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IDENTIFYING AND ASSESSING CONFLICTS BETWEEN FUTURE DEVELOPMENT AND CURRENT MIGRATORY BIRD HABITAT AROUND FARMINGTON BAY, UTAH

by

Aubin A. Douglas

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Bioregional Planning

Approved:

Keith Christensen, PhD Major Professor	Karin Kettenring, PhD Committee Member

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UTAH STATE UNIVERSITY
Logan, Utah

2018

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ABSTRACT

Identifying and Assessing Conflicts Between Future Development and Current Migratory Bird Habitat Around Farmington Bay, Utah

by

Aubin A. Douglas, Master of Science

Utah State University, 2018

Major Professor: Keith Christensen, PhD
Department: Landscape Architecture and Environmental Planning

Every year, the Great Salt Lake (GSL) and its associated wetlands provide critical habitat for over 250 migratory bird species from both the Pacific and Central Flyways. The GSL borders the Wasatch Front, which is the fastest growing and most populous region in Utah. To support the ever-increasing working population, the government of Utah aspires to increase the robust economic growth of the region through economic incentives and development of infrastructure. As this area continues to develop, greater pressure will be placed on the surrounding natural resources, including the GSL, its wetlands, and the open space and agricultural land that act as buffers from the urbanizing Wasatch Front. The primary objective of this research was to identify and assess possible conflicts between current migratory bird habitat and three proposed future development projects around Farmington Bay of the GSL.

To identify and assess potential conflicts, I first created habitat maps for three migratory bird guilds that use the Farmington Bay area by combining five individual

species' habitat distributions within each guild. Then, I collected and prepared spatial data for three proposed development projects that are likely to develop by the year 2040. Next, I overlaid the development projects onto each guild's and species' habitat map to first identify conflict areas and then assess the spatial impacts to habitat for each species and guild. Finally, I made recommendations for future development that promote the conservation of migratory bird habitat within the study area.

Overall, I found that all three of the proposed development projects produce substantial amounts of conflict with the current migratory bird habitat in the region. Based on these findings, I recommend three development initiatives. First, promote 'centered growth' and higher-density housing to reduce the sprawl of single-family residential neighborhoods. Second, retain and protect open space and agricultural lands as buffers around Farmington Bay to reduce habitat fragmentation and urban encroachment. Third, reconsider the construction of a new four-lane highway along the eastern edge of Farmington Bay. If these recommendations are implemented, the region's migratory bird habitat will have greater protection from economic expansion and urban development.

(169 pages)

PUBLIC ABSTRACT

Identifying and Assessing Conflicts Between Future Development and Current Migratory Bird Habitat Around Farmington Bay, Utah

by

Aubin A. Douglas

The Great Salt Lake (GSL) is a large, terminal lake in Utah that provides crucial habitat to millions of migratory birds from around the world every year. To the east of the GSL is the Wasatch Front — one of the fastest growing and most populous regions in the United States. To support the growing labor force, the government of Utah aims to intensify economic growth in the region through economic incentives and the development of infrastructure, such as roads, residential areas, and commercial areas. As the area along the Wasatch Front continues to urbanize, greater amounts of open space and agricultural land are likely to be developed. The purpose of this research was to identify and assess potential conflicts between current migratory bird habitat and three proposed future development projects around Farmington Bay of the GSL. To do this, I first created habitat maps for three types of migratory birds. Then, I gathered spatial data of three proposed development projects in the area. I overlaid these data to identify areas of conflict where development plans to displace habitat. I found that all three proposed development projects produce substantial amounts of conflict with the current migratory bird habitat in the region. Therefore, I recommend that local decision-makers promote and build higher-density housing, protect sensitive areas (wetlands, open space, and

farmland), and reconsider the construction of a new proposed highway in order to maintain critical migratory bird habitat for future generations.

ACKNOWLEDGMENTS

First and foremost, I must thank my advisors and committee members, Keith Christensen, Karin Kettenring, and, of course, Barty Warren-Kretzschmar, for all of the help and guidance they provided during this process. I would also like to thank Scott Festin of the Wasatch Front Regional Council for all of his time and patience answering my many questions. Thank you to Evan Curtis, Josh Vest, Ann Neville, Laura Ault, Frank Howe, Jason Jones, David England, Randy Jefferies, the Salt Lake City GIS Department, and the USGS GAP Program for answering my questions and providing the help and data resources that made this research possible.

Thank you to my friends, family, and especially my boyfriend, Andy. I would have been lost without their unending support and encouragement. I dedicate this work to my family for the limitless love, laughter, and fun that they bring to my life.

Jamais Arriere.

Aubin A. Douglas

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CHAPTER 1

INTRODUCTION

Over 75% of Utah's wetlands are located around the Great Salt Lake ("GSL" or "the Lake") (Friends of Great Salt Lake, 2014). These wetlands provide critical habitat for over 250 migratory bird species from both the Pacific and Central Flyways on an annual basis (Figure 1) (Friends of Great Salt Lake, 2014; National Audubon Society, 2017; Sorenson and Martinson, 2016; Sumner et al., 2010). The GSL ecosystem acts as an oasis in the arid and expansive region, known as the Great Basin. For this reason, the GSL and its surrounding wetlands have been included as integral parts of the Western Hemisphere Shorebird Reserve Network and have been deemed Globally Important Bird Areas (IBAs) by BirdLife International (Friends of Great Salt Lake, 2014; Sorenson et al., 2016). Since the Lake and its wetlands provide essential habitat for migratory birds, they are heavily studied and managed by private and government agencies. Large portions of the Lake and wetlands are buffered by open space and irrigated cropland, which also provide habitat for many bird species. Conserving the health and quantity of habitats in this region is of utmost importance for sustaining healthy migratory bird populations regionally, nationally, and globally (National Audubon Society, 2017; Vest and Donnelly, 2013).

Just as the GSL is vital for migratory birds, the Wasatch Front (which consists of

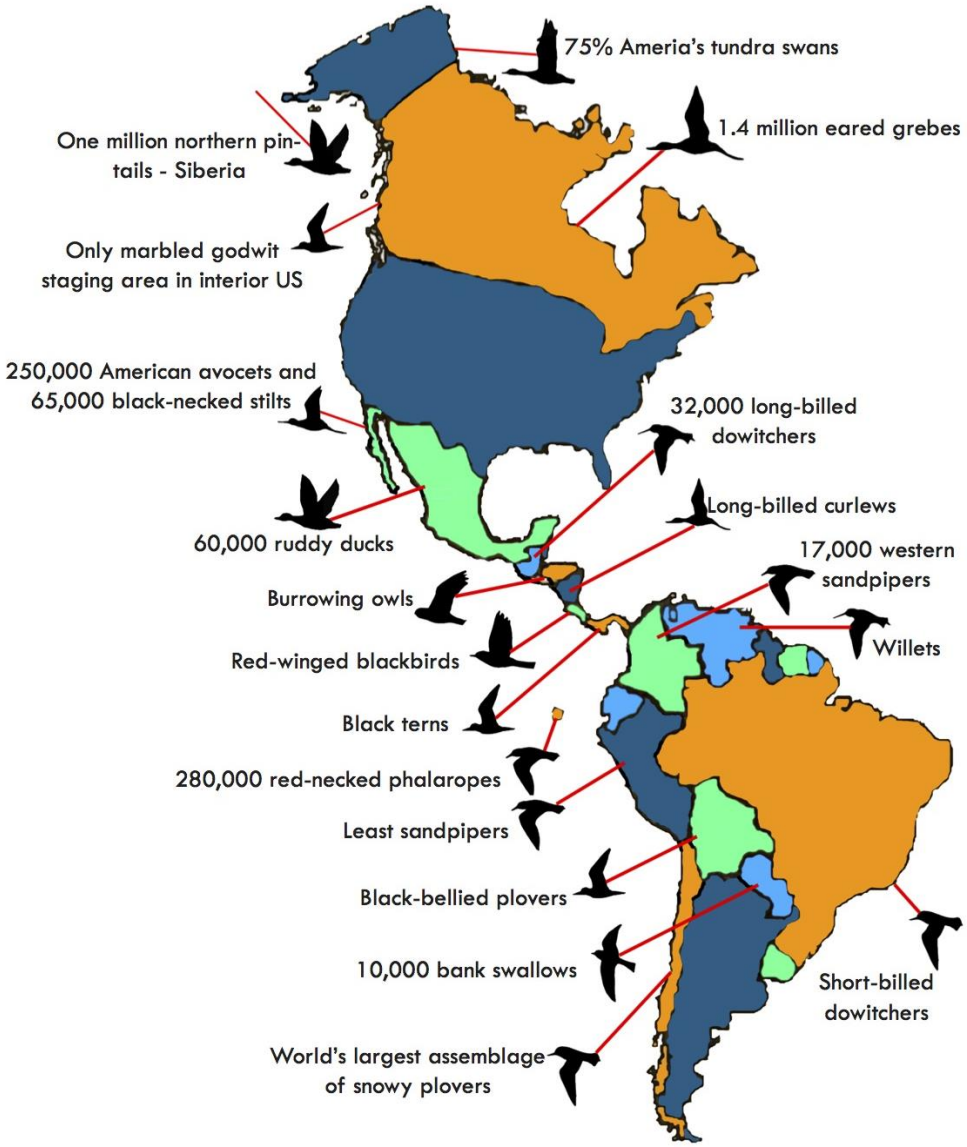

Figure 1. Infographic of several migratory bird species that migrate to the Great Salt Lake
(Utah Rivers Council, 2015)

Weber, Davis, Salt Lake, and Utah Counties) is home to over two million people, and represents 80% of Utah's population (Schott, 2014; World Population Review, 2018). In 2016, Utah had the fastest relative population growth in the U.S (Tanner, 2017; U.S. Census Bureau, 2016). This trend is expected to continue, leading to the doubling of Utah's population by 2060 with the majority of growth concentrated along the Wasatch Front (Kem C. Gardner Policy Institute, 2016). This trend suggests an ever-increasing human impact on the GSL ecosystem and the surrounding natural resources. Because of this concentrated population growth, increased upstream water diversions and nutrient loading of freshwater inputs to the GSL are expected to alter the hydroperiods and plant community composition of these wetlands (Downard et al., 2014; Utah Rivers Council, 2015; Wilsey et al., 2017; Wurtsbaugh et al., 2017). Land uses are also likely to change as more people move to the area; a typical way for cities and counties to accommodate larger populations is through buying and converting nearby open space and agricultural land to new development (Hubbard, 2017). Both of these expected changes (impacts on freshwater resources and land use changes) are likely to affect the quality and quantity of habitat available to migrating birds (Alminagorta et al., 2016; Downard et al., 2014; Wurtsbaugh et al., 2017).

A looming question remains: can this crucial migratory bird habitat endure adjacent to an expanding human population? Furthermore, how can planners and decision-makers accommodate the projected growth while mitigating conflict with migratory bird habitat?

Study Area

The study area for this project is nearly 372,000 acres (150,543 ha) in size, including Farmington Bay, Antelope Island, Farmington Bay Waterfowl Management Area (FBWMA), The Great Salt Lake Shorelands Preserve, multiple duck clubs and mitigation wetlands, 14 municipalities, including Syracuse, Kaysville, Bountiful, Salt Lake City, Farmington, and parts of Davis and Salt Lake Counties (Figure 2). As opposed to using natural boundaries, such as watersheds, this study area was constructed as a "free cut" to incorporate both important biophysical features and municipal, human-created boundaries. It extends just north of the Antelope Island Causeway, west of Antelope Island, south of UT-201, and east of Interstate 15 (I-15) to the edges of the Wasatch Mountain Range. While it is common to use watershed boundaries in bioregional planning projects, doing so did not suit the purposes of this study, which instead required a more focused assessment of an urbanizing area and a globally important ecosystem. There are three types of landowners within in the study area including state agencies (197,418.66 acres or 79,892.5 ha), private landowners and interests (161,391.37 acres or 65,312.8 ha), and federal agencies (12,989.49 acres or 5,256.7 ha).

The vast majority of GSL wetlands are found on the eastern side of the Lake, along with all three major freshwater inflows. The land to the west of the Lake is dry and barren as it borders the West Desert Basin, which is the most arid region of Utah (Utah Department of Natural Resources, 2010). Farmington Bay is relatively isolated from the rest of the GSL, since it is essentially diked off from Ogden Bay via the Antelope Island

Causeway that leads from Syracuse to Antelope Island. It is additionally separated from Gilbert Bay to the west during drought events or drier times of the year, when a land bridge forms at the southern shores of Farmington Bay and stretches north to Antelope Island. Farmington Bay also has its own freshwater input: the Jordan River.

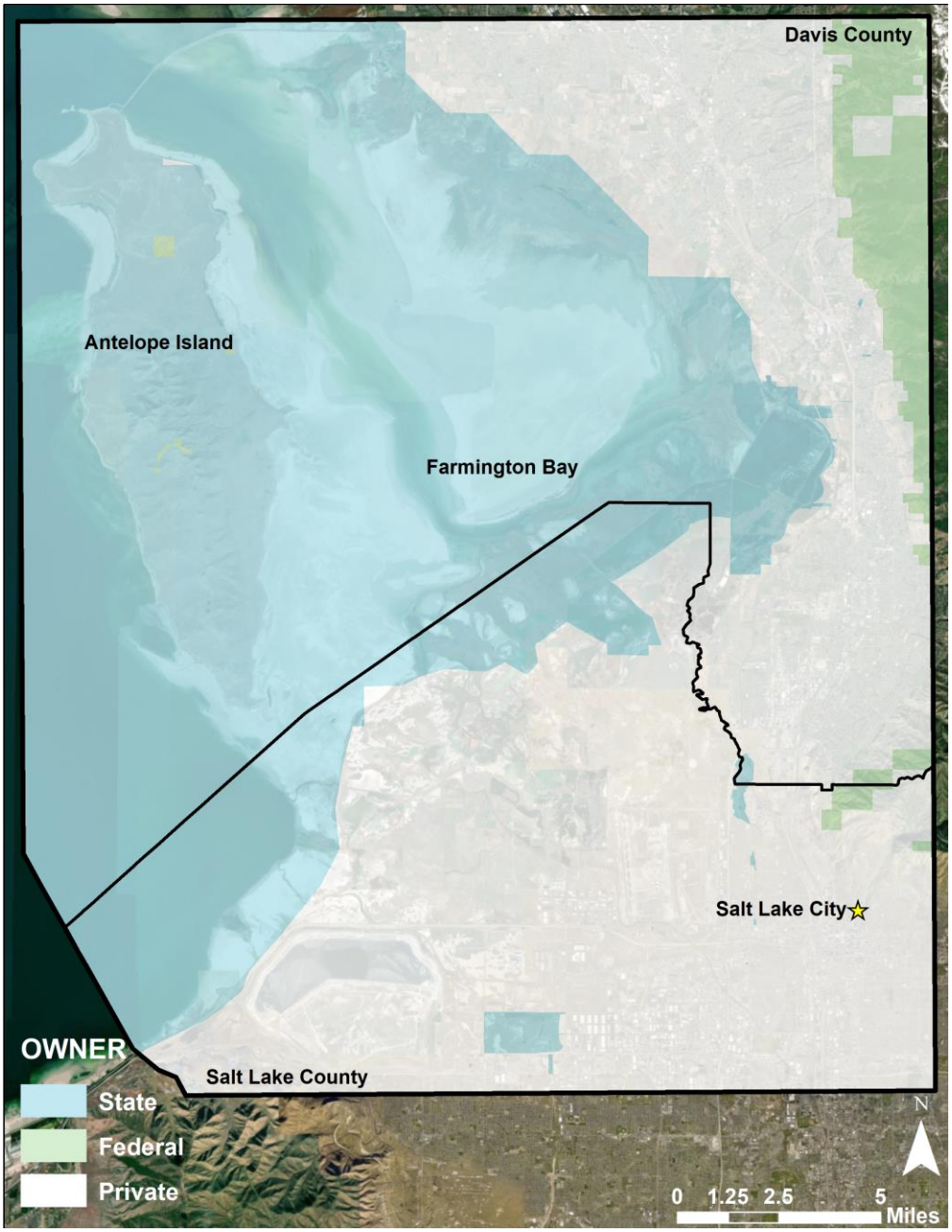

Figure 2. Study area map with landownership. The study area (white boundary line) in relation to the Great Salt Lake (western section), and the three main types of landowners. The majority of developed land is private (white) and the Lake and Antelope Island are primarily state-owned (blue), with a small portion of Federal land in the eastern mountains (green).

While the other rivers that feed the GSL (Bear and Weber Rivers) are primarily facing issues pertaining to water quantity due to increased upstream diversions, the Jordan River faces greater concerns regarding water quality in and around Farmington Bay (Cirrus Ecological Solutions, 2017). The Jordan River flows north out of nearby Utah Lake, a shallow freshwater lake which has recently experienced large, harmful algal bloom (HAB) events, due to the combination of high-nutrient runoff from nearby agricultural fields and increasing temperatures (Penrod, 2016; Wurtsbaugh and Marcarelli, 2006). When in bloom, cyanobacteria are transported from Utah Lake via the Jordan River, along with urban and industrial runoff from surrounding areas, into Farmington Bay (Wurtsbaugh and Marcarelli, 2006; Penrod, 2016).

The fringe wetlands along the southern border of Farmington Bay, which are largely protected for migratory bird habitat, improve the water quality from the Jordan River, as it is well documented that wetland ecosystems are highly efficient at burying and removing water-borne contaminants and toxins (Clarkson et al., 2013; Doherty et al., 2014; Jessop at el., 2015; Maltby and Acreman, 2011; Mitsch and Gosselink, 2000; Zedler and Kercher, 2005). This characteristic ability of wetlands is especially important to the Utah Department of Environmental Quality, specifically the Division of Water Quality (DWQ), as they are required to enforce both state and federal water quality standards for all of Utah's surface and groundwater resources (Utah Department of Environmental Quality, 2017). The natural filtration abilities of wetlands are influential enough that the DWQ created the Wetlands Program to aid their mission in conserving

and improving Utah's water quality while supporting essential habitat for Utah's wildlife (Utah Department of Environmental Quality, 2017). Farmington Bay and its associated wetlands play important roles in water quality control, and provide crucial habitat to many bird species that use the area. Since migratory bird wetland habitat around Farmington Bay abuts the populated and expanding Wasatch Front, the study area boundary lines were drawn to focus this research on the most contentious area between development and migratory bird habitat.

Importance of the Great Salt Lake Region for Migratory Birds

The regional, hemispheric, and global importance of the Lake is highlighted in prominent national and international publications, reports, and networks such as the Western Hemisphere Shorebird Reserve Network, BirdLife International, the National Audubon Society, the U.S. Shorebird Conservation Plan, the North American Waterfowl Management Plan, and the Intermountain West Regional and Continental Conservation Plans for shorebirds and waterbirds (Paul and Manning, 2002; Sorenson and Martinson, 2018). Aside from small secretive marsh birds, there are three main bird guilds that are drawn to and rely on the GSL wetlands and are the focus of this study: shorebirds, waterbirds, and waterfowl.

Shorebirds, such as plovers, sandpipers, American avocets, and phalaropes, tend to use sparsely vegetated sandy and cobbly beaches, mudflats, and playas for nesting and typically forage in less than seven inches of water, or hunt insects on land along the water's edge (Isola et al., 2000; Thomas et al., 2013). Waterbirds, such as gulls, herons,

egrets, and cranes, use wet meadows, shallow freshwater and saline lakes, and adjacent emergent wetlands for their nesting and staging habitats (Zimmerman et al., 2013). Waterfowl, such as mallards, geese, swans, and pintails, use open water for forage, and dryer uplands near wetlands and open water for nesting (Isola et al., 2000; Jones and England, personal communication; Petrie et al., 2013). All three guilds are frequently found around Farmington Bay, but use their habitats in varying ways.

While the GSL is a haven and a major hub for migratory birds, it is not without its issues. The Great Basin, where many western U.S., in-land, saline lakes (including the GSL) are located, is an expansive, arid environment that many migratory birds must traverse on their migratory routes. Many saline lakes in the Great Basin are facing water shortages, which are projected to worsen in the coming years due to climate change effects and increased diversions (Senner et al., 2018; Wilsey et al., 2017). The GSL is not immune to these troubles; as Utah's population center continues to expand, more water must be diverted from rivers and streams for development, meaning less water is likely to reach the Lake and its surrounding wetlands (Downard et al., 2014; Welsh et al., 2013; Wurtsbaugh, 2014; Wurtsbaugh et al., 2017). As more farmland is converted to development, even less water will reach the Lake; while irrigated fields tend to have return flows downstream, municipal users tend to not produce as much return flow (Downard et al., 2014).

Water quantity is not the only issue GSL migratory birds face; since the 1980s flood events that scoured and drowned established wetland communities at the GSL, a

non-native lineage of *Phragmites australis* (*Phragmites*) has spread and supplanted many of the previously native wetland communities (Kettenring et al., 2012; Kettenring et al., 2016; Long et al., 2016). The invasive lineage of *Phragmites* is highly competitive, and has been replacing stands of native wetland vegetation that provide forage and habitat to the majority of migratory birds (Petrie et al., 2013; Thomas et al., 2013; Wilsey et al., 2017; Zimmerman et al., 2013). Without the continuous, concentrated management efforts of wetland managers, sustaining habitat for the current populations of migratory birds that visit the GSL would be impossible.

New Development

The majority of wetlands are located along the eastern shore of the Lake and are predominantly managed for avian habitat by private duck clubs, NGOs like The Nature Conservancy and the National Audubon Society, and the Utah Division of Wildlife Resources (UDWR). Federal and state agencies, counties, municipalities, NGOs, private companies, and individual citizens all own portions of the study area, and all have varying land management techniques, policies, resources, and objectives. However, the local municipalities along the Wasatch Front agree that population and industry will and should continue to grow in the coming decades (Wasatch Front Regional Council, 2017). Salt Lake County is expecting to convert over 12,200 acres (4,937.2 ha) of farmland and open space to housing and infrastructure development by 2050 (Wasatch Front Regional Council, 2017). In the same timeframe, Davis County is expecting to develop nearly 10,000 acres (4,046.9 ha) of open space and farm land (Wasatch Front Regional Council,

2017). According to the *West Davis Corridor Final EIS*, the number of households in Davis and Weber Counties is expected to increase 65% by 2040 (2017).

To combat the expected automobile congestion, a new 19-mile long highway from West Point to Farmington City has been proposed that will directly border Farmington Bay wetlands on the eastern edge (Figure 3). The West Davis Corridor (WDC) will connect with both the Legacy Parkway and I-15 at its southernmost point, and continue north into Weber County. It will be a four-lane highway, with some two-lane sections. Unlike the Legacy Parkway, the WDC will allow semi-trucks and have a speed limit of 65 instead of 55 miles per hour. To mitigate some expected impacts, the WDC will feature noise-reducing pavement and lighting only at interchanges (UDOT, 2017). The Final EIS and Record of Decision were made public in the fall of 2017, with the Preferred Alternative directly bordering the highest quality habitat found in the study area (Figure 4). To offset some environmental impacts, the Utah Department of Transportation (UDOT) must "acquire and improve" over 1,000 acres (404.7 ha) of the very wetlands it is expecting to impact (west of the corridor), and then donate these wetlands to The Nature Conservancy's Great Salt Lake Shorelands Preserve and FBWMA. Construction is expected to begin in 2020, after the design phase of the corridor finishes in 2019 (UDOT, 2010; 2013).

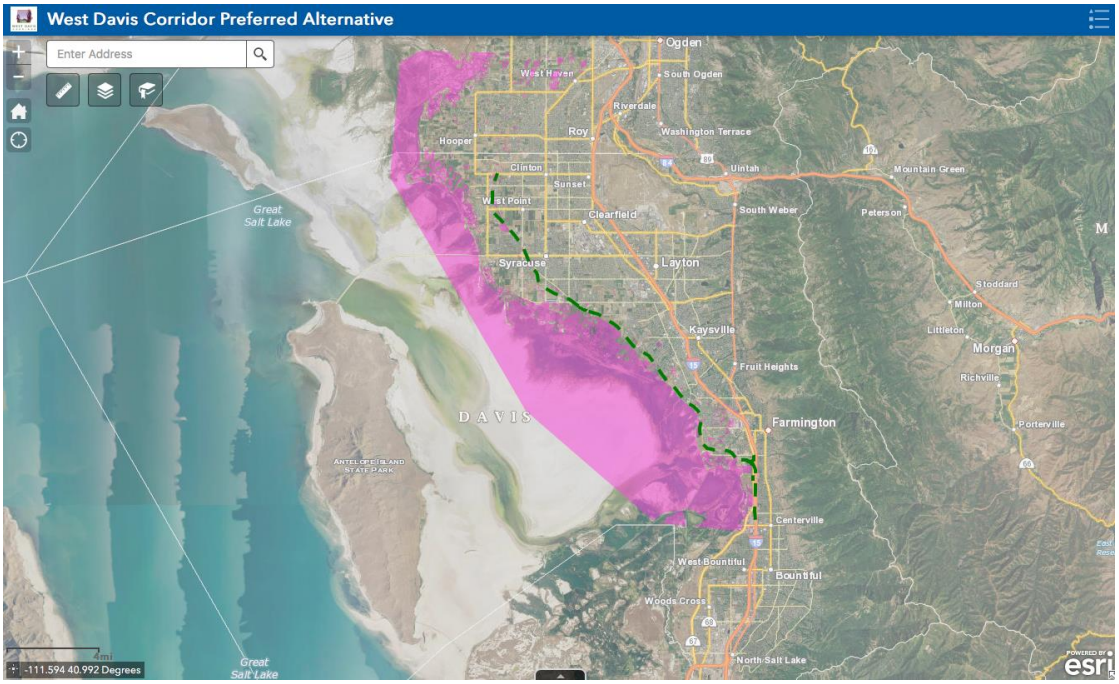

Figure 3. West Davis Corridor Preferred Alternative (green dotted line). It directly borders much of the wetlands (pink area) along the eastern edge of Farmington Bay. (UDOT, 2017)

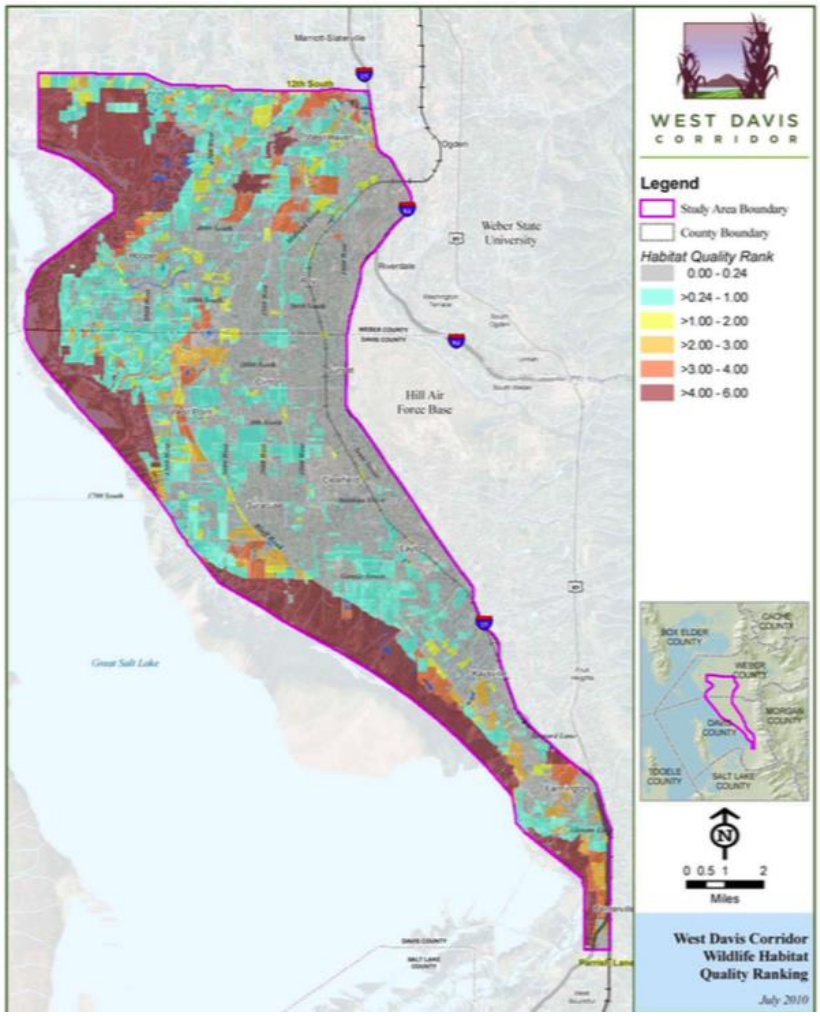

Figure 4. West Davis Corridor EIS Habitat Quality Ranking Map showing the rankings of habitat for multiple indicator species in their study area (red being the highest quality habitat).
(Parker, 2013)

The Northwest Quadrant (NWQ) of Salt Lake City has been recently rezoned predominantly for "light industrial" development (Sorenson and Martinson, 2018). The NWQ is a large piece of undeveloped land (28,000 acres (11,331.2 ha), or about 40% of Salt Lake City's land) on the western side of the city that spans north toward the GSL

shoreline and west to the Kennecott Utah Copper Inland Sea Shorebird Reserve, shown in Figure 5 (Salt Lake City, 2016; Sorenson and Martinson, 2018). Until just recently, the city was looking to develop 9,000 acres (3,642.2 ha) of land suitable for development north of I-80, which is adjacent to the SLC International Airport and the neighboring "International Center." The city acknowledged that this is an important wildlife area, and was making plans to lessen the impact on migratory bird species by implementing environmentally minded policies, regulations, and plans such as avoiding unnecessary lighting to reduce light pollution, screening glass to reduce bird collisions with windows, buffering nesting areas to decrease stress or disturbance to birds, and using native flood and salt tolerant vegetation for landscaping purposes (Figure 6) (Salt Lake City, 2016).

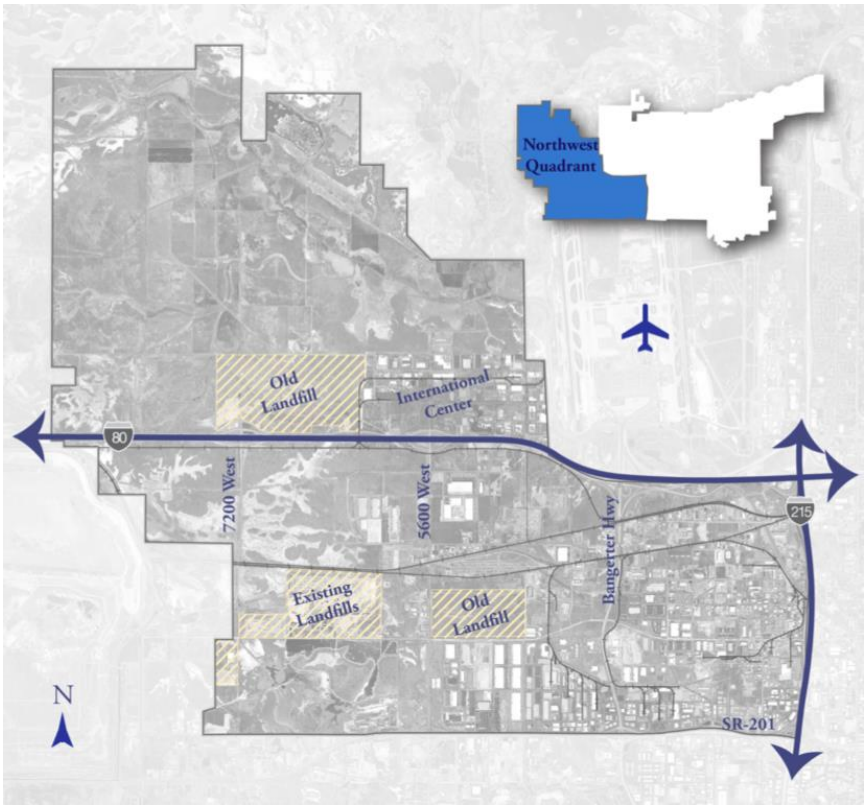

Figure 5. Map of the Northwest Quadrant in relation to Salt Lake City. It is largely undeveloped, and has many brownfields (old and existing landfills and mining sites). (Salt Lake City, 2016)

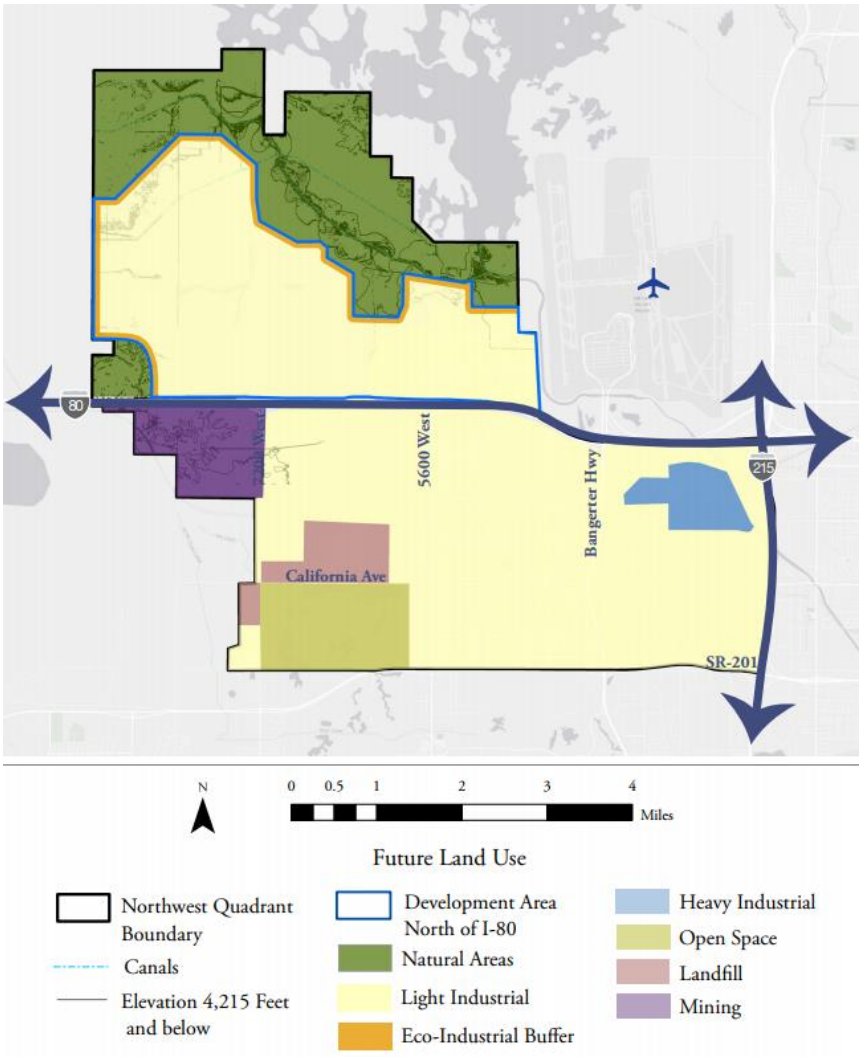

Figure 6. Salt Lake City's rezoned Northwest Quadrant future land use map (Salt Lake City, 2016)

However, on March 16, 2018, Utah's Governor, Gary Herbert, signed Senate Bill 234 (SB234) into law, affirming that the State of Utah will create an Inland Port Authority for the NWQ, meaning SLC no longer holds taxation or development rights for the land (Davidson, 2018). SB234 was proposed to attract more businesses to the area, and to designate a special Foreign Trade Zone in Utah that allows inbound and outbound

overseas goods to be received and processed while bypassing coastal ports of entry (Anderson, 2018; Cambridge Systematics, Inc., 2017). It is likely that a greater environmental footprint will ensue with this new plan for development in the NWQ, as an inland port will require more roads, warehouses, office buildings, and greater connectivity to railways and the airport than Salt Lake City's Master Plan for the NWQ (Cambridge Systems, Inc., 2017; Erickson, 2018; Salt Lake City, 2016).

Ultimately, the Wasatch Front is expected to grow in both population and infrastructure in the coming years. Unfortunately, the fastest growing region in Utah is directly adjacent to some of the most vital and at-risk migratory bird habitat in the western hemisphere (Duvall et al., 2013; Sorenson and Martinson, 2018; Western Hemisphere Shorebird Reserve Network, 2017). Studies show that increased urban development in close-proximity to migratory bird habitat has definitive impacts on migratory bird fitness and diversity (Clarke et al., 2013; Geschke et al., 2018). Under the Migratory Bird Treaty Act of 1918, stipulations protect not only migratory birds themselves, but also any habitats and environs necessary for their survival (U.S. Fish and Wildlife Service, 2017). Since it is an international treaty, this federal law overrides any and all provisions of state-based laws and regulations, as per the 1920 Supreme Court ruling in the case of *Missouri v. Holland*. As the Wasatch Front continues to expand and develop in the coming decades, it is of utmost importance to accommodate and plan for migratory bird habitat in order to avoid irretrievable impacts to sensitive species, and susceptibility to litigation.

I had two main objectives for this research: (1) assess and understand conflicts between three proposed future development projects (the West Davis Corridor, the Northwest Quadrant, and the Wasatch Choice 2040 Regional Vision) and current migratory bird habitat for three guilds (shorebirds, waterbirds, and waterfowl); and (2) provide policy and planning recommendations for future development to accommodate migratory bird habitat while meeting projected development needs for the area.

CHAPTER 2

METHODS

The methods for this project include four main steps as shown in Figure 7:

1) Build Guild Habitat Maps for three migratory bird guilds that use the Farmington Bay area by combining five individual species' habitat distributions for each guild;

2) Map Development Projects for three major proposed projects in the area that are likely to be constructed by the year 2040;

3) a. Identify Conflict Areas by overlaying the development projects onto each guild's and species' habitat map and locating areas of overlap (conflict areas);

b. Assess Project Impacts in terms of the acreage of habitat in conflict with each project and development type (e.g. industrial, commercial, etc.);

4) Make Recommendations for future development that promote the accommodation and conservation of important migratory bird habitat within the study area. These steps are further detailed and explained in the following sections.

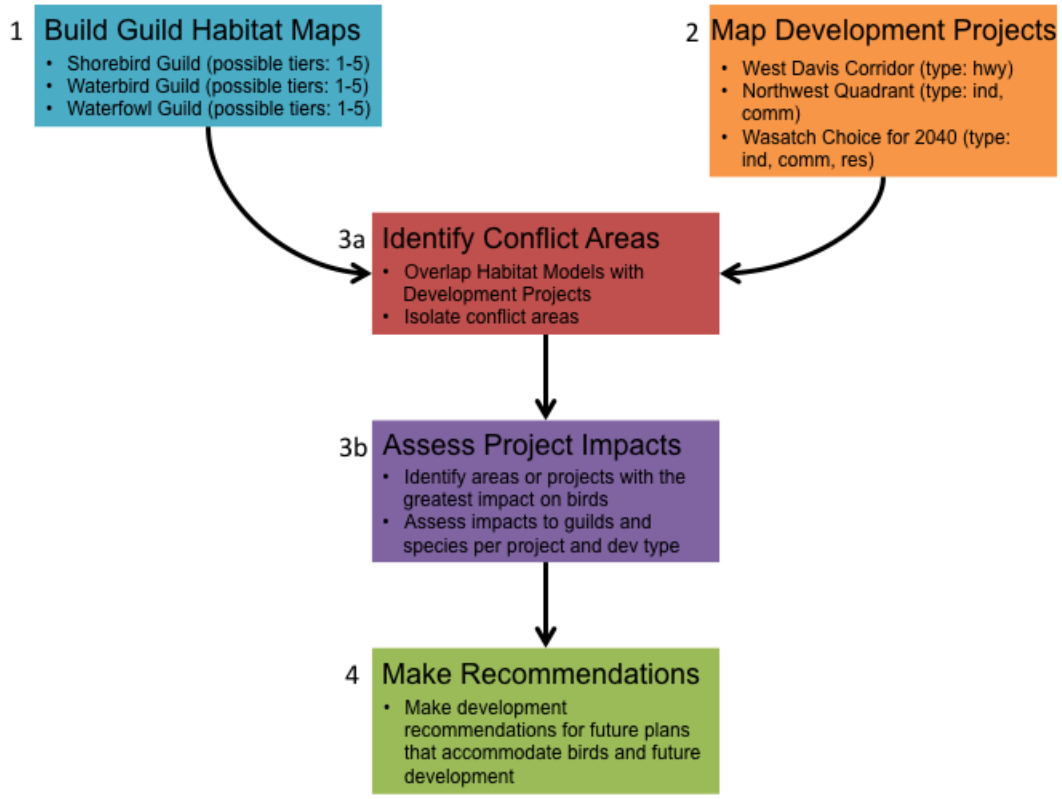

Figure 7. Methods diagram - overall steps and flows for the methods of this research.

