Use of Traditional Phenological Knowledge Indicators to Predict Lake Sturgeon Spawning Timing on the Seine River

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Abstract

Temperature and photoperiod are the two basic classes of environmental cues for phenological responses such as spawning fish. This study provided a comparison Traditional Phenological Knowledge (TPK) indicators identified by Seine River First Nation knowledge holders with photoperiod and water temperature as indicators for the lake sturgeon spawn in Seine River. To identify the lake sturgeon spawning timing; egg mats, underwater camera videography, and larval drift data was collected for the 2012 to 2015 field seasons. This spawning timing was compared to size of trembling aspen leaves and the presence of tiger swallowtail butterflies, two of the TPK indicators identified by Seine River First Nation knowledge holders. The results of this study indicate that observations of tiger swallowtail butterflies as a TPK environmental indicator is an effective tool for predicting the approximate timing of lake sturgeon spawning in the Seine River. While not as accurate as water temperature as a lake sturgeon spawning indicator, the presence of tiger swallowtail butterflies near Seine River would serve as an excellent indicator if water temperature data was not available.

1.0 Introduction

According to Lechowicz (2001), "Phenology is the study of the seasonal timing of events in nature: when flowers bloom, trees leaf out, birds migrate, animals hibernate, fish spawn, phytoplankton blooms, lakes freeze and the like." It has been documented that people were paying close attention to the seasonal timing of natural events long before scientific interest in phenology arose in the 19th Century (Lechowicz 2001). With the changing climatic conditions that are altering phenological relationships around the world (Visser & Both 2005; Cleland et al. 2007; Forrest & Miller-Rushing 2010) understanding these relationships, while challenging, is particularly important (Miller-Rushing et al. 2010). Although phenological observations of freshwater organisms are particularly scarce (Parmesan 2007), recent studies have demonstrated a link between fish spawning timing to terrestrial biotic indicators (Pepino et al. 2013). The environmental cues for phenological responses fall into two basic classes: photoperiodic and climatic. Temperature is the predominant climatic cue, although precipitation may also play a role (Lechowicz 2001).

For Anishinabe peoples, the timing of natural events was critical for survival as the need to be in certain areas at specific times (e.g. wild rice harvest, fish spawning, blueberry harvest) was of paramount importance to ensure sustenance of the people. Lantz and Turner (2003) introduced and defined the term, "traditional phenological knowledge" (TPK) to encompass indigenous knowledge regarding phenology:

> All knowledge of biological seasonality, including the observation of life cycle changes in specific plant of animal species or animal species to indicate the timing of the onset of growth stages in other species, linguistic references to phenological events,

traditional conceptions of time as they relate to seasonal change, and spiritual beliefs about cause and effect relationships of seasonal change.

Direct TPK refers to the observation of phenological changes in one species (the indicator species) to signal the seasonal timing of another species (the secondary species) (Armatas et al. 2016).

Lake sturgeon (*Acipenser fulvescens*) in northwestern Ontario have been designated by the Committee on the Status of Species at Risk in Ontario (COSSARO) as a threatened species (Kerr et al. 2010). The operation of peaking hydroelectric facilities can have a dramatic impact on the spawning success of lake sturgeon (Auer 1996). Dams alter the normal pattern of water temperature, flow regime, water chemistry, nutrient transport, fish movement, and community structure in a river system which can affect spawning and recruitment of sturgeon (MacDonell 1995, Bednarek 2001, Threader et al. 2005, Haxton and Findlay 2009, Mora et al. 2009). Shifts in the timing of naturally occurring peak flows and reductions in these flows below hydroelectric facilities are directly related to sturgeon spawning success and year class strength (Koroshko 1972, Zakharyan 1972, Votinov and Kasyanov 1979, Veshchev 1991). Generally, there are two basic operating regimes at hydroelectric facilities: "peaking" and "run-of-river". A "peaking" operation is one in which water is stored in the reservoir for a period of time and then spilled through the turbines to produce electricity. Typically, water is stored in the reservoir and released through turbines to generate electricity during the day or season when demand for electricity is highest (Kerr et al. 2010). This results in a dramatic reduction in downstream flows for a period of many hours which has often been attributed to lowered biological diversity downstream of these sites (Cushman 1985). The reduction or elimination of flow during the night can also impact the downstream drift of larval lake sturgeon. This type of operation is generally believed to impair recruitment in lake sturgeon (Haxton and Findlay 2009).

