Chapter 5

Relative recapture rate, movement and growth of age-0 and age-1 hatchery-reared Lake Sturgeon released into the Winnipeg River, Manitoba

Klassen, C.N. Growth rate and size variability within juvenile Lake Sturgeon cohorts. PhD Dissertation, University of Manitoba, Winnipeg, MB (in progress)

Abstract

Artificially propagated Lake Sturgeon, *Acipenser fulvescens*, were released into the Winnipeg River, Manitoba as age-0 fall fingerlings (FF) or age-1 spring yearlings (SY) to determine the influence of age/size-at-release on relative recapture rate, movement and growth. A total of 10,000 FF (114.4 ± 6.1 mm TL, 5.4 ± 0.8 g) and 415 SY (244.0 ± 16.0 mm TL, 59.1 ± 11.7 g) were released, of which 51 individuals were recaptured and identified as hatchery-reared fish from previously applied fin clips and/or passive integrated transponder (PIT) tags over a two year period. Gillnetting efforts from 2009 and 2010 showed that relative recapture rate was 24 fold greater for SY than FF. Lake Sturgeon released as yearlings also displayed higher site fidelity (100%) than FF (71%) and the mean total length ±SD of SY (338.9 ± 23.3 g) recaptured at age-2 were significantly greater than similarly aged FF (301.4 ± 55.0 mm). However, release location affected post-stocking performance among FF. For instance, FF were captured in greater numbers and displayed higher site fidelity following release into Numao Lake, a known nursery area for wild juveniles. One FF individual showed exceptional growth when located in a stretch of river known to have low Lake Sturgeon densities. Overall, the condition (K_{TL}) of hatchery-reared individuals was similar between SY (0.36 to 0.41) and FF (0.35 to 0.41), and comparable to wild juveniles of similar total lengths. Although length-at-release associated with different ages appears to influence post-release performance, inter-individual differences in size among hatchery-reared fish within stocking events could not be related to recaptures or movement distance. Longer acclimation periods prior to release and better marking techniques may have increased the overall recapture rates in this study, particularly among FF, and further research on these matters is suggested.

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Introduction

Lake Sturgeon, *Acipenser fulvescens*, are large cartilaginous fish inhabiting the fresh waters of the Great Lakes, Hudson-James Bay and Mississippi River watersheds (Scott and Crossman, 1973). At the turn of the 20th Century, commercial exploitation led to a precipitous decline in Lake Sturgeon populations across North America (Harkness and Dymond, 1961). Today most Lake Sturgeon populations are protected and closed to commercial fishing (Auer, 2004). However, recovery following the collapse has been slow and attributed to a number of factors including their unique life history characteristics of late maturation and infrequent spawning, blocked migratory paths and habitat degradation (Peterson et al., 2007). In Canada, eight designatable units (DU's) have been defined for Lake Sturgeon of which two have been assessed as special concern, one as threatened and five as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2006). In response, a number of government and conservation agencies have developed recovery and management plans for this species (ALSRT, 2011; MCWS, 2012; SRSMB, 2012).

Habitat protection is generally considered of primary importance in sturgeon conservation, though difficult to implement (Harkness and Dymond, 1961; Waldman and Wirgin, 1998; Van Eenennaam et al., 2001; Wilson and McKinley, 2004). As such, hatchery programs to enhance depleted sturgeon populations, including Lake Sturgeon, have become an essential element in recovery efforts (Auer, 2004; Pikitch et al., 2005). Simulation modeling suggests that early life stages have the greatest effect on overall population growth in sturgeon (Gross et al., 2002), yet it has been traditionally accepted and more recently confirmed that mortality is highest at this stage (Nilo et al., 1997; Caroffino et al., 2010). Stocking activities are driven by the understanding that loss of critical life history stages may be avoided through release of older, less vulnerable, individuals (Brown and Day, 2002). Despite the implementation of stocking programs in fisheries management for over a century, including those for Lake Sturgeon (Harkness and Dymond, 1961; Smith and Dingley, 1984), its overall effectiveness remains uncertain. Survival estimates of hatchery-reared sturgeon following release events have been variable and attributed to a number of factors including, but not limited to, gamete collection, rearing environment, size-at-release, and density-dependant effects (Justice et al., 2009; Crossman et al., 2011; Mann et al., 2011). Not unique to Lake Sturgeon stocking programs, Molony et al. (2003) points out that the majority of studies assessing stock enhancement programs have fallen below expectations, but that results are more likely than not associated with poor planning and lack of evaluation. In fact, evaluations of fish stocking programs have been rare in the past, with emphasis placed more on total numbers released (Blankenship and Leber, 1995; Bartley, 1999; Molony et al., 2003) and political support for stocking programs often remains high despite limited information on overall effectiveness (Fenton et al., 1996).

Information about Lake Sturgeon enhancement programs does exist but have generally focused on the recovery of more southern populations (Schram et al., 1999; Runstrom et al., 2002; Chalupnicki et al., 2011) with limited accounts from similar programs within their northern range. The need to expand recovery efforts in Canada following assessment by COSEWIC on population status requires better understanding of the effectiveness of such programs throughout their northern distribution. For example, all five Lake Sturgeon designatable units assessed by COSEWIC to be endangered are represented within the borders of Manitoba, Canada (COSEWIC, 2006) and stocking activity has been a commonly implemented strategy in Lake Sturgeon recovery efforts throughout the province (MCWS, 2012). The first account of Lake Sturgeon stocking into provincial waters using artificially propagated individuals was in 1926 at Gull Harbour on Lake Winnipeg (Harkness and Dymond, 1961); however, planned release events have been implemented on a more consistent basis since 1994 (MCWS, 2012). Stocking activity has primarily occurred in the fall with release of age-0 fingerlings but, improved culture techniques have allowed for an increasing number of age-1 yearling release events (MCWS, 2012). Assessment of these stocking events has been rare, and likely a function of inefficient collection methods for young age classes (Benson et al., 2005). Recent advances in juvenile collection procedures (Barth et al., 2009) have allowed for review of artificial propagation programs within the province.

The primary objective of this two year study was to compare post-release performance (movement and growth) and survival of hatchery reared age-0 fall fingerlings (FF) and age-1 spring yearlings (SY) from the 2008 Lake Sturgeon year class stocked into the Winnipeg River. Where possible, results were related to length-at-release within stocking events, geographic release location and behaviour of wild conspecifics in the same reach.

Materials and methods

Study area

Lake Sturgeon stocking assessments were conducted within an impounded area of the Winnipeg River between the Slave Falls (50º13’21”N, 95º34’06”W) and Seven Sisters (50º07’09”N, 96º01’03”W) Generating Stations (GS), a stretch of approximately 40 river km. Following establishment of both facilities in the early 1930’s, the river widened in a number of areas creating lake-like environments bounded by in- and out-flow constrictions of fast-flowing water (>1.0 m/s). In this study, ‘lake’ boundaries were adopted from Barth et al. (2011) and gillnetting effort occurred within the stretch of Numao Lake downstream of Scotts Rapids (4 km long), Nutimik Lake (4 km long), Dorothy Lake (9 km long), Margaret Lake (5 km long), Eleanor Lake (4.5 km long), Sylvia Lake (2 km long), and Natalie Lake (11 km long) (Figure 5.1).

Conditions are known to vary spatially and temporally within this reach of the Winnipeg River. The depths along the main channel are generally between 10-25 m (max. 45 m), and environmental variables differ with distance from the Slave Falls GS. For example, areas upstream of Dorothy Lake have greater water velocities (0.2 to 0.8 m/s) and larger particle sizes (>0.063 mm) than areas downstream of Nutimik Lake which have lower relative water velocities (<0.2 m/s) and particle sizes (<0.063 mm) (Barth et al., 2011). Flow rates within this river section vary seasonally within a normal range of 500 and 1500 m^3/s, but may exceed these levels in some years despite being heavily regulated. For example, in 2008 and 2009 flow rates reached levels that were among the highest recorded since 1958 (approximately 2400 m^3/s) (Cousins et al., 2012). Wild Lake Sturgeon are present within this reach of the Winnipeg River and, despite being a part of DU5 assessed to be endangered by COSEWIC (2006), the resident population is considered healthy (Cleator et al., 2010; MCWS, 2012). Recent study has also shown that the wild juvenile population is more heavily concentrated in the upper reaches (e.g., Numao and Nutimik Lakes) (Barth et al., 2011).

Rearing and marking

Stocked Lake Sturgeon originated from wild adults (8 females, 16 males) collected at an established spawning site within the Winnipeg River directly downstream of the Slave Falls GS. Eggs were transported to the Canadian Rivers Institute Field Station near Pinawa, Manitoba (50º08’54”N, 95º55’01”W) on 28 & 29 May, 2008 within two hours of shore-side fertilization. Synchronization of egg collection was facilitated by the use of a commercially available hormonal agent (Ovaprim, Syndel Laboratories Ltd., Vancouver, BC, Canada). The total dose administered to females was based on body weight (0.5 ml per kg) with a priming injection (10% of total dose) followed 12 hours later with a second injection (90% of total dose). Milt was collected opportunistically from males gillnetted on the spawning grounds.

