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Influences Of Nesting Behaviors In Common Eiders (Somateria Mollissima Sedentaria) In The Western Hudson Bay

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INFLUENCES OF NESTING BEHAVIORS IN COMMON EIDERS (*SOMATERIA MOLLISSIMA SEDENTARIA*) IN THE WESTERN HUDSON BAY

by

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Bachelor of Science, University of North Dakota 2016

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This thesis, submitted by Tanner Stechmann in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota is hereby approved.

Dr. Chris Nelson, Associate Dean
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4/26/19
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Title	Influences of Nesting Behaviors in Common Eiders (*Somateria mollissima sedentaria*) in the Western Hudson Bay
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Name Tanner Stechmann
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For instilling in me a love and passion for the outdoors.

ABSTRACT

Reproductive decisions of birds are shaped by minimizing predation while meeting physiological needs of parents and offspring. As a result, birds must make decisions about investment in offspring that allows them to maximize their overall fitness. This often drives nesting behaviors and can provide insights into reproductive success. Common eiders (*Somateria* mollissima) are thought to have high nest attendance (time spent tending the nest) and use substantial energetic resources during breeding. However, the specific behaviors at the nest of these birds are not well studied, with even less known about the Hudson Bay common eider (*S. m. sedentaria*). The objectives of this study were to determine (1) if colony characteristics and nest age influence nest attendance patterns, (2) if these patterns influence the probability of predation from a specific predator, and (3) what invertebrate resources are available to eiders and what factors impact the availability of those resources. To address our first and second objectives we used data collected during the summers of 2014 to 2017 where we captured nest attendance patterns and their fates at 103 common eider nests using time-lapse imagery from trail cameras. We found eiders spend 95.65% of a day on the nest on average, take 1.4 recesses per day and are gone on recess for an average duration of 43.51 minutes. We did not find nest age or colony characteristics to be major drivers in attendance patterns. Common eider nest predators included arctic foxes (*Vulpes lagopus*), red foxes (*Vulpes vulpes*), grizzly bears (*Ursus arctos*), polar bears (*Ursus maritimus*), sandhill cranes (*Antigone canadensis*), herring gulls (*Larus argentatus*), and bald eagles

(*Haliaeetus leucocephalus*). Annual variation was the most important factor driving nest success. When exploring what predator would consume a nest, we found the best predictor was timing within the breeding season. For our third objective, we collected aquatic invertebrates in June and July of 2016 and 2017 and compared our findings to data collected in 2003 and 2004. We created models and used AIC model selection to determine the factors that most simply and best explained abundance of individuals in each invertebrate. We found flow, season, substrate type and sediment depth appeared in most of our models. When comparing our findings to the initial collections in 2003 and 2004, we found increased sedimentation across our sampling sites. Finally, we used ANOVAs and discriminate analyses to investigate if stable isotope values of ^{13}C and ^{15}N collected from aquatic invertebrates were different among the four different water types they were collect in (Mast River freshwater, Wawao Creek freshwater, brackish, and marine). We found that no difference in ^{13}C samples between our two freshwater sources, but did find variation in our ^{15}N samples which are likely different from the proportions of different types of invertebrate categories collected. Our brackish samples to not be different from freshwater sources but did find marine samples to be unique from all other samples. Findings from this study provide important natural history information on the nesting ecology of the common eider and provide a foundation for future research exploring availability of invertebrate resources for breeding birds in the area.

CHAPTER I

BACKGROUND AND LITERATURE REVIEW

Parental Investment

Trivers (1972) describes parental investment as any investment by a parent to an offspring that increases the likelihood of survival while decreasing the parent's ability to invest in other offspring or other activities. Many factors can influence the behaviors of the attending parent including: sex and age of the parent, timing of the breeding season, habitat quality, clutch age, and energy reserves (Trivers 1972, Montgomerie and Weatherhead 1988, Burnam et al. 2012). For birds, reproduction demands substantial resources from females for both egg production and incubation (Coates and Delehanty 2008, Burnam et al. 2012). Because of this, birds must manage time between their own self maintenance and that of the developing offspring while minimizing the threat of predation (Coates and Delehanty 2008, Burnam et al. 2012, Ellis-Felege and Carroll 2012, Winder et al. 2016). A parent's ability to balance incubation requirements with daily energetic demands is a constant trade-off (Burnam et al. 2012, Ellis-Felege and Carroll 2012) influenced by daily and seasonal factors, environmental conditions, as well as individual physical characteristics of the parent. Managing these daily requirements and energetic needs becomes increasingly more difficult for bird species where only one sex incubates, like common eiders (*Somateria mollissima*) (Coates and Delehanty 2008).

Common Eiders

Common eiders (hereafter eider) are a long-lived seaduck that have a circumpolar distribution in high latitude regions of the Arctic and sub-Arctic (Baldassarre 2014). Eiders are large bodied birds weighing 1300–2600g and are easily identified by their sexually dimorphic plumage during the breeding season (Goudie et al. 2000, Peterson 2008). Males have a white dorsum and a black ventral and can be identified from other eider species by their black crowns with green napes. In contrast to males, females (or hens) have a brown to gray color with dark cryptic bands that allow them to hide in dense foliage when on the nest. Female common eiders can often be mistaken for female king eiders (*S. spectabilis*) because of their overlapping wintering distributions and similar appearance. These two species can be distinguished by barring patterns on their breast feathers; female common eiders have linear barring while female king eiders have crescent shaped barring (Goudie et al. 2000, Peterson 2008, Baldassarre 2014).

Population Status

While some populations have experienced short-term increases in numbers (Rockwell et al. 2013), globally eider numbers continue to decline (Mehlum 1991a, Goudie et al. 2000, SDJV 2007, Stien et al. 2010, Iles et al. 2013, Baldassarre 2014). According to the Sea Duck Joint Venture (SDJV) (2007), there are 2,196,000 eiders in North America with 225,000 found along the Hudson Bay. Hudson Bay common eiders (*S. m. sedentaria*) are considered to be declining by SDJV and should be considered a population of high conservation priority. Recently, a population of eiders nesting on the Mast River along the western portion of the Hudson Bay have seen extremely low apparent nest success (Iles 2012, Iles et al. 2013), where at least one egg hatches from the nest. Complete colonial nest failure was recorded 2014 (Rockwell 2014), and the colony had only a 9.7% apparent nest success in 2015 (Rockwell and Ellis-Felege 2015). In addition to reduced nest success, the number of nests in the colony has declined to only 150–200 nests in recent years compared to historical numbers of 300 nests or more (Schmutz et al. 1983). From 1978 to1980, Schmutz et al. (1983) found 1,295 eider nests in the Mast River. In contrast from 2013 to 2015, only 738 nests were located (Rockwell, Koons, and Mulder 2013, Rockwell 2014 and Rockwell and Ellis-Felege 2015). Few numbers of nests and low apparent nest success could be due to increased nest predation by arctic foxes (*Vuples logopus*). Predation by red foxes (*Vulpes vulpes*) also has been reported but at a much lower rate. Predation rates by arctic foxes on eider nests are influenced by small mammals, like lemmings (*Dicrostonyx* and *Lemmus spp.*), in the area (Roth 2002;2003, Iles et al. 2013). During years of low lemming numbers arctic foxes will use alternative prey sources like waterfowl and their eggs (Bêty et al. 2002, Roth 2002;2003). Eider nest success tends to be low during years of low small mammal abundance because of a shift in arctic fox diet (Bêty et al. 2002, Iles 2012, Iles et al. 2013). Continuing long-term decreases in eider populations can influence the success of predators, like Arctic foxes, during years of low abundance of small mammals.

Decreases in eider populations could have consequences for large predators as well, like polar bears (*Ursus maritimus*) and grizzly bears (*Ursus arctos*). There has been increased observations of polar bears preying on eider nests and their young not only along the Hudson Bay (Rockwell and Gormezano 2009) but also in other regions of the Canadian Arctic (Dey et al. 2017, Dey et al. 2018). Northern arctic and sub-arctic regions are facing the greatest effects of climate change than other regions on Earth (Dey et al. 2017, Dey et al. 2018) with significant changes to sea ice that could have implications for food webs.

These changes to sea ice include earlier melting and a latter formation; meaning less time for polar bears to be on the sea ice hunting their main winter food source of seals (Rockwell and Gormezano 2009, Gormezano and Rockwell 2015, Lunn et al. 2015, Rode et al. 2015, Pilfold et al. 2016) and other marine mammals. Polar bears are spending more time onshore during the ice free period (Rockwell and Gormezano 2009, Gormezano and Rockwell 2015, Lunn et al. 2015, Rode et al. 2015, Pilfold et al. 2016), which is advancing 0.571 days sooner per year (Rockwell et al. 2011) and are taking advantage of land-based food resources, like eider nests (Gormezano and Rockwell 2013b;a, Rockwell et al. 2013, Rockwell 2014, Rockwell and Ellis-Felege 2015, Rode et al. 2015, Dey et al. 2017, Dey et al. 2018).

Polar bears are not the only species of bears documented in the La Pérouse Bay area feeding on eider nests. Grizzly bears have also been documented (Rockwell 2014, Rockwell and Ellis-Felege 2015, Gormezano et al. 2017) taking eggs from eider nests. Grizzly bears have been observed foraging on other species of birds, like snow geese in the La Pérouse Bay area (Rockwell 2014, Rockwell and Ellis-Felege 2015) as well as other portions of the Canadian Arctic (Johnson and Noel 2005, Edwards et al. 2011). Increased predation risks, from any of these predators, could influence the behaviors of eiders at their nest during a crucial period of breeding.

Nest Attendance

Insights into brood success, fitness tradeoffs, resource use, habitat quality and life history characteristics can be obtained by studying nesting behaviors of birds. The patterns of behavior on the nest and time spent incubating eggs is highly variable among bird species. These patterns are often reflective of the environmental condition present during incubation or the condition of the female at the start of incubation (Sénéchal et al. 2010) and result in behavioral trade-offs between investment and mortality risk. *Nest attendance* is defined as the behavior by birds to care for their nest, which usually involves sitting on their nest to shade, protect and incubate the eggs.

Incubation constancy is the proportion of time a bird spends engaging in nest attendance daily and times spent off the nest are known as *recesses*. Female eiders incubate without the help of a male and based on some limited studies are thought to have one the highest incubation constancies of any waterfowl species spending 90–97% of their time on the nest (Mehlum 1991a, Afton and Paulus 1992, Criscuolo et al. 2002, Bolduc and Guillemette 2003b, Kristjánsson and Jónsson 2011, Baldassarre 2014, Waltho and Coulson 2015). Nest attendance can be influenced by factors such as clutch size or incubation age, resulting in variation in behavioral decisions based on perceived investment (Bourgeon et al. 2006, Criscuolo et al. 2006, Hennin et al. 2015). This suggests that current and past investment of resources into the nest can affect future effort an eider will put into her nest. Timing of allocation of resources can have a great effect on the success of the nest.

Resource Allocation and Energetics

Waterfowl use two main strategies to allocate resources during the breeding season: income or capital. Income breeders obtain much of their energy needed during the breeding season at their breeding grounds (Morrison and Hobson 2004, Sénéchal et al. 2011, Janke et al. 2015, Jaatinen et al. 2016), whereas capital breeders have much of their energy stored prior to arriving at their breeding grounds. Small bodied waterfowl tend to be income breeders and large bodied waterfowl, like eiders, tend to be capital breeders because of their ability to store large amounts of energy (Criscuolo et al. 2006, Sénéchal et al. 2011, Janke et al. 2015). However, Jaatinen et al. (2016) found that eiders will use a hybrid strategy as well. Smaller females arriving early to the breeding grounds will have more time to allocate local resources whereas larger females will have enough stored energy to begin egg production shortly after arriving to the breeding grounds.

In eiders, large amounts of a female's resources (i.e., fat stores) are consumed during egg production and incubation (Criscuolo et al. 2002, Hennin et al. 2015, Jaatinen et al. 2016). Incubating eggs utilizes resources in order to maintain the proper thermoregulation of eggs for development; this is especially important for eiders nesting in the harsh climates of northern latitudes where extreme low and high temperatures occur during the breeding season. When eiders leave their nests for a recess event, heat is lost and upon return much of the eider's energy is used to reheat the eggs (Criscuolo et al. 2000, Bolduc and Guillemette 2003b). Incubating eiders therefore tend to take very few recesses, have reduced feeding opportunities, and use large amounts of stored energy reserves. As a result, females may lose up to 32% of their body mass during incubation and could lose up to 50% of their total body mass during the entire breeding season

(Baldassarre 2014, Kristjánsson and Jónsson 2015a). Allocation of resources is extremely important to the success a female will have during the breeding season. Energy stored prior to the breeding season can affect the success of a nest and the success of the brood post hatch. Timing of energy stores and rate of consumption may also affect brood success post hatch. If female eiders use too much of their fat stores they may not have enough energy to care for their young post hatch.

Fat stores that females have when entering the breeding season can be reflective of the habitat quality of their wintering area (Jaatinen et al. 2016). Females with minimal fat stores may have been feeding in a habitat of low quality. A nesting female's fat storage when arriving to the breeding grounds influences her patterns of nest attendance and results in fitness tradeoffs during the breeding season as she balances her own energetic needs with that of the developing offspring (Sénéchal et al. 2010). A female's ability to effectively store energy directly influences time allocation at the nest as an individual hen with insufficient energy stores may have to take more recesses to feed. These increased absences during incubation leaves the nest exposed to the thermal stresses of the environment and increased risk of predation (Criscuolo et al. 2000, Bolduc and Guillemette 2003b).

Predation Risks

It is well documented that the largest threat to ground nesting birds is predation (Stien et al. 2010, Iles et al. 2013). Exposed nests and increased activity at the nest can result in increased nest predation (Criscuolo et al. 2000, Criscuolo et al. 2002, Stien and Ims 2016). Nest success (i.e., the proportion of nests to hatch at least one egg) can be severely impacted by local predator communities, as nests are at risk of predation throughout the incubation period. The main nest predators of eiders nesting in the La Pérouse Bay are arctic fox and herring gulls (Iles 2012, Iles et al. 2013, Rockwell 2014, Rockwell and Ellis-Felege 2015). Some species of birds defend their nest from predators (Montgomerie and Weatherhead 1988) causing them to use additional stored energy. Eiders do not actively defend their nests from predators by attacking the predator, but they do engage in distraction displays that can result in increased predation on themselves and increased energetic demands (Kay and Gilchrist 1998). The primary form of nest protection is through attendance. Nest predation from species like herring gulls (*Larus argentatus*) and ravens (*Corvus corax*) is often avoided by high nest attendance by eiders (Mehlum 1991a, Andersson and Waldeck 2006).

Changes in incubation patterns and incubation constancy directly impact the nesting female and her clutch. Female eiders with high incubation constancy spend more time on their nest improves the success of her clutch, but depletes her stored energy. Increasing her time away from the nest to feed and replenish herself with nutrients, increases the clutches risk to predation and the elements. Since a female's attendance patterns at the nest are often reflective of the habitat quality from where most of her energy was obtained, changing environmental conditions at both the wintering and breeding grounds can have dramatic impacts on the success of a nest. These environmental changes can affect the habitat the eiders nest and winter in, potential food sources in these areas and possible nest predator populations. Understanding possible drivers of nest attendance and nest success of common eiders may provide insight into possible causes in increased population declines.

Use of Cameras to Monitor Nest Behaviors

Access to nest locations, dense nesting cover, or cryptic coloration of nesting birds can make it difficult to monitor nesting behaviors (Ellis-Felege and Carroll 2012). Remote cameras placed at the nest give researchers the ability to monitor nesting behaviors and nest predators, while minimizing disturbance at the nest. Research presence at the nest can influence nesting behaviors as well as behaviors of nest predators (Ellis-Felege and Carroll 2012). Remote cameras can be placed at the nest and do not require maintaining for multiple days, allowing for detailed observations of nesting behaviors. Studying predation at nests is often done by using evidence at the nest (e.g., egg shell fragments, scat, or tracks) which can often be limiting and misleading (Staller et al. 2005, Andes et al. 2019). Remote cameras give researchers the capability to confirm when predation events occurred, when they occurred, and confirm the nest predator.

Monitoring of eider nesting behaviors have been done using observers and optics (Kristjánsson and Jónsson 2015a), temperature monitors (Kristjánsson and Jónsson 2011), scales (Criscuolo et al. 2002, Bolduc and Guillemette 2003b) and remote cameras (Mehlum 1991a, Kristjánsson and Jónsson 2011). Studies that have used remote cameras have done so with small sample sizes (<11 nests) and have done so with poor sampling design. Kristjánsson and Jónsson (2011) used a single camera at a single nest and monitored for only five days and manipulated the nest and camera every other day. As a result of limited samples sizes and methodological approaches, there is a gap in understanding eider nesting behaviors.

Study Objectives

The overarching goal of this study was to investigate influences on nest attendance and general nesting behaviors, identification and timing of nest predator species, and the available invertebrate resources to incubating female eiders in La Pérouse Bay near Churchill, Manitoba, Canada. Factors influencing general nesting behaviors and success relative to colony characteristics (e.g. distance of nest from the center of the colony, distance to the nearest neighboring nest) and the characteristics of the nest (e.g. nest age) were explored in Chapter 2. We also investigated how these factors and date within the breeding season influenced predation events. In Chapter 3, seasonal, temporal, and spatial changes in the communities of freshwater aquatic invertebrates of two rivers were examined. As well as, characterization of isotopic signature of these invertebrates for future comparison of isotopes found in the tissues of nesting eiders. In Chapter 4, we draw final conclusions from our results and make recommendations to future work and monitoring.

Study Locations

This research was conducted by members of the University of North Dakota in collaboration with the Hudson Bay Project (HBP) research program. The study location was in Wapusk National Park (WNP), Manitoba, Canada along the La Pérouse Bay within the Hudson Bay (Figure 1.1). The park is 11,475 km^2 and contains a variety of habitats (e.g., peat bog, coastal saltwater marsh, and boreal forest) across the park. Due to the remoteness of the park, there is very little human activity, except for researcher activity during the eider breeding season. Field operations were based out a HBP's remote field camp (Nestor 2) located along the northwest border of the park (N 58.725388º, W -93.464288º).

Eiders were studied along the Mast River within WNP and an adjacent wildlife management area. Eiders usually nest along the edges of islands (1–300 m^2 in size) in the braided river deltas, within each river, in dense vegetation, mainly a mixture of shrubs (*Myrica gale, Betula glandulosa, Salix sp.*) approximately 0.6m – 4m in height (Schmutz et al. 1983).

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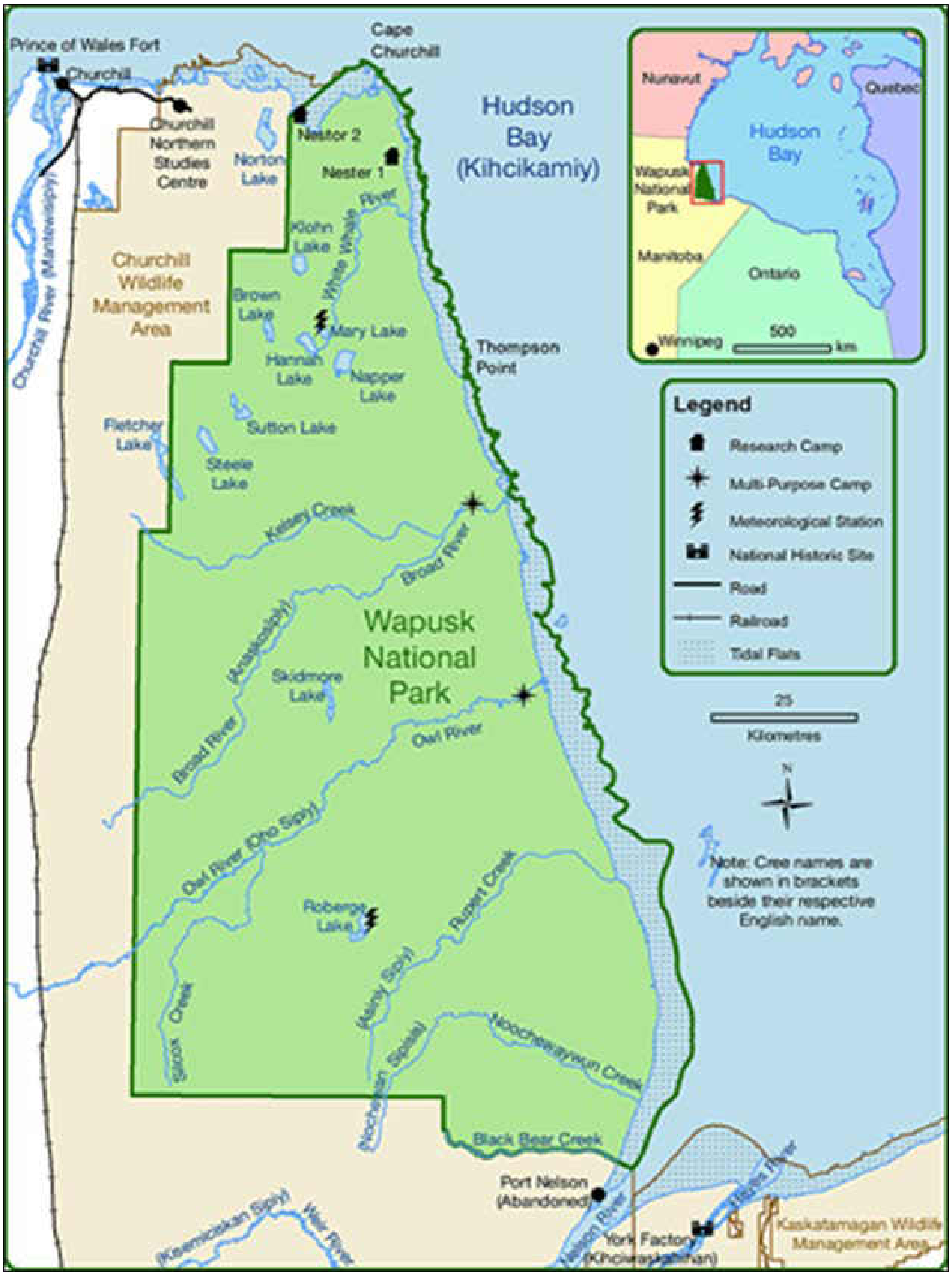

Figure 1.1. Wapusk National Park, Manitoba, Canada. Study area was located at the Nestor 2 field camp in the northwest region of the park and extended into the Churchill Wildlife Management Area. Credit Parks Canada.

CHAPTER II

INFLUENCES ON NEST ATTENDANCE OF COMMON EIDERS IN LA PÉROUSE BAY, WESTERN HUDSON BAY, MANITOBA, CANADA

Abstract

Remote cameras at bird nests are a growing tool and can allow researchers to monitor nesting behavior with minimal disturbance to the nest. Monitoring nesting attendance can provide insights into how seasonal and habitat characteristics can influence parental investment. Nesting behaviors and specifically nest attendance is an understudied aspect of common eiders (*Somateria mollissima*) ecology. The goal of this project was to investigate influences on nest attendance, identification and timing of nest predator species. We monitored nest attendance patterns of 103 common eider nests using time-lapse imagery in Wapusk National Park, Manitoba, Canada from 2014 to 2017. We found eiders spend 95.65% of a day on the nest on average, take 1.4 recesses per day and are gone on recess for an average duration of 43.51 minutes. From a repeated measures mixed-model on 78 nests, we found individual bird variation to be the best explanation of the data. We found annual variation was our top model of recess number and year + day of incubation was our top model of recess duration. From a logistic regression, we found annual variation to be the largest driver of nest success. We created a multinomial regression from 103 nests and found timing within the breeding season presented as a quadratic function best predicted predation probability by a specific

predator. We also found that as the breeding season increases so does that number of predators present on the landscape. We concluded that annual variation in the predator community is likely the biggest driver in nest attendance and nest success, and contributed insights into nest attendance patterns that were limited in the literature.

Introduction

Parental Investment

Reproductive success in many animals, specifically birds, is dependent on the quantity and quality of investment parents give to their offspring. Parental investment is described by Trivers (1972) as any investment given by a parent that increases the overall survival of a single offspring, while decreasing the amount of investment the parent can make in other offspring. Parental investment in birds is given in the form of producing eggs, incubating the eggs, and caring for hatched young (Gill 2007). The role and amount of parental investment may differ among species, between sexes and vary by time of the year (Trivers 1972, Sibley et al. 2009). Species also will differ in their investment based on the type of offspring (e.g., precocial vs altricial) they produce (Sibley et al. 2009). Regardless of the mating strategies and types of offspring produced, parental investment tends to increase more in one sex than the other as the breeding season progresses (Trivers 1972).

For birds, increased parental investment by one sex over another is most apparent in species where only one parent is solely responsible for tending the nest or incubating eggs. These individuals must balance the needs of their clutch while trying to meet their own energy demands. Parents face a constant trade-off between itself and its' offspring while also trying to avoid predation of themselves or the nest (Ellis-Felege and Carroll 2012). Depletion of parental resources is most apparent in species where the female incubates alone. In some species (e.g. Phalaropes) males will incubate, but they do not have the extra burden of producing eggs. Female common eiders (*Somateria mollissima*) lose up to 18% of their body fat during egg production and up to 56% during the entire breeding season (Baldassarre 2014, Kristjánsson and Jónsson 2015b). The depletion of energy resources may likely limit care for the developing offspring (Burnam et al. 2012).

Nest attendance is described as any behavior (e.g. shading, protecting, or incubation) to care for the nest. Nest attendance can be measured by monitoring recess events. *Recesses* are times where the incubating parent is away from the nest (Winder et al. 2016). A better understanding of nest success can be gained by monitoring the number and duration of recess events (Winder et al. 2016). The proportion of time in a 24-hour period in which a bird spends incubating the nest is known as *incubation constancy* (Afton and Paulus 1992, Winder et al. 2016). Nest attendance can be driven by many factors including but not limited to clutch age, energy resources of the parent, habitat quality, neighboring nests, and predators (Trivers 1972, Montgomerie and Weatherhead 1988).

Many of the factors that can influence nest attendance patterns are often linked to one another. Nesting in the right habitat can assist the parent in maintaining a microclimate at the nest (Coates and Delehanty 2008). The age of the clutch may also help to maintain temperatures at the nest. As the cardiovascular system develops in the egg, temperatures in the egg fluctuate less from a more maintained environment within the egg (Mortola and Gaonac'h-Lovejoy 2016). The correct habitat can protect parents from predation events as well. Coates and Delehanty (2008) reported a correlation between nest success and vegetation characteristics in greater sage-grouse (*Centrocercus urophasianus*). They suggest birds may increase incubation constancy at nests with more visual obstructions. Increased visual obstructions allow for more uninterrupted incubation patterns, resulting in less exposure of the nest and eggs to predators and the environment. Clutch age or timing within the breeding season can influence the energy demands of the nesting parent (Burnam et al. 2012). Incubation is extremely demanding and as incubation progresses recess number tends to increase, as parents will feed more to sustain their physical needs (Afton and Paulus 1992, Burnam et al. 2012). Birds may also nest closer to other birds for safety in numbers or may have some sort of cooperative breeding (Kristjánsson and Jónsson 2015b). Birds may nest closer to relatives who may help to incubation or cover eggs when the attending parent is away from the nest (Kristjánsson and Jónsson 2015b)

Attendance patterns by a parent are critical in reproductive success (Croston et al. 2018a, Croston et al. 2018b) and are often linked to nest predation (Burnam et al. 2012). Birds with a higher rate of nest attendance or incubation constancy tend to have a lower rate of predation (Coates and Delehanty 2008, Burnam et al. 2012). Nesting in a colony can provide a dilution effect giving better odds of survival if a predator were to enter a colony (Schreiber and Burger 2001, Waltho and Coulson 2015). Schmutz et al. (1983) and Mehlum (1991a) found lower egg loss at common eider nests that were in close proximity to other nests and suggested these nests received early predator detection from neighboring nests. Nesting among other birds, however, could increase predation risk (Schreiber and Burger 2001, Waltho and Coulson 2015). More individuals nesting together could attract more predators to the area, therefore increasing the chance of predation. Schreiber and Burger (2001) suggest the "swamping" effect of the colony should result in predation being isolated to the colony perimeter.

Remote Cameras to Monitor Nest Attendance

Remote cameras are an important tool to monitor nesting behaviors of nesting birds (Ellis-Felege and Carroll 2012). Monitoring nesting behaviors of gamebirds, like waterfowl, can be challenging; dense nesting cover, access to the nest location, and cryptic coloration of most nesting waterfowl can make it difficult to conduct field observations. Further, observing predation at the nest can also be difficult, as it may occur at night or a researcher's presence may alter the interaction. As a result, predator identification is often done using evidence left at the nest after a predation event (Ellis-Felege and Carroll 2012). This is often difficult to do and can be misleading when trying to understand when the predation event occurred and what predator caused it (Staller et al. 2005, Andes et al. 2019). Remote cameras can be placed at a nest and left to monitor the nest for multiple days; resulting in reduced research disturbance at the nest and accurate identification of nest predators.

Common Eiders

An ideal candidate to investigate influences into nest attendance and its role in nest success are common eiders (hereafter eider(s)). Eiders are large, colonial nesting sea ducks found circumpolar around in the Arctic (Baldassarre 2014). These birds are uniparental nesters with females solely incubating the nest. Males may stay during the early stages of incubation to defend a female from other males but often leave following egg laying (Baldassarre 2014). Female eiders have extremely high incubation constancy; some studies have recorded 99% incubation constancy (Mehlum 1991a, Afton and Paulus 1992, Criscuolo et al. 2002, Bolduc and Guillemette 2003b, Kristjánsson and Jónsson 2011, Waltho and Coulson 2015). However, these results are based on limited sample sizes (<24 nests) and could be overestimating incubation constancy. High incubation constancy is thought to have developed as a way to defend the nest from aerial predators such as gulls (Mehlum 1991a, Fast et al. 2010, Waltho and Coulson 2015). Waltho and Coulson 2015 found that most gull predation occurs during egg laying while eiders are taking more frequent recess events.

Hudson Bay common eiders (*S. m. sedentaria*) are a unique subspecies of eiders. Hudson Bay eiders are thought to spend the entire year within the Hudson Bay, migrating from breeding areas to polynyas for the winter (Robertson and Gilchrist 1998, Baldassarre 2014, Waltho and Coulson 2015). This subspecies nests in areas with more shrubs compared to Northern eiders (*S. m. borealis*) in Iceland (Kristjánsson 2016) and northern Canada and Pacific eiders (*S. m. v-nigrum*) in western Canada and United States (Noel et al. 2005). Eiders in this region have a complex community of predators consisting of arctic foxes (*Vulpes lagopus*), red foxes (*Vulpes vulpes*), grizzly bears (*Ursus arctos*), polar bears (*Ursus maritimus*), herring gulls (*Larus argentatus*), sandhill cranes (*Antigone canadensis*), bald eagles (*Haliaeetus leucocephalus*) and common ravens (*Corvus corax*) making them extremely vulnerable to predation throughout the breeding period (Rockwell and Gormezano 2009, Iles 2012). Further, this subspecies is understudied, compared to other subspecies, with most of the research occurring in the Belcher Islands (Freeman 1970b, Freeman 1970a, Robertson and Gilchrist 1998, Gilchrist and Robertson 2000, Robertson et al. 2001) and at La Pérouse Bay (Schmutz et al. 1983, Watson et al. 1993, Robertson 1995, Andersson and Waldeck 2006, Ahlers et al. 2010, Iles 2012, Iles et al. 2013). Despite eiders being well studied elsewhere, few studies have monitored nest attendance or the factors that could influence it (Mehlum 1991a, Afton and Paulus 1992, Criscuolo et al. 2002, Bolduc and Guillemette 2003b, Kristjánsson and Jónsson 2011). Information on eider nest attendance is lacking, non-existent in the Hudson Bay subspecies, and is essential to better understanding a critical aspect of eider ecology.

Objectives

The goal of this project was to investigate nesting behaviors and predation of the Hudson Bay common eider nesting in Wapusk National Park, Manitoba Canada using camera technology. Specifically, we were interested in determining the factors, such as colony characteristics (e.g. distance to the center of the colony and the distance to the nearest neighboring nest) and nest age (day of incubation), have on nest attendance patterns. We evaluated the influence of variables such as colony characteristics, nest age and incubation constancy had on nest success. Finally, we examined phenology of nest predators to determine when eiders were most vulnerable to specific groups or species of predators.

Methods

Study Location

We studied eiders nesting in the northwest corner of Wapusk National Park Manitoba, Canada (Figure 1.1), along a braided river delta where the Mast River drains into La Pérouse Bay. The study area consists of islands covered in a mixture of shrubs and grasses, ranging in size from 1 to 300 m^2. Detailed site descriptions can be found in Schmutz et al. (1983), Waldeck and Andersson (2006), Iles (2012), Iles et al. (2013).

Field Methods

We searched for nests in historic areas of known eider nesting along Mast River. We conducted nest searches and nest rechecks every 7-10 days to reduce researcher disturbance. We marked nest identification number on a tongue depressor, recorded GPS coordinates, and clutch size (Iles et al. 2013). We determined incubation age via candling (Weller 1956, Klett et al. 1986). Reconyx PC-800 Hyperfire trail cameras (Holmen, WI) were deployed at a subset of nests, which were programmed to capture an image every 2 minutes and a burst of 30 images when motion was detected. Cameras were attached to wooden or steel posts, mounted approximately 0.5–1.5 m off the ground. Cameras remained at the nest until failure or hatch. We considered nests to be successful if at least one egg in the nest hatched; this was determined by the presence of ducklings or egg membranes in the nest and for nests with cameras later confirmed from images. Unsuccessful nests were determined if all eggs were missing from the nest, eggs were cold suggesting abandonment, or if eggs were found destroyed in the nest (Iles et al. 2013). Cause-specific nest failures from signs remaining are often unreliable (Staller et al. 2005) so identification of predators was confirmed from camera images. Data collection was conducted in accordance to Wapusk National Park permits: WAP-2012-11199, WAP-2015-18760, WAP-2018-27940; Canadian Wildlife Services Permits 11-MB-SC001 and 16-MB-SC001; Utah State University IACUC Protocols 2208 and 2018 University of North Dakota IACUC approvals #A3917-01, Protocols 1505-10, 1601-2, and 1801-3C.

Image Review

We reviewed images from time-lapse photography to determine nest attendance patterns of the female. We recorded daily recess events from the time the female left her nest to the time the female returned to the nest. Incubation constancy was calculated as a proportion of total time the bird was on the nest during a 24-hour period. On days of nest checks when birds were flushed from their nests or days when predation occurred, we omitted these days from subsequent analysis of attendance patterns. We recorded species and presence of any nest predator along with the time they were at the nest; this also included the presence of humans. We recorded date and temperature from camera measurements of any event that occurred at the nest. We reviewed images until the fate of the nest was determined. If ducklings were present in the camera, the nest was considered successful and image review was completed. We reviewed images up to three days after the nest failed, predator consumed the nest or hen abandoned, in order to capture secondary predators.

Nest Attendance Analysis

We used recorded GPS coordinates of nests found within the Mast River to calculate mean center in ArcGIS (Version 10.6) with the use of the Spatial Statistics Measuring geographic distributions Mean center tool. Distance from the center of the colony to each nest and the distance from each nest to its' nearest neighbor was calculated in ArcGIS using the Analysis tools Proximity Near tool.

We calculated summary statistics for all behaviors (e.g., average incubation constancy, average number of daily recess events, average duration of daily recess events, timing of recess) and predictor variables (e.g., distance to the center of the colony and distance to the nearest neighboring nest). For timing of recess events, night was defined between 22:00 and 03:59 and day was considered to be between 4:00 and 21:59. Night and day times were determined from average sunset and sunrise times for June and July.

We conducted a repeated measures regression using PROC GLIMMIX in SAS Studio 3.7 (Cary, NC, USA) to account for multiple observations at each nest over several days to assess average incubation constancy, number of daily recess events, and duration of daily recess events. All models included random effects for the individual birds monitored. We used a Beta distribution for average incubation constancy, a Poisson distribution for number of daily recess events, and a normal distribution for duration of daily recess events. Our predictor variables were day of incubation (nest age), year, distance to the center of the colony and distance to nearest neighboring nest. We used Akaike's Information Criterion (AICc), where the smallest AIC score reflects the simplest model to select which model best explained our data (Burnham and Anderson 2002).

Nest Success Analysis

We calculated summary statistics for predictor variables (e.g., incubation constancy, distance to the center of the colony, distance to the nearest neighboring nest, and age of the nest) relative to nest success. We calculated summary statistics only from nests that met our nest attendance standards (i.e., no researcher disturbances or predation events). To investigate predictors that may influence success, we created a logistic regression using PROC LOGISTIC in SAS Studio 3.7 using a binary response of success or fail. Our predictor variables were average incubation constancy, distance to the nearest neighboring nest and distance to the center of the colony. We used AIC scores to select the simplest model that best explained our data (Burnham and Anderson 2002).

To explore Schmutz et al. (1983) findings of higher nest success in nests that are closer to other neighboring nests, specifically those < 10 m apart, we sorted the 78 nests in to four categories. Categories were based on the distance of a nest to their nearest neighbor (0–0.99 m, 0–4.99 m, 0–9.99 m, and >10 m). We calculated summary statistics for nest attendance and apparent nest success for each category. We repeated this process for all 518 nests found, regardless of installation of a camera, from 2014–2017. We sorted the nests in the same four categories based on distance to their nearest neighbor (0–0.99 m, 0–4.99 m, 0–9.99 m, and >10 m). We then calculated summary statistics for apparent nest success and then compared our results to Schmutz et al. (1983) findings.

Nest Predator Analysis

For the entire dataset of camera monitored nests, we calculated summary statistics of what predators and when they were observed at the nest. We then classified predators into groups based on behaviors and total observations. We summarized the range of dates of when predators were present in the colony. We also calculated an average nest initiation date by subtracting 1 day for every 1 egg found in the nest from the age of the nest when it was found (Swennen et al. 1993, Bolduc and Guillemette 2003b). We then added 28 days of incubation (Schmutz et al. 1983) to the average initiation date to create an average breeding season. For comparisons to predator phenology, the breeding season was divided into three periods (egg laying, incubation, and hatching). We determined egg laying to be the period from average nest initiation to a number of days equal to the average number of eggs. The period of incubation is from the end of egg laying until the start of hatching. Approximately 2 days after hatching the female then takes her ducklings away from the nest (Waltho and Coulson 2015). To account for the 2 days of hatching we added 2 days after 28 days of incubation.

We were interested in whether date of observation and female behaviors played a role in the probability of predation by a specific predator or predators so we categorized predators into groups based on number of predation events and how predators behave. Grizzly bears, polar bears and cranes were classified in their own categories. Red foxes and arctic foxes were grouped into one category of fox, and herring gulls and bald eagles were categorized as aerial predators. We calculated the time of predation events in the year by converting predation event dates to Julian date. We created a multinomial logistic regression using PROC LOGISTIC and the GLOGIT link in SAS Studio 3.7 to investigate probability of a predation event by a specific predator category. Our predictor variables were incubation constancy, Julian date and Julian date^2. We used AIC scores to choose the simplest model that best explains our data (Burnham and Anderson 2002). Using the top AIC model, we graphically represent estimates of the probability of each predator category consuming a nest relative to the aerial predators that were constantly present throughout the breeding season.

Results

Nest attendance

We found 518 eider nests from 2014–2017 (Figure 2.1). Of those nests, 93 cameras were deployed for 501 observation days capturing 4,458,102 images from 103 nests (some cameras captured multiple nest in the field of view; Table 2.1). Following image review 78 nests met our standards (Table 2.2). On average eiders took 1.4 (range: 1–10) daily recess events that lasted 43.51 (range: 0.88–1432.0) minutes long and had an incubation constancy of 95.65% (range: 0.0–99.94) (Table 2.2). We found eiders nested on average 538.66 (range: 8.26–1648.06) meters away from the center of the colony and 53.96 (range: 0.0–458.80) meters away from their nearest neighbor (Table 2.2). Eiders had more total recess events during the day (473) then at night (235), but the single period with the most recess events (77) was between 23:00 and 24:00 (Table 2.3, Figure 2.2). We observed a rise in daily recess events during the day between 12:00 and 19:00 and then again at night between 24:00 and 02:00 (Figure 2.2).

The individual variation only model (intercept + random effects for individual birds) ranked highest over our predictor variables for incubation constancy (Table 2.4). Estimates from our second best model that included the fixed effect of year, suggest that year may be a driver of incubation constancy (Table 2.5). Over the 501 observation days, nesting females had an incubation constancy ≥ 95% 439 of those days (~88% of observations). In other words, females with an incubation constancy ≥ 95% were on the nest for at least 72 minutes longer than females with an incubation constancy ≤ 95%. Our top model for number of daily recess events and daily recess duration was year (Table 2.6 and 2.7).

Nest success

A total of 37 (of the 78) nests were successful, resulting in an apparent nest success of 47.44% (Table 2.8). Nests success varied between years (Table 2.9); 2014: 0 (0.00%), 2015: 3 (10.00%), 2016: 23 (92.00%) and 2017: 11 (64.71%). Females at successful nests averaged 11.19 (range: 2.0–28.0) daily recess events, had an average recess duration of 30.02 (range: 8.66–104.65) minutes, had an incubation constancy of 97.33% (range: 92.26–99.37), averaged 19.92 (range: 4.0–30.0) observation days and took 0.83 recesses per observation day (Table 2.8). Females at unsuccessful nest took an average of 7.17 (range: 1.0–29.0) daily recess events, had an average recess duration of 55.68 (range: 7.81–509.50) minutes, had an incubation constancy of 94.14% (range: 43.61%–99.39%), averaged 11.88 (range: 3.0–22.0) and took 0.59 recesses per observation day (Table 2.8).

From our top model in our logistic regression for nest success, we found that year alone was the most important predictor of nest success (Table 2.10). We found year to be in all models within two delta AIC of our top model. Estimates from our model (Table 2.11) depicted what was observed in annual apparent nest success (Table 2.9). Nest success was lowest in 2014 and 2015 and highest in 2016.

For comparisons with Schmutz et al. (1983) using our 78 nests, we explored incremental changes to nearest neighbor to see if birds behave different or are more successful. We found 12 nests that were located < 1 m from their nearest neighboring nest; 2 of those nests were successful and accounted for 16.67% of all successful nests. Females nesting < 1 m from their nearest neighboring nest had an incubation constancy of 92.22% (Table 2.12). A total of 29 nests were found < 5 m from their nearest neighboring nest; 6 (20.69%) of which were successful and accounted for 16.22% of all successful nests. Nests within 5 m of their nearest neighbor had an incubation constancy of 95.28% (Table 2.12). Of the 35 nest found within 10 m of their nearest neighboring nest; 8 (22.86%) were successful and only accounted for 21.62% of all successful nests

(Table 2.12). Females nesting < 10 m from their nearest neighbor had an incubation constancy of 95.25% (Table 2.12). A total of 43 nests were found >10 m from their nearest neighboring nest; 29 (67.44%) of those nests were successful and accounted for 78.38% of all nests that were successful. Nests found >10 m from their nearest neighboring nest had an incubation constancy of 95.64% (Table 2.12).

