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Environmental Factors Influencing Spring Migration Chronology of Lesser Scaup (Aythya affinis)

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Biology

ENVIRONMENTAL FACTORS INFLUENCING SPRING MIGRATION CHRONOLOGY OF LESSER SCAUP (*Aythya affinis*)

(Thesis format: Monograph)

by

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Graduate Program in Biology

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Abstract

Weather likely affects the timing and rate of migration by waterfowl to their breeding grounds. I hypothesized that timing of migration by lesser scaup during spring is affected by annual variation in temperature, precipitation and ice cover. I used satellite telemetry data, waterfowl survey data and corresponding weather data to evaluate competing models that explained variation in timing and rate of migration by lesser scaup. Timing of spring migration occurred earlier and faster when lesser scaup encountered warmer temperatures and greater precipitation, both of which are known to influence thermoregulation and habitat availability for waterfowl. Migration chronology of lesser scaup and mallards differed suggesting surveys designed for mallard migration may be biased for scaup. My thesis provides insight into how environmental factors and annual variation in weather influences scaup migration chronology, and could be used to potentially improve survey techniques and breeding population estimates for lesser scaup.

Keywords

lesser scaup, mallards, migration chronology, weather, satellite transmitter

Co-Authorship Statement

I was responsible for all intellectual and analytical aspects of the development and completion of my thesis under the supervision of Dr. Scott Petrie and Dr. Irena Creed. I received satellite telemetry data from Dr. Scott Petrie, Long Point Waterfowl, and Dr. Alan Afton, United States Geological Survey, Louisiana Cooperative Fish and Wildlife Research Unit. I received survey data from Mr. Mike Johnson and Mr. Michael Szymanski, North Dakota Game and Fish. With the assistance of Dr. Michael Schummer (Senior Scientist with Long Point Waterfowl), I developed modeling procedures that I executed in SAS. Monograph draft edits were received from, Dr. Scott Petrie, Dr. Irena Creed, Dr. Michael Schummer and Dr. Al Afton. All work within this thesis has been authored by Taylor A. Finger and will be published with co-authors Alan D. Afton, Scott A. Petrie, Irena F. Creed and Michael L. Schummer.

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List of Acronyms

LPW	Long Point Waterfowl
USGS-LACFWRU	United States Geological Survey, Louisiana Cooperative Fish and Wildlife Research Unit
SWE	Snow Water Equivalence
FDD	Freezing Degree Days
TDD	Thawing Degree Days
WBPHS	Waterfowl Breeding Population and Habitat Survey
US	United States
PTT	Platform Terminal Transmitters
LC	Location Class
AIC	Akaike's Information-Criterion
NARR	North America Regional Reanalysis
NCDC	National Climatic Data Center
VIF	Variance Inflation Factor

1.0 Introduction

1.1 Environmental Factors Influencing Spring Migration Chronology In Birds

Endogenous circannual rhythms initiate migration in birds and produce cues that determine the timing and spatial course of migration (Gwinner 1996). In northern temperate and arctic environments, migration is initiated by photoperiod and the annual cycle, however as migration progresses timing and rate correlate with relatively consistent annual changes in habitat and weather conditions (Gwinner 1996). The timing of bird migration also is influenced by relatively less predictable weather fluctuations including short term variability in temperature, precipitation, and snow and ice cover (Berthold 2001, Schummer et al. 2010). Because species of birds acquire, store and use energy reserves differently, the effect of weather cues on the timing of migration differs inter-specifically (Newton 2008).

Photoperiod and annual variation in weather patterns influence the timing of spring migration (i.e., migration chronology) in birds (Both et al. 2005). The relative influences of these cues may determine whether the migration strategy is fixed or flexible (Alerstam and Hedenström 1998, Newton 2008). During spring migration, annual differences in ambient temperatures and snow and ice cover influence when habitat and food resources become available. Thus, in flexible migrants, the chronology of annual movements coincides with available and increasing abundances of habitat and food resources in association with decreasing severity of weather on staging and breeding grounds (Newton 2007). Species that exhibit fixed migration generally settle to breed and initiate nests largely insensitive to spring conditions (Drever et al. 2012). However, long term changes in weather patterns could influence migration timing and distribution even in species that exhibit a fixed migration strategy (Gurney et al. 2011, Drever et al. 2012). Determination of how these weather and environmental factors influence bird migration provides insight into how climatic change may influence spring migration chronology in birds that exhibit fixed and flexible migration patterns.

Spring migration in birds often is influenced by habitat and nutrient requirements, and what habitat and nutrients birds require often group them into guilds based on foraging strategies and habitat requirements (Root 1967, Newton 2008). Terrestrial guilds include species that exploit upland habitats and foods, whereas wetland obligate guilds restrict their habitat use and foraging to aquatic habitats. Guilds are further separated based on dietary selection (e.g., granivores, insectivores, molluscivores, and omnivores; DeGraaf et al. 1985). Overall, type and breadth of habitat use and foraging requirements of birds (i.e., generalist *versus* specialist) can influence species-specific resource availability during migration (McNaughton and Wolf 1970). Migratory birds that exploit food resources from a prior growing season (e.g., terrestrial granivores) often are able to acquire nutrients during spring migration prior to the thawing of lacustrine and palustrine habitats. This ability may favour earlier migration as compared to birds that specialize on wetland foods (i.e., wetland obligates; Bellrose 1980, Kaminski and Weller 1992, Alerstam and Hedenström 1998, Naugle et al. 2001, Newton 2008).

1.2 Lesser Scaup Life History Strategies

Diets and foraging strategies of birds often vary seasonally to allow birds to meet nutritional requirements and allow for exploitation of changing resource availability (Krapu and Rienecke 1992, Molokwu et al. 2011). Lesser scaup (hereafter scaup) primarily eat macroinvertebrates by diving, and often select large, open water bodies, and are thus considered a wetland obligate species in the diving duck guild (Stephenson 1994, Austin et al. 1998). Scaup rely heavily on Amphipoda and Chironomidae, but eat some aquatic vegetation (Afton and Hier 1991, Anteau and Afton 2008, Anteau and Afton 2011). In the Great Lakes, the invasion of Quagga (*Dreissena rostriformis*) and Zebra (*Dreissena polymorpha*) mussels has resulted in substantial increases in the number of staging scaup, thereby causing modifications in migration patterns and chronology (Custer and Custer 1996, Petrie and Knapton 1999).

The migration strategy used by scaup differs depending on where they settle to breed, individuals that settle in the prairies tend to arrive and spend a lengthy amount of time prior to initiating nests (Afton 1984), whereas individuals that settle in the boreal forest attempt to acquire nutrient reserves throughout spring migration to be ready to initiate egg laying shortly after arriving on the breeding grounds (Esler et al. 2001, Gurney et al. 2011). Recent studies, however, have detected declines in the quality and availability of food for scaup on wintering, spring migration, and breeding grounds in the Mid-continent region of North America (Anteau and Afton 2004, 2008, 2009). Scaup now are arriving on breeding grounds with fewer stored reserves and must acquire nutrients to begin nesting, potentially delaying nest initiation and decreasing female productivity (Anteau and Afton 2004, 2008, 2009). In contrast, the invasion of zebra and quagga mussels in the Upper Great Lakes region has increased food availability, potentially increasing the ability of scaup to acquire nutrients during staging events prior to reaching breeding sites in the boreal forest (Custer and Custer 1996, Petrie and Knapton 1999).

Scaup are relatively fixed regarding nest initiation, in that they generally settle to breed over a two week period in June, independent of spring conditions (DeVink et al. 2008, Gurney et al. 2011, Drever et al. 2012). However, my study aims to identify how scaup migration timing and rate, on an individual scale, may be affected by the weather factors. Scaup generally settle to breed later than dabbling duck species, but primarily migrate during March, April, and May (hereafter spring; Bellrose 1980, Austin et al. 1998). Variation in migration chronology in scaup may be related to the seasonal availability of habitat and capacity to store lipids (Anteau and Afton 2006, Anteau and Afton 2008). Progression of spring migration for scaup may be affected by their foraging requirements and diving habits, relatively limited capacity for lipid storage to fuel migration, and dependence on available, ice-free semi-permanent and permanent wetlands along their route.

Migration is influenced depending on how weather influences habitat availability, both at a regional and a local scale (Greenwood et al. 1995, Johnson et al. 2005, Anders and Post 2006). Key life history requirements may dictate how large an influence weather and environmental factors have on spring migration. For waterfowl, habitat availability may be influenced differently by weather factors in different migration routes, thus influencing migration chronology. Scaup in my study migrated used two major routes, the Mid-continent route and the Eastern route (Figure 1). The Mid-continent migration route includes the Prairie Pothole Region, which is comprised largely

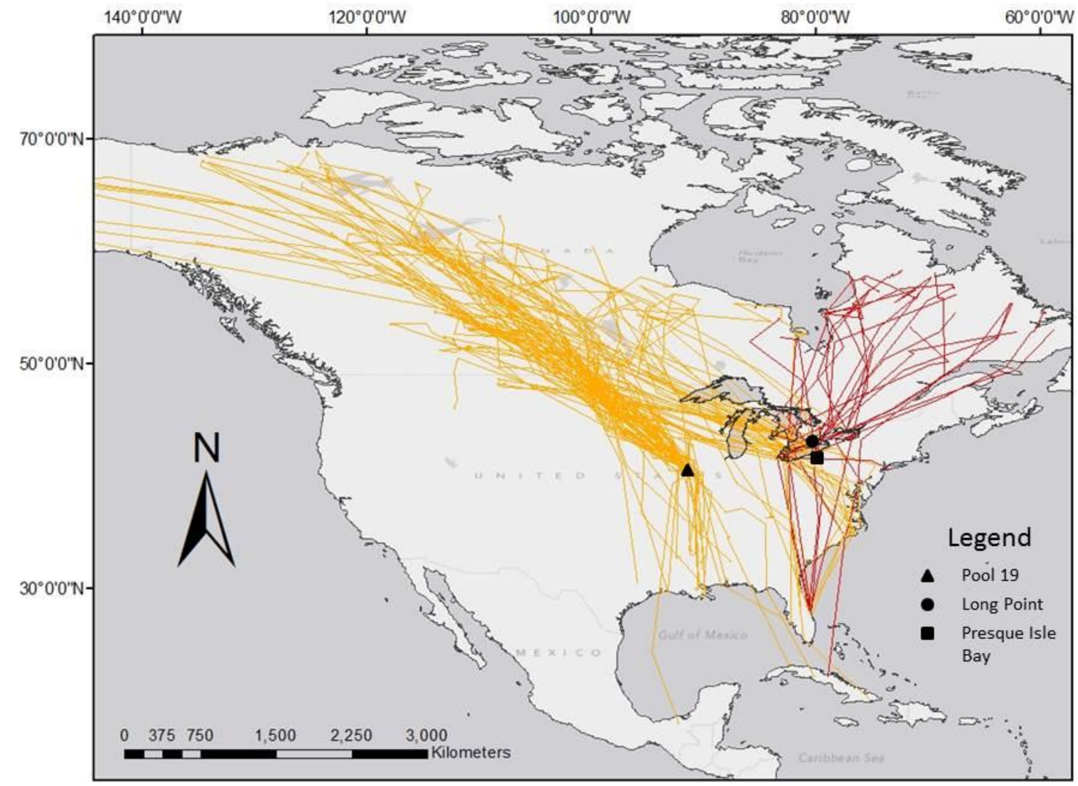

Figure 1. Capture and satellite telemetry implant locations in Illinois, Ontario and Pennsylvania and lines (Orange [Mid-continent], and Red [Eastern]) representing spring migration routes of lesser scaup (*Aythya affinis*) tracked with satellite telemetry and from 2005-2010 (n=78).

of small seasonal and semi-permanent bodies of water susceptible to fluctuations in spring temperature and precipitation (Greenwood et al. 1995, Larson 1995, Johnson et al. 2005). Conversely, the Eastern migration route is primarily comprised of the Great Lakes and boreal forest regions, where water is abundant on a permanent basis, and the availability of water is therefore not as greatly influenced by year-to-year fluctuations in spring temperature and precipitation (Bonan and Shugart 1989, Magnuson et al. 1997). Weather and environmental factors may influence habitat availability in turn also affecting the availability of food resources. When the Canadian prairies experience conditions that negatively influence habitat availability, nutrient availability will be limiting as well, potentially delaying migration (Larson 1995, Austin et al. 2002). In contrast, in the Eastern migration route, nutrient availability may not be limiting, because of the warming climate and invasion of *Dreissenid* mussels into the Great Lakes (Custer and Custer 1996, Magnuson et al. 1997, Petrie and Knapton 1999). Understanding weather conditions and interannual and spatial variability in those conditions that influence migration chronology in scaup would inform development of predictive models or indices of spring migration. Because timing of migration may influence population estimates from annual waterfowl surveys and population estimates are used to manage these birds in North America, my models will be useful in conservation and management of this species.

1.3 Scaup Populations and the use of the Waterfowl Breeding Population and Habitat Survey to Estimate Duck Populations

The Waterfowl Breeding Population and Habitat Survey (WBPHS) is largely an aerial survey, however, with a ground component in the prairies. The survey is conducted by stratum in the Prairie Pothole region, Western boreal forest and tundra since 1955 and the Eastern boreal forest region since 1990 (Smith 1995, United States Fish and Wildlife Service 2012; Figure 2). WBPHS data are used to estimate population sizes and trends of waterfowl, and are used to set annual harvest regulations and to make other management decisions (Smith 1995, Gregory et al. 2004, Conant et al. 2007). Survey timing was established to coincide with spring migration and settling patterns of mallards (*Anas platyrhynchos*) and other early-nesting waterfowl (Smith 1995). Concerns have been expressed that this survey design does not adequately enumerate certain species of waterfowl, especially sea ducks (Tribe Mergini) and late-nesting species, such as scaup (Smith 1995, Afton and Anderson 2001). Identifying weather factors associated with the timing of migration and settling patterns of waterfowl on breeding grounds could provide justification for modifying the timing of the WBPHS or including correction factors for certain species.

