TRANSCANADA HYDRO NORTHEAST INC.

ILP Studies 14 and 15

Resident Fish Spawning in Impoundments and Riverine Sections Studies

Revised Final 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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EXECUTIVE SUMMARY

The goal of these two studies was to assess effects on resident fish spawning from project-related water level fluctuations in the Wilder, Bellows Falls and Vernon impoundments (Study 14) and project-related flow fluctuations in riverine reaches downstream of these project dams (Study 15). This revised final study report makes minor changes and corrections in certain tables and figures in Sections 5.2, 5.3, 6.1, 6.4, and 7.0, and one data correction in Appendix F. Clarifications are made where needed in response to stakeholder comments received on the final study report, and new information is presented in Section 6.4.1. Revised tables and panels in figure series are indicated as such in the table or figure panel title.

Impoundment target species included Smallmouth Bass (*Micropterus dolomieui*), Largemouth Bass (*M. salmoides*), Black Crappie (*Pomoxis nigromaculatus*), Pumpkinseed (*Lepomis gibbosus*), Bluegill (*L. macrochirus*), Chain Pickerel (*Esox niger*), Northern Pike (E. lucius), Walleye (*Sander vitreus*), Yellow Perch (*Perca flavescens*), White Sucker (*Catostomus commersonii*), Golden Shiner (*Notemigonus crysoleucas*), Spottail Shiner (*Notropis hudsonius*), and Fallfish (*Semotilus corporalis*). Riverine target species included Smallmouth Bass, White Sucker, Walleye, Fallfish, and Spottail Shiner. The objectives of these studies were to conduct a field study within a subset of likely resident fish spawning locations to characterize spawning habitat, identify spawning periodicity, and assess the potential effects of project related water-level fluctuations on spawning success. The study area included 29 sites within project impoundments (17 tributary confluence and 12 backwater habitats) and 24 sites within riverine reaches (12 island/bar and 12 riffle/run habitats), most of which were selected at random from a geographic database of existing habitats.

Assessment of White Sucker and Walleye spawning was conducted from April 16 to May 29, 2015 by deploying egg blocks within the lower, project-influenced reaches of 16 impoundment tributaries, and within 12 mainstem riverine riffle or run habitats. In total, 242 egg blocks were deployed and retrieved three times per week for a total fishing time of 4,168 block-days. Despite the intense level of effort, eggs of target species were only captured at two sites in the Wilder Impoundment and one site in the Bellows Falls riverine reach.

White Sucker eggs were collected in lower Oliverian Brook and in lower Hewes Brook from May 6 to May 11. Water level loggers installed proximal to the blocks where sucker eggs were captured did not show the diurnal changes in water surface elevation (WSE) that are indicative of project operations, and thus both egg block locations in these tributaries appeared to be upstream of the extent of impoundment operation or influence (maximum impoundment elevation). Most successful blocks had fewer than 5 eggs (maximum 24 eggs); also suggesting that spawning had likely occurred upstream beyond project influence. A single walleye egg was captured on May 4 in the lower reach of the Cold River, tributary to the Bellows Falls riverine reach.

Twelve backwaters were sampled twice per week in the impoundments from April 28 to July 2, involving 183 survey transects, most of which extended over one mile in length. Water clarity limited visual observations to shallow water areas (typically less than 4-5 ft), which are the habitats most vulnerable to project effects. Deeper, less vulnerable spawning sites were likely present but un-observed; hence estimates of egg or nest dewatering are likely inflated. Over 800 Yellow Perch egg masses were observed from initiation of the backwater surveys to the 2nd week of May. Water level loggers installed at each sampled backwater habitat were used to compare changes in WSEs to measured elevations of perch egg masses. The vulnerability of perch egg masses to dewatering varied between study sites, but using highly conservative (i.e., protective) assumptions about incubation characteristics, the estimated mortality of egg masses in shallow backwater habitats due to dewatering ranged from 0% to 100%, with an overall estimated mortality of 71% in 2015. Many of the dewatered egg masses were draped over high branches well above the typical project-related WSE based on water level logger data, and were believed to be the result of spawning during an earlier extended period of high flows above station capacity that occurred in mid-April. Northern Pike and Chain Pickerel are other early-spring spawners that were observed in most backwaters throughout the sampling period; however, neither species was observed in a spawning aggregation or otherwise exhibiting spawning behavior and no esocid eggs were collected despite repeated net sweeps and larval fish trawls through vegetated backwater areas.

Backwater surveys continued into the late-spring and early summer to assess spawning by Centrarchid and Cyprinid species. Gravid Spottail and Golden Shiners were occasionally captured by crews using minnow seines or minnow traps in mid- to late-June, but specific spawning activities or spawning locations were not identified for these two species. Nevertheless, Cyprinid larvae (including Spottail Shiners) were caught in trawl samples, and post-larval Spottail Shiners were the most abundant species captured throughout the study area as part of Study 10 – Fish Assemblage Study (Normandeau, 2016b). Late-spring backwater surveys did identify exact spawning locations and habitat at five Largemouth Bass nests and 120 sunfish (Bluegill and Pumpkinseed) nests between late May and mid-June. Comparison of sunfish nest elevations and fluctuations in backwater WSEs suggested that 0-50% (overall = 23%) of sunfish nests may have been subject to depths less than 0.5 ft, which was assumed to potentially lead to nest abandonment by adult sunfish. Although actual abandonment was never formally observed, complete nest dewatering was estimated to occur at five sunfish nests, which was assumed to result in egg or fry mortality.

Late spring sampling within 17 impoundment tributary confluence and 12 riverine island/bar habitats occurred from May 20 to July 2 and targeted Fallfish, Smallmouth Bass, and Spottail Shiner. Although no Spottail Shiner spawning locations were identified, 26 active Fallfish nests were observed and measured in late May, with similar numbers in tributary and island/bar habitats. The 12 Fallfish nests located in impoundment tributaries did not appear vulnerable to dewatering from project operations as most minimum WSEs completely inundated the nest mounds and remained well above the base of the nest where eggs are laid. Fallfish nests were much more vulnerable to lower WSEs in the riverine reaches, where 5 of 14 nests (36%) were observed or expected to be (from water level data) either completely dewatered or subject to depths less than 0.5 ft during periods of low WSEs.

Smallmouth Bass appeared to have just initiated spawning in late May, and active nests were observed until June 26. Elevation and habitat data was collected at 75 nests containing a resident adult, eggs, or fry. In general, the 31 bass nests observed in the impoundment tributary confluence study sites did not appear to be vulnerable to normal project operations, although a reduction in impoundment elevation due to high flow impoundment operations procedures just before a large flow event did dewater (or nearly dewater) three bass nests in lower Mink Brook just upstream of Wilder dam. A fourth nest in the lower Williams River was also subject to depths less than one foot, although fry appeared to successfully rear at that nest. In contrast, 14 of 44 bass nests (32%) observed in the riverine reaches were subject to minimum depths of less than one foot, which was assumed to potentially result in nest abandonment by the guarding adult bass. Several nests at Stebbins Island in the Vernon riverine reach appeared to have been dewatered, and one abandoned nest contained dead eggs covered in fungus. Despite these impacts, smallmouth bass remained the most common species captured in the three riverine reaches during Study 10 (Normandeau, 2016b).

It should be noted that late-spring surveys in both impoundment and riverine reaches were hampered by high flows and poor visibility conditions throughout much of June, which generally limited the identification and monitoring of bass and sunfish nests to shallow water habitats which would be potentially most vulnerable to project-related effects. Although deeper, less vulnerable nests were seen during periods of clear water and lower flows, these nests are likely under-represented in this spawning assessment.

Assessment of project effects on spawning success generally followed two stages: 1) comparison of 2015 spawning observations with WSEs measured at each site during the 2015 spawning period; and 2) comparison of 2015 spawning observations with predicted WSEs at each site during five different water year types using the Operations Model (Study 5 [Hatch, 2016]). In the second stage, modeled WSEs were used to estimate the proportion of days within a species spawning period when WSEs dropped below specified elevation criteria.

Overall, WSEs in 2015 most often dropped below spawning elevation criteria in the Wilder impoundment and Wilder riverine reaches for all four principal species and in most modeled hydrologies, with high frequencies of exceedance also occurring in the Vernon riverine reach for Smallmouth Bass and, in one modeled hydrology, for Fallfish. Proportions of spawning days with WSEs below median spawning elevations equaled or exceeded 50% of days in some modeled hydrologies within the Wilder impoundment for observed Yellow Perch egg masses and sunfish nests, and in the Wilder riverine reach for Smallmouth Bass and (in one modeled year) Fallfish nests. In contrast, proportions typically averaged less than 10-25% in the Bellows Falls impoundment and riverine reaches and in the Vernon impoundment.

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°C	degrees Celsius
CRWC	Connecticut River Watershed Council
DO	dissolved oxygen
FERC	Federal Energy Regulatory Commission
ft	foot/feet
FWS	U.S. Department of the Interior-Fish and Wildlife Service
GPS	Global Positioning System
ILP	Integrated Licensing Process
µS/cm	micro-siemens per centimeter
mg/l	milligrams per liter
NHDES	New Hampshire Department of Environmental Services
NHFGD	New Hampshire Fish and Game Department
NTU	Nephelometric Turbidity Units
RSP	Revised Study Plan
RTK	Real Time Kinematic Unit
SSR	Site Selection Report
su	standard units
TransCanada	TransCanada Hydro Northeast Inc.
USR	Updated Study Report
VANR	Vermont Agency of Natural Resources
WSE/WSEL	Water surface elevation
2D	Two-Dimensional Hydraulic Model

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1.0 INTRODUCTION

This revised final study report presents the final results of the 2015 Resident Fish Spawning in Impoundments Study (ILP Study 14) and Resident Fish Spawning in Riverine Sections Study (ILP Study 15) 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). This report updates the interim study report filed March 1, 2016 to include analysis of Operations Model (Study 5 [Hatch, 2016]) output and to respond to comments provided during the Study Report meeting on March 18, 2016 and written comments received by May 2, 2016. TransCanada provided responses to those comments in a May 31, 2016 FERC filing.

This revised report makes minor changes and corrections in certain tables and figures in Sections 5.2, 5.3, 6.1, 6.4, and 7.0, and one data correction in Appendix F (see yellow highlighted cell in the Revised Appendix F, filed separately in Excel format). Clarifications are made where needed in response to stakeholder comments received on the final study report, and new information is presented in Section 6.4.1. Revised tables and panels in figure series are indicated as such in the table or figure panel title.

The three major modifications to the previous study report involve:

1. using an alternative metric for estimating mortality of Yellow Perch egg masses (i.e., changing from a mean study site estimate of 56% mortality to an overall estimate of 71%);
2. extending the incubation times for Yellow Perch (i.e., removing the May 15 truncation date); and
3. extending the residence times for Smallmouth Bass fry from 20 to 26 days, all per stakeholder requests.

Note that our responses to comments dated October 31, 2016 suggested that the extended incubation and fry residence times would not influence the estimated mortality rate for Smallmouth Bass but may affect the mortality for one Yellow Perch egg mass. However, following re-analysis of the spawning observation dates the extended periodicities did not affect the survival estimates for either species.

Operations at TransCanada’s Wilder, Bellows Falls and Vernon hydroelectric projects (projects) may affect resident fish spawning in the impoundments and riverine reaches downstream of project dams. In their study requests, U.S. Department of the Interior-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), and Connecticut River Watershed Council (CRWC) expressed concern that water-level fluctuations due to project operations have the potential to create conditions that could adversely impact success of fish spawning in project impoundments and riverine reaches downstream of the projects.

Revised Study Plans (RSP) 14 and 15 as supported by stakeholders in 2013 and approved by FERC in its February 21, 2014 Study Plan Determination, specified that a subset of project-affected locations would be evaluated for potential effects of water-level fluctuations on resident fish spawning. FERC modified the RSP for Study 14 to include recording of species data (e.g., spawning habitat presence and depth of spawning habitat) of Eastern Silvery Minnow (*Hybognathus regius*) if the species is found during other target species surveys, and then evaluate project effects on this species.

Initial site selection reports were posted on TransCanada's working group website on December 5, 2014 and comments were received during an aquatics working group meeting held on December 17, 2014. The final sampling locations were randomly selected and presented in the Revised Site Selection Reports (SSRs [Normandeau 2015a, 2015b]) which included modifications that addressed all working group discussion and comments. The Revised Site Selection Reports were filed with FERC on September 14, 2015 as Volumes II.E and II.F of TransCanada's Updated Study Report (USR), with corresponding geodata of final study site locations filed as Volume II.I of the USR.

This report provides results from data collected at the selected study locations during the period from April 21 to July 2, 2015 at impoundment study sites and from April 16 to June 26 at study sites in riverine reaches. This report also includes analysis based on Hydraulic and Operations Model data (Studies 4 and 5) that was not available at the time of filing of the interim report.

2.0 STUDY GOALS AND OBJECTIVES

As stated in the RSP, the goal of these studies was to assess whether water-level fluctuations from project operations of Wilder, Bellows Falls, and Vernon dams negatively affect resident fish spawning in impoundments and riverine reaches downstream of project dams.

Specific objectives for Study 14 were to:

- delineate, quantitatively describe (e.g., substrate composition, vegetation type and abundance), and map shallow-water aquatic habitat types subject to inundation and exposure due to normal project operations, noting and describing additional areas where water depths at the lowest operational range are wetted to a depth less than 1 foot, such as flats, near shoal areas, and gravel bars with very slight bathymetric change;
- conduct analysis of the effects of the normal operation and the maximum licensed impoundment fluctuation range on the suitability of littoral zone habitats for all life stages of target species likely to inhabit these areas;
- conduct field studies to assess timing and location of fish spawning under existing conditions; and
- conduct field studies to assess potential effects of impoundment fluctuation on nest abandonment, spawning fish displacement, and egg dewatering.

Objectives for Study 15 were to:

- conduct field studies in the project-affected areas downstream of the Wilder, Bellows Falls, and Vernon dams to locate and map nesting locations and spawning sites; and
- conduct field studies in the project-affected areas below Wilder, Bellows Falls, and Vernon dams to assess potential effects of operational flows and water-level fluctuations on nest abandonment, spawning fish displacement, and egg dewatering.

3.0 STUDY AREA

Locations for the assessment of resident fish spawning entailed a combination of purposive sampling at sites reported to be utilized by spawning adults of the various target species (based on personal communication with agency biologists and local fishermen), nest observations noted by field biologists during 2014 field studies, and random sampling in study sites known to possess habitat characteristics meeting the basic spawning requirements for each species group. Habitat characteristics required for spawning (e.g., depth, substrate, vegetation, etc.) were recorded as part of Study 7 - Aquatic Habitat Mapping (Normandeau, 2015c).

3.1 Target Species

The RSP for Study 14 identified 13 fish species for inclusion in the study. Assessing the spawning periodicity, location, and impoundment fluctuation effects on each species individually would require a vast level of effort; consequently the 13 species were assigned into two “species groups”, where species within each group possess similarities in spawning habitat preferences. Each of the two species groups were then further partitioned according to spawning periodicity (early-spring vs. late-spring). The species groups for impoundment resident fishes are:

- Backwater/Setback Spawners
  - Early-Spring (Northern Pike, Chain Pickerel, and Yellow Perch)
  - Late-Spring (Largemouth Bass, Bluegill, Pumpkinseed, Black Crappie, Spottail Shiner, and Golden Shiner)
- Tributary Confluence Riffle/Shoal Spawners
  - Early-Spring (Walleye and White Sucker)
  - Late-Spring (Smallmouth Bass, Spottail Shiner, and Fallfish)

The RSP for Study 15 identified four fish species for inclusion in the study: the early-spring broadcast spawning species (Walleyes and White Suckers), and the late-spring nest builders (Smallmouth Bass and Fallfish). In accordance with the RSP, if identified as representing a significant portion of the riverine fish communities during the fish assemblage study (Study 10 [Normandeau, 2016b]), the spawning success of additional fish, such as Longnose Dace (*Rhinichthys cataractae*) and Rainbow Trout (*Oncorhynchus mykiss*), would also be monitored. Characteristics describing the spawning periodicity, location, and habitat parameters for these four species were used to assign them into the following two "species groups", in order to focus efforts to detect and assess spawning activities:

- Early-Spring Riffle Spawners (Walleyes and White Suckers)
- Late-Spring Island/Bar Spawners (Smallmouth Bass and Fallfish)

Walleye and White Suckers are both broadcast spawners that spawn in specific locations possessing shallow, rocky substrates with significant current velocities. Smallmouth Bass and Fallfish spawn later in the spring when they build nests in locations with slow (Smallmouth) or moderate (Fallfish) water velocities and gravel/cobble substrates.

Spawning by each of these four species groups was assessed at study sites selected to maximize the likelihood of encountering spawning adults, and where the potential impacts of water level fluctuations were expected to occur. Appendix A provides detailed spawning habitat characteristics for the target species, reproduced from the Revised Site Selection Reports (SSRs) for these studies (Normandeau, 2015a, 2015b).

3.2 Study Sites

Study sites were selected in accordance with the process described in the Revised SSRs with concurrence from the aquatics working group, and summarized in the following sections.

3.2.1 Impoundment Sites

Prior to the selection of potential study sites, areas were excluded that were not expected to provide significant spawning habitat, e.g. steep banks; silty mid-channel habitat; tributary reaches outside of project operations influence; and areas possessing hazardous working conditions (e.g., immediately above project dams). Also, water visibilities were expected to limit visual surveys to depths less than 5-6 ft, which was deeper than the normal impoundment fluctuations of approximately 1-2 ft. Large backwaters connected by culverts were also excluded from selection due to the significant reduction in speed and magnitude of water level changes resulting from the narrow connection to the main channel. Potential study sites that did meet the basic spawning requirements of the two species groups were selected based on several criteria, principally:

- Known presence of spawning (purposive sampling, all species groups)
- Size of potential spawning area (random sampling, all species groups)
- Presence of required habitat characteristics, namely:
    - Backwater habitats with minimal current velocities and significant areas of inundated terrestrial vegetation or submerged aquatic vegetation (SAV) (early- and late-spring backwater/setback spawners).
    - Riffle habitats in lower tributary reaches possessing moderate to swift current velocities with sand, gravel, or cobble substrates, and

shallow shoal or delta habitats at the impoundment confluence (early- and late-spring riffle/shoal spawners).

Random selection of non-purposive study sites was weighted based on tributary size (stream order) or habitat area (acres) of potential spawning habitat in order to maximize both the number and diversity of adult spawners or nests encountered at each sampling location. Larger study sites were also expected to contain a wider and more diverse range of microhabitat attributes than would a small study site. Finally, selection of a fixed number of larger sites would yield a much greater sampling area than would a similar number of small sites, again increasing the likelihood of achieving the goals of this study.

Twelve study sites were selected to assess spawning for the backwater/setback species group, and 16 study sites were selected for the tributary confluence riffle/shoal species group. In addition, Jarvis Island in the Bellows Falls impoundment was monitored for spawning by Smallmouth Bass (and other species), due to its known utilization by spawning bass (Gabe Gries, formerly with NHFGD, personal communication). The selected study sites were distributed among the three project impoundments in proportion to the length of each impoundment (Figures 3.2-1- 3.2-3, Tables 3.2-1 and 3.2-2).

- Wilder Impoundment: 6 backwater sites and 7 tributary confluence sites
- Bellows Falls Impoundment: 3 backwater sites, 5 tributary confluence sites, plus Jarvis Island
- Vernon Impoundment: 3 backwater sites and 4 tributary confluence sites

To further ensure adequate longitudinal distribution of the study sites, each impoundment was first stratified into upper, middle, and lower thirds prior to selection of study sites. To the extent possible, two backwater/setback habitats were selected in each of the three Wilder impoundment reaches. The three backwater study sites located in the Bellows Falls and Vernon impoundments were also distributed among the upper, middle and lower portions of the impoundments (i.e., one in each third).

Selection of specific study sites began with identification of known spawning areas. For example, reports from NHFGD biologists and fishermen identified three backwater locations within the Bellows Falls impoundment where bass nests have been observed and dewatering was reported (Gabe Gries, formerly with NHFGD, personal communication). Consequently, these three backwaters were purposively selected to represent the backwater species group in the Bellows Falls impoundment. In contrast, no information was available regarding specific spawning locations for bass or other backwater spawners in the Vernon impoundment; consequently all three backwater study sites in that study reach were selected randomly, based on impoundment segment (lower, middle, or upper) and spawning habitat surface area.

The acreage of potential spawning habitat for the backwater/setback species groups was determined by outlining all identified backwater habitats using the polygon tool in ArcGIS. The area of potential riffle and shoal spawning habitat at impoundment tributary mouths was approximated by filtering the list of tributaries to those of stream order 4, 5, or 6 to represent "large" tributaries, whereas "medium" tributaries were those of 2nd or 3rd order. Medium-sized tributaries that did not possess a shallow (<5 ft) gravel/cobble dominated delta or shoal (based on Study 7 habitat mapping) were not available for selection. Small (1st order) tributaries were also unavailable for selection due to the expectation that such tributaries would not produce sizeable shoals at the impoundment confluence, nor would they provide a significant area of spawning habitat within the stream channel due to their small size and intermittent flow characteristics. Tributaries not already specifically identified as spawning areas for that species group were selected by random sampling from these tributaries, with greater weight for the larger tributaries than for the medium tributaries.

A variance from the RSP and Revised SSR was associated with the replacement of two tributary confluence study sites used for egg-block and nest spawning surveys. Beaver Brook (14-BT-016) in the Bellows Falls impoundment and Partridge Brook (14-VT-018) in the Vernon impoundment were both judged by field crews to be lacking in the gravel and cobble substrates preferred for spawning by suckers and Walleyes. Based on field conditions, Beaver Brook was replaced with the Sugar River (14-BT-002) and Partridge Brook was replaced with Mill Brook (14-VT-016). Both of these alternative sites appeared to contain suitable spawning habitat for the early spring spawners. These two sites were subsequently retained for the late-spring tributary nesting species. In addition, Jarvis Island (14-BT-001) was added as a study site.

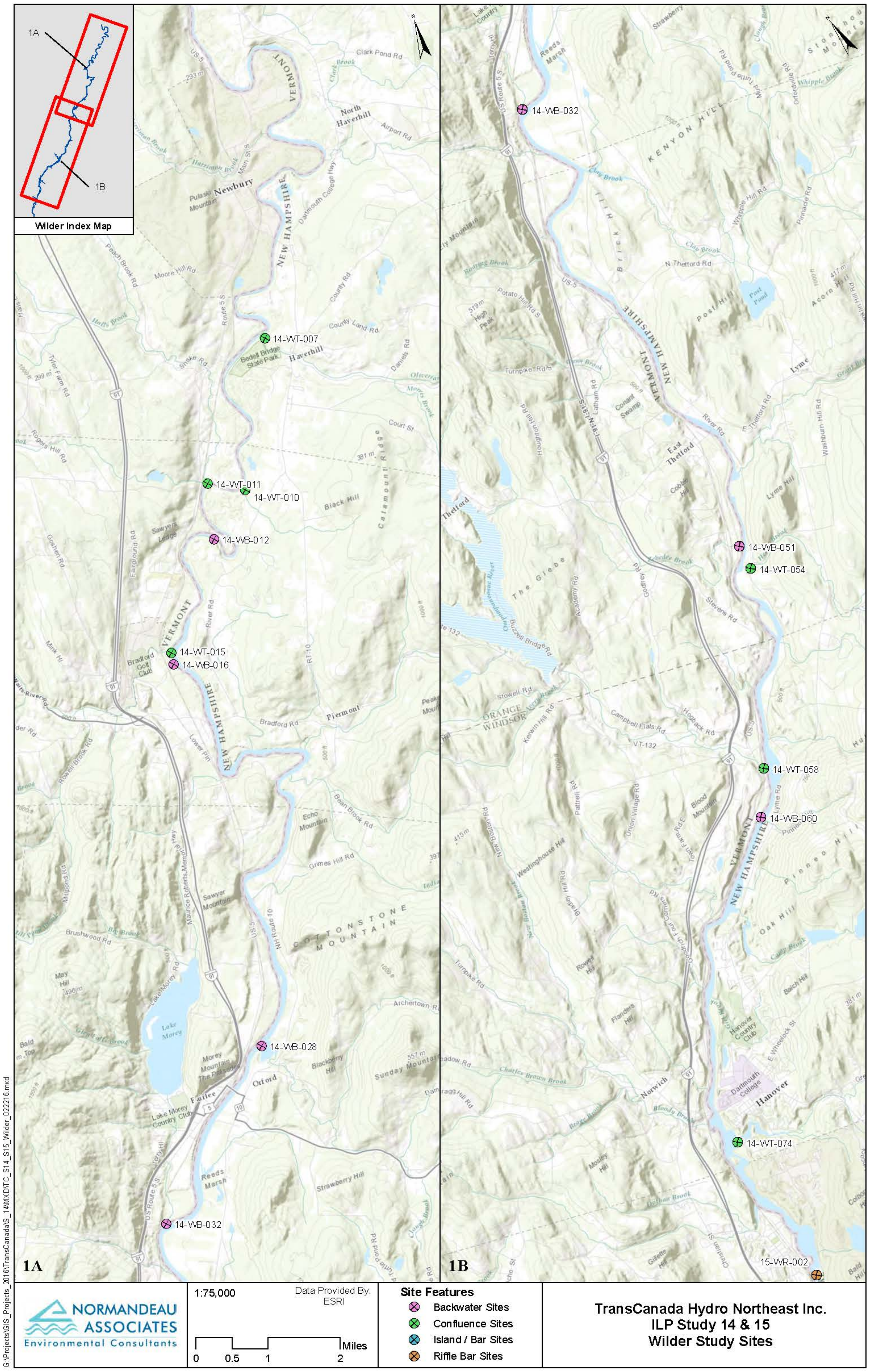

Figure 3.2-1. Wilder impoundment study sites.

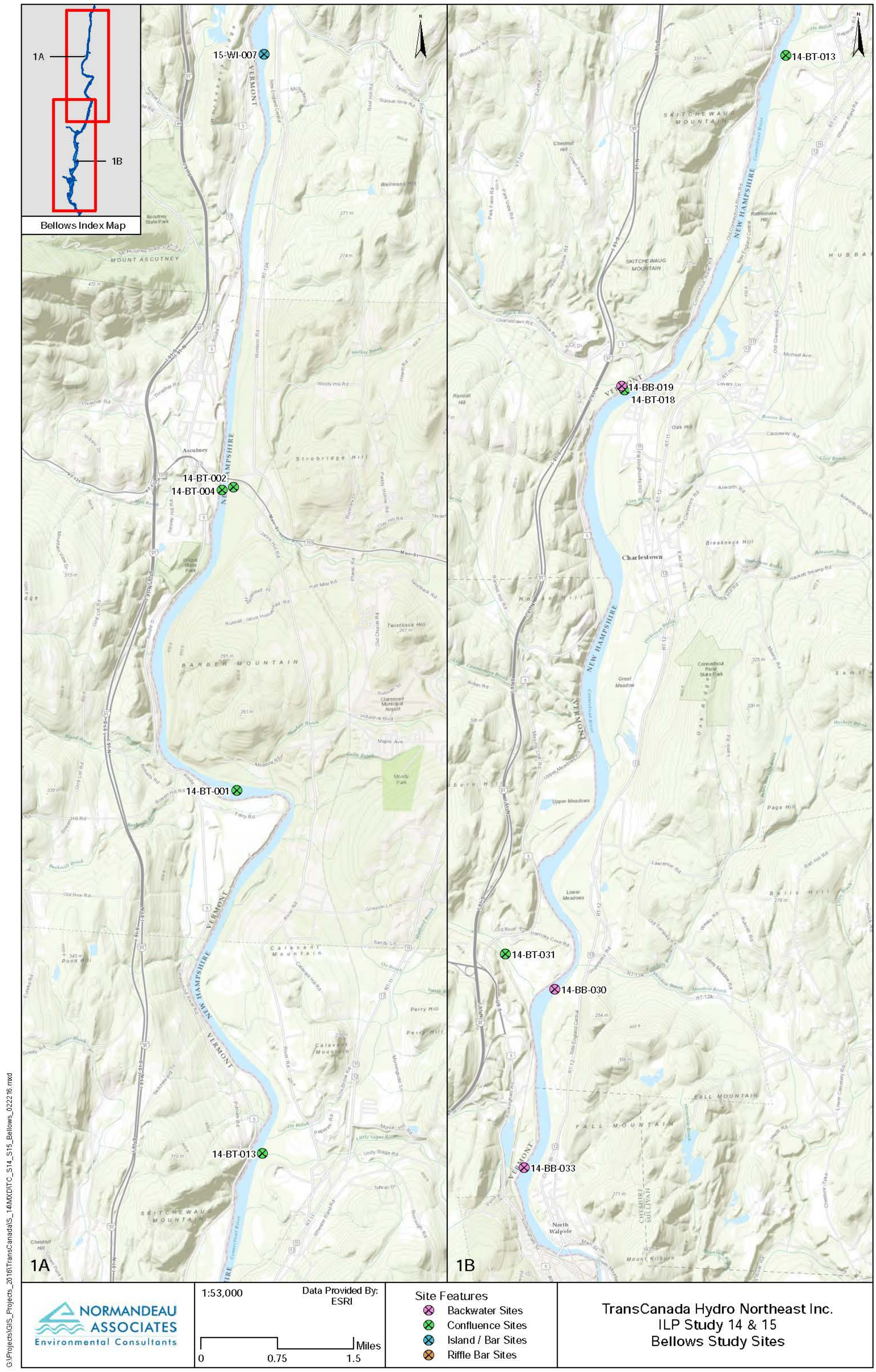

Figure 3.2-2. Bellows Falls impoundment study sites.

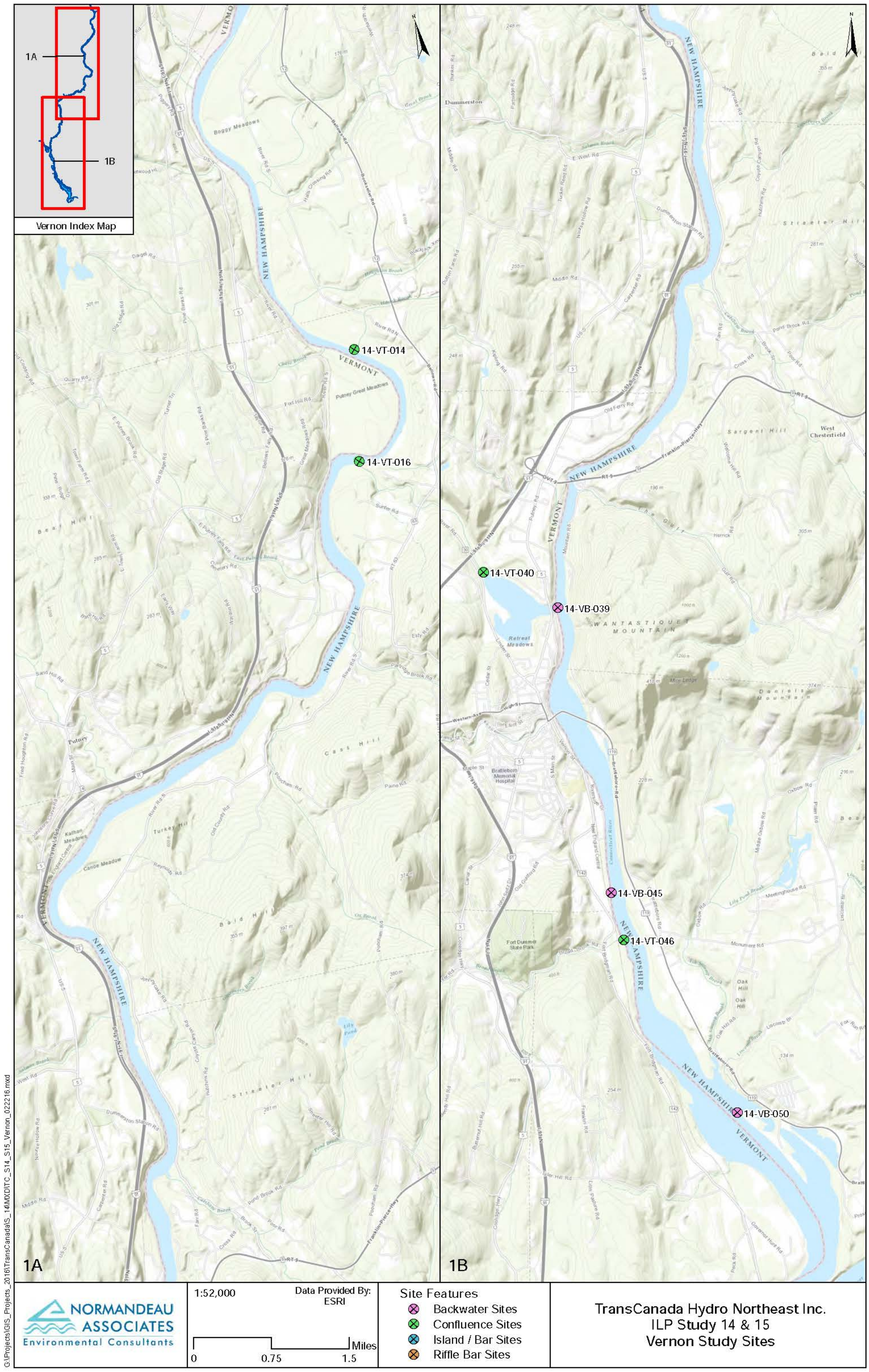

Figure 3.2-3. Vernon impoundment study sites.

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Table 3.2-1. Backwater (BW) study sites in the Wilder (W), Bellows Falls (B), and Vernon (V) impoundments.

Site ID	Backwater Identification	Backwater Acreage	Location (DD NAD83 UTM Z18N)	
			X	Y
14-WB-012	Oxbow BW	39.3	-72.094977	44.013396
14-WB-016	Waits BW	3.2	-72.11699	43.996719
14-WB-028	Jacobs BW	27.9	-72.128039	43.913843
14-WB-032	Unnamed BW	43.4	-72.169201	43.886168
14-WB-051	Zebedee BW	5.5	-72.19697	43.790152
14-WB-060	Unnamed BW	18.5	-72.238832	43.744675
14-BB-019	Black BW	31.8	-72.431304	43.260741
14-BB-030	Williams BW	96.9	-72.447862	43.175331
14-BB-033	Unnamed BW	84.3	-72.454938	43.150119
14-VB-039	Retreat Meadows	78.7	-72.554979	42.866687
14-VB-045	Unnamed BW	73.4	-72.546375	42.826753
14-VB-050	Unnamed BW	249.0	-72.523773	42.795531

Table 3.2-2. Tributary confluence study sites in the Wilder (W), Bellows Falls (B), and Vernon (V) impoundments.

Site ID	Stream Name	Stream Order	Location (DD NAD83 UTM Z18N)	
			X	Y
14-WT-007	Oliverian Brook	4	-72.063421	44.04834
14-WT-010	unnamed	2	-72.082269	44.020686
14-WT-011	Halls Brook	4	-72.09165	44.024386
14-WT-015	Waits River	5	-72.116407	43.994532
14-WT-054	Hewes Brook	3	-72.198336	43.785259
14-WT-058	Ompompanoosuc River	5	-72.229813	43.752059
14-WT-074	Mink Brook	4	-72.299583	43.696202
14-BT-001	Jarvis Island [1]	n/a	-72.400187	43.358744
14-BT-004	Mill Brook	3	-72.401287	43.401497
14-BT-013	Little Sugar River	4	-72.397392	43.307053
14-BT-002	Sugar River	6	-72.399043	43.401833
14-BT-018	Black River	5	-72.430748	43.260172
14-BT-031	Williams River	5	-72.457251	43.180537
14-VT-014	Aldrick Brook	3	-72.44957	43.01516
14-VT-016	Mill Brook	4	-72.454414	42.999961
14-VT-040	West River	6	-72.568874	42.87194
14-VT-046	Broad Brook	4	-72.544267	42.820087

[1] Jarvis Island sampled for late-spring species only

3.2.2 Riverine Sites

Several of the habitat characteristics required for spawning by these species (e.g., mesohabitat type, dominant substrate, etc.) were recorded as part of Study 7 - Aquatic Habitat Mapping (Normandeau, 2015c). Prior to the selection of potential study sites, areas were excluded that were not expected to provide significant spawning habitat, including areas dominated by sand or silt substrate; areas >10 ft deep that would not be vulnerable to normal operational fluctuations in water surface elevations; and areas expected to contain velocities too slow for Walleye and sucker spawning (e.g., non-riffles) or too rapid for Smallmouth Bass spawning (e.g., riffles). Potentially hazardous areas, such as locations immediately below project dams, were also excluded from selection. Potential study sites that met the basic spawning requirements of the two species groups were then selected based on several criteria, principally:

- Known presence of spawning (purposive sampling, all species groups);
- Size of potential spawning area (random sampling, all species groups); and
- Presence of required habitat characteristics, namely:
    - Riffles dominated by rock (gravel, cobble, or boulder) substrate (early-spring riffle spawners); and
    - Presence of gravel/cobble bars not vulnerable to excessive velocities during normal late spring flow (late-spring island/bar spawners).

Random selection of non-purposive study sites was based on the surface area (acres) of potential spawning riffles for Walleyes and suckers, and the relative size of island habitats measured by perimeter, for Smallmouth Bass and Fallfish which utilize the gravel/cobble bars and margin-formed eddies that are characteristic of mid-channel islands. Habitat area was used for random selection in order to maximize both the number and diversity of adult spawners or nests encountered at each sampling location. Larger study sites were also expected to contain a wider and more diverse range of microhabitat attributes than would a small study site. Finally, selection of a fixed number of larger sites would yield a much greater sampling area than would a similar number of small sites, increasing the likelihood of achieving the goals of this study.

Twelve study sites were selected in the study area to assess spawning activities and habitat for each of the two species groups for a total of 24 study sites. To the extent possible, the sites were distributed among the three riverine reaches in proportion to the length of each reach (Figures 3.2-4 – 3.2-6, Tables 3.2-3 and 3.2-4). Using these criteria the following sample size goals for each of the two species groups was produced:

- Wilder riverine reach: 7 riffles and 7 islands
- Bellows Falls riverine reach: 3 riffles and 3 islands
- Vernon riverine reach: 2 riffles and 2 islands

Selection of specific study sites began with identification of known spawning areas. For example, regular electrofishing surveys by NHFGD have routinely captured ripe Walleyes in riffle areas just downstream of the three project dams (Gabe Gries, formerly with NHFGD, personal communication). Consequently, one of the study sites for Walleye/sucker spawning in each riverine reach was purposively selected from the closest riffle (or other swift, cobble-dominated habitat) below each dam that was deemed safe at all survey flows. Other known spawning locations included Fallfish nests identified during the selection and measurement of study sites in Study 9 – Instream Flow Study (Normandeau, 2016a). These sites were likewise purposively selected in order to maximize the likelihood of detecting spawning activities and assessing flow-related effects on nest success.

Where actual spawning observations had not been noted, potential study sites were randomly selected based on area of potential spawning habitat. The surface area of potential spawning habitat for the early-spring riffle spawning species group was determined by calculating the area of all riffle habitats identified during the mesohabitat mapping study (Study 7 [Normandeau, 2015c]) in ArcGIS. If a riverine reach did not contain enough riffle habitats to fulfill the sample size goals (along with known spawning areas), additional sites were selected from shoal habitats associated with large tributary mouths, which were known or suspected to support spawning by Walleyes or suckers.

For late-spring nesting Fallfish and Smallmouth Bass, it was noted that many of the observed Fallfish nests were associated with mainstem island habitats. Fishermen reports of bass spawning in the Bellows Falls study area also suggested an association between island habitats and spawning for that species. Most islands in each riverine reach possessed large gravel/cobble bars at the island head that may be utilized by Fallfish and the low velocity eddies alongside and below islands may be particularly important to Smallmouth Bass in riverine reaches. In addition, the split channels associated with islands typically produce more diversity in habitat, with a larger number of shorter habitat units and a higher proportion of bank-related features (e.g., shallow water, shade, woody debris) than in single channel areas. Consequently, study sites selected for the late-spring island/bar spawning species group were based on known observations of nest locations as well as potential spawning area associated with primary (wooded) islands. Selection of islands for the late-spring island/bar spawning species group was based on the availability of island habitats in each reach; if the number of available islands exceeded the sample size goals listed above, islands were randomly selected based on the size of the island's perimeter.

A variance from the Revised SSR included shifts in egg-block locations in the Wilder and Vernon riverine reaches. High flows present during deployment of egg-blocks in Wilder riffles made identification of optimal locations difficult, and riffle site WR-094 did not appear to contain suitable habitat for egg-block deployment. Consequently egg-blocks were moved from WR-094 to a more suitable location 0.8 miles downstream and re-labeled as site WR-100. In the Vernon riverine reach, crews were unable to access the side channel at VR-006 during block deployment so they moved that location to the large shoal area alongside Stebbins Island (VR-002).

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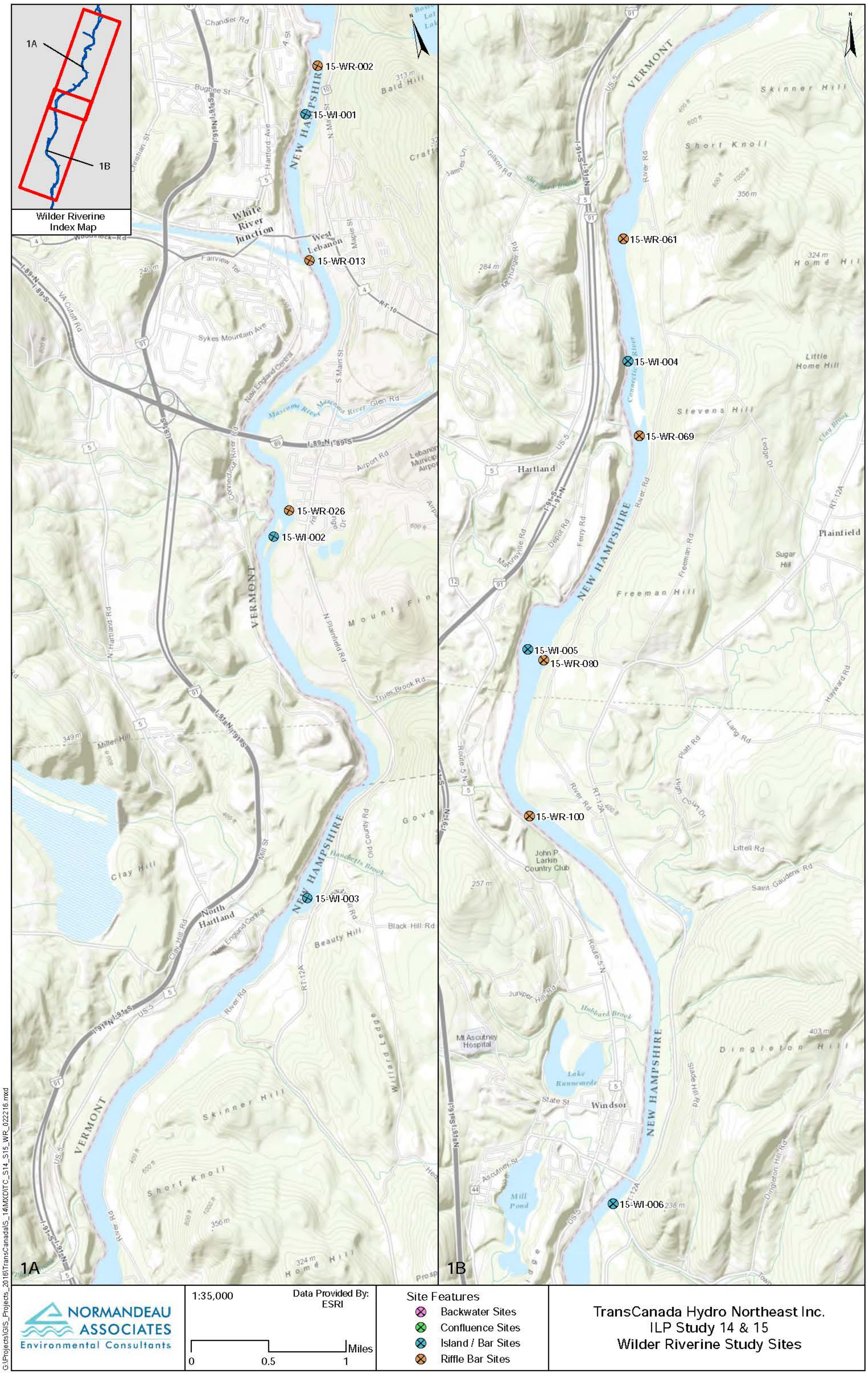

Figure 3.2-4. Wilder riverine study sites.