Using data obtained from 518 nests found from 2014–2017, we found eiders nested on average 44.47 meters away from the nearest neighboring nest. We found 64 (12.36%) nests to be < 1 m of their nearest neighboring nest (Figure 2.3) and 14 (21.88%) of which were successful (Table 2.13). When compared to tall 518 nests monitored during our study period, nests found < 1 m from the nearest neighbor had an apparent nest success of 2.70% (Table 2.13). We found 225 (43.44%) nests within 5 m of their nearest neighboring nest and 59 (26.22%) of them to be successful (Table 2.13). Of all nests found, those within 5 m had an apparent nest success of 11.39%. A total 248 (47.88%) nests were found to be < 10 m from their nearest neighbor and 72 (29.03%) of them were successful (Table 2.13). Compared to all nests, nests within 10 m of a neighboring nest had an apparent nest success of 13.9% (Table 2.13). We found 270 (52.12%) nests to be > 10 m from their nearest neighboring nest and found 176 (65.19%) of them to be successful (Table 2.13). When compared to the 518 total nests found, nests > 10 m from a neighboring nest had an apparent nest success of 33.98% (Table 2.13).

Nest Predators

Of all 103 nest monitored, 37 nests were successful at hatching at least one egg. Nest predators captured on camera were arctic fox, red fox, grizzly bears, polar bears, sandhill cranes, herring gulls, and bald eagles. Our top nest predators were arctic fox

(24), herring gulls (10) and grizzly bears (9) (Table 2.14). We found partial predators to be arctic foxes (2), red foxes (2), bald eagles (2) and herring gulls (1) (Table 2.15). Partial predators were defined as predators that did not completely destroy the nest and resulted in abandonment or hatch. Arctic foxes (7), herring gulls (9) and sandhill cranes (1) were found to be secondary predators (Table 2.16). Secondary predators were predators that took eggs from the nest after an abandonment or partial predation event.

The earliest arctic foxes were captured on camera was Julian date 159 (June 8) and the latest was 181 (June 30) (Figure 2.4). The earliest and latest red foxes were captured on camera were 162 (June 11) and 187 (July 6) (Figure 2.4). Arctic and red foxes tend to be seen consuming nests through egg laying and much of incubation but are seen less at the end of incubation and the start of hatching. Grizzly bears were observed later in incubation and were present for a shorter period. Grizzly bears were seen from 176 (June 25) to 186 (July 5) (Figure 2.4). We captured polar bears on camera on Julian days of 166 (June 15) and 201 (July 20) (Figure 2.4). Polar bears were observed early in incubation and later during hatching. Herring gulls were observed throughout the duration of breeding, acting as a constant threat of predation. The earliest and latest herring gulls were observed on camera were Julian date 156 (June 5) and 190 (July 9), respectively (Figure 2.4). The earliest sandhill cranes were captured on camera was 164 (June 13) and the latest was 174 (June 23) (Figure 2.4). Sandhill cranes were observed from the start to middle of incubation. Bald eagles were first observed on Julian date 159 (June 8) and last observed on 181 (June 30) (Figure 2.4). Like herring gulls, bald eagles were found for the majority of the breeding season, from the start of egg laying through most of incubation. We observed 6 out of the 7 documented nest predators between 176

(June 25) until 181 (June 30), establishing the period in the breeding season with the most complex predator community (Figure 2.4).

Predation events happened throughout the entire day but the highest number of predations happened at night (Figure 2.5). Arctic fox predations occurred from 23:00 to 11:00 and the highest number of predation events happened from 0:00 to 05:00 (Table 2.17). No predation events from arctic foxes happened from 12:00 to 22:00. Predation events by red foxes occurred infrequently (Table 2.17) and happened at random times (03:00, 17:00, and 23:00). Polar bear predation events were similar to red foxes (Table 2.17), occurring at low rates and at random times (03:00, 15:00, and 18:00). The majority of grizzly bear predations were in the morning (01:00 to 04:00), but also occurred throughout the day (Table 2.17). Herring gulls predations did occur at night but most predation events were between12:00 and 19:00 (Table 2.17). Sandhill crane predations happened as single predation events (Table 2.17) and at random times (08:00, 19:00, and 20:00). Timing of predation for each species can be found in Appendix A (Figure 1-7).

When we examined all 53 nests with observed predators found our top model to be Julian Date of Predation and Julian Date of Predation^2 (Table 2.18). We used estimates from our top model to graphically display probability of predation from specific predator category relative to the aerial predators as the breeding season progressed (Table 2.19). Compared to aerial predators, arctic foxes had a peak probability of 93% from 170–172 (Figure 2.6). Sandhill cranes had a peak probability of 86% from 171–173 (Figure 2.6). We found grizzly bears had a peak probability of 89% on 182 and 183 (Figure 2.6). Five predation events by polar bears were captured on days 166 (4) and 201 (1), resulting in an apparent constant increase of probably as the breeding season progresses, but given the limited sample size should be interpreted cautiously (Figure 2.6). When we examined the 29 nests with observed predators and measurable incubation constancy our top model was still Julian Date of Predation and Julian Date of Predation^2 (Table 2.20).

Discussion

Nest Attendance

Despite how well common eiders have been studied, incubation constancy is rarely investigated. We were able to find only five studies that reported incubation constancy (Mehlum 1991a, Afton and Paulus 1992, Criscuolo et al. 2002, Bolduc and Guillemette 2003b, Kristjánsson and Jónsson 2011). Only two of those studies reported a range of incubation constancy (Criscuolo et al. 2002, Bolduc and Guillemette 2003b). Compared to these studies (96.3%, 99.86%, 99.6%, 99.5%, 97% and 96%, respectively), eiders we monitored had a slightly lower incubation constancy on average (95.65%). These studies monitored two different subspecies of eiders *S. m. mollissima* in Denmark (Bolduc and Guillemette 2003b) and *S. m. borealis* in Norway (Criscuolo et al. 2002), Iceland (Kristjánsson and Jónsson 2011) and in Svalbard (Mehlum 1991a). Incubation constancies from these studies were based on low sample sizes (5-24 nests) and were monitored without the use of cameras. Our study is one of the most detailed documentations of common eider nest attendance with the largest sample size of nests. Without the use of cameras, it would have been difficult to obtain this level of detail or number of nests to monitor (Ellis-Felege and Carroll 2012).

More daily recess events occurred during the day than at night. This is contradictory to what Bolduc and Guillemette (2003b) and Swennen et al. (1993) found of most recess events occurring at night. Eiders increasing daily recess events at night is likely a way for eiders to avoid predation from diurnal avian predators (Swennen et al. 1993, Bolduc and Guillemette 2003b). Eiders nesting along the Mast River may have an added protection from nesting cover that protects their nests from being discovered from aerial predators. This allows them to take recesses during the day. Midday recesses are common in upland nesting waterfowl (Gloutney et al. 1993). Gloutney et al. (1993) recommends to not conduct nest searches after 14:00 because this is when many species of upland nesting waterfowl tend to be on recess. This correlates with the hottest part of the day which would result in the nest losing the least amount of heat while the female is away.

We expected to find that colony and nest characteristics would be the most important predictors of incubation constancy, but that was not the case in our data. Incubation constancy was high and with limited variation given most of our observation days eiders were spending ≥ 95% of their time on the nest. Thus, our model that only incorporated individual bird variation as a random effect ranked highest. Other factors like body condition and age, that we did not measure, may play a more important role in explaining incubation constancy. These factors should be investigated in the future.

Nest Success

We examined Schmutz et al. (1983) prediction of lower egg predation at artificial nests that were < 1 m from the nearest neighboring nest and found the opposite results. We found the lowest nest success (64 nests; 2.70%) at nests that were < 1 m from a neighboring nest. It is possible that lower nest success occurred at nests that were in close proximity to another nest because it was easier for predators to find (Schreiber and

Burger 2001). Scent from a concentration of eiders may attract more predators, specifically mammalian predators, to a specific area making it easier for the predator to find a nest. Once a single nest is found, it is very simple for a predator to then search the rest of the island and find all neighboring nests. This is apparent when high rates of predation by polar bears have been reported (Rockwell and Gormezano 2009, Dey et al. 2017, Dey et al. 2018) and arctic foxes (Iles et al. 2013) resulting in large scale colony failures. The use of artificial nests could have also influenced the behaviors of predators and may underestimate that actual rate of predation.

Another possibility of our findings being contradictory to what Schmutz et al. (1983) found is the composition of the eider colony has changed. From 1978–1980 Schmutz et al. (1983) found 1,295 nests with 56% of them being within 10 m of another nest resulting in a fairly dense colony. Our nest searches were conducted in 2014–2017 in the exact same areas as Schmutz et al. (1983) where we were able to find 518 nests with 47.88% of them within 10 m of another nest. The present colony has 60% fewer individuals in it and is more dispersed. This is likely a result of higher predation rates by arctic fox, polar bears, and herring gulls following the exodus of snow geese (*Anser caerulescens*) from the area (Iles et al. 2013). Historically, there has been high numbers of nesting snow geese in the area adjacent to the Mast River eider colony. These high numbers of nesting snow geese attracted higher concentrations of predators to this area (Iles et al. 2013), but provided nest defense to the neighboring nesting eiders (Robertson 1995).

Schmutz et al. (1983) would not have been able to predict that snow goose populations in the area would have continued to increase substantially resulting in geese degrading the habitat and forcing them to move further away from the eider colony. The shift of the snow goose colony away from the eider colony resulted in an increase in predation of eider nests by arctic foxes and herring gulls as an alternative prey source (Iles et al. 2013). As a response to higher predation rates, eiders will disperse across the landscape (Dey et al. 2017) creating a larger distance between nests. The larger distance between nests could make it more difficult for predators to find nests. We were able to find this with higher nest success in nests that were > 10 m from other nests.

We found annual variation to be the primary driver of nest success. Variation in nest success between years could be the result of multiple factors (e.g., habitat availability, habitat quality, weather and a number of other factors), but the most likely predictor for eiders is predators. Changes in annual variation in nest success is likely reflective of annual variation in the predator community. Fluctuations in the number of individual predators and the composition of different species is likely the most influential driver in nest success.

Nest Predators

Complex predator communities are important drivers in nest success but so are numbers of individual predators. High numbers of herring gulls may not influence nest success as much as mammalian predators. High numbers of foxes (observed in 2014) and bears can have devastating effects on nest success (Rockwell and Gormezano 2009, Iles et al. 2013, Rockwell et al. 2013, Rockwell 2014, Dey et al. 2017). When numbers of these predators are low, eider nest success tends to be high (observed in 2016). Resulting in eiders having "boom and bust" years of nest success (Iles et al. 2013, Dey et al. 2018)

Arctic fox populations in the La Pérouse Bay area tend to follow small mammal populations (Roth 2003, Iles et al. 2013). Years when small mammal populations are high, arctic foxes tend to not feed on alternative prey items (i.e., eider eggs) and presence of in the eider colony decreases (Angerbjörn et al. 1999). This was likely what was observed in 2014 when arctic foxes predation was high and in 2016 when it was low. Arctic and subarctic regions, like the Hudson Bay Lowlands, are facing extreme effects of climate change (Dey et al. 2017, Dey et al. 2018). Most of these changes are observed in earlier melting and later formation of sea ice (Mulder et al. 2016). Earlier melting of the sea ice will result in earlier presence of polar bears in eider colonies (Rockwell and Gormezano 2009, Rode et al. 2015, Dey et al. 2017, Dey et al. 2018). Climate change on the region could be having an effect on increased grizzly bear presence in the area as well (Clark et al. 2018, Barnas et al. In Review). Increasing presence of both grizzly and polar bears could have severe consequences on eider nest success when coupled with years where arctic fox presence is high.

From plotting the earliest and latest predation event by each observed predator and comparing that to our calculated breeding season, we documented predator community changes throughout the breeding season. We found the predator community becomes increasingly complex as the breeding season progresses. Aerial predators like herring gulls and bald eagles tend to be present for the entirety of the breeding season. Because their breeding seasons in this area encompasses the same time period as eiders they are a constant threat to the nest. Foxes and sandhill cranes tended to be present at the onset of egg laying and were observed through more than half of the breeding season. Grizzly bears tended to be present later in the breeding season and were usually present for a short period of time. Barnas et al. (In Review) documented grizzly bears arriving in the eider colony around the same time each year and identified an individual by facial scarring. This suggests that a small number of bears may utilize the area around this time and may be attracted to the colony based on past experiences (Clark et al. 2018). This was also true for polar bears. Polar bear presence in the colony corresponds with sea ice breakup (Dey et al. 2017, Dey et al. 2018, Barnas et al. In Review) resulting in years where polar bears may be present when nests are available or years where very few to no nests are available.

Predation events by all predators occurred throughout the day and night, but when examining arctic fox and herring gull predation events they mimic eider recesses. The majority of arctic fox predation occurred at night or at dawn and dusk when eiders were most commonly present at the nest. This suggests that there may be an added benefit for eiders being present at the nest when arctic foxes are searching for nests. When looking at eider recesses occurring in the afternoon, we did not see any arctic fox predations. We did however find the majority of herring gull predations occurred at this time. This suggests the consensus that eiders have high incubation constancy in order to deter gull predation and that gulls tend to prey on unattended nests (Waltho and Coulson 2015).

Future Directions

Our research suggests the largest driver of incubation constancy, nest success and predation of common eiders is annual variation. Annual variation in the predator communities has the most influence on nest success and is observed in diversity in predator species and populations. We have presented one of the most detailed studies of common eider nest attendance and suggest the continued monitoring of nest attendance of eiders to better understand how nest attendance can change among years and if a larger role is present in nest success. Further study of the Hudson Bay common eider is important as it is one of the least studied subspecies (Robertson and Gilchrist 1998) and is in a region facing rapid effects of climate change (Rockwell and Gormezano 2009, Mulder et al. 2016).

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Tables

Table 2.1 Total common eider nests found, cameras deployed, nests monitored with cameras and images collected along the Mast River in Wapusk National Park, Manitoba, Canada. Some cameras captured multiple nests in one frame.

Year	Total Nests	Cameras Placed	Nests with Cameras	Images
2014	156	9	13	129,128
2015	152	36	42	1,100,040
2016	126	29	29	1,566,556
2017	84	19	19	1,662,378

Table 2.2 Summary statistics from 78 common eider nests observed using trail cameras in Wapusk National Park, Manitoba Canada.

	Average	**Standard Deviation**	**Median**	**Range**
Number of Daily Recess Events	1.40	0.50	1.21	1-10
Daily Recess Event Duration (Minutes)	43.51	85.36	23.18	0.88-1432.0
Incubation Constancy (%)	95.65	8.94	98.07	0.0-99.94
Distance from Center of the Colony	538.66	312.39	504.54	8.26-1648.06
Distance to Nearest Neighboring Nest	53.96	78.69	22.28	0.0-458.80

Table 2.3 Total daily recess events taken in a one-hour period (e.g., 0:00 = 00:00-00:59).

0:00	**1:00**	**2:00**	**3:00**	**4:00**	**5:00**	**6:00**	**7:00**	**8:00**	**9:00**	**10:00**	**11:00**
58	38	11	10	7	10	13	7	10	17	24	32
12:00	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
49	40	54	49	42	45	39	23	12	18	23	77

Table 2.4 Results of mixed model evaluating incubation constancy of common eiders monitored. χ^2/df = 1.00

Model	AICc	ΔAICc	Weight	-2 Log Likelihood
Individual Variation	1954.99	0.00	0.97	1948.94
Year	1962.54	7.55	0.02	1950.36
Distance to Nearest Neighboring Nest	1966.88	11.89	0.00	1958.80
Day of Incubation	1966.90	11.91	0.00	1958.82
Distance to Center of Colony	1969.51	14.52	0.00	1961.42
Year + Distance to Nearest Neighboring Nest	1975.14	20.15	0.00	1960.90
Year + Day of Incubation	1977.13	22.14	0.00	1963.13
Year + Distance to Center of Colony	1977.36	22.37	0.00	1963.13
Year + Day of Incubation + Distance to Center of Colony + Distance to Nearest Neighboring Nest	2005.48	50.49	0.00	1987.10

Table 2.5 Model estimates from second top model of year from a mixed model of incubation constancy of common eiders monitored.

Solutions for Fixed Effects						
Effect	**Year**	**Estimate**	**Standard Error**	**DF**	**t Value**	**P Value**
Intercept		3.9559	0.2937	73	13.6	<0.0001
Year	2014	-0.3237	0.6629	417	-0.49	0.6256
Year	2015	-0.9942	0.3597	417	-2.76	0.006
Year	2016	-0.4282	0.3643	417	-1.18	0.2405
Year	2017	0	.	.	.	.

Table 2.6 Results of mixed model evaluating number of daily recess events of common eiders monitored. $\chi^2/\mathrm{df} = 0.5$

Model	**AICc**	**ΔAICc**	**Weight**	**-2 Log Likelihood**
Year	**1284.77**	**0**	**0.5792**	**1276.77**
Year + Day of Incubation	1285.55	0.78	0.3921	1275.42
Year + Distance to Center of Colony	1285.98	1.21	0.3163	1275.86
Year + Distance to Nearest Neighboring Nest	1286.88	2.11	0.2017	1276.76
Year + Day of Incubation + Distance to Nearest Neighboring Nest + Distance to Center of Colony	1288.74	3.97	0.0796	1247.51
Distance to Center of Colony	1294.21	9.44	0.0052	1290.18
Individual Variation	1295.71	10.94	0.0024	1293.7
Distance to Nearest Neighboring Nest	1296.35	11.58	0.0018	1292.32
Day of Incubation	1297.55	12.78	0.001	1293.53

Table 2.7 Results of mixed model evaluating duration of daily recess events of common eiders monitored.

Model	AICc	ΔAICc	Weight	-2 Log Likelihood
Year	**6106.1**	**0.0**	**0.5**	**6093.9**
Year + Day of Incubation	6106.4	0.3	0.4	6092.1
Year + Distance to Nearest Neighboring Nest	6108.7	2.6	0.1	6094.5
Year + Distance to Center of Colony	6111.5	5.4	0.0	6097.3
Year + Day of Incubation + Distance to Nearest Neighboring Nest + Distance to Center of Colony	6115.2	9.1	0.0	6096.8
Individual Variation	6130.1	24.0	0.0	6124.0
Day of Incubation	6130.1	24.0	0.0	6122.0
Distance to Nearest Neighboring Nest	6133.6	27.5	0.0	6125.6
Distance to Center of Colony	6136.0	29.9	0.0	6127.9

Table 2.8 Summary statistics of nest behaviors from 78 common eider nests relative to successful (at least one egg hatched) or failed fates. Apparent nest success was 47.44%.

	Successful	**Failed**
N	37	41
Average Daily Recess Events	11.19	7.17
Average Daily Recess Event Duration	30.02	55.68
Incubation Constancy (%)	97.33	94.14
Average Number of Observation Days	19.92	11.88
Average Daily Recess Events/Observation Days	0.83	0.59

Table 2.9 Total number of cameras positioned at nests each year and their fates.

Year	Total Nests	Success	Fail	ANS
2014	6	0	6	0.00%
2015	30	3	27	10.00%
2016	25	23	2	92.00%
2017	17	11	6	64.71%

Table 2.10 Results from a binary logistic regression of common eider nest success.

Model	AIC	ΔAIC	Weight	-2 Log Likelihood
Year	**63.3**	**0.0**	**0.35**	**55.3**
Year + Distance to Center of Colony	64.1	0.8	0.23	54.1
Year + Incubation Constancy	64.4	1.1	0.21	54.4
Year + Distance to Nearest Neighboring Nest	65.2	1.9	0.13	55.2
Year + Incubation Constancy + Distance to Nearest Neighboring Nest + Distance to Center of Colony	66.5	3.2	0.07	52.5
Distance to Center of Colony	106.2	42.9	0.00	102.2
Distance to Nearest Neighboring Nest	106.9	43.6	0.00	102.9
Incubation Constancy	107.2	43.9	0.00	103.2
Individual Variation	108.6	45.3	0.00	106.6

Table 2.11 Model estimates from the top model of year from a binary logistic regression of common eider nest success. Only models within two delta AIC of the top model are presented.

Analysis of Maximum Likelihood Estimates						
Parameter		**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	**P Value**
Intercept		1	-2.8291	45.6265	0.0038	0.9506
Year	2014	1	-9.3762	136.9	0.0047	0.9454
Year	2015	1	0.6696	45.6285	0.0002	0.9883
Year	2016	1	5.2714	45.6294	0.0133	0.908

Table 2.12 Summary statistics of 78 common eider nests that were sorted into categories of < 1 m, < 5 m, < 10 m, and >10 m of their nearest neighboring nest.

Distance to Nearest Neighboring Nest (m)	0-0.99	0-4.99	0-9.99	>10
N	12	29	35	43
Number of Successful Nests	2	6	8	29
Apparent Nest Success	16.67%	20.69%	22.86%	67.44%
Proportion of Successful Nests/ Total Successful Nests	5.41%	16.22%	21.62%	78.38%
Average Daily Recess Events	1.64	1.52	1.57	1.32
Average Daily Recess Event Duration	67.68	42.50	43.07	42.36
Average Incubation Constancy	92.22%	95.28%	95.25%	95.64%

Table 2.13 Summary statistics of apparent nest success for 518 common eider nests that were sorted in categories of < 1 m, < 5 m, < 10 m, and > 10 m from their nearest neighboring nest.

Distance to Nearest Neighboring Nest (m)	0-0.99	0-4.99	0-9.99	>10
N	64	225	248	270
Number of Successful Nests	14	59	72	176
Percent of All Nests	12.36%	43.44%	47.88%	52.12%
Apparent Nest Success (Successful Nests/N)	21.88%	26.22%	29.03%	65.19%
Apparent Nest Success (Successful Nests/All Nests)	2.70%	11.39%	13.90%	33.98%

Table 2.14 Total number of common eider nests consumed by specific nest predators from 2014 to 2017. As well as, nests fates of hatched, abandoned, and unknown.

Predator	**N**	**Percentage**
Hatch	37	35.92%
Arctic Fox	24	23.30%
Red Fox	1	0.97%
Grizzly Bear	9	8.74%
Polar Bear	5	4.85%
Sandhill Crane	3	2.91%
Herring Gull	10	9.71%
Bald Eagle	1	0.97%
Abandoned	5	4.85%
Unknown	8	7.77%

Table 2.15 Total number of partial predation events by a specific predator species. Partial predators were defined as predators that did not completely destroy the nest and resulted in abandonment or hatch.

Partial Predator	N	Percentage
Arctic Fox	2	28.57%
Red Fox	2	28.57%
Grizzly Bear	0	0.00%
Polar Bear	0	0.00%
Sandhill Crane	0	0.00%
Herring Gull	1	14.29%
Bald Eagle	2	28.57%

Table 2.16 Total number of secondary predation events by specific a predator species. Secondary predators were predators that took eggs from the nest after an abandonment or partial predator.

Secondary Predator	**N**	**Percentage**
Arctic Fox	7	41.18%
Red Fox	0	0.00%
Grizzly Bear	0	0.00%
Polar Bear	0	0.00%
Sandhill Crane	1	5.88%
Herring Gull	9	52.94%
Bald Eagle	0	0.00%

Table 2.17 Number of predation events taken in a one-hour period (e.g., 0:00 = 00:00-00:59).

	0:00	**1:00**	**2:00**	**3:00**	**4:00**	**5:00**	**6:00**	**7:00**	**8:00**	**9:00**	**10:00**	**11:00**
Arctic Fox	2	5	4	0	1	3	1	1	2	1	2	2
Red Fox	0	0	0	1	0	0	0	0	0	0	0	0
Polar Bear	0	0	0	1	0	0	0	0	0	0	0	0
Grizzly Bear	0	1	0	2	2	0	0	0	2	0	0	0
Herring Gull	0	0	0	1	1	1	0	0	0	0	1	0
Bald Eagle	0	0	0	0	1	0	0	1	0	0	0	0
Sandhill Crane	0	0	0	0	0	0	0	0	1	0	0	0
	12:00	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
Arctic Fox	0	0	0	0	0	0	0	0	0	0	0	2
Red Fox	0	0	0	0	0	1	0	0	0	0	0	1
Polar Bear	0	0	0	1	0	0	3	0	0	0	0	0
Grizzly Bear	0	0	0	1	0	0	0	0	0	1	0	0
Herring Gull	1	0	2	1	0	0	1	2	0	0	0	1
Bald Eagle	0	0	0	0	0	0	1	0	0	0	0	0
Sandhill Crane	0	0	0	0	0	0	0	1	1	0	0	0

Table 2.18 Results from a logistic regression of probability of a predation event from a nest predator category compared to aerial predators using 53 failed nests with observed predators.

Model	AIC	ΔAIC	Weight	-2 Log Likelihood
Julian Date of Predation + Julian Date of Predation^2	**115.96**	**0.00**	**1.00**	**91.96**
Julian Date of Predation	143.09	27.13	0.00	127.09
Julian Date of Predation^2	143.52	27.56	0.00	127.52
Intercept Only	151.39	35.43	0.00	143.39

Table 2.19 Model estimates from the top model from a logistic regression of probability of a predation event from a nest predator category compared to aerial predators.

Analysis of Maximum Likelihood Estimates					
Parameter		**Estimate**	**Standard Error**	**Wald Chi-Square**	**P Value**
Predator	Fox	-665.00	269.70	6.08	0.01
Predator	Polar Bear	-12.08	101.90	0.01	0.91
Predator	Grizzly Bear	-3327.60	1681.70	3.92	0.05
Predator	Crane	-967.90	919.50	1.11	0.29
Julian Date of Predation	Fox	7.82	3.20	5.97	0.01
Julian Date of Predation	Polar Bear	0.11	1.16	0.01	0.93
Julian Date of Predation	Grizzly Bear	36.50	18.42	3.92	0.05
Julian Date of Predation	Crane	11.28	10.78	1.10	0.30
Julian Date of Predation^2	Fox	-0.02	0.01	5.84	0.02
Julian Date of Predation^2	Polar Bear	0.00	0.00	0.00	0.94
Julian Date of Predation^2	Grizzly Bear	-0.10	0.05	3.93	0.05
Julian Date of Predation^2	Crane	-0.03	0.03	1.08	0.30

Table 2.20 Results from a logistic regression of probability of a predation event from a nest predator category compared to aerial predators using 29 failed nests with observed predators and measureable incubation constancy.

Model	AIC	ΔAIC	Weight	-2 Log Likelihood
Julian Date of Predation + Julian Date of Predation^2	**52.95**	**0.00**	**1.00**	**28.95**
Julian Date of Predation^2	72.008	19.06	0.00	56.01
Julian Date of Predation	72.189	19.24	0.00	56.19
Intercept Only	84.002	31.05	0.00	76.00
Incubation Constancy	89.748	36.80	0.00	73.75

Figures

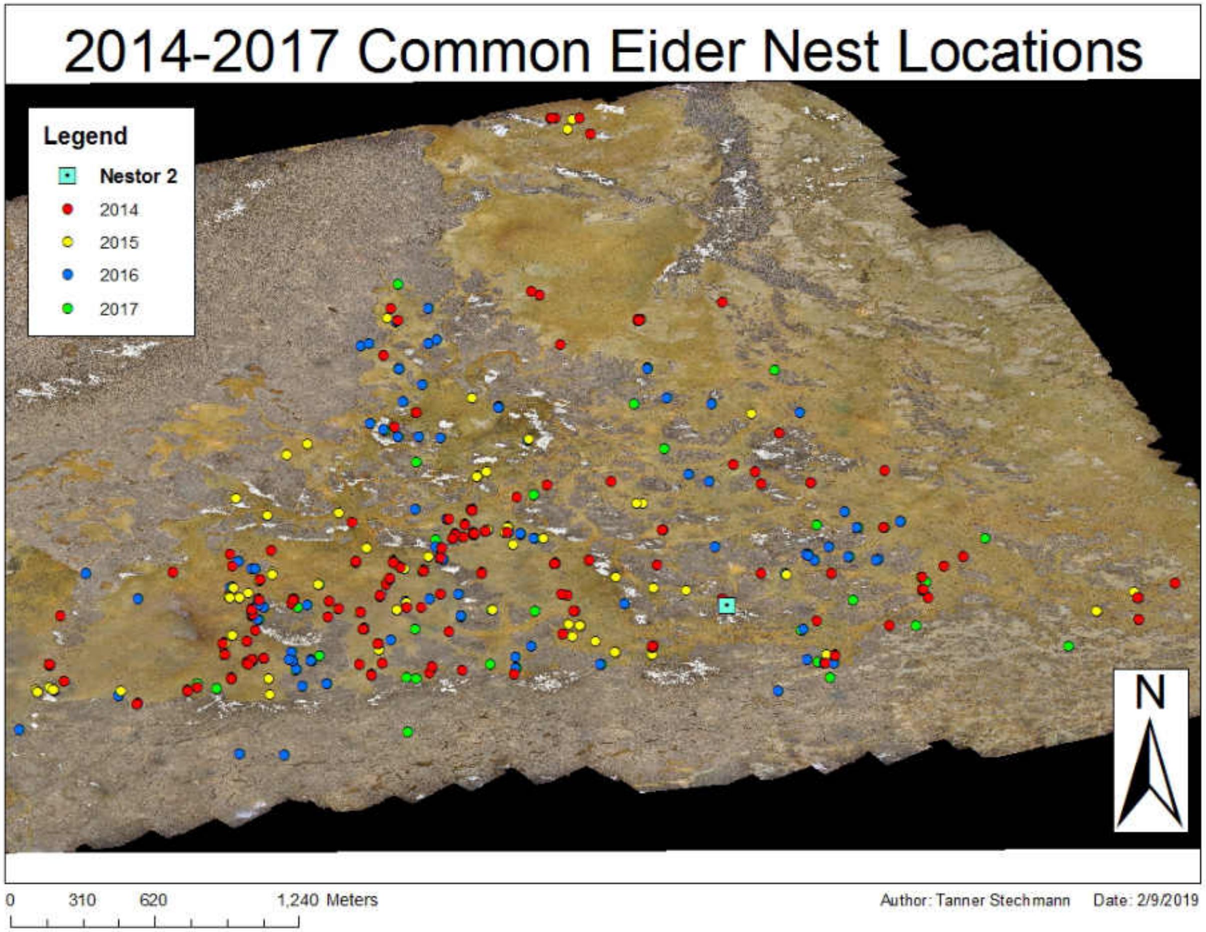

Figure 2.1 Locations of all nests found in 2014-2017 along the Mast River in Wapusk National Park, Manitoba, Canada.

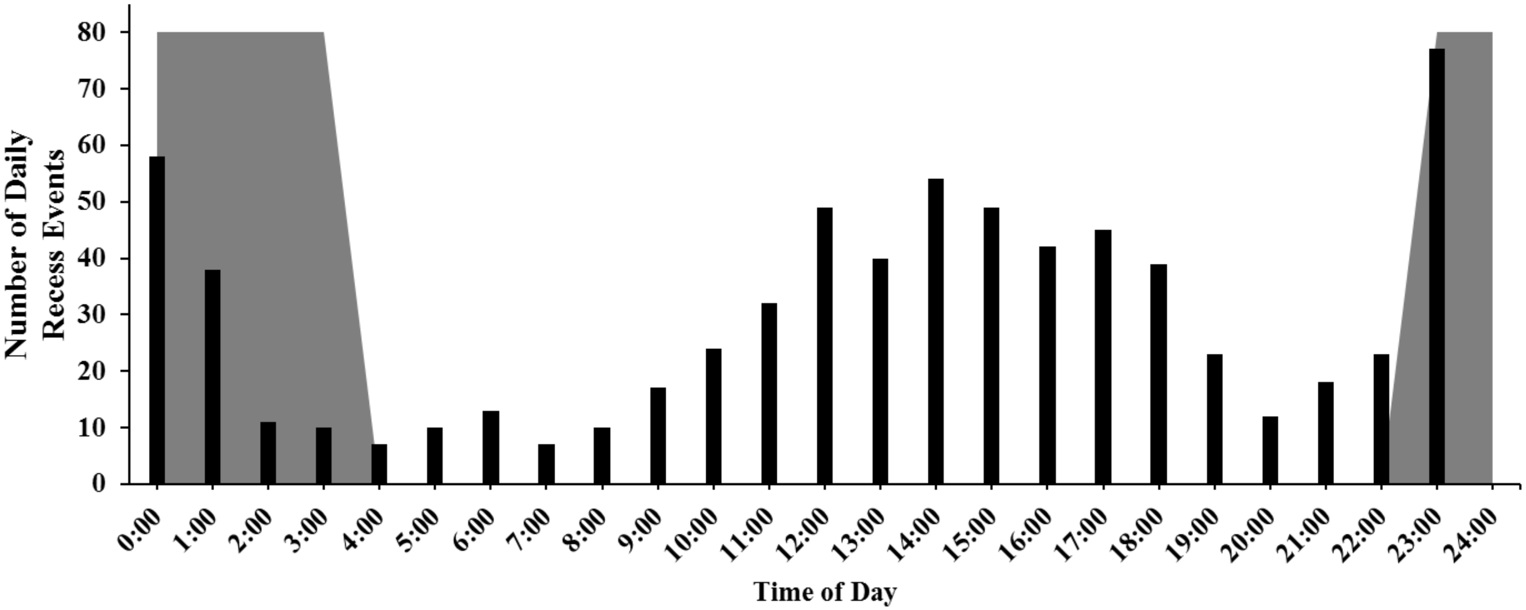

Figure 2.2 Timing of common eider daily recess events. Night is between 22:00 and 03:59 and is represented with shading.

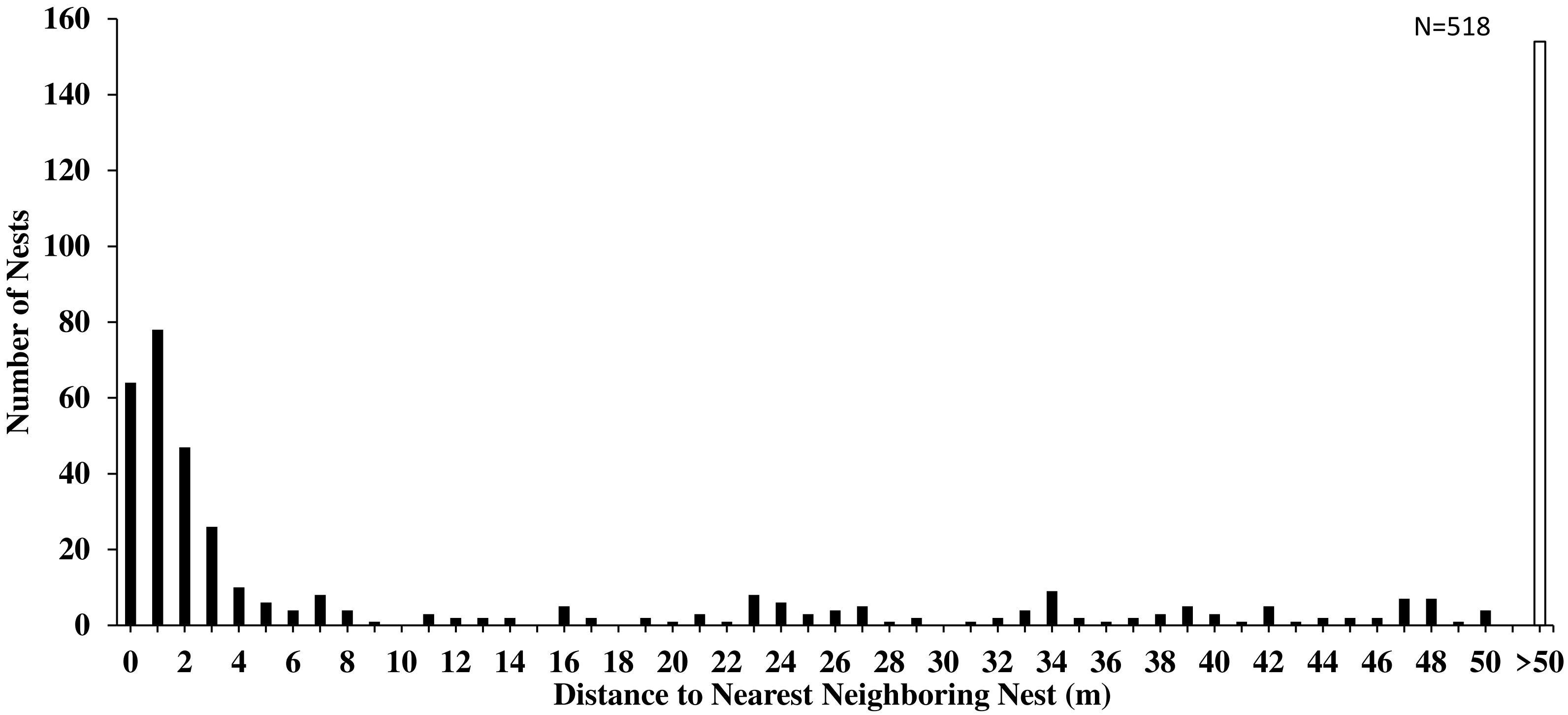

Figure 2.3 Total number of nests found at distances between nests and the nearest neighboring nest.

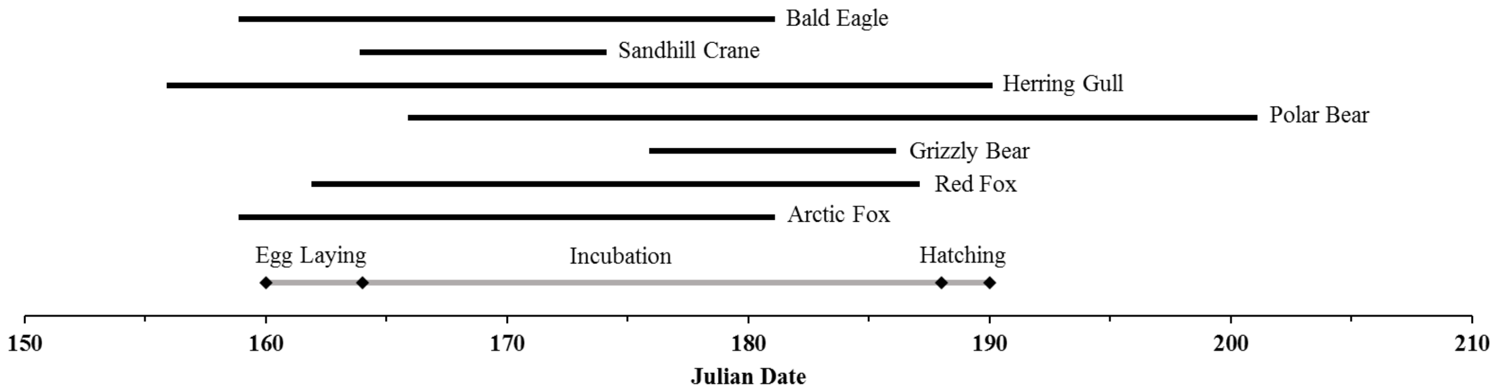

Figure 2.4 Earliest and latest predation event of each nest predator. Julian date 150 is May 29 and 210 is July 28.

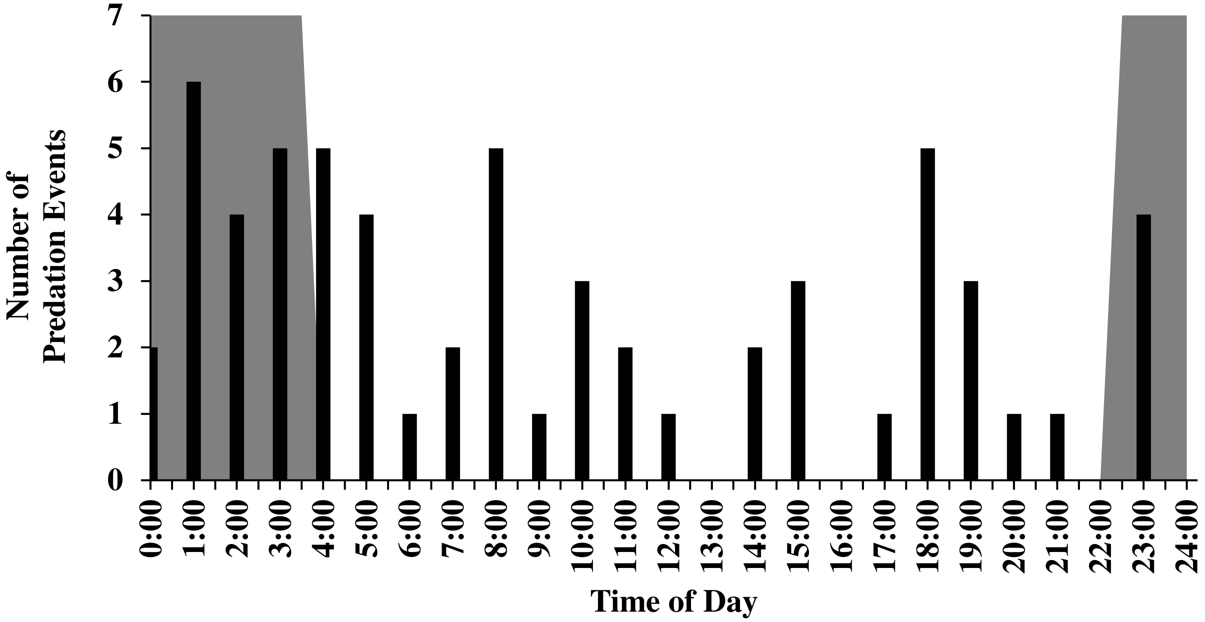

Figure 2.5 Timing of predation events. Night is between 22:00 and 03:59 and is represented with shading.