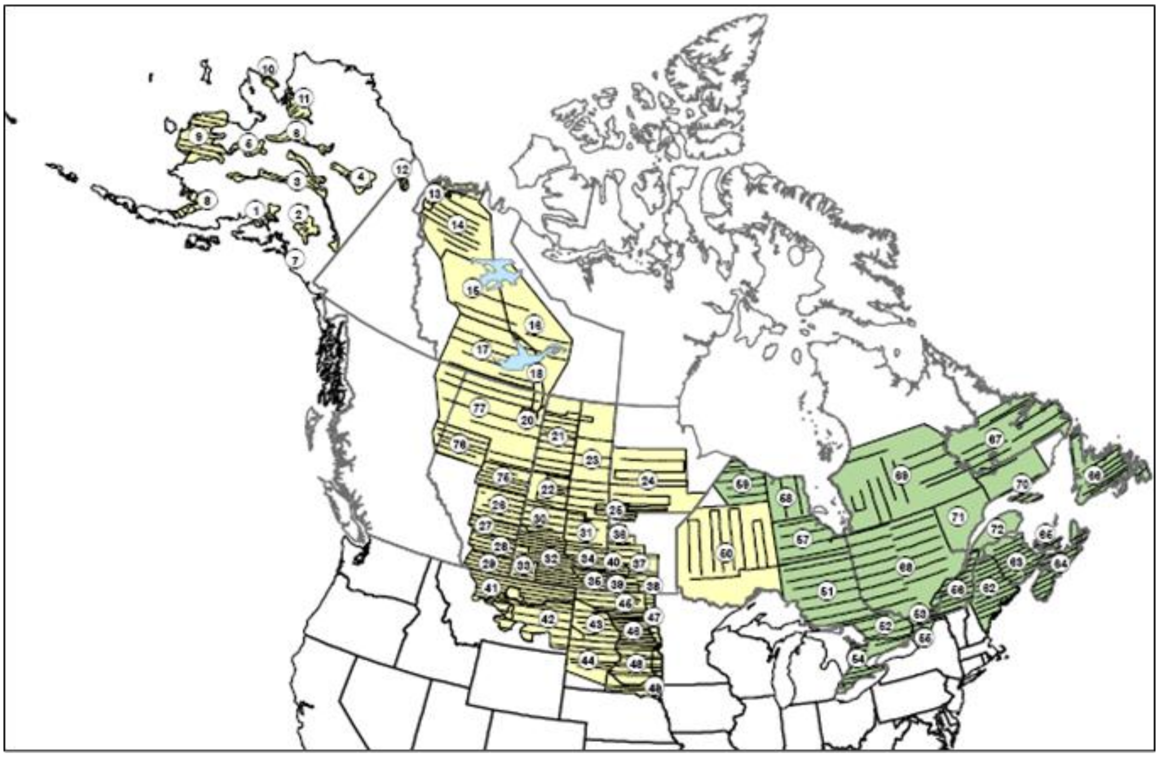

Figure 2. Strata and transects of the Waterfowl Breeding Population and Habitat Survey (yellow = Mid-Continent Survey Area, green = Eastern Survey Area; USFWS 2012).

Scaup have the most protracted spring migration of all North American ducks (Bellrose 1980). In the Prairie Pothole region, scaup arrive as early as mid-March when the first permanent and semi-permanent wetlands begin to thaw, and may continue to migrate through the region into late-May (Holland 1997, Austin et al. 1998). However, nest initiation generally does not occur until late-May or early-June (Gurney et al. 2011). Because scaup nest late and have high migration variability, breeding population estimates for scaup obtained using the WBPHS may be biased. For example, scaup may continue to migrate through the southern part of the WBPHS area while surveys are being conducted or the surveys could have already been flown before the majority of scaup have arrived in the area (Afton and Anderson 2001). Therefore, individual scaup may be counted multiple times or not at all depending on the movement of survey crews from south to north due to environmental factors that influence progression of birds during spring migration (Crissey 1975). Inaccurate estimates and improbabe between-year changes in population estimates could result from multiple counting or missing individuals in the survey area (Bowden 1973, Crissey 1975, Austin et al. 1998, 2000, Naugle et al. 2000, Afton and Anderson 2001, Mallory et al. 2003). For instance, between 1970 – 1971 the WBPHS estimate suggested that the continental scaup population increased by nearly 3 million birds, which is biologically implausible (Afton and Anderson 2001, United States Fish and Wildlife Service 2012). Therefore, investigation of weather factors influencing spring migration chronology of scaup, and comparisons of migration chronology between scaup and mallards (the WBPHS was designed for mallard chronology), may help refine population estimates for scaup. Furthermore, understanding of how recent changes in food availability and its influence on migration chronology indicate that a comparison of scaup migrating in the Mid-continent and Eastern migration routes would be informative.

1.4 Objectives, Hypotheses and Predictions

I conducted my study at two scales. First, I used a broad scale approach whereby I analyzed weather factors across large geographic areas hypothesized to influence the timing of arrival by scaup at specific locations (e.g., date of arrival on breeding grounds). The broad scale approach evaluated how the timing and rate of migration by scaup were influenced by environmental and weather conditions at the large geographic scale (e.g., weather conditions across the Prairie Pothole region). Second, I conducted my study at a local movement scale, where I analyzed how local factors influenced the likelihood of each migratory movement until a duck reached its breeding location. My local movement analysis investigated how individual migration events by scaup were influenced by local environmental and weather conditions during migration.

I also compared the timing of peak migration between scaup and mallards through the Mid-continent migration corridor in north-central North Dakota using annual roadside migration survey data to describe differences and interannual variation in the timing of arrival by these two species into areas surveyed by the WBPHS. Because the WBPHS is designed based on mallard migration characteristics, identifying whether scaup migration is timed differently may identify potential bias in the current survey design and techniques.

I developed models of spring migration chronology for scaup to provide information useful for developing unbiased and accurate population trend estimates. Annual variation in spring migration chronology of scaup may be influenced by ambient temperature, freezing and thawing degree days, rainfall, ice cover, and snow water equivalency. Increasing temperature decreases energy expenditure in homeotherms and increases seasonal habitat availability by melting ice and snow (Alerstam 1990, Kaminski and Weller 1992, Naugle et al. 2001, Newton 2007, Schummer et al. 2010). Ice cover influences energy acquisition (i.e., food accessibility) in wetlands and thereby potentially affects lipid stores and the timing of spring migration (Lovvorn 1989, Brook et al. 2009). The combination of water released from snow and spring rainfall influences wetland habitat availability for waterfowl (Krapu et al. 1983, Hayashi et al. 2003). Freezing degree days and thawing degree days are measures of both the duration and magnitude of above and below freezing temperatures over a specific period of time. Freezing degree days are an index of ice cover for lacustrine and palustrine habitats, and it has been applied as an index of winter severity (Assel 1980). Thawing degree days are an index for ice and snow melt during spring and of growing days for plants and invertebrates (Hebert and Hann 1986, Walker et al. 1994). By using freezing degree days and thawing degree days I created an index of availability of wetland habitat and foraging resources to scaup during spring. I developed a suite of competing candidate models to investigate which environmental/weather factors or combination of these factors best explained variation in the timing of migration in scaup.

Objective 1. To take a broad-scale approach, investigating weather factors that could influence spring migration of satellite transmitter implanted scaup.

Hypothesis 1. I hypothesized that the timing of scaup migration during spring would be affected by annual variation in temperature, precipitation and ice cover at a regional scale.

Prediction 1a (scaup arrival dates – satellite data). I predicted that the standardized date (1 Jan. = day 1 and 31 Dec. = day 365) of arrival by scaup into the WBPHS area and on breeding areas would: 1) vary negatively with mean spring ambient temperature, maximum snow water equivalent (SWE, the maximum amount of water available within the snowpack measured in kg/m^3) and average spring precipitation (the average amount of rainfall), and 2) vary positively with average spring indices of ice cover (Freezing Degree Days [FDD; mean daily temperature below 0 degrees Celsius] and Thawing Degree Days [TDD; mean daily temperature above 0 degrees Celsius]).

Prediction 1b (scaup migration rate – satellite data). I predicted that the rate of spring migration by scaup (km/day) from implantation sites to the WBPHS area and inferred breeding sites would be related: 1) negatively to spring indices of ice cover, and 2) positively to mean spring ambient temperature, mean spring precipitation, and maximum snow water equivalent.

Objective 2. To use weather factors to predict habitat and nutrient availability in Mid-continent and Eastern migration routes, and determine how annual variability in environmental conditions influences the spring migration chronology of satellite implanted scaup.

Hypothesis 2. I hypothesized that weather factors would affect scaup using the Mid-continent migration route to a greater degree than scaup using the Eastern migration route, because of generally greater habitat and nutrient availability in the eastern route.

Prediction 2a. I predicted that scaup migration chronology in the Mid-continent route would be correlated with weather factors influencing habitat and nutrient availability, because the availability of seasonal and semi-permanent wetlands would vary: 1) positively with temperature, rainfall and SWE, and 2) negatively with indices of ice cover.

Prediction 2b. Because habitat and nutrient availability probably are less dependent on weather factors in the Eastern migration route, I predicted that scaup migration chronology in the Eastern migration route would not be influenced as strongly by environmental factors.

Objective 3. To investigate weather factors that could influence the spring migration chronology of satellite transmitter implanted scaup at a local scale.

Hypothesis 3. I hypothesized that at the local scale, the probability of departure by scaup would be influenced by local variation in temperature, precipitation and ice cover.

Prediction 3. I predicted the probability of departure of scaup would be increase with increased local temperature, SWE, rainfall and TDD, and be inversely related to FDD.

Objective 4. To compare the timing of arrival during spring into North Dakota between mallards and scaup from 1980 – 2010.

Hypothesis 4. I hypothesized that scaup would migrate later than mallards through North Dakota due to the more specialized habitat requirements of scaup at stopover and breeding sites, as compared to mallards.

Prediction 4. I predicted that when the standardized date of peak abundance by mallards was earlier than that of scaup in North Dakota, weather indices would indicate a greater number of freezing degree days, low maximum snow water equivalence, and low average spring precipitation in North Dakota.

2.0 Methods

2.1 Study Area

Scaup were captured at areas traditionally used by scaup during spring migration, including: 1) Long Point, Lake Erie, Ontario (42.55, -80.25), 2) Pool 19 of the Mississippi River (40.5, -91.35) and 3) Presque Isle Bay, Lake Erie, Pennsylvania (42.15, -80.10; World Geodetic System; Figure 1). Long Point is a sand-spit extending 35 km east from the southern edge of Ontario into Lake Erie that has facilitated the formation of the Inner and Outer Long Point Bays and their associated freshwater marsh complexes, which attract an abundance of waterfowl during migration (Petrie 1998). Because 99% of the inner bay is covered with submerged aquatic vegetation, and with the invasion of zebra and quagga mussels to the Great Lakes, Long Point has become an important staging location during migration (Petrie 1998, Petrie and Knapton 1999). Pool 19 is an important mid-latitude stopover area between Hamilton and Dallas City, Illinois and between Keokuk and Fort Madison, Iowa, where substantial numbers of scaup stage prior to migration through the Upper Midwest (Havera 1999). Because Pool 19 is relatively shallow and is comprised of dense aquatic vegetation and fingernail clams, it attracts vast numbers of staging waterfowl along the Mississippi River (Thompson 1973, Havera 1999). Presque Isle Bay is a natural embayment bounded by a recurved 7.2 km long peninsula extending from Pennsylvania into Lake Erie. With the combination of high densities of aquatic vegetation and macroinvertebrates (i.e., zebra and quagga mussels), Presque Isle Bay has become a key staging locale for waterfowl in the Lower Great Lakes Region (Philips 2008).

I categorized migration by scaup into two major routes: 1) the Mid-continent western Prairie Pothole Region (hereafter Mid-continent region) and 2) the Eastern boreal forest region (hereafter Eastern region). The Mid-continent region included: 1) Alaska-Yukon Territory-Old Crow Flats, 2) central and northern Alberta-northeastern British Columbia-Northwest Territories, 3) northern Saskatchewan-northern Manitoba-western Ontario, 4) southern Alberta, 5) southern Saskatchewan, 6) southern Manitoba, 7) Montana-western Dakotas and 8) eastern Dakotas (United States Fish and Wildlife Service 2012, Figure 2). The Eastern region included: 1) western Ontario-central Quebec, 2) eastern Ontario-southern Quebec and 3) Maine and the Maritimes (i.e., New Brunswick, Nova Scotia, Newfoundland, and Labrador; United States Fish and Wildlife Service 2012; Figure 2).

Scaup generally nest in three distinct biomes: tundra, prairie-parkland, and boreal forest (Afton and Anderson 2001). On average, 68% of breeding scaup are observed in the boreal forest, 25% in the prairie-parkland, and 7% on the tundra in the Mid-continent region (Afton and Anderson 2001). Little is known about the breeding range of scaup using the eastern region, but they are presumed to nest in the boreal forest (Badzinski and Petrie 2006).

2.2 Capturing and Implanting

Long Point Waterfowl and US Geological Survey, Louisiana Cooperative Fish and Wildlife Research Unit, captured after-hatch-year (AHY) female scaup using swim-in and dive-in traps baited with a mixture of corn, wheat, and barley. Traps were baited daily throughout the spring staging season until birds departed (mid- to late April).

Captured birds were removed from traps repeatedly daily and placed in feed bags or crates, and transported to shore. Sex and age were determined on shore using plumage and cloacal examination (Haramis et al. 1982, Pace and Afton 1999). A random sub-sample of female scaup at weighing ≥ 630 g (Pool 19) and ≥ 600 g (Lake Erie), and without any visible injuries were implanted with Platform Terminal Satellite Transmitters (PTT; Microwave Telemetry Inc., Columbia, Maryland; Appendix A).

Captured scaup were anesthetized with 5% isoflurane, intubated using a 3-0 to 4-0 endotracheal tube, maintained at 2-3% isoflurane at a flow rate of 1 L of oxygen per minute, positive-pressure ventilated during surgery once each 10 s, and monitored with a stethoscope (heart rate) to ensure health and safety throughout the surgery.

Scaup were surgically prepared at two sites: the dorsal synsacrum and the ventral abdominal muscles. Incisions were made on the ventral abdomen where a 38 g model 100 PTT transmitter was digitally implanted. Gentle pressure was used to force the antennae through the skin at the prepped dorsal sites. PTT's were placed along the right body wall and the ventral incision was sutured closed as was the dorsal skin to anchor the antennae to the skin on the dorsum of the scaup. Scaup were allowed to recover using an ambubag, a self-re-inflating bag used during resuscitation, and once females regained the ability to right themselves they were held in a warm quiet area for two hours prior to release at the capture site.

2.3 Satellite Location Data and Data Processing

2.3.1 Location Data

Duty cycles, or period of time that satellite transmitters were recording, varied among sites to optimize data collection, meet specific project objectives, and conserve battery life during breeding and winter (Table 1). The Argos satellite system (Service Argos 2008) was used to determine locations of marked scaup throughout spring migration. Upon receiving satellite data, the Argos system provided measures of latitude, longitude, date, time, and provided estimates of location error. Locations were calculated from received frequency as the satellite passed over the transmitter, and transferred to processing centers that made the data available to Long Point Waterfowl and the US

Geological Service, Louisiana Cooperative Fish and Wildlife Research Unit. The Argos satellite system separated fixes into four location classes (LC) LC-3: <250 m, LC-2: 250-500 m, LC-1: 500 – 1,500 m, and LC-0: where no location accuracy was given, to provide measures of accuracy for recorded fixes. I used the Douglas Filter and chose a set of filtering criteria (Douglas 2006). The criteria I selected included location classes 1, 2 and 3, to capture complete representation of migration. I retained locations that were closest to previous or immediately prior selected location (Peterson et al. 1999, Hatch et al. 2000). I specified maximum rate of movement between locations (<100 km/hour; Miller et al. 2005). I set a minimum accepted angle among 3 subsequent points (15 degrees). Lastly, I selected the best location class within duty cycle (Peterson et al. 1999). I imported locations that passed my filtering criteria into ARCMap 10 (ESRI 2011). I plotted locations and manually confirmed each location to provide a dataset with the most accurate and likely locations for all marked scaup.