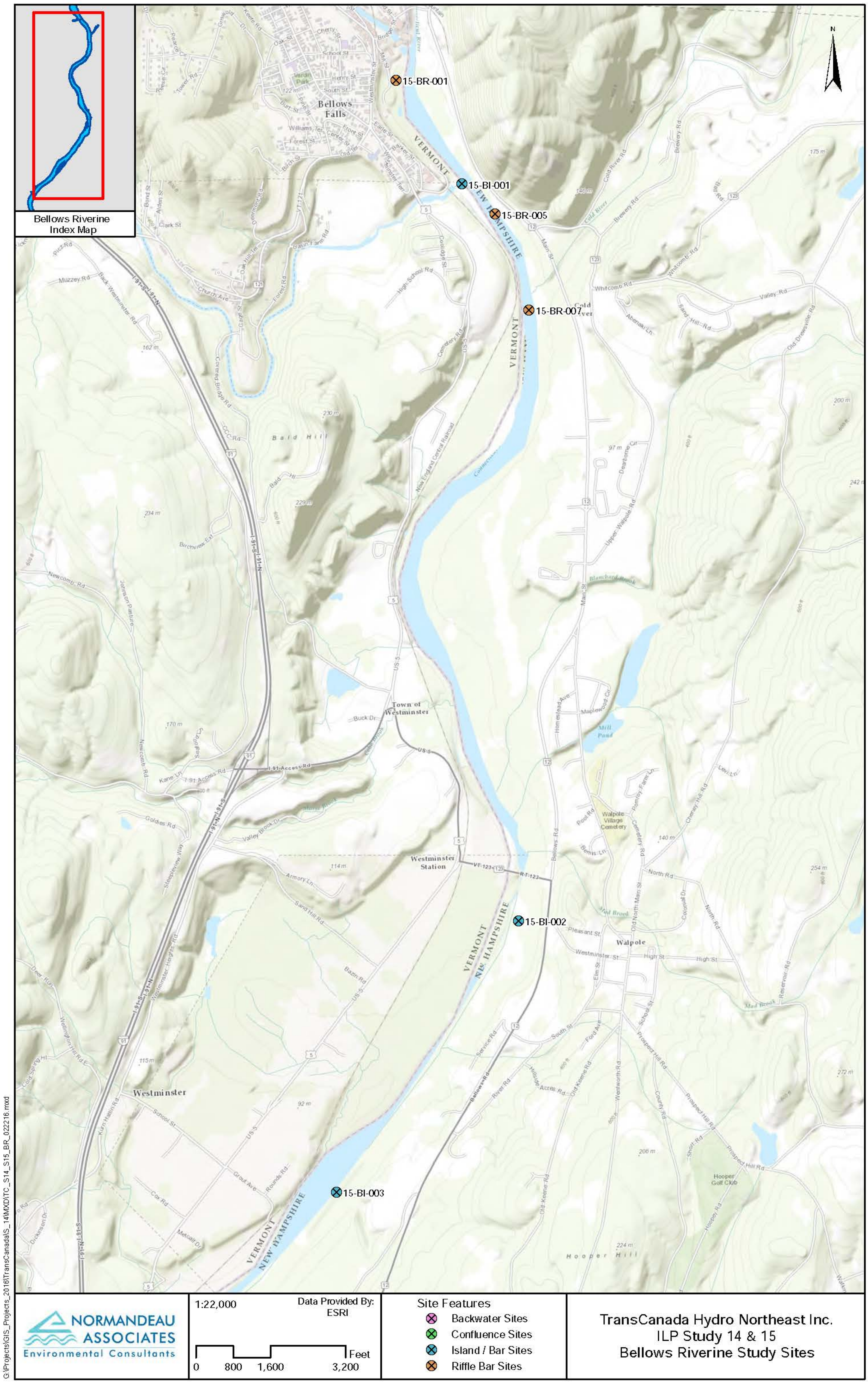

Figure 3.2-5. Bellows Falls riverine study sites.

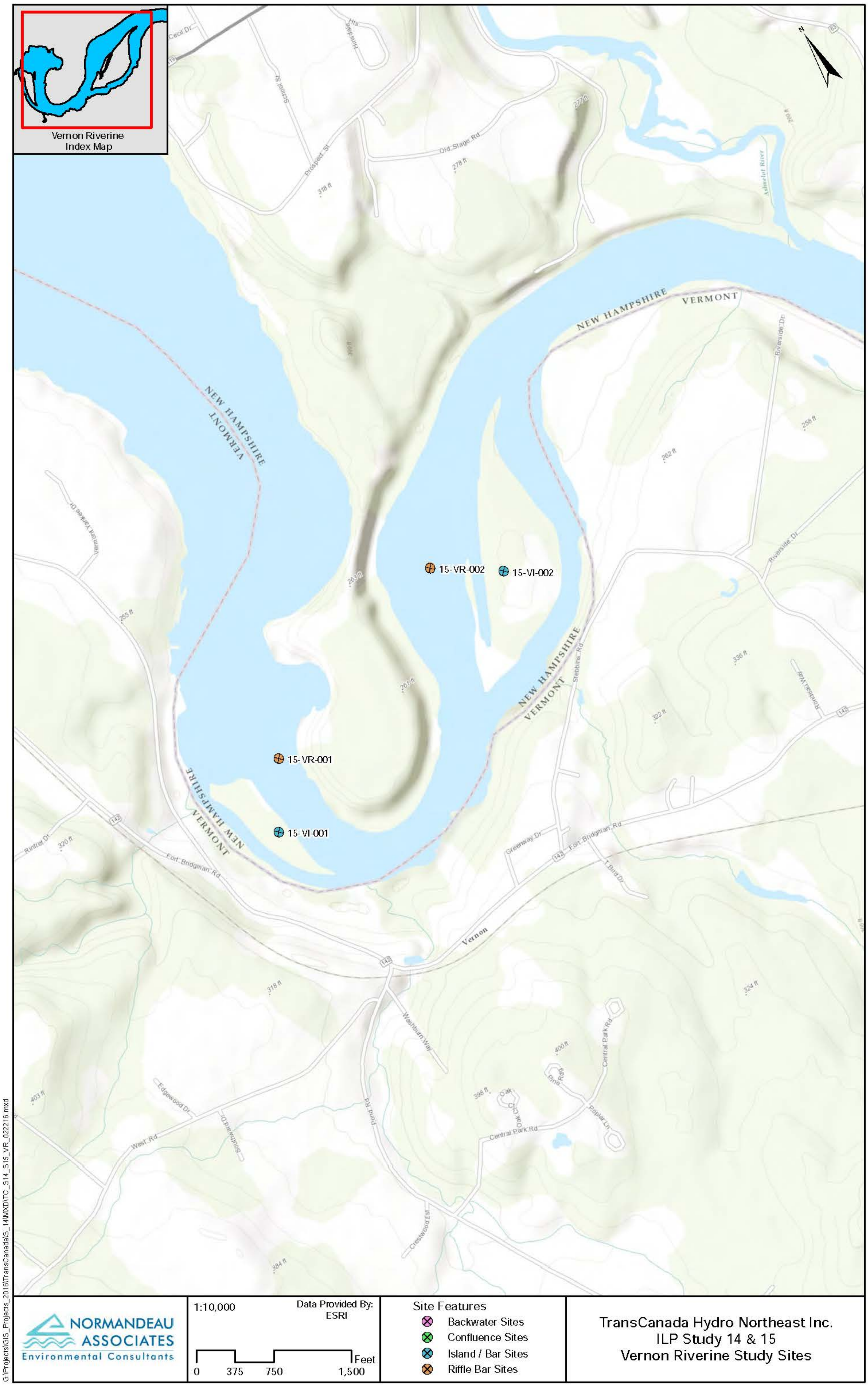

Figure 3.2-6. Vernon riverine study sites.

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Table 3.2-3. Riffle study sites in the Wilder (W), Bellows Falls (B), and Vernon (V) riverine reaches.

Site ID	MesoHabitat Type	Habitat Size (ac)[1]	Location (DD NAD83 UTM Z18N)	
			X	Y
15-WR-002	Riffle	1.21	-72.305109	43.665343
15-WR-013	Riffle	1.87	-72.314184	43.648322
15-WR-026	Riffle	2.98	-72.327021	43.62674
15-WR-061	base of Sumner Falls	-	-72.381033	43.5618
15-WR-069	Riffle	3.27	-72.379756	43.543314
15-WR-080	Riffle	4.73	-72.392952	43.522591
15-WR-100	Impoundment neck	-	-72.395427	43.508031
15-BR-001	Below Bellows Falls tailrace, VT side	-	-72.442272	43.131177
15-BR-005	Riffle	6.88	-72.434658	43.12316
15-BR-007	Run	10.11	-72.432188	43.117495
15-VR-001	Run	7.84	-72.51327	42.76833
15-VR-002	Run/Glide	-	-72.504899	42.770291[a]

Table 3.2-4. Island/bar study sites in the Wilder (W), Bellows Falls (B), and Vernon (V) riverine reaches.

Site ID	Island Name	Island Perimeter (ft)	Habitat Size (ac)[a]	Location (DD NAD83 UTM Z18N)	
				X	Y
15-WI-001	n/a	2704	3.0	-72.308651	43.661409
15-WI-002	Johnston Is.	5155	8.4	-72.329968	43.624874
15-WI-003	Burnap's Is.	1527	2.8	-72.340817	43.591786
15-WI-004	Fallfish nest	-	-	-72.380907	43.550322
15-WI-005	Hart Is.	6274	28.3	-72.394997	43.523613
15-WI-006	Fallfish nest	-	-	-72.38153	43.474960
15-WI-007	Chase Is.	3526	12.1	-72.390409	43.463315
15-BI-001	Saxtons River bar	1098[b]	-	-72.437393	43.124857
15-BI-002	n/a	1155	-	-72.434533	43.081773
15-BI-003	Dunshee Is.	4224	-	-72.449738	43.066225
15-VI-001	n/a	3199	8.8	-72.514745	42.766711
15-VI-002	Stebbins Is.	5965	32.7	-72.502771	42.769141

a. Habitat size not utilized for purposively-selected study sites.

b. Approximate length of tributary delta.

4.0 METHODOLOGY

4.1 Field Sampling

4.1.1 Deployment of Data Loggers

Onset HOBO (Model U20-001-01 or U20-001-04) water level and water temperature data loggers (vertical accuracy of ±0.1 inch) were deployed at 62 in-water locations over the course of these spawning studies. Twenty-seven loggers were installed in selected backwater study sites at (or shortly after) initiation of backwater surveys. One logger was deployed within each backwater and a second was deployed in the main channel just outside of the backwater. The mainstem logger was deployed both to assess any attenuation of water surface elevation (WSE) changes within the backwater, and to provide backup in the event of logger failure or loss. A total of 18 loggers were deployed at impoundment tributary confluence study sites, 7 were deployed at riverine riffles, and 10 were deployed at riverine island/bar study sites. In contrast to the 12 backwater study sites, loggers were only deployed at the tributary, riffle, and island/bar study sites when and if spawning was documented at those locations.

During logger installation the date/time, exact position of each unit (latitude, longitude and probe elevation), and the existing WSE was recorded using a Leica GS-14 Real Time Kinematic (RTK) unit. Loggers were programmed to collect temperature and pressure information at 15-minute intervals and were deployed according to the methodologies described in Study 13 – Tributary and Backwater Fish Access and Habitat Study (Normandeau, 2015d). Loggers deployed in deeper mainstem riverine reaches sometimes utilized a cinder-block methodology, where loggers were zip-tied inside a cinder block which was lowered into deeper water (below minimum impoundment elevation) and retrieved for data downloading via an attached buoy. Logger elevations at deep water sites were calculated as the difference between measured WSE and depth at the base of the cinder block (probe sensors were affixed approximately 0.1 ft above the base of the block).

Barometric reference loggers were also installed at three locations longitudinally distributed across the study area for use in processing water level logger data collected at each spawning location. Data processing procedures following logger downloading were described in Study 13.

4.1.2 Water Quality Measurements

Water quality data was collected at each spawning study site at each visit. Water temperature (°C), specific conductivity (µS/cm), pH (standard units or su), dissolved oxygen (mg/l and % saturation), and turbidity (NTU) was measured at a depth of 1 ft using a YSI Model 6920 with multi-sensor probe. The probe was calibrated using standard solutions at least 3 times per week.

4.1.3 Egg Block Sampling for White Suckers and Walleye

Egg blocks were deployed to detect spawning by White Suckers or Walleyes at 16 impoundment tributary confluence sites (Table 3.2-2) and at 12 riverine riffle sites (Table 3.2-3). Field crews navigated to the selected tributary or riffle habitat via GPS and assessed the area for the presence of appropriate sucker or Walleye spawning habitat (e.g., gravel or cobble substrates with moderate to swift velocities, see Appendix A). In larger tributaries, such as the West, Williams, and Black rivers, crews sometimes had to progress well upstream from the mouth to find suitable habitat, but strived to remain within the zone influenced by project operations. GIS-derived elevation maps and on-site visual clues (e.g., vegetation lines) were used to identify the upstream extent of project influence in tributary confluence sites.

Once appropriate spawning habitat was located, 3-13 egg blocks (mean=9 blocks) were deployed at each site in a linear or staggered manner over a range of depths. Blocks were deployed in both shallow margins subject to dewatering and in deeper locations (e.g., 6-10 ft in mainstem riffles) that remained wetted at all WSEs (Figure 4.1-1). The location and elevation of blocks deployed in shallow water

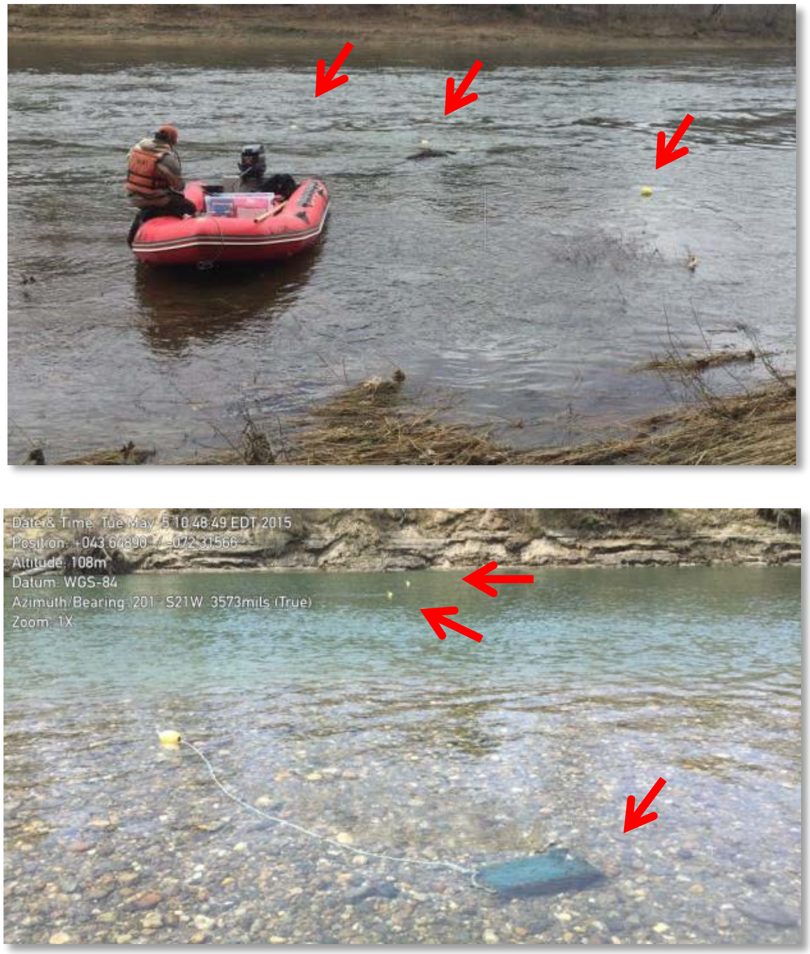


Figure 4.1-1. Example of egg blocks deployed across the stream channel at 2 study sites (additional blocks not shown).

along stream margins or within smaller tributaries was measured with the RTK GPS; elevations of deeper blocks was calculated by measuring block depth with a stadia rod from the boat and subtracting the depth from the concurrently measured WSE using the RTK GPS.

Egg blocks were constructed of standard 8-inch x 16-inch concrete blocks wrapped in a sleeve of hog's hair synthetic filter media that forms an ideal surface to collect the broadcasted and adhesive White Sucker and Walleye eggs. Blocks were attached to 6-20 ft polypropylene lines with labeled buoy(s) to allow retrieval of the egg block for inspection and re-deployment to the same location and bed elevation.

Each time an egg block was retrieved, the synthetic "sleeve" was carefully inspected to determine if either Walleye or sucker eggs were trapped in the fibers (Figure 4.1-2). If so, the eggs were picked, counted, attributed to species by reference to egg identification keys, and recorded on field data forms. Most collected eggs were also placed into a labeled sample jar containing 6% formalin and transported to the Normandeau biological laboratory for positive identification. After inspection of the sleeve and removal of eggs and debris, the cleaned block was re-deployed to its original location. Egg blocks were typically inspected three times per week on Mondays, Wednesdays, and Fridays.

Figure 4.1-2. Inspection of egg blocks from a mainstem study site.

Egg blocks were sometimes moved to different locations within the selected riffle or tributary study site if repeated visits yielded no eggs and if additional spawning habitat was available nearby. Such blocks were given unique labels and their locations and elevations were measured as described above. Block locations at each study site are illustrated in Appendix B.

4.1.4 Backwater Sampling

Twelve backwaters were sampled in the study area: 6 in the Wilder impoundment and 3 each in the Bellows Falls and Vernon impoundments (see Table 3.2-1). Backwater sampling targeted early-spring spawning by Yellow Perch, Northern Pike, and Chain Pickerel, followed by late-spring spawning by Largemouth Bass, Bluegill, Pumpkinseed, Black Crappie, Golden Shiner, and Spottail Shiner. Backwaters were generally sampled twice per week on Tuesdays and Thursdays. Surveys typically involved two biologists with polarized glasses slowly traversing the shallow spawning flats by boat (motoring or poling) and/or by wading through flooded vegetation (Figure 4.1-3). Biologists carefully scanned the substrate and vegetation for Yellow Perch egg masses, recently constructed bass or sunfish nests, or adult fish (esocids or shiners) exhibiting spawning behavior.

Shallow spawning flats were targeted for several reasons: WSE fluctuations in backwaters were typically less than 2 ft, thus potential impacts would be greatest for the shallowest habitats; most of the target species are known to prefer relatively shallow water for spawning; and low water clarity prevented visual identification of eggs or nests in deeper water. Because of this latter factor, the maximum depth at which the biologists felt they could effectively identify spawning activities was eye-estimated for each survey. This estimate was periodically calibrated by measuring depths using a stadia rod.

Because backwater, tributary mouth, and island/bar surveys were all based on visual observations of spawning sites, periods of limited water visibility restricted the identification and monitoring of deeper egg or nest sites, and consequently the estimated proportion of spawning sites impacted by project operations is likely to be over-estimated in this report. Other indicators, such as fish assemblage data (from Study 10 [Normandeau, 2016b]), larval trawl data (from this study and Study 21 [Normandeau, 2016e]), and literature-based ranges in spawning depths (Appendix A), all suggest that successful spawning likely also occurs in deeper water despite lack of observations in this study.

Figure 4.1-3. Backwater surveys were conducted by boat and by wading.

At each observed egg mass or spawning nest (hereafter referred to as a “spawning observation”), the location and elevation of the spawning observation was measured with an RTK GPS. Elevations of Yellow Perch egg masses were measured on the substrate adjacent to the egg mass, unless the egg mass was suspended over branches (Figure 4.1-4). While some egg masses were dewatered, some were not and in-water egg masses were observed to also hang vertically. For suspended egg masses, elevations were measured at the highest elevation (e.g., at the suspending branch) and in some cases also at the lowest elevation (e.g., typically the substrate). Such egg masses frequently exhibited a 1-2 ft range in elevation (range 0.6-2.1 ft, mean 1.3 ft). For each egg mass, only the upper elevation was used for comparison with measured WSEs; consequently any WSE that dropped below this maximum elevation was conservatively assumed to dewater the entire egg mass, even if a significant proportion of the egg mass remained within the water column at low water levels.

Figure 4.1-4. Examples of Yellow Perch egg masses showing vertical orientation.

Elevations of nesting species (bass and sunfish) were measured immediately adjacent to the nest pit. Some elevations were also measured within the pit of sunfish nests if no eggs or fry were present; differences in elevations ranged from 0.0 ft to 0.5 ft with a mean of 0.2 ft. All comparisons of nest elevations and WSEs utilized the more conservative and higher measurement adjacent to the nest site. Crews were careful to collect data only at “new” nests that were visually distinct from old nests by their cleaned appearance. Data were not collected at new but “vacant” nests where the adult species could not be identified, except for sunfish (Bluegill and Pumpkinseed) which could be difficult to distinguish between species during periods of poor visibility, and because sunfish nests are readily distinguished from bass nests by their small size and densely clustered distribution. Prior to collecting elevation or habitat data, observed nests were carefully inspected to determine if an attending adult fish was associated with the nest, and if eggs or fry were present (often by use of a view tube or underwater camera). All life-stages present at a nest were recorded, along with size of attending adult.

Although no definitive spawning observations were made for Northern Pike or Chain Pickerel, RTK locations, bottom elevations, proximal habitat, and adult lengths were measured or estimated where many adult fish were first observed.

In most cases individual measurements were taken at each egg mass or each nest location; however, different protocols were sometimes used where high densities of Yellow Perch egg masses or sunfish nests were encountered. In some cases, RTK elevations were measured at the shallowest and deepest locations of a cluster of nests or egg masses, and the number of eggs/nest was recorded. In other cases where Yellow Perch egg masses were particularly abundant, crews conducted a "strip count" within specified depth intervals. This was accomplished by counting all egg masses along a specific bank that were out-of-water, in-water at depths up to 2 ft, in-water at depths from 2-4 ft, and in-water at depths >4 ft (if clarity permitted). A WSE measurement was also taken in association with these strip counts. In the above two examples, the egg or nest observations included both the number of spawning observations and the range of elevations in which they occurred. This data was subsequently expanded to produce estimated elevations for each egg or nest, by evenly distributing the nests across the range of known elevations. For example, if a single cluster of 10 sunfish nests occurred over a 2-ft range of elevations from 300.0 ft to 302.0 ft, the data was converted into 10 individual observations at the following elevations (ft): 300.0, 300.2, 300.4, 300.6, 300.8, 301.0, 301.2, 301.4, 301.6, and 301.8. This expansion allowed a more detailed and accurate assessment of potential dewatering of eggs or nests than using a single (e.g., maximum or mean) elevation. Habitat attributes were also measured at each spawning observation, including:

- type and percentage of dominant substrate,
- type and percentage of subdominant substrate,
- percent of fines for nesting species (mud, sand or silt),
- dominant cover type within 10 ft of the spawning observation, and
- distance to that cover object (if present).

Substrate was visually assessed (typically with a view-tube and a 2-inch square marker for scale) immediately adjacent to Yellow Perch egg masses and within active sunfish, Fallfish, or bass nests. Table 4.1-1 lists the substrate and cover codes.

Table 4.1-1. Substrate and cover codes used to assess spawning habitat.

Substrate	Substrate Size (in)	Cover Type
Organics (ORG)	-	none
Mud (MUD)	-	submerged aquatic veg (SAV)
Silt (SLT)	-	emergent veg (EAV)
Sand (SND)	<0.1	terrestrial veg (TERRV)
Gravel (GRV)	0.1-2.5	woody debris (WD)
Cobble (COB)	2.5-10	Boulder (BLD)
Boulder (BLD)	>10	
Bedrock (BED)		

Repeat observations were conducted at a subset of sunfish or bass nests in order to track ultimate success of spawning and to assess any observed changes in substrate characteristics (e.g., an increase in fines). In some nests, a 2-inch-square washer was placed within or immediately adjacent to the nest and photographed with an underwater camera for later assessment of substrate composition.

Substrate and cover was also assessed at locations where adult Northern Pike and Chain Pickerel were observed. Date and time were recorded for all spawning observations in order to correlate the measured depths with WSE data recorded by the nearby data logger. Photographs (both above water and underwater) and video clips were recorded at many spawning observations to characterize backwater habitats.

Several other sampling protocols were initiated in an attempt to verify successful spawning within a backwater habitat, particularly targeting those species for which actual spawning locations were not identified (e.g., Northern Pike, Chain Pickerel, Black Crappie, and shiners). Angling was employed to determine the presence and ripeness (by expressed eggs or milt) of captured adult fish. All angled fish were released back into the water unharmed. View tubes and net sweeps were used in flooded vegetation near adult Northern Pike and Chain Pickerel observations to look for attached eggs. Baited minnow traps were deployed at several backwaters to capture adult shiners and assess them for ripeness (then released unless retained for identification). Finally, larval trawls were routinely conducted in most backwaters to assess if spawning was successful as indicted by the presence of newly hatched larvae. Larval fish samples were placed into labeled jars containing 6% formalin and transferred to the Normandeau laboratory for identification.

Note that only the visual survey methods were capable of documenting the specific locations of spawning activities (e.g., nest or egg depths and elevations), but such surveys were highly influenced by water clarity. Most backwater surveys conducted throughout May allowed confident visual identification of eggs or nests down to 3 ft, with some days of over 4 ft visibility. Water clarity was generally less throughout June due to high water conditions and many days provided visibility conditions <2 ft, which were judged insufficient to adequately identify new spawning activities or to re-locate existing nests or eggs. In some cases water clarity was sufficient but WSEs were so high that previously identified nests were too deep to relocate. Because of these limitations, it should be clearly evident that all visually-based spawning observations in backwaters (as well as tributaries and riverine islands) are biased towards shallow spawning, as deeper nests or eggs were less likely to be detected.

4.1.5 Tributary Mouth and Island/Bar Sampling

Late-spring spawning surveys for Smallmouth Bass, Fallfish, and Spottail Shiners were conducted in the lower portions of impoundment tributaries or their deltas (Table 3.2-2), and at riverine island or bar habitats (Table 3.2-4). The same general methodologies were used at both habitat types.

Two biologists used polarized glasses and sometimes view tubes to search for nests while drifting, poling, or slowly motoring along the margins of each site. Shallow delta areas and tributary mouths were assessed by wading, and snorkeling was employed at one location (Hart Island, WI-005) to compare the efficiency of wading vs. snorkeling for detecting nests and to assess if nests were constructed in deeper water. Snorkeling was conducted along the 3,300 ft length of Hart Island's west channel, under conditions of optimal water visibility (6-8 ft). Snorkeling did not reveal any nests in deeper mid-channel areas, but did locate a nest in a shallow mid-channel location not observed by the wading crew. In contrast, the wading crew located a nest within a woody debris jam that was not detected by the snorkeler. Because the snorkeler could only see 6-8 ft to either side of the dive path, in comparison to the wading or boating crews that could typically see a much wider strip due to their elevated position, snorkeling was not considered advantageous when surveying for shallow spawning nests.

Procedures for assessing Smallmouth Bass nesting were identical to the methods described for backwater nesting species, including the assessment if an attending adult, eggs, or fry were present at each nest. The presence of an adult was indicative of a nest being "active", whether or not eggs or fry were also present. An "unknown" nest was a newly prepared nest (as evidenced by its cleaned appearance) that did not contain eggs or fry and which no attending adult bass was ever observed. In contrast to sunfish nests, which are readily identified by their nest characteristics, unknown nests were generally not measured due to uncertainty of species, as Largemouth Bass and Rock Bass (*Ambloplites rupestris*) construct similar nests and were also spawning at the same time.

Although generally unmeasured, some elevation data was collected on unknown nests for comparison with nests known to be active bass nests. If an unknown nest was later seen with an attending adult Smallmouth Bass, or if eggs or fry were subsequently present and identified as Smallmouth Bass, its status was changed to "active" and nest data was then collected. As described above, repeat observations were conducted at many bass nests in order to track progress and nesting success. Changes in substrate composition were monitored at a subset of bass nests by repeatedly photographing or visually assessing the nest with the 2-inch scale marker.

It should be noted that Smallmouth Bass were typically very defensive of a nest containing eggs or newly hatched fry, but prior to egg deposition (and likely as fry grew larger) attending adults were not as strongly dedicated to a nest. Consequently, many unknown nests or repeat visits to active nests without an attending adult may have in fact had an unseen adult nearby, particularly during periods of limited visibility. For this reason, crews typically remained proximal to such nests for several minutes to determine if an adult returned to an observed nest.

Fallfish nests were easily identified due to their large size and unique appearance (Figure 4.1-5), except during periods of high flow and/or low water clarity. Old Fallfish nests (presumably from prior years) were evident at some locations, but new nests were readily apparent due to the cleaned appearance of the nest materials. Fallfish nest elevations were measured at two locations: at the base of the nest and at the top of the nest mound. Note that Fallfish eggs are deposited at the original bed elevation prior to being covered by the mound (Reed, 1971; Magee, 1989; Maurakis & Woolcott, 1992), therefore comparison of Fallfish nest elevations with WSE data utilized the RTK elevation measured at the base of the nest mound.

Figure 4.1-5. Fallfish nests showing mound of clean substrate.

In addition to nest location, nest elevation(s), and presence of life-stages, substrate and cover data were collected at each nest as described for backwater spawners. While searching for bass and Fallfish nests, biologists also looked for aggregations of shiners at the tributary mouths. When observed, specimens were captured with a seine or hand-net for species identification and to assess if gravid (by extended belly or by expression of milt or eggs). Substrate materials were also collected by hand to look for attached or loose eggs.

4.2 Data Analysis

Assessment of project effects on spawning success generally followed two stages: 1) comparison of 2015 spawning observations with WSEs measured at each site by water level loggers during the 2015 spawning period; and 2) comparison of 2015 spawning observations with predicted WSEs at each site during five different water years using the Operations Model (Study 5 [Hatch, 2016]).

The assessment of potential effects on spawning success in 2015 due to project operations was conducted by directly comparing the measured elevations of egg masses or spawning nests with the concurrent WSEs measured by the data loggers (or estimated as described above). This comparison allowed calculation of depth of water over each spawning location over the period of egg incubation and (for sunfish and bass) fry residence. For most spawning observations, the elevation of each individual egg mass or nest was plotted against the concurrent WSE. However, due to the large number of Yellow Perch egg masses and aggregations of sunfish nests, the comparison of spawning elevations with WSEs required grouping individual egg mass and sunfish nest elevations into “bins” of 0.1 ft for plotting.

Analysis of the pressure and temperature data downloaded from the in-water and barometric data loggers followed the procedures detailed in ILP Study 13

(Normandeau 2015d). Output files containing calibrated WSEs were compared to actual WSEs measured with the RTK GPS to ensure that estimated and observed values matched on the date and time of logger deployment. Unfortunately, 11 of 62 data loggers deployed for this study were either lost, were not deployed or redeployed properly, or contained corrupted or missing data.

4.2.1 Treatment of Missing or Corrupted Logger Data

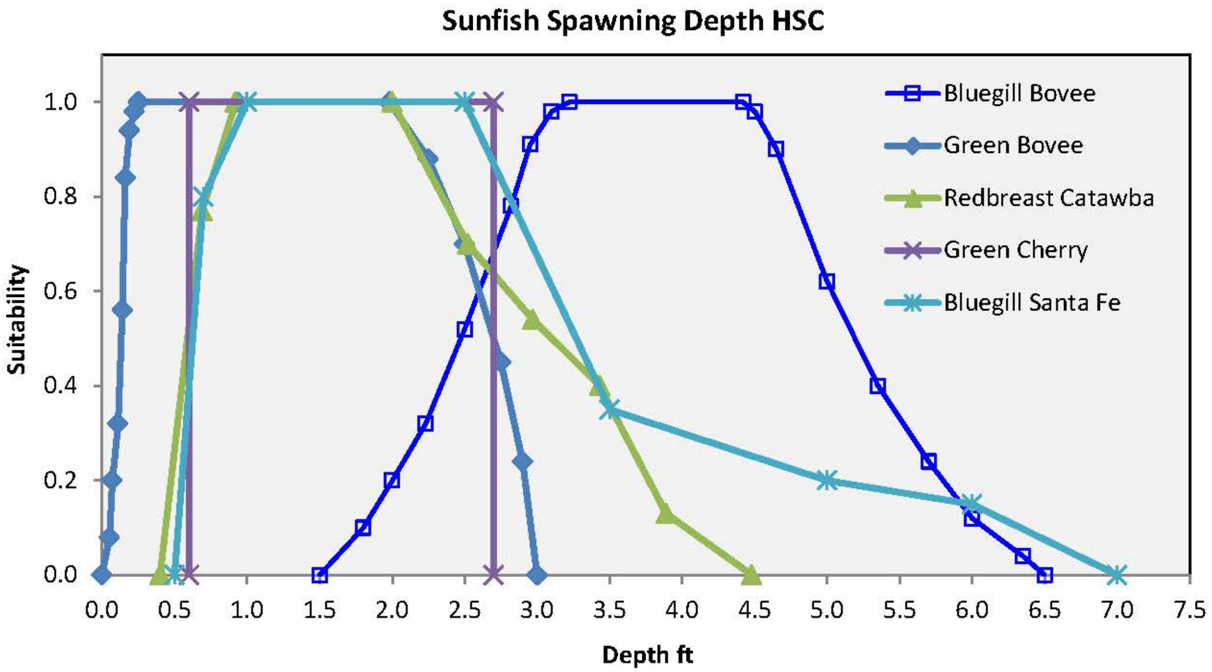
In many cases it was possible to estimate the missing data using a nearby data logger or other source of WSE data. For example, the logger installed within the WB-032 backwater stopped logging data a week after deployment, but the logger deployed just outside of the backwater functioned properly. Comparison of the abbreviated WSE data from the inside logger with the full dataset from the outside logger showed a high correlation (0.83) and a mean difference of 0.35 ft. This difference was used to adjust the outside WSE data in order to estimate the inside backwater WSE values over the period of missing data. In other cases, linear regression was used to estimate missing WSE data based on the comparison of matched data from proximal data loggers, while accounting for lag time (only evident in larger backwaters). At one study site where the entire WSE dataset was missing or corrupted, measured WSEs from Study 9 (Normandeau, 2016a) transects proximal to the missing logger site and proximal to an upstream study site (with logger data) were compared at several flows to estimate a correction factor to replicate the missing data. Despite these efforts, gaps in WSE data occurred at some study sites where missing data could not be estimated with high confidence.

4.2.2 Minimum Depth Criteria

Dewatering and egg or nest failure was assumed to occur when the WSE dropped below the elevation of an egg mass or active nest. Yellow Perch eggs are encapsulated within a moist, gelatinous mass, and brief periods of exposure did not appear to affect viability. Differences in the appearance between egg masses suspended well above the WSE and those suspended just above the WSE were evident, with the higher egg masses clearly desiccated and limp, whereas lower hanging egg masses typically appeared firm and moist. Nevertheless, to be conservative it was assumed that any evidence of dewatering would result in total mortality of perch egg masses, even those hanging well down into the water column.

Potential nest abandonment by nest-guarding species (i.e., sunfish and bass) was assessed by comparing the minimum depth over a nest with criteria representing minimal tolerable depths for attending adults. The minimum depth criteria were based on available habitat suitability criteria for the spawning life stages of each species (Figure 4.2-1), as well as revisit data for Smallmouth Bass and sunfish from this study. These datasets suggest that optimal depths for sunfish spawning occur from 1 to 3 ft, whereas depths <0.5 ft are generally unsuitable. For Smallmouth Bass, most datasets show optimal spawning depths starting at 2.0 ft, whereas depths <1.0 ft are generally unsuitable. Consequently, potential nest abandonment was assumed when nest depths dropped to <0.5 ft for sunfish or <1.0 ft for Smallmouth Bass.

In like manner, it was assumed that a minimum depth of 0.5 ft at Fallfish nests would be protective of eggs and larvae, which are known to occupy the basal area of the nest mound, as stated above. Fallfish nests measured in this study had an average nest height of 0.9 ft (range 0.5-1.3 ft). Although basal widths were not typically measured at observed Fallfish nests, one nest with a measured height of1.11 ft had an estimated basal width of 3.5 ft, giving an estimated mound slope of 32°. These measurements produced a total estimated nest volume of 3.6 ft^3 (based on area of a cone), of which 83% of nest volume occurred in the lower 0.5 ft. Similar calculations for the remaining nests, assuming a mound slope of 32°, suggested that a depth of 0.5 ft above the nest base would inundate an average of 90% of the total nest volume (range 77-100%).



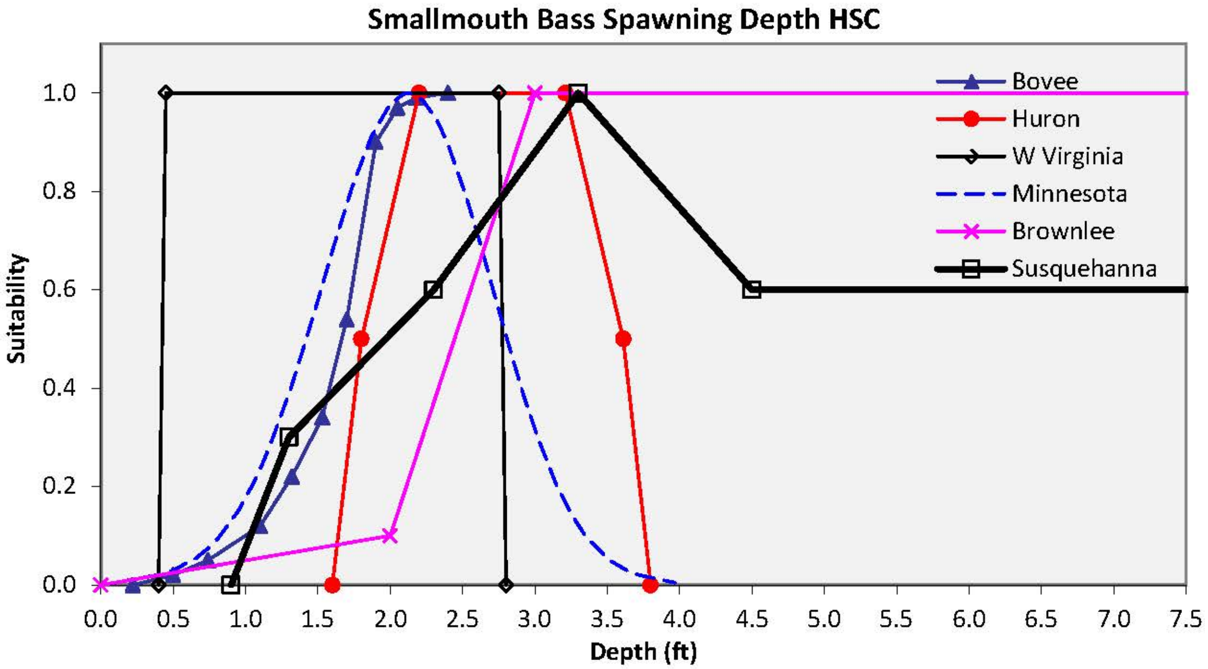


Figure 4.2-1. Habitat suitability curves for spawning sunfish (top) and Smallmouth Bass (bottom). See Appendix A for source data.

4.2.3 Periodicity of Adult Presence, Egg Incubation, and Fry Residence Times

The duration of egg incubation for Yellow Perch and Fallfish was estimated using literature-derived incubation/temperature relationships (Figure 4.2-2) and mean daily water temperatures from the on-site data loggers. Egg and fry residence times for sunfish and Smallmouth Bass were based on literature sources and data from revisit observations as part of this study (see below). Because surveys were conducted at 2 to 3 day intervals, the period of incubation assessment was projected forward in time for most spawning observations, assuming that new observations represented recent egg deposition or nest construction. Exceptions to this forward-looking assessment are noted below.

The temperature-egg incubation relationship was used to estimate the length of time an observed Yellow Perch egg mass persisted at a particular location, based on the recorded water temperatures from the date the egg mass was first detected and over the following 1-3 weeks (depending on temperature). For example, if a cluster of egg masses was observed on April 20 and mean daily temperatures over the following 2-3 weeks averaged 10°C, it was assumed that the egg mass would be present, and potentially vulnerable to dewatering, for a 20-day period beyond the observation date (see intersection of 10°C and 20 days on Figure 4.2-2), or in this example, from April 20 to May 10. Although repeated backwater surveys indicated that Yellow Perch fry had hatched and egg masses were no longer present in the Bellows Falls backwater habitats by May 12, and Wilder backwaters appeared devoid of egg masses by May 14, the Yellow Perch incubation assessments extended beyond those dates for the occasional late-season egg masses.

Elevation and habitat characteristics were collected for all “active” sunfish nests. Active sunfish nests were defined as a newly cleaned bed, typically with an attending adult, but sometimes not. Because both species construct small, saucer-shaped nests in dense clusters, a newly cleaned nest without an adult was often identified and assessed as a sunfish spawning observation because no other species produce such distinctive nests. Comparison of sunfish nest elevations with measured WSEs over the course of this study required assumptions regarding adult persistence and egg incubation. Sunfish eggs typically have short incubation times, with most eggs typically hatching in a few days at typical spawning temperatures. (approximately 3 days at 20°C, Becker, 1983). Fry residence times are also short as sunfish fry, unlike bass fry, disperse into nearby vegetation soon after hatching (Moyle, 1976).

Consequently, sunfish spawning assessments assumed a conservative incubation time of five days from the date when eggs were first observed (although hatching likely occurred sooner). It is more uncertain how long an adult sunfish will remain at a nest until spawning has commenced, as this information was not found in literature reviews, and crews did not observe an individual nest that first contained an adult but on repeat visits observed eggs. However one nest was first observed with an adult and on a revisit nine days later was found to contain fry. Consequently, for the purpose of this assessment, it is assumed that a nest with a guarding adult remained active for a period of 10 days following the initial nest observation. For those active nests where no adult was observed, it was assumed the nest was active for the preceding 10 days. Assessing potential nest success backwards in time was conducted for sunfish due to the distinct appearance of cleaned sunfish nests and the short egg incubation and fry residence times.

Assessment of WSEs over active Smallmouth Bass nests was conducted forward in time from the first date of observation. Although adult bass may occupy a nest area for a length of time prior to egg deposition (see below), they are not known to remain at nest sites after fry dispersal. Consequently an active bass nest with an attending adult, with or without eggs or fry, was considered successful at that point in time and thus assessment of WSE effects was conducted forward in time according to adult, egg, and fry residence times.

Assessment of Smallmouth Bass nest elevations in relation to WSEs assumed periodicity functions for adult bass residence, egg incubation, and fry presence (Table 4.2-1). These periodicity functions were based on literature values for egg incubation times (Becker, 1983; Smith, 1985), and estimates of adult, egg, and fry persistence from this study's nest revisit data. Based largely on the site-specific data below, the nest vs. WSE assessments assume potential continued residence of adult bass observed at empty nests for up to 30 additional days following the last adult observation, thus allowing time for egg deposition, incubation, and fry rearing. For nests containing eggs, nests were assumed to be potentially active for an additional 25 days after eggs were first observed, allowing for continued egg incubation and fry rearing. Nests containing fry were assumed to remain active for an additional 26 days following the first observation of fry. The period of potential nest activity was terminated at all nests on any date when a subsequent observation failed to identify the presence of an adult, eggs, or fry.

Table 4.2-1. Duration of Smallmouth Bass life-stages in nests visited 2 or more times. Not shown are 4 nests where adult was only observed on 1 occasion.

Life-Stage Sequence	No. Nests	Min No. Days	Max No. Days
Adult Presence	13	2	25
Adult to Egg	4	2	12
Egg Presence	2	2	13
Adult to Fry	1	9	9
Fry Presence	8	5	26

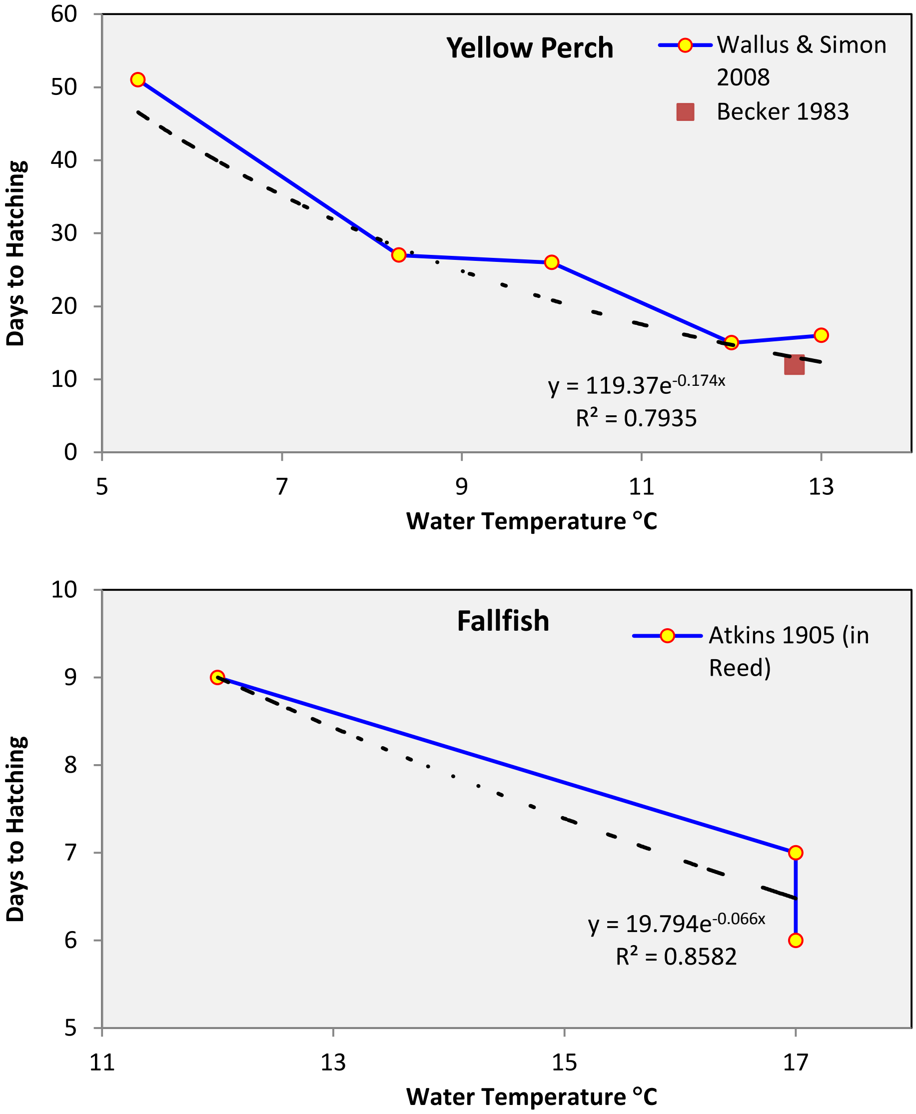


Figure 4.2-2. Revised temperature-incubation curves for Yellow Perch and Fallfish.