Step 1: Building Guild Habitat Maps

To map the habitat for each migratory bird guild, I used distribution data for five species from three migratory bird guilds (15 species altogether). Each species selection was guided by expert opinion from biologists and ornithologists familiar with the area (Dr. Frank Howe, Utah State University and the Utah Division of Wildlife Resources; Jason Jones, Manager, Farmington Bay Waterfowl Management Area (FBWMA); David England, Assistant Manager FBWMA; Dr. Josh Vest, Scientist, Intermountain West Joint Venture), and relevant literature and sources (National Audubon Society, the Cornell Lab

of Ornithology, the Intermountain West Joint Venture (IWJV), and the Great Salt Lake Waterbird Survey: 1997-2001). Based on this research and expert opinions, fifteen species were selected for the purposes of this study (Table 1).

Table 1. Selected species for each of the three guilds.

	Shorebirds	Waterbirds	Waterfowl
1	American Avocet	Black-crowned Night Heron	Cinnamon Teal
2	Long-billed Curlew	Eared Grebe	Gadwall
3	Snowy Plover	Franklin's Gull	Lesser Scaup
4	Willet	Great Blue Heron	Northern Pintail
5	Wilson's Phalarope	White-faced Ibis	Redhead

Each species that was selected is either a) a species of concern locally, regionally, nationally, or internationally, b) a species that frequently uses the area, or c) a species that is important for human activities in the area (i.e. hunting and birding). An additional requirement for a species' selection was the availability of spatial distribution data via the U.S Geological Survey's National Gap Analysis Program (GAP data). While I initially intended to include other species such as the black-necked stilt, long-billed dowitcher, and American white pelican, appropriate datasets were either redundant of another species' distribution, unavailable, or did not lend themselves to the purpose of this study (i.e., their distribution data indicated they were only found in open water). Within the aforementioned pool of selectable species, I chose species that exhibited varying spatial distributions to reflect the full expanse of habitat for each guild as best as possible. In this way, the habitats of the other 250 migratory bird species that were not selected for

assessment remain relatively well-represented by the combined distributions of these 15 "umbrella species."

Species distribution data were retrieved from the U.S. Geological Survey's (USGS) National Gap Analysis Program (GAP). The USGS's species distribution data are created using deductive models that predict suitable areas for a particular species within that species' known range. They are generated at the same data resolution as the National Land Cover Data, which is a cell size of 30 meters. The USGS GAP species distribution data are based on "habitat associations from published literature and core data sets, such as elevation and land cover," as well as "hydrological characteristics, human avoidance characteristics, forest edge, ecotone widths, etc." (USGS, 2014). The published literature and core datasets that inform the attributes used in the GAP distribution models are supplemented with data from other USGS GAP regional projects, NatureServe data, and the International Union for Conservation of Nature and Natural Resources (IUCN) data (USGS-GAP, 2014). These datasets have been used in national reports, such as the national *2011 State of the Birds*, and the data program has been honored and recognized by both private companies and governmental committees (e.g. ESRI and the Federal Geographic Data Committee) (National Gap Analysis Program, 2011; 2016). Since the GAP distribution data predict suitable habitat for each species, the words "distribution" and "habitat" are used interchangeably in this report. To access the USGS' GAP species data, visit https://gapanalysis.usgs.gov/species/viewer/, launch the species viewer, select the species in the drop-down menu, and select "Model Report" at

the bottom of the page. For more detailed metadata about these distribution models, visit https://gapanalysis.usgs.gov/wp-content/uploads/2013/09/GAPSpeciesDistributionModelmetadata.pdf.

Once I obtained the distributions for all 15 selected species, I created distributions for each guild by rasterizing each species' distribution map using the 'Feature to Raster' tool, and then added them together using the 'Raster Calculator' tool in ArcGIS 10.5. There were six possible categories for each guild's habitat: areas where only one species' distribution occurred had a value of 1, areas where two species' distributions overlapped had a value of 2, and so on to a maximum value of 5 (Figures 10-12). Areas where no species were found had a value of zero. Creating rasterized habitat data in this way allowed for the spatial analysis of area where there are conflicts between development and migratory bird habitat. For instance, an area that was suitable habitat for all five species in a guild could be considered valuable for conservation purposes, and might have a greater negative impact on migratory birds if development were to occur there instead of in an area where only one species' habitat occurred. I also retained the distribution maps for each species, as I performed a conflict analysis not only for the guilds, but also for each species. To gain an overall view of broad impacts to migratory bird habitat in my study area, I combined all 15 species' distributions into one raster layer with values ranging from 0 (where there was no habitat) to 15 (where all species' distributions would overlap) (Figure 34). However, there were no areas where all 15 species' distributions overlapped. In total, I created 15 species distribution maps, three

guild distributions maps, and one distribution map that included all 15 species' distributions.

Step 2: Map Development Projects

Through online investigation, I found that future development plans had been created via the Wasatch Choice 2040 Regional Vision (Envision Utah, 2016a; Powers, 2017; Wasatch Front Regional Council, 2017). The Wasatch Choice 2040 Regional Vision (the Vision) was led by the Wasatch Front Regional Council (WFRC), the Mountainland Association of Governments (MAG), and Envision Utah but included many other agencies, organizations, and individual citizens (Wasatch Front Regional Council, 2017). The Vision is a development map for the Wasatch Front that focuses on accommodating future population growth in a thoughtful, more sustainable way that promotes 'centered growth' (Figure 27). The idea of 'centered growth' is one of the key strategies that the Vision set out to realize; it focuses on making changes to already developed areas that will create 'hubs' and 'centers' throughout the Wasatch Front, and allow for greater mixed development uses such as commercial, residential, and transportation (Envision Utah, 2016a). Among other goals, the Vision, if realized, is expected to create walkable communities, reduce the amount of traffic on roads, and help businesses reach more consumers and be closer and more accessible to their employees, while meeting the projected growth needs for the area (Envision Utah, 2016b; Scott Festin, personal communication).

In order to take advantage of the professional planning work carried out in the Vision, I contacted the WFRC's Senior Planner and Demographer, Scott Festin. Mr. Festin provided the necessary spatial data for the Vision. While the data are extensive and helpful for assessing land use changes along the I-15 corridor, there were two recent major development projects that were not included in the Vision, as they were decided upon after the final 2040 Vision was published: the West Davis Corridor (WDC) and the Northwest Quadrant (NWQ).

The WDC is a proposed four-lane highway with multiple interchanges that would span 19 miles from West Point City to Farmington City just east of Farmington Bay (UDOT, 2017). The goal of this project is to relieve the expected increase in traffic congestion along the I-15 corridor, so that by 2040, there is no noticeable increase in traffic based on the current levels of traffic for the area. The WDC would connect to both I-15 and the Legacy Parkway, near the southeastern tip of Farmington Bay (UDOT, 2017). The Final Environmental Impact Statement has been published, and the Preferred Alternative (B1) is slated for construction in 2020. I obtained the GIS data for the Preferred Alternative from the UDOT Project Manager, Randy Jefferies. Since habitat that is within 300 feet of the actual constructed highway is likely to be impacted (HDR Engineering, Inc., 2017), I buffered the highway, interchanges, and other on-the-ground aspects of the project by 300 feet to assess habitat impacts associated with this project (Figure 13). 300 feet was chosen as a buffer because, "UDOT anticipates that biological and hydrological functions provided by wetlands within 300 feet of right-of-way will be

indirectly affected" (p. 27, HDR Engineering, Inc., 2017). Even though some of the areas within the 300-foot buffer are not composed of wetlands, other relevant sources indicate that wildlife and its associated habitat are either directly or indirectly impacted by the construction of a four-lane highway (BIO-WEST, 2011; Jacobson, 2005; Kociolek et al., 2015). In order to assess possible impacts to migratory birds, I buffered the entire length of the proposed project so any overlap between habitat and the 300-foot buffer would be captured in my analysis.

The Northwest Quadrant (NWQ) is a large piece of land just south of Farmington Bay in Salt Lake County that was recently owned by Salt Lake City, but has been rezoned by the State of Utah for development as an inland port (Figure 20). Once the State Bill 234 (SB 234) was passed by the state legislature and signed into law by Governor Herbert in March 2018, plans have been underway to begin designing and building the infrastructure required to support the inland port. While Salt Lake City had just recently rezoned the NWQ from largely agricultural and open space uses to "light industrial" with some commercial areas, the designation of an inland port will require far greater infrastructure that is likely to have a greater negative impact on both human health and migratory birds that frequent the area (Cawley, 2018; Erickson, 2018; Harkins, 2018). More roads, railroads, storage facilities, and industrial manufacturing complexes are required for an inland port. Unfortunately, this change in landownership is so new that there has not been enough time for the Utah Inland Port Authority to generate plans or designs for the area yet (Evan Curtis, personal communication).

While it is likely that the Inland Port Authority will either expand or intensify the land uses for the purposes of accommodating the inland port, I was advised that the best available data are the zoning data provided by Salt Lake City (Evan Curtis, personal communication). Therefore, I used the zoning data for the NWQ from Salt Lake City's GIS Department. However, SLC's NWQ plan features zoning for open space, natural areas, and lighter industrial uses, and should be considered a "best case scenario" in terms of impacts to migratory bird habitat, as the inland port is likely to feature impactful land uses and land covers for birds, such as new industrial roads, greater connectivity to railways and the airport, more warehouses and manufacturing plants, and other supporting infrastructure (e.g. sewage, telecommunications systems, transmission lines, natural gas system, etc.) (Cambridge Systematics, Inc., 2017).

Once I finished preliminary data cleanup on these projects (i.e. clipping to the study area, buffering the WDC project, re-projecting data to the correct projection, selecting and isolating development types that would impact migratory bird habitat (e.g., commercial, industrial, residential, and highway)), I divided the projects into four different types of development so I could analyze conflict patterns based on development type. The four development types I used were highway ("hwy"), industrial ("ind"), commercial ("comm"), and residential ("res"). I divided them into these categories based on the type of land use or development that was predicted to occur in the area. The Vision data were divided into commercial, industrial, and residential development types; the NWQ was divided into commercial and industrial; and the WDC was entirely the

highway development type. There were 4,113 acres (1,664.5 ha) of overlap between these projects making it impossible to assess impacts from all three projects together since there was disagreement on types of land uses that should be constructed (Figure 41).

Steps 3a & 3b: Identify Conflict Areas & Assess Project Impacts

Once I had both the habitat data and the future development projects data prepped, I constructed a model in ArcGIS ModelBuilder to identify and separate all conflict areas for each guild or species based on the three development projects (Figure 9). I built a model for each guild (three in total), and a model for each individual species (15 total). I also built one model that used a raster input of all species' habitats combined into one layer. The sole differences between the models were the habitat inputs and the specifications in the Cell Statistics, Reclassify, and Extract by Attributes tools. Each model relies on adding the raster datasets together using the Cell Statistics tool, and then using the Reclassify tool to identify and create new values for the cells in conflict. Finally, I used the Extract by Attributes tool that allows the user to extract cells with specific values from a raster, which provided the cells in conflict for each project and habitat input. All 19 models were built for a specific habitat input, whether it was for a single species, a guild, or all species combined; this input is indicated by the second blue circle in the model figures (Figure 9). The conflict areas were separated by development type and project. For example, in each model, there were six outputs: NWQ commercial development, NWQ industrial development, WDC highway development, 2040 Vision

commercial development, 2040 Vision industrial development, and 2040 Vision residential development. Once I had separated the conflict areas in this fashion, I went through each outputs' attribute table in ArcGIS, and copied the number of conflict cells into an Excel spreadsheet, along with the data of species or guild, development type, and project (Figure 8). Since the raster data had a resolution of 30 meters by 30 meters, I knew each cell was equal to 900 square meters. To find the acreage of conflict for each project and development type for every guild or species, I multiplied the number of cells by the conversion factor from 90 square meters to acres (0.222395). This calculation gave me the acreage of conflict for every project and development type for every species, guild, and for all species combined. I saved the spreadsheets and then uploaded them into RStudio Version 1.0.153 and used the "tidyverse" package to assess the amount of conflict in varying ways (i.e. by project, by guild, by development type, by species) and to make graphs of said data (Wickham, 2016). The "tidyverse" package is a suite of packages that use a similar design, philosophy, grammar and data structure in RStudio (Tidyverse, no date).

	Species	Guild	Conflict_Cells	Conversion	Acres_Conflict	Dev_Type	Project	Proj_acres	Percent_of_Proj_Conflict
1	American Avocet	SB	0	0.222395	0.000000	comm	nwq	255.7543	0.000000000
2	American Avocet	SB	3865	0.222395	859.556675	ind	nwq	15208.9269	5.651658941
3	American Avocet	SB	120	0.222395	26.687400	hwy	wdc	2376.0682	1.123174841
4	American Avocet	SB	0	0.222395	0.000000	comm	wfrc	3407.5362	0.000000000
5	American Avocet	SB	194	0.222395	43.144630	ind	wfrc	7520.2869	0.573709892
6	American Avocet	SB	1	0.222395	0.222395	res	wfrc	7271.2045	0.003058572
7	Long Billed Curlew	SB	124	0.222395	27.576980	comm	nwq	255.7543	10.782608696
8	Long Billed Curlew	SB	9247	0.222395	2056.486565	ind	nwq	15208.9269	13.521575738
9	Long Billed Curlew	SB	4623	0.222395	1028.132085	hwy	wdc	2376.0682	43.270310745
10	Long Billed Curlew	SB	792	0.222395	176.136840	comm	wfrc	3407.5362	5.169037985
11	Long Billed Curlew	SB	2232	0.222395	496.385640	ind	wfrc	7520.2869	6.600621026
12	Long Billed Curlew	SB	3958	0.222395	880.239410	res	wfrc	7271.2045	12.105826579
13	Snowy Plover	SB	0	0.222395	0.000000	comm	nwq	255.7543	0.000000000
14	Snowy Plover	SB	474	0.222395	105.415230	ind	nwq	15208.9269	0.693114188

Figure 8. An example of my data layout in RStudio. The "Acres_Conflict" column denotes the number of acres of conflict between the specific development type ("Dev_Type"), project ("Project"), and species ("Species"). The "Percent_of_Proj_Conflict" column denotes the percent of the specific development type and project that is in conflict with the associated species (e.g., about 860 acres of the industrial development type of the NWQ is in conflict with American avocet habitat, which is 5.65% of the entire area slated for industrial development in the NWQ project).

Step 4: Make Recommendations

In my discussion section, I make data-driven final recommendations for policies and planning for future development projects, considering different types of development and important habitat areas. I make recommendations about preserving the highest priority habitat areas (i.e., where there is the greatest overlap in habitats) based on relevant literature and studies, and provide overarching motifs and ideas that will help planners and decision-makers accomplish current and future goals for the region.

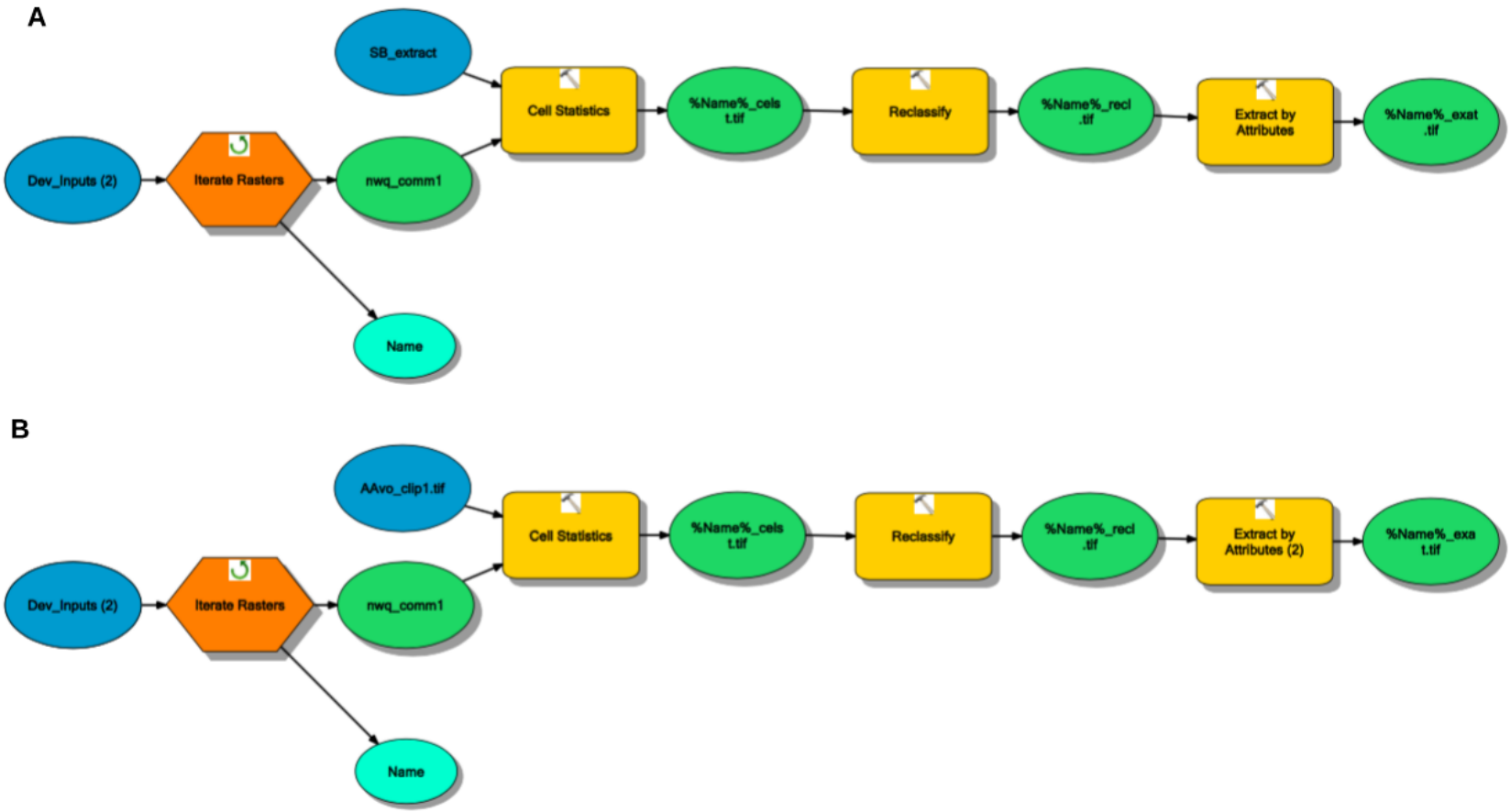

Figure 9. Modelbuilder Model examples. The models I built to identify and separate conflict areas for each guild (A) and species (B). The Iterate Rasters tool allows each model to run through all rasters within the "Dev_Inputs" folder, which contained raster data on the locations and extents of each project and development type. Cell Statistics combined development inputs with habitat inputs. Reclassify split up conflict areas from everything else. Extract by Attributes extracted the identified conflict areas for each project and habitat input.

CHAPTER 3

RESULTS

Within my study area, the West Davis Corridor (WDC) project encompasses 2,376.1 acres (961.6 ha) of land, the Northwest Quadrant (NWQ) project encompasses 15,464.7 acres (6,258.3 ha) of land, and the Wasatch Choice 2040 Vision (Vision) project encompasses 18,199.0 acres (7,364.9 ha) of land. My entire study area includes 371,796 acres (150,460.5 ha) of land in parts of Davis and Salt Lake Counties. Overall, the WDC, NWQ, and Vision projects respectively cover 0.64%, 4.16%, and 4.89% of the study area. However, only 43.4% of the study area (161,390 acres (65,312.2 ha)) is private land, which is developable by city and county entities. The remaining 46.6% of the study area is largely owned by the state, and a small percentage is owned by the Federal Government and is predominantly managed by the US Forest Service in the Wasatch Mountains in the northeastern corner of the study area.

All three of the projects assessed in this research are currently located on private land; the WDC, NWQ, and Vision projects respectively cover 1.5%, 9.6%, and 11.3% of the private land in the study area. While there are important habitat areas held by both state and private parties within the study area, the areas most at risk for habitat loss and degradation due to the expansion of development are on private land. Based on my spatial assessments, I have found that the WDC, NWQ, and Vision projects have

potential conflicts with all three guilds, and all 15 bird species, with the exception of the snowy plover and the WDC project where no potential conflict was found.

Quantifying Shorebird Habitat in the Study Site

One of the prime motivations for this research was to gain a better understanding of potential conflicts between future development and current migratory bird habitat in the area. It is paramount to first understand the scope and overlap of species' distributions within each guild's habitat to fully comprehend my assessment and identification of conflict areas. The shorebird habitat is located predominantly around the edges of the lake and at the mouth of the Jordan River inlet (Figure 10). The majority of their habitat occurs on private and state-owned land, and all of the development projects in this study occur on private land, which is the only developable land in the region. There are a few areas owned and managed by the federal government, but the majority of this land is located in the Wasatch Mountain range, away from the habitat of the three guilds assessed in this report.

The overall shorebird distribution encompasses 115,907 acres (46,905.9 ha), which is about 31% of the entire study area. There was no habitat in 69% of the study area and there was no area where all five shorebird species' habitats overlapped. Four species' habitats overlapped for 7% of the study area; three species' habitats overlapped for about 3% of the study area; two species' habitats overlapped for 9% of the study area; and areas with one shorebird species' habitat comprised 12% of the area. These species

prefer open, non-vegetated shorelines near shallow, open water, and with some nearby structure, such as rocks or pickleweed; some species within this guild also use irrigated cropland, wet meadows, and open fields for foraging (Thomas et al., 2013). The shorebird guild's species habitat distributions are further broken down in Table 2. The habitat maps for all 15 bird species is included in Appendix A of this report.

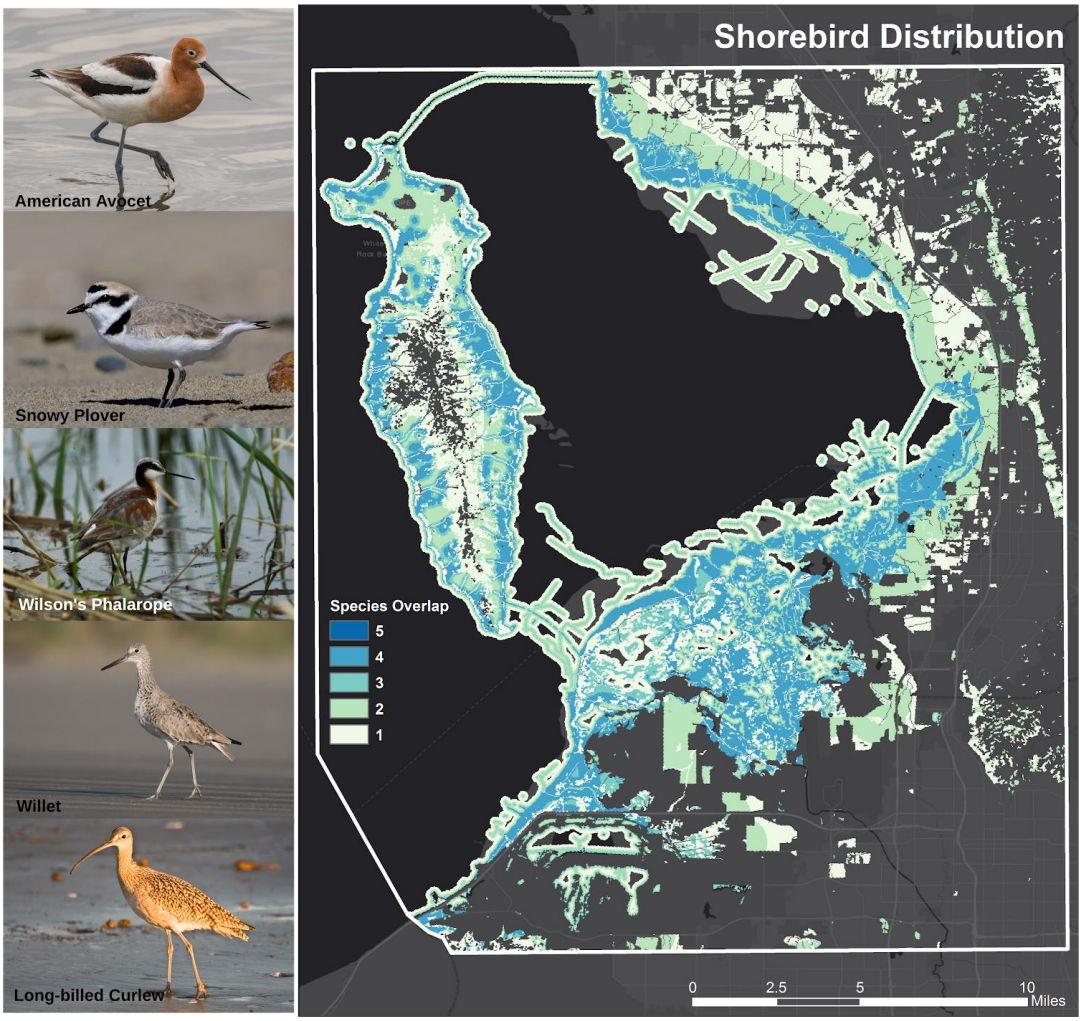

Figure 10. Shorebird guild distribution map. The combined distributions (from the USGS GAP data) of the five selected shorebird species. The darker blue colors indicate areas where more species' distributions overlap. Since I combined all five distributions, it was

possible for all distributions to overlap; however, there are no areas within my study area where all five distributions overlap. The greatest overlap was between four species' distributions. Photographs from the Google Images "labeled for reuse" section.

Table 2. Shorebird Species Acreage within the study site. The acreage of habitat within the study area for each of the five shorebird species in this study. It also includes the total percent of the study area that each species' distribution covers. All of the birds have similar percent covers of the study area, except for the snowy plover. While the snowy plover does not have extensive habitat in the study area, it is listed as "threatened" under the Endangered Species Act, and since this species breeds and nests at the Great Salt Lake, it is important to understand any conflicts development may have with important nesting habitat for this species, and the implications for the stability of their populations.

Species	Acres of Habitat	Percent of Study Area
American Avocet	58464.8	15.7
Long-billed Curlew	58851.5	15.8
Snowy Plover	12310.5	3.3
Willet	66430.9	17.9
Wilson's Phalarope	54096.2	14.5

Quantifying Waterbird Habitat in the Study Site

The waterbird habitat is located predominantly around the edges of the lake and in wetlands and agricultural land, particularly around The Nature Conservancy's Great Salt Lake Shorelands Preserve on the eastern edge, and the Farmington Bay Waterfowl Management Area on the southeast tip of the Bay (Figure 11). The overall waterbird distribution is the largest of all three guilds and encompasses about 283,422 acres (114,696.8 ha), which is about 76% of the entire study area. There was no habitat in 24% of the study area. Five species' habitats overlapped for about 5% of the study area; four species' habitats overlapped for nearly 1% of the study area; three species' habitats

overlapped for about 5% of the study area; two species' habitats overlapped for 14% of the study area; and areas with one waterbird species' habitat comprised 51% of the area. The guild's species habitat distributions are further broken down in Table 3.

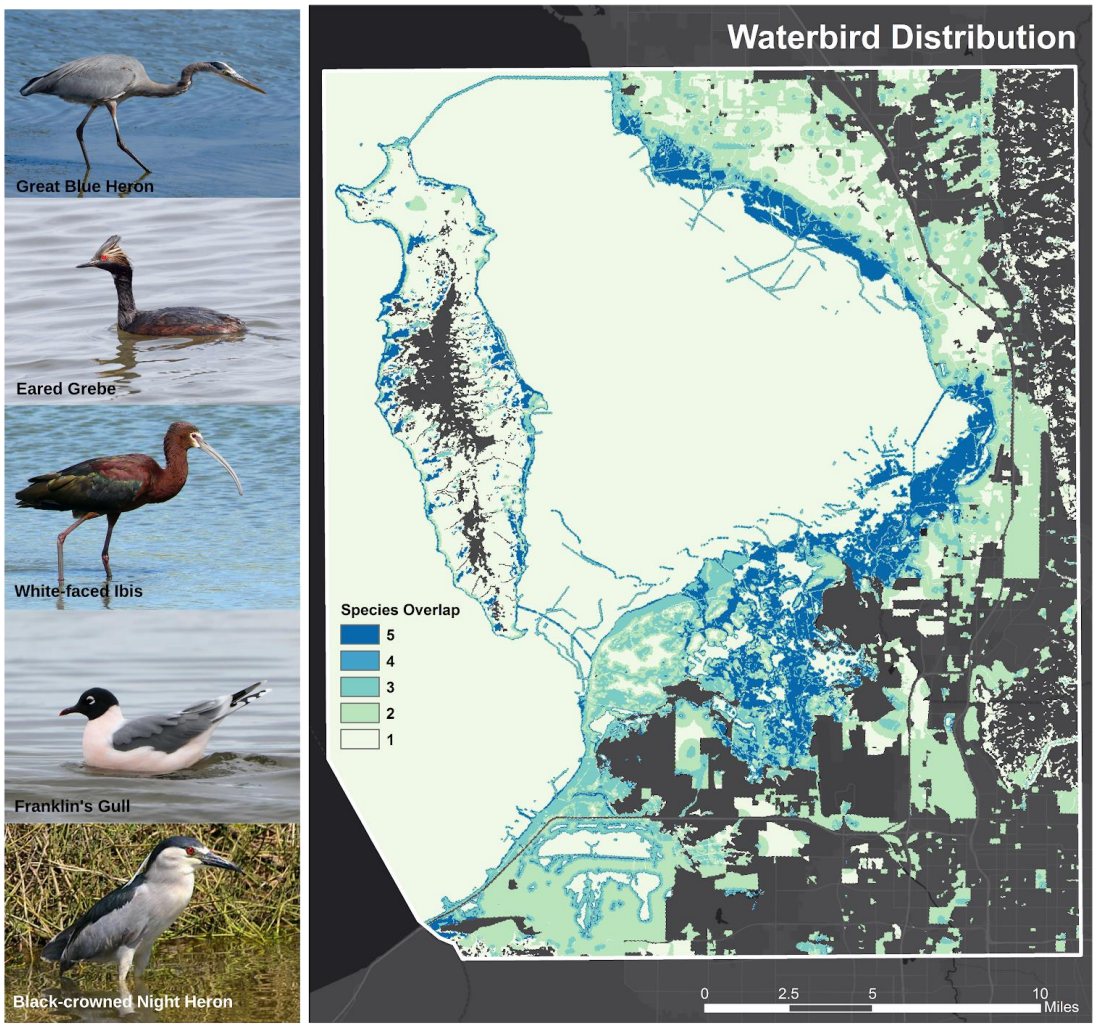

Figure 11. Waterbird guild distribution map. The combined distributions (from the USGS GAP data) of the five selected waterbird species. The darker blue colors indicate areas where more species' distributions overlap. The greatest overlap was between all five species' distributions. Photographs from the Google Images "labeled for reuse" section.

Table 3. Waterbird species acreage within the study site. The acreage of habitat within the study area for each of the five waterbird species in this study. It also includes the total percent of the study area that each species' distribution covers. All of the birds have similar percent covers of the study area, except for the Eared Grebe. Grebes are different from the other waterbirds in this selection, as they use open water for courtship, feeding, and resting, but require wetland areas for creating floating nests. The large amount of open water in my study area is the reason for the high percent cover of the study area.

Species	Acres of Habitat	Percent of Study Area
Black-crowned Night Heron	48776.1	13.1
Eared Grebe	190079.4	51.1
Franklin's Gull	41070.4	11.0
Great Blue Heron	77525.6	20.9
White-faced Ibis	102014.8	27.4

Quantifying Waterfowl Habitat in the Study Site

The waterfowl habitat is located predominantly around the edges of the lake, particularly at The Nature Conservancy's Great Salt Lake Shorelands Preserve on the eastern edge, the Farmington Bay Waterfowl Management Area on the southeast tip of the Bay, and at the wetlands just northwest of the Salt Lake City International Airport (Figure 12). While these species require some open water, the majority of them (with the exception of the Gadwall) prefer to stay close to shorelines, wetlands and other shallow-water structure for resting, nesting, and protection from predators. Other waterfowl species, such as the Tundra Swan or Snow Goose, use open water habitat similar to the Gadwall, but since the objectives of this research focus on identifying possible future conflicts with development, it was pertinent to select species that are more susceptible to development conflicts. The overall waterfowl distribution encompasses about 235,006 acres (95,103.6 ha), which is about 63% of the entire study area. There was no habitat in

37% of the study area. Five species' habitats overlapped for about 6% of the study area; four species' habitats overlapped for less than 6% of the study area; three species' habitats overlapped in less than 1% of the study area; two species' habitats overlapped for 5% of the study area; and areas with one waterfowl species' habitat comprised 46% of the area. The guild's species habitat distributions are further broken down in Table 3.

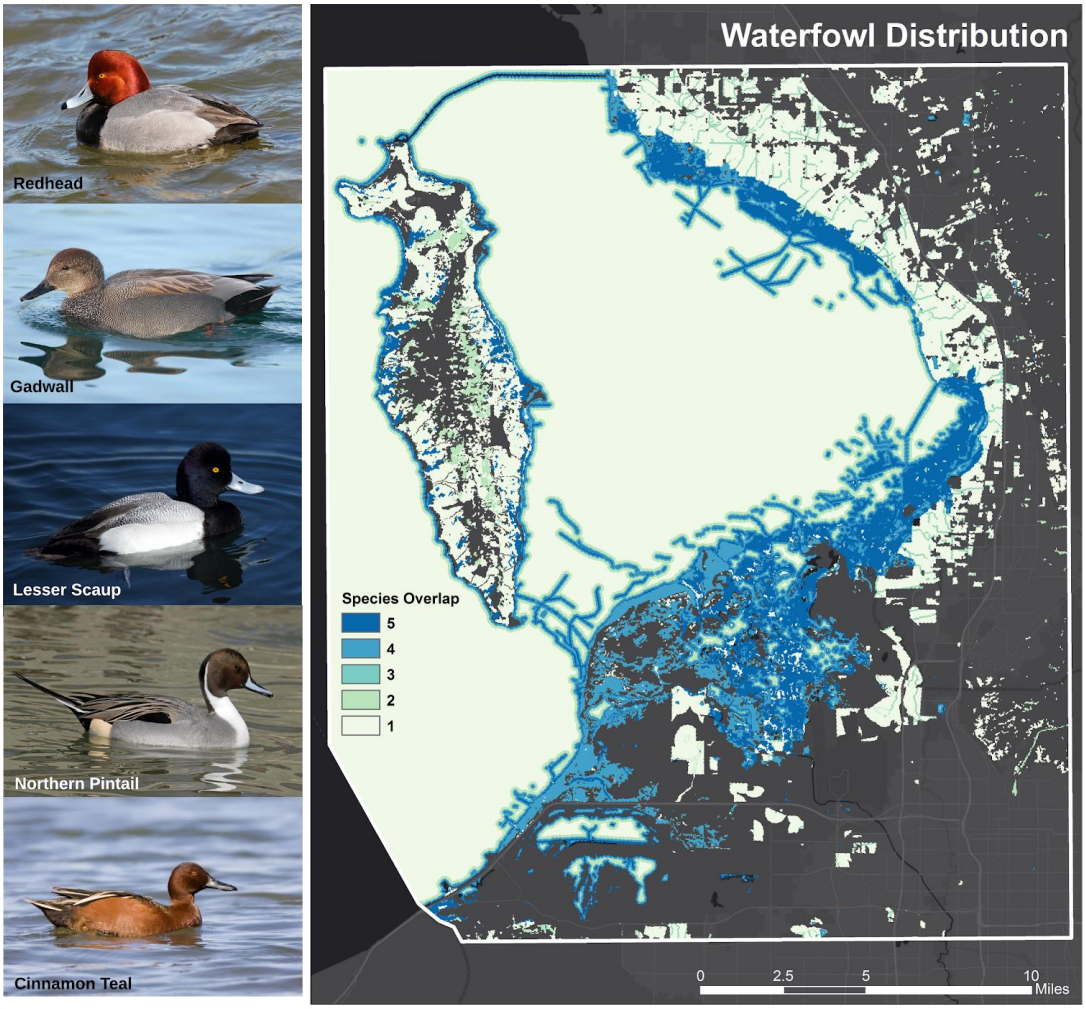

Figure 12. Waterfowl guild combined distribution map of the five selected waterfowl species. The darker blue colors indicate areas where more species' distributions overlap. Photographs from Google Images "labeled for reuse" section.

Table 4. Waterfowl species acreage within the study site. The acreage of habitat within the study area for each of the five waterfowl species in this study. It also includes the total percent of the study area that each species' distribution covers. All of the birds have similar percent covers of the study area, except for the Gadwall. Gadwalls are more amenable to feeding on plants and invertebrates in deeper, more open water than the other waterfowl species in this study. The large amount of open water in my study area is the reason for the high percent cover of the study area.

Species	Acres of Habitat	Percent of Study Area
Cinnamon Teal	32731.7	8.8
Gadwall	189641.1	51.0
Lesser Scaup	45727.7	12.3
Northern Pintail	96855.7	26.1
Redhead	49746.6	13.4

Quantifying the West Davis Corridor Conflicts with Migratory Bird Habitat

The West Davis Corridor project is a proposed 19-mile long four-lane highway located just east along Farmington Bay (Figure 13). It is likely to generate 2,090.74 acres (846.1 ha) of conflict for the three migratory bird guilds included in this assessment (Figure 14). Altogether, nearly 88% of this planned project is in conflict with the current migratory bird habitat, based on the USGS's GAP datasets. Each guild shows differing amounts of conflict with the WDC project: the shorebird (SB) guild shows the least amount of conflict with 1,762 acres (713.1 ha), the waterbird (WB) guild shows the greatest amount of conflict with 2,091 acres (846.2 ha), and the waterfowl (WF) guild shows 1,862 acres (753.5 ha) of conflict (Figure 14).

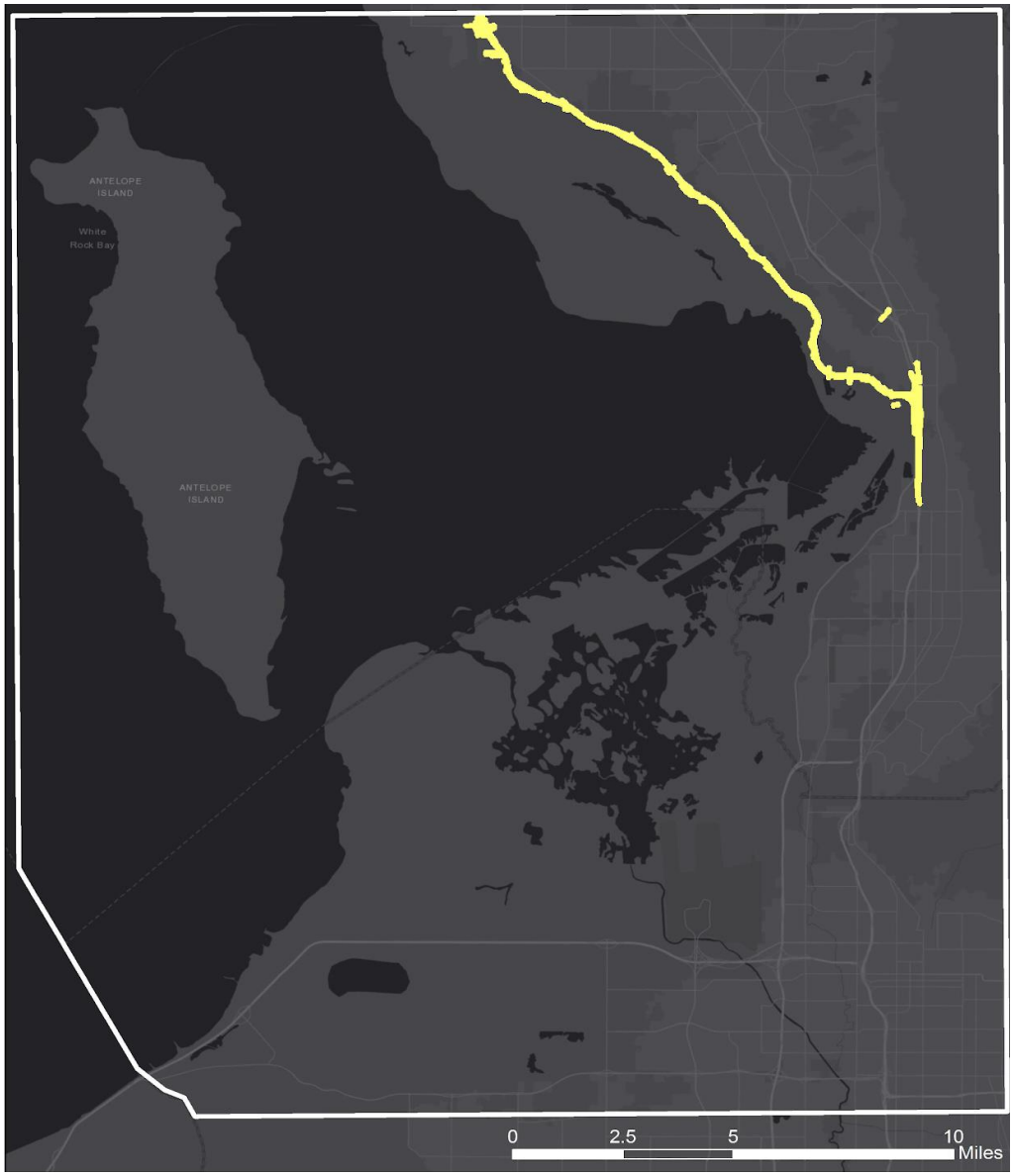

Figure 13. West Davis Corridor project extent map. The extent of the West Davis Corridor development project. It includes all of the spatial data from the WDC Project Manager (Randy Jefferies, personal communication). I buffered this project 300 feet to encapsulate some of the impacts (such as noise, light, and water pollution) to bordering wetlands, and other habitats that migratory birds use. There is only one development type for this project: *highway*. However, it is important to note that other types of development typically follow the construction of a highway, including gas stations, billboards, shops, and other infrastructure.