Table 1. Duty cycles of satellite transmitters deployed on lesser scaup (*Aythya affinis*) marked at Long Point, Pool 19, and Presque Isle Bay between 2005 and 2010.

	Start Date	**End Date**	**Hours On**	**Hours Off**
Pool 19	1-Mar	10-Jun	4	30/24 = 1.25 days
	11-Jun	12-Sep	5	168
	13-Sep	16-Dec	4	74
	17-Dec	28-Feb	5	168
Long Point & Presque Bay	1-Mar	10-Jun	4	72/24= 3.00 days
	10-Jun	28-Feb	4	240

2.3.2 Data Processing

I used linear mixed effects modeling with an information theoretic approach using Akaike's information-criterion (AIC) or AIC corrected for small sample sizes (AICc), when appropriate, to test a set of biologically plausible candidate models which represented competing hypotheses thought to influence variation in spring migration chronology (Burnham and Anderson 2002). I developed models at two spatial scales: 1) a broad scale to identify how a large geographic area influences the timing and rate of migration (i.e., broad scale analysis) and 2) a fine scale to investigate how weather influences migration of individuals at a local scale (i.e., local movement analysis).

For the broad scale analysis, I obtained weather data for four regions that scaup migrate through in the Mid-continent and Eastern regions of the WBPHS from 2005-2010 (Appendix B). I acquired weather data from the North American Regional Reanalysis (NARR) database supplied by the National Climatic Data Center (NCDC) using software developed by David Douglas (US Geological Survey – Alaska Fish and Wildlife Research Center) to query data (Mesinger et al. 2004). I used the following steps to determine sizes and location of the four regions: 1) determine the least number of regions required to capture >95% of migrating implanted scaup in my study, 2) select regions located to capture at minimum, one spring migration from each bird, but not required to capture every recorded migration from each bird, and 3) locate these regions in known migration corridors, as demonstrated by prior research (Figure 3).

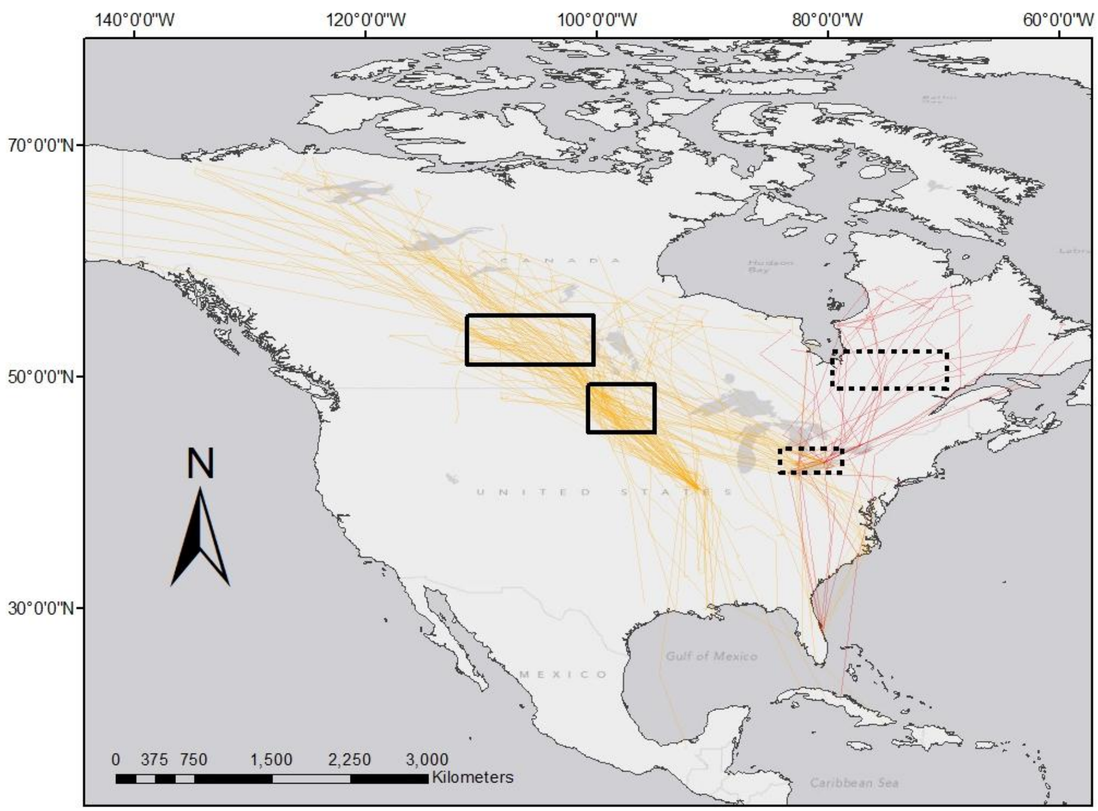

Figure 3. Polygons (Solid [Mid-continent], and dashed [Eastern] areas) representing regions where weather data were collected in the Mid-continent and Eastern survey areas of the Waterfowl Breeding Population and Habitat Survey from 2005-2010. Lines represent migration routes (Orange [Mid-continent], and Red [Eastern]) of lesser scaup (*Aythya affinis*) tracked with satellite telemetry (n=78) for the same time period.

I used four response variables in my investigation of scaup migration chronology. First, the standardized date when satellite-marked scaup first reached the WBPHS area (stratum). I considered a marked Lake Erie scaup located within the WBPHS area 1.5 days prior to when it was detected and 0.625 days for scaup tagged at Pool 19, given the slight difference in duty cycles (Table 1). Following Miller et al (2005), I used 1.5 days as a median to account for the 3-day PTT duty cycle used by Long Point Waterfowl and 0.625 days to account for the 1.25-day PTT duty cycle used by United States Geological Survey-Louisiana Cooperative Fish and Wildlife Research Unit. Secondly, the standardized date when scaup were considered settled on their breeding grounds; a scaup was considered settled on the breeding ground after observing no movement >8 km for ≥

30 d. I used 30 d because it slightly exceeds incubation length for scaup (Afton and Ankney 1991, Austin et al. 2005) and the 30 d definition has been used in other research to describe possible settling in other species of waterfowl (Miller et al 2005, Krementz et al. 2011), Third, rate (km/day) that scaup migrate from staging areas (i.e., Great Lakes and Pool 19) to the WBPHS area. Finally, rate (km/day) that scaup migrate from staging areas (i.e., Great Lakes and Pool 19) to the breeding location, calculated as one measure for the whole migration route.

For my local movement analysis, I acquired weather data for the locations of each implanted scaup that made a complete migration, which was defined as an individual having undergone migration and settled on the breeding grounds. I obtained weather data at the finest scale provided by NARR (i.e., 32 km^2) at recorded locations of scaup during migration. If a scaup moved >32 km between duty cycles, I considered the movement a migratory event. The percentage of movements <32 km was 51% (441 of 863), 32 to 100 km 8% (68 of 863), and movements >100 km were 41% (354 of 863). For each migratory movement, I obtained daily weather data for: 1) the duck location the day immediately prior to the migratory movement, 2) the terminal location of the migratory movement and 3) one location selected randomly between the last two migratory movements (i.e., staging). Combined, I used these three data points per migratory movement to include weather conditions thought to be related to migration, staging, and/or stoppage of migration (i.e., terminal location). Inclusion of these three points per duck migration movement allowed me to model the likelihood of migration based on a candidate suite of environmental condition based models.

I also examined spring scaup and mallard migration through North Dakota using data collected from annual roadside spring migration surveys conducted by the North Dakota Game and Fish Department from 1980-2010. I described the timing of peak migration by investigating the influences of a candidate suite of environmental condition based models on the difference in timing of peak migration by scaup and mallards.

2.3.3 Model Development

I developed a candidate set of models for the broad scale, local movement and North Dakota peak migration analyses using weather variables that potentially influence spring migration chronology of scaup and mallards, which included: spring daily mean temperature (TEMP), freezing and thawing degree days (FDD and TDD, respectively), spring monthly mean rainfall (RAIN), snow water equivalence (SWE), percent snow cover (SNOW) and stratum and breeding latitudes (STRAT LAT and BREED LAT; Appendix C).

For satellite telemetry marked scaup, I included bird identification number (BIRD ID) and the year the bird was implanted (YEAR) as repeated random measures to account for sampling the same individual across multiple years (i.e., control of autocorrelation within individual animals), and to determine the amount of annual variation in migration chronology not explained by measured weather variables.

2.4 Data Analyses

2.4.1 Broad Scale Analysis

I tested whether variation in dependent variables was best explained by weather variables in the southern or northern regions. For each dependent variable, and when more than one model was ≤ 2.0 ΔAICc, I only used the region with the lowest AICc to compute ΔAICc, because it was not appropriate to model-average between migration routes.

My data approximated a normal distribution so I applied general linear mixed models to each of my response variables: the standardized date when satellite marked scaup first reached the WBPHS area, standardized date when scaup were considered settled on their breeding grounds and rates (km/day) that scaup migrated from staging areas to survey and breeding locations, incorporating weather conditions as explanatory variables (PROC MIXED; SAS Institute Inc. 2009). I tested weather variables for multicollinearity using Variance Inflation Factor (VIF) prior to subjecting candidate models to AICc, and I did not include variables together in models when VIF >5 (Craney and Surles 2002). For each of the four regions (Canadian Prairies, North Dakota, Great Lakes, and Boreal Forest) I designed eight candidate models (16 models per route) to include variables influencing habitat availability and suitability, while also including factors influencing thermoregulation and nutrient requirements (Appendix D). I detected statistical bias when models included spring mean rainfall and SWE, in that positive and negative signs switched, so I removed the variable with the least effect on the model parameters and greatest confidence intervals (at 95%). I used ΔAICc and AICc weights (w*i*) to assess which model had the greatest influence on migratory movements using the statistical package PROC MIXED in SAS (SAS Institute Inc. 2009). Initially capture and marked locations (i.e., Pool 19 and Lake Erie) were included within models and in no case did they improve the AICc models, therefore location as a variable was removed. All models included latitude as a variable to control for the effect of distance migrated. I did not include WBPHS stratum 50 because Lake Erie scaup were implanted in this stratum. Instead, I included the next WBPHS stratum scaup encountered for my analysis. Models within 2.0 ΔAICc units of the top-ranked model were considered to have biological significance, and I used model averaging to estimate parameters and included 95% confidence intervals.

2.4.2 Local Movement Analysis

I used stepwise binary logistic regression using PROC LOGISTIC in SAS to predict migratory movements of implanted scaup (SAS Institute Inc. 2009). I designated location immediately prior to migratory movement and location terminus and staging as my response variables, and TEMP, FDD, TDD, RAIN, SWE, STRAT LAT, BREED LAT, and migration route as the explanatory variables. All independent weather and route variables were included in my initial models and removed in a stepwise manner until only significant variables remained ($\alpha = 0.05$; SAS Institute Inc. 2009).

2.4.3 North Dakota Peak Migration Analysis

For the North Dakota peak migration analysis, I applied general linear mixed models to my response variable, which was the difference in standardized dates of peak migration between scaup and mallards among the same years (DATE DIFF), and incorporated weather conditions as my explanatory variables (PROC MIXED; SAS Institute Inc. 2009). I tested weather variables for multicollinearity using VIF prior to using candidate model’s AICc to evalulate, and I did not include variables together in models when VIF > 5 (Craney and Surles 2002). I calculated AICc for each model for my response variable DATE DIFF, and used ΔAICc and AICc weights (w*i*) to assess which models including variables TEMP, FDD, TDD, RAIN, SWE and SNOW had the greatest influence on differences in timing of peak migration into North Dakota (PROC MIXED; SAS Institute Inc. 2009). I included year of the survey (YEAR) as a repeated random measure to account for autocorrelation among years of data collected from the same location and to ensure results were applicable beyond the time series within which data were collected. Models within 2.0 ΔAICc units of the top-ranked model were considered to have biological significance, and I used model averaging to estimate parameters and 95% confidence intervals for the sample mean. Model averaging is the process of taking AICc weights and weighing the parameter estimates and standard error of the same variables from the top models, combining them to a comprehensive model.

3.0 Results

My dataset before filtering included 49,325 locations from 78 female scaup from Pool 19 (n = 45) and Lake Erie (n = 33). After filtering I had 7,403 locations from scaup that migrated through the WBPHS Mid-continent survey area (n = 63 scaup) and 1,092 from the Eastern survey area (n = 15). Forty-six and 10 of the satellite marked scaup made full migrations and settled on breeding areas in the Mid-continent and Eastern survey areas, respectively. Several of my telemetry units lasted only one spring migration (Pool 19: n = 21, Lake Erie: n = 20), but I also had telemetry units that lasted >1 migration (Pool 19: n = 24, Lake Erie: n = 13), thus increasing our final dataset sample size (Pool 19: n = 68 migrations; Lake Erie: n = 55 migrations). Data are presented in tabular format in sections below; for graphical depiction, refer to appendices E to S.

3.1 Broad Scale Analysis for the Mid-Continent Survey Area

The top ranked model indicated that the date that a scaup reached the WBPHS area varied negatively with the amount of spring mean rainfall and TDD in the Canadian Prairies, and varied positively with FDD and latitude of the WBPHS area (Table 2, Table 3). Weather on the Canadian Prairies influenced scaup migration to the WBPHS area, on average, as follows, 1) for every 1 cm increase in spring mean rainfall scaup arrived 0.6 days earlier, 2) for every 100 TDD scaup arrived 16 days earlier, 3) for every 250 FDD scaup arrived 1 day later, and 4) for every degree in latitude north that a scaup arrived in the WBPHS survey area, scaup arrived 3 days later.

Table 2. Mixed effects models for chronology of spring migration of lesser scaup (*Aythya affinis*) implanted at Pool 19, Illinois, USA and Lake Erie, Canada using the Waterfowl Breeding and Habitat Survey Mid-continent survey area from 2005-2010. Models incorporated parameters of spring daily mean temperature (TEMP), spring mean rainfall (RAIN), snow water equivalency (SWE), freezing degree days (FDD), thawing degree days (TDD), latitude where settled to breed (BREED LAT) and latitude when first recorded in WBPHS stratum (STRAT LAT). Year (2005-2010) and Bird ID were included as random repeated variables.

