authority of the Nebraska Nongame and Endangered Species Conservation Act (Revised Statutes of Nebraska 1943; Neb. Stat 37–903; Neb. Stat 37–804). Federal and state listing provides protections for the birds, chicks, eggs, and their habitat.

State and federal agencies, landowners, industries, and others all affect the form and function of the Lower Platte River. These stakeholders will make management decisions (including the decision to take no action) on how to manage the future of the river. These decisions will determine the form, function and future of the river, as well as the fate of terns, plovers, and other wildlife that depend on the river.

While a large number of stakeholders affect the function of the Lower Platte River, the number of entities working proactively on tern and plover management is quite small. The Nebraska Game and Parks Commission (NGPC) and the Tern and Plover Conservation Partnership (TPCP), in cooperation with the U.S. Fish and Wildlife Service (USFWS), are the only organizations that currently implement management actions directed toward terns and plovers. These actions have generally been implemented in response to specific situations. Collectively, these actions constitute a *de facto* tern and plover management policy for the Lower Platte River.

We prepared this document to improve policy and decision-making on the Lower Platte River with respect to Interior Least Tern and Piping Plover management, conservation, and recovery. The information contained in the document addresses two distinct, albeit interrelated, themes:

> **Management**: Includes actions where NGPC, TPCP and USFWS <u>are</u> the principal decision-makers. This includes actions such as small-scale habitat management, nest protection, research, and monitoring. We propose to move our efforts toward an adaptive management framework. In adaptive management, stakeholders work to define the management problem, establish objectives to resolve the problem, determine alternative approaches to resolving the problem, identify consequences of implementing the alternative approaches, and assess tradeoffs associated with each alternative approach. By following this process, decision-makers may avoid making poor management decisions (Gregory and Keeney 1994, 2002).
>
> **Policy**: Includes actions where NGPC, TPCP and USFWS <u>are not</u> the principal decision-makers, but serve as providers of information so that better informed decisions are made. Our intent in preparing this document was to offer information on an array of topics of concern to decision-makers. By providing information in this way, we believe better, more-informed policy decisions can be made.

This document is non-regulatory and does not represent the official policy of any state or federal agency or organization. We plan to regularly revise the document, updating it as new information and developments require. Here, we define the problem and review and synthesize the information that is currently available.

FOCUS AREA

The Platte River is one of several large river systems (e.g. Missouri, Niobrara, Canadian, and Red) in the mid-continent of North America. It flows primarily west to east across the central Great Plains region of the United States, ultimately joining the Missouri and Mississippi Rivers and the Gulf of Mexico (National Research Council 2005). The Platte River Basin drains an area of 223,000 km^2 (86,000 mi^2) in Wyoming, Colorado, and Nebraska. It is formed from the confluence of the North Platte and South Platte Rivers. The North Platte River rises in the Medicine Bow Mountains and flows northward from Jackson County, Colorado into Wyoming, then eastward into Nebraska (Eisel and Aiken 1997; National Research Council 2005). The South Platte River rises in the Rocky Mountains and flows in a northeastern direction from Park County, Colorado, to west-central Nebraska (Eisel and Aiken 1997; National Research Council 2005). The two rivers meet in western Nebraska, near the city of North Platte, Lincoln County; from there, the Platte River flows for approximately 500 km (310 mi) through most of the state, draining an area of 77,441 km^2 (29,800 mi^2; Currier et al. 1985; Figure 1). The Lower Platte River, described below, comprises the focus area of this document.

<u>Geography</u>

The Platte River downstream of the North Platte and South Platte River confluence (41.1156 N, -100.6801 W) is separated into two segments, the Central Platte and the Lower Platte. In this document, we consider the Central Platte River as the portion of the Platte River from Lexington, Dawson County to Chapman, Hamilton County, Nebraska (approximately from RM 155 to 251). This conforms with the boundary of the Platte River Recovery Implementation Program (USDOI 2006). Similarly, we define the Lower Platte River as the stretch of 103 river miles (RM) from the confluence of the Platte and Loup Rivers (41.397656, -97.317667) near Columbus, Platte County, to the mouth near Plattsmouth, Cass County, where the Lower Platte joins the Missouri River (41.0546 N, -95.8818 W; Figure 4). River miles are numbered 0 at the mouth and increase as one moves upstream; thus, the Platte-Missouri River confluence is RM 0, and RM 102 is located downstream of Loup-Platte confluence. It should be noted that, under definitions currently in use by various organizations (e.g. USDOI 2006; NGPC 2008; Sherfy et al. 2008), there are portions of the Platte River that are not included in either subsection (e.g. from the North and South Platte River confluence to Lexington, Dawson County, and from Chapman, Merrick County to the Loup-Platte River confluence).

In addition to the Loup River, several other tributaries join the Lower Platte River below RM 102. The Elkhorn River joins the Platte (41.1226 N, -96.3122 W) at approximately RM 33, near Gretna, Sarpy County. The Elkhorn drainage includes a large portion of northeastern Nebraska, flowing southeast towards the Lower Platte River through cultivated fields, wet meadows and marshy plains. The Loup and Elkhorn rivers both originate in the Nebraska Sand Hills, the largest sand-dune ecosystem in the Western Hemisphere (Peterson et al. 2008). The Salt Creek confluence (41.031961 N, -96.308594 W) is at approximately RM 24, near Ashland, Saunders County. The Salt Creek drainage is relatively small compared to the Loup and Elkhorn Rivers and includes much of Lancaster and southern Saunders County. Several small creeks also flow into the Lower Platte River, including Shell Creek, Lost Creek, and Cedar Creek.

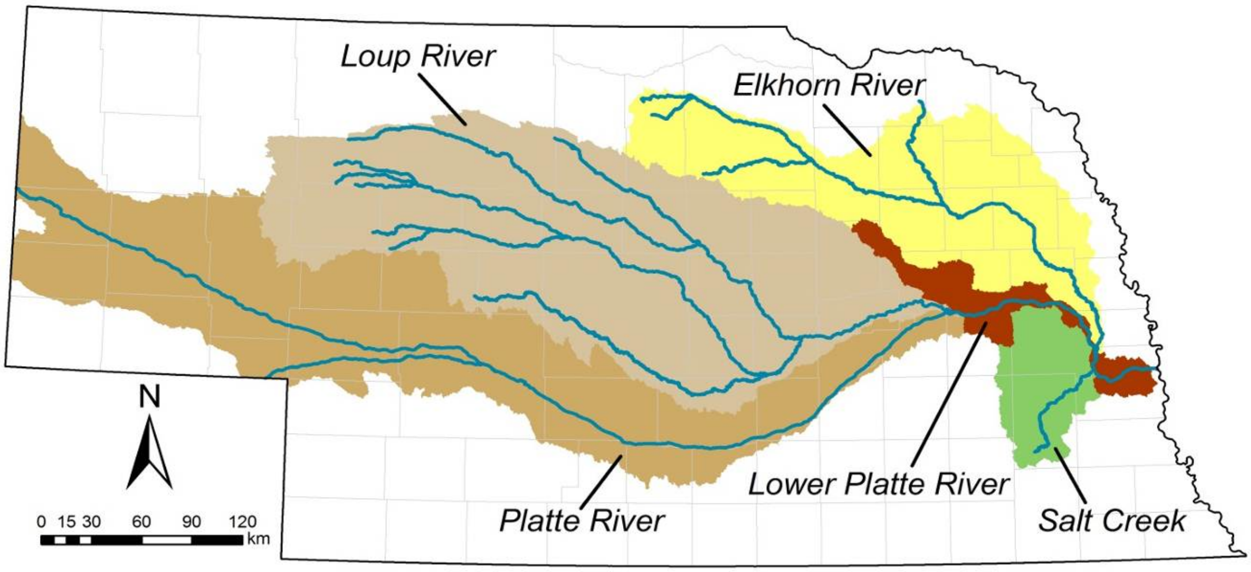

Figure 1. Watersheds of the Platte River and its tributaries in Nebraska. The Lower Platte River drainage is shown in red. The Tern and Plover Conservation Partnership, together with the Nebraska Game and Parks Nongame Bird Program, have monitored and protected tern and plover nests along this reach since 1999.

<u>Topography</u>

Near the headwaters in the mountains of Colorado, the Platte River Basin has elevations greater than 4,200 m (14,000 ft). Moving eastward, the Great Plains region of the basin forms a gentle slope, with elevations decreasing from 1,800 m (5,900 ft) to less than 300 m (1,000 ft). This topographically flat region consists of sand and loess sheets, sand hills, and river valleys (National Research Council 2005).

The river valley sits on an alluvium of clay, silt, sand, and gravel (Currier et al. 1985). This alluvium is relatively young, dating from the Quaternary Period (i.e., 2 million years ago; Kuzelka et al. 1993). Below the alluvium are beds of clay, silt, sand, sandstone, and gravel (Currier et al. 1985). The river itself has a bed of sand and sandy gravel (Bentall 1989) and sand comprises most of the bed load (Joeckel and Henebry 2008; Elliott et al. 2009).

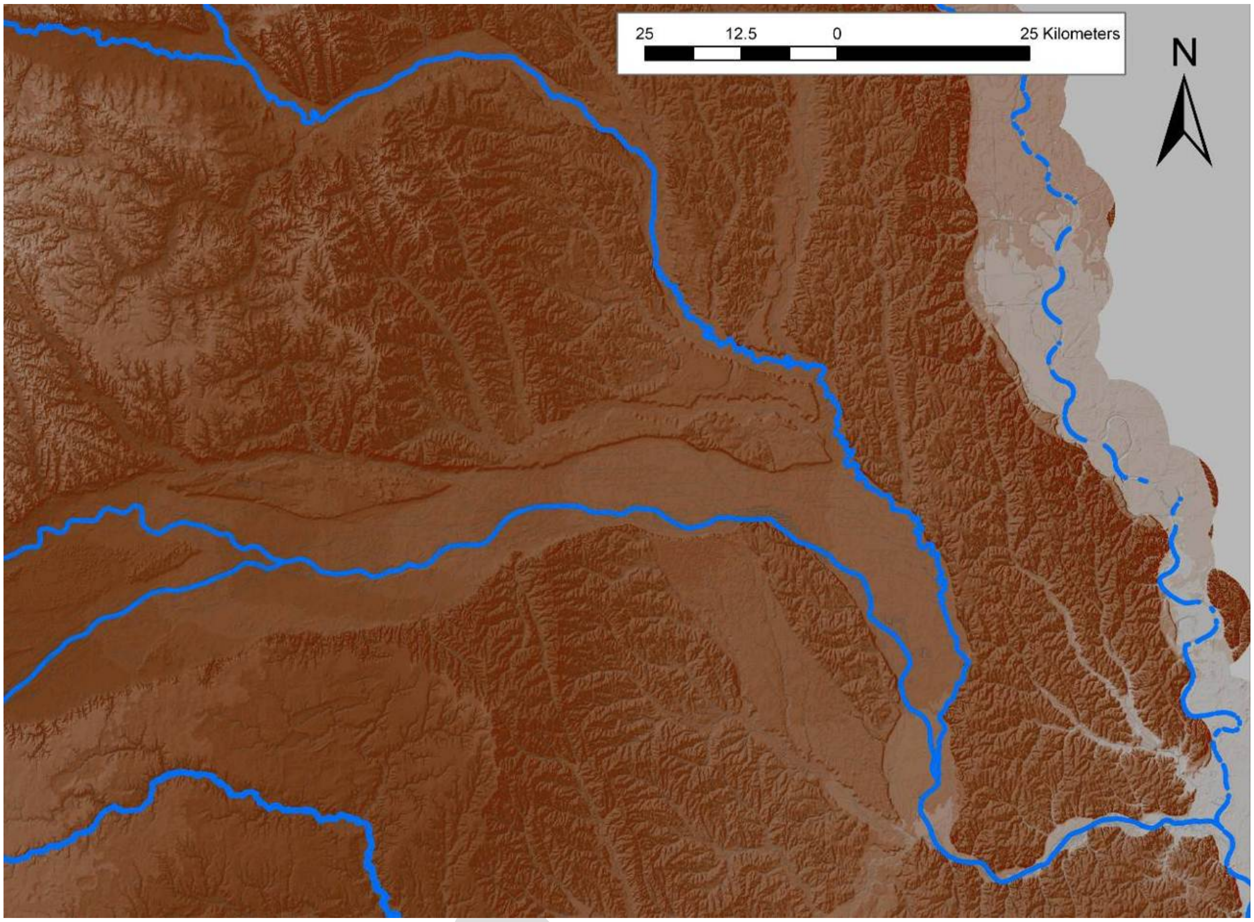

Figure 2. The topography of the Lower Platte River in Nebraska. The Platte River flows eastward through Nebraska until reaching the confluence with the Missouri River along the state's eastern border. The area is characterized by wide channels with shallow water; most of this water originates as precipitation in the Rocky Mountains. Elevations in this area range from approximately 3,090 feet (942 m) to less than 1,000 feet (300 m; National Research Council 2005; USGS 2010).

The Lower Platte River is located in a region of varied geology and topography (Figure 2). Its westernmost section (between Columbus, Platte County and Fremont, Dodge County) flows through a broad valley surrounded by rolling loess plains. From Ashland eastward, the river flows through a shallow gorge of eroded Pennsylvanian sedimentary rock, which dates from 320–286 million years ago (Kuzelka et al. 1993; Joeckel and Henebry 2008). Unlike the Central Platte, some portions of the Lower Platte River flow adjacent to steep bluffs. Sandbars, islands, and anabranches are characteristic features of the Lower Platte River, giving it a braided morphology (Smith 1971; Joeckel and Henebry 2008). The river channel is wide, ranging from 450–600 m (1,400–1,900 ft); the floodplain varies from 10–18 km (6 –11 mi) in width (Smith 1971).

<u>Climate</u>

The Platte River flows through a section of North America with a continental climate, characterized by hot summers and cold winters. Annual rainfall varies from less than 38 cm (15 in) in northwestern Nebraska to more than 91 cm (36 in) in the southeastern corner of the state

(Lawson 1977). Precipitation occurs primarily from May to September (Currier et al. 1985). Thunderstorms occur frequently during the spring and summer months. Annual snowfall averages less than 64 cm (25 in) in the southeast to less than 101 cm (40 in) in the northwest (Lawson 1977). Climatic conditions follow a west-east gradient, with semiarid conditions in the western part of Nebraska, dry subhumid conditions in the central region, and moist subhumid conditions in the eastern part of the state (Kuzelka et al. 1993). Winds prevail from the south/southwest in summer and north/northwest in winter (Kuzelka et al. 1993).

Hydrology

The Platte River obtains most of its water from snowmelt runoff in the Rocky Mountains. However, snowmelt varies annually in volume and melting rate so this contribution to the flow is not consistent between years (Kuzelka et al. 1993). Precipitation in the form of rain in the basin also contributes to the flow (Currier et al. 1985). Flows show tremendous interannual variation; between 1896 and the late 1940s, yearly peak discharge ranged from 2,000 to 45,000 cfs (Beshore 2002). Historically, the variable nature of the water sources for the Platte caused periods of little to no flow within a year (Kuzelka et al. 1993; Beshore 2002). High flows in spring and early summer deposit sediment, creating sandbars in the river channel. In addition, these flows remove vegetation from sandbars, maintaining bare areas of sand.

The Loup River, Elkhorn River, and Salt Creek all contribute flows to the Lower Platte River, with the Loup and Elkhorn contributing the majority of flows (Figure 3). Reduced flows in mid- to late summer cause water levels to recede, exposing sandbars. Because the Loup and Elkhorn Rivers obtain most of their flows (87% and 66%, respectively; Peterson et al. 2008) from groundwater, their hydrology is less variable than the Platte (Kuzelka et al. 1993). The two also contribute sediment to the Lower Platte (Elliott et al. 2009). The Loup River transports fine to medium-grained quartz-rich sand, sand eroded from older Platte River deposits, and feldspathic gravel (Beshore 2002). A variety of wetlands occur outside the main river channel and include saturated wet meadows, semipermanently-flooded channel remnants, and oxbows (LaGrange 2005).

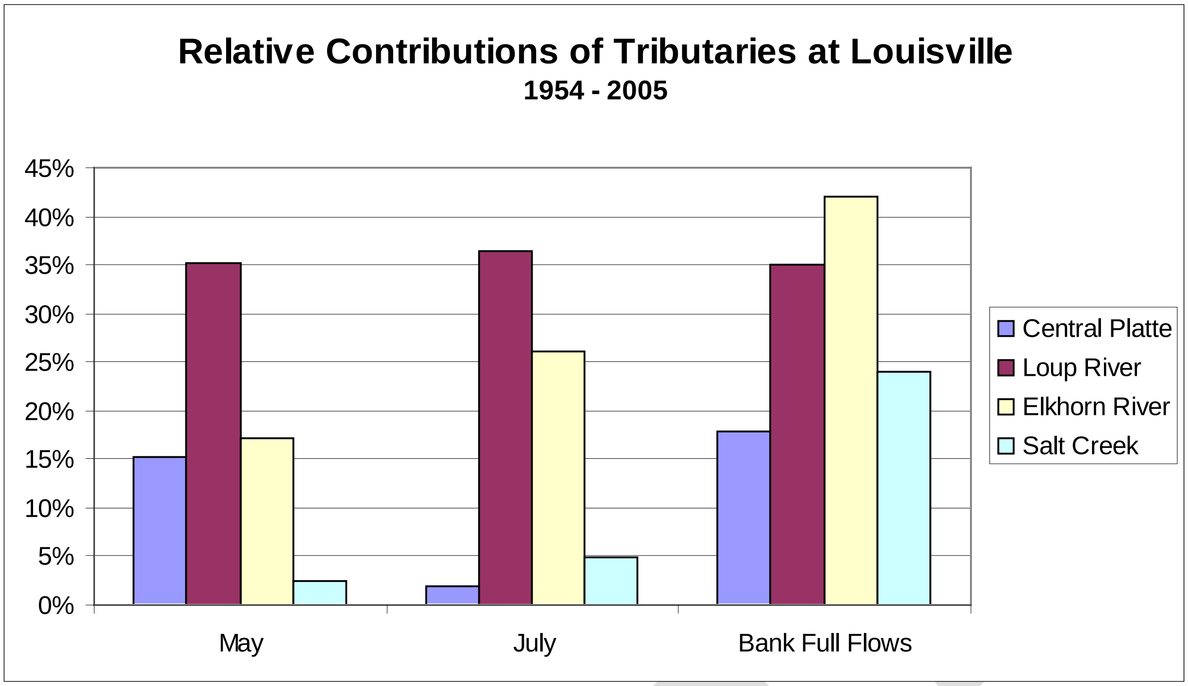

Figure 3. The relative contributions of larger tributaries to flows in the Lower Platte River. May and July statistics were based on the 80% exceedance for the period 1954–2005. (from Nebraska Game and Parks Commission 2008).

<u>Vegetation</u>

Prior to European settlement, the Platte River valley was dominated by a mosaic of woodland, grassland, and wetland vegetative communities (Kaul et al. 2006). Areal coverage of native plant communities has been greatly reduced, mostly due to conversion to agriculture. Within the river valley, dominant native communities include riparian forests, lowland tall-grass prairie, and upland deciduous forest (Kaul et al. 2006). Riparian woodlands occur on the floodplains of the Platte River and are dominated by deciduous trees and shrubs such as Eastern Cottonwood (*Populus deltoides*), willow (*Salix* spp.), Ash (*Fraxinus pennsylvanica*), and elm (*Ulmus* spp.; Steinauer and Rolfsmeier 2003). Lowland tall-grass prairie is dominated by warm-season grasses such as Big Bluestem (*Andropogon gerardii*) and cordgrass (*Spartina* spp.; Steinauer and Rolfsmeier 2003). Upland deciduous forest occurs on bluffs adjacent to the river valley and includes trees such as Bur Oak (*Quercus macrocarpa*) and American Linden (*Tilia americana*; Steinauer and Rolfsmeier 2003). Wetland vegetation is varied and includes riparian forest, riparian dogwood – False Indigobush (*Cornus spp.*, *Amorpha fruticosa*) shrub, and herbaceous communities (Steinauer and Rolfsmeier 2003).

River sandbars are sparsely vegetated when newly formed or after scouring events but are rapidly colonized by herbaceous plants including annual sedges (*Cyperus* spp.), grasses (*Echinochloa* spp.), cockleburs (*Xanthium* spp.), and cottonwood and willow seedlings (Currier et al. 1985; National Research Council 2005).

Invasive species have altered the structure and functioning of native plant communities. Many of these species were brought to North America from Europe and Asia in the 1800s (Decker

2010). Eastern Red Cedar (*Juniperus virginiana*), a native species, dominates upland woodlands along the Central Platte River, and along with Kentucky Bluegrass (*Poa pratensis*), has invaded tall-grass prairies (Friesen et al. 2000; Narumalani et al. 2009). Russian Olive (*Elaeagnus angustifolia*), Eastern Red Cedar, and buckthorn (*Rhamnus* sp.) are replacing cottonwood and willow in riparian woodlands (Gehring and Bragg 1992; Schneider et al. 2005; Narumalani et al. 2009). Saltcedar (*Tamarix ramosissima*) occupies river banks, islands, and sand bars along the North Platte River as well as the Central Platte (Friesen et al. 2000; Narumalani et al. 2009). Reed Canary Grass (*Phalaris arundinacea*), Common Reed (*Phragmites australis*), and Smooth Brome (*Bromus inermis*) are found in wetlands adjacent to the river as well as on sand bars (Friesen et al. 2000). Purple Loosestrife (*Lythrum salicaria*) has also been documented along the Platte River (Decker 2010). As of this writing, the Lower Platte River has been less impacted by invasive plant species than the Central Platte River.

<u>Economic Setting</u>

A wide array of economic activities occurs within the focus area. Agriculture is the dominant land use throughout the Lower Platte River watershed. More than 1,900,000 acres are used as cropland, and land can sell for as much as $3,642 per acre (2007 data, National Agricultural Statistics Service 2007). Upland and valley areas are used for grazing, and locally-owned farms raise cattle, pigs, poultry, and sheep (National Agricultural Statistics Service 2007; Lower Platte River Corridor Alliance 2010). Agricultural sales net more than $1.5 billion annually in counties along the Lower Platte River (National Agricultural Statistics Service 2007).

The Platte River's historical geomorphology produced large deposits of sediment outside the river channel. Deposits, which can be more than 150 feet deep, are produced by transport and deposition of eroded bedrock and surficial materials (Meador and Layher 1998; Tern and Plover Conservation Partnership 2010). Commercial operations mine these areas for sand, gravel, lime and limestone (Lower Platte River Corridor Alliance 2010). Sand and gravel pits are typically located within 3 miles of the river channel (Brown and Jorgensen 2009). Mining of nonmetallic minerals employs more than 9,000 people and generates $800 million annually in Nebraska (National Mining Association 2010). Nearly all (96%) sand and gravel mined in the U.S. is used for construction projects, which include buildings and roads (Langer 1988). In many cases, sand and gravel pits are eventually converted to lakeshore housing developments after mining operations cease.

Tourism in Nebraska is a 2.8-billion-dollar per year industry, and five of the 25 top tourist attractions (Mahoney State Park, SAC Museum, Omaha Henry Doorly Zoo, Quarry Oaks Golf Course, and Lozier IMAX Theater) are located along the Lower Platte River. Other attractions in the Lower Platte River area include state recreation areas, an aquarium, youth camps, wildlife clubs, and marinas. More than 3 million people visit these areas each year, adding $30 million to the state's economy (Lower Platte River Corridor Alliance 2010).

<u>Political Setting</u>

Policy related to the Lower Platte River involves many entities at different levels of governance (Table 1). At the federal level, the U.S. Fish and Wildlife Service (USFWS) is the authority charged with administering the Endangered Species Act (ESA) of 1973, which protects threatened and endangered species and the habitats they require for survival. State and federal agencies must consult with USFWS if projects they authorize or implement have the potential to jeopardize the continued existence of ESA listed species or their habitat. USFWS has the authority to designate portions of rivers or other areas as critical habitat, which affords these areas special protection under federal law. The U.S. Environmental Protection Agency (EPA) oversees the protection and restoration of the nation's surface waters by setting water quality standards as authorized by the Clean Water Act of 1972 (33 U.S.C. §1251) and determines whether or not pesticides or herbicides used in a given area will affect any species listed under the ESA (see Listing Background below).

It is the policy of the state of Nebraska to protect and improve the quality of surface water for the benefit of people, wildlife, and the environment (e.g., Nebraska Department of Environmental Quality Title 117 Ch. 4). The Nebraska Department of Natural Resources (DNR) has jurisdiction over matters pertaining to the use of surface water, including instream flows. Water appropriations are set for rivers in the state, including the North and South Platte Rivers, the Platte River, and the Loup and Elkhorn Rivers (Nebraska Department of Natural Resources 2010). The Nebraska Department of Environmental Quality (DEQ) serves as the state's environmental regulatory agency, much like the federal EPA for surface and ground water resources.

A variety of local government jurisdictions have authority within the Lower Platte River watershed. Eight counties are located along the Lower Platte River (Table 2), which serves as a boundary between several of these counties. Three Natural Resource Districts (NRDs) occur along the Lower Platte River (Figure 5). The NRDs are mandated to protect the natural resources of a specific watershed (Nebraska Association of Resources Districts 2010). To meet this mandate, the NRDs in the Lower Platte River maintain 280 dams and 27 miles of levees (Nebraska Association of Resources Districts 2010). NRDs oversee a variety of programs dealing with flood control, water supply for urban, rural and economic users, and management of surface and ground water (Nebraska Association of Resources Districts 2010). Major cities along the Lower Platte River include Columbus, Schuyler, Fremont, Wahoo, Lincoln, Plattsmouth, and Omaha (Figure 6). These cities have planning commissions or boards which develop land-use plans, maintain zoning regulations, and review development applications (City of Lincoln 2010).

Another organization active in the Lower Platte River is the Lower Platte River Corridor Alliance, a consortium of six state agencies and three NRDs. The Alliance offers river management assistance to counties, communities, governments, and other organizations by providing land-use planning assistance, water quality studies, and educational workshops (Lower Platte River Corridor Alliance 2010).

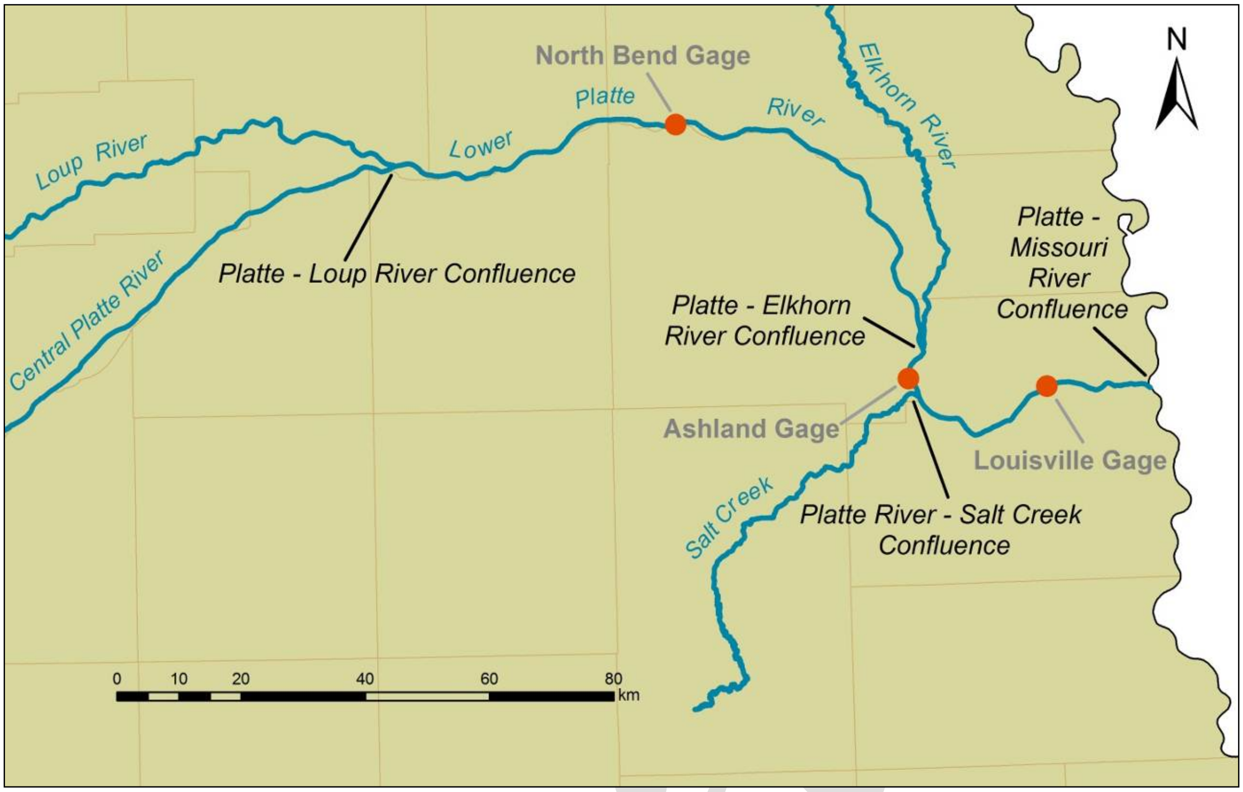

Figure 4. Locations of USGS stream gages on the Lower Platte River.