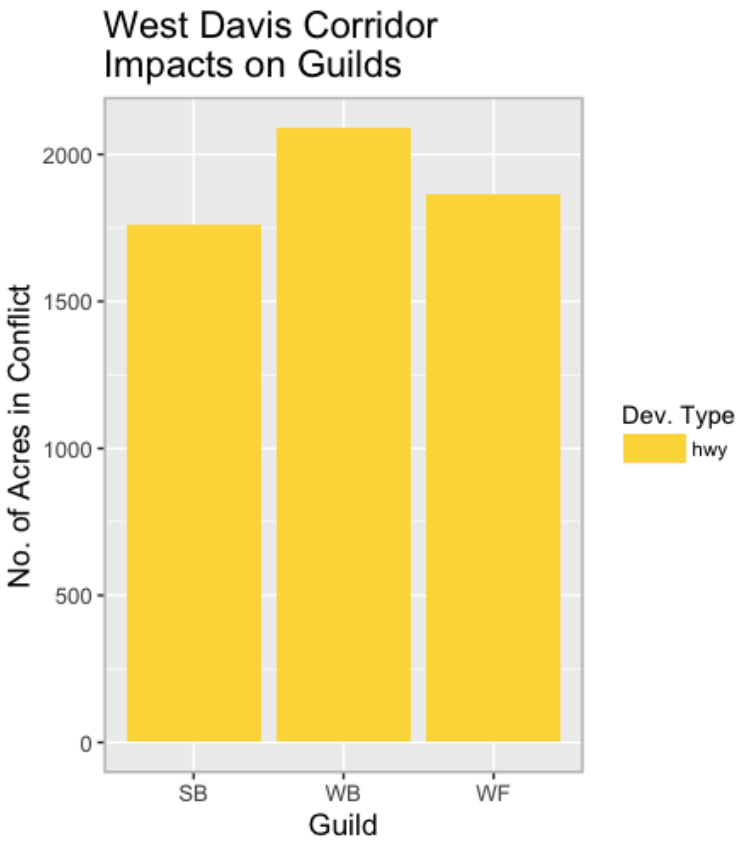

Figure 14. Graph of the West Davis Corridor guild habitat impacts. The overall impacts from the WDC project on each guild. The WDC project features one type of development: highway (yellow). The waterbird (WB) guild shows the greatest amount of conflict with this project, followed by the waterfowl (WF) guild, and lastly, the shorebird (SB) guild.

I initially performed the conflict assessment analysis solely for the three migratory bird guilds, and not for the individual species. However, the findings from the guild assessment created more questions than answers because the majority of conflict acres were primarily affecting one to three species, but I did not know which species, and to what extent they might be impacted. Each of the guild's distributions (Figures 10-12) demonstrate where multiple species' distributions overlap (darker blue), and where they do not (white). In order to address the disparities in conflicts between species within

guilds, I performed a conflict analysis for each species as well as each guild. Figure 15 shows conflict between the WDC project and each species' habitat in terms of the number of acres of habitat affected.

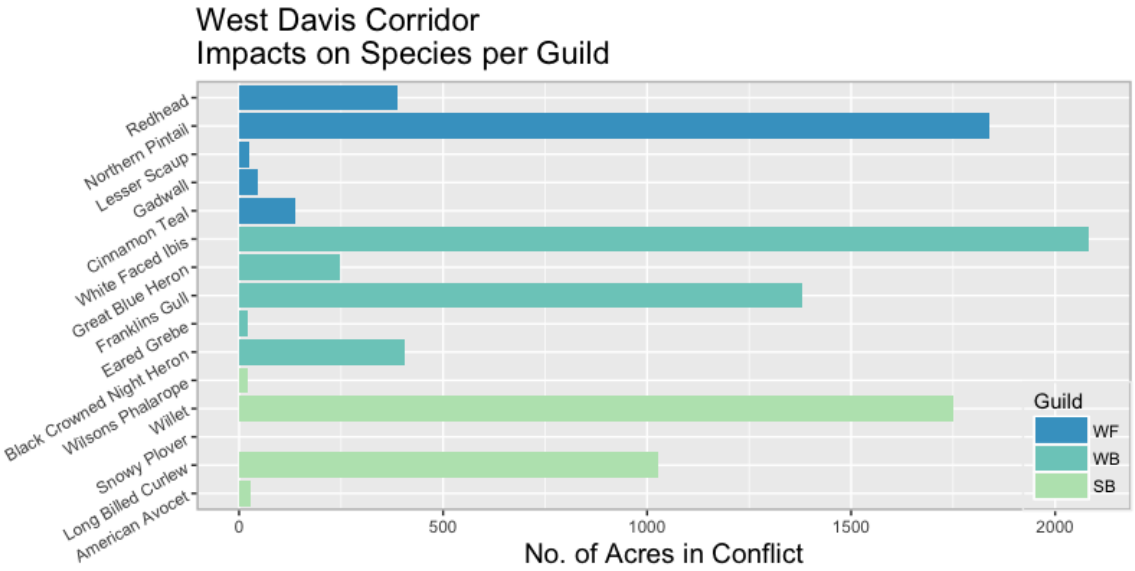

Figure 15. Graph of the West Davis Corridor species habitat impacts. The impacts from the WDC project on individual species' distributions. The species are grouped by guild: the shorebirds (SB) are the lightest teal, the waterbirds (WB) are the medium teal, and the waterfowl (WF) are the darkest teal.

The five species that show the greatest conflict with the WDC project are the white-faced ibis (2,083 acres (843.0 ha)), the northern pintail (1,838 acres (743.8 ha)), the willet (1,751 acres (708.6 ha)), Franklin's gull (1,381 acres (558.9 ha)), and the long-billed curlew (1,028 acres (416.0 ha)); all three guilds are represented in this list. These particular species' habitats are the primary reason for the high level of conflict with this project (Figure 15). All five species have an expansive amount of habitat along the eastern edge of Farmington Bay, which is where this project is planned to be built. There was one species that had no conflict with this project: the snowy plover. This result is

unsurprising as this bird is a small shorebird that nests along sandy, non-vegetated shores near open water, which are primarily located farther south in the study area. The guilds show similar areas of conflict for this project (Figures 16-19). There are small differences in conflict areas, but the main difference lays around the highway interchange between the WDC project, and the Legacy Parkway and I-15 Highway (at the southern tip of the WDC project). Ultimately, the high level of congruency between conflict areas for all three guilds and the fact that nearly 90% of this project shows direct conflict with current migratory bird habitat makes this project a highly contentious project concerning impacts to migratory bird habitat in the area.

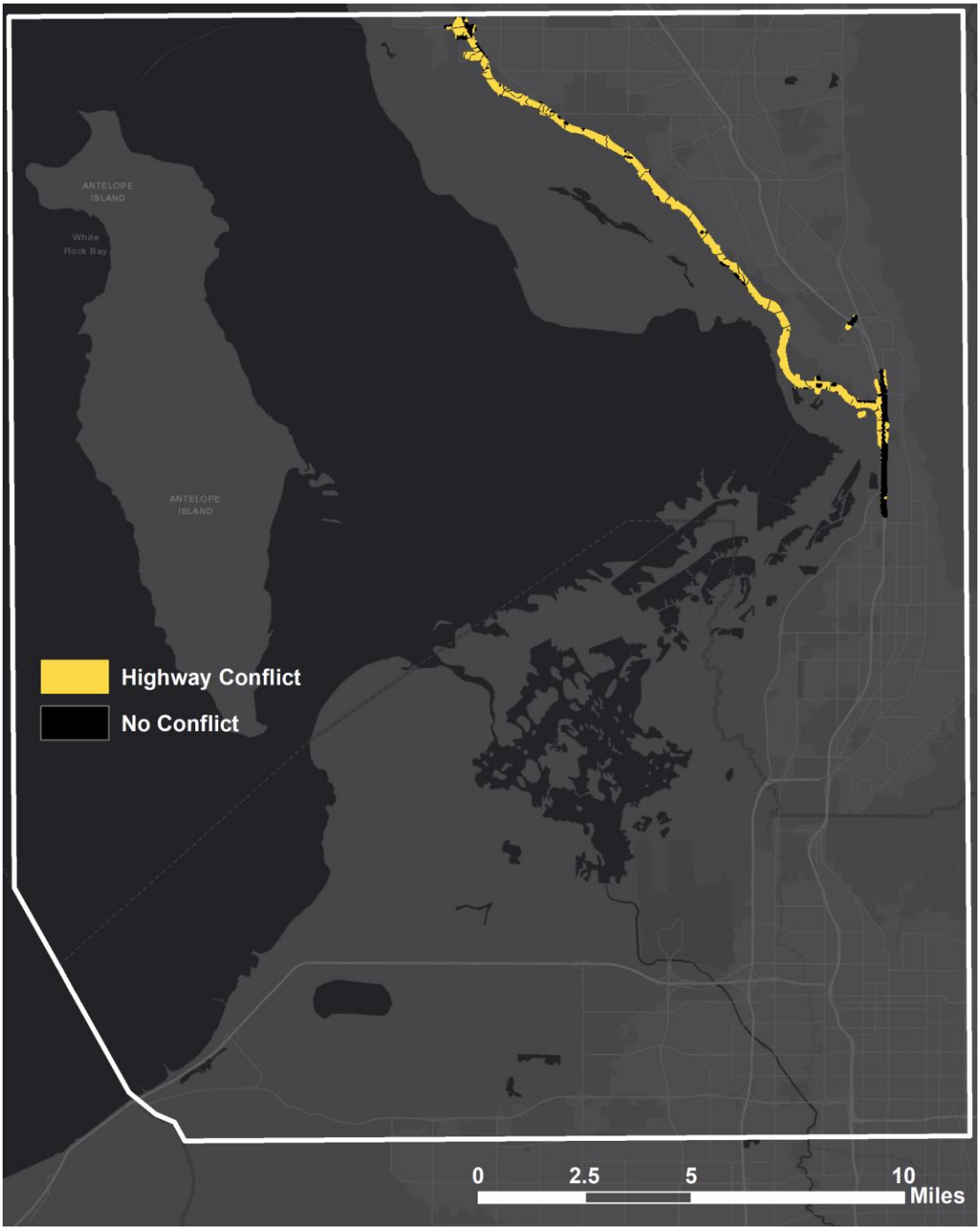

Figure 16. Map of the West Davis Corridor conflicts with shorebird habitat. All areas of the WDC project that are in conflict with the current shorebird distribution, totaling 1,762 acres of conflict (about 74% of the total project area).

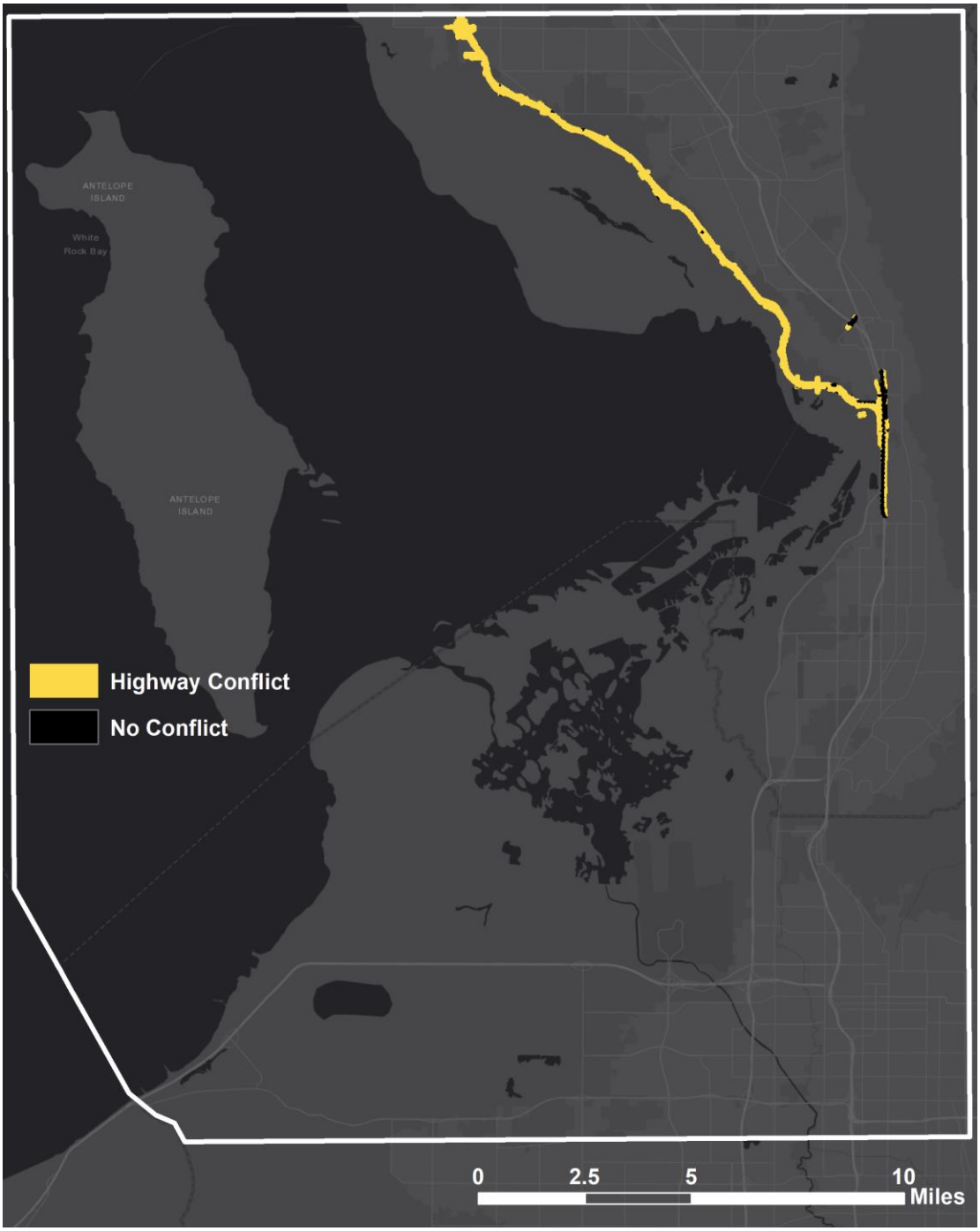

Figure 17. Map of the West Davis Corridor conflicts with waterbird habitat. All areas of the WDC project that are in conflict with the current waterbird distribution, totaling 2,091 acres of conflict (about 88% of the total project area).

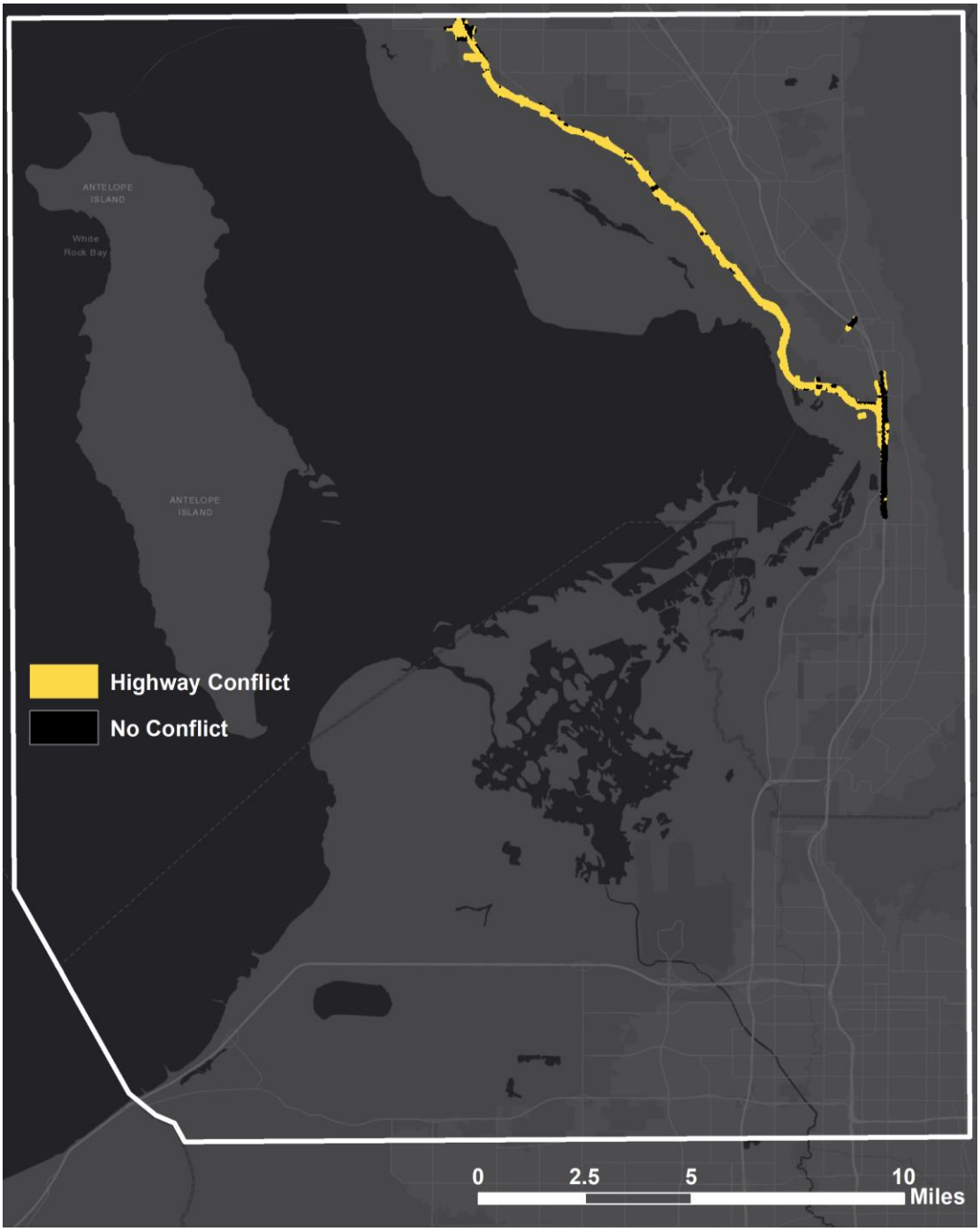

Figure 18. Map of the West Davis Corridor conflicts with waterfowl habitat. All areas of the WDC project that are in conflict with the current waterfowl distribution, totaling 1,862 acres of conflict (about 78% of the total project area).

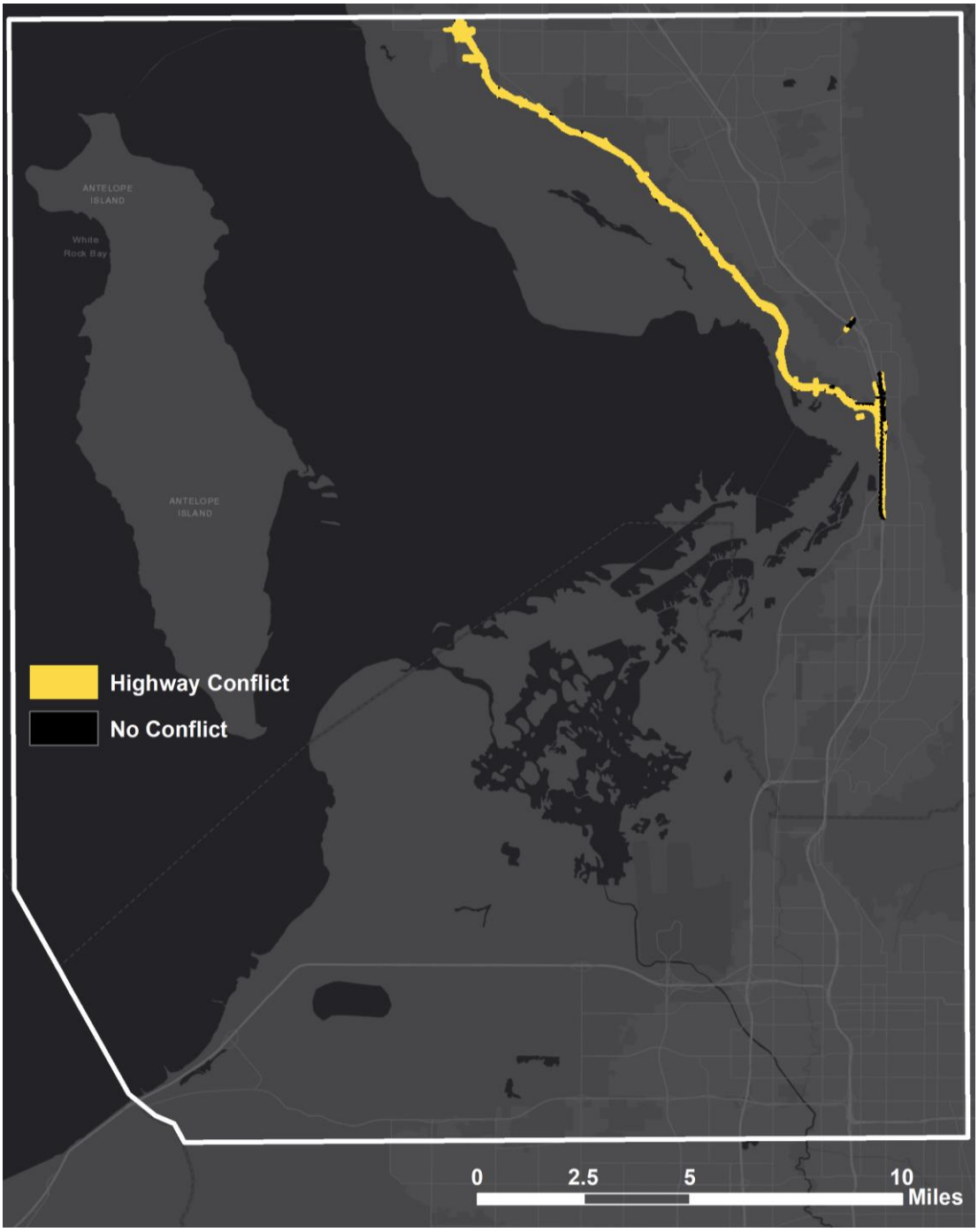

Figure 19. Map of the West Davis Corridor conflicts with all migratory bird habitat. All areas of the WDC project that are in conflict with the all three combined migratory bird distributions for this study. About 88% (2,091 acres) of this project is in conflict with the current migratory bird habitat in the area.

Quantifying the Northwest Quadrant Conflicts with Migratory Bird Habitat

The Northwest Quadrant project is a large proposed development project located south of Farmington Bay, and west of downtown Salt Lake City (Figure 20). It is likely to generate 4,526.85 acres (1832.0 ha) of conflict for the three migratory bird guilds included in this assessment. Altogether, nearly 30% of this planned project is in conflict with the current migratory bird habitat, based on the USGS's GAP datasets. Each guild shows differing amounts of conflict with the NWQ project: the shorebird (SB) guild shows 3,421 acres (1,384.4 ha) of conflict (3,342 from industrial development and about 79 from commercial development), the waterbird (WB) guild shows the greatest amount of potential conflict with 4,522 acres (1,830.0 ha) (4,438 from industrial development and about 84 from commercial development), and the waterfowl (WF) guild shows the least amount of potential conflict with 2,166 acres (876.5 ha) (2,137 from industrial development and about 29 from commercial development) (Figure 21). Industrial development is by far more disruptive than commercial development in this project, based on the number of acres in conflict with current migratory bird habitat (Figures 21-26).

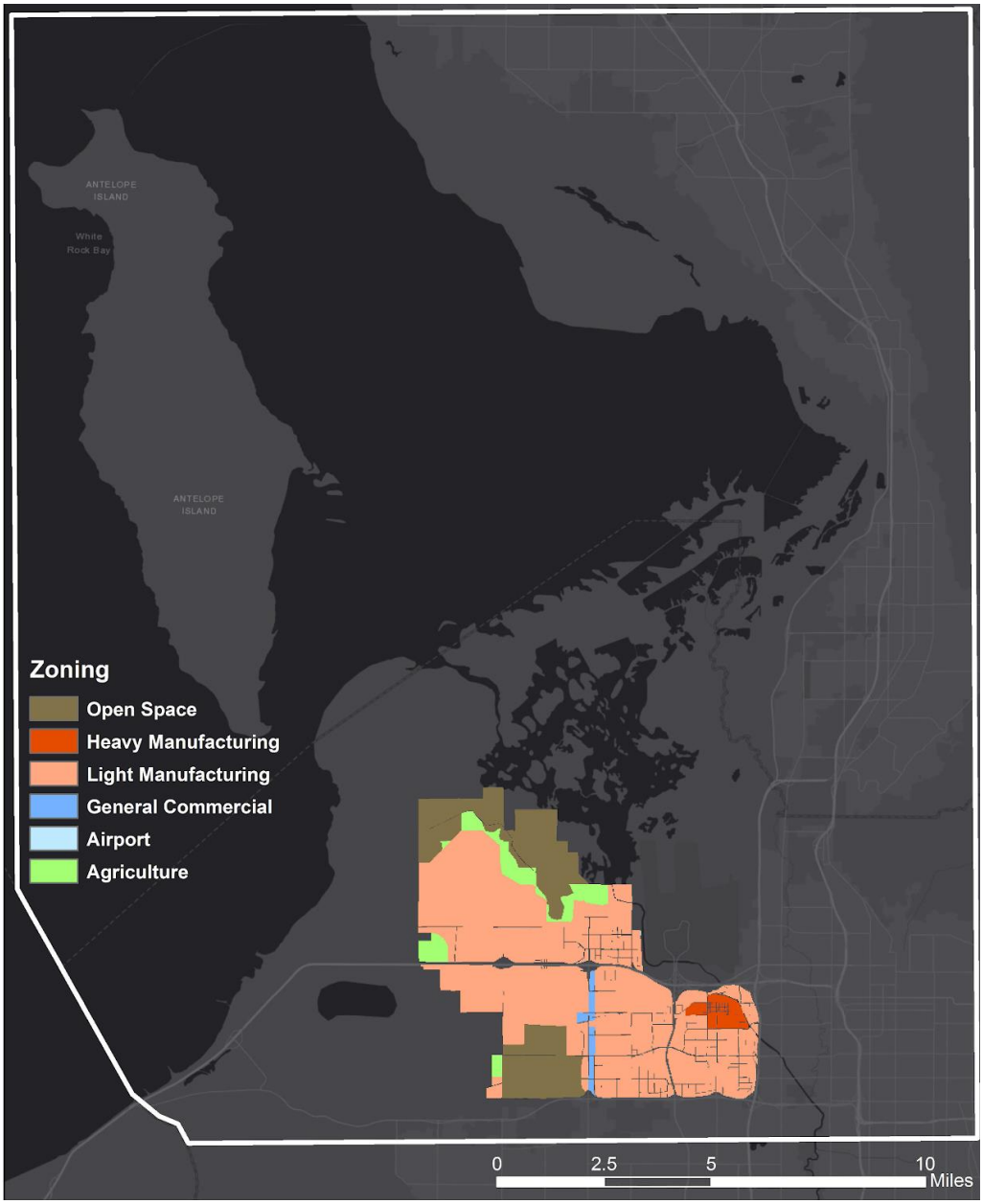

Figure 20. Northwest Quadrant project extent map. The extent of the Northwest Quadrant development project. It includes all of the spatial data from Salt Lake City's GIS website. This is zoning data for Salt Lake City's development of the NWQ, and not the actual zoning for the NWQ as an inland port, as that data has yet to be made available. Since open space and agricultural land uses are typically used by birds as habitat, I only used the areas zoned for "Heavy Manufacturing," "Light Manufacturing," "General Commercial," and "Airport" in my analysis on impacts to bird habitat. The manufacturing and airport data were combined to form the *industrial* development type, and the commercial data was used for the *commercial* development type for this project.

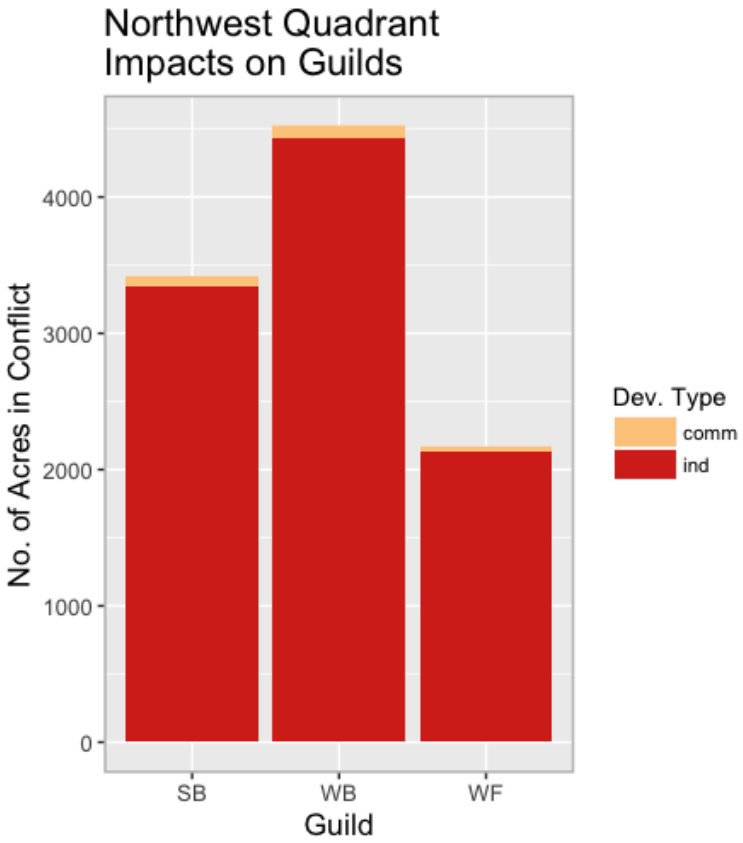

Figure 21. Graph of the Northwest Quadrant guild habitat impacts. The overall impacts from the NWQ project on each guild. The NWQ project features two types of development: commercial (tan) and industrial (red). The WB guild shows the greatest amount of conflict with this project, followed by the SB guild, and lastly the WF guild, which showed the least amount of conflict with this project in terms of the total number of acres in conflict.

The conflict analysis for all 15 species show that four species in particular are likely to be the most impacted by the NWQ project: the white-faced ibis (4,457 acres (1,803.7 ha)), the willet (2,716 acres (1,099.1 ha)), the long-billed curlew (2,084 acres (843.4 ha)), and the northern pintail (2,041 acres (826.0 ha)); all three guilds are represented in this list (Figure 22). There are three waterbird species that show similar levels of conflict around 1,200 acres (485.6 ha): Franklin's gull, the black-crowned night

heron, and the great blue heron. The two species with the least amount of conflict with the NWQ project are the snowy plover (105 acres (42.5 ha)) and Wilson's phalarope (78 acres (31.6 ha)) (Figure 22).

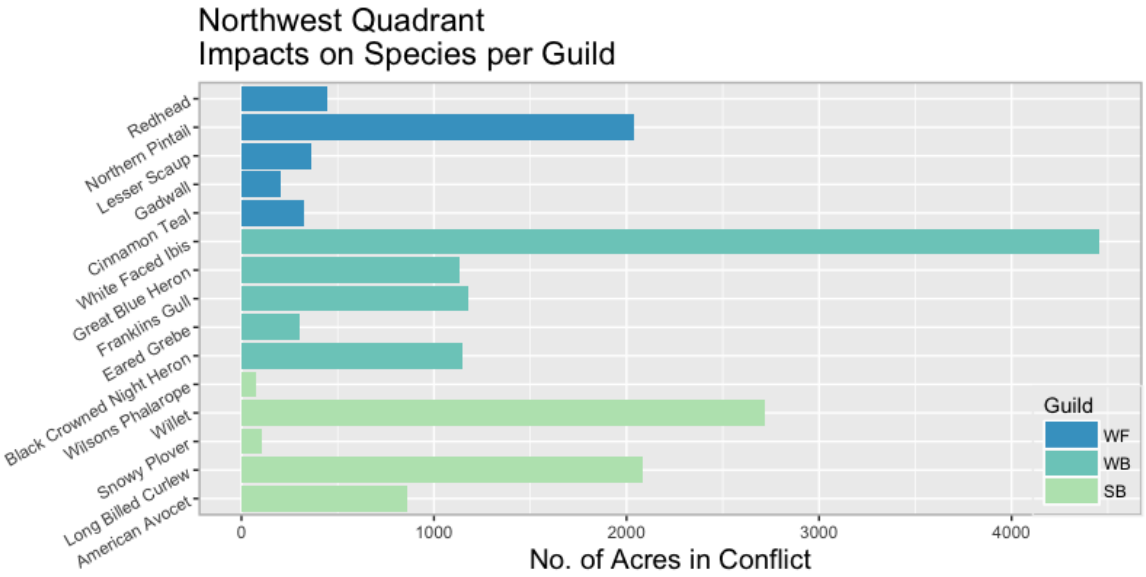

Figure 22. Graph of the Northwest Quadrant species habitat impacts. The impacts from the NWQ project on individual species' distributions. The species are grouped by guild: the shorebirds (SB) are the lightest teal, the waterbirds (WB) are the medium teal, and the waterfowl (WF) are the darkest teal.

The four most impacted species have habitat around the southern portion of Farmington Bay, where the NWQ project is located. Most of their habitats are located in and around open space, agricultural land, and wetlands in the area, while other species, particularly some shorebirds, use the mudflats, playas, and even evaporation ponds that expand and contract as floods occur and the water level changes. The Northwest Quadrant area is going to have very different land covers and land uses as an inland port, with much more industrial and commercial development in the way of storage facilities, office space, roads, and manufacturing buildings, as well as more human comforts and

amenities, such as parking lots, restaurants, and shops (Cambridge Systematics, Inc., 2017).

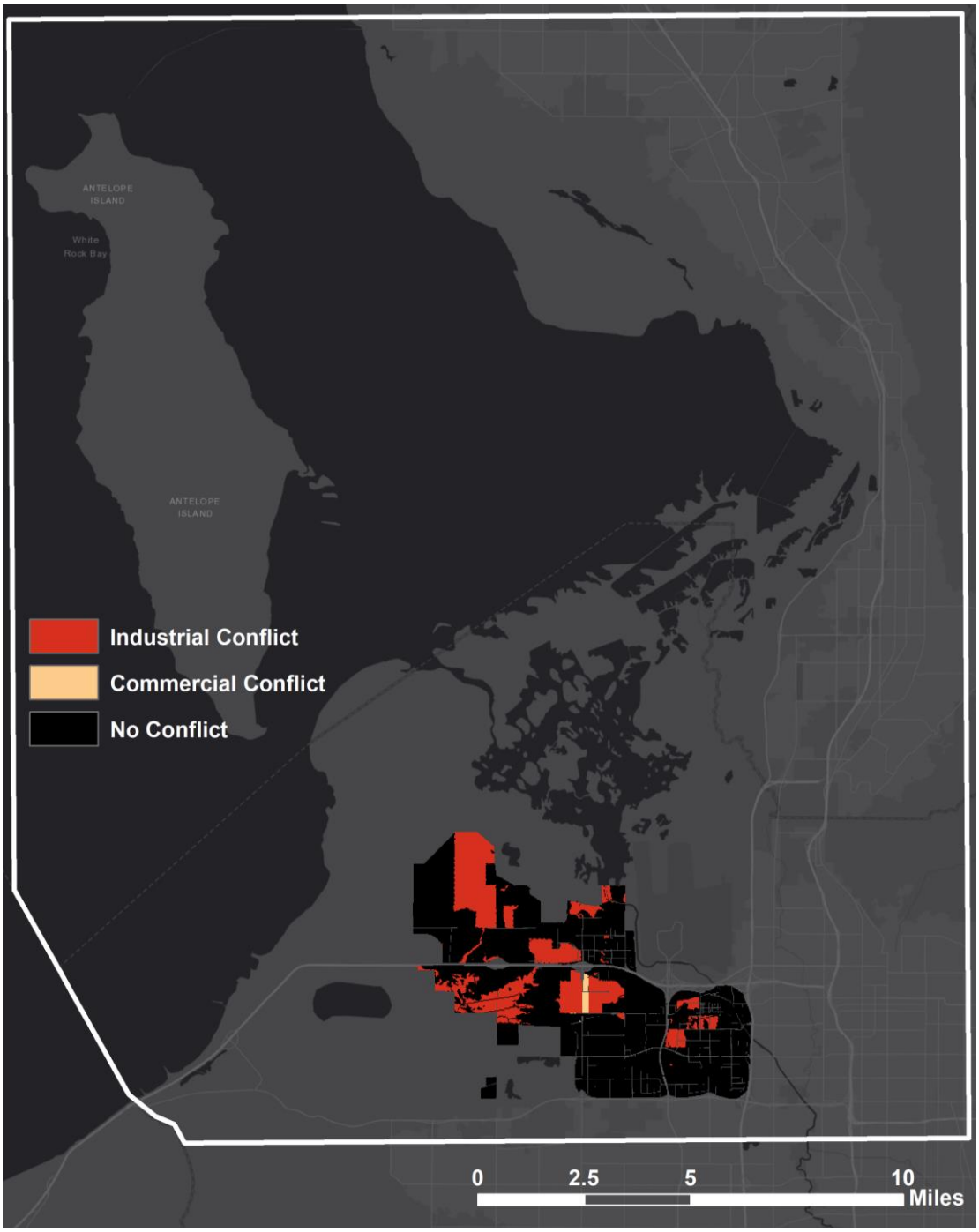

Figure 23. Map of the Northwest Quadrant conflicts with shorebird habitat. All areas of the NWQ project that are in conflict with the current shorebird distribution, totaling 79 acres of commercial development conflict (tan), and 3,342 acres of industrial development conflict (red), totaling 3,421 acres of conflict altogether (about 22% of the total project area).