Majority hatch occurred nine days following fertilization using McDonald hatching jars at an incubation temperature of 12ºC ± 1ºC. Yolk-sac larvae were transported to the Grand Rapids Fish Hatchery, Grand Rapids, Manitoba (53º09’46”N, 99º16’37”W) prior to first-feeding for grow-out until release. Lake Sturgeon were fed an exclusive diet of live brine shrimp nauplii (*Artemia* spp.; Argent Laboratories, Redmond, WA, USA) for the first month of exogenous feeding at which time fish were transitioned to a diet of frozen bloodworm (Diptera: Chironomidae; Hikari, Hayward, CA, USA). Feedings were ad libitum. During the summer Lake Sturgeon were reared in a flow-through water system using a blend of well and surface (Cedar Lake, Manitoba) water at a temperature of 17ºC ± 1ºC. Prior to the fall stocking event, a total of 7,500 Lake Sturgeon fingerlings were divided into three groups and marked by removing the pelvic or anal fin depending on designated release location (Table 5.1). A subsample of individuals from each release group were measured for total length (TL) and body mass before being implanted with an 8 mm passive integrated transponder (PIT) tag (Biomark, Boise, ID, USA) in the body cavity by way of a mid-ventral incision. Tagged Lake Sturgeon fingerlings had a mean TL of 114.4 ±6.1 mm (±SD) and mean body mass of 5.4 ±0.82 g (±SD). An additional 2,500 fingerling Lake Sturgeon were released into Sylvia Lake but did not receive any mark.

Remaining Lake Sturgeon fingerlings were switched to a water recirculation system on 1 Nov, 2008 to maintain overwintering temperatures near summer rearing temperatures for continued growth until the spring release. A total of 415 Lake Sturgeon yearlings were available for a spring stocking event and on 14 May, 2009 all individuals were measured for TL and body mass when implanted with a 12 mm PIT tag (Biomark, Boise, ID, USA) in the abdominal cavity as described above. Yearlings were divided into two groups for release into Numao and Dorothy Lakes (Table 5.1). Lake Sturgeon yearlings had a mean TL of 244.0 ±16.0 mm and mean body mass of 59.1 ±11.7 g.

Release

Lake Sturgeon fingerlings were released mid September 2008 into Sylvia, Dorothy, Nutimik and Numao Lakes (Table 5.1, Figure 5.1). Fish were transported in a non-insulated plastic tank during day-light hours approximately 535 km by truck from the Grand Rapids Fish Hatchery to Pinawa, Manitoba (50º09'01"N, 95º52'47"W). Upon arrival, Lake Sturgeon were transferred to a tank assembled on a pontoon boat and driven to the release site. Water exchanges on route to the release site provided acclimation to ambient river temperatures. The boat was positioned slightly upstream of the targeted release site and allowed to drift as crew members used nets to fish out the fingerlings and release them into the river.

The following spring a similar procedure was undertaken to transport yearlings to the designated release sites on 12 June, 2009 using a custom transport trailer holding two insulated fiberglass tanks. A divider placed within the tank on the pontoon boat allowed both groups to travel to their respective release sites concurrently.

Fish capture and sampling

Post-release information on hatchery-reared Lake Sturgeon was gathered using 25 mm stretched twisted nylon mesh gill nets (Leckie's Lakefish Net and Twine, Winnipeg, Manitoba, Canada) of between two or four panels, each measuring 22.9 m long and 1.8 m deep. This mesh size was selected as it has been shown to capture Lake Sturgeon within the targeted size range (<300 mm FL) and minimizes mortality of juvenile Lake Sturgeon and other species (Barth et al., 2009). Nets were bottom-set at various locations along the Winnipeg River between 14 June and 2 October in 2009 and 11 May and 6 October in 2010. Gill nets were set overnight and mean (± SD) set duration was 20.5 (± 2.5) hours in 2009 and 23 (± 3.1) hours in 2010. The coordinates of each site was recorded using a handheld GPS unit (Garmin, model #GPS 76, Olathe, Kansas). In both years, a concentrated effort was placed at or near the stocking location and these efforts occurred multiple times throughout the field season to account for seasonal changes. Additional sites were arbitrarily selected in 2009 to survey prospective areas where fish may be found, whereas in 2010, sites were selected based on previous year successes and areas known to support wild Lake Sturgeon in the same impounded stretch of river (Barth et al., 2009; Barth et al., 2011; Henderson, 2013).

All Lake Sturgeon captured were checked for a previously applied tag or fin clip. Detection of PIT tags were conducted using a Biomark Pocket Reader (Biomark Inc., Boise, Idaho). Lake Sturgeon were measured for total length and body mass. In 2009, unmarked Lake Sturgeon of sufficient size were marked with an individually numbered Floy FD-94 T-bar anchor tag (Floy Tag Inc., Seattle, WA, USA) applied between the basal pterygiophores of the dorsal fin using a Dennison Mark II tagging gun. Lake Sturgeon measuring less than 350 mm TL received a 12 mm PIT tag inserted into the body cavity as described above. In 2010, unmarked Lake Sturgeon received a Floy and/or PIT tag when supplies were available. Other species of fish were enumerated and measured for fork length, but this data is not presented here.

On occasion, hatchery-marked individuals were captured in the gill nets of other studies in the Winnipeg River. Information received from field programs other than the present study was incorporated into analyses where appropriate.

Recaptures

Catch-per-unit-effort (CPUE, #LKST/100m/24hr) was calculated to standardize information between 1) fall and spring Lake Sturgeon release groups, 2) hatchery-reared and wild Lake Sturgeon, and 3) sampling lakes using the following equation:

$$CPUE\ (\#\ LKST/100m/24h) = \sum Lake\ Sturgeon\ captured \div \sum Effort\ x\ 24\ hr,$$

where *Effort* is expressed as gillnet hours and calculated by taking set duration (in hours), multiplying by the total net length (m), and dividing by 100 m (standardized measure). Only hatchery-reared individuals collected from the gillnetting efforts of this study were included in CPUE calculations.

To account for the different stocking rates, 'relative recapture rate' between the two Lake Sturgeon release groups was compared using the following equation (after Brooks et al., 2002):

$$Relative\ Recapture\ Rate = (y_f/Y_f)/(f_e/F_e),$$

where y_f = number of yearlings stocked in location f and later recaptured, Y_f = number of yearlings stocked in location f, f_e = number of fingerlings stocked in location e and later recaptured, and F_e = number of fingerlings stocked in location e. Relative recapture rate was calculated for each lake when at least one Lake Sturgeon was recovered from both release events (e.g., fall and spring). As such, relative recapture rates could not be compared for Nutimik Lake because yearlings were not stocked within this lake. All recaptured hatchery-reared fish during the 2009 and 2010 field seasons were included in calculations, including those captured in other study efforts.

Length-frequency distributions were plotted using intervals of 20 mm (e.g., 210-229 mm) for Lake Sturgeon captured in the gillnetting efforts of this study. Incorporated into the plot were the frequencies of hatchery-reared individuals. To clarify, the number of wild, FF and SY in each length interval was divided by the overall number of Lake Sturgeon captured within that study year, regardless of background. Only hatchery-reared individuals collected in the gillnetting efforts of this study were plotted.

To determine if recapture rates of FF and SY was dependant on size at release, the length-at-release for all PIT tagged individuals recaptured in the Winnipeg River (e.g., including other study efforts) were plotted at intervals of 5 mm (e.g., 105-109 mm) and compared to the length-at-release distribution for all PIT tagged individuals stocked. A Two Sample Kolmogorov-Smirnov (K-S) test was used to compare length-at-release frequencies among stocked and recaptured individuals from fall and spring release events, respectively.

Movement

Site fidelity was assessed by comparing the number of FF and SY that moved through the downstream constriction defining the lower lake boundary from where they were released with those individuals that did not. A Fishers exact test was used due to small sample sizes and assumption violations for the Chi-square test.

For all recaptured hatchery-reared Lake Sturgeon in this and other study efforts, the distance (river km) between recapture and release site was measured using computer software (Google Earth, version 4.1). Of interest was movement in relation to size-at-release. As such, the initial size-at-release of all recaptured individuals containing a PIT tag was plotted against the total downstream (- values) or upstream (+ values) distance moved. Linear regression was used to assess the relationship between size-at-release and distance moved for all released hatchery-reared fish, as well as, for FF and SY independently.

Growth

Mean total length, body mass and condition of all hatchery-reared Lake Sturgeon recaptured in 2009 and 2010 were compared between FF and SY using the Mann-Whitney U test. Condition factor (K) was calculated using the following equation (after Fulton 1911 *in* Ricker 1975):

$$K_{(TL)} = W \times 10^5 \div TL^3,$$

where W = body mass (g) and TL = total length (mm).

Statistical analyses were completed using SYSTAT (version 9) at a significance level of $P \leq 0.05$.

Results

During the gillnetting efforts of this study, 238 and 303 sites were sampled across the Winnipeg River in 2009 and 2010, respectively. Overall, 12 FF and 17 SY were recaptured and accounted for a very small percentage of the total catch (e.g., 0.37% and 0.46%, respectively). Wild Lake Sturgeon made up 42.5% of the overall catch with all other species accounting for 56.7%.

Other field programs operating within the same stretch of river in 2008 and 2009 produced an additional 22 FF and 2 SY. Table 5.2 and Table 5.3 summarize the information for all recaptured FF and SY, respectively.