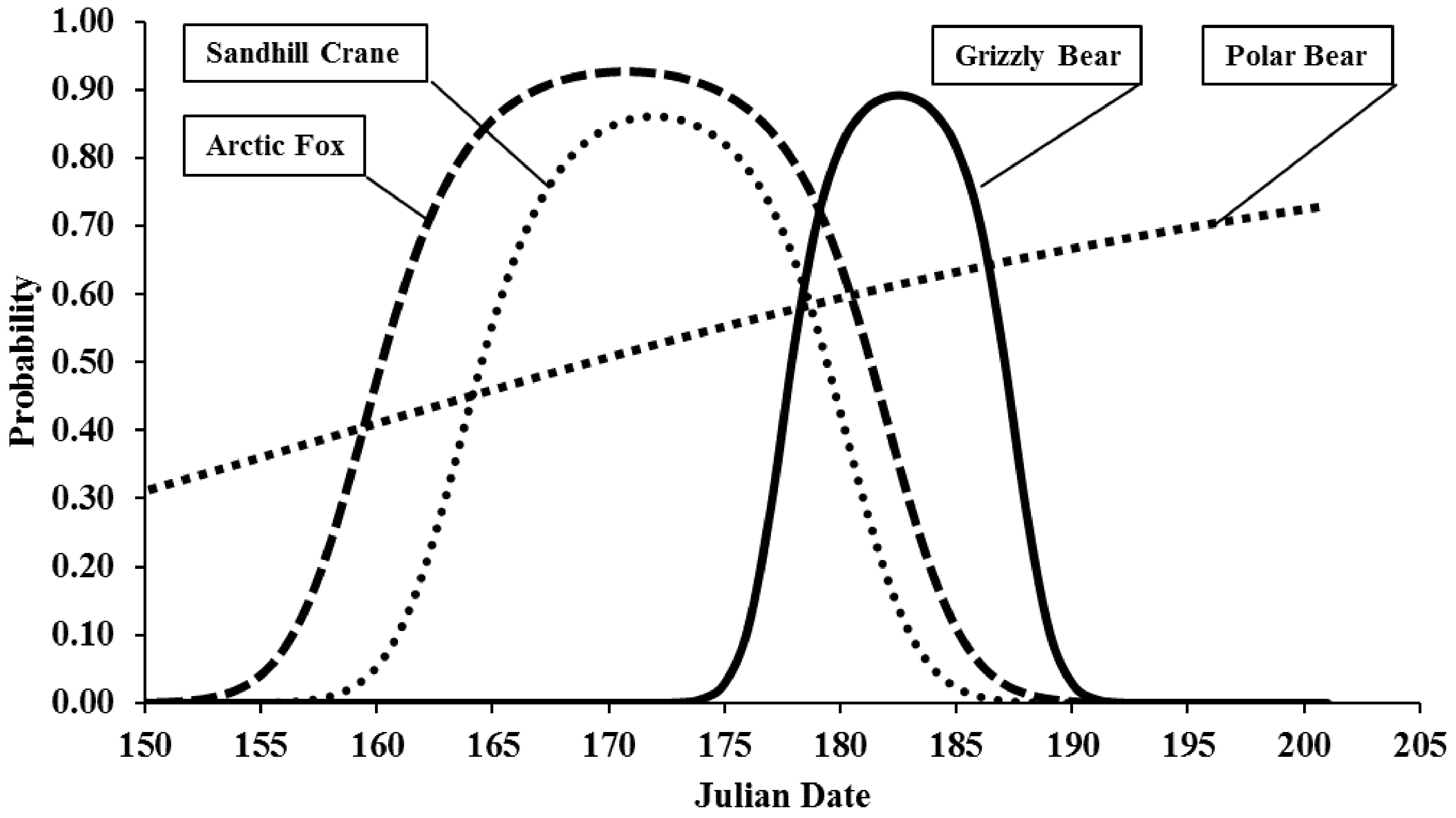

Figure 2. 6 Probability of a predation event by a predator category compared to aerial predators as the breeding season progresses. Julian date 150 is May 29 and 205 is July 24.

CHAPTER III

AQUATIC INVERTEBRATE ABUNDANCE IN WAPUSK NATIONAL PARK: INVESTIGATING POSSIBLE TECHNIQUES TO STUDY BIRDS DIETS

Abstract

Aquatic invertebrates are prey items for a large number of birds in the Hudson Bay Lowlands. These invertebrates are an indicator of habitat quality, and their community composition can often change with a changing environment. Climate change and severe habitat degradation in this region of the Arctic is resulting in potential shifts in invertebrate community dynamics. The goal of this project was to examine invertebrate community and habitat changes since 2003 and 2004 and collect stable isotopes from invertebrates to determine if they could be used to investigate diet in birds, specifically common eiders (*Somateria mollissima*). In 2016 and 2017, we collected 6,853 individual invertebrates and created a mixed model to estimate changes in invertebrate numbers and compare these to previously collected data. Our results showed a decrease in abundance in invertebrates, and that substrate type and sediment depth were important in predicting invertebrate numbers. We found habitat, as measured by substrate, changed to smaller particulate sizes since the initial sampling, indicating an increase in sedimentation. From ANOVAs and discriminate analyses we found isotopes collected in freshwater locations were not different from brackish samples but were different from marine ones. We concluded that substrates are changing in the Mast River and could be decreasing the

presences of invertebrates and that these changes may be important to a variety of bird species. Nitrogen and carbon isotope ratios could be used from aquatic invertebrates, but specific categories of invertebrates should be targeted based on known and probable prey items since invertebrate trophic levels play an important consideration in isotopic signatures.

Introduction

Invertebrate communities are important to a wide range of organisms, both in aquatic and terrestrial ecosystems (Covich et al. 1999, Malmqvist 2002). Fish rely heavily on macroinvertebrates as a food source (Malmqvist 2002) and will consume aquatic invertebrates early in life with some species continuing to feed on insects as their major food source as adults (Moyle and Chech Jr. 2004, Tyus 2012, Anderson et al. 2016). Aquatic invertebrates are also important to terrestrial predators like bats and birds who may depend heavily on the emergence of adult aquatic insects (Malmqvist 2002, Fukui et al. 2006). Some bird species depend more on the larval stages of these insects and other benthic invertebrates. Therefore, invertebrate communities are extremely important members of the food web that can impact bird species during migration, breeding, and post-breeding.

Many shorebird and some duck species will feed extensively on abundant aquatic invertebrate species found at their breeding grounds (Milakovic et al. 2001, Milakovic and Jefferies 2003). According to Sibley (2009), Scolopacidae (sandpipers, phalaropes, and allies) feed on larval and pupal stages of insects like midges (Chironomidae and Ceratopogonidae) and crane flies (Tipulidae). Some ducks like, greater scaup (*Aythua marila nearctica*), lesser scaup (*Aythya affinis*), and northern pintail (*Anas acuta*) tend to have a larger portion of their diet consisting of aquatic invertebrates during the breeding season (Baldassarre 2014). Other ducks that rely on aquatic invertebrates for the majority of their diet may exploit different invertebrates depending on the time of the year. Some sea ducks like the black scoter (*Melanitta americana*) and surf scoter (*Melanitta* perspicillata) will change their diet from mostly mollusks to a diet that contains a large portion of insect larvae during the breeding season (Cottam 1939, Baldassarre 2014). Long-tailed ducks (*Clangula* hyemalis) will feed on aquatic insects during the breeding season and will even change their feeding behaviors with the emergence of Chironomidae and Tipulidae larvae (Rockwell et al. 2009, Baldassarre 2014). Many of the sea duck adults and ducklings will utilize aquatic invertebrates following hatching (Baldassarre 2014).

Cantin et al. (1974) found that between 30% and 97%, depending on age, of common eider (*Somateria mollissima*; hereafter eider(s)) ducklings' diets in the St. Lawrence estuary were periwinkle (*Littorina* spp.). Cantin et al. (1974) also found that insects were important in the first two weeks of life with an increasing importance of Amphipoda and periwinkle as the ducklings grew. The diets of adult females are very similar to duckling diets after hatch (Cantin et al. 1974, Baldassarre 2014, Waltho and Coulson 2015). The females will temporarily move their ducklings to feeding areas more suitable for adults so females can feed on blue mussels (*Mytilus edulis*) and other larger prey (Waltho and Coulson 2015). Therefore, reductions in invertebrate communities could have negative effects on breeding and recruitment in duck populations.

Arctic and subarctic regions are experiencing some of the most rapid climate changes (Gough and Wolfe 2001, Rockwell and Gormezano 2009, Gormezano and

Rockwell 2013b, Jaatinen et al. 2016). This could have significant effects not only to the sea ice which sea ducks like eiders use during the winter but also the invertebrate community they feed on (Jaatinen et al. 2016). Changes in sea ice patterns, to include longer persistence of fast ice, could hinder access to marine invertebrates that eiders rely on in the winter and early breeding season (Jaatinen et al. 2016). Water temperature changes could also affect the quantity, quality and timing of invertebrates that they feed on, reducing fledgling success and fecundity (Jaatinen et al. 2016).

An increase in temperature of 3.9 to 4.5 °C is predicted for the Hudson Bay (Gagnon and Gough 2005) which could have implications on the birds that use that area to breed or as stopover foraging locations. Thousands of birds migrate to the Hudson Bay lowlands every spring before heading farther north (Rockwell et al. 2009). In particular, common eiders (*Somateria mollissima*; hereafter eider(s)), along with many species of shorebirds, breed along the western Hudson Bay in an area known as La Pérouse Bay. Eiders commonly feed on marine invertebrates (e.g. mussels and urchins) from post breeding and throughout the winter (Baldassarre 2014) and will travel to breeding areas with stored resources. Jaatinen et al. (2016) found that eiders will use local sources of mussels at the breeding grounds if they have an insufficient amount of stored resources from their wintering grounds. Eiders nesting at La Pérouse Bay have a unique opportunity to utilize local freshwater invertebrates in rivers and creeks that thaw before the Hudson Bay. For example, the Mast River and Wawao Creek may provide food options just prior to nesting to supplement insufficient nutrient stores, especially in years when sea ice persists longer in the spring making the preferred mussels inaccessible.

Objectives

The goal of this project was to estimate aquatic invertebrate abundance and community composition by examining seasonal, temporal, spatial, and habitat characteristics for a river and a creek in Wapusk National Park, Manitoba, Canada. We were also interested in determining habitat changes within the river and creek. We characterized the stable isotopic signatures of the invertebrates collected that later could be used to investigate resource accumulation in eiders and other breeding birds in Wapusk National Park.

Methods

Study Locations

We collected aquatic invertebrate samples in Mast River and Wawao Creek (Figure 1.1) in northwestern Wapusk National Park, Manitoba, Canada located along La Pérouse Bay in June and July (2003, 2004, 2016, and 2017). Additional samples were collected at the mouth of the Mast River and near Churchill, Manitoba, Canada (2016 and 2017). Detailed site descriptions of this area can be found in Schmutz et al. (1983), Waldeck and Andersson (2006), Iles (2012), Iles et al. (2013). Both the Mast River and Wawao Creek tend to be shallow (22.6 cm average depth) with cobble to sand bottoms and varying amounts of silt deposits. Vegetation on the islands within the river and creek deltas is mainly a mixture of shrubs (*Betula glandulosa, Myrica gale, and Salix* spp). (Schmutz et al. 1983).

Sampling Sites

In 2003, invertebrates were collected at 12 freshwater sites in the Mast River and 6 of the original 12 freshwater sites were sampled in 2004. To investigate temporal changes in the number and type of specific aquatic invertebrate species, in 2016 and 2017 we revisited these freshwater sites and added an additional 9 sites along the Mast River. We also sampled 6 marine areas, 8 brackish areas at the mouth of the Mast River (Figure 3.1), and 6 freshwater sites in the Wawao Creek (Figure 3.2, Table 3.1). See Appendix B Table 1 for exact sampling locations.

Field Methods

Samples from freshwater and brackish water sites were collected using a 30.5 cm^2 (12 in^2) Surber Sampler (Bogan et al. 2017). We collected three replicate samples within one meter of each individual sampling site in June and repeated in July. Larger rocks within the frame of the Surber sampler were removed and smaller rocks, cobble, gravel and sediment were dislodged to approximately 2.5 cm depth in order to disturb invertebrates on the rocks or in the sediment. Collected materials were washed into a one-gallon zip-lock bag followed by an additional wash to remove any remaining specimens into the bag. We recorded a variety of habitat characteristics at each sampling site during the 2016 and 2017 surveys. We measured water salinity in 2017 but not in 2016, due to a lack of equipment, using a 70 parts per thousand (ppt) salinity probe (TekcoPlus Ltd, Hong Kong, China). Approximate water flow (slow, medium, or fast), substrate type (gravel, silt/mud, or cobble), substrate size (small, medium, or large), presence of litter (yes or no), and presence of vegetation (type of vegetation) were determined by visual inspection. We measured water depth and sediment depth to the nearest half-centimeter using a meter stick. We also recorded water temperature (Appendix B Table 2).

Initially in 2003, samples were sorted into 9 families or orders (hereafter categories). In 2004, samples were further sorted into 15 categories (Tipulidae, Chironomidae, Certopogonidae, Plecoptera, Trichoptera, Ephemeroptera, Gastropoda, Oligochaeta/Nematoda (lumped), Coleoptera, Simuliidae, other Diptera, Hirduinea, Amphipoda, Bivalvia, and Other) based on potential as food sources for birds in the area (Rockwell et al. 2009, Sibley et al. 2009). Samples were sorted into these 15 categories in 2016 and 2017. While common eider were of primary interest, we also considered diets of the following bird species: long-tailed ducks (*Clangula hyemalis*), lesser yellowlegs (*Tringa flavipes*), solitary sandpipers (*Tringa solitaria*), spotted sandpiper (*Actitis macularius*), short-billed dowitcher (*Limnodromus griseus*), Hudsonian godwit (*Limosa haemastica*), semi-palmated sandpiper (*Calidris pusilla*), least sandpiper (*Calidris minutilla*), dunlin (*Calidris alpine*), and red-necked phalarope (*Phalaropus lobatus*). Abundance of each invertebrate category at each sampling location was recorded.

In 2016, all sorted invertebrate samples were placed into a single bag for each sampling site and frozen for stable isotope analysis. The goal of lumping these samples was to understand the stable isotope ratios at a landscape level. Samples were further sorted into plastic sampling envelopes by Amphipoda, Tipulidae, other or Bivalvia (in marine samples) for isotopic analysis in 2017 to better investigate specific potential prey items for eiders. These four specific sub-sampling delineations were created based on potential prey of Amphipoda and Tipulidae and the regular diet of mussels (Bivalvia).

Eiders could be actively seeking these organisms because they are easier to see and catch. Amphipoda also were sorted separately because they are found across the entire salinity gradient and could be a better representation of isotope ratios. All samples were frozen in preparation for isotopic analysis upon return to the United States.

Marine samples were collected by hand or with a small net along six, 100 meter transects (Figure 3.1). Marine samples were only collected once, in July, due to a lack of access to sampling sites from fast ice in June. Five sampling sites were selected near the brackish water sampling sites and one was selected near Churchill, MB, Canada in an area known to have blue mussels (*Mytilus edulis*), a regular food source for eiders. Samples were sorted and frozen in the same manner as the freshwater and brackish samples with the addition of a category for mussels (Bivalvia) in the subsampling.

Isotopic Preparation

In preparation for isotopic analysis, samples were placed into individual 1.5 mL microcentrifuge tubes (USA Scientific, Ocala, FL, USA) by sample site and invertebrate type. In 2016, mussels were not removed from shells and were placed into 50 mL conical centrifuge tubes (Corning, Corning, NY, USA). In 2017, mussels were removed from shells prior to drying and were placed in 1.5 mL centrifuge tubes. Samples were then dried using a Savant™ SpeedVac™ (Thermo Scientific, Waltham, MA, USA) with no heat and under vacuum (Banack et al. 2014). Mussel samples were dried in a FreezeZone 2.5 L freeze dryer (LabConco, Kansas City, MO, USA) because of the size of the tubes. Dried samples were then powdered in the tube using a pestle and then weighed to 1.5 mg ± 0.5 mg. Weighed samples were placed into 5 x 9 mm tin capsules (Costech, Valencia, CA) and placed into a 96 well plate.

Stable Isotope Analysis

Isotopic analysis was conducted by the U.S. Environmental Protection Agency Atlantic Ecology Division laboratory where carbon and nitrogen isotope analysis was conducted, using a Calo-erba NA 1500 series II elemental analyzer (Lakewood, NJ, USA) interfaced with an Elementar Optima™ isotope ratio mass spectrometer (Beverly, MA, USA). Samples were burned at 1,020°C in the presence of a chromic oxide catalyst. Carbon and nitrogen isotope ratios were measured by the mass spectrometer from evolved gases. Two internal laboratory standards were used for every ten unknown samples in a sequence. Stable isotope ratios were expressed in δ notation as parts per thousand (‰) and were compared with Vienna Pee Dee Belemnite for carbon or atmospheric air for nitrogen. Reference material analyzed over the course of the sample analysis was measured with a ± 0.30 ‰ precision.

Data Analysis

Collected invertebrate samples were compared to historical invertebrate samples (collected in 2003-2004) to investigate temporal changes. Distribution, abundance, and diversity of invertebrate categories were compared to better understand invertebrate community changes. Mixed models were constructed using a Poisson distribution in PROC GLIMMIX in SAS Studio 3.7 (Cary, NC, USA). Response variables were number of individuals in each invertebrate category. Fixed effects were year and season (June or July sampling). Random effects included river (what river sampled from), river*site (where in the river it was sampled), and river*site*year*season (when the sample was specifically taken). We included summary statistics for samples in 2003, but since they were sorted differently (i.e., Chironomidae, Ceratopogonidae, Coleoptera, Simuliidae, Hirudinea, and Mollusca were not collected), we excluded them from subsequent analysis.

Silt depth and substrate type were compared to understand landscape changes that could influence invertebrate abundance and possible future nest site locations (Mehl et al. 2005). From the 2017 data, we investigated the importance of these habitat variables on abundance of specific invertebrate categories using the same mixed model approach as previously described. We excluded marine samples from this analysis because samples were collected only once during the year. Fixed effects were water depth, silt depth, substrate type, salinity, temperature, season and flow. We standardized the fixed effects of water depth, silt depth, salinity, and temperature to a mean of zero. We used Akaike Information Criterion (AICc) to select the best predictors for estimating number of individuals.

We performed an analysis of variance (ANOVA) in R Studio v1.2 (R Studio Boston, MA, USA) followed by a Tukey's HSD test to investigate differences in $\delta^{13}C$ and $\delta^{15}N$ values among the different water types (Mast River freshwater, Wawao Creek freshwater, Brackish, and Marine). ANOVA's were conducted for individual years 2016, 2017, and by pooling data from 2016 and 2017 together. We explored $\delta^{13}C$ and $\delta^{15}N$ values in Amphipoda samples collected in 2017 among the different water types because Amphipoda were the only category found in all water types. We also investigated $\delta^{13}C$ and $\delta^{15}N$ values in samples collected in 2017 among the different sub-sorting categories using an ANOVA. We further assessed $\delta^{13}C$ and $\delta^{15}N$ values among the different water types using a discriminant analysis.

Results

Invertebrate Community Changes

A total of 2,046 invertebrates collected in 2003 (887 total; 73.92/site) and 2004 (1,159 total; 193.16/site) from 7 different categories in 2003 (9 possible categories) and 10 in 2004 (15 possible categories) (Table 3.2). Compared to 6,853 invertebrates were collected in 2016 (4,215 total; 102.8/site) and 2017 (2,638 total; 61.35/site) from 14 different categories in 2016 and 12 in 2017 (Table 3.2). The most abundant categories collected in 2003 and 2004 were Plecoptera (547; 26.74%), Tipulidae (354; 13.34%), and Oligochaete/Nematoda (346; 16.91%) (Appendix B Table 3). The most abundant categories collected in 2016 and 2017 were Chironomidae (1476; 21.54%), Plecoptera (1271; 18.55%), and Trichoptera (828; 12.08%) (Appendix B Table 3). A total of 8,899 invertebrates were collected in all years. The most abundant categories for all years were Plecoptera (1,818; 20.43%), Chironomidae (1,749; 19.65%), Ephemeroptera (1,199; 13.47%), and Trichoptera (967; 10.87%) (Appendix B Table 3).

We found overall abundance of individuals within each invertebrate category increased between our two sampling seasons (i.e., more invertebrates later in the summer) but decreased across years (Table 3.3). We compared the total number of individuals collected at the six historic sites sampled in 2004 (D, I, K, L, S5, S6) and compared them to the total number of individuals collected in 2016 and 2017. A total of 1,159 (193.16/site) individuals were collected in 2004 and a total of 548 (91.33/site) and 394 (65.66/site) individuals collected in 2016 and 2017, respectively. This resulted in a 53% and 66% decrease in number of individuals since 2004. Because total numbers were low in 2016 and 2017 compared to 2004, we also compared total number from 2004 to a combined total of 2016 and 2017 (Table 3.4). We observed decreases in four categories (i.e., Ceratopagonidae 70%, Tipulidae 59%, Chironomidae 37%, and Oligochaete/Nematoda 29%) important to shorebirds and to waterfowl species like eiders (Table 3.4, Figure 3.3). Because methods and personnel changed across the years of study, and because individual sorting of invertebrates can be researcher biased, loss in overall individual abundance should be interpreted cautiously.

Habitat Changes

Substrate types categorized at historical sites in 2016 and 2017 were compared to those categorized in 2003 and 2004. Between consecutive years, there was very little change in substrate types (two changed in 2017). However, between 2003 and 2017, we observed changes in substrate for 10 sites. We found 7 sites changed from cobble to gravel, 2 from cobble to silt, and 1 from gravel to silt (Table 3.5). When comparing the six historical sites from the section above, we see that half of the sites increased in sedimentation (i.e., cobble to silt and cobble to gravel).

We found that each aquatic invertebrate category had a different top model; however, we did find that flow, season, substrate type, and sediment depth were important predictors for most categories. We found flow, season, substrate type, and sediment depth in 100%, 94%, 75%, and 69% of our top models, respectively. We present the top models within two delta AIC scores for simplicity (Table 3.6; full model sets are in Appendix B Table 4). Even though salinity, temperature and water depth were in the full model, which was the top model for several categories, the estimates for these predictors do not suggest they were important drivers of invertebrate abundance based upon broad confidence intervals (Appendix B Table 5).

We found little variability in salinity among the Mast River, Wawao Creek, and brackish water samples (Appendix B Table 6, 7, and 8). Average salinity for both the Mast River and brackish water samples were 0.09 ppt. Average salinity readings from the Wawao Creek were 0.32 ppt. However, freshwater and brackish samples did differ from marine water samples, which had a salinity of 5.31 ppt (Appendix B Table 9). We found an increase in salinity from June to July for Mast River, Wawao Creek and brackish water samples (Appendix B Table 6, 7, and 8). Salinity levels at all sites remained less than 1.0 ppt.

Aquatic Invertebrate Stable Isotopes

From the ANOVA, we found marine δ^{13}C samples to have statistically significant differences from the other three water types when examined within year (Figure 3.4, 3.5, 3.6). We found no statistically significant difference between Mast River and Wawao Creek δ^{13}C samples when examined within year but we did some difference between freshwater samples and brackish (Figure 3.4, 3.5, 3.6). We found no statistically significant differences in δ^{13}C samples among categories (Figure 3.7), but did find marine to be different when investigating within Amphipoda (Figure 3.8). For δ^{15}N samples, we found statistically significant differences among the Mast River, Wawao Creek, and marine when examining within year (Figure 3.9, 3.10, 3.11). Differences between Mast River and Wawao Creek samples are likely due to different proportions of categories in the samples (Table 3.7). When we examined δ^{15}N samples among categories we found statistically significant difference between Amphipoda and other but did find Bivalia and Tipulidae to be unique (Figure 3.12 and 3.13. We found no statistically significant difference between Mast River and marine $\delta^{15}N$ samples within Amphipoda, but did find brackish to be different (Figure 3.14).

Based on our conclusions from the ANOVA, we found a lack of differences between the Mast River and Wawao Creek $\delta^{13}C$ sources. As a result, we combined those categories into freshwater for the discriminant analysis. We found marine samples were grouped with marine samples, meaning marine samples were uniquely marine (Table 3.8, 3.9, 3.10, 3.11, 3.12, 3.13) when examined among years and categories. Freshwater samples were often classified as freshwater, but were also classified as brackish at a lower percentage (Table 3.8, 3.9, 3.10, 3.11, 3.12, 3.13). Brackish samples were classified with brackish samples at a low percentage and were often classified with freshwater samples, meaning brackish samples were not that unique from freshwater samples (Table 3.8, 3.9, 3.10, 3.11, 3.12, 3.13).

Discussion

Our work suggests a significant loss in overall number of individuals within a category from 2004 to 2017. These losses could be an indication of habitat or substrate changes across the sampling locations. According to Mandaville (2002) aquatic invertebrates are often used as indicators of stream health, where specific assemblages of aquatic invertebrates are expected to be found in specific habitat types and water qualities. For example, the majority of Plecoptera species are found in clear, fast flowing water with a rocky substrate and are commonly used as an indicator species (Frison 1935). We conclude changes in abundance of specific invertebrate categories could be an indicator that the habitat is indeed changing and that is likely linked to the increased sedimentation we have observed since 2003.

Much of the landscape surrounding the Mast River and Wawao Creek deltas has been severally degraded due to lesser snow goose (*Anser caerulescens caerulescens*) destructive foraging (Abraham and Jefferies 1997). This has resulted in hypersalinity, soil degradation, desertification of marshes and drastic losses of vegetation (Iacobelli and Jefferies 1991, Srivastava and Jefferies 1996). The intense loss of vegetation has led to decreased soil moisture, increased evapotranspiration rates and increased the deposition of salts (Srivastava and Jefferies 1996). The resulting high salinity of the soil can limit the survival and growth of plants leaving much of the soil exposed to erosion from rainfall and spring melt runoff (Pinmentel et al. 1995). The exposed soil washes into rivers and streams causing increased sedimentation. Such changes may greatly alter brackish or freshwater areas, by increasing sedimentation and salinity.

Arctic and subarctic regions, like the Hudson Bay Lowlands, are currently facing some of the greatest effects of climate change on Earth (Dey et al. 2017, Dey et al. 2018). Most of these changes are observed in sea ice with earlier melting and later formation, resulting in greater year-to-year variation in sea ice conditions (Mulder et al. 2016). Models produced by Gough and Wolfe (2001), predict that with an increase in atmospheric CO_2 the Hudson Bay will be ice-free from May until September by 2040. This increases the ice-free period of the Hudson Bay by nearly two months, which could cause dramatic changes not only to local communities but also to the entire region. They also predict that with an increase in earlier ice breakup there will be an increase in spring and summer precipitation. The increased precipitation will cause a positive feedback increasing the rate of earlier ice breakup as well as increasing the flow of rivers leading to increased erosion and sedimentation.

Gough and Wolfe (2001) and Gagnon and Gough (2005) predict an increase in temperature will cause a land warming experience during June and July, ultimately increasing the rate of evaporation on the landscape. This increase in temperature and evaporation will lead to a decrease in soil moisture and an increase in the thawing of the region's permafrost (Gagnon and Gough 2005). As the permafrost melts, it will decrease the soil moisture, increase evaporation and land warming, decrease the amount of above ground biomass and inevitably increase the amount of soil erosion into rivers and streams. Changes in substrate and sedimentation may simply be caused by the river naturally changing.

During our research, we observed eiders in the Mast River diving and dabbling working upstream of fast moving water feeding on invertebrates prior to incubation. This suggests that eiders in La Pérouse Bay are using freshwater aquatic invertebrates prior to and during egg laying and therefore could be using these local resources during incubation. To identify if eiders were in fact feeding on freshwater invertebrates we collected stable isotopes from aquatic invertebrates to compare to stable isotopes in eiders in the future. However, we were unable to find clear differences among stable isotope ratios of $\delta^{13}C$ from aquatic invertebrate samples collected in the Mast River and Wawao Creek. This was not surprising since these locations are both freshwater sources. We did find differences in $\delta^{15}N$ samples, but this is likely due to samples have different proportions of invertebrates from different feeding habits (Merritt and Cummins 1978). We expected to find unique stable isotope values as we moved across the salinity gradient from freshwater environments to marine. We found that stable isotope ratios from freshwater and brackish sources were different from marine samples but were not unique from one another. The lack of variability in stable isotope ratios is likely due a lack of variability between freshwater and brackish water sources. The stable isotopes we chose may not have provided the best signatures needed for these evaluations. Stable isotopes of Sulfur may be a better option for future research (Winiarski et al. 2012).

From our salinity readings, we found that our brackish sampling locations were not different from our freshwater locations as we did not hypothesize. We predicted that the areas we sampled as brackish locations were in close proximity to the Hudson Bay and would experience tides providing a brackish environment. Average salinity of marine sampling locations did differ from freshwater and brackish samples, but when we looked directly at the salinity values we found that sites B, D, and E were all below 1 ppt. This suggests these three marine sites and the brackish sites experience less tidal action than initially predicted, causing these sites to be more like freshwater sites. Spring melt runoff and a lack of tidal action until the melting of fast ice could also be increasing the amount of freshwater in these areas.

When investigating differences among sub-sorted categories of aquatic invertebrates, we were unable to find any differences in our $\delta^{13}C$ samples. This is likely due to the fact that aquatic invertebrates in our samples are using the same carbon sources (Inger and Bearhop 2008). It is also possible that our sample size of Bivalvia was too small resulting in a lack of diversity in our $\delta^{13}C$ samples. We would expect to find that samples from a marine environment would have a different carbon signature because marine carbon sources tend to come from marine algae (Inger and Bearhop 2008). Mussels collected in these areas may be feeding on more freshwater biota that enters the system from increases discharge during spring melt and these areas may be less saline than predicted.

When we examined our $\delta^{15}N$ samples from sub-sorted categories, we were unable to find differences in Amphipoda and Other. The lack of difference between the two groups is likely due to the lack of difference in functional feeding groups (Mandaville 2002). Amphipoda tend to be collector-gatherers and Other (pooled sampled) consists of collector-gatherers, scrapers, shredders and predators (Mandaville 2002). Unique values for Amphipoda may be hidden due to the smaller sample size. Only 12 samples of Amphipoda were collected in 2017 compared to 69 samples of Other.

However, we did find a difference among Bivalvia (group a), Amphipoda and Other (group b), and Tipulidae (group c) like we predicted. It is most likely that we found a difference among these groups because they have different feeding habits and are found in different functional feeding groups (Merritt and Cummins 1978). Bivalvia are collector-filterers and feed on suspended particles like phytoplankton (Merritt and Cummins 1978, Hobson and Welch 1992), Amphipoda are collector-gatherers and feed on dead organisms, detritus, or other food particles (Merritt and Cummins 1978) and Tipulidae are shredders and feed on plant material that has usually fallen into the water (Merritt and Cummins 1978). We would expect to find that invertebrates with different feeding habits should have different $\delta^{15}N$ values and would be found at different trophic levels (Bennett and Hobson 2009). When we look at the location of these groups, we can see that the majority of Tipulidae is at the lowest trophic level, Amphipoda and Other are in the middle and Bivalvia is at the highest trophic level, relative to the samples we collected.

Future Directions

Findings from our research suggest that the aquatic invertebrate abundance has been lost over the past 13 years, and it could be influenced by changes in the local habitat. We suggest the continued monitoring of the aquatic invertebrate community and habitat to better understand the effects of lesser snow goose degradation and climate change. Continuing to monitor the aquatic invertebrate community could also provide insights into losses of local bird abundance and diversity. Even though we found little variation in our stable isotope ratios among water types we still believe that it is important continue to investigate differences in stable isotope ratios that may exist in prey items. We suggest changing the sampling locations of our marine locations and targeting specific prey items from different water types to establish unique stable isotope ratios of those prey items. We suggest establishing stable isotope ratios of blue mussels from marine environments and stable isotope ratios of Tipulidae larvae from freshwater environments. Once these isotope ratios are established, we can then investigate if these isotopes are in tissues of female common eiders. We also suggest using other stable isotopes, which could give unique ratios that we were unable to obtain with ^{13}C and ^{15}N.

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Tables

Table 3.1 Number and type of aquatic invertebrate sampling sites collected from 2016 and 2017. All freshwater and brackish water sites were collected using a Serber sampler. All marine sites were collected by hand along a 100-meter transect. Samples were collected in Wapusk National Park, Manitoba, Canada.

Type	2003	2004	2016	2017
Mast River	12	6	21	23
Wawao Creek	0	0	6	6
Brackish	0	0	8	8
Marine	0	0	6	6

Table 3.2 Total number of aquatic invertebrates collected, number of sampling sites, and categories in each sampling year.

	2003	**2004**	**2016**	**2017**
N	887	1,159	4,215	2,638
Sampling Sites	12	6	41	43
N/Sampling Site	73.92	193.17	102.80	61.35
Categories	7	10	14	12
Possible Categories	9	15	15	15

Table 3.3 Results of mixed model with a Poisson distribution from aquatic invertebrate samples collected along the Mast River and Wawao Creek in Wapusk National Park, Manitoba, Canada. DNC stands for Did Not Converge.

			Total Tipulidae	Chironomidae	Ceratopogonidae	Plecoptera	Trichoptera	Ephemeroptera	Gastropoda
	Chi-Square/DF		0.81	2.14	0.98	1.59	1.58	DNC	1
	River		1.2012	0.73	0.2935	0.2234	0*	DNC	0.001225
	River*Site		1.4027	0.06985	0.05858	1.256	0.5925	DNC	0.2836
	River*Site*Season*Year		0.8119	0.7191	1.8807	1.6309	0.6577	DNC	1.2713
Year									
	Solutions Estimates								
		2004	0*	0*	0*	0*	0*	DNC	0*
		2016	-1.8704	-1.1805	-2.33	-1.613	-0.2261	DNC	-2.6075
		2017	-1.6028	-1.562	-2.6204	-1.5486	-0.7544	DNC	-3.3616
	Least Squares Means Estimates								
		2004	-0.2561	2.4937	0.5076	0.865	0.2315	DNC	1.1232
		2016	-2.1264	1.3132	-1.8224	-0.7481	0.005349	DNC	-1.4843
		2017	-1.8589	0.8975	-2.1128	-0.6837	-0.523	DNC	-2.2384
	F Value		9.93	15.35	13.29	5.39	5.34	DNC	27.39
	Trend (+/-/=)		-	-	-	-	-		-
Season									
	Solutions Estimates								
		June (A)	0.05791	-3.8993	0.1017	1.8417	0.4148	DNC	0.03698
		July (B)	0*	0*	0*	0*	0*	DNC	0*
	Least Squares Means Estimates								
		June (A)	-1.3848	1.3735	-1.0917	0.7319	0.112	DNC	-0.848
		July (B)	-1.4428	1.7628	-1.1934	-1.1098	-0.3028	DNC	-0.885
	F Value		0.06	6.45	0.09	49.9	5.84	DNC	0.02
	Trend (+/-/=)		-	+	-	-	-		=

Table 3.3 Continued

		Oligochaete/Nematoda	Coleoptera	Other Diptera	Simuliidae	Hirudinea	Amphipoda	Mollusca
Chi-Square/DF		1.33	0.59	0.86	0.54	DNC	DNC	1.17
River		1.828	0.04321	0.1738	0.6222	DNC	DNC	1.6048
River*Site		0.5878	0*	0.01064	0.03197	DNC	DNC	0*
River*Site*Season*Year		0.4402	0.7945	1.8136	4.3279	DNC	DNC	1.1181
Year								
Solutions Estimates								
	2004	0*	0*	0*	0*	DNC	DNC	-
	2016	-0.5417	-1.2943	-0.2595	-0.43235	DNC	DNC	0*
	2017	-1.0208	-1.4533	-0.7443	0.02444	DNC	DNC	-1.4421
Least Squares Means Estimates								
	2004	-0.2319	-1.187	-0.9018	-3.7958	DNC	DNC	-
	2016	-0.7736	-2.4814	-1.1612	-4.2194	DNC	DNC	-3.1186
	2017	-1.2527	-2.6403	-1.646	-3.7714	DNC	DNC	-4.5607
F Value		8.45	5.27	1.59	0.25	DNC	DNC	10.53
Trend (+/-/=)		-	-	-	=			-
Season								
Solutions Estimates								
	June (A)	0.2343	-1.2135	-0.7115	-2.9898	DNC	DNC	-2.6085
	July (B)	0*	0*	0*	0*	DNC	DNC	0*
Least Squares Means Estimates								
	June (A)	-0.6356	-2.7096	-1.5921	-5.4237	DNC	DNC	-5.1439
	July (B)	-0.8699	-1.4961	-0.8806	-2.434	DNC	DNC	-2.5354
F Value		2.41	11.86	5.45	10.5	DNC	DNC	16.79
Trend (+/-/=)		-	+	-	+			+

Table 3.3 Continued

			Other	Total Categories
	Chi-Square/DF		0.47	0.72
	River		0.08928	0*
	River*Site		0.1309	0.06984
	River*Site*Season*Year		1.0725	0.02254
Year				
	Solutions Estimates			
		2004	0*	0*
		2016	-0.5486	-0.4683
		2017	-1.0895	-0.6319
	Least Squares Means Estimates			
		2004	-2.0826	1.7308
		2016	-2.6312	1.2625
		2017	-3.172	1.0989
	F Value		1.84	18.14
	Trend (+/-/=)		-	-
Season				
	Solutions Estimates			
		June (A)	-1.4068	-0.2799
		July (B)	0*	0*
	Least Squares Means Estimates			
		June (A)	-3.332	1.2241
		July (B)	-1.9252	1.504
	F Value		11.08	25.66
	Trend (+/-/=)		+	+

*No Standard Error

Table 3.4 Total individual aquatic invertebrates from each category collected at historic 6 sites in 2004 and combined total collected in 2016 and 2017. Invertebrates were collected along the Mast River in Wapusk National Park, Manitoba, Canada.

Year	Total	Total Tipulidae	Chironomidae	Ceratopogonidae	Plecoptera	Trichoptera
2004	1159	118	273	61	261	62
2016 + 2017	942	48	172	18	253	50
Percent Loss or Gain	-19%	-59%	-37%	-70%	-3%	-19%

Year	Ephemeroptera	Gastropoda	Oligochaete/Nematoda	Coleoptera	Other Diptera
2004	0	196	141	14	17
2016 + 2017	216	22	100	8	20
Percent Loss or Gain	+216%	-89%	-29%	-43%	+18%

Year	Simuliidae	Hirudinea	Amphipoda	Bivalvia	Other
2004	7	0	0	0	9
2016 + 2017	2	11	1	12	9
Percent Loss or Gain	-71%	+11%	+1%	+12%	0%

Table 3.5 Substrate classification for sampling sites in 2003, 2004, 2016 and 2017. Comparisons were made between 2003 and 2017 because of the greatest time sampling. S5 and S6 were only sampled in 2004 and 2017. A total of 10 sites changed: 7 from cobble to gravel, 2 from cobble to silt, and 1 from gravel to silt. Bolded means changed.

River	2003	2004	2016	2017
A	**Cobble**	-	Silt	**Gravel**
B	**Cobble**	-	Gravel	**Gravel**
C	**Gravel**	-	Silt	**Silt**
D	Gravel	Gravel	Gravel	Gravel
E	**Cobble**	-	Gravel	**Gravel**
F	**Cobble**	-	Silt	**Gravel**
G	**Cobble**	-	Silt	**Silt**
H	**Cobble**	-	Silt	**Gravel**
I	**Cobble**	Cobble	Silt	**Silt**
J	**Cobble**	-	Gravel	**Gravel**
K	Cobble	Cobble	Gravel	Cobble
L	Gravel	Cobble	Gravel	Gravel
S5	-	Gravel	-	Gravel
S6	-	**Cobble**	-	**Gravel**

Table 3.6 Top models within 2 delta AICc scores that best predict overall number of individual aquatic invertebrates from each category. Aquatic invertebrates were collected from the Wapusk National Park, Manitoba, Canada in 2017.

Categories	**Model**	**AICc**	**ΔAICc**	**Weight**	**-2 Log Likelihood**
Tipulid	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	245.85	0.00	0.40	222.35
	flow + substrate type + season + sediment depth + water depth	246.14	0.29	0.34	227.93
	flow + substrate type + season + sediment depth	246.70	0.85	0.26	231.01
Chironomidae	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	735.49	0.00	0.37	712.00
	flow + substrate type + season + sediment depth	735.51	0.02	0.36	719.81
	flow + substrate type + season + sediment depth + water depth	736.20	0.71	0.26	717.98
Ceratopogonidea	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	132.12	0.00	0.80	108.63
Plecoptera	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	542.52	0.00	1.00	522.03
Trichoptera	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	690.56	0.00	1.00	667.07
Ephemeroptera	**flow + substrate type + season**	492.59	0.00	0.46	479.33
	flow + substrate type + season + sediment depth + water depth	493.75	1.16	0.26	475.54
	flow + substrate type + season + sediment depth	494.30	1.71	0.19	478.60
Gastropoda	**flow + substrate type + season + sediment depth**	132.90	0.00	0.46	117.20
	flow + substrate type + season + sediment depth + water depth	133.20	0.30	0.40	114.99
Oligochaete/Nematoda	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	333.48	0.00	1.00	309.99
Coleoptera	**flow + season**	85.93	0.00	0.42	77.35
	flow + substrate type + season	86.00	0.07	0.41	72.75
Diptera	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	218.24	0.00	1.00	194.75
Simuliidae	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	128.73	0.00	1.00	105.23
Hirudinea	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	81.39	0.00	0.76	57.90
Amphipoda	**flow + sediment depth**	78.60	0.00	0.45	70.02
Mollusca	**flow + season**	63.52	0.00	0.37	54.94
	flow	64.54	1.02	0.22	58.20
Other	**flow + season**	74.32	0.00	0.47	65.74
	flow + substrate type + season	75.53	1.21	0.26	62.28
	flow + substrate type + season + sediment depth	76.05	1.73	0.20	60.36
Categories	**flow + substrate type + season**	417.50	0.00	0.70	404.25

Table 3.7 Total number of individuals captured in each aquatic invertebrate category from Mast River and Wawao Creek sampling locations

		Total Crane Flies	**Chironomidae Non-Biting Midges**	**Ceratopogonid Sandflies (Biting Midges)**	**Plecotera Stoneflies**	**Trichoptera Caddiesflies**	**Ephemeroptera Mayflies**	**Gastropoda Snails**	**Oligochaete/Nematoda Worms**
Mast	**Total**	138	716	54	586	198	589	65	373
	%	4.42%	22.92%	1.73%	18.76%	6.34%	18.85%	2.08%	11.94%
Wawao	**Total**	7	607	95	67	62	275	11	14
	%	0.54%	46.80%	7.32%	5.17%	4.78%	21.20%	0.85%	1.08%

Table 3.7 Continued

Coleoptera Beetles	**Other Diptera Flies**	**Simuliidae Black Flies**	**Hirudinea Leeches**	**Amphipoda Amphipods**	**Mollusca Bivalves**	**Other**		
26	73	42	26	21	48	31	**Total All**	3124
0.83%	2.34%	1.34%	0.83%	0.67%	1.54%	0.99%		
4	70	3	71	0	1	3	**Total All**	1297
0.31%	5.40%	0.23%	5.47%	0.00%	0.08%	0.23%		

Table 3.8 Number of observations and percent classified into water types from discriminant analysis of stable isotopes. Stable isotopes were collected from aquatic invertebrates in 2016.