Response Variables	**Models**	**K**	**ΔAICc**[a]	**w_i**
Standardized date to stratum	CPRAIRIES RAIN, CPRAIRIES FDD, CPRAIRIES TDD, STRAT LAT	5	0.00	0.62
	NULL	1	61.30	0
Standardized date to breeding	CPRAIRIES TEMP, BREED LAT	3	0.00	0.45
	CPRAIRIES FDD, CPRAIRIES TDD, BREEDING LAT	4	1.10	0.26
	NULL	1	2.70	0.13
Rate to stratum	CPRAIRIES RAIN, CPRAIRIES FDD, CPRAIRIES TDD, STRAT LAT	5	0.00	0.77
	NULL	1	2.50	0.22
Rate to breeding	ND SWE, ND FDD, ND TDD, BREED LAT	5	0.00	0.52
	ND RAIN, ND FDD, ND TDD, BREED LAT	5	0.90	0.33
	NULL	1	34.10	0

[a]Models are sorted by AICc, and models with ΔAICc ≤ 2.0 and null models are shown. The AICc values for the top models were 749.8, 580.5, 1063.1, and 483.4 for Standardized date to stratum, Standardized date to breeding, Rate to stratum, and Rate to breeding, respectively.

Table 3. Parameter estimates (θ), standard errors, and 95% confidence intervals derived from candidate models (ΔAI C ≤ 2) for chronology of spring migration of scaup implanted at Pool 19 and Lake Erie using the Mid-continent migration route from 2005-2010. Abbreviations: CPRAIRIES= Canadian Prairies represented area of data collection in broad scale analysis; ND = North Dakota representing area of data collection in broad scale analysis; RAIN = average spring mean rainfall; TEMP = average spring daily mean temperature; FDD = freezing degree days; TDD = thawing degree days.

Response Variables	**Parameters[a]**	**θ**	**SE**	**95% CI**
Standardized date to stratum	INTERCEPT	78.04	41.63	-4.55 to 160.65
	CPRAIRIES RAIN	-2.04	0.37	-3.37 to -0.70
	CPRAIRIES FDD	0.01	0.01	-0.00 to 0.01
	CPRAIRIES TDD	-0.08	0.03	-0.15 to -0.02
	STRAT LAT	2.77	0.34	2.08 to 3.46
Standardized date to breeding	INTERCEPT	118.70	21.63	75.21 to 162.20
	CPRAIRIES TEMP	-3.75	1.37	-6.54 to -0.97
	CPRAIRIES FDD	0.027	0.01	0.01 to 0.04
	CPRAIRIES TDD	-0.01	0.06	-0.13 to 0.10
	BREED LAT	0.59	0.36	-0.14 to 1.33
Rate to stratum	INTERCEPT	-330.38	239.41	-805.54 to 144.78
	CPRAIRIES RAIN	10.99	3.95	3.14 to 18.83
	CPRAIRIES FDD	-0.01	0.03	-0.08 to 0.05
	CPRAIRIES TDD	0.04	0.18	-0.32 to 0.41
	STRAT LAT	-0.91	1.99	-4.87 to 3.03
Rate to breeding	INTERCEPT	58.09	34.56	-10.95 to 127.15
	ND SWE	-1.69	1.40	-4.55 to 1.15
	ND RAIN	0.02	0.19	-0.38 to 0.41
	ND FDD	-0.03	0.01	-0.04 to -0.01
	ND TDD	0.01	0.03	-0.02 to 0.04
	BREED LAT	1.19	0.20	0.77 to 1.61
	BREED LAT	1.19	0.20	0.77 to 1.61

[a]Model-averaged parameter estimates are reported for Rate to breeding, whereas statistics for Standardized date to stratum, Standardized date to breeding, and Rate to stratum are based on models with lowest AICc score.

Variables that I model-averaged to explain date when scaup reached their inferred breeding areas included temperature, FDD, TDD in the Canadian Prairies and breeding latitude. For every 1^{o} C increase in the spring mean temperature in the Canadian Prairies scaup arrived, on average, 3 days earlier on their breeding grounds, for every 250 FDD scaup arrived 6.1 days later, for every 100 TDD scaup arrived 9.2 days earlier, and for every degree in latitude north where a scaup arrived on their inferred breeding area, scaup arrived on average 0.6 days later.

The model best explaining rate of migration to the WBPHS area varied positively with spring rainfall and TDD in the Canadian Prairies and negatively with FDD and the latitude at which a scaup was first recorded in the WBPHS area (Table 2, Table 3). Weather on the Canadian Prairies influenced scaup migration rates to the WBPHS area, on average, as follows: 1) for every 1 cm increase in rainfall scaup migrated 3.6 km/day faster, 2) for every 100 TDD scaup migrated 13.8 km/day faster, 3) for every degree north in latitude a scaup arrived within the WBPHS area scaup migrated 2.2 km/day slower, and 4) for every 250 FDD, scaup migration was 4.3 km/day slower.

Variables that I model-averaged to explain the rate of migration to breeding areas included North Dakota SWE, FDD, spring mean rainfall, TDD and breeding latitude (Table 2, Table 3). Weather in North Dakota influenced scaup migration rates to inferred breeding grounds, on average, as follows: 1) for every degree north in latitude a scaup settled on the breeding grounds migrated 1 km/day faster, 2) for every 100 TDD scaup migrated 0.4 km/day faster, 3) for every 1 cm increase in rainfall scaup migrated 0.9 km/day faster,4) for every 1 cm of water from SWE scaup migrated 4.5 km/day slower, and 5) for every 250 FDD scaup migrated 2.5 km/day slower.

3.2 Broad Scale Analysis for the Eastern Survey Area

Variables that I model-averaged to explain the date that a scaup reached the Eastern WBPHS area included spring mean temperature, SWE, and stratum latitude (Table 4). For every degree in latitude north scaup arrived at the WBPHS area on average scaup arrived 1.2 days later, for every 1 ºC increase on the Great Lakes during spring, scaup migrated 0.9 days later to the WBPHS area, and for every 1 cm increase in water from SWE, scaup arrived 2.8 days later.

Table 4. Mixed effects models for chronology of spring migration of scaup implanted on Lake Erie using the Eastern migration route from 2005-2010. Models incorporated parameters of spring daily mean temperature (TEMP), spring mean rainfall (RAIN), snow water equivalency (SWE), freezing degree days (FDD), thawing degree days (TDD), latitude where settled to breed (BREED LAT), latitude when first recorded in WBPHS area (STRAT LAT). Year (2005-2010) and Bird ID were included as random repeated variables.

Response Variables	Models[a]	K	ΔAICc[a]	wi
Standardized date to stratum	GL TEMP, GL SWE, STRAT LAT	4	0.00	0.60
	GL TEMP, STRAT LAT	3	1.60	0.27
	NULL	1	3.50	0.10
Standardized date to breeding	BOREAL SWE, BOREAL FDD, BOREAL TDD BREED LAT	5	0.00	0.91
	NULL	1	4.80	0.08
Rate to stratum	GL SWE, GL FDD, GL TDD, STRAT LAT	5	0.00	0.58
	GL RAIN, GL FDD, GL TDD, STRAT LAT	5	1.00	0.35
	NULL	1	12.60	0
Rate to breeding	GL TEMP, BREED LAT	3	0.00	0.91
	NULL	1	6.00	0.05

[a]Models are sorted by AICc, and models with ΔAICc ≤ 2.0 and null models are shown. The AICc values for the top models were 166.8, 113.1, 160.8, and 90.3 for Standardized date to stratum, Standardized date to breeding, Rate to stratum, and Rate to breeding, respectively.

The model best explaining the date of arrival by scaup to a breeding location varied negatively with SWE and FDD in the Eastern Boreal Forest, and positively with TDD and breeding latitude (Table 4, Table 5). Weather in the Eastern Boreal Forest influenced scaup date of arrival on inferred breeding grounds, on average, as follows: 1) for every 1 cm of water from SWE scaup arrived 21.9 days earlier, 2) for every 250 FDD scaup arrived 7.5 days earlier, 3) for every 100 TDD scaup arrived 19 days earlier, and 4) for every degree north in latitude scaup settle on their breeding grounds scaup arrived 1.2 days earlier.

Table 5. Parameter estimates (θ), standard errors, and 95% confidence intervals derived from candidate models (ΔAI C ≤ 2) for chronology of spring migration of lesser scaup implanted on Lake Erie using the Eastern migration route from 2005-2010. Abbreviations: GL= Great Lakes represented area of data collection in broad scale analysis; BOREAL = Eastern Boreal Forest representing area of data collection in broad scale analysis; RAIN = average spring mean rainfall; TEMP = average spring daily mean temperature; SWE = maximum snow water equivalency; FDD = freezing degree days; TDD = thawing degree days.

Response Variables[a]	**Parameters**[b]	**θ**	**SE**	**95% CI**
Standardized date to stratum	INTERCEPT	40.37	32.40	-26.63 to 107.44
	GL TEMP	2.49	1.87	-1.38 to 6.36
	GL SWE	2.76	1.19	0.29 to 5.23
	STRAT LAT	1.27	0.51	0.20 to 1.60
Standardized date to breeding	INTERCEPT	235.44	77.24	65.08 to 405.80
	BOREAL SWE	-19.14	1.94	-23.49 to -14.79
	BOREAL FDD	-0.02	0.01	-0.03 to -0.01
	BOREAL TDD	0.03	0.01	-0.00 to 0.06
	BREED LAT	1.44	1.42	-1.70 to 4.58
Rate to Stratum	INTERCEPT	-524.30	2.20	-789.97 to -253.30
	GL SWE	3.12	6.20	-10.91 to 17.15
	GL RAIN	0.90	0.36	0.14 to 1.65
	GL FDD	0.35	0.08	0.18 to 0.52
	GL TDD	-0.05	0.05	-0.16 to 0.05
	STRAT LAT	3.37	0.59	2.12 to 4.61
Rate to Breeding	INTERCEPT	-60.30	40.98	-149.18 to 28.56
	GL TEMP	-4.26	1.16	-6.75 to -1.76
	BREED LAT	2.12	0.67	0.64 to 3.59

[a]Model-averaged parameter estimates are reported for Rate to stratum, whereas statistics for Standardized date to stratum, Standardized date to breeding, and Rate to breeding are based on models with lowest AICc score.

Variables that I model-averaged to explain rate of migration to the WBPHS survey area areas included Great Lakes SWE, TDD, spring mean rainfall, FDD, and stratum latitude (Table 4, Table 5). Weather in the Great Lakes influenced scaup migration rates to the WBPHS area, on average, as follows: 1) for every 1 degree north in latitude scaup arrival was first recorded in the WBPHS area scaup migrated 2.5 km/day faster, 2) for every 250 FDD scaup migrated 16.8 km/day faster, 3) for every 100 TDD scaup migrated 6 km/day slower to the WBPHS area, and 4) for every 1 cm increase in rainfall scaup migrated 0.2 km/day faster.

The model best explaining the rate of migration by scaup to the inferred breeding grounds varied negatively with spring mean temperature in the Great Lakes and positively with breeding latitude (Table 4). For every 1 degree north in latitude that scaup settled on the breeding grounds scaup migrated 2.5 km/day faster, and for every 1º C increase in spring mean temperature at Great Lakes, scaup migrated 5 km/day slower.

3.3 Local Movement Analysis

A total of 50 implanted scaup using both Mid-continent and Eastern migration routes with 60 combined complete migrations were used to predict probability of migration during spring. After removing non-significant variables, TDD was the only variable retained ($f = 19.40_{844.3}$, $p < 0.001$). Probability of migration for scaup tracked with satellite telemetry was zero (0) when TDD was < 500 and, thereafter increased 10% for every increase of 100 TDD (Figure 4).

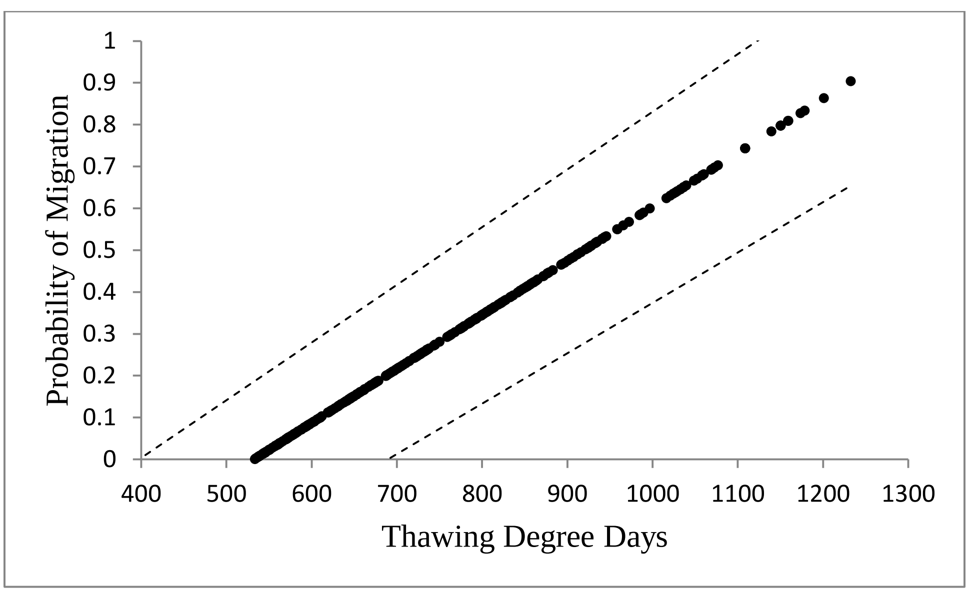

Figure 4. Relationship between predicted probability of lesser scaup (*Aythya affinis*) spring migration and thawing degree days (n=60) using satellite location data from 2005-2010.

3.4 North Dakota Peak Migration Analysis

Timing of peak abundance of scaup was earlier than mallards in 19 of 31 years between 1980 and 2010 (standardized date, 104.5 ± 1.9), while timing of peak abundance for scaup and mallards was the same for 6 of 31 years and peak scaup abundance was later during 6 of 31years (109.6± 3.9). The most parsimonious model explaining variation in the difference in dates of peak migration between scaup and mallards into the North Dakota study area was spring mean temperature (Table 6). For every 1 ºC increase in spring mean temperature, the difference in peak migration decreased by 3.4 days up until peak arrival was the same (Figure 5). However, a substantial amount of variation in differences in timing of peak migration was not explained by mean spring temperature. The second most parsimonious model was the NULL model which was 2.0 ΔAICc units from my top model (Table 6), suggesting that although spring mean temperature had the lower AICc value, I could not differentiate whether temperature was better at predicting differences in migration than random chance.

Table 6. Mixed effects models for date difference in peak migration between lesser scaup (*Aythya affinis*) and mallards (*Anas platyrhynchos*) from annual spring migration roadside surveys conducted by North Dakota Game and fish (1980-2012).

Response Variable	**Models**[a]	**K**	**ΔAICc**[b]	**w**$_i$
Date Diff	TEMP	2	0.00	0.41
	NULL	1	2.00	0.15

[a]Models incorporated the parameter of spring daily mean temperature (TEMP). Year (2005-2010) and Bird ID were included as random repeated variables.
[b]Models are sorted by AICc, and models with ΔAICc ≤ 2.0 and null models are shown. The AICc values for the top models were 272.4 and 274.4 for TEMP and NULL respectively.

