Birds Across Time: An Assessment of Historic and Current Waterfowl Surveys within Nisqually National Wildlife Refuge

by

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ABSTRACT

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Nisqually National Wildlife Refuge lies at the southern tip of the Puget Sound in western Washington State. This estuary is not only an important wintering and breeding site for local, resident waterfowl species but also acts as a stop-over site for birds migrating both north and south along the Pacific Flyway. Since the establishment of Nisqually NWR in the mid-1970's, biologists and volunteers alike have been monitoring waterfowl presence and behavior using a variety of different survey methods. This thesis project sought to create a comparable database using two of those survey types, aerial and ground waterfowl surveys both performed by United States Fish and Wildlife. This research project also analyzed the historical waterfowl trends that occurred before the estuary's restoration in 2009, and explored preliminary trends using a post-restoration dataset collected by United State Geological Survey. Through these analyses, qualitative descriptions of pre- and post-restoration conditions were created. This research also explored the benefits and limitations of waterfowl surveys in general. Overall, the data indicates that historical waterfowl trends were stable, and trends since the estuary restoration have also remained steady. Many years of continued data collection will be needed to fully assess the effects that the restoration and other exogenous factors have had on Nisqually River estuary waterfowl trends.

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1. INTRODUCTION AND BACKGROUND

The 2009 tidal marsh restoration at Nisqually National Wildlife Refuge (NWR or Refuge) in Olympia, Washington reestablished natural estuarine processes to a human-altered ecosystem. This ecological reestablishment created multiple research opportunities, which included an assessment of the effects of the restoration on endemic bird species. From this arose the need to analyze the historical avian data whose collection began not long after the establishment of the Refuge. However, the lack of compiled and synthesized pre-restoration survey data as well as less than two years of post-restoration data made assessing any fluctuations in avian presence, abundance or distribution difficult to impossible. The purpose of this research seeks to change that, focusing specifically on waterfowl species. The term waterfowl in this study includes all species classified as diving ducks, dabbling ducks, geese or swan.

1.1 OVERVIEW

This research had four main objectives. The first objective is to compile Nisqually NWR legacy, pre-restoration waterfowl data into a comparable database. Second, it assesses Nisqually NWR waterfowl trends through analyses of survey data from three different survey methods used over a period of more than three decades. Third, this thesis seeks to provide qualitative descriptions of pre-restoration and current post-restoration conditions of Nisqually NWR. The fourth objective discusses the benefits and limitations of both pre and post-restoration waterfowl surveys and each specific methodology used in this research.

Collection of waterfowl data began in 1975, not long after the Refuge's establishment one year prior. The data analyzed in this research is derived from pre-restoration aerial (February 1984 to January 2009) and ground-based waterfowl surveys (February 1998 to November 2008) as well as pre and post-restoration monthly high-tide surveys (October 2009 to January 2011). These specific datasets were selected as oppose to the entire historical dataset because they employed clearly defined methods and field observations by trained biologists and volunteers. This allows for a more sound final analysis than if each of the complete datasets, 1975-2011, were used.

1.2 WHAT IS AN ESTUARY?

The Environmental Protection Agency (EPA) describes estuaries as some of the most dynamic, nutrient-rich of all nature's ecosystems. Estuaries are comprised of a complex patchwork of habitats that can include combinations of salt marsh, freshwater marsh, river delta, open grasslands, riparian woodlands/wooded swamp, sea grass beds, tidal pools, mangrove forests, reefs, rocky shores, sandy beaches, open water, open mudflats or upland habitats whether forested or open (Harvey 1998). They can also be referred to as a firth, mouth, delta, bay, lagoon, harbor, inlet, sound, or embouchure. Popular sources define estuaries as semi-enclosed bodies of water that act as a transition zone between riverine and stream mouths with that of oceanic environments. They are subject to influx of both marine waters as well as fresh, riverine water and sediment. The infusion of saltwater and freshwater distributes high levels of nutrients into both the water column and benthic sediment. These high nutrient levels allow estuaries to be counted as some of the most productive ecosystems in the world. Such productivity can be measured by the amount of organic energy exported to estuaries and coastal environments (Odum 1961).

Estuaries are also known for their natural cleansing abilities (Mitsch and Gosselink 2000). Upland water drainage carries sediments, nutrients, and other pollutants to estuaries. As the water flows through wetlands such as swamps and salt marshes, much of the sediments and pollutants are filtered out. This filtration process creates cleaner water, which benefits both the health of marine life and humans. Wetland plants and soils also act as natural buffers between the land and ocean, absorbing flood waters and storm surges. Salt marsh grasses and other estuarine plants also help prevent erosion and stabilize shorelines. This protects upland habitat as well as valuable real estate from storm and flood damage.

Estuarine biodiversity has often been referred to as a "biological supermarket" due to the ability to support of complex, intricate food webs. Thousands of species of birds, mammals, fish, and other wildlife depend on estuarine habitats as places to find shelter, feed, and reproduce. Because they are so biologically productive, estuaries provide ideal areas for migratory birds to rest and re-fuel during their long journeys. Many marine organisms, including most commercially-important such as threatened and endangered species of fish, depend on estuaries at some point during life-cycle development. Due to the reliance on the sheltered spawning places provided by estuaries, they are often called the "nurseries of the sea."

Along the southern shores of the Puget Sound in western Washington State lays one such ecosystem: the Nisqually River estuary. Also referred to as the Nisqually Delta, this unique locale is the site of the largest estuary restoration project in the Pacific Northwest (Figure 1, pp 5). Due to the plethora of nutrients and microorganisms it provides, this diverse landscape supports native plants and over 300 species of wildlife that include birds, mammals, reptiles, amphibians and fish (fws.gov 2012). This includes the Endangered Species Act (ESA) threatened Nisqually Fall Chinook salmon (*Oncorhynchus tshawytscha*), an important cultural symbol for the local Nisqually Indian Tribe as well as the Bald Eagle (*Haliaeetus leucocephalus*), the national emblem of the United States.

Restoration and protection of estuaries are critical actions that have been at the forefront of recent ecological management practices. One reason for this is an estuary's suite of biological resources and services such as those just discussed. Another reason is their aesthetic contribution. Communities residing around estuaries utilize them for spiritual and cultural enjoyment. Another reason is their provision of measureable commercial commodities in the form of tourism, fisheries and recreational activities (boating, fishing, swimming, and bird-watching to name a few) all while acting as a prime locations for education and scientific study. Each of these factors is considered immeasurable those who benefit from them.

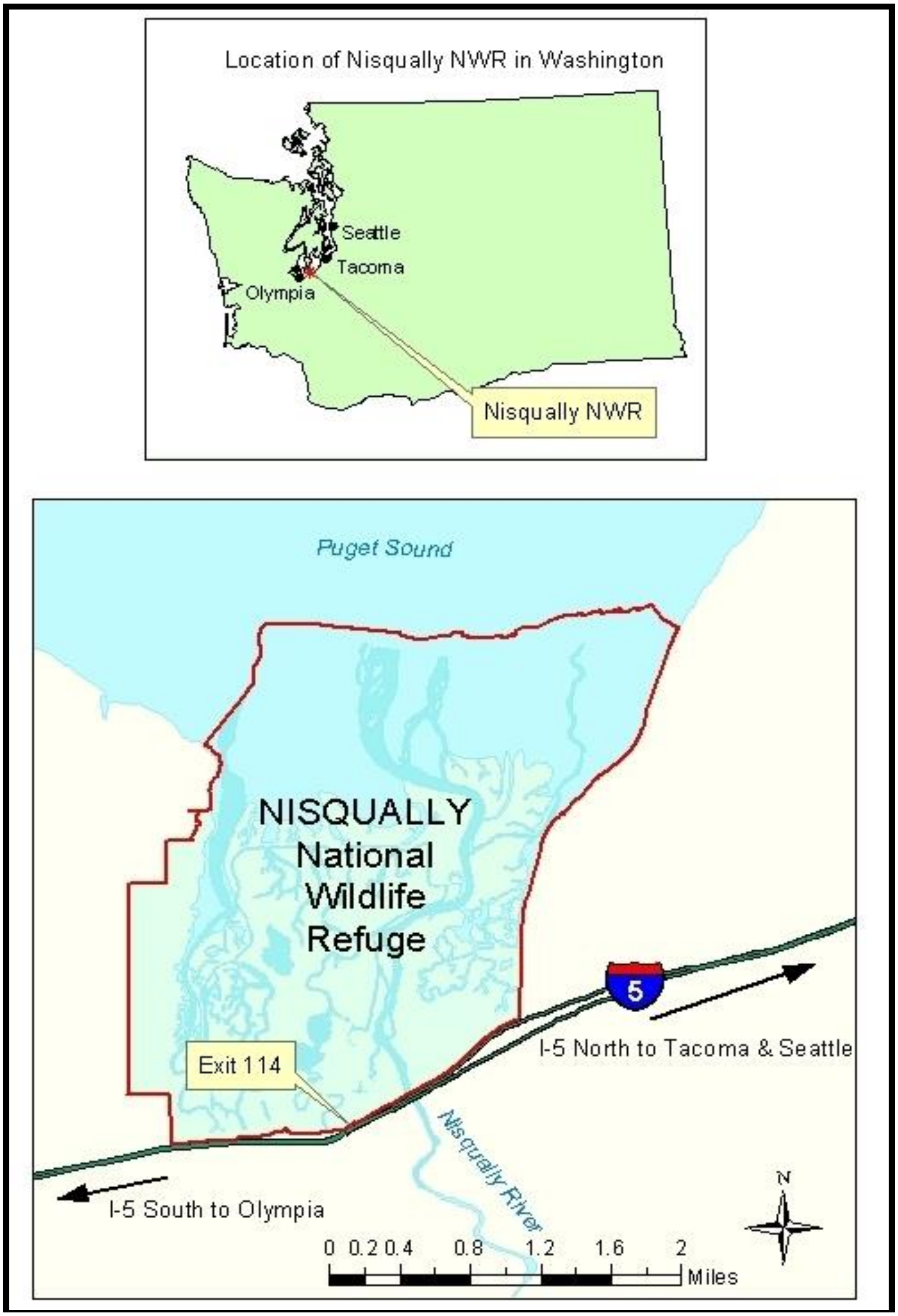

Figure 1: Nisqually National Wildlife Refuge
(Source: U.S. Fish and Wildlife Service)

The top figure represents the relative location of Nisqually National Wildlife Refuge within Washington State, while the bottom figure defines the Refuge's boundaries and specific location within the Nisqually River delta.

The economy of many coastal areas is based on the natural beauty and bounty of estuaries. When those natural resources are imperiled, so too are the livelihoods of those who live and work in estuarine watersheds. Over half the U.S. population lives in coastal areas, including along the shores of estuaries. According to a 2007 study, coastal watershed counties provided 69 million jobs and contributed $7.9 trillion to the Gross Domestic Product. Coastal counties are growing three times faster than counties elsewhere in the nation (National Ocean Economics Program, 2009).

Unfortunately this increasing concentration of people upsets the natural balance of estuarine ecosystems and imposes increased pressures on their vital natural resources. What happens on the land indirectly affects the quality of the water and health of the organisms that live in an estuary. Excessive nutrients, runoff, marine debris, pathogens, metals, invasive species and atmospheric deposition can cause ecosystem disturbances including but limited to eutrophication and algal blooms. This in turn leads to animal illness and die-off, fish kills, brown and red tides, and even human sickness. This highlights the final reason described by the Coastal and Estuarine Research Federation. They estimate that 80% of tidal marshes in the Puget Sound have been degraded or destroyed over the past 150 years. These anthropogenic actions combined with the threat of rapid global climate shift compromise any remaining estuaries including the well-being of fauna and flora that inhabit them. It is for these reasons that Nisqually NWR and the recent restoration that took place is critical to the overall health of the ecosystem and the wildlife that inhabit it, as the primary purpose of the restoration was to provide shelter and food resources to the various ecologically, economically and culturally important Nisqually salmon species.

A secondary example of the importance of the Nisqually Delta is a major non-coastal resting and feeding area for over 275 species waterfowl migrating between the Skagit Flats and Columbia River within the Pacific Flyway (fws.gov 2012). The Nisqually NWR provides thousands of acres of resting and nesting grounds for not only migrating waterfowl but also songbirds, gulls, shorebirds, raptors and wading birds. The Pacific Flyway stretches from the Arctic Circle down the Pacific coast to Central America. Waterfowl migrating within the Pacific Flyway begin arriving in the Nisqually Delta in September with some remaining throughout the winter months (Figure 2, pp 8).

1.3 NISQUALLY NATIONAL WILDLIFE REFUGE

Nisqually National Wildlife Refuge is managed by United States Fish and Wildlife Service. It is located just off of Interstate-5 in Thurston and Pierce Counties between the cities of Olympia and Tacoma, Washington. Refuge boundaries lie within the Nisqually Delta on the west side of the Nisqually River, adjacent to the neighboring Nisqually Indian Tribe lands. In 1845, James McAllister and his family settled Medicine Creek, now known as McAllister Creek. By 1852, he had begun developing the land by damming the creek and building a sawmill.