4.2.4 Assessment of Project Effects on Spawning Success Using Operations Model

As noted above, assessment of potential egg or nest dewatering in 2015 utilized the 2015 spawning data and the concurrently measured WSEs at each study site. This analysis provided estimates of potential egg mortality or nest abandonment over a single study year. To generalize the results, the Hydraulic Modeling (Study 4, GEI, 2016) and the Operations Model (Study 5 [Hatch, 2016]) were used to predict WSEs at each site during each species spawning periodicity in order to assess how often eggs or nests might be dewatered (again, using 2015 spawning data) under actual flow and reservoir elevation regimes of different water year hydrologies.

Modeled WSEs were used to estimate the proportion of days within a species spawning period when WSEs dropped below specified elevation criteria at each study site.

Multiple spawning elevation criteria were derived from the 2015 spawning observations at each site to assess the frequency that such eggs or nests would be dewatered under various water year types. Minimum, median, and maximum spawning elevations were calculated for each species and study site and compared to WSEs predicted by the Operations Model. The maximum elevation criteria was used to represent the proportion of spawning days when no eggs or nests would be dewatered, whereas the minimum criteria represents the proportion of days when all observed eggs or nests would be dewatered. The median elevation criteria represent the proportion of days when one-half of all observed eggs or nests would be dewatered.

The above analysis was conducted for those time periods when the project operated normally (i.e., not during periods of high uncontrolled flow or when high flow events were imminent). The analysis was repeated under special operating conditions when anticipated inflows are higher than maximum station generating capacity. As part of its operating procedure for high flow management, TransCanada lowers WSE at the dams in anticipation of inflows greater than maximum generating capacity at each project. This is done under Article 32 of the existing project licenses and in accordance with the coordination agreement with the US Army Corps of Engineers which operates flood control dams in the Connecticut River basin. These high water operations are initiated in order to manage upstream water elevations within certain flowage rights and to reduce the potential for river flows to spill outside of the normal bank full conditions. These conditions and operating protocols are not considered normal project operations but occur each spring during the spring freshet coinciding with the spawning periodicities of many resident fishes, and any other times when anticipated flows exceed downstream station capacities.

5.0 RESULTS AND DISCUSSION

Spawning surveys commenced on April 16, 2015 and concluded on July 2, 2015. During most of this period, four crews of two biologists each sampled backwater, riffle, tributary mouth, or island/bar study sites five days per week. Crews sampled 12 backwaters and 16 lower tributaries in impoundments and 12 riffles and 12 island/bar habitats in the riverine reaches. Over 240 egg blocks were deployed and fished for over 4,000 block-days. Crews also conducted over 180 surveys within backwater habitats, where most of these boat and wading surveys extended over one mile in length. Tributaries were visited for smallmouth and Fallfish nesting over 130 times, along with 50 surveys of riverine island habitats.

In sum, crews collected location, elevation, and habitat data at 161 locations representing over 800 Yellow Perch egg masses; 123 sunfish (Bluegill and Pumpkinseed) nests, 5 Largemouth Bass nests, 79 Smallmouth Bass nests, and 26 Fallfish nests. White Sucker eggs were collected on three days at two study sites and a single Walleye egg was collected at a third site. Rosyface Shiners (*Notropis* *rubellus*), a non-target species, were observed in a spawning aggregation over a Fallfish nest in the Wilder riverine reach on June 8 (Figure 5.0-1).

Figure 5.0-1. Spawning aggregation of Rosyface Shiners over a Fallfish nest.

Non-spawning observations were collected for nine Northern Pike (angling and visual surveys), 14 Chain Pickerel (angling and visual surveys), and two Black Crappie (angling). Ripe Golden Shiners were captured in a Wilder backwater using minnow traps on June 18 and June 25, and a ripe Spottail Shiner was seined below Chase Island on June 22, however no spawning aggregations or spawning locations were observed for either species during visual surveys. Rainbow Trout were not observed spawning at any study sites, and neither Longnose Dace nor Eastern Silvery Minnows were observed or captured in the study area during these spawning studies. However, both species were captured in low numbers during Study 10 (Normandeau, 2016b).

Larval fish tows were conducted in most backwater habitats and some tributary or island habitats to detect if successful spawning occurred by target species. Larvae (and eggs) of target species were also collected during shad trawls in the Vernon and Bellows Falls riverine reaches. Appendix C lists the larvae of target species (based on laboratory identification) collected from larval trawls conducted as part of these studies and in Study 21 – American Shad Telemetry Study – Vernon (Normandeau, 2016e).

Sea Lampreys or their nests were regularly encountered in the Vernon and Bellows Falls reaches and these spawning observations are reported in Study 16 – Sea Lamprey Spawning Assessment (Normandeau, 2016c).

5.1 Environmental Conditions

5.1.1 Streamflow

Streamflow into project impoundments and through project dams varied widely over the spring and early summer of 2015. For example, rainfall events produced large variations in local water surface elevations, water temperatures, underwater visibility (e.g., turbidity), and other water quality parameters in impoundment reaches. These impoundment conditions and the frequent spill events carried over into the downstream riverine reaches, along with large effects on local water velocities. Each of these factors influenced the ability to identify and monitor spawning observations during portions of the study. The conditions experienced in the spring and early summer of 2015, which were not atypical of New England weather patterns, illustrate the limited capacity of the projects to absorb rainfall events as well as the relatively narrow band in which project operations influences flows and WSEs in both impoundment and riverine reaches.

Figure 5.1-1 shows streamflows below the three project dams in relation to the generation capacity of each project. Over the 77-day period of spawning surveys, (April 16-July 2) inflow and discharge at the Wilder project exceeded generating capacity for all or portions of 61 days, or approximately 79% percent of days, although the magnitude of spill was relatively minor (e.g., <1,000 cfs) throughout most of May. Spill occurred more frequently at the Bellows Falls project, for 69 of the 77 days (90%), when most of the spill events exceeded 5,000 cfs. In contrast, the Vernon project spilled on only 36 days, representing 47% of sampling days. Although many surveys were conducted during times of spill, sampling efficiency was reduced in some cases due to high WSEs, which sometimes prevented retrieval of egg blocks and made relocation of deeper nests impossible. The reduced visibilities associated with high flows and spill events also hampered the location or relocation of spawning sites, and likely served to over-emphasize the fate of shallower, more vulnerable spawning sites in comparison to unobserved deeper sites. Because of the danger associated with boating immediately below the project dams during times of spill, it was not possible to deploy blocks in close proximity to dam facilities, which appeared to be preferred areas for springtime Walleye angling.

5.1.2 Water Temperature

Mean daily water temperatures (based on water level logger data) ranged from <7°C in mainstem reaches in late April to 25°C in backwaters in late-May and mid-June. Additional details on water temperatures recorded during spawning surveys are presented with the species descriptions in following sections of this report.

5.1.3 Water Visibility

Water visibility also had an effect on most spawning surveys (excluding egg-block sampling), due to the visual nature of identifying and monitoring observed adult spawners, egg masses, or constructed nests. This factor necessarily biases the spawning assessment towards shallower habitats that are more vulnerable to

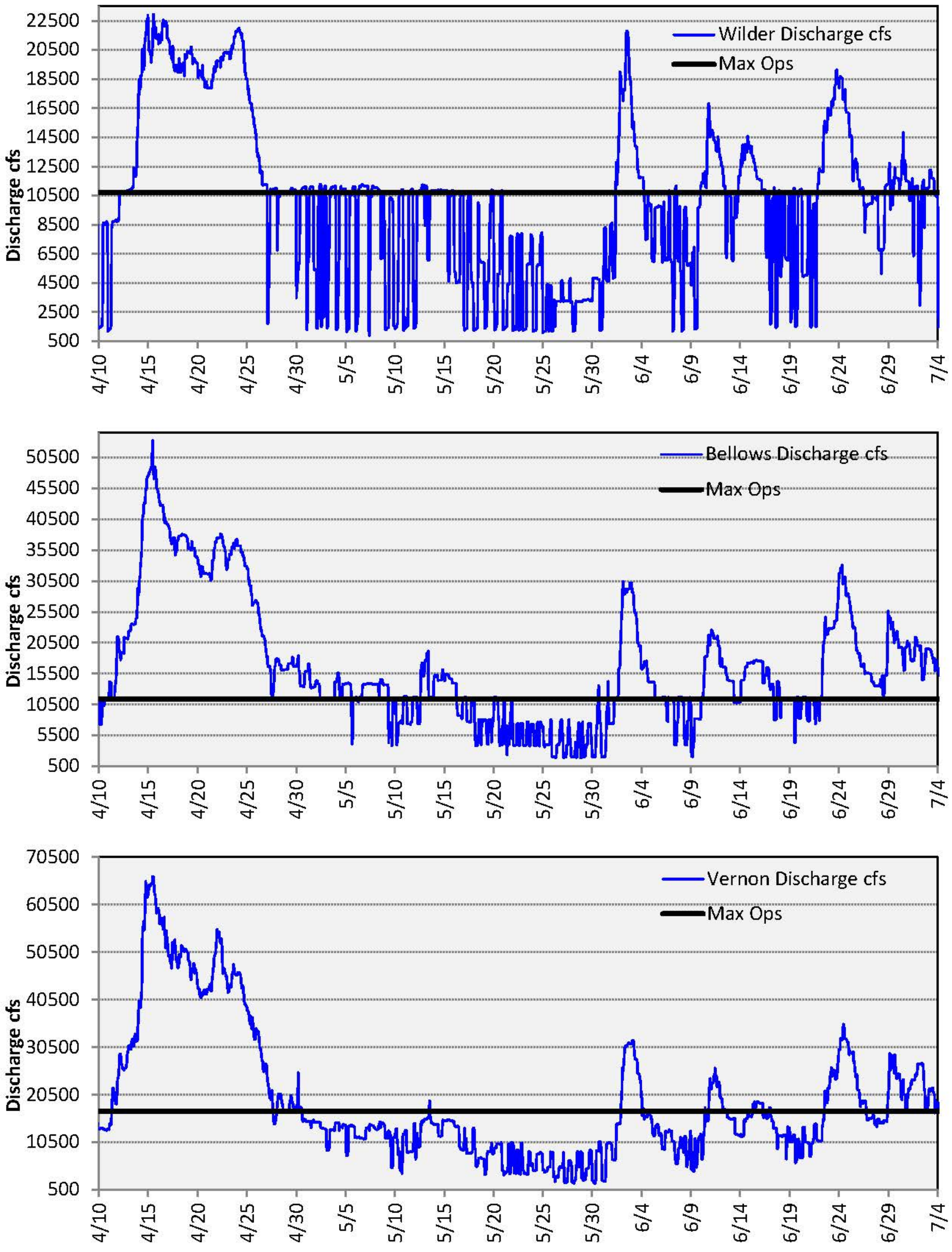


Figure 5.1-1. Discharge below project dams. Discharges greater than the maximum operation capacity represents spill.

dewatering, since deeper and less vulnerable eggs and nests were likely present, but largely undetected due to limitations in visibility. Consequently, estimates of project effects on egg or nest sites are conservative and likely to be over-estimated. Review of the literature on spawning behavior (Appendix A) for most of these species shows that observed ranges in spawning depths can exceed the 3-5 ft of visibility typical of the spawning surveys conducted in 2015. Water visibility was assessed using measurements of turbidity with water quality meters (discussed below), and by using ocular estimates of the maximum depth that crews could effectively identify a spawning observation. This latter metric, although qualitative and subjective in nature, is most directly correlated with the effectiveness of visual spawning surveys.

Eye-estimated water visibilities ranged from less than 1 ft under turbid conditions to over 5 ft under ideal conditions. At times rain and/or wind also reduced visibility independent of water clarity. Overall, estimated water visibilities less than 2 ft were judged to be insufficient for detecting all but the shallowest spawning observations and hindered the ability to track the progress of active bass or sunfish nests. Because changes in WSEs in impoundment backwaters were typically less than 2 ft, a visibility of 2 ft or greater would allow detection of eggs or nests that were most vulnerable to dewatering.

As can be seen in Figure 5.1-2, estimated water visibilities generally remained slightly above 2 ft during early-season surveys from late-April to mid-May, with peak visibilities (4-6 ft) the last week of May and first week of June. After this, however, high flow events (Figure 5.1-1) resulted in reduced visibilities (often <2 ft) through the remainder of the spawning surveys in the Wilder and Bellows Falls study areas. In general, early-season visibilities were highest in the Wilder impoundment and riverine reaches, but late-season visibilities were highest in the Vernon study area. Overall, 11% of estimated visibilities in the Wilder study area were less than 2 ft, whereas 25% and 17% of estimates were less than 2 ft in the Bellows Falls and Vernon areas, respectively.

5.1.4 Water Quality

Water quality parameters were collected at each study site and included temperature (°C), pH (standard units, su), conductivity (µS/cm), turbidity (NTU), DO (mg/l), and DO saturation (%). All measurements were taken with handheld field meters and data represent instantaneous readings. The study included collection and reporting of limited grab samples of water quality data during visits to each of the study sites. As a result, the data should not be used to characterize general site conditions or trends. Study 6 - Water Quality Monitoring Study (Louis Berger Group and Normandeau Associates, Inc., 2016) data provides the best data on overall water quality within the project-affected area.

Both New Hampshire and Vermont have numeric water quality standards for pH and DO, but only narrative criteria for the other parameters measured. Results of water quality sampling are summarized below. Appendix E (filed separately in Excel format) presents water quality sampling data from each documented spawning site on each sampling date.

Temperature ranged across all sites and the study season from 3.9°C to 26.1°C, generally increasing as the season progressed. Measurements of pH ranged from 6.1 to 8.7 su with two sites (14-WB-028 and 15-WI-002) having pH values less than the state standards of 6.5 su on one occasion each during the last week of June. Site 14-WT-058 had one pH measurement above the Vermont standard of 8.5 su, and readings on two other occasions above the New Hampshire 8.0 su standard. Several sites also had at least one pH measurement between 8.0 and 8.5 su but also had numerous readings within standards of both states, with no apparent trends.

Conductivity across all sites and the study season ranged from 41 to 444 µS/cm with all readings >300 µS/cm occurring at site 14-WT-074 (Mink Brook in the Wilder impoundment) where the lowest measured conductivity was 193 µS/cm. Sites 14-WB-012, 14-WB-028, 14-WT-007 and 14-WT-010 had the lowest conductivity, consistently below, or on occasion slightly above 100 µS/cm. No other trends were apparent. Turbidity was generally low (<10 NTU) for nearly 95% of all measurements. Site 14-WT-010 on one occasion measured 99.1 NTU. As discussed elsewhere in this report, sampling often occurred during high flows and runoff from tributaries that is likely the cause of high turbidity.

Dissolved oxygen ranged from 5.6 to 14.9 mg/l concentration and from 61.7 to 136.1 percent saturation. No measurements were less than the New Hampshire instantaneous standard of 5.0 mg/l but three backwater sites (14-WB-016 Waits River backwater; 14-BB-030 Williams River backwater; and 14-VB-039 Retreat Meadows backwater) had instantaneous measurements of 5.7 – 5.9 mg/l on one occasion each during late June, below the Vermont standard. Two of these sites also had DO on the same occasion that was less than Vermont's standard of 70% saturation (14-WB-016 at 61.7% and 14-BB-030 at 65.5%). New Hampshire's percent standard is a daily average and not applicable to the sampling conducted in this study.

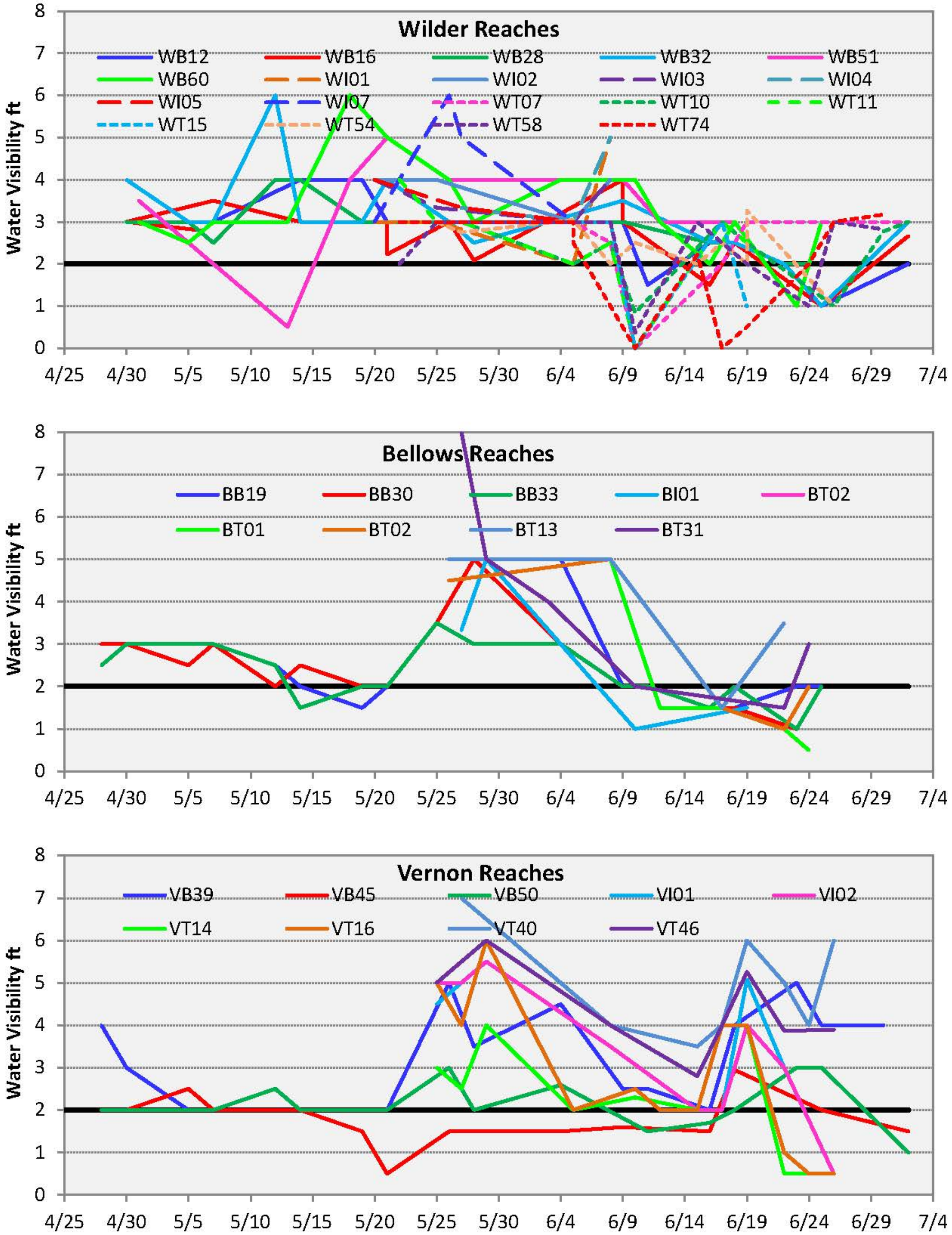


Figure 5.1-2. Eye-estimated water visibility during spawning surveys by reach and study site.

5.2 Early-Spring Spawners

Following is a description of sampling periodicities and spawning observations for each of the target species that spawn during early spring months.

5.2.1 White Sucker Spawning

Spawning by White Suckers (and Walleyes, see below) was assessed by deployment of egg blocks in the lower reaches or deltas of impoundment tributaries (Table 3.2-2) and in riverine riffle habitats (Table 3.2-3). Over the course of this study 242 egg blocks were deployed at 28 study sites for a total soak time of 4,168 block-days (Table 5.2-1). Of the 242 egg blocks used in this study, 153 were deployed within 16 tributary confluence sites (66 blocks in 7 tributaries to the Wilder impoundment; 40 blocks in 5 Bellows Falls tributaries; and 4 tributaries with 47 blocks in the Vernon impoundment) and 89 were deployed within 12 riffle habitats (47 blocks were deployed in 7 Wilder riverine riffle habitats; 31 blocks in 3 Bellows Falls riffles; and 11 blocks in 2 riffles below Vernon dam). Maps showing the relative location of egg blocks at each study site are shown in Appendix B. Egg blocks were typically retrieved, inspected, and re-deployed 3 days per week.

Table 5.2-1. Summary of egg block deployment periodicity and egg captures.

Habitat Type	Reach	Study Site	Site Name	Date Blocks Deployed	Date Blocks Removed	# Blocks Deployed	# Block Days Fished	# Block Surveys	# Blocks w Walleye Eggs	# Blocks w Sucker Eggs
Impoundment Tributaries	Wilder	14-WT-007	Oliverian Brook	23-Apr	27-May	11	141	14	0	7
		14-WT-010	unnamed	28-Apr	22-May	7	102	11	0	0
		14-WT-011	Halls Brook	23-Apr	20-May	6	86	11	0	0
		14-WT-015	Waits River	28-Apr	22-May	11	123	11	0	0
		14-WT-054	Hewes Brook	28-Apr	27-May	10	132	13	0	4
		14-WT-058	Ompompanoosuc	23-Apr	27-May	13	116	14	0	0
		14-WT-074	Mink Brook	23-Apr	20-May	8	109	11	0	0
	Bellows	14-BT-002	Sugar River	29-Apr	22-May	10	115	6	0	0
		14-BT-004	Mill Brook	22-Apr	22-May	9	120	11	0	0
		14-BT-013	Little Sugar River	22-Apr	22-May	3	111	12	0	0
		14-BT-018	Black River	22-Apr	22-May	13	178	12	0	0
		14-BT-031	Williams River	22-Apr	26-May	5	136	13	0	0
	Vernon	14-VT-014	Aldrick Brook	21-Apr	22-May	14	216	14	0	0
		14-VT-016	Mill Brook	29-Apr	22-May	6	138	11	0	0
		14-VT-040	West River	21-Apr	22-May	16	248	14	0	0
		14-VT-046	Broad Brook	22-Apr	22-May	11	179	13	0	0
Riverine Riffles	Wilder	15-WR-002	Riffle	29-Apr	22-May	8	166	8	0	0
		15-WR-013	Riffle	29-Apr	29-May	9	180	9	0	0
		15-WR-026	Riffle	28-Apr	22-May	6	144	9	0	0
		15-WR-061	base of Sumner Falls	30-Apr	5-Jun	5	180	8	0	0
		15-WR-069	Riffle	30-Apr	22-May	6	116	8	0	0
		15-WR-080	Riffle	28-Apr	22-May	7	160	9	0	0
		15-WR-100	Impoundment neck	30-Apr	22-May	6	120	8	0	0
	Bellows	15-BR-001	Bellows Falls tailrace, VT	17-Apr	22-May	6	93	7	0	0

Habitat Type	Reach	Study Site	Site Name	Date Blocks Deployed	Date Blocks Removed	# Blocks Deployed	# Block Days Fished	# Block Surveys	# Blocks w Walleye Eggs	# Blocks w Sucker Eggs
		15-BR-005	Riffle	23-Apr	22-May	13	203	5	0	0
		15-BR-007	Run	23-Apr	22-May	12	232	10	1	0
	Vernon	15-VR-001	Run	16-Apr	22-May	5	90	9	0	0
		15-VR-002	Run/Glide	16-Apr	25-May	6	234	13	0	0
					Totals:	**242**	**4,168**	**294**	**1**	**11**

Egg blocks were first deployed in riverine riffle habitats below Vernon and Bellows Falls projects on April 16 and 17 at water temperatures of 4-5°C (spot measurements) (Figure 5.2-1). Blocks were subsequently deployed in tributaries to the Vernon, Bellows Falls, and Wilder impoundments on April 21, 22, and 23, respectively, at water temperatures ranging from 4-8°C. Egg blocks were first deployed in the Wilder riverine reach on April 28 with water temperatures of 5-8°C. Mean daily water temperatures recorded by data loggers approximately 1-2 weeks after initiation of egg block sampling showed average temperatures of 5-10°C in mainstem locations, still well within the range of preferred spawning temperatures for White Suckers (Appendix A). Although data loggers were not deployed at tributary or riffle sites until eggs were captured (as per the RSP), mean daily temperatures in early May when eggs were captured remained within the range of sucker spawning temperatures.

Despite deployment of egg blocks in 28 study sites, White Sucker eggs were only collected from two Wilder tributaries (Oliverian and Hewes brooks) over three sampling dates: May 6, 8, and 11 (Figure 3.2-1). Oliverian Brook was also one of two tributaries where a school of suckers was observed staging at the tributary mouth. The other tributary was the Cold River in the riverine reach downstream of Bellows Falls (both schools were observed in early May). Net upstream counts at the three project fish ladders also showed maximum movement of suckers over the first two weeks of May (Study 17, Normandeau 2016d).

Most blocks had <5 eggs (maximum 24 eggs), suggesting that spawning did not occur in the immediate proximity of the egg-block locations (i.e., spawning likely occurred some distance upstream). Gravid female White Suckers typically contain over 10,000 eggs (Becker, 1983), thus more proximal spawning would be expected to result in much higher egg counts. For example, sucker studies conducted in the Grasse River, New York, yielded egg blocks with hundreds of attached eggs (Normandeau, unpublished data). Also, egg blocks were deployed in both upstream and downstream locations in both tributaries (Appendix B), yet all collected eggs were taken from the upstream blocks.

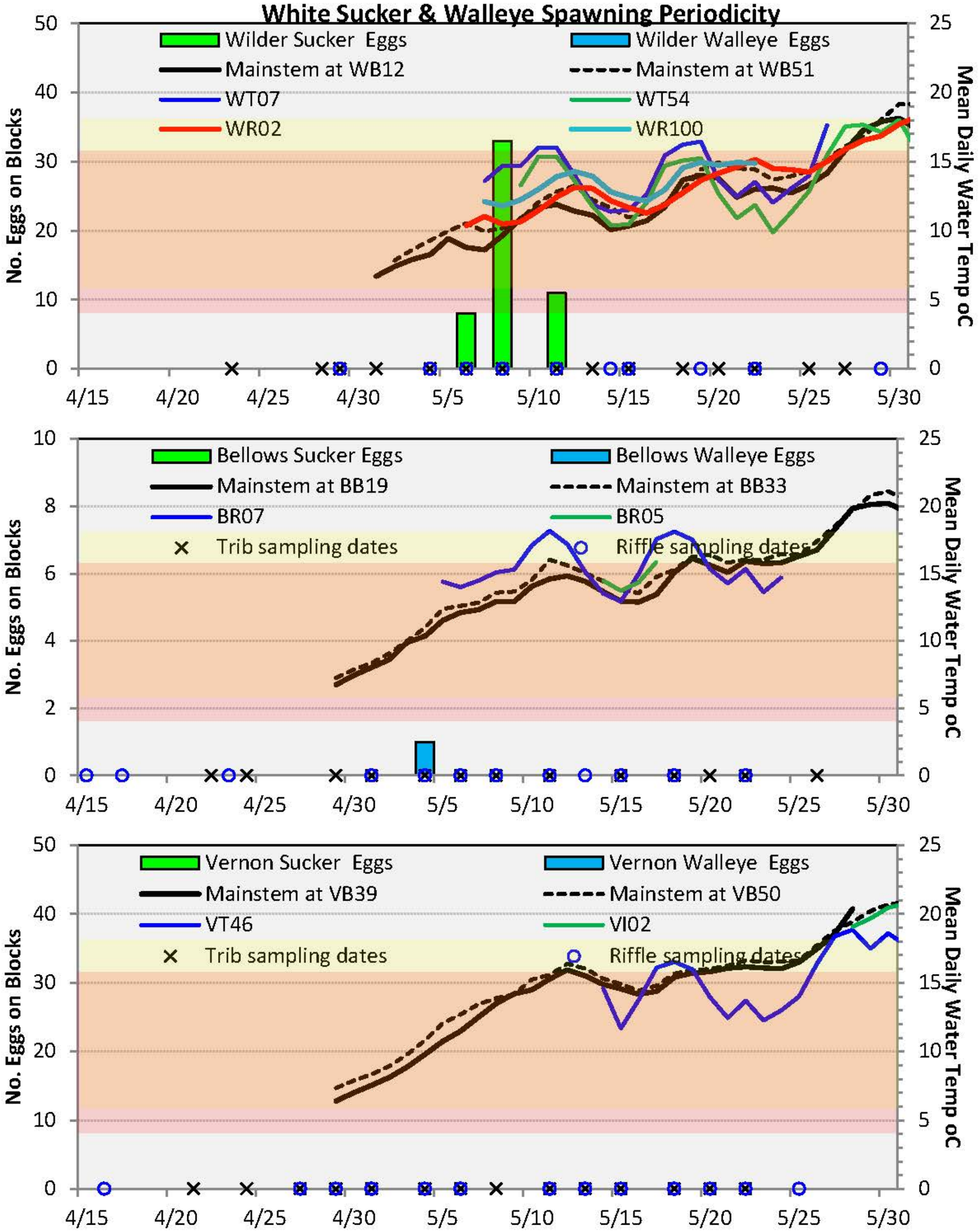


Figure 5.2-1. Periodicity of sucker and Walleye spawning observations (shaded horizontal bands) with range of known spawning temperatures (sucker = yellow shading, Walleye = red shading, overlap is orange shading), mean daily water temperatures at representative locations (lines), and sampling dates (“X’s” & “O’s”).

Although few sucker eggs were collected, some assessment of the elevations of blocks containing eggs with WSEs recorded by data loggers may be informative. The thick, solid portion of the egg block elevation lines in Figure 5.2-2 represent the range in time when eggs may have been deposited on the blocks. In other words, of the 2 dates bracketing a solid line segment, the later date is when eggs were found on the block. At Oliverian Brook (WT-007), blocks were initially deployed on April 23 (Figure 5.2-2, upper graph), but high tributary flows prevented the relocation and retrieval of the blocks until May 6, at which time six eggs were collected from block B and two eggs from block C. Although the thick line extends backwards to the deployment date on April 23, it is unknown what date those eggs were laid. In contrast, the collection of additional (new) eggs on May 8 (5 from block A, 24 from block B, and 4 from block C) reveals that spawning took place over the preceding two days. The school of staging suckers observed at the mouth of Oliverian Brook on May 8 also suggested that spawning was not yet completed. This fact was verified three days later when two new eggs were collected from block A and nine eggs from block B. Block B, on which 75% of the captured eggs were found, was located in the mid-channel of Oliverian Brook, where higher velocities would likely result in greater drift of eggs from upstream sources.

According to the egg block protocols, a data logger was deployed on the first date when eggs were observed (May 6), consequently WSE data is not available prior to that date. As previously noted, flows in Oliverian Brook were high during the initial deployment of egg blocks, and by the time of the May 6 site visit block C, which was the block highest in elevation (e.g., the shallowest), was barely wetted (although the 2 captured eggs appeared viable). Because of the drop in tributary flow, all blocks deployed on April 23 were redeployed in deeper water, hence the change in elevation of each block shown in Figure 5.2-2. The comparison of block elevations with WSEs after May 6 show that block C (and all deeper blocks) remained in-water until the blocks were removed on May 27, although sucker eggs would be expected to hatch within 8-10 days at the observed temperatures.

Although field crews attempted to deploy egg blocks only within the project-influenced reach of each tributary, detection of the maximum impoundment-influenced elevation was not always evident, and it is clear from the WT-007 WSE profile that these blocks were influenced only by changes in flow within Oliverian Brook (i.e., were just above the extent of project influence). This fact also supports the previous suggestion that spawning by White Suckers most likely occurs within the stream proper above the extent of project influence.

A combined total of ten White Sucker eggs were found on three egg blocks in Hewes Brook (Figure 5.2-2, middle graph) on two dates (May 8 and May 11). According to the associated WSE data, all blocks with eggs remained wetted until the conclusion of the early-spring sampling period (end of May), and like the Oliverian Brook blocks, the upper set of Hewes Brook egg blocks (where all eggs were captured) appeared to be just above the influence of impoundment fluctuations, whereas the lower set of egg blocks did not yield any sucker eggs.

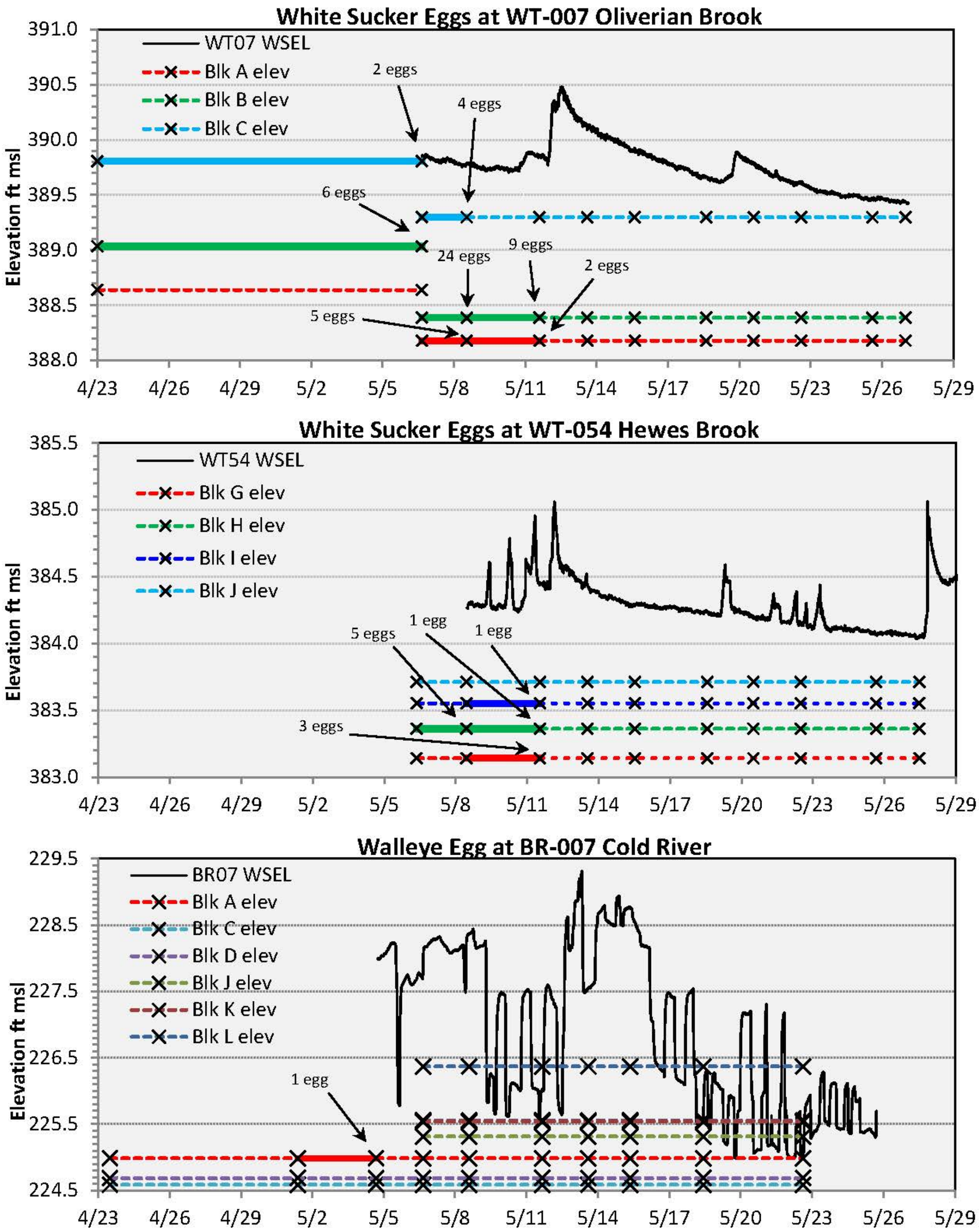


Figure 5.2-2. White Sucker and Walleye egg elevations and associated water surface elevations (WSEL). Thick, solid line segments represent periods when eggs may have been on blocks, "X's" represent sampling dates (deeper blocks without eggs not shown).

5.2.2 Walleye

Walleye are a popular game fish within the study area, and anglers were regularly observed fishing for this species below each of the project dams, as well as at specific locations such as Saxtons River and Sumner Falls. Because this species' spawning periodicity and spawning habitat requirements are similar to White Sucker (Appendix A), Walleye spawning was assessed using the same egg blocks that were deployed for assessing sucker spawning (Table 5.2-1). Despite placement of egg blocks at 28 locations, including riffle habitats as close as safely possible to the dams, as well as at the mouth of Saxtons River and immediately below Sumner Falls, only a single Walleye egg was captured on a block placed in the Cold River (BR-007), just downstream and across the river from Saxtons River (Figure 3.2-5).

Egg blocks were placed across the Cold River channel at three locations from just above the tributary mouth to just above the Highway 12 bridge (see map in Appendix B). The single Walleye egg was collected from block A (the middle set) on May 4, from a spawning event that occurred between May 1 (the previous block inspection date) and May 4. Block A remained wetted throughout the egg block survey period, although WSEs approached the block elevation by late May. The WSE data for this site showed daily fluctuations of 2-3 ft, which indicated that these blocks were within the project-influenced reach, unlike the blocks at Oliverian and Hewes brooks where sucker eggs were captured. This relative paucity of Walleye eggs found on this block close to the tributary confluence also suggests, as noted above for suckers, that most spawning likely occurred in the upstream reaches of the tributary outside of the project-affected reach. Also, the Vernon fish ladder revealed significant upstream movement of Walleyes during the spring period, when over 70% of net upstream movement occurred from the ladder opening on May 5 to May 17, which suggested continued spawning-related migrations into mid-May (Study 17 [Normandeau, 2016d]). Few Walleyes were observed in the other two project fish ladders.

Daily water temperatures in the days immediately following the egg capture in the Cold River averaged 14°C, with daily ranges from 10-18°C. Although these temperatures are towards the upper range of Walleye spawning temperatures, mainstem river temperatures averaged 2-4°C cooler than the Cold River during this time, which is in the middle of the published range of spawning temperatures. During the previous two weeks of egg block sampling, water temperatures were likely near the bottom end of the preferred spawning temperatures, as spot measurements in mid-April (prior to deployment of data loggers) showed water temperatures of 4-5°C at several locations.

Additional Walleye observation data is limited to capture of adult fish by angling. Angling was conducted to assess ripeness of adult fish in backwater habitats and resulted in the capture of 8 adult Walleyes from May 12 to June 30, none which appeared gravid. Angling was not routinely conducted in the riverine reaches or in the vicinity of impoundment tributary mouths.

5.2.3 Northern Pike and Chain Pickerel

Northern Pike and Chain Pickerel are early-spring spawners, like suckers and Walleyes, however their spawning habitat is generally described as shallow, still, highly vegetated habitats (Appendix A). Consequently, backwater surveys were conducted to identify spawning areas used by these two esocid species (and other backwater species). Backwater surveys were conducted in 12 study sites from April 28 to July 2, generally two days/week (Tuesdays and Thursdays). A total of 183 backwater surveys were conducted over the course of this study, although 28 of the surveys were conducted under marginal conditions with water visibilities of less than two ft (Table 5.2-2). Most of these individual surveys extended for over one mile in length and typical search widths (distance the crew could identify spawning observations to either side of the boat or wader) were 20-30 ft. Figure 5.2-3 shows an example of survey tracklogs and associated spawning observations in one backwater habitat.

Despite this level of effort and despite the visual observation of approximately 21 Northern Pike and 34 Chain Pickerel, none of the observations appeared to represent groups of adult fish or individuals exhibiting spawning behavior. Where adult fish were observed in shallow, vegetated habitats, visual inspections using view tubes along with net sweeps through the adjacent vegetation failed to locate any esocid eggs. Although both species have been noted to spawn shortly after ice-out in New England waters (as reported by NHFGD and VANR in written comments on the interim report), Northern Pike throughout most of its range are reported to spawn at water temperatures up to 10-17°C, with peak spawning at 7-12°C (Appendix A). Chain Pickerel spawn at similar temperatures (7-13°C). Mean daily water temperatures in 11 of the 12 backwater study sites and at representative mainstem impoundment locations show that conditions were in the low to middle range of preferred spawning temperatures when backwater sampling commenced in late April (Figure 5.2-4). Water temperatures exceeded the preferred spawning range by the second week of May in Bellows Falls and Vernon backwaters, and by mid to late May in Wilder backwaters; but mainstem temperatures remained within the spawning range until late May.

Although it is possible that spawning by pike and pickerel was initiated prior to the backwater surveys in late April, water temperature data suggest that conditions remained suitable for spawning throughout most of May. The lack of spawning observations may be due to low abundance of these species, or to a proclivity to spawn in deeper water, as was noted for Northern Pike in backwaters to the Saint Lawrence River (Farrell et al., 1996; Farrell, 2001).

Angling was also employed to determine if captured specimens appeared gravid, but only one of the 33 captured individuals (9 pike and 24 pickerel) expressed eggs, milt, or showed evidence of recent or imminent spawning. The gravid adult was a Chain Pickerel captured in the VB-050 backwater on May 7, when daily water temperatures averaged 15°C. Larval net tows were also conducted throughout most backwaters to determine if this species had successfully spawned, however only one of 1,083 fish larvae captured in backwater samples was an esocid, a pickerel from the Waits River backwater (WB-016) captured on May 19 (Appendix C).

Although crews were not instructed to collect location or elevation data on non-spawning fish, limited data was collected where 10 adult pike and 15 pickerel were observed along backwater margins or angled from deeper channels. Most locations possessed sandy or silty substrates with submerged or emergent aquatic vegetation. Most fish were observed at depths less than 2 ft, but several fish caught by angling were hooked at depths from 4-8 ft. The specific locations of 21 pike and pickerel observed or angled within backwater habitats are shown in the unit spawning maps in Appendix D.

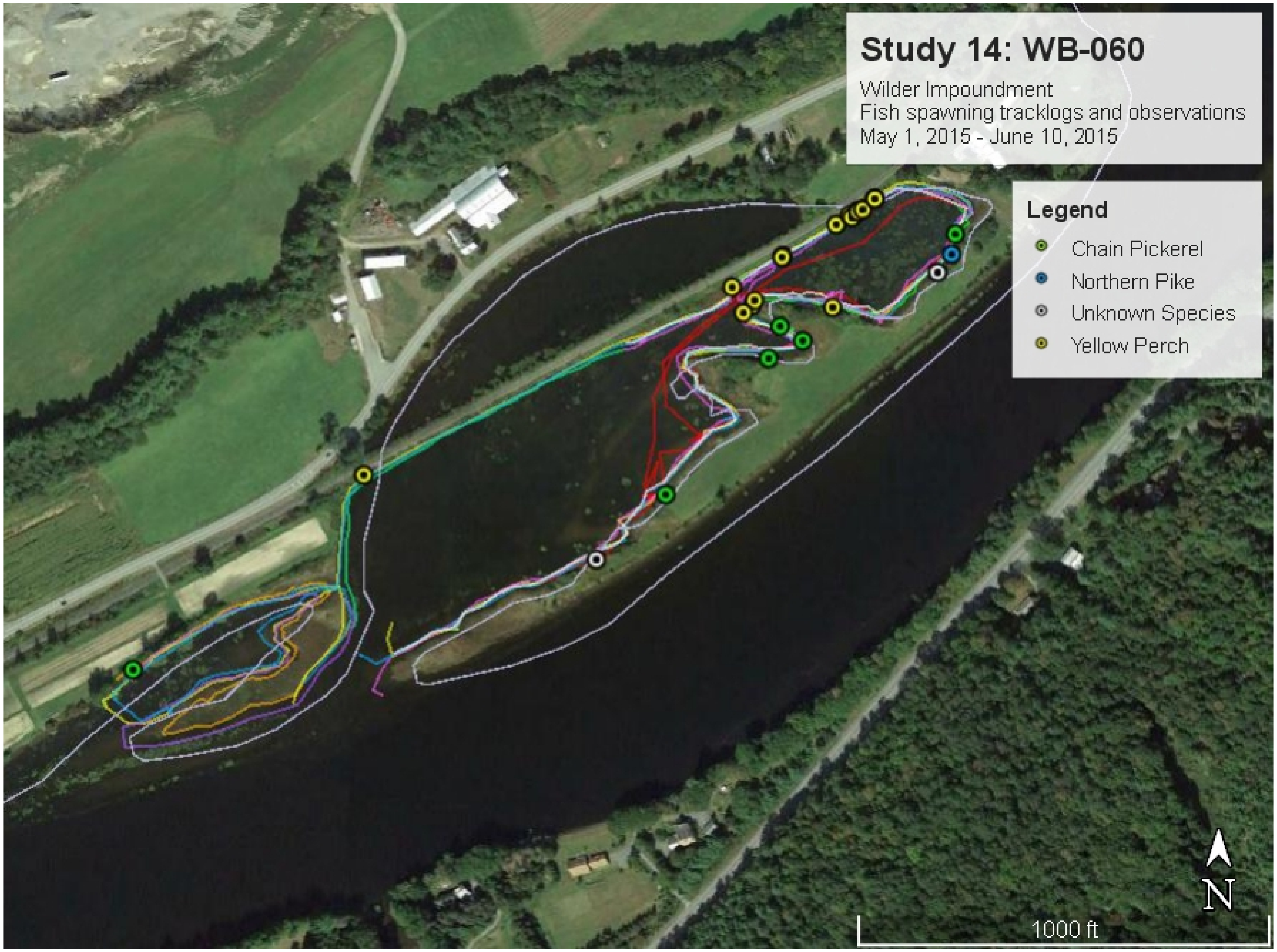


Figure 5.2-3. Example image of a backwater station (WB-060) showing survey tracklogs, location of fish, and spawning observations.