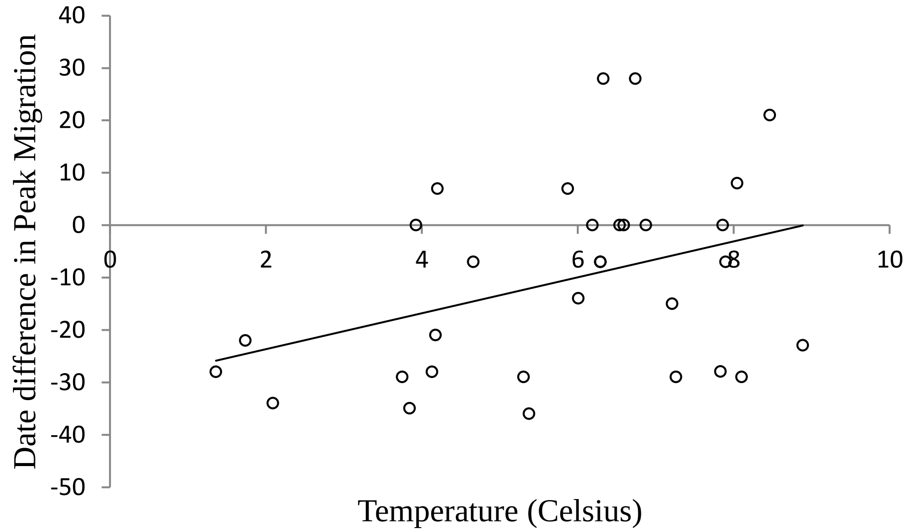

Figure 5. Variation in difference of dates of peak migration between lesser scaup (*Aythya affinis*) and Mallards (*Anas platyrhynchos*) in relation to spring mean daily temperature in North Dakota from annual spring migration roadside surveys conducted by North Dakota Game and fish (1980-2012).

4.0 Discussion

4.1 General Discussion

The degree of flexibility in the timing of spring migration and nesting varies intra- and inter-specifically among birds (Pulido 2007, Hedenström 2008, Newton 2008). Temperature and precipitation are common proximate cues for species exhibiting flexibility in the timing of migration, settling, and nest initiation (Crick et al. 1997, McCleery and Perrins 1998, Newton 2007, Drever et al. 2012). Among waterfowl, timing of migration varies by species; however, the behavioural responses to some endogenous cues are influenced by variation in weather severity (Albright et al. 1983, LaGrange and Dinsmore 1988, Austin et al. 2002, Schummer et al. 2010). Although spring migration in scaup is protracted compared to other species of waterfowl, nest initiation is typically late and relatively fixed (Gurney et al. 2011, Drever et al. 2012). When controlling for latitude and potential endogenous effects, I detected effects of weather on spring scaup migration. Notably, timing of migration by scaup using the Mid-continent migration route varied with annual fluctuations in temperature, precipitation, and ice cover. These weather variables may influence availability of habitat (Austin et al. 2002) and energy expenditure in waterfowl (Schummer et al. 2010). When estimating the effect of weather variables on scaup movements at a local scale, the probability of a migratory event increased with increasing temperatures during spring.

Previous studies modeled how weather and habitat conditions influenced the timing of spring migration by scaup in North Dakota and the Mid-continent region using standardized survey data of scaup populations (Austin et al. 2002, Anteau and Afton 2009). Austin et al. (2002) and Anteau and Afton (2009) reported that variation in scaup spring migration in North Dakota was related to temperature and May Pond Counts (a measure of habitat availability influenced by winter snow melt [i.e., SWE]). Using data from satellite tacked scaup migrating through the Mid-continent, I detected a similar relationship, in that spring migration varied with spring mean temperature, available water on the landscape (i.e. rainfall and SWE) and ice cover, all of which influence habitat availability.

4.2 Scaup Migration Chronology

Understanding the timing and rate of waterfowl migration, and how timing may influence not only measures of abundance and distribution, but survival and fitness as well has become increasingly important (Austin et al. 2000, Anteau and Afton 2004, Drever et al. 2012). I observed substantial variability in the timing of arrival into early and mid-migration latitudes, occurring from early-March through late-May. However, arrival on inferred breeding grounds occurred over a 25 day period, thus supporting the observation that early scaup migration is temporally variable, whereas arrival and nest initiation are relatively fixed in comparison to most waterfowl species (Drever et al. 2012). Variability in the timing and rate of spring migration by scaup may be related to the abundance and availability of habitat and food at staging sites (Austin et al. 2002, Anteau and Afton 2008). For scaup migrating through the Great Lakes, increased food abundance from the introduction of *Dreissenid* mussels also has been proposed as an explanation for scaup remaining longer through spring (Petrie and Knapton 1999).

A decline in scaup body condition has been observed over the past decades during spring migration at staging sites in the Midwest US, and this decline may affect the timing and rate of migration to breeding areas (Anteau and Afton 2004, 2006, 2008). When scaup arrive at spring staging sites in poor body condition, staging events generally last longer because of the increased need to acquire sufficient nutrients for migration (Anteau and Afton 2004, 2008). I also detected the potential effect of weather on nutrient availability when scaup migrated through the prairies during spring. Specifically, migration generally occurred earlier and faster with warmer temperatures, increased spring rainfall, and decreased ice cover. Warm temperatures and abundant and available habitat may increase nutrient acquisition in scaup during spring migration, because energetic costs of thermoregulation may be reduced and food availability and accessibility may increase.

Scaup breed from the tundra in Alaska, throughout the Canadian boreal forest, and throughout the Canadian prairies (Afton and Anderson 2001). Given the latitudinal breadth of the breeding range, I was able to detect a positive relationship between breeding latitude and arrival at breeding sites. Similar relationships have been documented in studies of Northern Pintail (*Anas acuta*) and mallards (Miller et al. 2005, Krementz et al. 2011). Intuitively, this observation makes sense in that the farther waterfowl migrate the longer it will take to arrive, and habitat at northern latitudes take longer to thaw and become available (Larson 1995, Johnson et al. 2005, Marra et al. 2005). The continued degradation of waterfowl habitat in the prairies and the boreal forest may be forcing scaup to migrate greater distances to find suitable nesting habitat, potentially causing detrimental effects on body condition and nesting success (Alerstam and Lindström 1990, Alerstram and Hedenström 1998).

4.3 Mid-Continent and Eastern Differences

Millions of ducks are produced annually within the Prairie Pothole Region, and it is one of the most important landscapes for breeding waterfowl in North America (Stewart and Kantrud 1974, Klett et al. 1988). This region, however, experiences considerable annual variation in temperature and precipitation, and these weather variables influence habitat availability and quality for migrating and breeding waterfowl (Klett et al. 1988, Larson 1995, Austin et al. 2002, Johnson et al. 2005). Scaup migration chronology in the Mid-continent route was influenced by weather to a greater degree than in the Eastern migration route. In the Eastern migration route I did not detect a predictable influence of weather variables, potentially because of the stability of the more permanent open water habitat and less limiting food sources (Bonan and Shugart 1989, Magnuson et al. 1997, Petrie and Knapton 1999).

Waterfowl habitat availability is estimated in the prairies using May Pond Counts (Austin et al. 2002); however, weather variables that influence habitat availability have not previously been measured for individual scaup during migration. On average, scaup migrated earlier and individuals migrated faster when winter and spring weather was conducive to available/open wetland habitat. The Mid-continent prairies are a major staging region for scaup, and wetland habitat in this region is influenced by annual variation in temperature and precipitation (Larson et al. 1995, Johnson et al 2005). When habitat and food resources are available and temperatures are relatively warm, scaup can migrate earlier and faster, and potentially more easily meet the energetic needs of migration; however, in years when conditions limit wetland habitat availability, scaup migration may be delayed (Austin et al. 2002, Afton and Anderson 2001).

In the Eastern route, waterfowl use of the Great Lakes as a staging and wintering site has increased in recent decades (Custer and Custer 1996, Petrie and Knapton 1999, Petrie and Schummer 2002). My study detected effects of weather factors on scaup migration using the Eastern route. Most of the effects that I detected contradict current knowledge concerning spring migration chronology in waterfowl. Following my prediction, in the Eastern route, weather that influences habitat availability had little effect on migration chronology or the timing of settling on breeding areas. With the invasion of *Dreissenid* mussels and increasing temperatures in the Great Lakes, diving waterfowl (including scaup) have access to an abundant year-round food source (Custer and Custer 1996, Magnuson et al. 1997). In contrast to the Mid-continent, wetland abundance and habitat availability in Great Lakes and boreal wetlands are relatively less influenced by weather because of their greater size and permanency. Therefore, wetland availability for staging scaup is less influenced by seasonal snowfall and rainfall events than in prairie habitats (Bonan and Shugart 1989, Prince et al. 1992, Drever et al. 2012). We may be observing shifts in waterfowl migration and distribution, highlighting the importance of a better understanding of spring migration patterns in relation to climatic variability to make more informed management decisions.

4.4 Influence of Weather on Timing and Rate of Spring Migration

As hypothesized, several weather variables influenced scaup spring migration. Temperature and precipitation apparently influence habitat availability (open water) and energetic costs associated with thermoregulation, and ultimately, serve as proximate cues for migration. Annual variation in spring temperature and precipitation influences habitat and nutrient availability at scaup staging sites in the prairies (Austin et al. 2002), and the condition and availability of staging sites during early migration influences migration chronology in birds (Marra et al. 2005). Similarly, I detected a negative effect of precipitation and ice cover on date of arrival to the WBPHS area and rate of migration during early migration. This effect was also observed for the rate of migration to breeding sites in my study. However, once scaup reached or approached the boreal forest, the effect of increasing temperature appeared to influence scaup to arrive at breeding sites earlier.

Scaup tended to linger at Great Lakes' staging sites, potentially because of readily available *Dreissenid* mussels as food sources, and then migrated rapidly to breeding areas in some individuals greater than 1000km single movements. Rapid migration has been documented in birds, including waterfowl (Richardson 1978, Kerlinger and Moore 1989, Dau 1992). Rapid migration may explain the relationships that I detected between timing of migration of scaup and temperature and ice cover along the Eastern migration route.

Observing local scale migration allows elucidation of how weather influences individual behaviour, and specifically the probability of migrating. Data of this nature allow detection of individual-specific conditions, thus identifying environmental factors that prompt migratory movements. Thawing Degree Days has been used as an index of vegetative growth, invertebrate hatch, and ice thaw (Assel 1980, Hebert and Hann 1986, Walker et al. 1994). Temperature (i.e., TDD) was the primary cue scaup used to initiate migration. However, temperature alone does not explain the timing of migration. A decline in the quality and availability of scaup food at stopover locations has been identified during spring migration, thus variation in the timing of arrival on breeding grounds may be, in part, explained by nutrient availability at stopover sites (Austin et al. 2000, Anteau and Afton 2004, 2006). However, increased temperature influences the ability of scaup to acquire nutrient reserves, and find available habitat (Afton and Ankney 1991, Koons and Rotella 2003, Anteau and Afton 2004, 2008, Corcoran et al. 2007). Therefore, scaup are able to 'recognize' suitable habitat conditions brought about by increasing temperatures and exploit newly available food resources.

My results could be used to model effects of climatic variability on annual timing of spring migration by scaup (Crick et al. 1997, McCleery and Perrins 1998, Drever et al. 2012). I detected an influence of temperature and other weather factors influencing habitat availability (i.e., SWE and/or rainfall), thus models predicting changes in precipitation, snow pack and temperatures could be applied to estimate potential changes in the timing of scaup migration during spring.

4.6 Implications for the WBPHS and Scaup Population Estimates

The combined continental population of lesser and greater scaup (*Aythya marila*) declined by approximately 50% between the mid-1980s and the late 1990s (Austin et al. 1998, Afton and Anderson 2001). However, scaup populations increased from 2005-2012, but still remain below the long-term average (United States Fish and Wildlife Service 2012; Appendix T). These population trends highlight the need for research targeting spring migration in scaup, and the need to determine whether the WBPHS survey design alone is a possible cause of the indicated breeding population decline. The Prairie Pothole region is surveyed 1 May – 25 May, whereas the Eastern boreal forest region is surveyed 12 May – 12 June (Smith 1995). Determining what factors cause differences in dates of peak arrival between scaup and mallards may provide for a better understanding of movement through the survey area. Therefore, managers could be provided with beter estimates of population productivity and distribution.

My broad scale and local movement results suggest that scaup spring migration was influenced by weather and environmental conditions; thus, I conclude that that there is substantial annual variability in migratory chronology. My analysis of the North Dakota peak migration dataset did not detect any effect of weather on difference in timing of peak migration between scaup and mallard. However, my analysis suggests that scaup migrate at different times than mallards, and that the annual difference in the timing of scaup migration did not change consistently with that of mallards. Peak scaup migration into North Dakota typically occurred over a 14 day period in early to mid-April, whereas mallard migration peaked at the end of March and again late in May. When considered in concert, my results suggest that basing the timing of the WBPHS on mallard migration likely provides biased population estimates for scaup (Afton and Anderson 2001, Austin et al. 2002).

Using individual tracking data, and given the variability of scaup migration chronology, I was able to explore how changing weather conditions affect scaup migration chronology. Specifically, I investigated if scaup move through the WBPHS area earlier than when the survey was conducted. If the Canadian prairies experienced a warmer and wetter spring than normal, scaup could move through the area prior to the survey period. Consequently, those individuals could be missed by the survey, which would provide an underestimate of continental populations. Alternatively, if the Canadian prairies experience a cooler and drier spring than normal, scaup may not have arrived in the WBPHS area when the survey was being conducted, and this asynchrony would also result in an underestimate of the breeding population of scaup.

The timing of scaup arrival to breeding areas in the Mid-continent migrants was related to breeding latitude and temperature. Managers could use my models to estimate if scaup counted during the WBPHS are on the breeding areas or still migrating. Novel and retrospective investigations of survey measures could be used to determine what proportion of scaup counted during surveys was on breeding areas by accounting for temperature and breeding latitude. Current and historical surveys adjusted for breeding latitude and temperature may yield a better representation of breeding population distribution and abundances over time.

5.0 Conclusions

My study identified the relative importance and influence of winter and spring weather on the migration chronology of satellite tracked scaup. Using a local movement analysis, I was only able to detect an influence of temperature on migratory movements, however because the analysis was limited to measures on a 32 km^2 scale, I was not able to detect the weather cues that drive migration at a regional scale. With my broad scale analysis measuring weather effects at a regional scale, I was able to detect the influence of temperature and precipitation on the timing and rate of migration. I detected the relative importance of habitat availability on spring migration by accounting for precipitation and ice cover effects. My North Dakota peak migration analysis, using count data to identify the difference in timing of peak migration between scaup and mallards, detected no substantial influence from weather factors. The results suggest that satellite telemetry data increase the ability to identify factors that influence migration chronology and provide more informed predictive models of scaup spring migration.