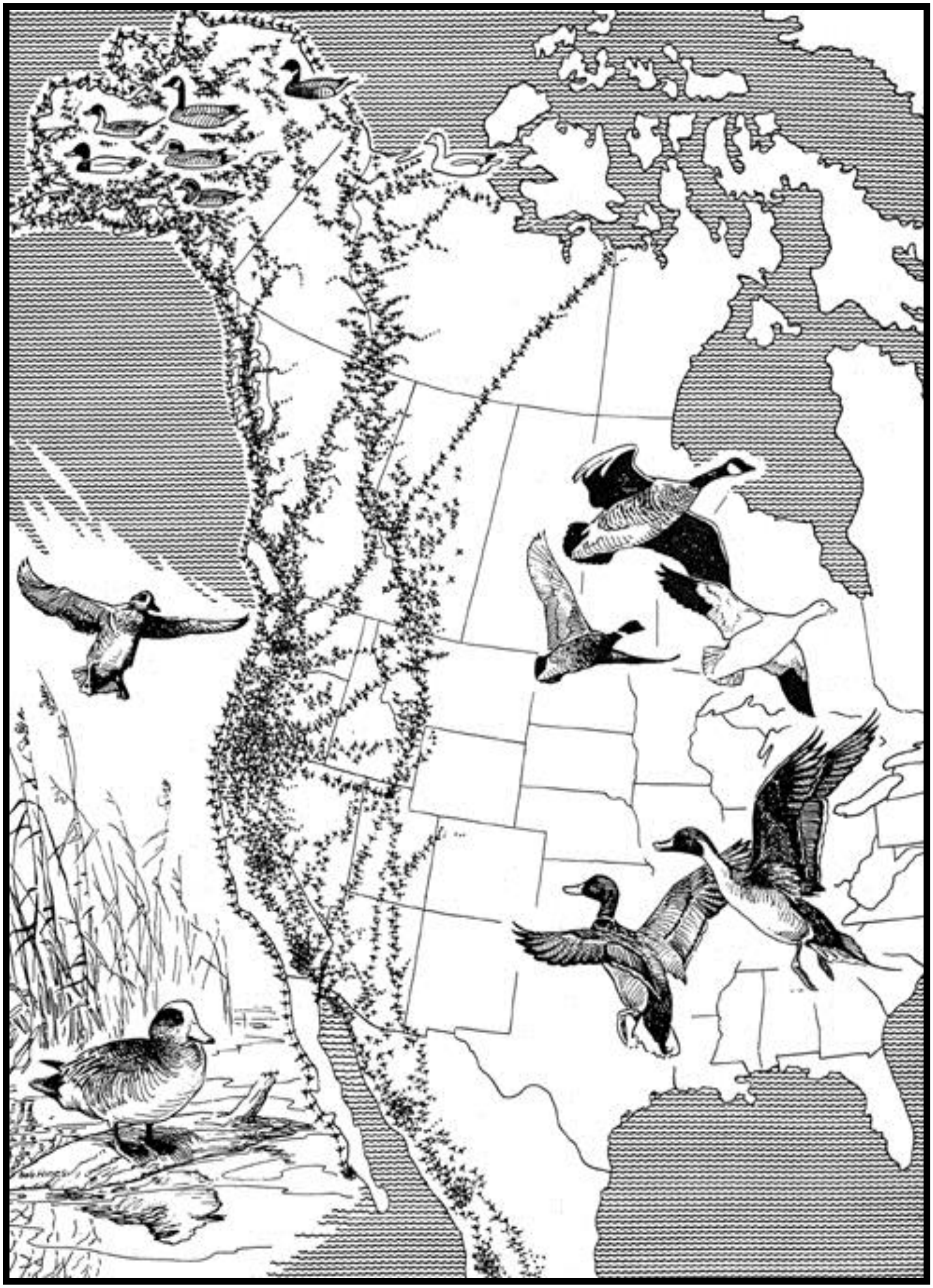

Figure 2: Pacific Flyway
(Source: USFWS)
The above figure represents the Pacific Flyway, one of four major North American avian migration flyways

In December 1854, the land became the site of an Indian treaty. Taking place at a grove of trees along the east bank of McAllister Creek, it was the first-ever Indian treaty to take place in Washington Territory. The agreement ensured fishing, hunting, and gathering rights for the surrounding tribes. Members of the Nisqually Tribe still exercise these rights to this day, fishing for various salmon species in Refuge waters.

In 1904, 2,350 acres of the Nisqually River estuary were purchased by Seattle lawyer Alson L. Brown and his wife, Emma. A crew of 30 men and a horse-drawn scoop built the original 6.44 km (4 mile) dike that prevented marine tidal inundation inside the designated area. The dike took three years to construct, and an additional three years was needed to dry and leach salts from the area (Figure 3, pg. 10). In 1910, the dike was reinforced ending the conversion of the delta into land for farming purposes. The main agricultural practices included cattle grazing and raising crops. The farm also raised chickens and hogs, ran a dairy, as well as maintained a general store and housing for the farm's crew.

Brown lost the farm after World War I, but it continued to operate under subsequent owners who rebuilt an even higher dike, as well as a cross-dike at McAllister Creek (fws.gov 2012). In 1919, the title was transferred to P.B. Truax, C.D. Clinton, and Robert Olden. Then in 1952, the land switched ownership again to Bruce Pickering who leased the land to dairy farmers for a short period of time (Farris 1974).

Figure 3: Nisqually Dike Construction
(Source: WA State Historical Society)
The above figure depicts a crew building the Nisqually dike in 1904.

In 1970, the Nisqually River Task Force was created to assist in the preservation and protection of the Nisqually River Delta. The group consisted of federal, state and local governments, natural resource business representatives, the Nisqually Indian Tribe, landowners and citizen activists. In 1987, each of these groups came together to create the Nisqually River Management Plan which provided recommended policies and implementation guidelines. The management plan also provided balanced stewardship of the area's economic resources, natural resources, and cultural resources.

In 1971, in recognition of the significance of the natural ecosystem, the U.S. Department of the Interior designated the estuarine portion of the Nisqually River Delta as a National Natural Landmark. The Nisqually River Task Force recommended in 1972 that the delta be set aside as a National Wildlife Refuge (nisquallyriver.org). Then in February 1974, in recognition of the area's unique fish and wildlife resources, the Brown Farm property and tidelands were acquired for inclusion in the National Wildlife Refuge System and became Nisqually National Wildlife Refuge (Nisqually NWR Comprehensive Conservation Plan 2005).

The Nisqually estuary restoration began in 1996 with the reintroduction of tidal flow to nine acres of land east of the Nisqually River by the Nisqually Indian Tribe in partnership with landowner, Ken Braget. This parcel, along with the rest of the Braget Farm was later acquired by the Nisqually Indian Tribe in 2000 and is cooperatively managed by the USFWS. Additional restoration action taken by the Tribe included the 8.5 hectare (21 acre) Phase I marsh in 2002, followed by the 40.5 hectare (100 acre) Phase II marsh in 2006. This earlier work culminated with the removal of the Brown Farm dike on the Nisqually NWR in October of 2009, allowing marine waters of the Puget Sound to infiltrate 308 hectares (762 acres) of land for the first time in over 100 years (Figures 4-6, pp 12-13). The area surrounding the Nisqually NWR headquarters remained diked to inhibit flooding of the Nisqually headquarters, maintenance building, educational center and visitor center.

Figure 4: Aerial Photograph Prior to the Removal of the Nisqually Dike
(Source: Nisqually NWR)

Figure 5: Aerial Photograph of Nisqually NWR in November 2009 Following the Dike Removal
(Source: Nisqually NWR)

Figure 6: Aerial Photograph of Nisqually NWR in January 2011 Following the Dike Removal (Source: Nisqually NWR)

The three figures above (4-6) represent time lapsed, aerial pictures of the Nisqually NWR dike. Figure 4 shows the dike before its removal in 2009. Both Figure 5 & 6 shows the dike remnants following its removal in 2009 and 2011 respectively.

This restoration was part of the Refuge's Comprehensive Conservation Plan, providing long-term guidance for management decisions, to set forth goals, objectives and strategies needed to accomplish refuge purposes and identify and Service's best estimate of future needs. The USFWS took habitat restoration into consideration when developing the CCP. The objectives of the CCP are to protect the Nisqually NWR resources and to contribute toward the goals of the Refuge. An excerpt of the CCP goals is as follows:

> *To conserve, manage, restore, and enhance native habitats and associated plant and wildlife species representative of the Puget Sound lowlands.*
>
> *To support recovery and protection efforts for Federal and State threatened and endangered species, species of concern, and their habitats.*
>
> *To provide quality environmental education opportunities focusing on fish, wildlife, and habitats of the Nisqually River Delta and watershed.*
>
> *To provide quality wildlife-dependent recreation, interpretation, and outreach opportunities to enhance public appreciation, understanding, and enjoyment of fish, wildlife, habitats and cultural resources of the Nisqually River Delta and watershed.*

An unaltered marsh within the Nisqually Delta, known as the Reference Marsh, has served as a benchmark for post-restoration monitoring performed by United States Geological Survey (USGS) and the Nisqually Indian Tribe. The restoration increased not only tidal marsh habitat but also the natural quality of the Nisqually NWR for public use and compatibility with National Wildlife Refuge System policies and guidelines (Nisqually NWR Comprehensive Conservation Plan 2005). USGS (Western Ecological Research Center, Coastal Marine Geology, and Western Fisheries Research Center), along with the Tribe and Nisqually NWR are continuing to lead monitoring and research efforts to track the biological and physical changes as a result of the restoration (Figure 7, pp 15).

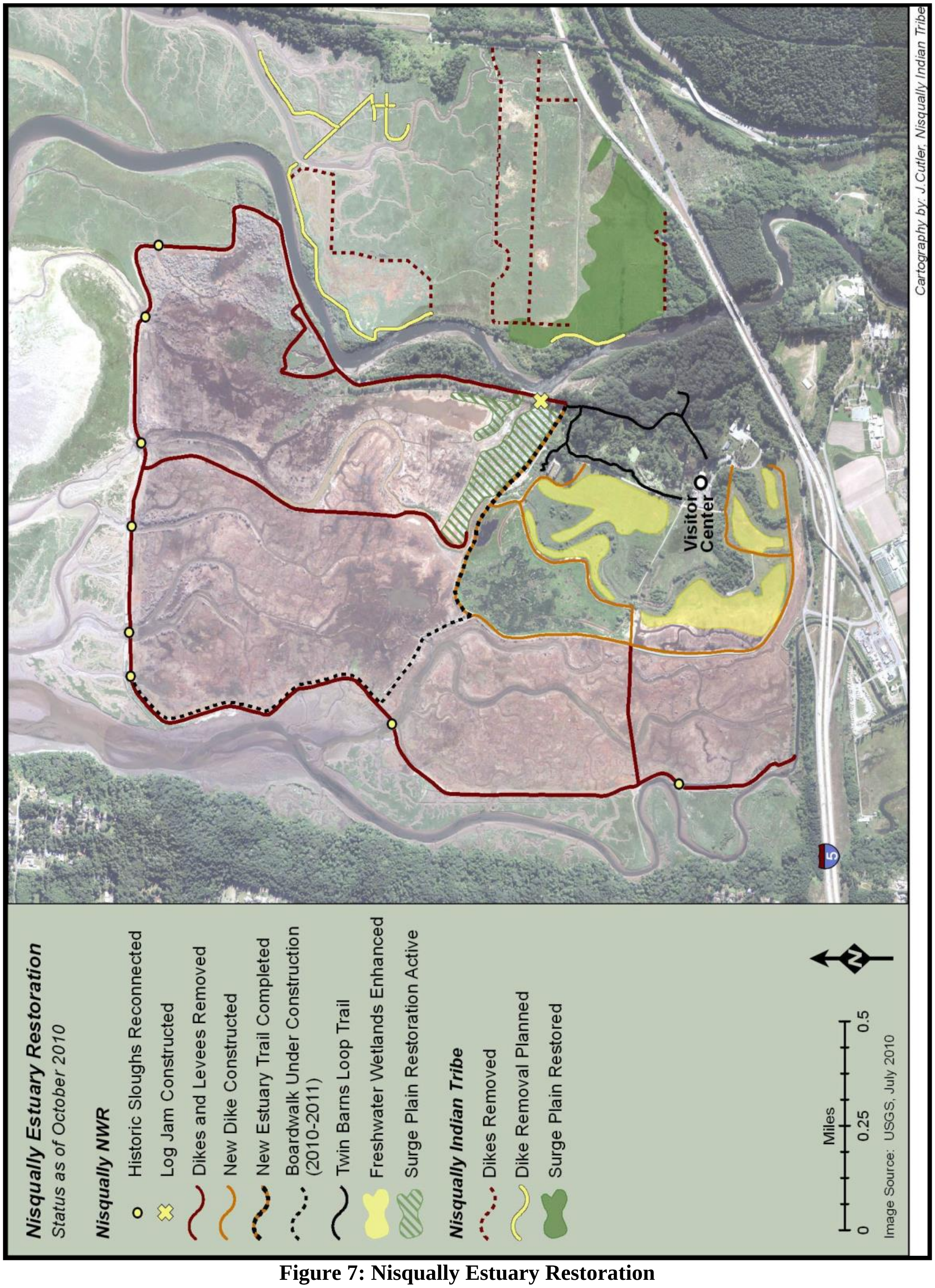

Figure 7: Nisqually Estuary Restoration
(Source: Jennifer Cutler, Nisqually Indian Tribe)

The above is a map of the Nisqually delta and each of the trails, habitats and tasks associated with its 2009 restoration. This reintroduced 762 acres to Puget Sound tides after 100 years. This combined with earlier restorations conducted by the neighboring Nisqually Indian Tribe, restored approximately 900 acres of estuarine habitat.

