TRANSCANADA HYDRO NORTHEAST INC.

ILP Study 20

American Eel Downstream Migration Timing Assessment

Study Report

In support of Federal Energy Regulatory Commission Relicensing of:

Wilder Hydroelectric Project (FERC Project No. 1892-026)
Bellows Falls Hydroelectric Project (FERC Project No. 1855-045)
Vernon Hydroelectric Project (FERC Project No. 1904-073)

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TABLE OF CONTENTS

List of Figures

List of Tables

List of Abbreviations

CRWC	Connecticut River Watershed Council
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Power Resources
FWS	U.S. Department of the Interior – Fish and Wildlife Service
NHDES	New Hampshire Department of Environmental Services
NHFGD	New Hampshire Fish and Game Department
RSP	Revised Study Plan
SSR	Site Selection Report
TransCanada	TransCanada Hydro Northeast Inc.
TU	Trout Unlimited
USR	Updated Study Report
VANR	Vermont Agency of Natural Resources
VDEC	Vermont Department of Environmental Conservation

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1.0 INTRODUCTION

This study report presents the findings of the American Eel Downstream Migration Timing Assessment (ILP Study 20) conducted in support of Federal Energy Regulatory Commission (FERC) relicensing efforts by TransCanada Hydro Northeast, Inc. (TransCanada) for the Wilder Hydroelectric Project (FERC Project No. 1892), Bellows Falls Hydroelectric Project (FERC No. 1855) and the Vernon Hydroelectric Project (FERC No. 1904).

The American Eel (*Anguilla rostrata*) is a catadromous species with the juvenile stage existing primarily in freshwater, but also in estuarine and nearshore marine environments for a period of years prior to downstream migration as an adult. Reaching maturity, American Eels begin migration to the Atlantic Ocean during late summer into the fall (August through November). Spawning occurs between February and April in the Sargasso Sea. Sizes range in the Connecticut River from approximately 6 inches for juveniles migrating up-river to a maximum of 30-60 inches for out-migrating adults (Langdon et al. 2006). During the freshwater phase, eels prefer lakes, rivers and ponds with mud or silt bottoms and can be found at a variety of depths. Eels are primarily predators, feeding on a variety of invertebrates and fish and typically are more active during night hours. Activity is restricted to the warmer months and winter is spent buried in the mud or silt.

In their study requests, US Fish and Wildlife Service (FWS), New Hampshire Department of Environmental Services (NHDES), New Hampshire Fish and Game Department (NHFGD), Vermont Agency of Natural Resources (VANR), Connecticut River Watershed Council (CRWC), and Trout Unlimited (TU) identified a potential issue related to the lack of understanding about the outmigration timing of silver phase American eels in relation to environmental factors and operations of mainstem hydropower projects on the Connecticut River, including the Wilder, Bellows Falls, and Vernon Projects, although the TU study request only included the Bellows Falls and Vernon Projects.

An amended Revised Study Plan (RSP) 20 was approved by FERC in its February 21, 2014 Study Plan Determination. On May 14, 2015, FERC issued an order granting TransCanada's request for rehearing (filed March 24, 2014) that removed the requirement to conduct the "Vernon Hydroacoustic Study" and as such eliminated the hydroacoustic study element in the analysis portion of this study.

This report provides results from the literature review and is intended to supplement information collected as part of TransCanada and FirstLight field studies of American Eel.

2.0 STUDY GOALS AND OBJECTIVES

As stated in the RSP, the goal of this study was to assess the timing of American eels migrating from the Connecticut River to their spawning grounds. The objective of this desktop study was to characterize the general migratory timing and presence of silver phase American eels in the Connecticut River relative to environmental factors, including air and water temperature, turbidity, rainfall, river flow, lunar phase, and flow-related operations of mainstem river hydroelectric projects. A thorough desktop review of existing eel downstream migration literature was conducted. Although initially intended to include and analyze the, field data collected at Cabot Station by FirstLight in its ILP Study 3.3.5 (Evaluate Downstream Passage of American Eel); their intended completion date for this study precludes including information for this report. However, once results from that study become available they will be reviewed and, if applicable, incorporated into a Study 20 report supplement or revision based on the nature of the additional information.

3.0 STUDY AREA

The literature review focused on existing Connecticut River Basin primary publications, reports, and data (as made available). In addition, existing information from basins in the Northeast were included to compare and contrast with specific information for the Connecticut River Basin. A broader search for information specific to cues that instigate migration was also included. Regardless of basin or even region, such information on migratory cues may be helpful for developing downstream passage plans in the Connecticut River Basin.

The Connecticut River originates in the Fourth Connecticut Lake near the Canadian border. TransCanada owns and operates six of the nine dams in New Hampshire and Vermont in the reach between the river source and Turner Falls dam (FERC No. 1889) in Massachusetts; including the three southernmost TransCanada projects currently up for relicensing: Wilder, Bellows Falls, and Vernon. All three projects are conventional hydroelectric stations.

The Wilder Project is the northernmost of the three with the dam and powerhouse located at River Mile (RM) 217.4. The impoundment extends up-river approximately 45 miles from the dam. Below the dam, a riverine stretch of approximately 17 miles exists before entering the Bellows Falls impoundment. The Bellows Falls Project is located at RM 173.4, approximately 44 miles downstream of Wilder. The impoundment extends upstream approximately 26 miles from the dam which includes a bypassed reach approximately 3,500 feet long. Below Bellows Falls, a riverine section extends approximately 6 miles before transitioning to the Vernon impoundment. Vernon dam and powerhouse are the southernmost project located at RM 141.9 and the impoundment extends up-river approximately 26 miles. The downstream FERC Project boundary is the downstream side of Vernon dam as the upstream boundary of the Turners Falls Project impoundment at normal reservoir elevation abuts the downstream face of the Vernon dam.