Table 5.2-2. Revised summary of backwater sampling periodicity and spawning observations.

Impoundment	Study Site	Site Name	Date First Survey	Date Last Survey	# Surveys (Total)	# Surveys (w Visib ≥2ft)	# Pike or Pickerel Spawning Locations	# Yellow Perch Spawning Locations	# Yellow Perch Egg Masses	# Largemouth Bass Nests	# Bluegill (BG) Nests	# Pumpkinseed (PS) Nests	# Sunfish Nests (BG+PS+UN)[a]
Wilder	14-WB-012	Oxbow	30-Apr	2-Jul	14	12	0	9	9	3	0	2	2
	14-WB-016	Waits BW	30-Apr	25-Jun	12	10	0	10	13	0	0	0	0
	14-WB-028	Jacobs BW	30-Apr	24-Jun	14	14	0	18	25	0	0	0	0
	14-WB-032	unnamed	30-Apr	2-Jul	15	14	0	10	23	0	0	2	2
	14-WB-051	Zebedee BW	1-May	25-Jun	12	10	0	9	12	0	0	0	0
	14-WB-060	unnamed	1-May	25-Jun	16	15	0	17	143	0	0	0	0
Bellows	14-BB-019	Black BW	28-Apr	25-Jun	17	14	0	14	305	2	8	28	36
	14-BB-030	Williams BW	28-Apr	25-Jun	17	14	0	19	188	0	0	10	10
	14-BB-033	unnamed	28-Apr	25-Jun	17	14	0	13	68	0	0	6	7
Vernon	14-VB-039	Retreat Mdws	28-Apr	30-Jun	18	18	0	30	30	0	10	2	12
	14-VB-045	unnamed	28-Apr	2-Jul	14	7	0	6	6	0	0	0	32
	14-VB-050	unnamed	28-Apr	2-Jul	17	13	0	6	6	0	9	0	21
				Totals	**183**	**155**	**0**	**161**	**819[b]**	**5**	**27**	**48[b]**	**120[b]**

a. UN = unidentified sunfish species (Bluegill or Pumpkinseed).

b. Totals do not include 9 Yellow Perch egg masses or 3 Pumpkinseed nests due to faulty WSE logger data at 14-WB-012.

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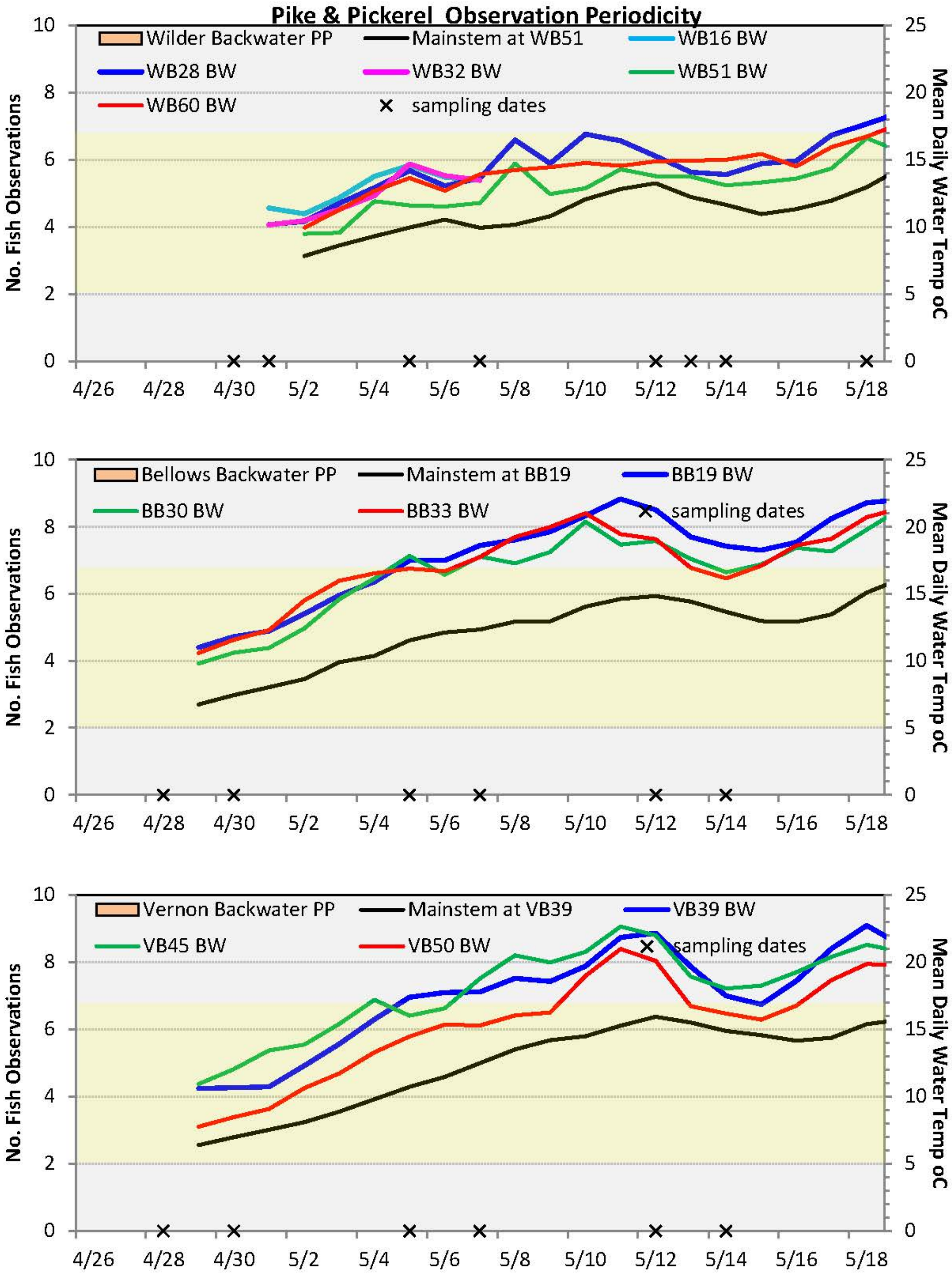


Figure 5.2-4. Range of known spawning temperatures (yellow shading) for Northern Pike and Chain Pickerel (PP), along with mean daily water temperatures at representative locations (lines) and sampling dates (“X’s”). Note: spawning by PP was not observed.

5.2.4 Yellow Perch

Yellow Perch were the last of the early-season spawners targeted by these spawning studies. Perch egg masses were visually located during the backwater surveys described above for pike and pickerel, and resulted in the observation of over 800 individual egg masses representing 161 locations (Table 5.2-2). Egg masses were observed in all 12 backwaters, and were present during the first surveys in the Wilder and Bellows Falls backwaters, and by the second survey in the Vernon backwaters (Figure 5.2-5). Mean daily water temperatures in the backwaters were mostly 10-12°C during these initial surveys, which is in the middle of the preferred range of temperatures for Yellow Perch spawning (7-15°C, Appendix A). Locations of Yellow Perch egg mass clusters observed within backwater habitats are shown in the unit spawning maps (Appendix D).

It was evident from the presence of dried-up egg masses hanging well above (1-3 ft) the backwater WSEs that some perch had spawned during the high flow events that took place in mid-April (Figure 5.1-1). The highest flows (and presumably the highest impoundment WSEs) of the spawning study occurred during the middle two weeks of April, prior to the first backwater surveys in late April. Evidence of new egg masses showed that Yellow Perch continued to spawn into early May in the Bellows and Vernon backwaters, whereas some egg masses persisted in the cooler Wilder backwaters until the middle of May.

Comparisons of actual egg mass elevations with backwater WSEs for 11 of the 12 backwaters are shown in Figure 5.2-6. The uppermost backwater, WB-012 (an oxbow channel) contained 9 egg mass measurements, however the data logger did not function properly and consequently the potential for dewatering in 2015 could not be assessed at this site. Likewise the backwater WSE data is not available for the periods prior to the initial sampling (or initial logger deployment date); consequently the potential for dewatering of egg masses deposited prior to the first observation cannot be assessed. However, as noted above, mid-April represented the period with the highest flow events and, as evidenced by numerous suspended egg masses, very high WSEs as well. Thus it is unlikely that egg masses observed in-water during late April and early May (under lower WSEs) were dewatered prior to sampling.

In many backwater study sites, egg masses were deposited over branches at relatively high elevations and were subject to extended periods of dewatering (Figure 4.1-4). Many of these “hanging” egg masses were deposited prior to the first survey, presumably during mid-April when flows exceeded 20,000 cfs at Wilder dam (Figure 5.1-1). However, in some study sites (e.g., WB-028) hanging egg masses were also observed at later dates in-between high flow events when shorter-term fluctuations in impoundment elevations occurred that were typical of non-spill conditions. Consequently, the estimated percentage of mortality of egg masses was relatively high in some backwaters (Figure 5.2-6).

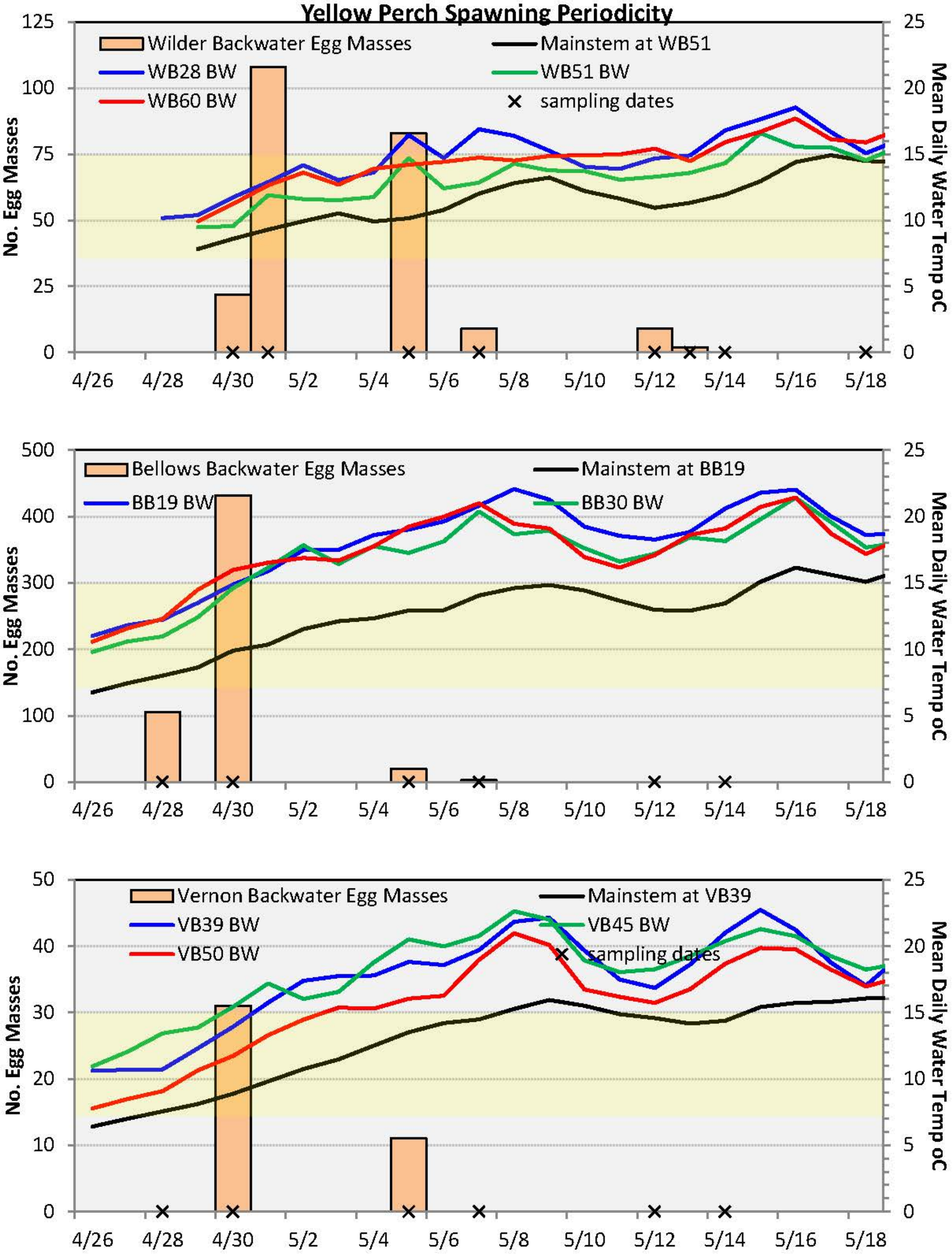


Figure 5.2-5. Egg mass observations (bars) and range of known spawning temperatures (yellow shading) for Yellow Perch, along with mean daily water temperatures at representative locations (lines) and sampling dates (“X’s”).

The estimated percentage mortality of Yellow Perch egg masses observed in shallow margins of backwater habitats vulnerable to project effects ranged from 0% in the VB-050 backwater to 99.9% in the BB-019 (Black River) backwater (Figure 5.2-6), with an overall estimated mortality rate of 71%. This estimated mortality rate is expected to be higher than actual rates for several of the reasons mentioned earlier. For example, the gelatinous mass that surrounded the Yellow Perch egg masses likely afford some protection against short-term dewatering events, but the relationship between exposure duration and egg viability is unknown. Consequently, this analysis adopted the most conservative assumption that any dewatering of an egg mass resulted in complete mortality of all its developing eggs or larvae. In addition, the assumptions of forward-only incubation periodicity (when flows were generally declining), the continuation of incubation beyond the period when egg masses were no longer observed (May 12 to 14), the use of maximum elevation of hanging egg masses to assess dewatering, and the difficulty of detecting egg masses in deeper, more protected areas, are all expected to inflate the estimates of perch egg mortality. Finally, as noted above, many of the mortalities appeared to be due to spawning under high WSEs outside of normal project operations control.

The observation of large numbers of perch eggs (whether inundated or exposed) and the frequent observation or catch of Yellow Perch by both spawning crews and fish abundance crews suggest a relatively robust population of this species in the study area. Yellow Perch were first in abundance in the Wilder impoundment according to Study 10 [Normandeau, 2016b]), and larval trawl data conducted for this study collected over 400 Yellow Perch larvae from 10 of the 12 backwater habitats. Larvae were first captured on May 18 (when trawls first began) until June 10, although shad trawls conducted for Study 21 (Normandeau, 2016e) captured Yellow Perch larvae as late as June 30 (Appendix C).

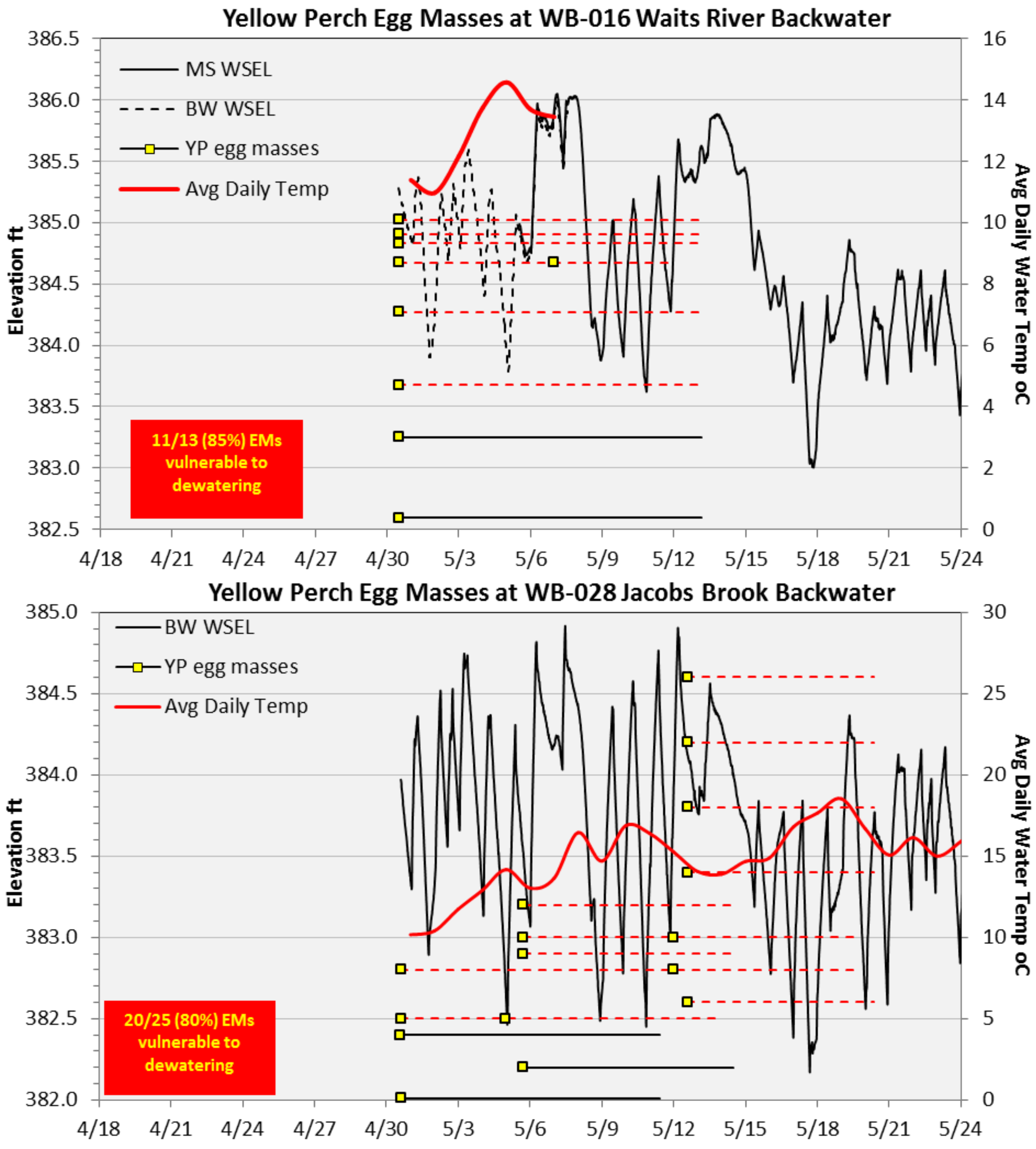
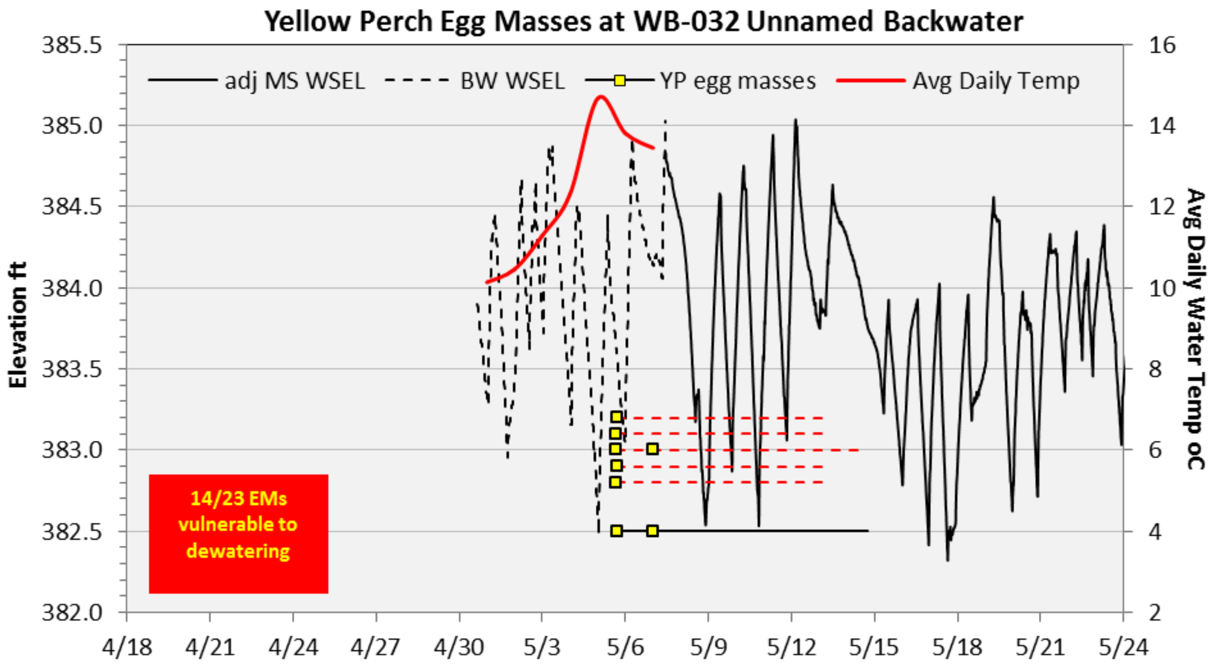


Figure 5.2-6. Revised Yellow Perch egg mass (EM) elevations and backwater (BW) and/or mainstem (MS) WSELs along with mean daily water temperatures. Red dashed lines indicate potential incubation periods of EMs vulnerable to dewatering, solid black lines are EMs not subject to dewatering. Yellow-filled symbols represent 1-5 EMs, blue symbols 6-10 EMs, red 11-20 EMs, and black >20 EMs. The total number of EMs assessed and the estimated potential mortality due to dewatering are also shown.



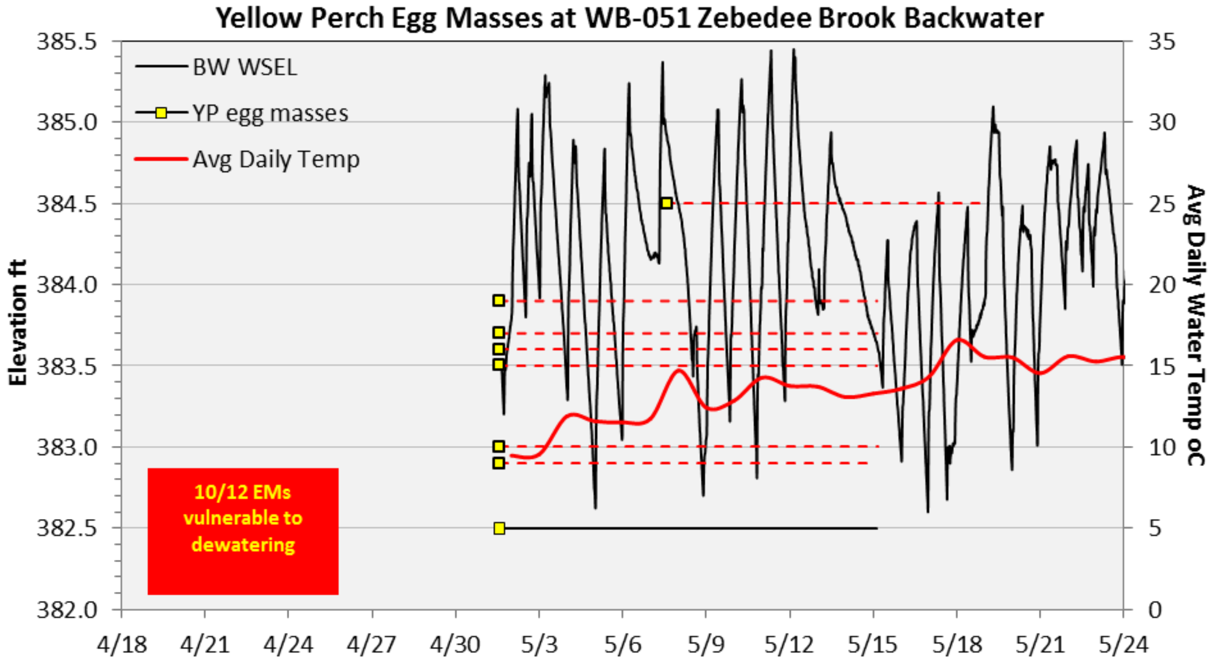


Figure 5.2-6. Revised (continued).

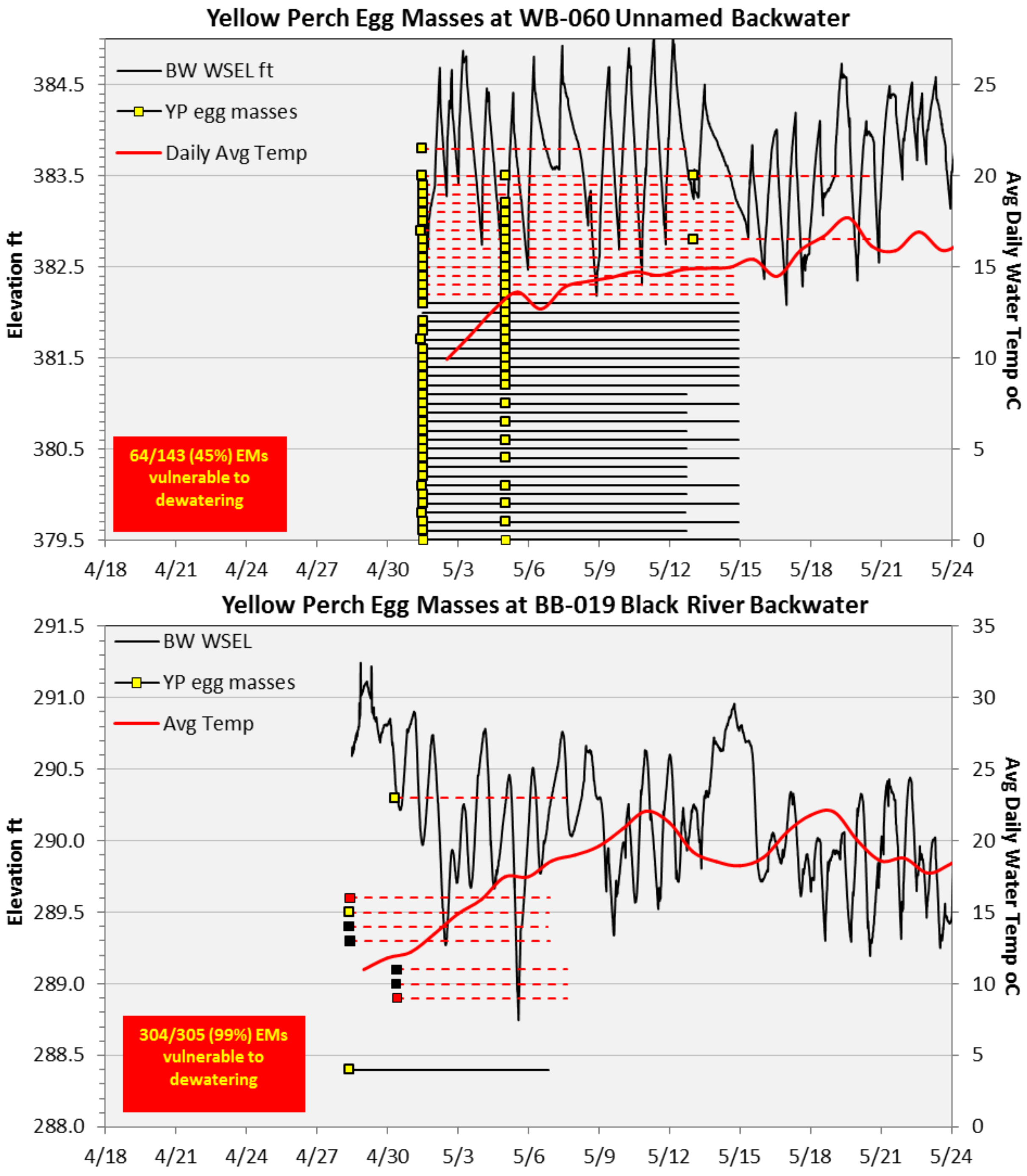
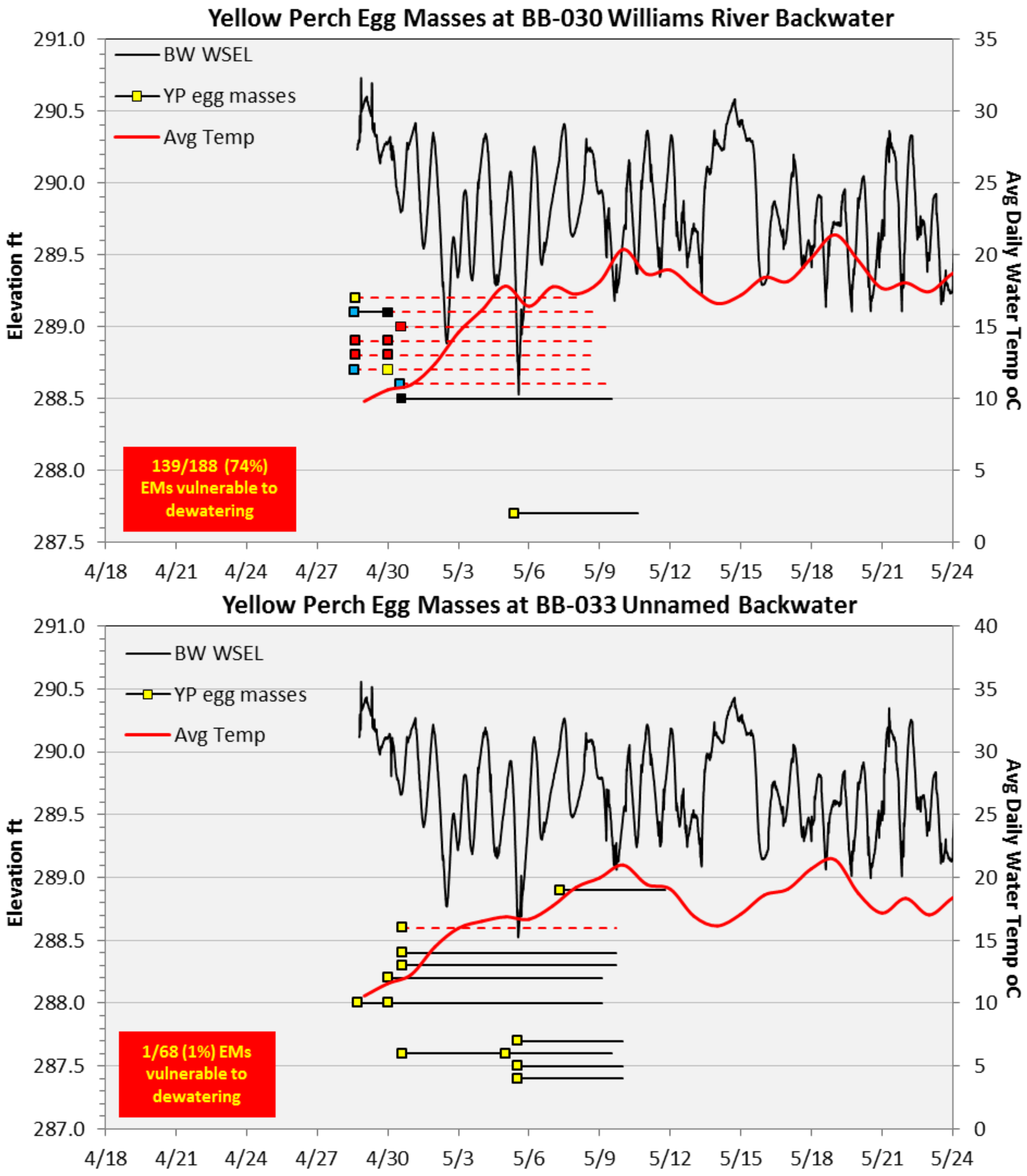


Figure 5.2-6. Revised (continued).



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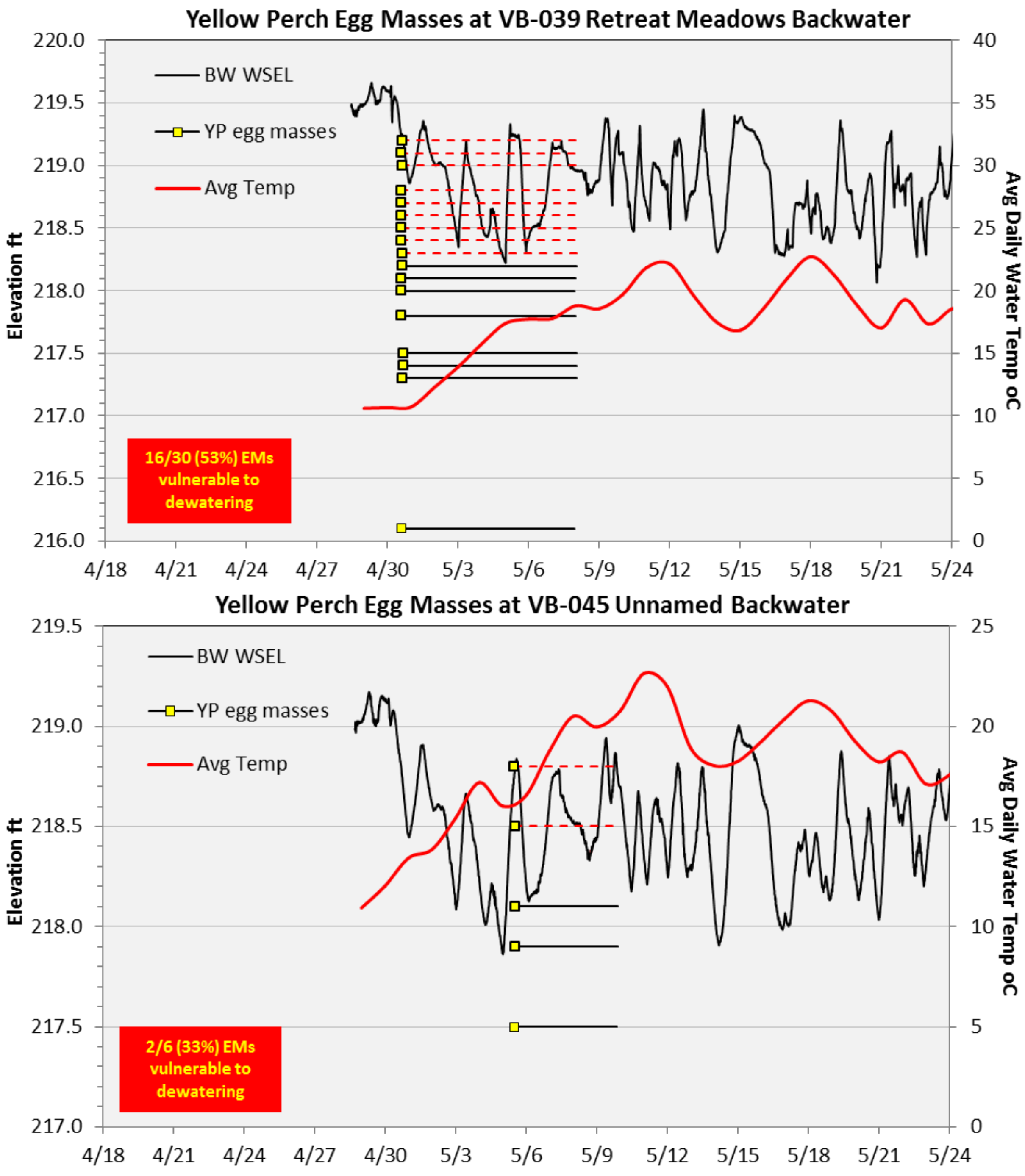


Figure 5.2-6. (continued).

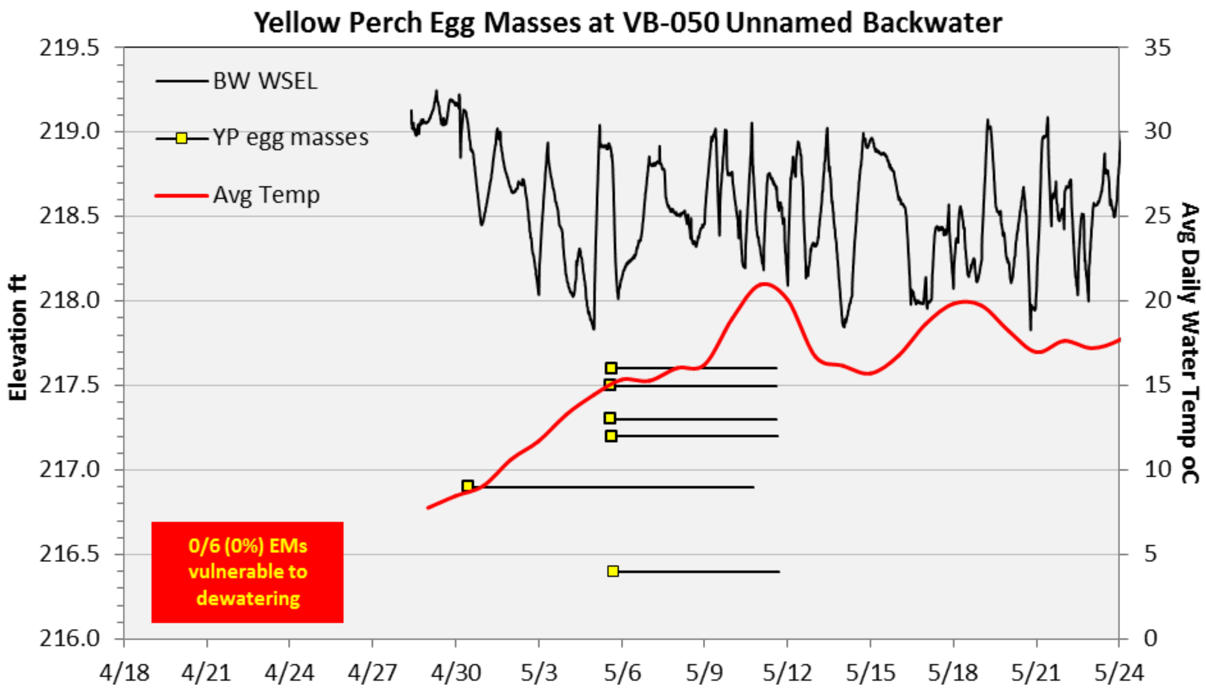


Figure 5.2-6. (continued).

5.3 Late Spring Spawners

The late-spring spawners targeted by this study include Largemouth Bass, Bluegill, Pumpkinseed, Black Crappie, Spottail Shiner, Golden Shiner, Fallfish, and Smallmouth Bass. Visual surveys for the first six species were conducted in backwater habitats, whereas Fallfish and Smallmouth Bass (along with Spottail Shiner) were surveyed at impoundment tributary mouths and at riverine island/bar complexes.

5.3.1 Largemouth Bass

Largemouth Bass were regularly observed during spawning surveys in many backwater habitats, and were frequently caught while angling for pike and pickerel, but only five Largemouth Bass nests were positively identified. Two nests were seen in the BB-019 (Black River) backwater on May 28, and 3 nests were observed in the WB-012 (oxbow) backwater on June 18 (Table 5.2-2). Mean daily water temperatures in BB-019 generally ranged from 18-24°C in late-May, and from 16-18°C in the mainstem adjacent to WB-012 in mid to late June (the backwater data logger did not function properly). All five nests contained eggs and one of the BB-019 nests held fry on June 4. Locations of the five nests are shown in the unit spawning maps (Appendix D). Because of the limited sample size of Largemouth Bass nests, plots comparing WSE with bed elevations are not shown, however minimum WSEs remained at least 1.5 ft higher than the two nests in BB-019. Although WSE was not available from within the WB-012 backwater, WSE data from the mainstem logger located opposite the oxbow suggested that two of the three nests in WB-012 remained at least 1 ft deep for the following three weeks, whereas depths over the third nest dropped to a minimum of 0.72 ft for a short period of time.

Three Largemouth Bass larvae were captured as early as May 26 in a Vernon backwater (Appendix C), which indicates that some spawning was initiated by mid-May at mean daily water temperatures of 16-20°C. A total of 30 additional larvae were captured in other backwaters until June 18, the last date at which larval trawls were conducted.

The relative lack of nest observations for this species, despite its apparent abundance from angling captures, may be due in part to the limited water visibility that occurred in most backwater study sites in early June (Figure 5.1-2) and to the depth at which Largemouth Bass spawn, which is generally deeper than sunfish (Appendix A). Also, the identified largemouth nests did not show the distinctly cleaned bottom that was characteristic of Smallmouth Bass nests, but instead often contained significant amounts of organic debris (Figure 5.3-1), which made visual detection of these nests more difficult.

Figure 5.3-1. Photos of Largemouth Bass nests with eggs adhered to organic debris.

5.3.2 Bluegill and Pumpkinseed

The two species of sunfish that inhabit the study area have generally similar spawning characteristics (Appendix A) and can be difficult to visually distinguish when water visibilities are suboptimal; hence many sunfish observations were recorded as “unknown” sunfish. Consequently, for this analysis Bluegill, Pumpkinseed, and “unknown” sunfish spawning observations were combined and are referred to herein as sunfish. Although spawning habitat was similar between the two species, aggregations of spawning nests appeared to be species-specific, i.e., Bluegill spawned in clusters with other Bluegill, and Pumpkinseed with Pumpkinseed. Also, some backwaters appeared to be dominated by Pumpkinseed (Bellows Falls backwaters), and others (Vernon backwaters) by Bluegill. Although sunfish were commonly observed in Wilder backwaters, spawning appeared to be delayed in that reach and only four active nests were observed in Wilder backwater by the conclusion of the spawning surveys. Spawning locations for both species are shown in Appendix D.

Active sunfish nests were observed in all three Bellows Falls backwaters and all three Vernon backwaters, but in only two of six Wilder backwaters, totaling 120 active sunfish nests (Table 5.2-2). "Active" sunfish nests were defined as a newly cleaned bed, typically with an attending adult, but sometimes not. Because both species construct small, saucer-shaped nests in dense clusters, a newly cleaned nest without an adult was often identified and assessed as a sunfish spawning observation because no other species produce such distinctive nests.

Although over 100 active sunfish nests were observed over the course of this study (Figure 5.3-2), only 10 nests had identifiable eggs, and 1 nest was subsequently seen to contain fry. The scarcity of egg or fry observations is due in part to the short incubation time of sunfish eggs (approximately 3 days at 20°C, Becker, 1983) and because sunfish fry, unlike bass fry, disperse into nearby vegetation soon after hatching (Moyle, 1976). Active nest building was first observed in Bellows Falls backwaters on May 21, with active nests appearing in Vernon backwaters by May 26 (Figure 5.3-3). Mean daily water temperatures ranged from 17-25°C when most nest observations were made, which were in the lower to middle range of preferred spawning temperatures (17-31°C) for these species.

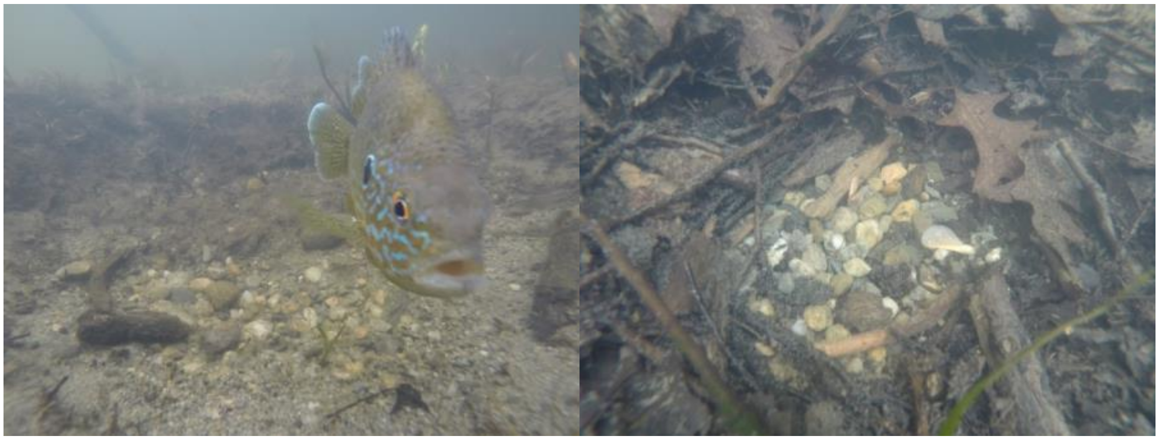


Figure 5.3-2. Pumpkinseed guarding nest (left) and Bluegill nest with eggs (right).