Recapture rate

Table 5.3 summarizes the overall CPUE values calculated for Lake Sturgeon in the present study. The number of SY captured during the two year study was slightly greater (0.04 fish/100m/24h) than for FF (0.03 fish/100m/24h). Regardless, the overall CPUE value for all hatchery-reared fish (0.72 fish/100m/24h) was well below that of wild Lake Sturgeon during the same two year period (3.7 fish/100m/24h). The highest CPUE value for hatchery-reared Lake Sturgeon was in Numao Lake (0.21 fish/100m/24h) and this was also true for wild Lake Sturgeon (10.0 fish/100m/24h). Interestingly, when assessing the data by release group, SY had the highest overall CPUE value in Dorothy Lake (0.09 fish/100m/24h) whereas the greatest number of FF were recaptured in Numao Lake (0.13 fish/100m/24h).

An unexpected increase in the CPUE values for Lake Sturgeon in Sylvia Lake suggests that unmarked hatchery-reared individuals were being captured in the gillnetting efforts of this study. However, of the 46 Lake Sturgeon captured in Sylvia Lake over two years, only 4 were within a length interval of other hatchery-reared Lake Sturgeon captured elsewhere (see below). Furthermore, 3 of these 4 individuals had been previously PIT tagged and were part of a study assessing wild juvenile Lake Sturgeon movements following transplantation to Sylvia Lake from other areas along the Winnipeg River (S. Peake, pers. com.).

Trends associated with recapture rates were quite pronounced when taking into account the different stocking rates between the two release groups. Across all lakes stocked, the recapture rate of SY during the two year study was 24.0 times greater than for FF. In fact, the overall recapture rate of hatchery-reared fish released in Dorothy Lake was 144.2 times greater for SY than FF. For individuals released into Numao Lake the relative recapture rate was 5.5 times greater for SY over FF.

Hatchery-reared Lake Sturgeon recaptured in the gillnetting efforts of this study were within the length intervals between 230 to 429 mm. In 2009, of the 393 Lake Sturgeon captured, 12.7% of individuals were within this size range (Figure 5.2a). Likewise, of the 1,025 Lake Sturgeon captured in 2010, 12.4% were within this size range (Figure 5.2b). Lake Sturgeon less than 230 mm represented 14.2% and 2.4% of the catch in 2009 and 2010, respectively. In this study the majority of Lake Sturgeon captured were greater than 429 mm and represented 73.0% and 85.2% of the catch in 2009 and 2010, respectively.

Significant differences were not found between the length-at-release frequency distribution of recaptured PIT tagged FF in comparison to the frequency distribution of all PIT tagged individuals stocked (Two sample K-S, P = 0.264; Figure 5.3a). In contrast, a significant difference was found between the length-at-release frequency of SY recaptured in comparison to the frequency distribution of all PIT tagged SY stocked (Two sample K-S, P = 0.038; Figure 5.3b). However, this discrepancy does not appear to be the result of a skewed distribution (e.g., favouring recapture of large or small individuals).

Movement

Spring Yearlings showed strong site fidelity following release. In contrast, 67%, 22% and 21% of all recaptured FF released into Dorothy, Nutimik and Numao Lakes, respectively, had dispersed past river constrictions and into the lake downstream of their release site. The proportion of FF recaptured in a downstream lake from that released (10 of 34) was significantly greater than for SY (0 of 10) (Fisher's exact test: P = 0.021).

A significant linear relationship was observed between length-at-release and distance moved (rkm), when incorporating both upstream (+) and downstream (-) direction for all recaptured and previously PIT tagged hatchery-reared Lake Sturgeon recaptured in this and other gillnetting efforts (Linear Regression, n = 29, P = 0.003, r^2 = 0.28; Figure 5.4). In contrast, when assessing the same relationship among FF and SY independent of each other, there was no evidence of one (FF: n = 12, P = 0.0.79, r^2 = 0.01; SY: n = 17, P = 0.42, r^2 = 0.04; Figure 5.4).

Growth

Lake sturgeon released as yearlings had the advantage of continuing their growth during the winter months. Spring yearlings maintained significantly greater total lengths during the 2009 and 2010 field seasons, but the difference in body mass was not significantly different by 2010 (Table 5.5). This result is somewhat misleading as the majority of FF were smaller than SY (Table 5.2, Table 5.3). The results of 2010 were highly influenced by a single FF that was recaptured in Eleanor Lake and attained a total length and body mass well above any other hatchery-reared Lake Sturgeon, including those released as yearlings. Removing this individual from analysis resulted in a significant difference between body mass among FF and SY in 2010 (Mann-Whitney $U = 26.5$, $P = 0.03$). Despite discrepancies in size, the condition (K_{TL}) of FF and SY was not significantly different at any period throughout the study (Table 5.5).

Discussion

Recovery efforts for threatened and endangered Lake Sturgeon populations have included the release of hatchery-reared individuals throughout their distribution, but assessments throughout their northern range are lacking. The primary objective of this study was to compare the post-release performance of hatchery-reared Lake Sturgeon from the same year-class stocked into the Winnipeg River, Manitoba, as fall fingerlings and spring yearlings. Over a two year field program relative recapture rates, site fidelity and growth patterns between both release groups were quantified.

Recapture rates for hatchery-reared Lake Sturgeon released as fingerlings and yearlings were low over the two year study, but relative recapture rate was 24 fold greater in the latter. This was not entirely unexpected and is in line with a number of studies that have found that stocking older, larger fish leads to greater post-release recapture rates than stocking younger, smaller individuals (Hoff and Newman, 1995; Salminen et al., 2007; Kampa and Hatzenbeler 2009), including different sturgeon species (Justice et al., 2009; Steffensen et al., 2010; Crossman et al., 2011). The cause for poor fingerling recapture rates was not quantified in this study but several reasons can be speculated.

Susceptibility to predation has been shown to increase with decreasing body size (Paradis et al., 1996) and high rates of predation for smaller individuals of other species following stocking events have been reported (Marsh and Brooks, 1989; Szendrey and Wahl, 1996; Buckmeier et al., 2005). However, vulnerability of small sturgeon to predation is equivocal (Gadomski and Parsley, 2005a,b; French et al., 2010) and, despite attempts to quantify it, predation was not observed among juvenile Lake Sturgeon in the present study site (Barth et al., 2009). Inadequate energy reserves among small fish resulting in high overwinter mortality following release is another potential cause for the reduced recapture rates of fingerlings (Thompson et al., 1991; Sutton and Ney, 2001) and this may have occurred in the present study. For instance, temperatures within the study site can drop to 1°C (Barth et al., 2011) and the mean size of fall fingerlings at 114 mm TL and 5.4 g appears to be less than wild young-of-the-year (YOY) in the same system where Henderson (2013) reported that the median size of age-0 Lake Sturgeon captured during fall of 2008 was 154 mm TL and 9.7 g (n = 19). Likewise, the smallest wild caught Lake Sturgeon in fall and spring gillnetting efforts of this study was 150 mm TL. A similar discrepancy was observed among wild and hatchery-reared Lake Sturgeon in the Wolf River, Wisconsin (Kempinger 1996) and stocking efforts in the Great Lakes have focused on producing Lake Sturgeon fingerlings to a size > 200 mm in order to improve post-stocking survival (Schram et al., 1999). However, PIT tag information from recaptured fall fingerlings revealed that the smallest known hatchery-reared fish to survive the first winter following stocking was 105 mm TL (5.0 g) indicating that the overwintering size threshold, if it exists for juvenile Lake Sturgeon, falls below the mean size of released FF. Gear selection may have favoured the capture of larger individuals (Millar and Fryer, 1999), but this seems unlikely as the 25 mm mesh gill nets used in this study did capture wild Lake Sturgeon individuals as small as 90 mm TL and the greatest number of fingerlings (n = 21, 61.8%) were captured within a two week period immediately post-release.

Another potential reason for reduced recapture rates of the stocked fingerling fish may have been that this group experienced higher rates of mortality as a result of stress due to transportation and/or limited river time acclimation. Hatchery-reared individuals were in transport over a 6 to 10 hour period from the Grand Rapids Fish Hatchery to their release location. However, in a recent study on fingerling sized Persian Sturgeon, *Acipenser persicus*, plasma levels of glucose, lactate, and cortisol (standard metrics of stress induced physiological impairment) did not differ between samples taken before and 24 hours after handling and 1.5 hours of transport (Falahatkar et al., 2012). Therefore, while delayed morality from transport stress such as increased predation or susceptibility to infection or alterations in social behaviour (Brown and Day, 2002) cannot be discounted, it is unlikely that differences in the ability of fingerlings and yearlings to cope with the stress of handling and transport would have resulted in the observed differences in recapture rates. It is possible that the fish in the present study received an inadequate acclimation period at the release site (< 2 hours), although, this was the same for both fingerlings and yearlings. Results from stream-side rearing studies by Crossman et al. (2011) indicated that the benefits of acclimation may be reduced with increasing age or body size suggesting that a longer acclimation time for fingerlings in the present study may have improved recapture rates. Clearly further research is required to determine optimal transport and acclimation for stocked juvenile Lake Sturgeon.

