Population Characteristics, Habitat Utilization, and Movement Patterns of Lake Sturgeon in the White River, Ontario

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Summary

The Anishinabek/Ontario Fisheries Resource Centre (A/OFRC), and various other partners, have been conducting Lake Sturgeon research in the Pic River of northeastern Lake Superior since 2006. From 2008 to 2010 a Lake Sturgeon radio telemetry study was undertaken to identify critical habitat and monitor movement patterns in the Pic River (Ecclestone, 2011). In July of 2010, the A/OFRC and Pukaskwa National Park partnered together to identify whether Lake Sturgeon existed in the White River, which is approximately 10 km south of the Pic River and protected by Pukaskwa National Park. Eight gill nets were set overnight and a total of 10 Lake Sturgeon were captured, indicating that Lake Sturgeon persisted in the White River and in relatively good abundance. The presence of Lake Sturgeon in the White River was encouraging as they were previously classified as extirpated from this system. Given this new evidence, the A/OFRC and Parks Canada, with funding from the Ontario Ministry of Natural Resources (SAR Stewardship Fund), initiated a Lake Sturgeon radio telemetry project in 2011 for the White River. This objectives of this project were to asses baseline population characteristics, identify critical habitat, and monitor Lake Sturgeon movement patterns and habitat utilization in the White River.

Field work was conducted from May 20th to August 29th of 2011 when mean daily water temperatures ranged from 10.92°C and 24.97°C. A total of 132 gill nets were set and 82 Lake Sturgeon were captured, resulting in a CPUE of 0.62 sturgeon per 100' net per day. The majority of nets were set immediately below Chigamiwinigum Falls (4.5 km from Lake Superior), in Stan's Honey Hole (3.5 km from Lake Superior), at the S-bend (2.5 km from Lake Superior), or near the mouth of the White River (0 km from Lake Superior). Once captured, physical attributes were recorded and radio tags were surgically implanted into forty adult Lake Sturgeon that exceeded 5 kg. Lake Sturgeon movements and habitat utilization were manually monitored throughout the river by boat and by two automatic base station receivers that were located at the mouth of the White River and near Chigamiwinigum Falls. A temperature data logger was also present near Chigamiwinigum Falls, which is the most likely spawning site in the White River.

Lake Sturgeon growth parameters and CPUE were elevated in the White River compared to other locations across its geographical range, however their condition factor and weight-length relationship was comparable to other populations that have been studied. Habitat utilization and movement patterns were comparable to observations in other spawning tributaries, whereby Lake Sturgeon showed a strong preference for pool mesohabitats and decreased their movements as water temperatures and GDD increased. Lake Sturgeon demonstrated a non-random distribution in the White River and were frequently located immediately below Chigamiwinigum Falls and in Stan's Honey Hole. The overall rate of emigration from the White River to the Pic River, and vice versa, was 15% and 10.4% respectively. Future studies in this Lake Sturgeon system should employ larger and smaller mesh sizes and conduct habitat mapping and spawning assessments. Additionally, two base stations in the White and Pic Rivers should continue to operate to monitor rates of immigration and emigration between each system, which has not been well studied in the literature. Finally, we conclude that the White River should be considered a priority tributary for Lake Sturgeon rehabilitation in Lake Superior as it contains a healthy and fast growing population that is ensured long-term protection from Pukaskwa National Park.

Acknowledgements

This project was graciously funded through the Species at Risk Stewardship Program, which is administered by the Ontario Ministry of Natural Resources (OMNR). Parks Canada and Pukaskwa National Park provided additional funding and onsite logistical support for the project. The A/OFRC and its board of directors also deserve recognition for their commitment and dedication to Lake Sturgeon research in northeastern Lake Superior. Other project partners included; Pic River First Nation, Pic Mobert First Nation, Fisheries and Oceans Canada (Sault Ste. Marie), and Wawa district OMNR. This project would not have been possible without the cumulative and collaborative efforts of each partner.

Table of Contents

List of Figure

List of Tables

List of Appendices

1.0 Introduction

Lake Sturgeon (*Acipenser fulvescens*) are one of the world's largest and longest lived freshwater fish species, and the only sturgeon species that is native to the Laurentian Great Lakes (Scott & Crossman, 1998). These potamodromous bottom-feeders have a primitive appearance and a downward facing snout that enables them to detect prey in soft bottom sediment using sensory pits and barbels (Harkness & Dymond, 1961; Peterson et al., 2007; Stelzer et al., 2008). Juveniles allocate a disproportionate amount of energy towards somatic growth (Beamish et al., 1996), and therefore sexual maturity is not reached until approximately 12-15 years for males and 18-27 years for females (Kempinger, 1988; Bruch & Binkowski, 2002; Peterson et al., 2007; Barth et al., 2009). These extreme life history characteristics of the Lake Sturgeon make it a difficult species to manage and research given the resource and time constraints of most fisheries projects.

Each spring, when water temperatures are between 11ºC to 21ºC, a portion of the adult population migrate upriver to reproduce at their natal spawning grounds that contain cobble-boulder-gravel substrates and fast flowing water (Harkness & Dymond, 1961; McKinley et al., 1998; Bruch & Binkowski, 2002; Peterson et al., 2007). Bruch & Binkowski (2002) found that spawning sites in the Winnebago system were close to deep overwintering pools (<2 km), had an extensive amount of spawning substrate (>700 m^2) that was comprised of clean rock and interstitial spaces, and high flows for aerating eggs. Several other studies report Lake Sturgeon spawning at depths of 0.1 m to 2.0 m over gravel or cobble substrate, and at water velocities that range from 15 cm/s to 70 cm/s (Priegel and Wirth, 1974; LaHaye et al., 1992; McKinley et al., 1998; Auer & Baker, 2002). Spawning temperatures can also vary quite substantially. A long-term study in the Wolf River found evidence of spawning at temperatures between 8.3ºC and 23.3ºC (Kempinger, 1988) and up to 21.5ºC in the L'Assomption River (LaHaye et al., 1992).

Most spawning, however, is observed between 13ºC to 18ºC (Scott & Crossman, 1973; Bruch & Binkowski, 2002; Peterson et al., 2007). Lake Sturgeon have a polyandrous mating system, whereby two to five males will fertilize eggs that are broadcasted by a spawning female while traversing the length of the spawning habitat (Harkness, 1988; Auer & Baker, 2002; Bruch & Binkowski, 2002; Hodgeson et al., 2006; Peterson et al., 2007). Since females only spawn every 3-5 years, and males every 1-3 years, inter and intra population variation in movement patterns and habitat utilization are often observed throughout the spring (Kempinger, 1988; Fortin et al., 1996; Rusak & Mosindy, 1997; Peterson et al., 2007). By late-summer, and throughout the fall and winter, populations typically reduce their home range size and show strong site fidelity for deep-water pools, which are typically located in the lower sections of rivers, or a connected lake (Hay-Chmielewski, 1987; Lyons & Kempinger, 1992; Fortin et al., 1993; Rusak & Mosindy, 1997; McKinley et al., 1998; Auer, 1999; Knight et al., 2002; Haxton, 2003b; Lallaman et al., 2008).

Lake Sturgeon were once considered one of the Great Lake's most abundant and widely distributed endemic fish species (Hay-Chmielewski & Whelan, 1997; Auer, 1999; Peterson, 2007). In the early-1800s Lake Sturgeon were so abundant and widely distributed that they were considered a nuisance species by most commercial fisheries (Stone & Vincent, 1900; Harkness, 1961; Hay-Chmielewski & Whelan, 1997). They were an essential bartering commodity during the fur trade era and have always been traditionally important to aboriginal peoples for subsistence and cultural purposes, especially in northern Ontario (Hannibal-Paci, 1998; Holzkamm & Waisberg, 2005; Ontario Ministry of Natural Resources, 2009; Kline et al., 2010). At the Rainy River, the 1868 spawning run attracted roughly 1,000 Ojibwa people from as far east as Winnipeg and as far west as Lake Superior (Holzkamm et al., 1988). While the purpose of these trips was to harvest the meat and medicinal benefits (Hopper & Power, 1991), the spawning runs also served as social gatherings where political discussions, religious ceremonies, or traditional teachings would occur (Holzkamm et al., 1988). Historical accounts report Lake Sturgeon being brought into the Detroit fish markets by the wagon load and piled like cord-wood where they would be sold for as low as 50 cents apiece and used for fertilizer or fuel (Stone & Vincent, 1900).

Beginning in the mid-1800s, a valuable and targeted commercial fishery for Lake Sturgeon developed, which was driven by the demand for fertilizer, isinglass, biofuel, and towards the start of the 20th century, caviar (Stone & Vincent, 1900; Harkness, 1988; Hay-Chmielewski & Whelan, 1997; Williamson, 2003). As catches exceeded the maximum sustainable yield in the late 1800s, Lake Sturgeon stocks rapidly collapsed throughout the Great Lakes (Baldwin et al., 1979; Hay-Chmielewski & Whelan, 1997; Auer, 1999; Baker & Borgeson, 1999). This led to heavy regulations in the 1920s followed by the closure of most American commercial fisheries by 1980 (Baldwin et al., 1979; Auer, 2003; Peterson et al., 2007) and the recent closure of the recreational fishery in Ontario and bordering states (Ontario Ministry of Natural Resources, 2009). Despite these mitigation measures, however, the majority of sturgeon populations have still not rebounded in the Great Lakes.

In more recent decades, the most prominent anthropogenic threat that is inhibiting the recovery of populations is habitat degradation and fragmentation (Hay-Chmielewski & Whelan, 1997; Auer, 1999; Peterson et al., 2007). Estimates suggest that Lake Sturgeon require 250 km to 300 km of unimpeded river-lake habitat as a minimum home range size to complete their life cycle (Auer, 1996). If Lake Sturgeon do not have access to this large river-lake habitat, then populations may become vulnerable to immediate extirpation when habitat is severely impacted or unreachable (Harkness & Dymond, 1961; Baker & Borgeson, 1999). Even if the effects of habitat fragmentation are not immediately felt, over time populations residing in unimpeded stretches of river have greater abundances and faster growth rates compared to populations occupying impounded sections of river (Haxton, 2002, 2003a; Haxton & Findlay, 2008). Natural barriers, such as fast flowing rapids or small waterfalls, may not fragment habitat or population connectivity (Welsh & McLeod, 2010). However artificial developments, such as hydroelectric developments or water diversions, have resulted in severely fragmented habitats, isolated populations, and altered spawning behaviour (Haxton, 2002; Daugherty et al., 2008a, 2008b; Paragamian et al., 2001). Furthermore, the altered flow regimes that often accompany such developments can also hinder the spawning ability and behavior of Lake Sturgeon, thus having an equally negative impact on the spawning success (Haxton, 2002; Paragamian et al., 2001). Beyond overfishing and habitat fragmentation, several other threats continue to inhibit the recovery of Lake Sturgeon, including invasive species and their control measures (Boogard et al., 2003), pollution and poaching (Auer, 1999), and the potential erosion of locally adapted genes (Welsh et al., 2008; Welsh et al., 2010).

Currently, the abundance of Lake Sturgeon in the Great Lakes is estimated to be less than 1 % of its historical level and 27 populations have become extirpated from historically active tributaries in the Great Lakes (Scott & Crossman, 1973; Hay-Chmielewski & Whelan, 1997; Auer, 1999; Ontario Ministry of Natural Resources, 2009). In response to this weakened state, Lake Sturgeon populations have been grouped into eight designatable conservation units throughout their native Canadian range by COSEWIC (Ferguson & Duckworth, 1997; COSEWIC, 2006; Welsh et al., 2008; Kjartanson, 2008; Hutchings & Festa-Bianchet, 2009). Designatable unit 8 (DU8) contains the Upper Great Lakes and the St. Lawrence River system, which has been further broken down into three designatable subunits (Lake Erie-Lake Huron (DU8a); Northern Lake Superior (DU8b); and St. Lawrence River (DU8c)) (Velez-Espino & Koops, 2009) and six genetically significant units (Welsh et al., 2010). These designatable subunits and genetically significant units have been developed in light of new evidence that focuses on population trends, biogeography, genetic differences, and life history characteristics within each area (Velez-Espino & Koops, 2009; Welsh et al., 2010). Furthermore, they have been listed as threatened or endangered by all states and provinces surrounding the Laurentian Great Lakes, which has led to an increasing amount of conservation and research efforts (Auer, 2003; Peterson et al., 2007; Ontario Ministry of Natural Resources, 2009).

1.1 Study Background and Objectives

Since 2006, the A/OFRC has undertaken several projects on northeastern Lake Superior tributaries that support Lake Sturgeon spawning, most notably in the Pic River from 2006 to 2010. In July of 2010, the A/OFRC and Pukaskwa National Park set nets in the White River to identify the presence of Lake Sturgeon in this tributary, which were listed as extirpated according to the Ontario Ministry of Natural Resources. A total of 9 Lake Sturgeon were captured in 8 overnight sets in 2010, which confirmed the presence of Lake Sturgeon in the White River and prompted further research initiatives for this tributary. In January of 2011 the A/OFRC and Parks Canada began formally discussing the possibility of undertaking a Lake Sturgeon research project in the White River. The project was officially undertaken in May of 2011 when the OMNR provided financial support through the Species at Risk Stewardship Program. The primary objectives of this study were to assess population characteristics, identify habitat utilization and critical habitat, and characterize movement patterns in the White River using radio telemetry. Additionally, we wanted to highlight any similarities or differences that were observed between the White and Pic River Lake Sturgeon populations by comparing population characteristics, movement patterns, and habitat utilization. We conclude this report by providing an overall assessment of the White River Lake Sturgeon population in relation to other Lake Superior populations and by identifying future research priorities that will contribute to the conservation and management of this extant Lake Sturgeon population.

1.2 Study Area

The White River is located in Pukaskwa National Park and is only accessible by boat via Lake Superior or by foot via the Lake Superior Coastal Hiking Trail. Lake Sturgeon are restricted to the lower 4.5 km of the river, from Lake Superior to the uppermost natural barrier of Chigamiwinigum Falls (Figure 1). The nearest communities to this section of the White River are Pic River First Nation and the town of Marathon, Ontario. There is no development as the study area is entirely protected by Pukaskwa National Park, however above Chigamiwinigum Falls there is an operating and a proposed hydroelectric development. Until 2010, Lake Sturgeon were believed to be extirpated from the White River. The nearest Lake Sturgeon spawning tributaries are the Pic and Michipicoten Rivers, which are located 10 km north and 150 km south of the White River, respectively. Throughout this report, four areas will be frequently referred to, they include; Chigamiwinigum Falls (4.5 km from Lake Superior), Stan’s Honey Hole (3.5 km from Lake Superior), the S-Bend (2.5 km from Lake Superior), and the mouth of the White River (0 km from Lake Superior).

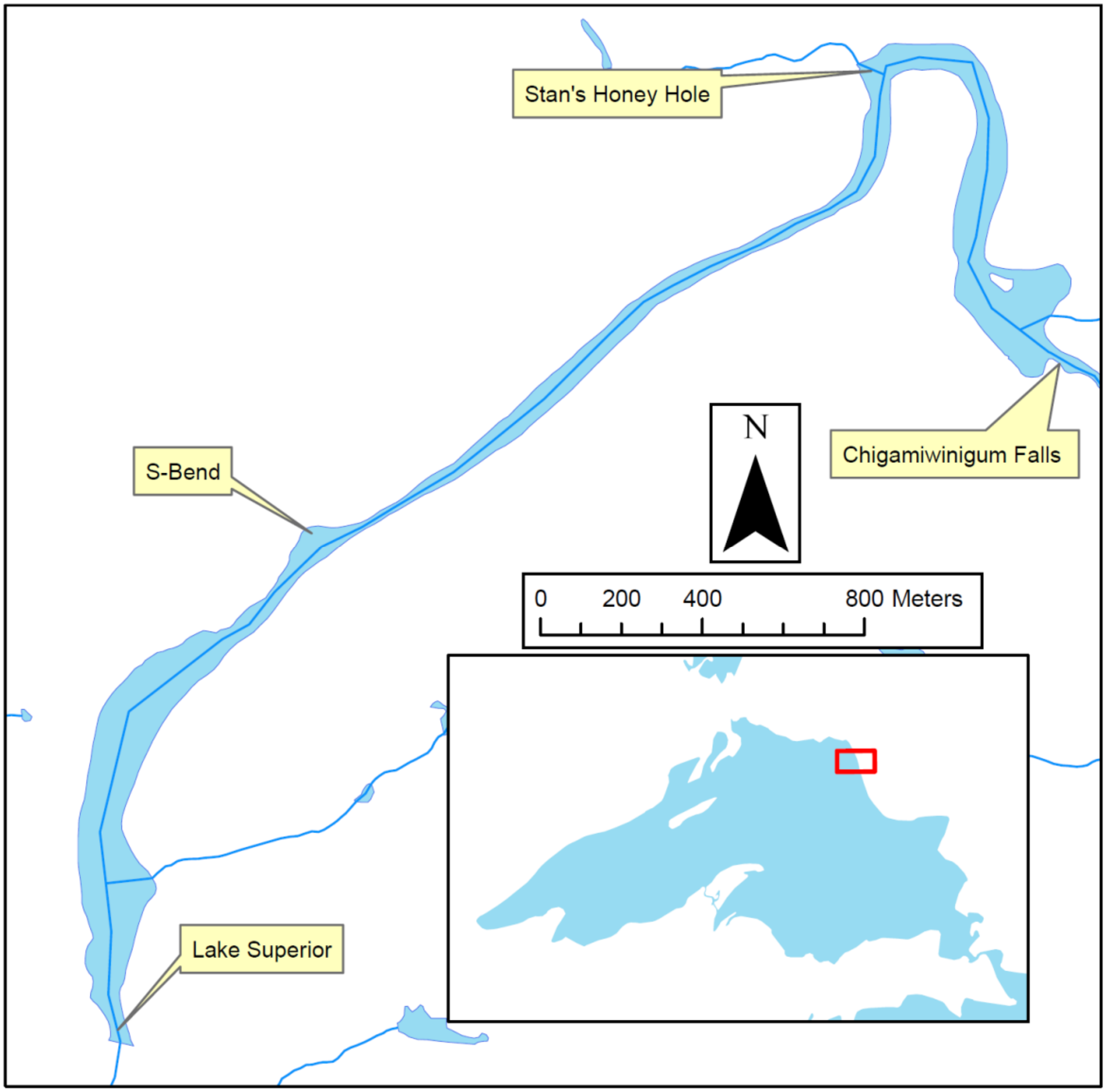


Figure 1 – Study Area for the White River Lake Sturgeon project, with the four significant areas that are frequently referred to throughout this report.

2.0 Methods

In 2011, field work at the White River began on May 20th when water temperatures were 10.92°C and finished by August 29th when water temperatures were 20.00°C. Mean water temperature during this period was 20.36°C, with a maximum water temperature of 24.97°C on August 8th and a minimum water temperature of 10.92°C on May 20th. Throughout this period, various sampling methods were applied to identify Lake Sturgeon movement patterns and habitat utilization in the White River. The various methods and equipment that were used to undertake this study will now be discussed.

2.1 Gill Netting

Gill netting in the White River occurred from May 20th, 2011, to July 28th, 2011, at which point gill netting was stopped due to concerns of Lake Sturgeon becoming stressed from warm water conditions (Appendix 1). A total of 132 nets were set during this time. Nylon gill nets were set perpendicular to shore at an angle of roughly 90°. Stretch mesh sizes ranged from 20.32 cm (8") to 25.4 cm (10"). Net lengths ranged from 30.5 m (100') to 60.7 m (200') depending on the width of the river where it was being set. Gill nets were set overnight for approximately 24 hours and upon retrieval the location, duration, depth, water temperature, net length, mesh size, cloud cover, and precipitation type were recorded for each set. Nets were set throughout the lower 4.5 km of the White River, from Lake Superior to Chigamiwinigum Falls. The majority of nets were set immediately below Chigamiwinigum Falls (4.5 km from Lake Superior), in Stan's Honey Hole (3.5 km from Lake Superior), at the S-bend (2.5 km from Lake Superior), or near the mouth of the White River (0 km from Lake Superior). The distance of each net from Lake Superior, in kilometers, was calculated using ArcMap.

Physical attributes of all captured Lake Sturgeon were recorded, including; fork length (mm), total length (mm), round weight (g), girth (mm), and the presence of sea lamprey wounds. If distinguishable, the sex and stage of gonadal development were also recorded based on criteria provided by Bruch et al. (2001). As well, the first fin ray from the left pectoral fin was removed for ageing and a small tissue sample from this location was taken for future genetic analysis. Ageing analysis was done by Aqua-Tech Services in Perth, Ontario. Lake Sturgeon were tagged with a 12 mm passive integrated transponder (PIT) tag under their third dorsal scute, a 32 mm PIT tag in their stomach, and a Floy tag to the left of their dorsal fin to identify and track future recaptures. Individuals exceeding 5000 g (5.0 kg) were given an internal radio tag to monitor their future movement patterns within the Pic River.

2.2 Radio Telemetry

Radio Tags and Surgeries

For this study, internal radio tags were surgically implanted into the abdominal cavity of Lake Sturgeon. Radio tags and receivers were purchased from Advanced Telemetry Systems Inc. (Isanti, Minnesota). Two different radio tags with unique frequencies and settings were used in this study (Table 1). Radio tags were only implanted in Lake Sturgeon that exceeded 9000 g (9 kg). Lake Sturgeon of this size were selected in order to minimize any harm or unnatural behaviour that may result from the application of the tag.

Table 1 – Specifications for the two different radio tags that were used in this study and purchased from Advanced Telemetry Systems Inc. (Isanti, Minnesota).

	Model Number F1850	Model Number F1855
Pulse Rate (pulses per minute)	35	55
Pulse Width (milliseconds)	22	20
Frequency Range (kHz)	152.002 to 152.523	151.226 to 151.893
Weight (g)	25	87
Battery Life (days)	1941	1095
Number of Tags	29	11

Surgical procedures were adopted from Friday's (2005a; 2005b; 2011) work on the Kaministiquai and Black Sturgeon Rivers and from guidelines provided by the Canadian Council on Animal Care (Ackerman et al., 2000). Lake Sturgeon were sampled and put into a large tub (Rubbermaid Commercial 4244-Bla 70 Gallon Stock Tank Black) with 60 L of river water, to which 32 mL of a clove oil and ethanol solution (1.2 mL clove oil to 10.8 mL of ethanol) was added as an anesthetizing agent. Fish remained in the anesthetizing tub until they could no longer control their orientation in the water, lacked locomotory skills, and their stomachs appeared to have a concave indent. Once fish showed these symptoms of the anesthetic (Ackerman et al., 2000), they were removed from the tub and placed in a canvas surgery sling that provided adequate water circulation around the gills. All surgical tools were thoroughly cleaned and decontaminated before commencing the surgical procedure using isopropyl alcohol. A 4 cm to 6 cm incision was then made along the mid-ventral line of the fish, using a size 10 scalpel, to expose the Lake Sturgeon's body cavity. Another small incision, using a 14 gauge needle tip, was then made posterior to the initial incision to feed the antenna tail of the radio tag outside of the body cavity. The radio tag was then activated, the frequency recorded, and carefully inserted into the body cavity. The 4 cm to 6 cm incision was then sutured together with three to five stitches (Ethicon Monocryl Plus, CT-1 36 mm ½ Circle, Violet Monofilament) and strengthened using tissue adhesive (3M™ Vetbond™). The Lake Sturgeon were immediately immersed in fresh river water and constantly monitored until they showed symptoms of recovery from the anesthetizing agent (Ackerman et al., 2000). The entire procedure took roughly 30 minutes and upon completion the Lake Sturgeon was then released in the river, away from any nets or debris.

Base Station Receivers

Base stations (model number: R4500S) (Advanced Telemetry Inc., Insanti, Minnesota) were powered by a deep cycle marine battery and charged by a solar panel. Each station had a 10 foot aluminum pole with two antennas, one antenna pointed directly upriver while the other pointed directly downriver or out to Lake Superior. The base stations could collect and store up to 88,000 bytes of information before overwriting previously recorded data, therefore downloading times were coordinated to avoid losing any data (roughly every week during the spring/summer and twice during the fall/winter). The stationary defaults of the base stations were set to a time out of 3 seconds, a scan time of 15 seconds, and a store rate of 60 minutes. Radio frequencies were inputted to frequency tables in the receiver once they were surgically implanted into Lake Sturgeon (Appendix 2). Two base stations were setup up on the White River, one was located at the mouth of the river (Easting: 553917, Northing: 5377629) and the other was 150 m below Chigamiwinigum Falls (Easting: 556165, Northing: 5379305). Upon setup, the location of each base station (UTM), the direction of each antenna (upriver or downriver), and the distance of the base station from Lake Superior were recorded. These base stations will provide critical data on the long term movements of Lake Sturgeon in the White River and on their overwintering habitat. At the time of this report, the base station receivers continue to collect data and will do so until spring of 2012 at which point the data will downloaded, compiled, and analysed. Once downloaded, we will report on the results of this data, however for the purposes of this report we will focus on the manual telemetry data as it provides more accurate results on the habitat utilization and movement patterns of Lake Sturgeon in the White River.