The identification of spawning timing below peaking hydroelectric facilities is an important component of ensuring that the impacts of these facilities on spawning success are minimized. The water temperatures at which lake sturgeon spawn can range from 10˚C to 20˚C in the late-spring or early summer (Kerr et al. 2010). The purpose of this study was to compare direct TPK indicators with the typical environmental cues (water temperature and photoperiod) as a means to determine lake sturgeon spawning timing in a dammed river in northwestern Ontario.

2.0 Materials and Methods

2.1 Study Area

In 1926, the Sturgeon Falls Generating Station (also known as the Crilly Falls Dam) was constructed along the Seine River to create hydroelectric power. The 7 Megawatt facility is currently owned by H20 Power. The height of this dam (approximately 20 m from the tailrace to the headpond) created a barrier to upstream fish passage. This is the first barrier to fish along the Seine River, located approximately 45 km upstream from Rainy Lake. Lake sturgeon pawning confirmation efforts focussed on the two main spawning areas on Seine River, with one area located immediately downstream of the Sturgeon Falls dam and the other located underneath and immediately downstream of the highway 11 bridge (located approximately 1 km southwest of the dam). The TPK indicators were measured in Seine River First

Nation (located approximately 10 km west-southwest of Sturgeon Falls dam) for the trembling aspen *(Populus tremuloides*) leaves and eastern tiger swallowtail (*Papilo glaucus*) observations were made during field work travels between Seine River First Nation and Sturgeon Falls dam).

2.2 Identification of Traditional Phenological Knowledge Indicators of Sturgeon Spawning

In the fall of 2012, Kenora Resource Consultants worked with the Elders of Seine River First Nation to identify TPK indicators of lake sturgeon spawning. During November and December 2012, twelve knowledgeable community members from Seine River First Nation were interviewed using four 1:50000 scale national topographic system (NTS) maps (52C09,10,15,16) which represent the land and water around the community. Interview sessions were comprised of the questions outlined below in the interview schedule. Participants were asked to record the locations of the information they shared on provided NTS maps, and audio recordings were made of each interview session (except for one interview, when the participant did not wish to be recorded).

In December 2012, once interviews were completed, a spatial database was created by the community researchers using Quantum GIS software. The information shared during the interview sessions was then categorized into three knowledge groups: sturgeon harvests, spawning, and ecological indicators of sturgeon spawning timing. The ecological indicator category was then further divided by the specie type of the indicators themselves.

The common TPK indicators of lake sturgeon spawning given during the interviews included “yellow monarch” (tiger swallowtail) butterflies and the size of the trembling aspen leaves near the community. During the 2013 to 2015 field seasons, efforts were made to document both of these TPK indicators to determine their relationship to the spawning timing of lake sturgeon in Seine River.

2.3 Lake Sturgeon Spawning Confirmation

2.3.1 Egg Mats

Egg mats were used to help determine spawning timing of lake sturgeon in the Seine River. During the 2012 to 2015 field seasons, the placement of egg mats focussed on potential spawning habitat immediately downstream of the Sturgeon Falls dam and/or near the Highway 11 bridge. The areas where egg mats were placed varied during different field seasons due to fluctuating water levels and dangerous flows.

For the egg mats, 39 cm X 19 cm X 9 cm blocks were used. Each block was wrapped with a 90 cm X 30 cm piece of blue furnace filter and then secured using a bungee cord. Each egg mat was then attached to a yellow float for deployment from the boat.