4.0 METHODOLOGY

Currently available peer-reviewed, grey literature, and relevant reports of studies related to American Eel downstream migration on the Connecticut River and other river systems in the Northeast as well as general eel migration biology were reviewed to quantify and characterize the expected outmigration of silver phase American eels. The review focused in particular on environmental cues that stimulate migration. Results of concurrent studies conducted by TransCanada were also reviewed to identify supplemental information useful to this study, and included:

- Study 10 – Fish Assemblage Study
- Study 11 – American Eel Survey
- Study 17 – Upstream Passage of Riverine Fish Species Assessment
- Study 18 – American Eel Upstream Passage Assessment
- Study 19 – American Eel Downstream Passage Assessment

Of these studies, only Study 19 results could potentially provide information on timing of silver eel downstream migration; however, eels were sourced from Newfoundland, Canada due to insufficient numbers available from Connecticut River sources. As a result, release dates for radio-tagged eels were delayed and largely dependent upon all the timing of acquisition, retention for required pathology testing, and transport of the eels. FirstLight is also conducting a downstream eel passage study as part of relicensing of the Turners Falls and Northfield Mountain Pumped Storage Projects. Results of that study are not available at this time but part of that study includes evaluation of Connecticut River eels emigrating naturally.

5.0 RESULTS AND DISCUSSION

5.1 General Eel Life History and Ecology

American Eel is a catadromous species, meaning spawning occurs in saltwater, but progeny return to coastal and freshwater areas for rearing and growth during the pre-reproductive period (Tesch, 1977; EPRI, 2001). American Eels spawn from February through April (or later) in one broadly overlapping region of the Sargasso Sea located in the southwestern North Atlantic Ocean (McCleave et al., 1987). The locations of the spawning areas were inferred from the collection of larval eels since spawning adults have never been directly observed. In 2014, Béguer-Pon et al. (2015) reconstructed the route of migration of one silver phase American Eel from Canada to the Sargasso Sea from pop-up satellite archival tags.

Elvers (immature eels) enter rivers in early spring and begin upstream migration (Helfman et al., 1987). As elvers feed and grow, they change pigmentation and transform to "yellow phase" eels. Upstream migration of both elvers and yellow

phase eels may occur over a broad seasonal period (March to October), with most movement from May through August (Dutil et al., 1988).

Eels remain in the yellow phase and grow for a number of years before reaching sexual maturation. Males mature at earlier ages and smaller sizes than females (Helfman et al., 1987; Krueger and Oliveira, 1997) and both male and female age and size at maturity are generally positively correlated with latitude. Females may spend extended periods (> 20 years) in freshwater before sexually maturing (Jessop, 1987).

Yellow phase eels undergo a number of changes to prepare for the spawning migration back to the Sargasso Sea (Pankhurst, 1982). The most notable changes are characterized by changes in pigmentation, i.e., "silvering", as well as a large increase in eye diameter (Winn et al., 1975). Habitat conditions including food availability and water temperature influence growth, resulting in variation in length and age at maturity among different habitats (USFWS, 2007). Environmental factors may play a role in the triggering of silvering, and it is believed that a drop in water temperature triggers final metamorphosis (USFWS, 2007; CESAR, 2010).

Downstream migration of eels is initiated at a point during the period when they are in their final stages of sexual maturation. Silvering and other morphological, physiological, and biochemical changes occur as they reach sexual maturity and transform from the immature yellow phase to the sexually mature silver phase (EPRI, 1999). Silver phase adult eels migrate downstream during a broad period in the fall (Vollestad et al., 1986; Helfman et al., 1987) when environmental conditions are appropriate.

5.2 Silver American Eel Migration Timing

The general timing of silver American Eel emigration in the Connecticut River has not been thoroughly studied, though some site-specific investigations have been undertaken. American Eel in the northern part of the range exhibit relatively slower growth and remain longer in freshwater and estuarine systems before beginning migration back to sea (Facey and LaBar, 1981).

In New England and mid-Atlantic tributaries, spawning emigrations begin in the late summer and continue through fall, however, winter emigrations have been noted (Facey and Helfman, 1985; Euston et al., 1997; 1998). Eels emigrate later in the southeastern states and in the Mid-Atlantic than in the northern states (ASMFC, 2009). Similar fall emigration periods have been reported by other researchers as well (Haro et al, 2003; Winn et al., 1975). Winn et al. (1975) documented American Eels emigrating in Rhode Island from September through November. The timing of emigration is also influenced by latitude, and seasonal emigration occurs earlier at high latitudes (Tesch, 1977). In the upper portion of the St. Lawrence River, American Eel emigration occurs from late June through early October (McGrath et al., 2003). However, EPRI (1999) citing Caron and Verreault (1997) found that the majority emigrated from mid-August to late October with a peak in mid-October in the St. Lawrence River, and Hatin et al. (2014) documented

emigration in June through September, peaking in July and August in the St. Lawrence River.

Thon (1999) indicates that the time of initiation of downstream migration generally differs among water bodies and the rate of migration varies, with pauses occurring while the silver eels wait for specific environmental cues (Richkus and Whalen, 1999). Emigrating eels have been noted to aggregate naturally, presumably in response to those cues (Versar, 2009). For example, it has been theorized that a migratory response to a drop in water temperature synchronizes emigrating eels, increasing their chances of reaching the Sargasso Sea simultaneously (USFWS, 2007; CESAR, 2010).