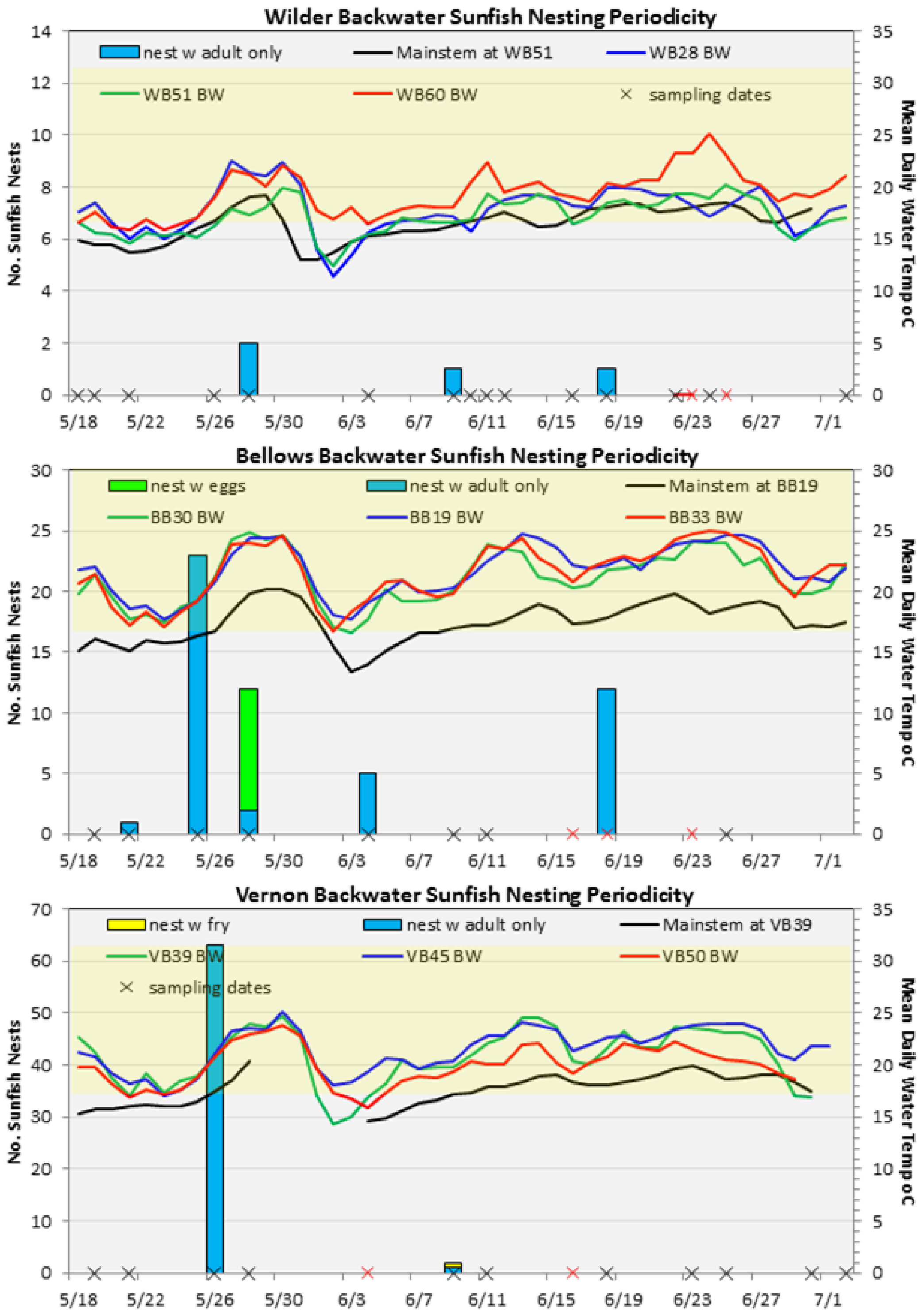


Figure 5.3-3. Nest observations (bars) and range of known spawning temperatures (yellow shading) for Bluegill and Pumpkinseed sunfish (SF), along with mean daily water temperatures at representative locations (lines) and sampling dates (“X’s”). Red “X’s” represent surveys when estimated water visibilities were <2 ft.

Comparison of sunfish nest elevations with measured WSEs over the course of this study required assumptions regarding adult persistence and egg incubation. As previously noted, sunfish eggs typically hatch in a few days at typical spawning temperatures. Consequently, the nest elevation plots assume a conservative incubation time of five days from the date when eggs were first observed (although hatching likely occurred sooner), or 10 days for an active nest without eggs. As described in Section 4.2.3, assessment of project effects on sunfish nests projected forward in time, except for active nests where no adult was observed, where it was assumed the nest was active for the preceding 10 days.

Because of the short incubation time and rapid dispersal of sunfish fry away from the nest, it is unclear if the presence of an adult guardian is critical to nest success, as is typically assumed to be the case for adult Largemouth and Smallmouth Bass which continue guarding the nest for an extended period of time. Nevertheless, to be conservative this assessment assumes that continued presence of the adult sunfish is necessary for successful reproduction, and that nest dewatering or adult abandonment (for whatever reason) prior to fry dispersal will likely result in egg or fry mortality. Nest elevation plots based on the above assumptions suggest that 0-50% of nests within shallow water margins of individual backwaters most vulnerable to project effects, or 28 of 120 (23%) of all sunfish nests observed in backwaters could be subject to loss due to dewatering or (most commonly) abandonment of the adult guardian (Figure 5.3-4). Note that site WB-032 includes estimated water level logger data and no temperature data due to logger failure, see Section 4.2; also backwater WB-012 (an oxbow channel), had a malfunctioning data logger and the 2 sunfish nests observed in that study site in 2015 could not be assessed for project effects (Table 5.2-2).

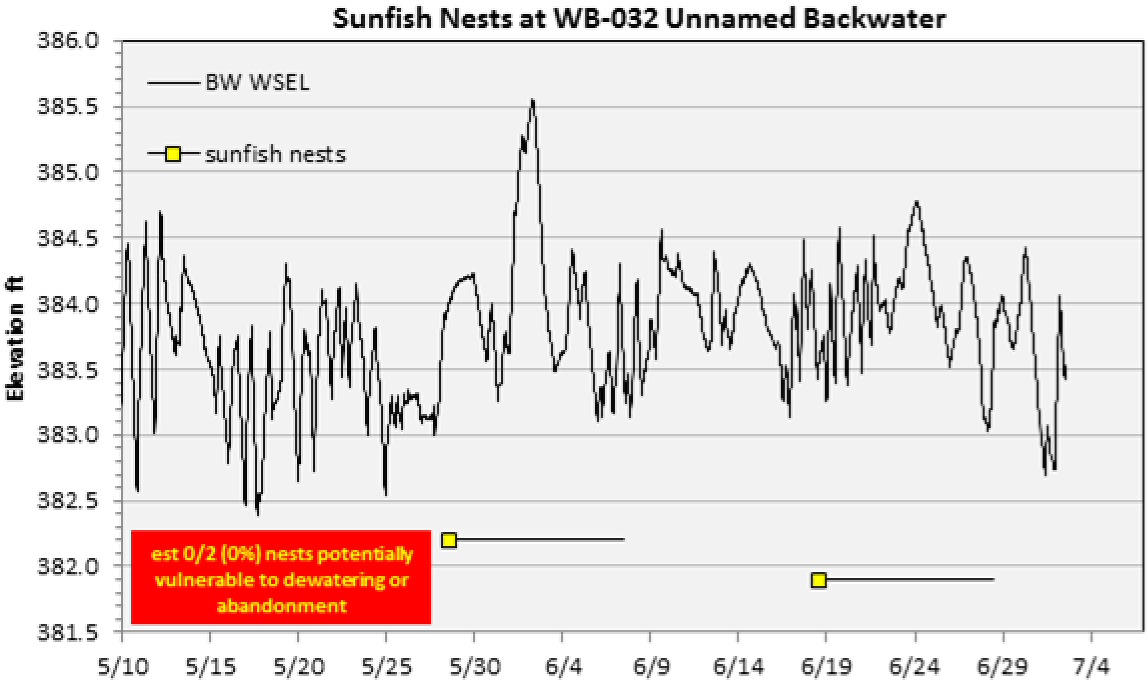
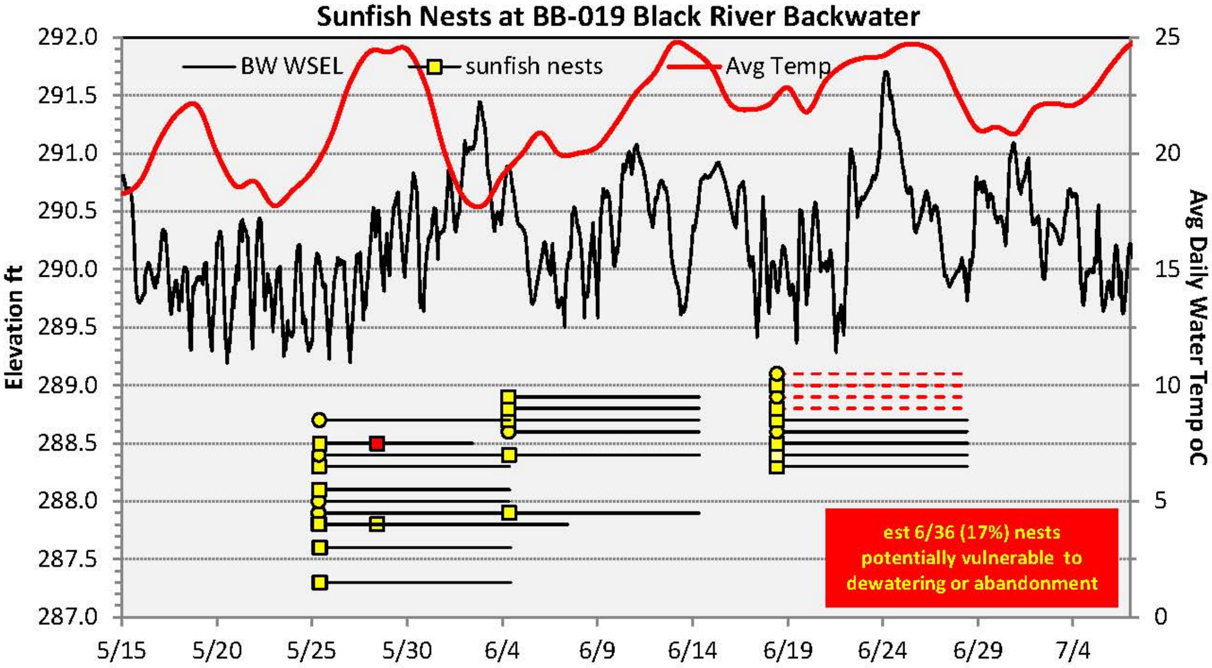


Figure 5.3-4. Bluegill and Pumpkinseed sunfish (SF) nest elevations and backwater WSELs along with mean daily water temperatures. Yellow symbols represent active nests with or without adults present; red symbols represent presence of eggs, and green represent fry. Square symbols represent single nests, circles represent 2-5 nests. Red dashed lines are vulnerable nests within 0.5 ft of WSEL. Active nests with adults, eggs, or fry present extend forward in time, active but empty nests extend backward in time.



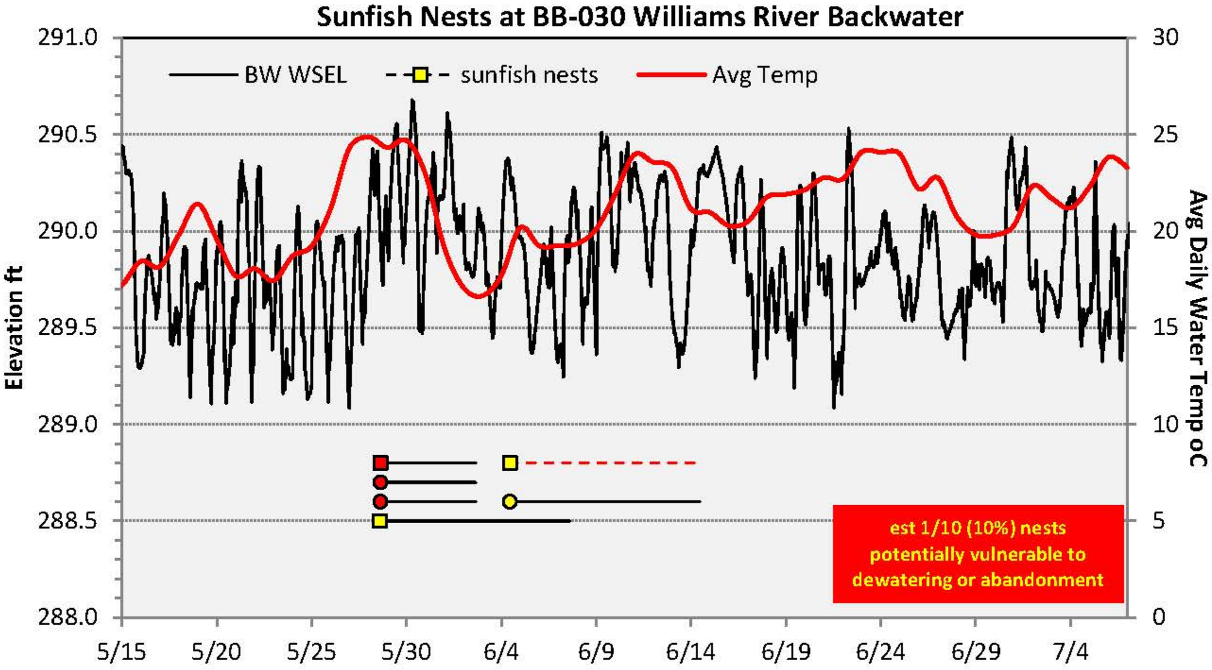
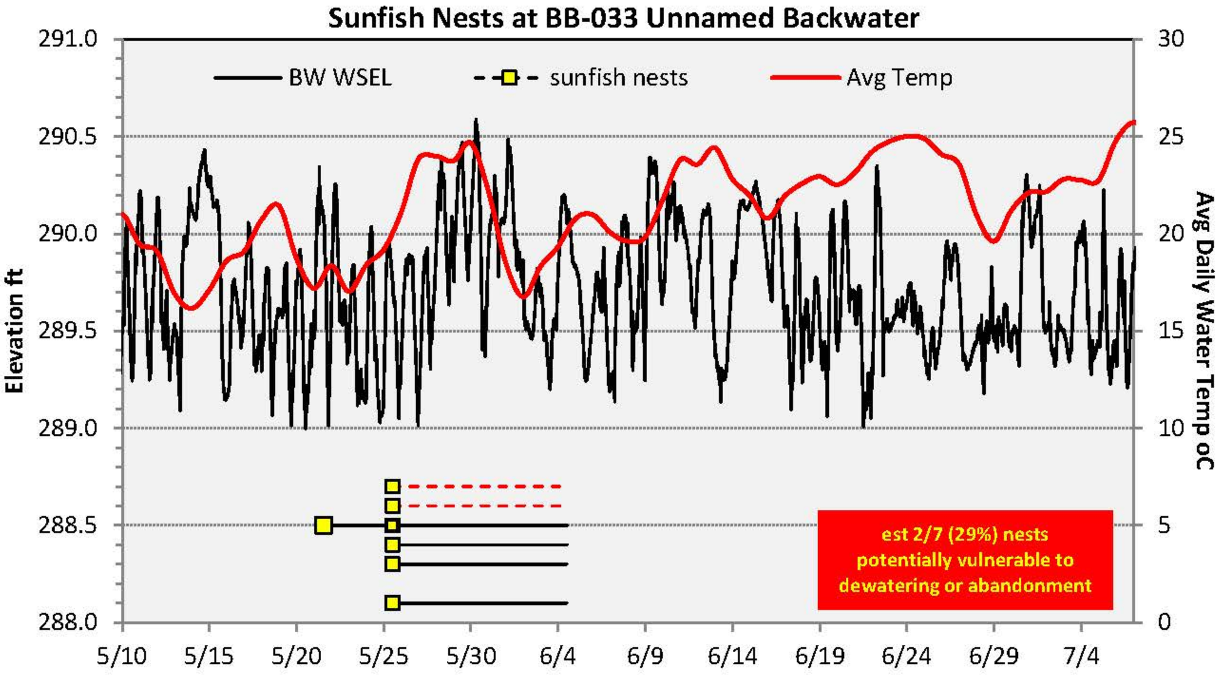


Figure 5.3-4. (continued).



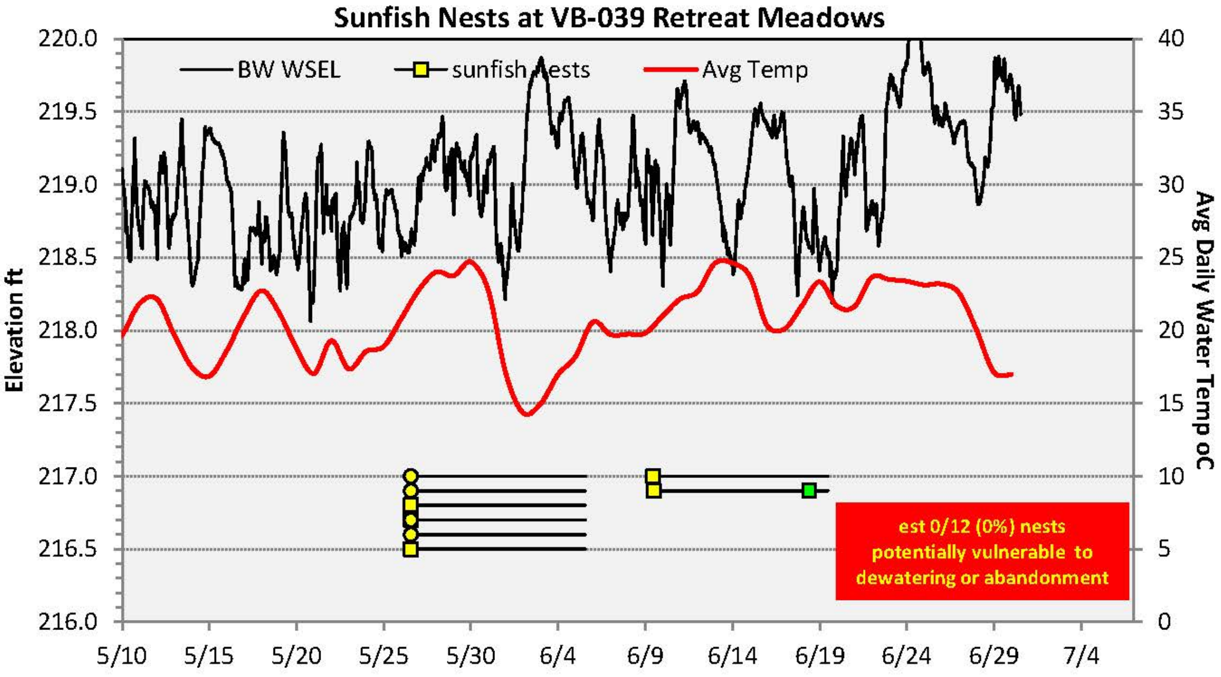
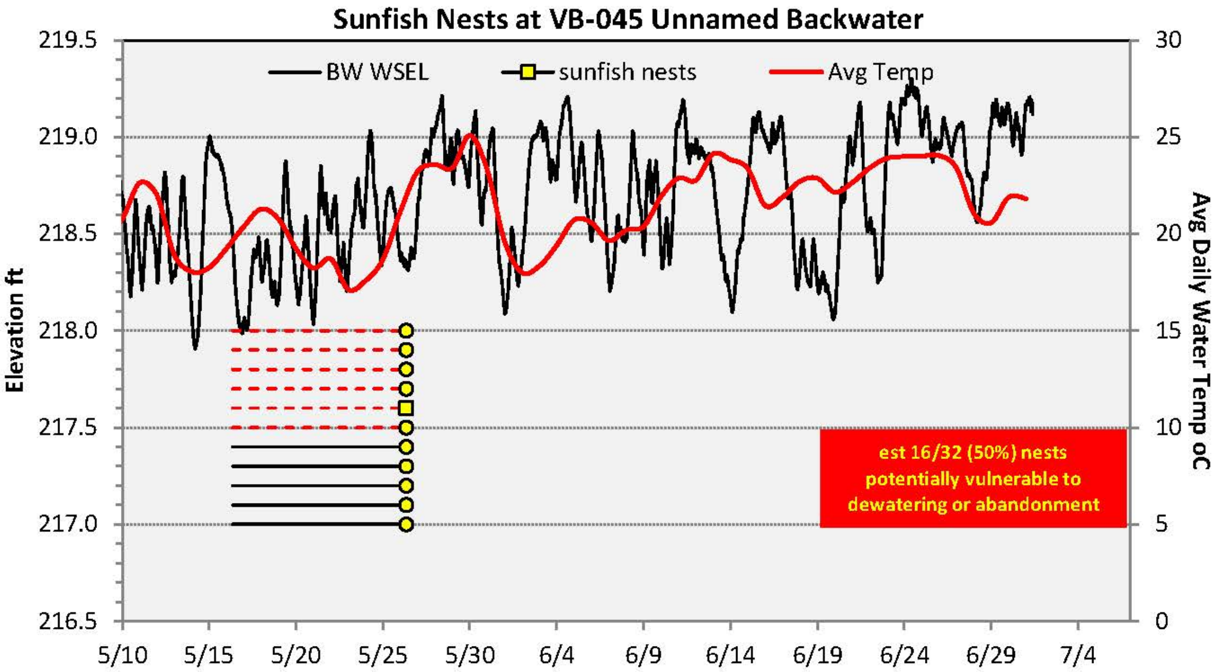


Figure 5.3-4. (continued).



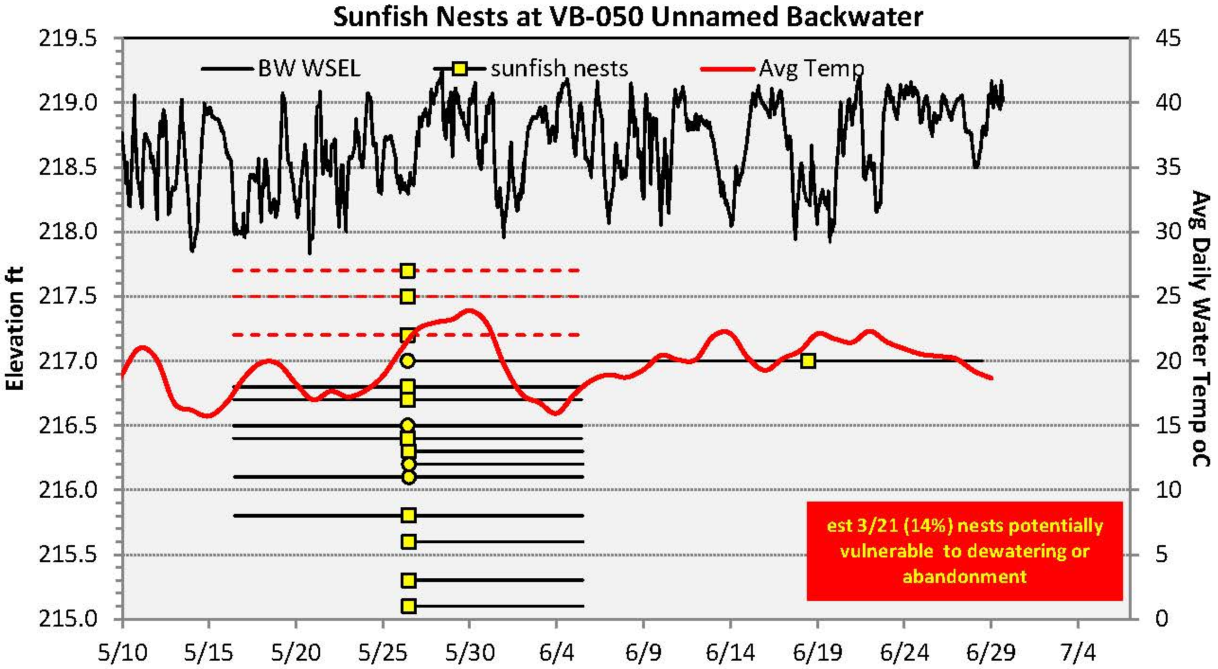


Figure 5.3-4. (continued).

Of the 28 potentially vulnerable nests, 23 (19%) may have been subject to loss due to insufficient depth (<0.5 ft), whereas five nests (4%) in VB-045 were potentially dewatered for approximately 2 hours. There were likely sunfish nests in deeper water that were not surveyed and/or not vulnerable to project effects. The "unknown" sunfish nests (newly cleaned nests without an attending adult) shown in VB-045 and VB-050 do not imply that the nests were abandoned due to WSE fluctuations, because 34 of the 53 combined nests remained deeper than 0.5 ft at all times, and 15 nests were no shallower than 1.0 ft. Instead, it is possible that these fish had spawned earlier (thus projected backwards in time), although nests were not observed in the previous two site visits (Figure 5.3-3), or else eggs were never deposited in these nests for other reasons (note: some of the nest symbols in VB-050 represent multiple nests both with and without attending adults, therefore the incubation lines extended both forwards and backwards in time).

5.3.3 Black Crappie

No spawning observations were made for Black Crappie, although two individuals were captured by angling in Vernon backwater habitats, one on May 12, another on June 25 (neither were gravid). Although Black Crappie are known to occur at high densities in some of the backwater habitats selected for sampling (Gabe Gries, NHFGD, personal communication), this species was rarely captured by the angling methods used in this study (in comparison to frequent catches of Largemouth Bass and Chain Pickerel), and less than one percent of the total fish catch in the fish assessment data (Study 10 [Normandeau 2016b]) was composed of Black Crappie. Also, backwater surveys resulted in hundreds of visual fish observations of target species including Largemouth Bass, Chain Pickerel, and sunfish, but no Black Crappie were observed at any study site. Larval trawl samples conducted by both spawning crews and shad crews (Study 21 [Normandeau, 2016e]) captured over 1,200 fish larvae, but none were identified as Black Crappie (Appendix C). Lastly, Black Crappie are known to prefer nesting within growths of aquatic vegetation, and constructed nests are typically somewhat deeper and may not be as well defined as other sunfish nests (Becker, 1983); thus, crappie nests would likely be more difficult to detect using visual survey methods under the visibility conditions encountered during this study.

5.3.4 Spottail Shiners

Although Spottail Shiners were visually observed and/or captured on several occasions by use of seines, dip-nets, and minnow traps, none of the captured fish were in spawning condition or were exhibiting spawning activities such as dense shoaling and mating behavior (Table 5.2-1). However, active spawning by another closely related species (Rosyface Shiners) was observed over a Fallfish nest in the Wilder riverine reach on June 8 at mean daily water temperatures of 16-17°C (Figure 5.0-1). This behavior has also been reported for other species of shiners (Reed, 1971), and may be an attribute of Spottail Shiner spawning as well. Two weeks later, the Study 10 (Normandeau, 2016b) crew captured gravid Spottail Shiners on June 22 below Chase Island at the head of the Bellows Falls impoundment, when mean daily water temperatures were approximately 18-20°C.

Larval fish trawls conducted for this study and Study 21 (Normandeau, 2016e) collected numerous cyprinid larvae, most of which were not identified to species, but three larvae captured in late June and early July were positively identified as Spottail Shiners (Appendix C). These larvae, collected in the Bellows Falls riverine reach and both Vernon impoundment and riverine reach, indicate some degree of successful spawning, as does the catch of over 2,500 Spottail Shiners in Study 10 (Normandeau, 2016b), which represented the highest proportional catch of all species in the study area.

Despite their apparent abundance in the study area, the small size, general schooling behavior (whether spawning or not), limited data on spawning habitat requirements (Appendix A), high flows, limited water clarity during spring months, and the vast expanse of the study area (approximately 120 miles) all contributed to lack of detection and actual observation of spawning by this species. The fortuitous observation of the Rosyface Shiners spawning aggregation may shed some light on the spawning periodicity and habitat of Spottail Shiners in the study area, but additional details, including the susceptibility of Spottail Shiner eggs to project-related water level fluctuations, cannot be adequately assessed. If Spottail Shiners regularly spawn over Fallfish nests, data described below suggests that Fallfish nests within the three impoundments were rarely exposed during 2015.

5.3.5 Golden Shiners

Like Spottail Shiners, Golden Shiners were never observed to be actively spawning. However, gravid Golden Shiners (expressing milt or eggs) were captured in minnow traps on two occasions in the Jacobs Brook backwater (WB-028), tributary to the Wilder impoundment (Figure 3.2-1). Eleven ripe male and female Golden Shiners were captured on June 18, and 11 additional ripe or spent shiners were captured the following week (June 24), when mean daily water temperatures ranged from 17-20°C. Because actual areas of egg deposition could not be identified from the minnow trap catches, the vulnerability of shiner eggs to project-related water level fluctuations could not be assessed. However larval fish collections from trawl data did contain 13 Golden Shiner fry, including captures from locations in the Bellows Falls and Vernon study areas (Appendix C), which indicated that successful spawning did occur in 2015.

5.3.6 Fallfish

The late-spring spawning Fallfish and Smallmouth Bass were sampled by surveying the lower reaches or mouths of tributaries in the impoundments (Table 3.2-2), and by surveying complex island/bar habitats in the riverine reaches (Table 3.2-4). Survey methodologies were similar to those used in backwater habitats, as exemplified by the tracklogs displayed for two example study sites (Figure 5.3-5). Twenty-six Fallfish nests were observed during the late-spring nesting surveys, with approximately equal numbers at island habitats and at tributary study sites (Table 5.3-1). Fallfish nests were readily identified during periods of adequate water visibility, due to the cleaned gravel and cobble materials constructed in a mound 2-4 ft in diameter and 0.5-1.3 ft in height (Figure 4.1-5). Because Fallfish lay their eggs at the level of the streambed prior to covering them with the mound of rocks

(Reed, 1971; Magee, 1989; Maurakis & Woolcott, 1992), Fallfish nest elevations were measured at the base of the nest mound, and any WSEs that maintained at

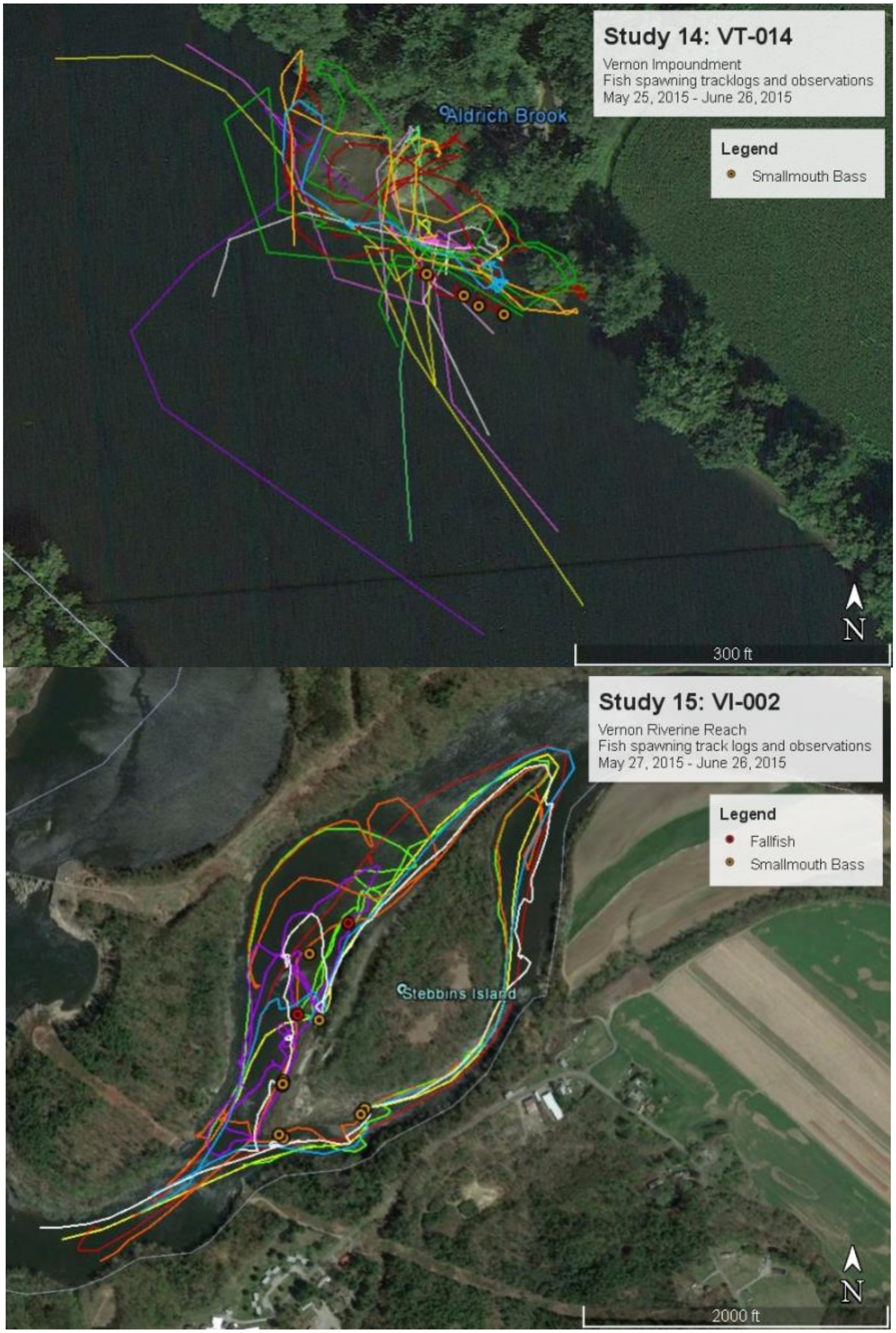


Figure 5.3-5. Example images showing survey tracklogs and location of spawning observations at the Aldrich Brook mouth and at Stebbins Island.

least 0.5 ft of depth at the base of the mound was considered to be fully protective of the eggs and larvae (as noted in Section 4.2.2, the lower 0.5 ft of Fallfish nests typically comprised 90% of the overall mound volume).

All but one of the Fallfish nests were identified during the first or second island/tributary survey date in the third week of May at water temperatures ranging from 17-20°C (Figure 5.3-6), and none of the nests appeared to be in the process of construction (typically a 2-4 day procedure, Maurakis & Woolcott, 1992). Consequently, it appears that Fallfish nesting had concluded by the time the late-spring nesting surveys had begun. Although water temperature data was not available at most Fallfish nest sites prior to the initial nest observations, the recorded temperatures at the time of observation would result in an incubation time of six to nine days. Consequently, Fallfish incubation duration was conservatively assumed to extend from 10 days prior to the initial observation to five days afterwards. Fallfish nest locations are shown in Appendix D.

In addition to the 26 fallfish nests observed at island/bar and tributary study sites, a cluster of three Fallfish nests was also identified by local residents (and subsequently reported to TransCanada) in late May just below the mouth of the Ottauquechee River (Figure 5.3-7), in a location subject to fluctuating release flows from both Wilder dam and peaking flows from the North Hartland dam on the Ottauquechee itself. High flows through the Wilder riverine reach in early June (Figure 5.1-1) prevented field crews from locating these Fallfish nests or deploying a nearby depth logger until well after eggs would have hatched and fry dispersed; consequently these nests were not further assessed.

Comparison of Fallfish nest elevations with changes in WSEs revealed differences in vulnerability among nests within the tributary reaches and those in the riverine tailwater reaches (Figure 5.3-8). None of the 12 Fallfish nests located in tributaries appeared to be vulnerable to dewatering, where the minimum depths ranged from 0.7 ft. to over 3 ft. Only the top of the shallowest nest in the Black River was likely to be dewatered, which would not be expected to harm the eggs or fry which are located closer the base of the nest. In contrast to the tributary nest sites, Fallfish nests were more likely to be exposed in the riverine reaches where WSE fluctuations were greater in magnitude.

Table 5.3-1. Summary of late-spring island/bar and tributary sampling periodicity and spawning observations.

Habitat Type	Reach	Study Site	Site Name	Date First Survey	Date Last Survey	# Surveys (Total)	# Surveys (w Visibility >2ft)	# Small-mouth Bass Nests	# Fallfish Nests
Impound-ment Tributaries	Wilder	14-WT-007	Oliverian Brook	22-May	2-Jul	8	7	0	0
		14-WT-010	unnamed	25-May	2-Jul	10	8	3	0
		14-WT-011	Halls Brook	22-May	19-Jun	8	7	0	0
		14-WT-015	Waits River	25-May	17-Jun	6	4	0	0
		14-WT-054	Hewes Brook	5-Jun	19-Jun	10	9	0	0
		14-WT-058	Ompompanoosuc	5-Jun	26-Jun	11	9	5	0
		14-WT-074	Mink Brook	22-May	30-Jun	12	9	6	0
	Bellows Falls	14-BT-001	Jarvis Island	26-May	8-Jun	6	2	4	0
		14-BT-002	Sugar River	26-May	8-Jun	5	3	6	0
		14-BT-004	Mill Brook	26-May	8-Jun	2	2	0	0
		14-BT-013	Little Sugar River	26-May	22-Jun	5	4	0	2
		14-BT-018	Black River	26-May	24-Jun	5	4	1	8
		14-BT-031	Williams River	27-May	24-Jun	6	5	2	2
	Vernon	14-VT-014	Aldrick Brook	25-May	19-Jun	11	8	4	0
		14-VT-016	Mill Brook	25-May	19-Jun	12	9	4	0
		14-VT-040	West River	27-May	26-Jun	9	9	0	0
		14-VT-046	Broad Brook	25-May	26-Jun	9	8	0	0
Riverine Islands	Wilder	15-WI-001	n/a	20-May	8-Jun	4	4	0	0
		15-WI-002	Johnston	20-May	8-Jun	4	4	0	0
		15-WI-003	Burnap's	20-May	8-Jun	4	4	1	0[a]
		15-WI-004	fallfish nest	21-May	8-Jun	3	3	2	2
		15-WI-005	Hart	20-May	5-Jun	3	3	3	1
		15-WI-006	fallfish nest	27-May	27-May	2	2	0	1
		15-WI-007	Chase	20-May	5-Jun	4	4	15	1
	Bellows Falls	15-BI-001	Saxons R bar	27-May	19-Jun	4	2	2	1
		15-BI-002	n/a	27-May	19-Jun	3	2	9	0
		15-BI-003	Dunshee	29-May	19-Jun	2	1	4	6
	Vernon	15-VI-001	n/a	25-May	26-Jun	9	8	0	0

Habitat Type	Reach	Study Site	Site Name	Date First Survey	Date Last Survey	# Surveys (Total)	# Surveys (w Visibility >2ft)	# Small-mouth Bass Nests	# Fallfish Nests
		15-VI-002	Stebbins	25-May	26-Jun	9	8	8	2
TOTAL						**186**	**152**	**75** [b]	**26**

a. Three Fallfish nests were reported by NHFGD just below the Ottauquechee River mouth but outside of the WI-003 Burnap's Island study site.

b. Total does not include 4 bass nests at 14-VT-014 due to faulty WSE logger data.

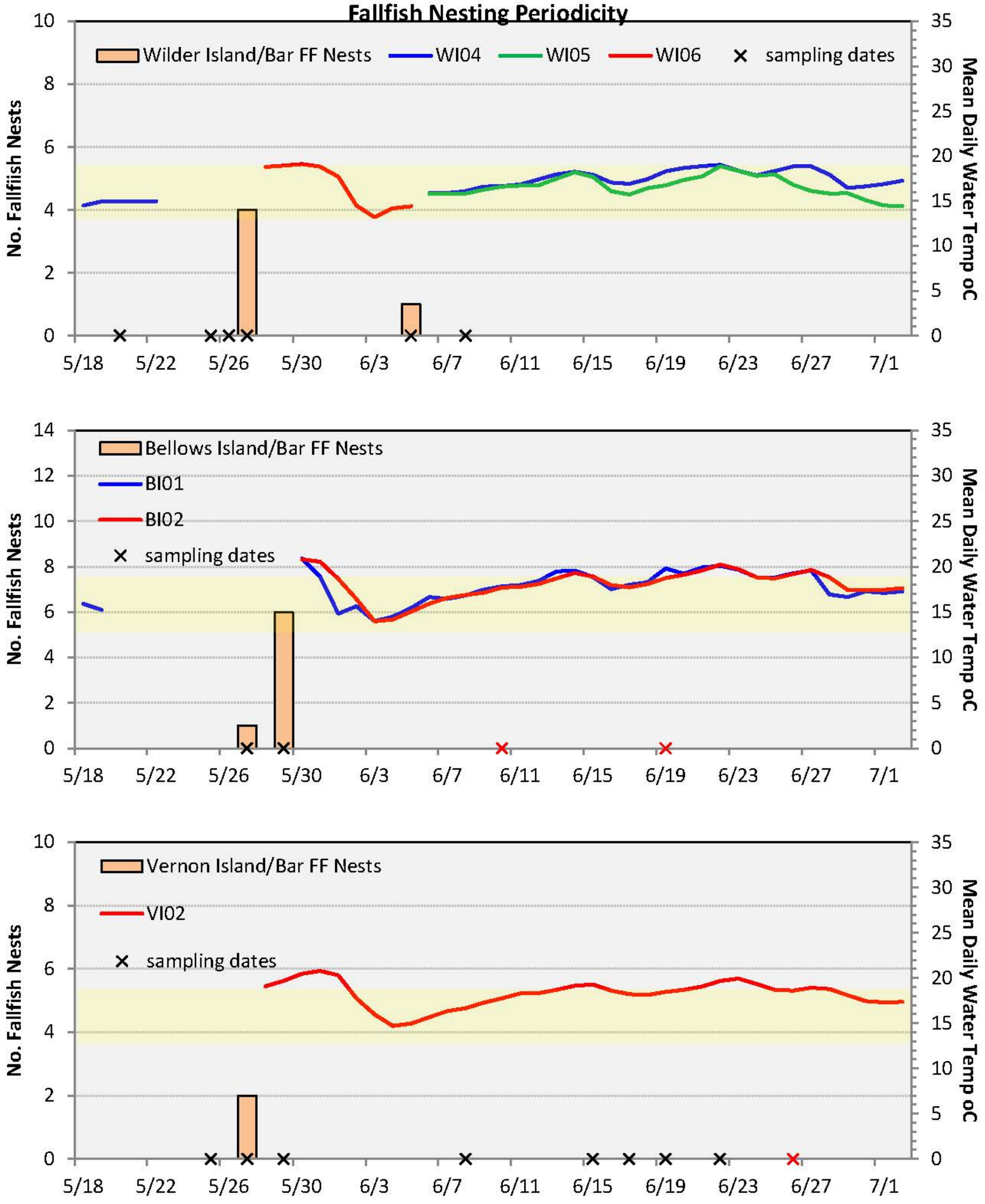


Figure 5.3-6. Nest observations (bars) and range of known spawning temperatures (yellow shading) for Fallfish (FF), along with mean daily water temperatures at representative locations (lines) and sampling dates ("X's"). Red "X's" represent surveys when estimated water visibilities were <2 ft.

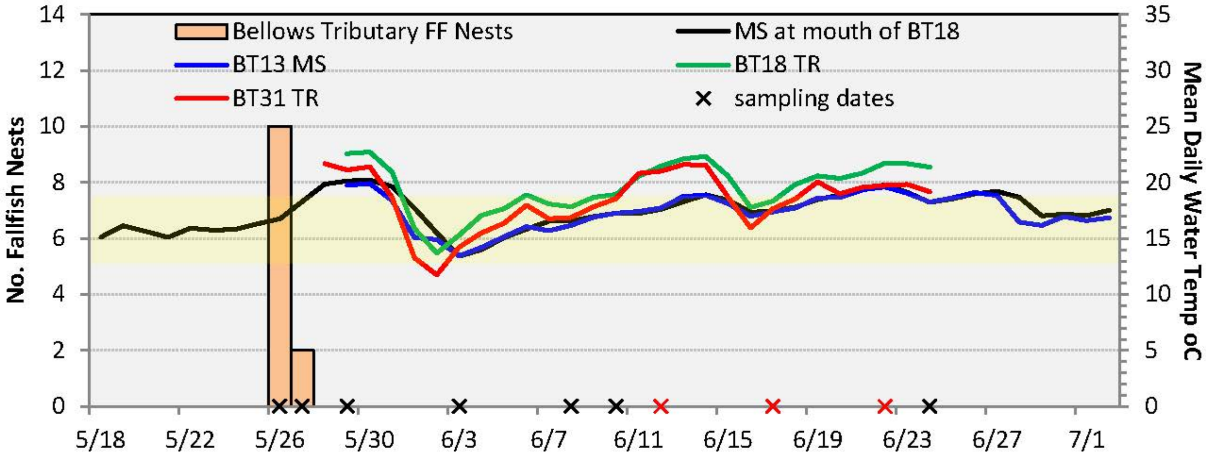


Figure 5.3-6. (continued).

Figure 5.3-7. Partially exposed Fallfish nests below the Ottauquechee River mouth (photos courtesy of Gabe Gries, NHFGD).

Four of the 14 riverine nests were either observed fully dewatered or expected to be fully dewatered at various times (2 nests at a bar below Sumner Falls and 2 at Stebbins Island, see Figure 5.3-9), and a fifth nest (at Hart Island) was exposed to minimum depths of less than 0.5 ft. Although not formally assessed, one of the unmeasured Fallfish nests below the Ottauquechee River appeared close to being fully dewatered when the photographs were taken (Figure 5.3-7). In contrast, the remaining nine nests appeared to maintain depths of at least 1.5 ft and were thus not likely to be impacted by project flows. There was no evidence that high release flows caused disturbance or scour of any riverine Fallfish nests, although scour could have occurred due to uncontrolled spill events.