My study addressed the lack of information on how weather influences scaup migration at broad and local geographic scales. I used historical survey data for scaup and mallards to test for differences in peak migration between the two species and determine whether weather conditions explained those differences. Using current spring migration data measuring migration chronology on mallards tracked with satellite telemetry, a comparison between scaup and mallards using the same set of weather and environmental factors could be conducted (Krementz et al. 2012, Beatty et al. 2013). This approach can thus be used to highlight potential differences and identify future survey and management strategies.

Acquiring a more accurate model of ice cover across the landscape could improve my migration models. FDD and TDD were used to provide an index of ice cover, but this index addresses only the general extent of ice cover, and does not address the thickness of ice or percentage of wetlands available during spring thaw. I propose that this shortcoming could be addressed by utilizing satellite imagery of ice cover. This approach would ultimately provide a better understanding of how ice influences scaup migration.

The next step in refining estimates and predictions of scaup migration chronology is to gather accurate estimates of permanency levels and quality of wetlands available to scaup during spring throughout their migratory range. My study identified the importance of habitat availability on migration chronology. By identifying and quantifying the annual variation in wetland habitat quality for scaup throughout migration, we may be able to produce better predictive models of migration chronology, particularly during spring.

By providing some baseline information on how scaup react to weather and environmental variables, we are better able to understand spring migration patterns in scaup. Because we have observed unrealistic and biologically impossible fluctuations in estimates of the continental scaup breeding population (Afton and Anderson 2001, Austin et al. 2002) and it has been predicted that global climate change will influence bird migration (Crick et al. 1997, McCleery and Perrins 1998, Drever et al. 2012), a better understanding of the timing and movements of scaup during spring is critical for interpreting population estimates, and for developing future management strategies.

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Appendix A

Satellite implanted Lesser scaup (*Aythya affinis*) captured at Long Point, Pool 19, and Presque Isle Bay between 2005 and 2010.

BirdID	Implant Location	Year	Migration Route	BirdID	Implant Location	Year	Migration Route
57069	Lake Erie	2005	Mid-continent	**72891**	Pool19	2007	Mid-continent
57071	Lake Erie	2005	Mid-continent	**72892**	Pool19	2007	Mid-continent
57072	Lake Erie	2005	Mid-continent	**72893**	Pool19	2007	Mid-continent
57073	Lake Erie	2005	Eastern	**72894**	Pool19	2007	Mid-continent
57074	Lake Erie	2005	Mid-continent	**72895**	Pool19	2007	Mid-continent
64782	Lake Erie	2006	Mid-continent	**72897**	Pool19	2007	Mid-continent
64783	Lake Erie	2006	Eastern	**72899**	Pool19	2008	Mid-continent
64784	Lake Erie	2006	Mid-continent	**72900**	Pool19	2008	Mid-continent
64785	Lake Erie	2006	Mid-continent	**72901**	Pool19	2008	Mid-continent
64788	Lake Erie	2006	Eastern	**80877**	Pool19	2008	Mid-continent
64792	Lake Erie	2006	Eastern	**80879**	Pool19	2008	Mid-continent
64793	Lake Erie	2006	Eastern	**80880**	Pool19	2008	Mid-continent
64795	Lake Erie	2006	Mid-continent	**80881**	Pool19	2008	Mid-continent
64796	Lake Erie	2006	Eastern	**80884**	Pool19	2008	Mid-continent
64799	Lake Erie	2006	Eastern	**80885**	Pool19	2008	Mid-continent
64800	Lake Erie	2006	Mid-continent	**80886**	Pool19	2008	Mid-continent
64801	Lake Erie	2006	Mid-continent	**80888**	Pool19	2008	Mid-continent
72601	Lake Erie	2007	Mid-continent	**80889**	Pool19	2008	Mid-continent
73357	Lake Erie	2007	Eastern	**80890**	Pool19	2008	Mid-continent
73359	Lake Erie	2010	Eastern	**80891**	Pool19	2008	Mid-continent
74719	Lake Erie	2008	Eastern	**80892**	Pool19	2008	Mid-continent
74719	Lake Erie	2007	Eastern	**80894**	Pool19	2008	Mid-continent
74721	Lake Erie	2007	Mid-continent	**80895**	Pool19	2008	Mid-continent
74722	Lake Erie	2007	Mid-continent	**80896**	Pool19	2008	Mid-continent
74723	Lake Erie	2007	Mid-continent	**80897**	Pool19	2008	Mid-continent
74724	Lake Erie	2007	Mid-continent	**80898**	Pool19	2008	Mid-continent
74725	Lake Erie	2007	Eastern	**92636**	Pool19	2009	Mid-continent
74726	Lake Erie	2007	Mid-continent	**92637**	Pool19	2009	Mid-continent
74727	Lake Erie	2007	Mid-continent	**92638**	Pool19	2009	Mid-continent
74728	Lake Erie	2007	Mid-continent	**92639**	Pool19	2009	Mid-continent
75666	Lake Erie	2010	Eastern	**92640**	Pool19	2009	Mid-continent
75667	Lake Erie	2010	Eastern	**92641**	Pool19	2009	Mid-continent
75669	Lake Erie	2010	Mid-continent	**92642**	Pool19	2009	Mid-continent
75671	Lake Erie	2010	Eastern	**92644**	Pool19	2009	Mid-continent
72882	Pool19	2007	Mid-continent	**92645**	Pool19	2009	Mid-continent
72883	Pool19	2007	Mid-continent	**92647**	Pool19	2009	Mid-continent
72885	Pool19	2008	Mid-continent	**92649**	Pool19	2009	Mid-continent

72886	Pool19	2007	Mid-continent	**92650**	Pool19	2009	Mid-continent
72887	Pool19	2007	Mid-continent	**92651**	Pool19	2009	Mid-continent
72890	Pool19	2007	Mid-continent				

Appendix B

Measures of mean, range and standard deviation of weather variables experienced by satellite tracked scaup during spring using the Mid-continent and Eastern migration routes from 2005-2010.

		Mid-Continent	**Eastern**
	Mean	3.71	3.41
Temperature	**Range**	0.414 - 8.10	-1.66 - 9.60
(C^{o})	**St. Dev.**	2.13	4.28
	Mean	10.32	12.27
Rainfall	**Range**	4.96 - 18.45	2.53 - 22.63
(cm)	**St. Dev.**	4.29	5.70
	Mean	3.07	3.79
SWE	**Range**	1.92 - 4.26	0.86 - 7.43
(cm)	**St. Dev.**	0.84	2.33
	Mean	1570.09	1058.03
FDD	**Range**	955.09 - 1925.00	227.16 - 1924.73
	St. Dev.	292.97	706.02
	Mean	428.21	583.71
TDD	**Range**	254.08 - 651.44	199.61 - 1001.70
	St. Dev.	124.37	343.09

Appendix C

Weather variables selected that potentially influence spring migration chronology of lesser scaup (*Aythya affinis*) and mallards (*Anas platyrhynchos*).

Spring Daily Mean Temperature (TEMP)	Ambient temperature influences waterfowl energy budgets and effects seasonal availability of habitats	Based on published observations, I assumed that scaup in our study are dependent on open water habitats for staging and energy acquisition during spring migration. .	Bellrose 1980, Alerstam 1990, Kaminski and Weller 1992, Naugle et al. 2001, Newton 2007, Schummer et al. 2010
Freezing and Thawing Degree Days (FDD and TDD)	Ice cover may influence energy acquisition (i.e., food accessibility) and long-term energy expenditure.	I used winter season Freezing Degree Day and March-April-May Thawing Degree Days as indices of ice coverage to measure the potential effect on energy reserves and movement throughout spring migration	Lovvorn 1989, Brook et al. 2009
Spring monthly mean spring rainfall (RAIN)	The amount of precipitation on a landscape within a given amount of time may be an indicator of available wetland habitat for waterfowl	I used mean spring precipitation to determine if rainfall explained variation in migration chronology of scaup during spring migration.	Krapu et al. 1983, Austin et al. 2002
Snow Water Equivalent (SWE)	The addition of water released from snow melt may influence the amount of available water on the landscape	I used maximum SWE December - March prior to initiation of snow melt to determine if amount of water available explained variation in movement during spring migration	Hayashi et al. 2003
Daily mean snow	Snow coverage has	I used the averaged	Albright et al. 1983,

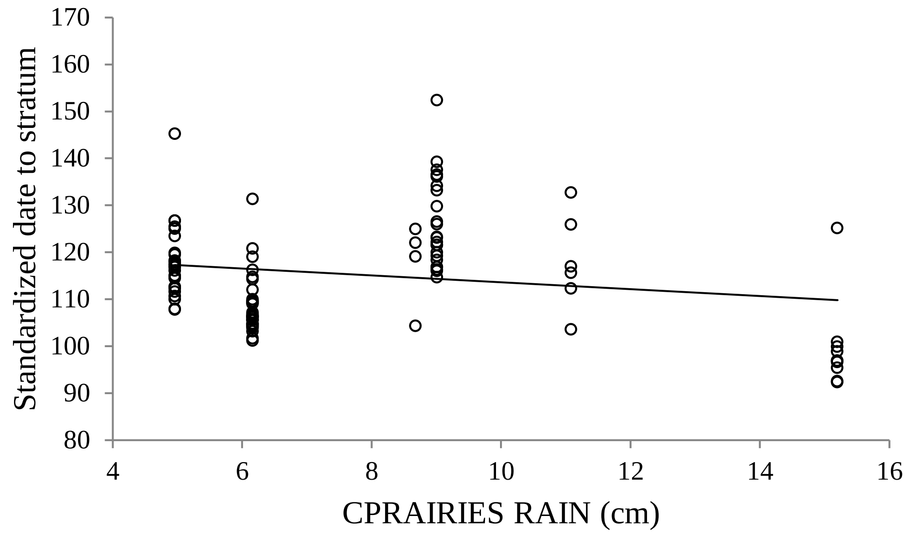
cover (SNOW)	been shown to influence habitat availability and foraging techniques (i.e. energy acquisition theory)	daily mean snow cover (cm) to determine area covered in snow and determine if snow cover explained variation in movement during spring migration	Jorde et al. 1983, Lovvorn 1994
Stratum and Breeding Latitude (STRAT LAT and BREED LAT)	Given the latitudinal breadth of the breeding range, distance migrated may have an effect on timing and rate in waterfowl migration	A measure of the latitude at which an implanted scaup is first recorded in the WBPHS area and when scaup are considered settled on the breeding grounds during spring migration.	Miller et al. 2005, Krementz et al. 2011

Appendix D

Candidate model sets conducted in SAS as General Linear Mixed Models and compared using AIC weights to determine influence on spring migration chronology of scaup from 2005-2010.

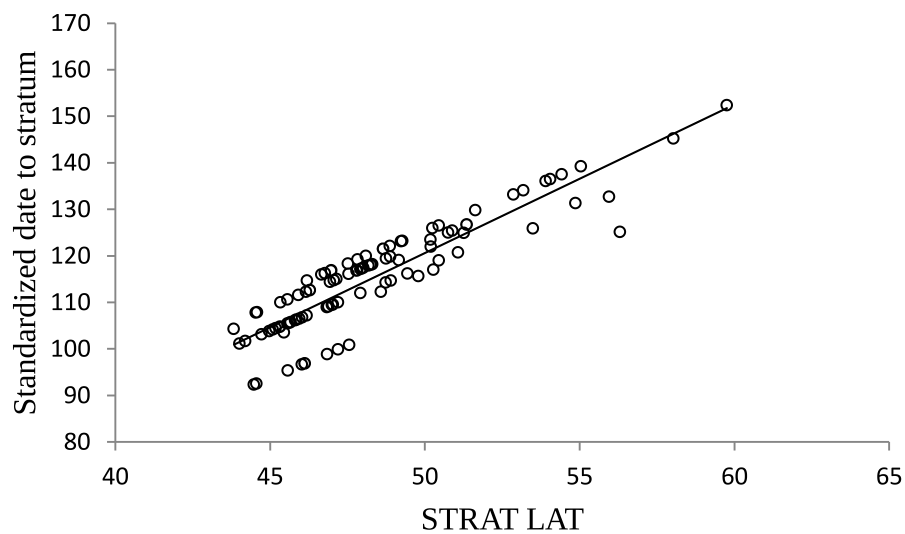
Models	Justification
TEMP+LAT	Influence on nutrient requirements, thermoregulation and distance
FDD+TDD+LAT	Influence on nutrient requirements, thermorgulation, habitat availability and distance
TEMP+RAIN+LAT	Influence on nutrient requirements, thermoregulation, habitat availability and distance
TEMP+SWE+LAT	Influence on nutrient requirements, thermoregulation, habitat availability and distance
FDD+TDD+SWE+LAT	Influence on nutrient requirements, habitat availability and distance
FDD+TDD+RAIN+LAT	Influence on nutrient requirements, habitat availability and distance
TEMP+RAIN+SWE+LAT	Influence on nutrient requirements, thermoregulation, habitat availability and distance
FDD+TDD+SWE+RAIN+LAT	Influence on nutrient requirements, habitat availability and distance

Appendix E



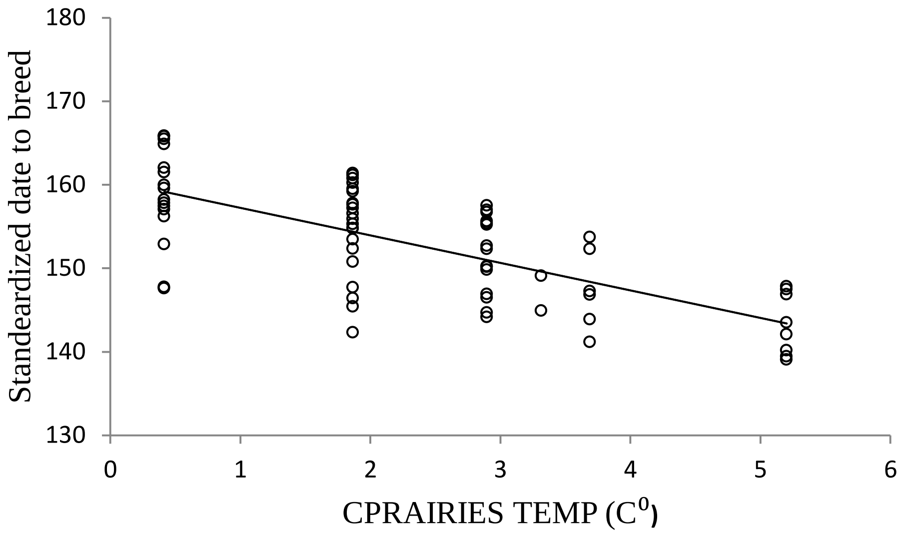
Variation in date of arrival by scaup in the WBPHS area in relation spring mean rainfall in the Canadian Prairies (CPRAIRIES RAIN) for scaup tracked by satellite telemetry (n= 100) that used the Mid-continent migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling

Appendix F



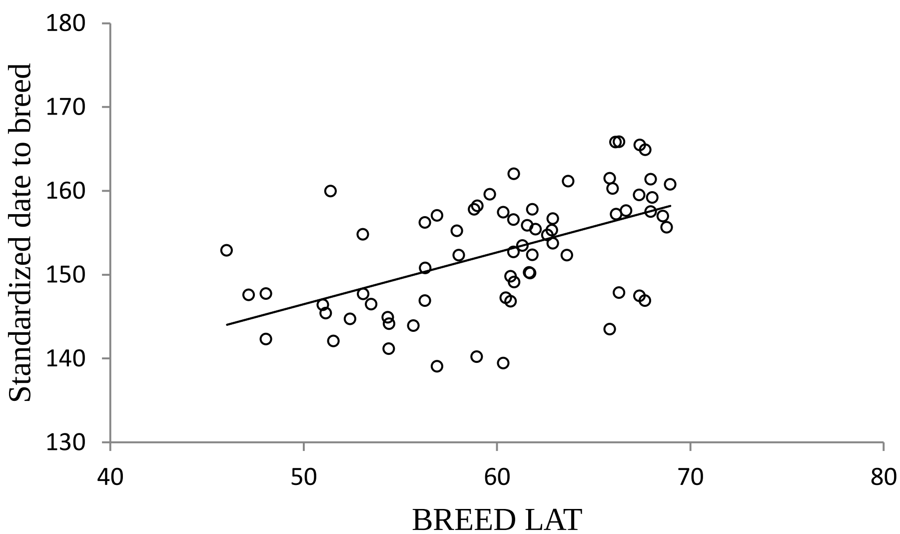
Variation in date of arrival by scaup in the WBPHS area in relation to Latitude when first recorded in the WBPHS area (STRAT LAT) for scaup tracked by satellite telemetry (n= 100) that used the Mid-continent migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix G



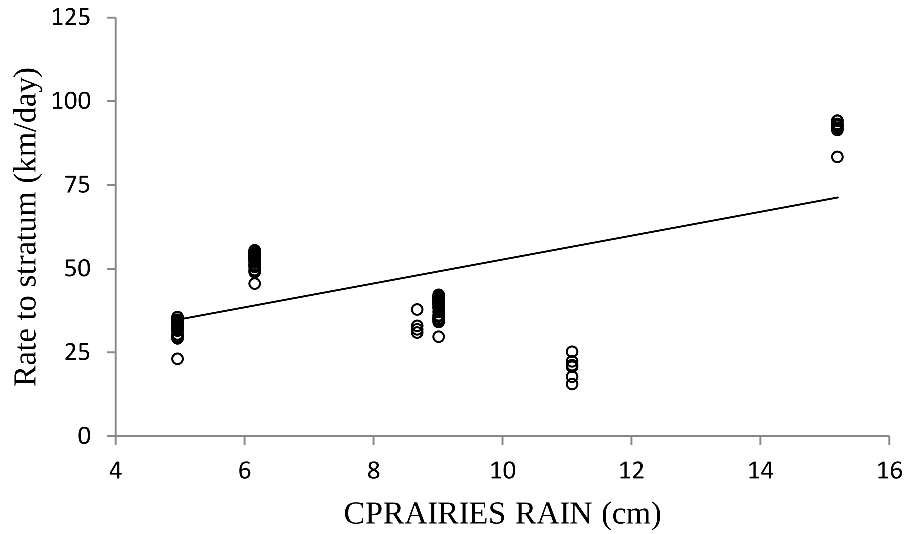
Variation in date of arrival by scaup on inferred breeding grounds in relation to spring daily mean temperature in the Canadian Prairies (CPRAIRIES TEMP) for scaup tracked by satellite telemetry (n= 68) that used the Mid-continent migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix H



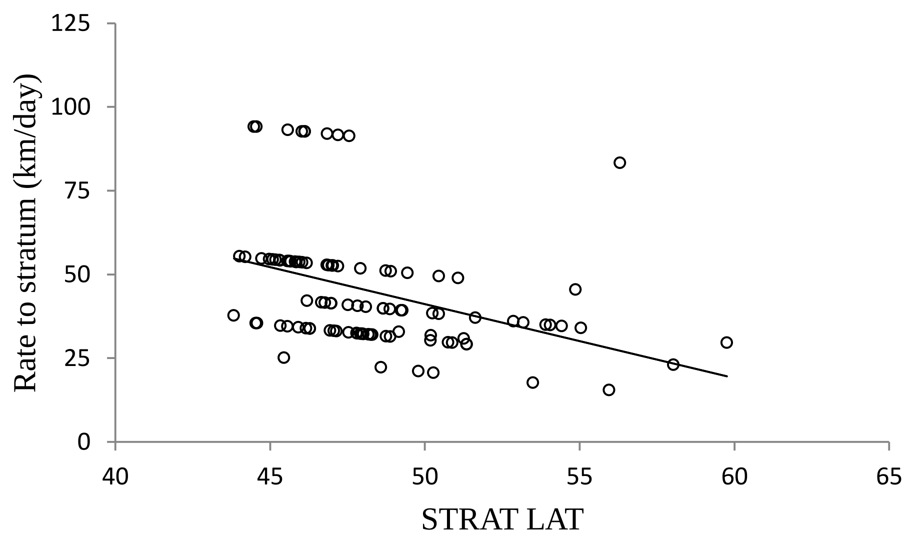
Variation in date of arrival by scaup on inferred breeding grounds in relation to Latitude of breeding grounds (BREED LAT) for scaup tracked by satellite telemetry (n= 68) that used the Mid-continent migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix I



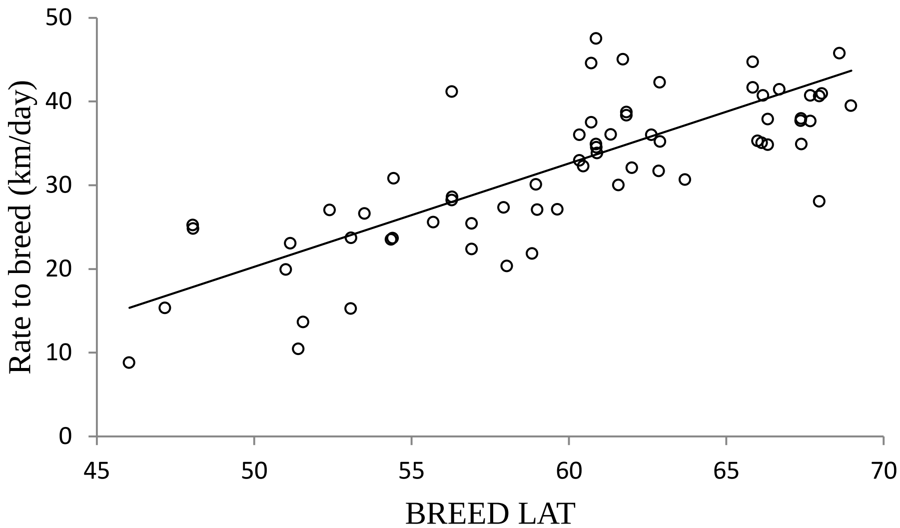
Variation in rate (km/day) scaup migrated to WBPHS area in relation to spring mean rainfall in the Canadian Prairies (CPRAIRIES RAIN) for scaup tracked by satellite telemetry (n= 100) that used the Mid-continent migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix J



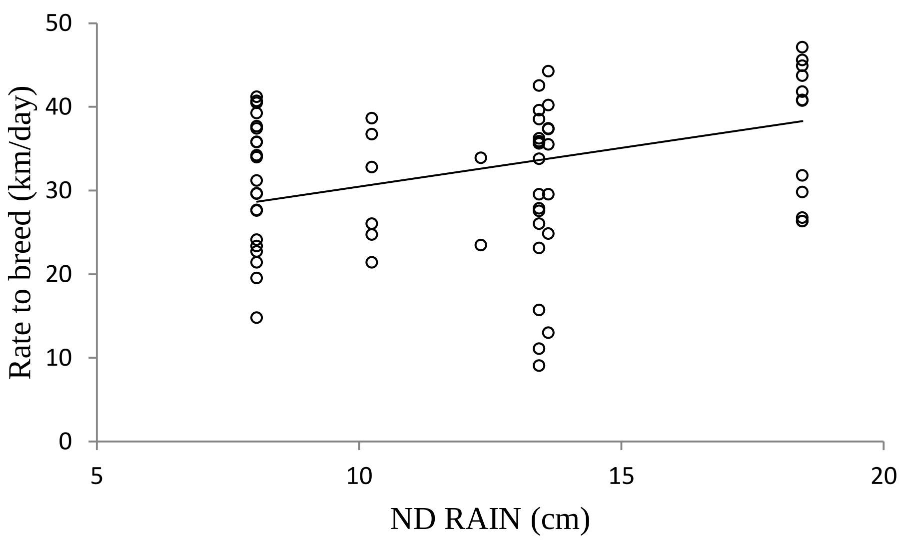
Variation in rate (km/day) scaup migrated to WBPHS area in relation to Latitude when first recorded in WBPHS area (STRAT LAT) for scaup tracked by satellite telemetry (n= 100) that used the Mid-continent migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix K



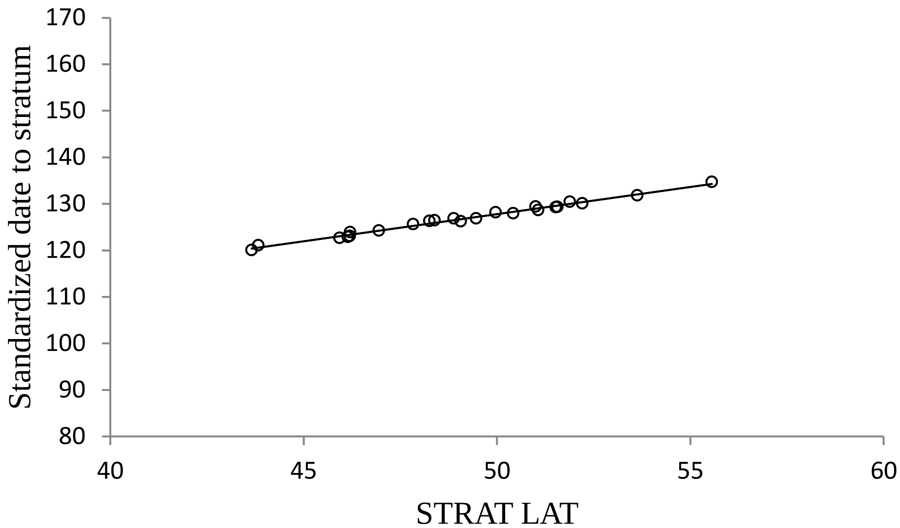
Variation in rate (km/day) scaup migrated to inferred breeding grounds in relation to Latitude of inferred breeding grounds (BREED LAT) for scaup tracked by satellite telemetry (n= 68) that used the Mid-continent migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix L



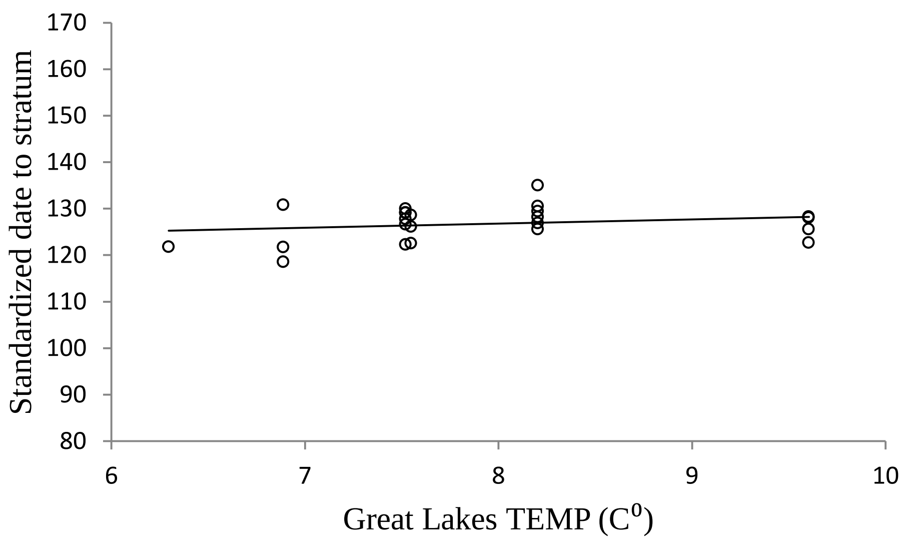
Variation in rate (km/day) scaup migrated to inferred breeding grounds in relation to spring mean rainfall in North Dakota (ND RAIN) for scaup tracked by satellite telemetry (n= 68) that used the Mid-continent migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix M



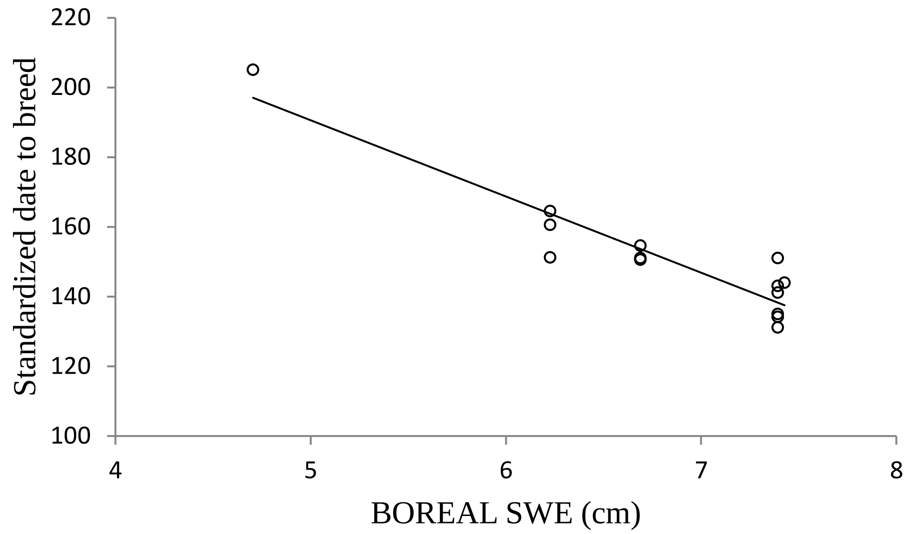
Variation in date of arrival by scaup into the WBPHS area in relation to Latitude when first recorded in WBPHS area (STRAT LAT) for scaup tracked by satellite telemetry (n= 15) that used the Eastern migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix N