Manual Telemetry

Manual telemetry sweeps of the river were frequently performed throughout the spring and summer to detect the location of radio tagged Lake Sturgeon. The radio telemetry receiver was purchased from Advanced Telemetry System Inc. (Isanti, Minnesota) (model number: R410). Telemetry sweeps were performed by travelling in a boat at a speed of approximately 6 to 8 km/h while scanning the active radio frequencies (3 – 4 seconds per frequency). Once detected from afar, the precise location of the individual (±1.5 m) would be identified by reducing the boat's speed and the amount of gain on the manual receiver (i.e. its search radius). Typically the location of radio tagged Lake Sturgeon was recorded with the manual receiver at 2 full bars of gain, however if Lake Sturgeon were in very deep water, then their location was recorded at 3 to 4 bars of gain at which point they became undetectable. When radio tagged Lake Sturgeon were found, the location, date, time, depth, and temperature were recorded at that location. Whenever a Lake Sturgeon was recorded, either manually or by base station, the distance of that Lake Sturgeon from Lake Superior was determined using ArcMap.

2.3 Temperature Data Logger

Water temperature was recorded once every two hours using a temperature data logger (model number: HOBO Water Temp Pro v2 Data Logger) that was located near Chigamiwinigum Falls (Easting: 556165, Northing: 5379305). The temperature data logger was attached to an anchor and recorded temperature at the bottom of the river where Lake Sturgeon were most likely to be. Mean daily temperature was based on 12 daily reading from the temperature data logger. Growing degree days (GDD) per week and since June 1^{st} were calculated based on mean daily water temperature.

2.4 Data Analysis

The overall catch per unit of effort (CPUE) was calculated to determine the relative abundance and density of Lake Sturgeon in the White River. Fulton's condition factor was calculated using the equation $K = RWT/TL^3$, whereby K is Fulton's condition factor, RWT is the round weight of the individual in grams, and TL^3 is the cubed total length of the individual in centimeters. To calculate the relative condition factor of Lake Sturgeon, a $\log_{10}$ transformed length-weight relationship was generated to determine the equation for the line of best fit. Once determined, the equation $K_n = W/\alpha \cdot TL^n$ was used to calculate the relative condition of each individual, whereby K_n is the relative condition factor, W is the actual weight of the individual, and α and n are the respective intercept and slope of the $\log_{10}$ transformed total length and weight relationship. Upon determining Fulton's condition factor (K) and the relative condition factor (K_n) for each Lake Sturgeon, the mean and standard error for K and Kn was plotted for each year class. To evaluate the length and age relationship for Lake Sturgeon in the White River, a von Bertalanffy growth model was generated using the program FAST (Fisheries Analyses and Simulation Tools, Version 2.1, Auburn University).

ArcMap™ 10.0 (ESRI® Canada, Inc.) was used to evaluate the spatial distribution, location, and habitat utilization of radio tagged Lake Sturgeon. Point density analysis was used to identify areas of the White River that were frequently utilized by radio tagged Lake Sturgeon. The spatial test statistic module from the telemetry software analysis package FishTel version 1.4 was used (Colorado Division of Wildlife, Denver) to determine whether radio tagged Lake Sturgeon exhibited a random or non-random distribution in the White River. Instructions for this analysis were taken from chapter 14 of *Analysis and Interpretation of Freshwater Fisheries Data* (Rogers & White, 2007). Five control subjects, with 25 randomly located detections per control subject, were included in the analysis to ensure that FishTel modelling could reliably detect a random distribution pattern in the White River. Minimum displacement per day (MDPD), measured in meters per day, was used to evaluate differences and/or relationships in the movement patterns of radio tagged Lake Sturgeon. MDPD was only evaluated if an individual was detected two or more times within a 48-hour interval to ensure that movement rates were accurately calculated and not underestimated. ANOVAs were used to identify significant differences in Log_{10} MDPD between sexes, size classes, study weeks, and locations. Multiple regression analysis was performed to determine if Log_{10} MDPD was correlated with size classes, mean daily water temperature, depth, growing degree days (GDD) since June 1st, or GDD per week. All statistical analyses were considered significant at a p-value of 0.05 and were performed using XL Toolbox in Microsoft Excel 2007.

3.0 Results

In 2011 a total of 82 Lake Sturgeon were captured, 15 of these individuals were recaptured and 40 of these individuals were radio tagged (Appendix 3). The overall CPUE, which is a measure of fish density and relative abundance, was 0.62 sturgeon per net day, whereby one net day consisted of a single 100’ gang that was set for 24 hours. The mean total length and round weight for all of the captured individuals (n=82) was 1205.0 mm (+/- 20.5 mm) and 12,195.5 g (+/- 565.3 g), respectively. The mean total length and round weight of the radio tagged individuals (n=40) was 1,275.7 mm (+/- 18.5 mm) and 13,666.1 g (+/- 555.0 g), respectively. The frequency of catches in each size class is presented in Figure 2a, while the CPUE by location is presented in Figure 2b. The greatest CPUE was observed near Chigamiwinigum Falls (0.911 sturgeon/net day), which was closely followed by Stan’s Honey Hole (0.806 sturgeon/net day). CPUE at other locations in the White River, which include the mouth of the river, the S-Bend, and the back bay north of Chigamiwinigum Falls, ranged from 0.416 to 0.509 sturgeon/net day.

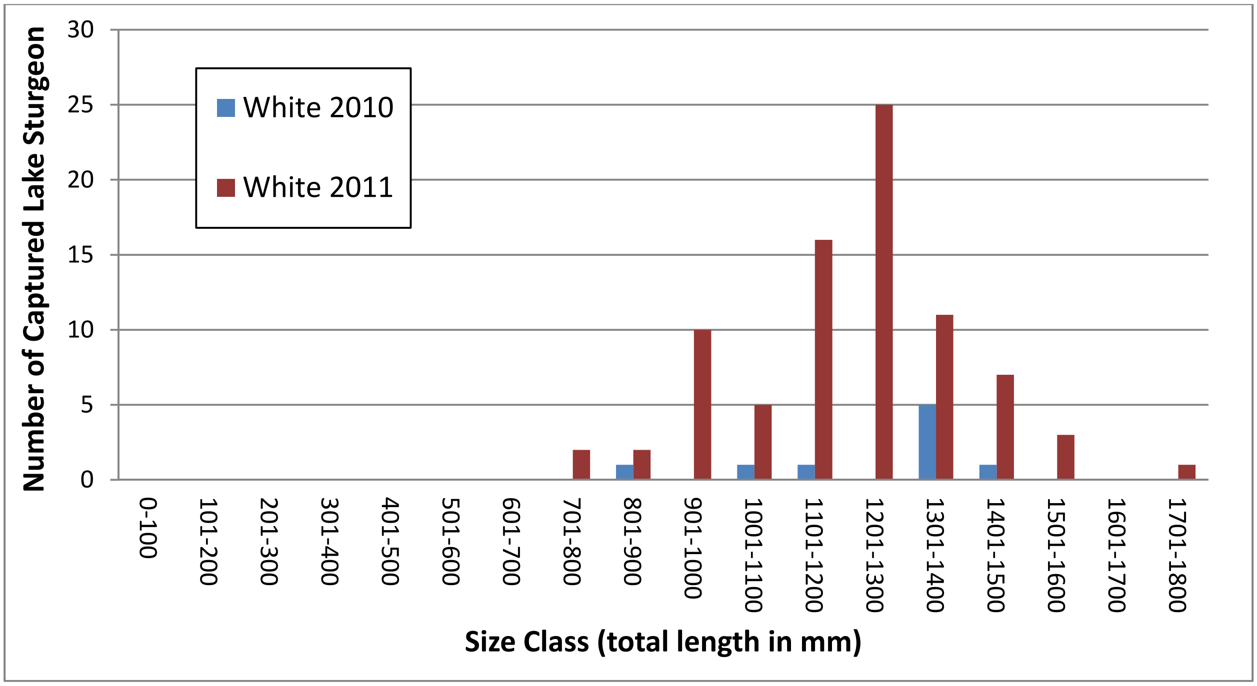


Figure 2a – Size class frequency of captured Lake Sturgeon in the White River from 2010 and 2011.

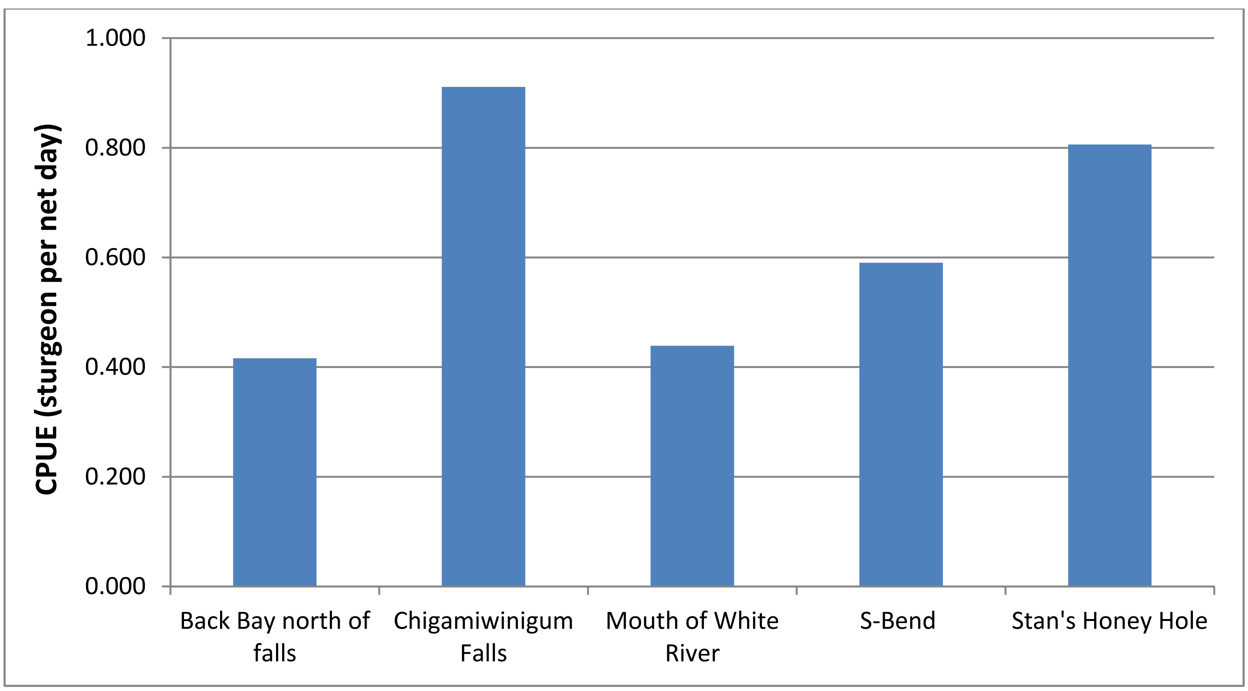


Figure 2b – Lake Sturgeon CPUE in different locations of the White River in 2011.

3.1 Population Characteristics

Length-Weight Relationship and Condition

The $\log_{10}$ transformed length-weight relationship for all Lake Sturgeon was $\log_{10}(WT)=2.7412 \cdot \log_{10}(TL)-7.3821$, which can be rewritten as $(WT)=(4.15x10^{-8}) \cdot (TL^{2.7412})$ (Figure 3). Using this equation, the relative condition factor for all Lake Sturgeon was calculated using the equation $K_n=W/\alpha \cdot TL^n$, whereby K_n is the relative condition factor, W is the actual weight of the individual, and α and n are the respective intercept and slope of the $\log_{10}$ transformed total length and weight data. Overall, the relative condition factor for Lake Sturgeon was 1.009, indicating that the population is healthy and in relatively good condition. Fulton's condition factor for the entire population was 0.6697, indicating that Lake Sturgeon condition in the White River is average compared to other locations across its geographical range. Figure 4 shows Fulton's condition factor and the relative condition factor for each year class of Lake Sturgeon that was captured in the White River (n=62). Fulton's condition factor decreased slightly with age (slope = -0.003), while the relative condition factor increased slightly with age (slope = 0.0003). Given that both condition indices were relatively unchanged with age, and one showed a positive trend (K) while the other showed a negative trend (Kn), we conclude that Lake Sturgeon condition was not influenced by year class in the White River as reported by previous studies (Craig et al., 2005).

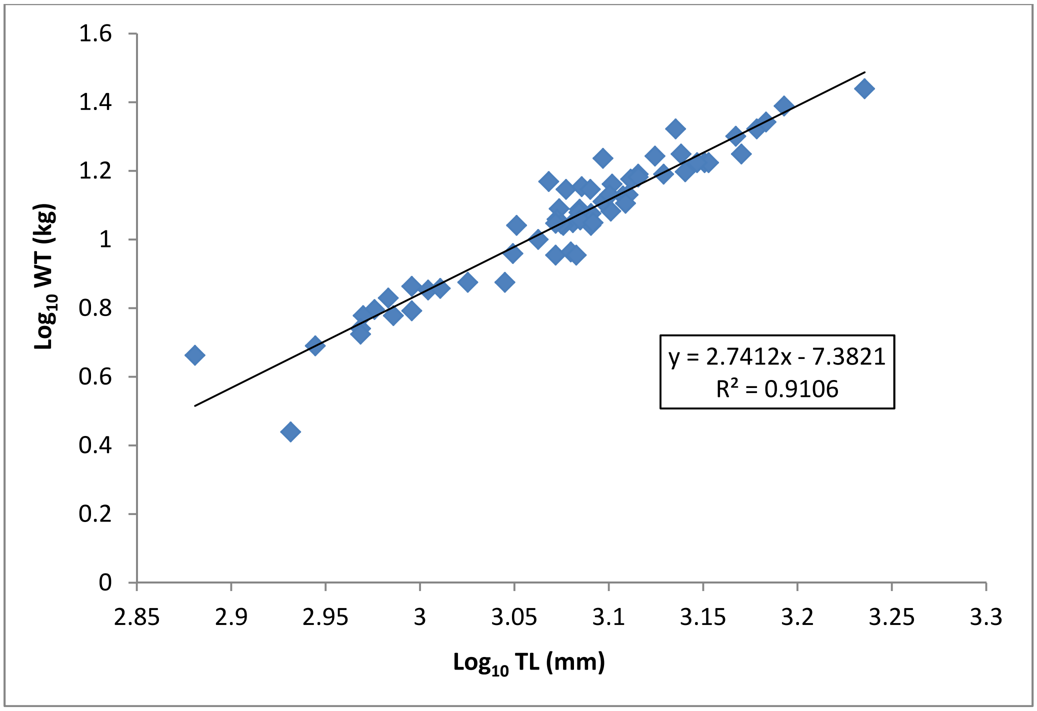


Figure 3 – Least-squares regression of $\log_{10}$WT x $\log_{10}$TL for Lake Sturgeon in the White River.

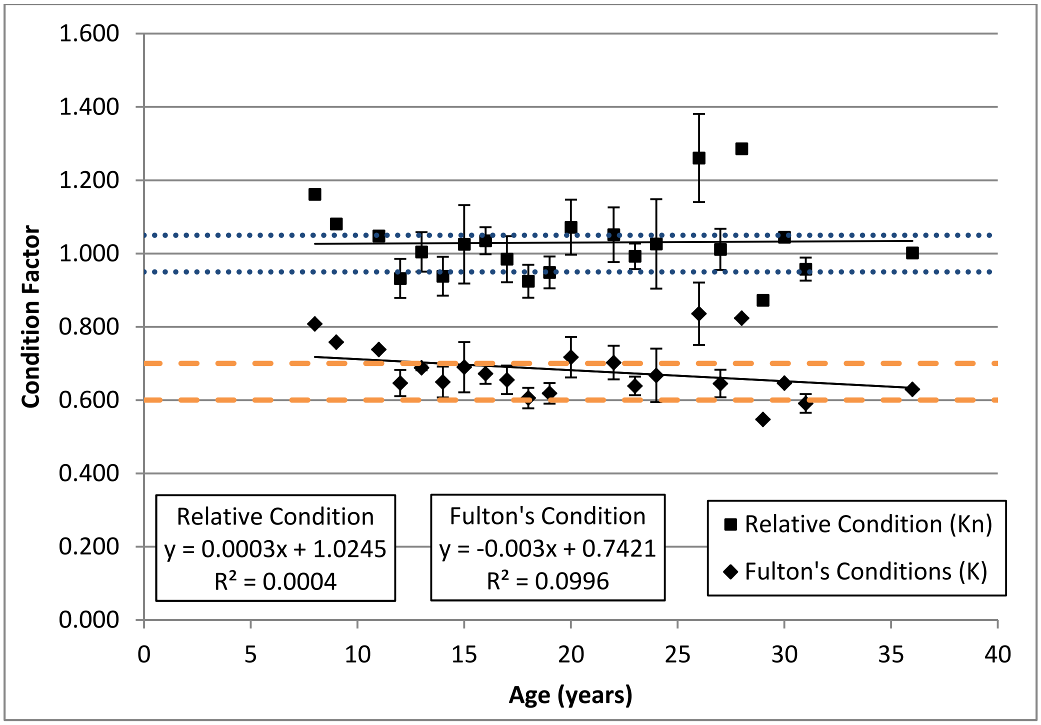


Figure 4 – Mean body condition as measured by Fulton's condition factor and the relative condition factor for each year class of Lake Sturgeon that was captured in the White River. The area between the orange and blue lines represents the average value for the respective condition factor across the geographic distribution of Lake Sturgeon.

Length-Age Relationship and Growth

A von Bertalanffy growth model was generated using FAST© to describe the growth rate of Lake Sturgeon in the White River. We removed three individuals from the analysis whose estimated age appeared to be inaccurate (fish numbers 36, 39, and 44 (Appendix 3)). The von Bertalanffy growth equation for Lake Sturgeon in the White River was determined to be $L_T=2088.75\cdot(1-e^{-0.031(t+9.386)})$, therefore indicating that the asymptotic length ($L\infty$) was 2088.75, the growth coefficient (k) was 0.031, and the length at T_o was -9.386. The mean total length of each year class that was captured in 2011 is presented in Figure 5, while the length at age as modelled by the von Bertalanffy growth model is presented in Figure 6. Comparisons between the White River population and other populations are made in the discussion of this report.

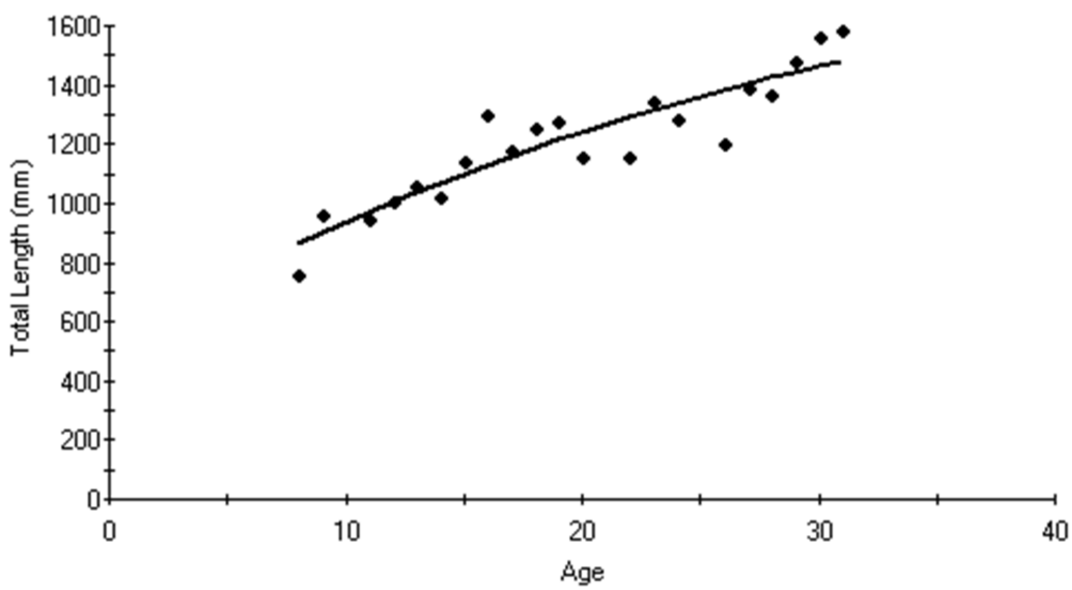


Figure 5 – Mean length at age for captured Lake Sturgeon in the White River during 2011.

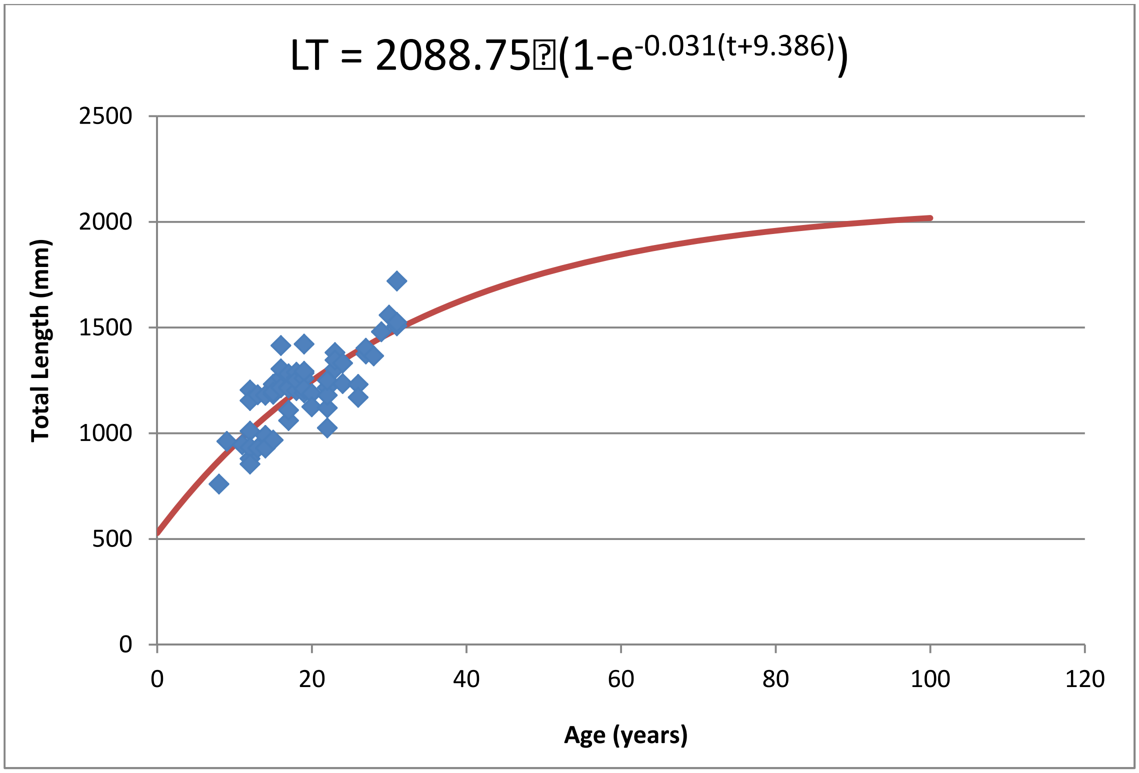


Figure 6 – Von Bertalanffy growth model for Lake Sturgeon in the White River (red line, equation above chart) with the actual age and length of sampled individuals plotted in blue.

3.2 Habitat Utilization and Movement Patterns

Thirty-six manual telemetry sweeps of the White River were performed from May to August and forty four radio tagged individuals were detected a total of 617 times. Five of the forty four Lake Sturgeon were previously radio tagged in the Pic River, which is approximately 10 km north of the White River via Lake Superior. The movement of these individuals indicates that Lake Sturgeon immigration and emigration occurs with some regularity between the Pic and White Rivers. For example, fish 151.206 was detected near the mouth of the Pic River during the fall of 2010 and approximately 23 km up the Pic River on May 31st and again on June 24th in 2011. It then travelled to the White River where it was detected in Stan's honey hole from July 13th to July 28th and again from August 14th and 15th. Fish 151.248 showed a similar movement pattern whereby it was detected throughout the lower 20 km of the Pic River from May 10th to July 9th and in the White River from August 26th to August 29th. These two individuals showed evidence of emigration from the Pic River to the White River, however the opposite trend was also observed. Six of the forty four individuals that were radio tagged in the White River in 2011 were later detected in the Pic River, showing emigration from the White River to the Pic River. For example fish 152.192 was radio tagged on July 14th and was last detected in the White River on August 16th. By August 22nd this individual had travelled to the Pic River and was located near the Highway 17 Bridge, which is approximately 15 km from Lake Superior. The habitat utilization and movement patterns of each individual Lake Sturgeon are shown in Appendix 4 and summarized below.

Lake Sturgeon were most heavily concentrated in two areas of the White River, while the rest of the river served as a corridor to facilitate movements (Figure 7). Two of the deepest pools (16 m to 22 m), which were located immediately below Chigamiwinigum Falls (4.5 km from Lake Superior) and at Stan’s Honey Hole (3.5 km from Lake Superior), served as primary habitat for Lake Sturgeon in the White River (Figure 8). Lake Sturgeon were also detected near the vicinity of the S-bend (2.5 km from Lake Superior), however they were not detected here as frequently as the two aforementioned locations. Lake Sturgeon detected outside of these areas were typically migrating between locations or to and from Lake Superior. Based on the timing of movements and the duration of time spent at each location, it is believed Stan’s Honey Hole is a significant foraging location, while the pool below Chigamiwinigum Falls serves as an important staging and foraging location. The small bay to the north of Chigamiwinigum Falls may also serve as important staging habitat for spawning Lake Sturgeon or as a refuge area to shelter Lake Sturgeon from woody debris in the spring. Spawning is believed to occur immediately below

Chigamiwinigum Falls, however we were unable to confirm this via the collection of eggs or larvae in 2011.