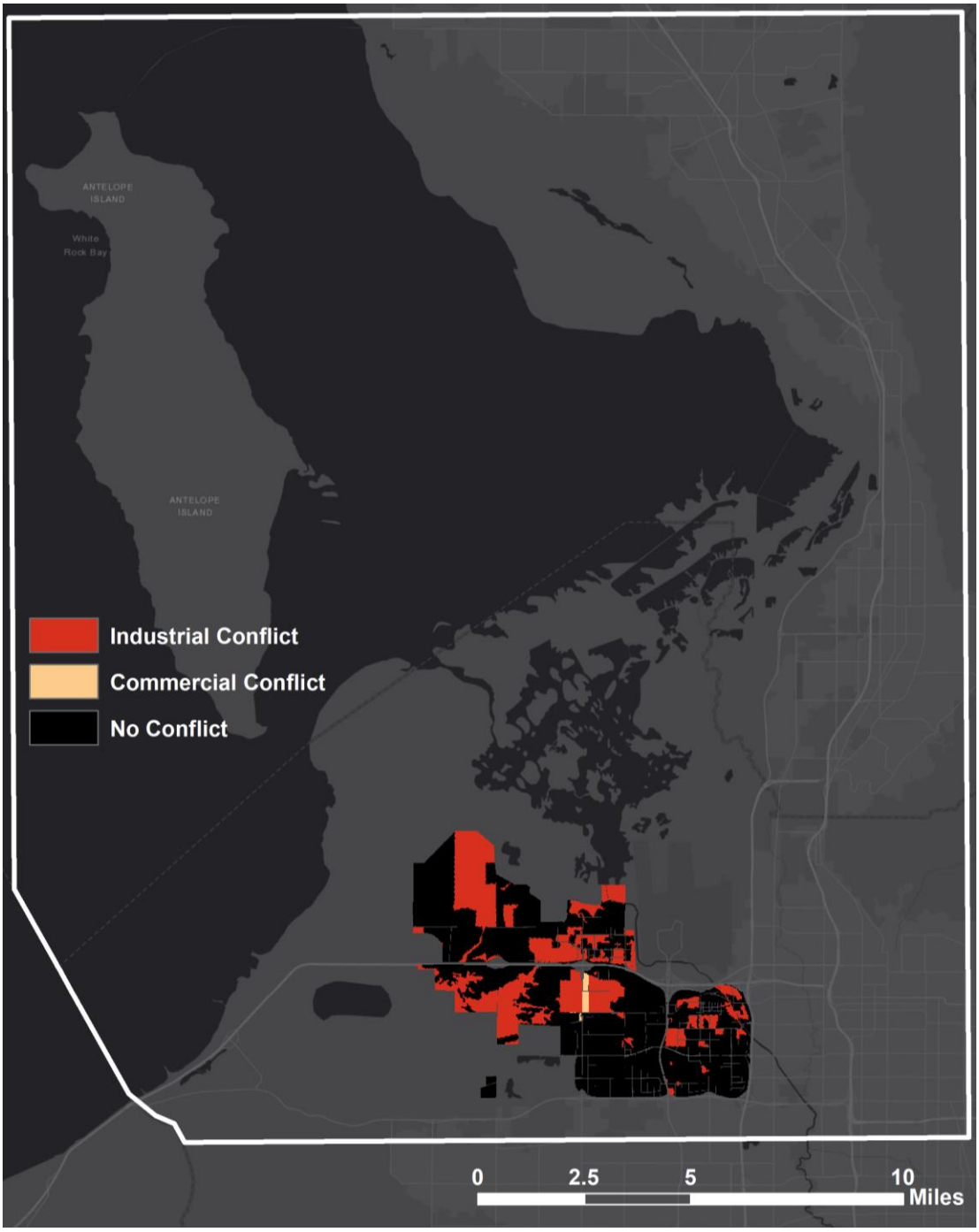

Figure 24. Map of the Northwest Quadrant conflicts with waterbird habitat. All areas of the NWQ project that are in conflict with the current waterbird distribution, totaling 84 acres of commercial development conflict (tan), and 4,438 acres of industrial development conflict (red), totaling 4,522 acres of conflict altogether (about 29% of the total project area).

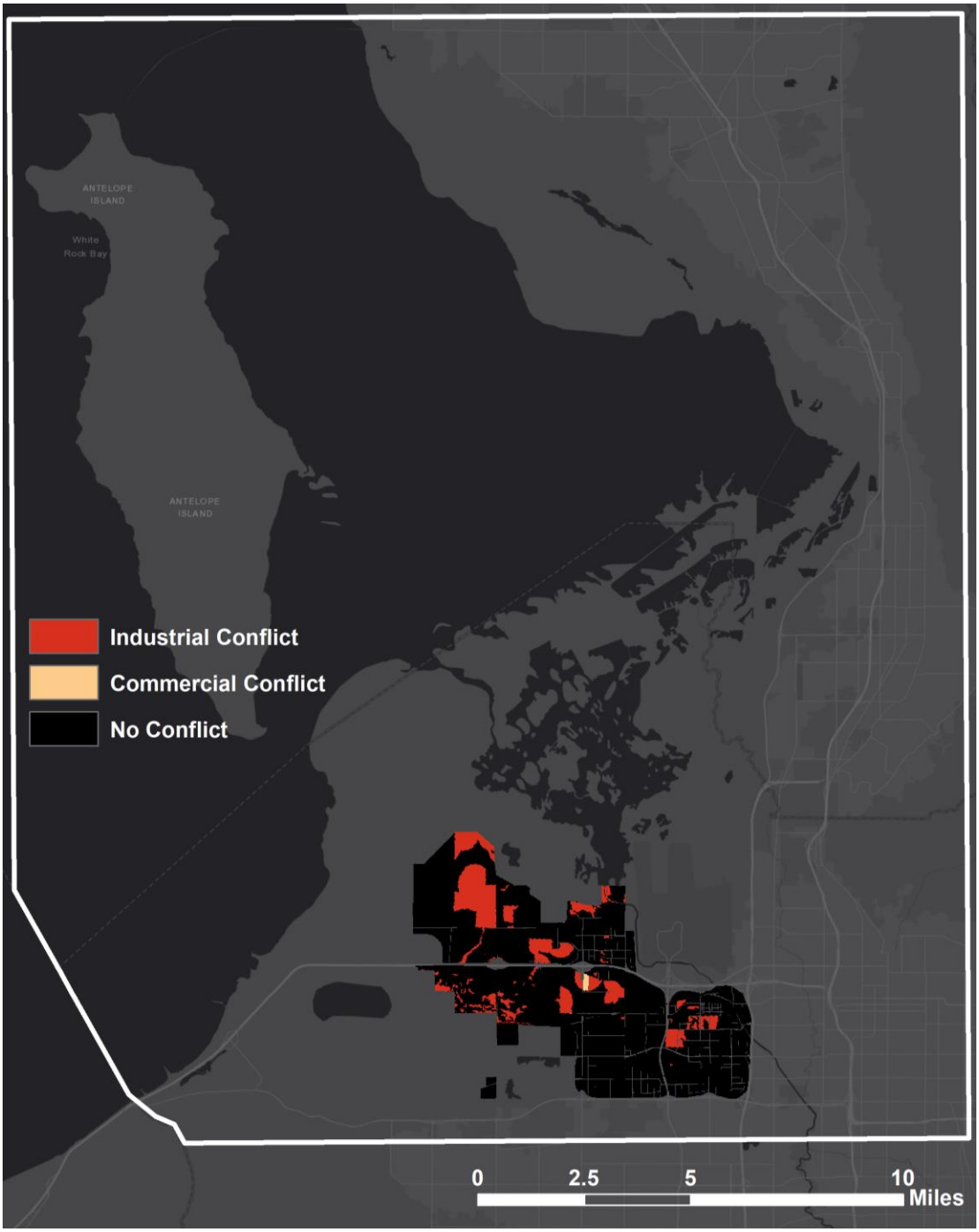

Figure 25. Map of the Northwest Quadrant conflicts with waterfowl habitat. All areas of the NWQ project that are in conflict with the current waterfowl distribution, totaling 30 acres of commercial development conflict (tan), and 2,137 acres of industrial development conflict (red), totaling 2,166 acres of conflict altogether (about 14% of the total project area).

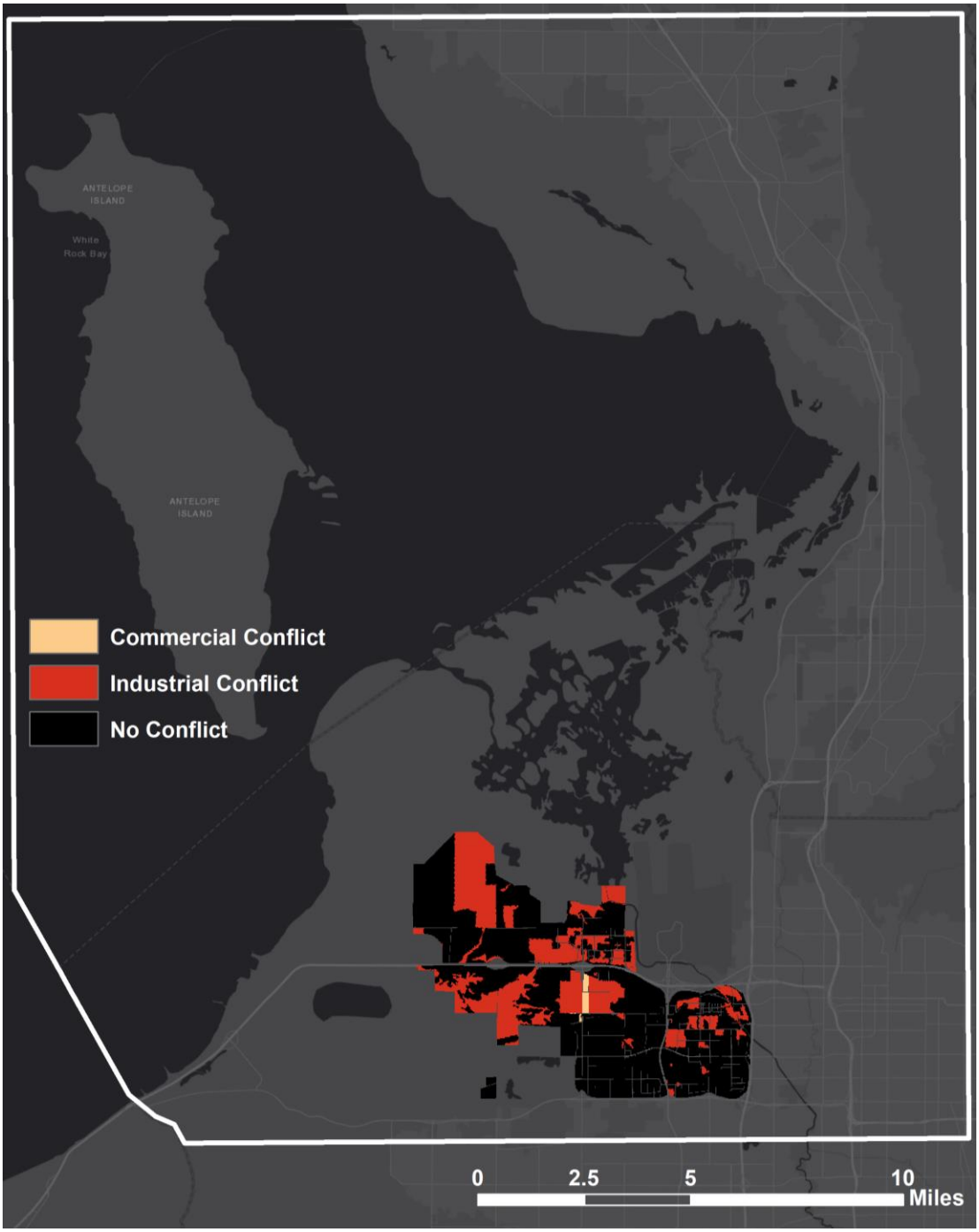

Figure 26. Map of the Northwest Quadrant conflicts with all migratory bird habitat. All areas of the NWQ project that are in conflict with the all three combined migratory bird distributions for this study. Nearly 30% (4,522 acres) of this project is in conflict with the current migratory bird habitat in the area with commercial development conflicts shown in tan, and industrial development conflicts shown in red.

Quantifying the Wasatch Choice 2040 Vision Conflicts with Migratory Bird Habitat

The Wasatch Choice 2040 Vision project is a comprehensive development plan that focuses on meeting future needs of the Wasatch Front, while promoting growth in centers throughout the region (Figure 27). It is likely to generate 8,980.31 acres (3,634.2 ha) of conflict for the three migratory bird guilds included in this assessment. Altogether, nearly 50% of this planned project is in conflict with the current migratory bird habitat, based on the USGS's GAP datasets. Each guild has differing amounts of conflict with the Vision project: the shorebird (SB) guild has 6,050 acres (2,448.3 ha) of conflict (4,262 acres from residential development, 1,252 from industrial development, and 536 from commercial development), the waterbird (WB) guild has 8,861 acres (3,586.0 ha) of conflict (5,694 from residential development, 2,285 from industrial development, and 882 from commercial development), and the waterfowl (WF) guild has 5,703 acres (2,307.9 ha) of conflict (4,385 from residential development, 847 from industrial development, and 471 from commercial development) (Figure 28). Residential development is by far the most disruptive of the three development types involved in this project, based on the amount of acres in conflict with current migratory bird habitat (Figures 28-33).

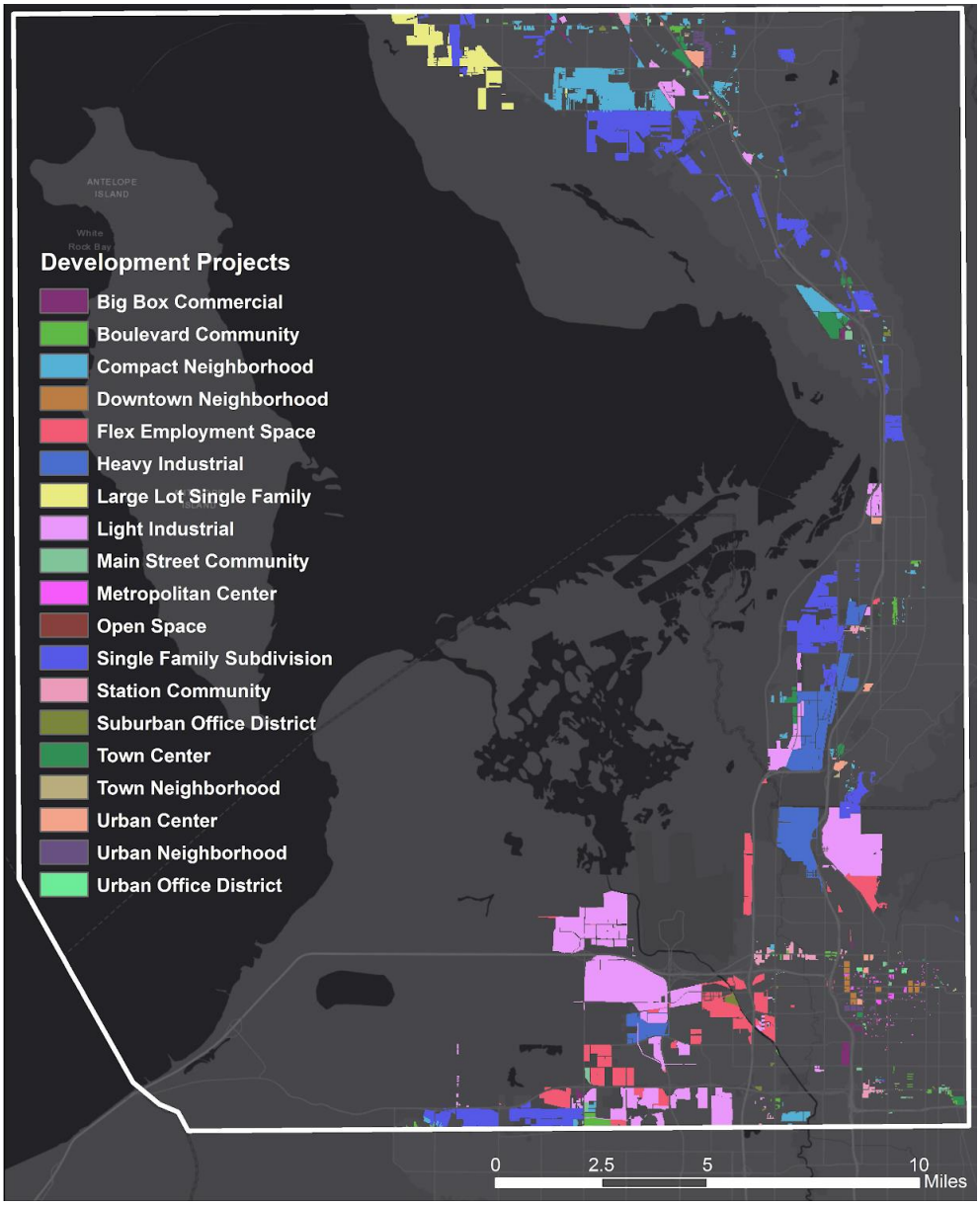

Figure 27. Wasatch Choice 2040 Vision project extent map. The extent of the Wasatch Choice 2040 Vision development project, including the spatial data from the Wasatch Front Regional Council (Scott Festin, personal communication). The *industrial* development type of this project is composed of the light and heavy industrial land uses, and the "Metropolitan Center." The *commercial* development type is composed of the "Station," "Main Street," and "Boulevard" communities, and the "Flex Employment Space," "Big Box Commercial," "Town Center," "Urban Center," "Suburban Office District," and "Urban Office District" land uses. The *residential* development type is composed of the "Compact," "Town," and "Downtown" neighborhoods, as well as the "Single Family Subdivision," "Urban Neighborhood," and "Large Lot Single Family"

land uses. These land uses were assigned to each category based on their descriptions in the Wasatch Choice 2040 Regional Vision Report.

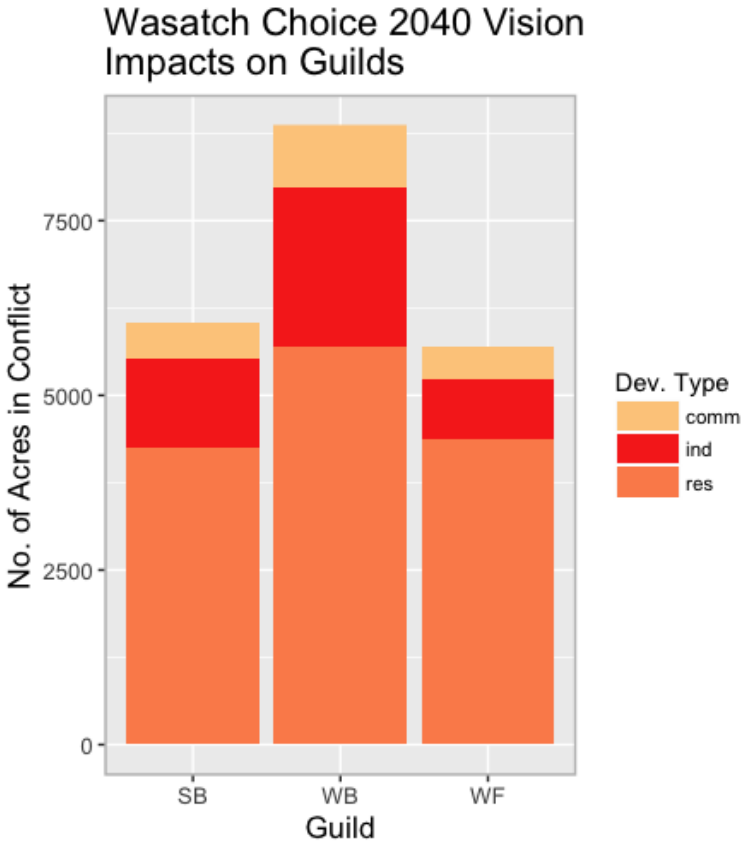

Figure 28. Graph of the Wasatch Choice 2040 Vision guild habitat impacts. The overall impacts from the Vision project on each guild. The Vision project features three types of development: commercial (tan), industrial (red), and residential (orange). The WB guild shows the greatest amount of conflict with this project, followed by the SB guild, and lastly the WF guild, which showed the least amount of conflict with this project in terms of the total number of acres in conflict. Of all three development types, residential development created the most conflict.

The conflict analysis for all 15 species show that five species in particular are likely to be the most impacted by the Vision project: the white-faced ibis (8,421 acres (3,407.9 ha)), the northern pintail (5,632 acres (2,279.2 ha)), the willet (5,541 acres (2,242.4 ha)), the great blue heron (3,088 acres (1,249.7 ha)), and Franklin's gull (2,196 acres (888.7 ha)); all three guilds are represented in this list (Figure 29). The species with

the least amount of conflict with the Vision project is the snowy plover (23 acres (9.3 ha)), closely followed by the American avocet (43.4 acres (17.6 ha)), the lesser scaup (43.4 acres (17.6 ha)), and the eared grebe (44.0 acres (17.8 ha)).

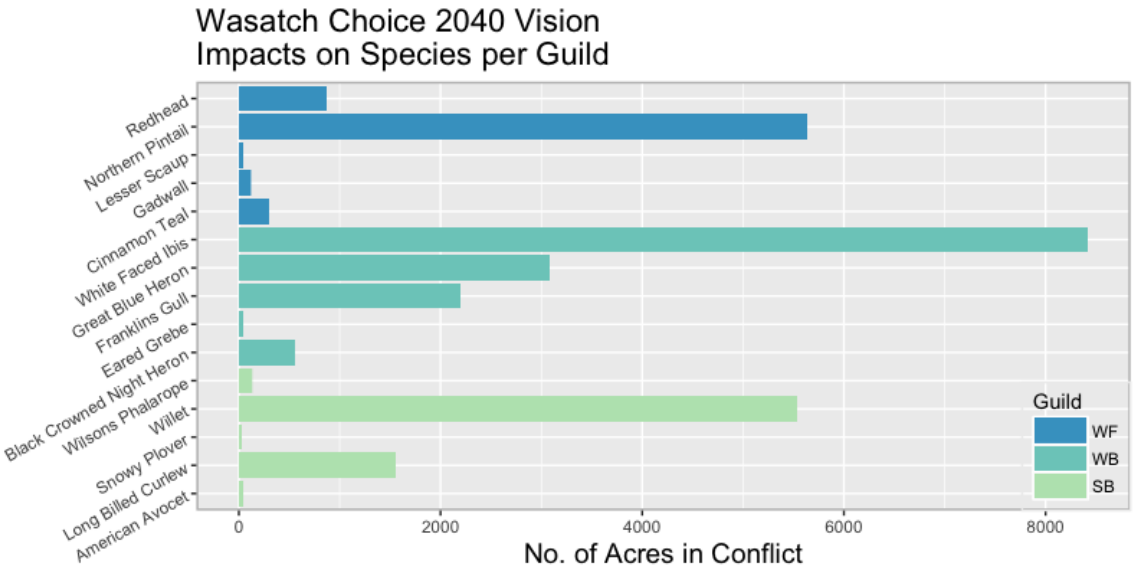

Figure 29. Graph of the Wasatch Choice 2040 Vision species habitat impacts. The impacts from the Vision project on individual species' distributions. The species are grouped by guild: the shorebirds (SB) are the lightest teal, the waterbirds (WB) are the medium teal, and the waterfowl (WF) are the darkest teal.

The five most impacted species have habitat located throughout the Wasatch Front, particularly on the northeastern side of Farmington Bay, which is where a large portion of residential development has been proposed in this project (Figures 30-33). Industrial development conflicts are the biggest concern in the southern portion of the study area, near the proposed inland port and just south of North Salt Lake City, east of I-15. Small areas of commercial development conflict are scattered throughout the corridor. Open space, parks, agricultural land, fields, and ponds all provide habitat to

species from all three guilds. As development expands, these smaller, urban habitats are likely to decrease in quality and quantity in terms of habitat for birds.

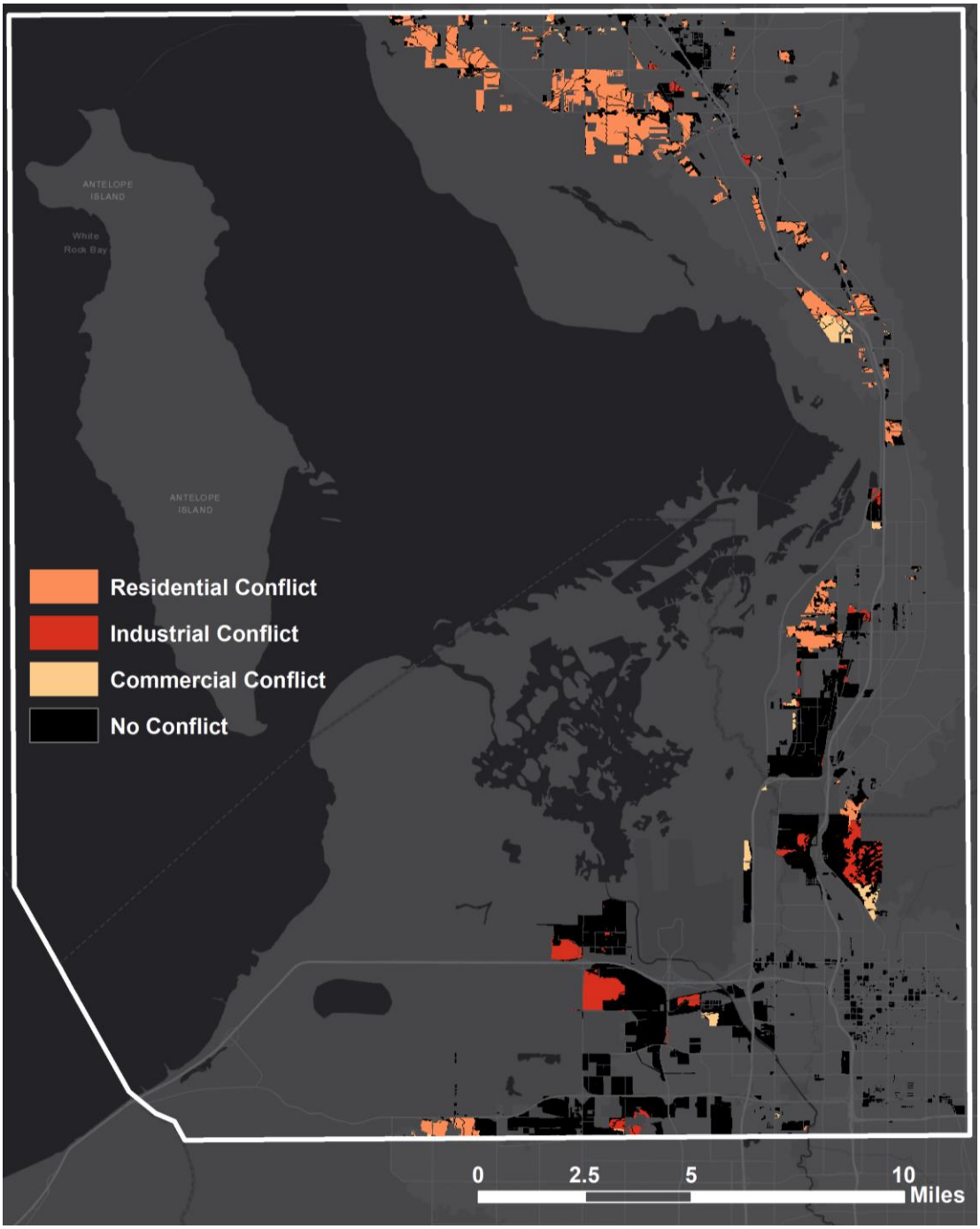

Figure 30. Map of the Wasatch Choice 2040 Vision conflicts with shorebird habitat. All areas of the Vision project that are in conflict with the current shorebird distribution, totaling 536 acres of commercial development conflict (tan), 1,252 acres of industrial development conflict (red), and 4,262 acres of residential development (orange), totaling 6,050 acres of conflict altogether (about 33% of the total project area).

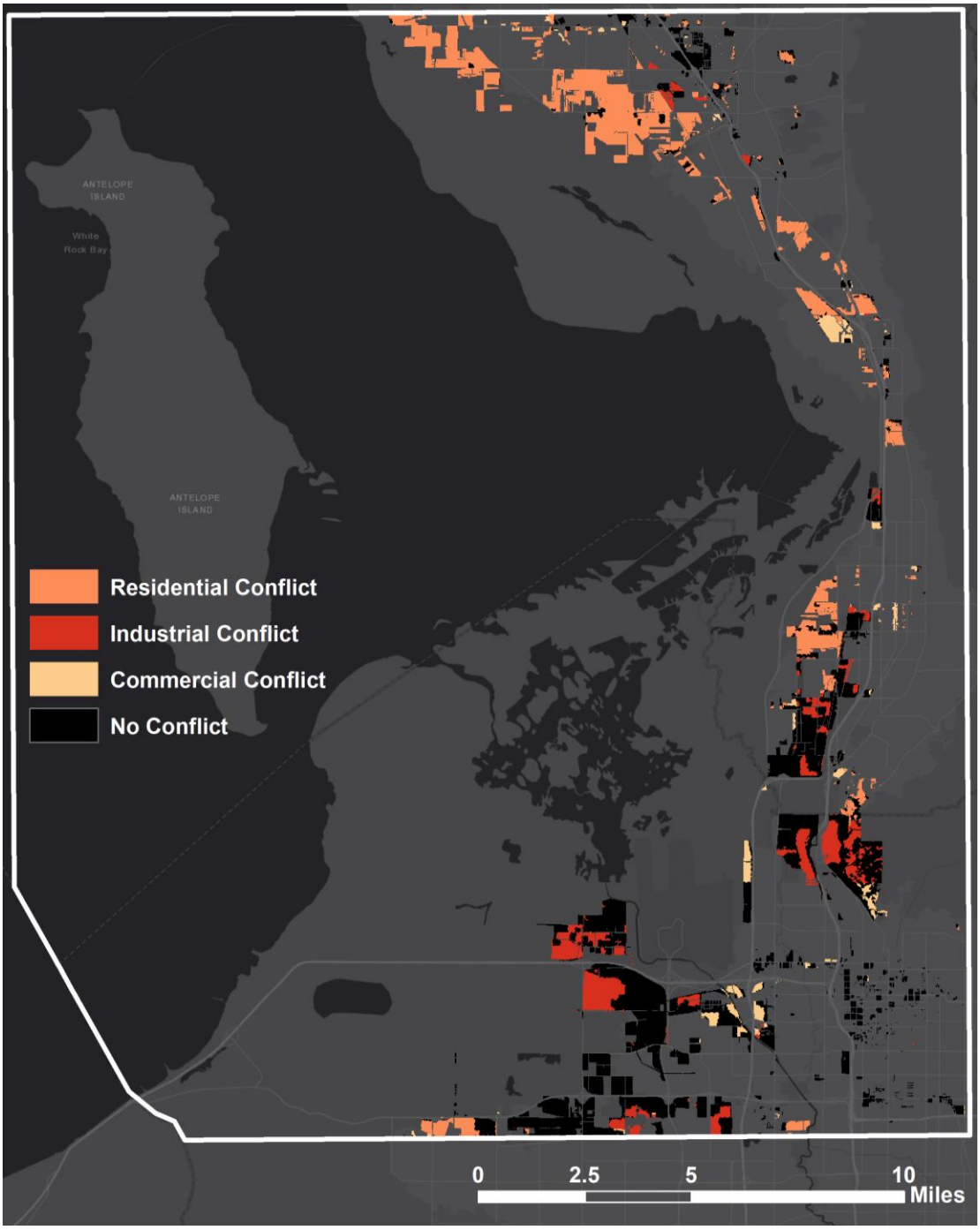

Figure 31. Map of the Wasatch Choice 2040 Vision conflicts with waterbird habitat. All areas of the Vision project that are in conflict with the current waterbird distribution, totaling 882 acres of commercial development conflict (tan), 2,285 acres of industrial development conflict (red), and 5,694 acres of residential development (orange), totaling 8,861 acres of conflict altogether (about 49% of the total project area).

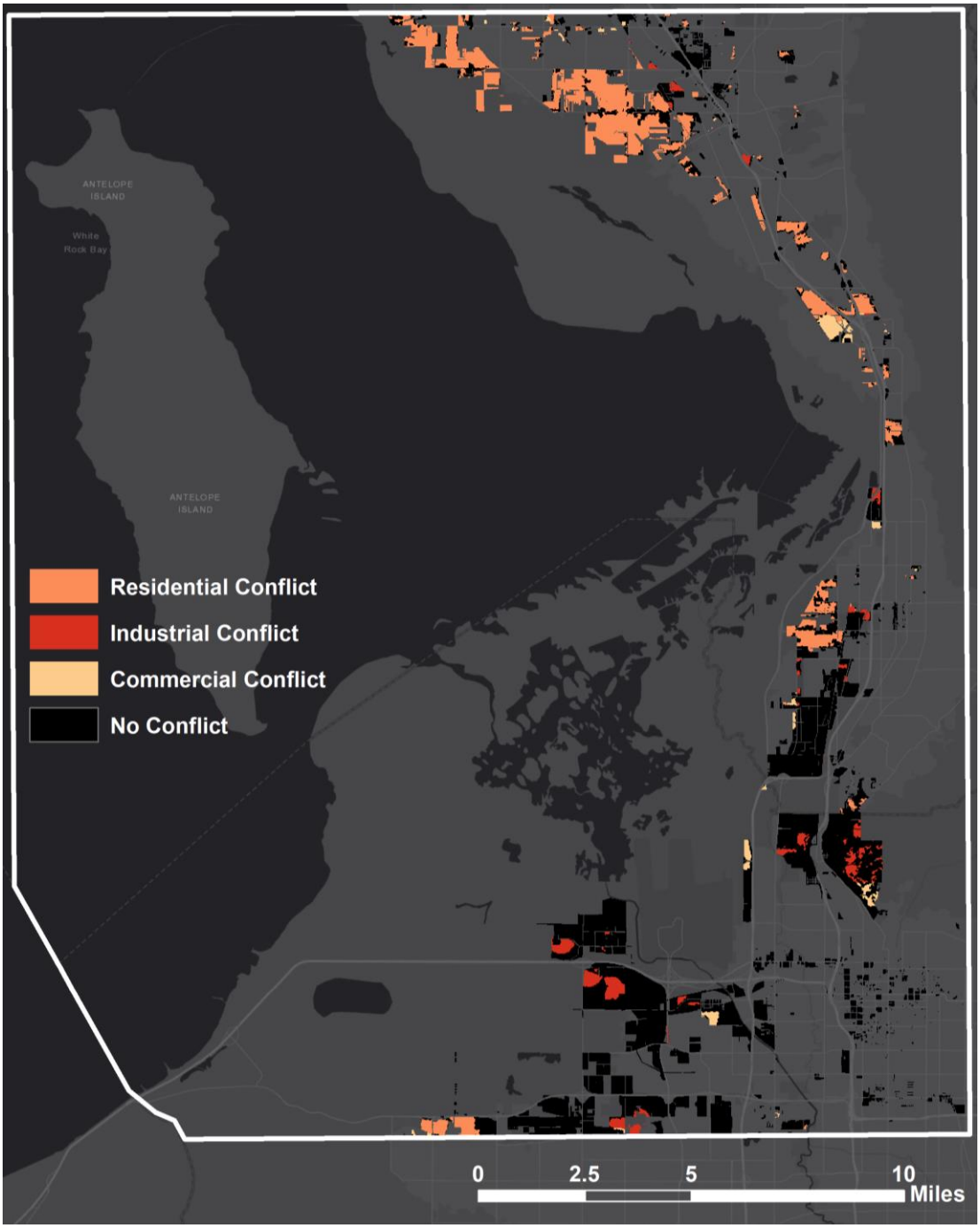

Figure 32. Map of the Wasatch Choice 2040 Vision conflicts with waterfowl habitat. All areas of the Vision project that are in conflict with the current waterfowl distribution, totaling 471 acres of commercial development conflict (tan), 847 acres of industrial development conflict (red), and 4,385 acres of residential development (orange), totaling 5,703 acres of conflict altogether (about 31% of the total project area).

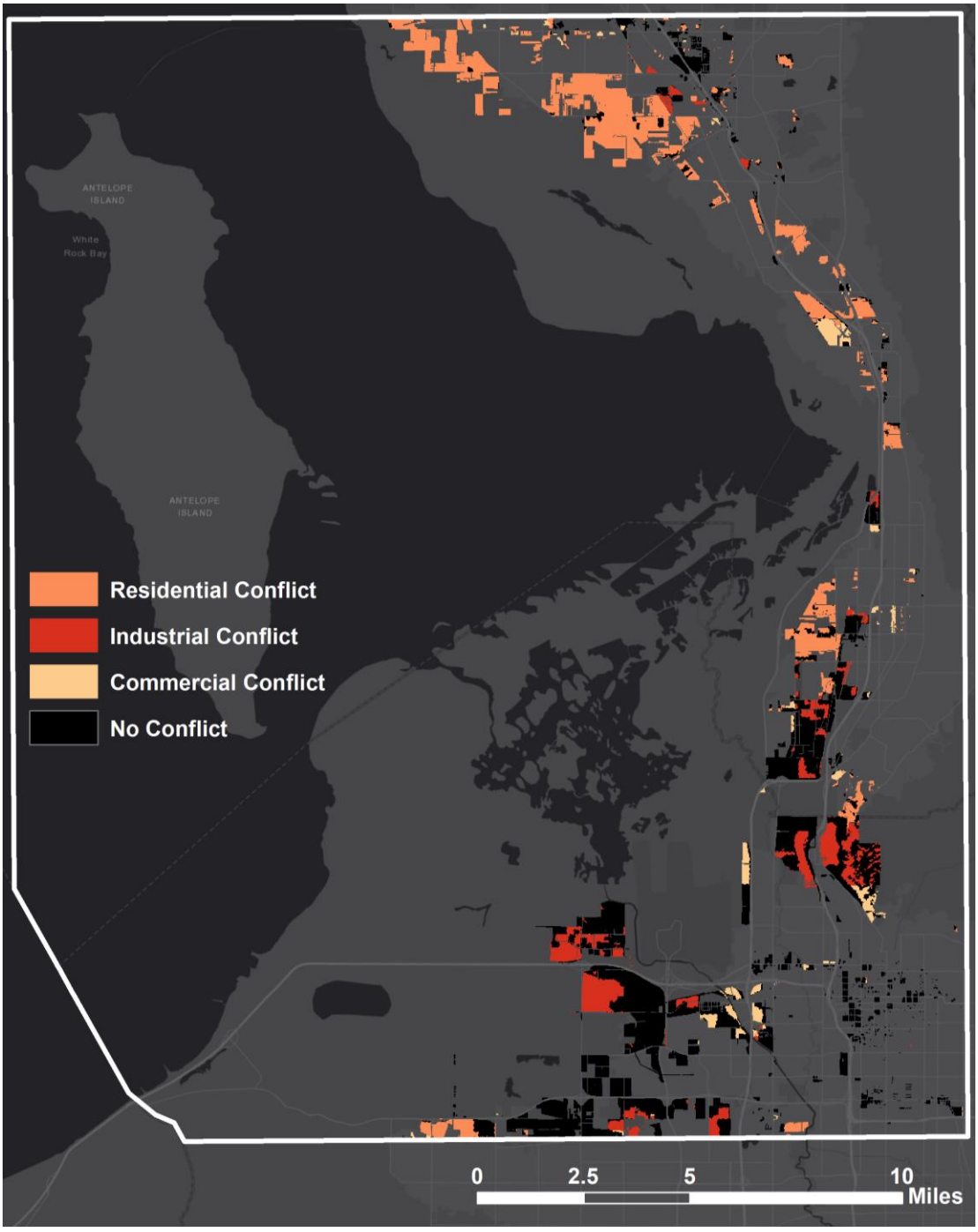

Figure 33. Map of the Wasatch Choice 2040 Vision conflicts with all migratory bird habitat. All areas of the Vision project that are in conflict with the all three combined migratory bird distributions for this study. Nearly 50% (8,980 acres) of this project is in conflict with the current migratory bird habitat in the area with commercial development

conflicts shown in tan, industrial development conflicts shown in red, and residential development conflicts shown in orange.

All Species and Conflict

Overall, the WDC project shows the greatest potential for conflict in terms of the percentage of the project that would affect migratory bird habitat (88% of the project is in conflict). However, the WDC (2,091 acres (846.2 ha)) and NWQ (4,527 acres (1,832.0 ha)) projects show less conflict than the Vision project in terms of the total number of acres affected for all guilds (8,980 acres (3,634.1 ha)). As demonstrated in Figures 15, 22, and 29, the greatest impacts from each project were shown to be particularly poignant for four to five species spanning all three guilds, meaning none of the guilds escape impacts to their current habitat distributions. Tables 5 and 6 show the breakdown of the number of acres in conflict for each guild (Table 5) and for each species (Table 6). The waterbird guild is the most impacted by each of the development types for all projects. Shorebirds are the next most impacted guild for all development types and projects, with the exception of the WDC project and the Vision's residential development type, where waterfowl show a greater amount of conflict than shorebirds.

Table 5. Table of acreage of conflict between guilds and development types. The number of acres in conflict between each bird guild and every development type for all three projects. The WB guild is the most impacted by each of the projects, with the greatest impact from the Vision project (8,861 acres of conflict). The most impactful project is the Vision project, showing the highest total number of conflict acres for all three guilds.

	West Davis Corridor	Northwest Quadrant		Wasatch Choice 2040 Vision		
	Highway	*Commercial*	*Industrial*	*Commercial*	*Industrial*	*Residential*
Shorebirds	1762	78.7	3342	536	1252	4262
Waterbirds	2091	83.8	4438	882	2285	5694
Waterfowl	1862	29.4	2137	471	847	4385

The white-faced ibis (of the waterbird guild) shows the greatest amount of conflict of any species for all development types and projects. The species showing the least amount of conflict with all development types and projects is the snowy plover (of the shorebird guild). Eight of the species showed no conflict with commercial development for the NWQ project, and four of those same species did not show conflict with commercial development for the Vision project, making commercial development the least conflicting of the four possible development types, despite occurring in two projects. Industrial and residential development types show the greatest amount of conflict with current habitat.