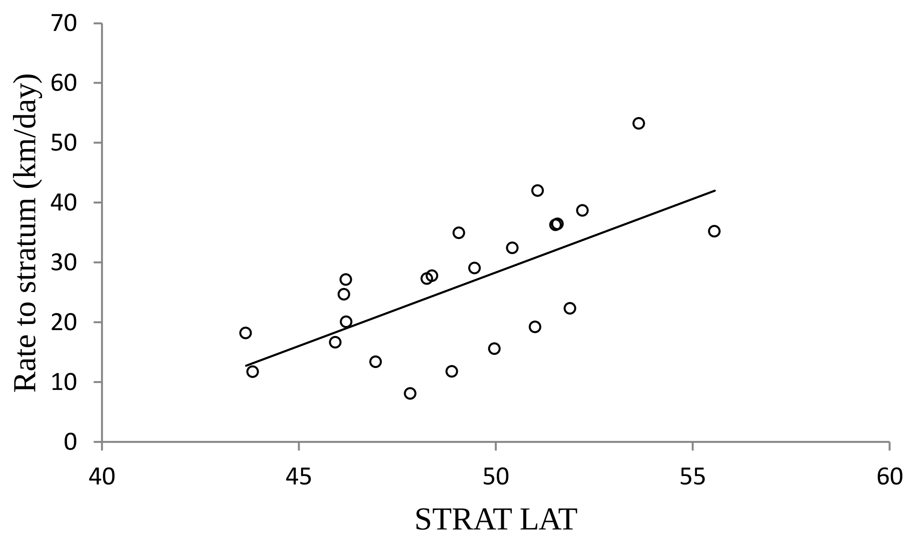
Variation in date of arrival by scaup into the WBPHS area in relation to spring mean temperature in the Great Lakes (Great Lakes TEMP) for scaup tracked by satellite telemetry (n= 15) that used the Eastern migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix O



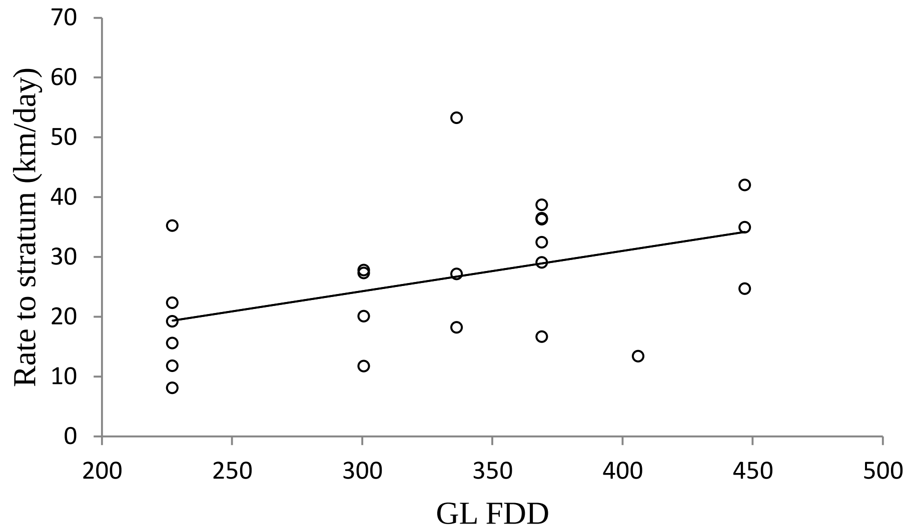
Variation in date of arrival by scaup to inferred breeding grounds in relation to snow water equivalency in the Eastern Boreal Forest (BOREAL SWE) for scaup tracked by satellite telemetry (n= 10) that used the Eastern migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix P



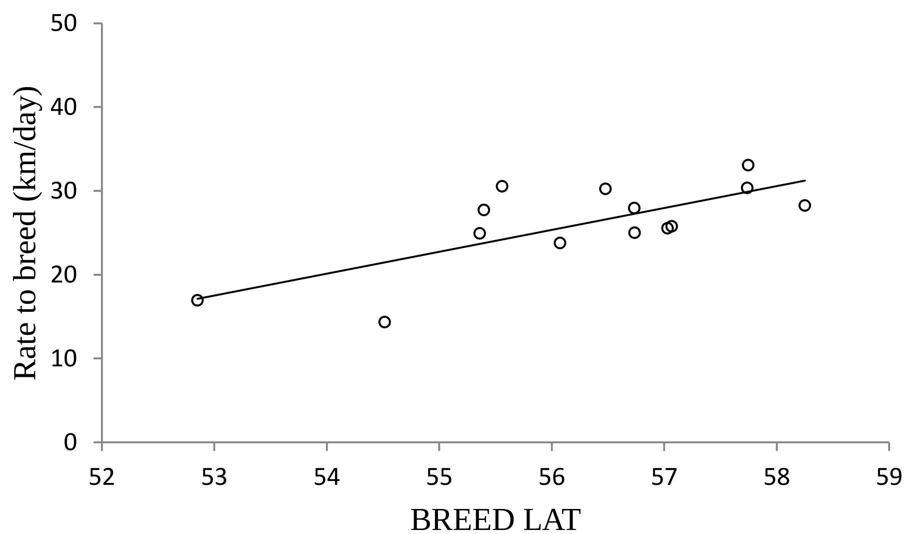
Variation in rate (km/day) scaup migrate to WBPHS area in relation to latitude when first recorded in WBPHS area (STRAT LAT) for scaup tracked by satellite telemetry (n= 15) that used the Eastern migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix Q



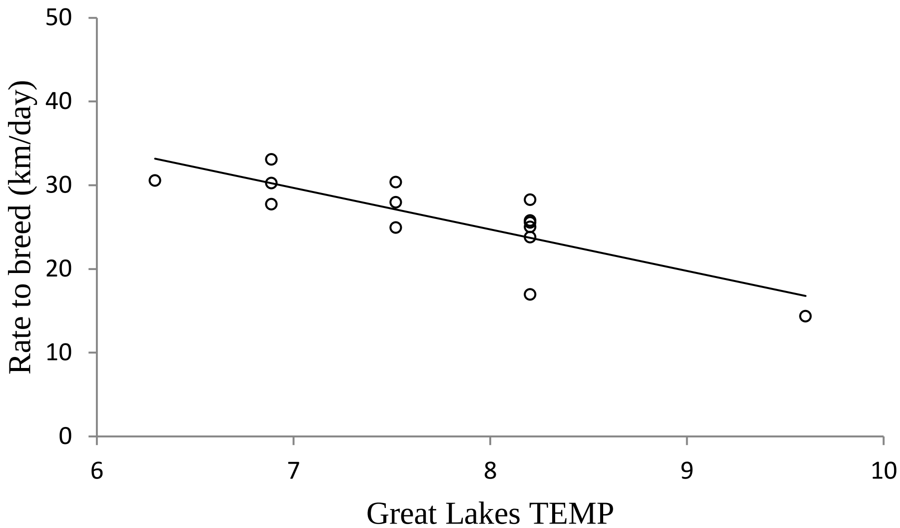
Variation in rate (km/day) scaup migrate to WBPHS area in relation to freezing degree days in the Great Lakes (GL FDD) for scaup tracked by satellite telemetry (n= 15) that used the Eastern migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix R



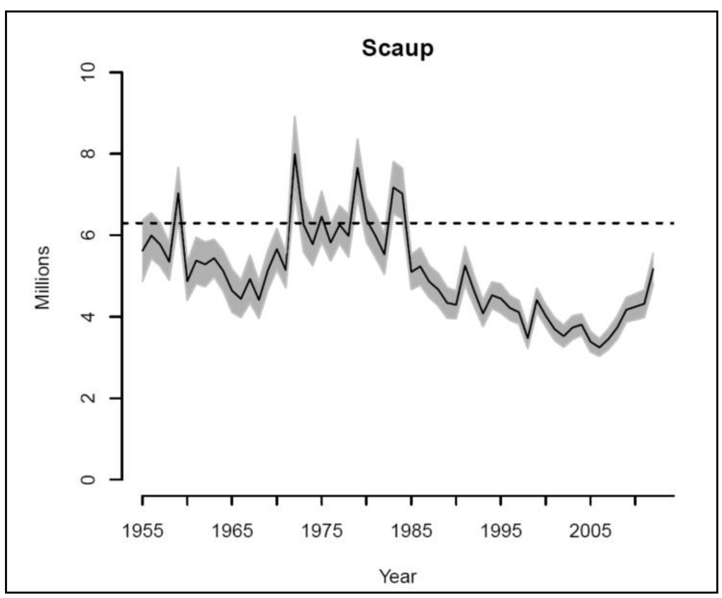
Variation in rate (km/day) scaup migrate to inferred breeding grounds in relation to latitude of inferred breeding grounds (BREED LAT) for scaup tracked by satellite telemetry (n= 10) that used the Eastern migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix S



Variation in rate (km/day) scaup migrate to inferred breeding grounds in relation to spring mean temperature in the Great Lakes (Great Lakes TEMP) for scaup tracked by satellite telemetry (n= 10) that used the Eastern migration route from 2005-2010. Residuals represent remaining variation unexplained after modeling.

Appendix T



Breeding population estimates from the Waterfowl Breeding Population and Habitat Survey, including 95% confidence intervals, and North American Waterfowl Management Plan population goal (dashed line) for Scaup (*Aythya affinis and A. marila).*

Curriculum Vitae

Taylor Finger

Employment

Assistant Migratory Game Bird Ecologist, December 2013 – Present
Wisconsin Department of Natural Resources, Madison, WI

This position includes developing and updating waterfowl and other migratory game bird management plans, survey reports and harvest reports. Establishing waterfowl rules based on Fish & Wildlife Service season and population frameworks and biological parameters. Coordinating statewide surveys and banding efforts as they relate to migratory game bird management. Preparing information for the Mississippi Flyway states, statewide waterfowl interest groups, and the public. Responding to migratory game bird inquiries through e-mail, telephone, and written correspondence.

Research Assistant, December 2011 – December 2013
Long Point Waterfowl, Port Rowan, Ontario

This position provided assistance to research being conducted at Long Point Waterfowl. Primary duties consisted of data management and analysis to determine spring migration chronology of lesser scaup. Secondary duties consisted of assisting in processing waterfowl for energetic analysis, trapping and handling of Long-tailed ducks, and conducting spring Tundra swan surveys.

Natural Resource Research Technician, April 2011 – August 2011
Wisconsin Department of Natural Resources, Madison, WI

This position provided assistance to 3 research studies: Evaluation of Landscape Management in the Glacial Habitat Restoration Area Program, Evaluation of Blue-winged Teal Survival and Production in the Great Lakes Region, and Evaluation of Nesting Islands for Duck Production. Duties included determining pheasant abundance by triangulation of crowing males on roadside routes, constructing pens for rearing gamefarm cinnamon teal, sterilize and incubate teal eggs and monitor hatching, rear ducklings to flight stage in indoor and outdoor pens, and search grassland nest cover for duck nests and collect data on nests.

Waterfowl Research Technician, October 2010 – March 2011
University of Delaware, Galloway, NJ

Assisted graduate students in conducting behavioral observations of over-wintering waterfowl along coastal New Jersey. Worked during diurnal, nocturnal, and crepuscular periods collecting behavioral data for time-energy budgets and bioenergetic models of American black ducks and Atlantic Brant. Conducted habitat sampling for black duck food research, with the use of core sampling, throw traps, and vegetation dredge. Worked also as a volunteer for the New Jersey division of Fish and Wildlife. Access to observation location required use of ATV's and outboard boats.

Waterfowl Intern, June 2009 – September 2009
Minnesota Department of Natural Resources, Bemidji, MN

Captured waterfowl via drive-trapping and night-lighting in north central, west-central, and northwestern Minnesota. Identified, aged, sexed, banded, and humanely handled waterfowl. Other duties included accurately recording location (GPS) and waterfowl capture data, entering data, writing project summaries, maintaining and repairing field equipment, contacting and communicating with private landowners, and dealing with the public and coworkers in a professional manner.

Education

Master of Science (In Progress; Projected finish Dec. 2013)
Department of Biology
University of Western Ontario
Subject area: Zoology

Bachelor of Science, 2010
Department of Natural Resources
University of Wisconsin – Stevens Point
Subject areas: Wildlife Management and Biology
Honors: *cum laude*

Master of Science Research

Factors influencing spring migration chronology of Lesser Scaup (Aythya affinis)

Teaching Experience

Teaching Assistant

Wildlife Ecology and Management – Spring of 2012 and 2013 (University of Western Ontario)
Conservation Biology – Fall 2012 (University of Western Ontario)
Organismal Physiology – Fall 2012 (University of Western Ontario)

Skills and Field Experience

Experienced in identification, sexing, and banding of most waterfowl species.
Experienced in conducting avian influenza sampling.
Experienced in waterfowl survey techniques.
Experienced in waterfowl drive trapping, night lighting, floating mist nets, and lift net capture techniques.
Physically fit with proven strength and endurance as well as tolerance for adverse conditions.
Provide management and leadership skills as well as ability to work in a team setting.
Competent in use of GPS and GIS as tools in document field resources.
US Fish and Wildlife Service Defensive Driving certified.
US Fish and Wildlife Service ATV safety certified.
Experience in use of trucks, ATV'S and outboard motor boats.
Experienced in rearing captive waterfowl.
Experienced in extensive data management.

PROFESSIONAL

Manuscript in Progress

Finger, T., M. L. Schummer, S. A. Petrie, A. D. Afton, M. L. Szymanski, and M. Johnson. *In Prep*. Factors influencing spring migration chronology of Lesser Scaup (*Aythya affinis*) and Mallards (*Anas platyrhynchos*). Journal of Wildlife Management

Contributed Presentations

Finger, T., M. L. Schummer, S. A. Petrie, A. D. Afton, M. L. Szymanski, and M. Johnson. 2013. (accepted). Factors influencing spring migration chronology of Lesser Scaup (*Aythya affinis*) and Mallards (*Anas platyrhynchos*). 6th North American Duck Symposium, Memphis, Tennessee.

Finger, T., S. A. Petrie, I. Creed, M. L. Schummer, A. D. Afton, and M. Johnson. 2013. Factors influencing spring migration chronology of Lesser Scaup (*Aythya affinis*) and Mallards (*Anas platyrhynchos*). Annual Lower Great Lakes Scientific Advisory Committee Meeting, Port Rowan, Ontario

Finger, T., S. A. Petrie, I. Creed, M. L. Schummer, A. D. Afton, and M. Johnson. 2012. Factors influencing spring migration chronology of Lesser Scaup (*Aythya affinis*) and Mallards (*Anas platyrhynchos*). 3rd Annual Biology Graduate Research Forum, London, Ontario.

Finger, T., S. A. Petrie, I. Creed, M. L. Schummer, A. D. Afton, and M. Johnson. 2012. Factors influencing spring migration chronology of Lesser Scaup (*Aythya affinis*) and Mallards (*Anas platyrhynchos*). Department of Biology Seminar Series, London, Ontario.

<u>Affiliations</u>

Long Point Waterfowl
Ducks Unlimited, Inc.
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Wisconsin Waterfowl Association
Wildlife Society