From Water	Brackish	Freshwater	Marine	Total
Brackish	10	6	0	16
Percent Classified	62.5	37.5	0.00	100.00
Freshwater	14	40	0	54
Percent Classified	25.93	74.07	0.00	100.00
Marine	0	0	3	3
Percent Classified	0.00	0.00	100.00	100.00
Total	24	46	3	73
Percent Classified	32.88	63.01	4.11	100.00
Priors	0.3333	0.3333	0.3333	

Table 3.9 Number of observations and percent classified into water types from discriminant analysis of stable isotopes. Stable isotopes were collected from aquatic invertebrates in 2017.

From Water	Brackish	Freshwater	Marine	Total
Brackish	11	9	1	21
Percent Classified	52.38	42.86	4.76	100.00
Freshwater	26	57	3	86
Percent Classified	30.23	66.28	3.49	100.00
Marine	1	0	6	7
Percent Classified	14.29	0.00	85.71	100.00
Total	38	66	10	114
Percent Classified	33.33	57.89	8.77	100.00
Priors	0.3333	0.3333	0.3333	

Table 3.10 Number of observations and percent classified into water types from discriminant analysis of stable isotopes. Stable isotopes were collected from aquatic invertebrates in 2016 and 2017.

From Water	Brackish	Freshwater	Marine	Total
Brackish	23	13	1	37
Percent Classified	62.16	35.14	2.70	100.00
Freshwater	41	96	3	140
Percent Classified	29.29	68.57	2.14	100.00
Marine	2	0	8	10
Percent Classified	20.00	0.00	80.00	100.00
Total	66	109	12	187
Percent Classified	35.29	58.29	6.42	100.00
Priors	0.3333	0.3333	0.3333	

Table 3.11 Number of observations and percent classified into water types from discriminant analysis of stable isotopes. Stable isotopes were collected from aquatic invertebrates in 2017 that were subsorted into Amphipoda.

From Water	Brackish	Freshwater	Marine	Total
Brackish	0	1	0	1
Percent Classified	0.00	100.00	0.00	100.00
Freshwater	4	1	0	5
Percent Classified	80.00	20.00	0.00	100.00
Marine	0	0	5	5
Percent Classified	0.00	0.00	100.00	100.00
Total	4	2	5	11
Percent Classified	36.36	18.18	45.45	100.00
Priors	0.3333	0.3333	0.3333	

Table 3.12 Number of observations and percent classified into water types from discriminant analysis of stable isotopes. Stable isotopes were collected from aquatic invertebrates in 2017 that were subsorted into Tipulidae.

From Water	Brackish	Freshwater	Total
Brackish	5	1	6
Percent Classified	83.33	16.67	100.00
Freshwater	5	22	27
Percent Classified	18.52	81.48	100.00
Total	10	23	33
Percent Classified	30.30	69.70	100.00
Priors	0.5	0.5	

Table 3.13 Number of observations and percent classified into water types from discriminant analysis of stable isotopes. Stable isotopes were collected from aquatic invertebrates in 2017 that were subsorted into Other.

From Water	Brackish	Freshwater	Marine	Total
Brackish	7	7	0	14
Percent Classified	50.00	50.00	0.00	100.00
Freshwater	25	29	0	54
Percent Classified	46.30	53.70	0.00	100.00
Marine	1	0	0	1
Percent Classified	100.00	0.00	0.00	100.00
Total	33	36	0	69
Percent Classified	47.83	52.17	0.00	100.00
Priors	0.3333	0.3333	0.3333	

Figures

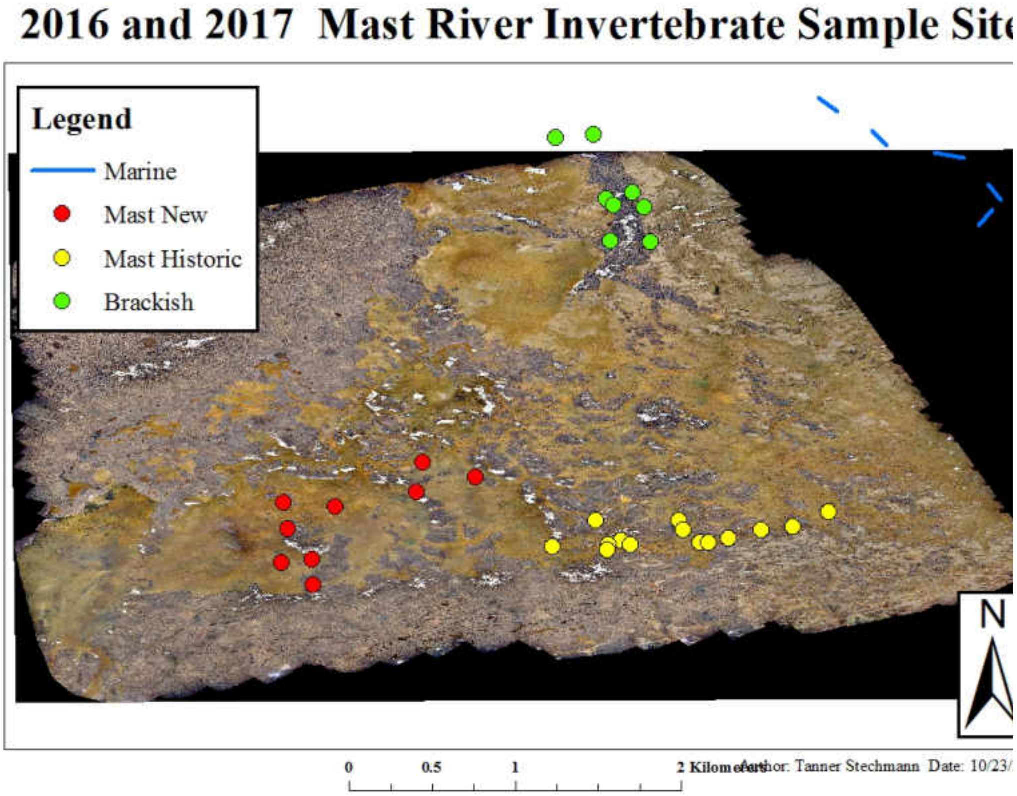

Figure 3.1 Mast River (23), Brackish (8), and Marine (6) aquatic invertebrate sampling sites. Mast River sampling sites were divided into historical sites (14) and new sites (9) that were added in 2016. Only 5 marine transects are shown because the 6th transect is located outside of Churchill, MB, Canada in an area known to have blue mussels (*Mytilus edulis*).

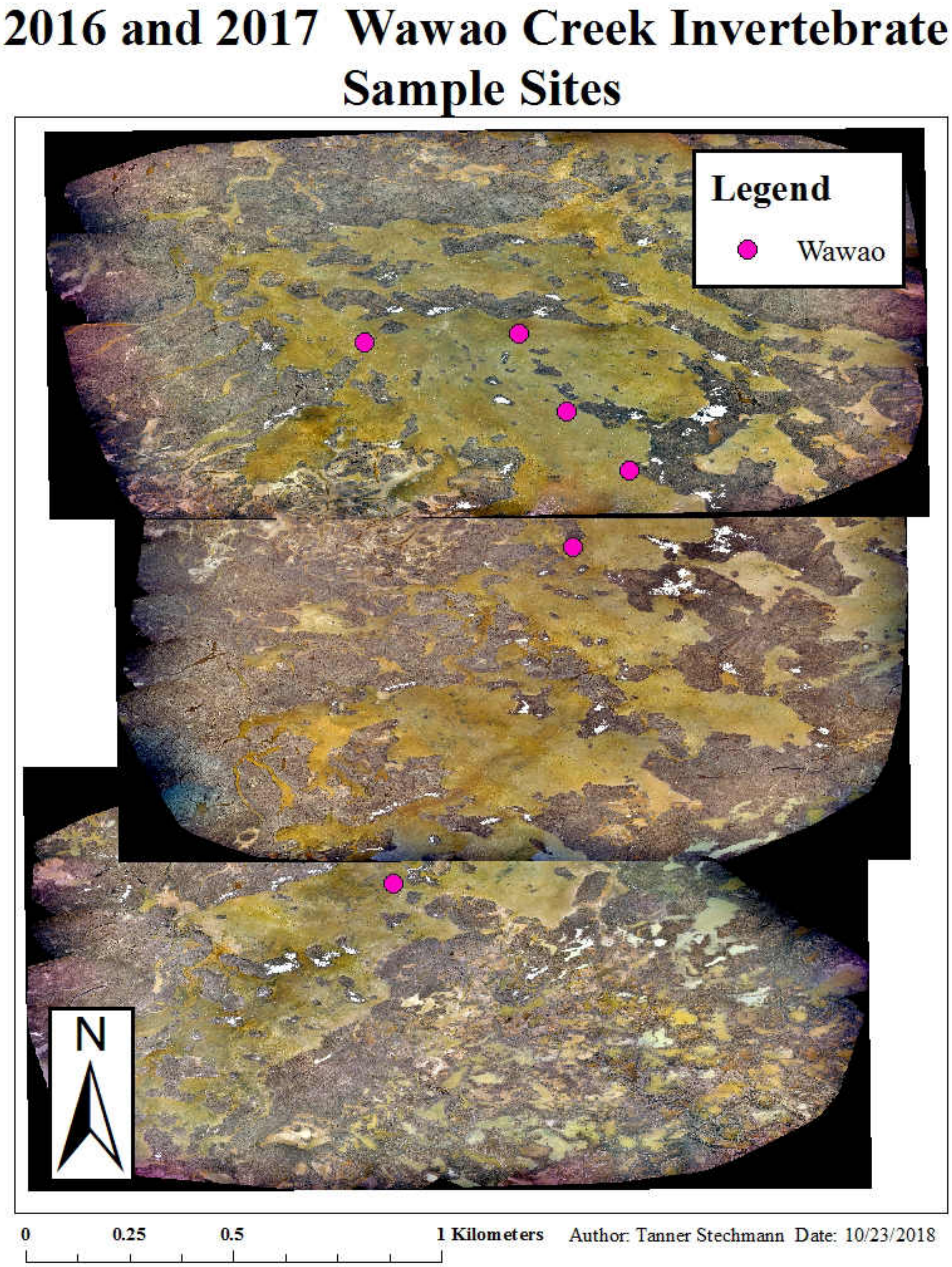

Figure 3.2 Wawao creek aquatic invertebrate sampling sites (6).

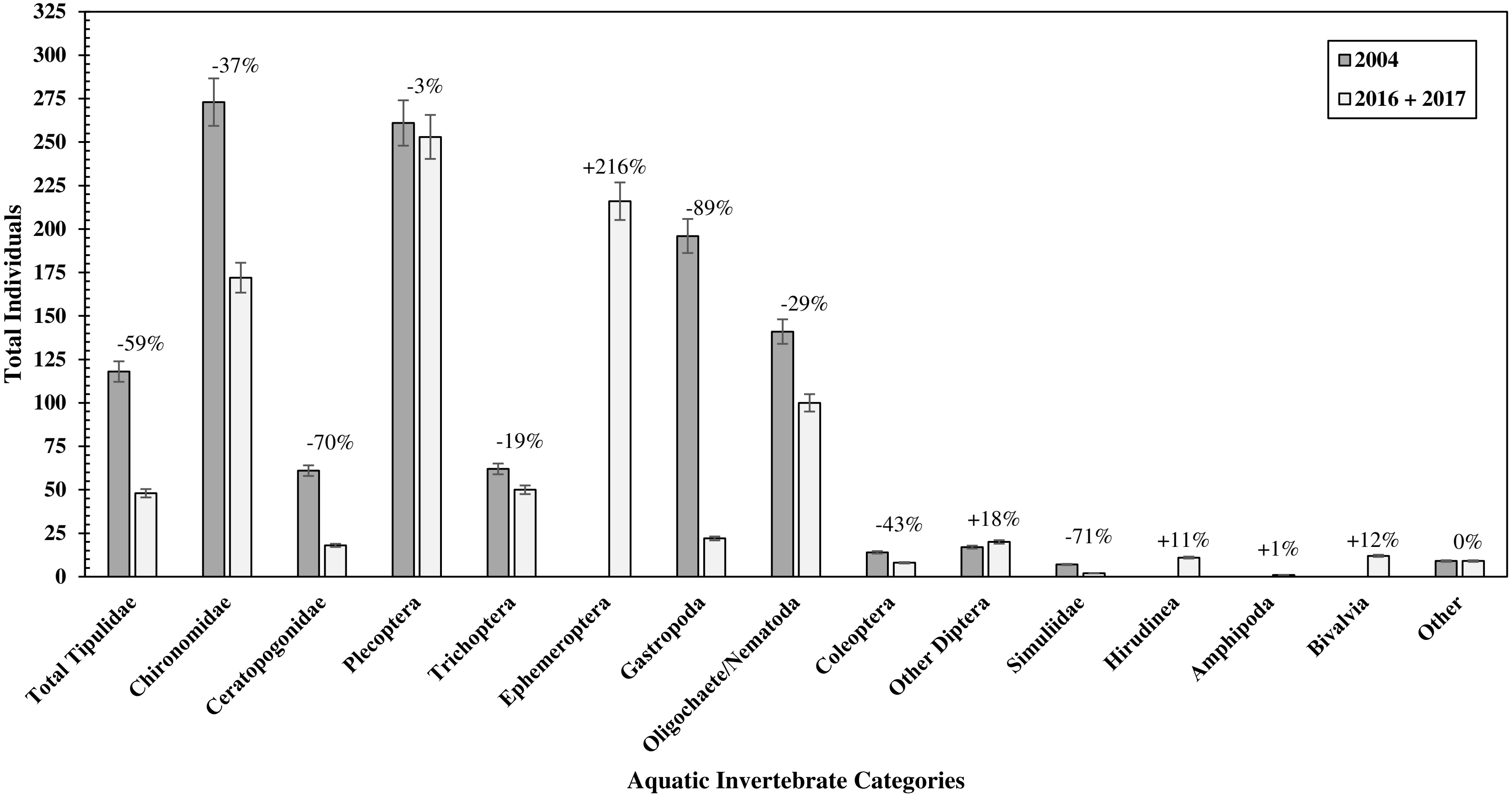

Figure 3.3 Total individual aquatic invertebrates from each category collected at 6 historic sites (D, I, K, L, S5, and S6) in 2004 and combined total collected in 2016 and 2017. Percent loss between years are listed above each category with 95% confidence intervals. Invertebrates were collected along the Mast River in Wapusk National Park, Manitoba, Canada.

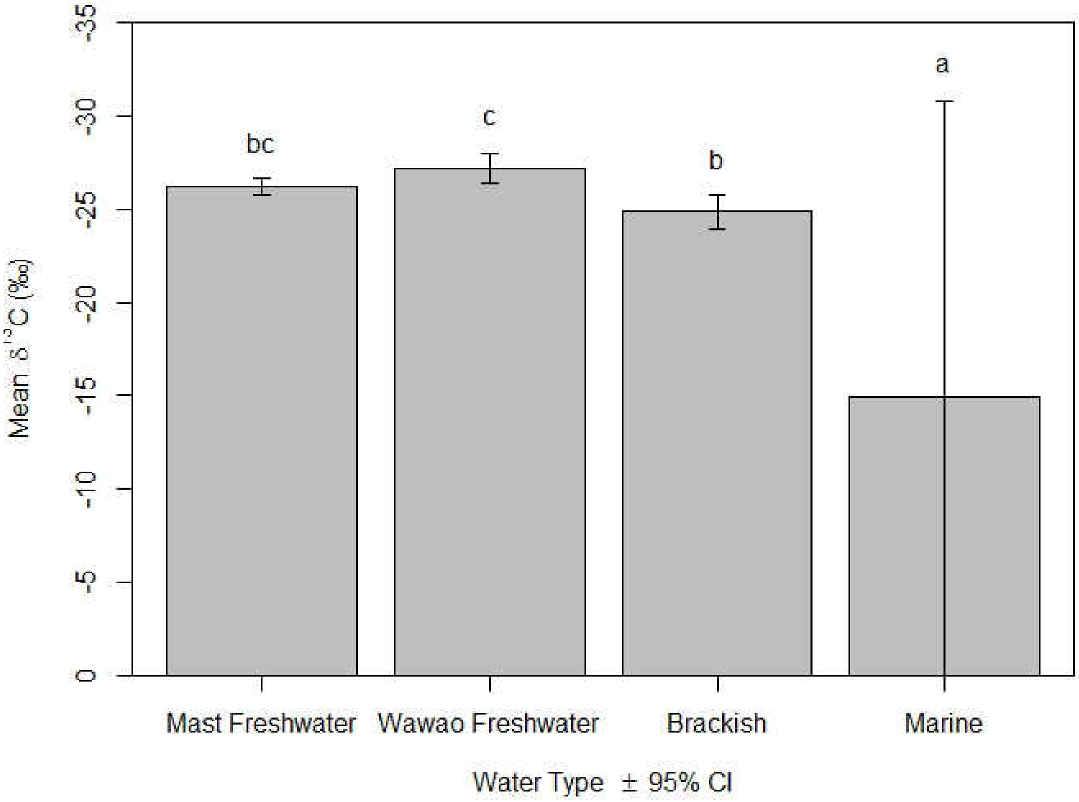

Figure 3.4 Means and 95% confidence intervals of $\delta^{13}C$ samples collected in 2016 by water type. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars. Sample sizes for each water type from left to right 41, 12, 16, and 3.

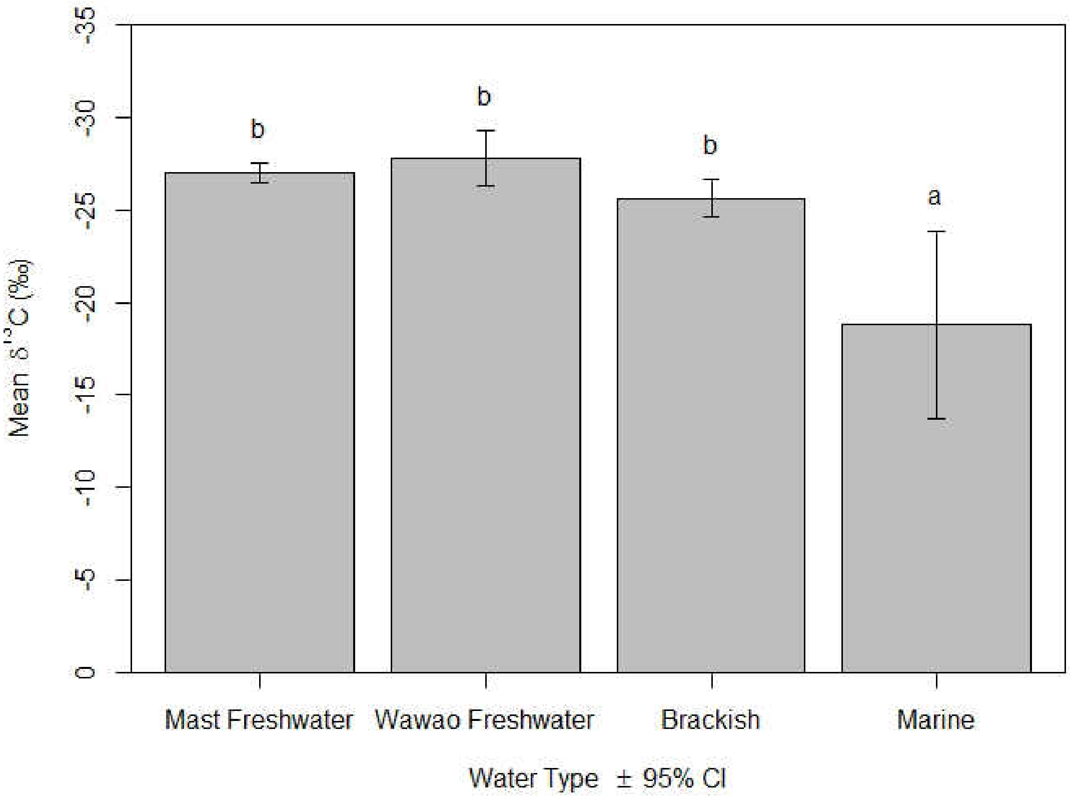

Figure 3.5 Means and 95% confidence intervals of $\delta^{13}C$ samples collected in 2017 by water type. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars.

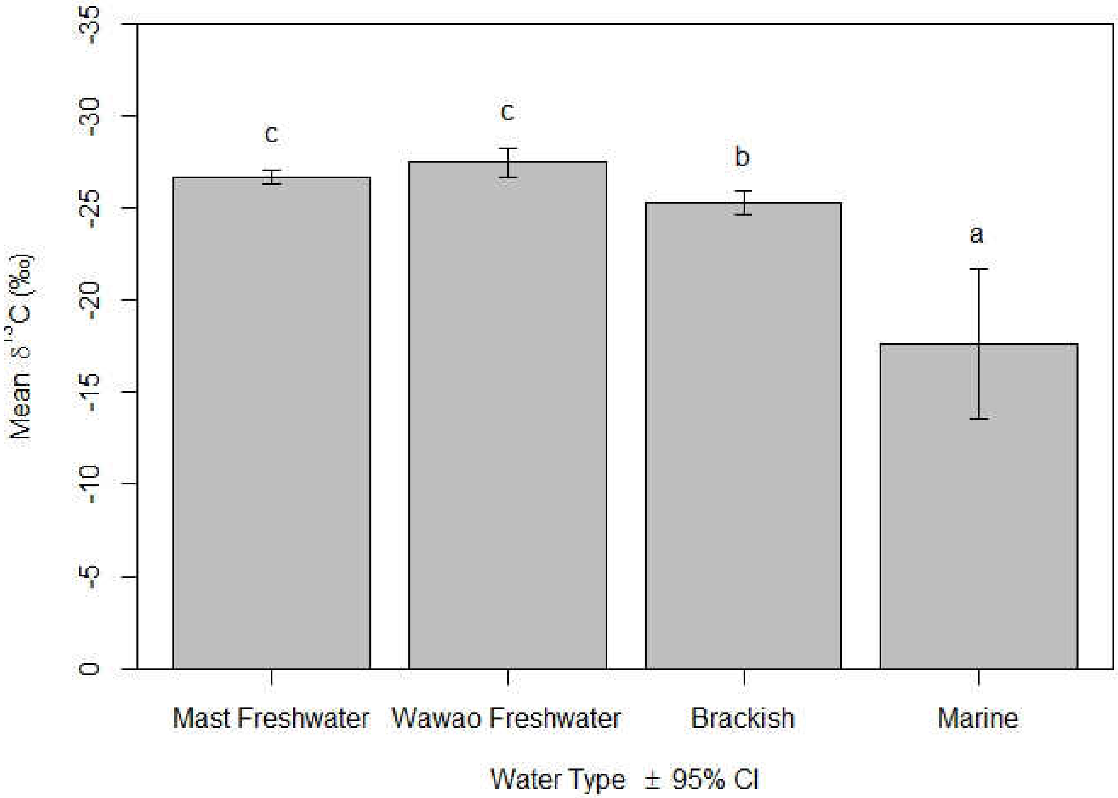

Figure 3.6 Means and 95% confidence intervals of δ^{13}C pooled samples collected in 2016 and 2017 by water type. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars.

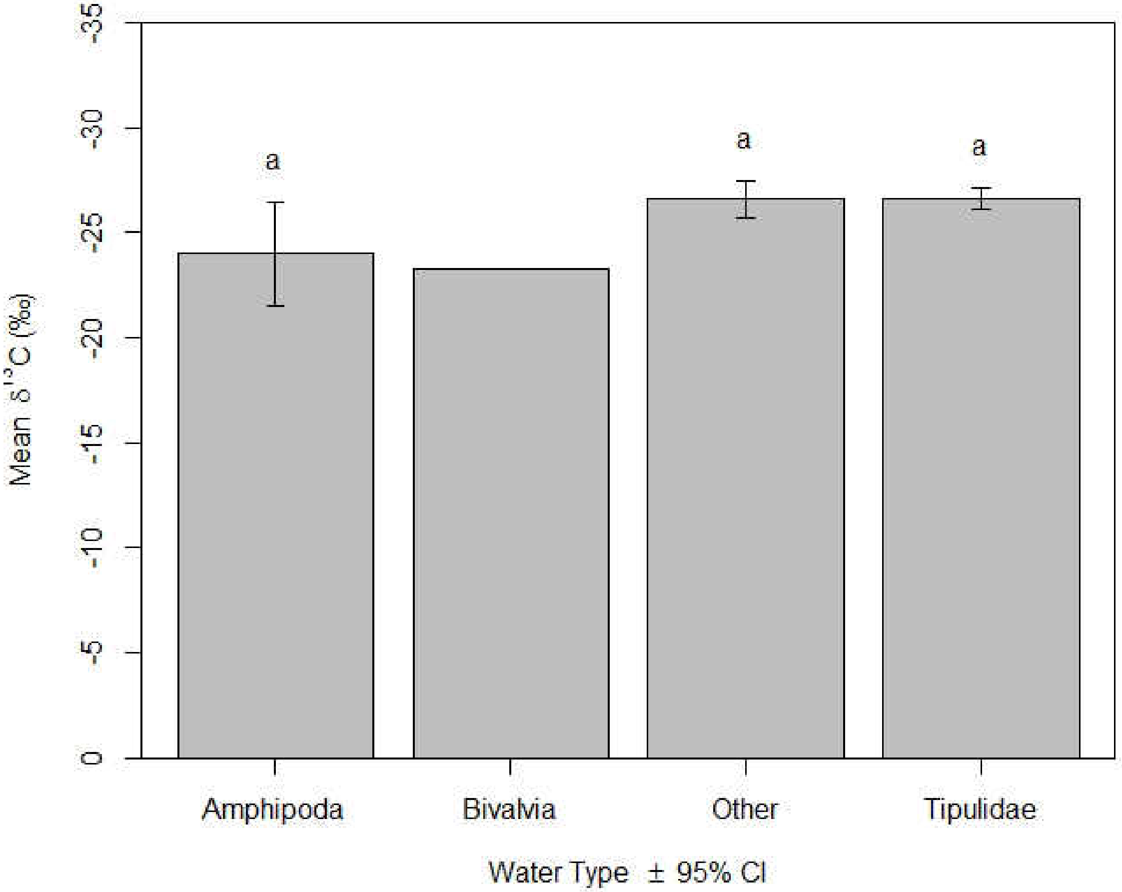

Figure 3.7 Means and 95 % confidence intervals of $\delta^{13}C$ samples collected in 2017 by category. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars. Confidence intervals could not be calculated for Bivalvia because only one sample was collected. Tukey's HSD post-hoc test placed Bivalvia in group a.

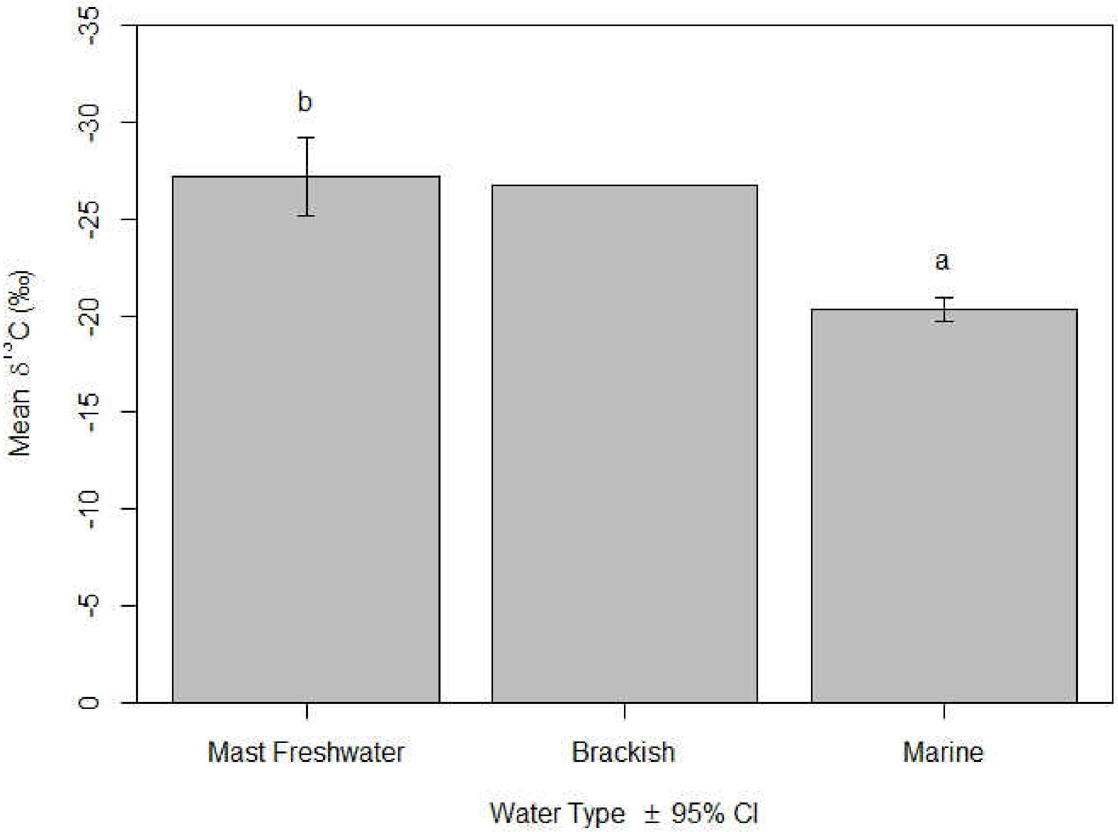

Figure 3.8 Means and 95% confidence intervals of δ^{13}C Amphipoda samples collected in 2017 by water type. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars. Confidence intervals could not be calculated for brackish samples because only one sample was collected. The Tukey's HSD post-hoc test placed brackish samples in group b.

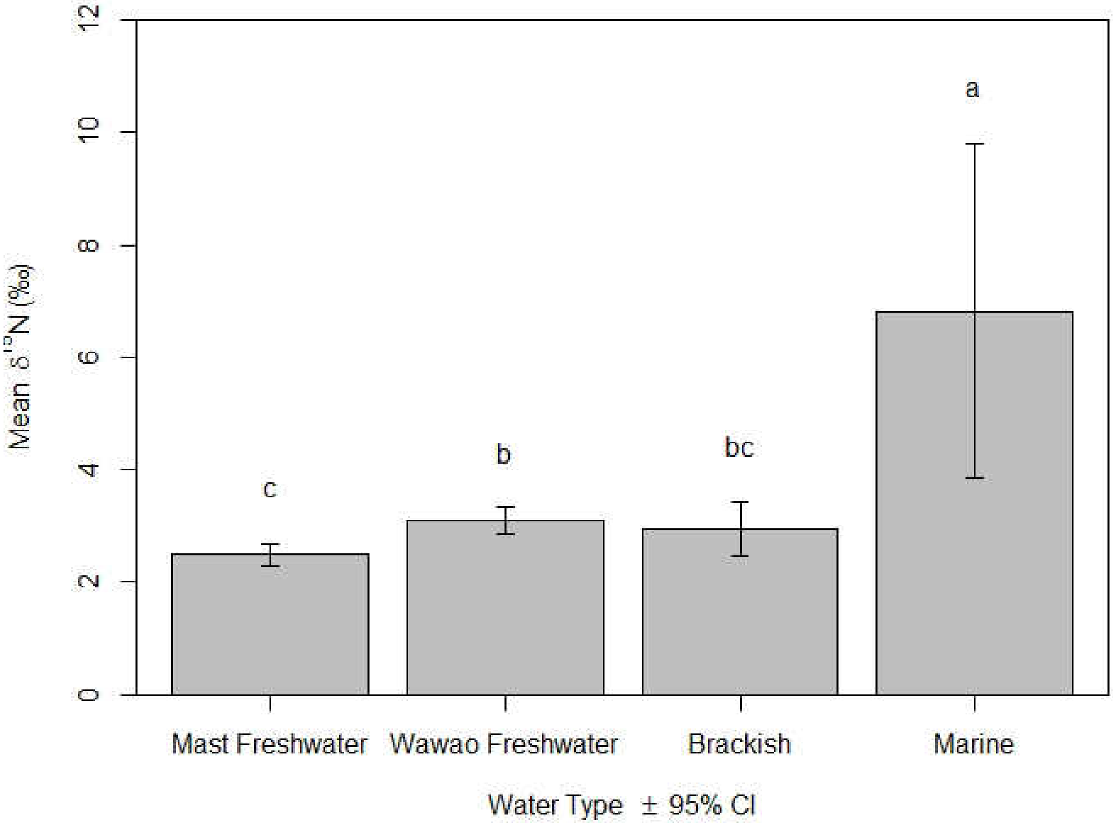

Figure 3.9 Means and 95% confidence intervals of $\delta^{15}N$ samples collected in 2016 by water type. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars.

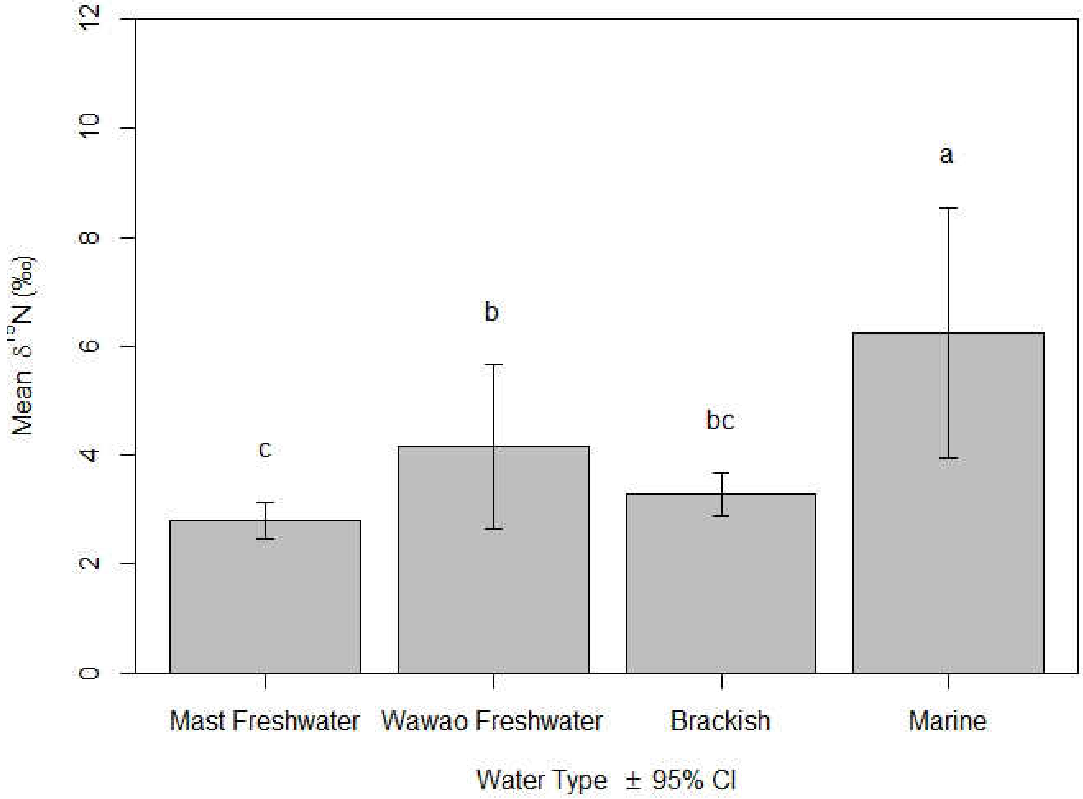

Figure 3.10 Means and 95% confidence intervals of δ^{15}N samples collected in 2017 by water type. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars.

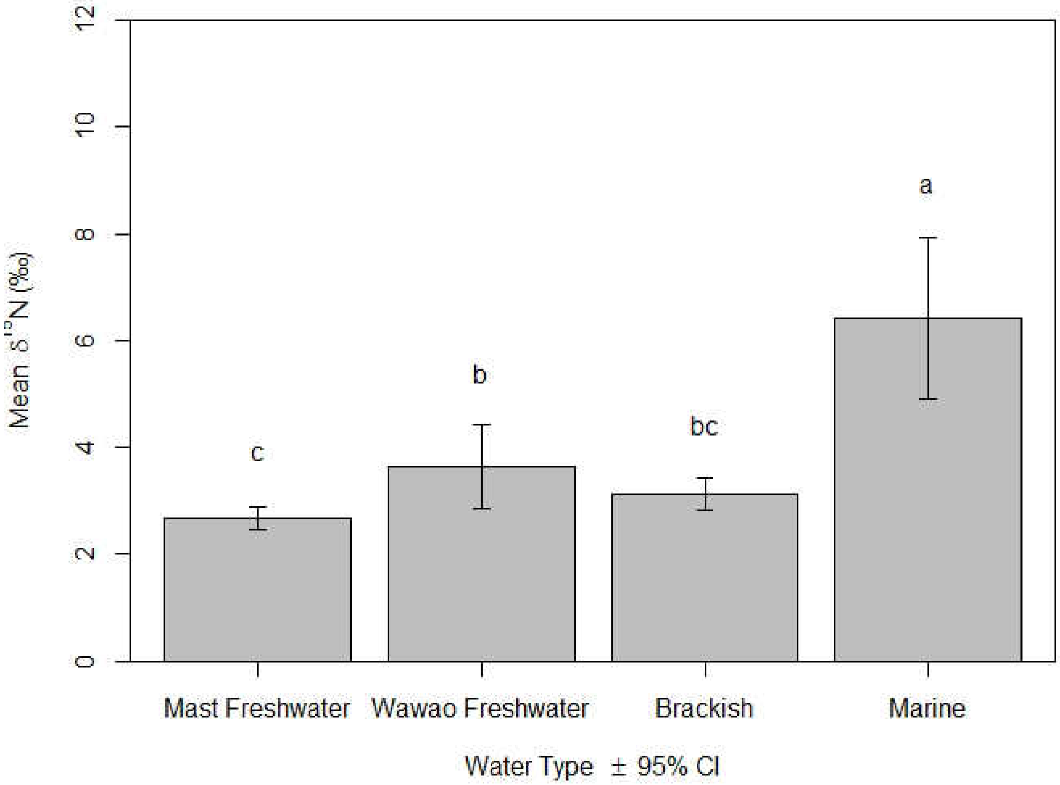

Figure 3.11 Means and 95% confidence intervals of $\delta^{15}N$ pooled samples collected in 2016 and 2017 by water type. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars.

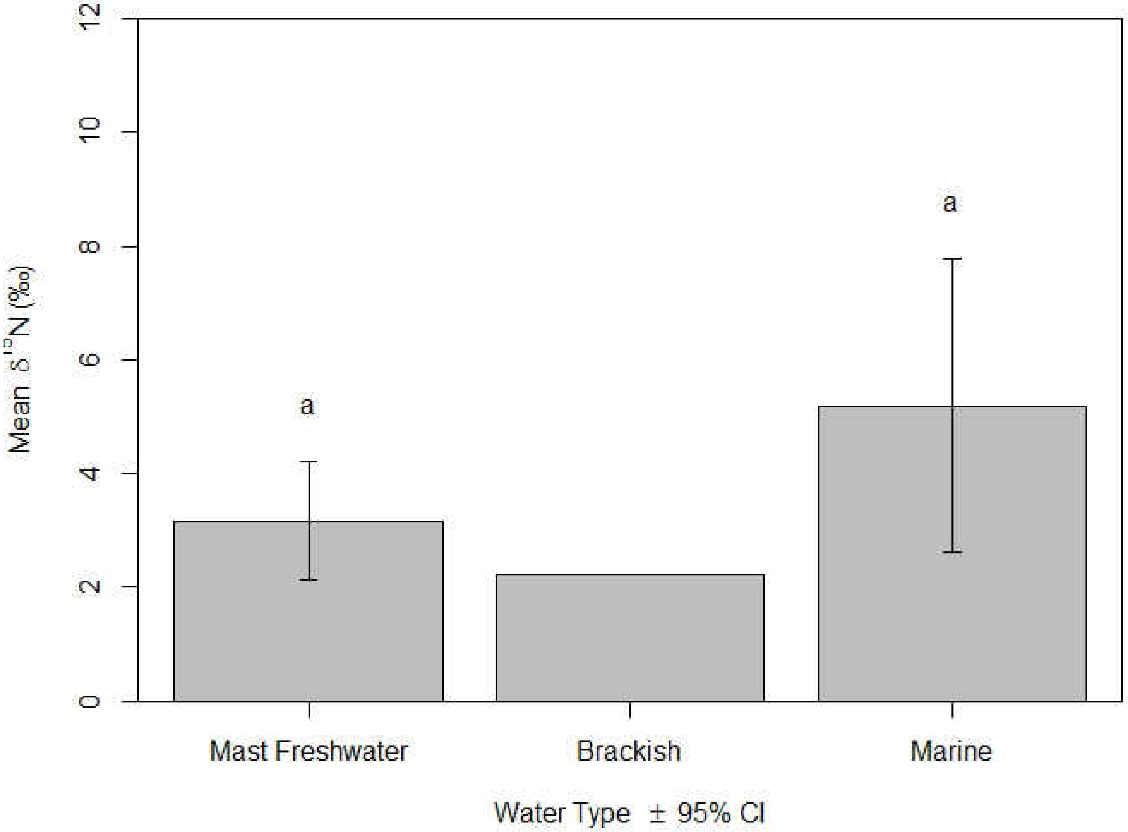

Figure 3.12 Means and 95% confidence intervals of $\delta^{15}N$ Amphipoda samples collected in 2017 by water type. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars. Confidence intervals could not be calculated for Brackish because only one sample was collected. Tukey's HSD post-hoc test placed Brackish in group b.