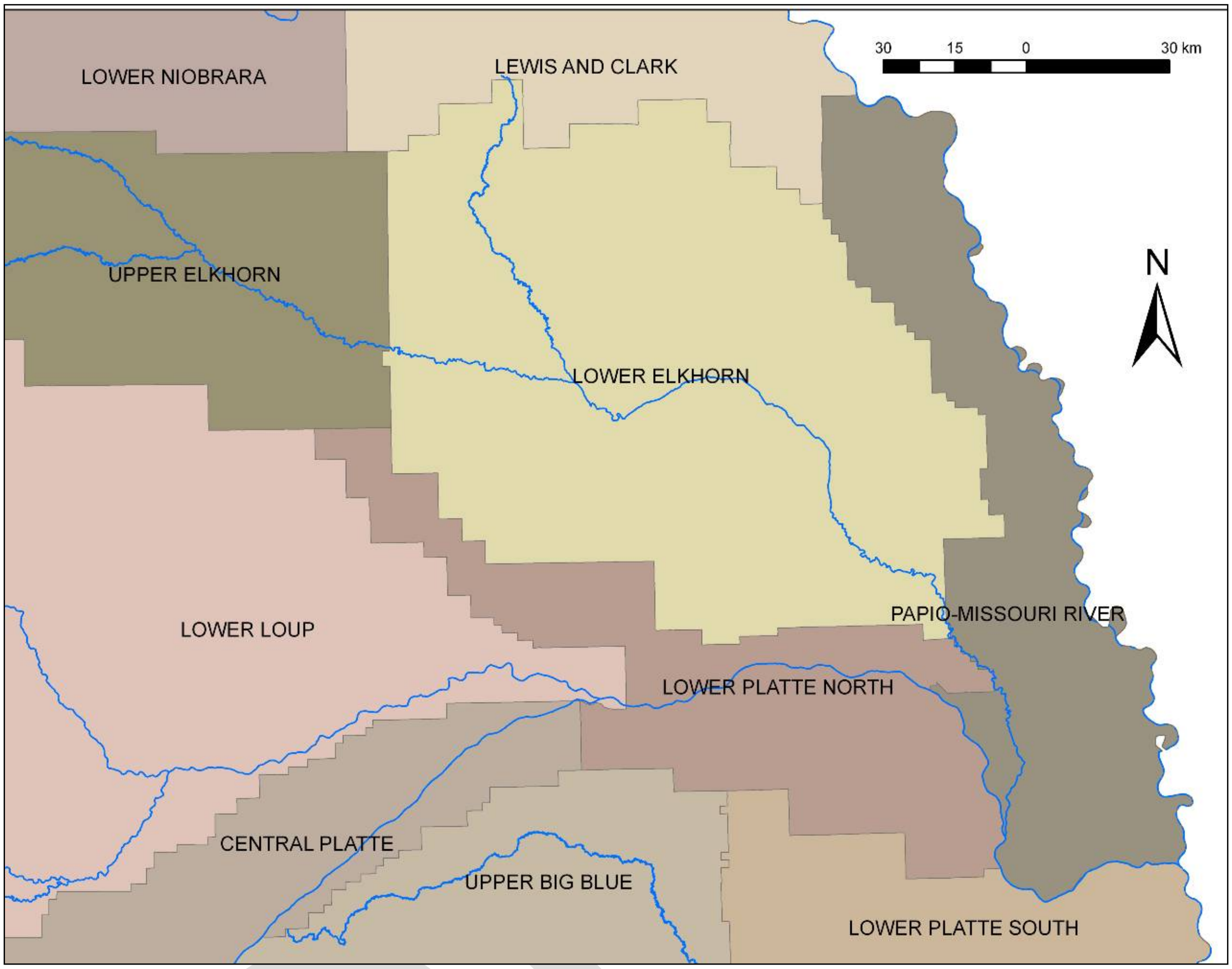

Figure 5. Natural Resource District boundaries within the Lower Platte River area.

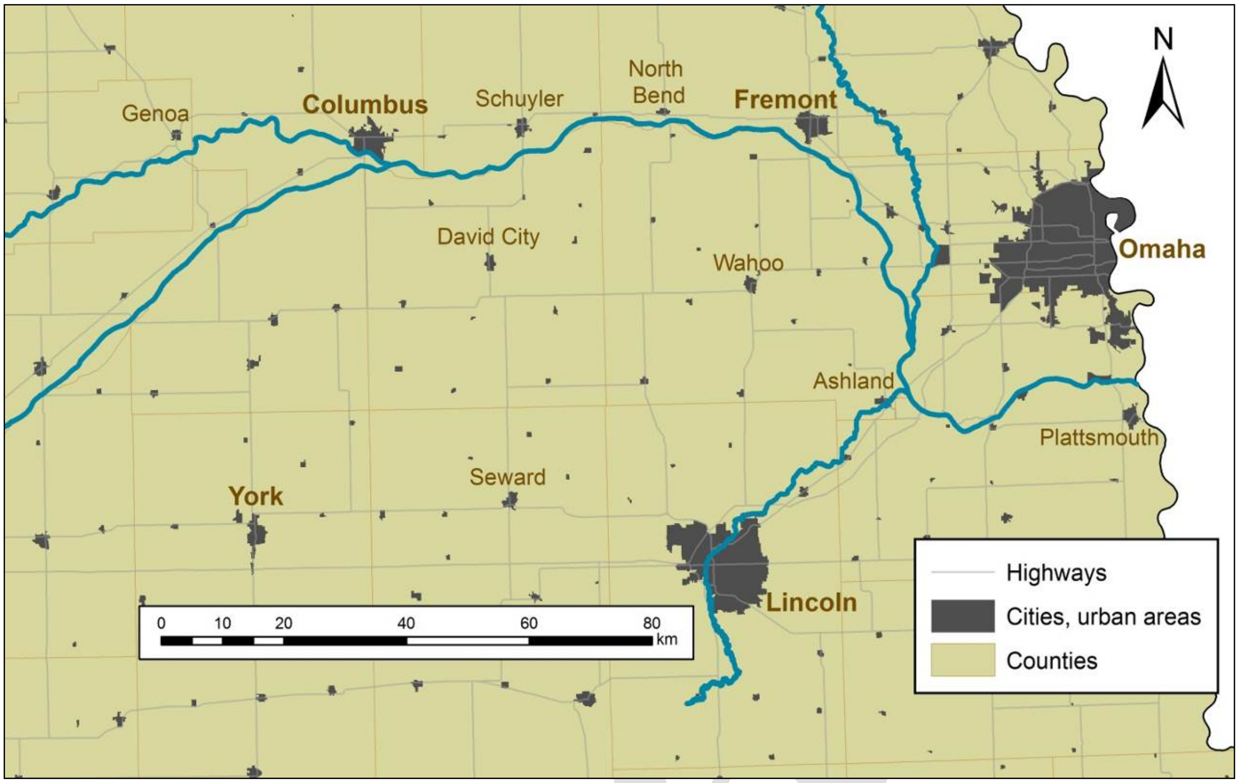

Figure 6. Cities and urban areas located in the Lower Platte River watershed.

Table 1. Agencies and organization with interests in the Lower Platte River. Note: this is a not a comprehensive list.

Political Entity	Level of Governance
U.S. Fish and Wildlife Service (USFWS)	Federal
U.S. Environmental Protection Agency (EPA)	Federal
U.S. Department of Agriculture (USDA)	Federal
National Park Service (NPS)	Federal
U.S. Bureau of Reclamation	Federal
Federal Energy Regulatory Commission (FERC)	Federal
Nebraska Department of Environmental Quality	State
Nebraska Department of Natural Resources	State
Nebraska Game and Parks Commission (NGPC)	State
Lower Platte North NRD	Local
Lower Platte South NRD	Local
Papio-Missouri River NRD	Local
Lower Platte River Corridor Alliance	Local
Columbus Planning Commission	Local
Lincoln Planning Commission	Local
Omaha Planning Board	Local
Plattsmouth Planning Commission	Local
Schuyler Development Company	Local
Wahoo Planning Commission	Local

Table 2. Counties lying within the Lower Platte River area. Population is based on the 2000 census.

County	Cities	Population
Butler	David City	8,767
Cass	Eagle, Louisville, Plattsmouth, Weeping Water	24,334
Colfax	Clarkson, Howells, Schuyler	10,411
Dodge	Dodge, Fremont, Hooper, North Bend, Scribner	36,160
Douglas	Bennington, Omaha, Ralston, Valley	463,585
Platte	Columbus, Humphrey	31,662
Sarpy	Bellevue, Gretna, La Vista, Springfield	122,595
Saunders	Ashland, Ceresco, Wahoo, Yutan	19,215

An Overview and History of the Interior Least Tern and Piping Plover Endangered Species Act Listing

The listing process for the Interior Least Tern began in November 1975, when the Oklahoma Ornithological Society petitioned the U.S. Fish and Wildlife Service to designate the species as endangered (49 Federal Register 2485–2488). On 30 December 1982, the USFWS published a notice of review, which identified the Interior Least Tern as under consideration for addition to the List of Endangered and Threatened Wildlife (47 Federal Register 58454–58460). The Interior Least Tern was assigned to Category 2, meaning that USFWS had information that was "possibly appropriate, but for which substantial data are not currently available" to support proposed federal listing. The USFWS then published a notice of findings on pending petitions on 20 January, 1984. This notice identified the petition for the Interior Least Tern as "warranted," which would lead to the publishing of a proposed rule (49 Federal Register 2485–2488). Accordingly, on 29 May 1984, the USFWS published a proposed rule that the Interior Least Tern be designated endangered. The USFWS solicited public comment, including a request for data relating to locations of any additional populations, additional information on the subspecies' range, and data concerning possible threats to the Interior subspecies or its habitat. Requests for public hearings were also solicited.

Although afforded some protection by the International Migratory Bird Treaty Act and threatened or endangered listing in eight states (including Nebraska), the USFWS argued that federal listing would protect crucial breeding habitat (49 Federal Register 22444–22447). The requisite 60-day public comment period for the proposed rule was extended in order to accommodate a public hearing held on 11 September 1984. A group of organizations, including the Central Platte Natural Resources District, Nebraska Water Resources Association, and Denver Water Department, opposed federal listing. They questioned the accuracy of the population estimate cited by USFWS in the proposed rule and suggested that Interior Least Terns were not decreasing (50 Federal Register 21785). The USFWS countered that Interior Least Terns warranted federal listing due to the contraction of their historic range, very low current population estimates, and the continued threat of habitat loss (50 Federal Register 21785). As a result, a final rule was published on 28 May, 1985 to list the Interior Least Tern as endangered in 18 states (50 Federal Register 21784–21792).

The listing process for the Piping Plover began in 1982, when the USFWS published a notice of review, which identified Piping Plovers as under consideration for federal listing throughout their breeding range (47 Federal Register 58454–58460). The Piping Plover was assigned to Category 2, meaning that USFWS had information that was "possibly appropriate, but for which substantial data are not currently available" to support proposed federal listing. On 8 November 1984, USFWS proposed endangered status for the Great Lakes Piping Plover and threatened status for the Great Plains, Atlantic, and wintering populations (49 Federal Register 44712–44715). The USFWS based proposed listing on "review of existing data, including recent status surveys, and consultation with biologists" (49 Federal Register 44712). The USFWS requested data and comments from the public on threats to the Piping Plover, locations of habitat, and its range and distribution (49 Federal Register 44714). Public hearings were held in Colorado and Nebraska in response to the proposed rule (50 Federal Register 50728). The pubic hearing in Nebraska was held on 18 January 1985 in Omaha. The requisite 60-day comment period was extended three times in response to requests from numerous organizations. Twenty-five water management organizations from Colorado, Wyoming, and Nebraska opposed federal listing of the Northern Great Plains Piping Plover. Their opposition arose from concerns that federal listing could curtail water development projects on the North Platte, South Platte, and Platte

Rivers (50 Federal Register 50728). They also questioned the adequacy of the data used to support federal listing. In addition, seventeen comments disagreed with the USFWS's decision to not designate critical habitat for the Piping Plover. After reviewing submitted comments and all available information, the USFWS determined that the Piping Plover should be listed as endangered in the Great Lakes region and threatened in the rest of its range. This decision was based on the species' low numbers and the continued threats of habitat loss, predation, and human disturbance on the nesting grounds. The final rule was published on 11 December 1985 (50 Federal Register 50726–50734).

<u>Recovery plans</u>

An explicit goal of listing species as threatened or endangered is the implementation of specific actions that will lead to their conservation and recovery (Hoekstra et al. 2002). Section 4(f)(1) of the Endangered Species Act requires that recovery plans be developed and implemented for federally-listed species. Originally, two recovery plans were published for the Piping Plover: one for the Great Lakes and Northern Great Plains (1988), and one for the Atlantic Coast (1988). The Atlantic Coast Piping Plover Recovery Plan was later revised (1996), and a separate recovery plan was published for the Great Lakes Piping Plover (2003). The Northern Great Plains Recovery Plan has not been revised. At the time of publication, there were an estimated 1,360 Northern Great Plains Piping Plovers (USFWS 1988). The primary goals, or recovery objectives, were to increase the number of breeding birds to 1,300 pairs and have that number remain stable for 15 years. More specifically, the goal was to increase the number of breeding birds in Nebraska to 465 pairs (USFWS 1988). The USFWS did not use a population viability analysis (PVA) to determine recovery goals (USFWS 1988). However, seven PVAs have been conducted since the recovery plan was released in 1988 (USFWS 2009a).

Recovery plans list a number of criteria that, if met, will lead to the delisting of the species. The Northern Great Plains Piping Plover Recovery Plan outlines four criteria and lists the actions considered necessary to accomplish these recovery criteria. These actions, termed recovery tasks, were given a priority level of 1, 2, or 3, with 1 "those actions absolutely necessary to prevent extinction of the species," 2 "those actions necessary to maintain the species' current population status," and 3 "all other actions necessary to provide for full recovery of the species" (USFWS 1988). Among the 27 recovery tasks outlined in the plan, the highest-priority tasks deal with surveying wintering populations, managing water levels to reduce egg and chick loss, and protecting breeding and wintering habitat (USFWS 1988).

Two recovery plans were created for Least Terns. The California Least Tern Recovery Plan was published in 1980, and the Interior Least Tern Recovery Plan was published in 1990. Neither Least Tern Recovery Plan has been revised. At the time of publication, an estimated 5,000 Least Terns occurred in the Interior United States (USFWS 1990). The primary recovery objectives included increasing the number of Interior Least Terns to 7,000 birds, with that number remaining stable for 10 years. In Nebraska, the recovery objective was 1,520 birds (USFWS 1990). It does not appear that the USFWS used a PVA to determine recovery goals. Recovery tasks, prioritized from 1–3, were divided by river system (i.e., Missouri, Mississippi, Arkansas, Red, or Rio Grande). The recovery team listed a total of 18 recovery tasks, with three tasks given a priority level of "1": managing water levels to reduce nest and chick loss, developing river management plans, and identifying river flow regimes to protect habitat (USFWS 1990).

Critical habitat designation and subsequent vacation

Section 4(a)(3) of the ESA requires that critical habitat be designated for federally-listed species. The ESA defines critical habitat as any area essential for the conservation of a threatened or endangered species (for complete definition, see p. 8). In both final rules for listing the Piping Plover and Least Tern, the USFWS deferred critical habitat designation, citing the "ephemeral nature" of their breeding habitat (49 Federal Register 22446; 49 Federal Register 44714). At this time, critical habitat has not been designated for the Interior Least Tern or the California Least Tern. Defenders of Wildlife filed lawsuits in 1996 and 1997 in response to the USFWS's decision to not designate critical habitat for the Piping Plover in the Great Lakes and Northern Great Plains (67 Federal Register 57642). In 2001, the U.S. District Court ordered the USFWS to publish a proposed critical habitat designation for breeding and wintering areas (67 Federal Register 57642).

In 2001, 35 critical habitat units were designated for Piping Plovers breeding in the Great Lakes region; critical wintering habitat was designated in 142 areas on the Atlantic and Gulf coasts (Table 3). Critical wintering habitat in both North Carolina and Texas has been revised by the USFWS in response to lawsuits (in 2008 and 2009, respectively; 73 Federal Register 62816–62841; 74 Federal Register 23475–23600). In 2003, two North Carolina counties and a beach access group filed a lawsuit against USFWS, challenging its designation of four units of critical habitat along the Cape Hatteras National Seashore (73 Federal Register 62816). The court vacated USFWS's proposed critical habitat and remanded the four units for reconsideration. In response, USFWS considered submitted public comments, conducted an economic analysis and environmental assessment, and revised the location of critical habitat in two of these units (73 Federal Register 62816). In 2006, the Texas General Land Office filed suit against USFWS's decision to designate 19 units of critical habitat along the Texas coast (74 Federal Register 23476). The court vacated and remanded the designation for reconsideration. After consideration of public comments and completion of economic and environmental assessments, USFWS revised the critical habitat under consideration to include 18 of the 19 units (74 Federal Register 23483).

Critical habitat was designated for Piping Plovers breeding in five Northern Great Plains states in 2002 (67 Federal Register 57638–57717). In Nebraska, critical habitat included more than 700 km along the Platte, Loup, and Niobrara Rivers (Table 3). The Nebraska Habitat Conservation Coalition (NHCC), a consortium of NRDs, public power districts, water users, and others, filed a lawsuit in Federal District Court in 2003 over the Nebraska critical habitat designation (NHCC 2006). In its lawsuit, the NHCC claimed that the USFWS used inadequate science in its designation and failed to show economic impacts of such a designation (NHCC 2006). A judge vacated the critical habitat designation in Nebraska in 2005, remanding it to the USFWS for redesignation. The judge also ordered the USFWS to complete a new economic assessment (Strom 2005). USFWS filed a notice of intent to appeal the ruling in 2006, and NHCC filed a notice of intent to cross-appeal the same year. No further action has been taken by either party, and therefore, critical habitat for the Piping Plover has not been designated in Nebraska at the present time.

Five-year reviews

Section 4(c)(2)(B) of the ESA requires that the USFWS conduct five-year reviews of threatened and endangered species. Such reviews use newly available data to determine whether a species should be delisted or reclassified (e.g. from threatened to endangered or delisted). A five-year review for the California Least Tern (*S. a. browni*) was released in 2006 (USFWS 2006). A five-year review for the Interior Least Tern (*S. a. athalassos*) has not been completed, but USFWS published a notice of initiation of review in 2008 (73 Federal Register 21643–21645).

A notice of initiation of five-year review was published in the Federal Register in 1991 for the Piping Plover. However, no new information was submitted, and the species' status remained unchanged (USFWS 2009a). A second five-year review (USFWS 2009a), initiated in 2008, resulted in the contribution of substantial amounts of recent data across the entire range of the species. The review team recommended that the threatened and endangered classifications for the three populations of Piping Plover be maintained. This was based on the fact that none of the recovery criteria had been met. Piping Plover populations in the Northern Great Plains had not reached the desired number of 1,300 pairs. Specific numbers for each state and Canadian province had also not been attained, although for most, the trend was in the positive direction. Several emerging threats, such as climate change and the impact of wind turbines and invasive species, were discussed in the five-year review. The review noted that more information was needed on the potential impacts of climate change and wind turbines before recovery criteria could be revised (USFWS 2009a).

The review team recommended that the Great Lakes and Northern Great Plains populations of *C. m. circumcinctus* be designated Distinct Population Segments (DPS). This recommendation was based on lack of interchange between the two populations, as well as the unique ecological setting in which the Great Lakes population occurs. Lastly, the review team compiled a list of recommended actions for Piping Plovers on the breeding, migration, and wintering grounds. Notable among these recommendations are the development of a conservation plan for plovers in wintering and migration habitats and a revision of the Northern Great Plains recovery plan. This list is included in Appendix A.

<u>State Listing</u>

The Nebraska Nongame and Endangered Species Act (NESCA; §37-801–811), passed in 1975, affords additional protections for Interior Least Terns and Piping Plovers in the state. The Act authorizes the Nebraska Game and Parks Commission to list species as endangered or threatened in the state, under the Act, any species that is federally listed must also be state listed. NESCA provides protection for state-listed species in a number of ways. First, the Act prohibits 'take' of any listed species, which constitutes a class I misdemeanor. State agencies must consult with NGPC before authorizing any action that may jeopardize the continued existence of a state-listed species. The Act also allows development and implementation of conservation programs, including habitat acquisitions that would benefit the listed species. In 1984, a provision was added to the statute establishing permanent funding for threatened and endangered species conservation through a voluntary check-off on state tax returns known as the Wildlife Conservation Fund.

Table 3. Locations of critical habitat, as designated by the USFWS, for Piping Plovers.

Location	Habitat Description	Habitat Type	Year Designated	Source
Michigan	223.4 km Great Lakes shoreline	Breeding	2001	66 Federal Register 22938–22969
Minnesota	0.2 km Great Lakes shoreline	Breeding	2001	66 Federal Register 22938–22969
Wisconsin	45.3 km Great Lakes shoreline	Breeding	2001	66 Federal Register 22938–22969
Illinois	10.2 km Great Lakes shoreline	Breeding	2001	66 Federal Register 22938–22969
Indiana	7.9 km Great Lakes shoreline	Breeding	2001	66 Federal Register 22938–22969
Ohio	4.0 km Great Lakes shoreline	Breeding	2001	66 Federal Register 22938–22969
Pennsylvania	6.0 km Great Lakes shoreline	Breeding	2001	66 Federal Register 22938–22969
New York	27.4 km Great Lakes shoreline	Breeding	2001	66 Federal Register 22938–22969
North Carolina	203.3 km Atlantic Coast shoreline	Wintering	2001	66 Federal Register 36038–36086
South Carolina	100.7 km Atlantic Coast shoreline	Wintering	2001	66 Federal Register 36038–36086
Georgia	134.7 km Atlantic Coast shoreline	Wintering	2001	66 Federal Register 36038–36086
Florida	340.8 km Atlantic Coast and Gulf Coast shoreline	Wintering	2001	66 Federal Register 36038–36086
Alabama	76.4 km Gulf Coast shoreline	Wintering	2001	66 Federal Register 36038–36086
Mississippi	204.1 km Gulf Coast shoreline	Wintering	2001	66 Federal Register 36038–36086
Louisiana	547.9 km Gulf Coast shoreline	Wintering	2001	66 Federal Register 36038–36086
Texas	1,283.8 km Gulf Coast shoreline	Wintering	2001	66 Federal Register 36038–36086
Minnesota	95.2 ha (Rocky Point, Morris Point, Pine & Curry Island)	Breeding	2002	67 Federal Register 57638–57717
Montana	40,423.1 ha (Ft. Peck Reservoir and other habitat, plus 201.8 km of the Missouri River)	Breeding	2002	67 Federal Register 57638–57717
North Dakota	33,710.8 ha (plus 570.5 km of the Missouri River)	Breeding	2002	67 Federal Register 57638–57717

Table 3 continued.

Location	Habitat Description	Habitat Type	Year Designated	Source
Nebraska*	708.1 km (405.5 km of the Platte River, 109.4 km of the Loup River, and 193.0 km of the Niobrara River)	Breeding	2002	67 Federal Register 57638–57717
Missouri River	1,235.2 km (portions of Montana, North Dakota, South Dakota, and Nebraska)	Breeding	2002	67 Federal Register 57638–57717

* Critical habitat as originally designated by USFWS; this habitat was later vacated as the result of a federal lawsuit (see text)

PIPING PLOVER

Taxonomy and Description

Class Aves
- Order Charadriiformes
  - Family Charadriidae
    - Subfamily Charadriinae
      - Genus *Charadrius*
        - Species *melodus*
          - Subspecies *melodus* and *circumcinctus*

Charadrius melodus Ord, 1824, in Wilson, American Ornithology (Ord reprint) 7:71. Great Egg Harbor, New Jersey (AOU 1998).

French: Pluvier siffleur   Spanish: Chorlitejo picocorto   German: Pfeifregenpfeifer

Piping Plovers (*Charadrius melodus*) are members of the order Charadriiformes, a large assemblage of species that includes the shorebirds, gulls, auks, and their allies (AOU 1998). Taxonomic relationships within and among the families in the order are unsettled, but the American Ornithologists' Union (AOU 1998) assigned Piping Plover to the family Charadriidae (lapwings and plovers) and sub-family Charadriinae (plovers). The family Charadriidae consists of about 65 species of small to medium-sized waders, generally found in open habitats (Marchant and Higgins 1993). The subfamily Charadriinae consists of about 34 species placed in seven genera, 27 of these in *Charadrius* (Dickinson 2003). The genus *Charadrius* consists of invertebrate-feeding waders, mostly characterized by breast bands or collars (Hayman et al. 1991). Genus and species-level taxonomy of Piping Plover is uncontroversial; the species was described by Ord in 1824 as *Charadrius melodus*, and the type specimen was collected in New Jersey (AOU 1998).

Subspecies

Currently, the AOU does not recognize any subspecies of Piping Plover (AOU 1998); however, two subspecies of Piping Plover, *C. m. melodus and C. m. circumcinctus,* were recognized in the past (AOU 1957). This was based on the observations of differences in the extent and brightness of the breast band between Atlantic and Interior birds (Moser 1942; USFWS 2009a). Two plumage variations have been noted (Moser 1942; Dunn and Alderfer 2006). The first is a single black band that, depending upon the individual bird, its sex, age, and perhaps location, extends partially or fully across the upper breast and around the upper back and lower neck. When in breeding (i.e., alternate or nuptial) plumage, the breast band is usually complete in Interior birds (*circumcinctus)*, but is sometimes incomplete in Atlantic Coast birds (*melodus)*. The second plumage variation is a black moustache that extends from the base of the bill to the sand-colored plumage of the upper cheek, exhibited by many Interior males breeding west of the Great Lakes (Elliott-Smith and Haig 2004). In general, male plumage is more pronounced (darker, more complete breast band, more bright orange on bill, more distinct white eye-line, and in some birds presence of moustache) than female plumage. Great Plains breeding birds tend to be brighter than Atlantic Coast breeders (Elliott-Smith and Haig 2004). While these are not reliable identification characters alone, when used together they allow an observer familiar with the plumages of birds from the two regions to identify individuals at the extremes of the range of plumage variation.

The two Piping Plover subspecies cannot be reliably differentiated by breast-band pattern, geographic distribution, or protein allozyme studies (Elliott-Smith and Haig 2004). However, recent analyses of both mitochondrial and nuclear DNA sequences provide support for subspecies status (Miller et al. 2010). This study was based on a robust dataset of more than 200 individuals from 23 different regions in the U.S. and Canada. Phylogenetic reconstruction and analysis of molecular variance (AMOVA) clearly differentiate Atlantic and Interior populations. In addition, microsatellite clustering analyses group Great Lakes birds with Interior birds; the authors recommend that Great Lakes birds be recognized as *C. m. circumcinctus*. Atlantic birds exhibited significant correlations between genetic isolation and geographic distance. Interior birds, however, did not show this genetic structuring. This lack of genetic structure may reflect lower natal and breeding site fidelity in Interior birds, as a result of variable environmental conditions (Miller et al. 2010). The observations of Haig and Oring (1988a) showing little movement of individuals between regions further support subspecies status. This observation suggests the presence of isolating mechanisms that minimize or preclude gene flow among populations.

Appearance

Piping Plovers are small, stocky birds about 17–18 cm long with a body mass of 43–63 g. The orange legs are a distinguishing characteristic separating Piping Plovers from the physically similar Snowy Plover (*C. alexandrinus*; Elliot-Smith and Haig 2004). The sexes are largely monomorphic; however, the dark breast band is sometimes incomplete in the female, and females may have a duller-colored bill and less-pronounced white eyeline (National Geographic 1987; NGPC 1995). Both sexes in breeding (alternate) plumage from the Great Plains population normally display a complete breast band. Juvenile birds and nonbreeding adults lack the orange bill and dark breast band (Sibley 2000). Precocial young are well-camouflaged in their sandy surroundings, with buff-colored upperparts and grayish speckling on the head (Baicich and Harrison 1997).