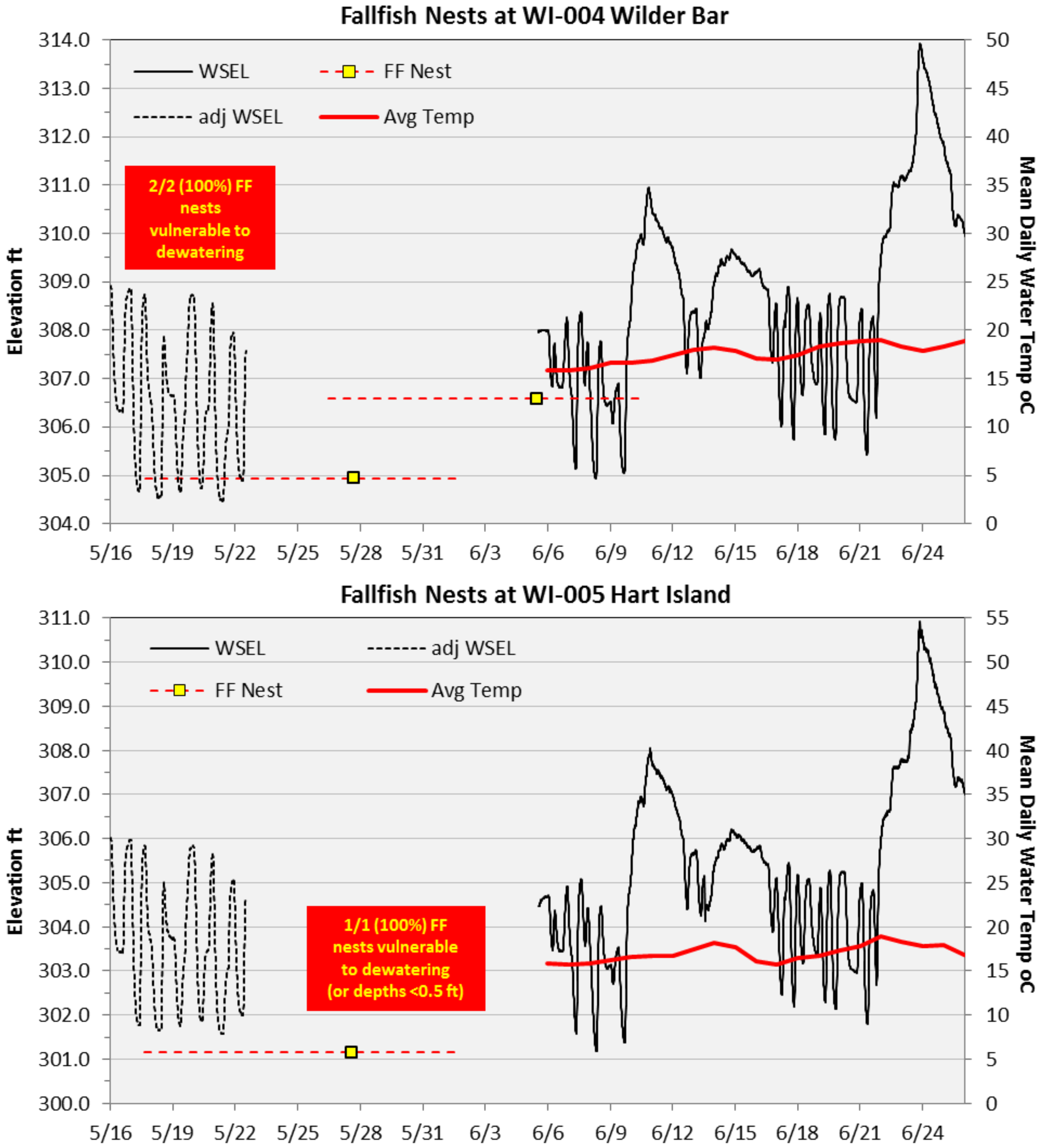
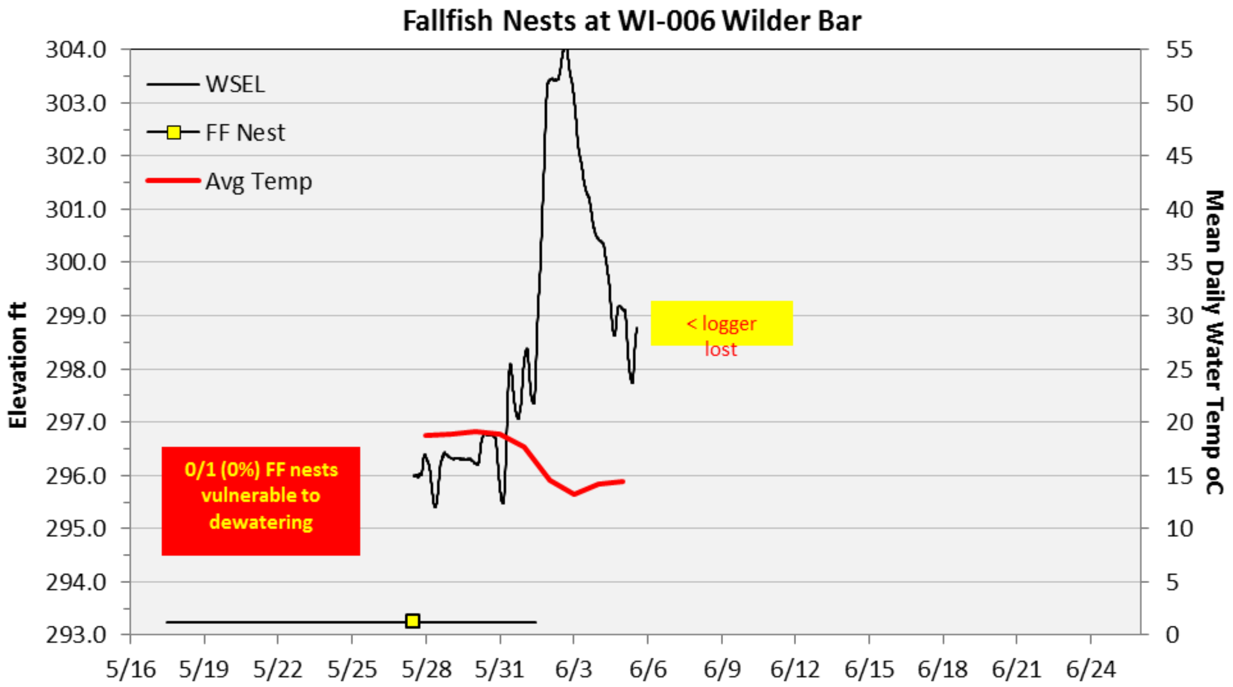


Figure 5.3-8. Fallfish (FF) nest elevations and WSELs along with mean daily water temperatures. Horizontal lines represent potential incubation times 10 days prior to nest observations and 5 days following observation. Red dashed lines indicate nests vulnerable to dewatering.



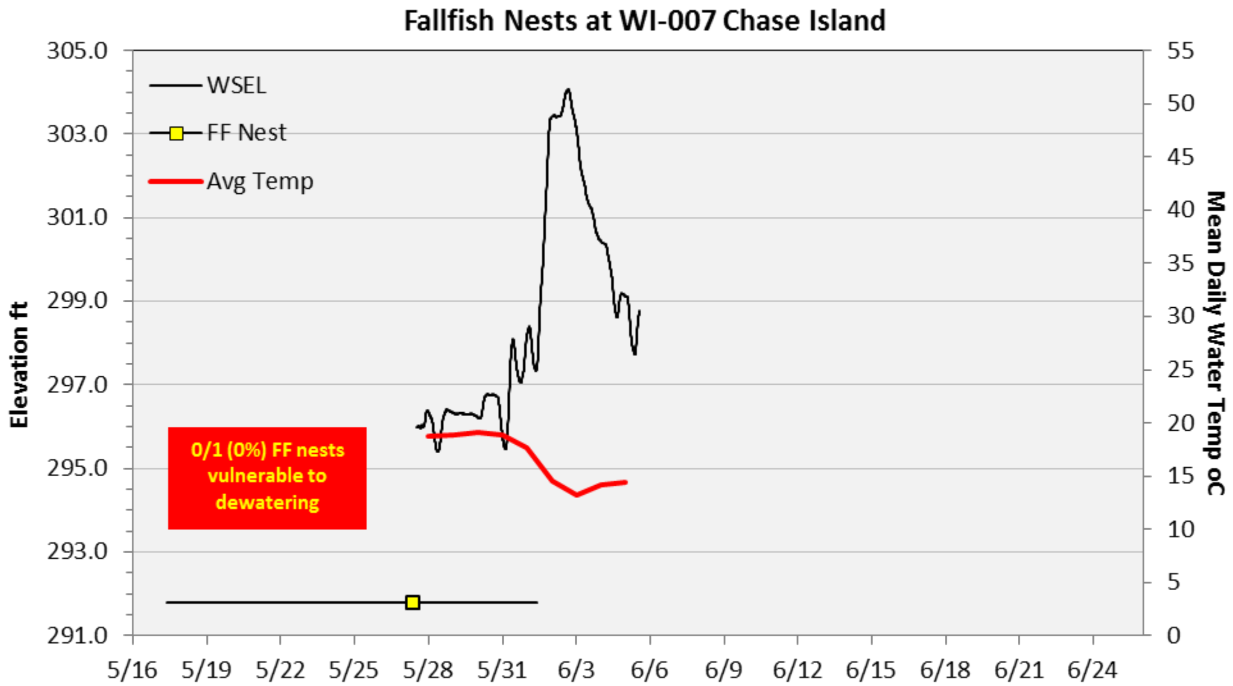
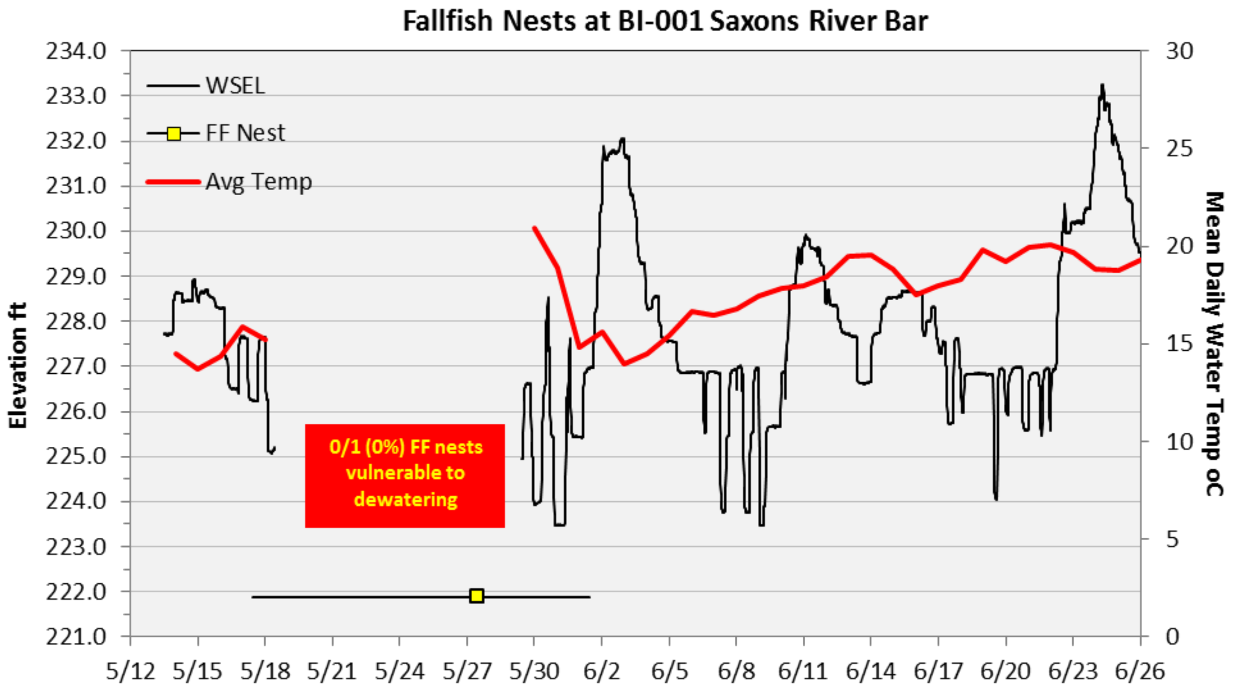


Figure 5.3-8. (continued).



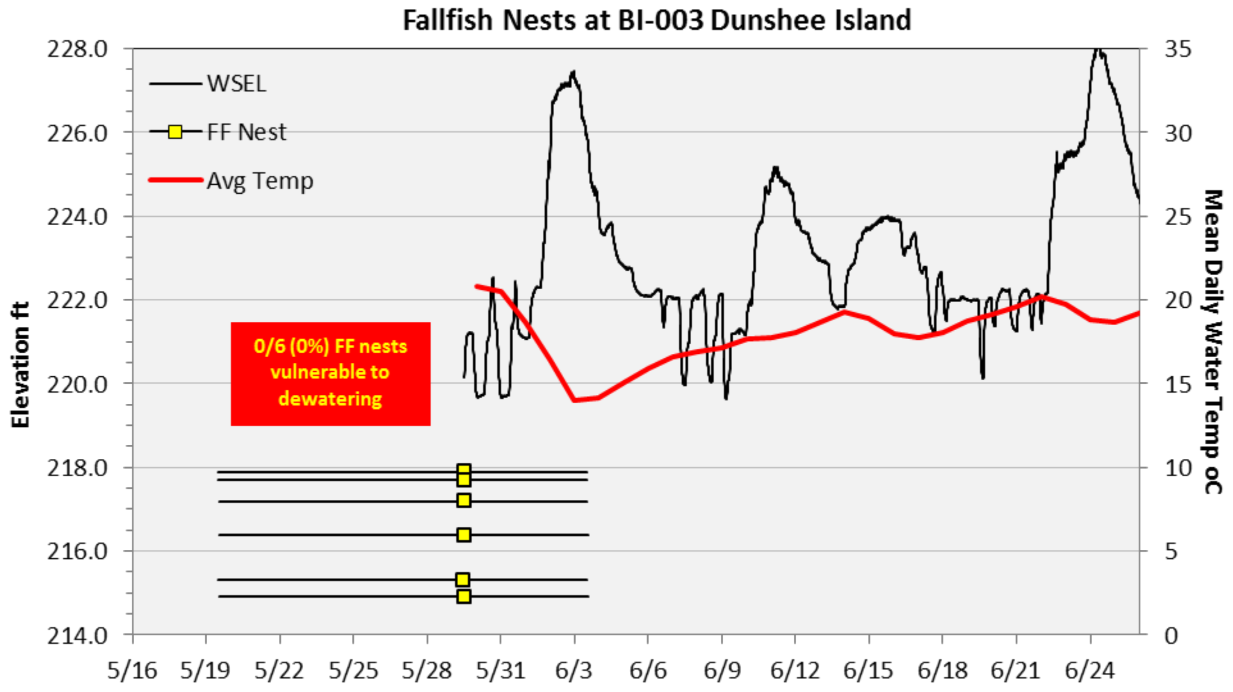
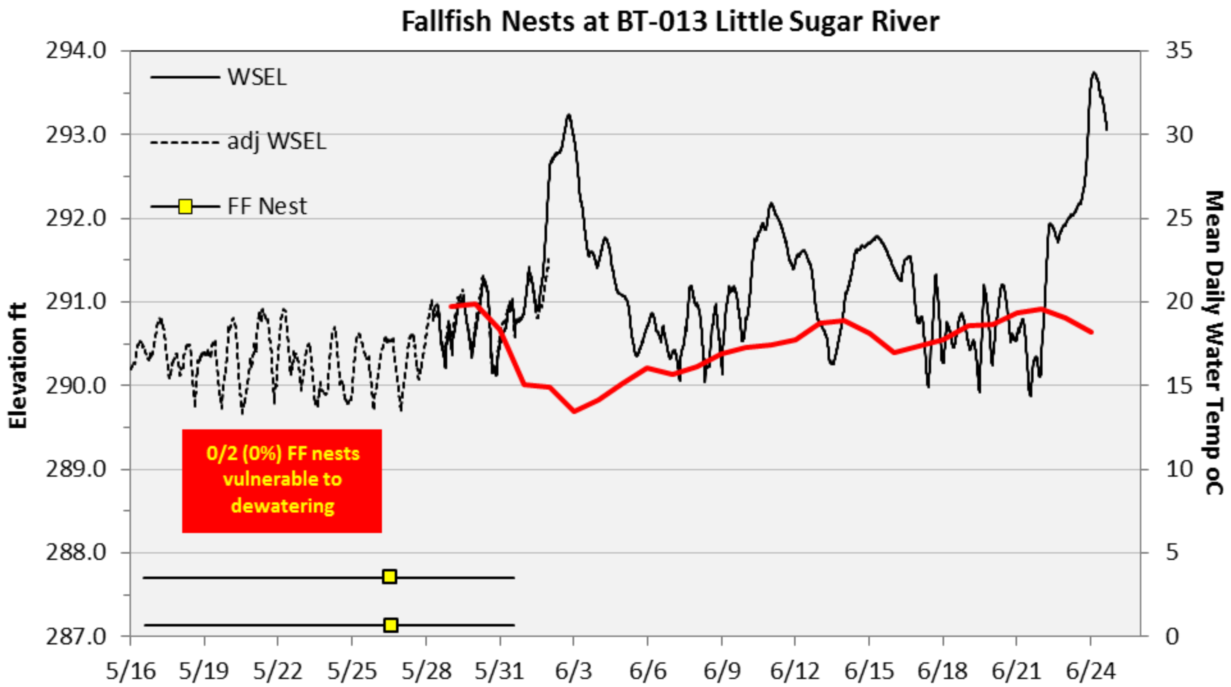


Figure 5.3-8. (continued).



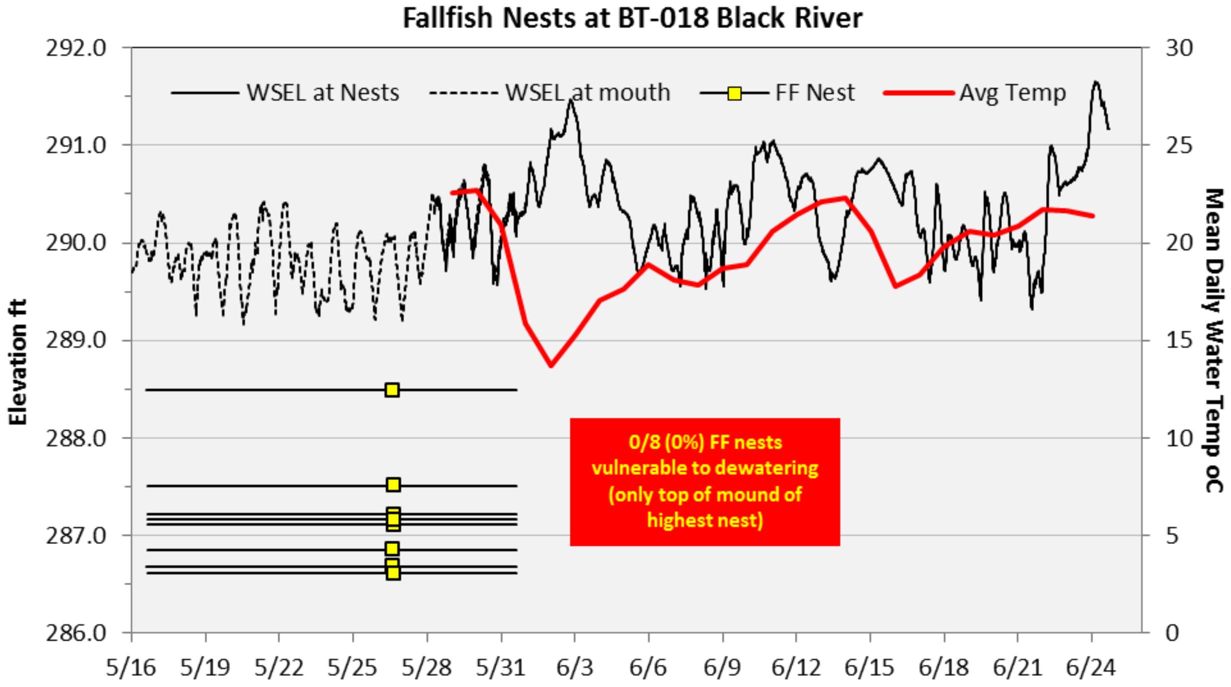
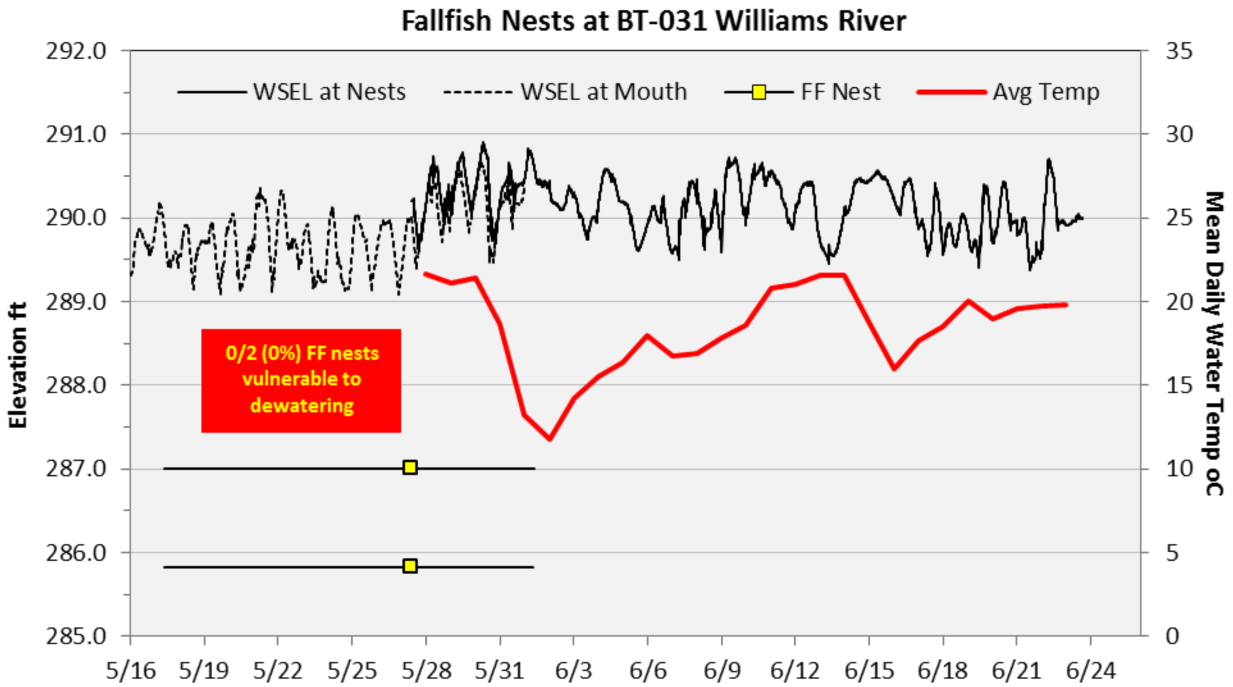


Figure 5.3-8. (continued).



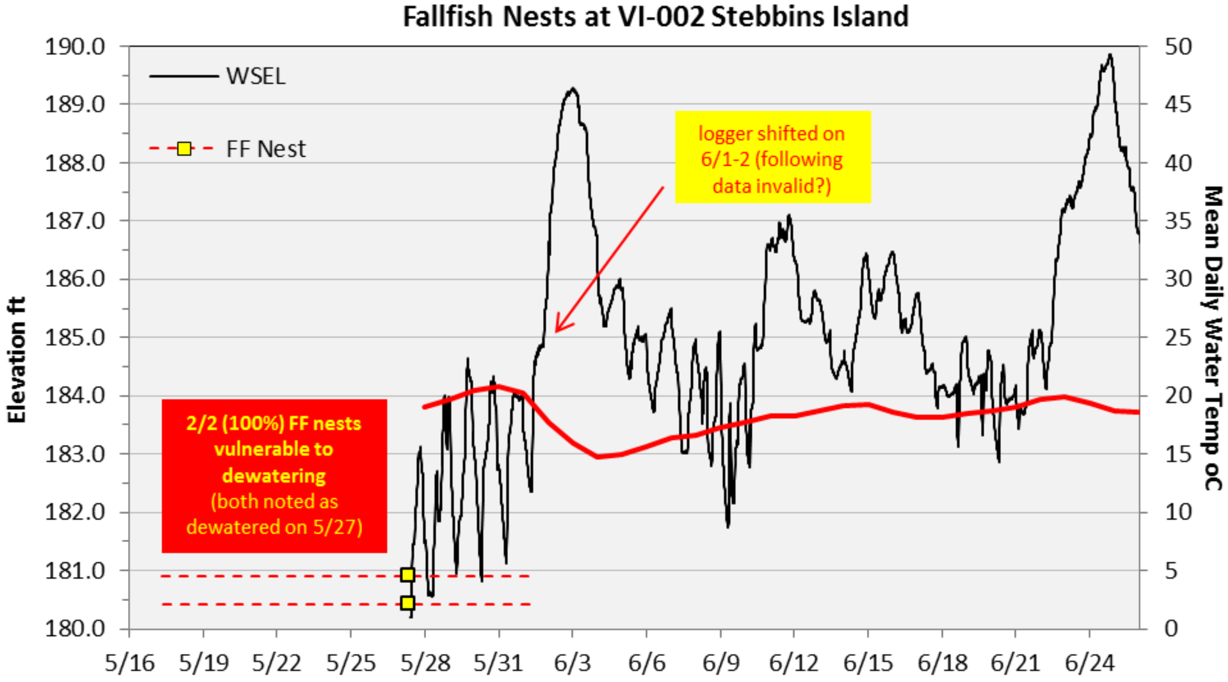


Figure 5.3-8. (continued).

Figure 5.3-9. Dewatered Fallfish nest on bar adjacent to Stebbins Island in the Vernon riverine reach.

In sum, none of the observed Fallfish nests in the impoundment tributaries appeared vulnerable to dewatering due to project operations, but five of the 14 nests (36%) assessed in the riverine reaches were subject to or potentially vulnerable to dewatering at low discharge levels.

5.3.7 Smallmouth Bass

Like Fallfish, Smallmouth Bass spawning was assessed at impoundment tributary study sites and at riverine island/bar sites. Overall, 75 active bass nests were monitored at nine of the 17 tributary sites and at eight of the 12 island/bar sites (Table 5.3-1), where each site with active spawning contained from one to 15 nests with an average of 4.6 nests/site. An “active” Smallmouth Bass nest was a nest where an adult bass was observed to reside at the nest area on at least one occasion, whether or not eggs or fry were ever observed in the nest. An “inactive” nest was either an old nest filled-in with silt, or a clean, newly constructed nest where an adult occupant was never observed or identified to species. Detailed data were not collected for such inactive nests, mostly because Largemouth Bass and Rock Bass were also observed spawning in the project area during the same time period and they construct nests similar to Smallmouth Bass. However, elevation and habitat data was collected on 25 of such inactive nests (discussed below).

Active bass nests were characterized as being occupied by an adult bass, eggs, or fry, or any combination of the above (Figure 5.3-10). At most sites bass spawning was underway when the late spring surveys commenced on May 25 - 26, although eggs were more commonly observed over the following days and fry were not commonly seen until the following week (Figure 5.3-11). These data suggest that bass spawning was initiated immediately prior to the late spring surveys. Water temperatures generally remained between 15-20°C at most sites throughout the observed spawning season, with somewhat colder temperatures in the Wilder tributaries and warmer temperatures in the larger Bellows Falls tributaries. As noted repeatedly in this report, high flows and associated turbidities limited the effectiveness of spawning surveys throughout most of June, or shortly following the initiation of bass spawning. Periods of marginal water visibilities did suggest, however, that most spawning had terminated by the third week of June, with the last eggs observed on June 19 and the last fry observed on June 26.

Unlike most other target species, Smallmouth Bass exhibit significant parental care, where adult bass may remain resident on an active nest for several weeks to a month during nest construction, egg incubation, and early (pre-dispersal) fry rearing. It is generally believed that eggs or non-dispersed fry (especially benthic sac-fry) are highly vulnerable to mortality in the absence of an adult male, who aggressively protects the eggs and fry from predation and sweeps the nest free of silt deposition during periods of high turbidity. Consequently, the loss of an attending male, whether due to removal by angling or abandonment due to insufficient depth over the nest, can lead to nest failure even if the nest itself remains inundated. No information was found in the literature describing the depths at which an adult bass might abandon a nest during low WSEs, or if an adult displaced by low WSEs would return to the nest as water levels rise again. Given the lack of minimum depth information, threshold depth criteria for Smallmouth Bass, like that for sunfish, were selected based on available habitat suitability criteria for nest depths, which suggested that few bass will construct a nest at depths less than one foot (Figure 4.2-1).

Ideally, the assessment of fluctuating WSE effects on nest success would be based on a continuum of observations on individual nests, e.g., from initial nest construction to deposition and incubation of eggs, then to fry emergence and early rearing, and finally nest abandonment following fry dispersal. However, despite the identification of 75 Smallmouth Bass nests, including 32 nests visited two or more times, none of the nests were individually tracked from pre-egg deposition to fry rearing and dispersal. This is largely a result of the high flows and turbidity levels that occurred in June shortly after spawning was initiated, which inhibited the relocation and monitoring of nests on a regular basis.

Figure 5.3-10. Images of adult Smallmouth Bass on active nest with eggs (top), close-up of eggs (bottom left), and newly hatched, benthic fry (bottom right). Note orange marker used for classifying substrate size.

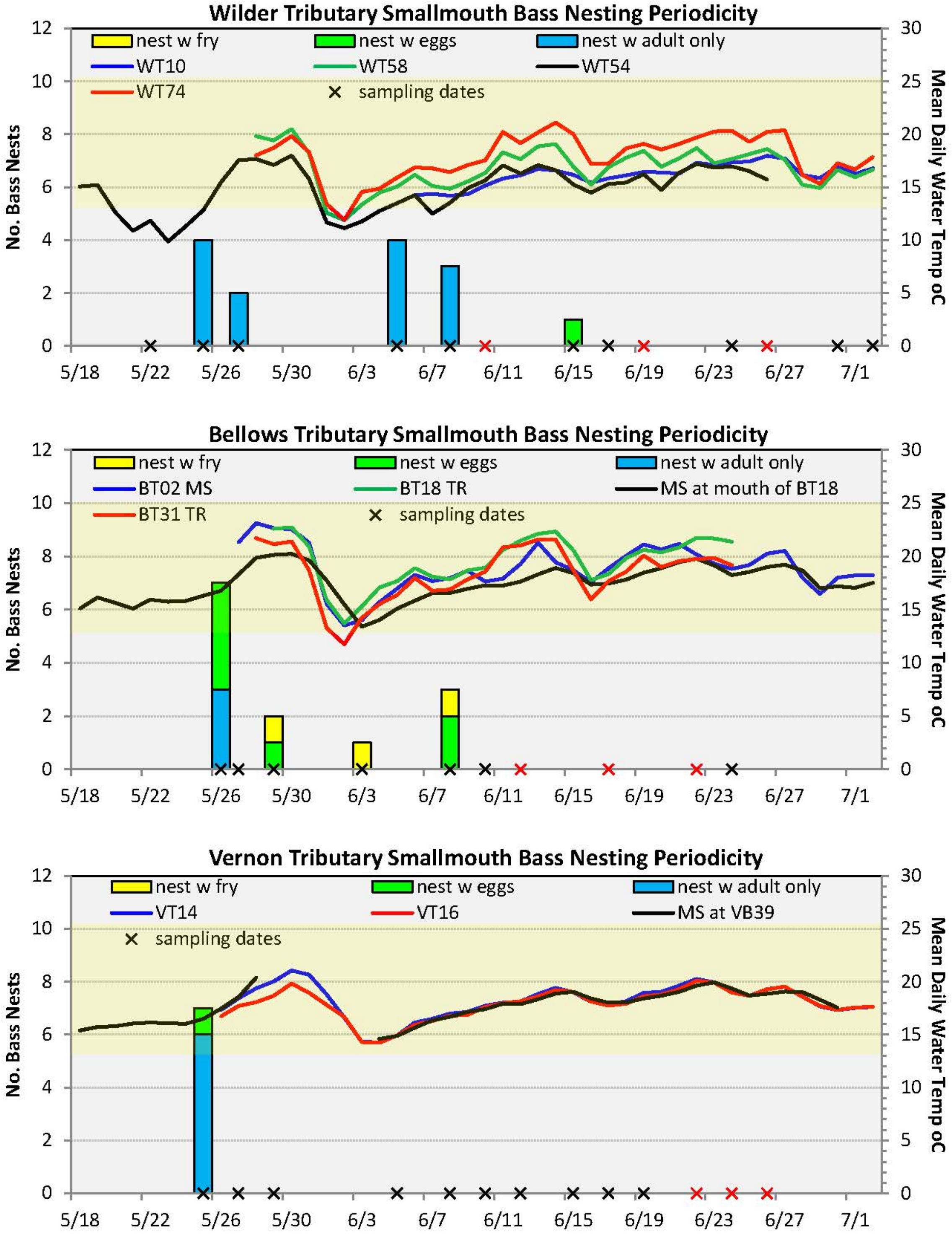
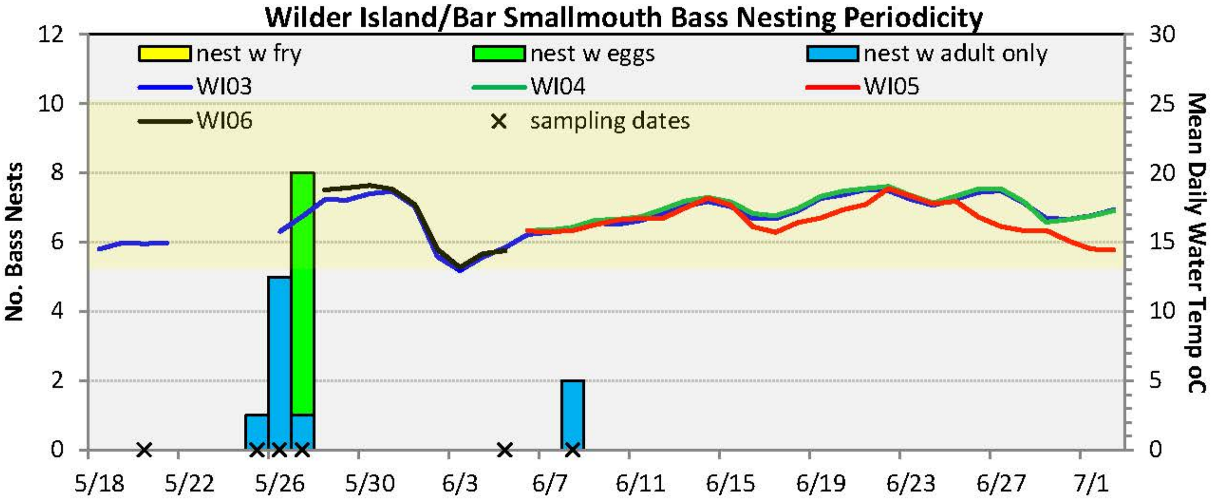
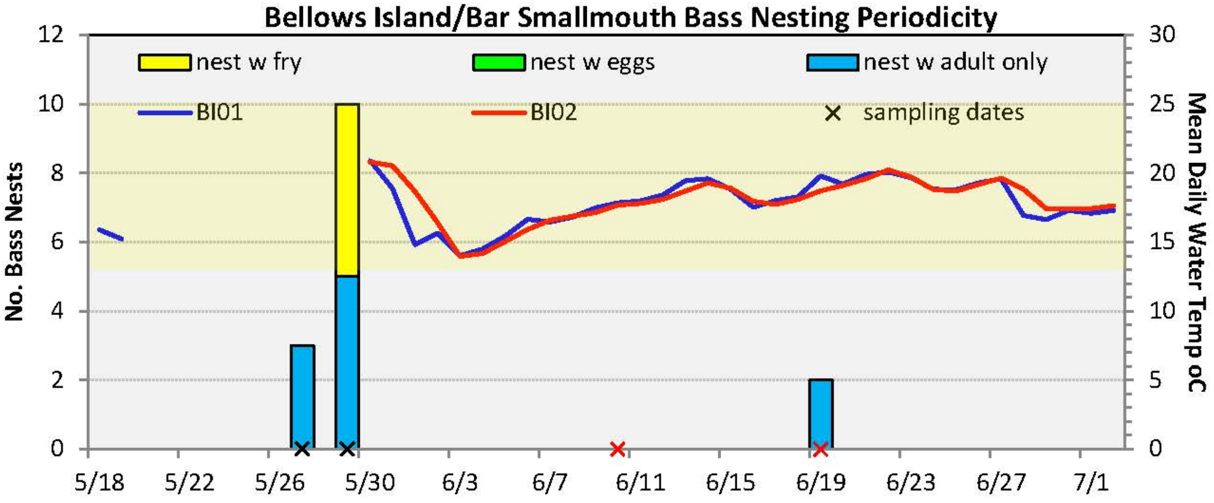


Figure 5.3-11. Nest observations (bars) and range of known spawning temperatures (yellow shading) for Smallmouth Bass by life stage, along with mean daily water temperatures at representative locations (lines) and sampling dates ("X's"). Red "X's" represent surveys when estimated water visibilities were <2 ft.





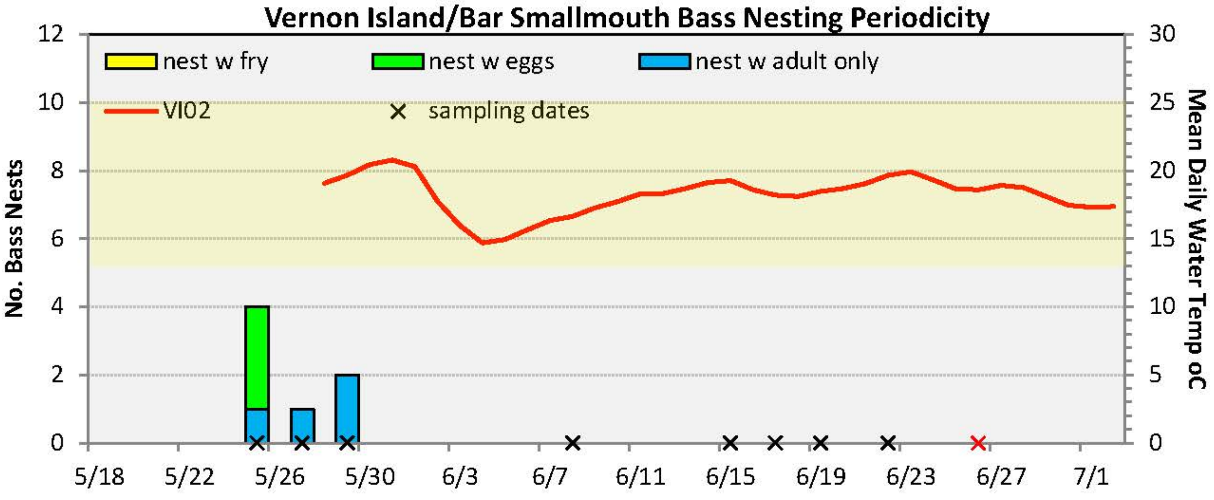


Figure 5.3-11. (continued).

The total number of nests observed according to life-stage present, as well as those nests observed two or more times, is listed in Table 5.3-2. Periodicity estimates for Smallmouth Bass nests at each stage of activity was largely estimated from these site-specific observations, as described in Section 4.2.3 and shown in Table 4.2-1.

Table 5.3-2. Summary of life-stages present at Smallmouth Bass (SB) nests. Revisits are individual nests observed on two or more occasions.

Life-Stage Present	**No. Nests (all nests)**	**No. Nests (w / revisits)**
Adult only	37	15
Adult w Eggs	28	7
Adult w Fry	12	8
Adult w Eggs then Fry	1	1
Eggs only [a]	1	1

a. Eggs identified in lab as SB.

Comparative elevations of 75 Smallmouth Bass nests with WSEs are presented in Figure 5.3-12 for 16 of the 17 tributary and island/bar study sites where bass spawning was observed. An inconsistency in WSE and nest elevation data prevented analysis of four bass nests located at VT-014 Aldrick Brook. As noted in Section 4.2.1, problems occurred with depth loggers at several other study sites which required estimation of WSEs using adjusted data from nearby loggers or from comparative WSE data from Study 7 transect data (Normandeau, 2015c).

In general, Smallmouth Bass nests constructed within the lower reaches of larger impoundment tributaries or at the deltas of smaller tributaries appeared safe from project-related fluctuations in WSEs. Of 31 nests observed in tributaries in shallow water margins or deltas most vulnerable to project effects, only four (13%) resulted in minimum depths less than one foot over the projected period of nest activity. One of these nests (nest 1 at WT-074 Mink Brook) held an adult bass for three visits including a visit after nest depth was estimated to drop to only 0.3 ft, which suggests that the adult resident either remained at the nest as water receded (unlikely) or else it returned to the nest as the water level rose (more likely). Although this nest did not appear to produce eggs, two other nests at a similar elevation (but constructed later) did produce fry. This shallow depth occurred during a sharp reduction in WSE on June 2, likely a response to a heavy rain event with impending high flows (exceeding 21,000 cfs later that day, Figure 5.1-1). There were likely additional bass nests in deeper water that were not observed and/or not vulnerable to project effects.

A similar sharp WSE reduction was evident in the Wilder Impoundment on June 22, immediately before spill flows reached over 19,000 cfs (Figure 5.1-1), due to high flow impoundment operations procedures. On that occasion, a different nest in WT-074 that had contained fry on three previous visits (June 5, 8, and 15) was just out-of-water (Figure 5.3-13) and no longer contained fry (Figure 5.3-12). It is likely that fry had developed sufficiently over the prior 17 days to disperse from the nest as the WSE dropped. However, a second nest that had contained eggs the prior week (June 15) was reduced to a shallow depth and eggs were no longer evident by June 24. The only other bass nest in a tributary site that appeared potentially vulnerable to project effects was a successful nest with fry in the Williams River (BT-031). This nest was observed with eggs and a guardian adult bass on May 29, then the adult was seen with fry on June 10, and finally fry were again observed on June 24. Water level data suggests that depths over this nest dropped to 0.7 ft just prior to the first fry observation, and dropped further to 0.5 ft prior to the last fry observation. This data and other shallow nest observations described in Figure 5.3-12 suggests that the 1-ft minimum depth criteria used in this analysis is conservative, and that bass nests can remain viable at depths as shallow as 0.5 ft.

As was noted for Fallfish above, vulnerability of Smallmouth Bass nests to potential dewatering was much greater in the riverine reaches than in the impoundments. A total of 44 bass nests were assessed at island/bar habitats in the riverine reaches, of which 14 (32%) were potentially vulnerable to dewatering or nest abandonment (Figure 5.3-12). On one nest at Burnap's Island (WI-003) an adult was observed on a single occasion, after which depths just barely dropped below 1.0 ft, so it is unknown if changes in WSE were influential on the subsequent lack of observations at that location. However, multiple nests located at the unnamed island (BI-002) just downstream of Walpole in the Bellows Falls riverine reach (Appendix D) were subject to depths <1 ft, including one nest that produced fry despite depths dropping to 0.8 ft on multiple occasions. A second nest located at a nearly identical bed elevation contained live fry on May 29, but on a revisit on June 19 the field crew discovered dead fry in the nest. Two additional nests were located within the 1-ft criteria, one of which contained only an adult during one survey, while the other nest contained eggs that were deposited late in the season (observed on June 19). This late-season nest was built 1.5-2 ft higher than the earlier nests, apparently in response to a sustained period of spill with high flows and associated high WSEs, and it appeared vulnerable to lower WSEs as flows receded.

Two shallow bass nests were observed at the bar habitat below the BI-001 Saxtons River study site, one of which held an adult with eggs and the other an adult only (Figure 5.3-12). Both nests were subsequently subject to depths of <0.5 ft, but high flows and turbidity prevented relocation and reassessment of either nest. One of the most productive study sites for Smallmouth Bass spawning was Stebbins Island (VI-002) just below Vernon dam (Appendix D). Eight active bass nests were observed over the first three surveys in late May, four of which contained eggs. Of these eight nests, only one nest occurred in water deep enough to maintain depths over one ft (by a slim margin). The other seven nests likely experienced dewatering (4 nests, 3 with eggs) or else were subject to minimum depths of 0.4-0.6 ft (Figure 5.3-14). The nest showing a minimum depth of 0.4 ft was observed on two occasions to only contain eggs without an attending adult, and on the second visit most of the eggs were found to be dead and encased in fungus. Despite repeated visits in June (with acceptable visibility), none of the eight nests appeared to be active and no adult bass or new nests were observed.