In general, migration of silver eel occurs mostly at night (Winn et al., 1975; Edel, 1976; Haro et al., 2000; McGrath et al., 2003, Bradford et al., 2009; Hatin et al., 2014). Haro et al. (2000, in ASMFC, 2009) reported that silver eels in the Connecticut River migrated primarily at night within several hours after sunset, and became inactive during the day. Sampling in the Connecticut River at Holyoke, MA showed that emigration occurs nightly between 17:00 and 04:00, with peak activity (70%) occurring in the two hour block between 19:00 and 21:00 in 2004, and was spread between 19:00 and 24:00 in 2005 (Figure 5.2-1; Kleinschmidt, 2006). Eel passage data collected through continuous radio telemetry monitoring of eels released at Wilder, Bellows Falls, and Vernon Dam in 2015 showed similar trends with peak movement times between 18:00 and 24:00 (Figure 5.2-2; Normandeau, 2016c).

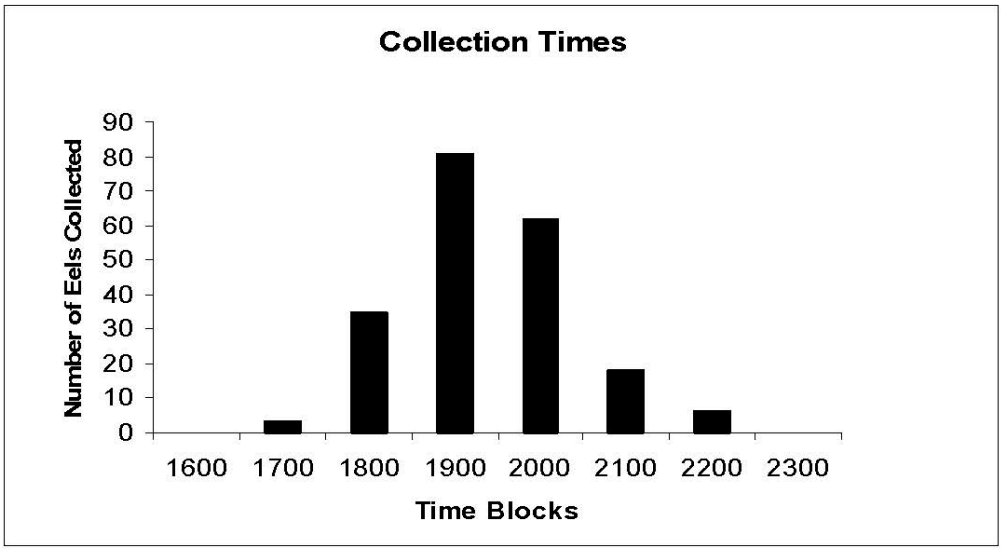

Figure 3a. Nightly timing of emigrating silver phase American eels at the Holyoke Louver Bypass, Holyoke MA. in 2004.

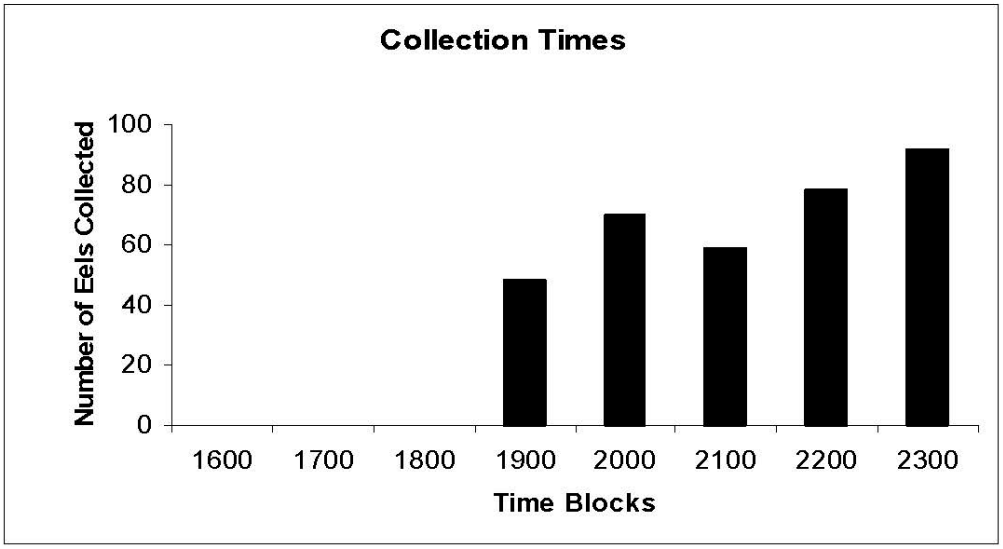

Figure 3b. Nightly timing of emigrating silver phase American eels at the Holyoke Louver Bypass, Holyoke MA. in 2005.

Figure 5.2-1. Nightly timing of emigrating silver eels at the Holyoke Bypass in 2004 and 2005 (reproduced from Kleinschmidt, 2006).