All egg mats were checked for presence of lake sturgeon eggs once daily during week days throughout the field season and once daily on weekends during potential peak spawning timing. The egg mats were removed from the water, investigated for presence of eggs using a focussed visual inspection, and then placed back into the water on the identified high potential spawning areas.

2.3.2 Underwater Camera Videography

Underwater video was recorded using the Aqua Vu House View system, with a Sony colour camera, and the Aqua Vu Mini Video Recorder DVR. The camera was mounted to a cement block using 1-inch wood material and cable clamps (Figure 6). The camera/cement block was then place in the water near the spawning habitat to observe the presence of fish in the area. Once the camera was settled into a location that allowed for acceptable visibility and stability, the camera cable was run overland to a large plastic container, which housed 12-volt RV deep-cycle batteries and DVR. The camera cable was then hooked up to the DVR and then, following confirmation that the video was providing a quality picture, the recording on to a 32 GB SD card began. The plastic container was then closed and then locked to a tree using a two-metre length of chain and two padlocks. There were one to two cameras placed near identified spawning areas below the dam and below the bridge during each field season from 2012 to 2015.

The cameras were checked daily, with a change of batteries and exchanging of the SD card conducted. The underwater video was then observed using an additional DVR and a television. The underwater footage was observed at a fast forward speed of eight times the real-time speed, with slower speeds (real-time or two times) used for viewing and documenting any fish observed.

2.3.3 Larval Drift Nets

During the 2012 to 2015 field seasons, larval drift nets were set below the dam and below the bridge downstream of identified spawning areas for lake sturgeon. The larval drift nets were tied to boulders close to the shoreline or king anchors using approximately 5 m of blue multi-braided polypropylene rope. The drift nets were set in water approximately 50 cm of water depth so that the top of the drift nets were just above the water when set. Drift nets were checked once daily by removing the detachable collection bucket and then sorting through the debris collected with tweezers to identify the presence of larval lake sturgeon. The detachable collection bucket was then reattached to the drift net and set again for approximately 24 hours.

When egg mat data and/or underwater camera videography did not produce spawning results, larval drift data was used to calculate the timing of the spawn. This method uses the first larvae captured to indicate the start of the drift. Using the date of the first larvae captured the cumulative thermal units (CTU) are used to determine when the spawning occurred. The daily CTU value is determined by taking the mean daily water temperature and subtracting 5.8^{o}C. This will provide a thermal unit for the day. The spawning data is determined by calculating the sum of all of the daily CTU values backdated from the first larval sturgeon capture. When this total equals or exceeds 150, this is the approximate spawning date (Friday, M.J. 2010).

2.4 Trembling aspen Leaf Measurements

Throughout the spring field season, technicians gathered leaves from a stand of trembling aspen located on the hill near the water tower on Seine River First Nation. Five sample leaves were gathered from four different sites located near the water tower. The length and width of each leaf was then measured using digital calipers and an average of all 20 leaves taken from the four sites was used to determine the leaf size on that date.

2.5 Tiger Swallowtail Observations

The butterflies identified by the Elders as “Yellow Monarchs”, or Easten Tiger Swallowtail were found on the roadsides during the 2013 to 2015 field seasons. The numbers and locations were documented as lake sturgeon spawning and larval drift netting field work was conducted. There were no formal tiger swallowtail surveys conducted, as it was felt that their propensity to aggregate on the gravel roads made the observations during field work activities sufficient for identifying their timing for comparison with lake sturgeon spawning timing.

2.6 Water Temperature/Water Level Measurements

During the 2011 to 2013 field seasons, OMNR Atikokan staff installed a Solinst Levelogger Gold in the Seine River at a near shore location upstream of the highway 11 bridge. The logger was secured to a metal plate weight and lowered in the water to a depth of approximately 1 m. The weight was tied off to shore. A Solinst Barologger Gold was secured to the base of a young balsam fir tree located approximately 5 m southeast of the Levelogger location. The data collected by the Barologger allows the depth measurements taken by the Levelogger to be corrected for changes in atmospheric pressure. Unfortunately, OMNR staff was unable to retrieve the Levelogger from beneath the bridge following the 2013 field season, so logger data on water levels and temperature is not available for this field season. The daily temperature readings taken by Seine River First Nation field technicians using a thermometer were used for data analysis during the 2013 field season.