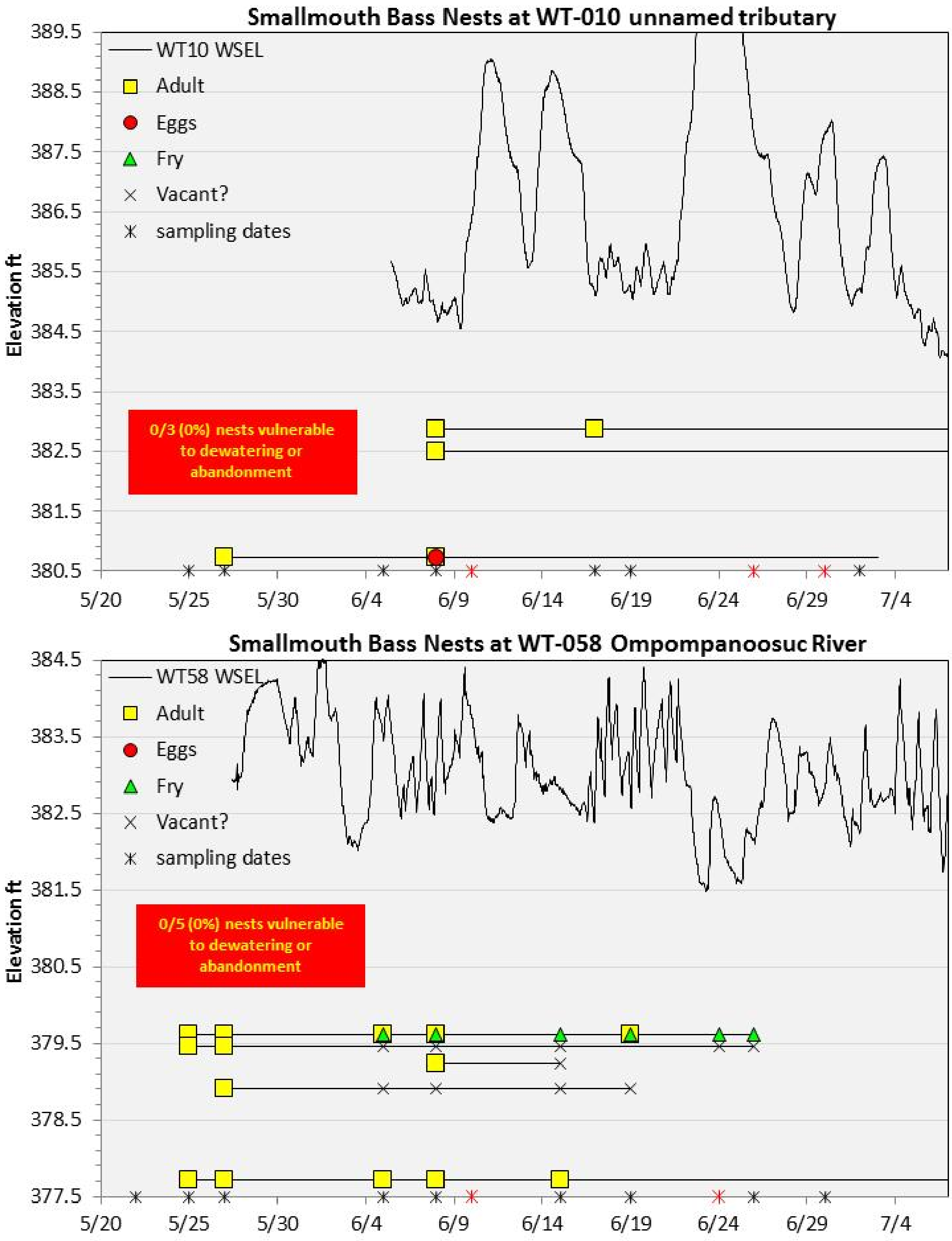
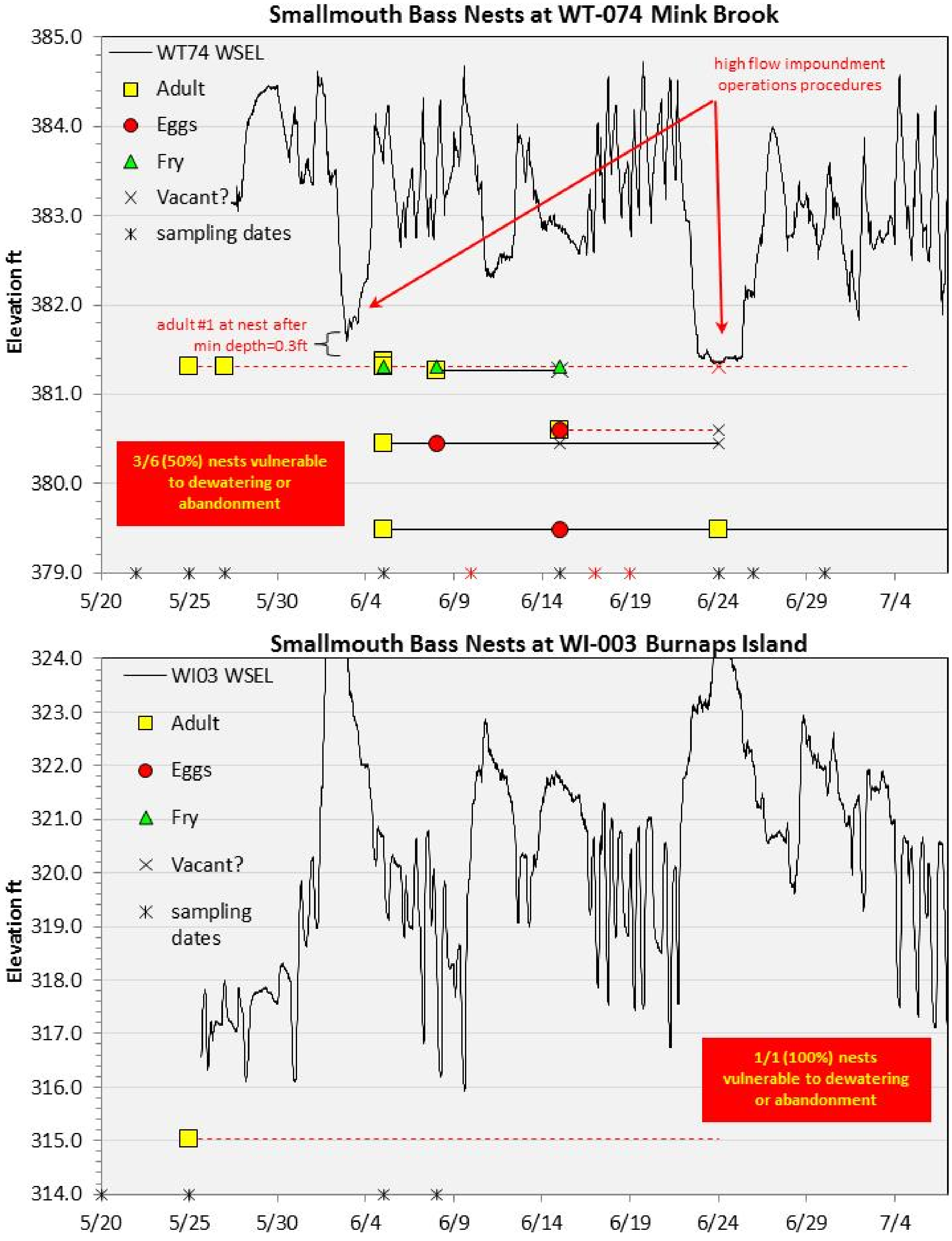


Figure 5.3-12. Revised Smallmouth Bass (SB) nest elevations and backwater WSELs. Yellow squares represent nests with adults present; red circles represent eggs, green triangles represent fry, and "X's" are dates with no life-stages observed. Red dashed lines are vulnerable nests within 1.0 ft of WSE. Asterisks on x-axis are sampling dates, red asterisks are days with visibility <2ft.


Smallmouth Bass Nests at WT-074 Mink Brook

high flow impoundment operations procedures

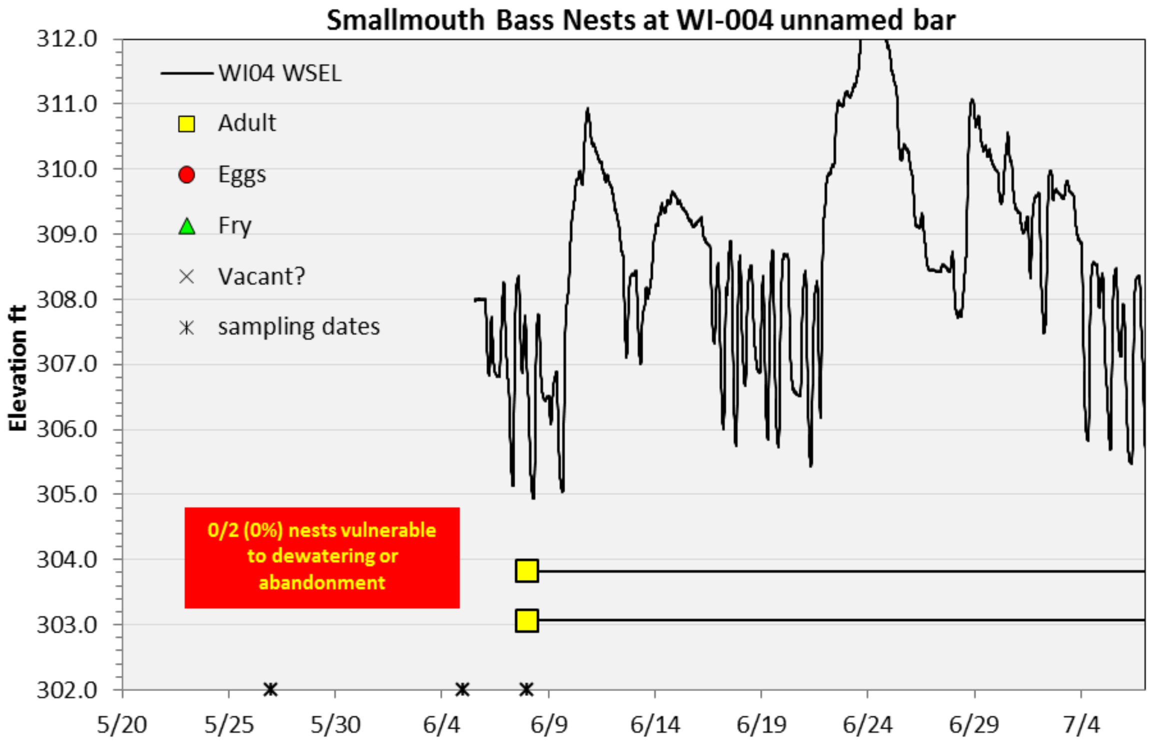
adult #1 at nest after min depth=0.3ft

3/6 (50%) nests vulnerable to dewatering or abandonment

Smallmouth Bass Nests at WI-003 Burnaps Island

1/1 (100%) nests vulnerable to dewatering or abandonment

Figure 5.3-12. Revised (continued).



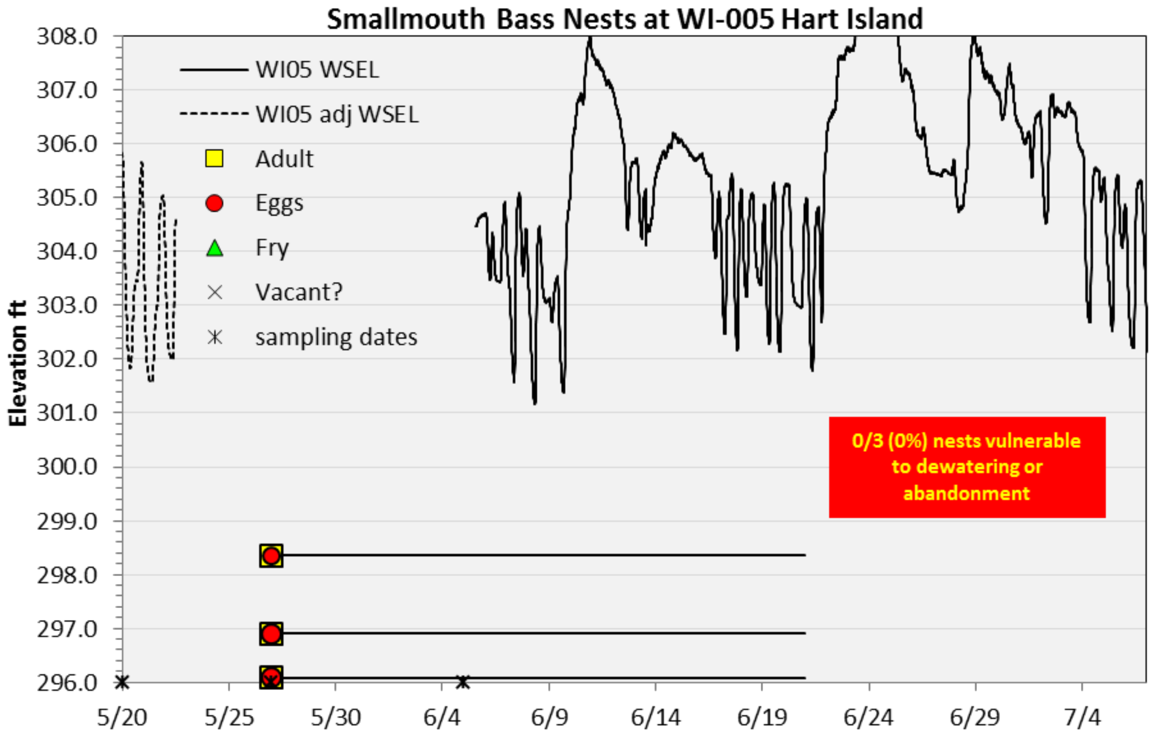


Figure 5.3-12. (continued).

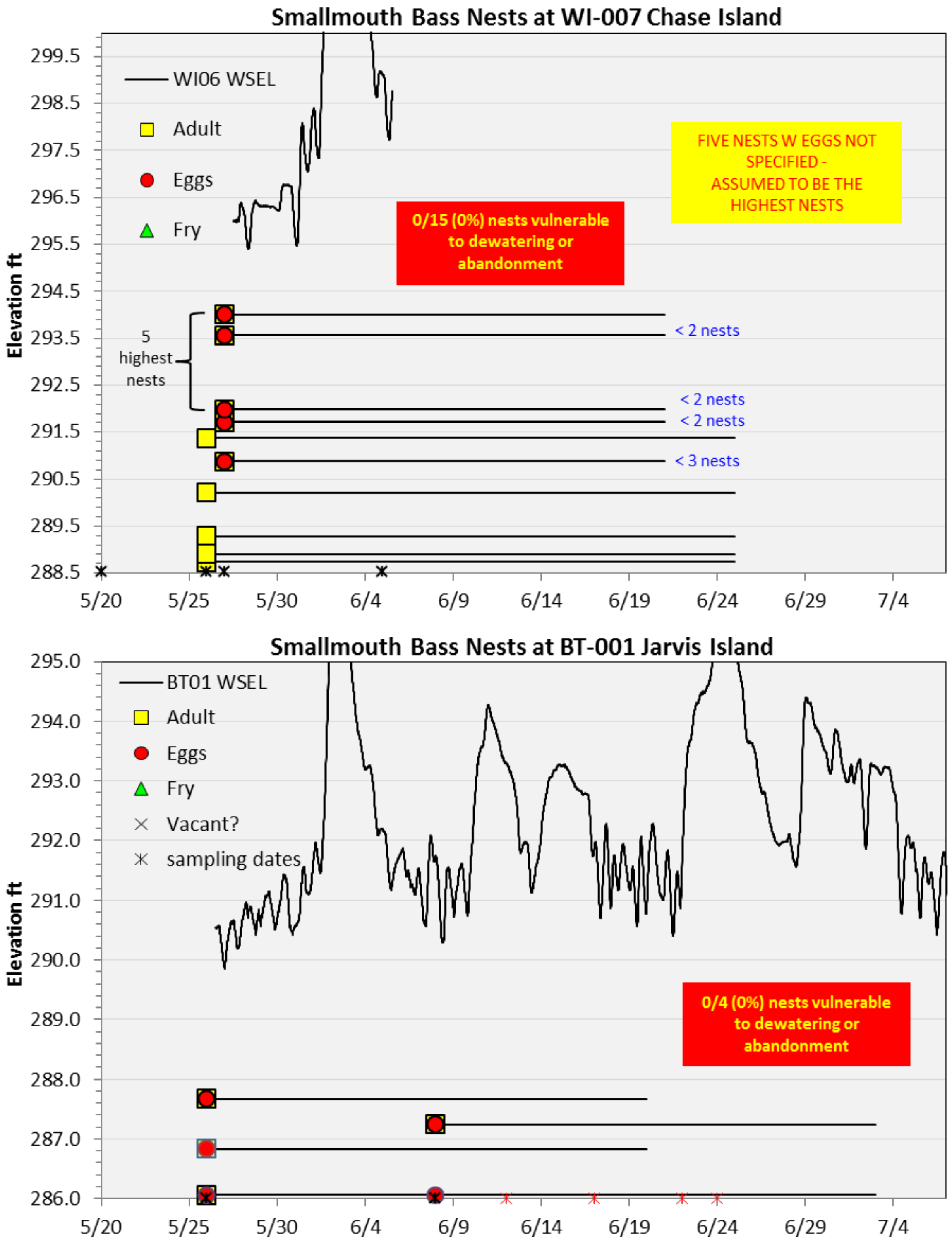
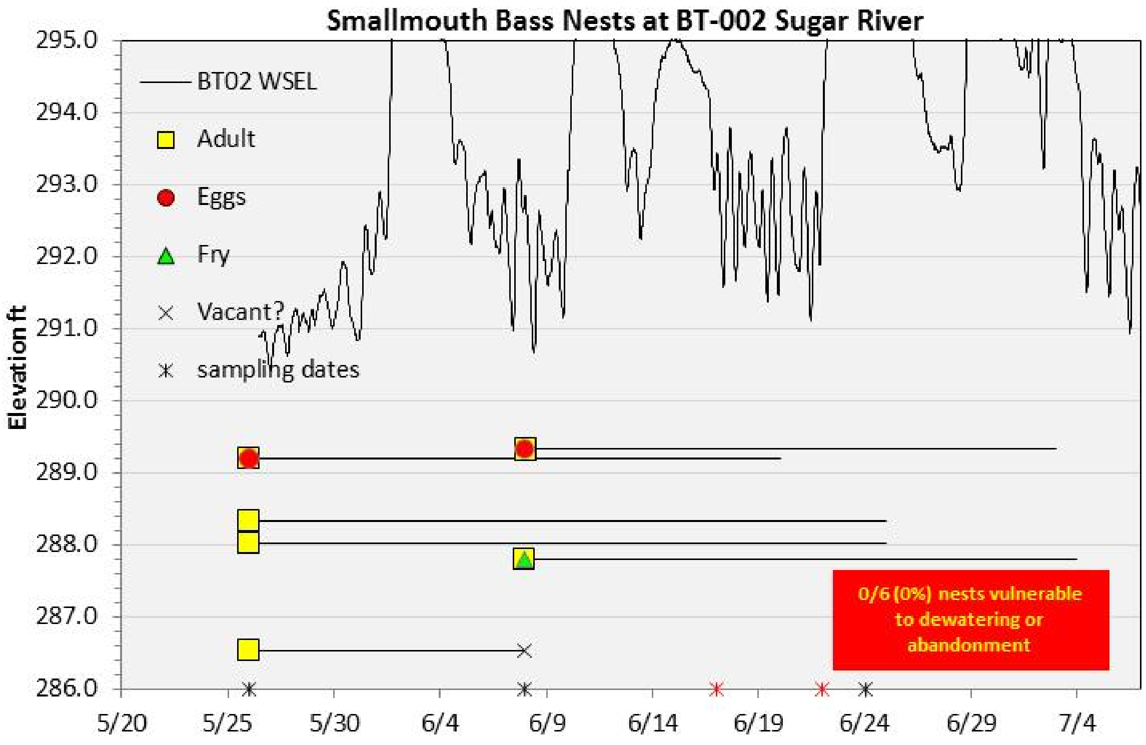


Figure 5.3-12. (continued).



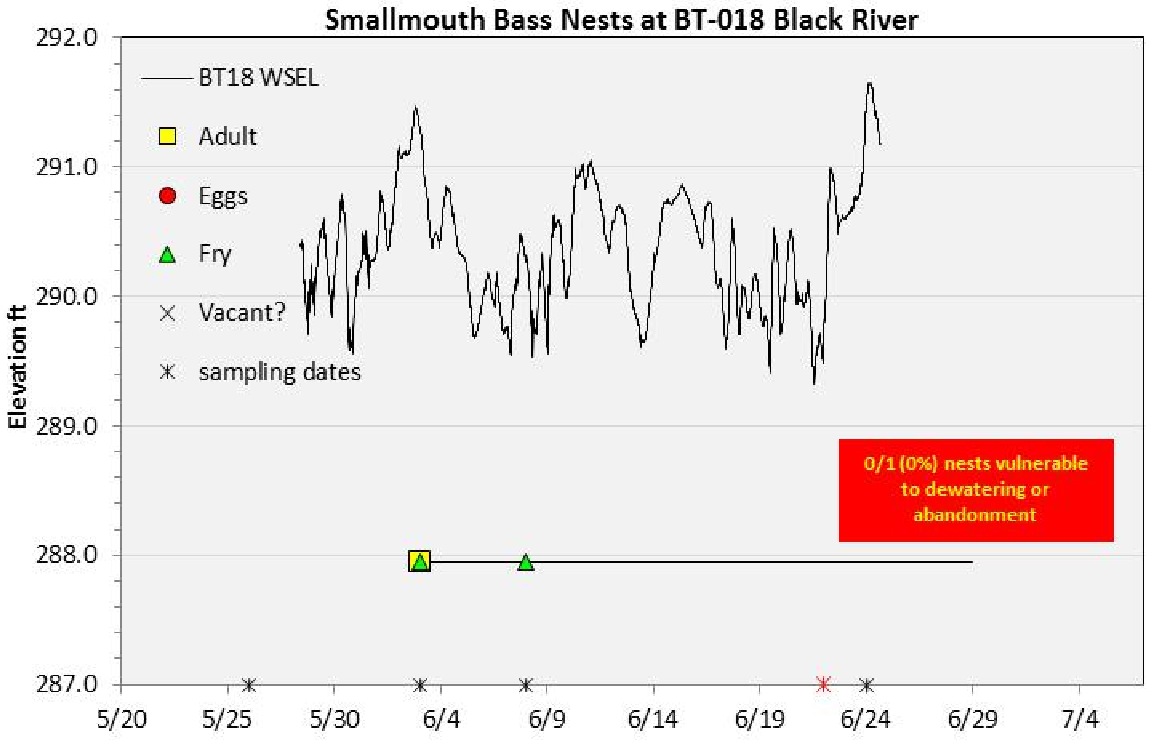


Figure 5.3-12. Revised (continued).

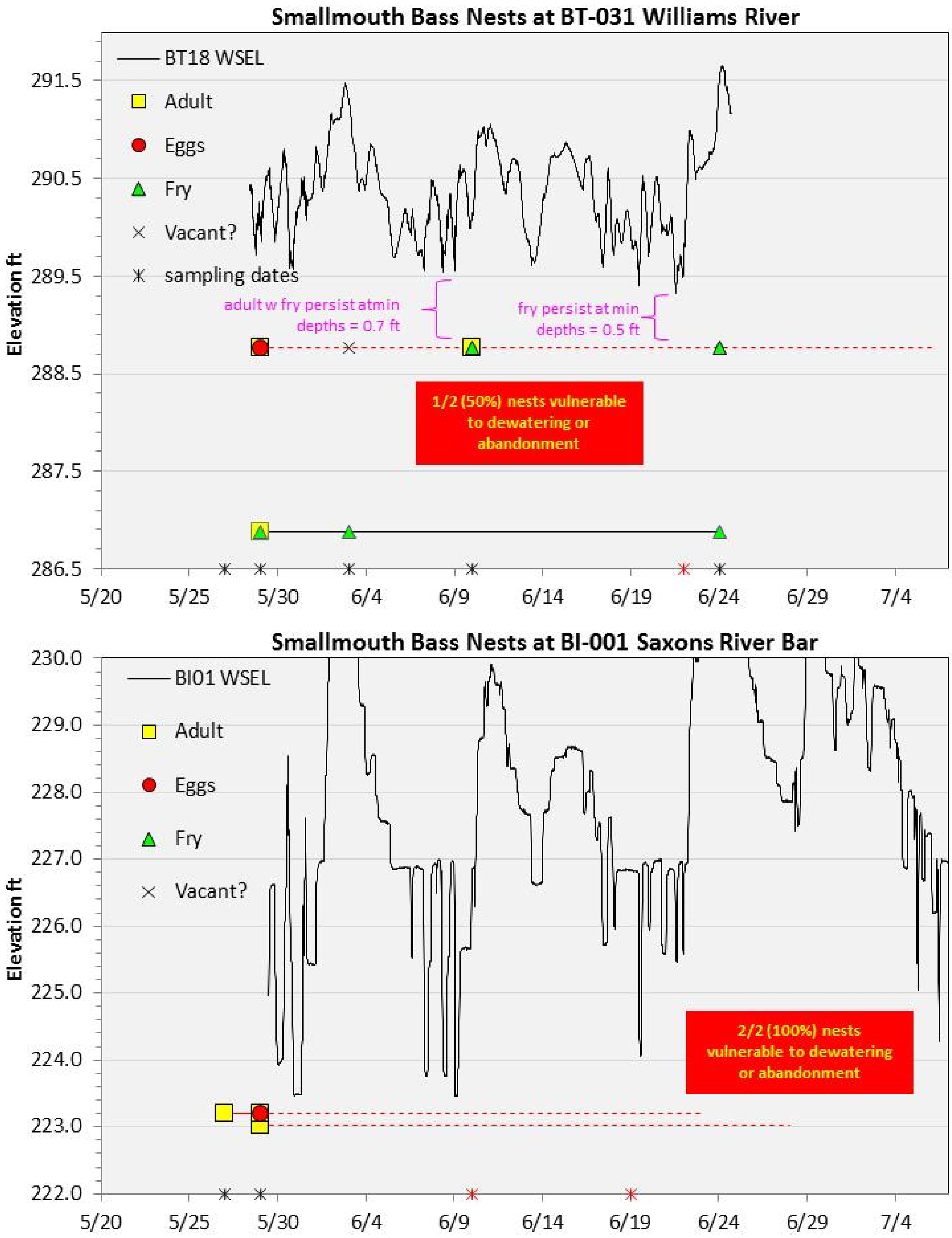


Figure 5.3-12. Revised (continued).

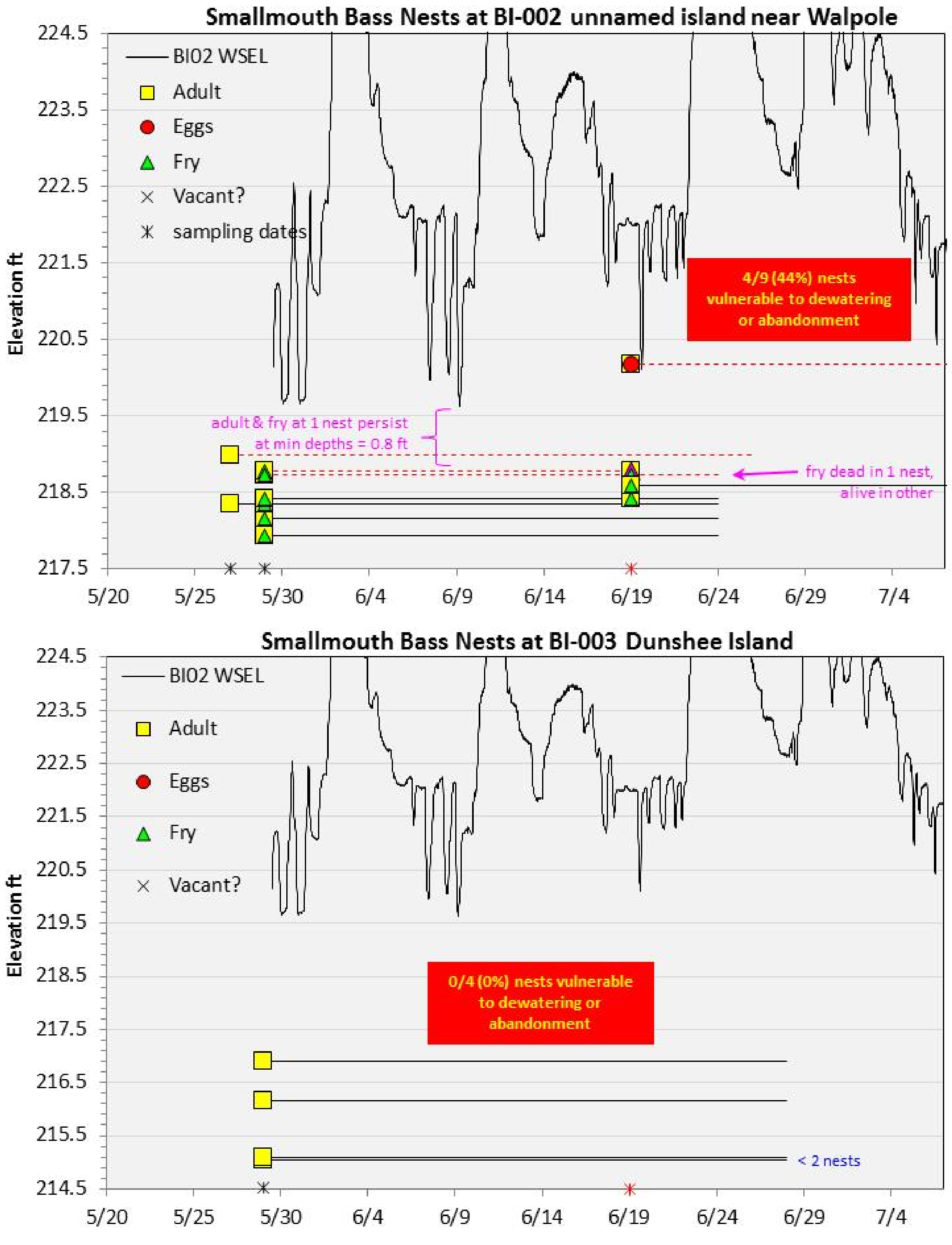
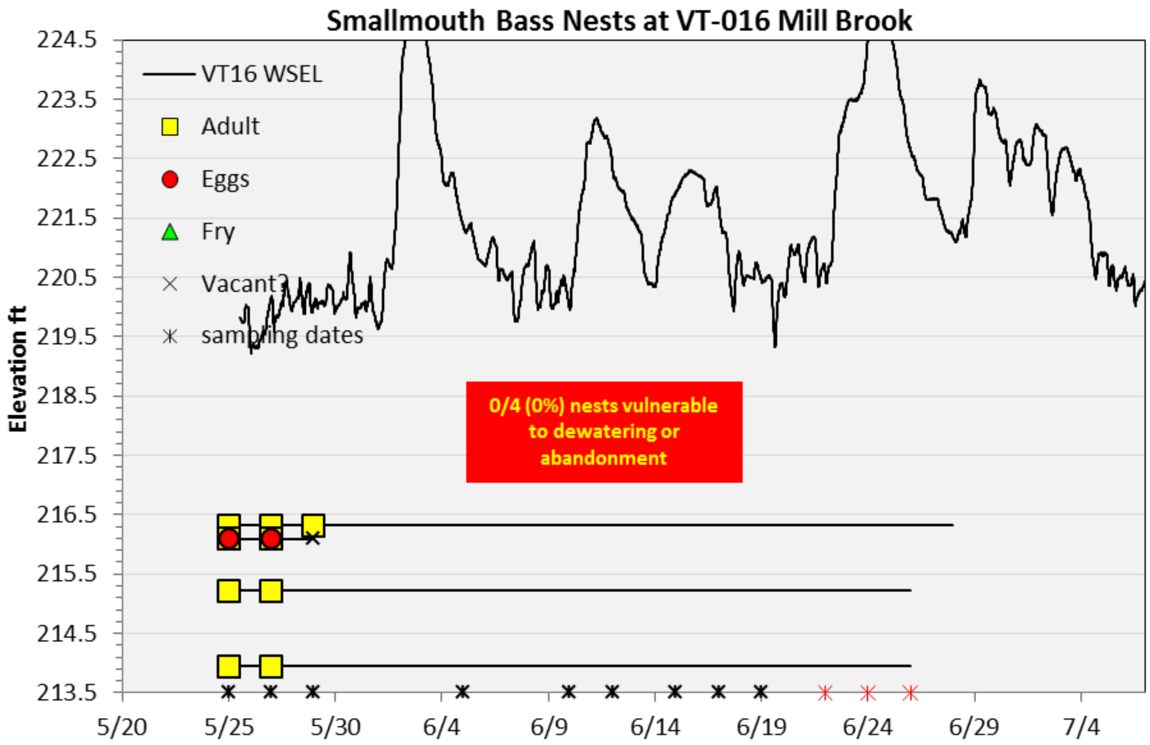


Figure 5.3-12. Revised (continued).



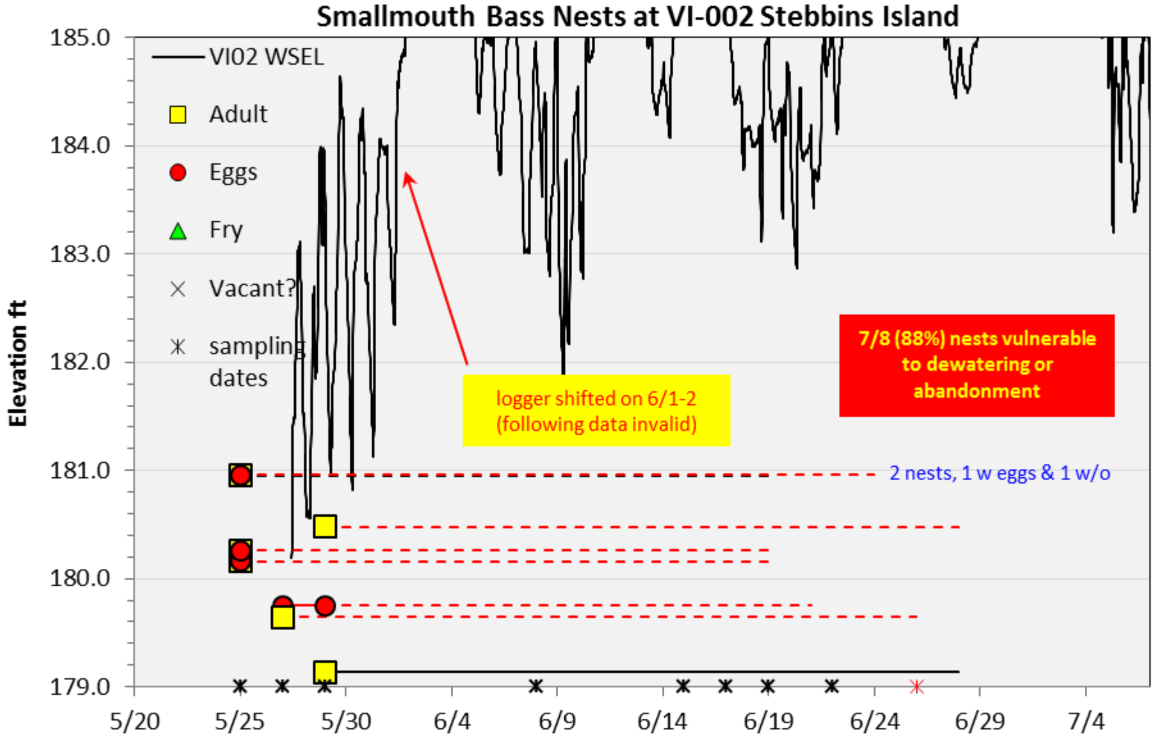


Figure 5.3-12. (continued).

Figure 5.3-13. Dewatered Smallmouth Bass nest at WT-074 Mink Brook, June 24, 2015.

Figure 5.3-14. Shallow water bass nest (left) and nest containing dead eggs with fungus (right) at Stebbins Island study site.

A consistent pattern in each of the three riverine reaches was a lack of nesting activity at study sites closest to the dams, with increased spawning at island/bar habitats farther downstream of the dams, where the rate and magnitude of WSE fluctuations are attenuated by distance from the dam as well as tributary inflow. For example, no bass nests (or Fallfish nests) were observed at either of the two upstream study sites in the Wilder riverine reach, including the Johnson Island complex which appeared to contain abundant spawning habitat for both species. Nor were bass or Fallfish nests observed at the small island just below Vernon dam.

The notable exception was at Stebbins Island (VI-002), which is located less than one mile below Vernon dam and was the site of significant spawning activities by both Fallfish and Smallmouth Bass. The lack of spawning in the upstream island habitats may be due to the more pronounced fluctuations in WSEs at those sites, which would make nests more vulnerable to dewatering, as was the case at Stebbins Island. In contrast, nests at islands more than four miles downstream of Wilder and Bellows Falls dams generally showed more bass spawning activity with fewer nests subject to dewatering.

As noted above, limited elevation data was collected for in-active nests that were never observed to be occupied by adult residents, but were believed to be Smallmouth Bass nests due to their physical characteristics and proximity to active bass nests. Comparison of active nests with adult resident bass and in-active (empty) nests showed that in-active nests were generally shallower (i.e., higher in elevation) than active nests at two of three study sites (WI-007 and WT-010). At a fourth site (BT-001), active nests containing both adult bass (A) and eggs (E) were significantly deeper (*t*-test, $P=0.02$) than nests containing eggs but no adult bass (Figure 5.3-15). It is unknown if the in-active nests (or BT-001 nests with eggs only) were absent of adult bass due to insufficient depths at low water (e.g., nest abandonment), or if some unknown reason (e.g., angling, predation) lead to nest vacancy. However, of the three sites with shallower in-active nests, all but one of the in-active nests maintained depths of at least 0.9 ft at low flow. Also, the one site where nest dewatering was most prevalent (VI-002, Stebbins Island) did not show any difference in elevation between active and in-active nests, which suggests that other factors may have been responsible for nest vacancy.

As previously stated, it is likely that some proportion of the observed vacant nests did in fact have an attending adult, but the fish were not detected by the field crews due to the limited water visibilities encountered throughout much of June.

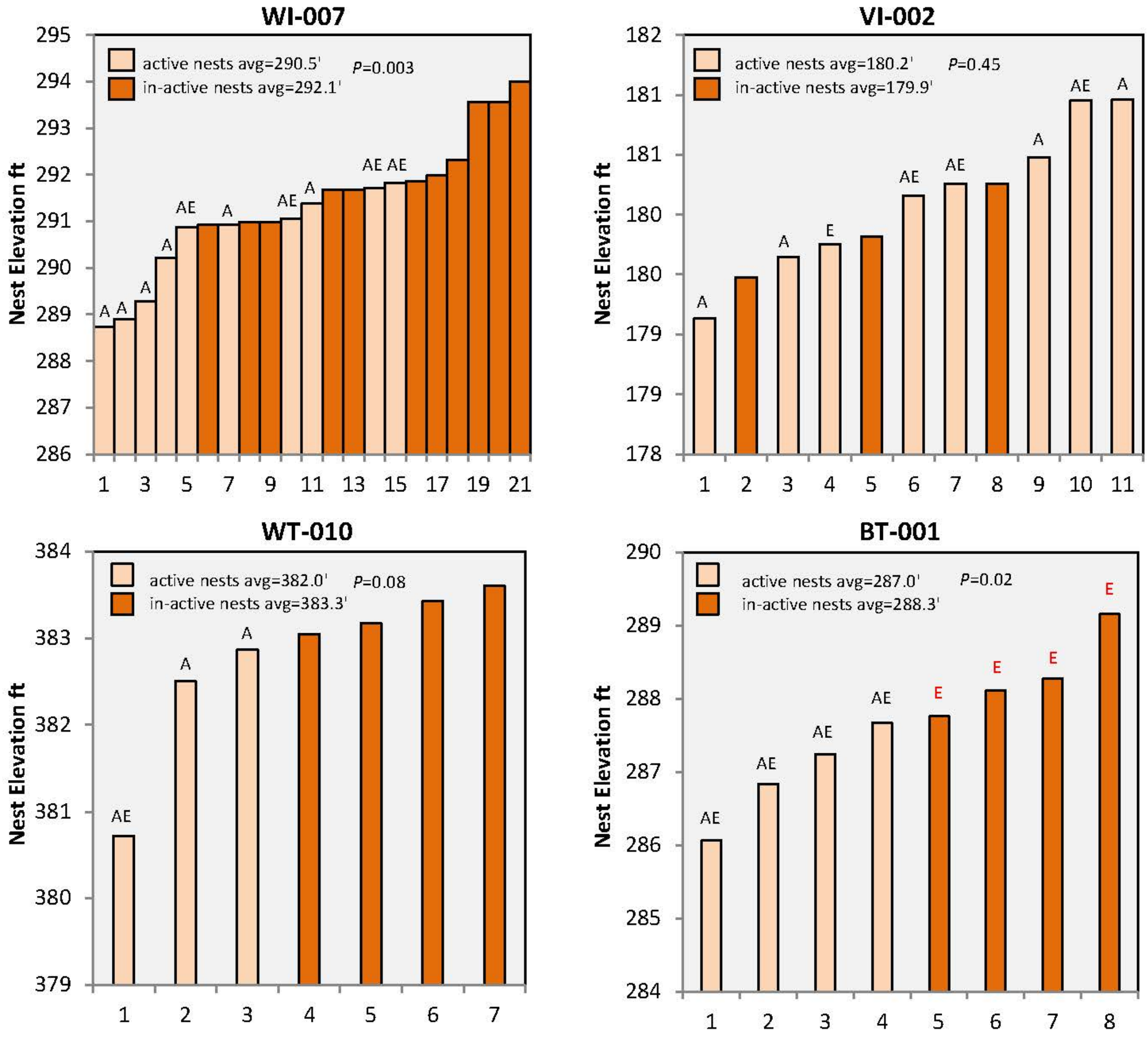


Figure 5.3-15. Comparison of elevations of active and in-active Smallmouth Bass nests. Presence of attending adult (A) or eggs (E) and the significance of difference in elevations is also shown.

5.4 Spawning Habitat Characteristics

Although the primary emphasis of this study was to assess the effects of project operations on spawning success by comparison of observed spawning elevations and concomitant WSEs, ancillary data was collected to describe the physical characteristics of spawning habitat used by target species. As noted in Section 4.1, documented habitat characteristics included an assessment of the substrate materials at the site of each egg mass or nest, as well as any observable cover components within 10 ft of a spawning observation. Particular emphasis was placed on characterizing the amount of fines (sand or silt) within Smallmouth Bass nests and how the percentage of fines changed over the course of nest development, e.g., from initial nest construction to egg deposition, fry rearing, and nest abandonment.

5.4.1 Dominant and Subdominant Substrate at Egg and Nest Sites

Substrate types found at spawning locations were clearly different for each species (Figure 5.4-1). With the exception of in-water branches (classified as organic substrate), Yellow Perch did not appear to exhibit any selectivity for substrate type where egg masses were deposited, but instead the distribution of substrate types appeared very similar to the availability of substrate types along the shoreline of backwater habitats. Sunfish appeared to show more selectivity by constructing nests in areas mostly composed of sand or gravel (the latter of which was typically swept clean of overlying silt). Silt and organic matter was rarely a dominant substrate type in active nests, in contrast to old (i.e., last year’s) nests which were typically filled with small organic matter such as leaves, sticks, or algae. Because many active sunfish nests contained a high proportion of sand, assessment of temporal changes in the percentage of fines (mud, sand, or silt) in nests was not routinely conducted.

Spawning Smallmouth Bass showed a definite preference for gravel substrate for nest construction (Figure 5.4-1), although in many locations the adult bass was required to sweep away a thick covering of sand, silt, or organic matter to expose the underlying gravel substrate (Figure 5.4-2). Although fines frequently surrounded the nest site, they rarely comprised more than 20% of the materials within the nest except for older nests with advanced (non-benthic) fry. Fallfish showed the most restrictive substrate selection of all species, with 100% of observed nests dominated by gravel or (less frequently) cobble substrate. Although few Fallfish nests were reported to contain any subdominant materials (e.g., most were classified as pure gravel or pure cobble), some nests contained a ring of sand along the downstream base of the mound (see Figure 5.0-1), due to deposition in the mounds eddy.

5.4.2 Instream Cover at Egg and Nest Sites

The instream cover characteristics at spawning sites also differed among species, with higher percentages of nearby cover for backwater spawning species than for the more riverine species (Figure 5.4-3). As mentioned above, Yellow Perch frequently spawned in close proximity to terrestrial vegetation, and seemed to prefer draping egg masses over submerged branches. Such hanging egg masses, if not dewatered by decreasing WSEs, likely reduced egg mortality from benthic-oriented predators, such as crayfish, suckers, catfish, or carp. With the exception of branch substrates, it did not appear that Yellow Perch actively selected spawning locations due to proximity of instream cover.

In contrast to perch, sunfish routinely prepared spawning nests in close association with submerged aquatic vegetation, although nearly as many nests were absent of nearby cover (Figure 5.4-3). This result may be partly a result of the dense clustering behavior of nesting sunfish, where nests on the outside edge of the cluster may be closer to instream cover compared to nests in the center. Also, backwater habitats differed in the extent of aquatic vegetation, where heavily shaded, sandy, or more steeply sloped locations possessed more open water.

Smallmouth Bass nests were more frequently associated with woody debris cover than any other species (Figure 5.4-2), although many nests were constructed well away from any dominant cover types (Figure 5.4-3). The importance of nearby cover is likely influenced by the habitat type in which the nest is constructed, as bass nesting in riverine reaches are more likely to require protection from excessive current velocities (to prevent displacement of fry) than nests constructed in more lacustrine areas, such as the deltas formed at impoundment tributaries. Fourteen of the 17 bass nests (71%) containing nearby woody debris were located at riverine island study sites, whereas most (66%) of the nests absent of nearby cover were at impoundment study sites. Fallfish were even more likely (75%) to build nests away from instream cover, which is not surprising given this species burial of eggs and the gravel-protected environment for hatched fry. Also, this study only considered boulder or rip-rap as a form of rocky cover, which types were generally rare in the project area, whereas cobbles, which were frequently found in or about Fallfish nests, were not classified as a cover element.

5.4.3 Changes in Percent Fines at Spawning Nests

Field crews attempted to monitor sedimentation within sunfish and bass nests by visually estimating the percentage of fines (silt or sand) within individual nests over multiple visits. Although revisit substrate data was collected at some sunfish nests, many new and active sunfish nests were initially constructed in areas with a high proportion of fines and organic debris, consequently assessing changes in fines was not routinely conducted for those species. Crews also noted that fines were common along the downstream base of Fallfish nests, undoubtedly due to the eddy formed by the large mound; however the magnitude of change in fines at these downstream edges was not assessed as fines were rare along the remainder of the nest perimeter and on the surface of the mound itself.