1.4 THE ESTUARY RESTORATION AND ITS IMPORTANCE TO AVIFAUNA

Estuarine ecosystems provide valuable amenities to fish, wildlife, and humans alike. The restoration of the Nisqually estuary to its historical salt marsh state was important for multiple reasons. Those reasons include the economic, aesthetic, recreational and ecological value to both the surrounding communities and the wildlife that inhabit the delta. This protected ecosystem also holds a cultural significance for those in the surrounding community including Native Americans groups such as the Nisqually Indian Tribe and other stakeholders.

Further reasoning supporting the importance of the restoration is the rich biodiversity that wetlands sustain. Due to the fact that salt marshes and open mudflats are washed by the changing tides of Puget Sound, rich nutrients are distributed to a variety of vegetation and invertebrates that reside in the mudflats and sediment. In turn, other species living within the Nisqually Estuary are provided a food resource. This includes the ESA listed Nisqually Fall Chinook salmon as well as the waterfowl that are the focus of this research project: diving ducks, dabbling ducks, geese, swan. Estuaries also provide migratory, breeding as well as overwintering grounds for multiple waterfowl species such as the Common merganser (*Mergus merganser*) and Cackling geese (*Branta hutchinsii*) (Figure 8, pp 17).

Figure 8: Avifauna Utilizing Nisqually National Wildlife Refuge
(Source: Nisqually NWR)
The above photo shows an example of the diversity of avian species that utilize Nisqually NWR.

The science of habitat restoration is relatively new with literature first emerging in the 1990's (Kusler and Kentula 1990; Marble 1992). Wetland restoration specifically began to emerge in the literature with a study of tidal wetland restoration by Zedler (1988) and also tidal salt marsh restoration by Broome et al (1990) among others. However, the decline of wetlands has also been documented, as many regard wetlands as more of a wasteland than an area essential to the survival of various species. Puget Sound saltwater wetland habitat loss due to diking, draining, filling and development are estimated to be more than 73% (estuaries.org 2009).

However, the value of wetlands is now recognized as a benefit to humans and other species and is protected under the Federal Water Pollution Control Act. According to the USDA, President George Bush Sr. implemented the No Net Loss Policy during his 1988-1992 presidential term. "No net loss" is the government's overall policy goal regarding wetland preservation. The goal of the policy is to balance wetland loss due to economic development with wetlands reclamation, mitigation, and restorations efforts, so that the total acreage of wetlands in the country does not decrease. The goal is to allow it to remain constant or increase. To achieve the objective of no net loss, the federal government utilizes several different environmental policy tools which legally protect wetlands, provide rules and regulations for citizens and corporations interacting with wetlands, and incentives for the preservation and conservation of wetlands.

Waterfowl ecology and management has also been studied by many scientists, including Johnsgard (1965), Bellrose (1978), Owen and Black (1990), Baldasarre and Bolen (1994) among others. In 1989, Weller examined management techniques for wetland enhancement, creation and restoration. This research gave special consideration to preserving natural landscapes, functional values and encouragement of waterfowl utilization. A study in British Columbia by Hirst and Eastope (1981) found that the number of American wigeon (*Anas americana*) observed in agricultural fields exhibited a strong correlation with adjacent estuaries and the amount of standing water in the fields. Hickman and Mosca (1991) looked at improvement of quality habitat in support of migratory waterfowl and nesting bird species and in 1999, Weller studied more intensely the relationship between waterfowl and wetlands.

The function and value of wetlands and the wildlife in which they provide for has catalyzed the conservation and preservation of remaining wetlands. It has also prompted the restoration of already degraded, altered and destroyed areas. Corrective practices backed by protective legislation are becoming more and more critical as the human population continues to increase and sprawl. As this encroachment continues, it threatens the livelihood of important wildlife habitat such as estuaries.

1.5 A BRIEF OVERVIEW OF WATERFOWL

Waterfowl are important both ecologically and economically. Not only are they an important part of biological webs worldwide, but they also attract an array of bird-watchers, photographers, naturalists and others who enjoy viewing or photographing them in their natural habitats. They draw in hunters as they are a popular game species. This in turn provides revenue during hunting season, contributes to the local and regional economies and tourist industry.

There have been multiple waterfowl species sighted within Nisqually NWR with occurrences ranging from common to rare (Table 1, pg. 20). According to Simenstad and Watson (1983), there are 59 bird species common to Pacific Northwest estuaries. When utilizing a migration route stopover site like Nisqually NWR, waterfowl species are known to feed on the following, depending upon species: small fish and fish eggs, various species of worm and mollusks, small crustaceans, grasses and weeds, algae and aquatic plants, frogs, salamanders and other amphibians, aquatic and terrestrial insects, seeds and grain, and small berries or fruits (Sibley 2000).

Table 1: Nisqually NWR Waterfowl Species

The table below lists each of the observed waterfowl species name, code used in analyses and type within Nisqually NWR

Common Name	Species Code	Type
American Green-winged Teal	AGWT	Dabbler
American Wigeon	AMWI	Dabbler
Barrow's Goldeneye	BAGO	Dabbler
Brant	BRAN	Geese
Bufflehead	BUFF	Diver
Blue-winged Teal	BWTE	Dabbler
Cackling Goose	CACK	Goose
Canada Goose	CAGO	Geese
Canvasback	CANV	Dabbler
Cinnamon Teal	CITE	Dabbler
Clark's Grebe	CLGR	Diver
Common Goldeneye	COGO	Dabbler
Common Loon	COLO	Diver
Common Merganser	COME	Diver
Eared Grebe	EAGR	Diver
Eurasian Wigeon	EUWI	Dabbler
Gadwall	GADW	Dabbler
Greater Scaup	GRSC	Diver
Greater White-fronted Goose	GWFG	Geese
Harlequin	HARD	Dabbler
Horned Grebe	HOGR	Diver
Hooded Merganser	HOME	Diver
Lesser Scaup	LESC	Diver
Long-tailed Duck	LTDU	Dabbler
Mallard	MALL	Dabbler
Mute Swan	MUSW	Swan
Northern Pintail	NOPI	Dabbler
Northern Shoveler	NSHO	Dabbler
Oldsquaw	OLDS	Dabbler
Pied-billed Grebe	PBGR	Diver
Red-breasted Merganser	RBME	Diver
Redhead	REDH	Dabbler
Ring-necked Duck	RNDU	Dabbler
Ring-necked Grebe	RNGR	Diver
Ruddy Duck	RUDU	Dabbler
Snow Goose	SNGO	Geese
Surf Scoter	SUSC	Diver
Trumpeter Swan	TRUS	Swan
Tundra Swan	TUSW	Swan
Western Grebe	WEGR	Diver
Wood Duck	WODU	Dabbler
White-winged Scoter	WWSC	Diver

The onset of season rainfall that occurs on an annual basis and begins in the early Fall signals the arrival of waterfowl migrating south along the Pacific Flyway. The Nisqually Delta and watershed is important for resting and foraging of waterfowl during strenuous migrations (Dahl 1991). For some species, Nisqually NWR is the end of their journey and they utilize the Refuge as nesting and rearing grounds for young. Waterfowl migration along the Pacific Flyway begin arriving in Nisqually in late September, and many remain throughout the winter and into the spring, while other resident birds stay throughout the year. They travel between the estuary and flooded agricultural or grass fields as well as wetlands on and off the Refuge. Those off-Refuge sites are primarily found south of I-5, on nearby farmland (Nisqually NWR Comprehensive Conservation Plan 2005).

Species such as Pied-billed Grebes (*Podilymbus podiceps*), Cinnamon Teal (*Anas cyanoptera*) and Canada Geese (*Branta canadensis*) have been observed nesting in Nisqually NWR. Both Canada and Cackling Geese (*Branta hutchinsii*) are common species found in the winter. However, the most prevalent species seen within Nisqually NWR have historically been American Wigeon, Mallard (*Anas platyrhynchos*), Northern Pintail (*Anas acuta*) (Figure 9, pp 22) and American Green-winged Teal (*Anas crecca*), all of which are dabbling waterfowl. It must be noted, that although waterfowl are among the most abundant birds seen within Nisqually NWR, species from all other avian foraging guilds have been sited utilizing all that the estuary has to offer.

Figure 9: Northern Pintail (*Anas acuta*)
(Source: National Audubon Society)
The above figure represents a Northern Pintail drake, a common dabbling duck species observed in Nisqually.

It is well-known that disturbance from human activities cause temporary changes in waterfowl behavior and locally affect temporal and spatial distribution of migratory and wintering species. To some extent however, birds can compensate for such disturbance by altering their behavior and habituating around these human activities. One example of this could potentially be the effect of hunting season on these waterfowl as disturbance from gunshots could cause the birds to flush. Fall through spring hunting is widely practiced throughout the world, although few studies have been conducted investigating the effects on waterfowl. Little is known though about how anthropogenic disturbance influences large-scale dispersion and population dynamics of waterfowl (Madsen 2008).

Seven different species of goose and swan have been sighted on the Refuge such as Cackling geese and Canada geese (Figure 10). Other species might include Trumpeter Swan (*Cygnus buccinator*) and Black Brant (*Branta bernicla*). Geese and swans can be identified by their large, heavy bodies and long necks. They feed by grazing or by tipping-up when swimming. They can be found in large flocks and are known for their loud calls (Sibley 2000).

Figure 10: Canada Goose (*Branta canadensis*)
(Source: National Geographic Society)
The above photograph depicts a Canada goose hen with her ten goslings as they swim.

Dabbling ducks are among the most common waterfowl species seen within Nisqually NWR and include 11 different species. The most common of species within this guild are Mallard, American Wigeon (Figure 11, pp 24), Northern Shoveler, American Green-winged Teal and Northern Shoveler (*Anas clypeata*). These species are known for their foraging behavior of dabbling their bills in the water and tipping forward. Dabbling ducks will rarely dive while feeding. An interesting aspect of their behavior is their ability to take-off in flight without running (Sibley 2000).

Figure 11: American Wigeon (*Anas americana*)
(Source: nisquallydeltarestoration.org)
The American wigeon, like those pictured above, are among the most common dabbling ducks species observed in Nisqually NWR.

The most diverse species of waterfowl are diving ducks. Eleven different species of diving ducks have been observed utilizing the Refuge, including Bufflehead (*Bucephala albeola*), Common Merganser (*Mergus merganser*) and Surf Scoter (*Melanitta perspicillata*). These species are known for diving underwater for food. However, as some dabblers will also dive, some divers will also dabble. Divers are more likely and better-able to dive due to their heavier bodies and higher wing loading. Wing loading, combined with faster wing beats, allow them to fly faster than other waterfowl. They are also known to run along the water's surface before becoming airborne (Sibley 2000).

Avian monitoring efforts are maintained by biologists, technicians and volunteers from both Nisqually NWR and USGS. Surveys are performed not only on the Refuge, but also on the Nisqually Tribe's Pilot, Phase I and Phase II sites. This research however, only concerns observed avian data that has been collected within the boundaries of Nisqually NWR using only data from 1984 to January 2011 was analyzed.

1.6 RESEARCH OBJECTIVES

The purpose of this thesis research is to assess decades of waterfowl data collected throughout the history of Nisqually NWR and produce a database that can be used to detect change in species frequency since the delta restoration in 2009. Analysis began with February 1984 aerial survey data and ends with January 2011 monthly high-tide survey data. Nisqually NWR waterfowl data analyses have occurred through collection, organization, entry and quality control of historical Refuge aerial and ground-based waterfowl data, as well as current USGS monthly high-tide data separately.

The objectives of this research are:

a. Compile Nisqually NWR pre-restoration waterfowl data into a standardized, comparable database;
b. Describe the spatial seasonality and abundance of waterfowl within Nisqually NWR using pre-restoration aerial and ground-based waterfowl survey data, as well as the preliminary results from ongoing USGS post-restoration monitoring efforts;

c. Provide a qualitative description of past and present conditions for waterfowl;
d. Discuss the benefits and limitations of waterfowl surveys and each specific methodology used.

Due to its premature nature, it is too early to determine the true effect the 2009 estuary restoration has had on waterfowl trends. Collection of current USGS monthly high-tide waterfowl data has only been collected since the restoration in October 2009 and monitoring is expected to continue for as long as funding allows. Data collected prior to and following restoration activities will greatly assist the evaluation of habitat management actions conducted by Nisqually NWR and create a database for future surveys to be incorporated and analyzed along with the data utilized in this research.

2. RESEARCH METHODS

The following section details each of the three waterfowl surveys used for analysis in this research. The ground and aerial waterfowl surveys were performed by Nisqually NWR biologists from soon after the establishment of the Refuge in 1974. Monthly high-tide surveys were performed by USGS, Refuge volunteers, and the author since the estuary restoration in 2009.

2.1 SURVEY METHODS

This research focuses analyses on three waterfowl datasets within Nisqually NWR. Two are historical aerial and ground-based waterfowl surveys performed by

Nisqually NWR staff. The third includes monthly high-tide surveys that take place on foot as well as by boat and are performed by USGS biologists and crew. Certain surveys targeted specific types of birds, while others may seek to record every species identified. For example, the Nisqually NWR aerial surveys targeted mainly waterfowl while USGS monthly high-tide surveys seek to record all bird species present within the survey area. Avian identifications are made based upon auditory or visual sightings.

Tide height, time of day, season and weather conditions also factor into where, when and if survey will be performed at that time as each of these factors greatly influence avian activity. It is for these reasons that survey data can sometimes be difficult to interpret and use, and surveys of different types provide information of varying quality. Most bird surveys tend to provide incomplete coverage that miss proportions of populations, so there are no definitive surveys for most species. Varying surveyors and recorders for these surveys can also create variability, as skill and observation levels also vary from person to person. For this research, a variety of different biologists and trained volunteers have aided in the observation, identification and recording of birds sighted during the various surveys (ground, aerial and monthly high-tide) discussed in this research.