Distribution (Figure 7)

Historic Breeding Range

Although the historical record is sparse for Piping Plovers, available evidence suggests that they were regular breeders in varying numbers throughout their range (Bent 1929; Ducey 1985; Haig and Oring 1985; U.S. Fish and Wildlife Service 1990; Thompson et al. 1997). Early naturalists, including John James Audubon and Alexander Wilson, described the Piping Plover as common on beaches of the Atlantic coast (Haig and Oring 1987).

In the Great Lakes region, Piping Plovers had a breeding range of 1,300 km (800 mi) lying east to west in New York, Pennsylvania, Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, and Ontario, Canada (U.S. Fish and Wildlife Service 2003a, 2009a). Russell (1983) estimated that the largest numbers of birds occurred in Michigan, Illinois, and Ontario. Historical records note nesting pairs along Lake Superior in Wisconsin from the Illinois state line north to the Door County peninsula and Green Bay (Russell 1983). Plovers also nested along the shoreline of Lake Michigan south of Menominee, Wisconsin (Russell 1983). A small population was known to breed at Lake Koshkonong, a wetland on Wisconsin's Rock River (Russell 1983). As recently as the early 1980s, small numbers of Piping Plovers bred in Duluth Harbor, Minnesota (U.S. Fish and Wildlife Service 2003a). An observer noted 30 pairs of this "very common summer resident" breeding along a two-mile stretch of Lake Michigan in Waukegan, Illinois during the summer of 1876 (Nelson 1876). The species was an "uncommon summer resident" in Indiana, with breeding records along the Indiana Dunes and in the town of Miller in Lake County (Ford 1956). In Michigan, breeding records exist for six counties in the Upper Peninsula and 12 counties in the Lower Peninsula (Russell 1983). Plovers breeding records exist for all Ohio counties along Lake Erie except Cuyahoga County; records also exist for the Lake Erie islands (Bent 1928; Russell 1983). Prior to the 1950s, small numbers of Piping Plovers nested at Presque Isle in Pennsylvania (Todd 1940). Piping Plovers once nested along Lake Ontario at three locations in two New York counties (Bull 1974). Nesting birds were observed in 18 different locations along Lakes Huron, Erie, and Ontario in Ontario province (Russell 1983).

In Interior North America, Piping Plovers have adapted to breed in ephemeral habitat. Historically, variation in natural conditions (e.g. flooding, drought, plant succession) determined the location of nesting sites. Though written accounts are rare, we know that Piping Plovers historically bred in Nebraska, both on river sandbars and along natural lakes. According to the Tern and Plover Conservation Partnership (2010):

> "Least Terns, along with Piping Plovers, are among the first birds to be described in Nebraska by western explorers. Of course, they were known by Native Americans well before that. In Nebraska, terns (and plovers) flourished along the Missouri River and its tributaries, the Platte, Loup, and Elkhorn rivers. During the Meriwether Lewis and William Clark expedition from 1803-1805, Least Terns and Piping Plovers were noted in their journals in 1804."

Lewis and Clark were the first explorers to describe the Piping Plover, which they referred to as a "small Kildee" (Johnsgard 2003). Ferdinand V. Hayden, naturalist for Lieutenant Warren's expedition of the Platte River in 1856–57, noted that Piping Plovers were very abundant on sandbars. He recorded five individuals on the Loup Fork of the Platte River in present-day Platte County, collecting three in breeding plumage on 8 July (Coues 1874; Ducey 2000). The appearance of these birds, coupled with the date on which they were collected, led Coues

(1874) to surmise that Piping Plovers bred in the state. Nearly a decade later, Aughey observed the species in May 1865 in Dakota County (Ducey 2000). Two nests were noted in July 1866 in both Dixon and Dakota Counties along the Missouri River (Bruner 1901; Moser 1942, Ducey 2000). Two nests were also found in July 1868 in Wayne County, and the species was observed in September of the same year in Sarpy County (Ducey 2000). Piping Plovers were noted to be rare to common migrants and "occasional summer resident[s]" that bred along Sandhills lakes as well as the Niobrara, Loup, and Platte Rivers (Bruner 1896; Bruner et al. 1901). Plovers were reported on the Middle Loup River in 1899 and 1900 and at Trout Lake, Cherry County, in 1900 and 1902 (Moser 1942). Plover nests were reported on the Niobrara River in Keya Paha County in the latter year as well (Moser 1942). The species was reported at the salt basin wetlands of western Lincoln, Lancaster County, in 1900 (Johnsgard 2000).

Current Breeding Range

Piping Plovers breed in three essentially non-contiguous areas, the Atlantic Coast, the Interior Great Plains, and a small number (<2% of the species' total population) in a very restricted range on the Great Lakes; the latter group is probably an isolated segment of the Great Plains population (USFWS 1988; Elliott-Smith and Haig 2004). The Atlantic Coast range was described by Elliott-Smith and Haig (2004) as "along beaches in New Brunswick, Prince Edward Island, Nova Scotia, Quebec, Newfoundland, Saint Pierre and Miquelon (France), southern Maine, New Hampshire, Rhode Island, Massachusetts, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina." In the Interior, Piping Plovers breed throughout most of the Great Plains "from alkali wetlands in southeastern Alberta through southern Saskatchewan and Manitoba to Lake of the Woods in southwestern Ontario and north-western Minnesota, south along major prairie rivers (Yellowstone, Missouri, Niobrara, Platte, and Loup), the Arkansas River and reservoirs in eastern Colorado, the Kansas River in Kansas, and alkali wetlands in northeastern Montana, North Dakota, South Dakota, Nebraska, and Iowa" (Elliott-Smith and Haig 2004; Table 4). Two breeding records exist for Optima Reservoir in Texas County, Oklahoma from 1987 and 1988 (Boyd 1991). Breeding sites in the Great Lakes region consist of several beaches along Lakes Superior, Michigan, and Huron in northern Michigan and Wisconsin (Elliott-Smith and Haig 2004). Since the mid-19th century, European settlement and an overall increase in human populations throughout the Piping Plover's range have led to significant changes in habitat availability. Range boundaries, however, have shown little apparent change. The Piping Plover's current breeding range in Nebraska is shown in Figure 8.

Current Winter Range

Piping Plovers spend the winter along the southern Atlantic Coast, the U.S. and Mexican Gulf Coasts, the Bahamas, Cuba, and other Caribbean islands (USFWS 2009a). Results from the 2006 International Piping Plover Census show that the largest concentrations of birds occurred in Texas, Florida, and the Bahamas (USFWS 2009a). Using re-sighting data for four breeding populations, Gratto-Trevor et al. (2009) found a geographic pattern wintering distributions. Most Prairie Canada and Great Plains Piping Plovers were found wintering along the Texas coast, whereas Eastern Canada and Great Lakes birds tended to winter along the Atlantic coast. Approximately 94% of the small Great Lakes population winters on the Atlantic Coast and Florida Gulf Coast, with a few overwintering further west along the Gulf Coast and in the Caribbean (Elliott-Smith and Haig 2004; Gratto-Trevor et al. 2009). Nonetheless, each breeding population showed a wide wintering distribution. For example, Great Plains Piping Plovers were found at all wintering locations. The Atlantic coast breeding population winters primarily on the Atlantic Coast with a few on the Gulf Coast of Florida (Elliott-Smith and Haig 2004).

Ten percent of the world's Piping Plovers have been found to winter along the northeast Mexican coast near Tamaulipas (A. Banda, pers. comm.). Small numbers of Prairie Canada and Northern Great Plains birds have been found wintering in this region (Gratto-Trevor et al. 2009). A Prairie Canada bird was seen even farther south along the Yucatán Peninsula (Gratto-Trevor et al. 2009). Small numbers of plovers winter in Cuba; some of these birds bred in eastern Canada and the northern Atlantic coast (Gratto-Trevor et al. 2009). More than 400 Piping Plovers were found wintering in the Bahamas, a far larger number than previously known; this constitutes 10% of the wintering population (Elliott-Smith et al. 2009). Given logistical constraints (i.e., the existence of more than 600 islands and cays), the Bahamas population was likely underestimated (Elliott-Smith et al. 2009). One of two marked birds in this area was from the Great Lakes; a Northern Great Plains bird was also seen in the Bahamas at a different time (Gratto-Trevor et al. 2009). Very small numbers of Piping Plovers winter in Puerto Rico, ranging from 2–6 individuals in the last two international censuses (Elliott-Smith et al. 2009). Twelve Piping Plovers were observed wintering in the Dominican Republic in 2006 (Elliott-Smith et al. 2009).

Figure 7. Range of Piping Plover (*Charadrius melodus*). (from The Birds of North America, Elliott-Smith and Haig 2004).

Table 4. Major river systems supporting breeding populations of Piping Plovers in the United States.

River	State(s)	Source
Missouri	Montana, North Dakota, South Dakota, Nebraska	Haig et al. (2005)
Yellowstone	Montana	Elliott-Smith and Haig (2004)
Niobrara	Nebraska	Elliott-Smith and Haig (2004)
Platte (including Loup River)	Nebraska	Elliott-Smith and Haig (2004)
Kansas	Kansas	Elliott-Smith and Haig (2004)
Arkansas	Colorado	Elliott-Smith and Haig (2004)

Habitat

Prior to European settlement of North America, Piping Plovers nested on coastal and Great Lakes beaches, along shorelines of alkali lakes, and on naturally-created sandbars of major inland rivers (Elliott-Smith and Haig 2004). In Nebraska, plovers were historically found on sandbars of the Platte, Missouri, Loup, Elkhorn, and Niobrara Rivers. Much of this natural habitat has been lost, however, due to anthropogenic changes to these rivers. Sandbar habitat in portions of the Missouri River, for instance, has been greatly diminished or virtually eliminated (USFWS 1990). Increasingly, Piping Plovers can be found using human-created habitats with features similar to those of natural areas. Such anthropogenic habitat includes reservoirs and sand and gravel mines.

<u>Breeding habitat</u>

On the Atlantic Coast, Piping Plovers nest above the high tide line on beaches and barrier islands (USFWS 1996). The latter are characterized by low dunes and sand-shell flats. Their low elevation makes these islands vulnerable to storm disturbances, which maintain the open habitat that the plovers prefer (Boettcher et al. 2007). Nests are often placed on foredunes, in blowout areas behind primary dunes, or washover areas cut into dunes or between them (USFWS 1996). Such areas have little to no vegetation, although plovers will sometimes nest in stands of vegetation such as American beachgrass (*Ammophila breviligulata*; Patterson 1988; MacIvor et al. 1990). Both adults and chicks use the interface between open beaches and vegetated marshes to forage and hide from predators (Boettcher et al. 2007). Beaches with high levels of erosion may be unsuitable for plovers, as they tend to be inundated frequently (Boettcher et al. 2007). Piping Plovers also tend to avoid narrow beaches separated from marshes by forest, continuous sand dunes, or shrub-scrub habitat (Boettcher et al. 2007). In addition to naturally-created habitat, plovers will nest in areas where dredge material has been deposited (USFWS 1996).

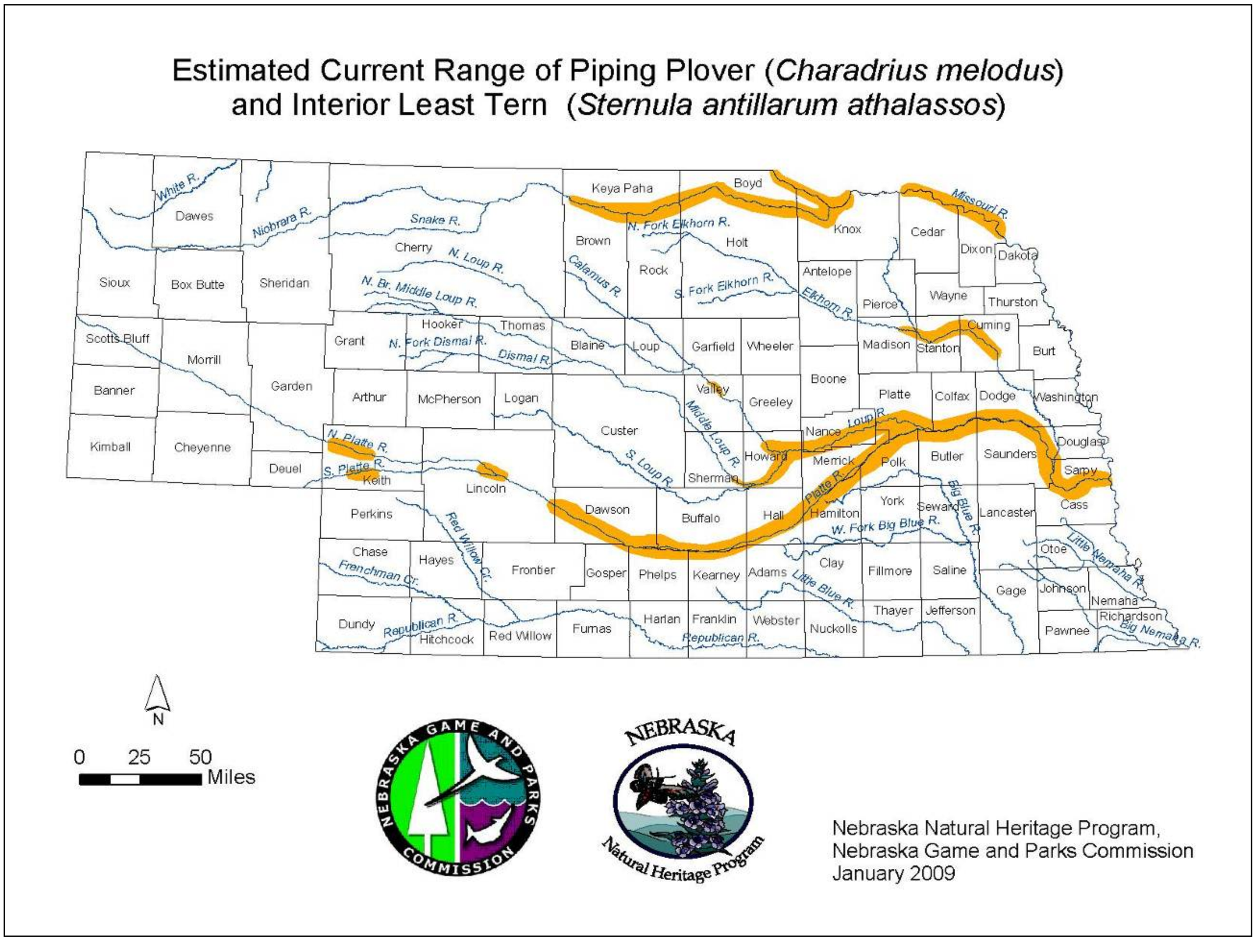

Figure 8. Breeding distribution (shown in orange) of the Piping Plover in Nebraska. Range map courtesy of the Nebraska Natural Heritage Program.

Great Lakes Piping Plovers breed along Great Lakes shorelines (USFWS 2003a). These unique areas consist of a number of different habitat types, including dunes, interdunal wetlands, sand beaches, and jack pine (*Pinus banksiana*) barrens (USFWS 2003a). Breeding habitat occurs in areas of unforested dunes and inter-dune wetlands; nests are placed on sandy substrates and often occur near ephemeral ponds or rivers (Pike 1985; Olivero 1994).

In the interior portion of their range, plovers nest on largely unvegetated sand or gravel bars in major river systems. They tend to place nests on higher ground away from the water (USFWS 1990). The extent of riverine breeding habitat may vary widely between years as a result of hydrological conditions (Schwalbach et al. 1988). Piping Plovers also breed in human-created habitat such as reservoirs and commercial sand and gravel mining operations, also known as sand pits (Boyd 1991; Sidle and Kirsch 1993). Sand pits are located within 3 miles (5 km) of rivers in Nebraska (Brown and Jorgensen 2008, 2009); they vary in size and shape, but all are associated with lakes created by the mining process (Sidle and Kirsch 1993). In some areas and in some years, sand pits provide most of the available breeding habitat (Sidle et al. 1991; Brown and Jorgensen 2008, 2009, 2010).

Migratory habitat

In general, migration routes and migratory habitat used by Piping Plovers are poorly understood (Elliott-Smith and Haig 2004). One reason for this is the overlap of breeding, wintering, and migratory routes for coastal birds; unless migrants are banded, they cannot be distinguished from breeding or wintering individuals (USFWS 2003a). Piping Plovers use coastal beaches and alkali flats as migratory habitat (Elliott-Smith and Haig 2004). Birds that breed and winter along the Atlantic coast migrate along a narrow strip of land in both the spring and fall (USFWS 1996). Both Eastern Canada and Great Lakes birds migrate along the Atlantic coast, and have been re-sighted in Massachusetts, New York, New Jersey, Maryland, Virginia, and North Carolina (Amirault et al. 2006; Stucker and Cuthbert 2006). The migratory routes used by Atlantic breeders wintering along the Gulf of Mexico or the Caribbean are unknown at this time (Pompei and Cuthbert 2006).

Migrating Great Lakes birds travel alone or in small groups, stopping at both inland and coastal sites (Pompei 2004; Pompei and Cuthbert 2006). Individuals have been seen using areas in Wisconsin, Michigan, Illinois, and Indiana. Plovers use shoreline habitat along Lake Michigan at the Indiana Dunes National Lakeshore and near Illinois Beach State Park (USFWS 2003a). In Illinois, they have also been seen further inland at Rend Lake, a reservoir in the southern part of the state (Robinson 1996). Migrating birds have been observed at 24 beaches in 20 counties in Michigan in either spring or fall (USFWS 2003a). In Wisconsin, they have been reported on beaches in 13 counties (Temple and Cary 1987). A literature review of all known stopover sites by Great Lakes birds found that use of stopover sites was not consistent from year to year. Instead, Piping Plovers appear to stop opportunistically in areas with available habitat (Pompei 2004).

The most common habitat used by migrating Great Plains birds is reservoir shorelines. However, birds will also use natural lakes, rivers, marshes, industrial ponds and fish farms as stopover sites (Elliott-Smith and Haig 2004). Lake McConaughy, a reservoir in Nebraska, is considered an important spring stopover site, with more than 100 Piping Plovers observed at one time (Pompei and Cuthbert 2006). As with Great Lakes birds, Great Plains Piping Plovers do not show consistent patterns with regard to use of stopover sites (Pompei and Cuthbert 2006). This may result from the considerable variation in habitat availability across years in interior North America (Skagen and Knopf 1993; DeLeon and Smith 1999).

Winter habitat

Current research suggests that Piping Plovers winter in areas with a matrix of habitat types. Birds wintering on the Atlantic coast are found on barrier islands, peninsulas, and inlets. Areas used by plovers are characterized by wide beaches and a mix of sandflats, mudflats, tidepools, and large inlets (Nicholls and Baldassarre 1990; Wilkinson and Spinks 1994). Birds forage on sandflats, sandy mudflats, and overwash areas (USFWS 1996). In North Carolina, birds were found in three different habitat zones: beaches along the ocean, beaches along sounds, and islands located in sounds. Individuals spent most of their time on sound islands compared to the two beach types (Cohen et al. 2008a).

On the Gulf coast, Piping Plovers occur in areas with wide beaches, sandflats, mudflats, tidepools, and small inlets (Haig and Oring 1985; Nicholls and Baldassarre 1990). Populations in the Gulf Intercoastal Waterway are found on barrier islands and spoil islands (Elliott-Smith and Haig 2004). In Texas, individuals used eight habitat types, but spent most of their time on algal flats and low-lying sandflats (Drake et al. 2001). Similarly, winter census data from 27 Gulf coast sites indicated a preference for sandflats adjacent to inlets or beaches (Haig and Oring 1985). Plovers also forage on exposed seagrass beds and oyster reefs in Texas (Elliott-Smith et al. 2009). Winter habitat on the Florida Gulf coast includes interior marsh flats and bayside habitat (Elliott-Smith et al. 2009).

Less is known about winter habitat in other parts of the species' range. Piping Plovers wintering in Cuba have been observed on cays of the Cabana Archipelago. Plovers frequented cays with beach and sandflat habitats located in close proximity (Elliott-Smith et al. 2009). Wintering birds in the Bahamas use large sandflats associated with cays and island beaches with intertidal flats (Elliott-Smith et al. 2009). In contrast to the Atlantic Coast, Piping Plovers occur in high densities on Bahamian beaches located far from inlets and overwash areas (Elliott-Smith et al. 2009).

Life History and Ecology

<u>Breeding</u>

Arrival and Courtship

Arrival on the breeding grounds varies with latitude. Plovers begin arriving in mid-March along the Atlantic Coast, early April in the Great Plains, late April in the Great Lakes region, and early May in Canada (Faanes 1983; USFWS 2003a; Elliott-Smith and Haig 2004). Territory establishment by males involves brief flights and runs, as well as scanning for intruders and preening (Cairns 1982). Preening may last several hours, with the goal of making the neck band appear larger and darker (Cairns 1982). Males respond to intruders with a horizontal threat display; this involves leaning forward with the head pushed back and the wings slightly raised. The male will then charge the intruder, although he will rarely make physical contact (Cairns 1982). Once males establish territories, they perform parallel run displays along shared boundaries. The two males stand erect, with heads raised high; they face each other, perform head-bobbing behavior, and then take turns running 1–10 m along the shared boundary line (Cairns 1982).

Males perform aerial courtship displays over territories, tilting the body side to side with slow wingbeats; such displays may last 30 minutes and include high-pitched, rapid calls (Cairns 1982). During the courtship phase, males also perform a nest-scraping display. They walk around the territory, tossing shells and pebbles aside. From time to time, they create scrapes in the substrate by leaning forward, moving from side to side, and kicking sand backward (Elliott-Smith and Haig 2004). Pairs may copulate in several nest scrapes (Elliott-Smith and Haig 2004).

Nests and Eggs

Males construct nests by digging scrapes in the substrate; both males and females line them with pebbles or shells. They usually create many scrapes, but it is unclear whether the male or female chooses the one that becomes the nest. A lined nest scrape takes one day to complete, but pairs take 5–10 days to choose a nest among several scrapes (Elliott-Smith and Haig 2004). Nests are often placed near objects such as wood or stones (Elliott-Smith and Haig 2004). Nest scrapes are shallow, measuring 1–2 cm in depth and 9–10 cm in diameter (Whyte 1985). Both adults add shells or pebbles to the nest lining during egg-laying and incubation (Elliott-Smith and Haig 2004). Percent vegetative cover and substrate type are important factors influencing nest-site selection (Cohen et al. 2008b). In one recent study, plover nests had higher vegetative cover compared to random sites, but mean cover was less than 8% (Cohen et al. 2008b). Furthermore, most nests were placed on sand with low amounts of pebbles and cobble (mean of 9%; Cohen et al. 2008b).

Eggs typically measure 32 by 24 mm and are buff-colored with fine splotches of black, brownish black, or purplish black (Cairns 1982; Baicich and Harrison 1997). Splotches are usually evenly distributed across the egg, but some eggs may have larger and darker splotches concentrated at the broad end. Egg surfaces are nonglossy to slightly glossy (Elliott-Smith and Haig 2004).

Nesting Densities

Nesting densities and territory sizes vary greatly. Territories include areas for nesting and foraging, but these areas may not be contiguous (Cairns 1982; Whyte 1985). Breeding sites may have just one pair of Piping Plovers or several pairs in a clumped (i.e., semicolonial) arrangement (Elliott-Smith and Haig 2004). Nests may be placed anywhere from 3–389 m apart (Cairns 1982; Murphy et al. 2001). In Nova Scotia, territory sizes ranged from 800–5000 m^2; in Saskatchewan, from 27,000–30,500 m^2 (Cairns 1982; Whyte 1985). Nesting densities vary annually; for example, a site in New York had nesting densities of 0–1.05 pairs/ha over a 13-year period (Cohen et al. 2009).

Egg-laying and Incubation

Females lay one egg every other day. Clutch size is usually four eggs (range: 3–5), resulting in an egg-laying period of six days (Elliott-Smith and Haig 2004). Females do not lay replacement eggs but will continue to incubate if one or more eggs are lost (Elliott-Smith and Haig 2004). If a clutch is lost, females will lay a replacement clutch (Baicich and Harrison 1997). Both males and females develop brood patches and take turns incubating the clutch (Elliott-Smith and Haig 2004). Incubation lasts for 28 days (Wilcox 1959; Cairns 1977; Whyte 1985). Length of incubation bouts varies; adults may perform exchanges every 13 minutes to as long as 120 minutes (Maxson 2000; Elliott-Smith and Haig 2004).

Brood-rearing

Adults and chicks leave the nest one to two days after hatching, but often remain within the territory (Elliott-Smith and Haig 2004). Both adults care for chicks after they hatch, exchanging care every 30–45 minutes (Elliott-Smith and Haig 2004). Adults care for chicks by remaining within several meters of them while foraging and by brooding (Elliott-Smith and Haig 2004). Adult birds brood chicks frequently when they are young, but much less once they reach 21 days of age (Elliott-Smith and Haig 2004). In some cases, females abandon broods, leaving males to raise them (Haig and Oring 1988b; Amirault et al. 2004).

Defense of Nests and Chicks

Piping Plovers respond to territorial intrusions (including chicks of other pairs) by chasing, pecking, or biting (Elliott-Smith and Haig 2004). To deter potential predators, adults can perform a number of different distraction displays. These include squatting, false brooding, and injury feigning (Cairns 1982). The latter involves one or both adults feigning a wing injury and walking away from the nest or brood (Cairns 1982). Incubating adults will flatten themselves on the nest in response to potential avian predators (Elliott-Smith and Haig 2004).

Chick growth and development

Piping Plover chicks are precocial and can walk short distances away from the nest several hours after hatching (Cairns 1977). Chicks begin pecking at the ground on the day they hatch, but probably do not eat very much for the first few days of life (Elliott-Smith and Haig 2004). In a Nova Scotia study, body mass ranged from 6.3–7.2 g at hatch day, 8.8–16.9 g at 10 days, and 35.6–37.2 g at 21 days (Cairns 1977). Chicks produced at off-river sites along the Lower Platte River attained their fledging mass at approximately 17 days of age (Brown and Jorgensen 2009). According to Cairns (1982), chicks failing to reach 60% of their adult weight by day 12 usually die. Chicks are capable of sustained flight by 21–35 days (Wilcox 1959; Gaines and Ryan 1988).

<u>Feeding Habitat and Habits</u>

The Piping Plover's diet consists of various aquatic and terrestrial invertebrates (Elliott-Smith and Haig 2004). These include marine worms, crustaceans, mollusks, and insects and their larvae. Although data are limited, samples from two Interior studies included large numbers of beetles (Coleoptera; Whyte 1985) and flies (Diptera; Nordstrom 1990; Nordstrom and Ryan 1996). Plovers capture food items by running and rapidly pecking at them. They also use a "foot-trembling" technique, moving one foot on wet sand, presumably to bring invertebrate prey to the surface (Cairns 1977; Elliott-Smith and Haig 2004). Individuals drink water, often while bathing (Elliott-Smith and Haig 2004).

Foraging habitat spans a range of types, depending on region and time of year (Elliott-Smith and Haig 2004). In general, both adults and chicks forage within five meters of the shoreline (Elliott-Smith and Haig 2004). Birds forage on open beaches, along ponds, and on upland gravel areas and vegetated dunes (Elliott-Smith and Haig 2004). Although they forage in many different habitats, research suggests that some areas are more productive than others. Piping Plovers on the Massachusetts coast, for example, were observed most often in two intertidal habitat types and foraged at higher rates in these areas (Fraser et al. 2005). Foraging rate has been suggested to be a good indicator of shorebird prey availability (Goss-Custard 1977; Pienkowski 1983; Wilson 1990).

<u>Migration</u>

Much remains to be learned about migration in this species. Piping Plovers may stage in flocks prior to spring or fall migration. These groups typically number 30 individuals, although flocks of more than 1,000 birds have been observed (Elliott-Smith and Haig 2004). Spring migration begins in March and peaks in mid-April; fall migration begins as early as late June in some areas and may last until September (Elliott-Smith and Haig 2004). Following the breeding season, females depart, followed by unpaired males, males with fledglings, and juveniles (Elliott-Smith and Haig 2004). Migrating individuals often give two-note calls in flight (Cairns 1982). Most individuals stop for one day, but stopovers of 56 days in spring and 61 days in fall have been reported (Pompei and Cuthbert 2006). Piping Plovers congregate in larger numbers at Atlantic Coast stopover sites compared to inland stopover sites ($\bar{x}$ =7.14 vs. 1.81; Pompei and Cuthbert 2006)

Habitat use and movements

Piping Plovers maintain nesting and feeding territories throughout the breeding season (Cairns 1982). Breeding birds often use several habitat types located in close proximity. For example, Piping Plover adults and young at three sites in New Jersey used ocean beaches and backbays for foraging and dunes primarily for resting (Burger 1994). In a pre-nesting study of plovers along the Massachusetts coast, Fraser et al. (2005) found that birds used three habitat types more than expected based on their availability. Birds appeared to use these habitats to meet different needs. They spent most of their time foraging in sound intertidal zones and tidal-pond intertidal zones, which are only exposed during low tide. In contrast, they spent most of their time resting or alert while in backshore areas.