Finally, studies of this nature require clear identification of the hatchery fish, especially when wild conspecifics are also present. Tag loss and/or fin regeneration among the FF may have led to underestimated recapture rates in the current study. Preliminary study in 2007 on PIT tag retention of 8 mm tags inserted into the abdominal cavity of fall fingerlings (n = 353) indicated low tag loss (1%) within two weeks of the procedure (C. Klassen, unpublished data). However, studies on fin regeneration among the FF group was not undertaken and is a possible source of error. Complete fin regeneration was observed in 23% of juvenile Coho Salmon, *Oncorhynchus kisutch*, when at least one-third of the adipose fin was left intact (Thompson and Blankenship, 1997). A similar phenomenon may have occurred in this study, particularly with respect to the anal fin mark, as it’s placement on the body made it difficult to remove the entire fin (C. Klassen, pers. obs.) and none of these marks were observed in 2009 or 2010 gillnetting efforts. Interestingly, the frequency of unmarked and presumed wild Lake Sturgeon captured within the 230 to 429 mm TL interval (i.e., hatchery fish sizes) was high over the two year gillnetting program (n = 198). Although it is plausible that some of these individuals were misidentified hatchery-reared fish, a large number of age-0 Lake Sturgeon were captured in the same stretch of river during the spring and summer prior to the 2008 fall stocking event (Barth, 2011; Henderson, 2013). As such, it may be more plausible that FF were required to compete with what was determined to be a strong naturally produced 2008 year-class (Barth, 2011). For instance, Laarman (1978) determined that walleye, *Sander vitreus*, stocking programs were only 5% successful when supplementing natural year-classes in comparison to 48% successful when introducing hatchery-reared fish to lakes with no previously existing natural population.

There are cases in the literature where stocking different sized hatchery fish is met with mixed results and attributed to annual variability or differences among release locations (Brooks et al., 2002; Saito et al., 2011). Interestingly, stocking location does appear to have greatly influenced relative recapture rates among the fingerlings and yearlings released in this study as the difference was 144 times greater in Dorothy Lake versus only 5.5 times greater in Numao Lake. Furthermore, the CPUE values for spring yearlings were relatively similar between the two lakes, while the CPUE value of fall fingerlings was higher in Numao Lake than Dorothy Lake. The specific environmental advantages Numao Lake provided to fingerlings is unclear. Jennings et al. (2005) found that hatchery-reared Walleye did the best in lakes that also supported wild conspecifics. Similarly, high concentrations of wild juvenile Lake Sturgeon are found in Numao Lake (Barth, 2011). In fact, of the 71 unmarked Lake Sturgeon < 230 mm TL captured in the gillnetting efforts of this study, 53 (74.6%) were located in Numao Lake, in contrast to just a single individual (1.4%) in Dorothy Lake. Justice et al. (2009) suggested that density-dependant factors affected the survival of juvenile sturgeon at sizes < 250 mm but this would not appear to be the case in our system where densities of wild juveniles are greatest in Numao Lake. In fact, it could be hypothesized that the fall fingerlings released into Numao Lake benefited from higher Lake Sturgeon densities as wild juveniles are known to congregate in deep waters within this river system (Barth et al., 2009) and lab studies have shown physiological benefits from being in the presence of conspecifics (Allen et al., 2009). If true, competition between existing and recently released individuals may not be occurring, as earlier suggested, or be dependent on a density threshold. Further research on the ability of hatchery-reared Lake Sturgeon to integrate into established populations (of wild or hatchery origin) for supplementary purposes or to establish a population within a previously unoccupied area would provide additional information in which to make stocking decisions.

Klassen, C.N. Growth rate and size variability within juvenile Lake Sturgeon cohorts. PhD Dissertation, University of Manitoba, Winnipeg, MB (in progress)

In regard to the importance of considering site selection of stock enhancement, spring yearlings from the present study were found to have greater site fidelity following release as all individuals were recaptured in the same lake they were stocked. Not only does this represent an advantage when stocking programs are trying to target specific locations but is representative of behaviour observed among wild juveniles from the same population. For example, only 6 of 714 (0.8%) recaptured wild juvenile Lake Sturgeon were found to move through downstream lake boundaries over a three year period in the same river system (Barth et al., 2011). In contrast, 10 of 34 (29%) fall fingerlings from this study were recaptured within a reach of the Winnipeg River downstream of their release lake. The furthest known distance moved by a hatchery-reared sturgeon in this study (10.3 rkm) occurred within 5 days post-release following the fall stocking event. In fact, 5 of 21 (24%) fall fingerlings captured within 12 days post-release had moved >4 rkm downstream, a distance not observed among released yearlings at any point from the same study and a rare occurrence among wild juveniles in the same river system (Barth et al., 2011). It is unknown if the downstream movements among fall fingerlings were volitional or not. Post stocking dispersal has been attributed to a number of reasons including chronic stress associated with release activities (Mueller et al., 2003), poor swimming abilities (Crossman et al., 2011) and search for suitable habitat (Secor et al., 2000; Trested et al., 2011).

Closer examination of the movement information for fall fingerlings by lake, shows that site fidelity was greater among individuals released into Numao Lake (15 of 19, 79%) than Dorothy Lake (2 of 6, 33%). Oldenburg et al. (2011) also found that release habitat was the most influential factor affecting post-release dispersal of juvenile Pallid Sturgeon, *Scaphirhynchus albus*, even when some fish were acclimated to increased water flows. The reasons why fall fingerlings were more inclined to stay within Numao Lake is unknown but, given the high concentrations of juvenile Lake Sturgeon located in the same area, it is likely a reflection of preferred habitat. However, critical swimming speeds (U_{crit}) for Lake Sturgeon within the size range of the fall fingerlings released in this study were estimated to be 0.31 m/s (Peake, 2004) and some areas of the Winnipeg River (e.g., main channel and channel margins) are known to exceed this velocity (Barth et al., 2009). Greater rates of upstream movement by released yearlings over the two year study than fall fingerlings suggests that the fall fingerlings may have struggled to navigate the river, given their smaller size. Closer proximity to areas known to have slower flows in Numao Lake (e.g., back bays) may have provided some refuge for released fall fingerlings post-release and thereby reduced downstream dispersal.

Length-at-release was shown to have a linear relationship with movement distance when assessing both FF and SY together, a result not observed among juveniles from the wild population of the same river (Barth et al., 2011). The latter study did not incorporate movement direction into the analysis and, similarly, if direction was taken out of the equation in the present study no significant linear relationship was observed between length-at-release and distance moved (Linear regression, n = 29, P = 0.060, r2 = 0.13). As such, the results of this study indicate that, while distance moved from the release site may be independent of size, the direction of movement was dependent on size.

Yearlings were larger, both in total length and body mass, than fingerlings at the point of release and this size advantage persisted over the first year. By the second year, differences in total length were weakly significant and body mass was not significantly different among the age-2 hatchery fish. Growth convergence between fish stocked at different ages/sizes after several years following stocking has been observed in other species (Pratt and Fox 2003; Amtstaetter 2004). However, results observed in the second year were highly influenced by a

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single FF that displayed exceptional growth in comparison to the other hatchery-reared individuals. Removal of this individual from analysis resulted in the persistence of significant differences in body mass between the two release groups at age-2. The growth of this large FF may be related to location, as it was the only hatchery-reared fish captured in Eleanor Lake during the final study year. The wild Lake Sturgeon population of this river system have also displayed increased growth rates among lakes downstream of Numao Lake and is thought to be a function of reduced sturgeon densities (Barth, 2011). As such, despite the fact most FF continued to be smaller in size than the similarly aged SY, it would appear that the FF have the capacity for high growth rates provided optimal foraging opportunities.

The smaller sizes observed among the FF was not a sign of inferior body condition, as K_{TL} was not significantly different between the two release groups in either year following stocking. In fact, all the hatchery-reared fish displayed mean conditions (e.g., 0.35 to 0.41) that were comparable (e.g., 0.36 to 0.41) to those reported for wild Lake Sturgeon in the same river system of similar sizes (e.g., 250 to 349 mm TL) (Barth, 2011).

Assessment of stocking programs in relation to size generally focuses on large-scale differences most often associated with different ages. Growth rate variability within the same year-class is often high in sturgeon culture environments (Nathanailides et al., 2002; C.Klassen, unpublished data) and this fine-scale variability could potentially have an impact on post-release performance. The secondary objective of this study was to assess size-at-release in relation to post-stocking performance of fingerling and yearling release events, respectively.

Contrary to expectation, size variability within the FF and SY release groups did little to predict the performance of individuals following release. Recaptured FF and SY were not representative of just the largest individuals released in the fall and spring stocking events, respectively. This is in contrast with a similar assessment of White Sturgeon by Justice et al. (2009) where recapture frequencies clearly favoured the larger individuals stocked. Discrepancies may be due to the range of sizes being assessed. For example the study by Justice et al. (2009) had a length distribution spanning approximately 350 mm. In comparison, the size range was much lower among FF (e.g., 69 mm) and SY (e.g., 104 mm) of this study and perhaps an insufficient range of sizes to detect length-at-release effects. Overwinter detection of juvenile Lake Sturgeon was also not related to fish size (Crossman et al., 2009) but, as in our study, the size range of study fish was smaller.

Length-at-release within stocking events have been shown to influence age-0 Lake Sturgeon movements (Crossman et al., 2011) but did not appear to have an effect on distance moved when assessing the FF or SY release groups of this study. However, the former study was looking at movement within a 24 hour period, whereas, the present study was assessing movements beyond this time window. As such, the affects of length-at-release on movement may be limited to very short periods post release.

In conclusion, stocking yearling Lake Sturgeon into the Winnipeg River resulted in higher relative recapture rates, higher site fidelity and, for the most part, a size advantage over those released as fingerlings throughout a two year period post-release. However, the extent to which SY outperformed FF depended on location, highlighting the need for site-specific assessments and decision-making, a sentiment endorsed following other reviews of stock enhancement programs (Brooks et al., 2002; Pratt and Fox, 2003; Leber et al., 2005). The results of this study also indicated that the advantages of greater body size are limited to large-scale differences associated with age and not fine-scale differences observed among fish of the same age. However, the present study design could not fully decipher size from age or season affects.