Table 6. Table of acreage of conflict between species and development types. The number of acres in conflict between each species and every development type for all three projects. The white-faced ibis is the most impacted species for all three projects, for all development types. The overall least impacted species for all three projects is the snowy plover.

		West Davis Corridor	Northwest Quadrant		Wasatch Choice 2040 Vision		
		Highway	*Commercial*	*Industrial*	*Commercial*	*Industrial*	*Residential*
Shorebirds	American Avocet	26.7	0	860	0	43.1	0.22
	Long-billed Curlew	1028	27.6	2056	176	496	880
	Snowy Plover	0	0	105	0	23.1	0
	Willet	1751	78.7	2638	458	893	4190
	Wilson's Phalarope	20.7	0	77.6	15.8	107	4
Waterbirds	Black-crowned Night Heron	405	0	1151	15.8	190	357
	Eared Grebe	20.9	0	300	0	43.8	0.22
	Franklin's Gull	1381	0	1181	62.7	253	1880
	Great Blue Heron	249	4.9	1128	442	1367	1279
	White-faced Ibis	2083	83.9	4373	803	2006	5611
Waterfowl	Cinnamon Teal	139	0.22	327	19.8	45.1	232
	Gadwall	44.7	0	205	0.22	113	6
	Lesser Scaup	24	0	361	0	43.1	0.22
	Northern Pintail	1838	29.4	2012	470	778	4383
	Redhead	388	1.11	448	56.7	114	701

Since guild habitats show some overlap, I combined all 15 species distributions into one map (Figure 34) to assess and identify areas of conflict for all migratory bird habitat in the area. Figure 35 shows all three of the proposed projects and their respective development types. Figure 36 identifies all of the areas of conflict between all migratory bird habitat and all development projects. Based on Figure 36, it is obvious there are some zones of conflict within the study area. Conflicts south of the southern tip of Antelope Island are primarily conflicts with industrial development, whereas the area north of that region are primarily highway and residential-based conflicts, with some commercial conflict areas dotted throughout.

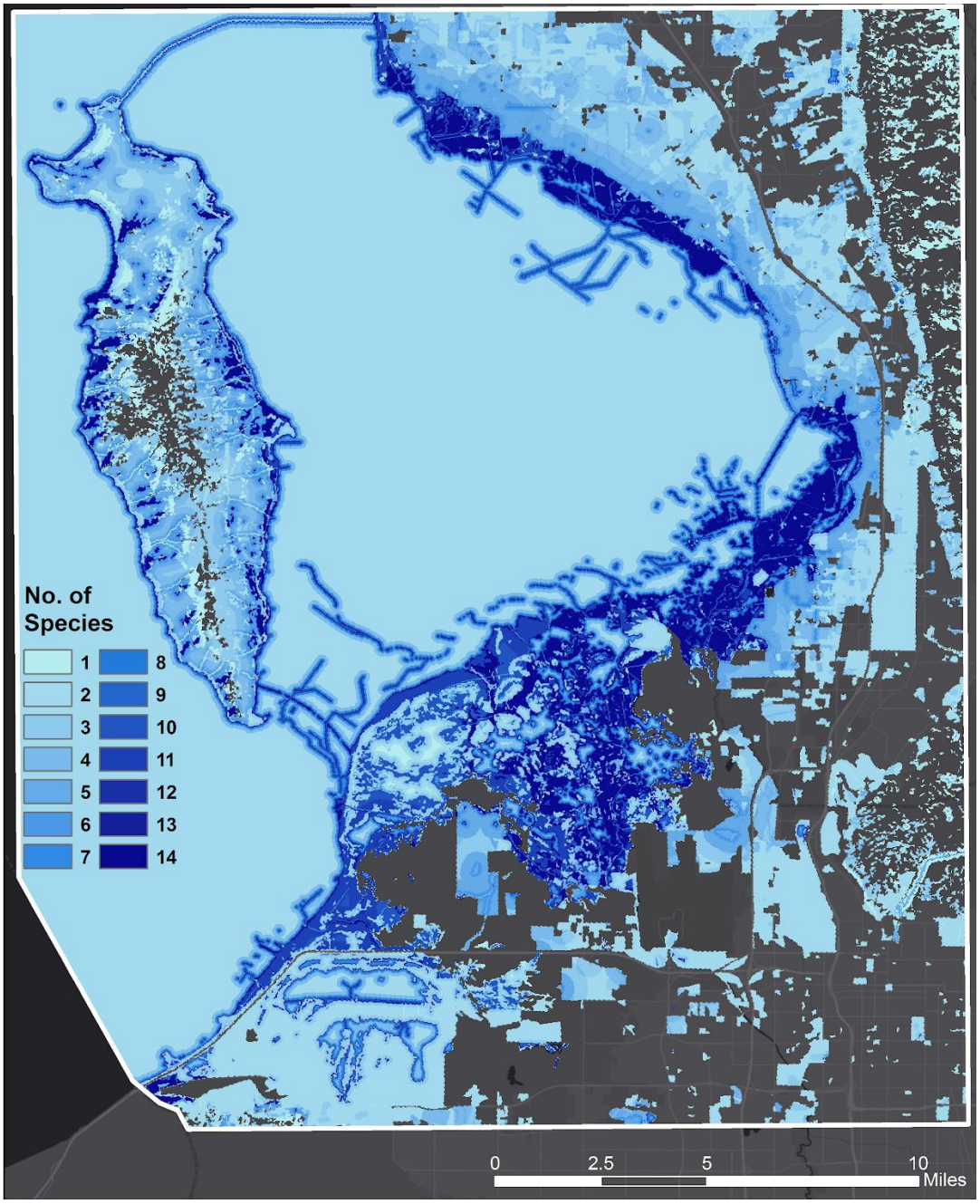

Figure 34. Map of all species' distributions. All of the species' distributions together. There were no areas where all 15 species' distributions overlapped, and so the highest number of overlap is 14 species. The darker blues indicate areas of greater overlap between species' habitats.

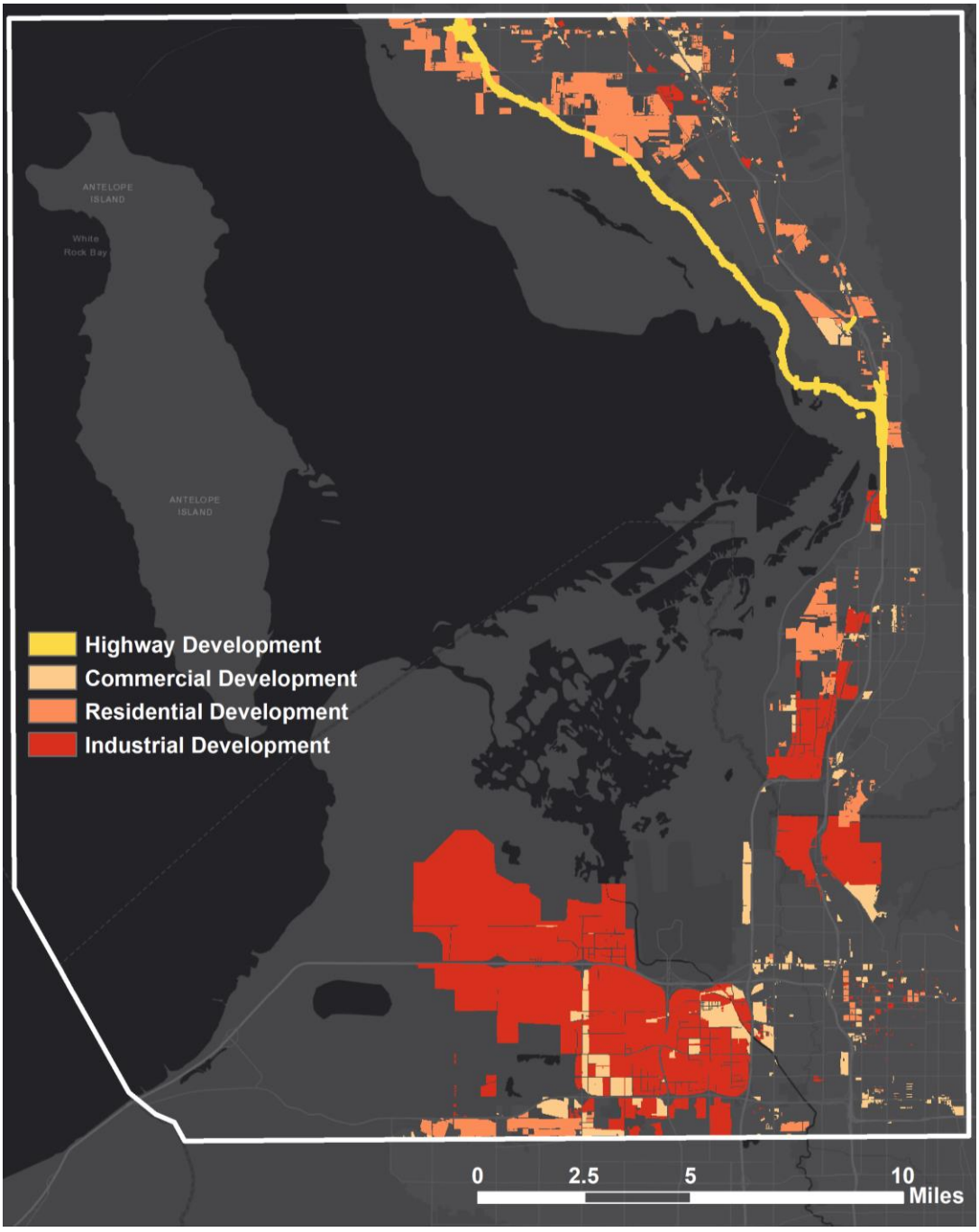

Figure 35. Map of all proposed projects and development types. All of the projects I assessed for this study area. They are displayed based on the development type they are expected to become (e.g. highway, commercial, etc.).

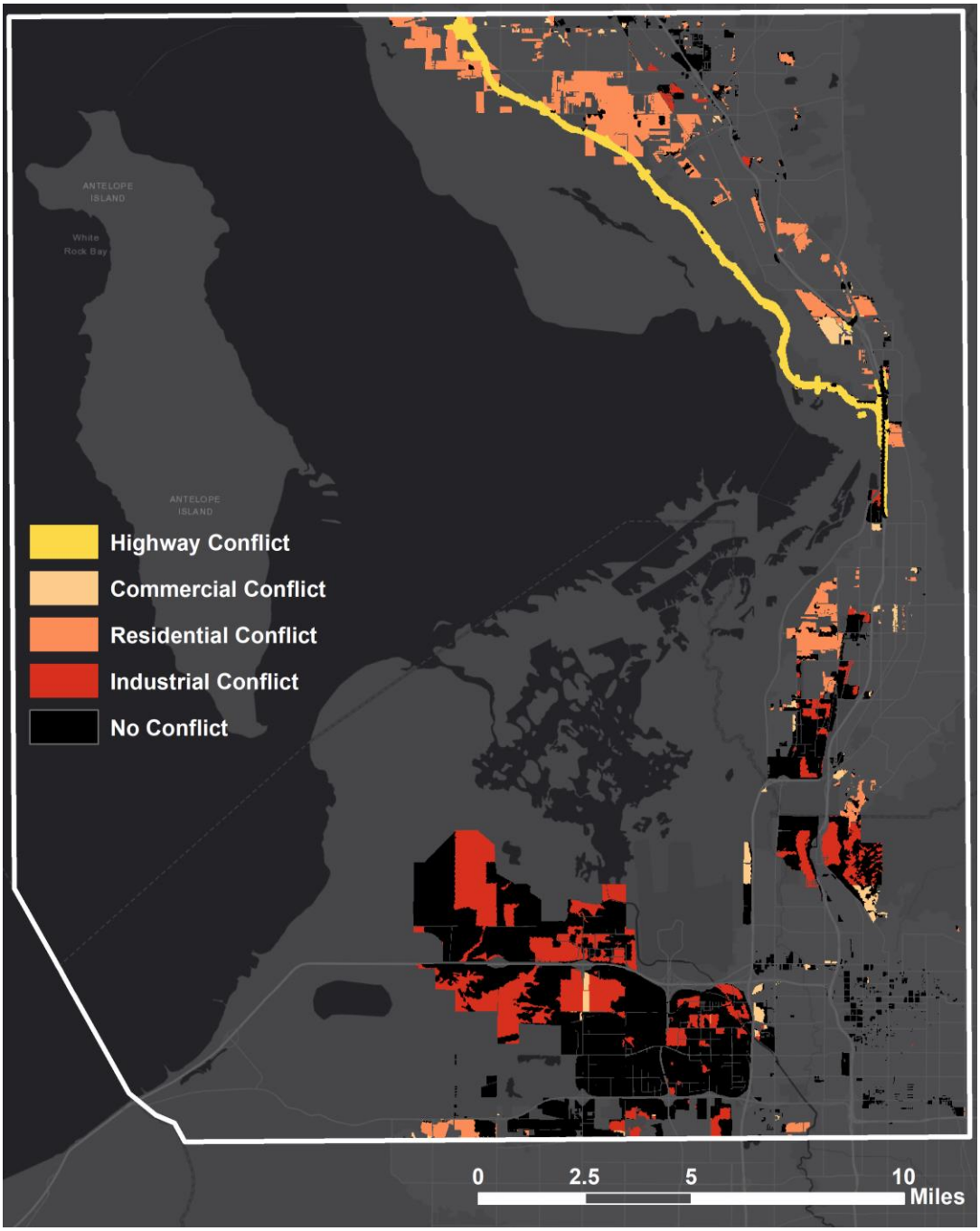

Figure 36. Map of all conflict areas. All conflict areas for all species from all development types and projects – development areas with no conflict with bird habitat are shown in black.

The WDC project shows the greatest amount of conflict with habitat is likely to occur where five species' habitats overlap (814 acres (329.4 ha) of conflict) (Figure 37). For the WDC project, there was little to no impact on areas where more than seven species' habitats overlapped. The NWQ project the greatest amount of habitat conflict is likely to occur where two (1,317 acres (533.0 ha)), three (1,252 acres (506.7 ha)), and five (916 acres (370.7 ha)) species' habitats overlap, though the project also impacts areas where there is greater overlap between species (e.g., areas where ten species' habitats overlap show 178 acres (72.0 ha) of conflict), though impacts are not to the same extent as the areas with less overlap (Figure 38). The Vision project the greatest amount of habitat conflict is likely to occur where two (2,995 acres (1,212.0 ha)), three (2,560 acres (1,036.0 ha)), and four (2,280 acres (922.7 ha)) species' habitats overlap. Similar to the WDC graph, there were not many impacts to areas where a larger number of species' habitats overlapped (Figure 39).

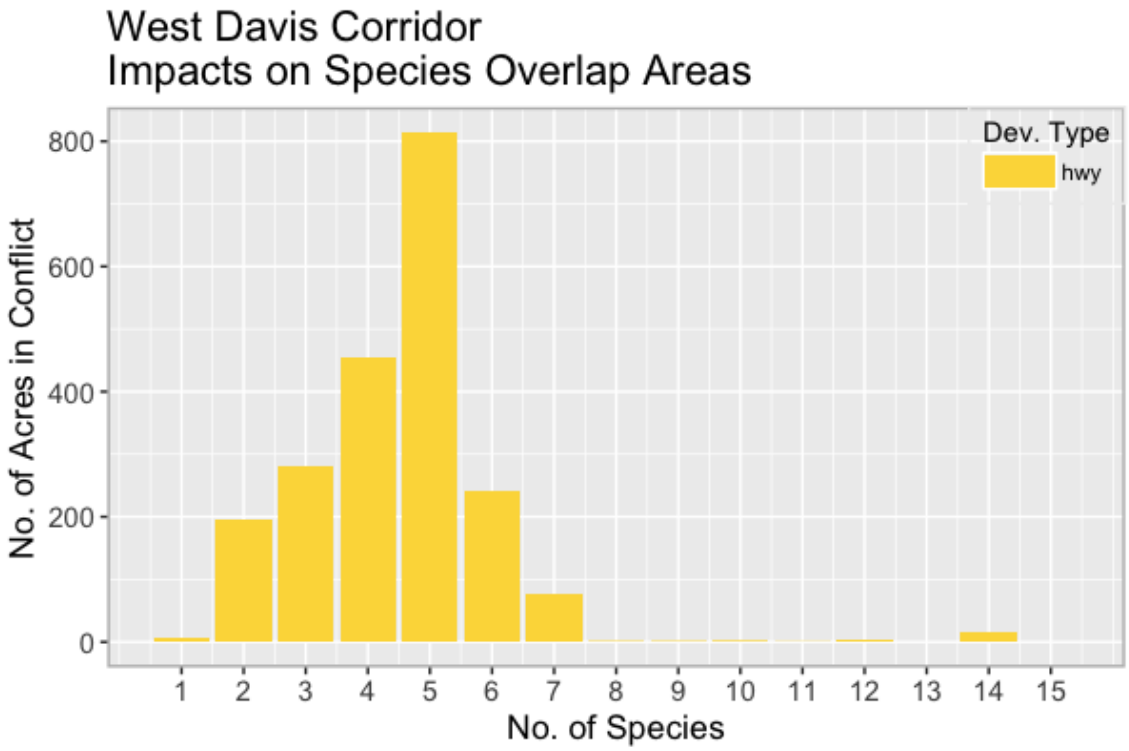

Figure 37. Graph of the West Davis Corridor impacts on areas of habitat overlap. The distribution of conflicts from the WDC project on areas of species' distribution overlap. Areas where five species' distributions overlapped show the greatest conflict in terms of the expected amount of acres in conflict with this development project.

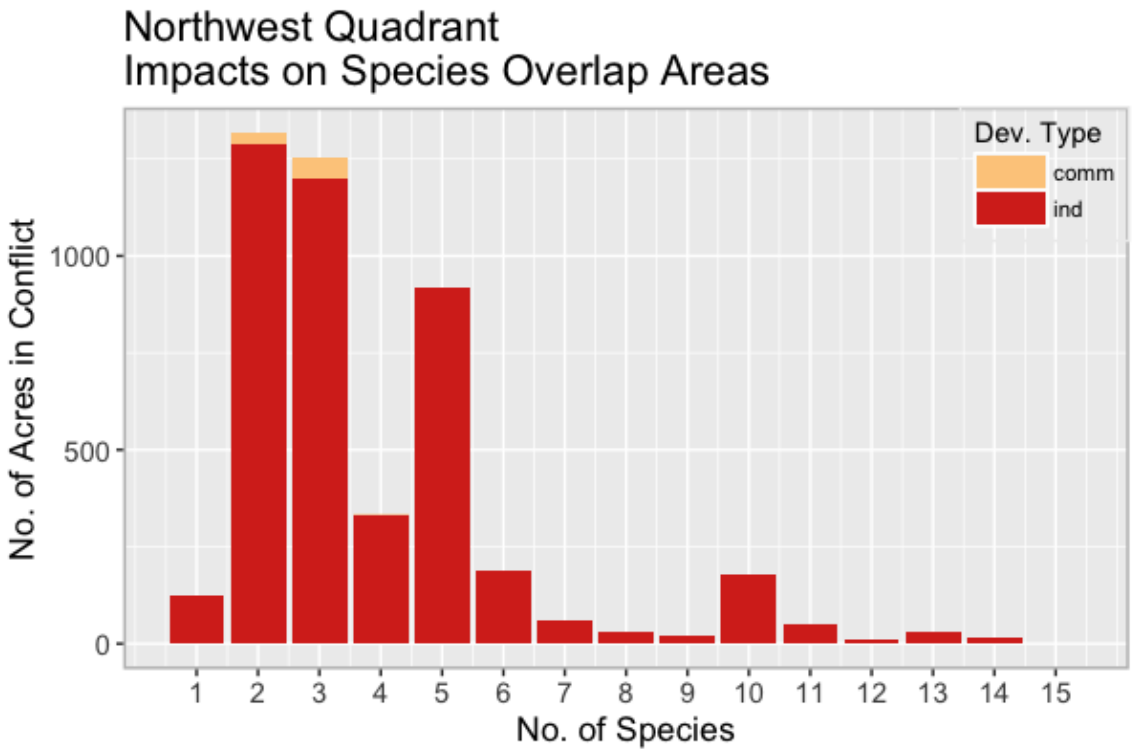

Figure 38. Graph of the Northwest Quadrant impacts on areas of habitat overlap. The distribution of impacts from the NWQ project on areas of species' distribution overlap. Areas where two, three, and five species' distributions overlapped show the greatest potential for conflict in terms of the expected amount of acres that would be impacted with this development project. Industrial development is by far the most disruptive development type for this project.

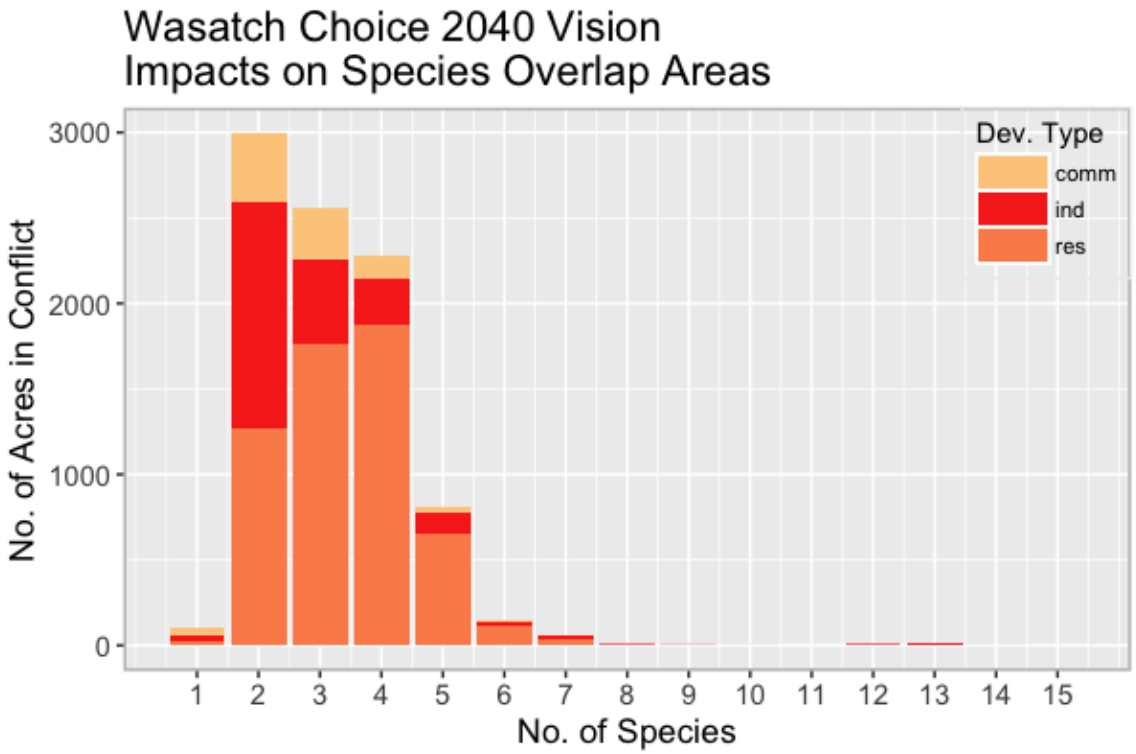

Figure 39. Graph of the Wasatch Choice 2040 Vision impacts on areas of habitat overlap. The distribution of impacts from the Vision project on areas of species' distribution overlap. Areas where two, three, and four species' distributions overlapped show the greatest potential for conflict in terms of the expected amount of acres that would be impacted with this development project. Residential and industrial developments are shown to be the most disruptive types of development for this project.

In summary, all three development projects assessed in this study show expected habitat impacts for all three migratory bird guilds. All three projects show the greatest impact on the waterbird guild and the white-faced ibis. The WDC project shows relatively equal impacts on the waterfowl and shorebird guilds, with a slightly greater impact on waterfowl habitat. The NWQ project shows a greater impact on shorebird habitat than waterfowl habitat by over 1000 acres (404.7 ha). The Vision project is expected to have similar impacts on both shorebird and waterfowl habitat. The three

species most likely to be impacted by these projects are all from separate guilds: the white-faced ibis (waterbird), the willet (shorebird), and the northern pintail (waterfowl). This result means that habitat for all three guilds are likely to be impacted, though some species are likely to face greater impacts to their habitats than others.

CHAPTER 4

DISCUSSION

Assessing Migratory Bird Habitat in the Study Area

Overall, the 15 species' distributions altogether cover 288,244 acres (116,648.2 ha), or about 77.5% of the entire study area (Figure 34). This large amount of existing bird habitat was surprising at first, since the Wasatch Front is a rapidly urbanizing area. However, I compared the USGS GAP distribution data for the site with bird sightings and distribution data on eBird, which is an online, worldwide, citizen-science project managed by the Cornell Lab of Ornithology and Audubon. eBird receives and stores data on bird distribution, habitat use, abundance, and trends (Audubon and the Cornell Lab of Ornithology, no date). Based on visual comparisons of where birds are reportedly seen around Farmington Bay, birds that migrate to the Great Salt Lake area are often seen near or within the surrounding urban settings (Appendix B, Figure 40). The eBird data supports the findings from the USGS GAP distribution data, because birds are spotted outside of Farmington Bay, despite the close proximity to an urban setting. As a primary data source, I chose not to use eBird data, as it can be biased toward rare or unusual species, and may not include all sightings of every species or bird that someone may see, because rare and unusual birds are species that birders (the primary users of eBird) typically set out to find. Still, the fact remains that people have seen and continue to see migratory birds not just in the Great Salt Lake itself, but also in and around the fringe of

wetlands and agricultural land, and even in urban parks, fields, ponds, backyards, and undeveloped land. This is likely due to two things: first, the Great Salt Lake attracts millions of birds of over 250 species every year from both the Pacific and Central Flyways. Second, the high concentration of birds congregating at the Great Salt Lake means there is likely some inter- and intraspecific competition among birds for resources, such as food and resting areas (Kirby et al., 2008), which could result in spillover from "prime" bird habitat to less suitable habitat near urban areas. As other viable habitats are replaced with unsuitable land cover (e.g. highways, warehouses, apartment complexes, etc.), options for spillover decrease, and competition may increase, or result in birds finding other areas for migratory stops. This phenomenon would increase impacts even on species whose habitat is not directly fragmented or destroyed by development. Land conversion will add stress to the majority of bird populations that depend on the Great Salt Lake as a nesting location or stopping point along their migratory routes, though a recent study suggests some urban-exploiting species, like crows, house sparrows, and common starlings, profit from increased urbanization (Geschke et al., 2018).

Development-Habitat Conflict

Based on the results from the conflict analyses, each of the proposed development projects shows the potential to greatly disrupt the current distribution of migratory bird habitat within the study area. While the WDC project shows the highest percentage of conflict with bird habitat (88% of the entire project footprint is in conflict),

overall, the Vision project causes the greatest amount of acreage of conflict for all three guilds. This result is not surprising since the Vision project has the largest footprint of all three projects. In terms of impacts to individual guilds' and species' habitats, industrial and residential developments pose the greatest threats to current habitat, followed by highway, and then commercial developments (Figures 14, 21, and 28).

The waterbird guild was the most impacted by all projects and development types. This result is due to the guild's large habitat coverage of the study area; of all three guilds, it shows the greatest amount of diversity in the types of ecosystems and land covers that it inhabits. Shorebirds are aptly named because they tend to stay close to flat, open shorelines around shallow water, though some species, like the long-billed curlew and the willet, use wet meadows, grasslands, and irrigated croplands as well (Kantrud and Higgins, 1992; Shuford et al., 2013). Waterfowl tend to inhabit wetlands and uplands close to open water, though some species will forage in fields during migration and over winter (Fox et al., 2017; Petrie et al., 2013). The waterbird species have varying morphologies, which is obvious when you compare wading birds (such as egrets and curlews) to open water birds (such as grebes) or to colonial seabirds (such as gulls). Even within a specific group of a guild, there can be obvious morphological differences (e.g. compare neck and leg lengths of a great blue heron to neck and leg lengths of a black-crowned night heron, Figure 11); these variances allow each species to use habitats differently, providing the overall waterbird guild a vast array of habitats.

The white-faced ibis' habitat was the most impacted for all projects. Out of all 15 species assessed in this study, it has the third largest habitat coverage of this study area (27.4%), surpassed only by deep, open water species (i.e. the gadwall and eared grebe) (Tables 2-4). Shallow water, freshwater marshes, and irrigated land are all suitable for the white-faced ibis (Kaufman, 2014). Open space and large amounts of irrigated farmland are affected by all three projects, hence the large conflict with this particular species. However, due to the many varying types of suitable habitat for this species, it could be considered a representative umbrella species for most migratory bird habitat in this area, with the exception of species preferring deep, open water habitat. If an organization or agency was interested in maximizing conservation of migratory bird habitat here, an umbrella species model using the white-faced ibis distribution data would protect many additional migratory bird species' habitats.

While the Vision project shows the greatest amount of acreage in conflict with current migratory bird habitat, the context of conflict is important to consider when identifying areas to avoid development. Geschke et al. (2018) found that as population density increases for an area, it becomes more important to densify and protect larger areas of land around the urbanizing area (i.e. a "land-sparing" design) instead of increasing sprawl (thereby decreasing density) with a "land-sharing" design when it comes to maintaining avifauna biodiversity and overall healthy populations of native bird species. In this case, it is important to have high-density, 'centered growth' along the Wasatch Front, and to conserve areas around the already urban zone for wildlife. The

WDC and NWQ projects would increase sprawl and development into areas that should be maintained for migratory bird habitat, i.e. a "land-sharing" design, whereas the Vision project promotes a more "land-sparing" design, especially if planners remove the proposed "Large Lot Single Family Housing" in the north of the study area in favor of high-density housing in the urban areas (Figure 27). Overall, a "land-sparing" design would benefit both wildlife and people along the Wasatch Front, as it is well known that Utahns enjoy open spaces and their agricultural heritage (Envision Utah, 2001). "Protecting Sensitive Lands" is the first tool listed in Envision Utah's *Urban Planning Tools for Quality Growth* (2001). Avoiding sprawl, increasing housing density, and promoting 'centered growth' would ensure that the area retains this important migratory bird habitat, and would set a prime example for other western cities that are struggling with similar development issues.

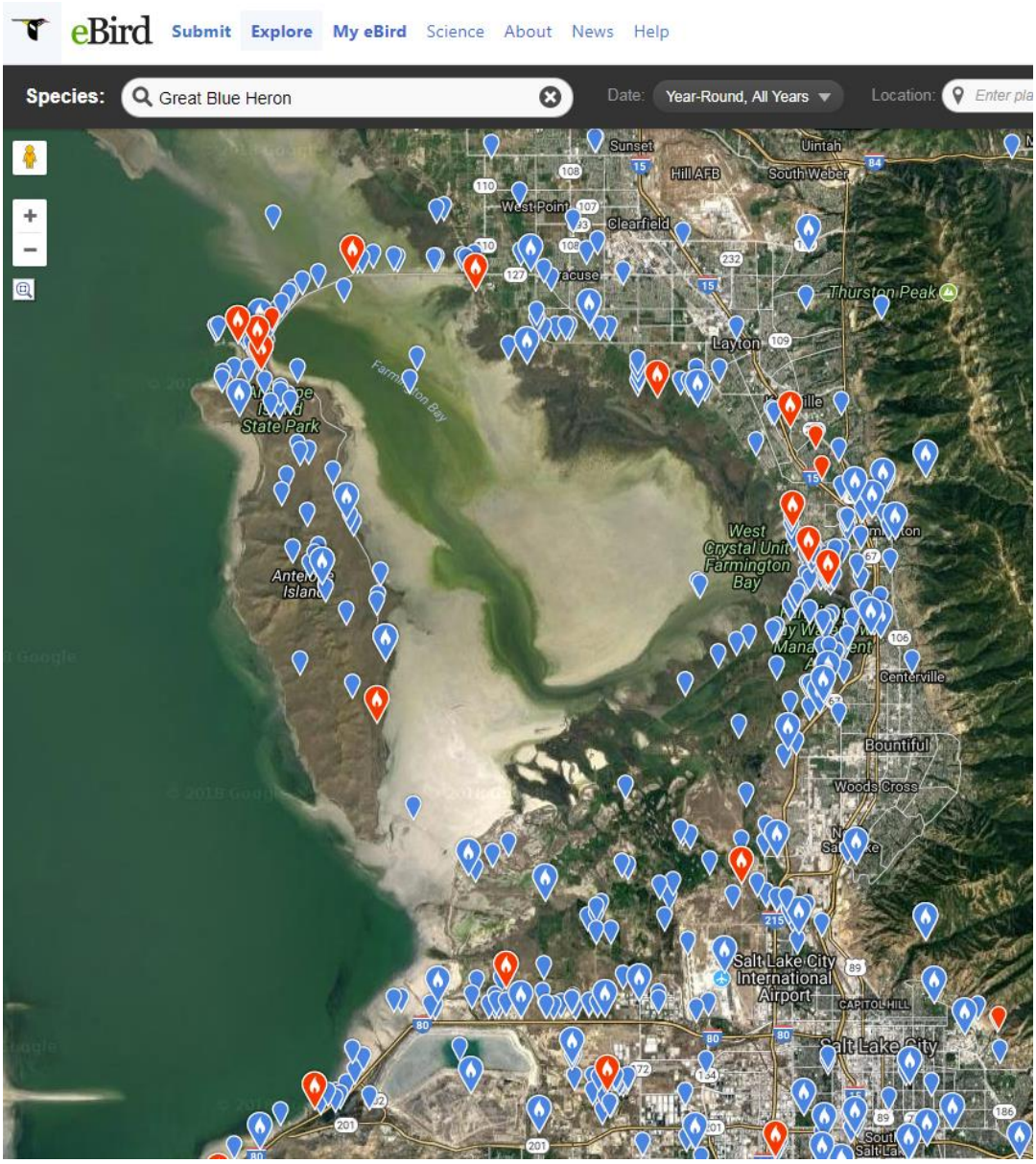

Figure 40. Example of eBird sightings data. Sightings data from eBird for the Great Blue Heron (waterbird) in and around Farmington Bay. Red balloons indicate sightings within the last 30 days, and blue balloons are older sightings. The flame emblem within some balloons indicates locations of "Birding Hotspots." Notice the high concentration of sightings around Farmington, Kaysville, Syracuse, and Salt Lake City. This screenshot was captured on July 8, 2018.

Limitations and Considerations

Project Overlap

While this report holds merit and important recommendations for planners, conservationists, and decision-makers, it is important to acknowledge the limitations involved with this research. The results of this research are disseminated based on impacts from individual development projects. It would have been interesting to compare and assess the total impacts of these proposed projects together on migratory bird habitat, but there is spatial overlap between the development projects; about 4,113 acres (1,664.5 ha) in total (Figure 41). However, since the projects were made independently of each other and show disagreement on development type in certain locations, it would be misleading to assess projects altogether, and instead were primarily assessed as they were made — independently.

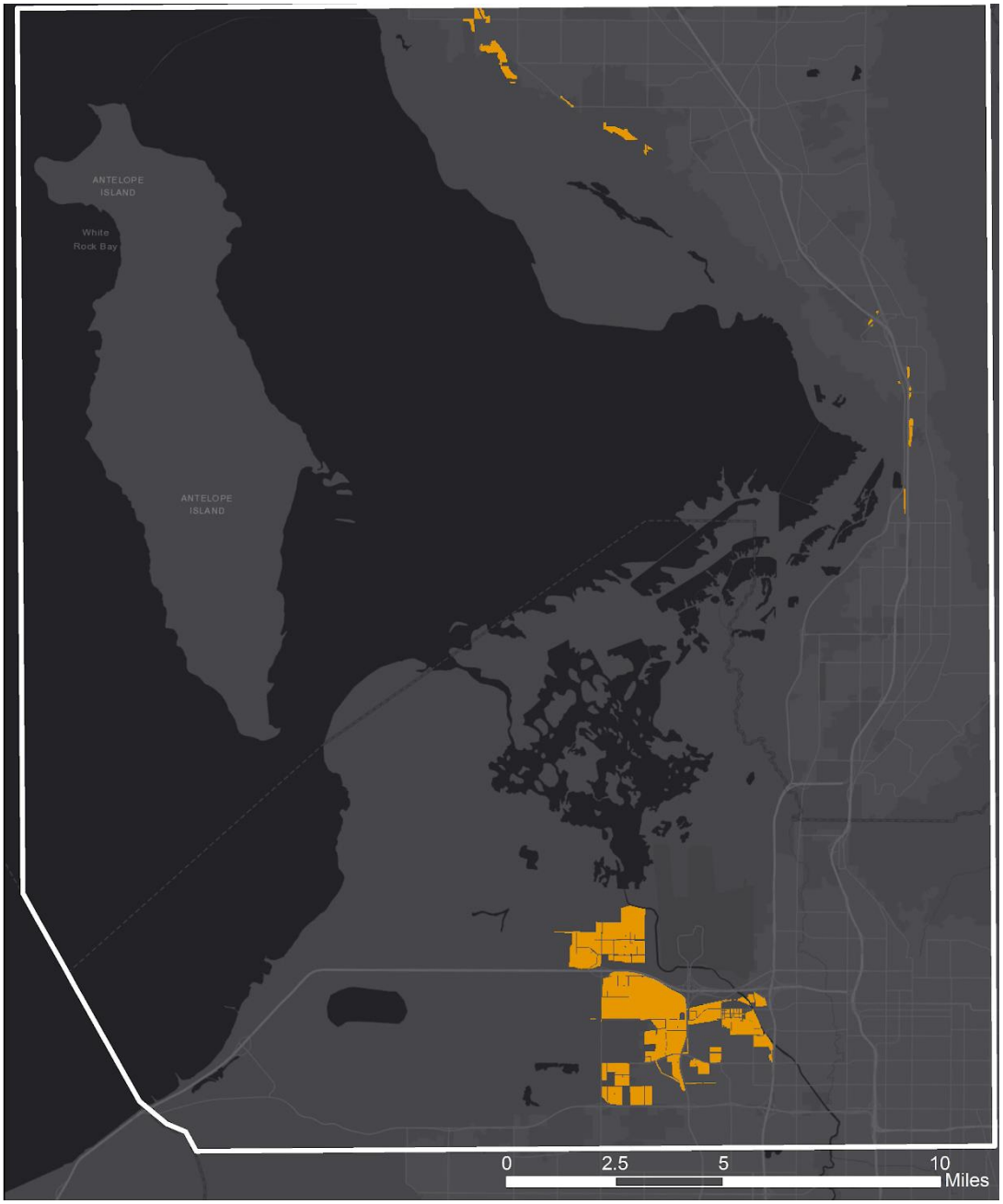

Figure 41. Map of areas of overlap between proposed projects. Areas of overlap between projects. There was no overlap between the NWQ and WDC projects; all of the disagreement is between the Vision project and the other two projects (shown in orange). While the projects were planned independently of each other, some areas of overlap between the NWQ and Vision projects agreed on the type of development should take place at that location (e.g. industrial, commercial, etc.).

Data

The USGS GAP data I used for distributions/habitat information are updated on regional, state, and national scales, and were not specifically tailored to this study site. The data has a relatively low resolution (30 meter raster cell size), though the USGS has stated that GAP data can be used for regional planning projects, specifically: "Coarse-filter evaluation of potential impacts or benefits of major projects or plan initiatives on biodiversity, such as utility or transportation corridors, wilderness proposals, habitat connectivity proposals, climate change adaptation proposals, regional open space and recreation proposals, etc." (USGS, 2014). While there were other species data options available for this study (e.g., eBird data and the Great Salt Lake Waterbird Survey), the GAP data was the best available option for assessing impacts to bird habitat for this study area since it provided spatial data on bird distributions that a) covered my entire study area (unlike the GSL Waterbird Survey), b) is more up-to-date (2014, which is more recent than the GSL Waterbird Survey of 2001), and c) show areas suitable for specific species, and not just where people see them from, which, in eBird does not account for distance sightings via binoculars or spotting birds flying overhead. When choosing a data source, this was the biggest problem with eBird data, as it showed sightings for open water birds, such as the American white pelican, along the shore and not on remote islands or on open water, which is known to be their prime habitats (Kaufman, 2014). However, for shorebirds, wading birds (like herons), and waterfowl that are found in

shallower water and closer to the banks, their data is more defensible. However, for the purposes of this research, the USGS GAP datasets were the best possible data available.