Another inconsistency is varying access to certain survey areas, vegetation that blocks hidden species and changing site boundaries over time. However, some consistencies within Nisqually NWR surveys includes the utilization of the same overall area boundary and all surveys have been performed using visual aids such as binocular or spotting scopes and each survey employed the master birding skills of Nisqually NWR biologists and/or volunteers to help insure accurate identification of avian species sighted.

2.1.1 AERIAL AND GROUND SURVEYS - NNWR

The purpose of the aerial and ground waterfowl surveys are to document the species and number of waterfowl using Nisqually NWR. These surveys provide a guide to assess wetland enhancement efforts and monitor habitat use. The aerial survey gives the biologist and managers an overview of Nisqually NWR as well as surrounding areas. Ground counts are conducted the same day in each location to supplement or cross-check the aerial data for accuracy. These waterfowl surveys are conducted near the beginning of each month starting in October and end in March or April. An annual mid-winter count also takes place and usually occurs the first week or two of January. Waterfowl surveys were conducted from 1974 through the present. The number of surveys varied from year to year, ranging from zero (1980) to six surveys (1976, 1986, 1987 and 1989) per season. Ground surveys were performed from 1998 to present. Gear utilized includes binoculars and wildlife spotting scopes as well as means to record the data.

Aerial surveys are conducted in a fixed wing Cessna or Beaver float plane flying a set flight path with an observer in the front passenger seat and often a second observer is positioned behind the pilot. The front passenger looks right while the secondary biologist riding behind the pilot surveys to the left. Data is recorded into either cassette recorder or computer microphone recorder. Notes and observations are also recorded on a standard data sheet. This included species, number observed and location of observation. For this survey, the Refuge is divided into units. Unit 1 included McAllister Creek and adjacent salt marsh habitats. Unit 2 included the Nisqually Flats, and the mudflats and salt marsh areas just north of the dike. Unit 3 included all of the interior diked area, consisting of grassland and freshwater wetland habitats. Unit 4 includes the Nisqually River, tidal, higher marsh, and intertidal habitat east of the River on the Nisqually Tribe sites, and the northeast corner of the Refuge. Unit 5 was a linear transect that extended off Refuge property from the northwestern corner of the Refuge to Johnson Point (Figure 12 (historical map with flight path), 13 (current map used), pp31-32). This particular unit will be omitted from analysis as they fall outside of the Refuge boundary. Approximately 4 hours are needed to complete these aerial surveys.

Nisqually NWR ground counts follow a set route and are conducted by vehicle. The count usually takes four hours or more to complete, and should not be started after 14:30 as it will be dark before the survey is complete. If necessary, the ground count is conducted the next day near the time the aerial flight took place the previous day. Again, a standard data sheet is used to record any observations made. Recordings are transcribed to data sheet after the flight.

Ideal aerial count time would be midtide, when there is water covering the mudflats, but not necessarily deep water. The Nisqually ground count however must take place soon after the plane has finished the count, in the same day. This is because the surveying plane may create disturbance causing the birds to flush. If this occurs during or before the aerial count the aerial observation will not be similar. Coordination between those conducting the ground count and aerial survey is critical.

2.1.2 MONTHLY HIGH-TIDE BIRD SURVEYS - USGS

Monthly, high-tide surveys are a relatively new survey that began just before the removal of the dike in the summer of 2009. As the name implies, they are performed once a month during a high-tide window on a delta-wide basis. The surveys are usually timed so that the high-tide window occurs during the morning to capture birds during active foraging hours. During this particular survey, all species types are recorded including their location and estimated abundances. A team of surveyors is sent to four sites within the Nisqually NWR. Location within Nisqually NWR is determined from predefined 250 meter by 250 meter grid system on a map (Figure 14, pp 33). For this research however, the Tribe sites will be omitted and only Nisqually NWR data will be analyzed due to time constraint. This survey is performed year-round.

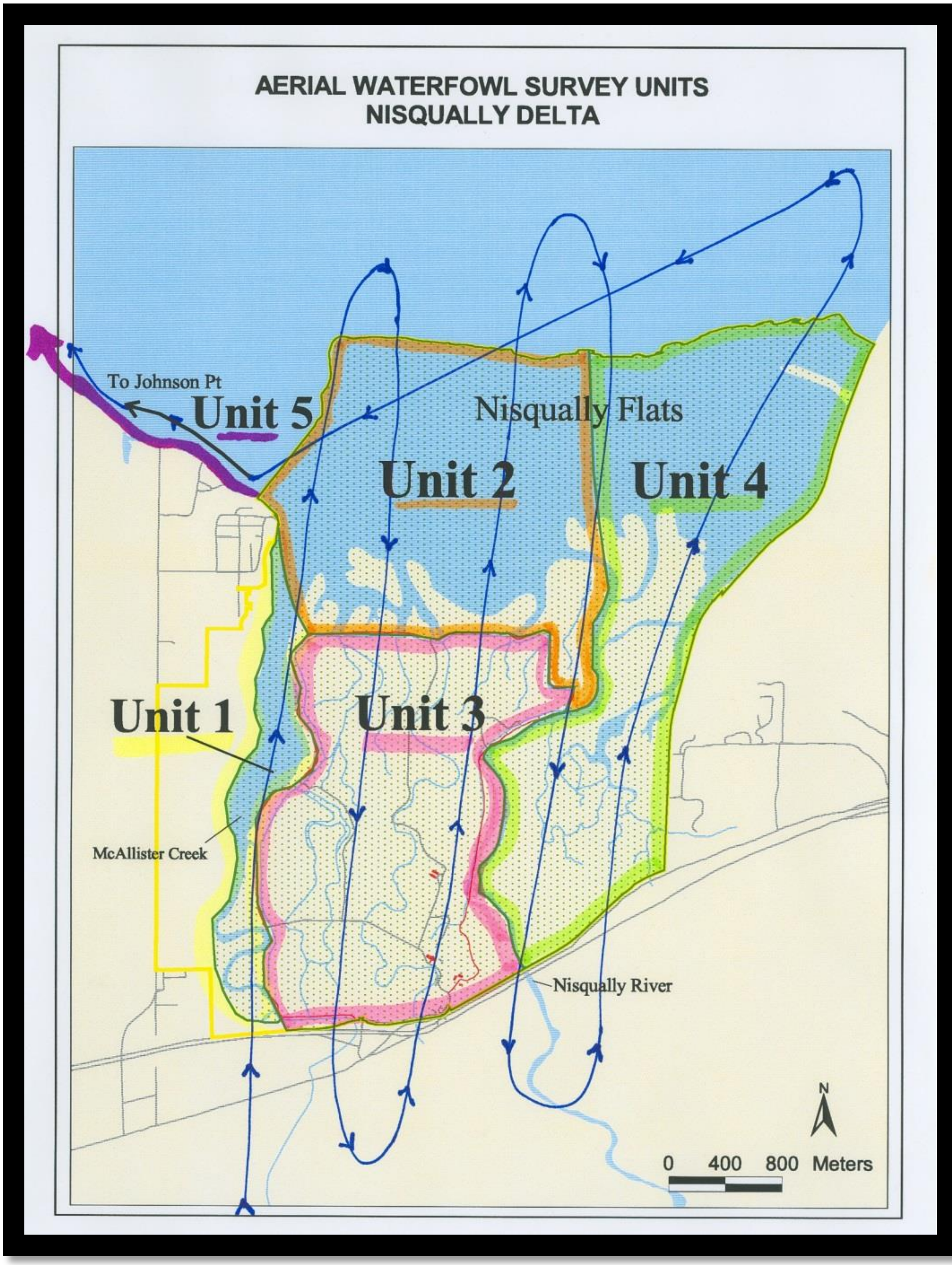

Figure 12: Historical USFWS Ground and Aerial Survey Map and Flight Path of Nisqually NWR (Source: Nisqually NWR)

The above map represents the area and units surveyed during ground and aerial waterfowl surveys before the 2009 Nisqually NWR dike removal, as well as the plane flight path taken during surveys (indicated in blue).

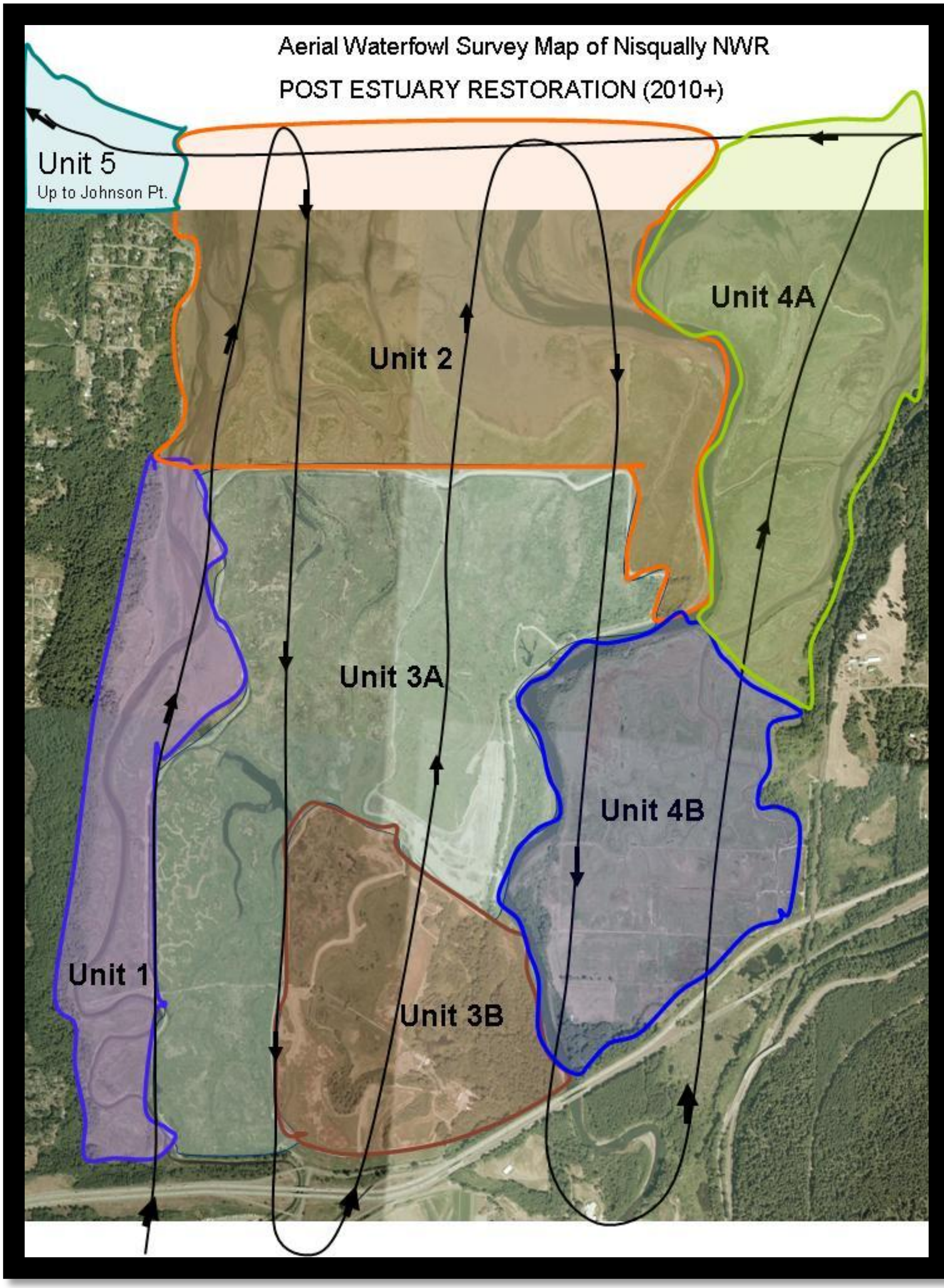

Figure 13: Current USFWS Ground and Aerial Survey Map and Flight Path of Nisqually NWR (Source: Nisqually NWR)

The above map represents the area and units surveyed during ground and aerial and ground waterfowl surveys after the Nisqually NWR dike removal and restoration