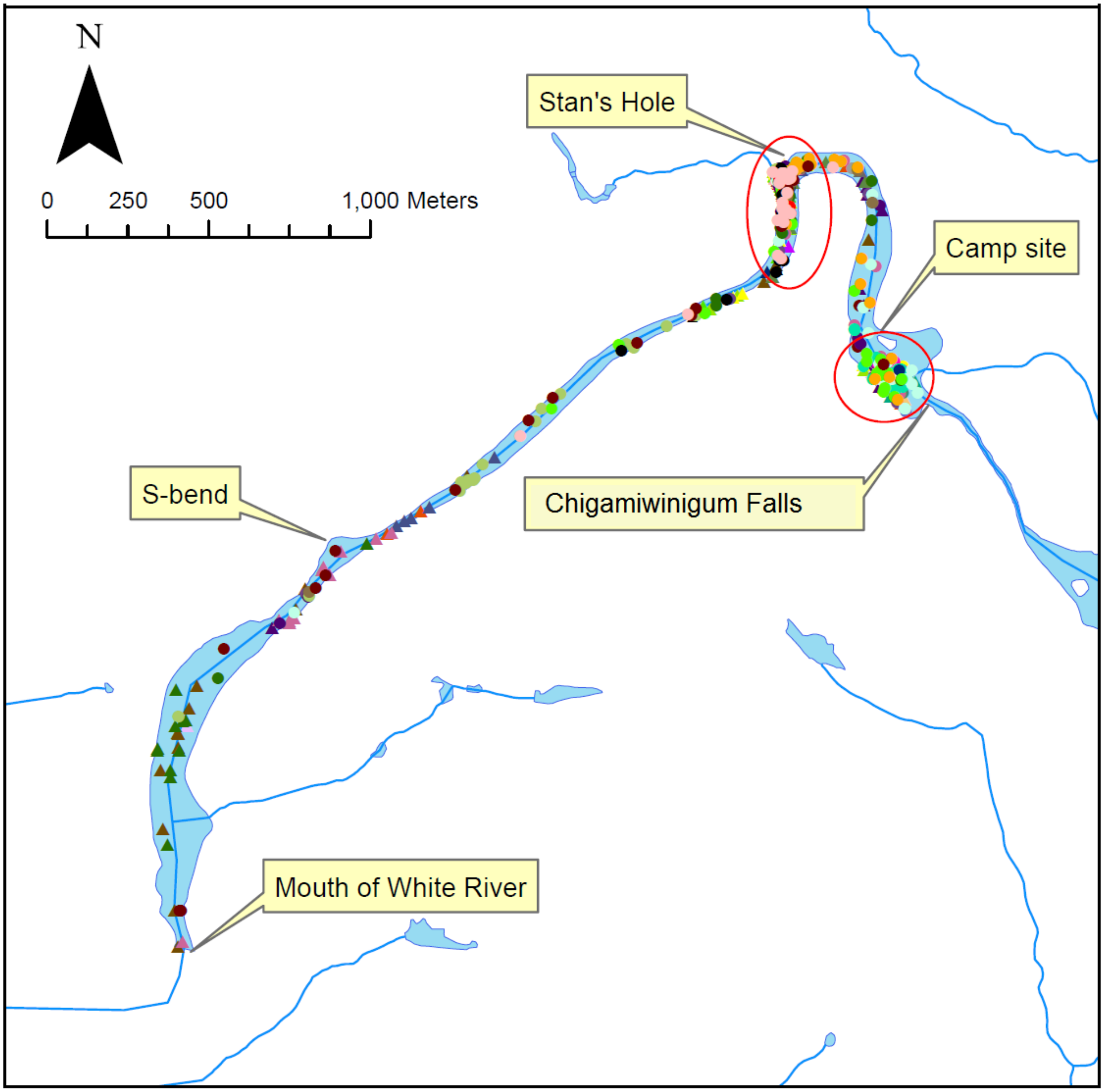


Figure 7 – The location of Lake Sturgeon throughout the White River from May to August of 2011. A total of 36 manual telemetry sweeps were performed and radio tagged Lake Sturgeon were detected a total of 617 times. Each colour/symbol represents the movements of one radio tagged individual throughout the sampling period.

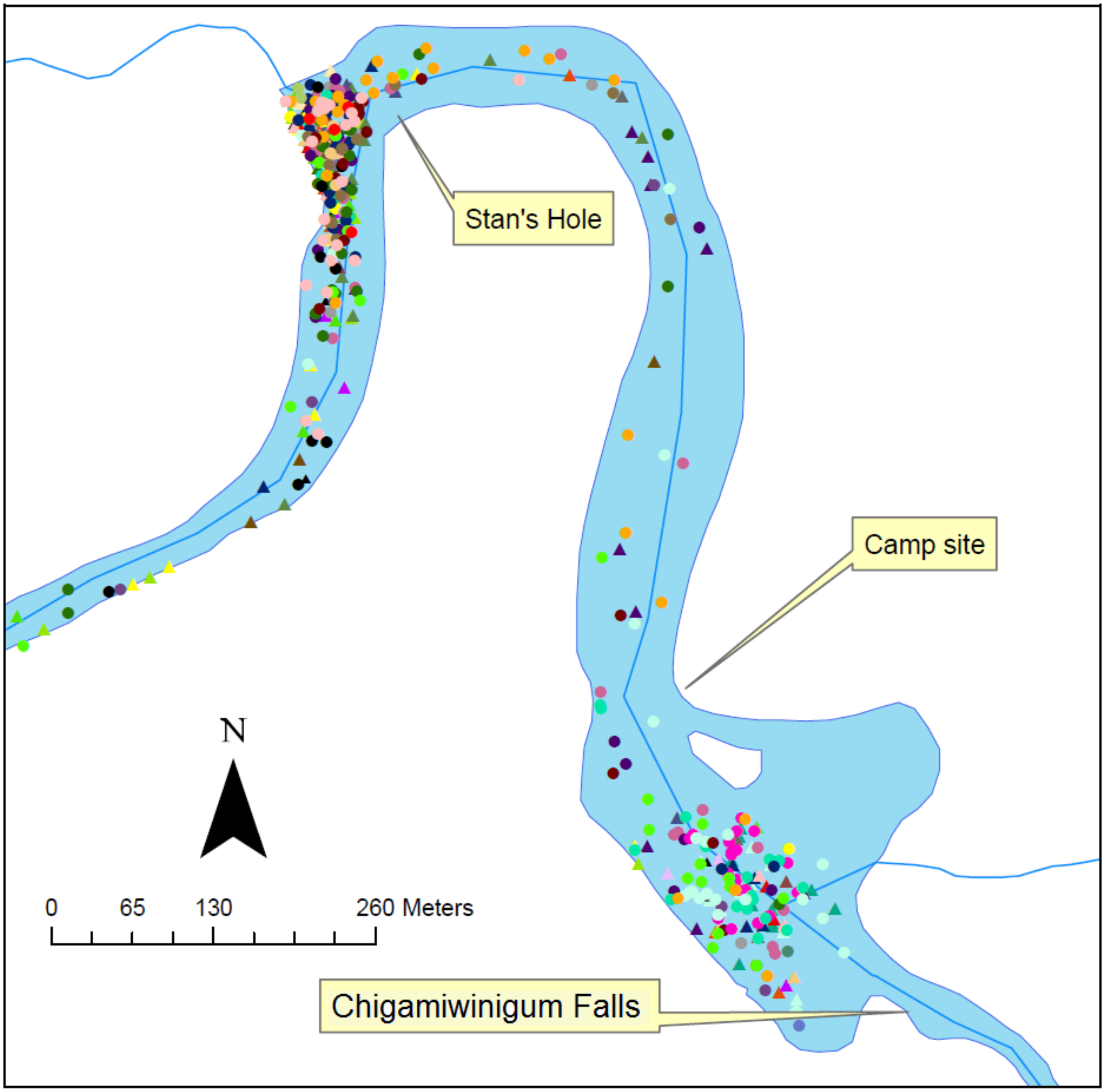


Figure 8 – The location of Lake Sturgeon in the two most frequently used locations of the White River from May to August of 2011. Both locations are deep pools in excess of 16 m and serve as either foraging and/or staging habitat. Each colour/symbol represents the movements of one radio tagged individual throughout the sampling period.

To test whether Lake Sturgeon showed a random or non-random distribution in the White River, the spatial test statistic module from the telemetry software analysis package FishTel version 1.4 was used (Colorado Division of Wildlife, Denver). First, the average mean variance for 5 control subjects that were hypothetically detected 25 times in randomly selected locations was 2,814.44 m^2, whereby the probability of obtaining a mean variance of 2,814.44m^2 or greater by random chance is extremely high ($p=0.8864$). This indicates that the spatial test statistic module could accurately distinguish between a random and non-random distribution pattern in the White River. Upon testing the model using our control subjects, the average mean variance for 38 Lake Sturgeon that were detected 6 to 21 times was 662,371 m^2, whereby the probability of obtaining a mean variance of 662,371.91 m^2 or greater by random chance is extremely low ($p<0.001$). At an individual level, 34 individuals showed a non-random distribution at the 99% confidence interval, 3 individuals showed a non-random distribution at the 95% confidence interval, and only 1 individual showed a random distribution ($p=0.0786$). This indicates that Lake Sturgeon distribution in the White River is significantly non-random, therefore suggesting that their distribution is aggregated. Point density analysis (ArcMap 10.0™, ESRI® Canada Inc.) was then used to confirm where Lake Sturgeon clusters were located. This analysis indicated that Lake Sturgeon distribution was highly clustered below Chigamiwinigum Falls and at Stan's Honey Hole (Figure 9). Therefore radio tagged Lake Sturgeon showed a non-random distribution in the White River and were heavily clustered near Chigamiwinigum Falls and at Stan's Honey Hole. These two locations represent the deepest habitat within the navigable portion of the White River, indicating the Lake Sturgeon were seeking deep cool water refuges that provided oxygen rich conditions.

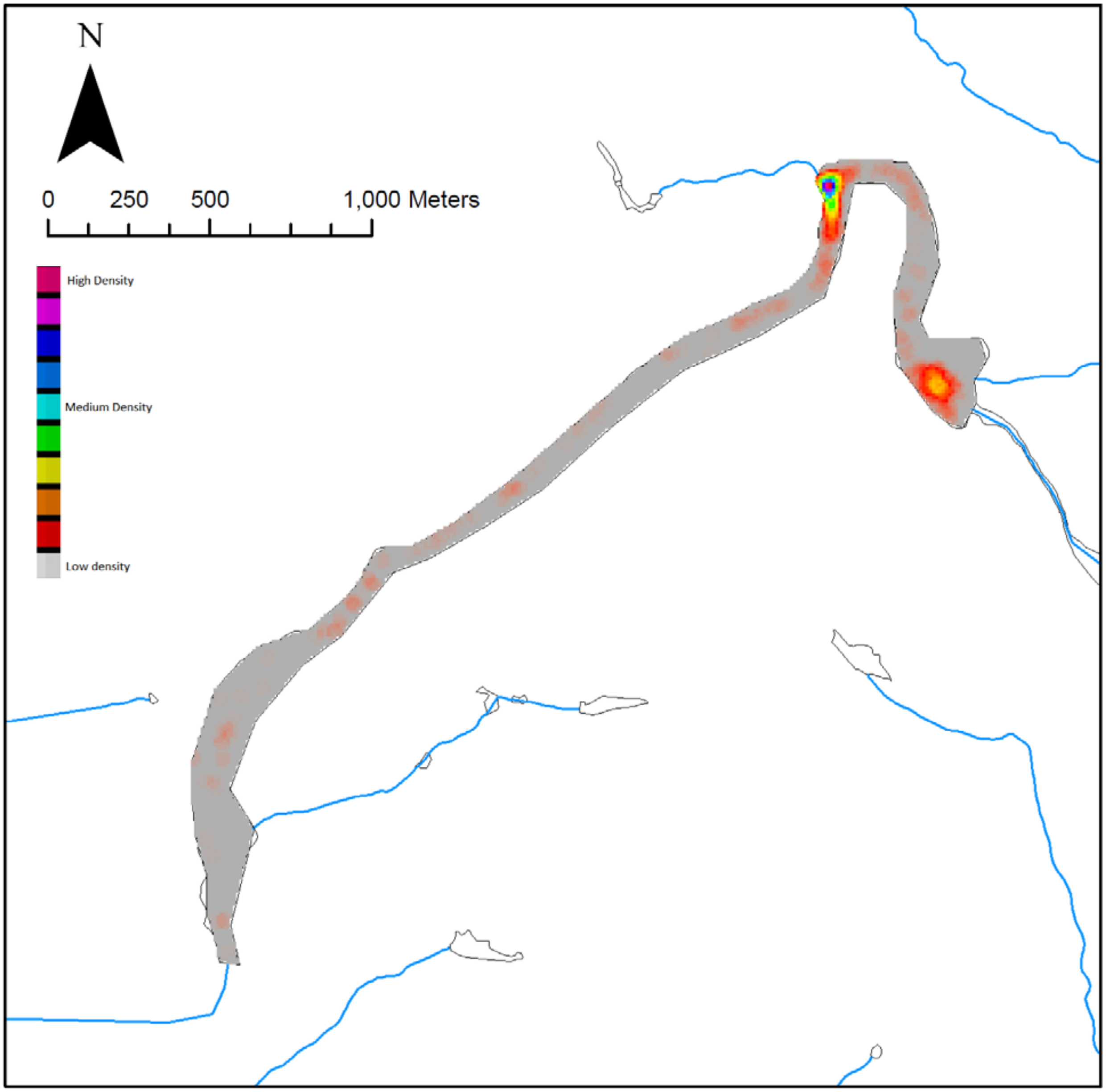


Figure 9 – The density of Lake Sturgeon in the White River from May to August of 2011 indicating that Lake Sturgeon were significantly clustered below Chigamiwinigum Falls and at Stan's Honey Hole.

The mean minimum displacement per day (MDPD) for all radio tagged Lake Sturgeon was 248.51 m/day. MDPD ranged from 1.74 m/day to 3524.60 m/day with a median of 53.66 m/day. An ANOVA found no significant differences in MDPD between different size classes or sex ($F_{(9,352)}$=1.71, p=0.085 and $F_{(1,361)}$=1.69, p=0.194, respectively), indicating that neither variable significantly influenced the movement rates of Lake Sturgeon. MDPD did significantly differ over the course of the summer though, with Lake Sturgeon movement rates decreasing as weeks passed and growing degree days (GDD) per week increased ($F_{(10,351)}$=3.357, p<0.001) (Figure 10). A Bonferoni's post-hoc test indicated that movement rates significantly decreased during weeks 35 to 37 when growing degree days per week peaked towards the end of August (Appendix 5). MDPD was also significantly different depending on the location of Lake Sturgeon within the White River, whereby movement rates were significantly lower when Lake Sturgeon were located near Stan's Honey Hole (3 km to 3.5 km from Lake Superior) or Chigamiwinigum Falls (4 km to 4.5 km from Lake Superior) ($F_{(2,360)}$=31.180, p<0.001) (Figure 11). Therefore it appears that Lake Sturgeon movement rates are heavily influenced by their location within the White River and by time which was measured in weekly intervals, with each week having an increase in GDD per week.

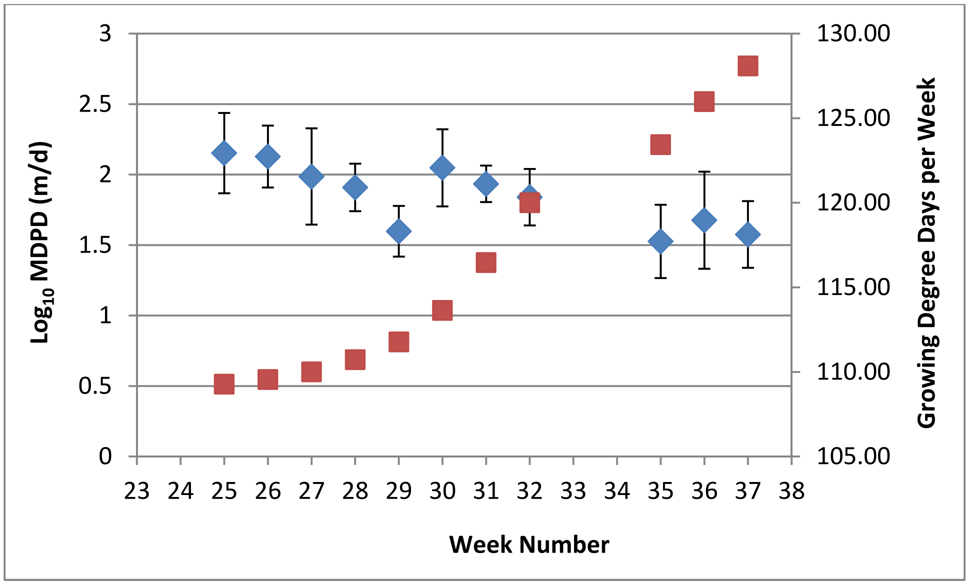


Figure 10 – ANOVA results indicated that Lake Sturgeon movement rates were significantly different between study weeks, especially towards the end of August when the number of growing degree days per week peaked.

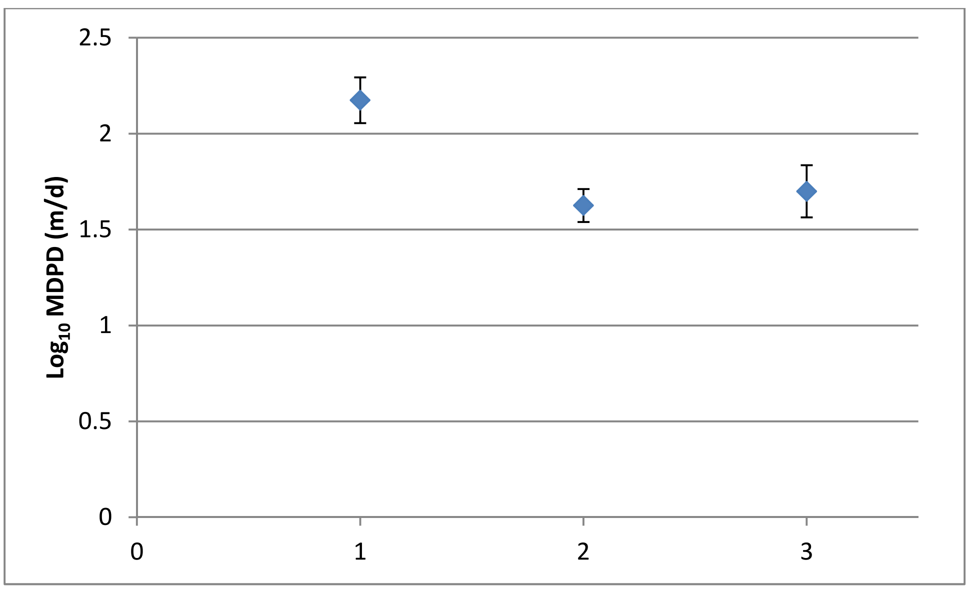


Figure 11 – ANOVA results indicated that Lake Sturgeon movement rates were significantly different depending on where Lake Sturgeon were located, whereby movement rates decreased if Lake Sturgeon were detected in either Stan's Honey Hole (#2) or near Chigamiwinigum Falls (#3) relative to anywhere else in the White River (#1).

For the multiple regression analysis, the dependent variable (DV) was $\log_{10}$ MDPD and the independent variables (IV) were fish size, mean daily water temperature, depth, GDD since June 1st, and GDD per week. Overall there was a significant correlation between Lake Sturgeon movement rates and the aforementioned IVs (R^2=0.1449, $F_{(5,357)}$=12.0949, p<0.001), whereby MDPD was significantly and negatively correlated with depth (β=-7.8590, p<0.001) (Figure 12), GDD per week (β=0.0954, p=0.0063) (Figure 13), and GDD since June 1st (β=-0.0014, p=0.0025) (Figure 14). Despite there being a significant and negative correlative between these IVs and MDPD, only a small proportion of the variation could be explained ($R^2_{overall}$=0.1449) indicating that MDPD is highly variable for individual Lake Sturgeon in the White River. Log_{10}MDPD was not significantly correlated with fish size (β=-0.0001, p=0.6685) or mean daily water temperature (β=0.0226, p=0.2922), indicating that neither variable significantly influences MDPD for Lake Sturgeon.

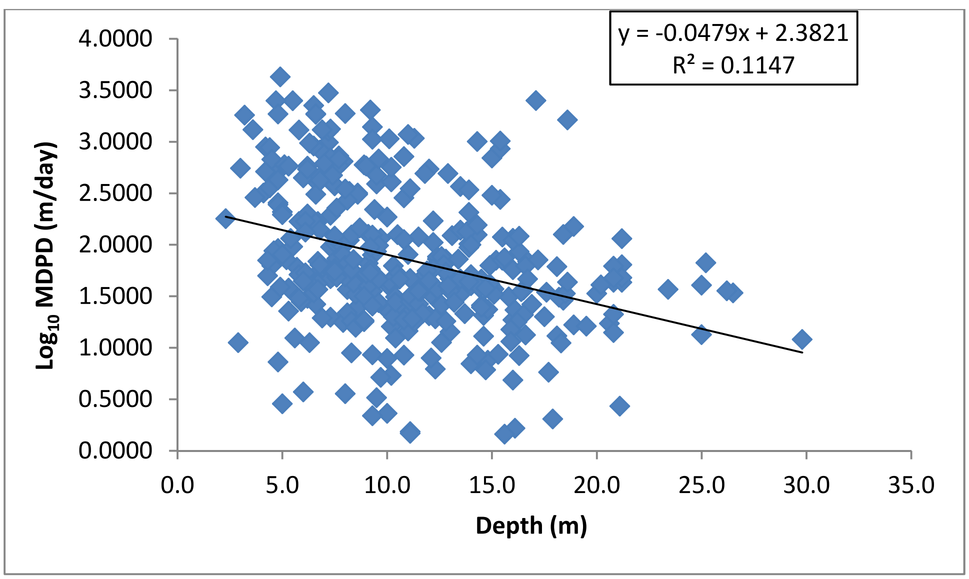


Figure 12 – Log_{10}MDPD was significantly and negatively correlated with depth (β=-7.8590, p<0.001).

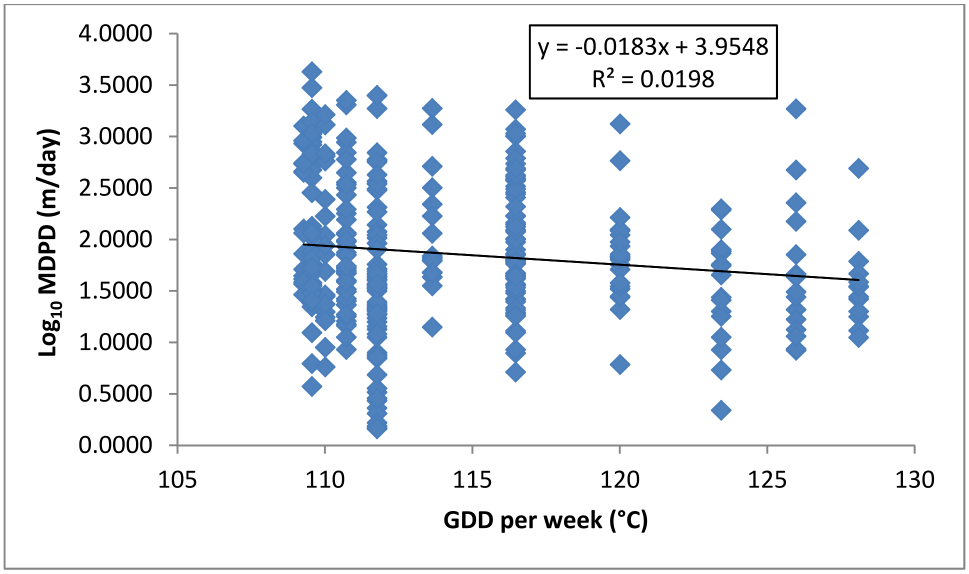


Figure 13 – Log_{10}MDPD was significantly and negatively correlated with GDD per week (β=0.0954, p=0.0063).

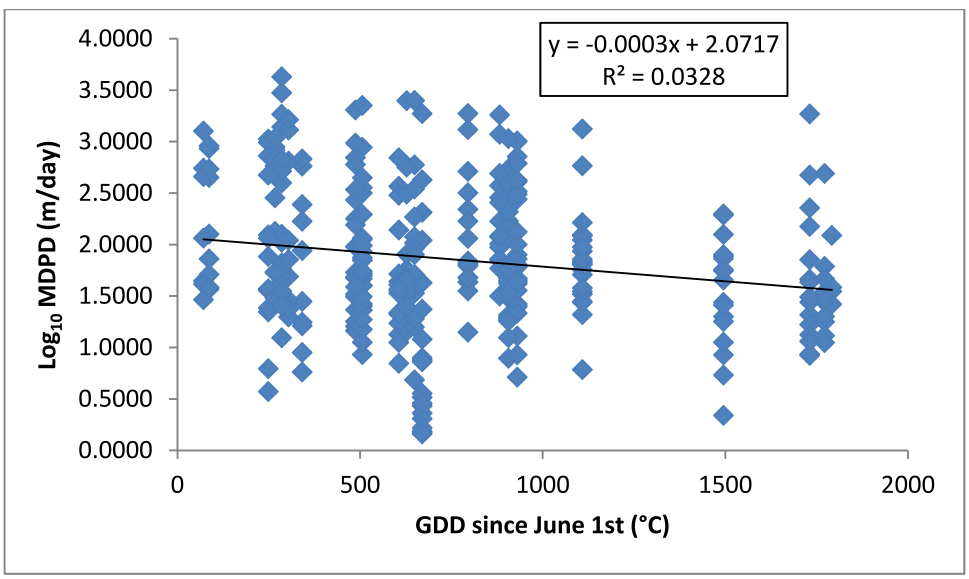


Figure 14 – Log_{10}MDPD was significantly and negatively correlated with GDD since June 1st (β=-0.0014, p=0.0025).