During the 2014 and 2015 field seasons, Seine River First Nation installed two Leveloggers and one Barologger in the study area on Seine River. One Solinst Levelogger was placed in the Seine River downstream of the highway 11 bridge and one downstream of the Sturgeon Falls dam. The loggers were secured to a metal plate weight and lowered to the bottom of the river behind boulders, with a cable wrapped around the boulder to facilitate retrieval of the logger. A Solinst Barologger was placed in the large plastic container used to house the underwater camera equipment immediately downstream of the bridge. The data collected by the Barologger allows the depth measurements taken by the Levelogger to be corrected for changes in atmospheric pressure.

At the end of the open water season, both Leveloggers and the Barologger were removed from the Seine River and a Solinst Leveloader was used to download the data from the two Leveloggers in addition to the Barologger. The collected data from the Leveloader was then downloaded to a PC for analysis.

3.0 Results

3.1 Environmental Cues

The measured water temperatures at the time of the peak spawning for lake sturgeon in the Seine River varied from 11˚C to 14.8˚C. During the 2011, 2014, and 2015 field seasons, lake sturgeon spawning activity began when water temperatures first exceeded 13˚C (on June 2nd in 2011, June 1st (bridge) and June 4th (dam) in 2014, and May 31st in 2015). During the 2012 field season, water temperatures were at 13.5˚C and had been above 13˚C for at least five days when spawning activity began (May 29th). During the 2013 field season, spawning activity began when water temperatures were at 11˚C (June 3rd). The water temperature data collected during the 2013 field season differed from the other field seasons as the Levelogger data was not retrieved so the temperature data was collected by field technicians once daily with thermometers. During the 2014 field season, there were two major spawning events at the dam, the first occurred on June 4th (three days after spawning at the bridge) when water temperatures first reached 13˚C and then a second spawning even when water temperatures were 14.8˚C and this occurred on June 9th (nine days after spawning was documented at the bridge and five days after peak spawning below the dam in 2014).

The water level changes on the date of the peak spawning events range from a decrease in water level of 29 cm in 2011 (this was part of a 53 cm drop over a 54 hour period) to a 8 cm increase in 2012. Two of the identified peak spawning events occurred on dates when water levels were decreasing (2012 and the second spawning event peak at the dam in 2014) and three of the identified peak spawning events occurred on dates when water levels were increasing (2012, 2015, and the first spawning event peak at the bridge in 2014). Note that the 2012 water levels were not available due to the Levelogger not being retrieved at the end of the field season.

The day length (sunrise to sunset) during the peak spawning activities varied from 15 hours and 46 minutes (May 29, 2012) to 16 hours and 2 minutes (June 9, 2014 – second peak spawning event at dam). The longest day length for a first peak spawning event was 15 hours and 54 minutes on June 3, 2013.

The spawning events listed in Table 2 below were determined using; visual confirmation in underwater video camera footage (2014); lake sturgeon eggs collected on egg mats (2013, 2014); capture of larval lake sturgeon and then using the capture date and water temperature data to calculate spawning timing (2012 and 2015); and milt expelled from male lake sturgeon captured near spawning site (2011).

3.2 Results

Trembling aspen leaves measured during peak spawning events ranged from approximately 35 mm in diameter (first spawning peak below the bridge in 2014) to approximately 51 mm (2015). The average leaf size measured on May 22nd, 2013 (22.44 mm) was the closest to the size identified by the Elders with lake sturgeon spawning (the size of a quarter – diameter 23.88 mm.).

The first sightings of tiger swallowtail butterflies during field work occurred one day prior to spawning activity in 2013; two days after the first peak spawn in at the bridge, one day before the first peak spawn below the dam, and six days prior to the second peak spawn in 2014; and four days prior to identified peak spawning activity in 2015.