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The results of this study should be considered cautiously as they represent the performance of a single year-class over a relatively short assessment period. In addition, the stocking event assessed could be considered supplementary in nature, as natural recruitment was present. Results, particularly those associated with recapture rates, may have been different if the study utilized a stretch of river where natural recruitment is not known to occur or is reduced. Conveniently, the wild Lake Sturgeon of this stretch of river are well studied and provided an opportunity to compare the performance of hatchery-reared sturgeon with that of wild conspecifics in the same system. It was encouraging to observe fall fingerlings utilizing known nursery areas in Numao Lake, spring yearlings actively moving to upstream areas in Dorothy Lake and body conditions comparable to similarly sized wild Lake Sturgeon.

References

Allen, P.J.; Barth, C.C.; Peake, S.J.; Abrahams, M.V.; Anderson, W.G., 2009: Cohesive social behaviour shortens the stress response: the effects of conspecifics on the stress response in lake sturgeon *Acipenser fulvescens*. J. Fish Biol. **74**, 90-104.

ALSRT (Alberta Lake Sturgeon Recovery Team), 2011: Alberta Lake Sturgeon Recovery Plan, 2011-2016. Alberta Environment and Sustainable Resource Development, Alberta Species at Risk Recovery Plan No. 22. Edmonton, AB. pp. 98.

Auer, N.A., 2004: Conservation. In: Sturgeons and paddlefish of North America. G.T.O. LeBreton; F.W.H. Beamish; R.S. McKinley (Eds). Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 252-276.

Barth, C.C.; Peake, S.J.; Allen, P.J.; Anderson, W.G., 2009: Habitat utilization of juvenile lake sturgeon, *Acipenser fulvescens*, in a large Canadian river. J. Appl. Ichthyol. **25**, 18-26.

Barth, C.C., 2011: Ecology, behavior, and biological characteristics of juvenile lake sturgeon, *Acipenser fulvescens*, within an impounded reach of the Winnipeg River, Manitoba, Canada. PhD Diss, University of Manitoba, Winnipeg, MB.

Barth, C.C.; Anderson, W.G.; Henderson, L.M.; Peake, S.J., 2011: Home range size and seasonal movement of juvenile lake sturgeon in a large river in the Hudson Bay drainage basin. Trans. Am. Fish. Soc. **140**, 1629-1641.

Barth, C.C.; Anderson, W.G.; Peake, S.J.; Nelson, P., 2013: Seasonal variation in the diet of juvenile lake sturgeon, Acipenser fulvescens, Rafinesque, 1817, in the Winnipeg River, Manitoba, Canada. J. Appl. Ichthyol. **29**, 721-729.

Bartley, D.M., 1999: Marine ranching: a global perspective. In: Stock enhancement and sea ranching. B.R. Howell, E. Moksness; T. Swasand (Eds), Fishing News Books, Oxford, pp.79-

90.

Benson, A.C.; Sutton, T.M.; Elliott, R.F.; Meronek, T.G., 2005: Evaluation of sampling techniques for age-0 lake sturgeon in a Lake Michigan tributary. N. Am. J. Fish. Manage. **25**, 1378-1385.

Blankenship, H.L.; Leber, K.M., 1995: A responsible approach to marine stock enhancement. Am. Fish. Soc. Symp. **15**, 167-175.

Brooks, R.C.; Heidinger, R.C.; Hoxmeier, R.J.H.; Wahl, D.H., 2002: Relative survival of three sizes of walleyes stocked into Illinois lakes. N. Am. J. Fish. Manage. **22**, 995-1006.

Brown, C.; Day, R.L., 2002: The future of stock enhancements: lessons for hatchery practice from conservation biology. Fish Fish. **3**, 79-94.

Buckmeier, D.L.; Betsill, R.K.; Schlechte, J.W. 2005: Initial predation of stocked fingerling largemouth bass in a Texas reservoir and implication for improving stocking efficiency. N. Am. J. Fish. Manage. **25**, 652-659.

Caroffino, D.C.; Sutton, T.M.; Elliott, R.F.; Donofrio, M.C., 2010: Early life stage mortality rates of lake sturgeon in the Peshtigo River, Wisconsin. N. Am. J. Fish. Manage. **30**, 295-304.

Chalupnicki, M.A.; Dittman, D.E.; Carlson, D.M., 2011: Distribution of lake sturgeon in New York: 11 years of restoration management. Am. Midl. Nat. **165**, 364-371.

Cleator, H.; Martin, K.A.; Pratt, T.C.; Barth, C.C.; Corbett, B.; Duda, M.; Leroux, D., 2010: Information relevant to a recovery potential assessment of Lake Sturgeon: Winnipeg River-English River populations (DU5). Canadian Science Advisory Secretariat, Department of Fisheries and Oceans, Research Document 2010/084, Winnipeg, Manitoba.

COSEWIC. 2006. COSEWIC assessment and update status report on the lake sturgeon Acipenser fulvescens in Canada. Committee on the Status of Endangered Wildlife in Canada.

Klassen, C.N. Growth rate and size variability within juvenile Lake Sturgeon cohorts. PhD Dissertation, University of Manitoba, Winnipeg, MB (in progress)

Ottawa, (www.sararegistry.gc.ca/status/status_e.cfm).

Cousins, R.; DeWolfe, M.; Blouin-Maurice, F., 2012: Year 2008 and 2009 high water levels in the English River basin. Lake of the Woods Control Board, Special Report, pp. 46.

Crossman, J.A.; Forsyth, P.S.; Baker, E.A., Scribner, K.T., 2009: Overwinter survival of stocked age-0 lake sturgeon. J. Appl. Ichthyol. **25**, 516-521.

Crossman, J.A.; Forsythe, P.S.; Scribner, K.T.; Baker, E.A., 2011: Hatchery rearing environment and age affect survival and movements of stocked juvenile lake sturgeon. Fisheries Manag. Ecol. **18**, 132-144.

Falahatkar, B.; Akhavan, S.R.; Efatpanah, I.; Meknatkhah, B., 2012: Primary and secondary responses of juveniles of a Teleostean, pikeperch *Sander lucioperca*, and a Chondrostean, persian sturgeon, *Acipenser persicus*, to handling during transport. N. Am. J. Aquacult. **74**, 241-250.

Fenton, F.; Mathias, J.A; Moodie, G.E.E., 1996: Recent and future demand for walleye in North America. Fisheries 21: 6-12.

French, W.E.; Graeb, B.D.S.; Chipps, S.R.; Bertrand, K.N.; Selch, T.M.; Klumb, R.A., 2010: Vulnerability of age-0 pallid sturgeon *Scaphirhynchus albus* to fish predation. J. Appl. Ichthyol. **26**, 6-10.

Gadomski, D.M.; Parsley, M.J., 2005a: Laboratory studies on the vulnerability of young white sturgeon to predation. N. Am. J. Fish. Manage. **25**, 667-674.

Gadomski, D.M.; Parsley, M.J., 2005b: Vulnerability of young white sturgeon, *Acipenser transmontanus*, to predation in the presence of alternative prey. Environ. Biol. Fish **74**, 389-396.

Gross, M.R.; Repka, J.; Robertson, C.T.; Secor, D.H.; Winkle, W.V., 2002: Sturgeon conservation: insights from elasticity analysis. In: Biology, management, and protection of North American sturgeon. W.V. Winkle, P.J. Anders, D.H. Secor, D.A. Dixon (Eds), American Fisheries Society, Symposium 28, Bethesda, MD, pp. 13-30.

Harkness, W.J.K.; Dymond, J.R., 1961: The lake sturgeon: the history of its fishery and problems of conservation. Ontario Dept of Lands and Forests, Fish and Wildlife Branch, Maple. pp. 121.

Henderson, L.M., 2013: Larval drift characteristics, habitat use, and environmental determinants of year-class strength in wild age-0 Lake Sturgeon, *Acipenser fulvescens*, within a large impounded river. MSc Thesis, University of New Brunswick, Fredericton, MB.

Hoff, M.H.; Newman, S.P., 1995: Comparisons of fingerlings and yearling lake trout introductions for establishing an adult population in Pallette Lake, Wisconsin. N. Am. J. Fish. Manage. **15**, 871-873.

Jennings, M.J.; Kampa, J.M., Hatzenbeler, G.R., Emmons, E.E., 2005: Evaluation of supplemental walleye stocking in northern Wisconsin lakes. N. Am. J. Fish. Manage. **25**, 1171-1178.

Justice, C.; Pyper, B.J.; Beamesderfer, R.C.P.; Paragamian, V.L.; Rust, P.J.; Neufeld, M.D.; Ireland, S.C., 2009: Evidence of density- and size-dependent mortality in hatchery-reared juvenile white sturgeon (*Acipenser transmontanus*) in the Kootenai River. Can. J. Fish. Aquat. Sci. **66**, 802-815.

Kampa, J.M.; Hatzenbeler, G.R., 2009: Survival and growth of walleye fingerlings stocked at two sizes in 24 Wisconsin lakes. N. Am. J. Fish. Manage. **29**, 996-1000.

Leber, K.M.; Cantrell, R.N., Leung, P., 2005: Optimizing cost-effectiveness of size at release in stock enhancement programs. N. Am. J. Fish. Manage. **25**, 1596-1608.