4.0 Discussion

The primary objectives of this study were to assess population characteristics, identify habitat utilization and critical habitat, and characterize movement patterns in the White River using radio telemetry. Additionally, we wanted to highlight any similarities or differences that were observed between the White and Pic River Lake Sturgeon populations by comparing population characteristics, movement patterns, and habitat utilization. This study successfully evaluated CPUE, weight-length relationship/equation, Fulton's and the relative condition factor, age-length relationship/equation, and growth parameters for Lake Sturgeon in the White River. Results indicated that Lake Sturgeon in the White River were abundant, fast growing, and large growing, however their condition was average and relatively stable across all year classes sampled. Additionally, habitat utilization and critical habitat were identified by manually tracking individuals to identify their distributions and core activity areas. Four deep water areas represented the most significant Lake Sturgeon habitat and Lake Sturgeon showed an aggregated distribution within the White River. Movement patterns and MDPD were negatively correlated with GDD/week, GDD since June 1st, and depth, and significant differences in MDPD were observed between study weeks and depending on location of the individual within the river. Population characteristics, habitat utilization, and movement patterns of Lake Sturgeon in the White River will now be discussed and compared to other locations across their geographical range, with a particular emphasis on comparisons that relate to the Pic River.

4.1 Population Characteristics

The overall CPUE for Lake Sturgeon in the White River was 0.62 sturgeon per net day, whereby one net day consisted of a 100' net being set for 24 hours. Compared to other locations in DU8b (i.e. northern Lake Superior), including the Big Pic River, Black Sturgeon River, Kaministiquia River, and Lake Nipigon, the CPUE for Lake Sturgeon was relatively high in the White River (Table 2). The CPUE in the White River was comparable to the Groundhog River, where Lake Sturgeon are listed as a species of special concern and not threatened as is the case for the White River. This suggests that Lake Sturgeon abundance and density in the White River is between 132% to 364% higher compared to other Lake Superior tributaries and to the Groundhog River. It is important to note that nets were not randomly set in any of these rivers and therefore CPUE can be sensitive to researcher bias. Furthermore, CPUE could be elevated in the White River because it is a relatively short tributary, therefore inflating CPUE and fish density. Despite this limitation, CPUE can provide a relative estimate of fish abundance and density in each location, which enables us to compare population statuses across geographical locations.

Table 2 – A comparison of the CPUE for Lake Sturgeon in selected tributaries and lakes, whereby the CPUE is expressed as the number of fish captured per 100' net per day.

Location	Designatable Unit	Year(s)	CPUE (fish per net day)	Source
White River	Upper Great Lakes (DU8b)	2011	0.62	Ecclestone, 2012
Kaministiquia River	Upper Great Lakes (DU8b)	2001 to 2006	0.47	Friday, 2005a
Big Pic River	Upper Great Lakes (DU8b)	2008 to 2010	0.28	Ecclestone, 2011
Black Sturgeon River	Upper Great Lakes (DU8b)	2002 to 2004	0.017	Friday, 2005a
Lake Nipigon	Upper Great Lakes (DU8b)	2006 to 2009	0.26	Tremblay, 2010
Groundhog River	Southern James Bay (DU7)	1996	0.43	Seylor, 1997

The equation of the $\log_{10}$ transformed length-weight relationship for Lake Sturgeon in the White River was $\log_{10}(WT)=2.7412 \cdot \log_{10}(TL)-7.3821$, whereby the length-weight relationship is equal to the slope (slope=2.74). Typically, the length-weight relationship for Lake Sturgeon is approximately 3.3 (Beamish et al., 1996; Power & McKinley, 1997). A slope of 2.74 indicates that Lake Sturgeon in the White River are less plump compared to other populations across their geographical range. There are few populations where the length-weight relationship is less the 3.0. Values of less than 3.0 have been reported in the Mattagami River (slope=2.923) (Power & Mckinley, 1997), Lake of the Woods (slope=2.974) (Rusak & Mosindy, 1997), Nelson River (Patalas, 1988), Black Sturgeon River (slope=2.7814) (Friday, 2005a), and Smoothrock Lake (slope=2.4519) (Tremblay, 2010). In the Pic River, the length-weight relationship varied from 3.0898 to 3.4438 between 2007 and 2009 with an overall relationship of 3.3911 (Ecclestone, unpublished). The most likely explanation for a reduced length-weight relationship in the White River is latitudinal variation and decreased thermal opportunity for growth (Beamish et al., 1996; Power & McKinley, 1997). Food availability and reproductive status could also influence this relationship, whereby a decreased food supply or the ripeness of individuals could influence the plumpness of individuals (Beamish et al., 1996; Power & McKinley, 1997).

Despite having a decreased length-weight relationship, the overall relative condition (Kn) and Fulton's condition factor (K) for Lake Sturgeon in the White River was 1.009 and 0.6697, respectively. These values are consistent with other body condition values across the Lake Sturgeon's geographical range. Fortin et al. (1996) reported that K ranges from 0.51 to 0.68, with a high degree of variability across its geographical range and age distribution. In the Pic River, the relative condition and Fulton's condition factor were 1.031 and 0.561, respectively, indicating that the Pic River Lake Sturgeon population had a slightly higher relative condition factor and a slightly lower Fulton's condition factor. A relative condition factor of 1.0 should be expected for a healthy population; however for Lake Sturgeon this can be highly variable because of seasonal changes in gonadal development, temporal variability in food supply, or temperature fluctuations (Bruch, 2008). For example, Lallaman et al. (2008) determined that the Kn for Lake Sturgeon in the Manistee River was only 0.72, however this population is highly disturbed and sampling may not have adequately captured a range of sexes and ages (Peterson et al., 2002). Craig et al. (2005) found that the overall Kn for Lake Sturgeon in the St. Clair River system was 1.009 (+/-0.004), but for females it was slightly higher (1.045 +/-0.010) and for males it was slightly lower (0.985 +/-0.046). One finding that this study did not uncover was an increasing K and Kn with age, which has been reported in numerous studies for Lake Sturgeon (Beamish et al., 1996; Craig et al., 2005). In this study the slope of K and Kn as they related to age was -0.003 and 0.0003, indicating that body condition was essentially parallel across the age distribution. Fulton's condition factor increased with age in the Pic River at a slope of 0.0041, but relative condition factor decreased with age at a slope of -0.0011. Typically, increases in body condition with age are associated with Lake Sturgeon becoming sexually mature and therefore increasing their length-weight relationship (Beamish et al., 1996; Craig et al., 2005). In this study, the majority of individuals that were sampled were captured after spawning, therefore we believe that increases in body condition with age were not observed because girthy spawning females were not captured in great abundances during the study period.

The growth curve for Lake Sturgeon in the White River according to the von Bertalanffy growth model was $L_T=2088.75\bullet(1-e^{-0.031(t+9.386)})$, indicating that the asymptotic length (L_∞) was 2088.75mm, the growth coefficient (k) was 0.031, and T_o was -9.386. In relation to other Lake Sturgeon spawning tributaries and nearby systems, the growth rate for Lake Sturgeon in the

White River is comparable; however L_∞ is much higher in the White River compared to most other locations (Figure 15). In the Pic River for example, L_∞ was 1506.14 mm with a growth rate of 0.092 and a T_o of -1.077 (Ecclestone, unpublished). The Pic River growth curve is very similar to the modelled growth curve for Lake Sturgeon in DU 8b, which found a L_∞ of 1528.3 with a growth rate of 0.058 (Velez-Espino & Koops, 2007) (T_o was assumed to be equal to 0). L_∞ in the White River was comparable to growth models for Lake of the Woods, which is a population of special concern and sampled prior to any major exploitation (Harkness, 1923). We believe that k, L_∞, and T_o are elevated in these results partially because juveniles (< 8 years) and old adults (>40 years) were not captured and sampled in great abundances in either the White or Pic Rivers. A lack juveniles could inflate T_o, while a lack of old adults could inflate L_∞, cumulatively these inflated variables could influence the modelled growth rates for Lake Sturgeon in the White and Pic Rivers (also see Figure 6). Despite this limitation, which we hope to resolve in the 2012 field season by setting larger and smaller mesh nets, we believe that the von Bertalanffy growth models that have been developed for the White and Pic River Lake Sturgeon populations provide a relatively good characterization of the populations' growth patterns.

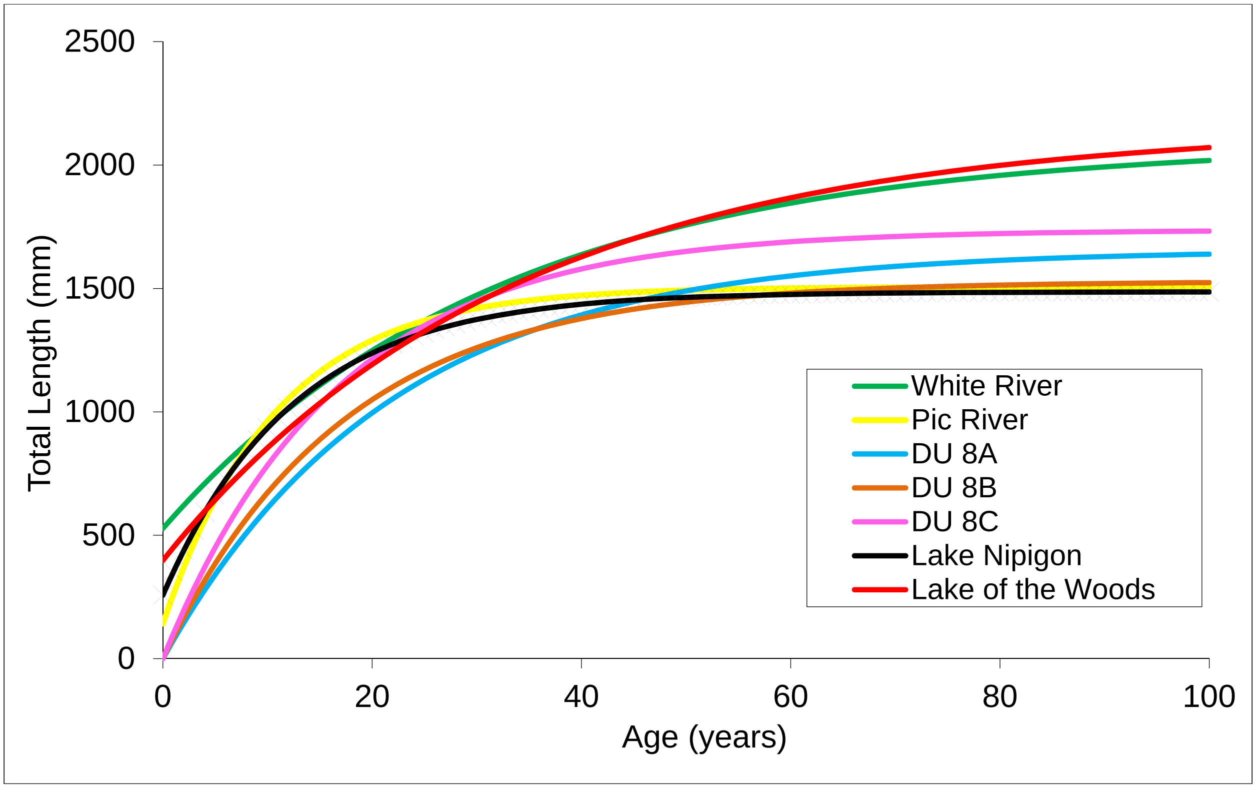


Figure 15 – Length at age as modelled by the von Bertalanffy growth model for the White River, Pic River (Ecclestone, unpublished), Lake Nipigon (Tremblay, 2010), Lake of the Woods (Harkness, 1923), and each designatable subunit of the Great Lakes (Valez-Espino & Koops, 2007).

Velez-Espino & Koops (2007) determined that the mean length at age 25 (TL_{25}) for DU 8b was 1172.0 mm. Our growth models for both the Pic River and the White River indicated that TL_{25} was 1369.39 mm and 1369.38 mm, respectively. Fortin et al. (1997) developed a regression equation for Lake Sturgeon growth that incorporated latitude and longitude (LAT/LON) in its predictions to estimate $TL_{23\text{-}27}$. Using the LAT/LON's of Stan's Honey Hole, the growth model predicts $TL_{23\text{-}27}$ to be 1168.06 mm (Fortin et al., 1997). However mean $TL_{23\text{-}27}$ ranged from 1170.0 to 1402.0 in the White River with a mean of 1308.67 m, while the growth model for the White River had a mean $TL_{23\text{-}27}$ of 1368.70 mm. Therefore it appears that that the White River

Lake Sturgeon population, and to a lesser extent the Pic River population, are relatively fast growing and grow to a large L_∞ compared to other populations that exist in their local and long-range geographical distribution.

4.2 Habitat Utilization and Movement Patterns

Lake Sturgeon showed a strong site fidelity for two locations in the White River, which included Stan's Honey Hole and the pool below Chigamiwinigum Falls. The non-random distribution analysis (FishTel version 1.4) and point-density analysis (ArcMap™ 10) (Figure 9) that was performed in this study provided strong evidence to support this claim. Lake Sturgeon habitat utilization varies quite substantially between and within different systems, and especially between natural and modified systems. One consistent finding, regardless of the system, is that Lake Sturgeon show strong site fidelity for specific pool mesohabitats within riverine systems. In the Pic River, Lake Sturgeon regularly congregated in six deep pools that were dispersed throughout a 5 km section of rapids (Ecclestone, 2011). In the Grasse River, 60% of all manual telemetry detections occurred within three areas over a 22-month period (Trested, 2010). In the Mississippi River, 50% of all manual telemetry detections occurred within one area over an 18-month period (Knight et al., 2002). In a natural reach of the Ottawa River, Lake Sturgeon had a tendency to remain within one basin, and although they may have left periodically, they always returned to the same basin (Haxton, 2003b). Finally, in the Kettle River, 80% of all manual telemetry detections occurred within a 1 km portion of the lower river over a 23-month study period (Borkholder et al., 2002). These locations have been identified as core areas (Knights et al., 2002) or activity centers (Borkholder et al., 2002) that Lake Sturgeon depend upon for foraging and/or spawning purposes.

Movement rates and MDPD were negatively correlated with GDD per week and GDD since June 1st, which resulted in significantly reduced movements as time progressed from early-spring to late-summer. MDPD was also negatively correlated with depth, which resulted in significantly less movement at Henry's Honey Hole and at the pool below Chigamiwinigum Falls. Several studies have reported a decrease in the movement rates of Lake Sturgeon as temperatures and GDD per week increase, such as Rusak and Mosindy (1997) in Lake of the Woods and Knights et al. (2002) in the Mississippi River. Trested et al. (2011) found that Lake Sturgeon MDPD in the Grasse River decreased from 930 m/day (± 110 m/day) in the spring to 100 m/day (± 170 m/day) in the summer. Rusak and Mosindy (1997) found that Lake Sturgeon movements decreased from 840 m/day (± 670 m/day) in the spring to 758 m/day (± 560 m/day) in the summer. If we use the same criteria to delineate spring and summer as these two studies, we find that Lake Sturgeon movement rates in the White River decreased from 386 m/day (± 75 m/day) in the spring to 197.5 m/day (± 24 m/day) in the summer. Therefore Lake Sturgeon movement rates decreased throughout the sampling period and from spring to summer, which is common amongst most Lake Sturgeon populations across their geographical range. Although not statistically tested in the Pic River because of sampling limitations, an observation was made that Lake Sturgeon displacement followed a similar pattern in this system (Ecclestone, 2011). McKinley et al. (1998) suggest that populations reduce MDPD during the summer to avoid thermal stress that is induced from increasing water temperatures; we suggest that this explanation serves well for our observations in the White River as well. Furthermore, we suggest that Lake Sturgeon selected deep water habitat and reduced their movements once encountering deep water as this habitat serves as a thermal refuge from elevated summer water temperatures. Finally, movements associated with spawning and reproduction could elevate springtime displacement rates as Lake Sturgeon ascend rivers to spawn at the uppermost navigable barrier (Bruch & Binkowski, 2002).

One finding that this study did uncover, which has been underreported for most Lake Sturgeon systems, is the magnitude and frequency of immigration and emigration that occurs between the White and Pic Rivers. Of the 48 individuals that had been radio tagged from 2008 to 2010 in the Pic River, five of them appeared in the White River at some point throughout the summer of 2011 and four of them appeared in both the Pic and White Rivers throughout 2011. Of the 40 individuals that were radio tagged in the White River in 2011, six of these individuals were later picked up in the Pic River within the same year. Therefore we can conservatively estimate that emigration from the White River to the Pic River occurs at a rate of approximately 15.0 % per year (6 emigrating individuals ÷ 40 radio tagged individuals), while emigration from the Pic River to the White River occurs at a rate of 10.4% per year (5 emigrating individuals ÷ 48 radio tagged individuals). In 2008, two Lake Sturgeon were captured in the Pic River that had originally been tagged in the Black Sturgeon River, approximately 200 km west of the Pic River near the city of Thunder Bay, Ontario (Dreary, 2008; Ecclestone, 2011). In the Sturgeon River, radio tagged Lake Sturgeon were captured 230 km east and 280 km west of the river, however they were captured in bays of Lake Superior and not within other spawning tributaries (Auer, 1999). Although it has been acknowledged in the literature that site fidelity and homing capabilities appear to be strong for Lake Sturgeon, these results suggest that straying is somewhat common amongst Lake Sturgeon populations. In light of this evidence, it is advocated that the concept of a metapopulation be given greater consideration for Lake Sturgeon. Metapopulation dynamics have been suggested for Lake Sturgeon in the St. Marys River (Bauman et al., 2011), for populations in the Lower Niagara and Detroit/St. Clair Rivers (Welsh

& McLeod, 2010), and for White Sturgeon in the highly fragmented Columbia River system (Jager et al., 2001; Coutant, 2004). The rate of immigration and emigration between the Pic and White Rivers will continue to be monitored in the coming years using the automated base station receivers. Genetic analysis will also be performed on Lake Sturgeon from the White and Pic Rivers to evaluate genetic similarities between these populations and to speculate on the magnitude of genetic exchange between these populations.

4.3 Conclusions & Future Directions

Lake Sturgeon growth parameters and CPUE were elevated in the White River compared to other locations across its geographical range, however their condition factor and weight-length relationship was comparable to other populations that have been studied. Habitat utilization and movement patterns were comparable to observations in other spawning tributaries, whereby Lake Sturgeon showed a strong preference for pool mesohabitats and decreased their movements as water temperatures and GDD increased. Although this study uncovered a lot of information on the White River Lake Sturgeon population, especially in regards to their movements between the Pic and White Rivers, there is still some information that needs to be collected in order to fully understand this system. First it is suggested that future studies incorporate larger (> 10") and smaller (< 8") mesh sizes to collect physical attributes from juvenile and old adult Lake Sturgeon in the White River. Secondly, it is encouraged that base stations remain at the mouth of both the Pic and White Rivers and at a second location further upstream on both rivers to continue monitoring the rate of immigration and emigration from and to both systems. Genetic studies could also be undertaken to identify genetic similarities and/or differences between the two populations, which could provide further resolution to the amount and rate of genetic exchange between these two systems. Consecutive day manual telemetry should also continue for the next one to two years in order to maximize the value of each radio tag since one to two years of battery life remains on each tag. Geospatial habitat mapping, which includes georeferenced information on the substrate and depth of the White River, should also be performed to identify the habitat characteristics that are associated with critical or frequently used habitat in the White River. Upon collecting this data, a habitat suitability model for Lake Sturgeon could be performed to assess and monitor changes in the quality and/or quality of significant Lake Sturgeon habitat. There may also be a spring or some other source of highly oxygenated water at the bottom of Stan's Honey Hole, which could explain the aggregated distribution at this location. Finally because of time constraints associated with labour intensive radio telemetry, we were not able to perform spawning assessments in the White River during the spring of 2012. To this point, we have captured ripe individuals near Chigamiwinigum Falls and suspect that this acts as the main spawning site within the river. However without the collection of eggs or larvae as evidence to confirm that spawning is occurring in the White River, we cannot conclusively suggest that Lake Sturgeon spawn in the White River. Therefore we strongly encourage that spawning surveys be undertaken in the White River to assess Lake Sturgeon spawning efforts in this tributary. Despite the aforementioned list of information gaps still required for the White River Lake Sturgeon population, this study has made great progress towards understanding this population, especially if you consider that no information existed prior to July of 2010. With the publication of this report we hope that other Lake Sturgeon biologists and management agencies will make the White River a priority tributary for Lake Sturgeon rehabilitation in Lake Superior as it contains a healthy and fast growing population that is ensured long-term protection from development and anthropogenic pressures.

Appendix

Appendix 1 – Date, time, duration, temperature, location, depth, size, and number of captured Lake Sturgeon in each net that was set in the White River throughout the spring and summer of 2011.

Set Date	Effort Number	Set Time	Lift Time	Duration (hrs.)	Duration (mins.)	Set Temp. (°C)	Lift Temp. (°C)	Easting	Northing	Start Depth (m)	End Depth (m)	Mesh Size (inch)	Net Length (feet)	Total New Captures	Total Recaptures	Total Captures
20-May-11	1	13:53	11:26	21	33	10.9	11.8	556291	5379125	3.3	13.6	9	100	0	0	0
20-May-11	2	14:18	12:00	21	42	11.0	11.8	556290	5379037	4.5	1.7	8	100	1	0	1
20-May-11	3	15:36	15:00	23	24	11.2	11.8	552936	5377622	1.2	8.9	10	300	0	0	0
20-May-11	4	16:23	17:09	24	46	11.1	11.5	555838	5379740	4.5	17.5	9	100	0	0	0
21-May-11	5	13:45	11:26	21	41	11.8	11.8	556263	5379034	0.5	2.0	9	100	0	0	0
21-May-11	6	17:14	18:05	24	51	11.6	12.0	555818	5379789	0.8	10.5	10	300	0	0	0
21-May-11	7	18:06	11:58	25	52	11.6	11.8	556286	5379143	1.4	5.2	9	100	1	0	1
22-May-11	8	14:37	11:35	20	58	11.8	12.0	556286	5379143	1.4	5.2	9	100	0	0	0
22-May-11	9	19:42	11:44	16	2	11.8	12.0	556282	5379210	2.8	5.4	10	200	0	0	0
23-May-11	10	11:41	10:22	22	41	12.0	11.0	556286	5379143	1.4	5.2	9	100	0	0	0
23-May-11	11	12:00	10:49	22	49	12.0	11.0	556340	5379217	2.1	4.5	10	200	2	0	2
23-May-11	12	17:30	10:17	16	47	12.0	11.0	556346	5379208	NA	NA	10	200	0	0	0
02-Jun-11	13	16:46	10:22	17	36	13.0	12.8	556339	5379210	2.0	5.2	9	100	0	0	0
02-Jun-11	14	17:04	10:41	17	37	13.0	12.8	556067	5379330	6.5	4.9	10	100	0	0	0
02-Jun-11	15	17:30	17:42	24	12	12.4	13.8	555842	5379758	2.5	6.3	9	200	0	1	1
02-Jun-11	16	17:30	10:57	17	27	13.0	12.7	556133	5379131	5.3	8.9	10	200	4	0	4
03-Jun-11	17	16:46	14:48	22	2	12.8	13.6	556339	5379210	2.0	5.3	9	100	1	0	1
03-Jun-11	18	17:20	16:20	23	0	13.8	13.6	556097	5379193	8.3	2.7	10	100	0	1	1
03-Jun-11	19	19:03	16:52	21	49	14.0	13.6	555852	5379793	1.7	17.0	9	100	0	0	0
04-Jun-11	20	15:00	11:32	20	32	13.6	14.0	556339	5379210	2.0	5.2	9	100	2	0	2
04-Jun-11	21	16:43	14:22	21	39	13.6	14.0	556213	5379049	6.1	3.2	9	100	0	0	0
04-Jun-11	22	17:08	15:08	22	0	13.8	13.8	555901	5379750	2.4	12.7	10	100	0	0	0
05-Jun-11	23	11:50	10:38	22	48	14.0	14.2	556339	5379210	2.0	5.2	9	100	0	0	0
05-Jun-11	24	14:55	10:49	19	54	13.8	14.0	556173	5379215	2.7	10.7	10	200	0	0	0