4.0 Discussion

4.1 Environmental Cues for Lake Sturgeon Spawning

The results of the 2011 to 2015 data collection indicate that water temperature and photoperiod (day length) are the two factors that could potentially trigger lake sturgeon spawning on the Seine River. The lake sturgeon spawning occurred as soon as the water temperature reached 13˚C as long as this temperature was reached when the photoperiod was between 15 hours, 49 minutes and 15 hours, 52 minutes. During the year when the water temperature reached 13˚C much earlier than in the other field seasons (2012), the spawning occurred when the photoperiod was 15 hours, 46 minutes. During the year when the water temperature reached 13˚C much later in the field season (2013), the spawning occurred when the photoperiod was 15 hours, 54 minutes.

Therefore, it is felt that the 2011 to 2015 data indicates that a potential environmental trigger for lake sturgeon spawning is the water temperature reaching 13˚C, providing that this temperature is reached when the photoperiod is between 15 hours, 46 minutes and 15 hours, 54 minutes. If the water temperature reaches 13˚C when the photoperiod is longer, the data indicates that a photoperiod day length of approximately 15 hours, 54 minutes could become the environmental trigger for lake sturgeon spawning. The data collected also indicates that if the water temperature reaches 13˚C when the photoperiod is shorter, than a photoperiod day length of approximately 15 hours, 46 minutes could be the environmental trigger for lake sturgeon spawning.

The water level results from the five-year study did not provide any indications of a potential relationship between flows/water levels and spawning timing. However, it is worth noting that the highest flows and water levels in the Seine River during the study period occurred during the 2014 open water season, which coincided with the highest numbers of spawning lake sturgeon and two distinct spawning peaks in Seine River that year.

The temperature/photoperiod relationship for spawning triggers could be an evolutionary response to reproductive success of lake sturgeon. It could be that spawning activity occurring prior to the day length of 15 hours, 46 minutes, increases the potential that colder weather could follow the spawning event. This colder weather could result in less food available for larval lake sturgeon when they begin to feed exogenously which can have major implications for future year class strength (critical period hypothesis). It could also be that spawning after the photoperiod has reached 15 hours, 54 minutes begins to reduce the length of the open water season for young of the year lake sturgeon to grow and survive their first winter, once again reducing reproductive success and future year class strength. This could be why lake sturgeon on Seine River have evolved to use water temperature as a spawning trigger providing it occurs within a specific time frame.

4.2 Terrestrial Biotic Cues for Lake Sturgeon Spawning

The primary TPK indicator for lake sturgeon spawning on Seine River was the first observation of tiger swallowtail butterflies. The observation of tiger swallowtails occurred between four days before (2015) and two days after (2014) the identified peak lake sturgeon spawning period on Seine River. The use of tiger swallowtail observations to predict lake sturgeon spawning resulted in less variation than the use of water temperature as the environmental indicator, as water temperature at 13˚C occurred seven days before identified peak lake sturgeon spawning in 2012 and five days after in 2013.

Using the mid-point of the variation of day-lengths for observed spawning activities (15 hours, 50 minutes) is a slightly more consistent environmental indicator of the identified peak lake sturgeon spawning activities in the Seine River. As an environmental indicator, the photoperiod of 15 hours, 50 minutes occurred two days after the identified peak lake sturgeon spawning in 2012 and three days after in 2013 which is less variation (five days) than shown with water temperatures (12 days) and tiger swallowtail observations (six days) above.

However, when it comes to predicting the exact peak spawning date, the water temperature at 13˚C achieved this three times (2011, 2014, 2015), the photoperiod at 15 hours, 50 minutes achieved this twice (2014, 2015) and the first observation of tiger swallowtails never did occur on the exact same date as the identified peak spawning on Seine River.

The data indicates that observations of tiger swallowtail butterflies as a TPK indicator would have been and is an effective tool for predicting the approximate timing of lake sturgeon spawning in the Seine River.