Klassen, C.N. Growth rate and size variability within juvenile Lake Sturgeon cohorts. PhD Dissertation, University of Manitoba, Winnipeg, MB (in progress)

Mann, K.A.; Holtgren, J.M.; Auer, N.A.; Ogren, S.A., 2011: Comparing size, movement, and habitat selection of wild and streamside-reared lake sturgeon. N. Am. J. Fish. Manage. **31**, 305-314.

MCWS (Manitoba Conservation and Water Stewardship), 2012: Manitoba lake sturgeon management strategy. Government of Manitoba, Fisheries Branch, Winnipeg, Manitoba. pp. 52.

Marsh, P.C.; Brooks, J.E., 1989. Predation by Ictalurid catfishes as a deterrent to re-establishment of hatchery-reared razorback suckers. Southwest. Nat. **34**, 188-195.

Millar, R.B.; Fryer, R.J., 1999: Estimating the size-selection curves of towed gears, traps, nets and hooks. Rev. Fish Biol. Fisher. **9**, 89-116.

Molony, B.W.; Lenanton, R.; Jackson, G.; Norriss, J., 2003: Stock enhancement as a fisheries management tool. Rev. Fish Biol. Fisher. **13**, 409-432.

Nilo, P.; Dumont, P.; Fortin, R., 1997: Climatic and hydrological determinants of year-class strength of St. Lawrence River lake sturgeon. Can. J. Fish. Aquat. Sci. **54**, 774-780.

Nathanailides, C.; Tsoumani, M.; Papazogloy, A.; Paschos, I., 2002: Hatching time and post-hatch growth in Russian sturgeon *Acipenser gueldenstaedtii*. J. Appl. Ichthyol. **18**, 651-654.

Oldenburg, E.W.; Guy, C.S.; Cureton, E.S.; Webb, M.A.H.; Gardner, W.M., 2011: Effects of acclimation on poststocking dispersal and physiological condition of age-1 pallid sturgeon. J. Appl. Ichthyol. **27**, 436-443.

Olson, M.H.; Brooking, T.E.; Green, D.M.; VanDeValk, A.J.; Rudstam, L.G., 2000: Survival and growth of intensively reared large walleye fingerlings and extensively reared small fingerlings stocked concurrently in small lakes. N. Am. J. Fish. Manage. **20**, 337-348.

Paradis, A.R.; Pepin, P.; Brown, J.A., 1996: Vulnerability of fish eggs and larvae to predation:

review of the influence of the relative size of prey and predator. Can. J. Fish. Aquat. Sci. **53**, 1226-1235.

Peake, S.J., 2004: Swimming and respiration. In: Sturgeons and paddlefish of North America. G.T.O. LeBreton; F.W.H. Beamish; R.S. McKinley (Eds). Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 147-166.

Peterson, D.L.; Vecsei, P; Jennings, C.A., 2007. Ecology and biology of the Lake Sturgeon: a synthesis of current knowledge of a threatened North American *Acipenseridae*. Rev. Fish Biol. Fisher. **17**, 59-76.

Pikitch, E.K.; Doukakis, P.; Lauck, L.; Chakrabarty, P.; Erickson, D., 2005: Status, trends and management of sturgeon and paddlefish fisheries. Fish Fish. **6**, 233-265.

Pratt, T.C.; Fox, M.G., 2003: Contributions and relative survival of age-0 walleyes stocked at two sizes in six eastern Ontario lakes. N. Am. J. Fish. Manage. **23**, 997-1005.

Ricker, W.E., 1975: Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. **191**, 382.

Runstrom, A.; Bruch, R.M.; Reiter, D.; Cox, D., 2002: Lake sturgeon (*Acipenser fulvescens*) on the Menominee Indian Reservation: an effort toward co-management and population restoration. J. Appl. Ichthyol. **18**, 481-485.

Saito, T.; Kaga, T.; Hasegawa, E.; Nagasawa, K., 2011: Effects of juvenile size at release and early marine growth on adult return rates for Hokkaido chum salmon (Oncorhynchus keta) in relation to sea surface temperature. Fish. Oceanogr. **20**, 278-293.

Salminen, M.; Alapassi, T.; Ikonen, E., 2007: The importance of stocking age in the enhancement of River Kymijoki salmon (Salmo salar). J. Appl. Ichthyol. **23**, 46-52.

SRSMB (Saskatchewan River Sturgeon Management Board), 2012: Saskatchewan River sturgeon management board: ten-year management plan review. A report prepared for SRSMB by North/South Consultants Inc., Winnipeg, Manitoba. pp. 31.

Schram, S.T.; Lindren, J.; Evrard, L.M., 1999: Reintroduction of lake sturgeon in St. Louis River, Western Lake Superior. N. Am. J. Fish. Manage. **19**, 815-823.

Scott, W.B.; Crossman, E.J., 1973: Freshwater fishes of Canada. Fish. Res. Board Can. **184**, 966.

Smith, T.I.J.; Dingley, E.K., 1984: Review of biology and culture of Atlantic (*Acipenser oxyrhynchus*) and shortnose sturgeon (*A. brevirostrum*). J. World. Maricul. Soc. **15**, 210-218.

Steffensen, K.D.; Powell, L.A.; Koch, J.D., 2010: Assessment of hatchery-reared pallid sturgeon survival in the lower Missouri River. N. Am. J. Fish. Manage. **30**, 671-678.

Sutton, T.M.; Ney, J.J., 2001: Size-dependent mechanisms influencing first-year growth and winter survival of stocked striped bass in a Virginia mainstream reservoir. Trans. Am. Fish. Soc. **130**, 1-17.

Szendrey, T.A.; Wahl, D.H., 1996: Size-specific survival and growth of stocked muskellunge: effects of predation and prey availability. N. Am. J. Fish. Manage. **16**: 395-402.

Thompson, J.M.; Bergersen, E.P.; Carlson, C.A.; Kaeding, L.R., 1991: Role of size, condition, and lipid content in the overwinter survival of age-0 Colorado squawfish. Trans. Am. Fish. Soc. **120**, 346-353.

Van Eenennaam, J.P.; Webb, M.A.H.; Deng, X.; Doroshov, S.I.; Mayfield, R.B.; Cech, J.J. Jr.; Hillemeier, D.C.; Willson, T.E., 2001: Artificial spawning and larval rearing of Klamath River green sturgeon. Trans. Amer. Fish. Soc. **130**, 159-165.

Waldman, J.R.; Wirgin, I.I., 1998: Status and restoration options for Atlantic sturgeon in North America. Conserv Biol. **12**, 631-638.

Wilson, J.A.; McKinley, R.S., 2004: Distribution, habitat, and movements. In: G.T.O. LeBreton;

F.W.H. Beamish; R.S. McKinley (Eds), Sturgeons and Paddlefish of North America. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 40-72.

Table 5.1 Summary of Lake Sturgeon groups released into the Winnipeg River, Manitoba.

Lake Released	Number Released	Date Released	Date(s) Tagged	Fin Clip Applied	Number PIT tagged
Fall Fingerlings					
Numao	2,500	17-Sep-08	15-Sep-08	Left Pelvic	631
Nutimik	2,500	16-Sep-08	14-Sep-08	Anal Fin	633
Dorothy	2,500	15-Sep-08	12 to 14-Sep-08	Right Pelvic	632
Sylvia	2,500	14-Sep-08	n/a	n/a	0
Totals	**10,000**				**1,896**
Spring Yearlings					
Numao	207	12-Jun-09	14-May-09	n/a	207
Dorothy	208	12-Jun-09	14-May-09	n/a	208
Totals	**415**				**415**

Table 5.2 Information for hatchery-reared Lake Sturgeon released as fingerlings in three locations along the Winnipeg River, Manitoba and recaptured over a two year period.

Stocking Data			Recapture Data							
Lake	TL (mm)	Mass (g)	Date	Lake	RKM[1]	TL (mm)	Mass (g)	Age (days)	Mark/ Tag[2]	Data Source
Numao	115	5.70	19-Sep-08	Numao	-2.05	116	5.4	106	LP;PIT	*L.M.H*
			19-Sep-08	Numao	-2.05	115	5.0	106	LP	*L.M.H*
			19-Sep-08	Numao	-2.05	117	5.3	106	LP	*L.M.H*
			19-Sep-08	Nutimik	-4.35	105	2.5	106	LP	*C.C.B*
	120	6.10	23-Sep-08	Numao	-1.10	134	3.6	110	LP; PIT	*L.M.H*
	131	8.03	23-Sep-08	Numao	-1.10	147	4.5	110	LP; PIT	*L.M.H*
			23-Sep-08	Numao	-1.10	135	3.5	110	LP	*L.M.H*
			23-Sep-08	Numao	-1.10	131	3.1	110	LP	*L.M.H*
			1-Sep-09	Numao	-0.90	270	51.2	453	LP	
	115	6.1	29-Sep-09	Numao	-1.92	278	78.0	481	LP; PIT	
			30-Sep-09	Numao	-2.15	236	45.0	482	LP	
	116	6.0	9-Jun-10	Numao	0.29	272	101.0	734	LP; PIT	
	108	5.7	10-Jun-10	Numao	-0.31	280	105.0	735	LP; PIT	
			6-Jul-10	Nutimik	-4.93	244	55.0	761	LP	
	125	6.8	7-Jul-10	Nutimik	-5.01	281	78.0	762	LP; PIT	
			22-Jul-10	Numao	0.35	255	53.0	777	LP	
	105	5.0	24-Aug-10	Numao	-0.28	281	90.0	810	PIT	
			25-Aug-10	Numao	-0.58	324	124.0	811	LP	
			10-Sep-10	Nutimik	-4.29	365	219.0	827	LP	
Nutimik			18-Sep-08	Nutimik		115		105	AF	*C.C.B*
			19-Sep-08	Nutimik	-0.37	119	3.9	106	AF	*L.M.H*
			19-Sep-08	Nutimik	-0.37	115	3.3	106	AF	*L.M.H*
	113	5.47	19-Sep-08	Nutimik	-0.37	113	2.7	106	AF; PIT	*L.M.H*
			19-Sep-08	Nutimik	0.34	113	3.3	106	AF	*C.C.B*
			19-Sep-08	Nutimik	0.34	113	3.4	106	AF	*C.C.B*
			19-Sep-08	Nutimik	0.34	112	3.6	106	AF	*C.C.B*
	112	5.20	23-Sep-08	Dorothy	-7.72	121		110	AF; PIT	*L.M.H*
	110	5.17	13-Jul-09	Dorothy	-7.70	195	31.6	403	AF; PIT	*S.J.P*
Dorothy			19-Sep-08	Dorothy	-0.74	111	3.2	106	RP	*L.M.H*
			19-Sep-08	Dorothy	-0.74	111	3.3	106	RP	*L.M.H*
			20-Sep-08	Eleanor	-10.32	125	3.8	107	RP	*C.C.B*
			26-Sep-08	Margaret	-7.13	124	4.2	113	RP	*C.C.B*
	112	4.60	26-Sep-08	Margaret	-7.13	114	2.9	113	RP; PIT	*C.C.B*
			10-Aug-10	Eleanor	-7.91	411	315	796	RP	