While I used the best available project data, there were a few unavoidable limitations involved with the planning data as well. Along with other involved groups and stakeholders, the Wasatch Front Regional Council and the Mountainland Association of Governments (MAG) closed the feedback window in March 2018 for the proposed Wasatch Choice 2050 scenarios. Unfortunately, the preferred choice scenario (or "Vision") for 2050 has not yet been finalized, and is still under deliberations though it is expected to be published in 2018 (Powers, 2017). When the 2050 Vision is finalized and made available, this same conflict analysis should be conducted again. Similarly, when the Inland Port Authority finalizes the zoning and development plans for the Northwest Quadrant, conflicts should be reassessed so planners, residents, and decision-makers understand the impacts to migratory birds, as the land uses and development may be more intensive and extensive than the currently available zoning data indicates (Cawley, 2018; Erickson, 2018; Evan Curtis, personal communication).

The West Davis Corridor project plans could also be made clearer and updated when other development is proposed along this new highway. Since the WDC project does interfere and affect wetlands along the eastern edge of Farmington Bay, the Utah Department of Transportation is required to mitigate the losses and impacts by creating and improving roughly 1,100 acres (445.2 ha) of wetlands in the area. Currently, UDOT plans to donate these mitigated wetlands to The Nature Conservancy's Great Salt Lake

Shorelands Preserve, and to the State's Farmington Bay Waterfowl Management Area (UDOT, 2017). If these mitigated wetlands provide the same quality of habitat that is being lost to the construction of this highway, then the overall footprint of this project should be considered smaller than the findings in this report. However, many mitigation wetlands, if not properly implemented and monitored, fail to meet the same quality of wetlands that were disturbed (Ambrose et al., 2006; Moreno-Mateos et al., 2012; Pruitt, 2013), and so the necessity of revising the overall impacts from this project remains to be seen.

Uncertainty

Since the area is expected to grow rapidly both in population and economically, development along the Wasatch Front is likely to continue expanding and evolving over time. As these projects evolve (e.g. with the new inland port zoning and the updated Wasatch Choice 2050 Vision) and other projects are proposed, there are likely to be further conflicts with the current migratory bird habitat in the area. However, this research set out to identify and assess possible conflicts of these three specific proposed projects, and so does not address other possible developments in the future. However, this research does support the recommendation to include important migratory bird habitat into future project planning endeavors. This will be necessary as other uncertainties begin to crystalize in the future, such as impacts from climate change, the rate of and types of regional economic development, changes in demographics, water quality and quantity issues, and so on. While these topics are beyond the scope of this work, it will be

imperative that future plans build off the work done here to address these issues in order to maintain the globally important migratory bird habitat in and especially around the Great Salt Lake.

Economic Impacts

I did not assess nor address the economic impacts of the construction of these projects to the region. Most planning projects involve an economic aspect, but that was outside the purview of this research, and had been addressed by the planning agencies involved in the projects, with the noticeable exception of economic impacts from habitat degradation on the local economy. The Great Salt Lake has a global reputation as a globally important bird habitat, and birders and hunters from around the state, region, nation, and globe recreate in the area for this reason (Bioeconomics, Inc., 2012). This is an aspect of the local economy I would recommend each project agency further address. The WDC EIS touches on economic impacts for the tourism industry in Davis County, stating that the construction of a major highway would not impede access to recreational areas, and would in fact enhance access; impacts of disturbed or fragmented bird habitat on the tourism and recreation industries was not discussed, though these industries are an important part of Utah's economy (UDOT, 2017).

Since these lead agencies addressed most of the economic implications involved with each project, this research provides a necessary overview of possible impacts on migratory bird habitat, as the other reports did not assess these impacts, with the exception to the West Davis Corridor Environmental Impact Statement (EIS). However,

their assessment was not based solely on migratory birds, but was based on eight representative species, including the mule deer and northern leopard frog; two of the bird species used in this research were also used in the WDC EIS – the American avocet and the long-billed curlew, which are both shorebirds. The USGS GAP datasets for both of these species have habitat in the area of this project, with 1,028 acres (416.0 ha) of the long-billed curlew's and 27 acres (10.9 ha) of the American avocet's habitats projected to be in conflict with this project. There are four other species whose habitat is in greater conflict with the WDC project: the white-faced ibis (2,083 acres (843.0 ha)), the northern pintail (1,838 acres (743.8 ha)), the willet (1,751 acres (708.6 ha)), and Franklin's gull (1,381 acres (558.9 ha)) (Figure 14). Three of these species are not in the shorebird guild; even though the WDC project did include "coordinated guidance" with the US Fish and Wildlife Service and the Utah Division of Wildlife Resources, the WDC's EIS representative species did not include any species from the waterfowl or waterbird guilds in their assessment of the potential impacts on wildlife (UDOT, 2017). The project biologists did consider other species that are of conservation concern (e.g. the yellow-billed cuckoo and the grasshopper sparrow), but these species use more upland areas, such as grasslands and woodlands.

Development Type Impacts

I did not include how varying development types would affect migratory bird habitat, though there are notable differences in terms of likely impacts (Blair, 1996; Higgins et al., 2002; Thomas et al., 2013; Zimmerman et al., 2013). Many of the

migratory bird species that use the GSL and its associated wetlands also use bordering agricultural land and open space for nesting, resting, and foraging (Petrie et al., 2013; Thomas et al., 2013; Zimmerman et al., 2013). The conversion of these land covers to other types of development, such as residential or highway development, would have impacts on the quality and quantity of habitat for birds, though in different ways (Petrie et al., 2013; Thomas et al., 2013; Zimmerman et al., 2013). When considering the impacts of land use changes, the type of development matters, and should be considered by developers and planners. It was beyond the purview of this research to assess how each development type would affect each species' habitat, though conservationists should undertake assessments, such as a bioenergetics carrying capacity assessment, to better understand how changes in land uses will alter the area's carrying capacity for bird populations in the Pacific and Central Flyways.

Other Impacts on Migratory Bird Habitat

I did not address other impacts on migratory bird habitat in this research. Other impacts, such as the spread of invasive plants, expansion of predator ranges, compounding effects of climate change, changes in lake level, water scarcity, and trends in habitat quantity and quality in other inland saline lakes along migratory routes, should be included in the decision-process of planners, land managers, and decision-makers. Including a comprehensive, bioregional approach to regional development will help stakeholders make decisions based on all relevant data, and not only economics and zoning laws. This research aimed to complement these three project's assessments by

addressing the possible direct impacts on migratory bird habitat around Farmington Bay of the Great Salt Lake, though other impacts on migratory bird habitat should be considered as well.

Other Avian Species Within the Study Area

It is also important to acknowledge that this research only looked at a handful of species distribution. While I selected representative species for the three bird guilds of interest, it is likely that some of the other 250 migratory bird species that use the GSL have habitat outside of the distributions I assessed. It is also imperative to note that only species from the shorebird, waterbird, and waterfowl guild were chosen; other groups of birds, such as songbirds, birds of prey, and ground-nesting upland birds (such as pheasants), use the area and were not included in this analysis. Land managers, planners, and decision-makers should include all bird guilds in comprehensive habitat assessments before changing current land uses and land covers.

Implications and Recommendations

Low Conflict Areas

Many of the projects in the northern half of the study site were in direct conflict with hotspots of migratory bird habitat. Figure 42 shows areas of projects (in white) that were not in direct conflict with any of the species' known distributions, totaling nearly 17,350 acres (7,021.3 ha) of project area. While these areas do not show conflict for the 15 species of birds used in this study, that does not mean they are free from conflict with

other bird species or other wildlife. A clear and comprehensive report on impacts to all wildlife and the environment should be conducted prior and during the planning period, and anytime amendments are made. I would also recommend planners and decision-makers assess indirect impacts to nearby habitat as well as direct impacts. For instance, there are habitat hotspots within and around the NWQ project; possible impacts to habitat quality should be considered when deciding where to construct new development types. Hard surfaces, such as concrete and pavement, create flashier runoff events during storms, as they decrease surface permeability (Arnold Jr. and Gibbons, 1996). If ground-nesting species are nearby, their nests or chicks may be lost to the excess flooding from these impervious surfaces (Reiley et al., 2017). Habitat fragmentation should also be limited as much as possible. While migratory birds have the ability to fly, breeding and nesting adults and their young require access to nearby forage and water (Petrie et al., 2013; Plauny, 2007; Thomas et al., 2013; Zimmerman et al., 2013), so conserving sensitive habitat in the middle of an urban area is perfectly fine, as long as there are protected, connective corridors to other habitat areas.

Ultimately, as the study area includes both important bird habitat and urbanizing areas important for continued economic prosperity, it would be shortsighted and illogical to protect all conflict areas for bird habitat. The region is going to continue developing infrastructure to support the economy and local human population, so removing all bird habitat from development considerations is infeasible. The impact to migratory birds can

be considerably lessened through the protection and conservation of habitat hotspots in the region.

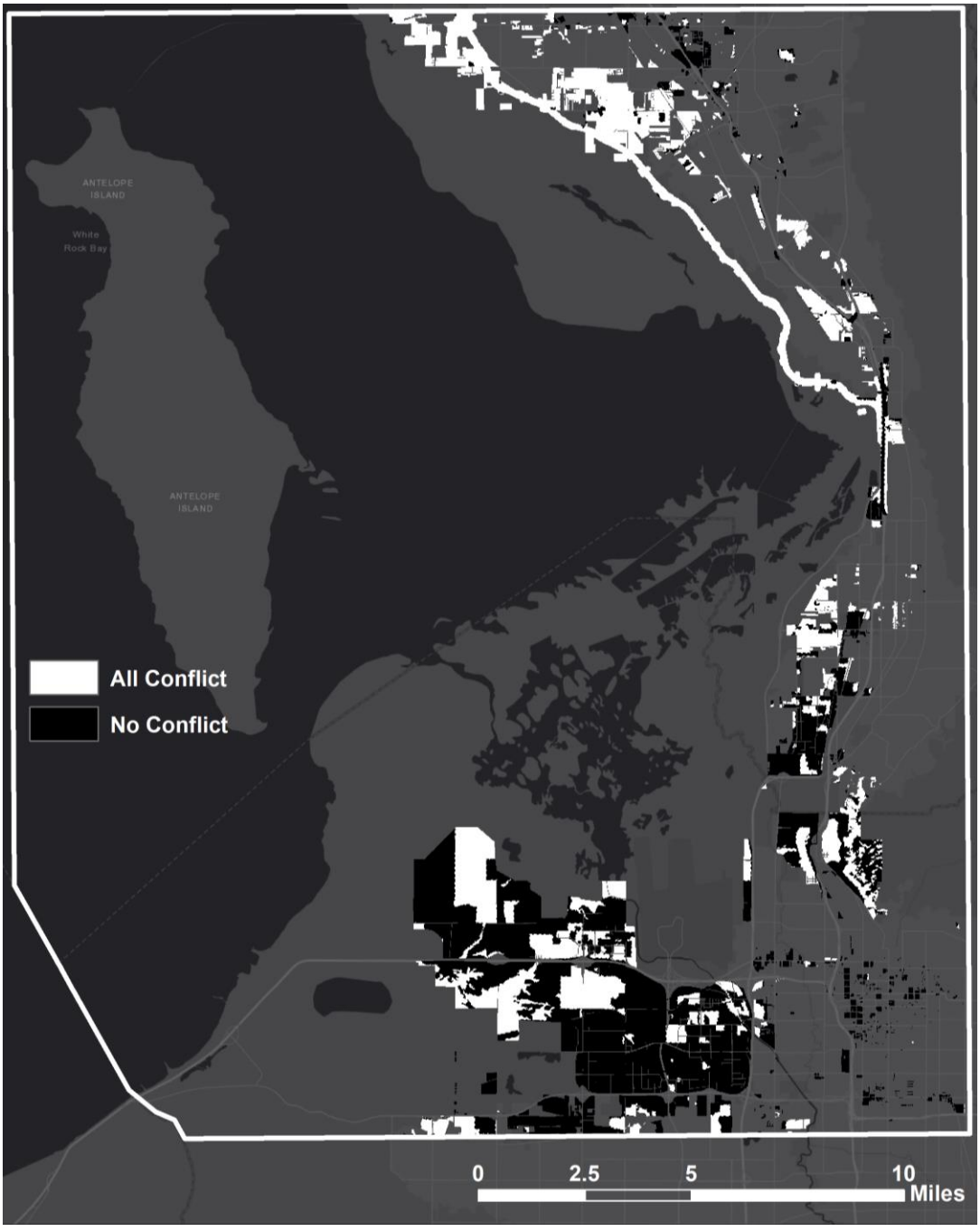

Figure 42. Map of project areas in conflict and proposed areas not in conflict. The overall split between project areas in conflict (white) and project areas not in conflict (black). The majority of project areas in the top portion of the study area are in conflict. Particular sections of the NWQ project show conflict. Several sensitive areas border the northern and western sides of the NWQ zoning area including private duck clubs and mitigation wetlands.

High Conflict Areas

In order to avoid impacting some of the most sensitive habitat, I recommend amending proposed project areas that overlap with four or more of the migratory bird species' habitats assessed in this research. If over 25% of the representative species from this research have habitat in the area, the area likely transcends use by singular guilds and could be used by many different types of birds and other wildlife. Figure 43 depicts these specific areas in blue. If protections are granted to areas where four or more species' habitats overlap, then development in any blue area should be avoided or mitigated. Figure 44 highlights the areas of development that are in conflict with these hotspot areas. If areas where only five or more habitats overlap were protected, then only project areas in dark blue would be protected. Table 7 shows the numerical difference between acres that would be protected under the four or more protection scenario, and the five or more protection scenario for each respective project.

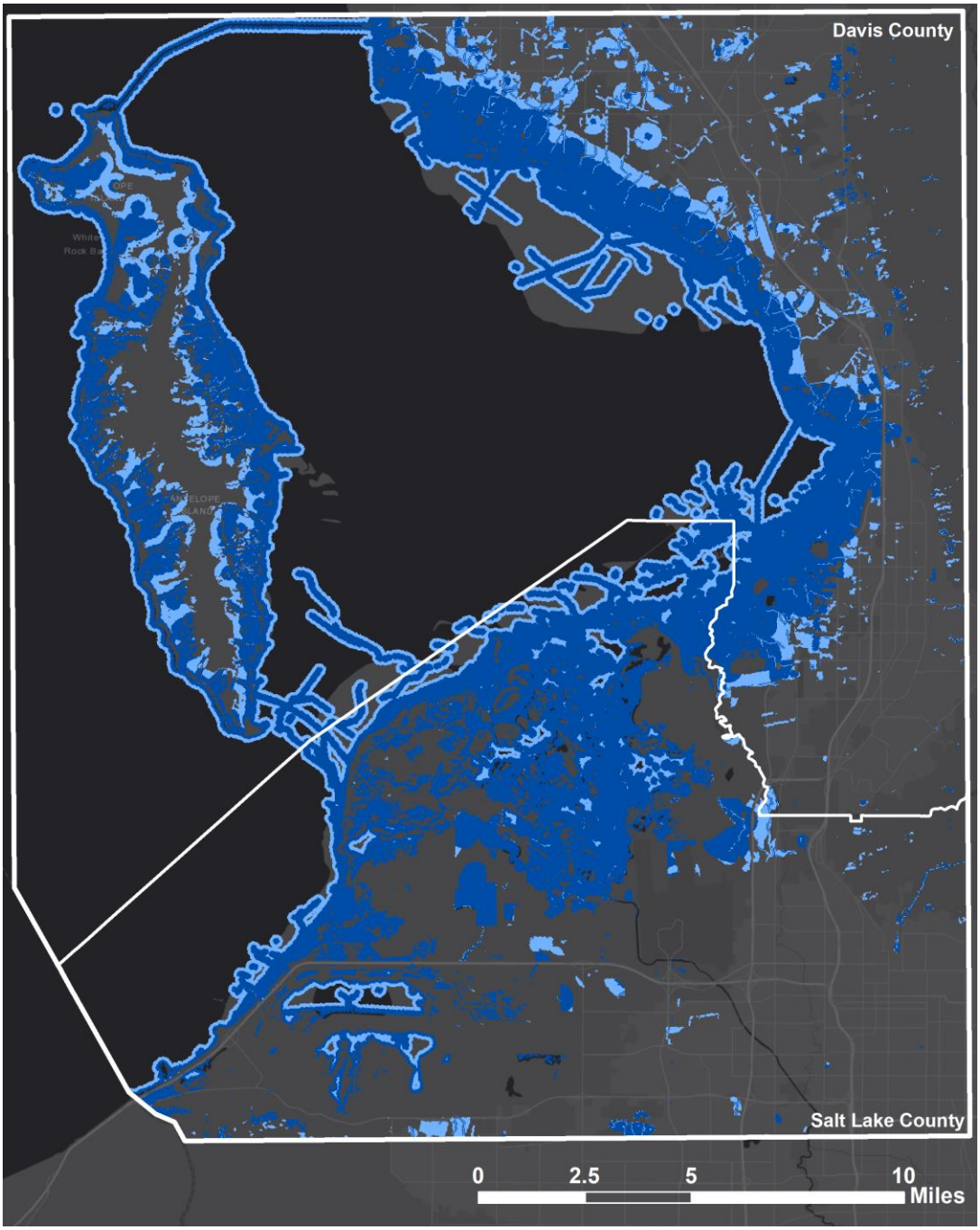

Figure 43. Hotspot areas where 4 (light blue) or 5 or more (dark blue) species' habitats overlap. These areas are located predominantly around the shores and fringe of Farmington Bay, and into the southern wetland complexes and areas.

Table 7. Table of acreage of project areas to avoid for habitat hotspot conservation. The amount of acres within each project that is in direct conflict of either four or more species habitats, or five or more species habitats. For more in-depth review of the breakdown of conflict acres by project, see Figures 37-39. Maps featuring each project's areas to avoid are located in Appendix C. Note that "All Projects" does not mean all avoidance acres for each project were added together; since there is project overlap (i.e. disagreement about development types at certain locations), I extracted areas where 4 and 5 or more habitats overlapped and then extracted these areas from a merged dataset containing all projects. The acres to avoid for "All Projects" is less than the sum of the individual project avoidance acres because I took the areas of overlap into account.

Project	Acres to Avoid for Areas of 4 or More Species	Acres to Avoid for Areas of 5 or More Species
WDC	1608.1	1154.9
NWQ	1831.8	1499.2
Vision	3321.2	1041
All Projects	6383.6	3573.4

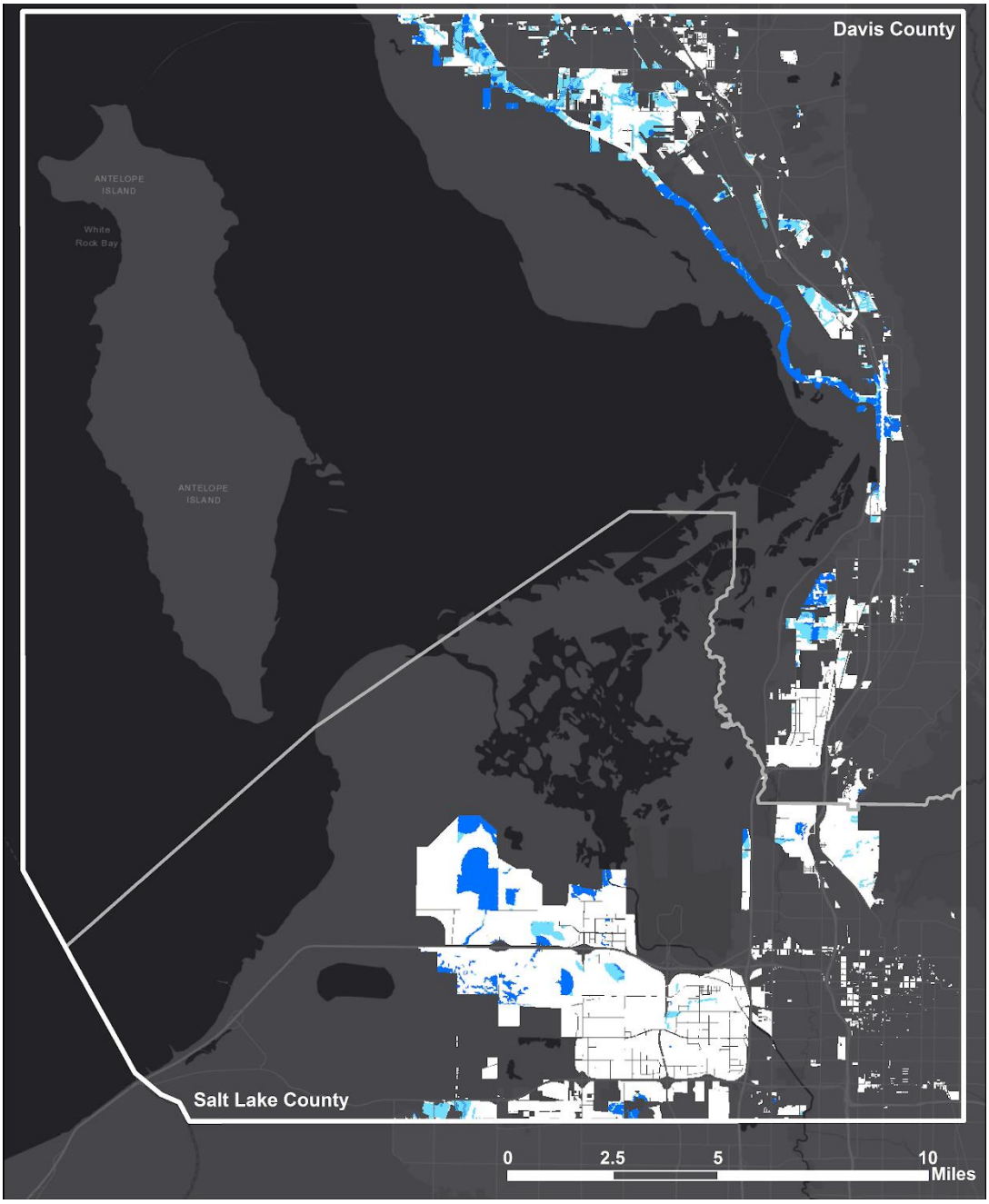

Figure 43. Map of project area footprints and areas to avoid that have high amounts of overlap between species' habitats. The footprint of all three projects in white, areas of conflict where five or more species' habitats overlap are shown in dark blue. The lighter blue indicate areas where habitats for four bird species overlap. All blue areas are hotspots for migratory birds, and are in direct conflict with at least one project. These are areas where development should be avoided at all costs.

There is a large difference in the overall amount of acres in conflict between four or more and five or more species overlap (2,810.2 acres (1,137.2 ha)). If conflict areas are avoided where five or more habitats overlap, the Vision project areas to avoid drops from the most acreage (3,321.2 acres (1,344.0 ha)) to the least amount of acres to avoid (1,041 (421.3 ha)). There are many residential development conflict acres in the northern portion of the study area that impact areas where four species' habitats overlap (see light blue areas in the top half of Figure 43). Much of the dark blue conflict areas (i.e., where five or more species' habitats overlap) in the north are caused by the WDC highway development, especially the southern half of the project. Residential and highway developments show the greatest amount of conflict with these hotspots of bird habitat, and are thus the most impacted in terms of mitigation and avoidance measures needed. Maps showing all development types (e.g., all industrial development for all projects, all commercial development for all projects, etc.) are located in Appendix D.

Next Steps for this Research

The next logical steps for this research would include analyzing impacts on habitat for different life-stages of migratory birds (e.g., from chick to breeding adult) as animals use habitats differently depending on the life-stage they are currently in. Presence-absence phenological data (i.e. where species are found and not found in the area throughout the year) should be updated based on habitat use by species for each season and life-stage to gain a comprehensive assessment of how different species and guilds are using habitat in the area. I also recommend expanding the conflict assessment

area to the entire Great Salt Lake watershed, as there are likely to be other large development projects proposed throughout the region.

Recommendations for Current Development

I have three major recommendations concerning the three proposed projects assessed in this research:

1. **Lean into 'centered growth':** One of the Wasatch Choice 2040 Regional Vision's key strategies is for the Wasatch Front to develop in a sustainable way with specific development centers located in convenient areas throughout the region (Envision Utah, 2016b). Supporting growth via changes in already developed areas will lessen the impacts to migratory birds by decreasing the conversion of open space or farmland to development. I also caution delegating large areas to the development of single-family home neighborhoods — a large portion of conflict in the north section of the study area is due to this kind of residential development from the Vision project. Research shows increasing housing density in already developed areas, and practicing "land-recycling" in developed areas not only saves municipalities money and prevents habitat loss, increasing density also decreases the amount of new infrastructure that needs to be built, such as roads, and helps protect natural resources, such as water and air quality, both of which require more attention along the Wasatch Front (Cirrus Ecological Solutions, LC, 2017; Environmental Protection Agency, 2006; Utah

Division of Air Quality, 2016).

2. **Maintain and protect 'the fringe':** Protect agricultural and open space land around the Great Salt Lake wetlands, as these are frequently used "spillover" habitats, and provide forage and resting habitat for waterbirds, and some species of shorebirds and waterfowl (Petrie et al., 2013; Thomas et al., 2013; Zimmerman et al., 2013). Much of the NWQ project is expected to displace open space and agricultural land that borders protected bird habitat, and so hotspot areas located within the project zone should be protected and include interconnecting corridors to each other and to other protected habitat areas (e.g. duck club land and mitigation wetlands). I would also strongly recommend that developers in the NWQ area follow the more environmentally conscious construction plans and policies that Salt Lake City laid out in their *Northwest Quadrant Master Plan* (Salt Lake City, 2016). Avoiding all development just west of the proposed WDC project is ideal, as there are large sections of habitat hotspots located in the vicinity. I would recommend that counties, cities, organizations, and other agencies (such as The Nature Conservancy) acquire conservation easements for these areas so they remain as open space and agricultural land, and be made unavailable for future development. Figure 45 shows the recommended areas for future conservation and development in the area. New research on land allocation between urbanizing areas and habitat conservation supports maintaining natural

buffers and habitat around cities for sustaining biodiversity in native avifauna species:

> "Given an ongoing increase in urban populations and expansion of urban boundaries, strategic zoning and protection of existing native vegetation on the fringes of urban environments combined with policies that encourage urban infilling - particularly within industrial and residential land - will be critical for future conservation" (p. 10, Geschke et al., 2018).

3. **Reconsider the West Davis Corridor:** The WDC project, although smaller in scope than the other two projects, creates a disproportionate amount of conflict with high quality, hotspot habitats (Figure 46). Studies show the construction of major highways has impacts beyond habitat fragmentation (Environmental Protection Agency, 1994; Trombulak and Frissell, 2001). A lot of time and effort has gone into this project, and the need for better transportation management and infrastructure for the future is imperative (UDOT, 2017). However, as a conservation planner, I recommend this project either be moved to a less contentious area (likely closer to the Wasatch Mountains), or be dismissed altogether in favor of focusing resources and efforts on improving and promoting public transportation and creating more opportunities for non-vehicular travel. While the WDC project aims to prevent any increase in road congestion from the current levels out to 2040, some studies have found that through 'induced

demand,' the construction of highways actually increase automobile use and does not alleviate traffic congestion (Brady, 1993; Duranton and Gilles, 2011; Handy, 2015; Jaffe, 2015). This highway also directly opposes the 'centered growth' principle from the Wasatch Choice 2040 Regional Vision project, which aims to keep people from having to travel long distances (usually on highways) for jobs or necessities and promotes walkable communities (Envision Utah, 2016b).

Figure 45. Map of the overall recommended future development and conservation areas.

Figure 46. Map of hotspot habitat conflicts with the West Davis Corridor project. Light blue areas indicate four species' habitats overlap, whereas dark blue indicates where five or more species' habitats overlap.

Recommendations for Planners

Going forward, I have several recommendations for land managers, planners, and decision-makers to help accommodate sensitive migratory bird habitat in the unique setting around Farmington Bay:

1. **Communicate & collaborate:** There are many types of landowners, policy-makers, and agencies in this region who would benefit from communicating with each other. Not to say some organizations are not already doing this, but greater interdisciplinary cooperation will strengthen the region as a whole and provide opportunities to build relationships across municipal and political boundaries. The environment and wildlife are not concerned with these boundaries, and so management and conservation objectives should transcend these boundaries as well. Federal, state, county, and municipal governing agencies need to communicate so all parties are well-informed of regional management objectives, and invested parties can identify potential collaborations and opportunities to work together. Look to regional collaborations, such as the Wasatch Front Regional Council or the Intermountain West Joint Venture, as leading examples of associations that have used collaboration as a tool to generate a greater impact. A similar joint venture should be created that focuses on the environment, wildlife, and creating a sustainable, regional development plan for all residents of the Wasatch Front.

2. **Collect, update, and share regional data:** While the USGS GAP data were the best available data for this project, new presence and absence data should be collected for the entire Wasatch Front region, including the area south around Utah Lake. The 1997-2001 Great Salt Lake Waterbird Survey sampling methods

could be used an example, and should be expanded upon to include the entire region, not just areas directly bordering the Lake. This will be a necessary feat every decade (or as often as funding permits) to assess how changes in climate, land use, and lake levels impact migratory bird populations and habitats; conservation and regional plans should be amended as new data becomes available. Data should be advertised and shared with other data-driven organizations, such as the regional Joint Ventures, the National Audubon Society, The Nature Conservancy, the Wild Utah Project, and others.

3. **See the forest for the trees:** Impacts from local land use and land cover changes are just one of the stresses that migratory birds face. Effects from climate change, over-allocation and increased upstream water diversions, habitat degradation and loss from invasive plants (such as *Phragmites australis*), increased predation from introduced species (such as raccoons and red foxes), and habitat degradation and loss elsewhere are some of the other stresses migratory birds are already facing (Wilsey et al., 2017). While the total amount of conflict acres identified in this research are comparatively small in terms of the entire habitat area for these species (being migratory animals, these birds have habitats dotted along migratory routes that can span from Chile to Alaska), it is important to understand that any impacts to a major migratory hub, such as the Great Salt Lake ecosystem, has far-reaching effects on the hundreds of bird species that use this habitat, and

therefore, affects hundreds of other locations and ecosystems throughout their migratory routes (Holdo et al., 2013). Conserving habitat at a crucial migration stopping point is but one tree in a forest of issues, which is why fostering collaboration, cooperation, and large-scale management approaches is a must for maintaining healthy migratory bird populations (Dayer, 2013).

4. **Update and perform conflict assessments as new projects are proposed:** Use this conflict assessment as a guide for identifying areas suitable for either new development (no or low conflict areas) or conservation (high conflict areas). Include distribution data for other flora and fauna to assess and avoid conflicts for multiple types of ecosystems and wildlife. This research shows conflict assessments can be performed without having to collect new data — there are other free available options, such as the USGS GAP program, the US Fish and Wildlife Service, the IUCN Red List data portal, and local sources such as universities, joint ventures, the Wild Utah Project, local duck clubs, and the UDWR. This is where connecting with other organizations and interested parties can help a lot.

CHAPTER 5

CONCLUSIONS

The Wasatch Front is a narrow North-to-South corridor running between the Wasatch Mountain Range to the east, and the Great Salt Lake to the west. The opportunity for development expansion is severely constrained by these two natural features. Even so, development is occurring farther east into the mountains, and further west into floodplains and wetlands, displacing much of the agricultural land and open space that buffers the Great Salt Lake. However, the Wasatch Front is the most densely populated and fastest growing area in Utah (Kem C. Gardner Institute, 2016). To support the ever-increasing working population, the government of Utah is striving to increase the robust economic growth of the region through economic incentives and infrastructure development. One of Governor Herbert's goals is to make Utah a leading economy in not only the U.S., but in the world (Drake, 2018). Much of the State's growth in both population and economics are expected to occur predominantly along the Wasatch Front, which will require new and improved development strategies to accommodate the expected expansion.

While the area is vital for socio-economic development, the area also provides crucial habitat for migratory birds, which has a positive impact on Utah's economy (Bioeconomics, Inc., 2012). Over 250 bird species from both the Pacific and Central Flyways use the GSL area during annual migrations, which provide unique recreational opportunities for birders and hunters. The Lake acts as an oasis in the desert for birds that

migrate thousands of miles across the arid Great Basin region, making this area so important that the National Audubon Society considers it “North America’s single most important interior wetlands for birds” (Sorenson et al., 2016).

Research shows that Utahns wish to maintain the region’s sensitive lands, which would also help maintain the area’s hemispherical importance to migratory birds (Envision Utah, 2001). Therefore, it is crucial for land managers, planners, and decision-makers to consider the full impacts of future development on critical migratory bird habitat when making plans and designs to accommodate future growth.

To alleviate conflict and maintain the region’s sensitive lands, I put forward three primary recommendations concerning these projects. First, promote the Wasatch Choice 2040 Regional Vision’s goal of creating ‘centered growth,’ thereby reducing sprawl, increasing mixed-use development areas, increasing housing density, and making communities more amenable to walking and biking as a main mode of transportation. Second, maintain the sensitive lands (such as wetlands and croplands) that surround Farmington Bay. If development must displace some of these areas, then mitigate for protection of other sensitive lands, and maintain habitat corridors between other habitat areas. Third, reconsider the West Davis Corridor project along the eastern edge of Farmington Bay, and instead use the monetary resources dog-eared for this project to promote and develop public transit, and walkable communities. This would help the region attain the EPA standards for air quality to the betterment of Utahns along the Wasatch Front. By following these recommendations, the conflict generated by the three

projects assessed in this study would be considerably lessened, and current migratory bird habitat would continue to exist in the face of this blossoming region.

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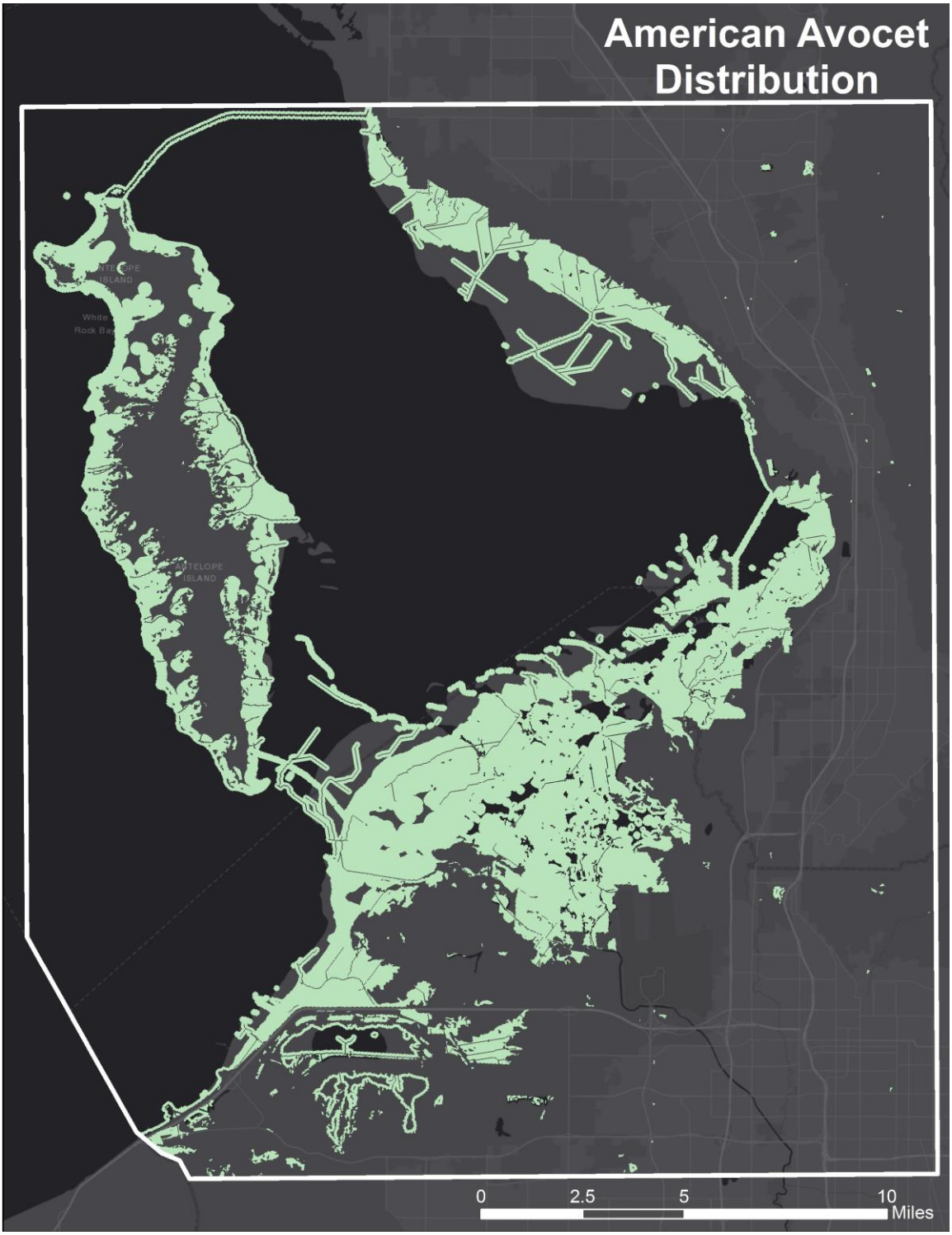
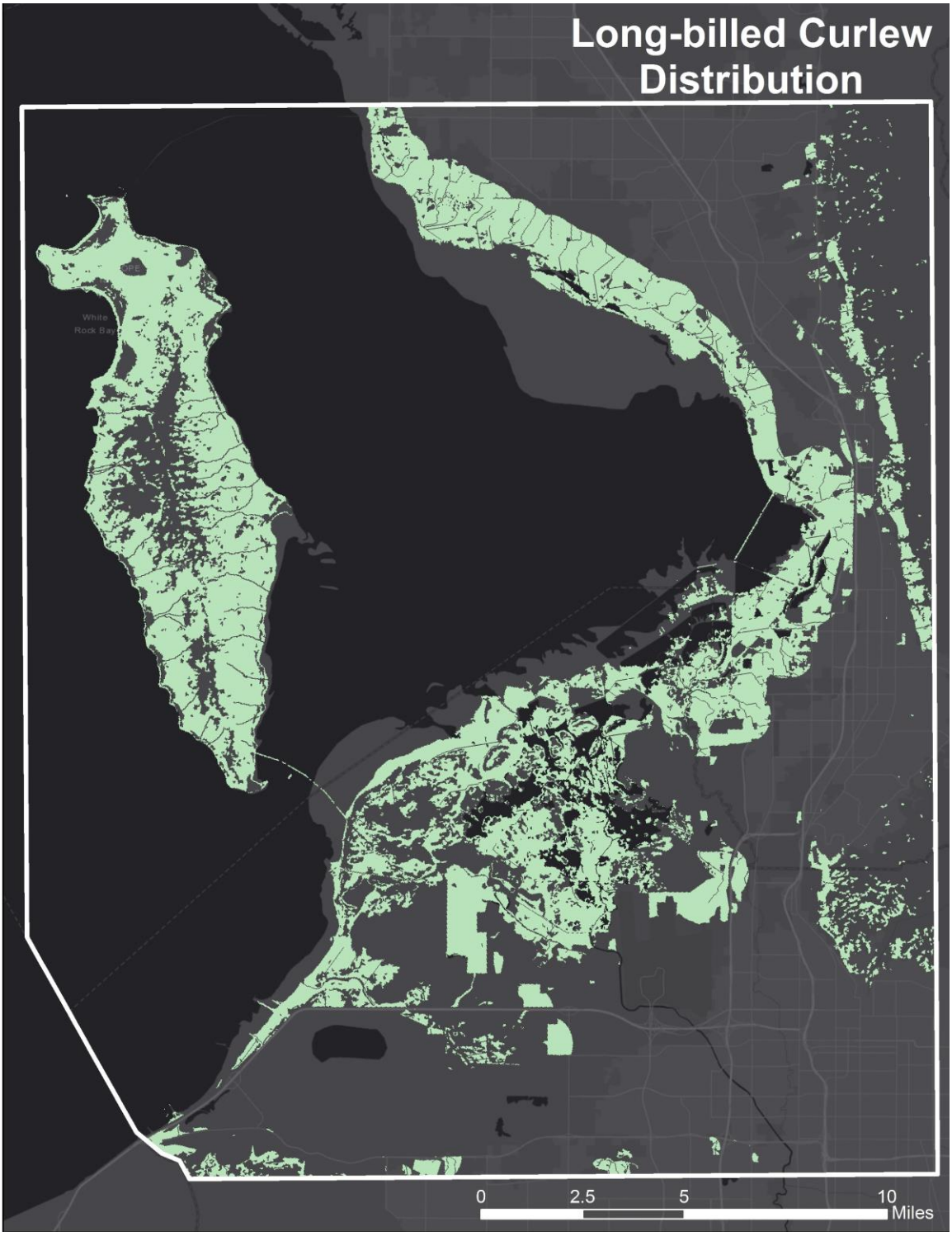
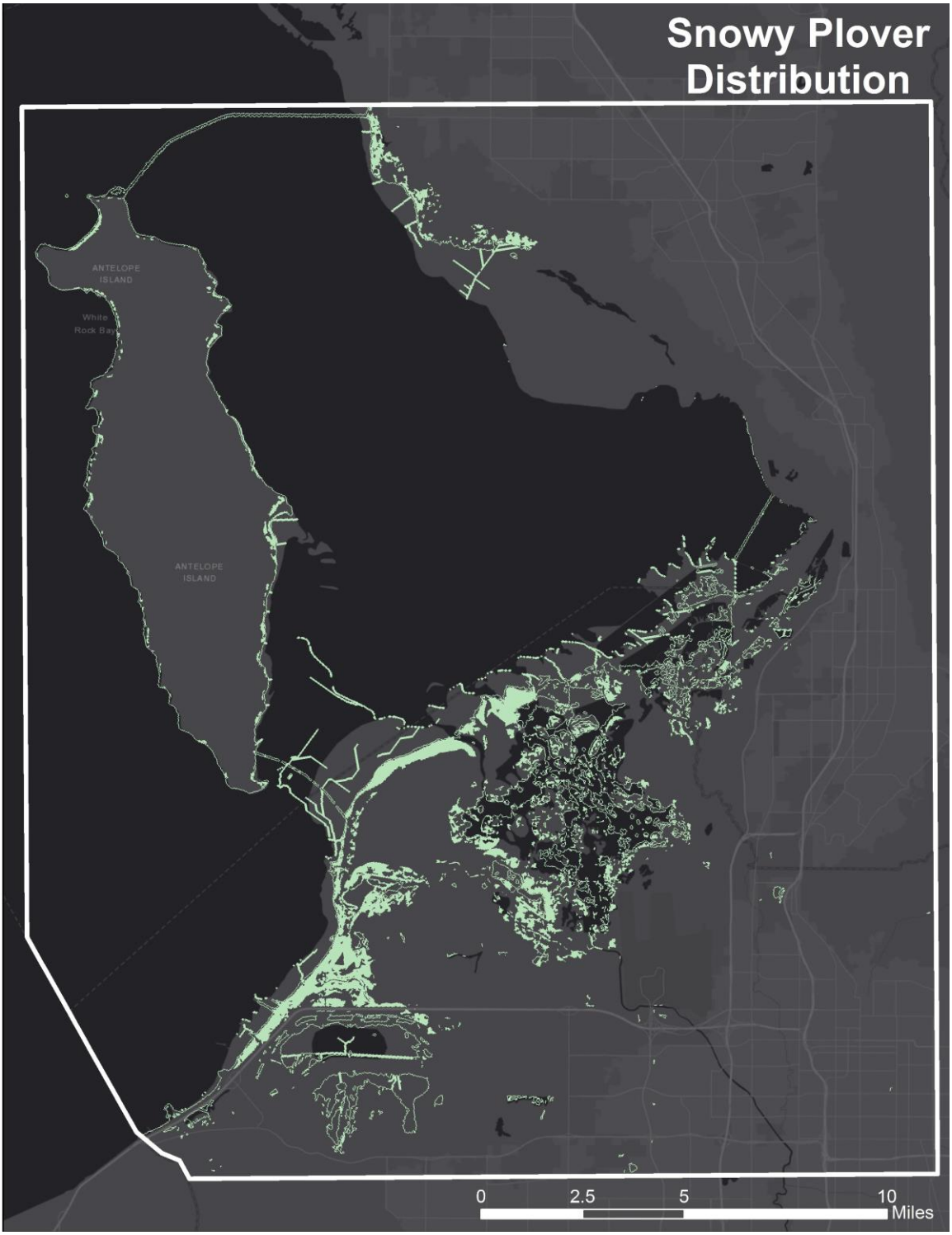
APPENDICES