05-Jun-11	25	15:14	11:32	20	18	13.8	14.0	555901	5379750	2.4	12.7	10	100	0	0	0
06-Jun-11	26	10:45	9:35	22	50	14.2	15.2	556339	5379210	2.0	5.2	9	100	2	0	2
06-Jun-11	27	11:05	10:48	23	43	14.0	15.0	556127	5379380	4.4	3.4	10	100	0	0	0
06-Jun-11	28	11:35	10:58	23	23	14.0	15.0	555865	5379693	5.2	16.9	10	100	2	0	2
06-Jun-11	29A	16:50	14:34	21	44	15.0	14.8	553928	5377976	1.1	6.6	10	200	0	0	0
14-Jun-11	29B	15:45	13:11	21	26	15.8	16.3	556338	5379228	3.0	3.3	10	100	1	0	1
14-Jun-11	30	16:00	13:34	21	34	15.8	16.2	556097	5379210	2.9	8.7	10	100	0	0	0
14-Jun-11	31	16:15	14:00	21	45	15.8	16.2	555898	5379714	8.3	17.0	9	100	0	0	0
14-Jun-11	32	15:05	9:34	18	29	15.8	16.0	553979	5377742	2.3	9.6	10	200	0	0	0
15-Jun-11	33	13:15	17:15	28	0	16.1	17.0	556318	5379321	4.9	4.8	10	100	0	0	0
15-Jun-11	34	13:47	17:34	27	47	16.3	17.0	556234	5379202	2.7	8.8	10	100	0	0	0
15-Jun-11	35	14:10	17:52	27	42	16.2	17.0	555859	5379678	25.6	7.3	10	100	2	0	2
15-Jun-11	36	9:46	13:53	29	7	16.1	17.0	553934	5537618	0.7	3.0	10	200	0	0	0
15-Jun-11	37	15:56	13:25	21	29	16.2	17.0	556140	5379132	12.6	14.9	8	100	1	1	2
15-Jun-11	38	16:11	14:45	22	34	16.2	17.0	555842	5379601	5.3	5.2	8	100	0	1	1
16-Jun-11	39	14:13	11:52	21	39	17.0	17.8	554006	5377526	5.8	4.3	10	200	0	0	0
16-Jun-11	40	17:30	9:41	16	11	17.0	17.2	556303	5379189	3.1	3.3	10	100	0	0	0
16-Jun-11	41	18:00	10:22	16	22	17.0	17.2	555859	5379678	12.9	7.3	9	100	0	0	0
16-Jun-11	42	16:00	9:53	17	53	17.0	17.0	556159	5379124	16.9	21.2	10	100	0	0	0
17-Jun-11	43	10:07	16:44	30	37	17.0	17.8	556268	5379043	1.2	1.6	8	100	0	0	0
17-Jun-11	44	10:40	17:23	30	43	17.0	17.4	555891	5379748	16.4	12.6	9	100	1	0	1
17-Jun-11	45	9:50	17:07	31	17	17.2	18.2	556323	5379222	6.2	5.2	10	100	0	0	0
17-Jun-11	46	12:10	18:00	29	50	17.8	17.2	553924	5377693	5.1	1.0	10	200	0	0	0
18-Jun-11	47	16:58	11:07	18	9	17.8	17.6	556182	5379065	6.2	8.7	8	100	1	0	1
18-Jun-11	48	17:16	10:55	17	39	18.2	17.8	556279	5379219	4.6	5.2	10	100	0	0	0
18-Jun-11	49	17:42	12:32	18	50	17.4	18.0	555887	5379755	6.1	18.1	9	100	0	0	0
18-Jun-11	50	18:08	12:51	18	43	17.2	18.0	553947	5377682	5.1	1.0	10	200	0	0	0
19-Jun-11	51	11:04	10:30	23	26	17.8	17.5	556345	5379218	4.4	6.2	10	100	0	0	0
19-Jun-11	52	11:16	10:17	23	1	17.6	17.2	556182	5379065	6.2	8.7	8	100	0	0	0
19-Jun-11	53	12:42	14:39	25	57	18.0	17.2	555878	5379557	11.4	9.7	9	100	0	0	0
19-Jun-11	54	13:10	15:30	26	20	17.8	17.0	554006	5377576	4.9	4.1	10	200	0	0	0
19-Jun-11	55	13:46	10:54	21	8	18.0	17.2	555863	5379695	4.2	12.1	8	100	3	0	3
19-Jun-11	56	15:47	16:02	24	15	17.6	17.2	554471	5378610	4.1	7.1	8	100	0	1	1
20-Jun-11	57	10:46	9:49	23	3	17.4	17.5	556277	5379131	5.2	6.6	10	100	0	0	0

20-Jun-11	58	10:28	10:01	23	33	17.0	17.8	556096	5379326	8.1	3.3	8	100	0	0	0
20-Jun-11	59	11:05	10:15	23	10	17.2	17.2	555863	5379695	4.2	7.1	8	100	0	0	0
20-Jun-11	60	14:55	10:35	19	40	17.4	17.2	555569	5379333	6.3	4.8	9	100	0	0	0
20-Jun-11	61	15:16	11:12	19	56	17.2	18.0	554522	5378633	4.6	5.5	8	100	0	0	0
20-Jun-11	62	15:35	11:26	19	51	17.0	16.2	553952	5377325	2.0	4.2	10	200	1	0	1
27-Jun-11	63	15:02	11:34	20	32	17.4	18.0	556331	5379219	4.1	2.3	9	100	0	0	0
27-Jun-11	64	15:15	11:57	20	42	17.4	17.0	556130	5379166	9.0	12.3	8	100	0	1	1
27-Jun-11	65	15:18	13:23	22	5	17.4	17.2	555863	5379671	5.7	6.1	10	100	2	0	2
27-Jun-11	66	15:29	15:34	24	5	17.2	17.4	554563	5378591	2.5	2.3	10	100	0	0	0
28-Jun-11	67	11:46	8:31	20	45	18.0	16.9	556302	5379194	1.4	4.0	9	100	0	0	0
28-Jun-11	68	13:15	8:21	19	6	17.0	17.0	556168	5379077	3.2	12.3	8	100	2	0	2
29-Jun-11	69	13:37	9:36	19	59	17.0	17.3	555863	5379671	5.7	6.1	10	100	0	0	0
29-Jun-11	70	15:44	9:55	18	11	17.4	17.3	554405	5378444	1.6	4.3	10	100	0	0	0
04-Jul-11	71	12:30	10:45	22	15	20.0	20.0	556128	5379137	2.5	8.8	10	100	1	0	1
04-Jul-11	72	12:45	11:38	22	53	21.0	20.0	556070	5379194	1.9	6.5	10	100	0	0	0
04-Jul-11	73	13:01	11:56	22	55	20.0	20.0	555859	5379696	4.6	3.0	9	100	2	0	2
04-Jul-11	74	13:08	13:45	24	37	20.0	20.0	554779	5378768	5.2	5.4	9	100	0	0	0
04-Jul-11	75	16:12	14:23	22	11	20.0	20.0	553932	5377666	1.6	4.2	10	100	0	0	0
04-Jul-11	76	16:20	14:59	22	39	20.0	20.0	554044	5378104	4.7	4.1	8	100	2	1	3
05-Jul-11	77	11:32	10:05	22	33	20.0	20.0	556152	5379103	10.0	16.7	10	100	1	0	1
05-Jul-11	78	11:48	10:55	23	7	20.0	20.0	556340	5379216	1.2	3.0	10	100	0	0	0
05-Jul-11	79	14:02	11:04	21	2	20.0	20.0	555907	5379744	6.0	18.0	9	100	1	0	1
05-Jul-11	80	14:47	11:52	21	5	20.0	20.5	553932	5377666	1.6	4.2	10	200	0	0	0
05-Jul-11	81	15:07	12:20	21	13	20.0	20.5	554078	5378142	2.2	4.3	8	100	0	0	0
06-Jul-11	82	10:10	10:20	24	10	20.0	20.5	556152	5379105	9.6	16.2	10	100	0	0	0
06-Jul-11	83	10:58	10:43	23	45	20.0	20.5	556320	5379208	2.3	3.4	10	100	1	0	1
06-Jul-11	84	11:14	11:17	24	3	20.0	20.5	555903	5379741	3.0	16.0	9	100	0	0	0
06-Jul-11	85	12:11	12:28	24	17	20.0	20.5	553912	5377739	2.7	3.8	10	200	1	0	1
06-Jul-11	86	12:28	10:52	22	24	20.5	20.5	554092	5378156	2.7	3.6	8	100	3	0	3
12-Jul-11	87	15:41	13:04	21	23	20.0	20.0	556317	5379201	1.2	5.0	8	100	0	0	0
12-Jul-11	88	15:50	13:25	21	35	20.0	20.0	556124	5379144	4.2	18.3	9	100	0	0	0
12-Jul-11	89	15:58	13:38	22	40	20.0	20.5	555912	5379663	5.0	11.8	10	100	0	0	0
12-Jul-11	90	16:15	14:02	21	47	19.6	20.8	554107	5378177	2.0	2.5	10	100	1	0	1
13-Jul-11	91	13:10	9:45	20	35	20.0	19.2	556328	5379212	1.9	5.1	8	100	0	0	0

13-Jul-11	92	13:30	9:54	20	24	20.0	19.0	556126	5379166	4.0	8.8	9	100	2	0	2
13-Jul-11	93	13:49	12:16	22	27	20.5	20.2	555886	5379735	7.9	15.2	10	100	2	1	3
13-Jul-11	94	14:18	15:50	25	32	20.8	20.1	554107	5378177	2.0	2.5	10	100	0	0	0
13-Jul-11	95	14:25	15:21	24	56	19.8	20.1	553945	5377296	5.4	6.2	8	100	0	0	0
14-Jul-11	96	9:47	11:02	25	15	19.2	20.5	556283	5379144	4.2	6.0	8	100	0	0	0
14-Jul-11	97	10:06	11:22	25	16	20.0	20.5	556126	5379166	4.0	8.8	9	100	0	1	1
14-Jul-11	98	12:30	11:49	23	19	20.0	20.5	555886	5379735	7.9	15.2	10	100	0	0	0
14-Jul-11	99	15:05	12:11	21	6	20.1	20.5	554338	5378379	4.1	7.6	10	100	0	0	0
15-Jul-11	100	11:11	16:02	28	51	20.5	20.5	556075	5379284	6.1	4.1	9	100	0	0	0
15-Jul-11	101	11:36	16:15	28	39	20.5	20.5	556237	5379092	5.4	13.0	9	100	3	1	4
15-Jul-11	102	11:55	19:18	31	23	20.5	20.5	555862	5379658	5.9	8.8	10	100	0	0	0
15-Jul-11	103	12:20	17:29	29	9	20.5	20.5	553954	5378093	4.1	5.0	10	100	0	0	0
16-Jul-11	104	16:08	10:22	18	14	20.5	20.8	556055	5379819	6.9	13.2	9	100	0	0	0
16-Jul-11	105	16:22	10:02	17	40	20.5	20.5	556237	5379092	5.4	13.0	9	100	0	1	1
16-Jul-11	106	19:21	10:57	15	36	20.5	21.0	555862	5379658	5.9	8.8	10	100	1	0	1
16-Jul-11	107	12:20	12:59	24	39	20.5	20.8	553954	5378093	4.1	5.0	10	100	0	0	0
17-Jul-11	108	10:13	9:41	23	28	20.5	21.2	556209	5379051	2.9	4.3	9	100	0	0	0
17-Jul-11	109	10:31	10:02	23	31	20.5	21.2	556138	5379610	5.9	3.1	9	100	2	0	2
17-Jul-11	110	10:48	11:39	24	51	21.8	22.0	555886	5379794	2.9	15.7	8	100	0	1	1
17-Jul-11	111	13:15	12:27	23	12	21.0	21.5	553947	5377630	5.5	1.4	10	200	2	1	3
17-Jul-11	112	13:45	12:08	22	23	20.5	22.0	554441	5378572	4.8	7.5	10	100	0	0	0
18-Jul-11	113	9:48	11:06	25	18	21.2	22.8	556167	5379187	3.4	21.2	9	100	0	2	2
18-Jul-11	114	10:31	11:38	25	7	21.2	22.8	556138	5379610	5.9	3.1	9	100	3	0	3
18-Jul-11	115	11:58	12:36	24	38	22.0	23.0	555862	5379700	8.9	8.5	8	100	4	0	4
18-Jul-11	116	12:14	13:55	25	41	22.0	23.0	554527	5378577	3.0	3.1	10	100	1	0	1
18-Jul-11	117	12:41	14:20	25	39	21.5	23.0	553945	5377600	1.9	4.1	10	200	0	0	0
19-Jul-11	118	11:39	10:03	22	24	22.8	23.0	556076	5379771	4.1	12.4	9	100	0	0	0
19-Jul-11	119	13:50	10:23	20	33	23.0	23.0	555350	5379233	7.0	4.6	8	100	0	0	0
19-Jul-11	120	14:00	10:43	20	43	23.0	22.5	554527	5378577	3.0	3.1	10	100	0	0	0
19-Jul-11	121	14:27	11:04	20	37	22.8	22.8	553945	5377600	1.9	4.1	10	200	0	0	0
26-Jul-11	122	13:47	10:10	20	23	20.8	20.5	556235	5379082	2.3	11.5	10	100	0	0	0
26-Jul-11	123	13:50	10:22	20	32	22.0	20.5	556329	5379218	3.9	5.7	8	100	0	0	0
26-Jul-11	124	14:11	10:32	20	21	21.0	21.1	555854	5379634	9.7	4.7	8	100	2	0	2
26-Jul-11	125	14:27	12:32	22	5	21.0	20.2	553949	5378021	5.1	3.3	10	200	2	1	3

26-Jul-11	126	14:36	12:04	21	28	21.0	20.2	554457	5378599	4.1	7.2	9	100	0	0	0
27-Jul-11	127	10:17	9:31	23	14	20.5	20.1	556137	5379143	3.4	16.6	10	100	0	0	0
27-Jul-11	128	10:26	9:41	23	15	20.5	20.1	556280	5379214	3.1	4.7	8	100	0	0	0
27-Jul-11	129	10:46	17:46	7	0	20.5	20.8	555854	5379634	9.7	4.7	8	100	0	0	0
27-Jul-11	130	12:12	9:57	21	45	20.2	20.1	554327	5378441	3.9	10.8	9	100	1	0	1
27-Jul-11	131	12:54	10:27	21	33	20.2	20.1	553949	5378021	5.1	3.1	10	200	1	0	1

Appendix 2 – Arrangement of radio frequencies in the frequency tables of base stations. Radio frequencies were sorted by pulse rate and contained radio tag frequencies from the White and Pic Rivers.

Frequency (kHz)	Frequency Table #	Tag Implanted in:
150.011	Table 1	Pic River
150.055	Table 1	Pic River
150.073	Table 1	Pic River
150.095	Table 1	Pic River
150.116	Table 1	Pic River
150.147	Table 1	Pic River
150.164	Table 1	Pic River
150.185	Table 1	Pic River
150.205	Table 1	Pic River
150.244	Table 1	Pic River
150.264	Table 1	Pic River
150.285	Table 1	Pic River
150.303	Table 1	Pic River
150.324	Table 1	Pic River
150.344	Table 1	Pic River
150.363	Table 1	Pic River
150.384	Table 1	Pic River
150.533	Table 1	Pic River
150.553	Table 1	Pic River
150.593	Table 1	Pic River
150.654	Table 1	Pic River
150.673	Table 1	Pic River
151.002	Table 1	Pic River
151.023	Table 1	Pic River
151.045	Table 1	Pic River
151.065	Table 1	Pic River
151.087	Table 1	Pic River
151.104	Table 1	Pic River
151.124	Table 1	Pic River
151.145	Table 1	Pic River
151.165	Table 1	Pic River
151.185	Table 1	Pic River
151.206	Table 1	Pic River
151.248	Table 1	Pic River
151.266	Table 1	Pic River
151.286	Table 1	Pic River

151.325	Table 1	Pic River
151.345	Table 1	Pic River
151.364	Table 1	Pic River
151.385	Table 1	Pic River
151.405	Table 1	Pic River
151.426	Table 1	Pic River
151.444	Table 1	Pic River
151.464	Table 1	Pic River
151.485	Table 1	Pic River
151.226	Table 2	White River
151.303	Table 2	White River
151.515	Table 2	White River
151.594	Table 2	White River
151.615	Table 2	White River
151.677	Table 2	White River
151.695	Table 2	White River
151.754	Table 2	White River
151.814	Table 2	White River
151.833	Table 2	White River
151.893	Table 2	White River
152.002	Table 3	White River
152.019	Table 3	White River
152.043	Table 3	White River
152.062	Table 3	White River
152.073	Table 3	White River
152.081	Table 3	White River
152.102	Table 3	White River
152.123	Table 3	White River
152.133	Table 3	White River
152.141	Table 3	White River
152.16	Table 3	White River
152.182	Table 3	White River
152.192	Table 3	White River
152.202	Table 3	White River
152.241	Table 3	White River
152.263	Table 3	White River
152.282	Table 3	White River
152.302	Table 3	White River
152.322	Table 3	White River
152.341	Table 3	White River
152.362	Table 3	White River
152.382	Table 3	White River
152.402	Table 3	White River

152.421	Table 3	White River
152.441	Table 3	White River
152.461	Table 3	White River
152.482	Table 3	White River
152.502	Table 3	White River
152.523	Table 3	White River

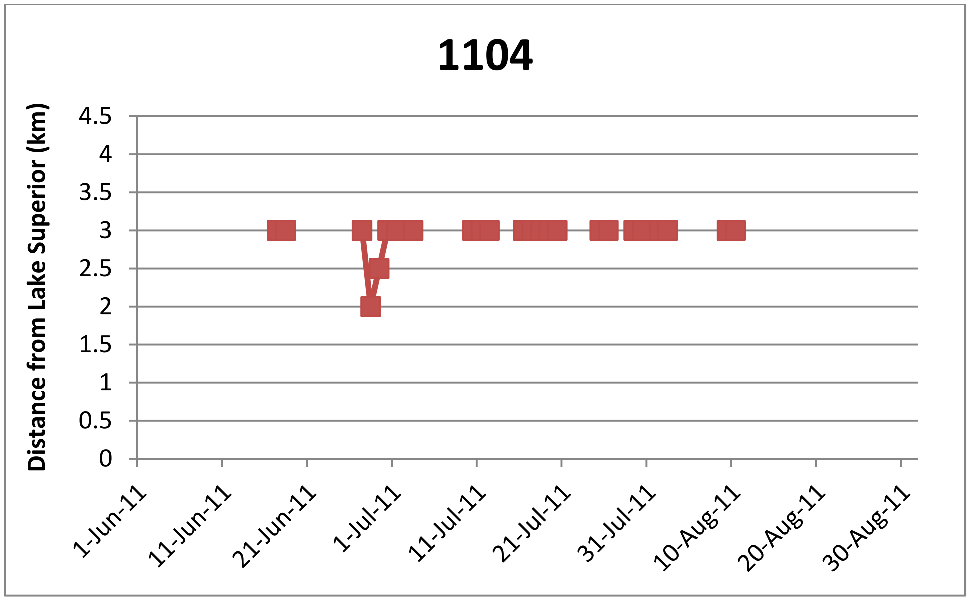
Appendix 3 – Raw data from the 82 Lake Sturgeon that were captured in the White River in 2011.

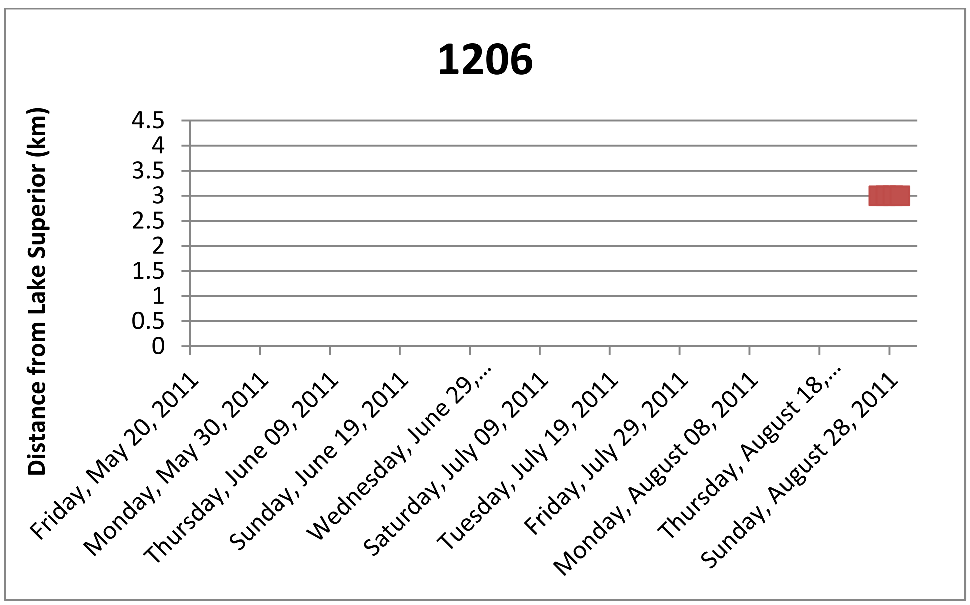
Fish Number	Lift Date	Sample #	FL (mm)	TL (mm)	Girth (mm)	Round Weight (g)	Age	Sex	Recap	12mm PIT Tag	32mm PIT Tag	Floy Tag #	Radio Tag #
1	21-May-11	2	1388	1508	572	21000	31	2	n	151315793A		5326 - yellow	
2	22-May-11	7	1150	1285	435	12750	19	1	n	151316137A	139143245	5327 - yellow	151.677
3	23-May-11	11	1425	1559	558	24500	30	2	n	150962354A	139142769	5328 - yellow	151.814
4	23-May-11	11	1121	1262	423	12100	18	1	n	151315215A	139143245	5329 - yellow	151.833
5	03-Jun-11	16	1295	1375	430	17750	27	2	n	122129497A	139143170	5330 - yellow	151.893
6	03-Jun-11	16	1100	1231	440	14000	26	1	n	133147467A	139143094	5331 - yellow	151.754
7	03-Jun-11	16	1239	1361	480	17000		2	n	132776650A	139142978	5332 - yellow	151.515
8	03-Jun-11	16	1170	1289	450	13500	18	1	n	133356522A	139142771	5333 - yellow	151.695
9	03-Jun-11	15	1265	1450	420	12500		1	y	9820091011340411	139142893	DFO-GLLFAS 6661 - yellow	151.615
10	04-Jun-11	17	1237	1332	501	17500	24	1	n	133263394A	139143236	5334 - yellow	151.594
RECAP	04-Jun-11	18	1121	1262	423	12100		1	y	151315215A	139143245	5329 - yellow	151.833
11	05-Jun-11	20	1118	1218	498	14250	17	2	n	132855463A	139143136	5335 - yellow	151.226
12	05-Jun-11	20	1115	1205	415	11200	12	1	n	133175194A	139143158	5336 - yellow	151.303
13	07-Jun-11	26	1109	1232	367	11000	15	1	n	133265632A		5337 - yellow	
14	07-Jun-11	26	1128	1235	412	11200	24	1	n	133277311A	139143272	5338 - yellow	152.322
15	07-Jun-11	28	1464	1525	521	22000	31	2	n	132636173A	139143114	5339 - yellow	152.362
16	07-Jun-11	28	1190	1305	492	15200	23	2	n	132915632A	139143279	5340 - yellow	152.461
17	16-Jun-11	35	1259	1170	470	14750	26	1	n	132812323A	139143120	5342 - yellow	152.133
18	16-Jun-11	35	1104	1191	420	11000	19	2	n	133316530A	139143082	5343 - yellow	152.282
19	16-Jun-11	37	1370	1490	472	17750		1	y	151315793A	139143282	5326 - yellow	152.441
20	16-Jun-11	37	1151	1264	488	14500	16	1	n	133309797A	139143004	5341 - yellow	152.382
RECAP	16-Jun-11	38	1119	1214					y	150962260A			
21	18-Jun-11	44	1055	1188	430	11100	20	1	n	132856734A	139142846	5344 - yellow	152.402
22	19-Jun-11	47	1089	1202	382	9200	18	1	n	133136680A	139143010	5345 - yellow	152.302
23	20-Jun-11	55	1025	1120	375	9100	22	2	n	132729540A	139143167	5346 - yellow	152.421
24	20-Jun-11	55	1117	1216	422	11400	22	2	n	133352621A	139143138	5347 - yellow	152.341
25	20-Jun-11	55	1040	1155	404	10000	12	1	n	132757525A	139143171	5348 - yellow	152.241