Tidal patterns appear to play an important role in habitat use on the wintering grounds. At high tide, Piping Plovers are often observed resting; at low tide, they forage on sandflats (Elliott-Smith et al. 2009). On the North Carolina coast, the amount of exposed intertidal zone area was positively correlated with use of sound islands and negatively correlated with use of ocean beaches (Cohen et al. 2008a). Birds spent most of their time feeding while on islands and sound beaches. When found on ocean beaches, birds spent more time preening or resting (Cohen et al. 2008a).

Plovers on the wintering grounds tend to move only short distances. A group of birds wintering along the North Carolina coast used a total area of $20.1 km^2$, but spent most of their time in a $2.2 km^2$ area (Cohen et al. 2008a). Movements by another Atlantic Coast population were also restricted: core areas were less than $1.5 km^2$ (Noel and Chandler 2008). Piping Plovers wintering on the Texas coast showed a similar pattern, with a core area of $2.9 km^2$ (Drake et al. 2001). These birds moved an average distance of 3.3 km (range 0–30 km), and nearly 80% of all movements were less than five km (Drake et al. 2001).

Site Fidelity and Dispersal

Breeding site fidelity varies greatly and may be influenced by a number of factors, including previous reproductive success, sex, and habitat availability (Elliott-Smith and Haig 2004; Cohen et al. 2006). Piping Plovers in one New York study showed very low site fidelity (24%; Wilcox 1959), whereas another New York population, as well as a Minnesota population, showed high levels (82% and 84%, respectively; Wiens and Cuthbert 1988; Cohen et al. 2006).

Individuals show strong site fidelity while on the wintering grounds. Movements tend to be local, i.e., up to several km (Gratto-Trevor et al. 2009). Home ranges and core areas of Piping Plovers wintering in Georgia were less than 6 and $2 km^2$, respectively (Noel and Chandler 2008). An analysis of four breeding populations wintering in seven regions found little to no movement of individuals among regions (0–2.5% of resighted birds); birds often remained at the same beach for the winter (Gratto-Trevor et al. 2009).

Individual birds also tend to be site faithful across years, often returning to the same beach each winter (Noel and Chandler 2008; Gratto-Trevor et al. 2009). On the Georgia coast, 44–69% of individuals returned to the same section of beach in consecutive years (Noel and Chandler 2008). Marked birds from the Great Plains and Atlantic breeding populations showed little to no movement among wintering regions across years (0–4%; Gratto-Trevor et al. 2009).

Chick dispersal is highly variable, as anywhere from 1–70% of chicks return to natal sites to breed (Haig and Oring 1988a). Dispersal distances of first-year birds range from 5–273 km (Haig and Oring 1988a). In areas where breeding habitat is limited, adults may disperse 300–600 km to breed (Haig and Oring 1988a). Cohen et al. (2006) found that females whose first nesting attempts failed tended to disperse relatively short distances (1–1.5 km) to renest.

Intra- and Inter-specific Interactions

Piping Plovers are considered semicolonial, i.e., nest distributions tend to be clustered, but pairs maintain their own territories (Elliott-Smith and Haig 2004). As a result, neighboring plovers often interact during the breeding season. Adults will peck, bite, or chase other birds entering their territory; this includes chicks from other broods, who are sometimes killed (Elliott-Smith and Haig 2004). Other agonistic interactions include parallel run and horizontal threat displays toward neighboring males (see *Arrival and Courtship* above). The horizontal threat display is also used in response to other species such as Killdeer (*Charadrius vociferus*), Ring-billed Gull (*Larus delawarensis*), and American Oystercatcher (*Haematopus palliatus*; Bergstrom and Terwilliger 1987; Elliott-Smith and Haig 2004). At one site, Piping Plovers interacted with 16 other species (Maxson 2000).

Piping Plovers often nest with Least Terns in tern colonies in the Great Plains and on the Atlantic coast (USFWS 1988, 1996). Piping Plovers have nested in association with American Avocets in North Dakota (USFWS 1988). Piping Plovers in parts of Canada and Minnesota nest in Arctic Tern (*Sterna paradisaea*) and Common Tern (*S. hirundo*) colonies (USFWS 1988), as well as with Wilson's Plovers (*C. wilsonii*) in Virginia.

Prior to migration, Piping Plovers often flock in association with other species of shorebirds such as Semipalmated Plover (*Charadrius semipalmatus*), Spotted Sandpiper (*Actitis macularius*), Greater Yellowlegs (*Tringa melanoleuca*), and Least Sandpiper (*Calidris minutilla;* Cairns 1982). On the wintering grounds, Piping Plovers often forage in mixed-species flocks (Elliott-Smith et al. 2009), such flocks often include Snowy Plovers (*Charadrius alexandrinus*).

As resources for courting, nesting, and foraging become scarcer, competition between species can ensue. For example, gulls compete with other shorebirds for space and food and serve as their predators (Niles et al. 2008). Some colonial waterbirds, such as gulls, have become so numerous in regions that they now cause problems for other nesters and humans (Parnell et al. 1988). Gulls frequently prey on Piping Plover eggs and young on the U.S. alkali lakes (Beyersbergen et al. 2004). In general, gulls have become highly adapted to human-altered landscapes and increasingly numerous over the last 40 years (Sauer et al. 2007).

Along the Loup River in Nebraska and in other regions, there is evidence that livestock are a threat to plover nests through the direct trampling of nests or interruption of breeding activities and chick-rearing (Prindiville 1986; Aron 2005; B. Wheeler, pers. comm.). Placing exclosures around these nests may not sufficiently protect them, as there is evidence that cattle rub on the cages, demolishing them (Aron 2005).

Many different species of birds, mammals, invertebrates, and reptiles serve as potential predators of Piping Plover adults, juveniles, and chicks (Table 4). Most mammalian predators take eggs and chicks, but mink (*Mustela vison*), short-tailed weasels (*M. erminea*), and feral or domestic cats (*Felis domesticus*) also prey on adults (Melvin et al. 1991; Elliott-Smith and Haig 2004). Avian predators include American Crows (*Corvus brachyrhynchos*) and Great Horned

Owls (*Bubo virginianus*; Brown 1987; Kruse et al. 2001). Snakes, beetles, and ghost crabs (*Ocypode quadrata*) are other documented predators (Loegering et al. 1995; Watts and Bradshaw 1995; Mabee and Estelle 2000).

Plovers depend on their colonial nesting neighbors for protection from predators, with safety in numbers. However, having too many or too few neighbors will facilitate predation. A colony size of approximately 150 nests may be ideal, large enough to limit losses to small mammals, yet small enough to lessen the appeal to Black-crowned Night Herons (Brunton 1999). If Piping Plover habitat is already limited, unusually-populous areas quickly become easy targets for predators. Abnormally small colonies are also more susceptible to predation. Plovers that must compete strenuously for nest sites or that renest after having lost first nests are more likely to suffer nest predation. This could be a compounded stressor on plover populations that experience untimely nest failures as a result of flooding or other factors.

Human alterations to the landscape can also affect the community of predators. Predators of shorebirds include mammals (e.g. fox and skunk) (Haig 1985; USFWS 1988), birds (e.g. corvids, gulls, and herons) (Avery et al. 1995; Brunton 1999; DeVault et al. 2005), snakes (USACE 2008), and even fire ants (Lockley 1995). Feral cats also regularly predate plovers (USFWS 1996). Specific tern and plover predators present along the Lower Platte and Loup Rivers include: coyotes (*Canis latrans*), red foxes (*Vulpes vulpes*), raccoons (*Procyon lotor*), dogs (*Canis familiarus*), American Crows (*Corvus brachyrhynchos*), Great Horned Owls (*Bubo virginianus*), American Kestrels (*Falco sparverius*), and Red-tailed Hawks (*Buteo jamaicensis*) (Lackey 1994). Some authors suggest that nesting sites connected to the mainland, such as sandpit sites (NRC 2005), or that are associated with particular landscape characteristics, like large branches or man-made structures for roosting hawks and owls, are more susceptible to predation (Soots and Parnell 1975; Sherfy et al. 2008). Piping plovers normally inhabit sites greater than 50 m from the tree line (Environment Canada 2006), likely in an attempt to avoid primary predator roosting and nesting habitat.

<u>Disease</u>

At this time, disease has not been a major contributing factor to Piping Plover mortality (USFWS 1988). It is challenging to find Piping Plover carcasses and determine the cause of death, but some specimens with West Nile virus have been discovered (Sherfy et al. 2008). Botulism is another potential threat to Piping Plovers (Haig 1986; USFWS 1988). Any population of birds, including Piping Plover, may be susceptible to Asian Bird Flu (H5N1). Avian cholera bacteria (Type 1 strain) spread readily from bird-to-bird contact, exposure to fluids or feces, drinking water and food, and even through the air (USGS 2008). Avian cholera has already had a significant presence in the Rainwater Basin of Nebraska, killing tens of thousands of waterfowl in prior years (Blanchong et al. 2006). Avian diseases could have overwhelming effects on bird populations, particularly threatened and endangered species. Colonial and semi-colonial birds could be especially vulnerable to an epidemic, given their propensity to nest and forage in close proximity.

Table 5. Documented predators of Piping Plover eggs, chicks, juveniles, and adults.

Predator	Life stage preyed upon	Location	Source(s)
American Crow (*Corvus brachyrhynchos*)	Egg	Cape Cod, Massachusetts; South Dakota	Brown (1987); MacIvor (1990); Kruse et al. (2001)
American Kestrel (*Falco sparverius*)	Chick	South Dakota	Kruse (1993); Kruse et al. (2001)
Beetle sp.	Egg	Southeastern Colorado	Mabee and Estelle (2000)
Black-billed Magpie (*Pica hudsonia*)	Egg	North Dakota	Licht and Johnson (1992)
Common Grackle (*Quiscalus quiscula*)	Egg, chick	Atlantic Coast; North Dakota; Montana	Deblinger et al. (1992); Ivan and Murphy (2005)
Common Raven (*Corvus corax*)	Egg, chick	Michigan; Alberta (Canada)	Cuthbert and Wemmer (1999); Schmelzeisen et al. (2004)
Coyote (*Canis latrans*)	Chick	Saskatchewan	Environment Canada (2006)
Crow (*Corvus sp.*)	Egg	New York, New York	Lauro and Tancredi (2002)
Domestic dog (*Canis familiaris*)	Egg	South Dakota	Kruse (1993); Kruse et al. (2001)
Ghost crab (*Ocypode quadrata*)	Egg, chick	Assateague Island National Seashore, Maryland	Loegering et al. (1995); Watts and Bradshaw (1995)

Table 5 continued.

Predator	Life stage preyed upon	Location	Source(s)
Great Horned Owl (*Bubo virginianus*)	Chick, juvenile, adult	South Dakota	Powell and Cuthbert (1992); Kruse (1993); Kruse et al. (2001)
Gull (*Larus sp.*)	Egg	New York, New York	Lauro and Tancredi (2002)
Herring Gull (*Larus argentatus*)	Chick	Virginia	Penn and Ailes (2003)
Merlin (*Falco columbarius*)	Adult	Alberta (Canada); Michigan	Michaud and Prescott (1999); Murphy et al. (2003); Roche et al. (2010)
Mink (*Mustela vison*)	Egg, chick, adult	South Dakota; Lake of the Woods, Minnesota	Kruse (1993); Kruse et al. (2001); Elliott-Smith and Haig (2004)
Northern Harrier (*Circus cyaneus*)	Chick	North Dakota; Montana	Ivan and Murphy (2005)
Peregrine Falcon (*Falco peregrinus*)	Adult	NA	Goossen et al. (2002)
Raccoon (*Procyon lotor*)	Egg	South Dakota; Saskatchewan (Canada)	Espie et al. (1992); Kruse (1993); Kruse et al. (2001)
Rat (*Rattus sp.*)	Egg	New York, New York	Lauro and Tancredi (2002)
Red-winged Blackbird (*Agelaius phoeniceus*)	Egg	Atlantic Coast	Deblinger et al. (1992)
Red Fox (*Vulpes vulpes*)	Egg, chick	Cape Cod, Massachusetts; Atlantic Coast; Maryland; Long Island, New York	MacIvor (1990); Deblinger et al. (1992); Loegering and Fraser (1995); Cohen et al. (2006)
Snake	Egg	Southeastern Colorado	Mabee and Estelle (2000)
Short-tailed Weasel (*Mustela erminea*)	Adult	NA	Elliott-Smith and Haig (2004)

Table 5 continued.

Predator	Life stage preyed upon	Location	Source(s)
Striped Skunk (*Mephitis mephitis*)	Egg	Cape Cod, Massachusetts	MacIvor (1990)
Thirteen-lined Ground Squirrel (*Spermophilus tridecemlineatus*)	Egg	Montana	Ivan and Murphy (2005)

<u>Population Trends</u>

Prior to Federal Listing

General trends for the Atlantic Coast population have been described based on limited historical records. Piping Plovers were common on the Atlantic coast through the mid-1850s (Haig and Oring 1987). Unregulated egg collecting and hunting resulted in declines by the early twentieth century (USFWS 1996). With the passage of the Migratory Bird Treaty Act of 1918, the population began to increase (Haig and Oring 1985). By the late 1940s, however, populations had declined again, primarily due to habitat loss (USFWS 1996). Although an estimate of the Atlantic Coast population was never made, many reports from 1950–1985 documented declines of local or statewide populations (Haig and Oring 1985). A dramatic example of local declines is illustrated by a decrease of 50–100% of breeding pairs at seven Massachusetts sites between 1970–1984 (Griffin and Melvin 1984).

The historic (i.e., late 1800s) Great Lakes population of Piping Plover was estimated at 492–682 breeding pairs (Russell 1983). Populations in Ontario, New York, Pennsylvania, Ohio, Indiana, and Illinois had become extirpated by the late 1970s (USFWS 2003a). An estimated 38–42 pairs of Piping Plovers were observed in the Great Lakes region (Minnesota, Wisconsin, and Michigan) in 1979; by 1982 only 17–19 pairs were counted (Russell 1983).

No estimates are available for the historic Great Plains population, but trends are similar to those for the Atlantic Coast population. In 1985, this population was estimated at 1,439 breeding pairs (50 Federal Register 50727). The majority of U.S. pairs occurred in Nebraska (*N*=355).

Since Listing Under the Endangered Species Act

Since the mid-1980s, when population declines became a major concern (Haig and Oring 1985; Elliott-Smith and Haig 2004), extensive efforts have been made to monitor Piping Plover populations (Haig and Oring 1985; Elliott-Smith and Haig 2004). Numerous state, federal, and provincial coordinators have conducted International Piping Plover censuses within the species' range. Four censuses of Piping Plover have been completed, in 1991, 1996, 2001, and 2006 with total numbers of adults estimated at 5,484, 5,931, 5,945, and 8,092, respectively (Elliott-Smith and Haig 2004; Elliott-Smith et al. 2009). Elliott-Smith and Haig (2004) note that the 2001 total of 5,945 was "very low for a species with such a widespread distribution." This represented an 8.4% increase from the 1991 estimate (Haig et al 2005).

The Atlantic Coast population has shown dramatic increases since federal listing. At the time of federal listing, an estimated 722 breeding pairs of Piping Plovers occurred along the Atlantic Coast (50 Federal Register 50726). The number of breeding adults increased 78% between 1991–2001. The most recent estimate of this population is 3,320 adults, which represents 41% of the total population and a 14% increase since the 2006 census (Elliott-Smith et al. 2009).

Although the Great Lakes population remained low post-listing, it has shown recent increases. At the time of federal listing, the breeding population, estimated at 17 pairs, was restricted to several locations in Michigan, Minnesota, and Wisconsin (50 Federal Register 50727; USFWS 2003a). Between 1986–2002, the Great Lakes population fluctuated from 12–51 breeding pairs (U.S. Fish and Wildlife Service 2003a). Between 1991–2001, the population exhibited an 80% increase, with 72 birds detected in 2001 (Haig et al. 2005). As of the last census, there were 110 Piping Plovers located in Michigan, Wisconsin, and Ontario (Elliott-Smith et al. 2009). Thus, the population increased 53% between the last two censuses.

The Great Plains population has shown mixed trends. One year after federal listing, the Great Plains population was estimated at 1,258–1,326 breeding pairs (USFWS 1988). The population declined by 15% from 1991–2001 to 2,953 adults (Haig et al. 2005). Nonetheless, the Great Plains population remains the largest of the three populations and was estimated at 4,662 adults in 2006 (Elliott-Smith et al. 2009). This represents 57% of the total population and a 58% increase since the previous census (Elliott-Smith et al. 2009).

Demography/Productivity

Productivity

Estimating avian productivity is an important step in developing management plans. Productivity for Piping Plovers is typically reported as a fledge ratio, which is calculated in one of two ways. The traditional calculation is the number of fledglings per adult pair or nest over a defined spatial or temporal area (Brown and Jorgensen 2009). The number of fledglings is based on the number of individuals observed (Brown and Jorgensen 2009). Chick survival determined by analyzing capture-recapture data (see below) provides an alternative method of calculating fledge ratios.

A recent analysis for the Lower Platte River found that the traditional calculation of fledge ratios produced estimates 1.5–3 times greater than the survival method (Brown and Jorgensen 2009). Productivity varies by site and year, and may be as low as 0.3 chicks per adult pair or as high as 3.0 chicks per adult pair, based on the traditional method of calculation (Elliott-Smith and Haig 2004). Overall productivity was estimated to be 1.3 chicks per adult pair for the Atlantic Coast population of Piping Plovers and 1.4 chicks per adult pair for the Great Lakes population (Wemmer 2000; USFWS 2003a). An examination of fledge ratios at natural and human-created sites in Nebraska reveals considerable variation in Piping Plover productivity (Table 4).

Table 6. Estimates of Piping Plover fledge ratios. Standard errors (if available) are in parentheses (NEP = no error provided for estimate). Table modified from Nebraska Game and Parks Commission (2008).

Year	Fledge ratio*	Location	Source
1981	0.9 (± NEP)	Maine	J. Arbuckle in Haig and Oring (1985)
1982	1.8 (± NEP)	Maine	J. Arbuckle in Haig and Oring (1985)
1983	1.2 (± NEP)	Maine	J. Arbuckle in Haig and Oring (1985)
1982	0.3 (± NEP)	Manitoba	Haig (1985)
1983	1.1 (± NEP)	Manitoba	Haig (1985)
1984	1.3 (± NEP)	Manitoba	Haig (1985)
1982	1.7 (± NEP)	Minnesota	Wiens and Cuthbert (1984)
1983	2.1 (± NEP)	Minnesota	Wiens and Cuthbert (1984)
1984	1.3 (± NEP)	Minnesota	Wiens and Cuthbert (1984)
1980	1.4 (± NEP)	New Jersey	A. Galli in Haig and Oring (1985)
1983	1.2 (± NEP)	New Jersey	A. Galli in Haig and Oring (1985)
1976	1.3–2.1 (± NEP)	Nova Scotia	Cairns (1982)
1983	1.2 (± NEP)	Nova Scotia	Flemming (1984)
1981	0.6 (± NEP)	Rhode Island	C. Raithel in Haig and Oring (1985)
1982	0.6 (± NEP)	Rhode Island	C. Raithel in Haig and Oring (1985)
1983	1.4 (± NEP)	Rhode Island	C. Raithel in Haig and Oring (1985)
1980	1.1 (± NEP)	Saskatchewan	A. Whyte in Haig and Oring (1985)
1981	0.4 (± NEP)	Saskatchewan	A. Whyte in Haig and Oring (1985)
1986–1990	0.52 (± NEP)	Central Platte River, Nebraska	Lingle (1993a)

*Chicks per adult pair

Table 6 continued.

Year	Fledge ratio*	Location	Source
1988–2000	0.37 (± NEP)	NE - Fort Randall Dam to Niobrara	USACE (1998) and unpubl. data
1988–2000	0.51 (± NEP)	NE - Lewis and Clark Lake	USACE (1998) and unpubl. data
1988–2000	0.75 (± NEP)	NE - Gavin's Point Dam to Ponca	USACE (1998) and unpubl. data
1988–2000	0.70 (± NEP)	NE – Combined Missouri River Adj. to NE	USACE (1998) and unpubl. data
1991–2000	1.34 (± NEP)	Central Platte River, Nebraska – gravel mines and artificial sandbars	Plettner (unpubl.data)
1992	0.71 (± NEP)	Lower Platte River, Nebraska – protected nests	Lackey (1994)
1992	0.44 (± NEP)	Lower Platte River, Nebraska – unprotected nests	Lackey (1994)
1992–2000	1.15 (± NEP)	NE – Lake McConaughy	Peyton and Wilson (unpubl. data)
1992–2000	1.07 (± NEP)	Upper Platte River	Peyton and Wilson (unpubl.data)
1993-1994	3.0 (± NEP)	Little Goosewing Beach, Rhode Island – broods with access to mudflats	Goldin and Regosin (1998)
1993-1994	1.4 (± NEP)	Little Goosewing Beach, Rhode Island – broods using beach and dunes	Goldin and Regosin (1998)
1999	0.73 (± NEP)	Lower Platte River, Nebraska – gravel mines	Marcus (unpubl. data)

*Chicks per adult pair

Table 6 continued.

Year	Fledge ratio*	Location	Source
2000	1.50 (± NEP)	Lower Platte River, Nebraska – gravel mines	Marcus (unpubl. data)
2001	1.93 (± NEP)	Lower Platte River, Nebraska – gravel mines	Marcus (unpubl. data)
2002	1.19 (± NEP)	Lower Platte River, Nebraska – gravel mines	Held (unpubl. data)
2003	0.86 (± NEP)	Lower Platte River, Nebraska – gravel mines	Held (unpubl. data)
2004	0.72 (± NEP)	Lower Platte River, Nebraska – gravel mines	Held (unpubl. data)
2005	0.83 (± NEP)	Lower Platte River, Nebraska – gravel mines	Held unpubl. data
2008	1.00 (± NEP)	Lower Platte River, Nebraska	Brown and Jorgensen (2008)
2008	1.53 (± NEP)	Lower Platte River, Nebraska – gravel mines	Brown and Jorgensen (2008)
2009	1.57 (± NEP)	Lower Platte River, Nebraska	Brown and Jorgensen (2009)
2009	3.30 (± NEP)	Lower Platte River, Nebraska – gravel mines	Brown and Jorgensen (2009)

*Chicks per adult pair

Nest Survival

Nest survival has traditionally been calculated using the Mayfield method (Mayfield 1961; 1975). This method accounts for the fact that nests found later in the nesting cycle are more likely to be successful, which tends to overestimate nesting success (Mayfield 1961). The Mayfield method incorporates the number of days the nest was under observation (exposure days) into the calculation of nest survival. Nest survival is expressed as the probability of a nest surviving a particular stage, and survival is assumed to be constant across time and across nests (Shaffer 2004). More recently, logistic regression has been used to estimate nest survival (Hosmer and Lemeshow 1989). This method models survival probability as a function of multiple explanatory variables or covariates (Shaffer 2004). Another method, logistic exposure, accounts for the variation in when nests are found by incorporating exposure days into the model. Program MARK models daily nest survival as a function of multiple explanatory variables or covariates, including time effects (White and Burnham 1999). Time-specific explanatory variables or covariates are allowed to vary, and nest survival is not assumed to be constant (Shaffer 2004). These newer methods are combined with an information-theoretic approach (e.g. AIC) to select the model(s) that best explain(s) nest survival.

Table 7. Estimates of Piping Plover nest survival. Standard errors (if available) are in parentheses (NEP = no error provided for estimate). Estimates made with different methods may not be comparable.

Year	Nest Survival	Location	Source	Survival Method
1994	0.976 (± 0.017)	Southeastern Colorado playas – protected nests (exclosure)	Mabee and Estelle (2000)	Mayfield
1994	0.988 (± 0.012)	Southeastern Colorado playas – unprotected nests	Mabee and Estelle (2000)	Mayfield
2000	0.356 (± NEP*)	Lower Platte River – sand and gravel mines (all nests)	Marcus (unpubl. data)	Mayfield
2000	0.328 (± NEP)	Lower Platte River – protected nests (fenced)	Marcus (unpubl. data)	Mayfield
2000	0.823 (± NEP)	Lower Platte River – protected nests (exclosure)	Marcus (unpubl. data)	Mayfield
2000	0.272 (± NEP)	Lower Platte River – unprotected nests	Marcus (unpubl. data)	Mayfield
2001	0.79 (± NEP)	Lower Platte River – sand and gravel mines (all nests)	Marcus (unpubl. data)	Mayfield
2008	0.919 (± 0.055)	Lower Platte River – sand and gravel mines, housing developments – protected nests (exclosure)	Brown and Jorgensen (2008)	MARK
2008	0.655 (± 0.174)	Lower Platte River – sand and gravel mines, housing developments – unprotected nests	Brown and Jorgensen (2008)	MARK
2009	0.386 (± NEP)	Lower Platte River – river sandbars	Brown and Jorgensen (2009)	MARK
2009	0.701 (± NEP)	Lower Platte River – sand and gravel mines, housing developments	Brown and Jorgensen (2009)	MARK

Table 7 continued.

Year	Nest Survival	Location	Source	Survival Method
2010	0.7229 (± 0.087)	Lower Platte River – sand and gravel mines, housing developments (all nests)	Brown and Jorgensen (2010)	MARK
2010	0.5227 (± 0.2343)	Lower Platte River – sand and gravel mines	Brown and Jorgensen (2010)	MARK
2010	1.00	Lower Platte River – housing developments	Brown and Jorgensen (2010)	MARK

Chick, Juvenile, and Adult Survival

Survival of different age classes can be calculated using many of the same methods used for estimating nest survival. In these analyses, a capture-recapture dataset of marked individuals is used. This dataset can then be used to estimate daily and seasonal survival probabilities (Brown and Jorgensen 2009). Chick, juvenile, and adult survival probabilities vary by region and year, underscoring the importance of continued monitoring. On the Atlantic Coast, seasonal survival probabilities on Cape Cod were estimated to be 0.48 for chicks and 0.74 for adults (Melvin and Gibbs 1994). Similar estimates were obtained for chicks and adults in Maryland and Virginia (Loegering 1992; USFWS 1996). In the Great Lakes region, chick and adult seasonal survival were estimated at 0.73–0.83 and 0.28, respectively (Wemmer 2000). In the Northern Great Plains, Larson et al. (2000) obtained a seasonal survival estimate of 0.318 for juvenile survival and 0.737 for adult survival. On the Lower Platte River, chick seasonal survival was estimated to be 0.299, and adult seasonal survival was estimated to be 0.391 at off-river sites (Brown and Jorgensen 2009).

Other approaches to calculating survival probabilities, such as the modified catch-curve method, have been developed and can be used if individuals are not marked (McGowan et al. 2009). This method estimates daily and seasonal survival based on the number of individuals observed in each age class (Skalski et al. 2006). Catch-curve analyses have a number of assumptions, including constant survival (Skalski et al. 2006). Using this method, McGowan et al. (2009) estimated seasonal chick survival on the Missouri River to be 0.126, 0.160, and 0.188 for three five-day time periods.

Table 8. Estimates of Piping Plover chick survival. Standard errors (if available) are in parentheses (NEP = no error provided for estimate). Estimates made with different methods may not be comparable.

Year	Chick Survival	Location	Source	Survival Method
1988–1990	0.45 (± NEP)	Assateague Island National Seashore, Maryland – bay beach	Loegering and Fraser (1995)	Mayfield
1988–1990	0.70 (± NEP)	Assateague Island National Seashore, Maryland – island interior	Loegering and Fraser (1995)	Mayfield
1988–1990	0.031 (± NEP)	Assateague Island National Seashore, Maryland – ocean beach	Loegering and Fraser (1995)	Mayfield
2009	0.299 (± NEP)	Lower Platte River, Nebraska – sand and gravel mines, housing developments	Brown and Jorgensen (2009)	MARK
2010	0.015 (± 0.164)	Lower Platte River, Nebraska – sand and gravel mines	Brown and Jorgensen (2010)	MARK
2010	0.517 (± 0.085)	Lower Platte River, Nebraska – housing developments	Brown and Jorgensen (2010)	MARK

Table 9. Estimates of Piping Plover juvenile survival. Standard errors (if available) are in parentheses (NEP = no error provided for estimate). Estimates made with different methods may not be comparable.