[1] Upstream (+) and downstream (-) distance moved (river km) between release and recapture site

[2] LP = Left-Pectoral; AF = Anal Fin; RP = Right-Pectoral; PIT = Passive Integrated Transponder Tag

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Table 5.3 Information for hatchery-reared Lake Sturgeon released as yearlings in two locations along the Winnipeg River, Manitoba and recaptured over a two year period.

Stocking Data			**Recapture Data**						
Lake	**TL (mm)**	**Mass (g)**	**Date**	**Lake**	**RKM[1]**	**TL (mm)**	**Mass (g)**	**Age (days)**	**Data Source**
Numao	225	46.14	3-Sep-09	Numao	-2.08	292	94	455	
	243	53.79	29-Sep-09	Numao	-1.20	332	127	481	
	240	50.15	9-Jun-10	Numao	0.09	329	170	734	
	252	68.20	10-Jun-10	Numao	-0.34	294	124	735	
	241	53.44	21-Jul-10	Numao	-1.20	348	156	776	
Dorothy	257	75.86	9-Jul-09	Dorothy	1.04	288		399	*S.J.P*
	202	38.60	10-Jul-09	Dorothy	1.04	235		400	*S.J.P*
	246	56.03	17-Jul-09	Dorothy	0.67	292	93	407	
	267	80.99	20-Aug-09	Dorothy	-2.80	332	143	441	
	252	56.70	20-Aug-09	Dorothy	-2.56	316	109	441	
	233	45.84	25-Aug-09	Dorothy	0.26	303	95	446	
	257	65.50	25-Aug-09	Dorothy	0.18	321	115	446	
	246	55.42	26-May-10	Dorothy	1.81	346	150	720	
	239	58.10	26-May-10	Dorothy	1.81	335	128	720	
	263	68.90	27-May-10	Dorothy	1.73	356	169	721	
	234	47.89	25-Jun-10	Dorothy	1.76	373	212	750	
	234	50.30	25-Jun-10	Dorothy	2.35	330	155	750	

[1] Upstream (+) and downstream (-) distance moved (river km) between release and recapture site

Table 5.4 Catch-per-unit-effort (CPUE) of wild and hatchery-reared Lake Sturgeon (FF: fall fingerlings, SY: spring yearlings) over a two-year gillnetting program in the Winnipeg River, Manitoba.

			WILD LKST		HATCHERY LKST					
	Gill Nets		Total	CPUE	FF	CPUE	SY	CPUE	Total	CPUE
Lake	**Duration**	**Effort**	**No.**	**(# LKST/100m/24hr)**	**No.**	**(# LKST/100m/24hr)**	**No.**	**(# LKST/100m/24hr)**	**No.**	**(# LKST/100m/24hr)**
Numao	2010.39	1500.82	627	10.027	8	0.128	5	0.080	13	0.208
Nutimik	2646.75	1964.66	623	7.610	3	0.037	0	0.000	3	0.037
Dorothy	3389.64	2569.79	63	0.588	0	0.000	10	0.093	10	0.093
Margaret	801.08	644.17	8	0.298	0	0.000	0	0.000	0	0.000
Eleanor	1481.65	1103.98	24	0.522	1	0.022	0	0.000	1	0.022
Sylvia	1250.96	944.31	46	1.169	0	0.000	0	0.000	0	0.000
Natalie	324.59	271.22	0	0.000	0	0.000	0	0.000	0	0.000
Total	11905.06	8998.95	1391	3.710	12	0.032	15	0.040	27	0.072

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Table 5.5 Total length, body mass and condition factor comparisons between fall fingerlings (FF) and spring yearlings (SY) during the 2009 and 2010 study years. An asterix denotes significant differences at P ≤ 0.05.

Variable	Year	Group	N	Mean	SD	Mann-Whitney U	P =	
TL	2009	FF	4	244.75	37.84			
(mm)		SY	9	301.22	30.08	3.0	0.02	*
	2010	FF	9	301.44	54.97			
		SY	8	338.88	23.29	16.0	0.05	*
Mass	2009	FF	4	51.45	19.50			
(g)		SY	7	110.53	18.99	< 0.001	0.01	*
	2010	FF	9	126.67	86.17			
		SY	8	158.00	27.55	16.5	0.06	
Condition	2009	FF	4	0.348	0.069			
(K_{TL})		SY	7	0.359	0.020	12.0	0.71	
	2010	FF	9	0.412	0.063			
		SY	8	0.407	0.055	38.0	0.85	

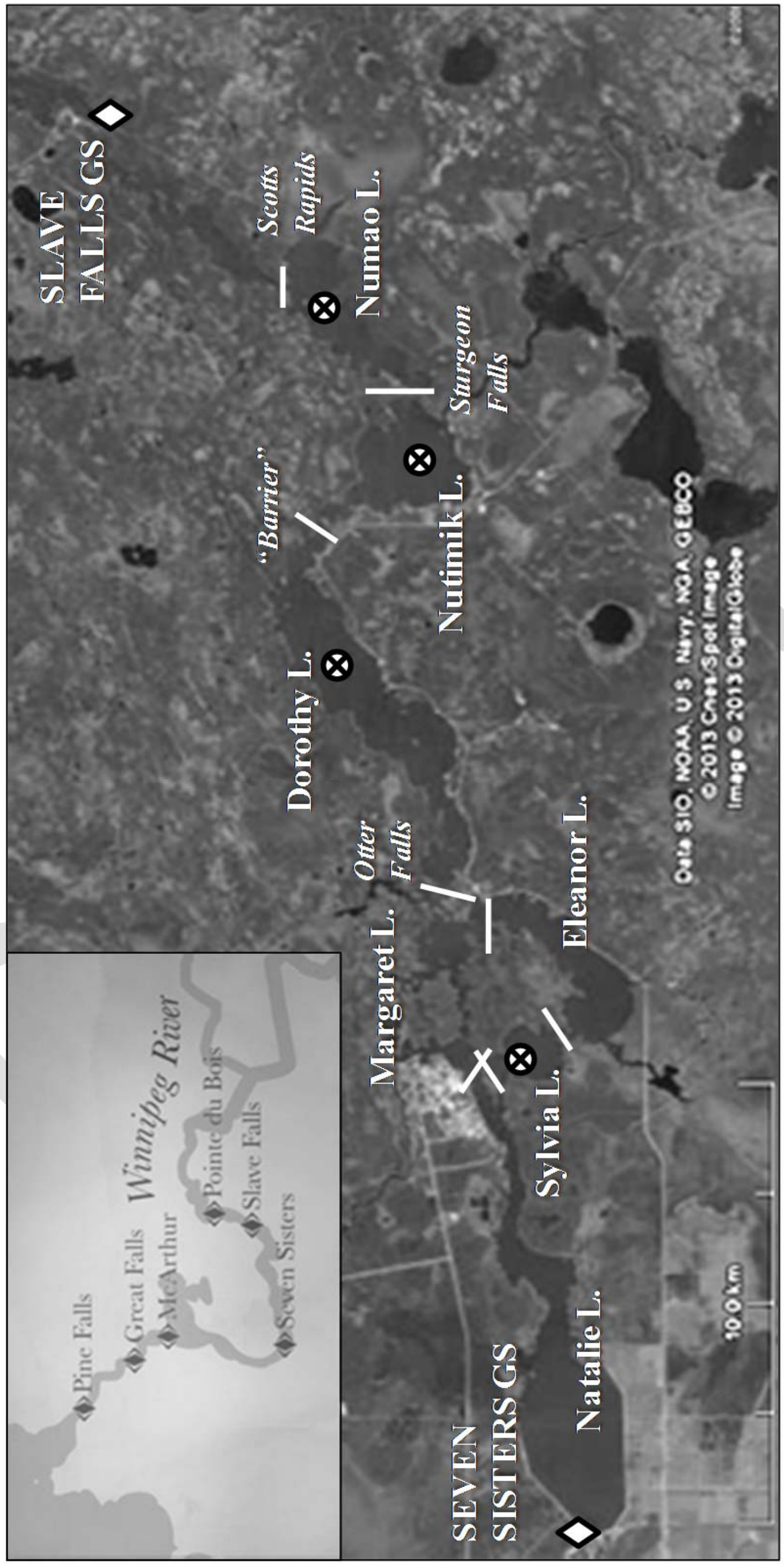

Figure 5.1. Study area between the Slave Falls and Seven Sisters Generating Station. Insert shows orientation with respect to four other generating stations along the Winnipeg River within the borders of Manitoba. Lake boundaries are defined after Barth et al (2011). The symbol ⊗ indicates Lake Sturgeon release locations.