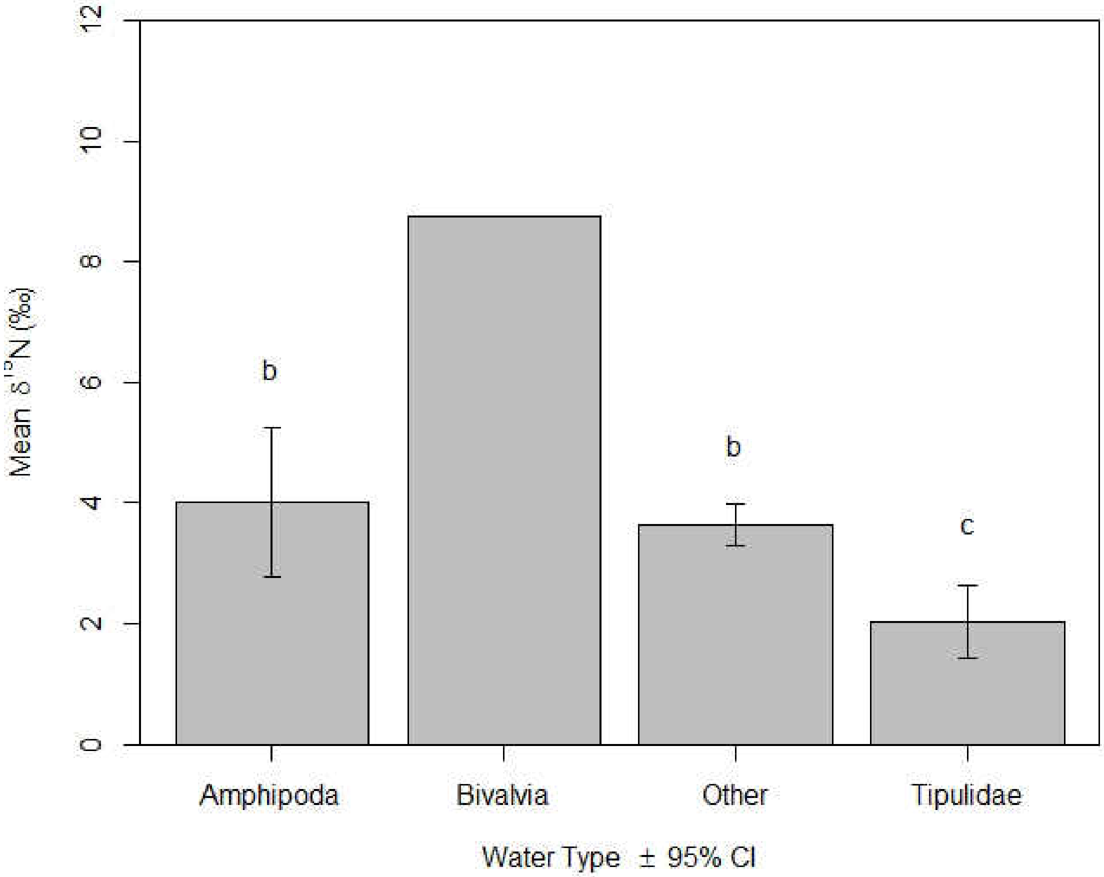

Figure 3.13 Means and 95% confidence intervals of $\delta^{15}N$ samples collected in 2017 by category. Groups were created based on results from Tukey's HSD post-hoc tests. Groups are listed above bars. Confidence intervals could not be calculated for Bivalvia because only one sample was collected. Tukey's HSD post-hoc test placed Bivalvia in group a.

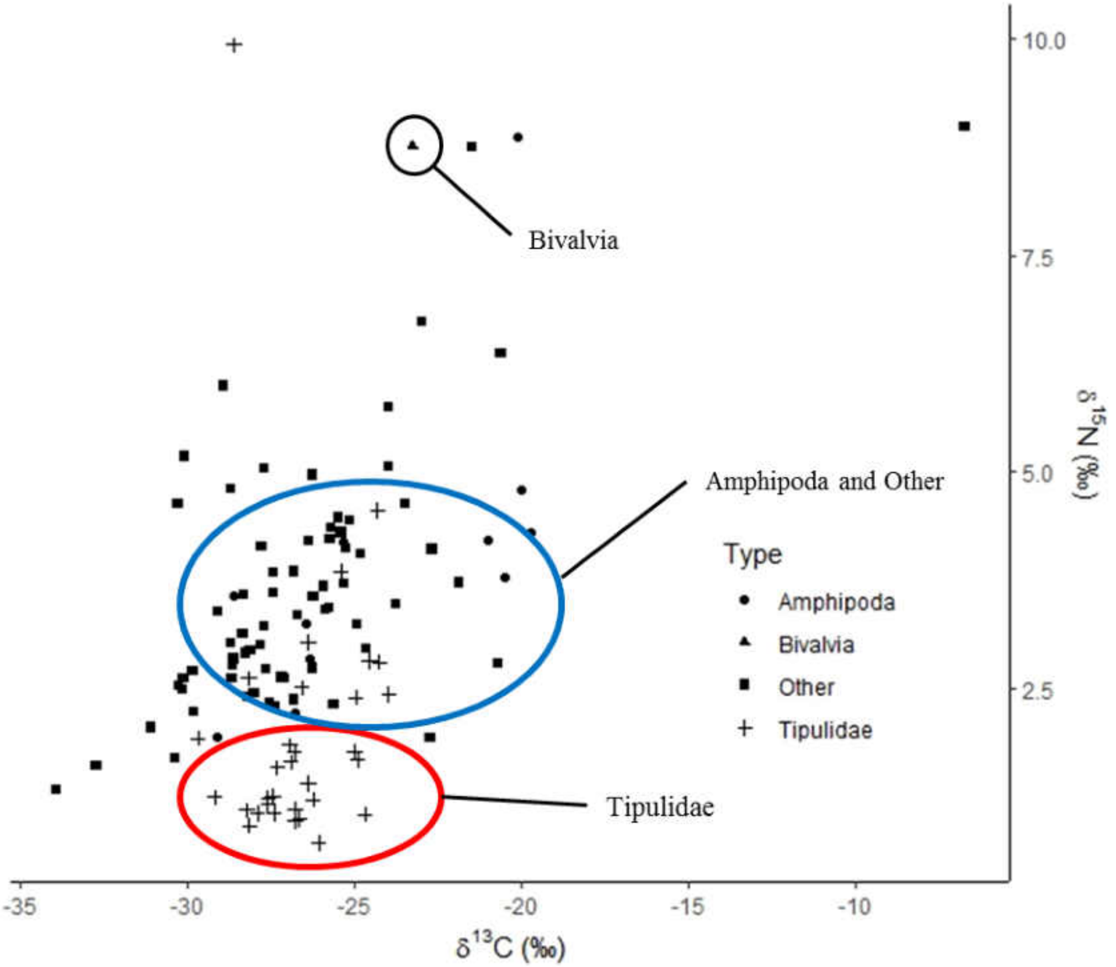

Figure 3.14 δ^{13}C values vs δ^{15}N values of aquatic invertebrate samples sorted into four different subset types in Wapusk National Park and Churchill, Manitoba, Canada in 2017. Approximant majority of groups are circled and labeled.

CHAPTER IV

FUTURE DIRECTIONS AND CONCLUSIONS

The goal of this research was to document nesting behaviors of a population of Hudson Bay common eiders (*Somateria mollissima sedentria*; hereafter eider(s)), their predators and possible food sources during incubation. This study is one of the most comprehensive studies on nesting behaviors of common eiders, despite how well studied they are (Waltho and Coulson 2015). Previous work examining nest attendance had small samples sizes (<24 nests), and there has been limited work on the Hudson Bay subspecies of eider (Baldassarre 2014, Waltho and Coulson 2015). Our study is the first to report the incubation constancy of the Hudson Bay subspecies and is the largest nest attendance study of common eiders. We present temporal and seasonal changes of the aquatic freshwater invertebrate community along the Mast River and Wawao Creek in Wapusk National Park. We also investigated the differences in stable isotope signatures among water type (e.g., freshwater, brackish and marine) from aquatic invertebrates. The goal of this was to understand how the aquatic invertebrate community has changed in the last decade and to explore if stable isotopes can be used to discern feeding locations of eiders.

Chapter II

Our goal was to investigate possible drivers of incubation constancy, nest success, and likelihood of predation from specific nests predators in Hudson Bay common eiders. We reviewed time-lapse imagery from trail cameras placed at a subset of nests from 2014–2017 along the Mast River in Wapusk National Park, Manitoba, Canada. We specifically examined predictors of colony characteristics (e.g., distance to the center of the colony and distance to nearest neighboring nest), nest characteristics (e.g., nest age), annual variation and date within the breeding season.

In summary, we found individual bird variation (modeled as a random effect) to be the best explanation of incubation constancy. We found that eiders nesting along the Mast River had lower average incubation constancy (95.65%) than other reported studies (Mehlum 1991a (96.3%), Afton and Paulus 1992 (99.86%), Criscuolo et al. 2002 (99.6%), Bolduc and Guillemette 2003b (99.5%), and Kistjánsson and Jónsson 2011 (96% and 97%)). We found annual variation to be the largest contributor to nest success and the likely mechanism was annual variation in predator communities. We observed a change in the predator community as the breeding season progressed with an increase in the complexity of the predator community later in the breeding season.

We recommend the continued monitoring of nesting behaviors across subspecies. Of the 116 articles on common eiders that we reviewed, only 14 of them discussed the importance of nest attendance (Mehlum 1991a, Afton and Paulus 1992, Criscuolo et al. 2002, Bolduc and Guillemette 2003b;a, Andersson and Waldeck 2006, Fast et al. 2007;2010, Kristjánsson and Jónsson 2011, Iles 2012, Kristjánsson et al. 2013, Kristjánsson and Jónsson 2015b, Kristjánsson 2016, Kristjánsson et al. 2016). Many of which described eiders having high incubation constancy, the benefit of high nest attendance as a deterrent of nest predation, or the relationship with body fat loss. Of those articles only 5 have reported data on average incubation constancy (Mehlum 1991a, Afton and Paulus 1992, Criscuolo et al. 2002, Bolduc and Guillemette 2003b, Kristjánsson and Jónsson 2011).

The studies that do report incubation constancy have very low sample sizes, monitor these nests for short periods of time or use methods that can be inaccurate or misleading (e.g. temperature sensors). Reviewed within Afton and Paulus (1992), eiders were reported to have an incubation constancy of 96.3% but, no other information of sample size, observation data or the method used to collect the data were presented. Mehlum (1991a) used video surveillance at 11 nests for a mean observation time of 178 hour, 31 minutes (~7 days) per nest and reported incubation constancy of 99.86%. This equates to approximately 25% of total incubation duration and could be overestimating the amount of time eiders are on the nest. Monitoring of these nests occurred in late June and early July when majority of females were in their second half of incubation. Criscuolo et al. (2002) monitored recesses at 10 nests using a scale to measure the weight changes when the eider is on or off the nests and reported a 99.6% incubation constancy. Weights were collected every 10 minutes, which can result in recesses being missed or an inaccuracies of recess duration. We observed females leaving the nest for as short as 0.88 minutes. Bolduc and Guillemette (2003b) also used a scale at 5 nests and reported an incubation constancy of 99.5%. Kristjánsson and Jónsson (2011) used temperature loggers at 24 nests and presented 2 incubation constancies based on manipulations (with down and replaced with hay) of the nests, 97% and 96%, respectively. Temperature readers can be an effective and inexpensive way to monitor waterfowl nest attendance (Croston et al. 2018b), but as the nest ages and ambient temperatures increase it can be more difficult to accurately record temperature changes. Without the use of cameras to confirm recesses, they can be missed or misestimated on their duration (Croston et al. 2018b). They used a video camera to record incubation recesses and rotation of the eggs but placed the camera at a single nest where it was left to record for only 4 days. This increase of temperature loggers could increase the accuracy of capturing recess events but again can be inaccurate without confirmation from imagery. The camera that was placed at a single can misrepresent the colony because the camera was left at the nest for an extremely short period of time and the nest was manipulated approximately every day which can influence the recesses events for that day (Kristjánsson and Jónsson 2011).

We examined apparent nests success (ANS) of all 518 nests located from 2014–2017 that were categorized by their distance to the nearest neighboring nest. Schmutz et al. (1983) found lower egg loss in nest that were < 1 m from the nearest neighboring nest and suggested an added benefit to nesting next to other eiders. We found lower ANS (2.7%) in nests that were within 1 m from their nearest neighbor. We found fewer nests in the colony itself compare to Schmutz et al. (1983) who found 1,295 from 1978–1980 and found nests were more dispersed. Schmutz et al. (1983) found 56% of nests were within 10 m of another nest, compared 48% we found. Our results align with findings of Dey et al. (2017) in that following widespread predation events (documented in 2014), eiders respond by dispersing away from other eiders, thereby reducing the probability of nest discovery by predators.

In the future, we recommend additional metrics on vegetation height be collected and compared to Schmutz et al. (1983). Vegetation height can conceal eiders from aerial predators (Dwernychuk and Boag 1972), but we suggest a more extensive examination vegetation cover. Avian predators are very efficient at exploiting fine details in the landscape (Dwernychuk and Boag 1972)and use these to find nests of incubating eiders (Stien et al. 2010). Nesting eiders use distinct paths between the thick vegetation to and from their nests, allowing the nesting female to escape her nest more quickly from predators. Avian predators could key in on these paths (Dwernychuk and Boag 1972) to find the location of the nest or by seeing the unprotected eggs, which are easily visible if there is little down around the nest, exposing the less cryptic egg coloration. While we did not do a formal nest site selection analysis, eiders could be selecting areas with more overhead vegetation in order better hide from avian predators that persist throughout the breeding season. Female eiders use their cryptic plumage to blend into their habitat and move very little while incubating. This, coupled with dense nesting cover, would make it more difficult for a mammalian predator to find a nest on sight alone. Mammalian predators may still use scent to find the nests but the nesting cove may make it more difficult to find or to reach. Schmutz et al. (1983) only examined vegetation height by sampling the height of 90% of stems within 1 m of the nest and did not investigate if vegetation height was correlated with nest success. We recommend using a spherical densitometer (Lemmon 1957, Silvy 2012) to measure overhead cover at the nest and using a Robel pole (Robel et al. 1970, Silvy 2012) to measure obstruction. This would provide a greater understanding of the total cover surrounding the nesting eider. It could also provide insights into nesting behaviors. Females with more nesting cover may take more recesses because their nests may be harder to find and access from predators, particularly herring gulls, when the female is away from the nest.

Chapter III

We sought to investigate changes to abundance of aquatic invertebrates from 15 categories of families and orders. We compared total organisms captured in each category from 2003-2004 to ones collected in 2016-2017 at six sites along the Mast River in Wapusk National Park, Manitoba, Canada. We also evaluated if stable isotope ratios of ^{13}C and ^{15}N from the aquatic invertebrates differed across three water types (freshwater, brackish, and marine).

In summary, we found that overall abundance of aquatic invertebrates had decreased from 2004 by 53% in 2016 and 66% in 2017. We found the largest decreases in categories that are important to breeding shorebirds and waterfowl (Tipulidae, Chironomidae, Ceratopagonidae and Oligochaete/Nematoda). To determine possible losses to individual abundance we compared substrate types collected at sampling sites in both sampling periods. We found that from 2003 to 2017, 10 of the 14 sites had changed in substrate types (7 from cobble to gravel, 2 from cobble to silt, and 1 from gravel to silt). When we examined just the six historical sites, we found half of the sites changed (cobble to silt and gobble to gravel). To understand the importance substrate type and sedimentation has on predicting individual abundance, we built a model from all of the environmental variables collected at each site in 2017. We found that the water flow, season (June or July), substrate type, and sediment depth were most important when predicting invertebrate abundance.

We were able to find that stable isotope samples from the marine environments tended to be different from freshwater and brackish samples. However, our ANOVA and discriminant analysis showed it was much harder to discern between samples from freshwater and brackish environments. This is likely because freshwater and brackish environments were not distinct from each other. Brackish environments may not have experienced as much tidal activity as we expected, resulting in them actually being more freshwater environments.

We conducted this research to establish long-term sampling of the invertebrate community surrounding common eider colonies along the Mast River and Wawao Creek. We also hoped to establish baseline measurements of stable isotopes in aquatic invertebrates that could later be used to explore diets of eiders and other birds in Wapusk National Park. As a result, this work should be used to facilitate future sampling efforts that will be better inform how invertebrate community and habitat changes are occurring in the area.

In the future, we recommend continuing sampling at the historic locations (A-L, S5 and S6) that were established in 2003 (Figure 3.1). These locations have established sampling and show the invertebrate community closest to severe goose degradation. We also recommend continuing to sample sites established in 2016 (M-U) in the heart of the eider colony (Figure 3.1). These sites demonstrate foraging areas that eiders could exploit just prior to incubation or during incubation. Sites V-AA were established as brackish sites during 2016 and 2017 but from our results, these appear to be freshwater sites (Figure 3.1). These locations had less tidal action than we had initially predicted. Given this, we encourage salinity to be measured at all sampling locations during each survey since there can be season and annual variation in salinities across these sites. The five marine transects located near the Mast River may be more brackish than marine. These locations were positioned farther south than originally planned due to high tides and polar bears near the vicinity of the desired location. We recommend using these transects as brackish locations and moving farther northeast when establishing new marine transects. These locations should began as close to the end of the tidal zone as possible to collect unique marine samples.

At each location, we recommend changing the way flow is collected at each site. Flow was collected in a way that was subjective to the researcher sampling due to a lack a proper equipment. We recommend sampling flow at each sampling stake with a flow meter and establishing specific ranges for fast, medium, and slow flow speeds.

Sampling and sorting of aquatic invertebrates was a time-consuming endeavor that required the help of all members in the field camp. In order to reduce the time of sorting we recommend that a subsampling method be used. In this study, samples were placed into a tub and then sorted into the 15 categories. We recommend that the sampling tub be gridded and then randomly sample grids until a predetermined number of organisms is collected from the overall sample (Mandaville 2002). This reduces the time spent sorting through samples and reduces the number of people needed to sort large sampling efforts. Mandaville (2002) does however recommend sorting a second subsample of equal size in about 10% of samples in order to account for subsampling error. A coarse particulate organic matter (CPOM) sample should also be collected to determine the number of shredders that are present at each site (Mandaville 2002). Although we recommend a faster sorting method, we do recommend increasing the number of sampling times throughout the season. This will give a better understanding of the seasonal changes that occur in communities and what impacts this may have on resources availability for breeding birds. For better understanding what functional groups (collector-filterer, collector-gatherer, predator, scraper, shredder, parasite, omnivore, piercer) are present, organisms should be sorted to genius or species when possible (Mandaville 2002).

Our isotopic sampling was unable to make clear distinctions among samples collected in different water types. Because of this, we recommend not targeting *where* the stable isotopes are collected from but target *what* they are collected from. If the goal is understanding resource accumulation, collecting known prey organisms would facilitate a better understanding of their isotopic signatures to target in tissues collected from eiders. We recommend collecting stable isotopes from blue mussels (*Mytilus edulis*) from multiple locations. Collecting samples from different areas along the Hudson Bay will inform us of any variation that may exist within mussels as a whole. We also recommend the collection of amphipods (another known prey organism) from both the marine and freshwater environments to investigate the variation that may occur.

Possible prey items from freshwater sources are more difficult to collect. Literature on diets of eiders in the marine environment is extensive. According to Baldassarre (2014), common eider food habits and feeding ecology is the most well studied among the sea ducks. However, little research has been done on the exportation of prey from freshwater sources. Because of this samples from gizzards and crops should collected from eiders that are observed using these freshwater sources. Once prey organisms are identified from these samples, collection of said prey items should occur with the same sampling method of collecting organisms from across a study site to identify any variation that may exist. One freshwater prey item could be exploited by eiders are Tipulidae larvae. They could be targeted because of their large size (<10 mm to greater than 30 mm).

Conclusions

Globally common eider populations are decreasing (Mehlum 1991b, Goudie et al. 2000, SDJV 2007, Stien et al. 2010, Iles et al. 2013, Baldassarre 2014) with a reported population of 2,196,000 by the Sea Duck Joint Venture (SDJV 2007). The Hudson Bay subspecies was reported in 2007 to have 225,000 and was recommended to be a population of high conservation priority (SDJV 2007). Robertson and Gilchrist (1998) reported a population of nesting eiders on the Belcher Islands had a 75% decline from 1986-1988. They concluded that was likely caused by a mass winterkill from polynyas and floe edges freezing over during the winter of 1991-1992. The population that was studied for this thesis has experienced low apparent nest success (Iles 2012, Iles et al. 2013). In 2014, Rockwell (2014) reported complete colony failure and Rockwell and Ellis-Felege (2015) reported an apparent nest success of only 9.7% in 2015. We also reported that number of nests within the colony have decreased in the last ~40 years. From 1978-1980 Schmutz et al. (1983) found 1,295 nests and we only found 518 from 2014-2017 (60% decrease).

Arctic and subarctic regions currently face extreme effects of climate change (Dey et al. 2017, Dey et al. 2018) and will continue to in the future. Most of the changes in the Hudson Bay region are observed in sea ice changes with earlier melting and later formation. Gough and Wolfe (2001) predict an increase in the ice-free period which could have dramatic effects to the region. Gagnon and Gough (2005) predicted an increase in air temperature which in turn could increase the temperature of the Hudson Bay. This increase in water temperature can have a dramatic effect on blue mussel (*Mytilus edulis*) populations that eiders almost exclusively feed on (Baldassarre 2014). Warmer water temperatures cause mussels to lose mass reducing their nutritional value for eiders (Jaatinen et al. 2016). Eiders are thought to be capital breeders and arrive at breeding areas with most of the resources they need to start incubation, but Jaatinen et al. (2016) found that eiders will take advantage of local resources when eiders are in poor condition. Eiders nesting in regions with access to freshwater may take advantage of freshwater invertebrate larvae to supplement their diet but still could be in poor quality to be successful breeders.

Breeding is energetically expensive to female eiders and with the effects of climate change, it could have negative consequences for females that are in poor body condition. If winter food quality decreases from warmer water temperatures, eiders likely will arrive on the breeding grounds in poorer body condition. This could result in changes to nest attendance leaving the nest and the female at greater risk of predation. Because female eiders do not reproduce until they are three or four years old (Baldassarre 2014, Waltho and Coulson 2015), increased failures will make it harder for increased recruitment in eider populations.

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APPENDICES

APPENDIX A
Chapter II

Figures

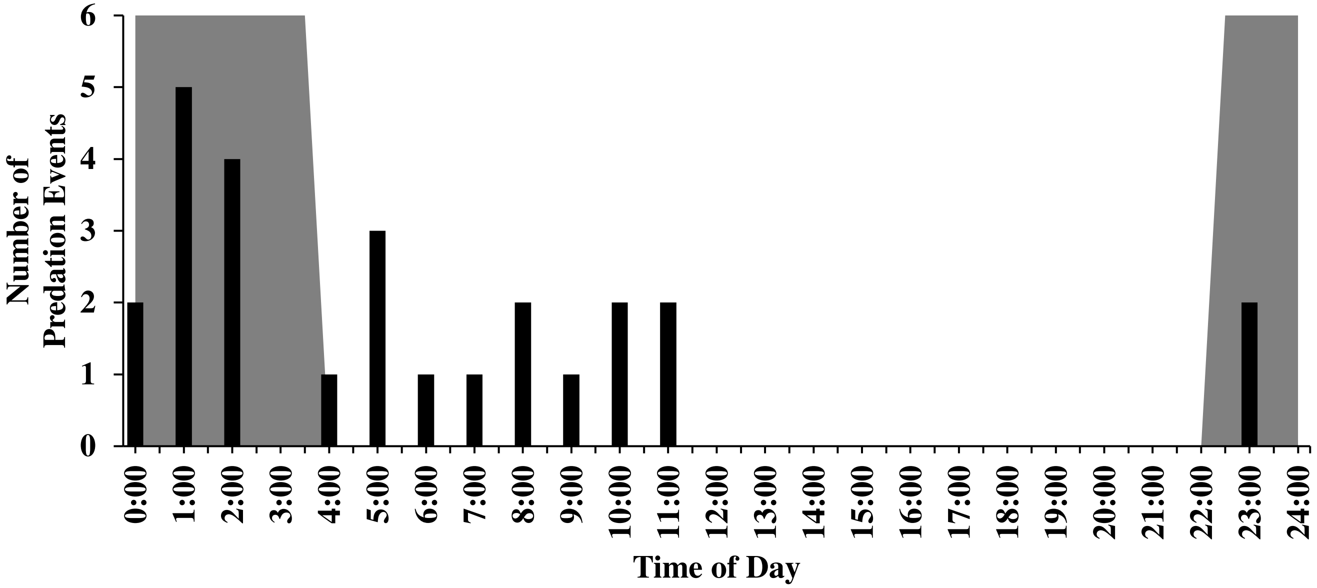


Figure 1 Timing of predation events by arctic foxes. Night is between 22:00 and 03:59 and is represented with shading.

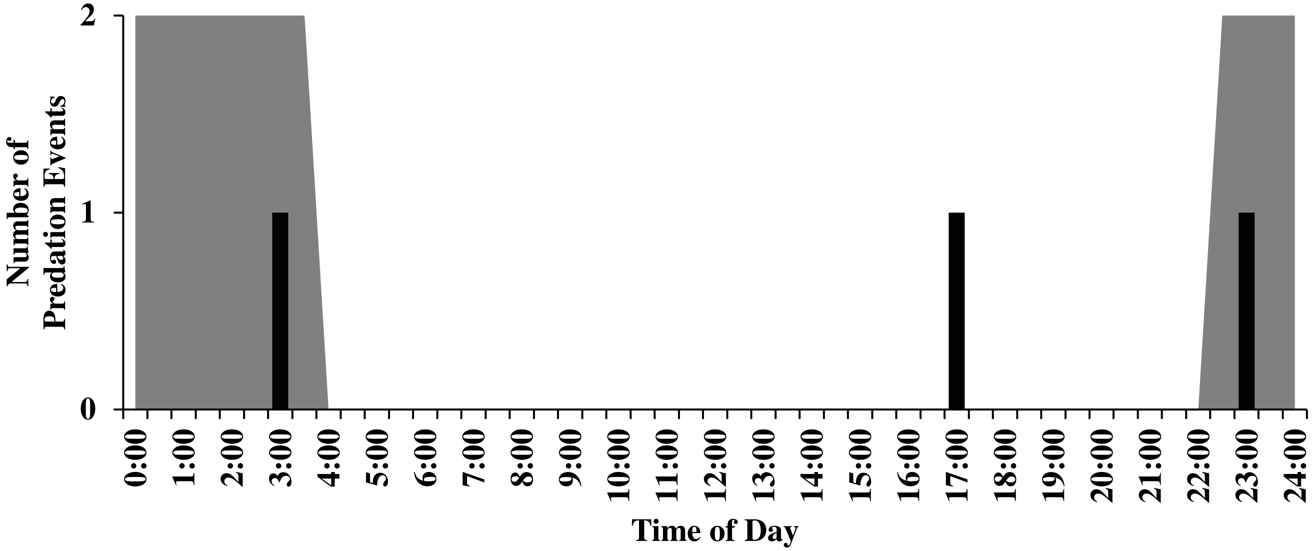


Figure 2 Timing of predation events by red foxes. Night is between 22:00 and 03:59 and is represented with shading.

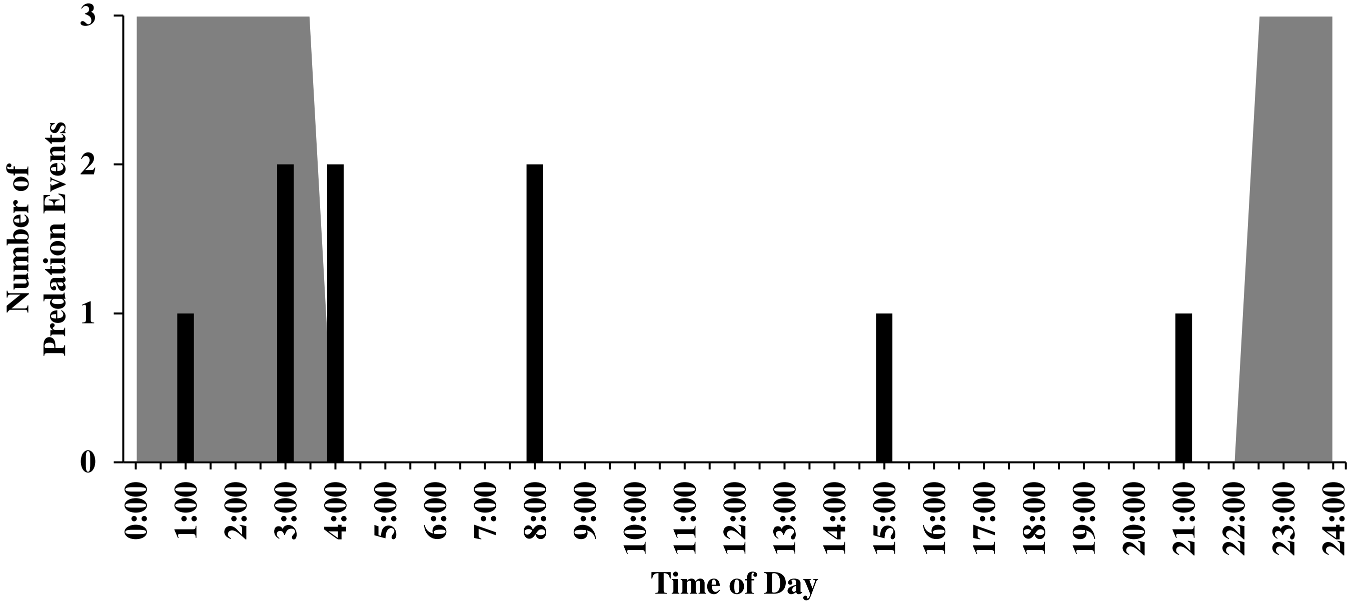


Figure 3 Timing of predation events by grizzly bears. Night is between 22:00 and 03:59 and is represented with shading.

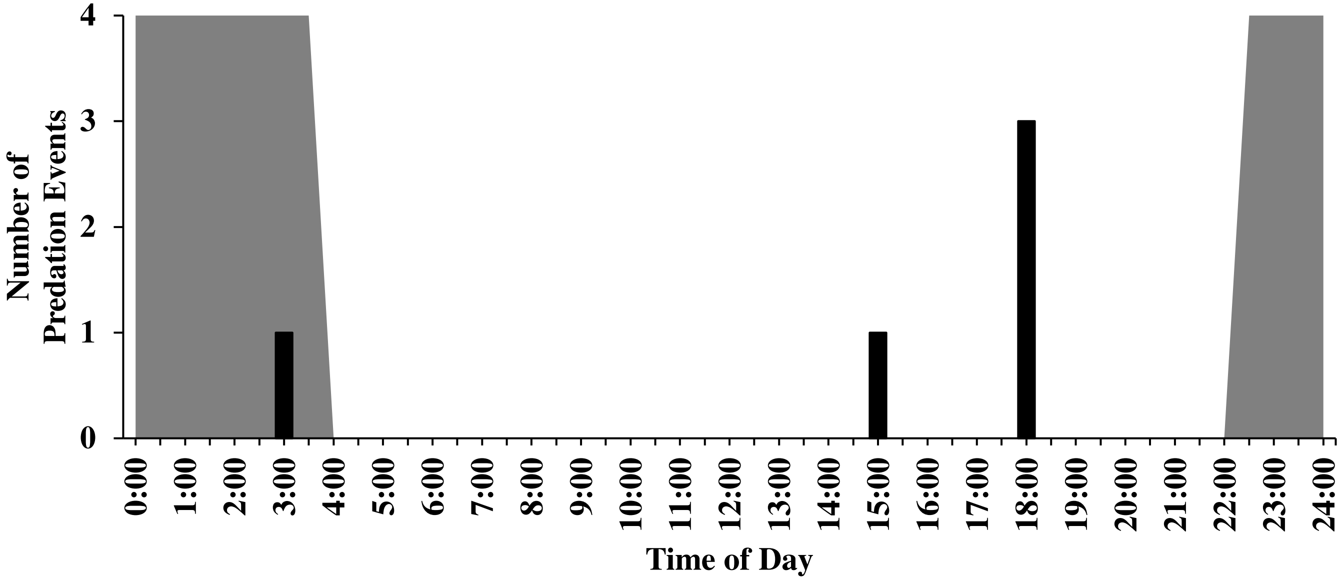


Figure 4 Timing of predation events by polar bears. Night is between 22:00 and 03:59 and is represented with shading.

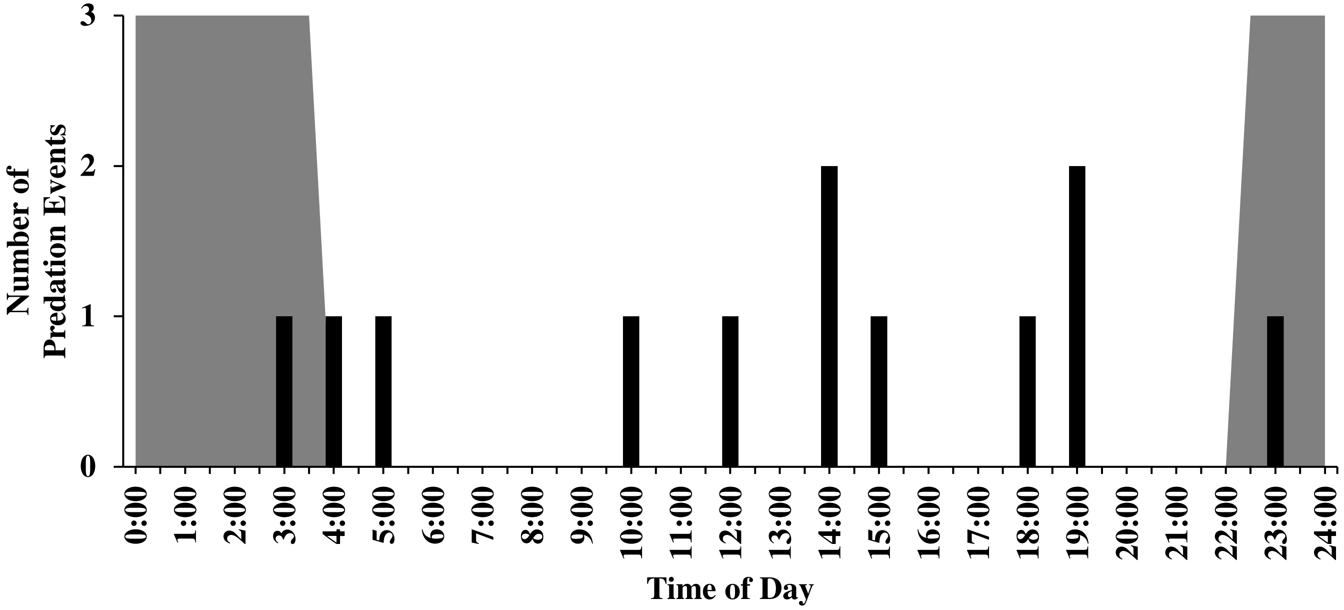


Figure 5 Timing of predation events by herring gulls. Night is between 22:00 and 03:59 and is represented with shading.

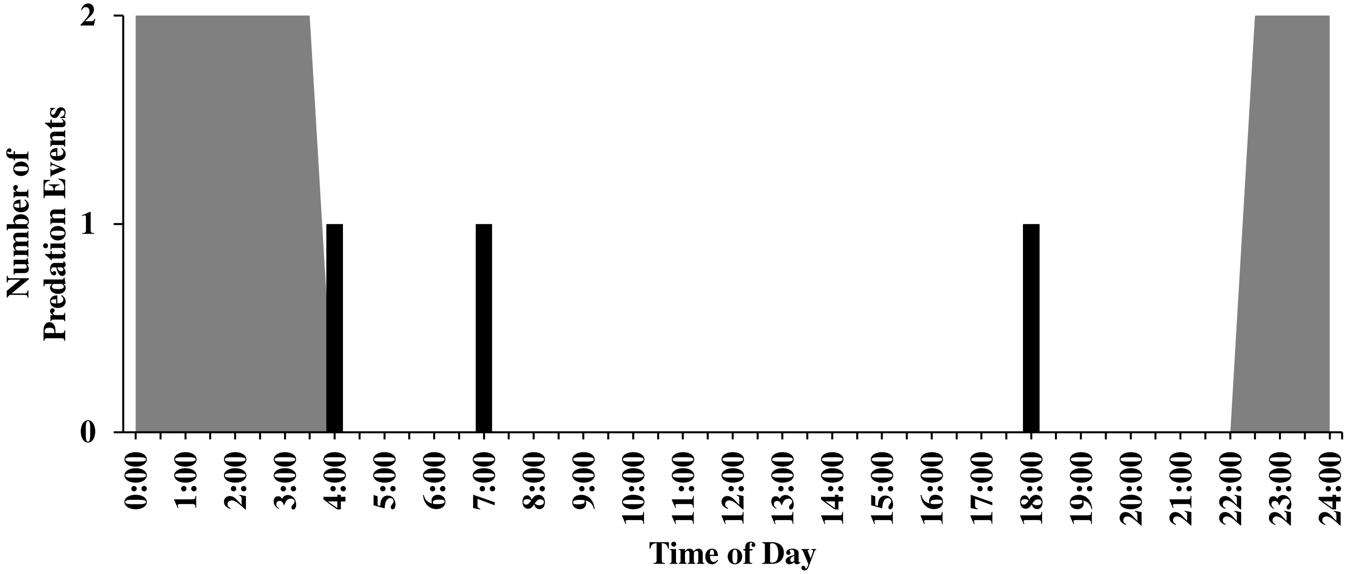


Figure 6 Timing of predation events by bald eagles. Night is between 22:00 and 03:59 and is represented with shading.

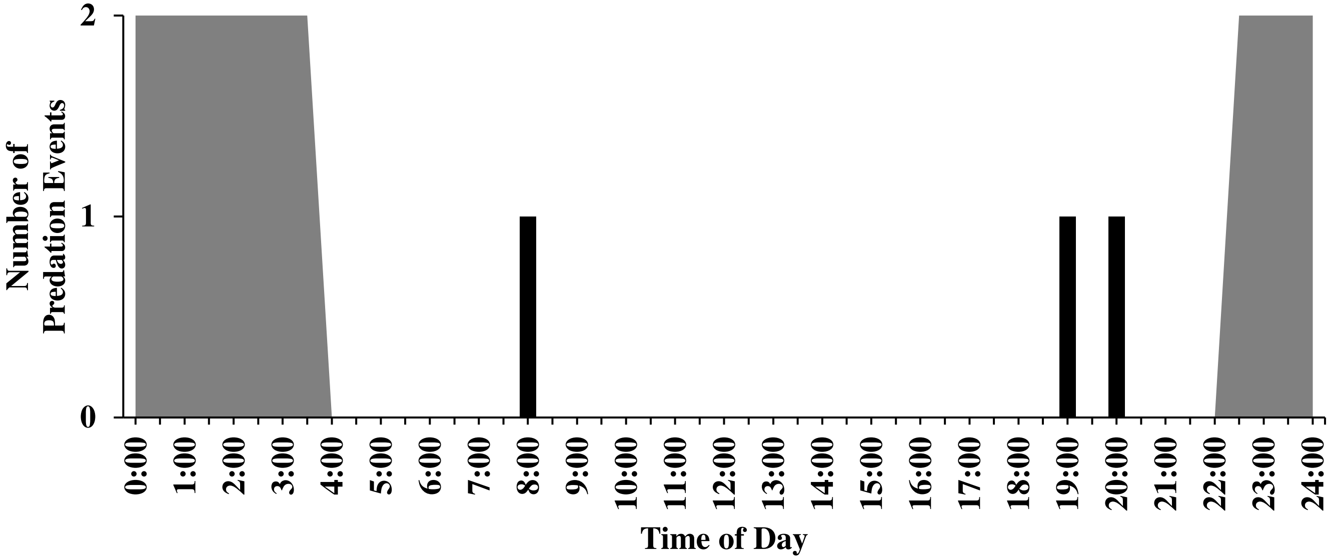


Figure 7 Timing of predation events by sandhill cranes. Night is between 22:00 and 03:59 and is represented with shading.

APPENDIX B
Chapter III

Tables

Appendix B Table 1. Variables collected at each sampling location.

	2003	**2004**	**2016**	**2017**
Water Salinity	No	No	No	Yes
Water Flow	Yes	Yes	Yes	Yes
Substrate Type	Yes	Yes	Yes	Yes
Substrate Size	Yes	Yes	Yes	Yes
Liter Presence	Yes	Yes	Yes	Yes
Vegatation Presence	Yes	Yes	Yes	Yes
Water Depth	Yes	Yes	Yes	Yes
Sediment Depth	Yes	Yes	Yes	Yes
Temperature	Yes	Yes	Yes	Yes

Appendix B Table 2. GPS locations of sampling sites

Location	Sample Site	Latitude	Longitude
Coast	A	58.74893602	-93.45363404
Coast	B	58.74717901	-93.45071303
Coast	C	58.74600797	-93.447372
Coast	D	58.74426998	-93.44443498
Coast	E	58.74291404	-93.44421697
Coast	F	58.76549003	-94.09562998
Mast	A	58.72496663	-93.46431669
Mast	B	58.72471668	-93.46381671
Mast	C	58.72471668	-93.46503334
Mast	D	58.72443337	-93.46505002
Mast	E	58.72461668	-93.46806667
Mast	F	58.726081	-93.46567296
Mast	G	58.72604999	-93.46116669
Mast	H	58.72551665	-93.46093333
Mast	I	58.72483335	-93.46003337
Mast	J	58.72486663	-93.45956666
Mast	K	58.72509998	-93.45849998
Mast	L	58.72556669	-93.45675001
Mast	M	58.72560013	-93.48235572
Mast	N	58.72704894	-93.48261212
Mast	O	58.72680612	-93.47983629
Mast	P	58.72377497	-93.48272896
Mast	Q	58.72394898	-93.481067
Mast	R	58.72257611	-93.48102325
Mast	S	58.72758999	-93.47542204
Mast	S5	58.72573	-93.45502
Mast	S6	58.72650	-93.45305
Mast	T	58.72919161	-93.47505013
Mast	U	58.72838946	-93.47221806
Mast	V	58.74302502	-93.463048
Mast	W	58.74379699	-93.46371898
Mast	X	58.74698304	-93.46582401
Mast	Y	58.74680903	-93.46787699
Mast	Z	58.74347001	-93.46514801
Mast	AA	58.74311797	-93.46473402
Mast	BB	58.74111302	-93.46271197
Mast	CC	58.74118402	-93.46490703
Wawao	A	58.70735901	-93.45674297
Wawao	B	58.70752699	-93.45339004
Wawao	C	58.70585798	-93.45238103
Wawao	D	58.70458226	-93.45102475
Wawao	E	58.70292851	-93.45223476
Wawao	F	58.69563852	-93.45611592

Appendix B Table 3. Water depth, silt depth and total aquatic invertebrates for each category collected from Wapusk National Park, Manitoba, Canada in 2003, 2004, 2016, and 2017.