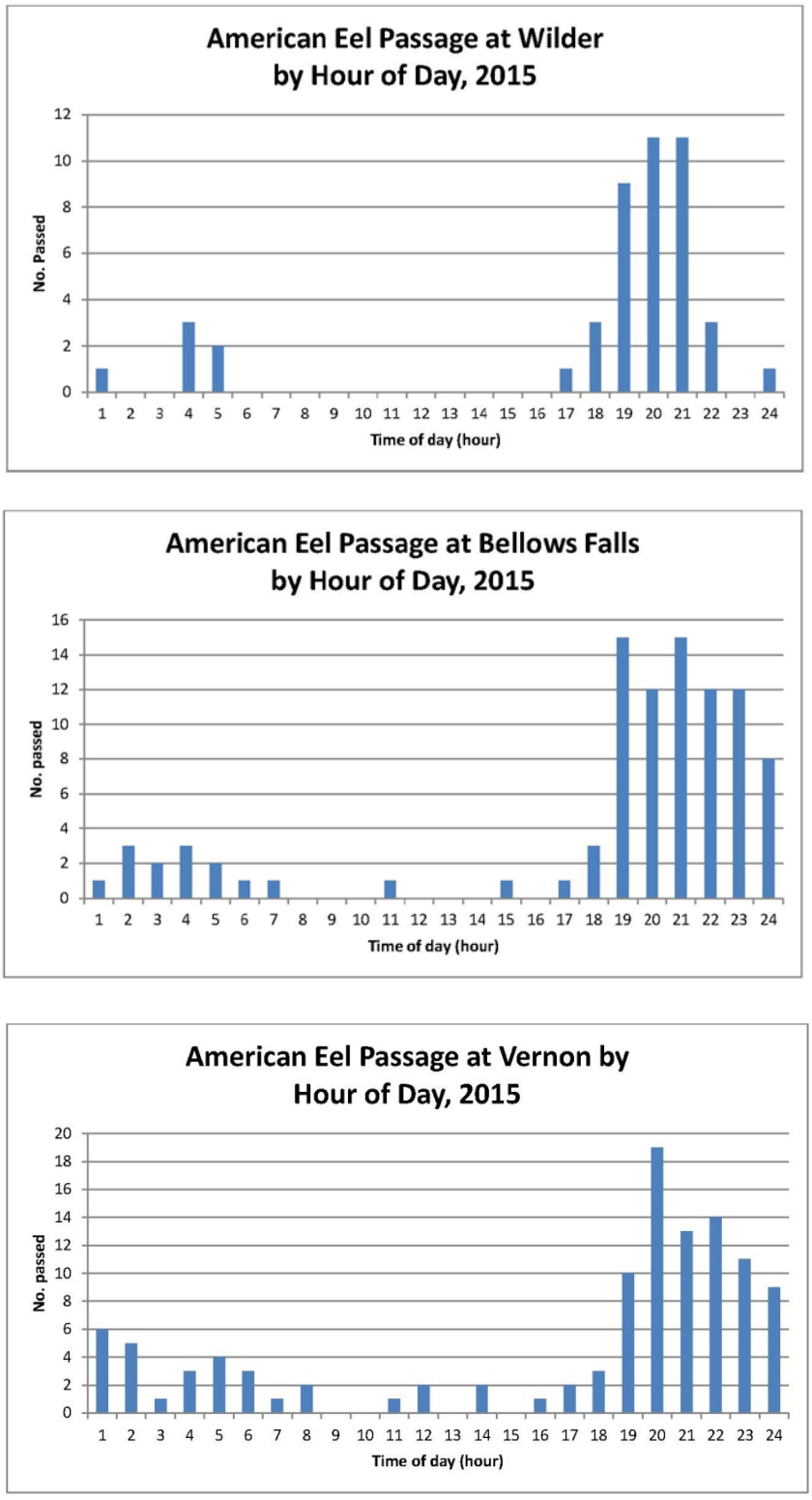

Figure 5.2-2. Hourly passage of radio-tagged silver eels at Wilder, Bellows Falls, and Vernon dams, fall 2015 (reproduced from Normandeau, 2016c).

5.3 Factors Affecting Emigration

5.3.1 River Flows and Rainfall

Because eels are inefficient swimmers, river flow may be an important mechanism for downstream transport. This suggests that emigrating eels respond to elevated flows to facilitate the emigration. Silver eel migration has been noted to coincide with periods of increased discharge (Winn et al., 1975; Vollestad et al., 1988; Euston et al., 1997; 1998). When encountering hydroelectric facilities, emigrating eels demonstrate vertical and horizontal swimming motions suggesting they search for zones of higher velocity (Haro et al., 2000; Brown et al., 2009) and typically respond to flows tending to pass via routes of dominant discharge. Normandeau (2016c) found similar results for out-of-basin radio-tagged eels released approximately three miles upstream of each dam. At Wilder and Bellows Falls dams most eel passage occurred at discharge flows near full generation (9,000-10,000 cfs at Wilder and 11,000-12,000 cfs at Bellows Falls). At Vernon most passage occurred 8,000-9,000 cfs with another smaller passage peak at 13,000-14,000 cfs (near full generation flows), (Figure 5.3.1).

Rainfall, which leads to increased river discharge, may also have an impact on silver eel migrations (Lowe, 1951; Winn et al., 1975; Euston et al., 1997 1998). Winn et al. (1975) noted increased migrations after rains and Haro et al. (2003) found that more eels were captured on, or soon after days with rain than on dry days in Maine. Kleinschmidt (2005) correlated silver eel catch to increased river flows but also indicated it was not the sole trigger for movement. Potential cues related to rain events other than increased flow have also been identified, including increased turbidity, olfactory indicators, and/or decreases in barometric pressure Haro (2003). Rain events have been documented as playing a major role in the stimulation of emigration in American Eel in the Connecticut River as well (Haro et al., 2003; Eltz, 2006).