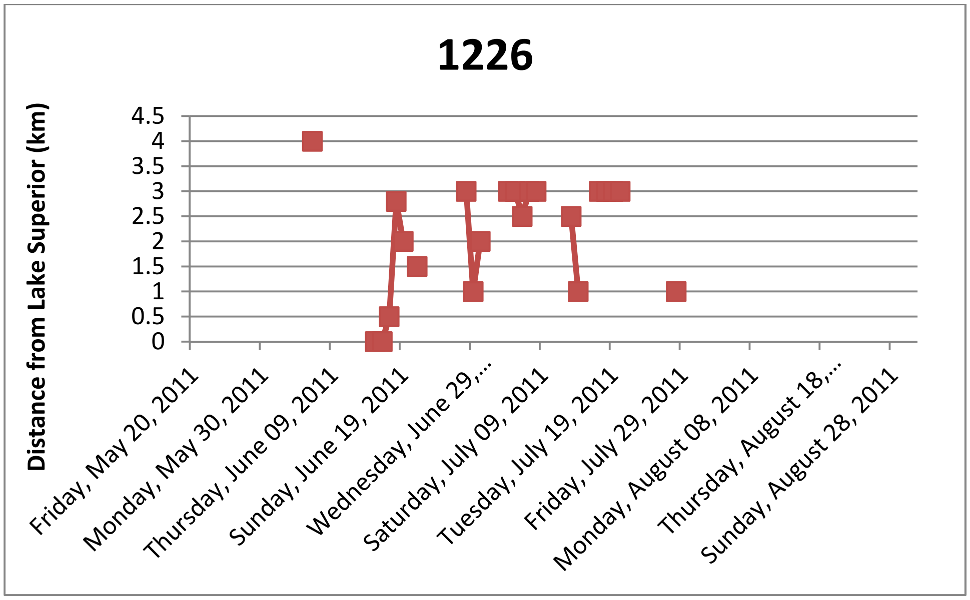
RECAP	20-Jun-11	56	1128	1235	412	11200		1	y	133277311A	139143272	5338 - yellow	152.322
26	21-Jun-11	62	1350	1480	482	17750	29	2	n	151347446A	139143109	5439 - yellow	152.263
27	29-Jun-11	64	1260	1337	505	16500		2	y	431049772C	139142899	DFO-GLLFAS 7364 - yellow	152.523
28	29-Jun-11	65	1245	1382	483	15750	23	2	n	151348167A	139143276	5350 - yellow	152.141
29	29-Jun-11	65	961	1060	388	7500	17	2	n	132666131A	139142090	5300 - yellow	152.502
30	30-Jun-11	68	768	880	340	4900	12	9	n	151348161A		5398 and 5299 - yellow	
31	30-Jun-11	68	907	1010	375	7125	12	1	n	151347047A	139143238	5297 - yellow	152.081
32	05-Jul-11	71	1155	1260	515	13500	19	9	n	151347721A		5296 - yellow	
33	05-Jul-11	73	880	962	311	6750	9	2	n	151347731A		5295 - yellow	
34	05-Jul-11	73	1215	1305	425	15500	16	9	n	151347476A		5294 - yellow	
35	05-Jul-11	76	1075	1180	415	11150	22	2	n	151347770A		5293 - yellow	
36	05-Jul-11	76	1110	1232	428	11900	8	2	y	150962260A	151348223A	5292 - yellow	
37	05-Jul-11	76	1560	1720	563	27500	31	2	n	150952634A		5290 - yellow	
38	06-Jul-11	77	885	990	360	7300	14	2	n	150953096A		5282 - yellow	
39	06-Jul-11	79	1088	1185	444	12300	8	1	n	150945270A		5288 - yellow	
40	07-Jul-11	83	1178	1293	460	15000	19	1	n	151348142A		5287 - yellow	
41	07-Jul-11	86	1094	1182	433	11450	13	2	n	151348316A		5286 - yellow	
42	07-Jul-11	86	840	933	320	6000	12	2	n	151348194A		5285 - yellow	
43	07-Jul-11	86	708	760	295	4600	8	1	n	151347462A		5284 - yellow	
44	07-Jul-11	85	1375	1470	500	20000	36	2	n	151347271A		5283 - yellow	
44	13-Jul-11	90	1118	1214	452	12000	17	2	n	150944117A	139143123	5282 - yellow	152.160
45	14-Jul-11	92	1121	1250	453	12900	18	2	n	150944496A	139143275	5281 - yellow	152.192
46	14-Jul-11	92	1140	1281	421	13400	17	2	n	150957356A	139143169	5280 - yellow	152.073
47	14-Jul-11	93	825	930	350	5500	13	9	n	150958593A		5279 - yellow	
48	14-Jul-11	93	1211	1346	482	15500	23	2	n	150951562A	139142770	5278 - yellow	152.182
RECAP	14-Jul-11	93	907	1010	375	7125		1	y	151347047A	139143238	5297 - yellow	
RECAP	15-Jul-11	97	961	1060	388	7500		2	y	132666131A	139142090	5300 - yellow	
49	16-Jul-11	101	1080	1184	450		15	2	n	150955214A	139142971	5277 - yellow	152.123
50	16-Jul-11	101	773	854	335	2750	12	9	n	150965113A		5276 - yellow	
51	16-Jul-11	101	1080	1210	420	9000	19	1	n	150955754A	139143265	5251 - yellow	152.002
52	16-Jul-11	101	1075	1180	415	11150		2	y	151347770A	139142901	5293 - yellow	152.019
53	17-Jul-11	106	1297	1402	465	16750	27	2	n	150937213A	139142784	5252 - yellow	152.043

RECAP	17-Jul-11	105	1080	1184	450			2	y	150955214A	139142971	5277 - yellow	
54	18-Jul-11	109	889	990	255	6200	14	9	n	150946544A		5253 - yellow	
55	18-Jul-11	109	1045	1125	418	11000	20	1	n	150938145A	139143085	5254 - yellow	152.482
56	18-Jul-11	111	1001	1109	370	7500	17	9	n	150944480A		5225 - yellow	
57	18-Jul-11	111	1290	1422	470	16750	19	2	y	985121020477062	139143079	5256 - yellow	152.202
58	18-Jul-11	111	1108	1236	450	12600		1	n	150964632A	139143313	5257 - yellow	152.101
RECAP	18-Jul-11	110	1115	1205	415	11200		1	y	133175194A	139143158	5336 - yellow	
59	19-Jul-11	114	867	968	349	6000	15	9	n	150951256A		5258 - yellow	
60	19-Jul-11	114	899	946	361	6250	11	9	n	150947735A		5259 - yellow	
61	19-Jul-11	114	839	930	339	5300	14	9	n	150952633A		5260 - yellow	
62	19-Jul-11	115	1129	1250	521	17250	22	2	n	150939195A		5261 - yellow	
63	19-Jul-11	115	1056	1180	392	9000	14	1	n	150936724A		5262 - yellow	
64	19-Jul-11	115	806	903	320	4850		9	n	150951452A		5263 - yellow	
65	19-Jul-11	115	868	960	316	5250		9	n	151313494A		5264 - yellow	
66	19-Jul-11	116	1146	1215	407	12250	16	2	n	151253256A		5265 - yellow	
RECAP	19-Jul-11	113	1080	1184	450			2	y	150955214A	139142971	5277 - yellow	
RECAP	19-Jul-11	113	1211	1346	482	15500		2	y	150951562A	139142770	5278 - yellow	
67	27-Jul-11	124	1204	1338	502	16000		2	n	151316257A		5266 - yellow	
68	27-Jul-11	124	1314	1366	499	21000	28	2	n	151316257A		5266 - yellow	
69	27-Jul-11	125	790	700	315	3800		9	n	151313371A		5367 - yellow	
70	27-Jul-11	125	1290	1415	499	16750	16	1	n		139142995	5268 - yellow	152.062
71	27-Jul-11	125	1093	1195	501	14000	15	2	y	982009101146312	139142329	5269 - yellow	152.123
72	27-Jul-11	130	938	1025	388	7200	22	1	n			5270 & 5271 - yellow	

Appendix 4 – Lake Sturgeon movements detected by manual telemetry sweeps. Stan's Honey Hole and Chigamiwinigum Falls are located 3.0 km to 3.5 km and 4.0 km to 4.5 km from Lake Superior, respectively.