Year	Juvenile Survival	Location	Source	Survival Method
1985–1989	0.48 (± NEP)	Cape Cod, Massachusetts	MacIvor et al. in USFWS (1996)	Jolly-Seber

Table 10. Estimates of Piping Plover adult survival. Standard errors (if available) are in parentheses (NEP = no error provided for estimate). Estimates made with different methods may not be comparable.

Year	Adult Survival	Location	Source	Survival Method
1984–1994	0.737 (0.092)	North Dakota	Larson et al. (2000)	MARK
1984–1990	0.664 (± 0.057)	Northern Great Plains	Root et al. (1996)	Jolly-Seber
1985–1989	0.74 (± NEP)	Cape Cod, Massachusetts	MacIvor in USFWS (1996)	Jolly-Seber
	0.71 (± NEP)	Assateague Island National Seashore, Maryland	Loegering (1992)	
2002–2004	0.703 (± 0.032)	Long Island, New York beaches	Cohen et al. (2006)	MARK
2008	0.584 (± 0.205)	Lower Platte River – sand and gravel mines, housing developments	Brown and Jorgensen 2008	MARK
2009	0.391 (± 0.040)	Lower Platte River – sand and gravel mines, housing developments	Brown and Jorgensen 2009	MARK
2010	0.776 (± 0.051)	Lower Platte River – sand and gravel mines	Brown and Jorgensen 2010	MARK
2010	0.579 (± 0.064)	Lower Platte River – housing developments	Brown and Jorgensen 2010	MARK

<u>INTERIOR LEAST TERN</u>

Taxonomy and Description

Class Aves
  Order Charadriiformes
    Family Laridae
      Subfamily Sterninae
        Genus *Sternula*
          Species *antillarum*
            Subspecies *S. a. antillarum, S. a. athalassos, S.a. browni*

Sternula antillarum Lesson, 1847, Oeuvres Compl. Buffon 20: 256. Guadeloupe, West Indies (AOU 1998).

French: Petite sterna   Spanish: Charrán mínimo, Gallito, Golondrinita marina

Least Terns (*Sternula antillarum*) are members of the order Charadriiformes, a large assemblage that includes the shorebirds, gulls, auks, and their allies (AOU 1998). The AOU (1998) assigned Least Tern to the family Laridae (skuas, gulls, terns, and skimmers) and sub-family Sterninae (terns). Laridae are a "large assemblage of small to very large seabirds" (Higgins and Davies 1996), consisting of about 97 species. Sterninae are a cosmopolitan group of seabirds with narrow pointed wings and long pointed bills (Higgins and Davies 1996), including about 44 species in seven genera, 33 of these in *Sterna* (Dickinson 2003). The genus

Sterna includes most typical white terns, and *Sternula* includes seven species of small white terns (Olsen and Larsson 1995; Banks et al. 2007). In 2006, the AOU resurrected five previously-recognized generic names for species placed within the genus *Sterna*; one of these resurrected generic names was *Sternula* (Banks et al. 2007). As a result, the Least Tern's generic name was changed from *Sterna* to *Sternula* (Banks et al. 2007). *Sterna* (*sensu* AOU 1998) was shown through mitochondrial DNA analyses correlated with plumage patterns (Bridge et al. 2005) to be paraphyletic. Bridge et al. (2005) therefore recommended "resurrection of four generic names [that were] placed in the synonymy of *Sterna*" (Banks et al. 2007). Originally described by Lesson (1847) as *Sternula antillarum*, for many years the Least Tern was considered to be conspecific with the Little Tern *Sterna* (now *Sternula*) *albifrons* (AOU 1957). This resulted from Hartert's (1921) elimination of the genus *Sternula* accompanied by the consolidation of all small tern species under *Sterna albifrons*, for which five subspecies were recognized (Massey 1998). Later, Massey (1976) provided data that indicated the Least Tern and Little Tern to be specifically distinct (AOU 1998). The AOU formally recognized this distinction in 1983.

Subspecies

The AOU (1957) lists three subspecies of Least Tern: *S. a. antillarum* on the Atlantic and Gulf Coasts, *S. a. athalassos* in the Interior or Great Plains, and *S. a. browni* on the Pacific Coast. However, as noted by Whittier et al. (2006), "The United States Fish and Wildlife Service (USFWS), which oversees endangered species management, does not recognize any subspecies for Least Terns due to taxonomic uncertainties, instead USFWS considers the California, Interior, and Eastern Least Tern to be distinct geographic variants…" Massey (1976), while showing that *S. antillarum* was specifically distinct from *S. albifrons*, was unable to demonstrate morphological, behavioral, or vocal differences between *S. a. antillarum* and *S. a. browni*. Olsen and Larsson (Thompson et al. 1997) concluded that "lack of clear differences among populations and evidence of movements among populations suggest that distinctions are dubious and variation is clinal."

Pyle (2008), following the views of Whittier et al. (2006), noted that the differences among the three populations are not adequate for subspecific recognition. Sufficient mitochondrial DNA gene-flow occurs to suggest female-based dispersal in Least Terns, a phenomenon reported in several members of the Laridae (Whittier et al. 2006). This gene flow would potentially minimize the genetic isolation of breeding populations, depending on fidelity of females to their natal or breeding sites. In support of this hypothesis, no differences were detected electrophoretically between *S. a. athalassos* and *S. a. antillarum* sampled from four Texas sites (Thompson et al. 1992), and a chick banded on the Texas Coast was found breeding in Kansas (Boyd and Thompson 1985).

Appearance

Least Terns are the smallest terns in North America at 21–23 cm with a wingspan of 48–53 cm (Thompson et al. 1997). According to Thompson et al. (1997), the Least Tern in definitive alternate (adult breeding) plumage exhibits a black cap and loral stripe contrasting with a white forehead. They have webbed feet, long, narrow wings, a short forked tail, and are distinguished by a yellow, slightly de-curved bill with a dark tip (Sibley 2000). The upper body is gray and the undersides are white with the outer 2–4 primaries black (Thompson et al. 1997). The sexes are similar in appearance, but the dark loral stripe may be wider in the male (Olsen and Larsson

1995). Immature birds and non-breeding adults display less black on the head (Sibley 2000; Thompson et al. 1997). Juveniles have faint barring on the back (Sibley 2000) and exhibit darker legs and bill (National Geographic Society 1987; Sibley 2000). Limited evidence suggests two variants for immature (i.e., first-summer) birds of *S. a. browni*. Immature birds of the *portlandica* variant, which is considered the first alternate plumage, have a black bill and black eye stripe. The black eye stripe extends back from the head to form a nuchal collar (Atwood and Massey 1982). Birds of the *pikei* variant, also first alternate plumage, have a yellowish bill with varying amounts of black or dusky coloration. The head pattern is similar to that of the definitive alternate plumage, but with white flecking (Atwood and Massey 1982).

<u>Distribution (Figure 9)</u>

Historic Breeding Range

Available evidence suggests that Least Terns were regular breeders in varying numbers throughout their range (Bent 1921, 1929; Ducey 1985; USFWS 1990; Thompson et al. 1997). The California Least Tern historically nested along the Pacific coast from Moss Landing, Monterey County, south to San José del Cabo in southern Baja California, Mexico (USFWS 2006). Most birds, however, tended to nest in southern California from Santa Barbara County to San Diego County (USFWS 1980).

Interior Least Terns historically nested on sandbars of major river systems including the Mississippi, Red, Rio Grande, Missouri, Arkansas, and Ohio (USFWS 1980). Barren sandbars were formerly abundant in these systems (USFWS 1980). Least Terns were uncommon to common on major river systems in Nebraska (Ducey 2000). The species was first described by Lewis and Clark during their travels on the Missouri River (Johnsgard 2003). The expedition recorded the Least Tern as a “frequently observed bird” nesting in August of 1804 (NGPC 1997). Lewis collected two birds at that time, in what is now Burt County (Ducey 2000) and wrote a very detailed description of the Least Tern, describing its vocalizations, habits, and feather measurements (Woodger and Toropov 2004). Lewis observed terns nesting on sandbars along the Missouri (Burroughs 1961). He also noted that members of the expedition caught several tern chicks, and that terns were more common on the northern stretch of the river (Burroughs 1961). In 1820, members of the Major Stephen Long Expedition reported finding Least Terns nesting along the Missouri River in the Engineer Cantonment area, in present day Washington County. In 1823, Paul Wilhelm, Duke of Wurttemberg, reported Least Terns flying near the mouth of the Platte River, in present day Cass County (Ducey 2000).

Ferdinand V. Hayden, the naturalist for Lieutenant Warren’s expedition of the Platte River in 1856-57, collected two Least Terns (one on the Platte and one on the Loup Fork of the Platte) on 8 July (Coues 1874). Naturalist George Suckley recorded a Least Tern along North Platte River in Keith County in 1859 (Ducey 2000). Young Least Terns were observed in Dakota County along the Missouri River in July of 1866 and 1866 in Dixon County (Bruner 1901, Moser 1942). Samuel Aughey made several observations of Least Terns on the Missouri River in Dixon, Cedar, and Sarpy Counties in July 1866, August 1867, June 1868, and June 1872. He also noted them in Lancaster County in June of 1873 and 1874 (Ducey 2000). By the end of the 19th century, authors described the Least Tern as a common to abundant migrant and “not uncommon” summer resident in Nebraska (Bruner 1896; Bruner 1901). Tern breeding activity was observed at Carter Lake near Omaha in 1893, continuing until development in the early 1940s (Bruner 1901; Ducey 1985). Similarly, Tout found five tern nests “on a basin near York” in 1896 and 1897 (Bruner 1901). Least Terns were reported as “common and breeding” on sandbars in the Niobrara River in July 1903 (Bruner 1901).

Current Breeding Range

As human populations have increased throughout its breeding range, habitat availability for the Least Tern has changed, but with little apparent change in overall range distribution. The Least Tern's breeding distribution overlaps with that of the Piping Plover along the Atlantic Coast and in the Interior Great Plains (Thompson et al. 1997). However, the breeding range includes many other areas, including the Pacific and Gulf Coasts, the Gulf of California, the Caribbean, and on islands off the coast of Venezuela (Carreker 1985; Thompson et al. 1997). Like Piping Plovers, the Atlantic Coast population is found "along beaches in New Brunswick, Prince Edward Island, Nova Scotia, Quebec, Newfoundland, Saint Pierre and Miquelon (France), southern Maine, New Hampshire, Rhode Island, Massachusetts, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina" (Elliot-Smith and Haig 2004). In the Interior, Least Terns breed throughout most of the Great Plains, as described by Elliott-Smith and Haig (2004): "from alkali wetlands in southeastern Alberta through southern Saskatchewan and Manitoba to Lake of the Woods in southwestern Ontario and north-western Minnesota, south along major prairie rivers (Yellowstone, Missouri, Niobrara, Platte, and Loup), the Arkansas River and reservoirs in eastern Colorado, the Kansas River in Kansas, and alkali wetlands in northeastern Montana, North Dakota, South Dakota, Nebraska, and Iowa." Within their respective ranges, populations of California and Interior Least Terns are "localized and increasingly fragmented" (Sidle et al. 1988, Thompson et al. 1997). Distribution data presented in Lott (2006), along with the range summary in Thompson et al. (1997), provide the most recent delineation of the breeding range of Interior Least Tern. A summary of these data is presented in Table 11. The current breeding distribution of the Interior Least Tern in Nebraska is shown in Figure 10.

Because of taxonomic uncertainty, Interior Least Tern, *athalassos,* is considered by the USFWS (1985) as any Least Tern nesting more than 50 kilometers from either coast. This definition could include instances noted by Thompson et al. (1997) of Eastern Least Terns, *antillarum*, breeding "locally at coastal sites from s. Maine south to s. Florida, including "both shores of Chesapeake Bay north to Baltimore and Queen Anne Cos., MD; also along extreme s. Delaware Bay" and "locally along Gulf Coast from s. Florida west to s. Texas." California Least Terns, *browni,* breed along the Pacific Coast of California (from San Francisco Bay southward) to Baja California; a breeding colony was discovered in Jalisco, Mexico, in the early 1990s (Garcia and Ceballos 1995; Thompson et al. 1997).

Possible breeding occurred at Lake Moultrie in South Carolina in 1991, along with an increased frequency of inland breeding, often on rooftops in Florida (Thompson et al. 1997). Because these reports are far removed from the Great Plains river systems occupied by Interior Least Tern, they would seem far more likely to involve Eastern Least Terns (*antillarum*). Widespread habitat loss and human disturbance have contributed to colony movement and constriction. Thompson et al. (1997) state that "dramatic fluctuations are documented in populations and distribution of colony sites across [the] species' breeding range;" although "breeding distribution in [the] 1990s is largely similar to historic geographic extent of breeding range a century earlier, but colony distribution within that area is much more fragmented, especially for interior and California populations."

Current Winter Range

Least Terns spend the winter south of the United States in coastal areas of Central and South America, ranging as far south as coastal Argentina (Thompson et al. 1997). The California population winters from central Mexico to Panama (USFWS 2009c). Wintering California Least Terns have been reported in Costa Rica, Panama, Guyana, El Salvador, Guatemala, and Peru (NGPC 1997; USFWS 2006), with relatively few records outside of the Americas. In rare instances, terns have been observed wintering as far north as the Gulf Coast of the United States (Thompson et al. 1997). In breeding plumage, Least Terns and Little Terns (*S. albifrons*) show subtle morphological differences (Massey 1976).

Figure 9. Range of Least Tern (*Sternula antillarum*) (from The Birds of North America; Thompson et al. 1997).

Table 11. Major river systems supporting breeding colonies of Least Terns in the United States.

River	State(s)	Source
Missouri	Montana, North Dakota, South Dakota, Nebraska, Iowa	Lott (2006)
Yellowstone	Montana	Lott (2006)
Cheyenne	South Dakota	Lott (2006)
Niobrara	Nebraska	Lott (2006)
Platte (and tributaries)	Nebraska	Lott (2006)
Kansas	Kansas	Lott (2006)
Mississippi	Cape Girardeau, Missouri to Baton Rouge, Louisiana	Lott (2006)
Ohio	Illinois, Indiana, Kentucky	Lott (2006)
Wabash	Indiana, Illinois	Lott (2006)
Arkansas	Arkansas, Oklahoma, Colorado	Lott (2006)
Salt Fork	Oklahoma	Lott (2006)
Cimarron	Oklahoma	Thompson et al. (1997)
Canadian (including North Fork)	Oklahoma	Thompson et al. (1997)
Red (and tributaries)	Louisiana, Oklahoma, Texas	Thompson et al. (1997)
Sabine	Texas	Thompson et al. (1997)
Trinity	Texas	Thompson et al. (1997)
Brazos	Texas	Thompson et al. (1997)
Colorado	Texas	Thompson et al. (1997)
Rio Grande	Texas, New Mexico	Thompson et al. (1997)

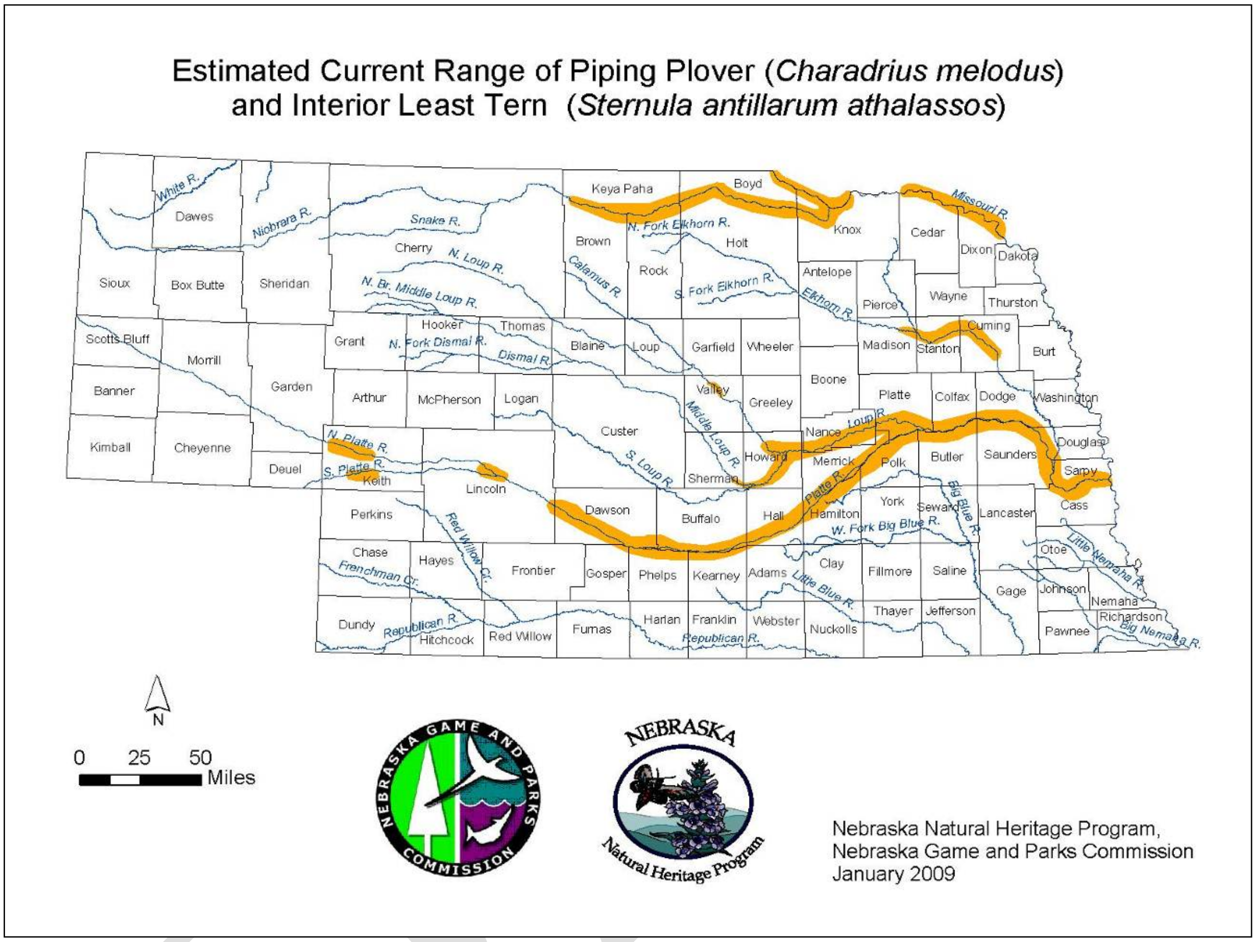

Figure 10. Breeding distribution of the Least Tern (shown in orange) in Nebraska. Range map courtesy of the Nebraska Natural Heritage Program.

Habitat

Before European settlement of North America, Least Terns nested on coastal beaches, on naturally-created sandbars of major inland rivers, and on alkaline flats (USFWS 1990). In Nebraska, terns were historically found on sandbars of the Platte, Missouri, Loup, Elkhorn, and Niobrara Rivers. Much of this natural habitat has been lost due to anthropogenic changes to these rivers. Sandbar habitat in portions of the Missouri River, for instance, has been greatly diminished or virtually eliminated (USFWS 1990).

<u>Breeding Habitat</u>

Least Terns primarily breed in coastal or riverine habitat characterized by bare or sparsely-vegetated sand, gravel, shell or mudflat substrate (Thompson et al. 1997). Regardless of habitat type, colonies are located in close proximity to water such as rivers, oceans, lagoons, or estuaries (Thompson et al. 1997). In coastal habitat, they breed on beaches, peninsulas, and islands, placing nests between the high tide line and dune formations (Carreker 1985). In northwestern Mexico, Least Terns breed on barrier beaches associated with bays and estuaries (Zuria and Mellink 2002). Least Terns also nest on dredged-material islands; pairs place their nests on either shell substrate or sand-silt substrate (Mallach and Leberg 1999). Least Terns appear to prefer nesting on shell substrates at dredged-material sites along the Louisiana coast (Leberg et al. 1995).

Inland nest sites are usually on river sandbars, which become exposed as river levels recede (Carreker 1985). In Nebraska, Least Terns nest on river sandbars and sand and gravel mines, which are located adjacent to major rivers. On the Central Platte River, the majority (> 90%) of Least Tern nests have been placed on sand pits and human-created sandbars since systematic surveys began in 1985 (Sidle et al. 1991; Sidle and Kirsch 1993; Jenniges 2005). Tern nests at sand pits along the Central Platte have low amounts of vegetation cover (< 10%) and are placed on coarse sand or gravel ≤ 6.3 mm in diameter (Wilson et al. 1993). Typical vegetation at sand pits includes grasses, forbs, sedges (*Carex spp.*), and cottonwood and willow seedlings or saplings (Wilson et al. 1993). Most nests (73%) on the Lower Platte occur on natural river sandbars (Sidle and Kirsch 1993).

Additional inland sites include alkaline flats, reservoirs, and rooftops (Grover and Knopf 1982; Gore 1991; Thompson et al. 1997; Butcher et al. 2007). Alkaline flats are largely devoid of vegetation with flat to gently sloping surfaces (Schweitzer and Leslie 1999). Vegetation typically consists of Inland Salt Grass (*Disticulus stricta*), Sea Purslane (*Sesubium verrucosum*), and Saltmarsh Bulrush (*Scirpus paludosis*; Whittier and Leslie 2009). Least Terns nesting on alkaline flats in Oklahoma placed their nests in coarser soil and closer to driftwood or debris compared to random points (Schweitzer and Leslie 1999). All of these nests were associated with very low levels of vegetative cover (0–1.2%; Schweitzer and Leslie 1999). In a number of states, particularly in the southeastern U.S., Least Terns nest on gravel-covered rooftops. Increasing numbers of terns have nested in these human-created habitats as numbers nesting on beaches have decreased (Murphy and Dodd 1995; Krogh and Schweitzer 1999). In South Carolina and Georgia, for instance, more than 61% and 70% of Least Terns nest on roofs within a breeding season (Murphy and Dodd 1995; Krogh and Schweitzer 1999). These sites consist of flat roofs with gravel or stones one to four cm in depth (Krogh and Schweitzer 1999).

<u>Migratory Habitat</u>

Habitat characteristics of migratory stopover sites have received little to no study. Least Terns migrate along major inland rivers and the Atlantic, Pacific, and Gulf coasts (Thompson et al. 1997). Prior to fall migration, Interior Least Terns stage at sites along interior rivers or reservoirs, such as Great Salt Plains Lake in Oklahoma (Talent and Hill 1985). Interior birds migrate along major river systems to their confluence with the Mississippi River, then south to the Gulf of Mexico; where they go after this remains unknown (Thompson et al. 1997). In some areas (e.g. Panama and Baja California), Least Terns migrate anywhere from 2–30 km offshore (Ridgely 1976; Howell and Engel 1993). The species is common during fall migration in Costa Rica (Stiles and Skutch 1989).

<u>Winter Habitat</u>

Little information is available on characteristics of wintering habitat (Thompson et al. 1997). The Interior and Atlantic Coast populations are believed to winter in Central and South America; banded Atlantic Coast juveniles have been resighted on the northern coast of South America

(Thompson 1982; Thompson et al. 1997). Habitat consists of marine coasts, bays, estuaries, and river mouths (Ffrench 1991). Least Terns wintering in Suriname feed along estuaries, lagoons, creeks, and on exposed mudflats (Spaans 1978). In Colombia, Least Terns have been observed along lagoons and mudflats (Hilty et al. 1986).

Habitat Use and Movements

Interior Least Terns nesting on sand pits use adjacent rivers to meet various needs, including foraging, loafing, and staging prior to migration (Lingle 1993b). On the Central Platte River, adult terns foraged along the river at distances of 0.25–1.5 mi from nest sites at sand pits (Lingle 1993b). Terns fledged on sand pits in central Nebraska move to Platte River, and in one case parents with a brood of 7-day-old chicks left a sand pit for the river (Lingle 1993b). Conversely, adults and fledglings using river sandbars will move to sand pits when sandbars become inundated (Lingle 1993b). River staging sites may be used for up to 30 days prior to migration (Lingle 1993b). Least Terns moved between 4 and 57 mi from nesting sites to staging sites on the Central Platte River (Lingle 1993b). When nests were lost, these birds moved 0.5–55 mi to a new site to renest (Lingle 1993b). California Least Tern adults and fledglings move from breeding colonies to nearby freshwater marshes and estuaries prior to migration (USFWS 1980).

Life History and Ecology

Breeding

Arrival and Courtship

Arrival times follow a latitudinal gradient. Least Terns may arrive on the breeding grounds as early as late March along the Gulf Coast to late May in Illinois and Iowa (Stiles 1939; Thompson 1982; Bohlen 1989). Pair formation occurs after arrival. Courtship lasts two to three weeks and begins in April or May, with a second period in some areas from June through early July (Thompson et al. 1997). The courtship period appears to show a longitudinal gradient, with birds in California and along the Gulf Coast beginning in April, birds in the Interior in late April to late May, and birds on the Atlantic Coast in May (Thompson et al. 1997). Courtship begins with a fish flight display, in which the male carries a fish in his bill and gives a four-note call. Following this display, pairs may land and the male presents a fish to the female, which may or may not end in copulation (Thompson et al. 1997). When presenting the fish, the male approaches the female from behind; the female squats on her belly while the male stands slightly above her and waves the fish back and forth (von Schmidt 1968). Once paired, males will periodically bring small fish to females through the incubation period (Thompson et al. 1997).

Nests and Eggs

Both adults dig scrapes, one of which is selected by the female to become the nest (Thompson et al. 1997). Nests are usually located in sandy substrate with bits of shell or gravel on elevated areas (Burger and Gochfeld 1990). Nests are usually unlined, typically measuring two cm deep by 7–10 cm in diameter (Thompson et al. 1997; Baicich and Harrison 1997). Nest initiation is relatively synchronous within colonies (Thompson et al. 1997).

Eggs measure 32 by 23 mm (Baicich and Harrison 1997). Egg background and spot color, as well as size, number, and distribution of spots, are highly variable, even within a clutch (Thompson et al. 1997). Eggs have a smooth, nonglossy surface (Thompson et al. 1997).

Nesting Densities

Nesting densities for Least Terns vary geographically as well as annually. On the Mississippi River, for example, relatively low nesting densities occurred (19.3 nests per colony) during low-water years, whereas during high-water years densities were an order of magnitude higher (100 nests per colony; Smith and Renken 1991). Nesting densities in Oklahoma were also low, ranging from 5–25 nests per colony, for overall densities of 0.1–0.75 nests/ha (Schweitzer and Leslie 1999). Low-density colonies tend to have nests spaced far apart (USFWS 1984). In some areas, nests are placed very close together, as in one Mississippi site, where the average internest distance was 3.1 m (Jackson and Davis 1996). At one human-created nesting area, nests were placed an average of 13.4–43.0 m apart (Brown et al. 2009).

Egg-laying and Incubation

Egg-laying commences within two days of nest construction (Thompson et al. 1997). Females lay one egg per day or one egg every two days; clutch size ranges from one to three eggs, with Interior birds usually having larger clutches than coastal birds (Kirsch 1996; Thompson et al. 1997; Baicich and Harrison 1997). Pairs raise one brood per season, and females do not lay replacement eggs. However, females will replace lost clutches (Baicich and Harrison 1997). Both sexes incubate clutches, but females may incubate up to 80% of the time (Davis 1968). Incubation lasts 19–22 days (Baicich and Harrison 1997).

Brood-rearing

Both the male and female care for chicks, brooding them for the first 24–48 hours after hatching (Thompson et al. 1997). When ambient temperatures are high, parents will soak their ventral feathers in order to cool chicks while brooding them (Jackson 1994). Both parents feed fish to chicks, and fish size increases with chick age (Atwood and Kelly 1984; Hill 1985). Feeding rates vary from 1–4 fish per hour (Dugger in Thompson et al. 1997).

Defense of Nests and Chicks

Birds respond to potential egg predators by leaving the nest when the predator is within 25–60 m (Burger 1987). Adults then dive at the intruder at a rate of 3–12 times/minute, giving alarm calls and often defecating on the intruder (Burger 1987; Thompson et al. 1997). They will also dive at chick predators (Burger 1989). Adults will abandon nests or chicks if they themselves feel threatened by predators such as foxes or dogs (Burger 1989).