Location	Sample Site	Date	Year	Visit Number	Water Depth	Silt Depth	S-Tipulid Crane Flies	M-Tipulid Crane Flies	L-Tipulid Crane Flies	XL-Tipulid Crane Flies	Total Crane Flies
Mast	A	6/5/2003	2003	1	.	.	0	3	7	0	10
Mast	A	7/7/2003	2003	2	.	.	0	5	7	3	15
Mast	B	6/5/2003	2003	1	.	.	0	18	14	0	32
Mast	B	7/7/2003	2003	2	.	.	0	10	11	1	22
Mast	C	6/5/2003	2003	1	.	.	0	12	4	0	16
Mast	C	7/7/2003	2003	2	.	.	0	0	4	0	4
Mast	D	6/5/2003	2003	1	.	.	0	13	2	0	15
Mast	D	7/7/2003	2003	2	.	.	0	2	7	1	10
Mast	E	6/5/2003	2003	1	.	.	0	2	0	0	2
Mast	E	7/7/2003	2003	2	.	.	0	0	2	0	2
Mast	F	6/5/2003	2003	1	.	.	0	9	0	0	9
Mast	F	7/7/2003	2003	2	.	.	0	0	5	0	5
Mast	G	6/5/2003	2003	1	.	.	0	2	0	0	2
Mast	G	7/7/2003	2003	2	.	.	0	0	3	0	3
Mast	H	6/5/2003	2003	1	.	.	0	10	3	0	13
Mast	H	7/7/2003	2003	2	.	.	0	3	11	1	15
Mast	I	6/5/2003	2003	1	.	.	0	2	1	0	3
Mast	I	7/7/2003	2003	2	.	.	0	0	2	0	2
Mast	J	6/5/2003	2003	1	.	.	0	22	3	0	25
Mast	J	7/7/2003	2003	2	.	.	0	4	5	0	9
Mast	K	6/5/2003	2003	1	.	.	0	3	3	0	6
Mast	K	7/7/2003	2003	2	.	.	0	3	3	0	6
Mast	L	6/5/2003	2003	1	.	.	0	1	3	0	4
Mast	L	7/7/2003	2003	2	.	.	0	2	3	1	6
Mast	D	6/21/2004	2004	1	28	.	0	5	2	0	7
Mast	D	7/5/2004	2004	2	27.5	.	0	3	1	0	4
Mast	I	6/21/2004	2004	1	30.5	.	0	25	10	0	35
Mast	I	7/5/2004	2004	2	22	.	0	6	19	0	25
Mast	K	6/21/2004	2004	1	28	.	0	1	0	1	2
Mast	K	7/5/2004	2004	2	24	.	0	4	1	0	5
Mast	L	6/21/2004	2004	1	20.5	.	0	3	0	0	3
Mast	L	7/5/2004	2004	2	25.5	.	0	2	0	0	2
Mast	S5	6/21/2004	2004	1	26	.	0	6	1	0	7
Mast	S5	7/5/2004	2004	2	23.5	.	0	6	10	4	20
Mast	S6	6/21/2004	2004	1	26	.	0	0	0	0	0
Mast	S6	7/5/2004	2004	2	25.5	.	0	2	5	1	8

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Chironomidae Non-Biting Midges	Ceratopogonidae Sandflies (Biting Midges)	Plecoptera Stoneflies	Trichoptera Caddiesflies	Ephemeroptera Mayflies	Gastropoda Snails
Mast	A	6/5/2003	2003	1	.	.	10	0	0	3
Mast	A	7/7/2003	2003	2	.	.	1	4	0	3
Mast	B	6/5/2003	2003	1	.	.	65	0	0	4
Mast	B	7/7/2003	2003	2	.	.	2	14	0	10
Mast	C	6/5/2003	2003	1	.	.	0	1	0	0
Mast	C	7/7/2003	2003	2	.	.	0	3	0	1
Mast	D	6/5/2003	2003	1	.	.	26	10	0	1
Mast	D	7/7/2003	2003	2	.	.	0	12	0	2
Mast	E	6/5/2003	2003	1	.	.	5	4	0	0
Mast	E	7/7/2003	2003	2	.	.	0	1	0	1
Mast	F	6/5/2003	2003	1	.	.	0	6	0	1
Mast	F	7/7/2003	2003	2	.	.	0	1	0	0
Mast	G	6/5/2003	2003	1	.	.	4	0	0	0
Mast	G	7/7/2003	2003	2	.	.	0	1	0	1
Mast	H	6/5/2003	2003	1	.	.	14	1	0	0
Mast	H	7/7/2003	2003	2	.	.	0	2	1	0
Mast	I	6/5/2003	2003	1	.	.	6	3	0	1
Mast	I	7/7/2003	2003	2	.	.	0	1	0	2
Mast	J	6/5/2003	2003	1	.	.	55	2	0	6
Mast	J	7/7/2003	2003	2	.	.	5	1	0	0
Mast	K	6/5/2003	2003	1	.	.	62	1	0	0
Mast	K	7/7/2003	2003	2	.	.	7	3	1	1
Mast	L	6/5/2003	2003	1	.	.	21	4	0	0
Mast	L	7/7/2003	2003	2	.	.	3	2	1	1
Mast	D	6/21/2004	2004	1	12	2	15	0	0	3
Mast	D	7/5/2004	2004	2	10	0	10	0	0	1
Mast	I	6/21/2004	2004	1	35	1	79	1	0	31
Mast	I	7/5/2004	2004	2	27	2	13	1	0	29
Mast	K	6/21/2004	2004	1	26	5	5	9	0	6
Mast	K	7/5/2004	2004	2	29	2	3	10	0	1
Mast	L	6/21/2004	2004	1	29	11	8	2	0	6
Mast	L	7/5/2004	2004	2	32	8	2	6	0	6
Mast	S5	6/21/2004	2004	1	8	9	82	4	0	39
Mast	S5	7/5/2004	2004	2	7	4	17	3	0	33
Mast	S6	6/21/2004	2004	1	33	12	11	6	0	16
Mast	S6	7/5/2004	2004	2	25	5	16	20	0	25

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Oligochaete/Nematoda Worms	Coleoptera Beetles	Other Diptera Flies	Simuliidae Black Flies	Hirudinea Leeches	Amphipoda Amphipods	Mollusca Bivalves
Mast	A	6/5/2003	2003	1	11	.	4	.	.	1	.
Mast	A	7/7/2003	2003	2	21	.	1	.	.	0	.
Mast	B	6/5/2003	2003	1	23	.	1	.	.	0	.
Mast	B	7/7/2003	2003	2	7	.	2	.	.	0	.
Mast	C	6/5/2003	2003	1	1	.	4	.	.	0	.
Mast	C	7/7/2003	2003	2	8	.	1	.	.	0	.
Mast	D	6/5/2003	2003	1	19	.	2	.	.	0	.
Mast	D	7/7/2003	2003	2	19	.	2	.	.	0	.
Mast	E	6/5/2003	2003	1	5	.	2	.	.	0	.
Mast	E	7/7/2003	2003	2	9	.	3	.	.	0	.
Mast	F	6/5/2003	2003	1	12	.	0	.	.	0	.
Mast	F	7/7/2003	2003	2	8	.	0	.	.	0	.
Mast	G	6/5/2003	2003	1	5	.	0	.	.	0	.
Mast	G	7/7/2003	2003	2	2	.	1	.	.	0	.
Mast	H	6/5/2003	2003	1	10	.	0	.	.	0	.
Mast	H	7/7/2003	2003	2	4	.	0	.	.	0	.
Mast	I	6/5/2003	2003	1	0	.	1	.	.	1	.
Mast	I	7/7/2003	2003	2	11	.	1	.	.	0	.
Mast	J	6/5/2003	2003	1	16	.	0	.	.	1	.
Mast	J	7/7/2003	2003	2	4	.	3	.	.	0	.
Mast	K	6/5/2003	2003	1	3	.	0	.	.	0	.
Mast	K	7/7/2003	2003	2	1	.	1	.	.	0	.
Mast	L	6/5/2003	2003	1	5	.	4	.	.	1	.
Mast	L	7/7/2003	2003	2	1	.	1	.	.	0	.
Mast	D	6/21/2004	2004	1	29	4	1	0	0	0	0
Mast	D	7/5/2004	2004	2	18	1	2	0	0	0	0
Mast	I	6/21/2004	2004	1	5	0	0	0	0	0	0
Mast	I	7/5/2004	2004	2	11	1	1	0	0	0	0
Mast	K	6/21/2004	2004	1	1	1	1	0	0	0	0
Mast	K	7/5/2004	2004	2	2	2	5	0	0	0	0
Mast	L	6/21/2004	2004	1	38	0	2	0	0	0	0
Mast	L	7/5/2004	2004	2	18	0	0	0	0	0	0
Mast	S5	6/21/2004	2004	1	1	0	0	7	0	0	0
Mast	S5	7/5/2004	2004	2	9	1	0	0	0	0	0
Mast	S6	6/21/2004	2004	1	3	2	1	0	0	0	0
Mast	S6	7/5/2004	2004	2	6	2	4	0	0	0	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Other	Categories
Mast	A	6/5/2003	2003	1	0	5
Mast	A	7/7/2003	2003	2	2	7
Mast	B	6/5/2003	2003	1	0	5
Mast	B	7/7/2003	2003	2	0	6
Mast	C	6/5/2003	2003	1	0	4
Mast	C	7/7/2003	2003	2	0	5
Mast	D	6/5/2003	2003	1	0	6
Mast	D	7/7/2003	2003	2	0	5
Mast	E	6/5/2003	2003	1	0	5
Mast	E	7/7/2003	2003	2	2	6
Mast	F	6/5/2003	2003	1	0	4
Mast	F	7/7/2003	2003	2	0	3
Mast	G	6/5/2003	2003	1	0	3
Mast	G	7/7/2003	2003	2	0	5
Mast	H	6/5/2003	2003	1	0	4
Mast	H	7/7/2003	2003	2	0	4
Mast	I	6/5/2003	2003	1	0	6
Mast	I	7/7/2003	2003	2	0	5
Mast	J	6/5/2003	2003	1	0	6
Mast	J	7/7/2003	2003	2	0	5
Mast	K	6/5/2003	2003	1	0	4
Mast	K	7/7/2003	2003	2	0	7
Mast	L	6/5/2003	2003	1	0	6
Mast	L	7/7/2003	2003	2	0	7
Mast	D	6/21/2004	2004	1	0	8
Mast	D	7/5/2004	2004	2	0	7
Mast	I	6/21/2004	2004	1	0	7
Mast	I	7/5/2004	2004	2	0	9
Mast	K	6/21/2004	2004	1	0	9
Mast	K	7/5/2004	2004	2	5	10
Mast	L	6/21/2004	2004	1	0	8
Mast	L	7/5/2004	2004	2	0	7
Mast	S5	6/21/2004	2004	1	0	8
Mast	S5	7/5/2004	2004	2	1	9
Mast	S6	6/21/2004	2004	1	1	9
Mast	S6	7/5/2004	2004	2	2	10

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Water Depth	Silt Depth	S-Tipulid Crane Flies	M-Tipulid Crane Flies	L-Tipulid Crane Flies	XL-Tipulid Crane Flies	Total Crane Flies
Coast	A	7/27/2016	2016	1	.	.	0	0	0	0	0
Coast	B	7/27/2016	2016	1	.	.	0	0	0	0	0
Coast	C	7/27/2016	2016	1	.	.	0	0	0	0	0
Coast	D	7/27/2016	2016	1	.	.	0	0	0	0	0
Coast	E	7/27/2016	2016	1	.	.	0	0	0	0	0
Coast	F	8/1/2016	2016	1	.	.	0	0	0	0	0
Mast	A	6/13/2016	2016	1	7	.	0	0	0	0	0
Mast	A	7/17/2016	2016	2	10.5	0.5	0	0	0	0	0
Mast	B	6/13/2016	2016	1	8	.	0	1	1	0	2
Mast	B	7/17/2016	2016	2	11	0	0	0	2	1	3
Mast	C	6/13/2016	2016	1	9	.	0	0	0	0	0
Mast	C	7/17/2016	2016	2	11	0	0	0	0	0	0
Mast	D	6/13/2016	2016	1	10	.	0	0	0	0	0
Mast	D	7/17/2016	2016	2	12.5	0.5	0	0	0	0	0
Mast	E	6/13/2016	2016	1	13	.	0	1	0	0	1
Mast	E	7/17/2016	2016	2	14.5	0.5	0	0	0	1	1
Mast	F	6/13/2016	2016	1	20	.	0	2	0	0	2
Mast	F	7/17/2016	2016	2	22	0.5	0	0	0	1	1
Mast	G	6/15/2016	2016	1	9	.	0	0	0	0	0
Mast	G	7/18/2016	2016	2	5	0.5	0	0	0	0	0
Mast	H	6/15/2016	2016	1	13	.	0	0	0	0	0
Mast	H	7/18/2016	2016	2	9	0.25	0	0	0	0	0
Mast	I	6/15/2016	2016	1	14	.	3	0	0	0	3
Mast	I	7/18/2016	2016	2	7	1	0	0	0	0	0
Mast	J	6/15/2016	2016	1	22	.	2	8	0	0	10
Mast	J	7/18/2016	2016	2	12	0.25	0	0	0	1	1
Mast	K	6/15/2016	2016	1	16	.	2	2	2	1	7
Mast	K	7/18/2016	2016	2	9.5	0	1	0	7	4	12
Mast	L	6/15/2016	2016	1	6	.	0	2	0	0	2
Mast	L	7/18/2016	2016	2	3.5	0.5	0	0	0	0	0
Mast	M	6/21/2016	2016	1	17	0	0	0	0	0	0
Mast	M	7/18/2016	2016	2	5.5	0.5	1	0	0	0	1
Mast	N	6/21/2016	2016	1	19	0	0	0	0	0	0
Mast	N	7/18/2016	2016	2	9.5	0.5	0	0	0	1	1
Mast	O	6/21/2016	2016	1	17	3	0	0	0	0	0
Mast	O	7/18/2016	2016	2	9	1	0	0	0	0	0
Mast	P	6/18/2016	2016	1	21	2	0	0	0	0	0
Mast	P	7/18/2016	2016	2	9	0.5	0	0	0	0	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Chironomidae Non-Biting Midges	Ceratopogonidae Sandflies (Biting Midges)	Plecoptera Stoneflies	Trichoptera Caddiesflies	Ephemeroptera Mayflies	Gastropoda Snails
Coast	A	7/27/2016	2016	1	0	0	0	0	0	0
Coast	B	7/27/2016	2016	1	0	0	0	0	0	0
Coast	C	7/27/2016	2016	1	0	0	0	0	0	0
Coast	D	7/27/2016	2016	1	0	0	0	0	0	0
Coast	E	7/27/2016	2016	1	0	0	0	0	0	0
Coast	F	8/1/2016	2016	1	0	0	0	0	0	28
Mast	A	6/13/2016	2016	1	0	0	1	2	0	1
Mast	A	7/17/2016	2016	2	12	1	1	1	0	1
Mast	B	6/13/2016	2016	1	16	0	72	0	0	3
Mast	B	7/17/2016	2016	2	22	0	7	0	10	0
Mast	C	6/13/2016	2016	1	0	0	0	17	0	1
Mast	C	7/17/2016	2016	2	11	0	0	3	20	0
Mast	D	6/13/2016	2016	1	3	0	7	6	0	0
Mast	D	7/17/2016	2016	2	13	0	0	3	57	0
Mast	E	6/13/2016	2016	1	0	0	4	3	0	0
Mast	E	7/17/2016	2016	2	12	0	0	2	25	0
Mast	F	6/13/2016	2016	1	24	0	35	3	0	0
Mast	F	7/17/2016	2016	2	6	8	0	2	8	0
Mast	G	6/15/2016	2016	1	7	0	0	1	3	0
Mast	G	7/18/2016	2016	2	10	4	0	4	0	0
Mast	H	6/15/2016	2016	1	10	0	0	1	3	0
Mast	H	7/18/2016	2016	2	6	3	0	1	39	0
Mast	I	6/15/2016	2016	1	5	0	0	3	1	0
Mast	I	7/18/2016	2016	2	12	12	1	2	23	1
Mast	J	6/15/2016	2016	1	12	0	72	10	0	11
Mast	J	7/18/2016	2016	2	11	4	1	2	54	3
Mast	K	6/15/2016	2016	1	2	0	140	4	0	8
Mast	K	7/18/2016	2016	2	6	2	5	0	52	0
Mast	L	6/15/2016	2016	1	8	0	20	12	0	0
Mast	L	7/18/2016	2016	2	5	0	0	0	23	0
Mast	M	6/21/2016	2016	1	5	0	1	10	0	1
Mast	M	7/18/2016	2016	2	1	0	1	0	3	0
Mast	N	6/21/2016	2016	1	5	0	22	9	0	0
Mast	N	7/18/2016	2016	2	9	2	0	1	12	0
Mast	O	6/21/2016	2016	1	3	0	1	3	0	0
Mast	O	7/18/2016	2016	2	9	0	0	6	23	1
Mast	P	6/18/2016	2016	1	11	0	0	3	0	0
Mast	P	7/18/2016	2016	2	23	0	0	6	5	2

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Oligochaete/Nematoda Worms	Coleoptera Beetles	Other Diptera Flies	Simuliidae Black Flies	Hirudinea Leeches	Amphipoda Amphipods	Mollusca Bivalves
Coast	A	7/27/2016	2016	1	0	0	0	0	0	0	10
Coast	B	7/27/2016	2016	1	0	0	0	0	0	0	8
Coast	C	7/27/2016	2016	1	0	0	0	0	0	0	5
Coast	D	7/27/2016	2016	1	0	0	0	0	0	0	5
Coast	E	7/27/2016	2016	1	0	0	0	0	0	17	0
Coast	F	8/1/2016	2016	1	0	0	0	0	0	57	11
Mast	A	6/13/2016	2016	1	33	0	0	0	0	0	0
Mast	A	7/17/2016	2016	2	4	0	1	0	1	0	1
Mast	B	6/13/2016	2016	1	5	1	0	0	0	0	0
Mast	B	7/17/2016	2016	2	1	0	4	0	0	0	0
Mast	C	6/13/2016	2016	1	21	0	0	0	0	0	0
Mast	C	7/17/2016	2016	2	6	0	0	0	1	0	0
Mast	D	6/13/2016	2016	1	11	0	0	0	0	0	0
Mast	D	7/17/2016	2016	2	4	0	7	0	0	0	8
Mast	E	6/13/2016	2016	1	6	0	0	0	0	0	0
Mast	E	7/17/2016	2016	2	4	0	0	0	0	0	8
Mast	F	6/13/2016	2016	1	10	0	0	0	0	0	0
Mast	F	7/17/2016	2016	2	3	0	10	0	2	0	1
Mast	G	6/15/2016	2016	1	4	0	0	0	0	0	0
Mast	G	7/18/2016	2016	2	1	0	0	0	2	0	2
Mast	H	6/15/2016	2016	1	4	0	0	0	0	0	0
Mast	H	7/18/2016	2016	2	2	1	2	0	1	0	3
Mast	I	6/15/2016	2016	1	11	0	0	0	0	0	0
Mast	I	7/18/2016	2016	2	4	2	1	0	3	0	0
Mast	J	6/15/2016	2016	1	5	0	0	0	0	0	0
Mast	J	7/18/2016	2016	2	3	0	4	0	1	0	0
Mast	K	6/15/2016	2016	1	3	0	0	0	0	0	0
Mast	K	7/18/2016	2016	2	2	0	2	0	0	0	3
Mast	L	6/15/2016	2016	1	9	0	0	0	0	0	0
Mast	L	7/18/2016	2016	2	7	0	1	0	1	0	0
Mast	M	6/21/2016	2016	1	3	1	0	0	0	0	0
Mast	M	7/18/2016	2016	2	0	0	1	0	2	0	11
Mast	N	6/21/2016	2016	1	10	1	0	0	0	2	0
Mast	N	7/18/2016	2016	2	8	1	0	0	0	0	0
Mast	O	6/21/2016	2016	1	1	0	1	0	0	1	0
Mast	O	7/18/2016	2016	2	2	0	0	0	0	0	0
Mast	P	6/18/2016	2016	1	0	0	1	0	0	0	0
Mast	P	7/18/2016	2016	2	1	0	0	0	0	1	3

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Other	Categories
Coast	A	7/27/2016	2016	1	0	1
Coast	B	7/27/2016	2016	1	0	1
Coast	C	7/27/2016	2016	1	0	1
Coast	D	7/27/2016	2016	1	0	1
Coast	E	7/27/2016	2016	1	0	1
Coast	F	8/1/2016	2016	1	0	3
Mast	A	6/13/2016	2016	1	0	4
Mast	A	7/17/2016	2016	2	0	9
Mast	B	6/13/2016	2016	1	2	7
Mast	B	7/17/2016	2016	2	0	6
Mast	C	6/13/2016	2016	1	0	3
Mast	C	7/17/2016	2016	2	0	5
Mast	D	6/13/2016	2016	1	4	5
Mast	D	7/17/2016	2016	2	4	7
Mast	E	6/13/2016	2016	1	0	4
Mast	E	7/17/2016	2016	2	1	7
Mast	F	6/13/2016	2016	1	0	5
Mast	F	7/17/2016	2016	2	2	10
Mast	G	6/15/2016	2016	1	0	4
Mast	G	7/18/2016	2016	2	1	7
Mast	H	6/15/2016	2016	1	0	4
Mast	H	7/18/2016	2016	2	0	9
Mast	I	6/15/2016	2016	1	0	5
Mast	I	7/18/2016	2016	2	0	10
Mast	J	6/15/2016	2016	1	1	7
Mast	J	7/18/2016	2016	2	1	11
Mast	K	6/15/2016	2016	1	1	7
Mast	K	7/18/2016	2016	2	0	8
Mast	L	6/15/2016	2016	1	0	5
Mast	L	7/18/2016	2016	2	0	5
Mast	M	6/21/2016	2016	1	0	6
Mast	M	7/18/2016	2016	2	1	8
Mast	N	6/21/2016	2016	1	0	6
Mast	N	7/18/2016	2016	2	0	7
Mast	O	6/21/2016	2016	1	0	6
Mast	O	7/18/2016	2016	2	0	5
Mast	P	6/18/2016	2016	1	0	3
Mast	P	7/18/2016	2016	2	1	8

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Water Depth	Silt Depth	S-Tipulid Crane Flies	M-Tipulid Crane Flies	L-Tipulid Crane Flies	XL-Tipulid Crane Flies	Total Crane Flies
Mast	Q	6/18/2016	2016	1	25	6	0	0	0	0	0
Mast	Q	7/18/2016	2016	2	8	2.5	0	0	0	0	0
Mast	R	6/21/2016	2016	1	13	7	0	0	0	0	0
Mast	R	7/18/2016	2016	2	5	0.5	0	0	0	0	0
Mast	S	6/21/2016	2016	1	19	9	0	0	0	0	0
Mast	S	7/19/2016	2016	2	10	0.5	0	0	0	0	0
Mast	T	6/21/2016	2016	1	7	5	2	0	0	0	2
Mast	T	7/19/2016	2016	2	1	3	0	0	0	0	0
Mast	U	6/21/2016	2016	1	21	2	0	0	0	0	0
Mast	U	7/19/2016	2016	2	11	2	0	0	0	0	0
Mast	V	6/19/2016	2016	1	13	0	2	2	3	1	8
Mast	V	7/20/2016	2016	2	8	0	0	0	4	2	6
Mast	W	6/19/2016	2016	1	9	0	0	0	0	0	0
Mast	W	7/20/2016	2016	2	1.5	3.5	0	0	0	0	0
Mast	X	6/19/2016	2016	1	5	0.5	1	0	1	0	2
Mast	X	7/20/2016	2016	2	4	3	0	0	0	0	0
Mast	Y	6/19/2016	2016	1	11	1	1	2	0	0	3
Mast	Y	7/20/2016	2016	2	10	0	0	0	0	0	0
Mast	Z	6/19/2016	2016	1	8	0.5	0	0	0	0	0
Mast	Z	7/20/2016	2016	2	3	0.5	0	0	0	0	0
Mast	AA	6/19/2016	2016	1	17		4	1	0	0	5
Mast	AA	7/20/2016	2016	2	5	0	1	1	0	0	2
Mast	BB	6/19/2016	2016	1	11	1	1	2	4	3	10
Mast	BB	7/20/2016	2016	2	8	6	0	0	3	4	7
Mast	CC	6/19/2016	2016	1	23	0.5	0	4	2	0	6
Mast	CC	7/20/2016	2016	2	16	0.5	0	0	0	1	1
WaWao	WA	6/30/2016	2016	1	18	1	0	0	0	0	0
WaWao	WA	7/14/2016	2016	2	15	0.5	0	0	0	0	0
WaWao	WB	6/30/2016	2016	1	14	1	0	0	0	0	0
WaWao	WB	7/14/2016	2016	2	14.5	.	0	0	0	0	0
WaWao	WC	6/30/2016	2016	1	10	1	0	0	0	0	0
WaWao	WC	7/14/2016	2016	2	8.5	1	0	0	0	0	0
WaWao	WD	7/4/2016	2016	1	10	1	0	0	0	0	0
WaWao	WD	7/14/2016	2016	2	8.5	0.5	0	0	0	0	0
WaWao	WE	7/4/2016	2016	1	14	1	0	0	0	2	2
WaWao	WE	7/14/2016	2016	2	12	0.5	0	0	0	1	1
WaWao	WF	7/4/2016	2016	1	10	4	0	0	0	0	0
WaWao	WF	7/14/2016	2016	2	9	1	0	0	0	0	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Chironomidae Non-Biting Midges	Ceratopogonidae Sandflies (Biting Midges)	Plecoptera Stoneflies	Trichoptera Caddiesflies	Ephemeroptera Mayflies	Gastropoda Snails
Mast	Q	6/18/2016	2016	1	7	0	0	0	0	0
Mast	Q	7/18/2016	2016	2	11	0	0	2	0	0
Mast	R	6/21/2016	2016	1	2	0	3	3	0	1
Mast	R	7/18/2016	2016	2	2	2	0	1	5	0
Mast	S	6/21/2016	2016	1	17	0	2	3	0	0
Mast	S	7/19/2016	2016	2	5	1	0	1	1	0
Mast	T	6/21/2016	2016	1	7	0	1	7	0	2
Mast	T	7/19/2016	2016	2	1	0	0	0	3	0
Mast	U	6/21/2016	2016	1	2	0	0	0	0	0
Mast	U	7/19/2016	2016	2	4	0	0	0	1	0
Mast	V	6/19/2016	2016	1	1	1	59	5	0	1
Mast	V	7/20/2016	2016	2	2	0	0	1	2	1
Mast	W	6/19/2016	2016	1	1	0	3	11	0	5
Mast	W	7/20/2016	2016	2	17	2	0	2	0	1
Mast	X	6/19/2016	2016	1	0	0	30	0	0	1
Mast	X	7/20/2016	2016	2	6	1	24	1	27	0
Mast	Y	6/19/2016	2016	1	5	0	65	7	0	2
Mast	Y	7/20/2016	2016	2	10	0	2	1	7	0
Mast	Z	6/19/2016	2016	1	3	0	54	42	0	11
Mast	Z	7/20/2016	2016	2	4	0	0	0	1	0
Mast	AA	6/19/2016	2016	1	8	0	35	23	0	8
Mast	AA	7/20/2016	2016	2	6	2	16	19	16	1
Mast	BB	6/19/2016	2016	1	7	0	7	3	0	1
Mast	BB	7/20/2016	2016	2	1	0	1	4	31	0
Mast	CC	6/19/2016	2016	1	1	0	106	173	0	5
Mast	CC	7/20/2016	2016	2	1	0	9	45	10	2
WaWao	WA	6/30/2016	2016	1	22	0	0	1	0	0
WaWao	WA	7/14/2016	2016	2	12	0	0	1	2	0
WaWao	WB	6/30/2016	2016	1	37	0	0	2	0	0
WaWao	WB	7/14/2016	2016	2	8	0	0	1	2	0
WaWao	WC	6/30/2016	2016	1	29	0	1	2	7	1
WaWao	WC	7/14/2016	2016	2	45	0	11	2	10	0
WaWao	WD	7/4/2016	2016	1	44	0	0	3	5	0
WaWao	WD	7/14/2016	2016	2	38	0	0	4	5	0
WaWao	WE	7/4/2016	2016	1	34	78	0	5	81	1
WaWao	WE	7/14/2016	2016	2	156	0	0	3	72	5
WaWao	WF	7/4/2016	2016	1	26	0	0	3	28	1
WaWao	WF	7/14/2016	2016	2	40	0	0	0	21	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Oligochaete/Nematoda Worms	Coleoptera Beetles	Other Diptera Flies	Simuliidae Black Flies	Hirudinea Leeches	Amphipoda Amphipods	Mollusca Bivalves
Mast	Q	6/18/2016	2016	1	0	0	0	0	0	0	0
Mast	Q	7/18/2016	2016	2	0	1	4	0	0	0	0
Mast	R	6/21/2016	2016	1	6	0	6	0	0	2	1
Mast	R	7/18/2016	2016	2	3	0	0	5	0	0	2
Mast	S	6/21/2016	2016	1	1	2	0	0	0	0	0
Mast	S	7/19/2016	2016	2	16	0	0	0	0	2	0
Mast	T	6/21/2016	2016	1	0	0	0	0	0	2	0
Mast	T	7/19/2016	2016	2	0	0	1	0	1	0	1
Mast	U	6/21/2016	2016	1	1	0	0	0	0	0	0
Mast	U	7/19/2016	2016	2	0	0	0	0	0	0	0
Mast	V	6/19/2016	2016	1	2	0	1	0	0	0	0
Mast	V	7/20/2016	2016	2	0	1	0	6	19	0	2
Mast	W	6/19/2016	2016	1	17	0	4	0	0	0	0
Mast	W	7/20/2016	2016	2	0	2	0	0	0	0	3
Mast	X	6/19/2016	2016	1	8	0	0	0	0	0	0
Mast	X	7/20/2016	2016	2	6	2	0	0	1	0	0
Mast	Y	6/19/2016	2016	1	6	1	0	0	0	0	0
Mast	Y	7/20/2016	2016	2	5	0	0	0	1	0	3
Mast	Z	6/19/2016	2016	1	10	0	4	0	0	0	0
Mast	Z	7/20/2016	2016	2	3	0	0	1	0	0	0
Mast	AA	6/19/2016	2016	1	24	0	7	0	0	0	0
Mast	AA	7/20/2016	2016	2	6	2	6	3	43	0	1
Mast	BB	6/19/2016	2016	1	6	0	3	0	0	2	0
Mast	BB	7/20/2016	2016	2	1	4	0	60	1	0	1
Mast	CC	6/19/2016	2016	1	2	0	6	0	0	0	0
Mast	CC	7/20/2016	2016	2	3	0	0	80	5	0	1
WaWao	WA	6/30/2016	2016	1	0	0	0	0	0	0	0
WaWao	WA	7/14/2016	2016	2	3	0	0	0	0	0	0
WaWao	WB	6/30/2016	2016	1	0	1	0	0	6	0	0
WaWao	WB	7/14/2016	2016	2	0	0	0	0	0	0	0
WaWao	WC	6/30/2016	2016	1	0	0	0	0	1	0	0
WaWao	WC	7/14/2016	2016	2	0	0	1	0	1	0	0
WaWao	WD	7/4/2016	2016	1	0	0	7	0	7	0	0
WaWao	WD	7/14/2016	2016	2	0	0	3	0	18	0	0
WaWao	WE	7/4/2016	2016	1	1	0	13	0	1	0	0
WaWao	WE	7/14/2016	2016	2	2	0	2	0	0	0	0
WaWao	WF	7/4/2016	2016	1	0	1	7	0	11	0	0
WaWao	WF	7/14/2016	2016	2	0	0	0	0	15	0	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Other	Categories
Mast	Q	6/18/2016	2016	1	0	1
Mast	Q	7/18/2016	2016	2	0	4
Mast	R	6/21/2016	2016	1	0	8
Mast	R	7/18/2016	2016	2	0	7
Mast	S	6/21/2016	2016	1	0	5
Mast	S	7/19/2016	2016	2	0	6
Mast	T	6/21/2016	2016	1	0	6
Mast	T	7/19/2016	2016	2	1	6
Mast	U	6/21/2016	2016	1	0	2
Mast	U	7/19/2016	2016	2	0	2
Mast	V	6/19/2016	2016	1	0	8
Mast	V	7/20/2016	2016	2	0	9
Mast	W	6/19/2016	2016	1	0	6
Mast	W	7/20/2016	2016	2	0	6
Mast	X	6/19/2016	2016	1	0	4
Mast	X	7/20/2016	2016	2	0	8
Mast	Y	6/19/2016	2016	1	0	7
Mast	Y	7/20/2016	2016	2	0	7
Mast	Z	6/19/2016	2016	1	0	6
Mast	Z	7/20/2016	2016	2	0	4
Mast	AA	6/19/2016	2016	1	0	7
Mast	AA	7/20/2016	2016	2	3	14
Mast	BB	6/19/2016	2016	1	1	9
Mast	BB	7/20/2016	2016	2	0	10
Mast	CC	6/19/2016	2016	1	0	7
Mast	CC	7/20/2016	2016	2	0	10
WaWao	WA	6/30/2016	2016	1	0	2
WaWao	WA	7/14/2016	2016	2	0	4
WaWao	WB	6/30/2016	2016	1	0	4
WaWao	WB	7/14/2016	2016	2	0	3
WaWao	WC	6/30/2016	2016	1	0	6
WaWao	WC	7/14/2016	2016	2	1	7
WaWao	WD	7/4/2016	2016	1	0	5
WaWao	WD	7/14/2016	2016	2	0	5
WaWao	WE	7/4/2016	2016	1	0	9
WaWao	WE	7/14/2016	2016	2	0	7
WaWao	WF	7/4/2016	2016	1	0	7
WaWao	WF	7/14/2016	2016	2	0	3

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Water Depth	Silt Depth	S-Tipulid Crane Flies	M-Tipulid Crane Flies	L-Tipulid Crane Flies	XL-Tipulid Crane Flies	Total Crane Flies
Coast	A	7/24/2017	2017	1	7	3	0	0	0	0	0
Coast	B	7/24/2017	2017	1	4	6	0	0	0	0	0
Coast	C	7/24/2017	2017	1	5	1	0	0	0	0	0
Coast	D	7/24/2017	2017	1	11	0	0	0	0	0	0
Coast	E	7/24/2017	2017	1	5	5	0	0	0	0	0
Coast	F	7/18/2017	2017	1	14.5	2.5	0	0	0	0	0
Mast	A	6/9/2017	2017	1	34	0	0	1	0	0	1
Mast	A	7/9/2017	2017	2	26.5	0	0	0	1	0	1
Mast	B	6/9/2017	2017	1	28	1	1	3	1	0	5
Mast	B	7/9/2017	2017	2	19	1.5	0	12	7	1	20
Mast	C	6/9/2017	2017	1	26	1.5	0	0	1	0	1
Mast	C	7/9/2017	2017	2	18	2	0	0	3	0	3
Mast	D	6/9/2017	2017	1	27.5	2	0	0	0	0	0
Mast	D	7/9/2017	2017	2	20.5	1.5	0	0	1	2	3
Mast	E	6/9/2017	2017	1	30	0.5	5	0	0	0	5
Mast	E	7/9/2017	2017	2	20.5	0.5	0	0	0	0	0
Mast	F	6/9/2017	2017	1	19	1	0	0	1	0	1
Mast	F	7/9/2017	2017	2	13	1	0	0	1	1	2
Mast	G	6/10/2017	2017	1	31.5	1.75	0	0	0	0	0
Mast	G	7/9/2017	2017	2	21	1.5	0	0	0	0	0
Mast	H	6/10/2017	2017	1	32	2	0	1	0	0	1
Mast	H	7/9/2017	2017	2	19	0.5	0	1	1	2	4
Mast	I	6/10/2017	2017	1	36	2	0	0	0	0	0
Mast	I	7/9/2017	2017	2	23.5	0.5	0	0	0	0	0
Mast	J	6/10/2017	2017	1	42	3	1	1	0	0	2
Mast	J	7/9/2017	2017	2	29	1.5	0	0	3	4	7
Mast	K	6/10/2017	2017	1	38	2	2	2	2	0	6
Mast	K	7/9/2017	2017	2	29.5	0	1	3	7	0	11
Mast	L	6/10/2017	2017	1	21	4	1	1	0	0	2
Mast	L	7/9/2017	2017	2	14.5	0.5	0	0	0	0	0
Mast	M	6/11/2017	2017	1	35	0.5	0	0	0	0	0
Mast	M	7/10/2017	2017	2	19	2	0	0	0	0	0
Mast	N	6/11/2017	2017	1	36	8	0	1	0	0	1
Mast	N	7/10/2017	2017	2	17	1	0	0	0	1	1
Mast	O	6/11/2017	2017	1	36	2	0	0	0	0	0
Mast	O	7/10/2017	2017	2	23	4	0	0	0	0	0
Mast	P	6/11/2017	2017	1	33.5	1.5	0	0	0	0	0
Mast	P	7/10/2017	2017	2	17	1	0	0	0	0	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Chironomidae Non-Biting Midges	Ceratopogonidae Sandflies (Biting Midges)	Plecoptera Stoneflies	Trichoptera Caddiesflies	Ephemeroptera Mayflies	Gastropoda Snails
Coast	A	7/24/2017	2017	1	0	0	0	0	0	0
Coast	B	7/24/2017	2017	1	0	0	0	0	0	0
Coast	C	7/24/2017	2017	1	0	0	0	0	0	0
Coast	D	7/24/2017	2017	1	0	0	0	0	0	0
Coast	E	7/24/2017	2017	1	0	0	0	0	0	0
Coast	F	7/18/2017	2017	1	0	0	0	0	0	34
Mast	A	6/9/2017	2017	1	10	0	1	1	0	0
Mast	A	7/9/2017	2017	2	24	0	3	0	7	1
Mast	B	6/9/2017	2017	1	28	0	27	1	0	0
Mast	B	7/9/2017	2017	2	6	0	7	2	43	2
Mast	C	6/9/2017	2017	1	13	3	8	3	0	0
Mast	C	7/9/2017	2017	2	10	0	0	1	10	2
Mast	D	6/9/2017	2017	1	2	0	0	1	0	0
Mast	D	7/9/2017	2017	2	22	0	2	4	7	0
Mast	E	6/9/2017	2017	1	11	5	4	3	0	1
Mast	E	7/9/2017	2017	2	3	0	2	1	0	0
Mast	F	6/9/2017	2017	1	7	0	10	2	0	0
Mast	F	7/9/2017	2017	2	19	0	0	0	12	0
Mast	G	6/10/2017	2017	1	11	1	2	4	0	0
Mast	G	7/9/2017	2017	2	3	0	0	0	2	0
Mast	H	6/10/2017	2017	1	4	0	14	1	0	0
Mast	H	7/9/2017	2017	2	15	0	9	3	23	4
Mast	I	6/10/2017	2017	1	1	2	0	2	0	0
Mast	I	7/9/2017	2017	2	72	1	0	1	0	2
Mast	J	6/10/2017	2017	1	0	0	9	7	0	0
Mast	J	7/9/2017	2017	2	6	0	3	1	33	5
Mast	K	6/10/2017	2017	1	1	0	33	0	0	0
Mast	K	7/9/2017	2017	2	0	0	20	1	39	1
Mast	L	6/10/2017	2017	1	3	0	12	2	0	1
Mast	L	7/9/2017	2017	2	0	0	0	0	0	9
Mast	M	6/11/2017	2017	1	4	1	0	0	0	0
Mast	M	7/10/2017	2017	2	4	0	0	1	1	0
Mast	N	6/11/2017	2017	1	2	1	7	2	0	0
Mast	N	7/10/2017	2017	2	5	0	0	3	3	0
Mast	O	6/11/2017	2017	1	6	0	2	1	0	0
Mast	O	7/10/2017	2017	2	4	0	0	3	4	0
Mast	P	6/11/2017	2017	1	0	0	0	0	0	0
Mast	P	7/10/2017	2017	2	5	0	0	1	26	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Oligochaete/Nematoda Worms	Coleoptera Beetles	Other Diptera Flies	Simuliidae Black Flies	Hirudinea Leeches	Amphipoda Amphipods	Mollusca Bivalves
Coast	A	7/24/2017	2017	1	0	0	0	0	0	15	0
Coast	B	7/24/2017	2017	1	0	0	0	0	0	5	0
Coast	C	7/24/2017	2017	1	0	0	0	0	0	15	0
Coast	D	7/24/2017	2017	1	0	0	0	0	0	6	0
Coast	E	7/24/2017	2017	1	0	0	0	0	0	0	0
Coast	F	7/18/2017	2017	1	0	0	0	0	0	36	6
Mast	A	6/9/2017	2017	1	1	0	0	0	0	4	0
Mast	A	7/9/2017	2017	2	8	1	1	1	1	0	0
Mast	B	6/9/2017	2017	1	5	0	0	0	0	0	0
Mast	B	7/9/2017	2017	2	1	0	3	12	0	0	3
Mast	C	6/9/2017	2017	1	1	0	2	0	0	0	0
Mast	C	7/9/2017	2017	2	10	1	3	2	0	0	0
Mast	D	6/9/2017	2017	1	4	0	0	0	0	0	0
Mast	D	7/9/2017	2017	2	13	1	0	0	0	0	0
Mast	E	6/9/2017	2017	1	3	0	0	0	0	0	0
Mast	E	7/9/2017	2017	2	8	0	1	0	0	0	0
Mast	F	6/9/2017	2017	1	8	0	0	0	0	0	0
Mast	F	7/9/2017	2017	2	1	0	1	5	0	0	0
Mast	G	6/10/2017	2017	1	1	0	0	0	0	0	0
Mast	G	7/9/2017	2017	2	3	1	0	0	0	0	0
Mast	H	6/10/2017	2017	1	11	0	0	0	0	0	0
Mast	H	7/9/2017	2017	2	5	1	9	7	1	0	0
Mast	I	6/10/2017	2017	1	10	0	0	0	0	0	0
Mast	I	7/9/2017	2017	2	8	0	1	0	7	0	0
Mast	J	6/10/2017	2017	1	3	0	0	0	0	0	0
Mast	J	7/9/2017	2017	2	9	0	0	0	1	0	1
Mast	K	6/10/2017	2017	1	1	0	1	0	0	0	0
Mast	K	7/9/2017	2017	2	3	0	0	1	0	0	0
Mast	L	6/10/2017	2017	1	2	0	0	0	0	0	0
Mast	L	7/9/2017	2017	2	1	4	1	0	0	0	0
Mast	M	6/11/2017	2017	1	0	0	0	0	0	0	0
Mast	M	7/10/2017	2017	2	1	0	0	0	0	0	0
Mast	N	6/11/2017	2017	1	6	0	0	0	0	0	0
Mast	N	7/10/2017	2017	2	10	1	0	7	0	3	0
Mast	O	6/11/2017	2017	1	1	0	0	0	0	0	0
Mast	O	7/10/2017	2017	2	1	0	0	1	0	1	0
Mast	P	6/11/2017	2017	1	0	0	0	0	0	1	0
Mast	P	7/10/2017	2017	2	0	4	1	0	0	0	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Other	Categories
Coast	A	7/24/2017	2017	1	0	1
Coast	B	7/24/2017	2017	1	0	1
Coast	C	7/24/2017	2017	1	0	1
Coast	D	7/24/2017	2017	1	0	1
Coast	E	7/24/2017	2017	1	0	0
Coast	F	7/18/2017	2017	1	0	3
Mast	A	6/9/2017	2017	1	0	6
Mast	A	7/9/2017	2017	2	1	11
Mast	B	6/9/2017	2017	1	0	5
Mast	B	7/9/2017	2017	2	3	11
Mast	C	6/9/2017	2017	1	0	7
Mast	C	7/9/2017	2017	2	0	9
Mast	D	6/9/2017	2017	1	0	3
Mast	D	7/9/2017	2017	2	0	7
Mast	E	6/9/2017	2017	1	0	7
Mast	E	7/9/2017	2017	2	0	5
Mast	F	6/9/2017	2017	1	0	5
Mast	F	7/9/2017	2017	2	0	6
Mast	G	6/10/2017	2017	1	0	5
Mast	G	7/9/2017	2017	2	0	4
Mast	H	6/10/2017	2017	1	0	5
Mast	H	7/9/2017	2017	2	2	12
Mast	I	6/10/2017	2017	1	0	4
Mast	I	7/9/2017	2017	2	0	7
Mast	J	6/10/2017	2017	1	0	4
Mast	J	7/9/2017	2017	2	2	10
Mast	K	6/10/2017	2017	1	0	5
Mast	K	7/9/2017	2017	2	0	7
Mast	L	6/10/2017	2017	1	0	6
Mast	L	7/9/2017	2017	2	0	4
Mast	M	6/11/2017	2017	1	0	2
Mast	M	7/10/2017	2017	2	0	4
Mast	N	6/11/2017	2017	1	0	6
Mast	N	7/10/2017	2017	2	1	9
Mast	O	6/11/2017	2017	1	0	4
Mast	O	7/10/2017	2017	2	0	6
Mast	P	6/11/2017	2017	1	0	1
Mast	P	7/10/2017	2017	2	0	5