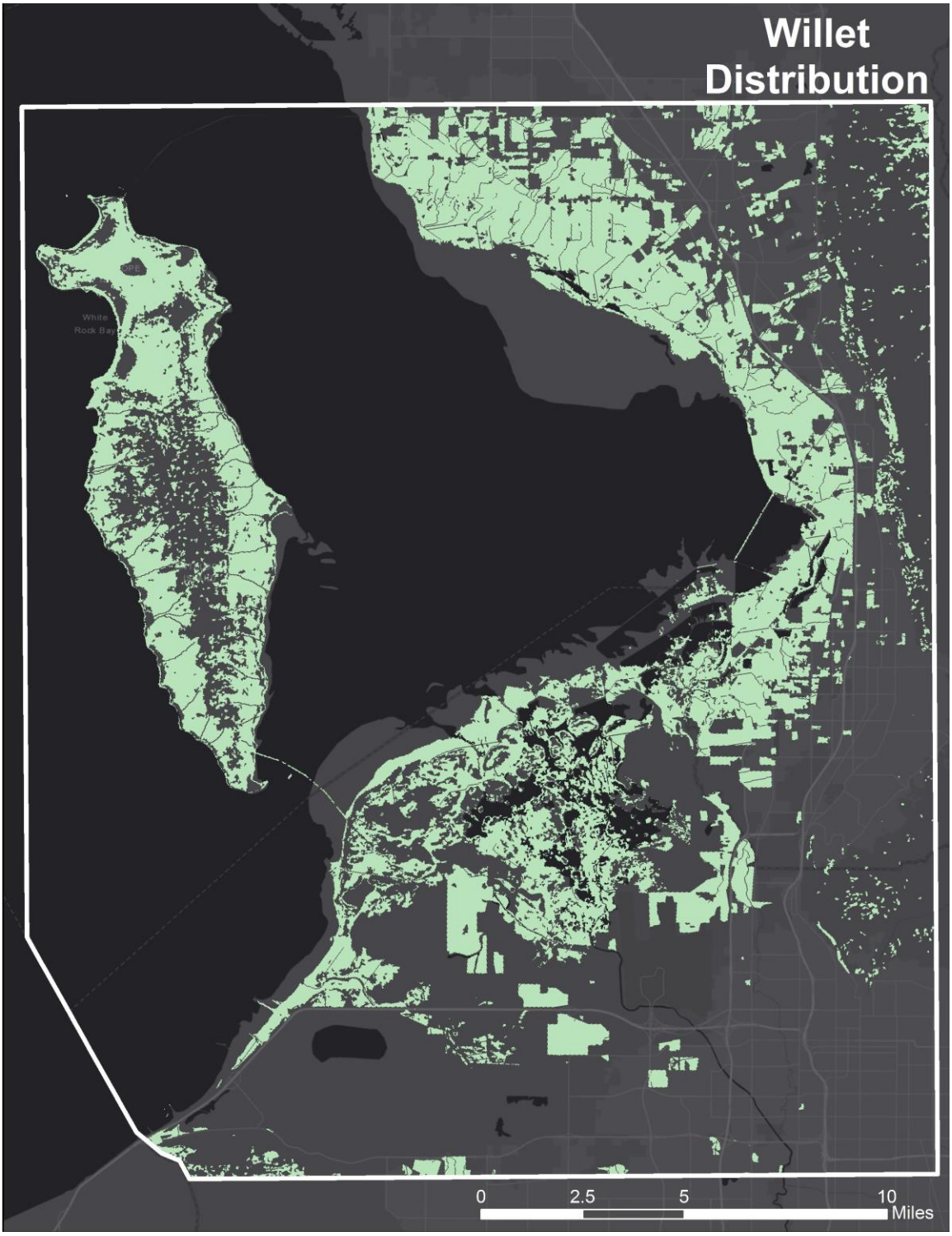
Appendix A

Species Habitat Distribution Maps

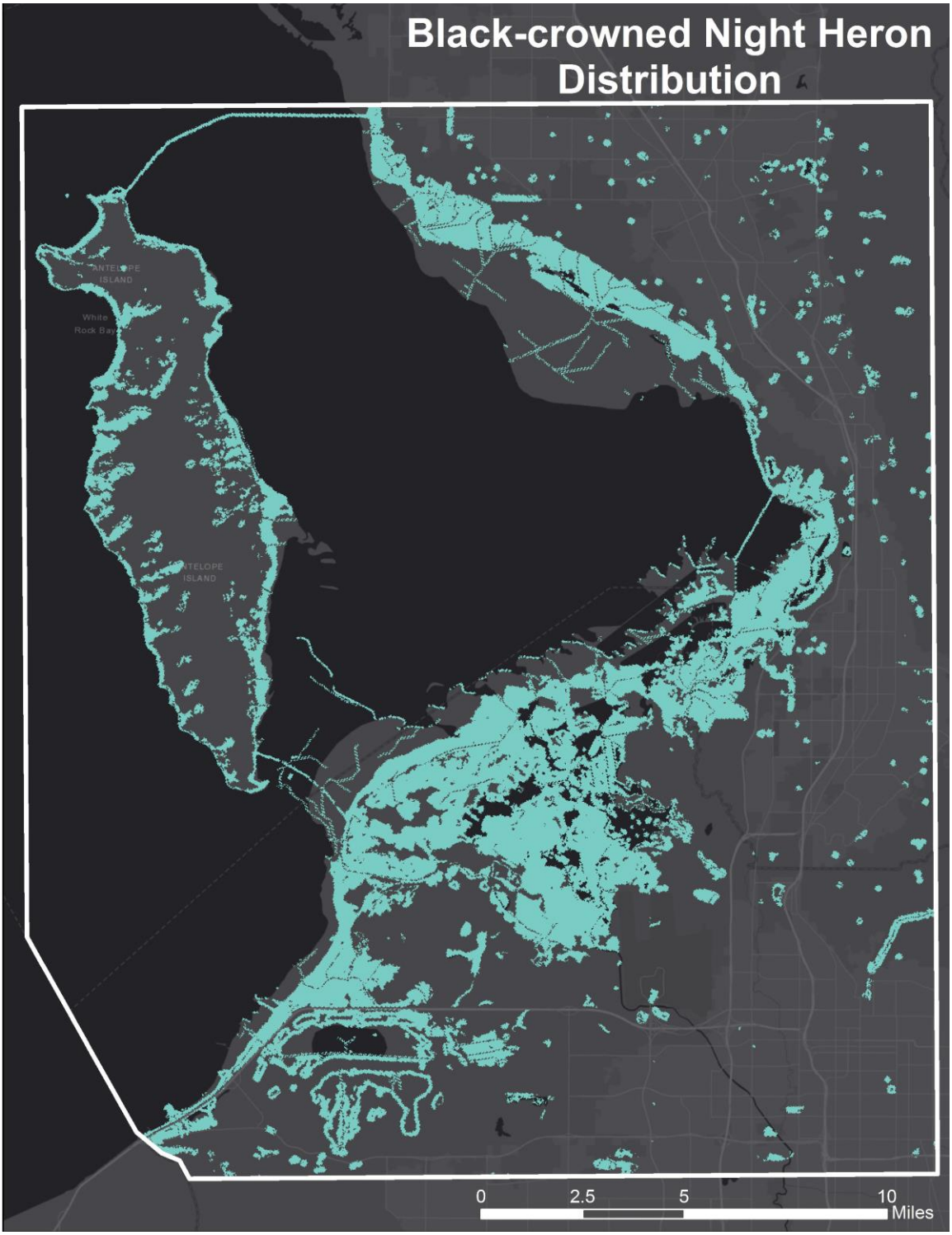

American Avocet
Distribution
0
2.5
5
10
Miles


Long-billed Curlew
Distribution
White
Rock Bay
0
2.5
5
10
Miles

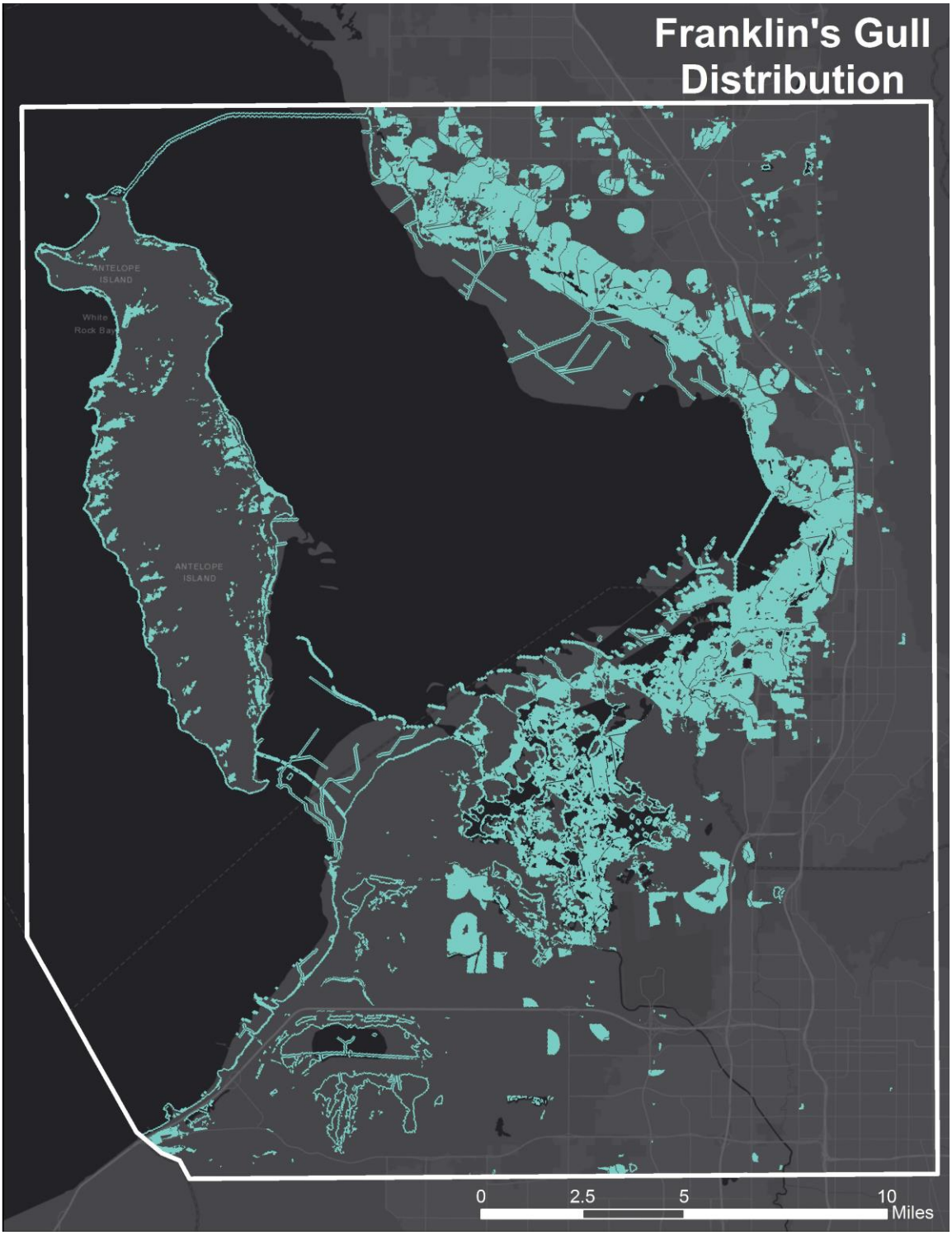

Snowy Plover
Distribution
ANTELOPE
ISLAND
White
Rock Bay
ANTELOPE
ISLAND
0
2.5
5
10
Miles

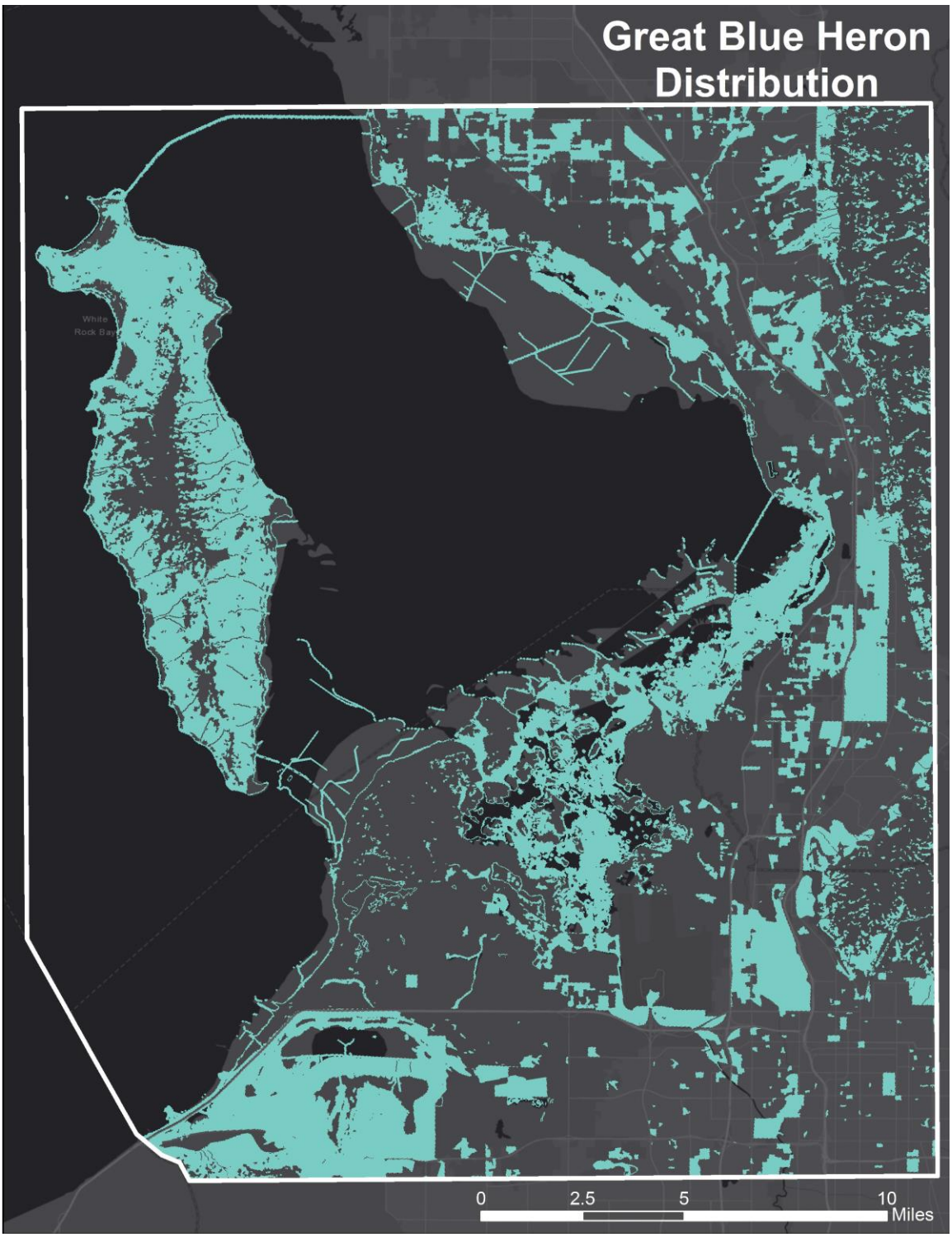

Willet
Distribution
White
Rock Bay
0
2.5
5
10
Miles

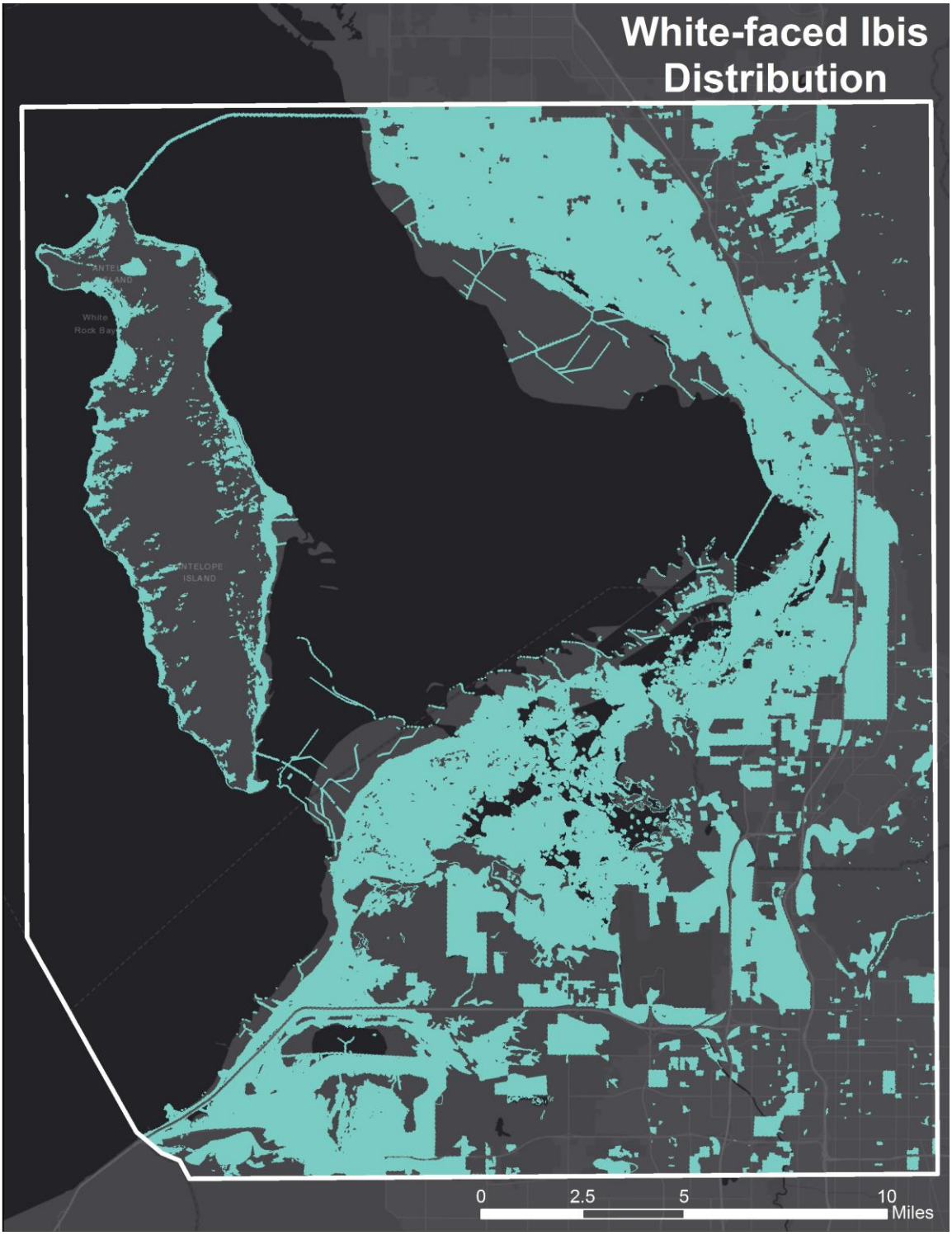

Wilson's Phalarope
Distribution
ANTELOPE
ISLAND
ANTELOPE
ISLAND
0
2.5
5
10
Miles

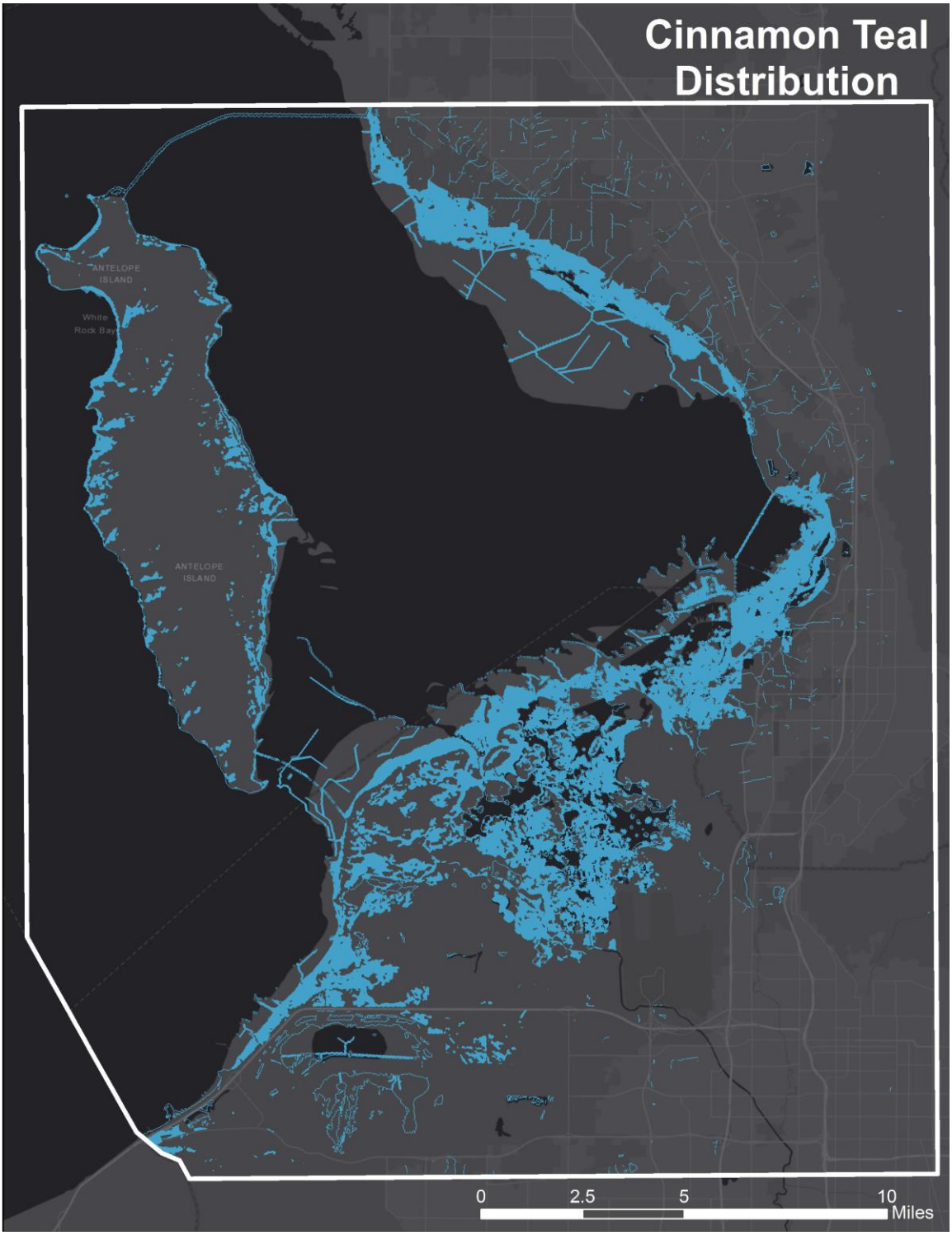

Black-crowned Night Heron
Distribution
ANTELOPE
ISLAND
White
Rock Bay
ANTELOPE
ISLAND
0
2.5
5
10
Miles

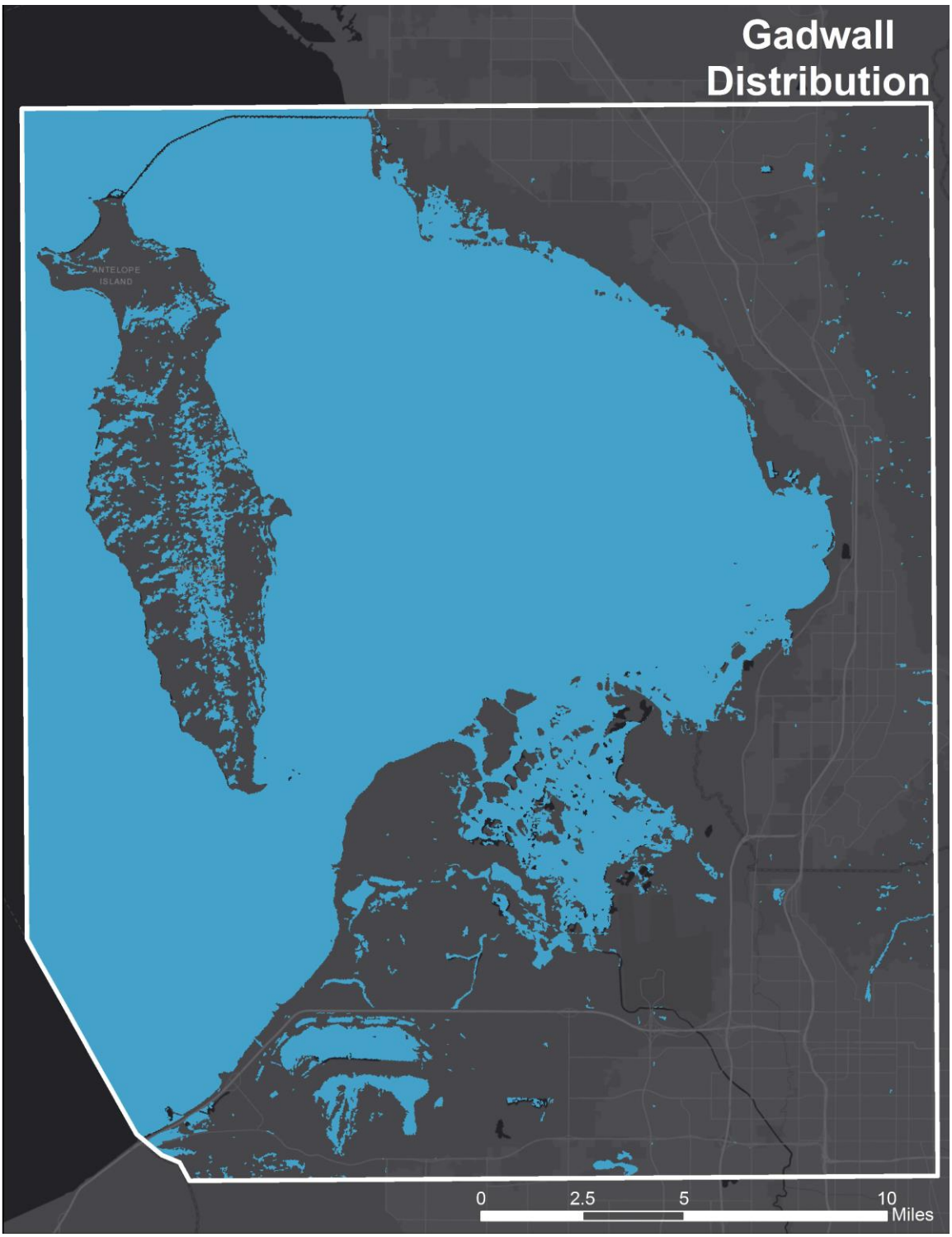

Eared Grebe
Distribution
ANTELOPE
ISLAND
ANTELOPE
ISLAND
0
2.5
5
10
Miles

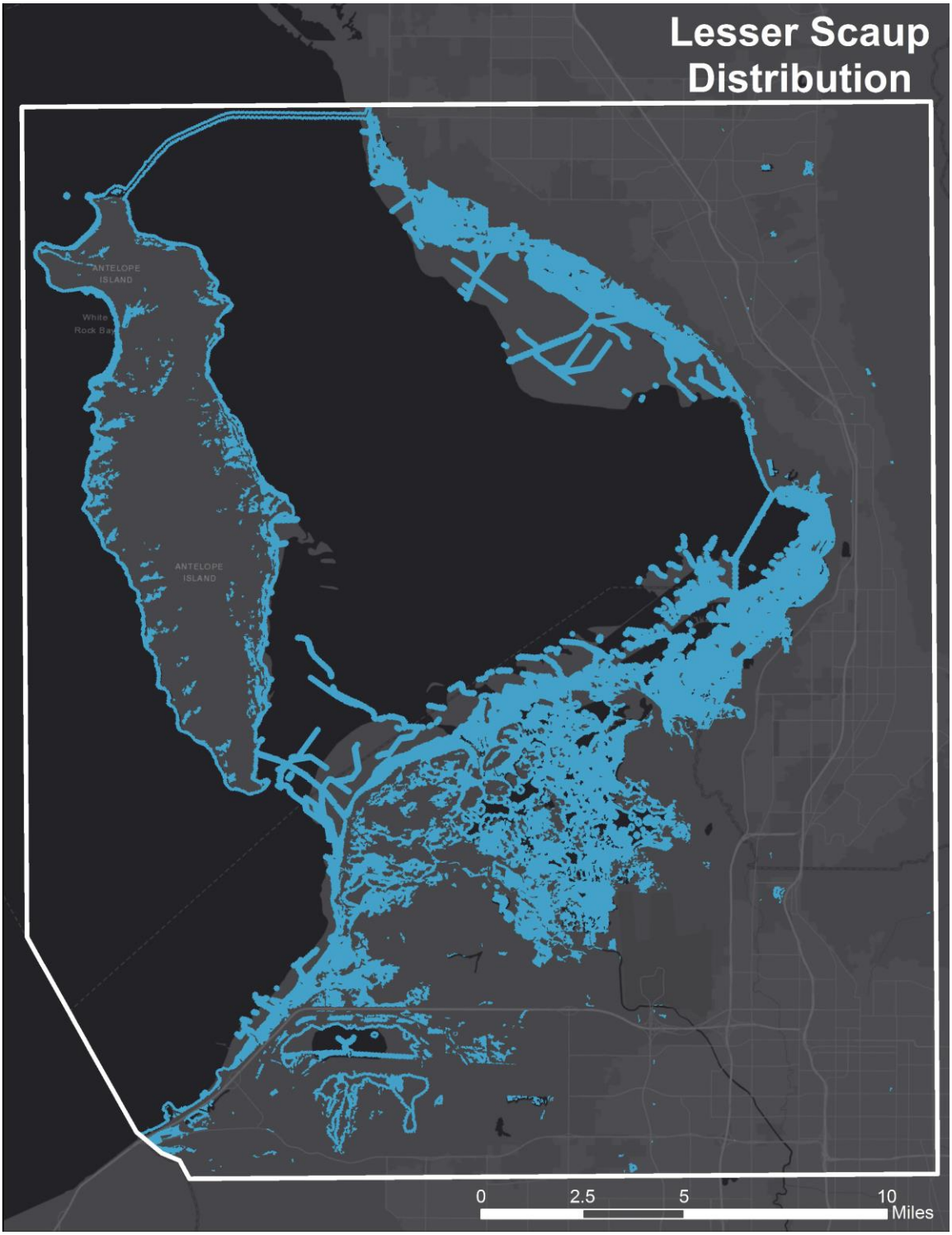

Franklin's Gull
Distribution
ANTELOPE
ISLAND
White
Rock Bay
ANTELOPE
ISLAND
0
2.5
5
10
Miles

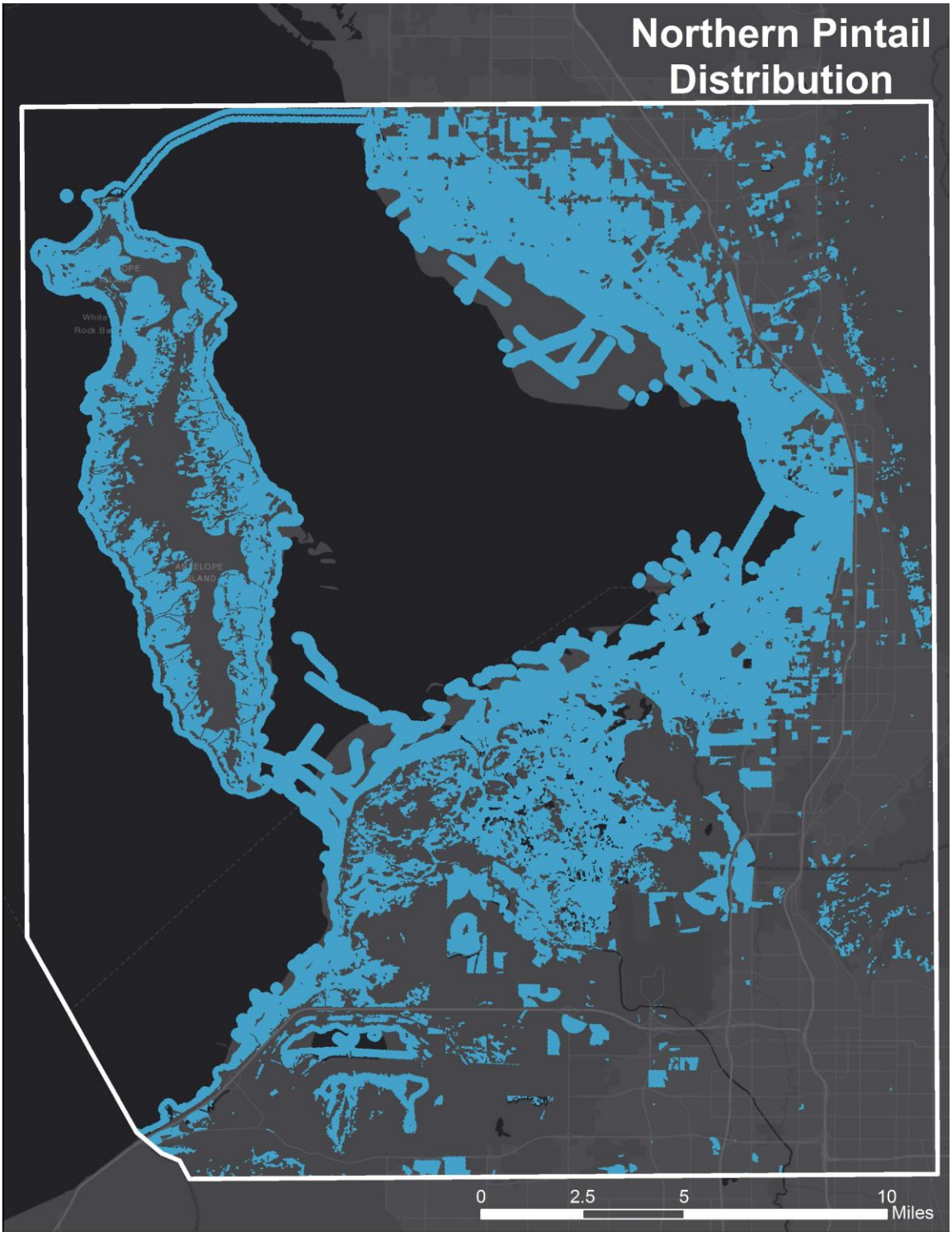

Great Blue Heron
Distribution
White
Rock Bar
0
2.5
5
10
Miles

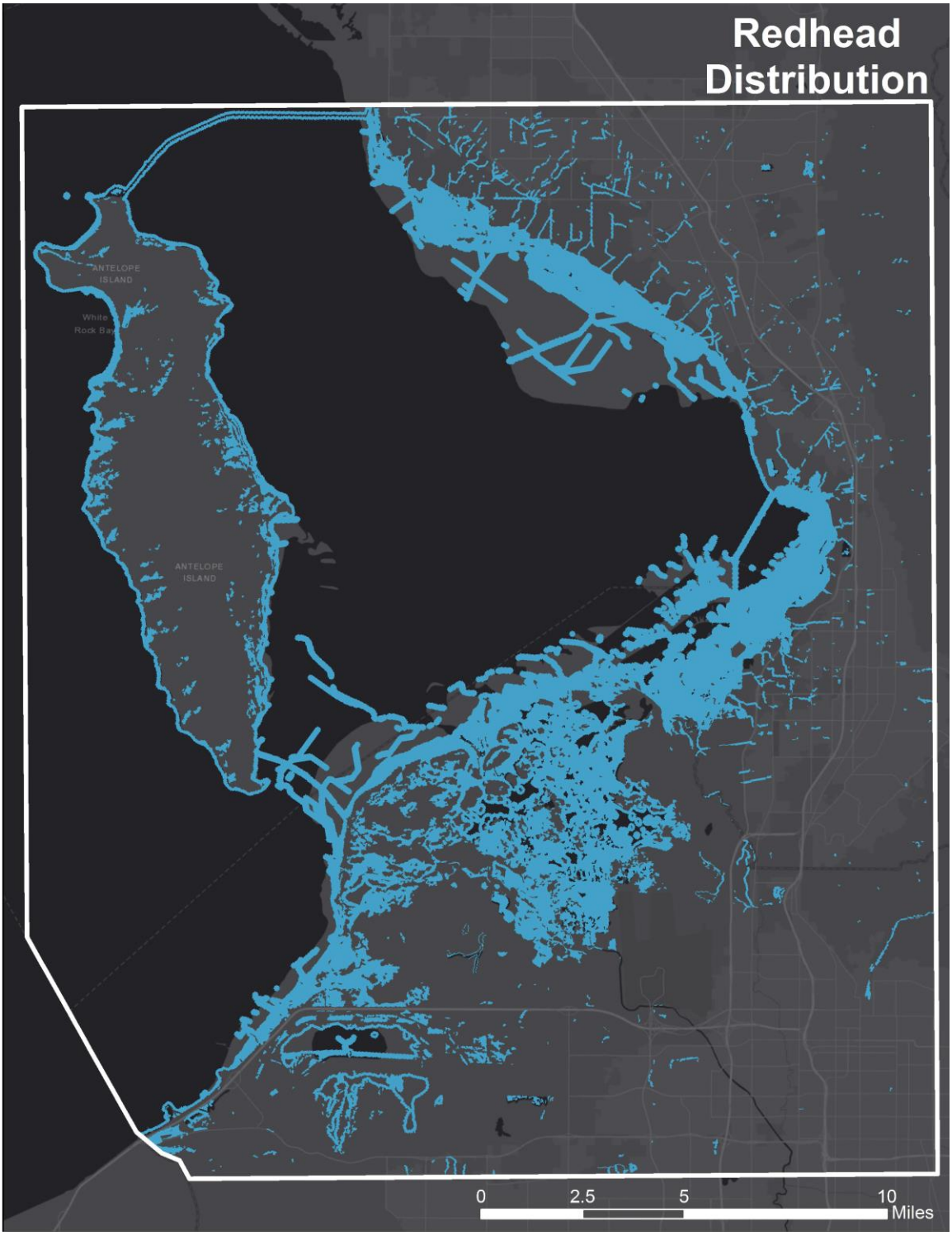

White-faced Ibis
Distribution
ANTELOPE
ISLAND
0
2.5
5
10
Miles


Cinnamon Teal
Distribution
ANTELOPE
ISLAND
White
Rock Bay
ANTELOPE
ISLAND
0
2.5
5
10
Miles