Chick growth and development

Least Tern chicks are semiprecocial and remain in the nest for two days (Thompson et al. 1997; Baicich and Harrison 1997). Chick weight at hatching ranges from 4.5 to 7.2 g (Massey 1974; Lingle 1988). Chicks weigh approximately 40 g at fledging (Thompson et al. 1997; Brown and Jorgensen 2008, 2009). Chicks produced on both river sandbars and off-river sites along the Lower Platte River attained their fledging mass at approximately 15 days (Brown and Jorgensen

2008, 2009). Chicks begin to fly at 20 days and fledge at 21 days (Thompson et al. 1997; Brown and Jorgensen 2008).

Feeding Habitat and Habits

Least Terns are largely piscivorous, and more than 50 species of fishes have been recorded as food items (Atwood and Kelly 1984). In marine habitats, terns also feed on shrimp and marine worms; other invertebrates such as ants may be consumed as well (Thompson et al. 1997). Fish prey range in size from 2–9 cm long and less than 1.5 cm deep and swim near the water's surface. Smaller fish are fed to tern chicks and vary with the chick's age (Thompson et al. 1997). Interior Least Terns breeding on the Platte River in Nebraska primarily consume gizzard shad (*Dorosoma cepedianum*); red shiner (*Notropis lutrensis*), plains killifish (*Fundulus zebrinus*), and creek chub (*Semotilus atromaculatus*) (Wilson et al. 1993; M.B. Brown, pers. obs.). Adults and chicks on the Central Platte also consume terrestrial insects while at the nest or in the air, including dragonflies (Wilson et al. 1993).

In the interior U.S., foraging habitat consists of shallow water in rivers, streams, marshes, and ponds. On the Atlantic and Pacific coasts, Least Terns forage in bays, lagoons, marshes, and estuaries (Thompson et al. 1997). A variety of human-created habitats such as reservoirs, dikes, and sand pits are also used by terns (Wilson et al. 1993; Thompson et al. 1997). Least Terns forage throughout the day, hovering 1–10 meters above the water's surface and then plunging to the surface to grab fish with their bills (Thompson et al. 1997). Adults will sometimes skim the water's surface to catch aquatic insects or tadpoles (Thompson et al. 1997). Interestingly, two immature Least Terns in Texas were observed foraging for beetle larvae in an agricultural field, employing the same technique seen over water (McDaniel and McDaniel 1963).

Migration

Least Terns migrate in small flocks, foraging in shallow offshore waters and resting on beaches, sandbars, docks, and pilings (Thompson et al. 1997). Coastal birds may remain with fledglings for six to eight weeks before departing the breeding grounds (Thompson et al. 1997). Birds from the Pacific and Atlantic Coast populations have been observed migrating in family units (Thompson et al. 1997). Spring arrival times follow a latitudinal gradient, with Gulf Coast breeders arriving in late March to early April, California birds in mid- to late April, and Illinois birds in mid- to late May (Toups and Jackson 1987; Massey 1974; Bohlen 1989). Fall migration can begin as early as June and persist through mid-November for Caribbean populations (Voous 1983).

Site Fidelity and Dispersal

Breeding site fidelity in Least Terns may depend on a number of factors, including the physical characteristics of a colony site, predation levels, and human disturbance (Atwood and Massey 1988). Evidence for breeding site fidelity varies substantially, with data indicating return rates of 28% to 97% (Thompson et al. 1997). Twenty-nine percent (*N*=117) of adult Least Terns banded on the Central Platte River between 1986 and 1991 returned to the same area to breed (Lingle 1993b). California Least Terns show high breeding site fidelity, with averages of 43–78% at three colony sites (Atwood and Massey 1988). The authors of this study note that the lower return rates likely resulted from lower search effort; thus they represent "underestimated, minimum values" (Atwood and Massey 1988). Similarly, interannual colony turnover rate on the

New Jersey coast was low ($\bar{x}$ =0.13), suggesting high site fidelity of these populations (Burger 1988).

Estimates of natal site fidelity vary temporally and geographically. In one study on the Central Platte River, 26% of banded chicks (*N*=222) returned to their natal site (Lingle 1993b). Natal site fidelity of California Least Terns at two sites differed across years, ranging from 33–64% (Atwood and Massey 1988).

Dispersal also varies, and may be as high as 274 km (170 mi) between natal sites and breeding sites (Lingle 1993b). Resighting data on the Platte River provide evidence for mixing of Central Platte and Lower Platte populations. For example, three chicks banded on the Lower Platte River were resighted as adults nesting up to 201 km (125 mi) away on the Central Platte (Lingle 1993b). Similarly, a chick banded near Kearney was later found with a nest near Fremont, a distance of 241 km (150 mi). California Least Terns, however, disperse only short distances between breeding sites. Seventy-seven percent of birds that used different breeding sites between years moved less than 15 km (9 mi); most of those dispersing farther moved to the next closest colony site (Atwood and Massey 1988).

<u>Intra- and Inter-specific Interactions</u>

Least Terns are colonial nesters, and as such, territoriality is limited to within 1 m of the nest (Thompson et al. 1997). Chicks from other broods tend to roam throughout the colony, but will be attacked if within striking distance of a neighboring nest or brood (Thompson et al. 1997). Males are territorial prior to nesting; they defend display sites from conspecifics as well as other species such as Common Terns (*Sterna hirundo*) and Black Skimmers (*Rynchops niger*; Wolk 1974; Burger and Gochfeld 1990). Least Terns often feed and migrate in flocks of 5–20 individuals, (Thompson et al. 1997). Birds form flocks of varied sizes at loafing sites associated with colonies (Thompson et al. 1997).

Least Terns often nest in association with Piping Plovers in the Great Plains and on the Atlantic coast (USFWS 1988; 1990). Least Terns also nest with Snowy Plover (*C. alexandrinus*) and American Avocet (*Recurvirostra americana*) on the Arkansas River and its tributaries and with Black Skimmers on the Atlantic and Gulf coasts (Burger and Gochfeld 1990; USFWS 1990; Thompson et al. 1997).

As resources for courting, nesting, and foraging become scarcer, competition between species can ensue. Some colonial waterbirds, such as gulls, have become so numerous in regions that they now cause problems for other nesters and humans (Parnell et al. 1988). Ring-billed Gulls (*Larus delawarensis*) were the primary predators of Least Tern model nests (75–100% of the time) in a predator identification study conducted in southwest Indiana in 2003–2004 (DeVault et al. 2005). In general, gulls have become highly adapted to human-altered landscapes and increasingly numerous over the last 40 years (Sauer et al. 2007).

A diverse suite of birds, mammals, invertebrates, and reptiles are known to prey on Least Tern adults, juveniles, chicks, and eggs (Table 12). Many species, including American Crow (*Corvus brachyrhynchos*), Black-crowned Night Heron (*Nycticorax nycticorax*), Ring-billed Gull (*Larus delawarensis*), raccoon (*Procyon lotor*), and red fox (*Vulpes vulpes*), prey on both eggs and chicks. Some avian predators, such as Great Horned Owls (*Bubo virginianus*), prey on nearly all life stages. Coyotes (*Canis latrans*), who prey on eggs and chicks, have been documented in the largest number of studies.

Table 12. Documented predators of Least Tern eggs, chicks, and adults.

Predator	Life stage preyed upon	Location(s)	Source(s)
American Crow (*Corvus brachyrhynchos*)	Egg, chick	California; New Jersey	Atwood et al. (1977); Burger (1984); Brunton (1997)
American Kestrel (*Falco sparverius*)	Chick, juvenile	California; South Dakota	Craig (1971), Atwood and Massey (1988), Kruse (1993), Kruse et al. (2001)
Black-crowned Night Heron (*Nycticorax nycticorax*)	Egg, chick	Connecticut	Brunton (1997)
Black Skimmer (*Rynchops niger*)	Chick	Mississippi	Jackson in Thompson et al. (1997)
Burrowing Owl (*Athene cunicularia*)	Adult, chick	California	U.S. Fish and Wildlife Service (1980)
Common Raven (*Corvus corax*)	Egg	California; Baja California (Mexico)	Avery et al. (1995), Zuria and Mellink (2002)
Coyote (*Canis latrans*)	Egg, chick	Oklahoma; California, Georgia; Nebraska; Sonora (Mexico)	Grover and Knopf (1982); Atwood and Massey (1988), Krogh and Schweitzer (1999), Zuria and Mellink (2002), Jenniges and Plettner (2008)
Domestic dog (*Canis familiaris*)	Egg, chick	Georgia; Nebraska	Krogh and Schweitzer (1999), Jenniges and Plettner (2008)
Great Horned Owl (*Bubo virginianus*)	Chick, Juvenile, Adult	Cape Cod National Seashore, Massachusetts; Nebraska; South Dakota	Minsky (1980); Kruse (1993); Kruse et al. (2001); Wilson et al. (1993)

Table 12 continued.

Predator	Life stage preyed upon	Location(s)	Source(s)
Greater Roadrunner (*Geococcyx californianus*)	Chick	California	Whelchel and Lansford (2006)
Gull-billed Tern (*Sterna nilotica*)	Chick	Mississippi	Densmore (1990)
House cat (*Felis domesticus*)	Egg, chick	Georgia	Massey and Atwood (1979); Krogh and Schweitzer (1999)
Loggerhead Shrike (*Lanius ludovicianus*)	Chick	California	USFWS(1980)
Northern Harrier (*Circus cyaneus*)	Chick	Massachusetts	Jenks-Jay (1980); Mostello and Melvin (2001)
Norway Rat (*Rattus norvegicus*); Unidentified rat sp.	Egg, chick	New Jersey	Massey and Atwood (1979); Burger (1984)
Raccoon (*Procyon lotor*)	Egg, chick	Georgia; Nebraska	Krogh and Schweitzer (1999); Jenniges and Plettner (2008)
Red-tailed Hawk (*Buteo jamaicensis*)	Chick	Nebraska	Jenniges and Plettner (2008)
Red Fox (*Vulpes vulpes*)	Egg, chick	Massachusetts	Minsky (1980); Rimmer and Deblinger (1992)
Red Imported Fire Ant (*Solenopsis invicta*)	Chick	Mississippi	Lockley (1995)
Ring-billed Gull (*Larus delawarensis*)	Egg, chick	Indiana	DeVault et al. (2005)
Roof Rat (*Rattus rattus*)	Egg, chick	U.S. Virgin Islands	Witmer et al. (1996)
Southern Fire Ant (*Solenopsis xyloni*)	Egg, chick	California	Hooper-Bui et al. (2004)
Snake sp.	Chick	Nebraska	Jenniges and Plettner (2008)
Striped Skunk (*Mephitis mephitis*)	Egg, chick	California; Massachusetts	Massey and Atwood (1979); Rimmer and Deblinger (1992)
Unidentified owl sp.	Chick	Georgia	Krogh and Schweitzer (1999)

Terns depend on their colonial nesting neighbors for protection from predators, with safety in numbers. However, having too many or too few neighbors will facilitate predation. A colony size of approximately 150 nests may be ideal, large enough to limit losses to small mammals, yet small enough to lessen the appeal to Black-crowned Night Herons (Brunton 1999). If Least Tern habitat is already limited, unusually-populous areas quickly become easy targets for predators. Abnormally small colonies are also more susceptible to predation. Brunton found that very small colonies (i.e., 10 nests or less) of Least Terns failed unequivocally (1999).

Nest position within a colony may also be important in determining the likelihood of predation. Shorebirds pushed to peripheral nesting locations because of limited habitat availability may be more likely to fall prey to crows (Brunton 1997). Yet, center nests in a heavily-populated colony (*N*=500 pairs) were more likely to be predated by Black-crowned Night Herons (Brunton 1997). This research suggests that the availability of numerous sandbar nesting sites is more important than a few large tracts of habitat, so that the density of shorebirds is adjusted to prevent high losses to predation.

Human alterations to the landscape can also affect the community of predators. Predators of shorebirds include mammals (e.g. fox and skunk) (Haig 1985; USFWS 1988), birds (e.g. corvids, gulls, and herons) (Avery et al. 1995; Brunton 1999; DeVault et al. 2005), snakes (USACE 2008), and even fire ants (Lockley 1995). Specific tern predators present along the Lower Platte and Loup Rivers include: coyotes (*Canis latrans*), red foxes (*Vulpes vulpes*), raccoons (*Procyon lotor*), dogs (Canis familiarus), American Crows (*Corvus brachyrhynchos*), Great Horned Owls (*Bubo virginianus*), American Kestrels (*Falco sparverius*), and Red-tailed Hawks (*Buteo jamaicensis*) (Lackey 1994). Some authors suggest that nesting sites connected to the mainland, such as sandpit sites (NRC 2005), or that are associated with particular landscape characteristics, like large branches or man-made structures for roosting hawks and owls, are more susceptible to predation (Soots and Parnell 1975; Sherfy et al. 2008).

Population Trends

Prior to 1985

California Least Terns were historically abundant; an account from the early 1900s (Shepardson 1909) mentions 600 pairs nesting along a 4.8-km stretch of beach in San Diego County, and Grinnell (1898) documented "good-sized" colonies in Los Angeles County. Populations experienced gradual declines over the 20th century, primarily as a result of habitat loss and human disturbance (USFWS 1985). Historic population estimates for the Interior Least Tern do not exist, but qualitative descriptions suggest that the population was common (Hardy 1957; Burroughs 1961). A survey by Downing (1980) detected 1,200 birds.

Since Listing Under the Endangered Species Act

Declines in populations of Least Terns were formally recognized in the 1970s and mid-1980s (Thompson et al. 1997; USFWS 2008), resulting in concentrated monitoring efforts (Lott 2006) and habitat restoration. Lott (2006) noted that the "minimum number of adult Least Terns present during the breeding season in the United States" is between 84,839 and 86,591, considerably higher than the previous estimate of 55,000 (Thompson et al. 1997).

Since the California Least Tern was federally listed in 1970, populations have increased. The minimum number of breeding pairs increased from 600 in 1973 to 7,100 in 2005 (USFWS 2006). An estimated 4,800 birds occurred in the Interior in 1987 (USFWS 1990). Between 1985–1988, the number of birds on the Platte River increased from 256 to 635 (NGPC, unpublished data). An estimated 350–420 breeding pairs occurred along the Platte River in Nebraska in the 1990s (USFWS 1991).

Demography/Productivity

Productivity

Productivity for Least Terns is typically reported as a fledge ratio, which is calculated in one of two ways. The traditional calculation is the number of fledglings per adult pair ot nest over a defined spatial or temporal area (Brown and Jorgensen 2009). The number of fledglings is based on the number of individuals observed (Brown and Jorgensen 2009). Chick survival determined by analyzing capture-recapture data (see below) provides an alternative method of calculating fledge ratios.

A recent analysis for the Lower Platte River found that the traditional calculation versus survival method of fledge ratios produced very different results; in one case, the traditional method produced an estimate 11 times greater than the survival method (Brown and Jorgensen 2009). Productivity varies by site and year, and may be as low as 0.067 chicks per adult pair or as high as 1.31 chicks per adult pair, based on the traditional method of calculation (Table 13). An examination of fledge ratios at natural and human-created sites in Nebraska reveals considerable variation in Least Tern productivity.

Table 13. Estimates of Least Tern fledge ratios. Standard errors (if available) are in parentheses (NEP = no error provided for estimate). Table modified from Nebraska Game and Parks Commission (2008).

Year	Fledge ratio*	Location	Source
1984	0.48 (± NEP)	New Jersey	Burger (1984)
1985	0.067 (± NEP)	Salt Plains NWR, Oklahoma	Hill (1985)
1986	0.20 (± NEP)	Missouri River, South Dakota	Schwalbach (1988)
1987	0.64 (± NEP)	Missouri River, South Dakota	Schwalbach (1988)
1986–1993	0.58 (± 0.15)	Lower Mississippi River, Missouri	Dugger et al. (2002)
1988	0.42 (± NEP)	Missouri River, North Dakota	Mayer and Dryer (1989)
1989	0.21 (± NEP)	Missouri River, North Dakota	Mayer and Dryer (1989)
1988	0.44 (± NEP)	Missouri River, South Dakota	Dirks (1990)

*Chicks per adult pair

Table 13 continued.

Year	Fledge ratio*	Location	Source
1989	0.55 (± NEP)	Missouri River, South Dakota	Dirks (1990)
1995	0.72 (± NEP)	Lower Mississippi River, Missouri – Rkm 1431	Dugger et al. (2000)
1995	1.0 (± NEP)	Lower Mississippi River, Missouri – Rkm 1481	Dugger et al. (2000)
1996–1997	0.04–0.26 (± NEP)	Gravel roofs, Georgia	Krogh and Schweitzer (1999)
1996–1997	0–0.12 (± NEP)	Dredged-material sites, Georgia	Krogh and Schweitzer (1999)
1996–1997	0	Ocean beaches, Georgia	Krogh and Schweitzer (1999)
1994–1997	0.56 (± NEP)	Central Platte River – unmanaged sandpits	Jenniges and Plettner (2008)
1991–2005	1.09 (± NEP)	Central Platte River – artificial sandbars	Jenniges and Plettner (2008)
1991–2005	1.31 (± NEP)	Central Platte River – managed sandpits	Jenniges and Plettner (2008)
1999	0.08–0.47 (± NEP)	Salt Plains NWR, Oklahoma	Whittier and Leslie (2009)
2008	1.07 (± NEP)	Lower Platte River, Nebraska – river sandbars	Brown and Jorgensen (2008)
2008	0.74 (± NEP)	Lower Platte River, Nebraska – sand and gravel mines, housing developments	Brown and Jorgensen (2008)

*Chicks per adult pair

Table 13 continued.

Year	Fledge ratio*	Location	Source
2009	0.74 (± NEP)	Lower Platte River, Nebraska – river sandbars	Brown and Jorgensen (2009)
2009	1.55 (± NEP)	Lower Platte River, Nebraska – sand and gravel mines, housing developments	Brown and Jorgensen (2009)

*Chicks per adult pair

Nest Survival

Nest survival has traditionally been calculated using the Mayfield method (Mayfield 1961, 1975). This method accounts for the fact that nests found later in the nesting cycle are more likely to be successful, which tends to overestimate nesting success (Mayfield 1961). The Mayfield method incorporates the number of days the nest was under observation (exposure days) into the calculation of nest survival. Nest survival is expressed as the probability of a nest surviving a particular stage, and survival is assumed to be constant across time and across nests (Shaffer 2004). More recently, logistic regression has been used to estimate nest survival (Hosmer and Lemeshow 1989). This method models survival probability as a function of multiple explanatory variables or covariates (Shaffer 2004). Another method, logistic exposure, accounts for the variation in when nests are found by incorporating exposure days into the model. Program MARK models daily nest survival as a function of multiple explanatory variables or covariates, including time effects (White and Burnham 1999). Time-specific explanatory variables or covariates are allowed to vary, and nest survival is not assumed to be constant (Shaffer 2004). These newer methods are combined with an information-theoretic approach (e.g. AIC) to select the model(s) that best explain nest survival.

Table 14. Estimates of Least Tern nest survival. Standard errors (if available) are in parentheses (NEP = no error provided for estimate). Estimates made with different methods may not be comparable.

Year	Nest Survival	Location	Source	Survival Method
1998	0.707 (± NEP)	Red River, Texas – sandbars and gravel bars	Conway et al. (2003)	Mayfield
2003–2006	0.138 (± NEP)	St. Croix, U.S. Virgin Islands – salt flats	Lombard et al. (2010)	MARK

Table 14 continued.

Year	Nest Survival	Location	Source	Survival Method
2003–2006	0.252 (± NEP)	St. Croix, U.S. Virgin Islands – beaches	Lombard et al. (2010)	MARK
2003–2006	0.215 (± NEP)	St. Croix, U.S. Virgin Islands – offshore cay	Lombard et al. (2010)	MARK
2003–2006	0.195 (± NEP)	St. Croix, U.S. Virgin Islands – industrial	Lombard et al. (2010)	MARK
2003–2006	0.511 (± NEP)	St. Croix, U.S. Virgin Islands – managed sites	Lombard et al. (2010)	MARK
2008	0.364 (± 0.045)	Lower Platte River, Nebraska – river sandbars	Brown and Jorgensen (2008)	MARK
2008	0.356 (± 0.036)	Lower Platte River, Nebraska – sand and gravel mines	Brown and Jorgensen (2008)	MARK
2008	0.356 (± 0.072)	Lower Platte River, Nebraska – housing developments	Brown and Jorgensen (2008)	MARK
2009	0.7910 (± 0.016)	Lower Platte River, Nebraska – river sandbars	Brown and Jorgensen (2009)	MARK
2009	0.6322 (± 0.027)	Lower Platte River, Nebraska – sand and gravel mines, housing developments	Brown and Jorgensen (2009)	MARK
2010	0.576 (± 0.038)	Lower Platte River – sand and gravel mines, housing developments (all nests)	Brown and Jorgensen (2010)	MARK

Table 14 continued.

Year	Nest Survival	Location	Source	Survival Method
2010	0.5120 (± 0.0434)	Lower Platte River – sand and gravel mines	Brown and Jorgensen (2010)	MARK
2010	0.7241 (± 0.0687)	Lower Platte River – housing developments	Brown and Jorgensen (2010)	MARK

Chick, Juvenile, and Adult Survival

Survival of different age classes can be calculated using many of the same methods that are used for estimating nest survival. In these analyses, a capture-recapture dataset of marked individuals is used. This dataset can then be used to estimate daily and seasonal survival probabilities (Brown and Jorgensen 2009). Chick, juvenile, and adult survival probabilities vary by region and year, underscoring the importance of continued monitoring. On the Lower Platte River in 2009, chick seasonal survival was estimated to be an order of magnitude higher for chicks hatched on river sandbars compared with those at off-river sites (Table 7). In 2010, chick survival at off-river sites was 3–5 times higher than the previous year (Brown and Jorgensen 2010).

Table 15. Estimates of Least Tern chick survival. Standard errors (if available) are in parentheses (NEP = no error provided for estimate). Estimates made with different methods may not be comparable.

Year	Chick Survival	Location	Source	Survival Method
1995	0.43 (± NEP)	Lower Mississippi River, Missouri – Rkm 1431	Dugger et al. (2000)	Jolly-Seber
1995	0.62 (± NEP)	Lower Mississippi River, Missouri – Rkm 1481	Dugger et al. (2000)	Jolly-Seber
1999	0.05–0.27 (± NEP)	Oklahoma	Whittier and Leslie (2009)	Kaplan-Meier
2008	0.434 (± 0.246)	Lower Platte River, Nebraska – river sandbars	Brown and Jorgensen (2008)	MARK

Table 15 continued.

Year	Chick Survival	Location	Source	Survival Method
2009	0.533 (± 0.149)	Lower Platte River, Nebraska – river sandbars	Brown and Jorgensen (2009)	MARK
2009	0.059 (± 0.099)	Lower Platte River, Nebraska – sand and gravel mines, housing developments	Brown and Jorgensen (2009)	MARK
2010	0.214 (± 0.337)	Lower Platte River, Nebraska – sand and gravel mines	Brown and Jorgensen 2010	MARK
2010	0.315 (± 0.303)	Lower Platte River, Nebraska – housing developments	Brown and Jorgensen 2010	MARK

Reasons for Decline and Impediments to Recovery

In this section, we summarize past, current, and anticipated threats that have caused or are expected to cause declines in the populations of these two species; such threats may be impediments to recovery. We list these threats in alphabetical order.

<u>Climate Change</u>

Climate change has the potential to negatively impact Least Terns and Piping Plovers, but the timing and severity of such impacts are not known. Climate modeling has predicted warmer temperatures, increased evaporation, and more drought-like conditions for the Midwest in 21st century. These changes will eventually lower water levels in lakes and rivers, rendering them more susceptible to algal growth and invasive plant species colonization (USGCRP 2000a). On plover and tern wintering grounds, modeling has forecasted an increase in sea level, coastal flooding, and erosion that will eliminate current shorelines (USGCRP 2000b) that the birds rely on annually.

Climate change has been associated with advanced arrival times in many migratory species. Problems arise when climatic conditions on the wintering grounds do not accurately predict those on the breeding grounds. Migratory birds that rely on such cues may arrive on breeding grounds under less than optimal conditions (Parry et al. 2007). This may be an issue for Least Terns, who migrate long distances between wintering and breeding grounds.

<u>Commercial Hunting, Egg-collecting, and Millinery Trade</u>

The practices of over-hunting and collecting eggs can decimate bird populations. Least Terns and Piping Plovers experienced significant mortality from over-hunting in the late 1800s and early 1900s (Bent 1929; USFWS 1988; Aron 2005). Least Terns, in particular, were severely impacted by the millinery trade, as their feathers were regarded as ideal ornamentation for women's hats (Stone 1937; National Audubon Society 2007). Unregulated hunting mainly occurred on the Atlantic Coast, where as many as 100,000 terns per season were killed in Virginia (Bent 1929). Bent (1927) also remarked that along the East Coast, "spring and autumn shooting…in the closing years of the nineteenth century, brought the bird nearly to the point of extinction." While some hunting may have taken place in Nebraska in the late 1800s and the early 1900s, we are unaware of any specific written accounts. Legislation, including the International Migratory Bird Treaty Act (1918) as amended, provided protection for native migratory bird species. Still, illegal hunting continues to occur on the birds' wintering grounds (Thompson et al. 1997).

<u>Contaminants</u>

There are numerous ways in which contaminants (i.e., point and non-point source pollutants) can negatively impact birds (Parnell et al. 1988). Ground-nesting birds, such as terns and plovers, are vulnerable to toxins in run-off from roads, households, farms, and industry. Such contaminants may negatively impact water quality, fish populations, and aquatic invertebrate communities, reducing resources available to terns and plovers potentially leading to lower productivity. There are four major groups of pollutants reported to affect birds: petroleum (oil), organo-chlorine compounds, organo-phosphorus pesticides, and metals (Parnell et al. 1988).

Petroleum exposure causes many problems for birds, including adult, egg and chick mortality, and reproductive failure (Ainley et al. 1981; Parnell et al. 1988). Birds exposed to petroleum preen their feathers in an attempt to remove it, which may cause them to ingest or inhale the oil, irritating the respiratory and digestive tracts and interfering with hormonal cycles and development (Cornell Lab of Ornithology 2010). Oiled feathers also lose their ability to retain body heat.

Oil contamination has received increased attention due to the BP-Deepwater Horizon oil spill on the United States Gulf coast in April 2010. At this time, the direct impacts of the oil spill on Least Terns and Piping Plovers are largely unknown. Least Terns nest along the Gulf coast, so individuals at all life stages are vulnerable to oil contamination. Piping Plovers winter along the Gulf coast and are thus vulnerable as well. Scientists are concerned about the direct effect of oiling to plovers as well as contamination of marine worms and other marine invertebrates on which the birds feed (Daley 2010). Limited evidence suggests that plovers can survive minimal oiling, but long-term effects remain understudied (Amirault-Langlais et al. 2007.) Even indirect effects, such as those associated with cleanup, can negatively affect terns and plovers. Along the Mississippi coast, cleanup crews have caused disturbance and habitat destruction in Least Tern colonies. Additionally, airboats repeatedly flushed terns from roosting sites (American Bird Conservancy 2010). The use of 'shoreseal' booms along beaches may also negatively impact tern colonies (American Bird Conservancy 2010). The long-term impacts of the oil spill are unknown but its effects will likely continue well into the future because the oil may persist for decades or even centuries (EVOSTC 2009). Indeed, the long-term impacts may ultimately exceed immediate losses, as was the case in the Exxon Valdez oil spill of 1989 (EVOSTC 2009). The oil spill's effects on fish eggs and larvae are also unknown, but scientists have determined that oil has persisted in the water column (Gillis and Robertson 2010) which could impact them. A recent government report indicated declining oxygen levels in the Gulf, which could also impact tern and plover forage species (Gillis and Robertson 2010). Lastly, chemical dispersants used to reduce the oil's impact may have long-term consequences for the Gulf ecosystem. At a more local scale, there remains a risk of diesel and fuel oil spills at mines near tern and plover nesting grounds.

Organo-chlorines and toxic metals will bioaccumulate in the tissues of piscivorous birds, such as Least Terns, which may cause death or infertility (Furness and Rainbow 1990). Chlordane and polychlorinated biphenyls (PCBs), although no longer produced, do not readily degrade and could be released from dredge material into rivers. Other endocrine-disrupting chemicals can concentrate in birds, making them sentinels for toxins in the environment. Elevated levels of mercury and selenium have been found in the Platte River valley, possibly affecting the reproductive success of terns in the area (NGPC 1997). Higher than normal selenium levels may be attributed to coal-fired power plants and irrigation return flows (NGPC 2008). Cattle feedlots also contribute selenium to waterways from run-off because the chemical is sometimes used as a feed additive (NGPC 2008). Overall, there has been little evidence to suggest a major decline in Piping Plover (Allan 1990) and Least Tern populations attributable to toxins (Welsh and Mayer 1993; Aron 2005). Nonetheless, contaminants require additional monitoring.