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Water Depth	Silt Depth	S-Tipulid Crane Flies	M-Tipulid Crane Flies	L-Tipulid Crane Flies	XL-Tipulid Crane Flies	Total Crane Flies
Mast	Q	6/11/2017	2017	1	37	3	0	0	0	0	0
Mast	Q	7/10/2017	2017	2	21	3	0	0	0	0	0
Mast	R	6/11/2017	2017	1	31.5	2.5	0	0	0	0	0
Mast	R	7/10/2017	2017	2	20	1	0	0	0	0	0
Mast	S	6/11/2017	2017	1	35.5	1.5	0	3	0	0	3
Mast	S	7/10/2017	2017	2	22	0	0	0	0	1	1
Mast	T	6/11/2017	2017	1	25	4	0	2	2	0	4
Mast	T	7/10/2017	2017	2	12	4	1	0	0	3	4
Mast	U	6/11/2017	2017	1	31	2	0	0	0	0	0
Mast	U	7/10/2017	2017	2	19	1	0	0	0	0	0
Mast	V	6/11/2017	2017	1	34	0	0	1	1	0	2
Mast	V	7/11/2017	2017	2	20	2	0	0	4	5	9
Mast	W	6/11/2017	2017	1	24	1	0	0	0	0	0
Mast	W	7/11/2017	2017	2	13	2	0	0	0	0	0
Mast	X	6/12/2017	2017	1	19	3	0	0	0	0	0
Mast	X	7/11/2017	2017	2	15.5	2	0	0	0	0	0
Mast	Y	6/12/2017	2017	1	24	6.5	0	0	0	0	0
Mast	Y	7/11/2017	2017	2	20	4	0	0	0	0	0
Mast	Z	6/12/2017	2017	1	16	1	0	0	0	0	0
Mast	Z	7/11/2017	2017	2	7	1	0	0	0	0	0
Mast	AA	6/12/2017	2017	1	34	0	0	1	1	0	2
Mast	AA	7/11/2017	2017	2	18	1	0	0	0	0	0
Mast	BB	6/12/2017	2017	1	28	2	1	0	2	0	3
Mast	BB	7/11/2017	2017	2	20	4	0	8	28	1	37
Mast	CC	6/12/2017	2017	1	34	6	0	0	0	0	0
Mast	CC	7/11/2017	2017	2	25	2	0	1	3	3	7
Mast	S5	6/10/2017	2017	1	30	1.2	1	0	0	0	1
Mast	S5	7/9/2017	2017	2	27.5	0.5	0	0	0	0	0
Mast	S6	6/10/2017	2017	1	24.5	4.5	0	1	0	0	1
Mast	S6	7/9/2017	2017	2	12	2	0	0	0	0	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Chironomidae Non-Biting Midges	Ceratopogonidae Sandflies (Biting Midges)	Plecoptera Stoneflies	Trichoptera Caddiesflies	Ephemeroptera Mayflies	Gastropoda Snails
Mast	Q	6/11/2017	2017	1	0	0	0	0	0	0
Mast	Q	7/10/2017	2017	2	7	0	0	0	0	0
Mast	R	6/11/2017	2017	1	14	0	3	0	0	0
Mast	R	7/10/2017	2017	2	2	0	0	0	0	0
Mast	S	6/11/2017	2017	1	12	0	4	4	0	0
Mast	S	7/10/2017	2017	2	13	0	0	1	2	1
Mast	T	6/11/2017	2017	1	19	1	6	2	0	0
Mast	T	7/10/2017	2017	2	4	0	0	0	6	0
Mast	U	6/11/2017	2017	1	0	0	1	0	0	0
Mast	U	7/10/2017	2017	2	7	0	0	2	0	0
Mast	V	6/11/2017	2017	1	5	0	18	1	0	0
Mast	V	7/11/2017	2017	2	1	0	9	3	53	1
Mast	W	6/11/2017	2017	1	0	0	0	0	0	0
Mast	W	7/11/2017	2017	2	1	0	0	0	62	1
Mast	X	6/12/2017	2017	1	0	2	1	1	0	0
Mast	X	7/11/2017	2017	2	5	0	0	0	8	0
Mast	Y	6/12/2017	2017	1	3	0	1	0	0	0
Mast	Y	7/11/2017	2017	2	36	0	0	2	6	0
Mast	Z	6/12/2017	2017	1	1	0	18	2	0	1
Mast	Z	7/11/2017	2017	2	2	0	0	0	6	0
Mast	AA	6/12/2017	2017	1	1	1	85	4	0	1
Mast	AA	7/11/2017	2017	2	3	0	5	14	51	0
Mast	BB	6/12/2017	2017	1	0	0	14	4	0	0
Mast	BB	7/11/2017	2017	2	0	0	1	20	24	0
Mast	CC	6/12/2017	2017	1	5	0	36	32	0	0
Mast	CC	7/11/2017	2017	2	0	0	6	139	14	1
Mast	S5	6/10/2017	2017	1	4	1	2	2	0	0
Mast	S5	7/9/2017	2017	2	4	0	2	2	11	0
Mast	S6	6/10/2017	2017	1	0	0	8	0	0	0
Mast	S6	7/9/2017	2017	2	9	0	1	5	3	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Oligochaete/Nematoda Worms	Coleoptera Beetles	Other Diptera Flies	Simuliidae Black Flies	Hirudinea Leeches	Amphipoda Amphipods	Mollusca Bivalves
Mast	Q	6/11/2017	2017	1	0	0	0	0	0	0	0
Mast	Q	7/10/2017	2017	2	0	0	0	0	1	0	0
Mast	R	6/11/2017	2017	1	2	0	0	0	0	0	0
Mast	R	7/10/2017	2017	2	0	0	0	0	0	0	0
Mast	S	6/11/2017	2017	1	5	0	0	0	0	0	0
Mast	S	7/10/2017	2017	2	7	1	1	0	0	0	0
Mast	T	6/11/2017	2017	1	2	0	2	0	0	0	0
Mast	T	7/10/2017	2017	2	1	1	0	1	0	0	0
Mast	U	6/11/2017	2017	1	1	0	0	0	0	0	0
Mast	U	7/10/2017	2017	2	1	0	0	0	0	2	0
Mast	V	6/11/2017	2017	1	1	0	0	0	0	0	0
Mast	V	7/11/2017	2017	2	0	3	0	1	0	0	0
Mast	W	6/11/2017	2017	1	0	0	0	0	0	0	0
Mast	W	7/11/2017	2017	2	0	0	0	0	0	0	1
Mast	X	6/12/2017	2017	1	0	0	0	0	0	0	0
Mast	X	7/11/2017	2017	2	0	2	0	0	0	0	0
Mast	Y	6/12/2017	2017	1	1	0	0	0	0	0	0
Mast	Y	7/11/2017	2017	2	1	0	2	0	0	0	2
Mast	Z	6/12/2017	2017	1	5	0	0	0	0	0	1
Mast	Z	7/11/2017	2017	2	1	0	0	0	0	0	0
Mast	AA	6/12/2017	2017	1	1	0	2	0	0	0	0
Mast	AA	7/11/2017	2017	2	2	0	0	24	1	0	0
Mast	BB	6/12/2017	2017	1	1	0	0	0	0	0	0
Mast	BB	7/11/2017	2017	2	3	0	23	0	0	0	0
Mast	CC	6/12/2017	2017	1	1	0	0	0	0	0	0
Mast	CC	7/11/2017	2017	2	3	0	0	0	0	1	0
Mast	S5	6/10/2017	2017	1	2	0	1	0	0	0	0
Mast	S5	7/9/2017	2017	2	1	0	1	1	0	0	1
Mast	S6	6/10/2017	2017	1	1	0	2	0	0	0	0
Mast	S6	7/9/2017	2017	2	3	1	2	0	0	1	0

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Other	Categories
Mast	Q	6/11/2017	2017	1	0	0
Mast	Q	7/10/2017	2017	2	0	2
Mast	R	6/11/2017	2017	1	0	3
Mast	R	7/10/2017	2017	2	2	2
Mast	S	6/11/2017	2017	1	0	5
Mast	S	7/10/2017	2017	2	0	8
Mast	T	6/11/2017	2017	1	0	7
Mast	T	7/10/2017	2017	2	0	6
Mast	U	6/11/2017	2017	1	0	2
Mast	U	7/10/2017	2017	2	0	4
Mast	V	6/11/2017	2017	1	0	5
Mast	V	7/11/2017	2017	2	0	8
Mast	W	6/11/2017	2017	1	0	0
Mast	W	7/11/2017	2017	2	1	5
Mast	X	6/12/2017	2017	1	0	3
Mast	X	7/11/2017	2017	2	2	4
Mast	Y	6/12/2017	2017	1	0	3
Mast	Y	7/11/2017	2017	2	0	6
Mast	Z	6/12/2017	2017	1	0	6
Mast	Z	7/11/2017	2017	2	0	3
Mast	AA	6/12/2017	2017	1	0	8
Mast	AA	7/11/2017	2017	2	0	7
Mast	BB	6/12/2017	2017	1	0	4
Mast	BB	7/11/2017	2017	2	0	6
Mast	CC	6/12/2017	2017	1	0	4
Mast	CC	7/11/2017	2017	2	0	7
Mast	S5	6/10/2017	2017	1	0	7
Mast	S5	7/9/2017	2017	2	0	8
Mast	S6	6/10/2017	2017	1	0	4
Mast	S6	7/9/2017	2017	2	0	8

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Water Depth	Silt Depth	S-Tipulid Crane Flies	M-Tipulid Crane Flies	L-Tipulid Crane Flies	XL-Tipulid Crane Flies	Total Crane Flies
Wawao	WA	6/13/2017	2017	1	30	0.5	0	0	0	0	0
Wawao	WA	7/12/2017	2017	2	13	2	0	0	0	0	0
Wawao	WB	6/13/2017	2017	1	30	4	0	0	0	0	0
Wawao	WB	7/12/2017	2017	2	16	2	0	0	0	0	0
Wawao	WC	6/13/2017	2017	1	26.5	1.5	1	0	0	0	1
Wawao	WC	7/12/2017	2017	2	14	1	0	0	0	0	0
Wawao	WD	6/13/2017	2017	1	30	2	0	0	0	0	0
Wawao	WD	7/12/2017	2017	2	13	1	0	0	0	0	0
Wawao	WE	6/13/2017	2017	1	27	1	0	1	2	0	3
Wawao	WE	7/12/2017	2017	2	11	1	0	0	0	0	0
Wawao	WF	6/13/2017	2017	1	33.5	1.5	0	0	0	0	0
Wawao	WF	7/12/2017	2017	2	11	3	0	0	0	0	0
				Total All	8899	**Total**	36	261	253	61	611
						Percentage	0.40%	2.93%	2.84%	0.69%	6.87%
						Average in a Sample	0	1	1	0	3
						Minimum in a Sample	0	0	0	0	0
						Maximum in a Sample	5	25	28	5	37

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Oligochaete/Nematoda Worms	Coleoptera Beetles	Other Diptera Flies	Simuliidae Black Flies	Hirudinea Leeches	Amphipoda Amphipods	Mollusca Bivalves
Wawao	WA	6/13/2017	2017	1	1	0	0	0	0	0	0
Wawao	WA	7/12/2017	2017	2	0	1	1	3	0	0	0
Wawao	WB	6/13/2017	2017	1	0	0	0	0	0	0	0
Wawao	WB	7/12/2017	2017	2	0	0	0	0	4	0	0
Wawao	WC	6/13/2017	2017	1	0	0	0	0	0	0	0
Wawao	WC	7/12/2017	2017	2	0	0	24	0	1	0	0
Wawao	WD	6/13/2017	2017	1	1	0	0	0	0	0	0
Wawao	WD	7/12/2017	2017	2	0	0	0	0	2	0	0
Wawao	WE	6/13/2017	2017	1	5	0	0	0	0	0	0
Wawao	WE	7/12/2017	2017	2	1	0	6	0	0	0	0
Wawao	WF	6/13/2017	2017	1	0	0	0	0	0	0	1
Wawao	WF	7/12/2017	2017	2	0	1	6	0	4	0	0
				Total	859	62	258	228	168	180	110
				Percentage	9.65%	0.70%	2.90%	2.56%	1.89%	2.02%	1.24%
				Average in a Sample	4	0	1	1	1	1	1
				Minimum in a Sample	0	0	0	0	0	0	0
				Maximum in a Sample	38	4	24	80	43	57	11

Appendix B Table 3. Continued

Location	Sample Site	Date	Year	Visit Number	Other	Categories
Wawao	WA	6/13/2017	2017	1	0	5
Wawao	WA	7/12/2017	2017	2	0	7
Wawao	WB	6/13/2017	2017	1	0	4
Wawao	WB	7/12/2017	2017	2	0	5
Wawao	WC	6/13/2017	2017	1	0	4
Wawao	WC	7/12/2017	2017	2	0	7
Wawao	WD	6/13/2017	2017	1	0	5
Wawao	WD	7/12/2017	2017	2	1	6
Wawao	WE	6/13/2017	2017	1	0	6
Wawao	WE	7/12/2017	2017	2	1	6
Wawao	WF	6/13/2017	2017	1	0	5
Wawao	WF	7/12/2017	2017	2	0	7
				Total	54	
				Percentage	0.61%	
				Average in a Sample	0	6
				Minimum in a Sample	0	0
				Maximum in a Sample	5	14

Appendix B Table 4. All habitat models for predicting individual aquatic invertebrate abundance for each invertebrate category collected.

Categories	Model	AICc	ΔAIC	Weight	-2 Log Likelihood
Tipulid	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	245.85	0.00	0.40	222.35
	flow + substrate type + season + sediment depth + water depth	246.14	0.29	0.34	227.93
	flow + substrate type + season + sediment depth	246.70	0.85	0.26	231.01
	flow + substrate type + season	259.34	13.49	0.00	246.08
	flow + substrate type	277.68	31.83	0.00	266.79
	flow + season	301.78	55.93	0.00	293.20
	flow + sediment depth	313.02	67.17	0.00	304.44
	flow	329.97	84.12	0.00	323.97
	substrate type	421.60	175.75	0.00	415.25
	salinity	531.11	285.26	0.00	526.94
	sediment depth	533.78	287.93	0.00	529.61
	Null	535.08	289.23	0.00	533.03
	temperature	536.91	291.06	0.00	532.74
	water depth	537.14	291.29	0.00	532.97
Chironomidae	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	735.49	0.00	0.37	712.00
	flow + substrate type + season + sediment depth	735.51	0.02	0.36	719.81
	flow + substrate type + season + sediment depth + water depth	736.20	0.71	0.26	717.98
	flow + substrate type + season	741.91	6.42	0.01	728.65
	flow + substrate type	797.13	61.64	0.00	786.25
	flow + season	832.77	97.28	0.00	824.19
	substrate type	840.44	104.95	0.00	834.09
	flow + sediment depth	870.76	135.27	0.00	862.18
	temperature	889.95	154.46	0.00	885.79
	flow	890.20	154.71	0.00	883.85
	salinity	914.86	179.37	0.00	910.69
	water depth	915.62	180.13	0.00	911.45
	sediment depth	918.04	182.55	0.00	913.87
	Null	931.94	196.45	0.00	929.88
Ceratopogonidea	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	132.12	0.00	0.80	108.63
	flow + substrate type + season	136.74	4.62	0.08	123.49
	flow + season	137.17	5.05	0.06	128.59
	flow + substrate type + season + sediment depth	138.12	6.00	0.04	122.43
	flow + substrate type + season + sediment depth + water depth	140.33	8.21	0.01	122.11
	water depth	157.58	25.46	0.00	153.41
	substrate type	158.59	26.47	0.00	152.25
	flow	160.17	28.05	0.00	153.83
	flow + sediment depth	162.08	29.96	0.00	153.50
	Null	162.77	30.65	0.00	160.71
	temperature	164.12	32.00	0.00	159.95
	salinity	164.49	32.37	0.00	160.32
	sediment depth	164.77	32.65	0.00	160.60
	flow + substrate type	185.48	53.36	0.00	147.59

Appendix B Table 4. Continued

Categories	Model	AICc	ΔAIC	Weight	-2 Log Likelihood
Plecoptera	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	542.52	0.00	1.00	522.03
	flow + substrate type + season + sediment depth	556.05	13.53	0.00	540.35
	flow + substrate type + season	557.66	15.14	0.00	544.40
	flow + substrate type + season + sediment depth + water depth	558.23	15.71	0.00	540.01
	flow + season	574.23	31.71	0.00	565.65
	flow + substrate type	762.42	219.90	0.00	751.54
	flow	783.38	240.86	0.00	777.04
	flow + sediment depth	785.62	243.10	0.00	777.04
	sediment depth	918.04	375.52	0.00	1149.76
	water depth	942.75	400.23	0.00	938.58
	temperature	1027.74	485.22	0.00	1023.57
	substrate type	1051.44	508.92	0.00	1045.10
	salinity	1073.71	531.19	0.00	1069.54
	Null	1156.90	614.38	0.00	1154.85
Trichoptera	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	690.56	0.00	1.00	667.07
	flow + substrate type + season + sediment depth + water depth	767.55	76.99	0.00	749.33
	flow + substrate type + season + sediment depth	778.49	87.93	0.00	762.79
	flow + substrate type + season	837.74	147.18	0.00	824.49
	flow + sediment depth	856.29	165.73	0.00	847.71
	flow + substrate type	866.95	176.39	0.00	856.06
	flow + season	873.03	182.47	0.00	864.45
	flow	914.79	224.23	0.00	908.45
	substrate type	1137.45	446.89	0.00	1131.11
	salinity	1192.38	501.82	0.00	1188.21
	sediment depth	1220.91	530.35	0.00	1216.75
	water depth	1229.14	538.58	0.00	1224.97
	Null	1239.15	548.59	0.00	1237.10
	temperature	1240.29	549.73	0.00	1236.12
Ephemeroptera	**flow + substrate type + season**	492.59	0.00	0.46	479.33
	flow + substrate type + season + sediment depth + water depth	493.75	1.16	0.26	475.54
	flow + substrate type + season + sediment depth	494.30	1.71	0.19	478.60
	flow + substrate type + season + sediment depth + salinity + water depth + temperature	495.78	3.19	0.09	472.29
	flow + season	592.61	100.02	0.00	584.03
	flow + substrate type	1206.15	713.56	0.00	1195.27
	temperature	1238.62	746.03	0.00	1234.45
	water depth	1258.68	766.09	0.00	1254.51
	flow + sediment depth	1265.38	772.79	0.00	1256.80
	flow	1275.03	782.44	0.00	1268.68
	substrate type	1333.22	840.63	0.00	1326.87
	sediment depth	1432.40	939.81	0.00	1428.23
	salinity	1438.82	946.23	0.00	1434.65
	Null	1455.99	963.40	0.00	1453.94

Appendix B Table 4. Continued

Categories	Model	AICc	ΔAIC	Weight	-2 Log Likelihood
Gastropoda	**flow + substrate type + season + sediment depth**	132.90	0.00	0.46	117.20
	flow + substrate type + season + sediment depth + water depth	133.20	0.30	0.40	114.99
	flow + substrate type + season + sediment depth + salinity + water depth + temperature	135.72	2.82	0.11	112.23
	flow + substrate type + season	139.37	6.47	0.02	126.11
	flow + season	143.76	10.86	0.00	135.18
	temperature	144.73	11.83	0.00	140.56
	sediment depth	150.31	17.41	0.00	146.14
	flow + sediment depth	152.68	19.78	0.00	144.10
	substrate type	155.18	22.28	0.00	148.83
	flow + substrate type	157.59	24.69	0.00	146.71
	water depth	157.80	24.90	0.00	153.63
	salinity	161.55	28.65	0.00	157.39
	Null	163.66	30.76	0.00	161.61
	flow	164.26	31.36	0.00	157.92
Oligochaete	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	333.48	0.00	1.00	309.99
	flow + substrate type + season + sediment depth + water depth	362.42	28.94	0.00	344.20
	substrate type	371.70	38.22	0.00	365.36
	flow + substrate type + season + sediment depth	373.86	40.38	0.00	358.16
	flow + substrate type	373.98	40.50	0.00	363.10
	flow + substrate type + season	375.63	42.15	0.00	362.37
	salinity	385.43	51.95	0.00	381.26
	temperature	411.47	77.99	0.00	407.30
	flow + sediment depth	413.06	79.58	0.00	404.48
	water depth	413.22	79.74	0.00	409.05
	sediment depth	413.23	79.75	0.00	409.06
	flow	413.38	79.90	0.00	407.04
	Null	413.67	80.19	0.00	411.61
	flow + season	413.67	80.19	0.00	405.09
Coleoptera	**flow + season**	85.93	0.00	0.42	77.35
	flow + substrate type + season	86.00	0.07	0.41	72.75
	flow + substrate type + season + sediment depth	88.38	2.45	0.12	72.68
	flow + substrate type + season + sediment depth + water depth	90.83	4.90	0.04	72.62
	flow + substrate type + season + sediment depth + salinity + water depth + temperature	93.72	7.79	0.01	70.23
	water depth	101.19	15.26	0.00	97.02
	temperature	107.34	21.41	0.00	103.17
	flow + substrate type	113.25	27.32	0.00	102.36
	flow + sediment depth	113.84	27.91	0.00	105.26
	flow	114.71	28.78	0.00	108.37
	sediment depth	119.11	33.18	0.00	114.95
	Null	119.49	33.56	0.00	117.44
	substrate type	120.51	34.58	0.00	114.16
	salinity	120.80	34.87	0.00	116.63

Appendix B Table 4. Continued

Categories	Model	AICc	ΔAIC	Weight	-2 Log Likelihood
Diptera	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	218.24	0.00	1.00	194.75
	flow + substrate type + season + sediment depth + water depth	288.11	69.87	0.00	269.89
	flow + substrate type + season + sediment depth	308.13	89.89	0.00	292.44
	flow + substrate type + season	318.78	100.54	0.00	305.52
	salinity	334.82	116.58	0.00	330.65
	flow + season	337.78	119.54	0.00	329.20
	temperature	347.24	129.00	0.00	343.07
	water depth	350.11	131.87	0.00	345.94
	flow + substrate type	375.96	157.72	0.00	365.08
	substrate type	378.75	160.51	0.00	372.41
	flow + sediment depth	400.46	182.22	0.00	391.88
	flow	401.07	182.83	0.00	394.73
	Null	409.71	191.47	0.00	407.65
	sediment depth	410.33	192.09	0.00	406.16
Simuliidae	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	128.73	0.00	1.00	105.23
	flow + substrate type + season + sediment depth + water depth	148.91	20.18	0.00	130.70
	flow + substrate type + season + sediment depth	171.81	43.08	0.00	156.11
	flow + substrate type + season	174.55	45.82	0.00	161.30
	flow + season	192.90	64.17	0.00	184.32
	flow + sediment depth	278.31	149.58	0.00	269.73
	flow + substrate type	285.41	156.68	0.00	274.53
	flow	288.45	159.72	0.00	282.11
	water depth	308.00	179.27	0.00	303.83
	temperature	320.98	192.25	0.00	316.81
	sediment depth	330.65	201.92	0.00	326.48
	substrate type	331.55	202.82	0.00	325.21
	Null	347.35	218.62	0.00	345.29
	salinity	349.20	220.47	0.00	345.03
Hirudinea	**flow + substrate type + season + sediment depth + salinity + water depth + temperature**	81.39	0.00	0.76	57.90
	temperature	84.05	2.66	0.20	79.88
	flow + substrate type + season	88.12	6.73	0.03	74.87
	flow + substrate type + season + sediment depth	90.35	8.96	0.01	74.66
	flow + substrate type + season + sediment depth + water depth	92.01	10.62	0.00	73.80
	flow + season	102.97	21.58	0.00	94.39
	salinity	113.58	32.19	0.00	109.41
	substrate type	117.00	35.61	0.00	110.65
	flow + substrate type	117.87	36.48	0.00	106.99
	water depth	120.96	39.57	0.00	116.79
	sediment depth	130.51	49.12	0.00	126.35
	Null	130.58	49.19	0.00	128.52
	flow + sediment depth	132.70	51.31	0.00	124.12
	flow	133.09	51.70	0.00	126.75

Appendix B Table 4. Continued

Categories	Model	AICc	ΔAIC	Weight	-2 Log Likelihood
Amphipoda	**flow + sediment depth**	78.60	0.00	0.45	70.02
	flow	80.89	2.29	0.14	74.55
	sediment depth	82.13	3.53	0.08	77.96
	flow + substrate type + season + sediment depth + salinity + water depth + temperature	82.45	3.85	0.07	58.96
	flow + season	82.82	4.22	0.05	74.25
	flow + substrate type	82.85	4.25	0.05	71.97
	salinity	83.04	4.44	0.05	78.87
	flow + substrate type + season + sediment depth	83.90	5.30	0.03	68.21
	Null	84.60	6.00	0.02	82.54
	flow + substrate type + season + sediment depth + water depth	84.78	6.18	0.02	66.56
	flow + substrate type + season	84.92	6.32	0.02	71.67
	water depth	86.69	8.09	0.01	82.52
	temperature	86.71	8.11	0.01	82.54
	substrate type	87.64	9.04	0.00	81.30
Mollusca	**flow + season**	63.52	0.00	0.37	54.94
	flow	64.54	1.02	0.22	58.20
	flow + sediment depth	66.76	3.24	0.07	58.18
	flow + substrate type + season	66.98	3.46	0.07	53.73
	Null	67.05	3.53	0.06	65.00
	flow + substrate type	67.88	4.36	0.04	57.00
	temperature	67.91	4.39	0.04	63.74
	water depth	68.10	4.58	0.04	63.93
	salinity	69.14	5.62	0.02	64.97
	sediment depth	69.16	5.64	0.02	64.99
	flow + substrate type + season + sediment depth	69.35	5.83	0.02	53.65
	substrate type	69.94	6.42	0.01	63.60
	flow + substrate type + season + sediment depth + water depth	71.80	8.28	0.01	53.58
	flow + substrate type + season + sediment depth + salinity + water depth + temperature	76.18	12.66	0.00	52.69
Other	**flow + season**	74.32	0.00	0.47	65.74
	flow + substrate type + season	75.53	1.21	0.26	62.28
	flow + substrate type + season + sediment depth	76.05	1.73	0.20	60.36
	flow + substrate type + season + sediment depth + water depth	78.54	4.22	0.06	60.32
	flow + substrate type + season + sediment depth + salinity + water depth + temperature	81.28	6.96	0.01	57.79
	temperature	86.07	11.75	0.00	81.91
	water depth	87.35	13.03	0.00	83.18
	sediment depth	90.28	15.96	0.00	86.11
	salinity	91.88	17.56	0.00	87.71
	Null	92.19	17.87	0.00	90.14
	substrate type	92.49	18.17	0.00	86.14
	flow + sediment depth	92.85	18.53	0.00	84.27
	flow	93.91	19.59	0.00	87.57
	flow + substrate type	95.00	20.68	0.00	84.12

Appendix B Table 4. Continued

Categories	Model	AICc	ΔAIC	Weight	-2 Log Likelihood
Categories	**flow + substrate type + season**	417.50	0.00	0.70	404.25
	flow + substrate type + season + sediment depth	419.94	2.44	0.21	404.24
	flow + substrate type + season + sediment depth + water depth	422.44	4.94	0.06	404.23
	flow + substrate type + season + sediment depth + salinity + water depth + temperature	423.86	6.36	0.03	400.37
	flow + season	427.00	9.50	0.01	418.42
	flow + substrate type	442.64	25.14	0.00	431.75
	substrate type	449.65	32.15	0.00	443.30
	temperature	451.29	33.79	0.00	447.12
	flow	456.20	38.70	0.00	449.86
	flow + sediment depth	458.06	40.56	0.00	449.48
	water depth	464.90	47.40	0.00	460.73
	salinity	468.46	50.96	0.00	464.29
	Null	470.90	53.40	0.00	468.84
	sediment depth	471.95	54.45	0.00	467.78

Appendix B Table 5. Parameter estimates of top models from habitat model selection.

Tipulidae

Top Model **WaterDepth+SedimentDepth+SedimentType+Salinity+Temperature+Flow+Season**

Effect	Flow	Silt Type	Season	Estimate	Standard Error	DF	t Value	P value
Intercept				0.3088	1.036	64	0.3	0.7666
Water Depth				-0.182	0.1416	64	-1.29	0.2033
Sediment Depth				0.2233	0.09665	64	2.31	0.0241
Sediment Type		Cobble		1.3617	1.0565	64	1.29	0.2021
Sediment Type		Gravel		2.6729	1.0198	64	2.62	0.0109
Sediment Type		Silt/Mud		0	.	.	.	.
Salinity				0.1147	0.2065	64	0.56	0.5804
Temperature				-0.636	0.2988	64	-2.13	0.0371
Flow	A			-2.4611	0.2628	64	-9.37	<0..0001
Flow	B			-1.5652	0.2387	64	-6.56	<0.0001
Flow	C			0	.	.	.	.
Season			A	-1.5349	0.4961	64	-3.09	0.0029
Season			B	0	.	.	.	.

Appendix B Table 5. Continued

Chironomidae

Top Model	**WaterDepth+SedimentDepth+SedimentType+Salinity+Temperature+Flow+Season**							
Effect	**Flow**	**Silt Type**	**Season**	**Estimate**	**Standard Error**	**DF**	**t Value**	**P value**
Intercept				2.561	0.1938	64	13.22	<0.0001
Water Depth				0.0914	0.07847	64	1.16	0.2484
Sediment Depth				-0.1949	0.06102	64	-3.19	0.0022
Sediment Type		Cobble		-1.3111	0.1518	64	-8.64	<0.0001
Sediment Type		Gravel		-0.6663	0.1045	64	-6.38	<0.0001
Sediment Type		Silt/Mud		0	.	.	.	.
Salinity				0.09279	0.05021	64	1.85	0.0692
Temperature				-0.2308	0.09674	64	-2.39	0.02
Flow	A			0.3752	0.1703	64	2.2	0.0312
Flow	B			1.0039	0.1686	64	5.95	<0.0001
Flow	C			0	.	.	.	.
Season			A	-1.0048	0.183	64	-5.49	<0.0001
Season			B	0	.	.	.	.

Ceratopogonidea

Top Model	**WaterDepth+SedimentDepth+SedimentType+Salinity+Temperature+Flow+Season**							
Effect	**Flow**	**Silt Type**	**Season**	**Estimate**	**Standard Error**	**DF**	**t Value**	**P value**
Intercept				-4.4704	1.2142	64	-3.68	0.0005
Water Depth				0.128	0.2786	64	0.46	0.6474
Sediment Depth				-0.05194	0.1936	64	-0.27	0.7893
Sediment Type		Cobble		0.3661	0.496	64	0.74	0.4631
Sediment Type		Gravel		-0.4266	0.4288	64	-0.99	0.3236
Sediment Type		Silt/Mud		0	.	.	.	.
Salinity				-0.1861	0.2937	64	-0.63	0.5285
Temperature				1.0307	0.2899	64	3.56	0.0007
Flow	A			1.7721	1.0611	64	1.67	0.0998
Flow	B			1.211	1.1007	64	1.1	0.2753
Flow	C			0	.	.	.	.
Season			A	3.3524	0.7347	64	4.56	<0.0001
Season			B	0	.	.	.	.

Appendix B Table 5. Continued

Plecoptera

Top Model	**WaterDepth+SedimentDepth+SedimentType+Salinity+Temperature+Flow+Season**							
Effect	**Flow**	**Silt Type**	**Season**	**Estimate**	**Standard Error**	**DF**	**t Value**	**P value**
Intercept				-4.4704	1.2142	64	-3.68	0.0005
Water Depth				0.128	0.2786	64	0.46	0.6474
Sediment Depth				-0.05194	0.1936	64	-0.27	0.7893
Sediment Type		Cobble		0.3661	0.496	64	0.74	0.4631
Sediment Type		Gravel		-0.4266	0.4288	64	-0.99	0.3236
Sediment Type		Silt/Mud		0	.	.	.	.
Salinity				-0.1861	0.2937	64	-0.63	0.5285
Temperature				1.0307	0.2899	64	3.56	0.0007
Flow	A			1.7721	1.0611	64	1.67	0.0998
Flow	B			1.211	1.1007	64	1.1	0.2753
Flow	C			0	.	.	.	.
Season			A	3.3524	0.7347	64	4.56	<0.0001
Season			B	0	.	.	.	.

Trichoptera

Top Model	**WaterDepth+SedimentDepth+SedimentType+Salinity+Temperature+Flow+Season**							
Effect	**Flow**	**Silt Type**	**Season**	**Estimate**	**Standard Error**	**DF**	**t Value**	**P value**
Intercept				3.0464	0.2691	64	11.32	<0.0001
Water Depth				0.3544	0.1069	64	3.31	0.0015
Sediment Depth				0.5018	0.05577	64	9	<0.0001
Sediment Type		Cobble		-0.9586	0.2805	64	-3.42	0.0011
Sediment Type		Gravel		-0.319	0.2303	64	-1.39	0.1708
Sediment Type		Silt/Mud		0	.	.	.	.
Salinity				-1.8414	0.2306	64	-7.98	<0.0001
Temperature				0.7095	0.1903	64	3.73	0.0004
Flow	A			-2.3298	0.1922	64	-12.12	<0.0001
Flow	B			-1.4128	0.1713	64	-8.25	<0.0001
Flow	C			0	.	.	.	.
Season			A	-1.1472	0.3173	64	-3.62	0.0006
Season			B	0	.	.	.	.

Appendix B Table 5. Continued

Ephemeroptera

Top Model **Flow+SedimentType+Season**

Effect	Flow	Silt Type	Season	Estimate	Standard Error	DF	t Value	P value
Intercept				2.4366	0.2286	68	10.66	<0.0001
Flow	A			-1.4533	0.1058	68	-13.73	<0.0001
Flow	B			-0.5982	0.1346	68	-4.45	<0.0001
Flow	C			0	.	.	.	.
Sediment Type		Cobble		1.7297	0.2179	68	7.94	<0.0001
Sediment Type		Gravel		0.8922	0.2149	68	4.15	<0.0001
Sediment Type		Silt/Mud		0	.	.	.	.
Season			A	-18.0933	347.4	68	-0.05	0.9586
Season			B	0	.	.	.	.

Gastropoda

Top Model **Flow+SedimentType+SedimentDepth+Season**

Effect	Flow	Silt Type	Season	Estimate	Standard Error	DF	t Value	P value
Intercept				-0.4175	0.6477	67	-0.64	0.5214
Flow	A			-0.5972	0.4087	67	-1.46	0.1486
Flow	B			-0.693	0.5227	67	-1.33	0.1894
Flow	C			0	.	.	.	.
Sediment Depth				-0.9283	0.3516	67	-2.64	0.0103
Sediment Type		Cobble		-0.9047	0.8746	67	-1.03	0.3047
Sediment Type		Gravel		0.6432	0.5614	67	1.15	0.256
Sediment Type		Silt/Mud		0	.	.	.	.
Season			A	-1.7625	0.5355	67	-3.29	0.0016
Season			B	0	.	.	.	.

Oligochaete/Nematoda

Top Model **WaterDepth+SedimentDepth+SedimentType+Salinity+Temperature+Flow+Season**

Effect	Flow	Silt Type	Season	Estimate	Standard Error	DF	t Value	P value
Intercept				0.8136	0.321	64	2.53	0.0137
Water Depth				0.2973	0.1192	64	2.49	0.0152
Sediment Depth				-0.2065	0.08378	64	-2.46	0.0164
Sediment Type		Cobble		-0.8471	0.3253	64	-2.6	0.0114
Sediment Type		Gravel		0.5324	0.2185	64	2.44	0.0176
Sediment Type		Silt/Mud		0	.	.	.	.
Salinity				-0.6742	0.2321	64	-2.91	0.005
Temperature				-0.327	0.2015	64	-1.62	0.1096
Flow	A			0.3048	0.2183	64	1.4	0.1676
Flow	B			0.5351	0.2367	64	2.26	0.0272
Flow	C			0	.	.	.	.
Season			A	-1.2698	0.3314	64	-3.83	0.0003
Season			B	0	.	.	.	.
Season			B	0	.	.	.	.

Appendix B Table 5. Continued

Diptera

Top Model	**WaterDepth+SedimentDepth+SedimentType+Salinity+Temperature+Flow+Season**							
Effect	**Flow**	**Silt Type**	**Season**	**Estimate**	**Standard Error**	**DF**	**t Value**	**P value**
Intercept				-0.6607	0.517	64	-1.28	0.2059
Water Depth				-0.5606	0.248	64	-2.26	0.0272
Sediment Depth				0.6037	0.1414	64	4.27	<0.0001
Sediment Type		Cobble		1.6958	0.6017	64	2.82	0.0064
Sediment Type		Gravel		2.1813	0.4779	64	4.56	<0.0001
Sediment Type		Silt/Mud		0	.	.	.	.
Salinity				0.8338	0.1595	64	5.23	<0.0001
Temperature				-0.1474	0.404	64	-0.36	0.7164
Flow	A			-2.1229	0.4003	64	-5.3	<0.0001
Flow	B			-0.8566	0.3787	64	-2.26	0.0271
Flow	C			0	.	.	.	.
Season			A	-1.3082	0.7613	64	-1.72	0.0906
Season			B	0	.	.	.	.

Simuliidae

Top Model	**WaterDepth+SedimentDepth+SedimentType+Salinity+Temperature+Flow+Season**							
Effect	**Flow**	**Silt Type**	**Season**	**Estimate**	**Standard Error**	**DF**	**t Value**	**P value**
Intercept				-1.1138	0.8347	64	-1.33	0.1868
Water Depth				-2.1867	0.4001	64	-5.47	<0.0001
Sediment Depth				-0.766	0.3643	64	-2.1	0.0394
Sediment Type		Cobble		0.673	0.7752	64	0.87	0.3885
Sediment Type		Gravel		0.1615	0.6715	64	0.24	0.8107
Sediment Type		Silt/Mud		0	.	.	.	.
Salinity				-2.912	0.73	64	-3.99	0.0002
Temperature				2.4579	0.6591	64	3.73	0.0004
Flow	A			-3.6819	0.5569	64	-6.61	<0.0001
Flow	B			-2.16665	0.4999	64	-4.33	<0.0001
Flow	C			0	.	.	.	.
Season			A	-12.874	462.63	64	-0.03	0.9779
Season			B	0	.	.	.	.

Appendix B Table 5. Continued

Hirudinea

Top Model **WaterDepth+SedimentDepth+SedimentType+Salinity+Temperature+Flow+Season**

Effect	Flow	Silt Type	Season	Estimate	Standard Error	DF	t Value	P value
Intercept				-1.8728	1.3729	64	-1.36	0.1773
Water Depth				0.9309	0.7109	64	1.31	0.195
Sediment Depth				1.2752	0.7254	64	1.76	0.0836
Sediment Type		Cobble		-0.8267	1.1541	64	-0.72	0.4764
Sediment Type		Gravel		-0.8919	0.5977	64	-1.49	0.1405
Sediment Type		Silt/Mud		0	.	.	.	.
Salinity				0.3063	0.2129	64	1.44	0.1552
Temperature				2.2516	0.8083	64	2.79	0.007
Flow	A			-0.6757	1.2705	64	-0.53	0.5967
Flow	B			1.7622	1.1339	64	1.56	0.1251
Flow	C			0	.	.	.	.
Season			A	-15.4952	513.6	64	-0.03	0.976
Season			B	0	.	.	.	.

Categories

Top Model **Flow+SedimentType+Season**

Effect	Flow	Silt Type	Season	Estimate	Standard Error	DF	t Value	P value
Intercept				2.5391	0.137	68	18.53	<0.0001
Flow	A			-0.3672	0.1015	68	-3.62	0.0006
Flow	B			-0.1606	0.1149	68	-1.4	0.1667
Flow	C			0	.	.	.	.
Sediment Type		Cobble		-0.1083	0.1291	68	-0.84	0.4048
Sediment Type		Gravel		0.2418	0.1071	68	2.26	0.0272
Sediment Type		Silt/Mud		0	.	.	.	.
Season			A	-0.4093	0.07886	68	-5.19	<0.0001
Season			B	0	.	.	.	.

Coleoptera

Top Model **Flow+Season**

Effect	Flow	Season	Estimate	Standard Error	DF	t Value	P value
Intercept			-14.6341	614.71	70	-0.02	0.9811
Flow	A		14.3596	614.71	70	0.02	0.9814
Flow	B		14.2286	614.71	70	0.02	0.9816
Flow	C		0	.	.	.	.
Season		A	-15.1212	403.85	70	-0.04	0.9702
Season		B	0	.	.	.	.