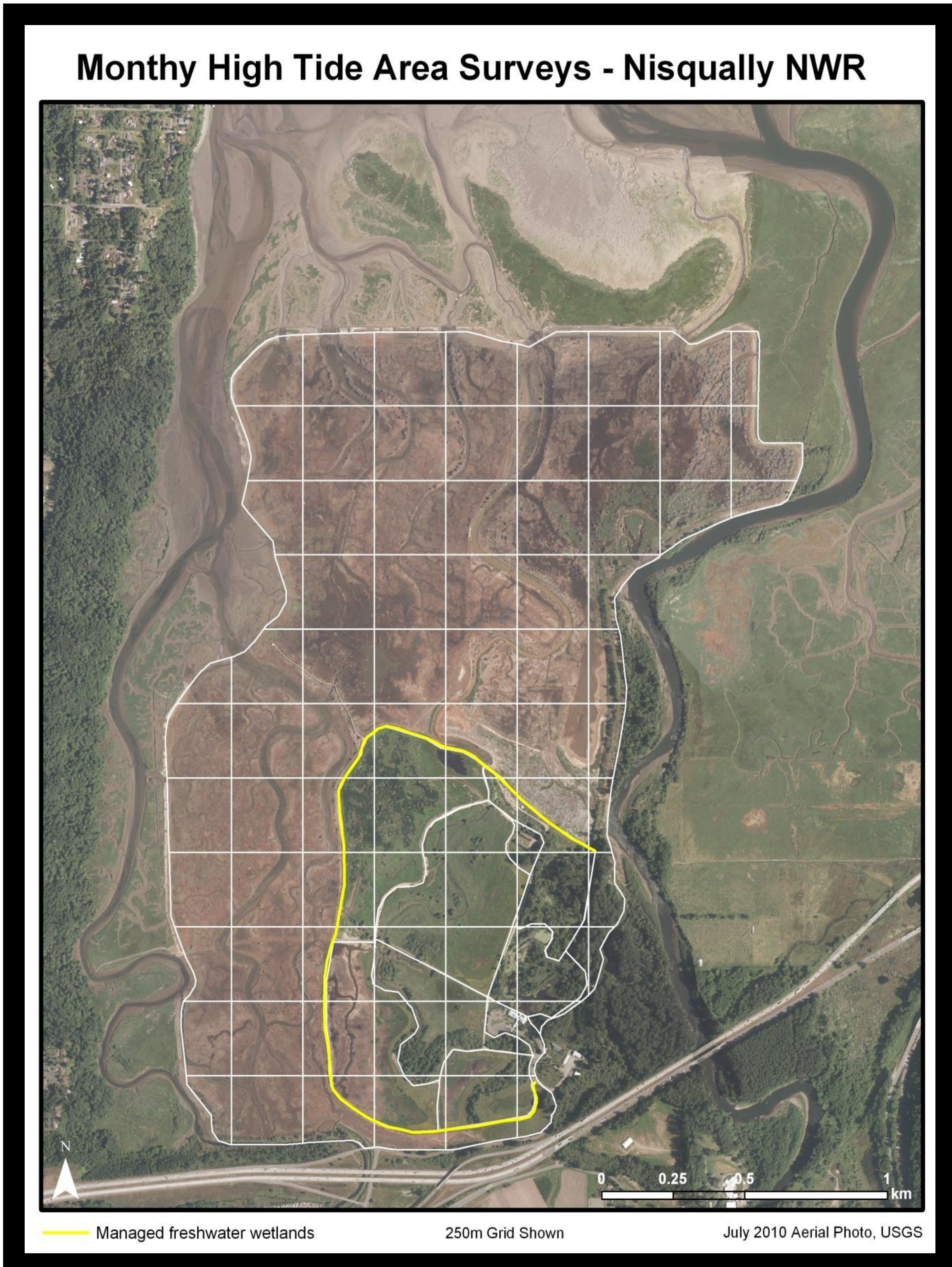

Figure 14: USGS Monthly High-Tide Survey Map of Nisqually NWR
(Source: Kelley Turner, USGS)
The above map represents the gridded area within Nisqually NWR that is surveyed during the Monthly High-Tide Survey beginning after the removal of the dike in 2009.

2.2 METHODS OF DATA ANALYSIS

The data was represented graphically in the following ways:

- Overall avian abundance detected over time
- Overall abundance by species over time
- Percent waterfowl by guild

3. RESULTS AND DISCUSSION

The following section details the results from the analyses performed for each of the three pre- and post-restoration survey types. The first section details the results from the aerial and ground surveys performed by Refuge crews. The second section discusses the results from post-delta restoration surveys led by USGS crews. It must be noted that although the surveys are essentially recording the same type of data, the survey methods for each differ and can therefore not be directly compared to one another.

3.1 AERIAL AND GROUND WATERFOWL SURVEYS

The first analysis examined change in total observed waterfowl abundance patterns over time using aerial survey data from February 1984 to January 2009 (Figure 15, pp 35). The data indicates a slight decrease in waterfowl abundances over time. However, when using the same analysis for the ground survey data, there is an upshift in waterfowl sightings from a ground perspective (Figure 16, pp 36). Again, each of these two survey methods are performed from separately and from a different perspectives and cannot be directly compared. It should be noted that although the aerial survey provides a different viewing perspective, the ground survey allows for not only visual sightings but

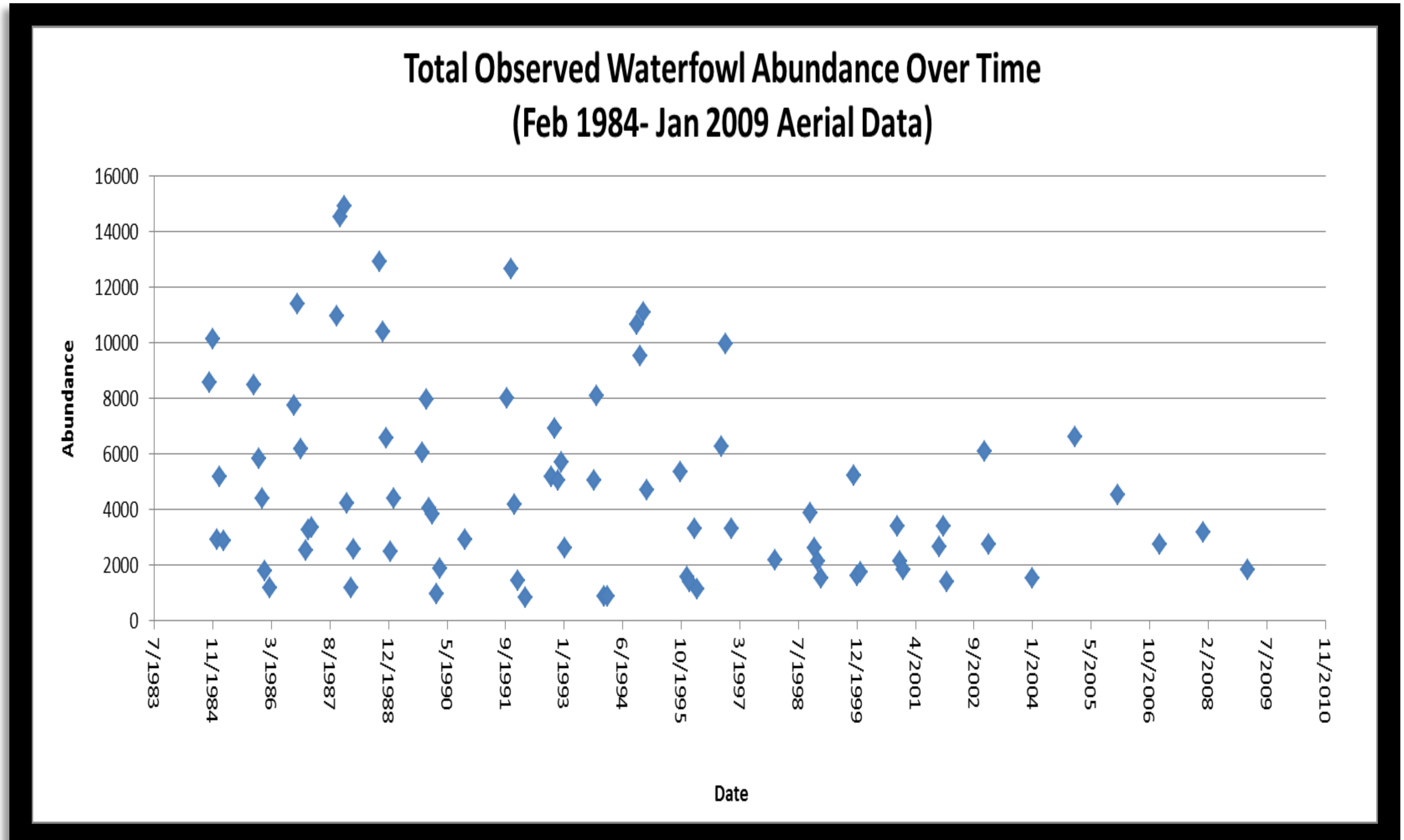

Figure 15: Observed Waterfowl Abundance Over Time (Aerial Data)
This figure represents the change in waterfowl abundance over time using aerial survey data from February 1984 through January 2009, and indicates a decrease in abundance until 2003 when surveys were only performed in January.

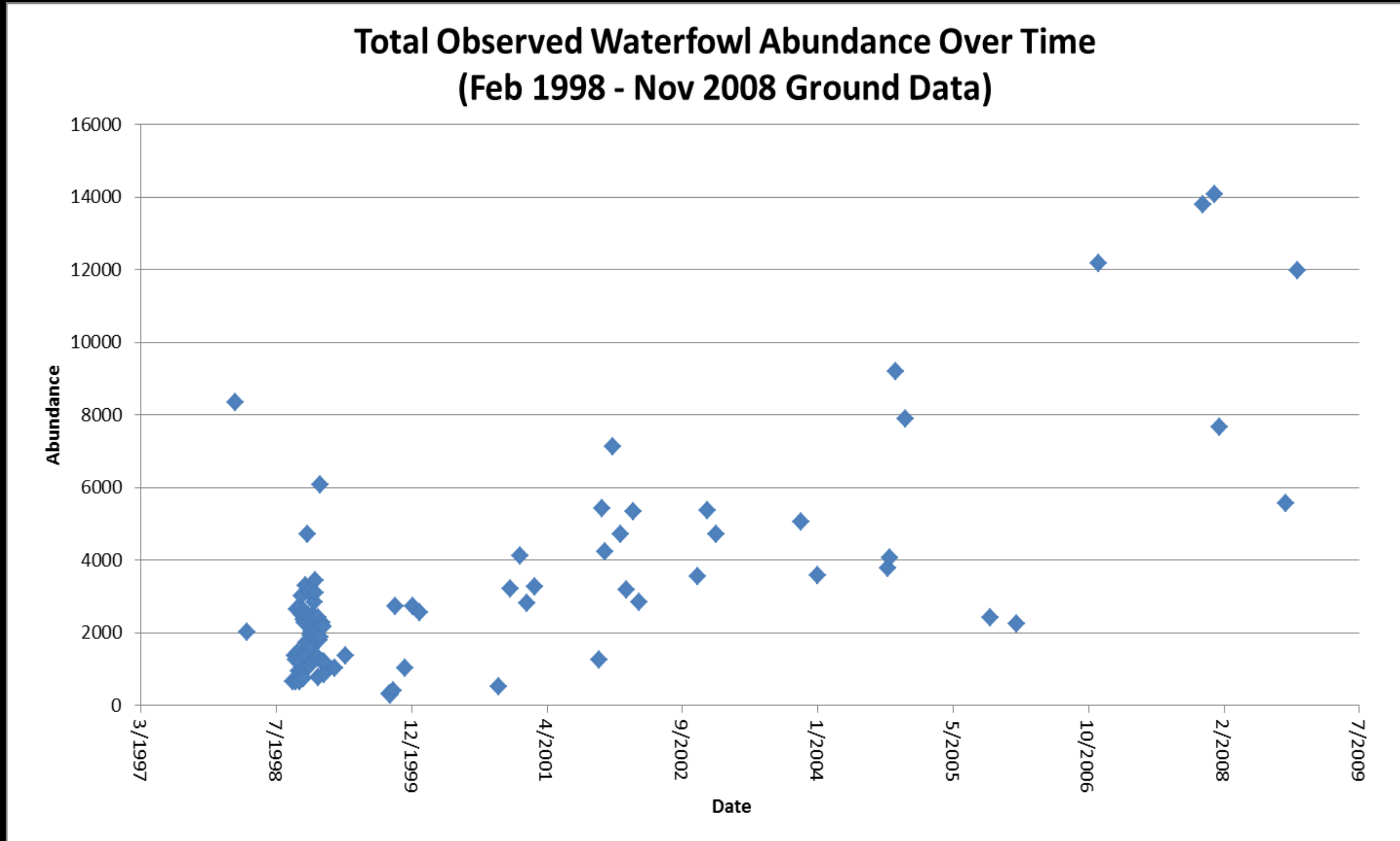

Figure 16: Observed Waterfowl Abundance Over Time (Ground Data)
This graph represents the change in waterfowl abundance over time using ground survey data from February 1998 through November 2008. The data indicates an upshift in waterfowl abundance over time.

audio identification as well. Ground surveys also allow for Unit 3 habitat penetration by foot which provides a ground-level analysis of that particular unit. It is also difficult to make inferences about which of these datasets is correct because neither are guaranteed to capture the true waterfowl Refuge usage as presence and numbers can vary greatly from day to day, hour to hour. In order to best evaluate this data in that way however, it should be standardized for survey month, tides, number of observers, weather conditions, etc. It should also be noted that after 2003, surveys were only conducted in January.

The next analysis explored each species' total individual abundance using the same aerial and ground survey datasets. From the aerial analysis, we see that American wigeon, American Green-winged Teal and Mallard were the most abundant species recorded (Figure 17, pp 38). When analyzing the ground data using the same method, we see that American wigeon, Canada geese and Mallard are the most abundant (Figure 18, pp 39). Please note that the species beginning with "UN" indicate unidentified species, and that Cackling geese were not historically recognized as a separate species.

The avian abundances were then converted into percentages and analyzed based on which waterfowl group made up the majority of waterfowl sightings. Dabblers were by far the most prevalent followed by geese and swan and finally by diving ducks (Figure 19, pp 40). The same method was done using ground data (Figure 20, pp 40). This analysis indicates that dabblers again yield that highest percent, but showed either an increase in abundance or perhaps an increase in guild diversity as geese and swan make up a larger percentage of a whole than observed during aerial surveys.