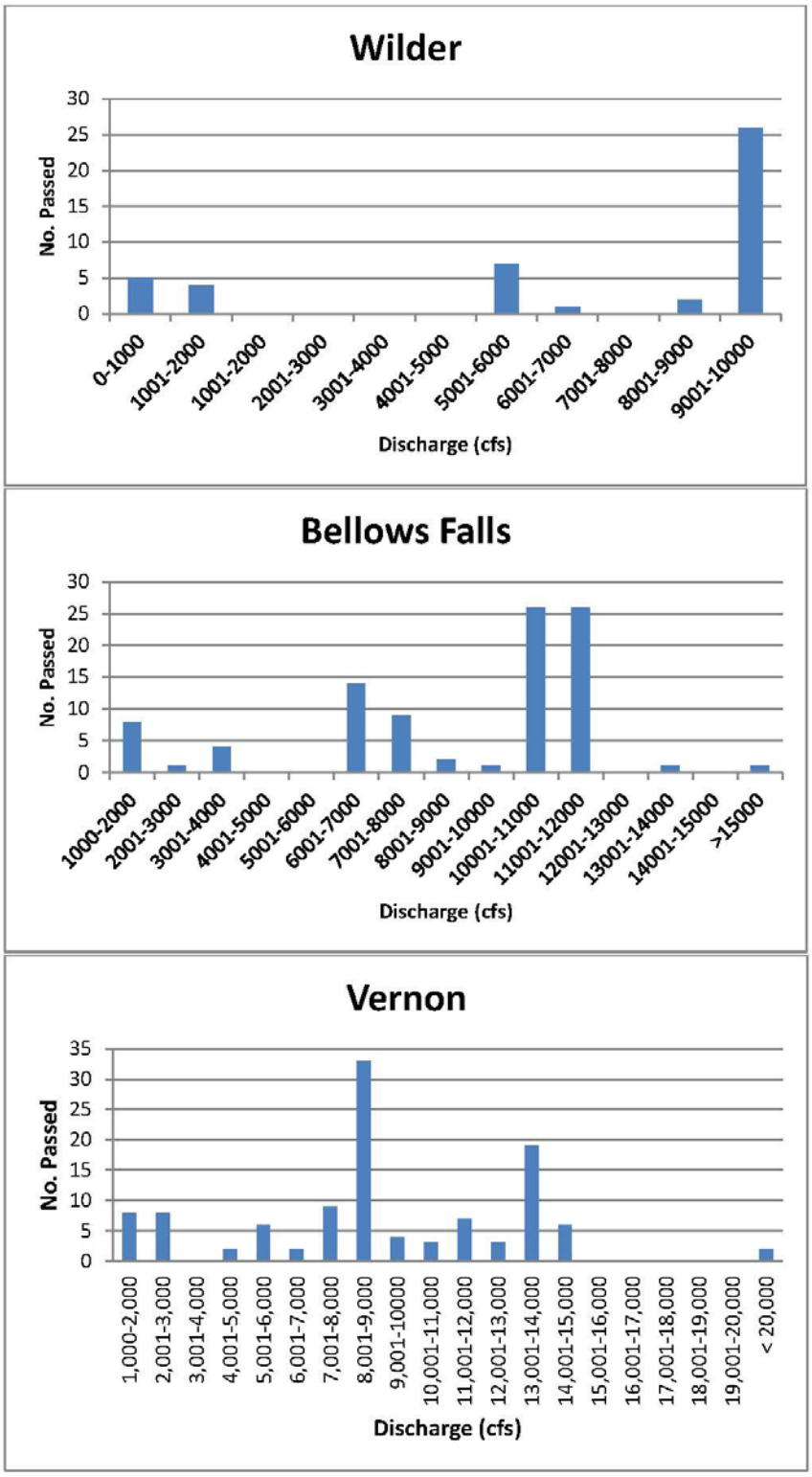

Figure 5.3-1. Passage of radio-tagged silver eels at Wilder, Bellows Falls, and Vernon dams by total river discharge (cfs) fall 2015 (reproduced from Normandeau, 2016c).

5.3.2 Water Temperature

Water temperature has been identified in the literature as having a significant effect on the timing of eel emigration; however, due limited daily variation it is unlikely that water temperature alone initiates an emigration event, but may serve as a seasonal bound to emigration (EPRI, 2001). The reported range of water temperatures when emigration occurs is generally consistent, albeit wide. A long term data set provided by Vollestad et al. (1986) presents the percent of all silver European Eels taken in the River Imsa over the period from 1975 to 1984. Eel emigration occurred between 3°C and 18°C with movement peaking between about 9°C and 12°C. Euston et al. (1997; 1998) found that American Eels in Virginia moved downstream when water temperature was from 6°C to 13°C, with most migration occurring between 5°C and 9°C.

In the Connecticut River, water temperature at Holyoke Dam ranged from about 7.5°C to 14.5°C during downstream passage of radio-tagged silver-phase eels (Normandeau, 2007). While the observed temperatures at passage were influenced by release date, the release date was largely determined by availability of emigrating eels for tagging. Haro et al. (2000) observed temperatures of 16.9°C (3 October) to 9.5°C (22 October) in 1996 and from 17.7°C (30 September) to 9.7°C (4 November) in 1997 during telemetry evaluations at Turners Falls. Those results were generally supportive of previous studies that indicated a range of temperatures during the emigration period of about 10°C to 20°C (Figure 5.3-2; Kleinschmidt, 2006). Water temperature was between 9.0 and 11.0 when the majority of tagged eels passed the Wilder, Bellows Falls, and Vernon dams in 2015; however, these eels were released to the study area late in the emigration season (due to delays associated with out-of-basin procurement) when water temperatures in the forebay sections of the lower impoundments ranged from approximately 9.0 – 10.2°C (Louis Berger and Normandeau, 2016), thus potentially influencing the passage temperature range (Figure 5.3-3; Normandeau, 2016c).