Appendix B Table 5. Continued

Mollusca

Top Model **Flow+Season**

Effect	Flow	Season	Estimate	Standard Error	DF	t Value	P value
Intercept			-0.6499	0.5286	70	-1.23	0.223
Flow	A		-0.9863	0.6459	70	-1.53	0.1312
Flow	B		-13.3868	377.17	70	-0.04	0.9718
Flow	C		0	.	.	.	.
Season		A	-1.2839	0.791	70	-1.62	0.1091
Season		B	0	.	.	.	.

Other

Top Model **Flow+Season**

Effect	Flow	Season	Estimate	Standard Error	DF	t Value	P value
Intercept			-0.1823	0.4472	70	-0.41	0.6848
Flow	A		-0.8393	0.5578	70	-1.5	0.1369
Flow	B		-0.9163	0.8367	70	-1.1	0.2772
Flow	C		0	.	.	.	.
Season		A	-14.8196	4141.4	70	-0.04	0.9716
Season		B	0	.	.	.	.

Amphipoda

Top Model **Flow+SedimentDepth**

Effect	Flow	Estimate	Standard Error	DF	t Value	P value
Intercept		-2.9097	1.0533	70	-2.76	0.0073
Flow	A	1.299	1.0439	70	1.24	0.2175
Flow	B	-11.9072	376.46	70	-0.03	0.9749
Flow	C	0	.	.	.	.
Sediment Depth		-1.0037	0.5704	70	-1.76	0.0829

Appendix B Table 6. Salinity measurements collected 2017 at aquatic invertebrate sampling sites on the Mast River in Wapusk National Park, Manitoba, Canada.

Location	Sample ID	Sampling	Year	Salinity
Mast River	A	June	2017	0.08
Mast River	A	July	2017	0.09
Mast River	B	June	2017	0.08
Mast River	B	July	2017	0.10
Mast River	C	June	2017	0.08
Mast River	C	July	2017	0.10
Mast River	D	June	2017	0.09
Mast River	D	July	2017	0.12
Mast River	E	June	2017	0.07
Mast River	E	July	2017	0.07
Mast River	F	June	2017	0.05
Mast River	F	July	2017	0.12
Mast River	G	June	2017	0.07
Mast River	G	July	2017	0.13
Mast River	H	June	2017	0.06
Mast River	H	July	2017	0.13
Mast River	I	June	2017	0.07
Mast River	I	July	2017	0.15
Mast River	J	June	2017	0.08
Mast River	J	July	2017	0.16
Mast River	K	June	2017	0.09
Mast River	K	July	2017	0.16
Mast River	L	June	2017	0.07
Mast River	L	July	2017	0.17
Mast River	M	June	2017	0.08
Mast River	M	July	2017	0.16
Mast River	N	June	2017	0.04
Mast River	N	July	2017	0.07
Mast River	O	June	2017	0.04
Mast River	O	July	2017	0.09
Mast River	P	June	2017	0.07
Mast River	P	July	2017	0.16
Mast River	Q	June	2017	0.09
Mast River	Q	July	2017	0.10
Mast River	R	June	2017	0.04
Mast River	R	July	2017	0.18
Mast River	S	June	2017	0.03
Mast River	S	July	2017	0.06
Mast River	S5	June	2017	0.05
Mast River	S5	July	2017	0.20
Mast River	S6	June	2017	0.08
Mast River	S6	July	2017	0.16
Mast River	T	June	2017	0.03
Mast River	T	July	2017	0.08
Mast River	U	June	2017	0.03
Mast River	U	July	2017	0.08
			Average	0.09
		Average June		0.06
		Average July		0.12

Appendix B Table 7. Salinity measurements collected 2017 at aquatic invertebrate sampling sites on the Wawao Creek in Wapusk National Park, Manitoba, Canada.

Location	Sample ID	Sampling	Year	Salinity
Wawao Creek	WA	June	2017	0.14
Wawao Creek	WA	July	2017	0.28
Wawao Creek	WB	June	2017	0.16
Wawao Creek	WB	July	2017	0.26
Wawao Creek	WC	June	2017	0.35
Wawao Creek	WC	July	2017	0.61
Wawao Creek	WD	June	2017	0.36
Wawao Creek	WD	July	2017	0.74
Wawao Creek	WE	June	2017	0.10
Wawao Creek	WE	July	2017	0.37
Wawao Creek	WF	June	2017	0.09
Wawao Creek	WF	July	2017	0.42
			Average	0.32
		Average June		0.20
		Average July		0.45

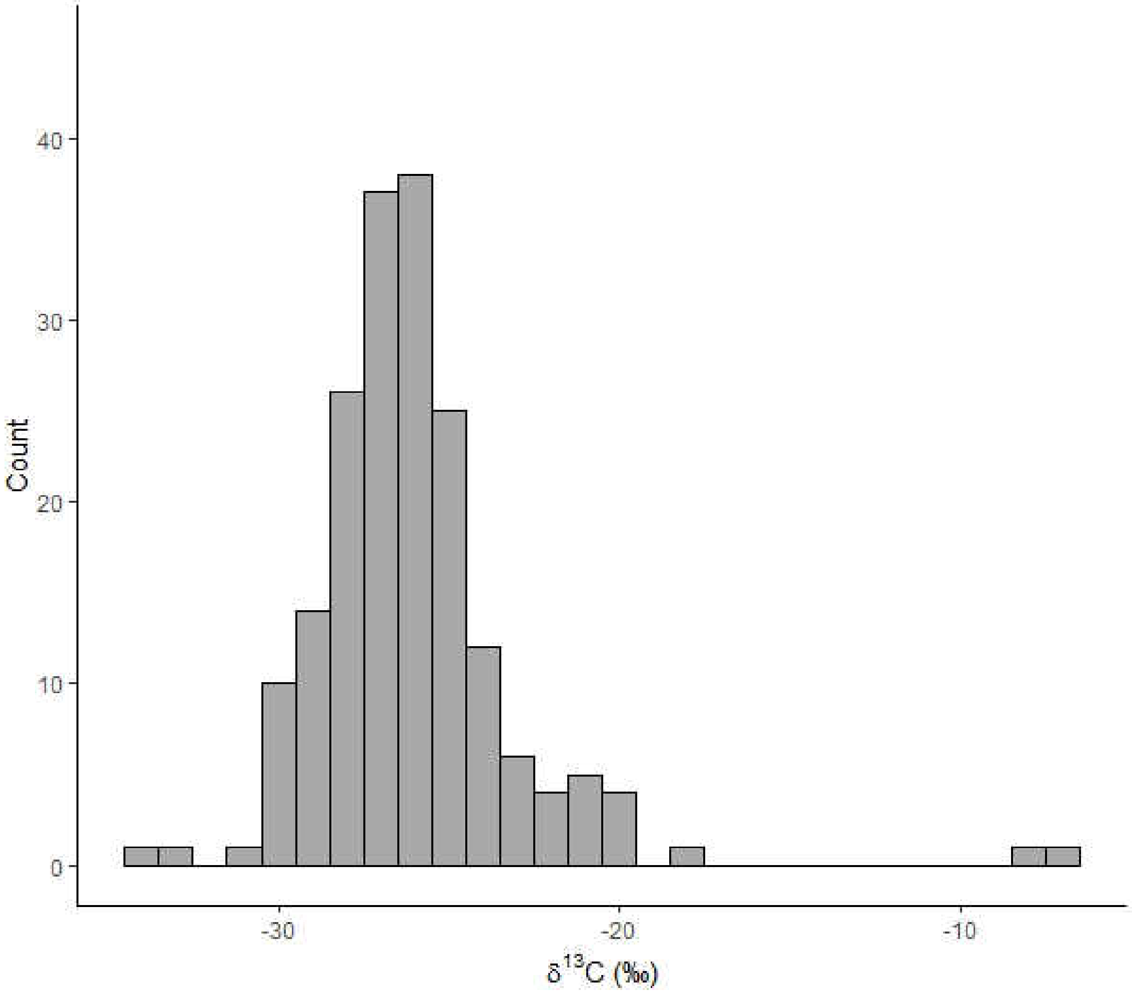
Appendix B Table 8. Salinity measurements collected 2017 at brackish water aquatic invertebrate sampling sites in Wapusk National Park, Manitoba, Canada.

Location	Sample ID	Sampling	Year	Salinity
Brackish	V	June	2017	0.05
Brackish	V	July	2017	0.14
Brackish	W	June	2017	0.04
Brackish	W	July	2017	0.15
Brackish	X	June	2017	0.08
Brackish	X	July	2017	0.16
Brackish	Y	June	2017	0.06
Brackish	Y	July	2017	0.15
Brackish	Z	June	2017	0.04
Brackish	Z	July	2017	0.15
Brackish	AA	June	2017	0.04
Brackish	AA	July	2017	0.13
Brackish	BB	June	2017	0.03
Brackish	BB	July	2017	0.14
Brackish	CC	June	2017	0.04
Brackish	CC	July	2017	0.06
			Average	0.09
			Average June	0.05
			Average July	0.14

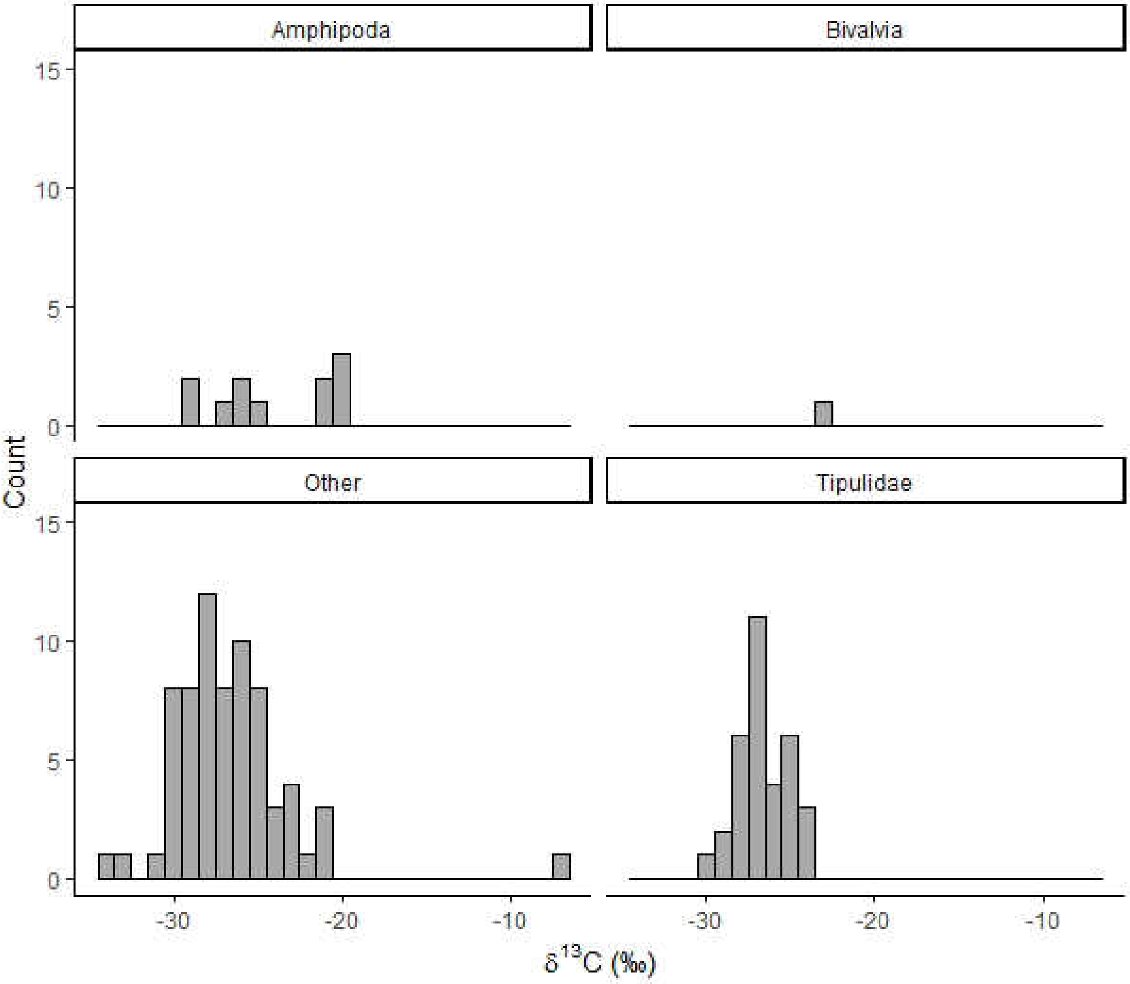
Appendix B Table 9. Salinity measurements collected 2017 at marine aquatic invertebrate sampling sites in Wapusk National Park, Manitoba, Canada.

Location	Sample ID	Sampling	Year	Salinity
Marine	A	July	2017	12.40
Marine	B	July	2017	0.82
Marine	C	July	2017	7.13
Marine	D	July	2017	0.32
Marine	E	July	2017	0.88
Marine	F	July	2017	10.30
			Average	5.31
		Sites A + C + F		9.94

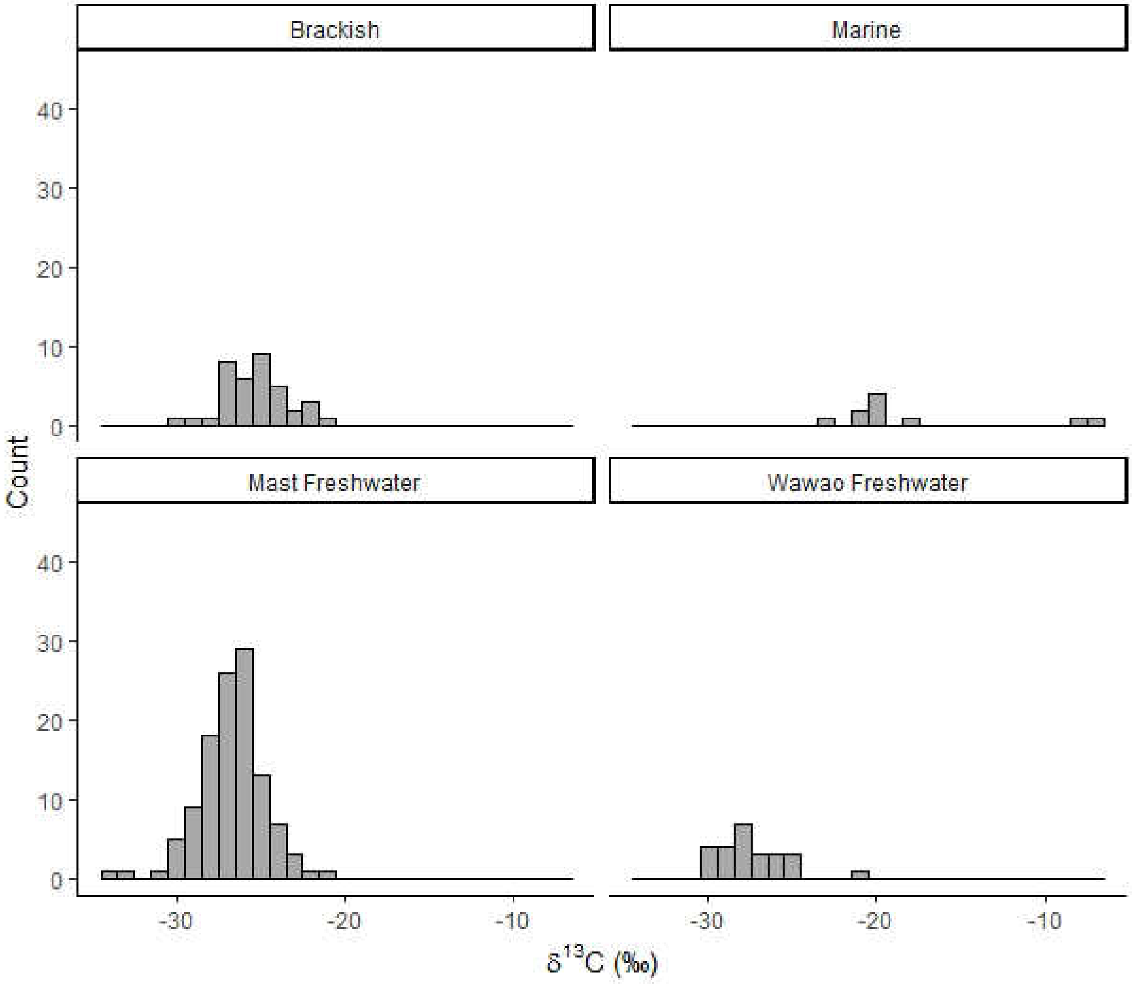
Figures



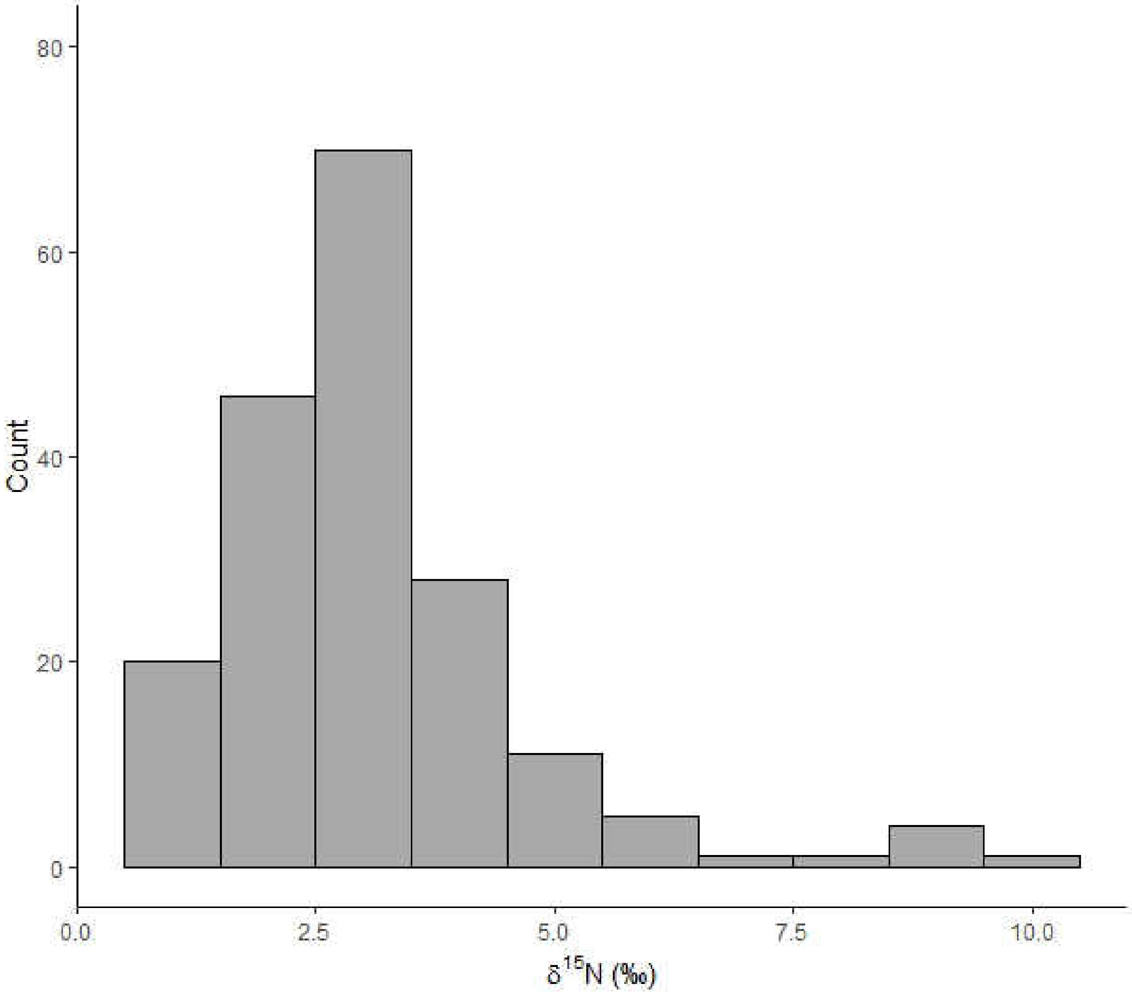
Appendix B Figure 1. Frequency of $\delta^{13}C$ values from aquatic invertebrate samples collected in 2017 in Wapusk National Park, Manitoba, Canada.



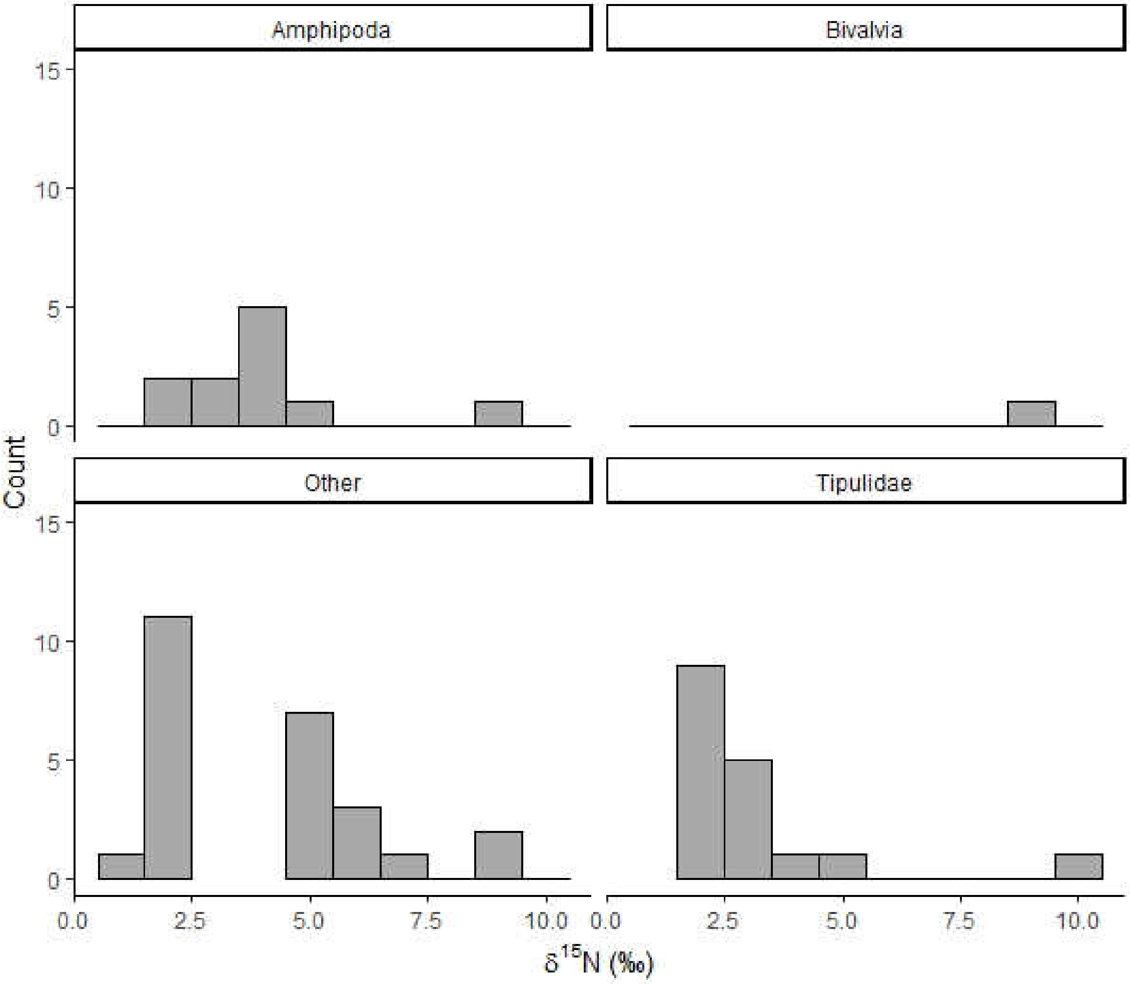
Appendix B Figure 2. Frequency of $\delta^{13}C$ values from aquatic invertebrate samples collected in 2017 in Wapusk National Park, Manitoba, Canada and sub-sorted into four categories.



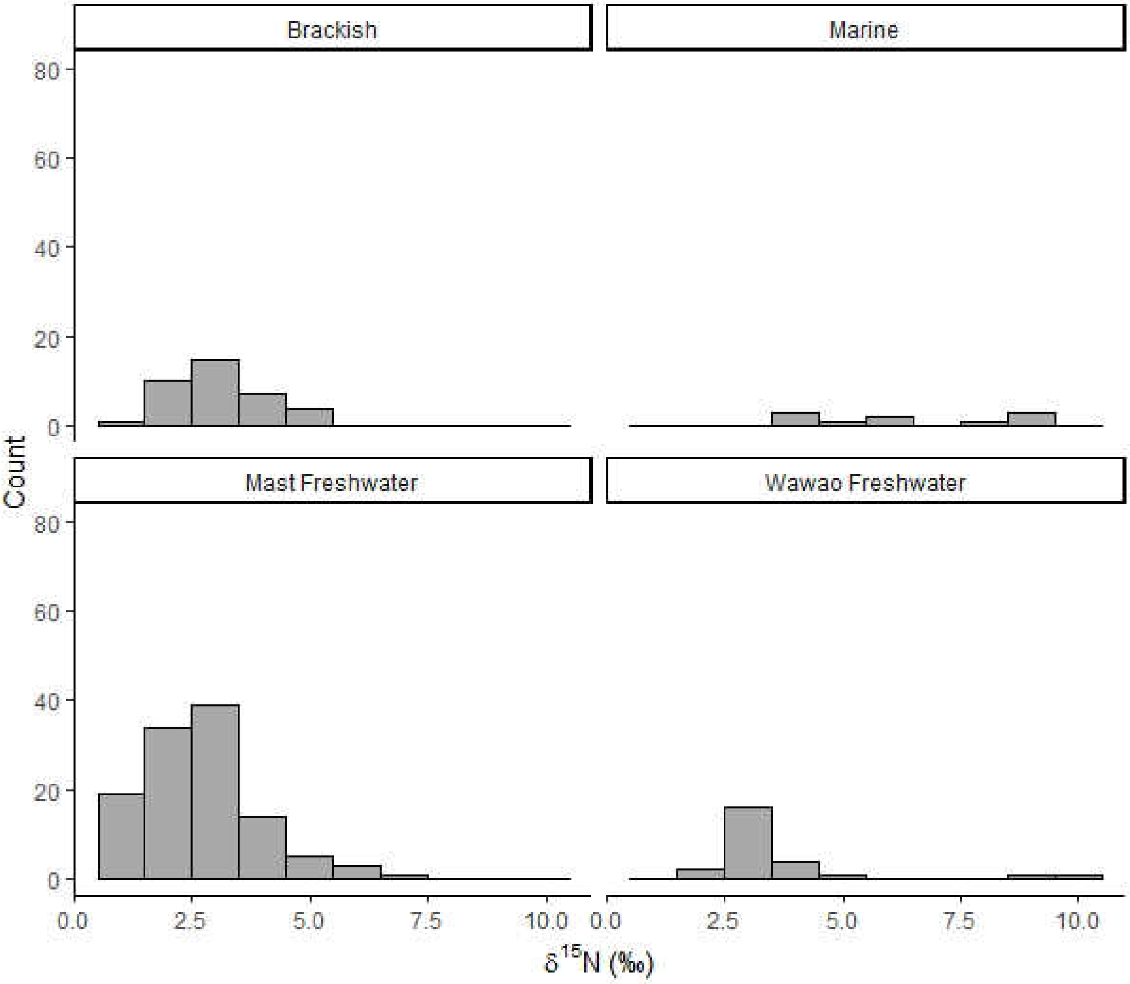
Appendix B Figure 3. Frequency of $\delta^{13}C$ values from aquatic invertebrate samples collected in 2017 in Wapusk National Park, Manitoba, Canada and sub-sorted into four water types.



Appendix B Figure 4. Frequency of $\delta^{15}N$ values from aquatic invertebrate samples collected in 2017 in Wapusk National Park, Manitoba, Canada.



Appendix B Figure 5. Frequency of δ^{15}N values from aquatic invertebrate samples collected in 2017 in Wapusk National Park, Manitoba, Canada and sub-sorted into four categories.



Appendix B Figure 6. Frequency of $\delta^{15}N$ values from aquatic invertebrate samples collected in 2017 in Wapusk National Park, Manitoba, Canada and sub-sorted into four water types.

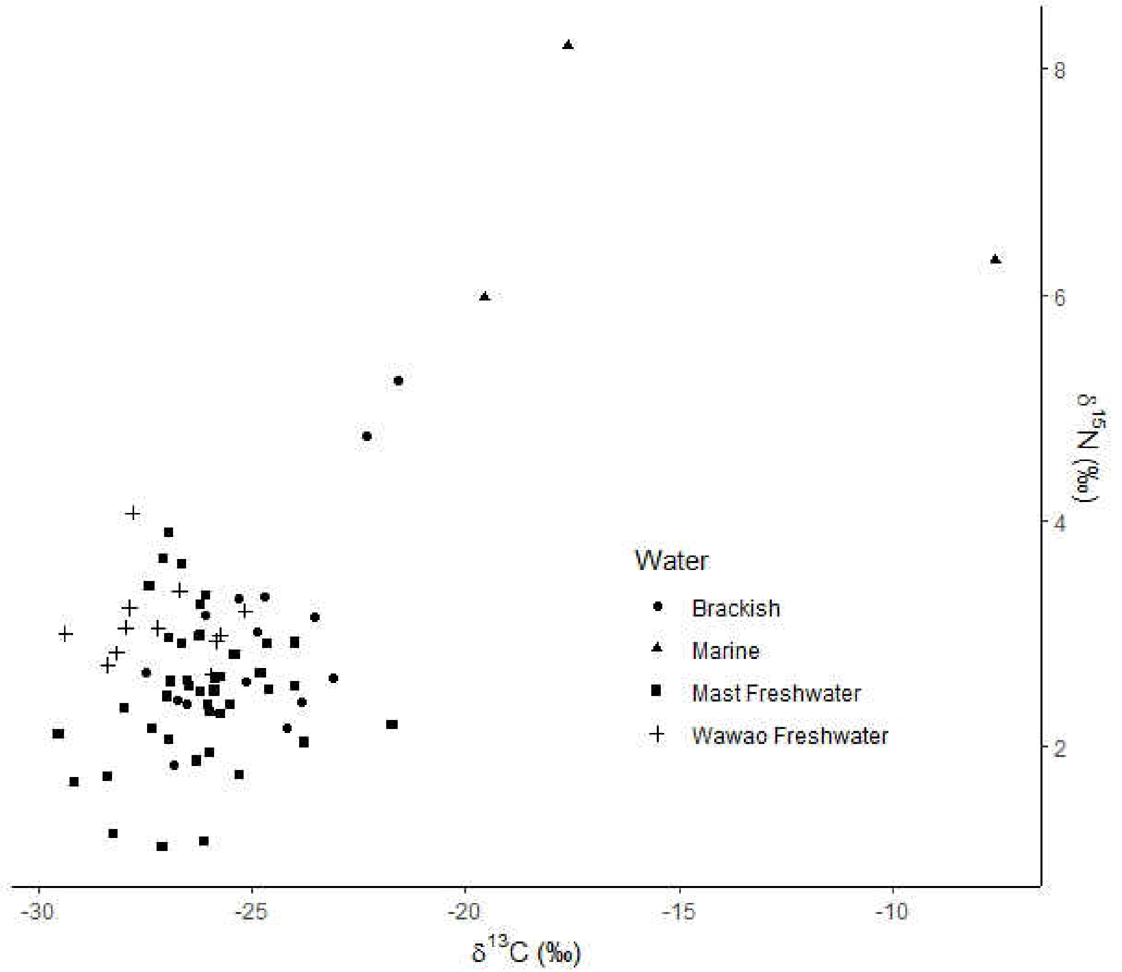


Figure 3.4. $\delta^{13}C$ values vs $\delta^{15}N$ values of aquatic invertebrate samples collected from four different water types in Wapusk National Park and Churchill, Manitoba, Canada in 2016.

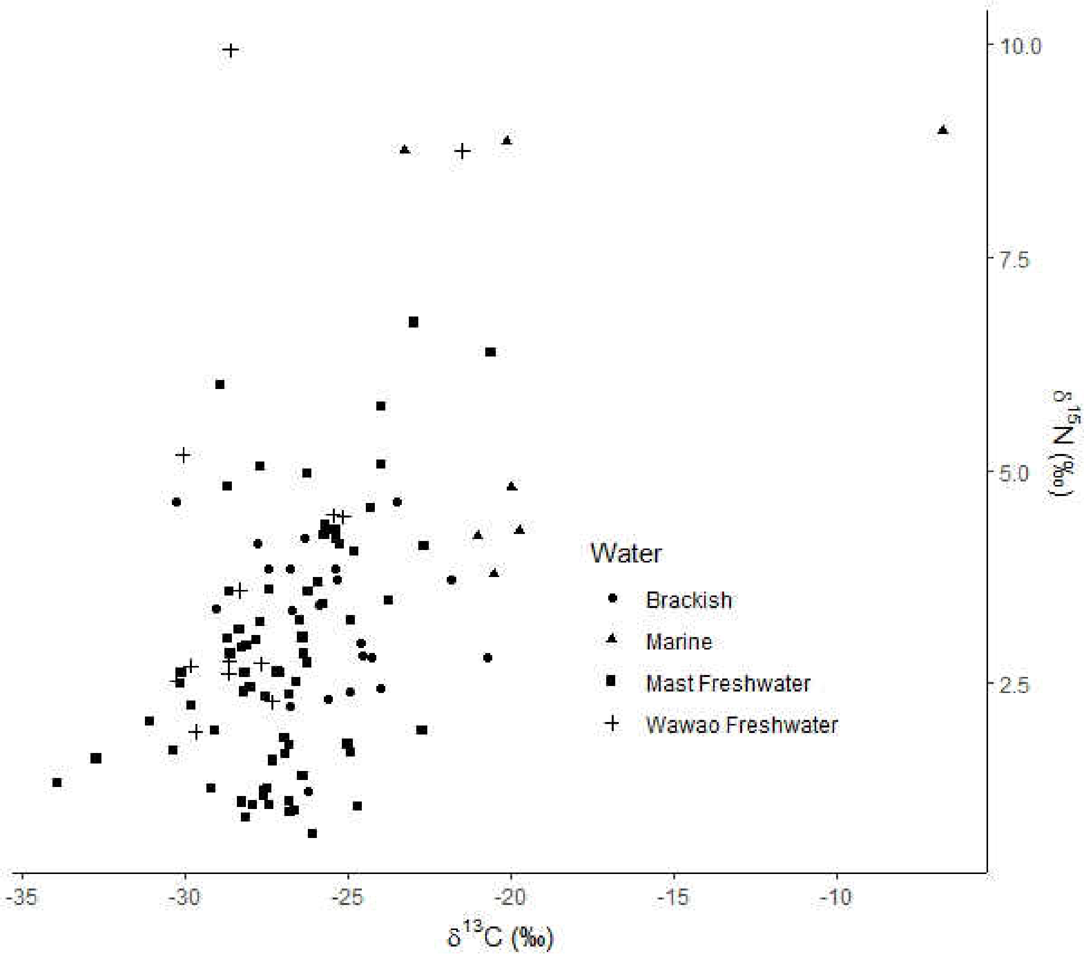


Figure 3.5. $\delta^{13}C$ values vs $\delta^{15}N$ values of aquatic invertebrate samples collected from four different water types in Wapusk National Park and Churchill, Manitoba, Canada in 2017.

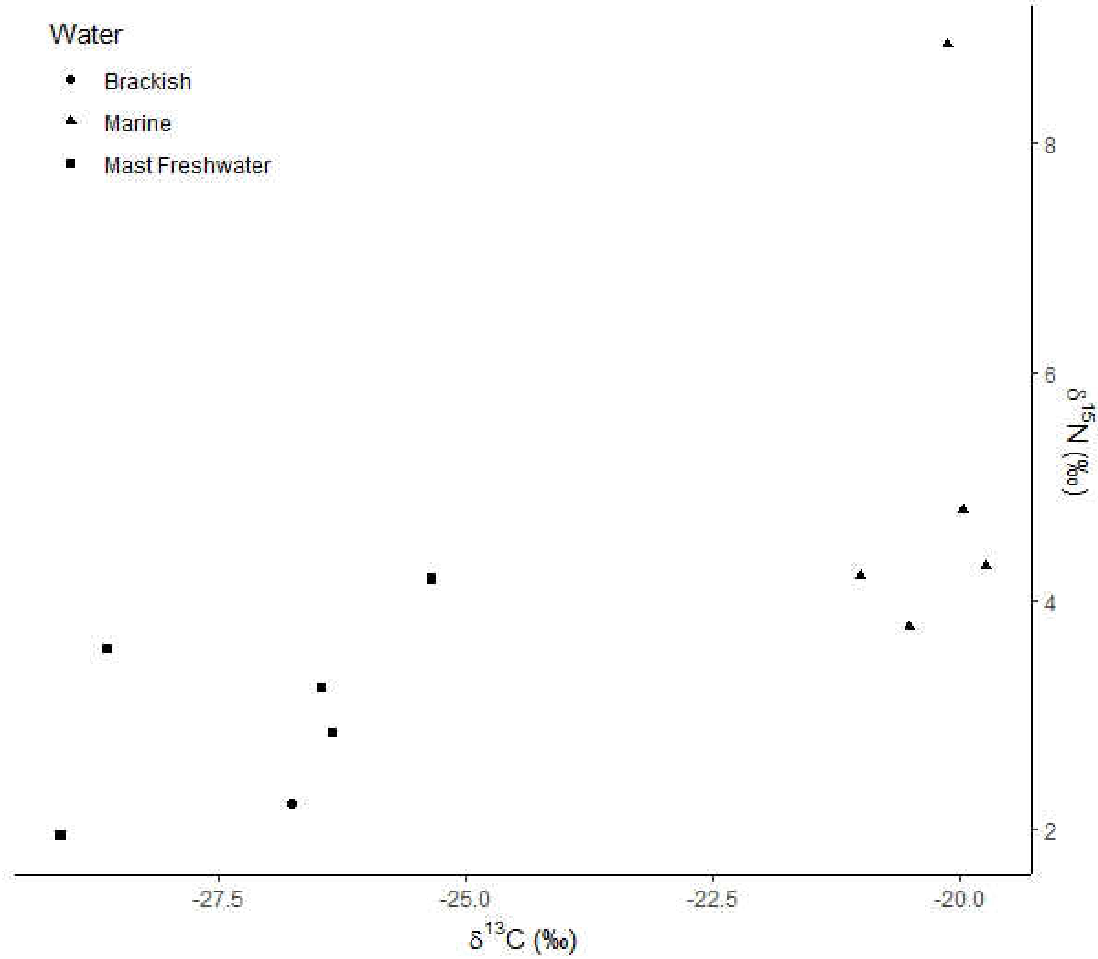


Figure 3.7. δ^{13}C values vs δ^{15}N values of Amphipoda samples collected from four different water types in Wapusk National Park and Churchill, Manitoba, Canada in 2017.

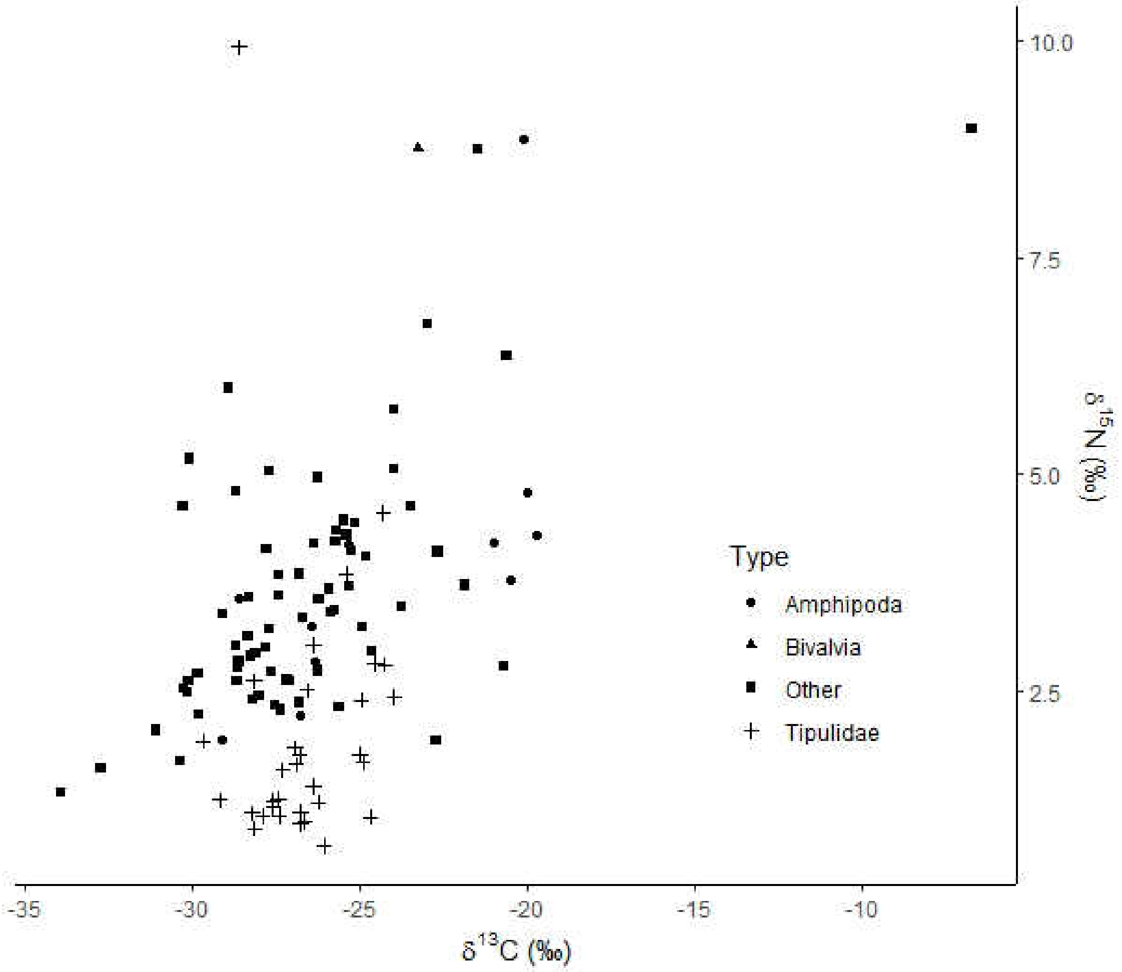


Figure 3.8. $\delta^{13}C$ values vs $\delta^{15}N$ values of aquatic invertebrate samples sorted into four different subset types in Wapusk National Park and Churchill, Manitoba, Canada in 2017.