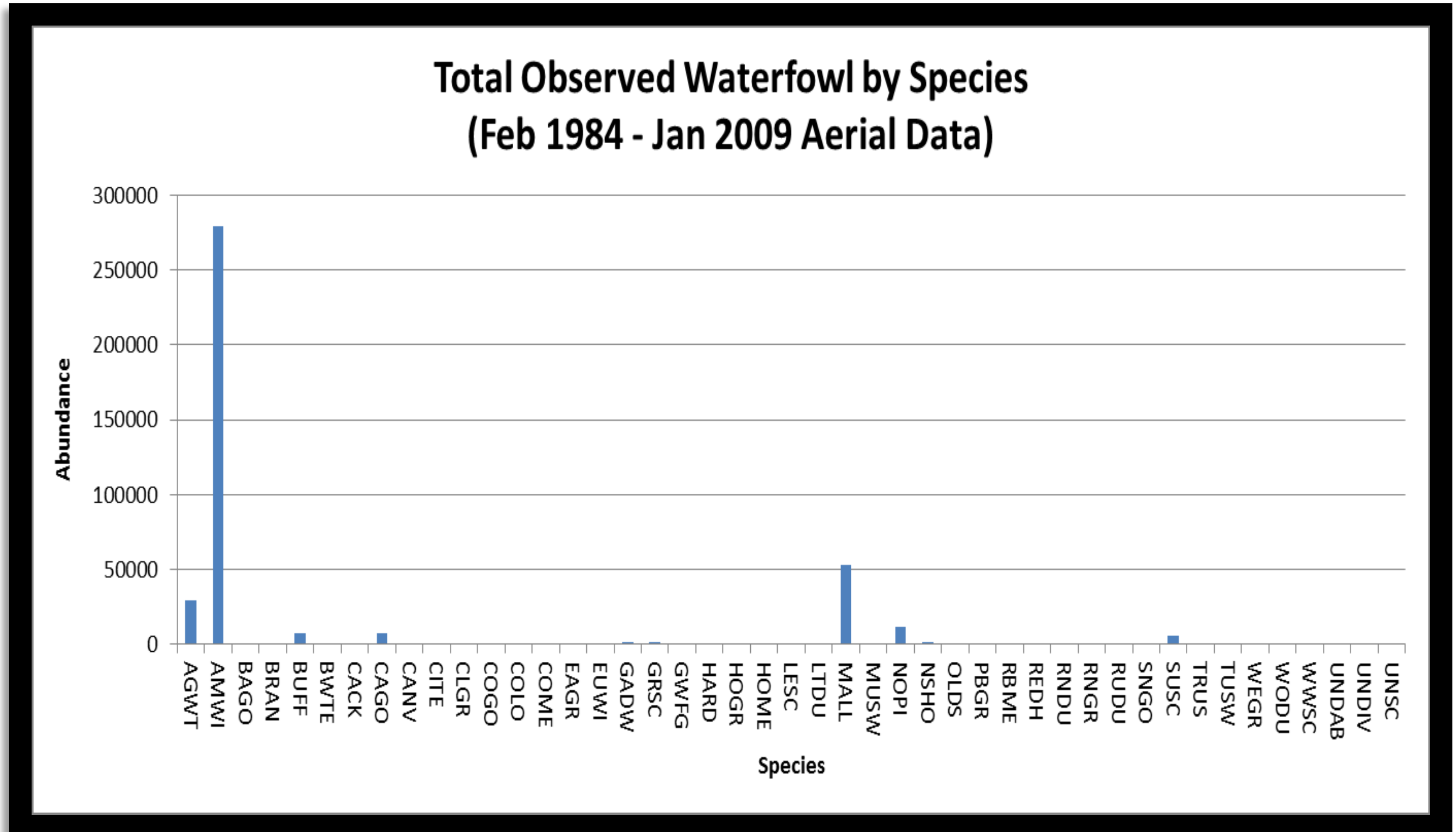

Figure 17: Observed Waterfowl Abundance by Species (Aerial Data)

The figure represents the total observed waterfowl using the aerial survey data from February 1984 to January 2009. American Wigeon were the most commonly observed species, followed by Mallard and American Green-winged Teal.

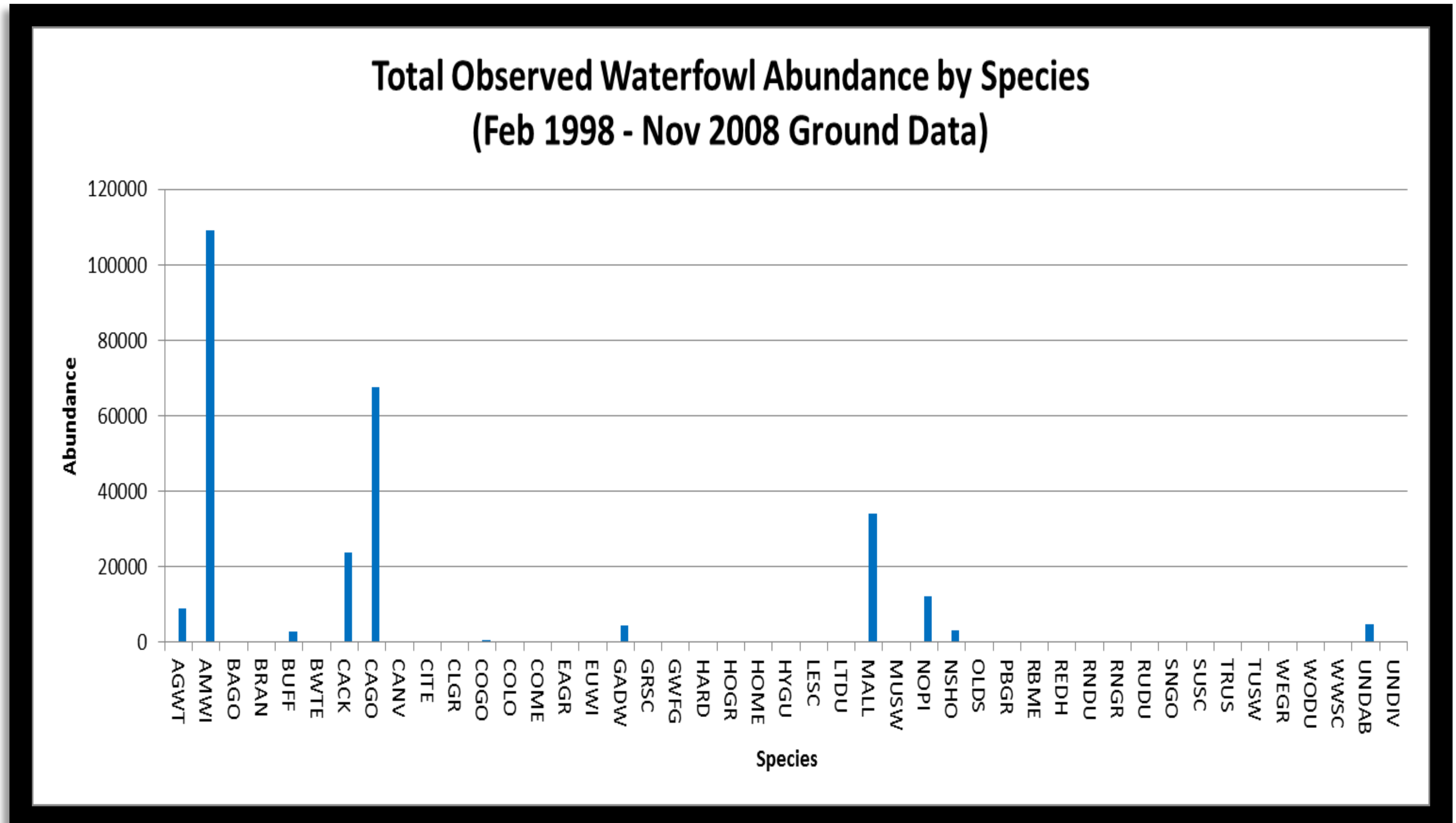

Figure 18: Observed Waterfowl Abundance by Species (Ground Data)

The graph shows the total waterfowl abundance by species using ground survey data from February 1998 to November 2008. American Wigeon and Canada Geese were the most commonly observed, followed by Mallard and Cackling Geese.

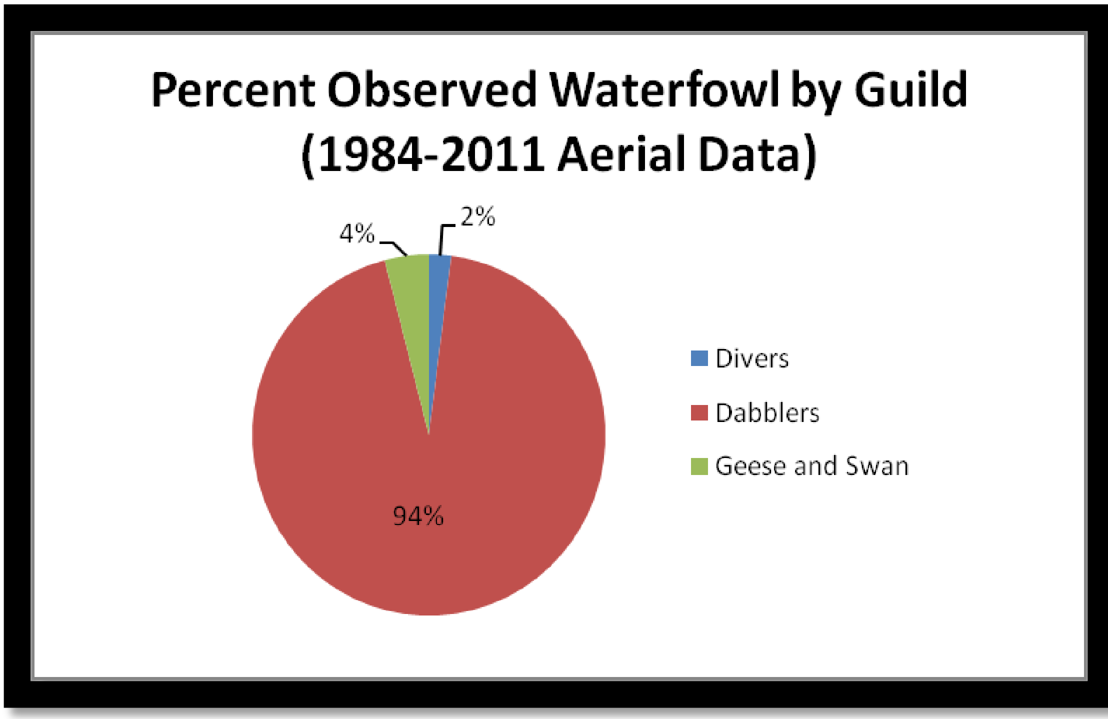

Figure 19: Percent Observed Waterfowl by Guild (Aerial Data)
The above graph shows the observed waterfowl by guild represented in percentages using aerial data from February 1984 to January 2009. Dabbling ducks made up the largest proportion at 94%, followed by geese and swan and finally divers.

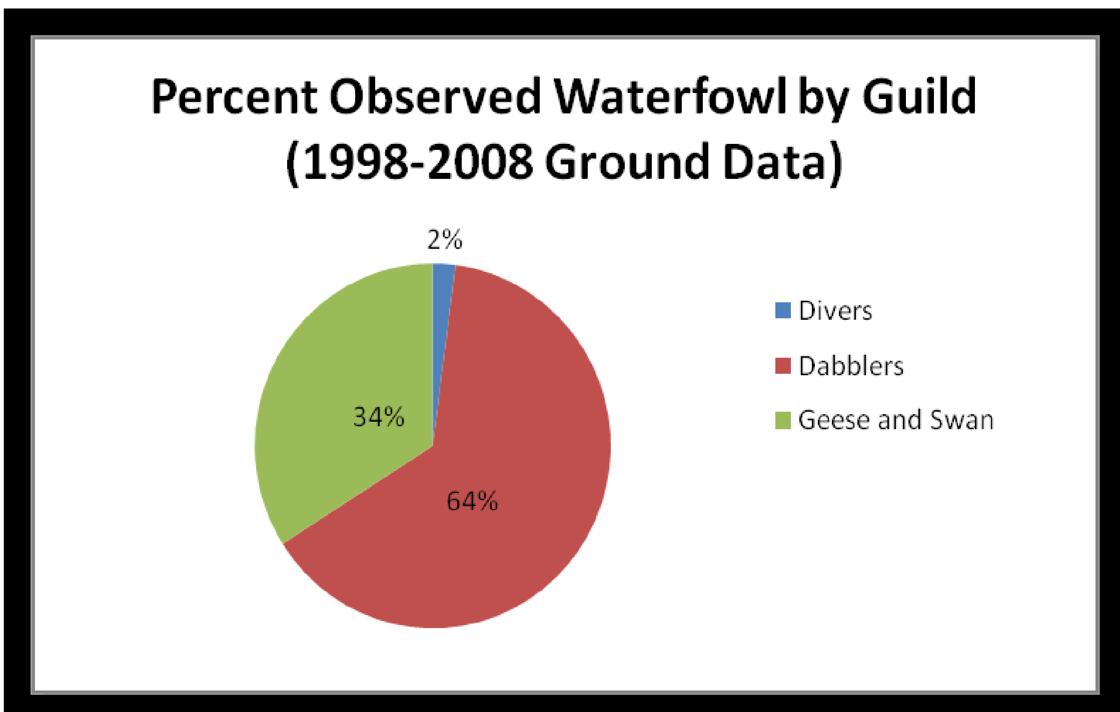

Figure 20: Percent Observed Waterfowl by Guild (Ground Data)
This graph shows the observed waterfowl by guild represented in percentages using ground data from February 1998 to November 2008. Again, dabbling ducks made up the largest proportion at 64%, followed by geese and swan and finally divers.