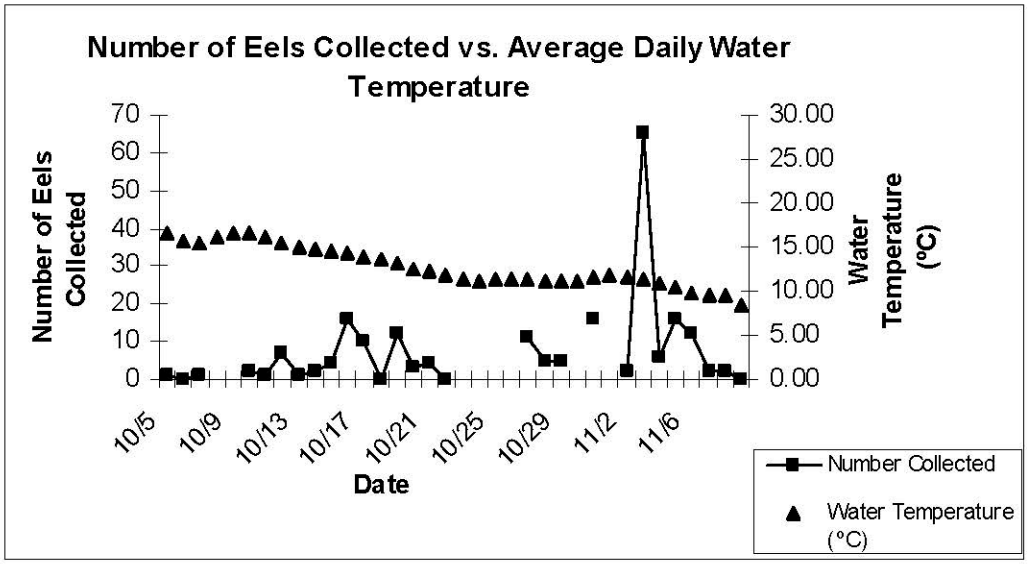

Figure 4a. The number of emigrating silver phase American eels collected at the Holyoke Louver Bypass, Holyoke MA. 2004 vs. the average daily water temperature.

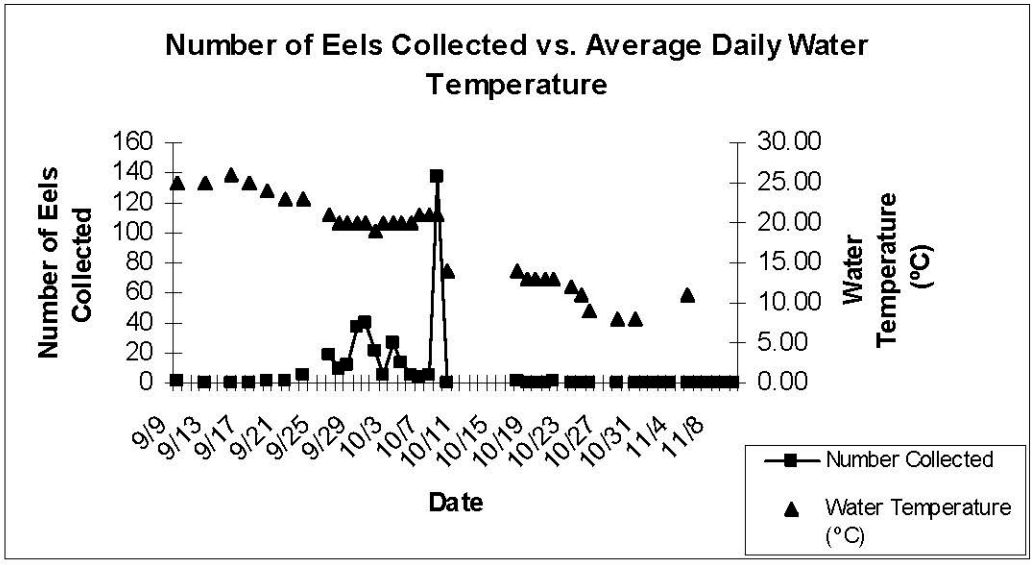

Figure 4b. The number of emigrating silver phase American eels collected at the Holyoke Louver Bypass, Holyoke MA. 2005 vs. the average daily water temperature.

Figure 5.3-2. Passage of emigrating silver eels at the Holyoke Bypass in 2004 and 2005 in relation to water temperature (reproduced from Kleinschmidt, 2006).