Gadwall
Distribution
ANTELOPE
ISLAND
0
2.5
5
10
Miles

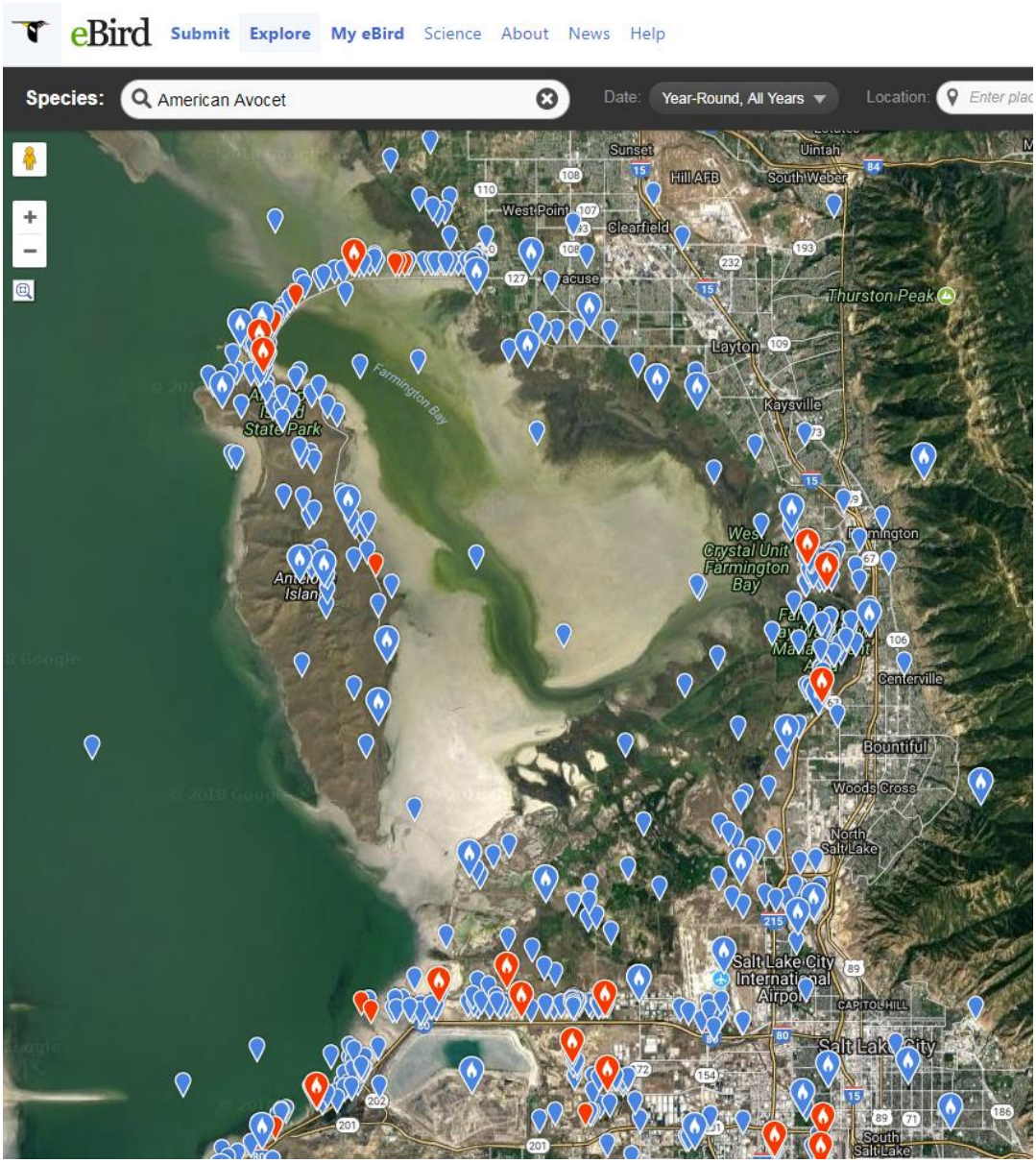

Lesser Scaup
Distribution
ANTELOPE
ISLAND
White
Rock Bay
ANTELOPE
ISLAND
0
2.5
5
10
Miles


Northern Pintail
Distribution
0
2.5
5
10
Miles

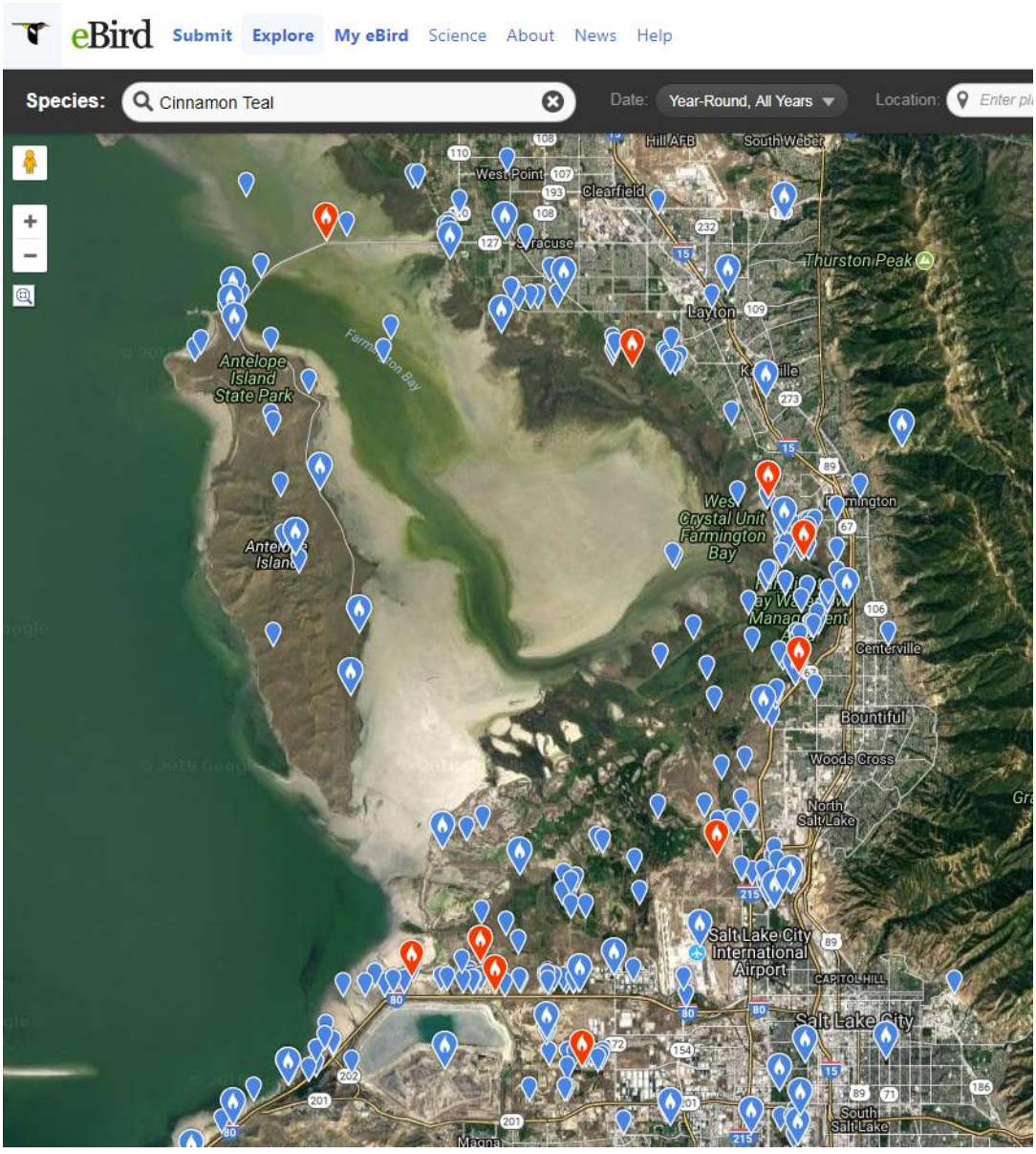

Redhead
Distribution
ANTELOPE
ISLAND
White
Rock Bay
ANTELOPE
ISLAND
0
2.5
5
10
Miles

Appendix B

eBird Sightings Maps



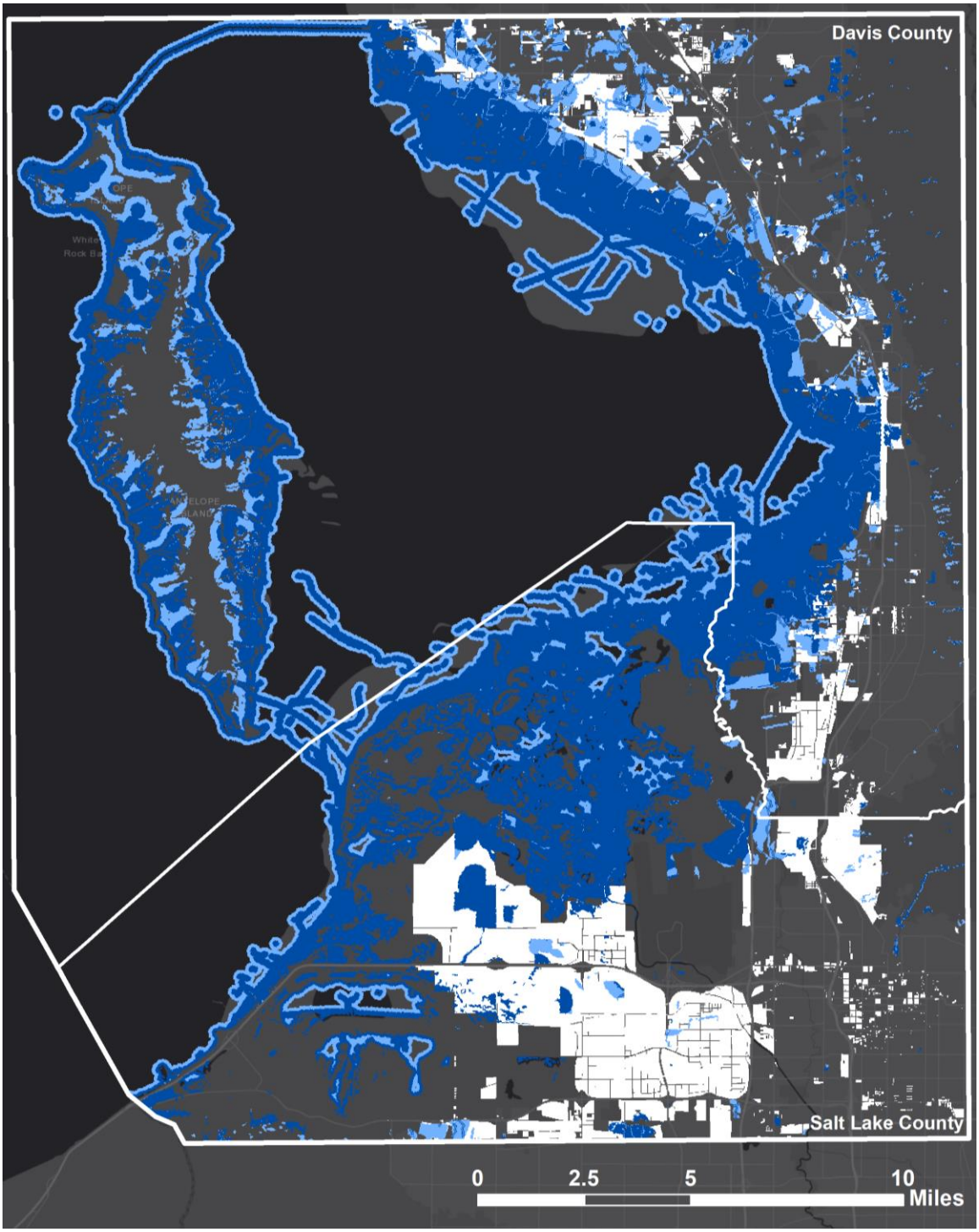
Sightings data from eBird for the American avocet (shorebird) in and around Farmington Bay. Red balloons indicate sightings within the last 30 days, and blue balloons are older sightings. The flame emblem within some balloons indicates locations of "Birding Hotspots." Notice the high concentration of sightings north of Highway 80 in the NWQ area, and just south of North Salt Lake City. This screenshot was captured on July 8, 2018.



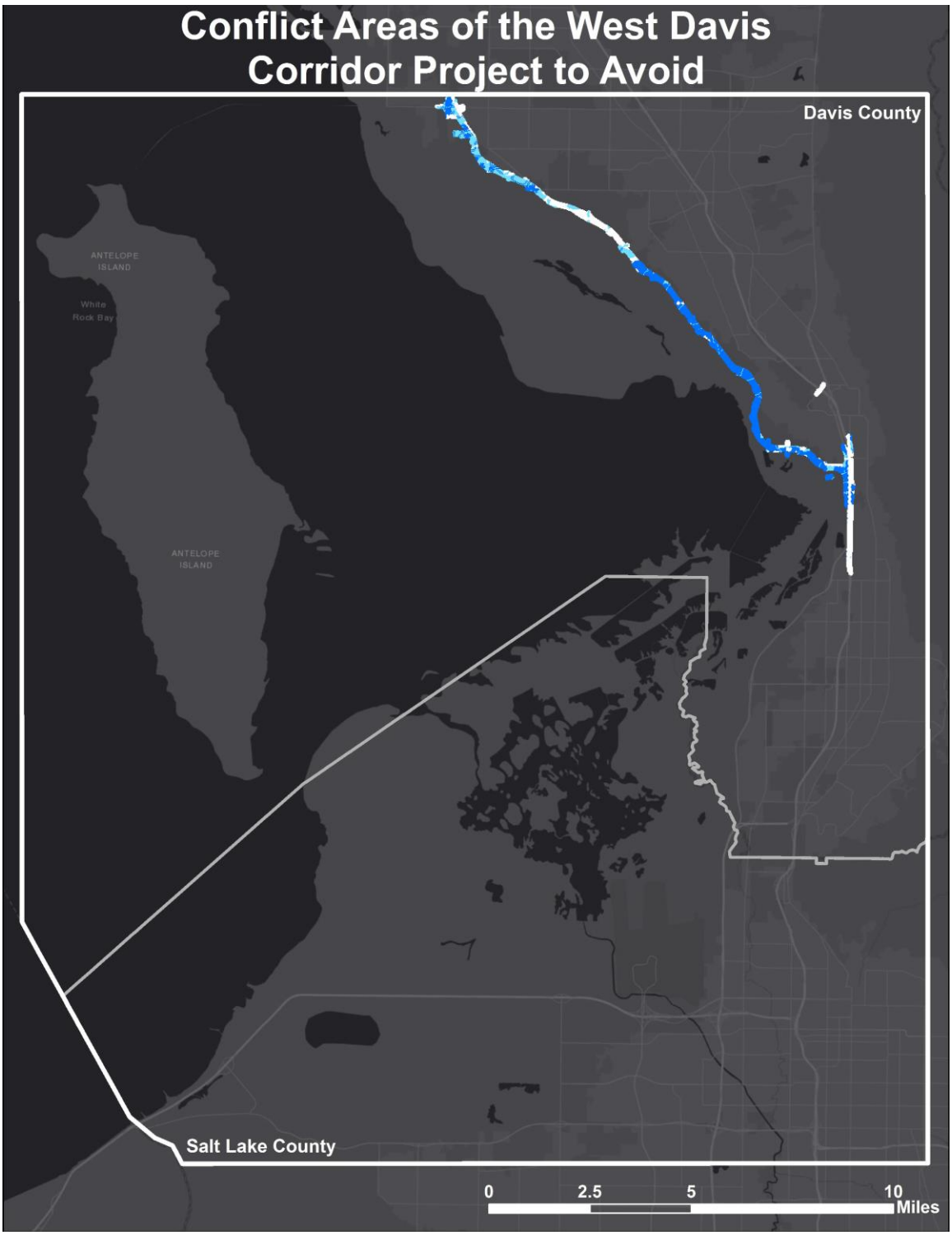
Sightings data from eBird for the Cinnamon Teal (waterfowl) in and around Farmington Bay. Red balloons indicate sightings within the last 30 days, and blue balloons are older sightings. The flame emblem within some balloons indicates locations of "Birding Hotspots." Notice the concentration of sightings north of the Salt Lake City International Airport and west of I-15 in Farmington and Salt Lake City. This screenshot was captured on July 8, 2018.

Appendix C

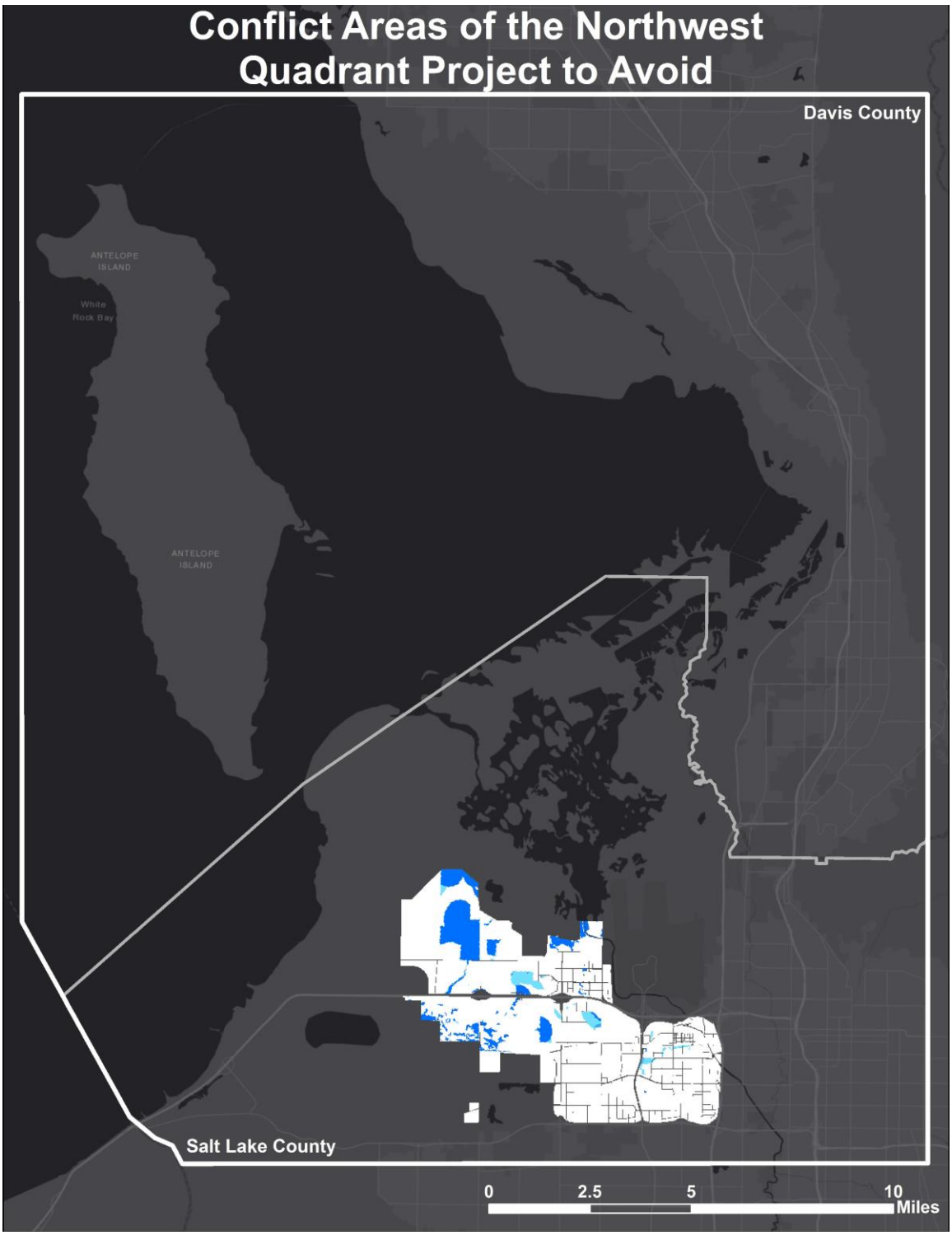
Hotspot and Avoidance Maps



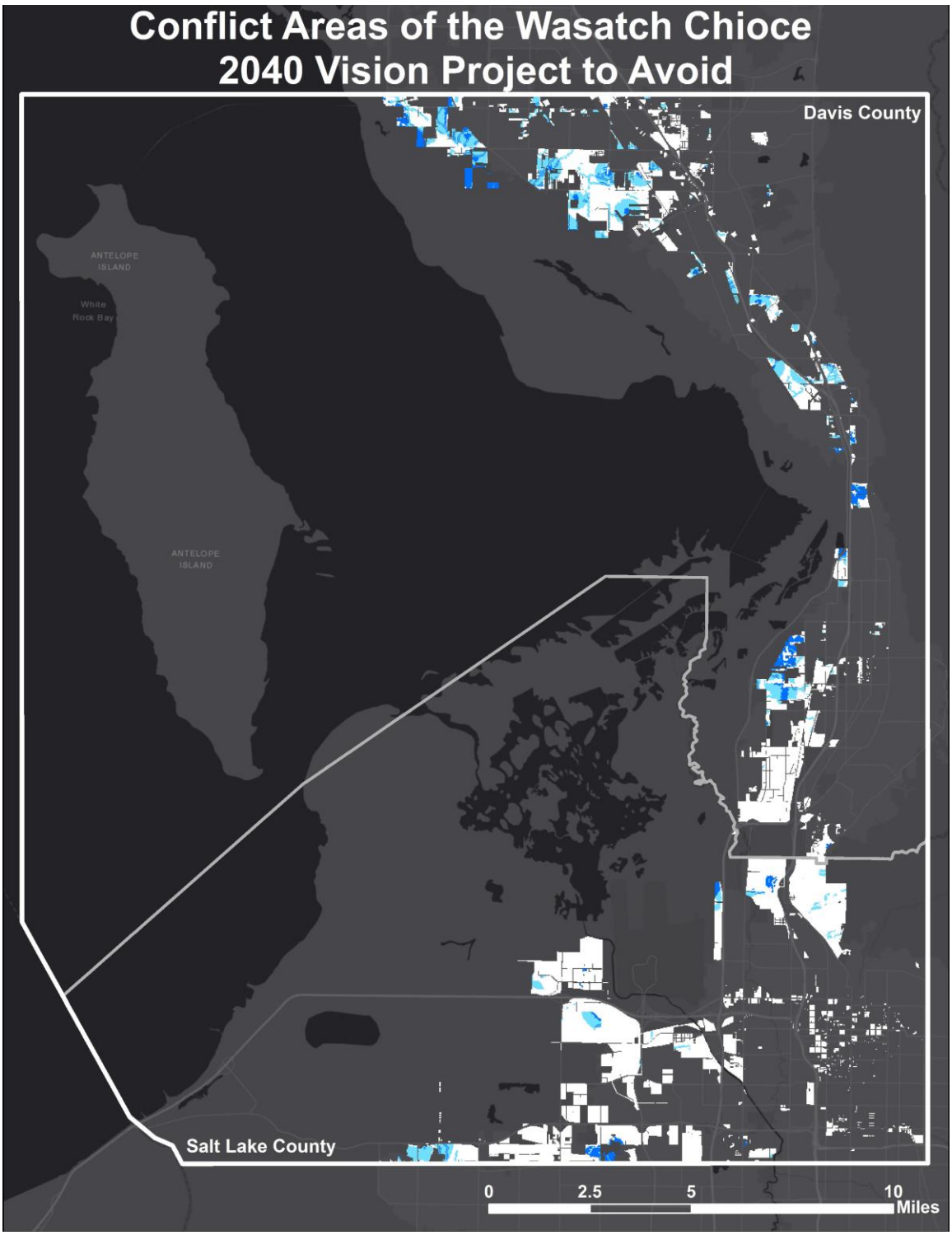
All hotspot areas (light and dark blue) and all project footprints (white).



WDC Project Areas to Avoid: Light blue areas are where four species' habitats overlap; dark blue areas are where five or more species' habitats overlap.



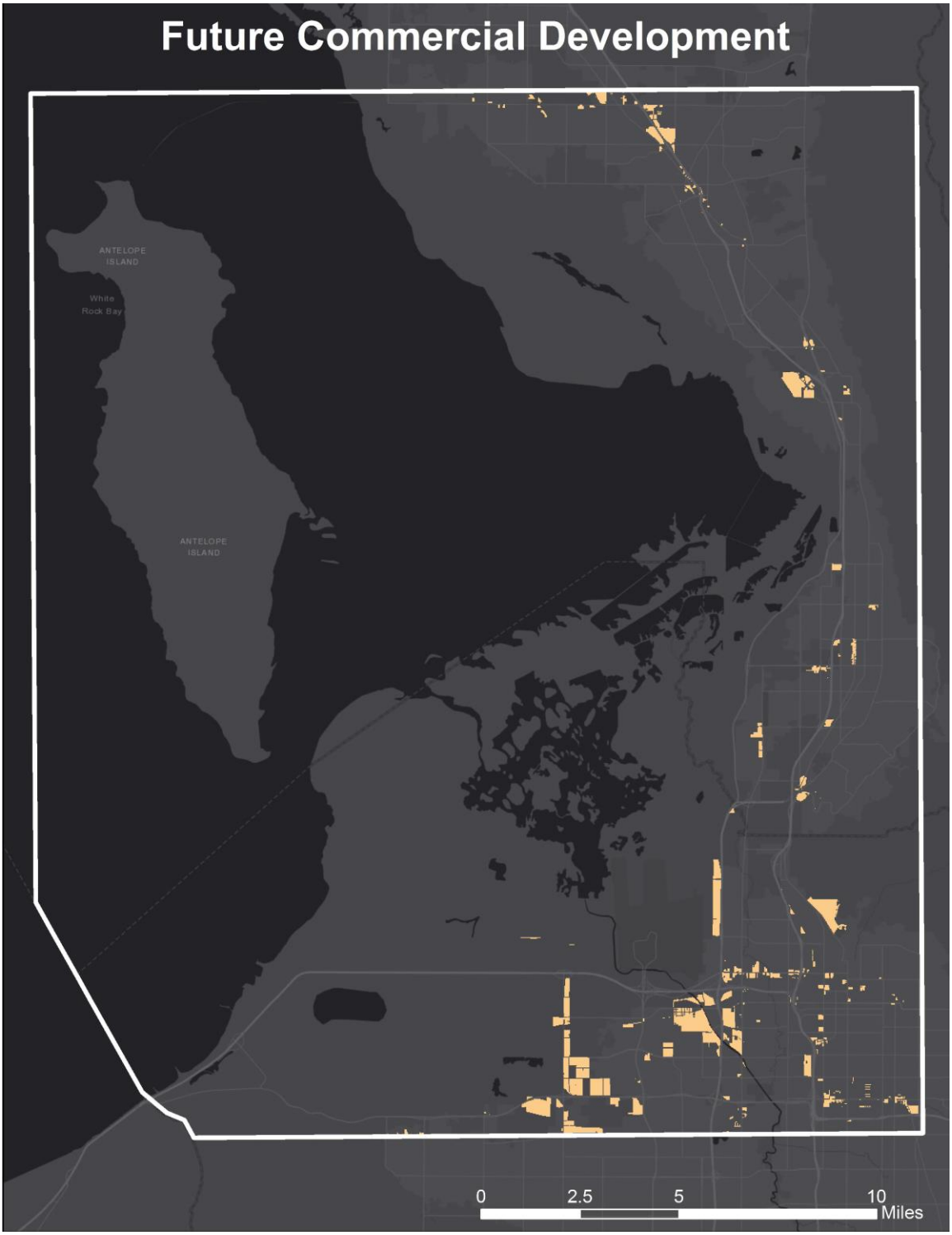
Northwest Quadrant Areas to Avoid: Light blue areas are where four species' habitats overlap; dark blue areas are where five or more species' habitats overlap.



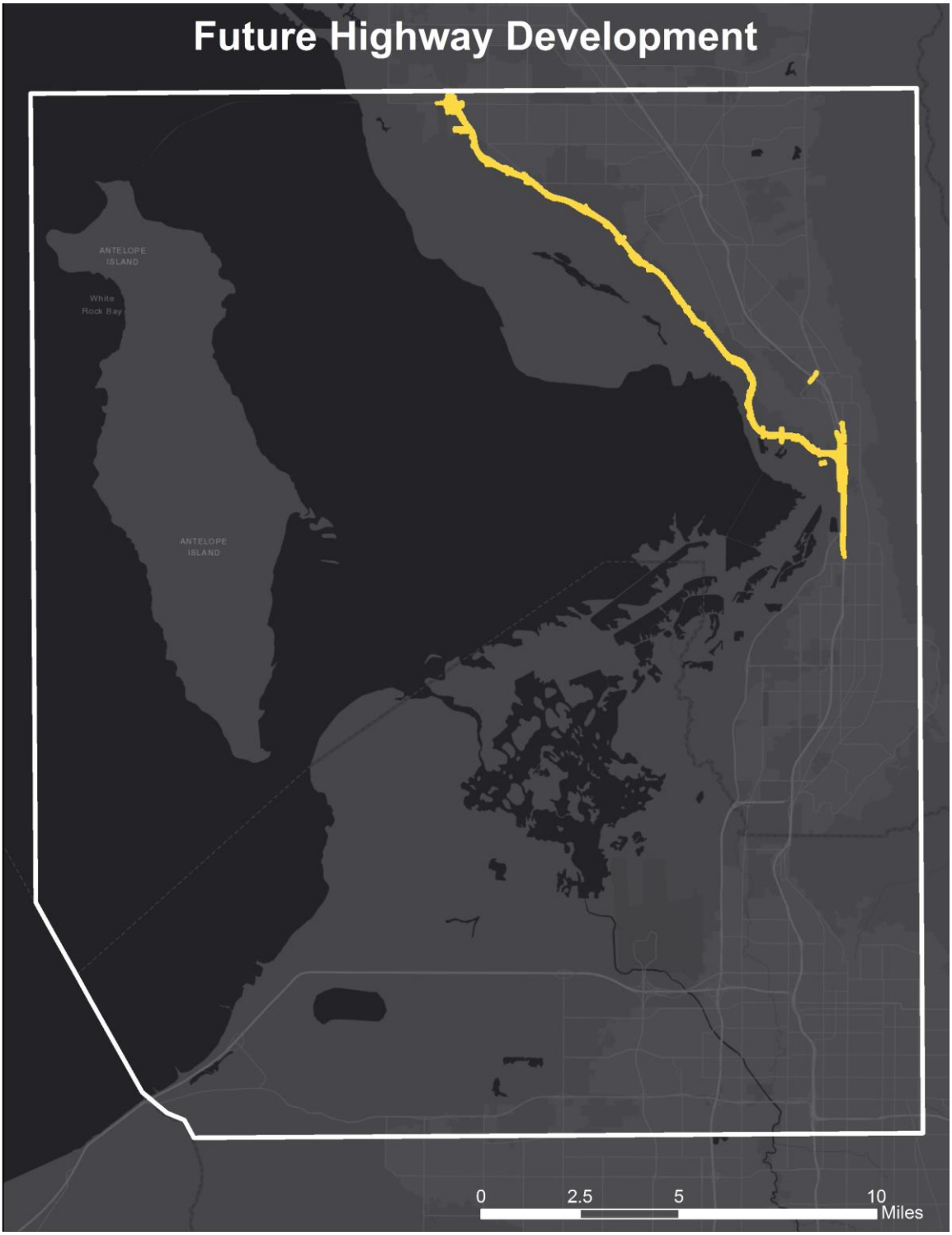
Wasatch Choice 2040 Vision Areas to Avoid: Light blue areas are where four species' habitats overlap; dark blue areas are where five or more species' habitats overlap.

Appendix D

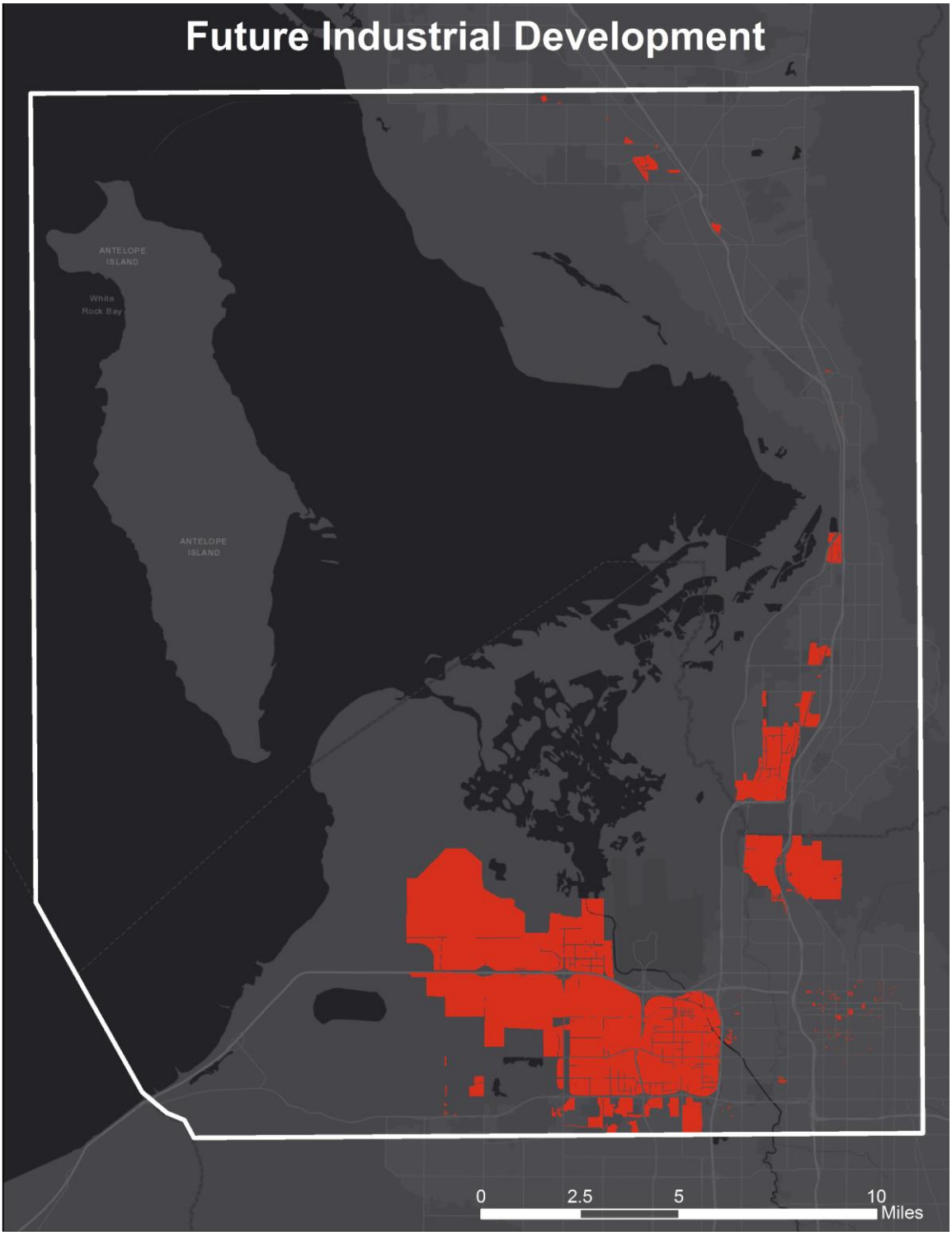
Development Type Maps



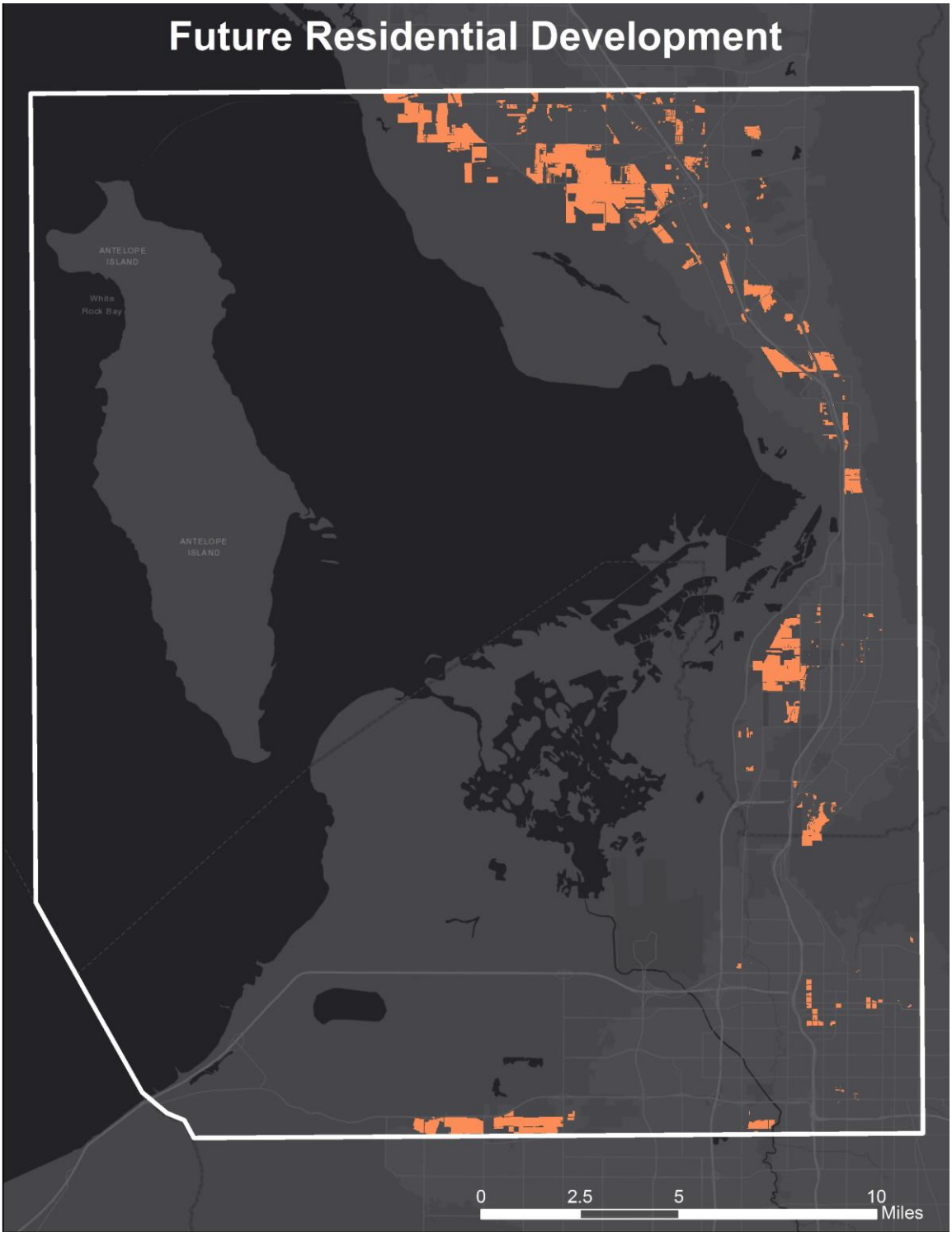
All proposed commercial development from the assessed projects.



All proposed highway development from the assessed projects.



All proposed industrial development from the assessed projects.



All proposed residential development from the assessed projects.