Herbicides are increasingly being used to inhibit natural vegetative succession on nesting grounds. Tern and plover recovery projects have proposed, and in some cases, already begun using herbicides such as imazapyr, norflurazon, Diuron 80, Sahara (mixture of imazapyr and diuron), triclopyr, Roundup and lime on sandy terrain; these chemicals have varying half-lives and some are not considered safe to use near surface and ground water (Aladesanwa and Akinbobola 2008; C. Lott, pers. comm.). The specifics of herbicide use protocol near plovers and terns are still being debated and the long-term effects of these chemicals on plovers and terns remain unknown.

Habitat Alteration

Broad-scale alterations of natural systems that traditionally provided breeding habitat for Least Terns and Piping Plovers are considered to be the most important factors in declines (USFWS 2009b). Across their ranges, encroachment of industry, housing, and other structures, as well as increasing numbers of humans recreating in tern and plover breeding habitat, have caused relocation or restriction of nesting site locations.

Habitat modification following European settlement has been significant. Much of this resulted from creation of reservoirs for flood control and irrigation and navigation structures on major rivers, leading to reduction of traditional sandbar breeding habitat (Ducey 1985; Lott 2006). Other significant habitat losses have occurred from river modifications including channelization, bank reinforcements, levees, water diversions, sediment reductions, and hydro-peaking. Along the Missouri River, sandbar habitat was reduced from 35,273 acres to only 57 acres during the period of 1890–1976 (NGPC 1997). Breeding birds using alkali lake shore and river habitat have been affected by changing water-table levels, mainly a result of agricultural practices (USDOI 2006). Habitat loss is compounded by additional threats that arise as a result of systemic alterations (e.g. exotic species invasions resulting from water diversion). In many cases, however, human intervention has provided unintended breeding habitat. Major examples are reservoir shorelines, especially in low-water years, such as at Lake McConaughy in Nebraska (Peyton and Wilson 2007), and exposed sandy areas associated with housing developments and sand and gravel mines (Brown et al. 2009). The possibility of significant shifts of the breeding population within the overall range as a result of habitat change has been noted (Lott 2006).

Prior to broad-scale systemic alterations, Nebraska's rivers had predictable, but variable, flow regimes with higher river discharge in the spring and lower levels through the summer and winter (USFWS 1988). Snowmelt and spring run-off largely determined seasonal high flows (USDOI 2006). High water flows and ice jamming are key in scouring vegetation to support bare sandbar habitat (Parham 2007). This natural cycle is important in recreating Least Tern and Piping Plover breeding habitat by transporting and depositing sediment.

Bank Stabilization and Island Armoring

Human-created river bank stabilization modifies natural river function (Florsheim et al. 2008) and reduces the width of river channels (Schmetterling et al. 2001). On the Lower Platte River, bank stabilization impairs or eliminates the erosional capabilities of the system (Williams 1978; Blodgett and Stanley 1980; Runge and Harms 2007). A recent study (Runge and Harms 2007) showed that 38.8% of the Lower Platte River's banks were stabilized. This was a larger proportion than the 25% reported in 1994 by the U.S. Army Corps of Engineers (USACE), the agency that authorizes bank stabilization projects, and larger than the 30% USACE (1994) predicted would be stabilized by 2020. At the present time, USACE does not have an up-to-date and accurate inventory of bank stabilization on the Lower Platte River (B. Latka, USACE, pers. comm.). Materials used for armoring (e.g. asphalt, concrete and discarded appliances and automobiles) have the potential to leach toxins into the water and alter soil or water chemistry (Elmendorf et al. 2001; D.C. Gosselin, pers. comm.).

Channelization

Channelization of river systems narrows and deepens the active channel, accelerates the river current, and decreases system heterogeneity. Narrowing and deepening of channels decreases the river system's ability to create sandbars. The Missouri River below Gavin's Point dam is an example of a large river that has been channelized. Levee construction and significant stream alterations have channelized 32% of the Missouri River (MREAP 1998), reducing its length by 127 miles (SC 2009). In the upstream portion of the Central Platte River, channel widths have decreased by 80–90% since the 1860s (USDOI 2006). Some channelization has also occurred along the Lower Platte River (Eschner et al. 1983; Chen et al. 1999). Reduced channel width has been associated with the establishment of native and invasive vegetation in the Platte River (McDonald and Sidle 1992). Channelization increases erosion in some areas, while bank-armoring decreases the amount of silt available for sandbar formation in other reaches (Biedenharn et al. 2001; Aron 2005). In the Platte River, water from low flows can accumulate in narrow channels rather than distribute broadly among sandbars (Kinzel et al. 2008).

Dams

Dams capture water and sediment, altering natural hydrologic and geomorphic regimes. One benefit of dams is that storage reservoirs control floods. However, reduction in the magnitude and frequency of flood or high flow events also affects creation and regeneration of macro-forms sandbars that are used as nesting sites by terns and plovers.

The state of Nebraska has 2,378 dams with heights of 6'–25' and storage capacities of at least 15–50 acre-feet (Figure 11; NDNR 2009). At least 73 of these dams have been constructed on the Platte River for uses such as storage, water diversion, navigation, hydropower, or flood control (NDNR 2009). The Loup and Elkhorn Rivers, both major tributaries of the Platte, have 29 dams each. The Lower Platte River still has characteristic braided channels (i.e., presence of islands) and shifting sandbars essential to terns and plovers (NRC 2005), making it a regionally important habitat. Nonetheless, 22 large reservoir storage dams managed by various groups are present on the Platte River basin, including the Loup River (Table 16), storing more than 6 million acre-feet of water (NRC 2005). Dams with relatively less storage capacity are present on the Elkhorn River, the other major tributary to the Platte River.

One consequence of dam and reservoir construction is the occurrence of irregular peak flows; these flows may occur during any given month of the year rather than only in the spring (USDOI 2006). On the Platte River, an estimated 1.5 foot exposed sandbar height is necessary for the duration of the 60-day nesting period of terns and plovers (Parham 2007). Habitat quality, highly dependent on river discharge, is limited (e.g. only two acceptable nesting periods in 10 years in the Platte River near Duncan, NE) and varies seasonally (Table 2) (Parham 2007). Suitable habitat, in terms of quantity and quality, has been markedly absent (< 2%), in the lower Platte River for several decades (Table 3) (Parham 2007). Such irregularity resulting from dam operation may preclude nesting in some areas.

Flows in the Platte River have been reduced by as much as 60-70% since the construction of dams and reservoirs (McDonald and Sidle1992**;** Parham 2007). Reservoirs trap much of the sediment that would normally pass downstream and contribute to sandbar development and refurbishment, resulting in increased riverbed degradation and channelization (USFWS 1988). Damming has caused excessive soil aggradation in sections of the Missouri River, leaving it unable to remove sediment deposited by the Niobrara River (Biedenharn et al. 2001).

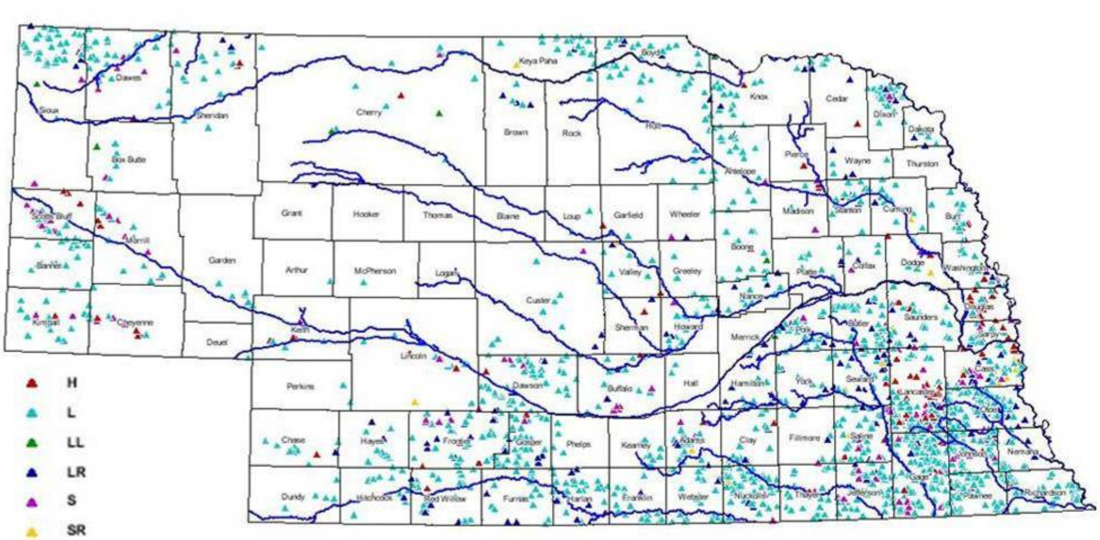

Figure 11. Distribution and density of dams in Nebraska (from NDNR 2009).

Table 16. Storage capacity, age, and ownership of large reservoir storage dams on the Platte (from NRC 2005) and Loup River basins (NDNR 2009; USBR 2009). Storage capacity is measured in acre-feet; 1 acre-foot = 325,851 gallons (an acre-foot of water covers 1 acre of land 1 foot deep).

Dam	River	Storage (acre-ft)	Year Completed	Owner
Eleven Mile Canyon	South Platte	128,000	1932	Denver Board of Water Commissioners
Prewitt	South Platte – off stream	51,387	1912	Logan Irrigation District
Cheesman	South Platte	87,227	1905	Denver Board of Water Commissioners
Antero	South Fork	115,000	1909	Denver Board of Water Commissioners
Empire	South Platte	52,280	1973	Bijou Irrigation Company
Jackson Lake	South Platte – tributary	47,000	1900	Jackson Lake Reservoir Company

Milton Lake	South Platte	39,660	1975	Farmers Reservoir and Irrigation Company
Julesberg #4	South Platte – tributary	38,600	1910	Julesberg Irrigation District
Spinney Mountain	South Platte	83,300	1982	City of Aurora
Chatfield	South Platte	355,000	1973	Corps of Engineers Northwestern Division Omaha District
Alcova	North Platte	184,300	1938	U.S. Bureau of Reclamation
Glendo	North Platte	1,118,653	1958	U.S. Bureau of Reclamation
Guernsey	North Platte	45,228	1927	U.S. Bureau of Reclamation
Pathfinder	North Platte	1,016,500	1909	U.S. Bureau of Reclamation
Seminoe	North Platte	1,017,279	1939	U.S. Bureau of Reclamation
Kingsley	North Platte	1,900,600	1941	Central Nebraska Public Power and Irrigation District
Sutherland	North and South Platte	65,000	1935	Nebraska Public Power District
Johnson Lake	Platte Canal	59,000	1941	Central Nebraska Public Power and Irrigation District
Riverside	Sanborn Draw	94,500	1904	Riverside Irrigation District
Virginia Smith	Calamus River	177, 623	1985	U.S. Bureau of Reclamation
Sherman	Oak Creek	125, 477	1962	U.S. Bureau of Reclamation
Davis Creek	Tributary to Davis Creek	46,179	198x	U.S. Bureau of Reclamation

Energy and Communication Infrastructure

Communication Towers

Communication towers, including structures for radio, television, and cell phone transmissions, have the potential to interfere with bird migration and breeding. In the United States, 5–50 million birds are killed annually after striking communication towers (ABC 2007). The U.S. Fish and Wildlife Service has established guidelines for communication tower installation, such as collocation, bird diverter devices, and specific lighting colors and patterns, in order to minimize bird strikes (Manville 2000). Birds often collide with the towers. Lights on these towers designed to alert oncoming aircraft attract and confuse birds migrating at night, particularly during conditions of low visibility. Because Piping Plovers may migrate during the night (National Audubon Society 2009), they may be vulnerable to tower mortality.

Electrical Transmission Lines

Collision with powerlines and power structures is a source of bird mortality (USFWS 2004). However, it is challenging to assess this threat due to the difficulty of obtaining bird strike data. Utilities have worked proactively with state and federal agencies to reduce bird mortalities caused by strikes and electrocutions by developing infrastructure standards (Avian Power Line Interaction Committee 1994). There are several transmission power lines crossing the Lower Platte River.

Hydropower

Hydropower is includes both damming of rivers and hydropower peaking. In a hydropower resource assessment prepared for the U.S. Department of Energy in 1997, 45 sites were identified in four of Nebraska's major river systems as having the potential for increased or new hydroelectric production (Rinehart et al. 1997). Currently 35 dams, including one on the Loup River and 12 on the Platte River and its tributaries, have been constructed in the state with the specific purpose of generating hydroelectric power (NDNR 2009). The development of hydrokinetic power facilities on wintering areas has the potential to negatively impact plovers and terns (M.B. Brown, pers. comm.).

Hydropower peaking

Hydropower peaking or hydro-peaking modifies the natural hydrograph and both decreases the amount of nesting habitat available to the birds and increases the probability of nest and colony inundation. Hydropower peaking concentrates power generation into certain times of the day, which results in rapid, large flow fluctuations in the reach below the generating facility. These flow fluctuations impact water depth (Figure 12). The effects of hydropower peaking on water levels are attenuated with increasing distance from the source.

Loup Public Power District (LPPD) operations on the Loup River and Canal produce daily flow fluctuations on the Lower Plate River, as a result of release from hydropower electrical generation (Figure 12). Hydropower peaking returns water to the Platte River at the LPPD tailrace canal (River Mile 102), near Columbus, Platte County.
Hydropeaking during the breeding season decreases available habitat and increases the probability that sandbars with nests and chicks will be inundated (Brown and Jorgensen 2008). High hydropeaking water levels occurring during May–June are particularly problematic for birds. In 2008, hydropower operations on the Missouri River inundated/drowned 252 eggs and young (USACE, unpubl. data). Hydro-peaking can also facilitate transport of invasive plant seeds (Verhoeff 2008), which establish on sandbars.

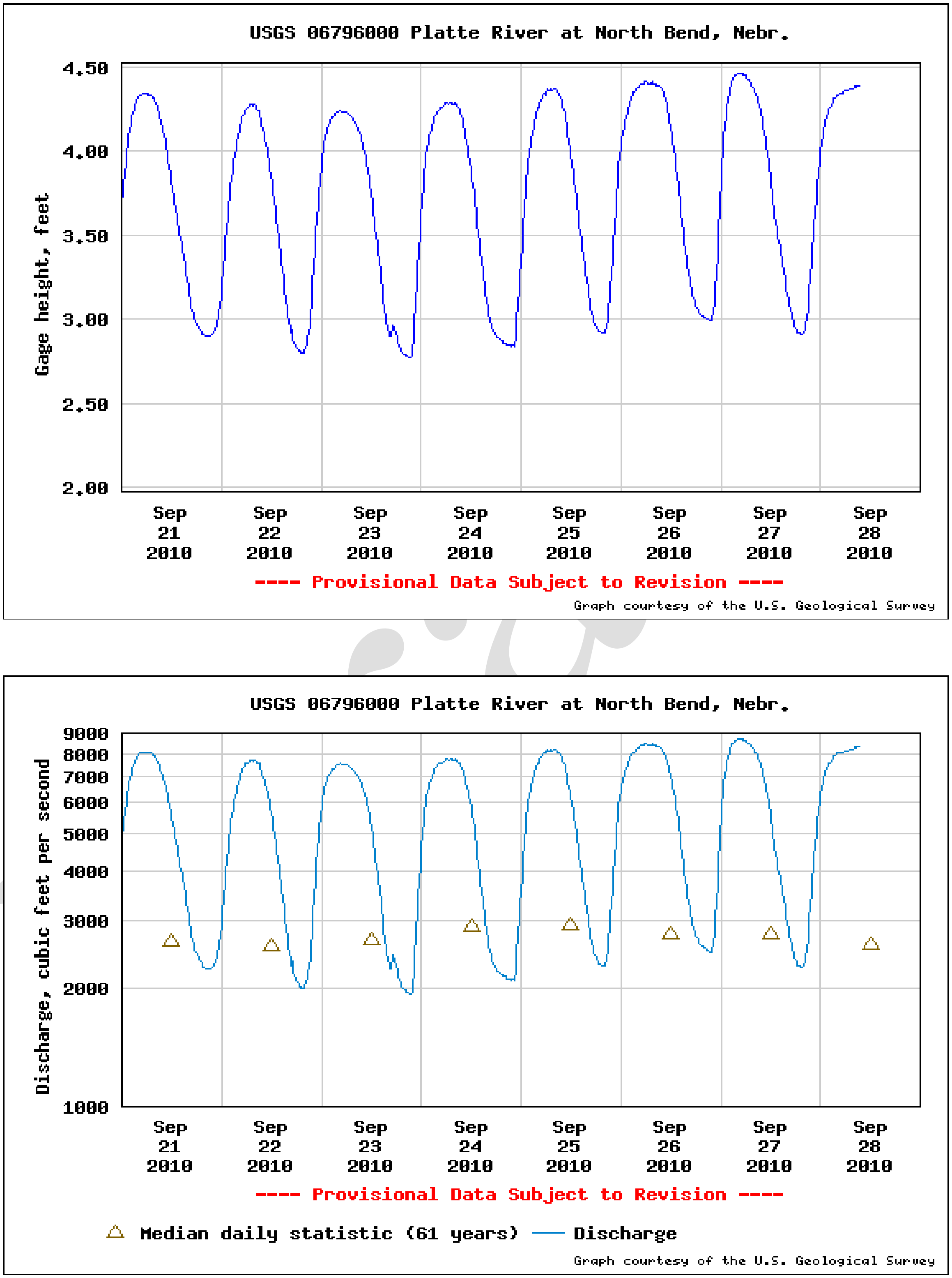

Figure 12. Daily elevation (top, in ft) and discharge (bottom, cubic feet per second (cfs) fluctuation of the North Bend gage station.

Oil and Gas Development

Oil and gas development is a concern in the northern Great Plains portion of the Piping Plover breeding range. Direct and indirect impacts from oil drilling and oil spills on the wintering range are also a concern (e.g., the April 2010 BP-Deepwater Horizon oil spill). Spills on the wintering grounds may cause acute mortality or may negatively affect habitat and food resources.

Power Plants

Least Terns have nested successfully at power plants, utilizing ash disposal areas (NGPC 1997). One such example is an interior colony at Cinergy Corporation's Gibson County Generating Station located in Indiana (Pruitt 2000).

Wind Power

Increased attention is being directed toward wind power generation on the Great Plains. Nebraska ranks 6th in the country for its wind energy potential, with the ability to generate average power of 99,100 megawatts (MW) or 868 billion kilowatt hours annually (B KWH) (American Wind Energy Association 2005). There are plans to develop as much as 7,800 MW of wind energy in Nebraska by 2030 (101st Legislature Legislative Resolution 83). On the Atlantic coast, four wind power facilities have already been constructed in areas used by Piping Plovers for migration and breeding (USFWS 2009a). Eleven additional projects in this region were under review as of 2009 (USFWS 2009a).

Wind turbines are a source of direct mortality to birds due to collisions. At the Altamont Pass wind resource area in Livermore, CA, one of the first wind farms in the country, poor design and placement of the turbines causes as many as 4,700 bird strikes each year (Bogo 2007). Research shows that habitat avoidance by birds is common at wind power facilities (Winkelman 1990; Pederson and Poulsen 1991). The potential impacts of wind farms on Least Terns and Piping Plovers are unknown but could be significant (USFWS 2009a). Local movements, migratory routes, and flight altitudes of these species are not known, making assessment of potential impacts difficult at this time (USFWS 2009a). The magnitude of impacts may be influenced by the size, number, and spatial configuration of wind turbines, as well as weather patterns and the spatial distribution of nesting and foraging habitat (USFWS 2009a).

Water Diversion

In Nebraska, irrigation for agriculture (farming and livestock production) accounts for most water usage (Figure 13). Most cities along the Platte River obtain their water from wells maintained by river flows (USDOI 2006). Surface water consumptive irrigation accounts for 1,640 kaf in the Platte River Basin (USDOI 2006). Appropriations are granted for flow, storage, wells within 50 feet of a stream, and for pumping from a lake.

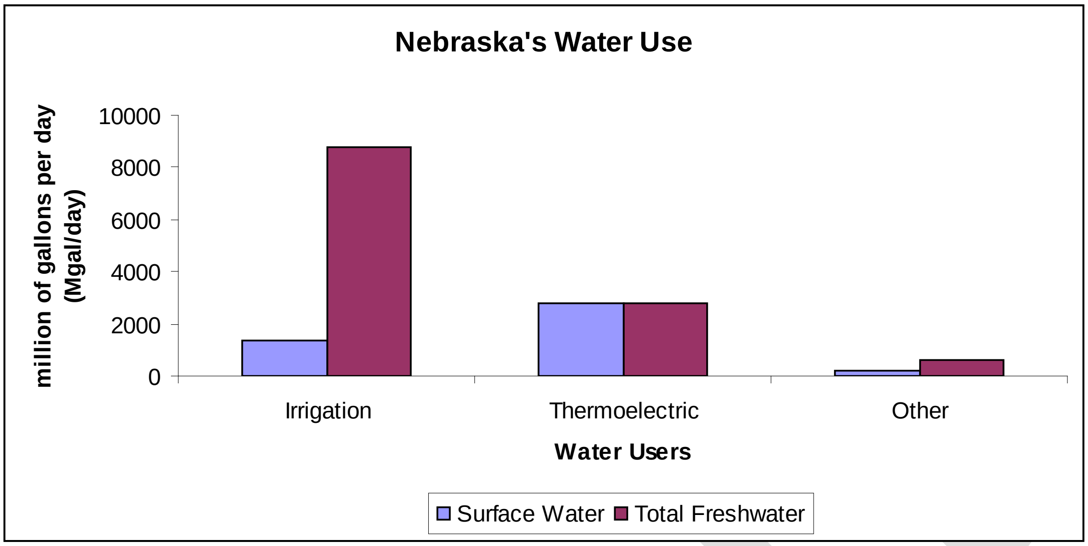

Figure 13. Surface water and total freshwater use in Nebraska. In 2000, 12,200 million gallons per day were consumed. Water users categorized as "Other" include: public, domestic, livestock, industrial, and mining for a combined surface water use of 4.7% and total freshwater use of 5.2% (Hutson et al. 2000).

Human Recreation

Piping Plovers and Least Terns encounter many disturbances related to human recreation. The birds' natural behaviors and cryptic eggs and chicks render them very vulnerable to human recreational dangers. Least Tern young are susceptible to mortality from all-terrain vehicles because of their tendency to remain immobile when threatened, relying on their instincts to camouflage themselves from predators (Wilcox 1959; Goldin 1993; Melvin et al. 1994; USFWS 1994). Piping Plover chicks run from danger, but do not have the ability to effectively escape fast-moving vehicles. Other recreational vehicles such as airboats have destroyed eggs and young (Thompson et al. 1997). Birds may also become entangled in fishing line or injured by lures and hooks (National Audubon Society 2007). Given this array of threats, many nests and chicks are lost during holidays or other times of increased human activity (Thompson et al. 1997).

Other disturbances have less obvious consequences, but also negatively impact tern and plover survival and productivity. Pedestrians and human activities often conflict with the birds' breeding behaviors (Brown and Jorgensen 2008). Recreational vehicles can reduce the birds' success, as Least Terns and Piping Plovers often abandon nests when overly disturbed (Blodget 1978). Tern and plover chicks may find it difficult to climb out of tire ruts (Strauss 1990). Discarded fishing bait draws in competitors such as gulls (National Audubon Society 2007), and litter accumulation on shorelines attracts predators (e.g. raccoons and skunks) on nesting grounds (USFWS 1985).

At Lake McConaughy near Ogallala, Keith County, the Central Nebraska Public Power and Irrigation District (CNPPID) found that least 9% (*N*=52) of Piping Plover nest losses resulted from human activities. This area supported the second-largest number of Piping Plovers (*N*=388, 50% of the Nebraska population, and 13% of the U.S. population) in 2006, making it a significant site for the birds (Jorgensen 2008).

Limited Food Resources

Adequate food resources are essential to any animal's survival and reproduction. Although terns and plovers nest side-by-side, their foraging ecology differs. Least Terns eat small fish, while Piping Plovers feed on invertebrates gleaned from or immediately below the substrate.

Piscivorous birds such as terns and gulls are sensitive to fluctuations in abundances and densities of forage fish (Tibbs 1995). Least Terns require an actively-reproducing fishery that offers varied sizes to feed adults and young in all life stages. Least Tern foraging opportunities are improved when shallow waters offer the greatest small fish densities and taxa richness (Tibbs 1995). Recently-fledged terns that are capable of flying to other areas in search of forage, may not be as vulnerable to a shortage of fish near nesting sites (Hill 1993; Aron 2005). Least Terns may fly up to two miles from nesting grounds to forage (NGPC 1997). Fluctuating water discharges from dams can influence fish spawning habits in stream systems, reducing foraging opportunities for Least Terns (Lingle 1993a; Aron 2005). Management activities that significantly alter these shallow-water habitats impede tern foraging.

Piping Plovers feed on macroinvertebrates such as fly larvae, beetles, and worms living within 1 cm underground (Cairns 1977; Whyte 1985; USFWS 1988). Adult plovers forage within 5 m of the water's edge, while the young use feeding grounds either close to the water or further from the shore (Whyte 1985; USFWS 1988). Moist sand is necessary for maintaining the invertebrate population; forage can be reduced for Piping Plovers when daily dam discharges cause water levels to fluctuate and alter stream chemistry and temperatures (Weisberg et al. 1990; Aron 2005). The U.S. Fish and Wildlife Service stressed the need to provide tern and plover foraging habitat, recognizing that human-created emergent sandbars on the Missouri River are usually associated with deep channels inadequate for suitable foraging conditions (USFWS 2003b), particularly when the birds prefer to forage in the wet sand of the shoreline (Matteson 1980; Wiens 1986; USFWS 1988).

Forage availability can vary substantially in different habitat types used by terns and plovers. Successful foraging and availability of prey is higher at riverine nesting sites than at sandpit sites for both species (Corn and Armbruster 1993; Lingle 1993a; Sidle 1993; Wilson et al. 1993; NRC 2005), so birds nesting at sandpit sites often return to the river to feed.

Mine Conversion and Construction Developments

Aggregate (sand and gravel) mining along the Lower Platte produces resources valued at $160 million annually (U.S. Bureau of Mines 1992; Verhoeff 2008). Piping Plovers and Least Terns frequently nest on sand piles created by commercial sand and gravel mining operations. Indeed, in recent years a majority of both species have nested at off-river sand and gravel mines. When river sandbar sites are unavailable during peak flows or otherwise not suitable for breeding purposes, plovers and terns will initiate nests on the alternative habitat of exposed sand and spoil piles (USFWS 1988, 1990); these sites have supplemented the populations (NGPC 1997). Unfortunately, such nesting grounds only exist temporarily as these areas typically become vegetated or are turned into lakeshore housing developments once mining operations cease. Many of these properties have septic tanks which have the potential to negatively affect water quality (Verhoeff 2008). Construction-related activities and increased predation can create problems for terns and plovers nesting at off-river sites (Brown and Jorgensen 2008).

Construction developments on wintering grounds may impact Piping Plovers and Least Terns as well. The birds are vulnerable to habitat loss on their breeding grounds, but habitat availability during migration and winter is also important to plover and tern recovery. Wintering habitat along the Gulf coast and along the Central American coast and northern coast of South America may continue to shrink or be completely lost in some areas because of industrial and urban expansion.

<u>Vegetation Encroachment</u>

Least Tern and Piping Plover nesting habitat is maintained by periodic disturbance. Vegetative succession is a natural process in which plants colonize suitable patches (Cowles 1898; Clements 1916). In the absence of disturbance, succession proceeds unabated. Increasing amounts of vegetation on sandy substrates reduce the amount of breeding habitat available to Least Terns and Piping Plovers. Damming and channelization change stream geomorphology and ultimately affect vegetation density and composition. Russian olive (*Elaeagnus angustifolia*) and native Red cedar (*Juniperus virginiana*) became more numerous after the settlement of the Platte River (Currier 1982; Johnson and Boettcher 2000; NRC 2005). Flow alterations exposed more streambeds, allowing cottonwood (*Populus deltoides*) and willow (*Salix* spp.) to establish and expand until the late 1960s (Currier 1982; Johnson 1994, NRC 2005). The development of dense woodlands with significant understory growth is a major factor in reduced habitat quality for shorebirds in the Platte River (NRC 2005). Noxious weeds such as Salt cedar (*Tamarix* spp.), Leafy spurge (*Euphorbia esula*), Absinth wormwood (*Artemisia absinthium*), and Canada thistle (*Cirsium arvense*) reduce habitat quality for plovers and terns (USACE 2007). Establishment of invasive *Phragmites australis*, Purple loosestrife (*Lythrum salicaria*), and brome grasses (*Bromus* spp.) has also been problematic.