1226
Distance from Lake Superior (km)
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4
3.5
3
2.5
2
1.5
1
0.5
0
Friday, May 20, 2011
Monday, May 30, 2011
Thursday, June 09, 2011
Sunday, June 19, 2011
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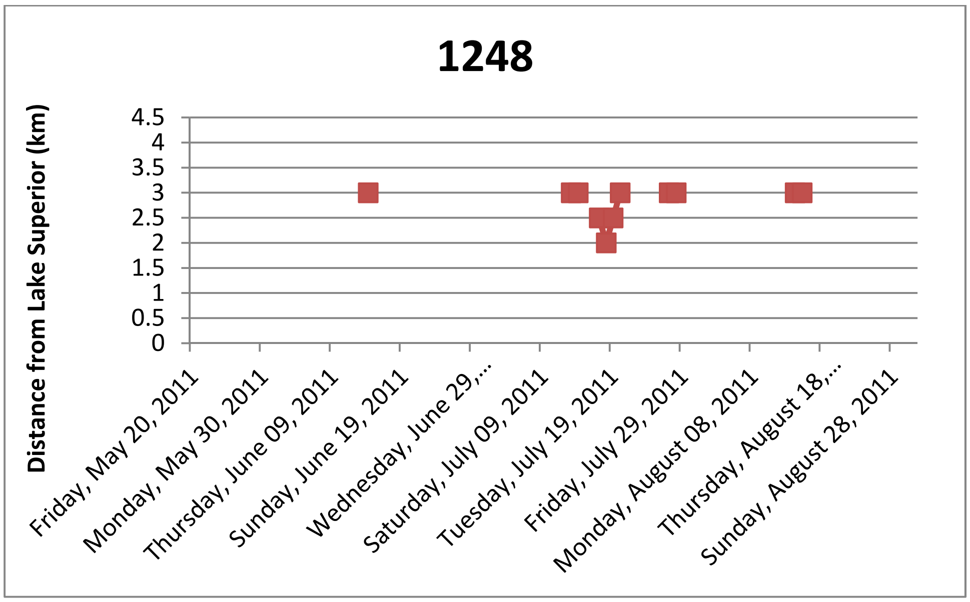
Sunday, August 28, 2011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Distance from Lake Superior (km)
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2.5
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0.5
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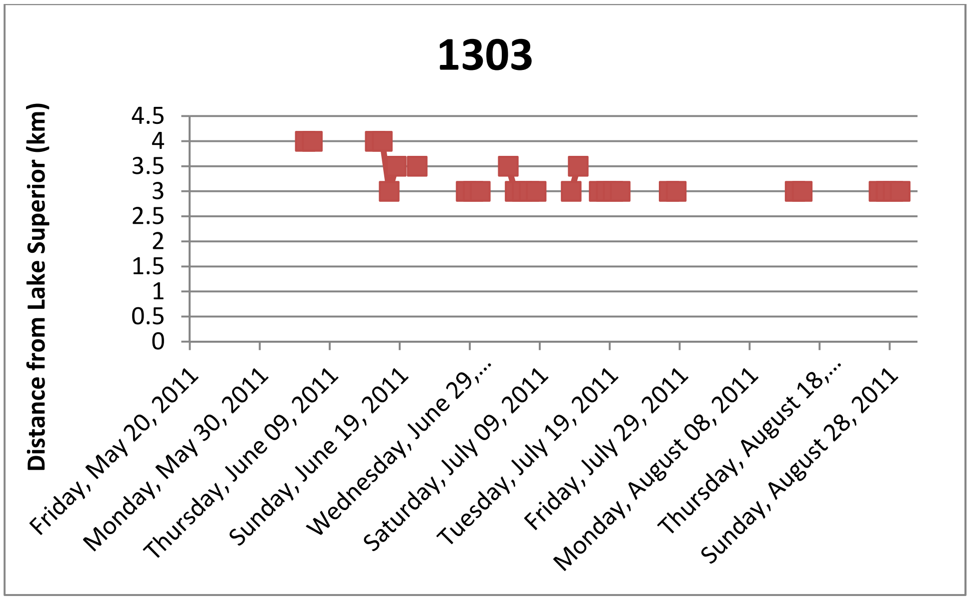
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Distance from Lake Superior (km)
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1.5
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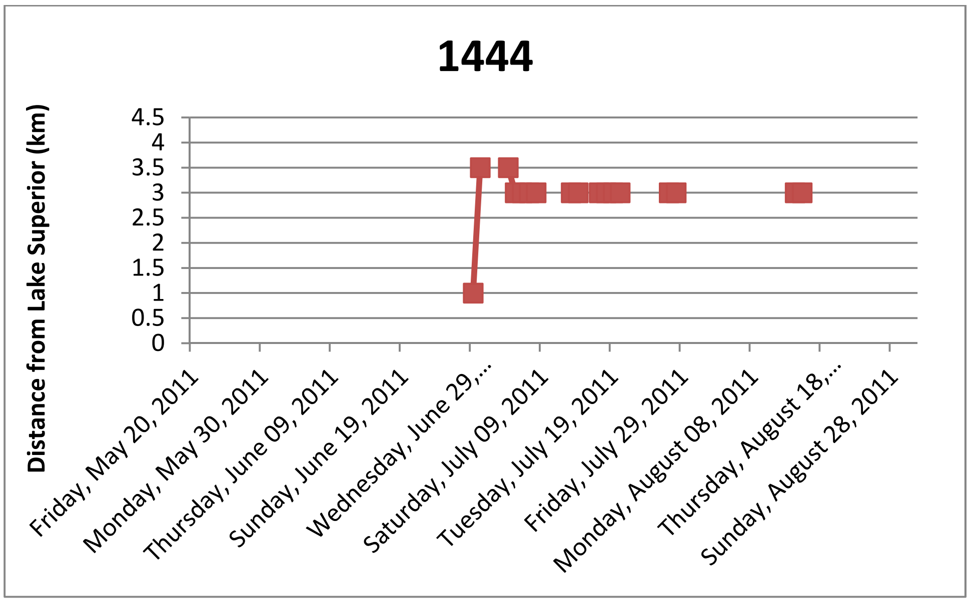
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Distance from Lake Superior (km)
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1.5
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0.5
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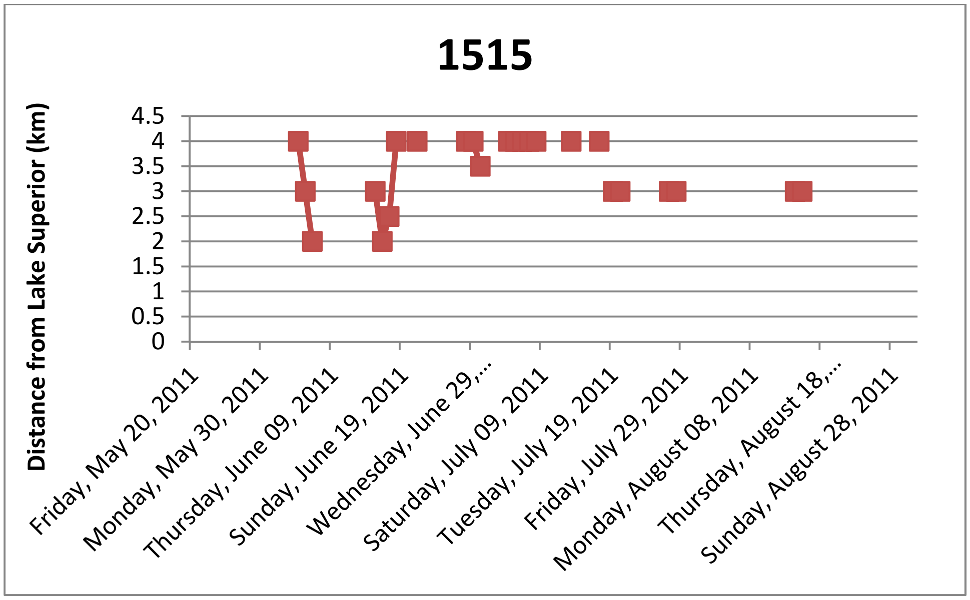
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Distance from Lake Superior (km)
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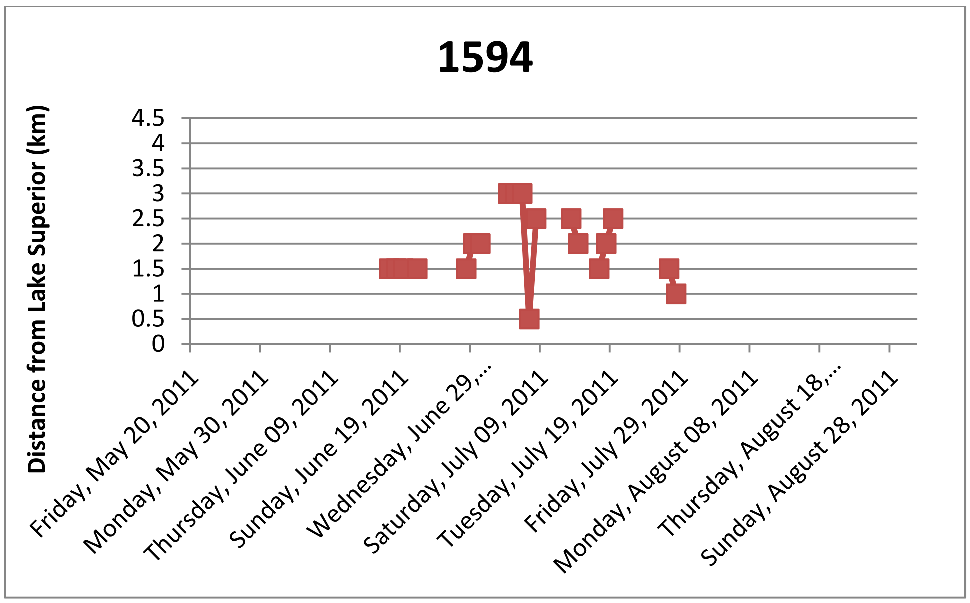
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Distance from Lake Superior (km)
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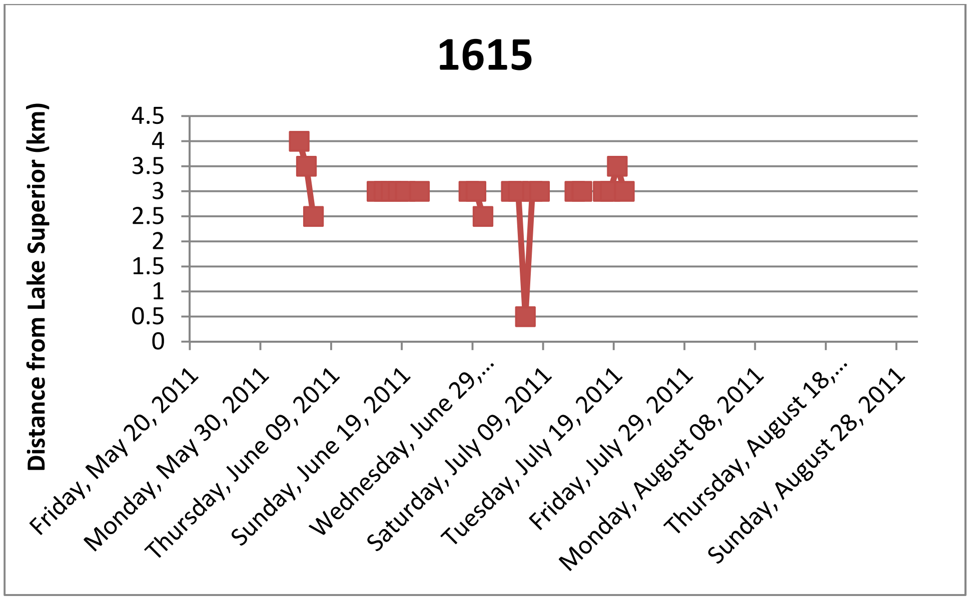
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Distance from Lake Superior (km)
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0.5
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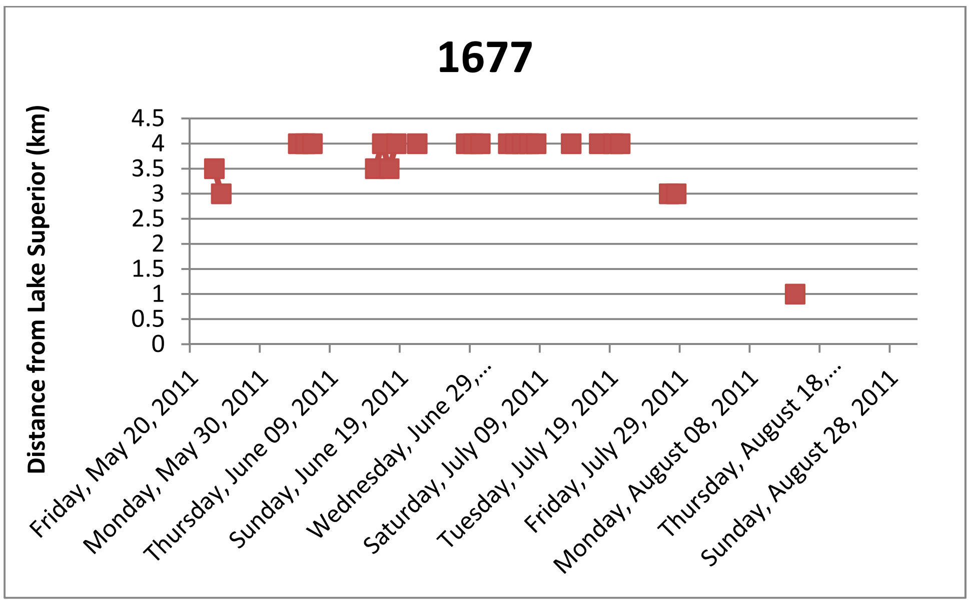
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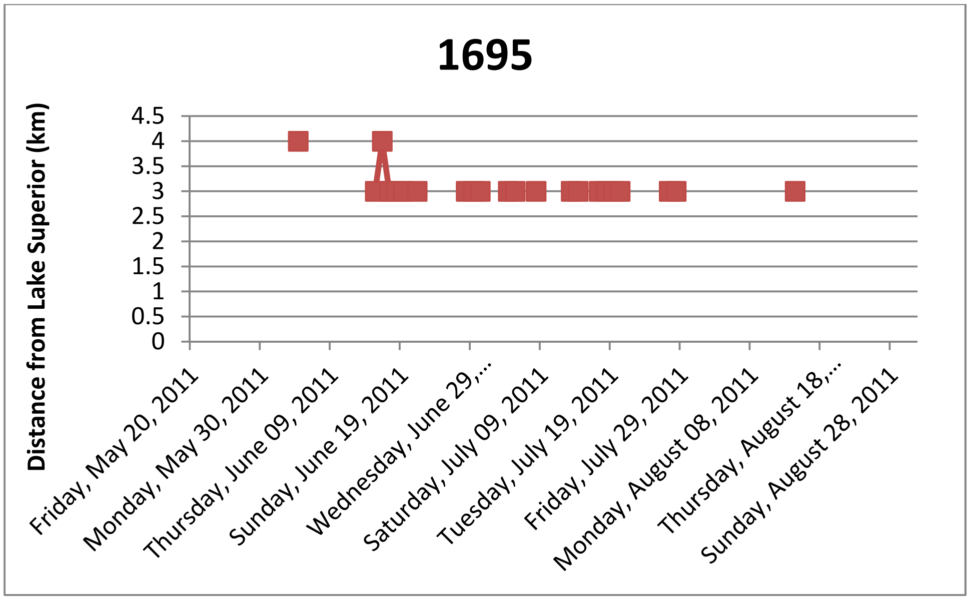
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Distance from Lake Superior (km)
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2.5
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1.5
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0.5
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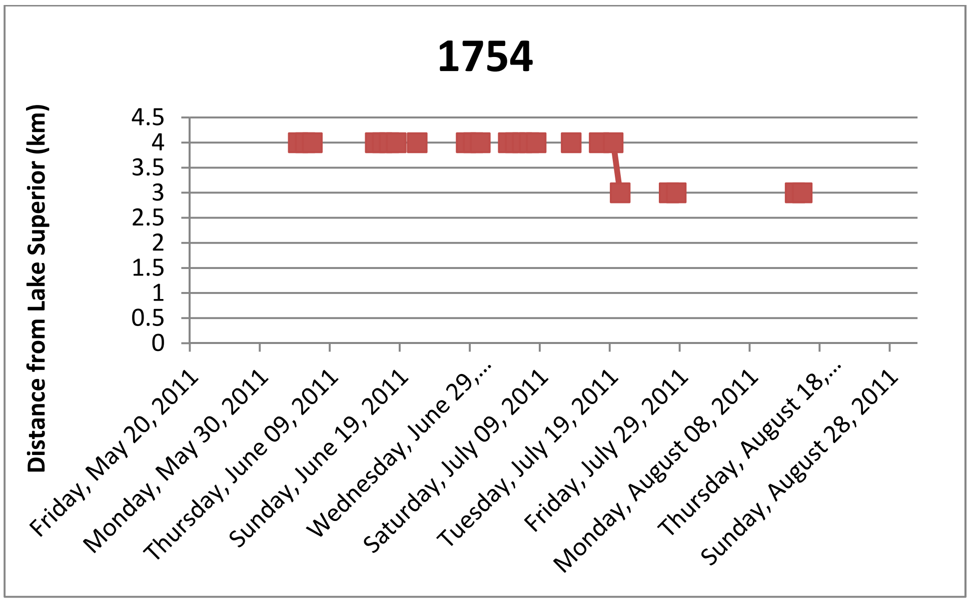
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Distance from Lake Superior (km)
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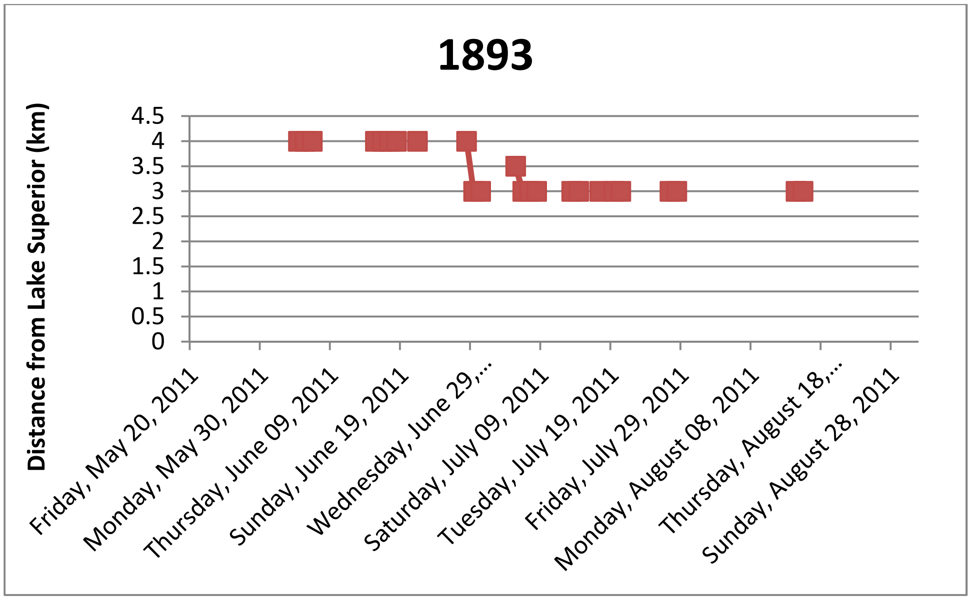
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Distance from Lake Superior (km)
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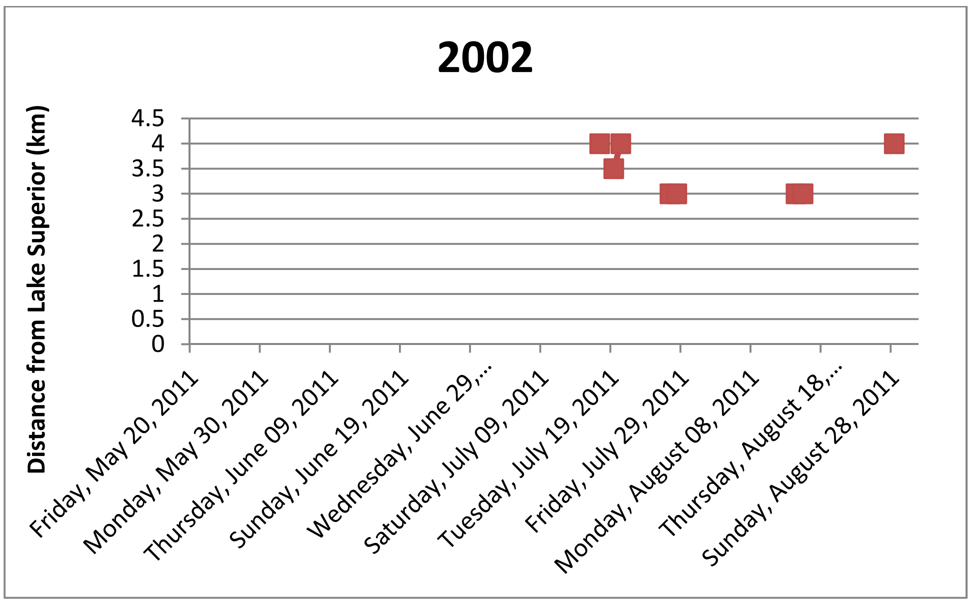
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0.5
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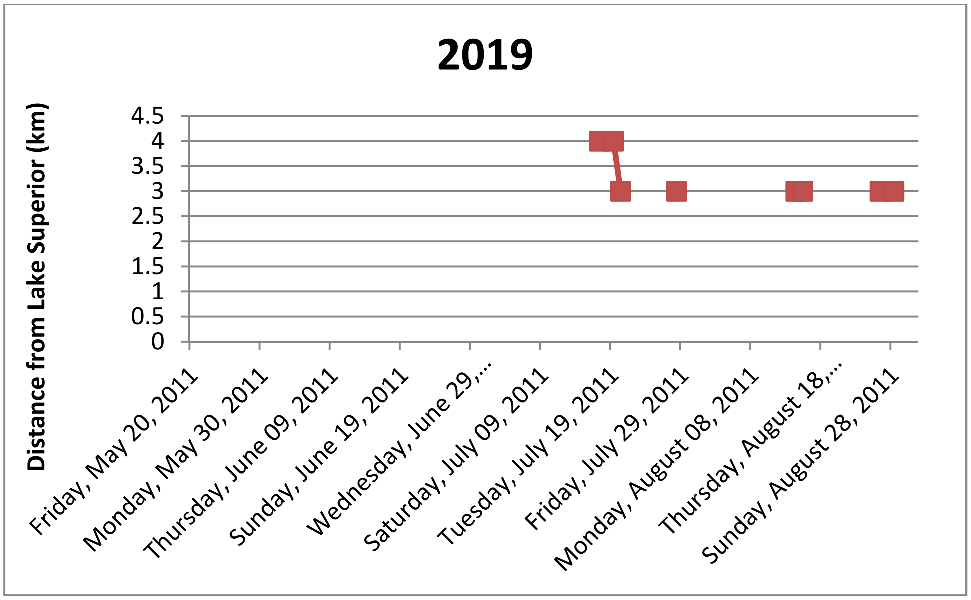
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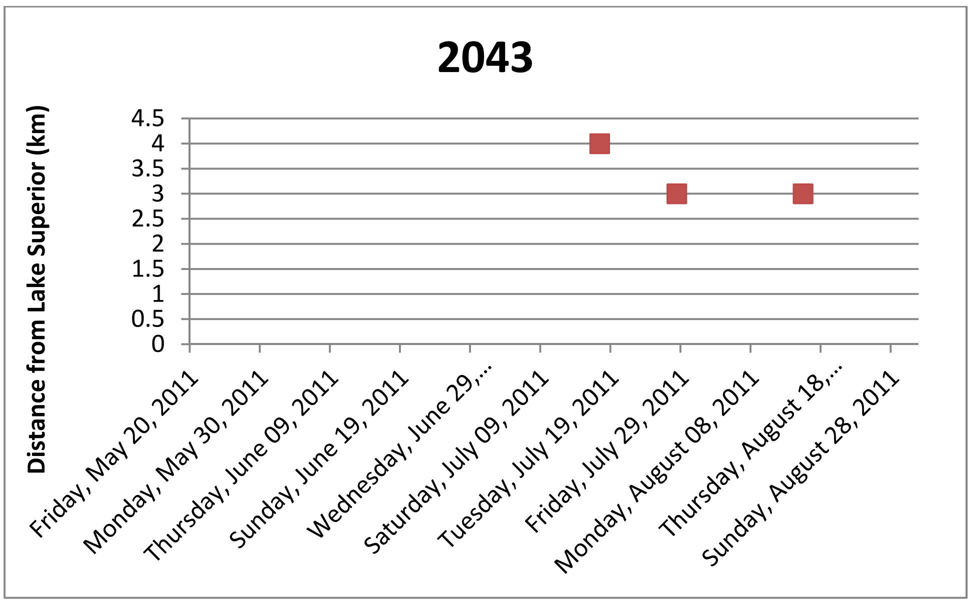
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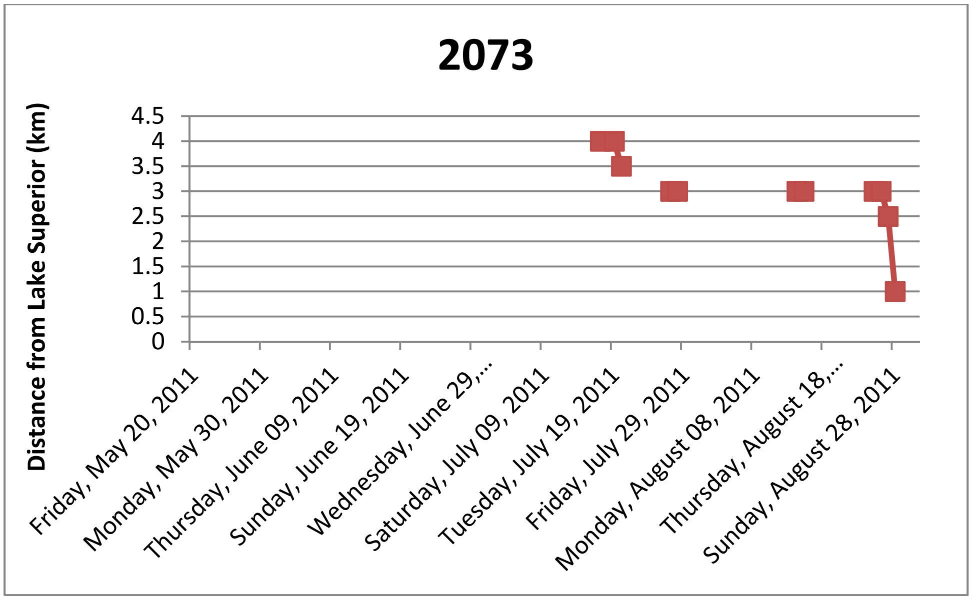
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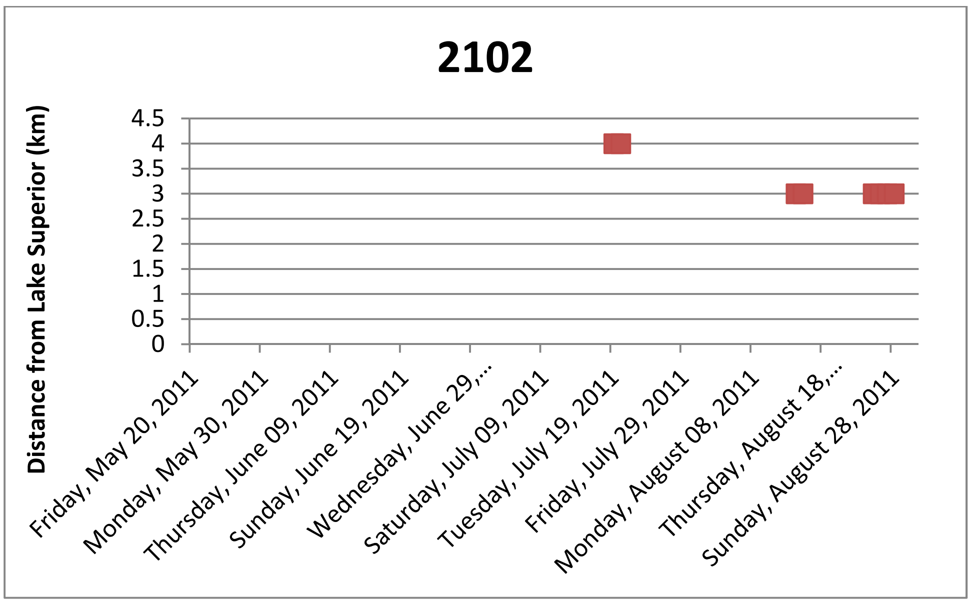
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Distance from Lake Superior (km)