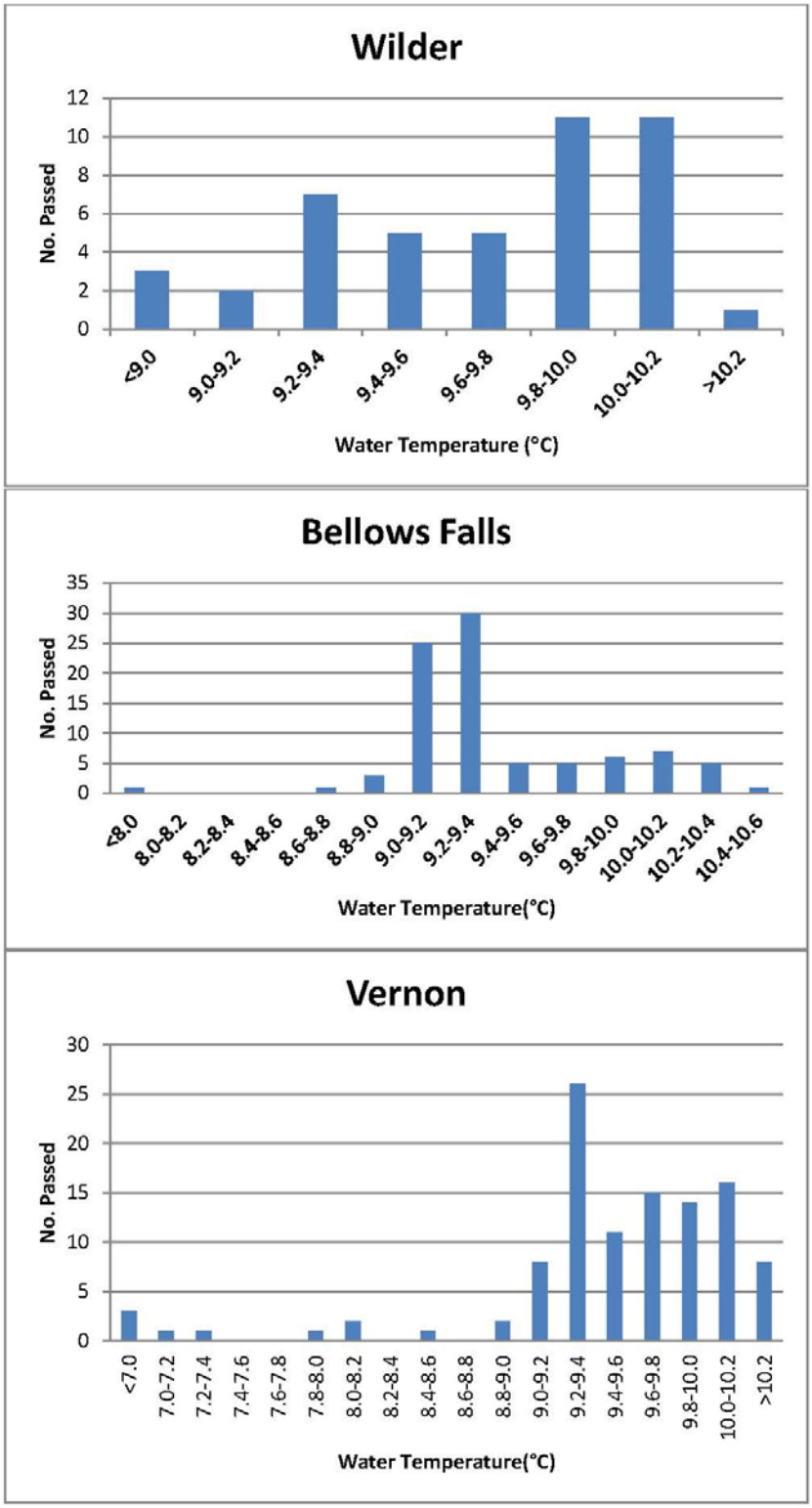

Figure 5.3-3. Passage of radio-tagged silver eels at Wilder, Bellows Falls, and Vernon dams by water temperature, fall 2015 - note varying scales (reproduced from Normandeau, 2016c).

5.3.3 Lunar phase

Researchers have indicated that moon phase has an influence on silver eel migration patterns (Tesch, 1977; Winn et al., 1975; Euston et al., 1997; 1998). Euston et al. (1997; 1998) found that activity increases between the last quarter moon and new moon. Winn et al. (1975) reported primary downstream migration after rains, but also observed downstream migration during the third and fourth lunar quarters when rain was not a factor. Studies also indicated that catch rates of American Eel are higher during the dark phases of the moon and when cloud cover is highest (Winn et al., 1975; McGrath et al., 2003). In some cases moon phase has been found to be less important than proximate environmental cues, such as water temperature and flow, when all factors are considered together (Vollestad et al., 1986). In the Connecticut River, Kleinschmidt (2006) indicated that moon phase did not seem to have any effect on eel movement in two years of monitoring at Holyoke Dam (Figure 5.3-4). Normandeau (2007) also found no discernable relationship there.

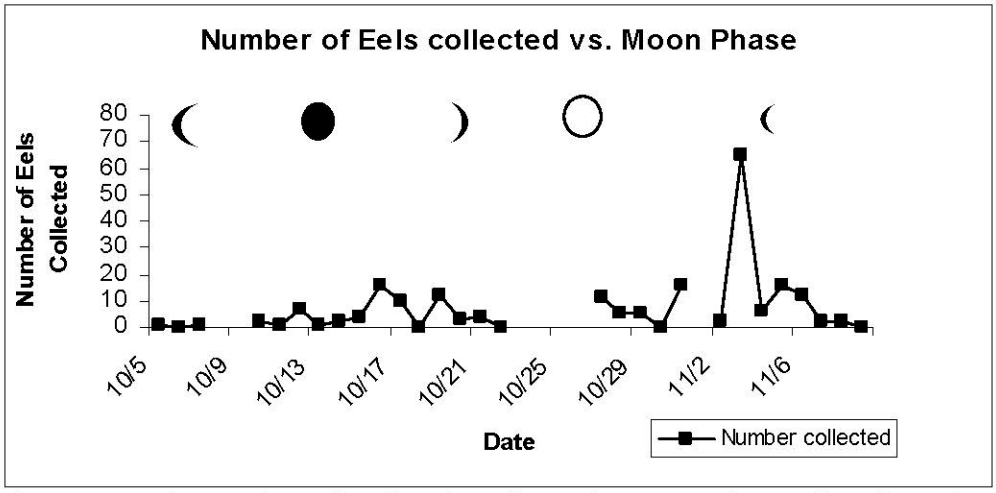

Figure 10a. The number of emigrating silver phase American eels collected at the Holyoke Louver Bypass, Holyoke MA. 2004 vs. moon phase.