3.2 MONTHLY HIGH-TIDE SURVEY

In analyzing the post-restoration monthly high-tide survey data, one analysis performed examined total observed waterfowl abundance change over time. From this analysis, we see that waterfowl numbers have remained relatively steady since the restoration (Figure 21, pp 42). The data indicates that peak waterfowl abundance occurred between September and March, which correlates with the migratory and overwintering season. Within the overwintering period, there are variable abundances between months. This could be due to a variety of factors including inclement weather conditions such as freezing temperatures or simply that the waterfowl were utilizing nearby resources and were not on the Refuge at the time of the survey. However, the lack of survey data at this point makes it difficult to impossible to make sound inferences.

The second analysis performed looked at the total abundance of each species individually. From this, it can be said that so far the most common waterfowl species observed have been American Green-winged Teal. Other commonly observed species include Cackling geese and American wigeon respectively. Mallard and Northern pintail were also frequently sighted(Figure 22, pp 43). Any unidentified or hybrid species' acronyms begin with "UN" or "HY", respectively.

The final analysis performed explored each waterfowl guild as a percentage. Dabbling ducks yielded the highest percentage, as seen in both the Refuge aerial and ground waterfowl survey data results. The USGS dataset also observed geese and swan contributing a large proportion of waterfowl presence at 30% (Figure 23, pp 44).

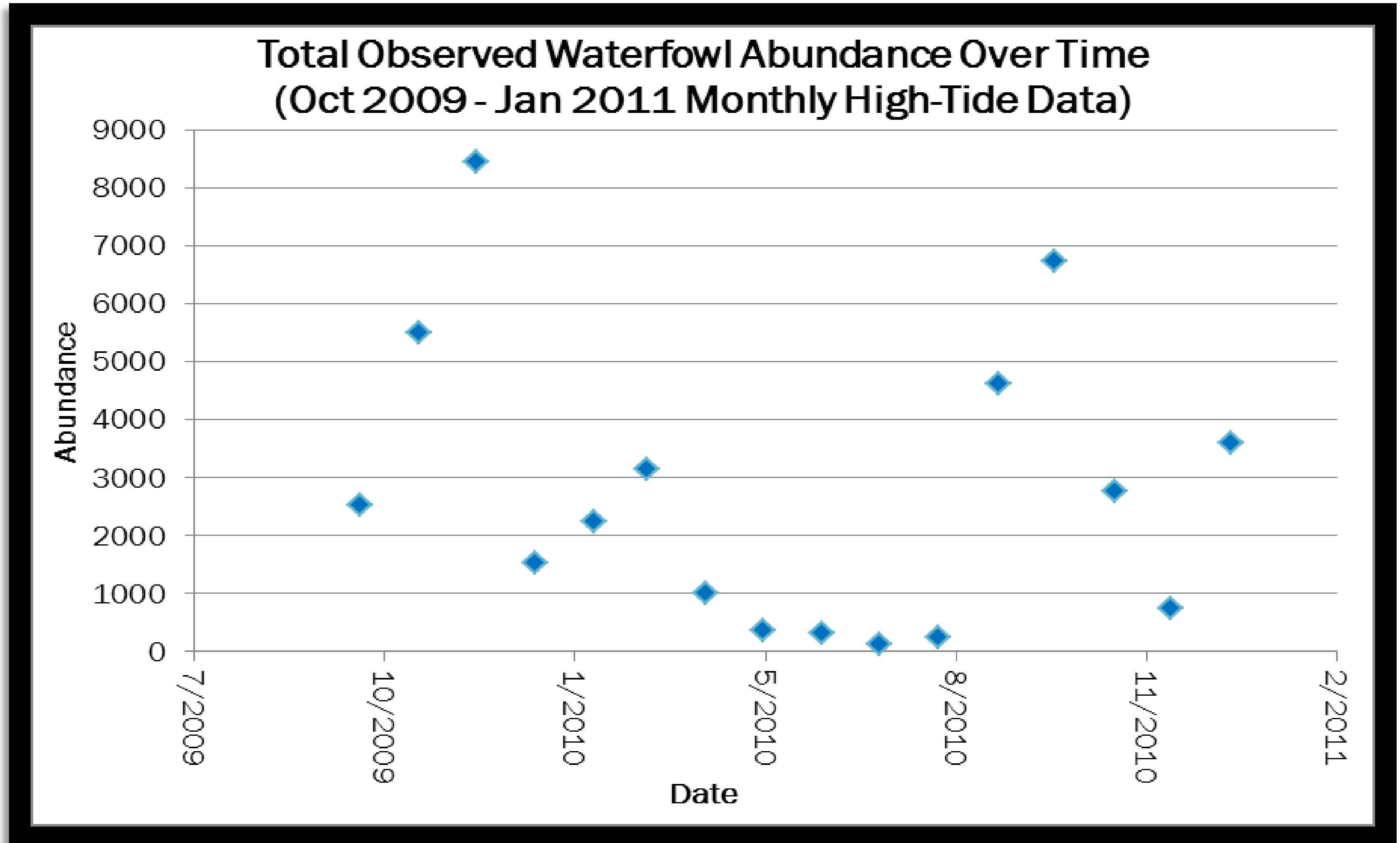

Figure 21: Observed Waterfowl Abundance Over Time (Monthly Data)
This figure represents the observed waterfowl abundance over time using monthly high-tide survey data from September 2009 to January 2011.

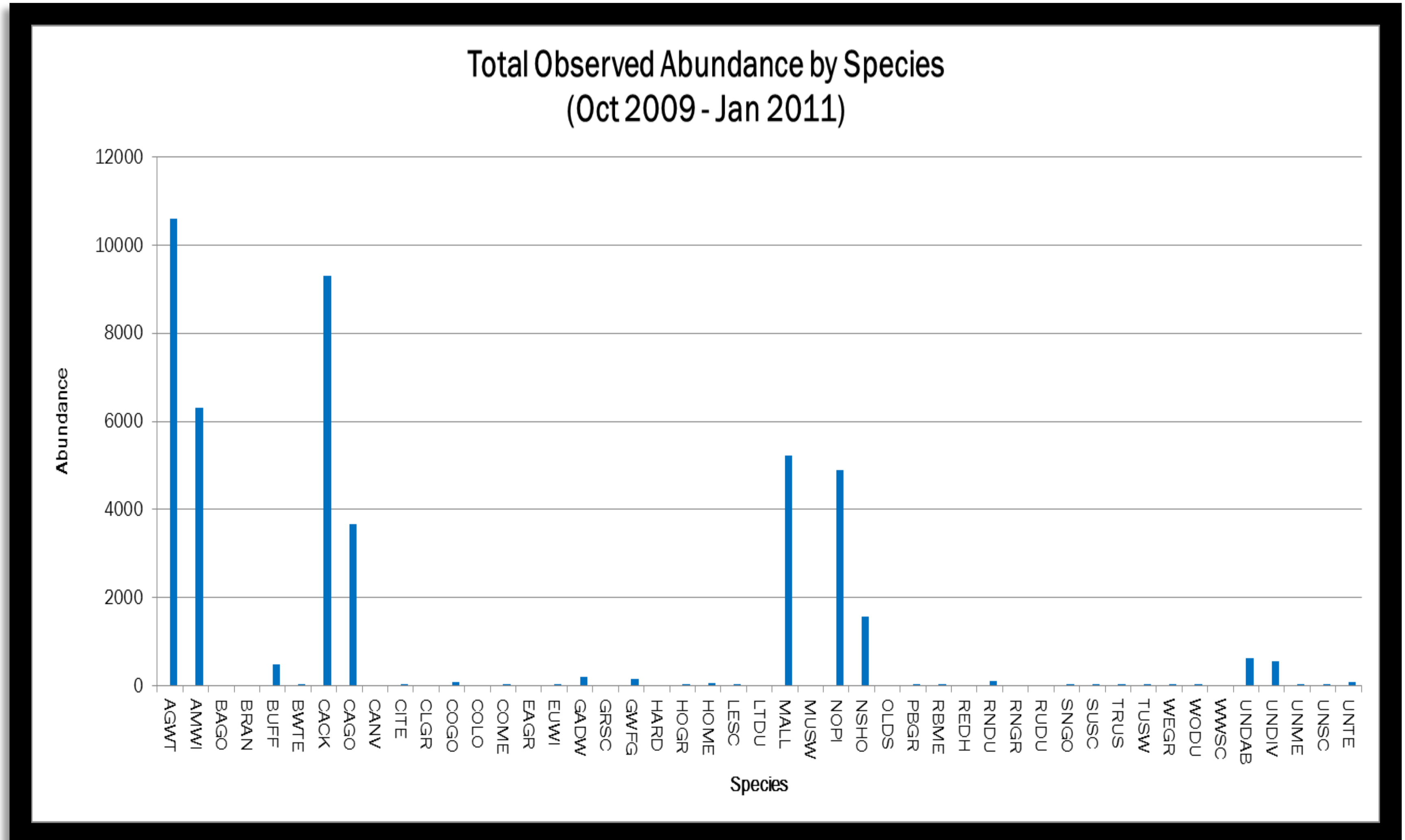

Figure 22: Waterfowl Abundance by Species (Monthly Data)

The above figure represents waterfowl abundance totals using September 2009 through January 2011 monthly high-tide survey data. American Green-winged Teal yielded the highest abundance total followed by Cackling Geese, Mallard and Northern Pintail (change color to blue).

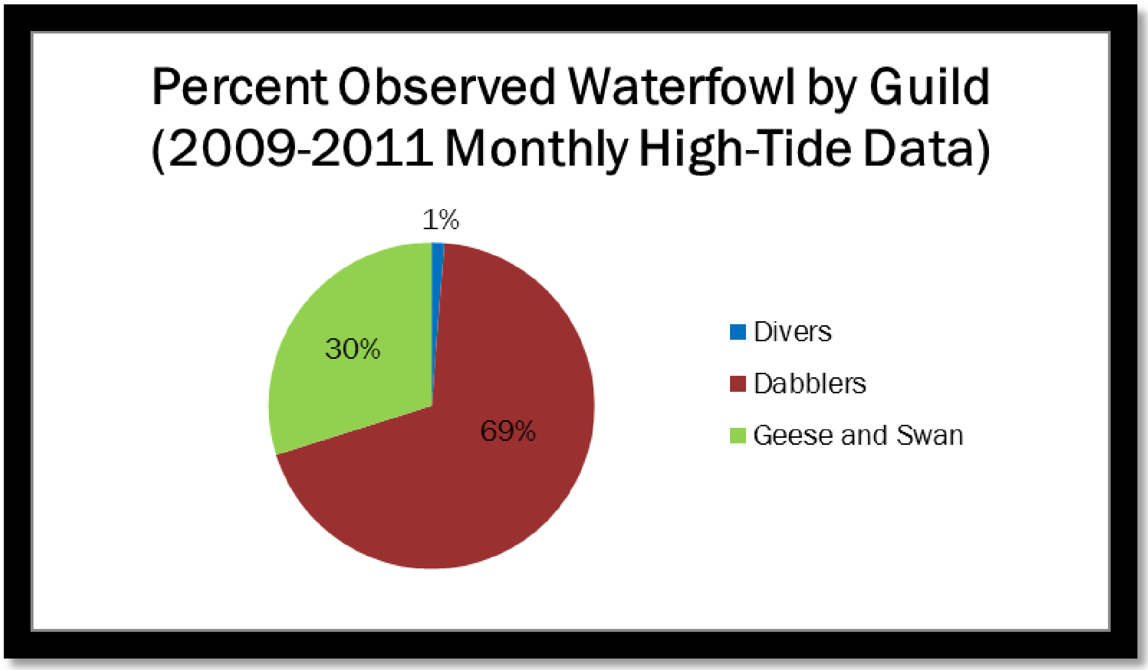

Figure 23: Percent Observed Waterfowl by Guild (Monthly Data)
This figure represents the proportion of waterfowl by guild using monthly high-tide survey data from September 2009 through January 2011. Dabblers make up the largest porportion at 69%, followed by geese and swan at 30%, and finally divers at 1% (change colors to coordinate with aerial and ground analyses).

4. CONCLUSION

The following sections detail the results from each of the three waterfowl surveys analyzed in this research; pre-restoration aerial and ground waterfowl surveys, and post-restoration monthly high-tide surveys. Also described in these sections is a description of pre and post-habitat restoration habitat conditions to provide a written demonstration of how greatly the restoration altered the ecosystem. Finally, this section details suggestions for future research that have arisen as a result of both the restoration and this thesis research.

4.1 SUMMARY OF RESULTS

For aerial surveys occurring from February 1984 to January 2009, the months yielding the highest average observed waterfowl abundance were October and November. During this particular survey, the top three most commonly observed waterfowl species included Mallard, American wigeon and American Green-winged Teal. For ground surveys occurring from February 1998 through November 2008, the months with the greatest average waterfowl abundance were November through March. During this survey, the most commonly observed waterfowl species included Mallard, American wigeon and Canada (Cackling) geese. Monthly high-tide surveys occurring from October 2009 through January 2011, no peak average waterfowl abundance month has yet to be recorded due to a limited amount of survey years. The three most commonly observed waterfowl species during this time period were American wigeon, Canada geese, Cackling geese and American Green-winged Teal. For monthly high-tide surveys, Canada geese and Cackling geese were identified as two separate species due to change in distinction in taxonomic classification.