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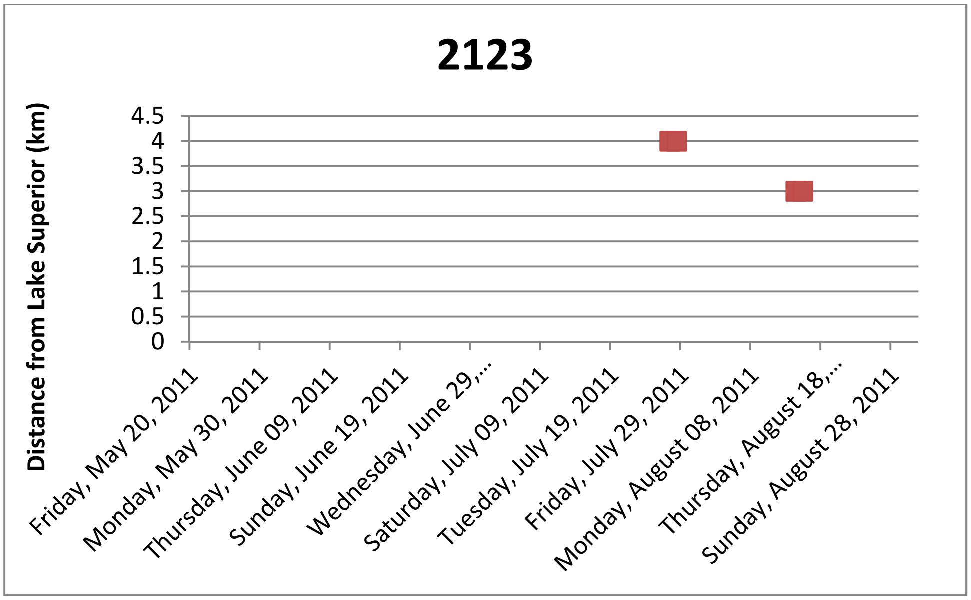
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Distance from Lake Superior (km)
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1.5
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0.5
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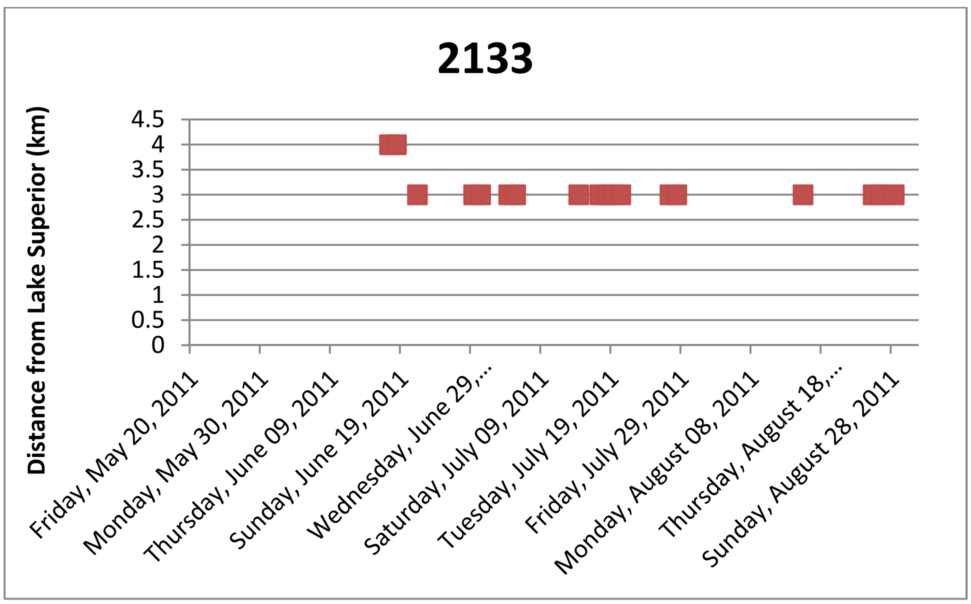
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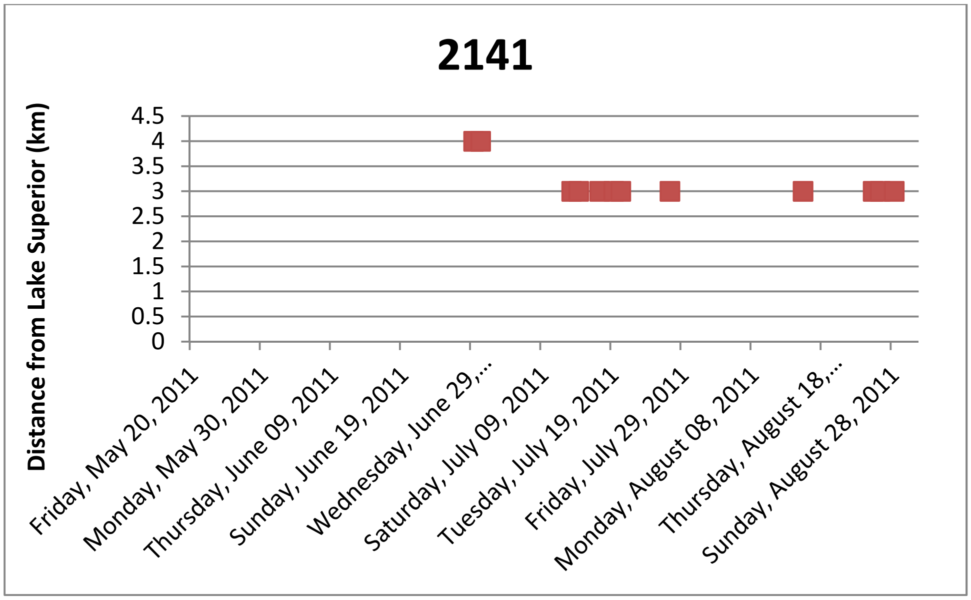
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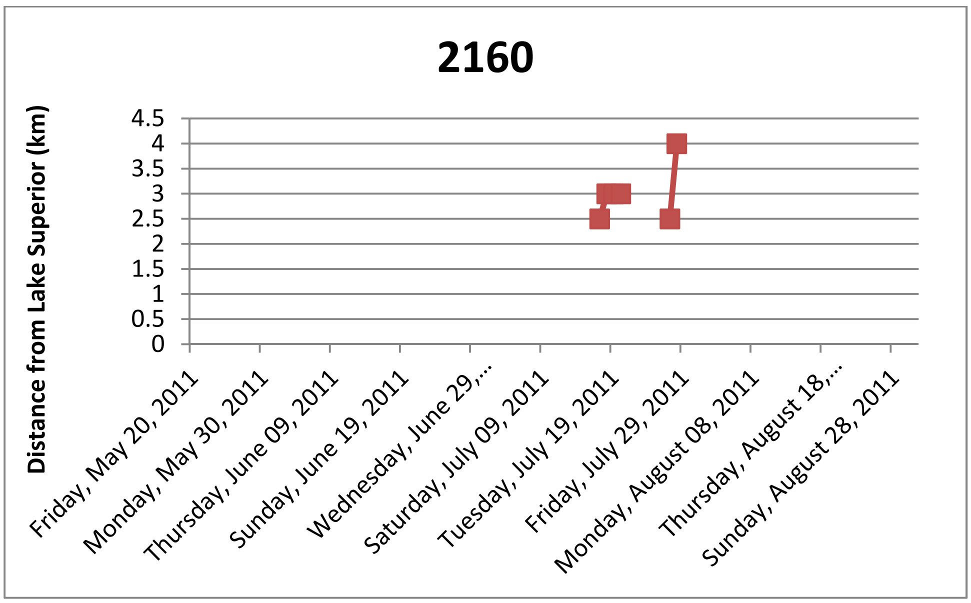
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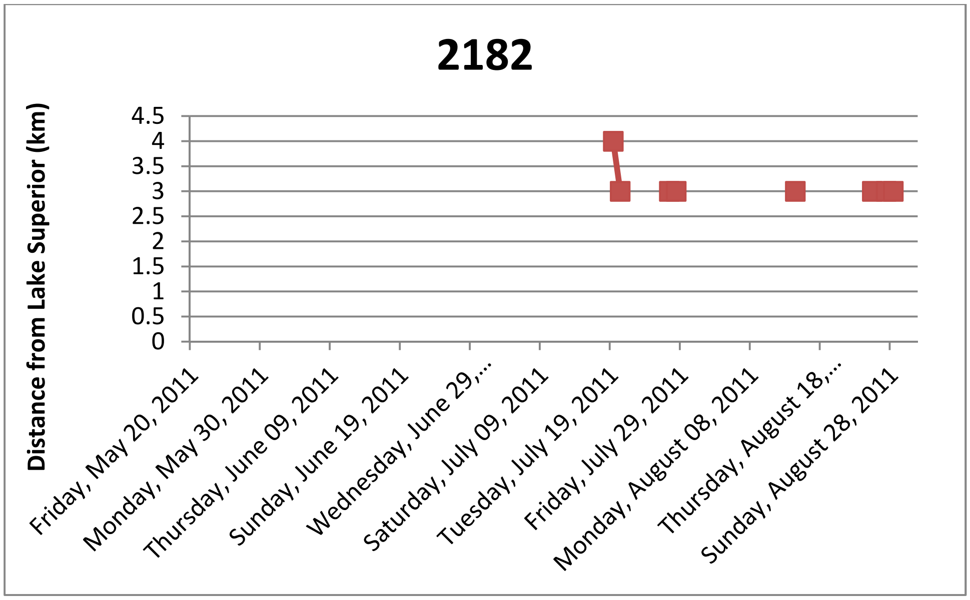
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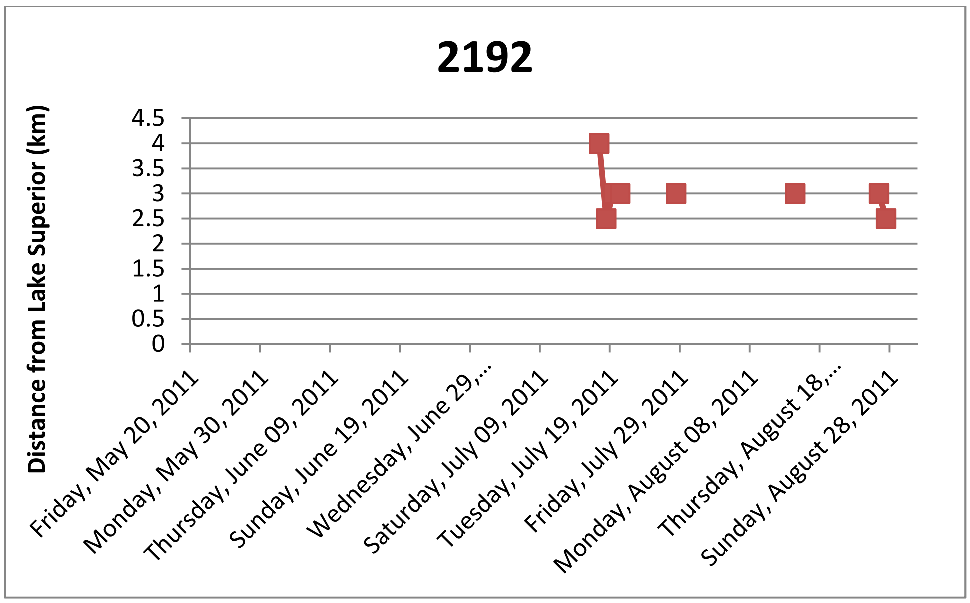
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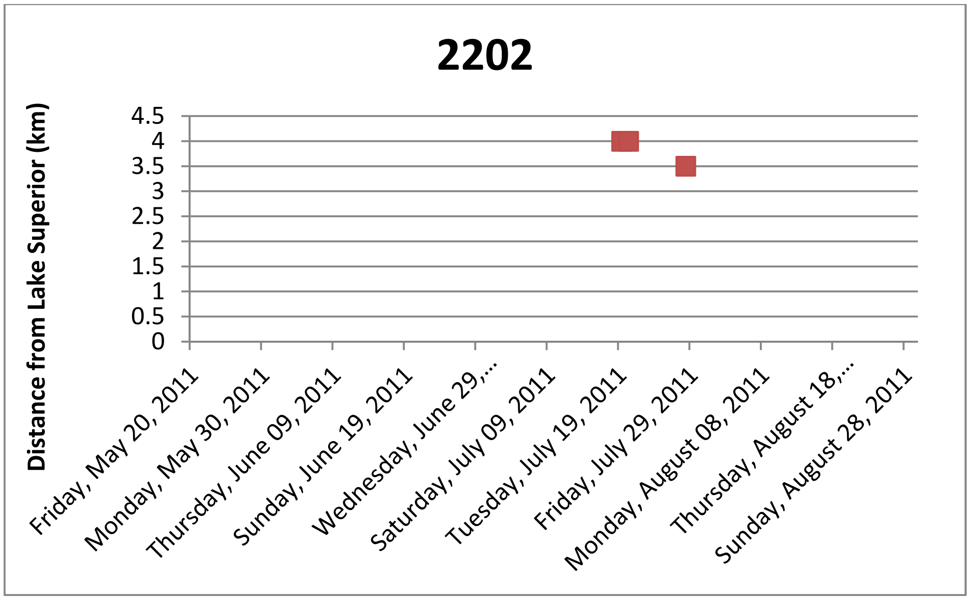
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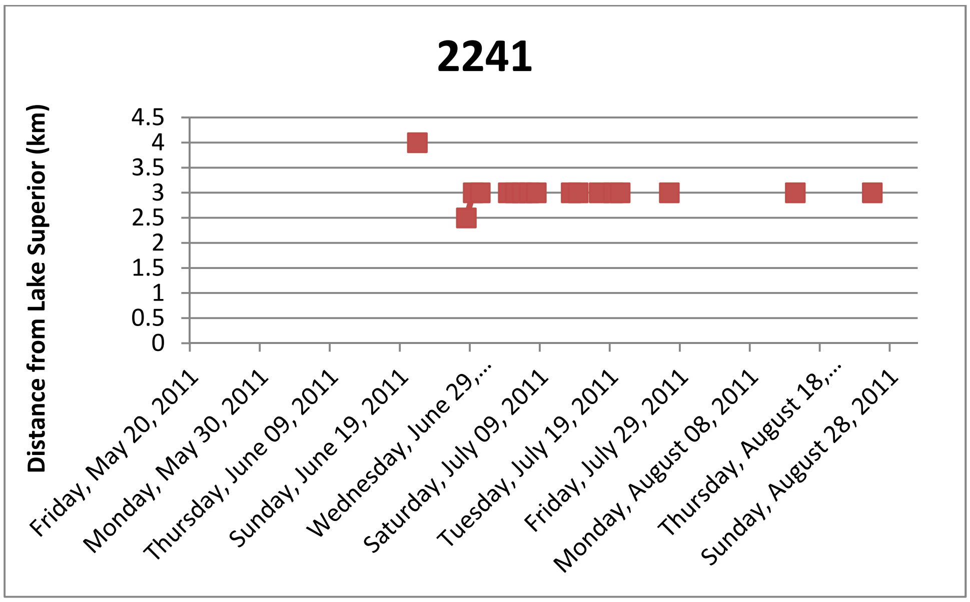
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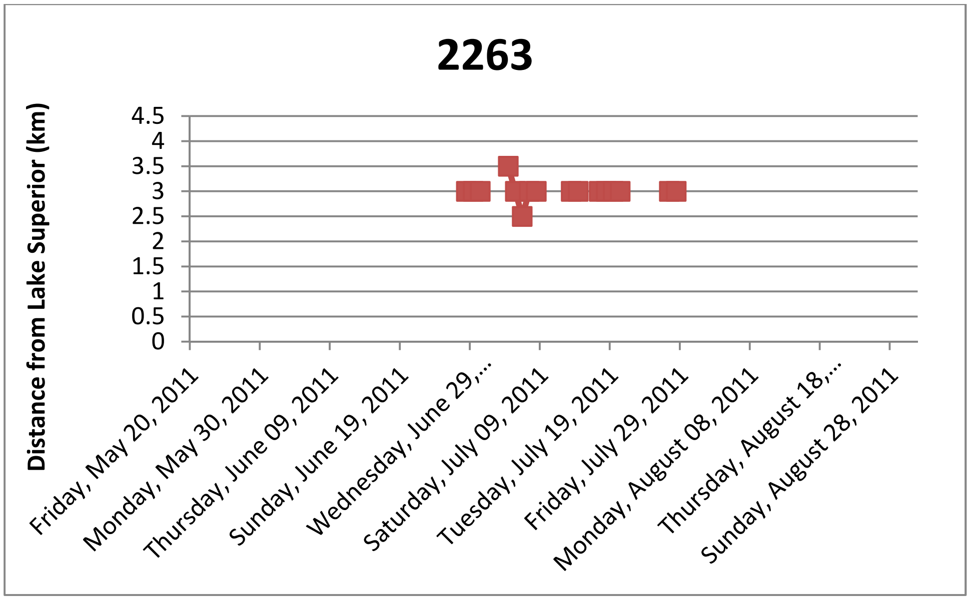
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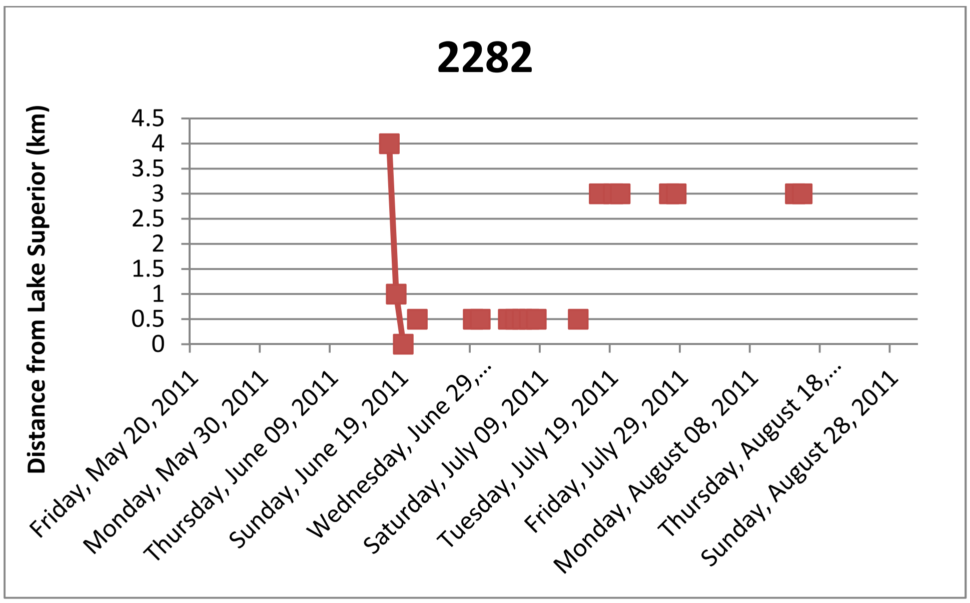
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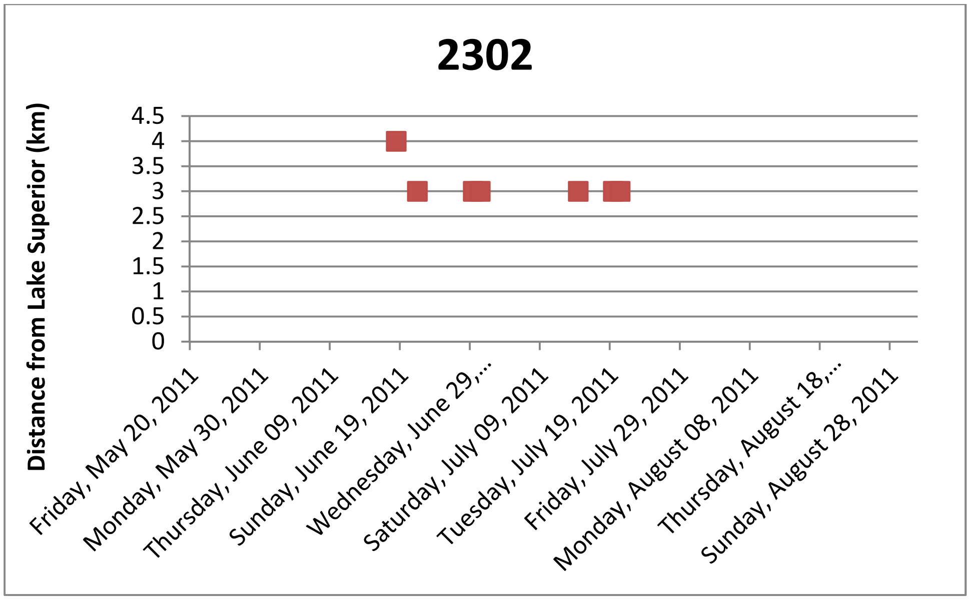
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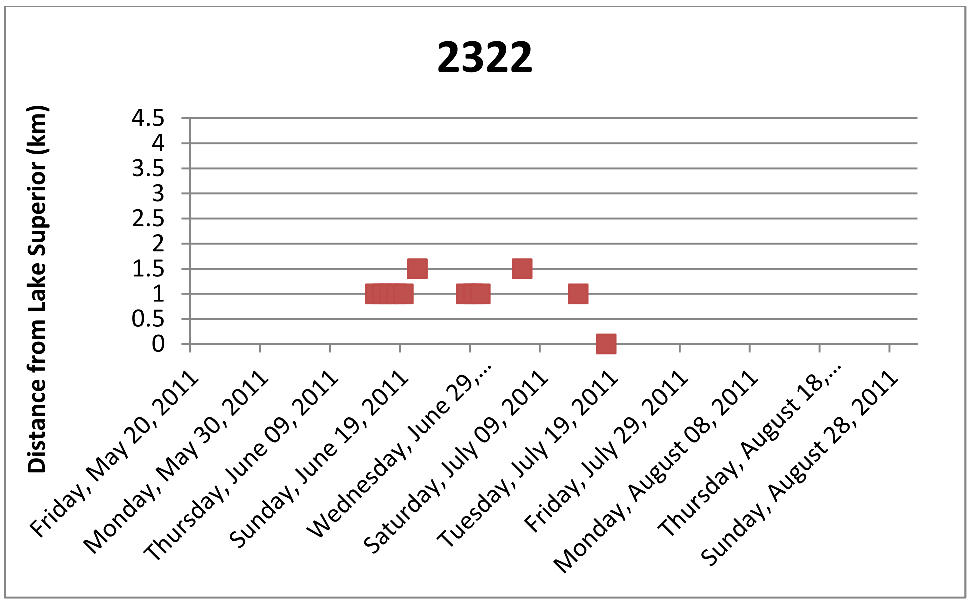
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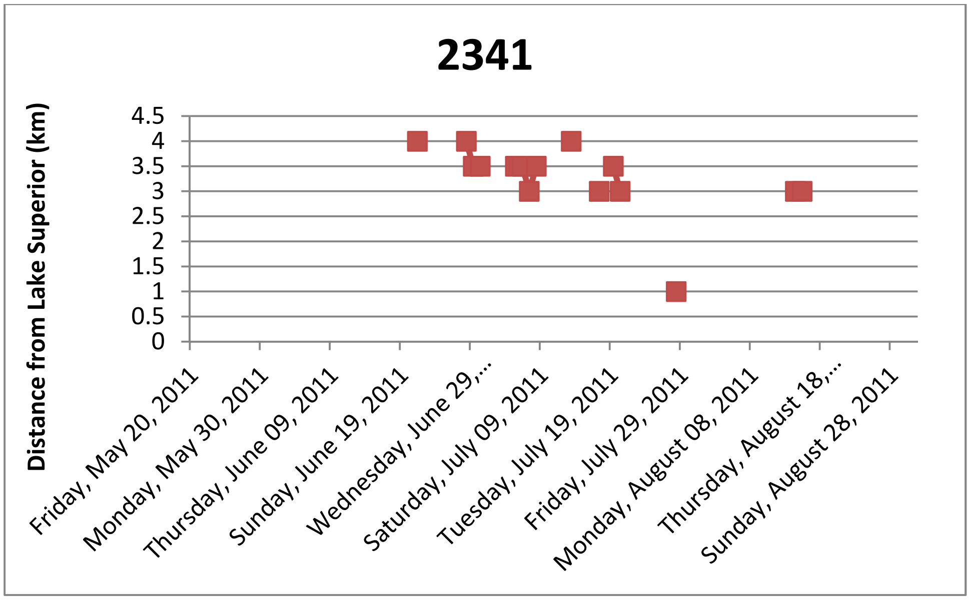
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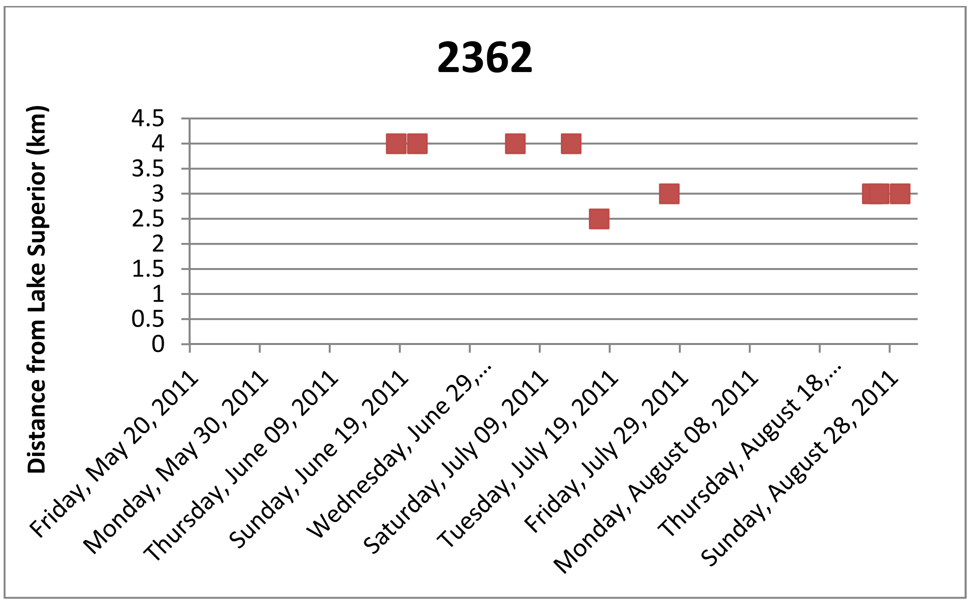
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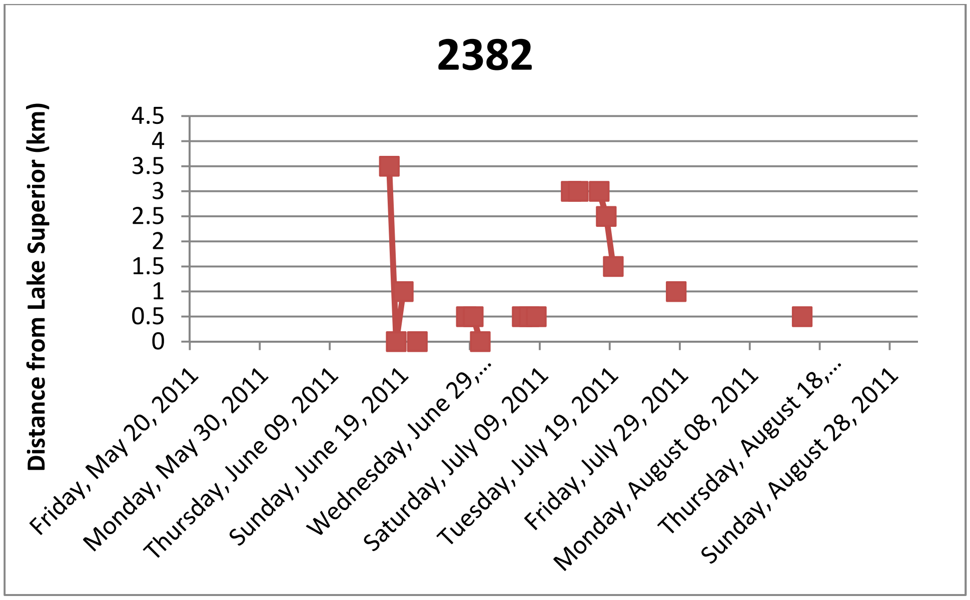
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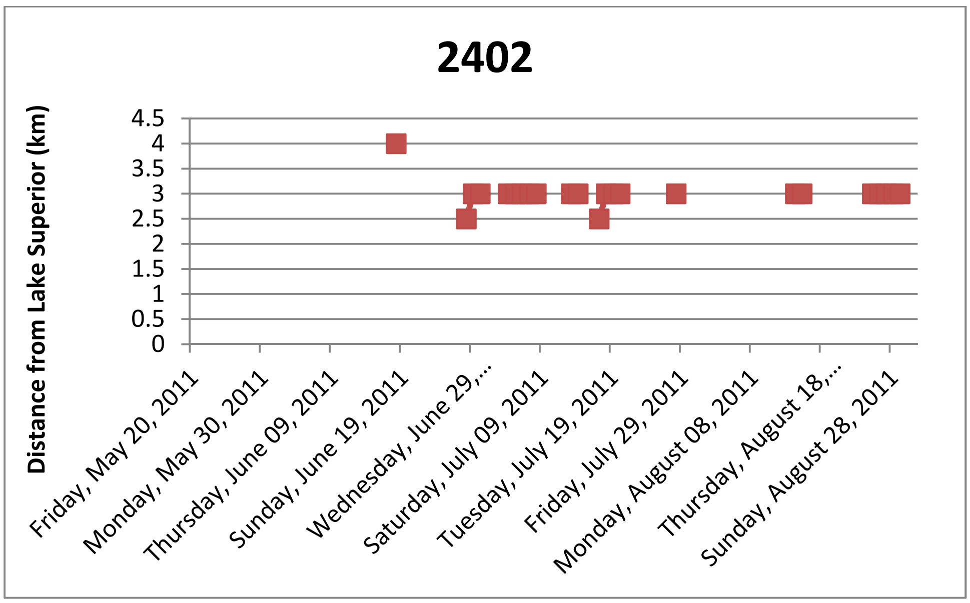
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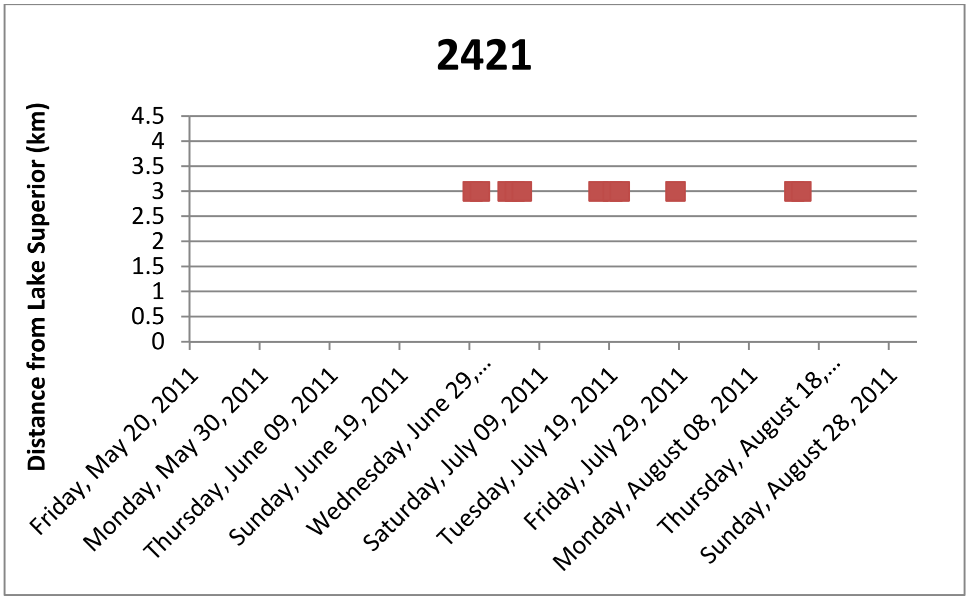
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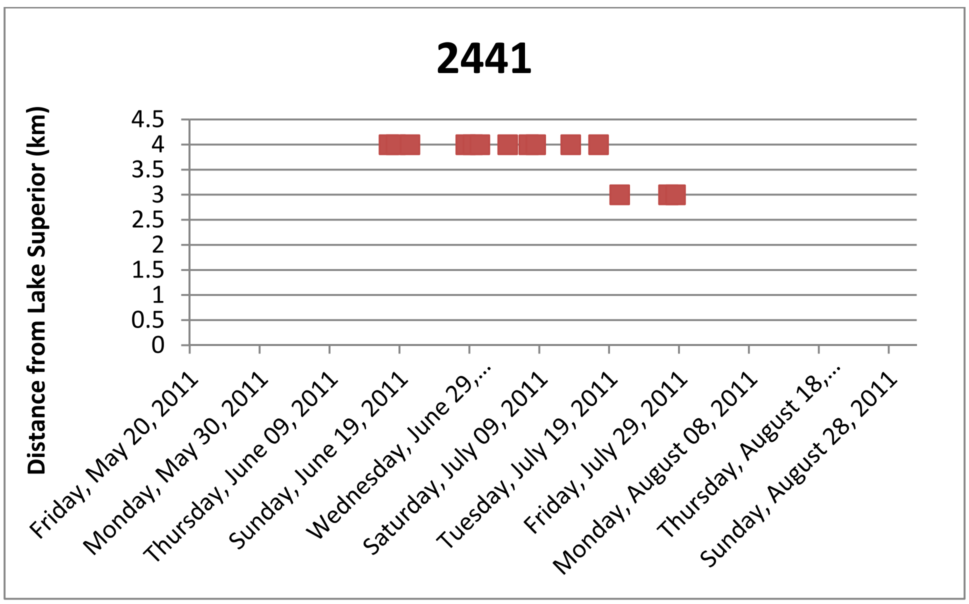
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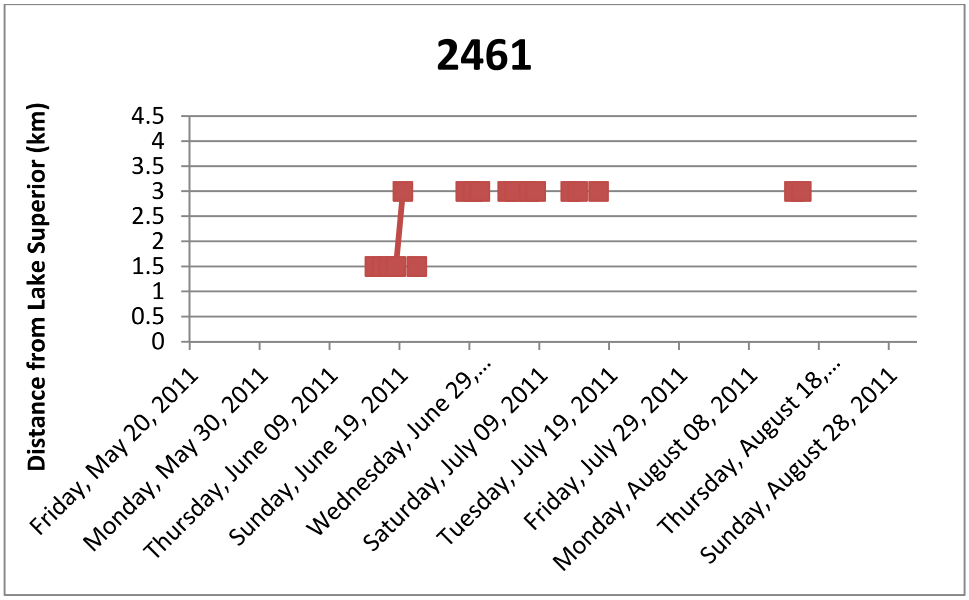
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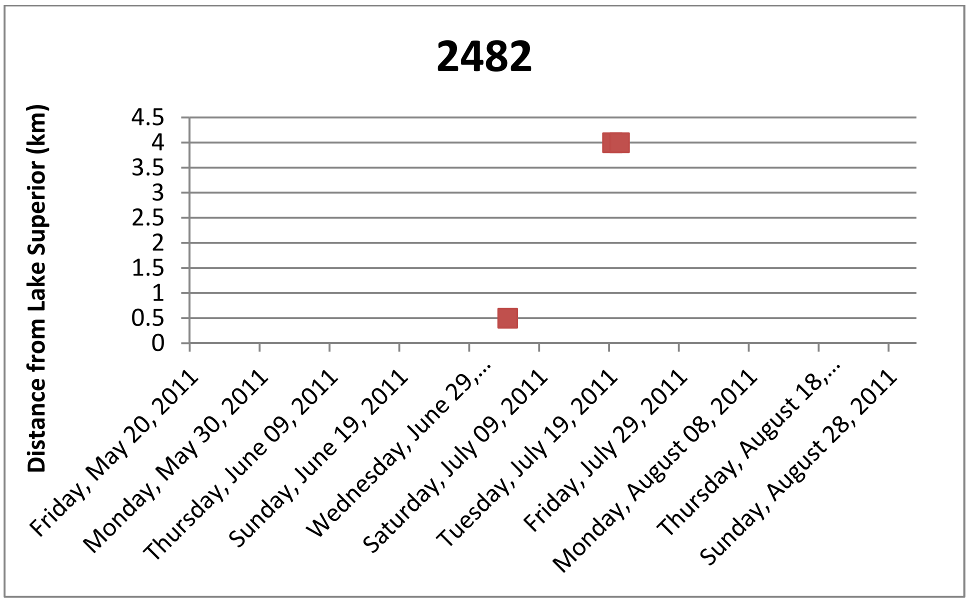
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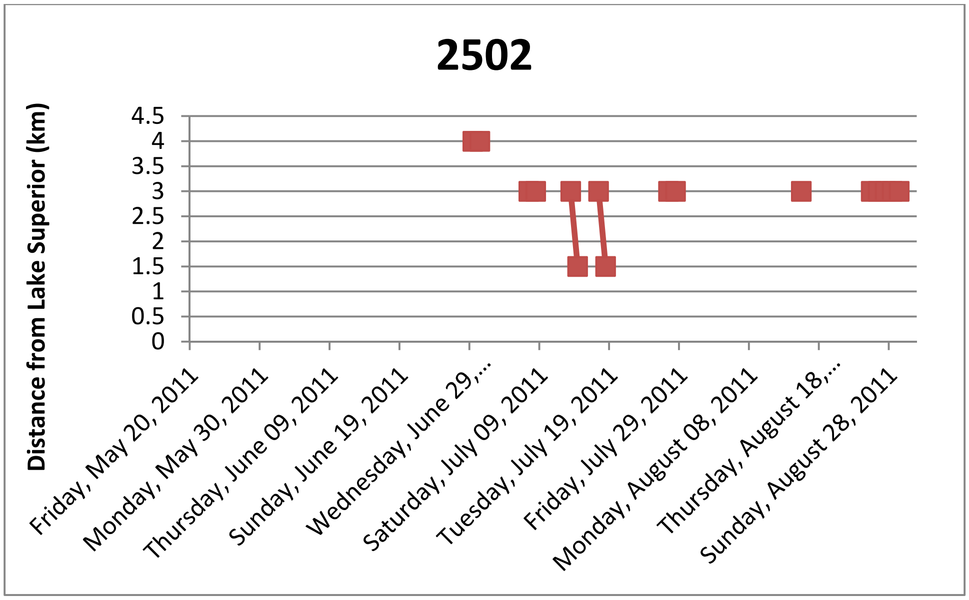
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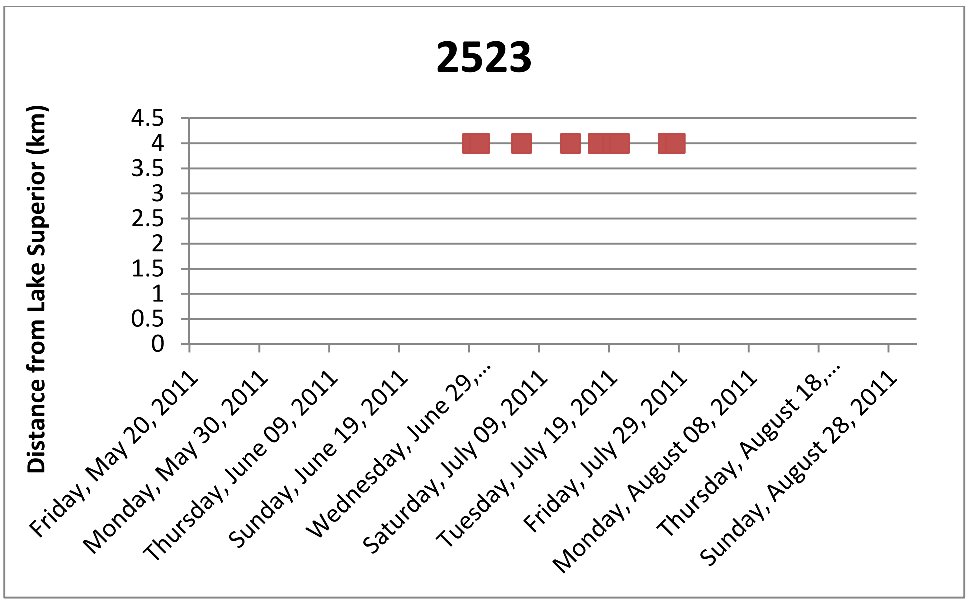
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Appendix 5 – Bonferoni's post-hoc test to test for significant differences between different weeks.

	25	26	27	28	29	30	31	32	35	36	37
25											
26	>0.05										
27	>0.05	>0.05									
28	>0.05	>0.05	>0.05								
29	**0.0119**	**0.0005**	>0.05	**0.022**							
30	>0.05	>0.05	>0.05	>0.05	**0.03**						
31	>0.05	>0.05	>0.05	>0.05	**0.003**	>0.05					
32	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05				
35	**0.0033**	**0.0036**	**0.048**	**0.024**	>0.05	**0.011**	**0.009**	>0.05			
36	**0.046**	**0.0425**	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05		
37	**0.0059**	**0.0137**	>0.05	>0.05	>0.05	**0.02**	**0.035**	>0.05	>0.05	>0.05	

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