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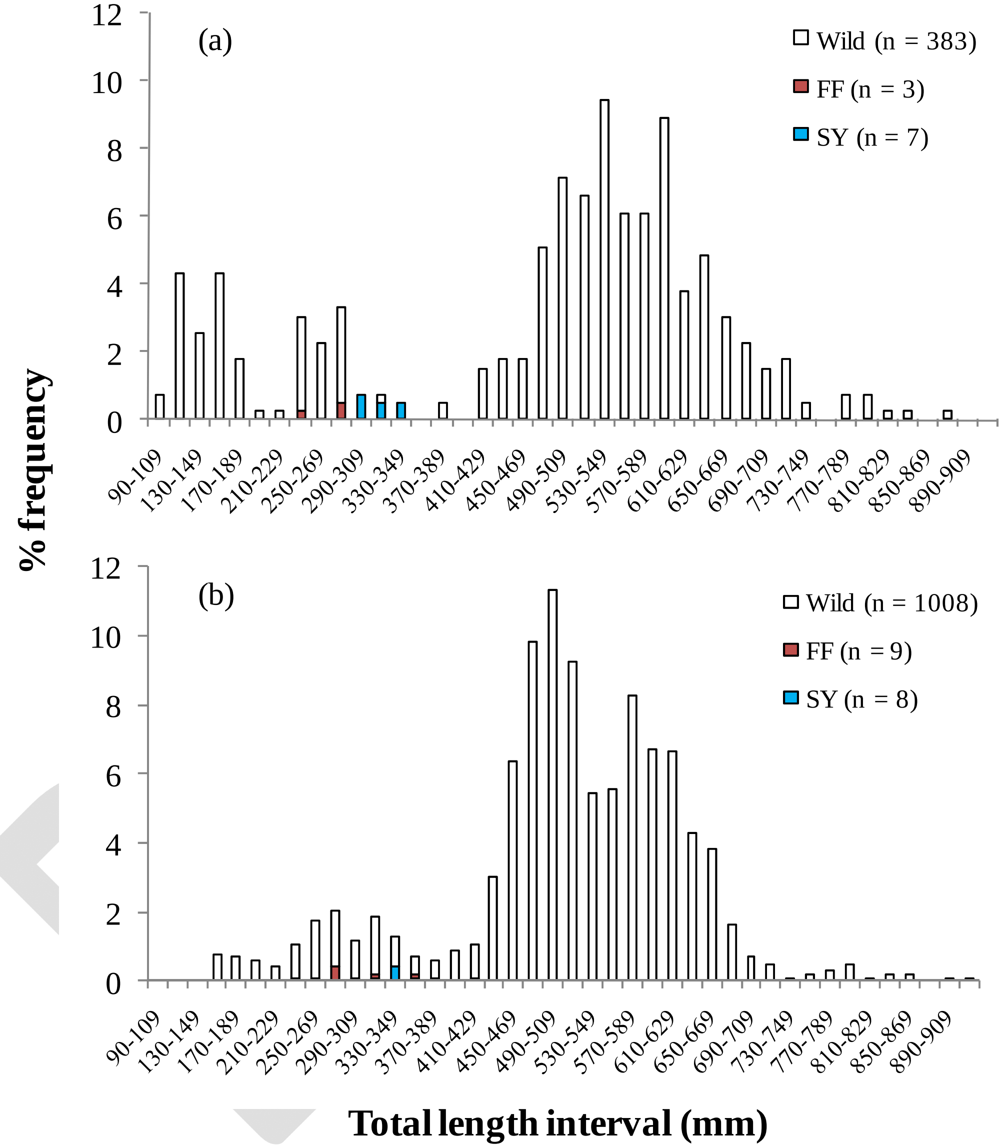

Figure 5.2 Total length (mm) frequency histograms (20 mm intervals) of juvenile Lake Sturgeon captured in 25 mm mesh gill nets set in the Winnipeg River, Manitoba during (a) 2009 and (b) 2010.

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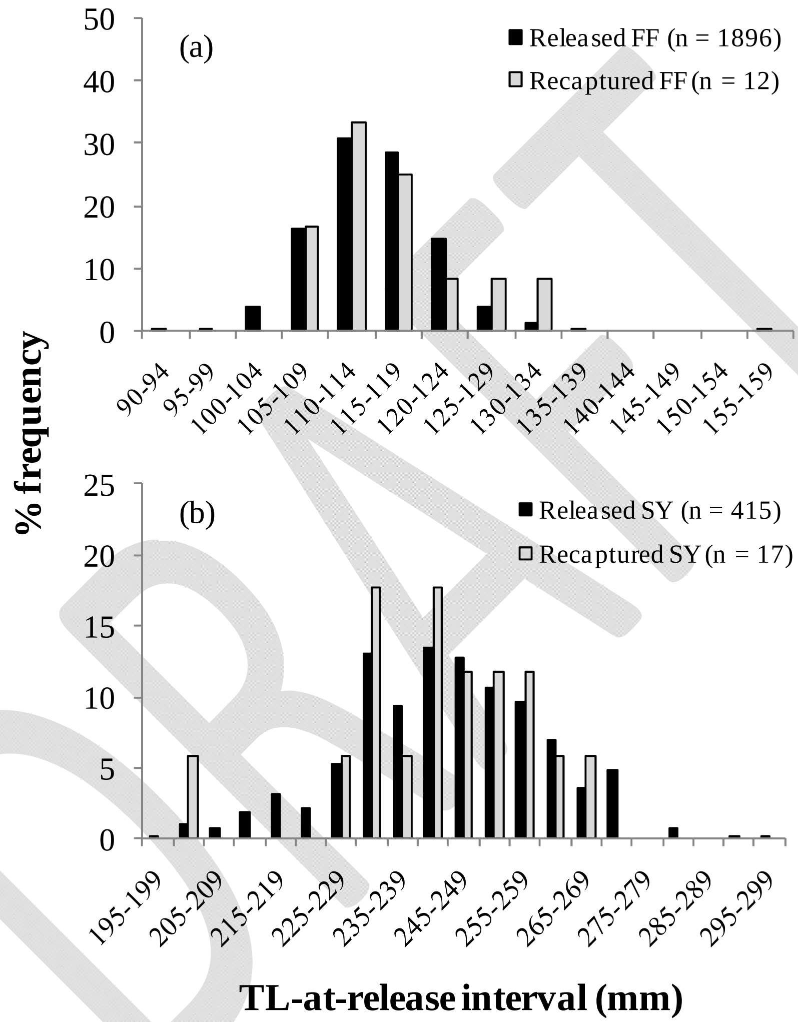

Figure 5.3 Length-at-release distributions for (a) fall fingerlings (FF) and (b) spring yearlings (SY) released into the Winnipeg River, Manitoba and subsequently recaptured over a two year period post-release.

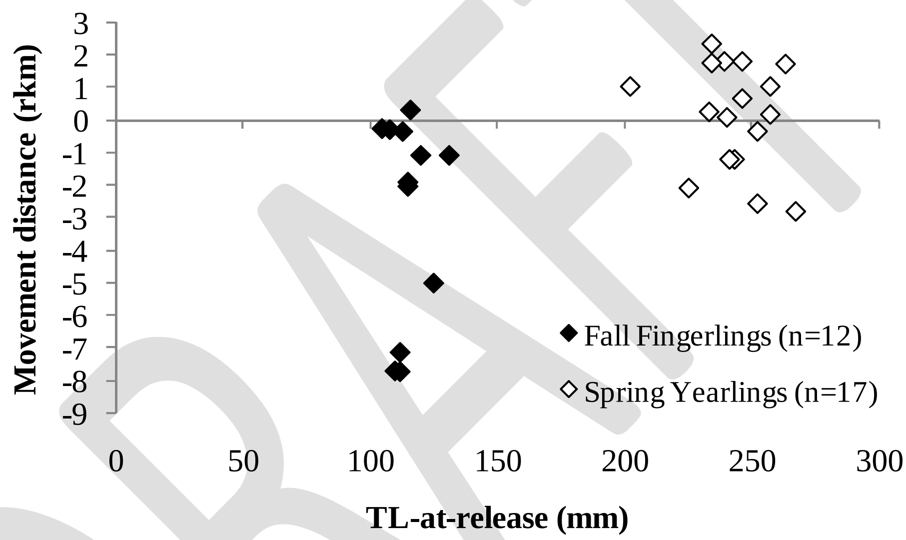

Figure 5.4 Scatterplot of the distance moved (rkm) by Lake Sturgeon fall fingerlings (FF) and spring yearlings (SY) recaptured in the Winnipeg River, Manitoba during 2009 and 2010 as it related to total length-at-release (mm). Positive and negative values indicate upstream and downstream movement, respectively.