For each type of survey conducted, the overall dominant waterfowl foraging guild was dabbling ducks. The American wigeon, also a dabbling duck, was the most common waterfowl species observed for each of these surveys. Peak waterfowl use of the Refuge spanned from the months of September through March. When considering that waterfowl begin south-bound waterfowl migration during the fall months and return in the spring, the peak months for waterfowl abundance within Nisqually National Wildlife

Refuge correlates with general Pacific Flyway migration patterns. According to spatial distribution analyses conducted using aerial and ground surveys, Unit 4 of the Refuge yielded the highest number of waterfowl with dabbling ducks as the most common foraging guild identified. Post-restoration data needs to be collected for many more years to be able to generate the power of analysis needed to detect change due to the restoration.

From the research, it became very clear that there are both benefits and limitations to each survey type. There are also limitations to any bird survey in general, as birds vary in size from large to very small and difficult to see. Many are also extremely well camouflaged and all have the ability to fly and move about a survey area. This often leads to double-counting or even completely missing a sighting of certain small-bodies or species that are well-hidden and camouflaged. Such inconsistencies affect how results are recorded and analytically interpreted.

The limitations of aerial surveys are the distance and speed at which surveyors have to count and identify bird species. Also included in aerial limitations is the expense of the flight itself. Inclement weather can inhibit a survey from taking place and also flying in general holds risks for any pilots and surveyors who partake in it. It is also more difficult to observe certain species, especially smaller waterfowl that are too minute or too well-hidden to be seen and recorded. Low flying aircraft can also cause the birds to flush and fly out of the survey area. Benefits include having a better view of survey areas with few physical obstructions by which to potentially block bird sightings. The aerial surveys are also able to be completed in a shorter amount of time. Shorter survey time can also help prevent the possibility of overcounting as they are less likely to move about the survey area. Maneuvering around high tides is also not an issue during this survey as it is when performed by foot.

There are also both benefits and limitations to ground and monthly high-tide surveys, as these are both terrestrial methods of surveying. Some limitations include visibility issues caused from high vegetation such as cattails or reed canarygrass (*Phalaris arundinacea*). For some of the units, there are also accessibility issues that inhibit the length and time that area can be surveyed due to threat of a rising tide. Limited staff can also lead to lengthy surveys which could in turn lead to double counting if the birds move about the survey area. There are also variable tide levels and survey times that must coincide in order for a survey to take place. Tides must be incoming and in the morning in order to capture optimal activity and behavior, as avian species are typically most active during the morning. However, there are also benefits. These include the slower pace of the surveys allowing for more accurate identification of species, and increase the likelihood of seeing the smaller species that might be difficult or impossible to see from an aerial survey. Audio identification is also used a great deal in bird surveys, as it is often said that the majority of bird identification occurs from a bird call rather than a sighting. These audio identifications are impossible by plane but are very commonly used in terrestrial surveys.

It is also important to note that there are not only general inconsistencies related to bird surveys, but also inconsistencies that vary throughout an individual month. To highlight the variability in observed monthly abundances, three ground waterfowl surveys with similar survey conditions including tide height and time of day were selected. These surveys occurred in January 1999. Survey 1 yielded 2229 birds, survey 2 yielded 6089 birds, and survey 3 yielded 895 birds. Though conditions were similar, each survey yielded very different total waterfowl abundances. This speaks to the "snapshot" nature of waterfowl surveys in which on a particular date and time, the number of birds observed can be very different and not necessarily reflect the true population numbers utilizing the site.

The above-mentioned highlights one of the primary difficulties in these types of waterfowl surveys in which the target animals have the ability to fly and move readily throughout the survey area. Refuge and USGS biologists have often noted birds flying south across Interstate-5 during surveys. It is believed that one way to try to account for this is to conduct more surveys throughout the month to better capture waterfowl use on the site. For many years, Refuge biologists tried to do exactly that, by conducting two to three surveys per month. This was thought to allow for a better understanding of waterfowl populations on the site as compared to once a month surveys. It is now understood that multiple surveys are not always useful as the previous example of variability within a single month shows. Performing multiple surveys each month also requires more resources, personnel, and time which make surveys at this level of intensity difficult to maintain.

There are many limitations to performing any wildlife survey. But from this research we see that to perform a survey in which the species has the ability of flight as a means of movement makes surveying such species much more difficult. But despite these limitations, we also see many benefits as well as necessity to monitor their numbers and behaviors. The most important of these is that with any sound scientific survey, despite difficulties or limits, it is better to have limited survey abilities and data than no survey or data collection at all.

4.2 PRE- AND POST-HABITAT RESTORATION CONDITIONS

From this research we can see that based on historical waterfowl numbers, the majority of waterfowl were dabbling ducks. This indicates that ecosystem conditions at Nisqually NWR were likely much drier prior to the restoration than of its natural estuarine state. This was in part due to construction of the dike that inhibited tidal influence, and also the addition of soil to the land to make it more suitable for agricultural purposes. Historical habitats consisted primarily of grasslands and riparian habitat suitable for certain waterfowl and other types of birds. These specific types of waterfowl included dabblers as mentioned before, but also geese and swan. Each used the area for purposes that included foraging, resting or waiting out the winter season. Beyond the dike and along the Nisqually River, diving waterfowl were also provided some suitable habitat and opportunities to forage.

After the removal of the dike, the habitat composition shifted. Due to this restoration, the amount of wetland habitat greatly increased. This increase created more opportunity for diving ducks to feed.   Although the amount of wetland susceptible to tide fluctuation expanded its range within Refuge boundaries, some upland habitats such as grasslands, riparian and forested habitat also remained allowing for continued geese, swan and dabbling ducks presence. From current waterfowl numbers, we see that dabblers are still the dominant foraging guild. Those numbers are expected to remain high based on the amount suitable habitat the Refuge still provides them. However, it could be predicted that the increase in tidally-influenced wetlands within Nisqually NWR boundaries may at some point in the future cause diving duck numbers to increase as well.

4.3 IDENTIFYING AND ACCOUNTING FOR SOURCES OF ERROR

As discussed in the previous section, most bird surveys tend to provide incomplete coverage. They can either miss proportions of populations for various reasons or even double count individual birds during the same survey. Therefore, there are no definitive surveys for most species. It is for these reasons that survey data can sometimes be difficult to interpret, and surveys of different types provide information of varying quality.

Another inconsistency is varying access to certain survey areas. Rough terrain or vegetation can be difficult to maneuver during surveys. Certain types of environmental barriers and even tall, thick vegetation types such as trees can inhibit view and block hidden species from being seen, especially among those species that are characteristically more secretive. These factors may also alter food and habitat availability. One particular plant species that has been known to cause visibility and mobility issues in the past is the invasive reed canarygrass. Now that the outbreak of this exotic plant is for the most part contained within Refuge boundaries, it will create little to no issues in the future.

Another issue discovered within the survey types used in this research included changing site boundaries over time. While some consistencies within Nisqually NWR surveys includes the utilization of the same overall area boundary, the units within the Refuge boundary have shifted and all surveys have been performed using visual aids such as binocular or spotting scopes and each survey employed the master birding skills of Nisqually NWR biologists and/or volunteers to help insure accurate identification of avian species sighted.

When surveying or monitoring wildlife populations, there is always a concern that an individual or entire group will be double counted in the data. This issue occurs when an individual or flock is recorded and then accidently counted a second time later in the survey as it moves about the habitat. This occurrence is especially true for avian populations as their size and ability to fly enables them to hide or move around with relative speed and efficiency. It is often difficult to discern whether or not a particular bird has been previously recorded as most individual birds do not possess characteristics or phenotypic variability by which to distinguish them from other individuals. One way to account for double counting is to note a bird or flock recorded while in flight as well as the time and direction in which they are travelling. If s similar bird or group is seen entering the survey area at a later time then it may be concluded that it is the same group. Note-taking is also important when multiple groups are surveying separate areas at different times. Collaboration between survey teams after the survey can help to determine is any data was double counted between the groups of surveyors.

The issue of missing an individual or group present may also occur. A majority of the time, avian presence is discerned based on auditory identification rather than a visual sighting. If the bird or flock is in a dense habitat and not calling or singing, they may not be recorded. Also, if they are immobile, small-bodied or well-camouflaged, they may not be visually observed. It is for these reasons that a thorough examination of the survey area must always take place.

Although maintaining consistent, specific surveyors when monitoring wildlife populations is strived for, it is not always possible. There will not always be the same skilled surveyor available for every survey, which could inhibit the quality of data recorded. This might occur because different surveyors have varying skill levels for audio and visual identification of birds. A variety of different biologists and trained volunteers have aided in the observation, identification and recording of birds sighted during the various surveys (ground, aerial and monthly high-tide) discussed in this research. The best way to account for this is to maintain participation of a team of observers with master-level skills in visual and vocal avian identification that are familiar with survey protocol.

Hunting is also a potential source of disturbance while in season. Spanning from October to January depending upon the targeted species, hunting season could have an effect on waterfowl survey data recorded during these months. The fire from a shotgun or rifle has the ability to flush birds from an area, and was even recorded doing so in some of the dataset notes in this project. Flushing of waterfowl because of gunfire could force more birds into the safety of the Refuge, or could cause them to seek shelter somewhere outside of the Refuge boundary. There is also the possibility that hunting has little effect on waterfowl overall and have adapted to this type of recreation. Further research is needed to reach a consensus. The best way to account for the possibility of hunting disturbance during waterfowl surveys is to note any change in behavior that might be seen as a result of nearby gunfire.

There are also other exogenous factors that could have an effect on waterfowl. Such sources include visitor disturbance or necessary maintenance such as mowing that may be occurring within the Refuge's boundaries. Nearby boat, automobile, commercial airport or military air traffic may also effect bird behavior and disrupt any potential for audio identification of species.

Tide height, time of day, weather conditions and season also factor into where, when and if survey will be performed at that time as each of these factors greatly influence avian activity. Shifts in seasonal weather or climate may also affect bird behavior and abundance from year to year creating anomalies within the data. Fog, frost and storms may also have an effect on avian presence and surveyor ability to identify or even participate in a survey.

Each of these factors can potentially affect the quality of the data. Some can even prevent a survey from occurring altogether. Despite these possibilities, the benefits of performing these particular wildlife surveys are great, and even imperative in assessing the overall health and management of their populations and habitats.

4.4 SUGGESTIONS FOR FUTURE RESEARCH

There are a variety of potential topics that can be derived from the basis of this research. For example, this research could be utilized as a basis for furthering the same Nisqually waterfowl studies in the future. Further study can provide a better understanding of how the avian populations within Nisqually NWR have changed over time. It can also provide a detailed description of how their populations have reacted to the 2009 restoration as current post-restoration data is insufficient to come to an accurate conclusion of the full effects the project has had. Approximately 5-10 years more data would need to be collected to come to such an accurate consensus.

It may also be of interest to concentrate in-depth on changes in other avian groups such as raptors, passerines and water birds in a study similar to this. When performing the monthly high-tide bird survey, all avian species are recorded, and the dataset is not just limited to waterfowl. One study in particular that may also be of interest is comparing the trends of insectivorous birds to any trends discovered using benthic invertebrate data also being collected from the Nisqually Delta. Invertebrate species are known to be indicators of a healthy estuary and are an important food item for various species of birds that utilize the estuary for foraging. Changes in vegetation dominance as a result of the restoration and corresponding elevation changes might also be a subject that could be compared to the waterfowl trends analyzed. Shifts in avian guild trends would also be interesting, as would analysis of trends from other avian surveys performed at Nisqually such as point-count surveys and Christmas bird counts, as well as the avian data collected from the Nisqually Tribal sites and Reference Marsh.

Disturbance from human activities could cause temporary changes in waterfowl behavior and locally affect temporal and spatial distribution of migratory and wintering species. To some extent however, birds can compensate for such disturbance by altering their behavior and habituating around these human activities (Madsen 2008). One example of this could potentially be the effect of hunting season on these waterfowl. Fall, winter and spring hunting is widely practiced throughout the world, although few studies have been conducted investigating the effects on waterfowl. Little is known though about how anthropogenic disturbance influences large-scale dispersion and population dynamics of waterfowl (Madsen 2008).

4.5 FINAL THOUGHTS

From this research, we have recognized the amount of survey work that needs to be done to monitor the plants and wildlife that call Nisqually NWR home. We have also identified the faults and deficiencies within these surveys. But with these sources of error stands a simple truth: surveys are imperative to monitoring the overall health of wildlife populations. The biologists, technicians and faithful volunteers of the Refuge are continuing to make this happen so that the true effects of the restoration on waterfowl populations can be accurately assessed.

We also see from this research that despite the differences in survey types spanning decades, one waterfowl guild stands out above the rest; dabbling ducks. Included within this popular guild is the American Wigeon, the most prominent of the dabbling duck species and poster child of Nisqually NWR itself. This particular species likely stands out above the rest because of the availability of shallow waters present both before the restoration due to seasonal rains, and following the restoration due to tide fluctuation. These shallow standing waters allow for ample amounts of suitable feeding habitat for both migrants and residential birds.

Finally, from this research we see the importance of suitable habitat for wildlife. Even more so, we understand how an estuarine ecosystem such as the one at Nisqually NWR supports an array of habitats and intricate food webs. One of the most notable wildlife groups that utilize the resources provided by such an ecosystem includes birds, specifically waterfowl. The Refuge is exactly what the name implies: a safe haven. It provides food items, breeding grounds, shelter and a place to rest on a long migratory journey. Nisqually NWR has provided this service for many decades, and will continue to do so since its dramatic transformation back into its natural estuarine state.

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