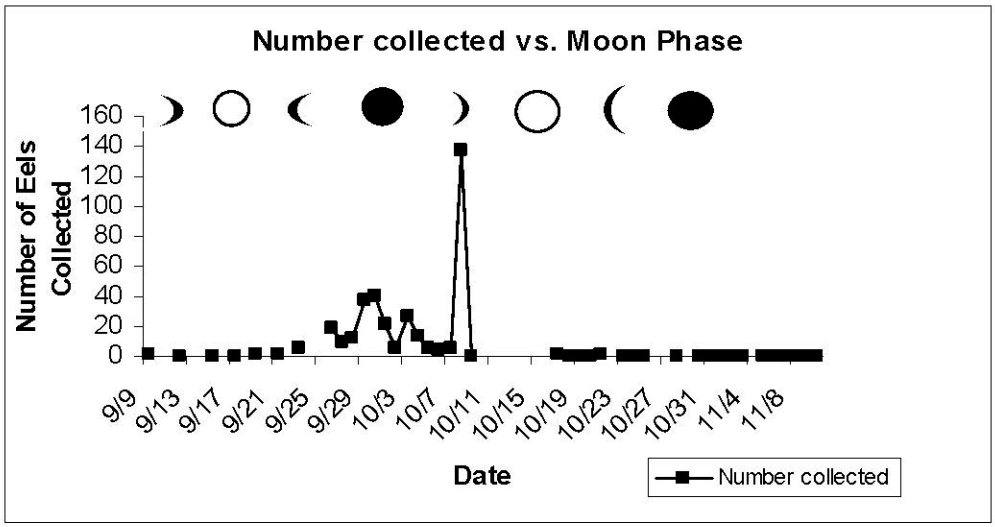

Figure 10b. The number of emigrating silver phase American eels collected at the Holyoke Louver Bypass, Holyoke MA. 2005 vs. moon phase.

Figure 5.3-4. Passage of emigrating silver eels at the Holyoke Bypass in 2004 and 2005 in relation to moon phase. Reproduced from Kleinschmidt (2006).

5.3.4 Travel Timing

Downstream eel passage studies conducted by TransCanada in the fall of 2015 provided an opportunity to evaluate travel times of radio telemetered silver eel past their three projects (Normandeau, 2016). For eels released above the Wilder dam at RM 217.4 and detected 75.5 river miles downstream in the Vernon impoundment (having passed the Wilder and Bellows Falls projects), median travel time was 5 days, 8 hours, 40 minutes and ranged from 3 days, 3 hours, 50 minutes to 7 days, 15 hours, 56 minutes. Additionally their median residency time in the Vernon study area was short, about 2 hours, 2 minutes. These eels covered a distance of nearly 76 miles between the two projects at an average travel rate of 0.6 miles per hour regardless of whether they moved continually or in daily pulses (e.g., moving at night and resting during the day).

6.0 STUDY CONCLUSIONS

The objective of this study was to attempt to characterize the general migratory timing and presence of silver phase American eels in the Connecticut River relative to environmental factors, including air and water temperature, turbidity, rainfall, river flow, lunar phase, and flow-related operations of mainstem river hydroelectric projects. The purpose of this desktop study was to supplement information collected in downstream eel passage field studies being conducted by FirstLight at Cabot Station. A thorough literature search was conducted and available literature of studies of American Eel emigration in the Connecticut River, and more generally in the Northeast was reviewed. Specifically, this effort consolidated information regarding the timing of emigration and the environmental cues that may trigger downstream migration of silver eels.

The understanding of migratory timing and those cues that trigger it remain only generally defined in terms of seasonality, water temperature, and river flow (specifically decreases in water temperature and increases in discharge). Even more poorly understood are the potential effects of atmospheric events and the physical variables associated with them, such as changes in atmospheric pressure, rainfall, increased flows, turbidity, and olfactory indicators.

The information collected and reviewed in this study is summarized in Table 6.0-1. The table indicates that there are several environmental variables that may be associated with factors that influence silver eel migration and that these variables may act independently or in concert with one or more other variables in different river systems. Overall, there does not seem to be one particular variable that alone dictates the onset of migration.

Results of the eel downstream passage radio telemetry studies at Wilder, Bellows Falls, and Vernon in 2015 provide only limited information relative to the general migration window (late summer to fall) due to delays in release of radio-tagged eels. However, the study die demonstrate that the median residency times for eels from arrival at a project until passage were short (approximately 2 hours), thus

eels tend to move rapidly past the projects and the projects do not appear to significantly affect the timing of emigration of American Eels.

Table 6.0-1. Literature-based summary of American Eel migration timing and environmental factors.

Factor	Study Area	Migration Range	Peak	Citation(s)
Seasonality	American Eel, general	Late summer – through fall	Mid-October	ASMFC, 2009; EPRI, 1999; Carron and Verrault, 1997; Euston et al., 1997; 1998.
	Northeast rivers	Mid-August - November	Mid-October	Haro et. al., 2003; Winn et al., 1975; McGrath et al., 2003; Kleinschmidt, 2005; 2006.
	Connecticut River	Mid-August - November	Mid-October	Haro, 2003; Kleinschmidt, 2005; 2006.
Water Temperature	American Eel, general	20°C-3°C	9°C- 5°C	EPRI, 1999; Vollestad, 1986; Euston et al., 1997; 1998.
	Northeast rivers	20°C-5°C	11°C- 9°C	Winn et al., 1975; EPRI, 1999; ASMFC, 2009.
	Connecticut River	20°C-5°C	11°C- 9°C	Normandeau, 2007; Kleinschmidt, 2005; 2006.
River Flow	American Eel, general	Variable reported but generally occurs with increased flows	Variable dependent upon System	ASMFC, 2009; EPRI, 1999; Winn et al, 1975; Vollestad, 1998; Euston et al., 1997, 1998; Lowe, 1952.
	Northeast rivers	Variable reported but generally occurs with increased flows	Variable dependent upon System	Haro et al., 2003; Winn et al., 1975
	Connecticut River	Variable reported but generally occurs with increased flows	Variable dependent upon System	Eltz, 2006; Kleinschmidt, 2005; 2006; Normandeau, 2016c.
Lunar Phase	American Eel, general	Variable reported	Last Quarter and New moon	Tesch, 1977; Winn et. al., 1975; EPRI, 1999; ASMFC, 2009; Euston et al., 1997; 1998.
	Northeast rivers	Variable reported	Last Quarter and New moon	Winn et al., 1975; McGrath et al., 2003.
	Connecticut River	Variable reported	No firm confirmation	Normandeau, 2007; Kleinschmidt, 2005; 2006.

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