The use of the size of trembling aspen leaves as a TPK indicator for lake sturgeon spawning in Seine River does not appear to as effective as tiger swallowtail butterflies. During the identified lake sturgeon spawning period on Seine River, the leaves were much larger than the size of a quarter or beaver's ear as described by the Elders and knowledge holders in Seine River First Nation. However, initial field work conducted in the Turtle River system during the 2015 field season indicate that the lake sturgeon in Turtle River spawn significantly earlier (up to two weeks earlier) than the Seine River spawning population. While subsequent data will need to be collected in future years, it is hypothesized that the size of the trembling aspen leaves is a potential TPK indicator for peak lake sturgeon spawning activities on the Turtle River system (which is another important sturgeon population for Seine River First Nation).

4.3 Applicability of Findings to Other Peaking Hydroelectric Facilities

A study was conducted during the 2012 and 2013 field seasons on the Upper Rainy River examining the spawning timing and larval drift time period for lake sturgeon downstream of the dam at Fort Frances/International Falls. Following is an excerpt from this study:

> "Lake sturgeon spawning took place at temperatures ranging from 8.5 to 16.5 °C, with eggs found from 10 May to 28 May 2012 and 25 May to 18 June 2013. The first

instances of lake sturgeon drift were seen 6 June 2012 and 18 June 2013, with eggs remaining at the spawning site for approximately 27 days in 2012 and 24 days in 2013." (Smith et al. 2014)

This indicates that the lake sturgeon activities in Rainy River downstream of the International Falls/Fort Frances dam occur at a wider range of temperatures and days than is typically found in Seine River downstream of the Sturgeon Falls dam. On Seine River the spawning activities were documented on May 29th in 2012 (water temperature 13.5˚C) and between May 31st and June 10th in 2013 (water temperatures ranging from 11 ˚C and 12.5 ˚C). The 2012 spawning activities on Seine River occurred after the documented spawning activities on the Rainy River and the 2013 Seine River spawning activities occurred within the same time period as that identified on Rainy River, but over a shorter time period. The first instance of larval drift in 2012 on Seine River was on June 13th, which was one week after larval drift began on Rainy River during the same field season. In 2013, the first instance of larval drift on the Seine River was on June 18th, the same date as the first instance of larval drift on Rainy River in the same field season.

The discrepancy between the results found during the two field seasons (2012 and 2013) for the field crews working independently on the Rainy River and Seine River indicate that, while there can be overlap and similarities in spawning and/or larval drift timing between the Rainy River and Seine River, the differences in timing illustrated by the 2012 results would indicate that the environmental and TPK indicators found for the lake sturgeon spawning timing on Seine River can likely not be applied to other peaking hydroelectric facilities in the area.

The spawning timing below the dam at Rainy River is typically approximately two weeks after the spawning activity in the smaller, free-flowing or natural tributaries to the Rainy River (Tom Heinrich, Minnesota DNR, personal communications by telephone, February 11, 2016). This relationship is very similar to the one found when comparing the spawning timing below the dam at Seine River to the free-flowing or natural Turtle River system.

For the Manitoba portion of the Winnipeg River, in particular the spawning populations at Pointe du Bois and Slave Falls dams, there is a wider range of environmental variability (water temperature, photoperiod etc.) associated with the spawning timing of lake sturgeon than was found in the Seine River study from 2011 to 2015 (Paul Cooley, North-South Consultants, personal communications by telephone, February 11, 2016).

In discussions with researchers and biologists working throughout the Rainy Lake/Lake of the Woods/Winnipeg River watershed, it was speculated that the spawning activities of lake sturgeon occur under a wider variety of environmental conditions in larger river systems. Given this hypothesis, it is possible that the environmental cues and TPK indicators found on Seine River may be able to be applied to any dam operations on waterbodies similar in size with similar flows as those found at the Sturgeon Falls dam, but they do not seem to apply to the dam operations on the larger river systems found elsewhere in the watershed.

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