Nest site quality for Piping Plovers and Least Terns is diminished at 5–20% vegetative cover (Ducey 1983; Faanes 1983; Schwalbach 1988; NRC 2005). Typically, Least Terns select nesting sites with as little as 0–1.2% vegetative ground cover (Schweitzer and Leslie 1999). Piping Plovers appear to be relatively tolerant of short forbs at nesting areas (Root 1996; Root and Ryan 2004) because of their need to maximize visibility and avoid predators (Haig 1992). However, sparse vegetation can provide some protection from predators (Environment Canada 2006).

<u>Weather Events</u>

Precipitation cycles and weather patterns directly influence habitat features (NRC 2005) for shorebirds. Drought can lower water levels, exposing sandbar nesting habitat, but possibly dewatering foraging locations. Heavy precipitation could lead to high water levels, inundating nests. Hail, strong winds, thunderstorms and even tornadoes regularly destroy nests and kill adults and chicks (Czaplewski et al. 2005; Brown and Jorgensen 2008). At Lake McConaughy, weather caused 18% of all Piping Plover nest failures from 1992–2008 (Jorgensen 2008).

BRIEF OVERVIEW OF CURRENT MANAGEMENT

Nebraska Game and Parks Commission Statutory Obligations

The Commission is the state agency responsible for administering the Nebraska Nongame and Endangered Species Conservation Act (NESCA; §37-801-811).

NGPC/TPCP current non-statutory activities on the Lower Platte River

The Tern and Plover Conservation Partnership (TPCP), based at the University of Nebraska-School of Natural Resources and the Nongame Bird Program (NBP), based at the Nebraska Game and Parks Commission (NGPC) work cooperatively on Interior Least Tern and Piping Plover monitoring, research, management, and education-outreach activities on the Lower Platte River. The joint program includes terns and plovers nesting at on-river habitats (midstream river sandbars) and off-river or human-created habitats (sand and gravel mines and lakeshore housing developments). The TPCP leads efforts at off-river habitats; the NBP leads efforts at on-river habitats.

The TPCP only implements management actions at off-river sites (sand and gravel mines and lakeshore housing developments). Before the birds return to the area and initiate nesting, TPCP personnel meet with the production managers of all sand and gravel mines and the homeowners' associations of all lakeshore housing developments. At these meetings we discuss production and construction plans for the season, safety concerns and access to the sites. We adhere strictly to the policies and regulations of the Mine Safety and Health Administration (MSHA) when on sand and gravel mine property. The results of these meetings are site-specific management and monitoring plans. These meetings also allow us to become better acquainted with the people living and working at these sites. This makes it easier for us to implement our plans and to modify them as necessary as the season progresses.

In order to protect tern and plover nests, we put up "Keep Out" signs around the perimeter of the nesting areas. The TPCP designed these signs in 2008. In areas where a substantial amount of human traffic, either on foot or in vehicles, is expected we put up 'psychological fencing'. This consists of black or orange cord tied between all of the 'Keep Out' signs. In order to make the cord more visible, we attach 8–10 inch long Mylar streamers to it.

Based on our site-specific management and monitoring plans, we map out areas that would be unsafe for the birds to nest in. For example, these are areas where the mines plan to pump slurry water or where home or road construction is expected. We know that terns and plovers will not nest in areas where the substrate is disturbed by raking, where there is any surface vegetation, where the substrate particle size is 'wrong' or where there is any physical disturbance (see Marcus et al. 2007 for details). Planting vegetation, resurfacing or raking the substrate is labor intensive so the physical disturbance method of preventing the birds from nesting in an area is usually the most practical to implement. In these areas we put up grids of three foot tall fiberglass poles with 16 foot long streamers of red-silver Mylar material attached to them. The poles are set up 16 feet apart. When the Mylar streamers blow in the wind they make a crackling sound and sweep the ground which discourages the birds from nesting in the area.

We place exclosures around most, but not all plover nests. At some sand and gravel mines it is not safe for us to walk out on the sand where the birds' nests are located, so we are not able to place exclosures around those nests. We do not place exclosures around tern nests as they will not accept any structures around their nests. These exclosures are 3 foot square by 3 foot tall cages made of 2 inch by 4 inch wire mesh panels and held in place by a piece of rebar at each corner. The tops are left open, with the mesh cut so wire prongs stick up, making it impossible for a predatory bird to perch on them. The mesh openings are large enough for an adult plover to step through, but small enough that most predators cannot step through. The bottom of the exclosure is buried approximately 6 inches in the sand to discourage predators from digging under the exclosure.

A substantial part of the TPCP's efforts to protect Interior Least Terns and Piping Plovers involves outreach and education. The TPCP is an important entity in Nebraska's conservation and environmental education community. TPCP personnel frequently give presentations, assist with symposia, workshops and festivals, participate in workgroups, and serve on committees. While the majority of our outreach efforts are focused on terns and plovers in Nebraska's Lower Platte River, we appreciate that we have broader a role in improving environmental literacy locally, regionally, and nationally. We take advantage of every opportunity to reach as many different constituencies as possible.

<u>Monitoring and Research</u>

At the present time, the NBP and TPCP are engaged in a multi-year cooperative research initiative. Monitoring of Interior Least Terns and Piping Plovers on the Lower Platte River by NGPC commenced in the mid-1980s and has continued since then. Monitoring has been limited in some years, usually because river conditions limited nesting or limited river access. Yearly summaries of the current research initiative are summarized in Brown and Jorgensen (2008, 2009, and 2010).

Nest Monitoring

Beginning in mid-April, TPCP personnel begin visiting all sand and gravel mines and lakeshore housing developments in the Lower Platte River; each site is visited every 4–5 days. When birds are observed at a site, the area is thoroughly searched for nests or evidence of nest scrapes; most nests are located by observing adult birds sitting on nests or nest scrapes. The location of every nest is recorded using a handheld GPS unit and each nest is assigned a unique number. The eggs in each nest are floated to determine when they were laid (Hays and LeCroy 1972); most nests are located from 1–6 days after the first egg was laid. Using this egg data, the expected hatching date of the eggs is calculated, assuming a 28-day incubation period for plovers and a 21-day incubation period for terns.

All nests at off-river sites are visited periodically during the incubation period, the nests are not disturbed during these visits. At some sites, particularly sand and gravel mines, terns and plovers place their nests in areas that are not accessible for safety reasons. In these cases, the number of nests, adults, juveniles, fledglings, and chicks that are visible from a safe distance are recorded. On each visit to a site, the total number of active nests and the total number of terns and plovers of each age class are recorded. The age classes used are:

- <u>Adults</u>: birds of both sexes in full adult plumage
- <u>Chicks</u>: 1–3 days, 4–10 days, 11–15 days
- <u>Juveniles</u>: chicks older than 15 days, but still dependent on their parents
- <u>Fledglings</u>: chicks capable of sustained flight and independent of their parents

The final status of each nest is scored based on the following criteria:

> Confirmed successful: 'pipped' eggs or newly-hatched chick(s) observed in or in the immediate vicinity (< 1 meter) of the nest cup
> Likely successful: empty but intact nest cup found with or without pieces of eggshell on or after the expected hatch date
> Confirmed failure: nest cup and/or eggs found destroyed
> Likely lost: nest not relocated on repeat visits prior to expected hatch date

If any birds, adults or chicks, with colored leg bands are observed, the color band combination is recorded. Any miscellaneous observations, including evidence of disturbance, vehicle tracks, weather conditions or injuries are also recorded.

A different approach is taken to monitoring the terns and plovers nesting on midstream river sandbars. Early in the nesting season, rather than surveying the river for birds and nests, river conditions are monitored (i.e., flows and depth at USGS gaging stations and bridges) for the presence of sandbar habitat. Once the river flow and depth decreases and sandbars are exposed, the river is surveyed by canoe and kayak for the presence of terns and plovers. Canoes and kayaks move slowly (< 10 kph) and quietly on the river which limits the amount of disturbance caused to nesting terns and plovers. The presence of birds foraging in the river indicates that birds might be nesting on a nearby sandbar. Nesting sandbars are identified by the vocal, aggressive behavior of adult terns. When a colony is located, the sandbar is thoroughly searched for nests. When located, nests on sandbars are treated in the same way as nests at off-river sites.

Estimating Survival Rates

Accurately estimating demographic parameters, such as daily and seasonal survival probabilities for individual birds and nests, provides a better understand the population dynamics of Interior Least Tern and Piping Plover on local and regional scales. We estimate nest, adult, and chick survival using capture-mark-recapture and statistical modeling techniques (Program MARK).

Banding is authorized by the USGS Banding Laboratory and the U.S. Fish and Wildlife Service through an intra-agencies agreement with the Nebraska Game and Parks Commission (MBB holds Federal Master Bird Bander Permit # 23545, with Threatened and Endangered Species endorsements and Nebraska Educational and Scientific Permit # 905; the TPCP holds Federal Threatened and Endangered Species handling permit #TE 070027-1; JGJ holds Federal Master Bird Bander Permit #20259, with Threatened and Endangered Species endorsements). All capture and banding protocols were developed to minimize disturbance to nesting birds. Personnel exercise caution when handling birds and do not capture or band birds during extreme weather (cold, windy, rainy, or when inclement weather was forecast) or when the temperature was above 85° F (30° C). Birds are observed after banding and on subsequent days to determine if there are any behavioral changes or visible signs of injury. We have not observed any problems or injuries to birds as a result of monitoring, capture, handling, or banding.

Adult Piping Plovers are captured, banded, and color banded during incubation. Color-band combinations are coordinated with the Piping Plover species coordinator, Greg Pavelka

(USACE) and others with an interest in plover color banding. Out of concern for the birds' safety, a simple box trap placed over the nest for capture. Box traps have no moving parts, so nesting birds and their eggs are not injured during capture; the bird walks through the door, settles on its nest, and is captured.

Figure 14. Wire box trap placed over a Piping Plover nest showing the bird approaching the trap (A), entering through the open "door" (B), and settling on the nest (C). Time elapsed is less than one minute.

Each plover receives an individually numbered USGS size 1A band on an upper leg. On the opposite upper leg, each bird receives a light blue plastic flag; the light blue color indicates that the bird was banded along the Platte River. The Lower Platte River blue flags are 'half length' and not crimped when placed on the bird's leg. On one lower leg, each bird receives a unique combination of two different color bands (black, gray, green, red or yellow) indicating its individual identity. On the opposite lower leg, each bird receives two color bands, the color combinations indicate where the bird was banded.

After banding, the mass of each plover is measured by placing the bird in a cloth bag and suspending it from a Pesola™ scale (± 0.3% accuracy). The following morphological measurements are taken of every adult plover: length of the left and right flattened wing chord (wrist to the distal end of the outermost primary feather), length of the left, right, and middle tail feather, length of the left and right tarsus (unfeathered leg above the hallux), length of the exposed midline ridge of the beak, width of the beak at the nostrils, and total skull length (distal end of the beak to the posterior end of the skull. All measurements are taken by one individual (MBB) to minimize measurement error. Each morphological measurement is taken twice so a "repeatability index" can be calculated. A composite metric of these measurements is calculated (the geometric mean) to provide an index of each individual bird's overall size. The left and right side of each bird is measured so a measure of bilateral symmetry can be calculated. Symmetry is a commonly used measure of an individual bird's "quality". The symmetry of skeletal parts reflects the nutrition and health of an individual during development. The symmetry of structures, such as feathers, that are grown or replaced regularly reflects the current nutrition and health of the individual. Measurements of symmetry provide a metric to access the "quality" of birds hatched at different types of nesting sites, on-river versus off-river and in different years. This metric also provides a way to assess the quality of the over wintering habitat for the birds; better foraging habitat would provide better over wintering survival, nutrition and health for nesting birds.

Piping Plover chicks are captured by picking them up off of the sand or from their nests. Plover chicks' legs are long enough that they can be banded and color banded them using the same protocol as used with adult plovers. Body mass is measured by placing chicks on a digital scale (Ohaus® SP401) which is accurate to ± 0.1 gram. Scales are calibrated using a standardized weight before and after chicks were weighed to ensure accuracy. Morphological measurements of plover chicks are not taken.

Interior Least Tern chicks are captured by picking them up off of the sand or from their nests. Tern chick's legs are very short they receive an individually numbered USGS size 1A band on one leg and a single color band on the other leg. Morphological measurements of tern chicks are not taken.

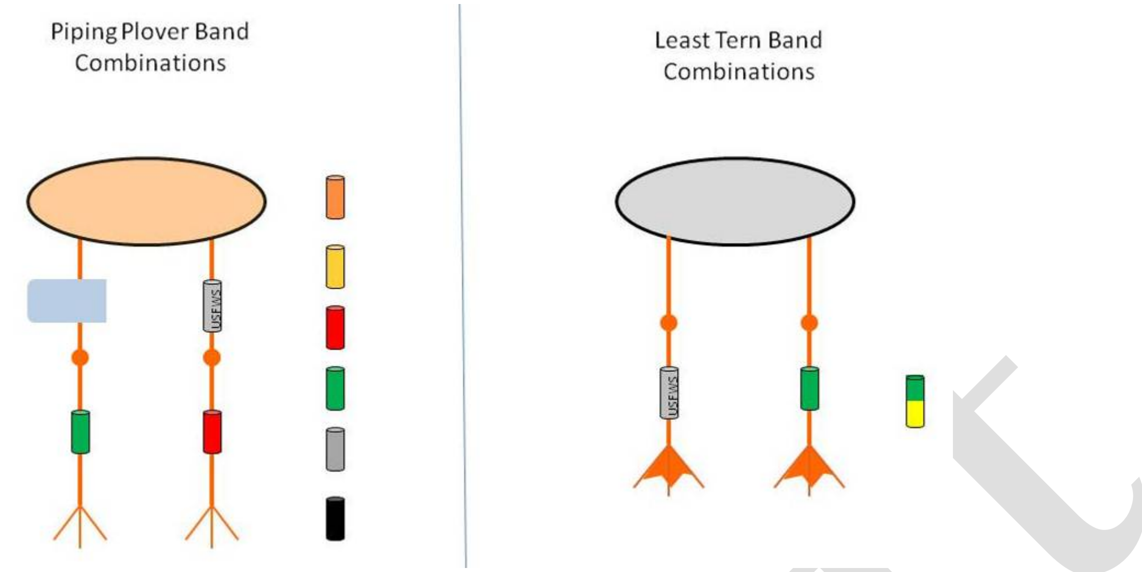

Figure 15. Schematic diagram illustrating the color banding scheme used with Piping Plovers and Interior Least Terns on the lower Platte River. The flags, metal bands and colored bands may be placed on either the bird's right or left legs.

Survival analyses

After individual Piping Plovers adults and chicks and Interior Least Terns chicks are banded and color marked, they are resighted as frequently as possible. Upon re-sighting where they were seen, which birds they were seen with, and what they were doing is noted. This capture-mark-recapture dataset is used to calculate daily and seasonal individual survival probabilities. Information from nest monitoring is used to calculate daily and seasonal nest survival probabilities.

Survival probabilities with the software program MARK (White and Burnham 1999) using the general methods of J.-D. Lebreton et al. (1992)**,** Burnham and Anderson (2002), and Dinsmore and Dinsmore (2007). Model fit for each analysis is assessed by the AIC (Akaike's Information Criterion); the model with the lowest AIC is considered the model that best fits the data. Generally, the model that includes constant survival and constant recapture probabilities {phi(c), p(c)}, is the best-fitting model; this is most likely due to small sample sizes.

Growth Curve Analysis

Growth curve analyses include Interior Least Tern and Piping Plover chicks from nests at on- and off-river sites. All tern and plover chicks are weighed when first encountered; they are reweighed every time they are subsequently encountered.

Sand Sampling

Sand substrate samples are collected from tern and plover nests to help describe their physical nest site requirements. The samples include one 6-inch long, 2-inch wide core taken through the nest cup and four 4-inch diameter, 1-inch deep core taken around the nest cup (oriented N, S, E, and W). The cores are analyzed by sifting the material through a series of sieves to sort the material by particle size; the material is then weighed. All sampling is done after the eggs have hatched and the chicks moved away from the areas.

Fledging Success

The index of nesting success for terns and plovers that is reported, and used for comparison between sites, is 'fledge ratio'. Fledge ratio is calculated as the number of fledglings per adult pair or nest over a defined spatial or temporal area; we calculate this as the number of fledglings per nest. The number of fledglings used in the calculation is based on numbers of birds directly observed.

POPULATION RECOVERY GOALS FOR THE LOWER PLATTE RIVER

The 1990 Interior Least Tern Recovery Plan set a population goal of 1520 adults, to be maintained for ten years, for Nebraska, with 750 of these birds in the Platte River. The 1988 Northern Great Plains Piping Plover Recovery Plan set a population goal of 140 Piping Plover pairs, to be maintained for 15 years, for the Platte River. Specific recovery objectives for the Central Platte River were subsequently developed (300 terns and 126 plovers; Lutey 2002). By subtracting the goal number of birds for the Central Platte River from the total Platte River recovery goals, specific population recovery objectives were identified for the Lower Platte River. These population recovery goals are:

Piping Plover – 77 breeding pairs
Interior Least Tern – 450 individuals

Recovery goals refer to sustained or sustainable population levels; recovery goals are to be sustained 10 years for terns and 15 years for plovers.

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Appendix A. Recommended future recovery actions as listed in the Piping Plover 5-Year Review (abridged version, from USFWS 2009)

Recommendations for Wintering and Migration Range

1. Develop a comprehensive conservation plan for piping plovers in the U.S. portion of their migration and wintering range.

2. Develop, in coordination with land managers, management plans for critical habitat sites or other sites that support or could support nonbreeding piping plovers.

3. Improve consistency in the approach used, and recommendations generated for, piping plover conservation in ESA section 7 consultations and Coastal Barrier Resources Act review across all USFWS field offices throughout the species' U.S. coastal migration and wintering range.

4. Develop a website specifically for wintering and migrating piping plover issues.

5. Focus the non-breeding portion of the International Census on enhancing understanding of piping plover abundance, distribution, and threat levels in seasonally emergent habitat (seagrass beds, oyster reefs, and mud flats) in Texas bays, and in Mexico and the Caribbean.

6. To further enhance understanding of spatial partitioning of the breeding populations (as well as the impacts of some threats) on the migration/winter grounds, USFWS should facilitate and encourage all efforts dedicated to (or incorporating) monitoring of color-banded piping plovers.

7. Further investigate the partitioning of survival within the annual cycle, and determine whether winter habitat quality influences reproductive success and survival. Explore opportunities for further comparison of survival rates among breeding populations to inform these issues.

8. Continue to refine characterization of optimal winter habitat and understanding of factors affecting piping plover use of different microhabitats (e.g., ocean intertidal zones, wrack, inlet shoreline, soundside flats). Research approaches should recognize that piping plovers may move among relatively nearby habitat patches. Plover habitat use patterns and needs may also vary geographically (across their nonbreeding range) and seasonally.

9. Develop strategies to reduce threats from accelerating sea-level rise.

10. Determine the extent that human and pet disturbance limits piping plover abundance and behavioral patterns in the wintering and migration habitats.

11. Determine the effect of human and pet disturbance on survival and reproductive fitness.

12. Support research to ascertain impacts of predation on wintering/migrating piping plovers, as well as to determine the effectiveness of predator control programs.

Recommendations for Great Lakes Population Breeding Range

1. Identify and secure reliable funding for various recovery program partners aimed at continued coordination and management of threats from human disturbance and predation, as described in recovery plan tasks.

2. Continue to build partnerships and increase participation of non-governmental groups and volunteers in conservation efforts.

3. Closely monitor the population for disease outbreaks and prepare response plans to address disease outbreaks, with emphasis on Type E botulism.

4. Pursue development of agreements needed to assure long-term protection and management to maintain population targets and productivity. Prototype agreements should be pursued at sites where there is a history of intensive and successful piping plover protection and a high degree of commitment to the piping plover protection program.

5. Continue efforts to purchase habitat and increase protection through conservation easements, deed restrictions, and other mechanisms.

6. Conduct further research on the genetic fitness and adequate effective size of the population through molecular genetic and pedigree analysis.

7. Update and refine population viability models to assess and potentially modify recovery goals for the population.

8. Develop strategies to reduce threats from the potential for water level decreases in the Great Lakes associated with climate change. Identify sites most likely to maintain (or increase) characteristics of suitable piping plover breeding and/or migration habitat.

9. Undertake studies addressing merlin foraging ecology and the relationship between merlins and piping plovers breeding areas in the Great Lakes.

10. Conduct studies to understand potential effects of wind turbine generators that may be located or proposed for the Great Lakes, nearshore, and within or between nesting or foraging habitats. Information needs include migration routes and altitude, flight patterns associated with breeding adults and post-fledged young of the year foraging at nearby sites that are not contiguous with nesting habitats, and avoidance rates under varying weather conditions.

Recommendations for Northern Great Plains Population Breeding Range

1. A draft and final revised recovery plan (or, alternatively, an interim conservation strategy) for the Northern Great Plains piping plover population should be developed.

2. Continue to construct habitat on the Missouri River system while exploring ways that flows could be altered to provide additional habitat for piping plover nesting and brood rearing.
3. Actively explore ways that the Missouri River reservoirs and shorelines can be

manipulated to provide breeding habitat under a variety of water conditions.

4. Ensure habitat availability. Identify how much habitat is needed over time on river systems to provide for a secure Northern Great Plains piping plover population. The Missouri and Platte rivers in particular are highly altered systems, leading to flooding of breeding habitat and suppressed reproduction. To date, sandbar creation efforts on the Missouri River have not kept pace with habitat loss.

5. Continue to perform monitoring and recovery actions annually throughout the U.S. Northern Great Plains population.

6. Identify and secure consistent funding for management, monitoring, and recovery efforts for the U.S. alkali lakes population.

7. Public outreach:
    a. increase public outreach and education in areas where there is the potential for human/plover interactions.

    b. Increase law enforcement activities in areas where human disturbance may be impacting reproductive success.

8. Habitat protection:
    a. Continue to work with landowners on the alkali lakes to ensure protection of piping plover alkali lakes and surrounding uplands. Where possible, obtain longterm agreements with landowners to protect these habitats. Increase efforts to remove trees, rockpiles, etc., that may harbor predators.

    b. On the river systems, obtain easements or fee-title on undeveloped land to reduce current and future pressure from human activities on nearby piping plover habitat. Keep as much of the river bank as possible from being stabilized, since this increases flow velocity and thus sandbar erosion rates and encourages development.

    c. Restrict public use of sandbar and shoreline areas as needed to provide for piping plover nesting and brood-rearing needs.

9. Explore the movement of birds within the Northern Great Plains. A study of large-scale piping plover movements over time would help to identify where to focus management actions to ensure that there is habitat available in areas where birds may go if habitat in one area is not suitable in a given year.

10. Predation control efforts are ongoing on the Missouri River system and the U.S. alkali lakes. However, predation control may not always have the intended effect. For example, caging nests may increase adult mortality if predators learn to key in on cages. Research is needed to determine if predation control is actually improving reproductive success in all areas where it is taking place.

11. The International Census is an extremely useful tool in the Northern Great Plains. Therefore, we recommend continuing the International Census for this population. It may also be worth exploring additional sampling techniques between International Censuses to better track piping plover population trends on the Northern Great Plains. A well-designed sampling approach in which a subset of sites is surveyed more frequently may supplement the International Census by providing information on population trends and bird movements.

Therefore, sub-sampling is unlikely to completely replace efforts to periodically survey the entire region. However, a combination of attempting to survey the entire area coupled with more frequent sub-sampling may provide more accurate and timely information about population trends.

12. Wind power is rapidly expanding in the Northern Great Plains. Research is needed to assess the threat this poses to piping plovers at breeding sites and in migration corridors. Special focus should be placed on the impact of associated power transmission lines.

13. Oil and gas exploration and production is rapidly expanding throughout Northern Great Plains breeding grounds. Work is needed to determine the short and long-term impacts of oil exploration and production, including short-term impacts such as seismic work or drilling, ongoing impacts of extraction, potential impacts of spills or leakage, and long-term, cumulative changes as more habitat is disturbed for well pads and roads.

14. Piping plover adult numbers appear to fluctuate in response to the quantity of water in the river system. A historical analysis of system storage and flows compared with adults surveyed and reproductive success may help in future river management.

15. There is very limited evidence suggesting that forage on alkali lakes may be generated from nearby prairies. Changes in surrounding habitat may impact plovers in other ways as well. Examining forage on alkali lakes in relation to surrounding land use may help to focus alkali lake management priorities over the long term.

Recommendations for Atlantic Coast Population Breeding Range

1. Increase efforts to restore and maintain natural coastal formation processes in the New York-New Jersey recovery unit, where threats from development and artificial shoreline stabilization are highest, and in the Southern recovery unit, where the plover's habitat requirements are the most stringent.

2. Identify and secure reliable funding to support continuing management of threats from human disturbance and predation.

3. Accelerate development of agreements needed to assure long-term protection and management to maintain population targets and productivity. Prototype agreements should be pursued at sites where there is a history of intensive and successful piping plover protection, a high degree of commitment to the piping plover protection program, and experienced on-site shorebird biologists who can provide expertise to devise and test alternative types of agreements.

4. Develop strategies to reduce threats from accelerating sea-level rise. Identify sites most likely to maintain (or increase) characteristics of suitable piping plover breeding and/or migration habitat. Identify human coastal stabilization practices that increase or decrease adverse effects of sea-level rise on coastal piping plover habitats.
5. Conduct studies to understand potential effects of wind turbine generators that may be located or proposed for the Outer Continental Shelf, nearshore, and within or between

nesting and foraging habitats. Information needs include migration routes and altitude; flight patterns associated with breeding adults and post-fledged young of the year foraging at nearby sites that are not contiguous with nesting habitats, and avoidance rates under varying weather conditions.

6. Conduct studies, including meta-analyses of local studies, to understand factors that affect latitudinal variation in productivity needed to maintain stationary populations of Atlantic Coast piping plovers.

7. Conduct demographic modeling to explore effects of latitudinal variation in productivity, survival rates, and the carrying capacity of habitat on population viability within individual recovery units and the Atlantic Coast population as a whole.

8. Review state laws within the Atlantic Coast piping plover's breeding and wintering range to assess protections that would be afforded if the species were removed from ESA listing.

9. Support effective integrated predator management through studies of ecology and foraging behavior of key predators; for example, studies assessing the adequacy of buffers between feral cat colonies and piping plover nesting sites would be useful.

Rangewide Recommendations

1. Clarify the piping plover ESA listing to recognize the subspecies *Charadrius melodus melodus and C. m. circumcinctus*, and, within *C. m. circumcinctus*, two DPSs.

2. The International Piping Plover Census has fostered widespread involvement in survey efforts and provided extensive data. However, as piping plover conservation efforts mature, it may be beneficial to shift the Census effort to address specific questions that are not answered by other ongoing efforts.

   Given ongoing recovery programs on the breeding grounds, the most important future International Census contribution to ESA recovery implementation and monitoring for all piping plovers is the abundance estimate for the Northern Great Plains breeding population (including Prairie Canada). The highest benefit can be realized by emphasizing completeness and quality control of this portion of the census and by expediting synthesis and reporting, so that managers can make timely use of this information (see recommendation 11 for the Northern Great Plains breeding range). Trends in abundance of Great Lakes and Atlantic Coast breeding populations (at least for the U.S. portion of their ranges) and progress toward their recovery are most effectively monitored through the annual surveys conducted in accordance with their recovery plans (see sections GL 2.3.2.2 and AC 2.5.2.2). During International Census years, Atlantic and Great Lakes population estimates based on the nine-day U.S. Atlantic Coast window census1 (see Atlantic Coast recovery task 1.11) and standard Great Lakes survey methods with special emphasis on complete coverage of all suitable habitat (see Great Lakes recovery task 1.12) can be used to provide a species-wide context.

The most valuable potential contribution from future winter censuses is improved understanding of the species' range in the Caribbean, Mexico, and other areas that may not have been fully covered in the past (e.g., seasonally emergent habitats within bays lying between the mainland and barrier islands in Texas). See recommendation 5 for the migration and wintering range. In other portions of the continental U.S., the winter census continues to provide beneficial information in the form of a fairly complete one-time survey coverage of wintering habitats, but it does not provide a true wintering "census." In some areas, participation in wintering census by a broadbased group of cooperators also fosters attention to piping plover conservation needs and collects data that otherwise would not exist. However, constraints associated with single, infrequent, mid-winter counts (section WM 2.2.1.3) limits inference from the International Census to the value of particular wintering sites for recovery of the species and to detect trends.