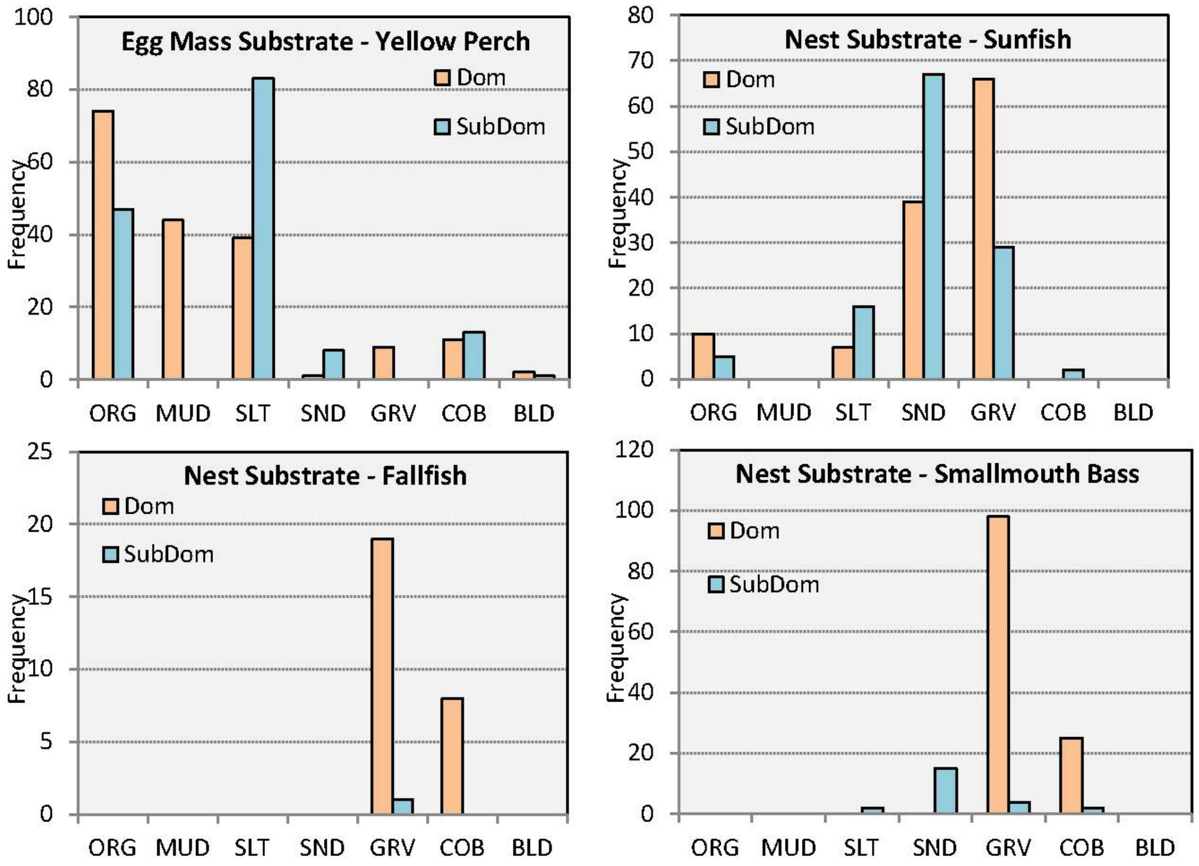


Figure 5.4-1. Frequency of dominant and subdominant substrate types at spawning locations according to species. See Table 4.1-1 for substrate classes.

Figure 5.4-2. Smallmouth Bass nest showing cleaned gravel substrate and proximal cover.

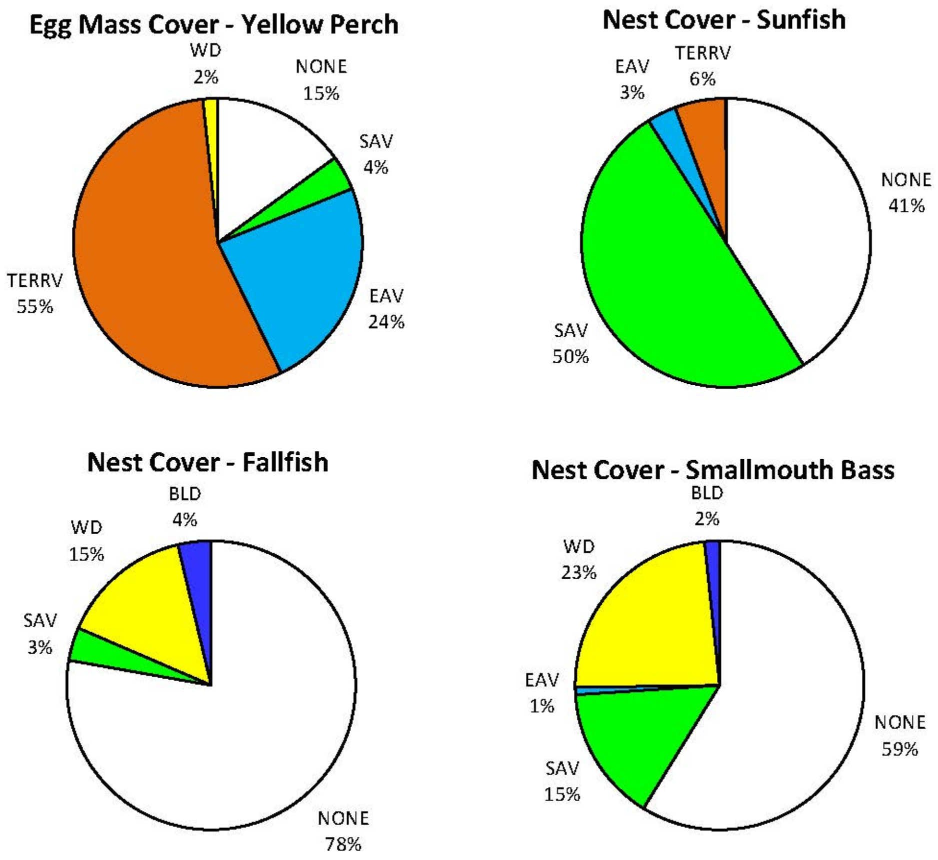


Figure 5.4-3. Percentage composition of dominant cover types within 10 ft of spawning observations according to species. See Table 4.1-1 for cover type definitions.

Time series data of percent fines was recorded at 19 Smallmouth Bass nests, representing nests at all stages of reproduction. These visual estimates showed trends consistent with expectations. For example, nests that were originally occupied by an adult but were subsequently found to be vacant, showed a low percentage of fines on the initial visit, but increased proportions of fines on subsequent visits (Figure 5.4-4, top left figure). In contrast, nests that were continually occupied by adults (even without eggs) generally remained clear of fines (≤20%) or showed only a slight increase (upper right figure). The three nests that were originally observed to contain adult bass but were last seen with deposited eggs showed very low or decreasing amounts of fines, ranging from 5-15% on the final visit (lower left figure). Finally, most nests that progressed from adult to fry typically showed a decreasing percentage of fines (during egg or benthic fry stages) followed by an increase in fines (lower right figure). The final increase in three of the nests was likely due to the fry developing swim bladders and suspending off the bottom, at which time the adult guardian likely ceased with fanning the nest substrate. This latter increase could also be associated with the high flows that occurred throughout most of June, although nests not yet containing eggs (upper right) continued to be kept clean of silt into June, which suggests that adults at those nests remained active in nest maintenance.

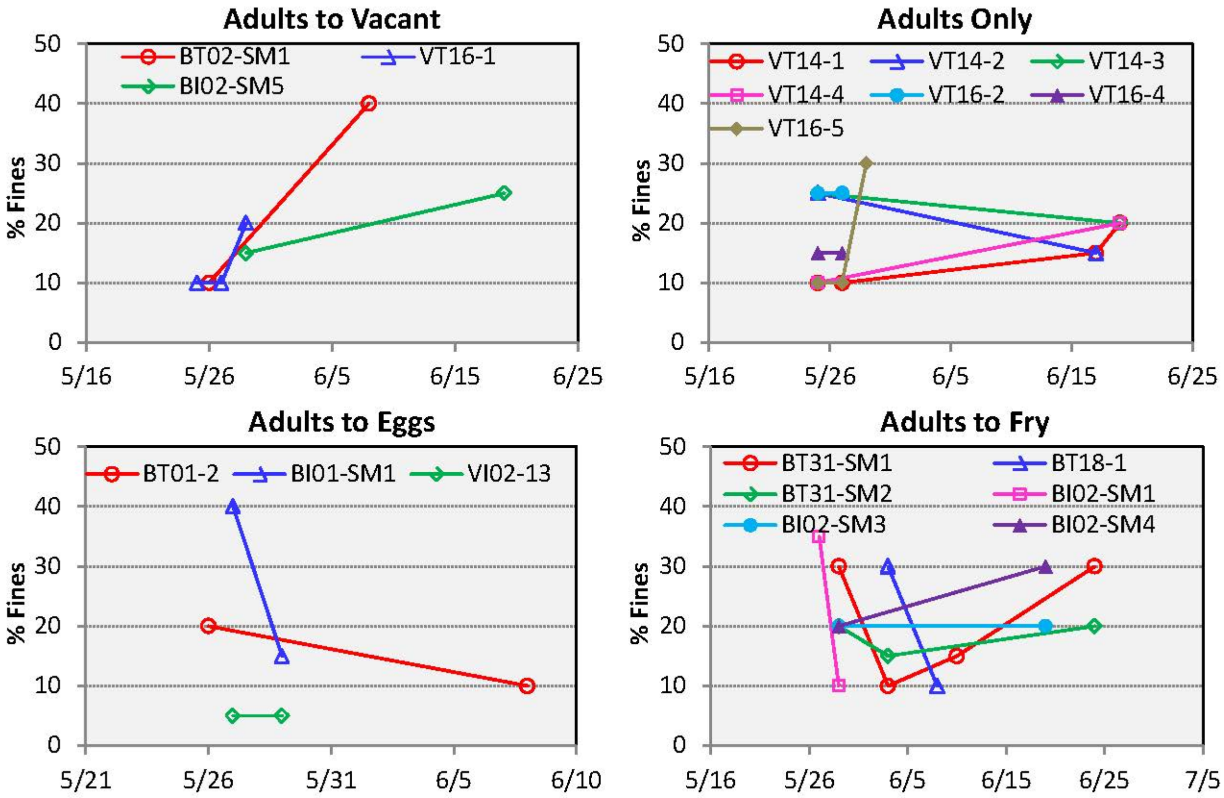


Figure 5.4-4. Changes in the percentage of fine sediments (mud, sand or silt) in individual Smallmouth Bass nests over time, according to nest development stage.

Smallmouth Bass nest WT-074 #2 was ultimately excavated 19 days after the percentage of fines was first assessed, and after the reared fry had dispersed from the nest and the nest was then found just out-of-water (Figure 5.4-5). The original, visual estimate of substrate composition was 80% gravel and 20% fines. Sieving the excavated nest materials showed a similar high proportion of larger substrate (73% gravel plus cobbles) with a lower proportion (23%) of sand and silt and minimal (4%) organic matter.

Figure 5.4-5. Images of Smallmouth Bass nest WT-074 #2 when first located on June 5 (left image) and just before substrate excavation on June 24 (right image).

As described above, repeat assessments of substrate composition were not routinely conducted for sunfish; however, substrate was visually estimated a second time for three nests followed by excavation after the second assessment (Figure 5.4-6). The two visual assessments generally produced differing estimates of substrate composition, some of which is likely due to poor water visibility throughout most of June, as well as differences in crew perceptions, despite the standardized use of a weighted scale marker (square washers in Figure 5.4-5). In terms of fine sediments, Pumpkinseed nest #37 contained approximately 20% of unspecified materials (but likely fines or organics) on the initial visit, and 25% of silt plus unspecified materials on the second visit 9 days later (Figure 5.4-6). Bluegill nest #23 was dominated by gravel according to both visual surveys, but contained 40% sand in the first assessment and 25% silt or other in the second survey. The third nest (Bluegill #20) appeared to contain at least 30% sand on the first visit but only 5% sand on the second.

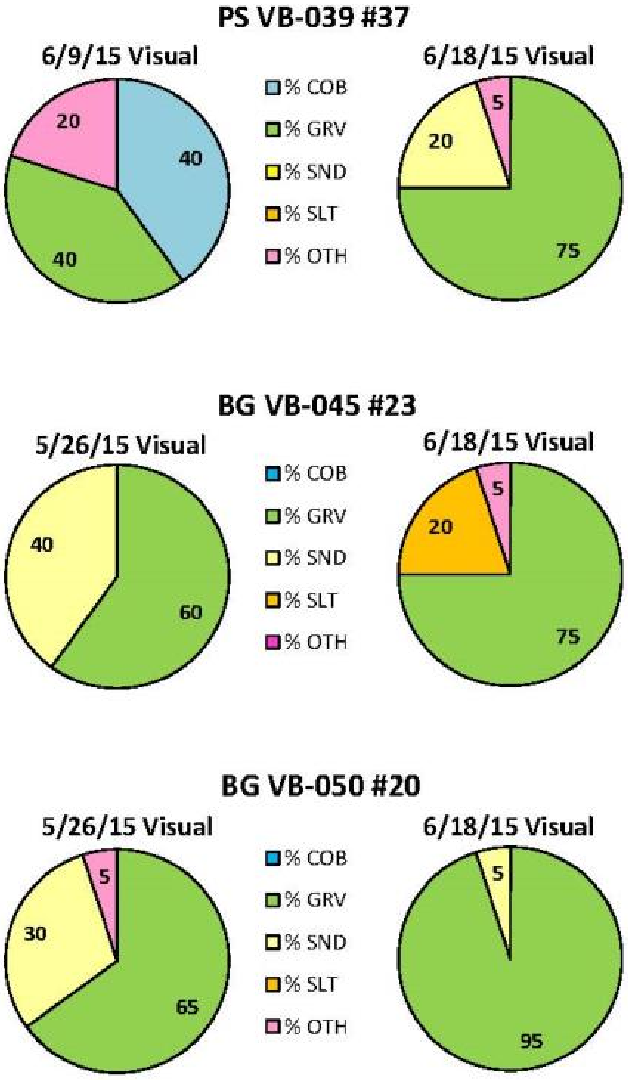


Figure 5.4-6. Visual estimates of substrate composition at Pumpkinseed (PS) and Bluegill (BG) nests.

6.0 ASSESSMENT OF PROJECT EFFECTS

Water-level fluctuations have the potential to create conditions that could limit successful reproduction of the target species through several mechanisms, including dewatering eggs or embryos of the 13 species included in these studies (White Suckers, Walleyes, Northern Pike, Chain Pickerel, Yellow Perch, Spottail Shiners, Golden Shiners, Bluegill, Pumpkinseed, Black Crappie, Largemouth Bass, Smallmouth Bass, and Fallfish). Impacts could also occur through displacement of attending adult males (bass and sunfish), who aggressively guard the nest against potential predators and may fan the nests to keep nests free of fine sediments. Excessive siltation could lead to reproductive failure through smothering of eggs or demersal fry. Finally, spawning failure could result from scouring of eggs or fry during high-flow events.

Egg-blocks were deployed in an attempt to locate and assess spawning habitat used by White Suckers and Walleye, and visual surveys were conducted to identify and assess spawning areas used by the remaining species. High flows and water clarity significantly limited the depth at which egg or nest observations could be made or repeated. This would affect the true representation of project effects as the more vulnerable sites were also the sites most commonly observed; whereas deeper and more protected nesting sites were more infrequently detected. Elevations were measured at all locations where spawning was detected (egg deposition sites or active nest sites), and depth loggers were installed proximal to each known spawning location in order to compare changes in WSEs to elevations measured at egg or nest sites throughout the course of each species' spawning period. Potential impacts to spawning success were observed to occur, or assumed to occur via analysis of logger data, whenever WSEs dewatered eggs or nests or when WSEs decreased to the extent that displacement of guarding adult males was likely.

Spawning locations were not identified for Northern Pike, Chain Pickerel, Black Crappie, or either species of shiner, although adult specimens of each species were captured by nets or angling, and larval fish of most species were captured in trawls. Very limited spawning data was collected for White Sucker and Walleye, however the two locations where White Sucker spawning was detected were in small tributaries just upstream of the project-influenced reach (no eggs were captured at downstream blocks within the project-influenced reach), and only a single Walleye egg was collected. However, field surveys were successful in locating and measuring the spawning locations (elevations and habitat characteristics) representing 838 Yellow Perch egg masses, 123 sunfish nests (Bluegill and Pumpkinseed), 26 Fallfish nests, and 79 Smallmouth Bass nests. Consequently, assessment of project effects is focused on these five species.

Detailed analysis of all spawning observations and WSE relationships in 2015 are given in Section 5.0; the following is a summary of those data. It should be considered that the spawning observations collected during the spring and early summer of 2015 represent spawning site selection under the specific flow and WSE conditions that occurred over the course of those surveys, and that each species selection of spawning sites is likely to be flexible if environmental conditions differ from 2015 conditions. Also, the reader should be reminded that the visual survey methodologies used to identify spawning locations were restricted to shallow-water habitats vulnerable to project effects due to limited water visibility; consequently the assessment of potential mortality due to low water surface elevations is likely to be overestimated.

6.1 Egg and Nest Dewatering or Adult Abandonment

6.1.1 Yellow Perch

Dewatered egg masses of Yellow Perch were relatively common during the initial surveys conducted in backwater habitats, which appeared to be influenced in part by the high, uncontrolled flows and high WSEs that occurred throughout the study area in the weeks preceding the first backwater surveys (Figure 5.1-1). Yellow Perch seem to be highly opportunistic in their spawning site selection, and choose higher elevation branches when water levels are high, but choose lower branches or deeper substrate areas when water surface elevations are low. Using highly conservative assumptions, the 2015 egg mass and water level logger WSE data suggests that as much as 71% of perch eggs may have been dewatered. Nevertheless, large numbers of perch eggs remained wetted throughout the incubation period. The relatively minor normal project-related WSE fluctuations (1.5-2 ft) generally present in backwater habitats ensures that a significant proportion of perch eggs remain wetted. WSE levels that keep the lowermost foot of riparian branches inundated are likely the most beneficial to Yellow Perch, as branches appear to be their preferred spawning habitat and likely helps to protect the egg masses from benthic predators (e.g., crayfish, suckers, bullhead, etc.) or from deposition of silt over the egg mass.

6.1.2 Bluegill and Pumpkinseed (sunfish)

Although sunfish are undoubtedly somewhat flexible in their selection of spawning areas, field crews routinely observed sunfish spawning within old nest clusters apparently used in prior years. The protected nature of backwater spawning areas and the relative stability of WSEs during the sunfish's late-spring/summer spawning period lends itself to the reuse of previous nesting areas. Overall, an estimated 23% of sunfish nests were potentially impacted by fluctuations in WSEs in 2015, mostly due to depths dropping below the assumed minimum criteria of 0.5 ft (to avoid adult displacement). Although adult displacement is likely to lead to increased mortality of eggs or fry, sunfish eggs hatch relatively quickly (approximately 3 days at 20°C, Becker, 1983). Sunfish fry also disperse from the nest soon after hatching, so adult displacement is not as likely to be a significant factor in sunfish nesting success as for bass, which require longer incubation and fry rearing times, and exhibit greater parental care. Also, displaced adult sunfish may return to the nest as water levels increase again and contribute to nest success, so long as the nest was not completely dewatered during the egg or early fry stage.

6.1.3 Fallfish

Old Fallfish nests were easily recognizable due to their large size, and like sunfish, the 2015 surveys suggested that Fallfish built new nests in the same areas each year. Because of the large size of their constructed nests (some exceed 1 ft in height), Fallfish do not appear to construct nests in very shallow water, and consequently none of the Fallfish nests assessed in impoundment tributaries appeared vulnerable to dewatering from normal project operations or high flow operations. However, the larger fluctuations in WSEs in riverine reaches, particularly at sites in close proximity to the upstream project dam, did result in observed or expected dewatering of at least five of 14 (36%) Fallfish nests. This estimate is based on the WSEs one-half ft above the base of each Fallfish nest, where eggs are deposited. It is unknown to what degree hatched fry will migrate within the nest mound, although one study reported fry movement towards the upstream side of the nest, but not higher in elevation (Maurakis and Woolcott, 1992). The 0.5 ft buffer criteria is expected to inundate, on average, 90% of the nests overall volume; however if fry occupy the uppermost regions of the nest mound the impacts could be greater than predicted.

6.1.4 Smallmouth Bass

Like sunfish, but unlike Yellow Perch or Fallfish, Smallmouth Bass exhibit parental care of eggs and fry, but over a significantly longer time period than for sunfish. Environmental conditions during spawning by Smallmouth Bass in the more dynamic riverine reaches presents challenges for this species, which typically builds nests in shallow, protected nearshore habitats that are susceptible to exposure and dewatering over an extended period of adult-dependent nest preparation, egg incubation, and early fry rearing. Nevertheless, bass spawning data from the impoundment tributary study sites suggested that normal project operations had relatively little impact on nesting success in 2015. The primary impacts to spawning in these reaches is likely due to natural high flow events that are beyond the control of normal project operations, or to special operations necessary to reduce flood-related damage. One example is the decrease in WSE of the Wilder impoundment just prior to high flows in June. Water level logger data from a study site in the lower two miles of the impoundment showed reductions in WSE on two dates just prior to high flow events that resulted in the dewatering or near dewatering of three bass nests. However, of the 31 bass nests observed in the impoundment tributary study sites, only one other nest was vulnerable to normal project-related operations.

As seen for Fallfish, Smallmouth Bass nests in the riverine reaches were more vulnerable to WSE fluctuations, where 14 of the 44 nests (32%) were subject to depths less than the 1-ft minimum criteria for adult residence (4 nests may have been fully dewatered). Although tracking the progression of individual bass nests was inhibited by high flows and poor water visibility during most of June, one of the potentially dewatered nests was a very late-spawning fish that constructed a nest at an unusually high elevation compared to other nests at that site. This choice of spawning location appeared to be influenced by the high flows that persisted over that time period, which occurred due to spill conditions at Bellows Falls dam and thus was not a project effect. This observation, as well as the numerous Yellow Perch egg masses observed to be suspended well above the water surface, illustrates that selection of spawning areas can be highly dependent upon the conditions that exist during any given year. Consequently, the 2015 dataset constitutes a year with high flows at the start of the perch and pike/pickerel spawning season and high flows during the bulk of the Smallmouth Bass spawning season, with mostly project-controlled flows during the interim Fallfish spawning and much of the later spawning by sunfish and (presumably) shiners.

6.2 Nest Siltation

Assessing changes in deposition of fines (sand or silt) over time was limited to Smallmouth Bass, whose eggs and embryos are benthic and susceptible to sedimentation for a relatively long period. Time series data of percent fines was recorded at 19 Smallmouth Bass nests, representing nests at all stages of reproduction. Comparison of visual estimates of fines followed an expected pattern with increasing fines for nests that were abandoned by adult bass, and nests with more advanced (e.g., non-benthic fry). In contrast, nests that maintained a resident adult bass, with or without the presence of eggs, remained relatively silt-free with little evidence of sedimentation.

This pattern of sedimentation is expected as a result of this species nesting behavior, including the active fanning of the nest pocket with its caudal fin, which serves to keep the eggs and/or benthic fry free of sand or silt. The efficacy of this cleaning process was demonstrated through the observation of numerous nests that were excavated through a thick silt layer to an underlying layer of clean, silt-free gravel. Under typical conditions it is highly unlikely that a nest containing a resident adult bass would accumulate enough fines to impact eggs or demersal fry, and older non-demersal fry are free of the substrate and thus not susceptible to sedimentation.

6.3 Nest Scouring

Field crews did not detect any evidence of scouring of eggs or nests due to normal project operations, whether at the mouths of impoundment tributaries or at riverine island/bar study sites. There was evidence of heavy silt deposition at some study sites associated with high flow events and uncontrolled spill, possibly associated with adult abandonment; however, those conditions were outside of the control of the projects. As noted previously, high flows and high turbidity levels throughout much of June limited the relocation and reassessment of many Smallmouth Bass and Fallfish nests in the riverine reaches where scour would most likely occur.

6.4 Project Effects Modeling

In general, normal project operations appeared to exert fewer effects on spawning within project impoundments than in the downstream riverine reaches. The presence of desiccated Yellow Perch egg masses suspended well above the surface of some backwater habitats appeared directly related to very high WSEs from uncontrolled, high flow events, and that species tendency to opportunistically spawn at whatever elevation is inundated during the moment of egg deposition. Although not observed in these studies, it is possible that Northern Pike and Chain Pickerel will also respond to periods of high, uncontrolled flow (which is common during the early-spring spawning season) by spawning in inundated fields and riparian habitats that are normally dry during periods of controlled flow (McCarraher and Thomas, 1972), although this was not observed in 2015. Late-spring and summer observations of spawning sunfish within impoundment backwater habitats did reveal some nests that appeared vulnerable to WSE fluctuations associated with normal project operations, however over 75% of observed nests appeared to maintain minimum depths of at least 0.5 ft over the nest, which was assumed to allow continued presence of guardian male sunfish and successful development of eggs and fry.

Fallfish and Smallmouth Bass also appeared to have spawned successfully at tributary study sites within the impoundment reaches, with limited evidence of nest dewatering. However, spawning sites of both species within the riverine reaches appeared to be at least partially dewatered during a portion of the spawning season at 30-40% of the observed nests, some of which were field-verified to be completely dewatered. Two bass nests were also observed to contain either eggs encased in fungus or dead fry.

The initial assessment of project effects was based on 2015 field survey data and water level logger data as discussed earlier in this report. Sites were also pre-screened for additional project effects analysis based on rating curves from the hydraulic model (Study 4 [GEI, 2016]). Rating curves at model cross sections located at or nearest to spawning sites were compared to the estimated minimum, median, and maximum WSEs for each species spawning locations found at each site. Not surprisingly, at all observed spawning sites (excluding sites 14-WT-007 - Oliverian Brook, and 14-WT-054 - Hewes Brook, both with observations located outside of the project-influenced tributary reaches), the estimated minimum water depth (1.0 ft for Smallmouth Bass, 0.5 ft for Fallfish and sunfish, and zero ft for all other target species) could be potentially dewatered under some conditions. Therefore, the WSEs of eggs or nests measured during 2015, excluding a few outlier spawning observations, were analyzed with output from the operations model to determine the frequency of potential dewatering under normal project operations and high flow operations.

6.4.1 Magnitude of Potential Dewatering

In general, the magnitude and rate of change in WSEs varies spatially within and between the impoundments and downstream reaches, as well as temporally, based on inflows and changes in project discharges. Typically, impoundment WSEs during periods of normal project operations fluctuate approximately 2.5 ft at Wilder dam, 1.8 ft at Bellows Falls dam, and 1.2 ft at Vernon dam on a daily or sub-daily basis. Fluctuations in water levels can alternately expose and inundate shallow margin habitats. In general, daily fluctuations in WSE in the three riverine reaches can be up to 5 to 6 ft just downstream of the dams during normal operations, though fluctuations are typically attenuated to 3 to 4 ft in the lower portions of riverine reaches (based on Study 5’s modeled hydrologies). Pool habitats, which represent

40 to 60 percent (by length) of aquatic habitat in the three riverine reaches (see Study 9), are less subject to streambed exposure during periods of minimum flow releases, due to their steeper streambanks and deeper habitat, than are shallower mesohabitat types such as glides and riffles. Riverine areas with expansive bar or shoal habitats, such as in the vicinity of Chase Island in the Wilder riverine reach or Stebbins Island in the Vernon riverine reach are subject to wide variations in wetted habitat area during normal Project operations. These areas are also heavily used for spawning by several species of fish as reported herein, and in Study 16 and Study 21.

In the impoundments, the majority of margin habitat along the mainstem channels are steeply sloped and mid-channel habitats are far deeper than the fluctuations in WSEs; consequently relatively little change in wetted width occurs during normal Project operations. Exceptions may occur in shallow, low-slope habitats such as those in the margins of backwaters, mid-channel island complexes, and at deltas formed at the mouths of tributaries. The change in acreage of wetted habitat from normal high water surface elevation to normal low water surface elevation was estimated for the 12 (of 41 total backwaters in the project-affected area) that were assessed for resident spawning. Percent reductions in habitat area ranged from a low of 4% in Vernon backwater 14-VB-045 to almost 90% in Wilder backwater 14-WB-016 (Table 6.4-1), with a mean change of 36% among the 12 backwaters. The larger magnitude of WSE fluctuations in the Wilder impoundment (assessed with a 3-ft WSE change, rounded up from the normal 2.5-ft operational range) is largely responsible for the high estimates of dewatered backwater habitat in that reach (averaging 55%), in comparison to the approximate 2-ft WSE fluctuations in Bellows Falls backwaters and the approximate 1-ft WSE fluctuations in Vernon backwaters, which produced estimated acreage reductions of 20% and 14%, respectively. Another factor is the relative location of backwater habitats in each impoundment. Four of the six sampled backwaters in the Wilder impoundment were located in the upper, shallower half of the impoundment. In contrast, all 13 available (and all six sampled) backwaters in both the Bellows Falls and the Vernon impoundments are located in the lower halves of each impoundment, and consequently have higher proportions of deeper water which is less subject to dewatering.

Because of the shallower nature and greater magnitude of WSE fluctuations in riverine reaches than in impoundment reaches, the associated changes in wetted area are also greater. The percent change in wetted widths in each of the three riverine reaches during normal project operations was estimated as part of the 1-D instream flow study conducted in Study 9 (analysis is ongoing at this time). Mean percent change in wetted widths varied by mesohabitat type, with the least change for riffles in the Bellows Falls riverine reach, and the largest changes for runs in Bellows Falls and Wilder riverine reaches, and riffles in the Wilder riverine reach, respectively (Table 6.4-2). Rearing or spawning by nest-guarding fish are not likely to inhabit such areas due to the regularity of dewatering, although extended periods of high flows outside of project control as a result of spring runoff or storm events can lead to egg deposition or nest building in areas that may be dewatered later when project operations return to normal.

Table 6.4-1. Change in backwater acreage under normal project operations.

Impoundment (WSE in NAVD88)	Study 14-15 Backwater Site ID	Acres @ High WSE	Acres @ Low WSE	% Reduction in Acres
Wilder High WSE: 384.0' Low WSE: 381.0' Diff: 3'	14-WB-012	34.25	25.26	26%
	14-WB-016	6.33	0.67	89%
	14-WB-028	33.25	13.27	60%
	14-WB-032	34.06	20.29	40%
	14-WB-051	5.08	1.06	79%
	14-WB-060	22.38	14.03	37%
			Average:	**55%**
Bellows Falls High WSE: 291.0' Low WSE: 289.0' Diff: 2'	14-BB-019	29.58	25.69	13%
	14-BB-030	170.7	121.19	29%
	14-BB-033	76.44	62.03	19%
			Average:	**20%**
Vernon High WSE: 219.0' Low WSE: 218.0' Diff: 1'	14-BB-039	133.66	107.37	20%
	14-VB-045	75.33	72.22	4%
	14-VB-050	256.68	211.45	18%
			Average:	**14%**

Table 6.4-2. Percentage change in riverine wetted width under normal Project operations.

Reach	Habitat Type	# Habitats	% Change in Wetted Width Under the Range of Normal Project Operations[a]		
			Min	Max	Mean
Wilder Riverine	Pool	13	5	38	16
	Glide	9	4	24	14
	Run	11	12	72	41
	Riffle	4	6	53	30
Bellows Falls Riverine	Pool	6	5	21	11
	Glide	7	5	49	23
	Run	4	27	72	47
	Riffle	2	4	9	7
Vernon Riverine	Pool	4	2	18	12
	Glide	3	3	37	15
	Run	6	9	61	27
	Riffle	0	-	-	-

a. Data from Study 9, unpublished at this time.

For 2015 observed spawning, the periodicity used to assess the magnitude of potential dewatering was species-specific and based on the timing of spawning observations (Table 6.4-3). The minimum, median, and maximum WSEs evaluated by operations model data were also species-specific and site-specific (see Section 4.2.4), and are listed in Table 6.4-4. The operations model was used to calculate the percent of days within the appropriate spawning period when WSEs dropped below these elevation criteria for at least one hour, according to species and study site for each of the five annual hydrologies included in the operations model. The operations model was also used to distinguish between days when project operations were conducted under normal conditions, versus days when special high flow operations procedures were initiated in advance of major flow events (Section 4.4.2). These special operations involved lowering impoundment elevations below normal ranges to minimize downstream flooding by temporarily increasing storage capacity.

Table 6.4-3. Spawning periodicity by species and reach, 2015.

Spawning Periodicity:	**Impoundment & Riverine Reaches**		
	Wilder	**Bellows**	**Vernon**
Yellow Perch (YP):	4/20 - 5/15	4/15 - 5/10	4/15 - 5/10
Walleye (WAL):	N/A	4/15 - 5/10[a]	N/A
White Sucker (SKR):	N/A	N/A[b]	N/A
Sunfish (SF):	5/20 - 6/30	5/15 - 6/20	5/15 - 6/20
Fallfish (FF):	5/15 - 6/5	5/10 - 5/30	5/10 - 5/30
Smallmouth Bass (SB):	5/20 - 6/20	5/20 - 6/20	5/20 - 6/20

a. Walleye spawning only detected in lower Cold River

b. No white sucker eggs found in project-influenced tributary reaches

Table 6.4-4. Elevation criteria used for operations modeling to assess project effects on spawning success under different hydrologies. See Section 4.2.4 for criteria definitions. WSEs are in NAVD88.

Species	**Site ID**	**Site Name**	**HEC-RAS Node #**	**Minimum Egg/Nest Elev [a]**	**Median Egg/Nest Elev [a]**	**Maximum Egg/Nest Elev [a]**
Yellow Perch	14-WB-012	Oxbow BW	1141	383.9	385.1	386.7
	14-WB-016	Waits BW	1124	382.6	384.7	385.0
	14-WB-028	Jacobs BW	1057	382.0	382.8	384.6
	14-WB-032	unnamed BW	1039	382.5	382.9	383.2
	14-WB-051	Zebedee BW	979	382.5	383.5	383.9
	14-WB-060	unnamed BW	951	379.5	381.8	383.8
	14-BB-019	Black BW	571	288.4	389.0	289.6
	14-BB-030	Williams BW	534	287.7	288.8	289.2
	14-BB-033	unnamed BW	522	287.4	288.1	288.9
	14-VB-039	Retreat Meadows	185	216.1	218.3	219.2
	14-VB-045	unnamed BW	120	217.5	218.0	218.8
	14-VB-050	unnamed BW	81	216.4	217.3	217.6
Sunfish	14-WB-012	Oxbow BW	1141	383.4	383.5	383.6

Species	Site ID	Site Name	HEC-RAS Node #	Minimum Egg/Nest Elev [a]	Median Egg/Nest Elev [a]	Maximum Egg/Nest Elev [a]
	14-WB-032	unnamed BW	1039	382.4	382.5	382.7
	14-BB-019	Black BW	571	287.8	289.0	289.6
	14-BB-030	Williams BW	534	289.0	289.2	289.3
	14-BB-033	unnamed BW	522	288.6	289.0	289.2
	14-VB-039	Retreat Meadows	185	217.0	217.3	217.5
	14-VB-045	unnamed BW	120	217.5	218.0	218.5
	14-VB-050	unnamed BW	81	215.6	216.8	218.2
Fallfish	15-WI-004	Fallfish nest	770	305.4	306.3	307.1
	15-WI-005	Hart Island	750	301.7	301.7	301.7
	15-WI-006	Fallfish nest	714	293.7	293.7	293.7
	15-WI-007	Chase Island	706	292.3	292.3	292.3
	14-BT-013	Little Sugar River	596	287.6	287.9	288.2
	14-BT-018	Black River	571	287.1	287.6	289.0
	14-BT-031	Williams River	534	286.3	286.9	287.5
	15-BI-001	Saxtons R bar	497	222.4	222.4	222.4
	15-BI-003	Dunshee Island	436	215.4	217.3	218.4
	15-VI-002	Stebbins Island	124 VR	180.9	181.2	181.4
Small-mouth Bass	14-WT-010	unnamed trib	1150	381.7	383.5	383.9
	14-WT-058	Ompompanoosuc	955	378.7	380.2	380.6
	14-WT-074	Mink Brook	899	380.5	381.9	382.3
	15-WI-003	Burnap's Island	806	316.0	316.0	316.0
	15-WI-004	Fallfish nest	770	304.1	304.4	304.8
	15-WI-005	Hart Island	750	297.1	297.9	299.4
	15-WI-007	Chase Island	706	289.7	291.9	295.0
	14-BT-002	Sugar River	666	287.5	289.2	290.3
	14-BT-001	Jarvis Island	633	287.1	288.0	288.7
	14-BT-018	Black River	571	289.0	289.0	289.0
	14-BT-031	Williams River	534	287.9	288.8	289.8
	15-BI-001	Saxtons R bar	497	224.0	224.1	224.2
	15-BI-002	unnamed island	447	218.9	219.6	220.0
	15-BI-003	Dunshee Island	436	216.0	216.6	217.9
	14-VT-014	Aldrick Brook	397	214.7	216.1	218.3
	14-VT-016	Mill Brook	387	214.9	216.7	217.3
	15-VI-002	Stebbins Island	124 VR	180.1	181.2	182.0

a. includes 0.5 ft buffer over base of sunfish and fallfish nests, 1 ft over bass nests

It is important to again note that this analysis compares elevations of spawning sites in 2015 with historical dam WSEs that occurred during five prior water years, as modeled at each study site. It is highly likely that spawning site selection in a given year will be influenced by the water conditions that exist in that year at the time that spawning occurs (e.g., higher or lower WSEs than other years at any given time). Consequently, this assessment based on operations model data should only be considered a rough approximation of potential project-related impacts to spawning success.

Estimates of the proportion of spawning periods when WSEs dropped below these three criteria, according to species, study site, and hydrologic year, under normal and special operating conditions, are given in Appendix F (filed separately in Excel format). Mean proportions under normal operating conditions, averaged over all study sites within a given reach and habitat type, are shown in Table 6.4-5 and Figure 6.4-1. A consistent pattern among all species and habitat types is the higher proportion of spawning days when WSEs drop below the study criteria used in this analysis in the Wilder reaches (both impoundment and riverine) than in the Bellows Falls or Vernon project-affected reaches. In most cases the Bellows Falls proportions are similar to, or somewhat higher than proportions in the Vernon reaches. For Smallmouth Bass and Fallfish, which spawn in both impoundment and riverine reaches, the proportions of days with below criteria WSEs are considerably higher in the riverine habitats (island/bars) than in the impoundment habitats (tributaries). These general patterns are consistent with results from the 2015 data described in Section 5.0.

Looking at the results on a per-species basis (Table 6.4-5, Figure 6.4-1), modeling results for Yellow Perch over the five hydrologic years suggest that WSEs rarely drop below the upper 50% of egg masses (using the median elevation criteria) in Bellows Falls and Vernon backwaters, and typically (0-21% of days) don’t drop much below the highest egg masses (using the maximum criteria). In contrast, WSEs may drop below the median egg mass elevation on 33-62% of days in the Yellow Perch spawning period in Wilder backwaters, and may even drop below the lowermost egg masses (using the minimum criteria) observed in 2015 on 8-27% of days. Comparing the model-based results for normal operations versus for special operations (Appendix F) reveals that many of the days (often more than 50%) when Wilder backwater WSEs drop below criteria occur just before or during high flow events when the impoundment WSE is dropped to lower elevations in anticipation of high inflows.

Modeling results for sunfish also show the highest proportion of below criteria WSEs in the Wilder backwaters, with intermediate proportions in Bellows Falls and the lowest proportions in Vernon backwaters (Table 6.4-5, Figure 6.4-1). WSEs drop below median spawning elevations an estimated 33-64% of sunfish spawning days in the Wilder reach, versus 2-22% in Bellows Falls backwaters, and 1-5% of days in Vernon backwaters. WSEs drop below the lowest observed nest elevations in 8-27% of days in Wilder backwaters, 0-10% of days in Bellows Falls backwaters, but do not drop below the minimum elevation criteria on any days in Vernon backwaters. Inspection of special operations criteria does not show any effect on sunfish nests, e.g., none of the below criteria WSEs are due to special operations (Appendix F).

WSEs modeled at Fallfish nest sites are highly skewed by island/bar habitats in close proximity to project dams. In the Wilder riverine reach, an average of 31-61% of Fallfish spawning days may show WSEs below the minimum, median, and maximum observed nest elevations at all island/bar habitats combined (Table 6.4-5, Figure 6.4-1), however these proportions are dominated by the upper two study sites (WI-004 and WI-005, Hart Island), whereas proportions in the downstream riverine sites (WI-006 and WI-007, Chase Island) are estimated to be less than 10% except in one modeled year (Appendix F). Fallfish proportions were not influenced by actions associated with special operations.

Tributary study sites showed relatively similar results for Smallmouth Bass spawning in each of the three impoundment reaches, with slightly higher proportions of WSEs exceeding median or maximum criteria in the Wilder tributary sites than in Bellows Falls or Vernon sites (Table 6.4-5, Figure 6.4-1). Mean proportions ranged from 11% to 41% for the median elevation criteria at Wilder locations, but were mostly between 30-40% using the maximum criteria. Comparative proportions for median elevation criteria remained below 10% in the Bellows Falls tributary sites, and ranged from 11-36% using the maximum elevation criteria. None of the modeled WSEs fell below any of the three elevation criteria at Vernon tributary sites. Elevation criteria were exceeded more frequently at the riverine island/bar study sites in all three reaches, particularly at Wilder study sites where WSEs dropped below median criteria an average of 39-54% of days, versus 1-34% of days at Bellows Falls study sites and 13-34% of days at Vernon sites. More importantly, modeling results suggest that WSEs may drop below the lowest bass nests on 40-50% of days in the Wilder riverine reach, whereas this criteria was rarely exceeded in either the Bellows Falls or Vernon island/bar study sites.

As was noted above for Fallfish, the high proportion of days when WSE criteria were exceeded for Smallmouth Bass was largely due to the island habitats closest to Wilder Dam, where up to 100% of days were estimated to dewater one half of the bass nests, versus 0-25% of days in the islands nearer the bottom of the reach (Appendix F). Although assessment of special operations actions did show that some of the criteria proportions were due to greater-than-normal reductions in WSEs (as was noted in 2015, Figure 5.3-12), such effects were generally minor and most evident at the Chase Island study site (Appendix F).

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Table 6.4-5. Average proportion of days WSEs drop below specified spawning elevation criteria according to species spawning periodicity, reach/habitat type, and modeled hydrologic year[1].

		DRIER <						**OPERATIONS UNDER NORMAL CONDITIONS (from Operations Model)**								**>WETTER**
		1992			**1989**			**1994**			**2007**			**1990**		
Species	**Reach/ Habitat Type Averages**	% Days Below Min.	% Days Below Median	% Days Below Max.	% Days Below Min.	% Days Below Median	% Days Below Max.	% Days Below Min.	% Days Below Median	% Days Below Max.	% Days Below Min.	% Days Below Median	% Days Below Max.	% Days Below Min.	% Days Below Median	% Days Below Max.
Yellow Perch	Wilder BWs	10%	45%	77%	8%	33%	69%	21%	53%	83%	21%	42%	65%	27%	62%	90%
	Bellows BWs	0%	0%	4%	0%	4%	13%	0%	5%	15%	0%	3%	8%	0%	0%	0%
	Vernon BWs	0%	0%	3%	0%	0%	0%	0%	5%	10%	0%	0%	8%	0%	1%	21%
Sunfish	Wilder BWs	62%	64%	70%	42%	50%	61%	26%	33%	45%	26%	43%	49%	32%	37%	42%
	Bellows BWs	10%	22%	47%	8%	17%	35%	0%	2%	12%	0%	23%	42%	6%	14%	31%
	Vernon BWs	0%	1%	25%	0%	5%	27%	0%	1%	14%	0%	4%	19%	0%	5%	23%
Fallfish	Wilder Islands	61%	61%	61%	33%	34%	34%	40%	40%	42%	35%	35%	36%	31%	32%	32%
	Bellows Tribs	0%	0%	5%	0%	0%	0%	0%	0%	2%	0%	0%	3%	0%	0%	0%
	Bellows Islands	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Vernon Islands	10%	14%	38%	0%	0%	0%	0%	5%	10%	0%	5%	5%	0%	0%	5%
Smallmouth Bass	Wilder Tribs	6%	41%	46%	0%	22%	35%	2%	11%	31%	2%	20%	31%	0%	19%	31%
	Bellows Tribs	4%	7%	36%	3%	6%	25%	0%	0%	11%	0%	6%	29%	2%	5%	20%
	Vernon Tribs	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Wilder Islands	48%	54%	79%	44%	50%	74%	38%	39%	64%	38%	48%	70%	40%	45%	69%
	Bellows Islands	5%	34%	46%	4%	22%	29%	0%	1%	6%	0%	29%	34%	4%	15%	25%
	Vernon Islands	6%	34%	78%	0%	16%	47%	0%	9%	28%	0%	22%	59%	6%	13%	47%

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[1] See Revised Appendix F (filed separately in Excel format) for site-specific estimates under both normal project operations and high flow operations.

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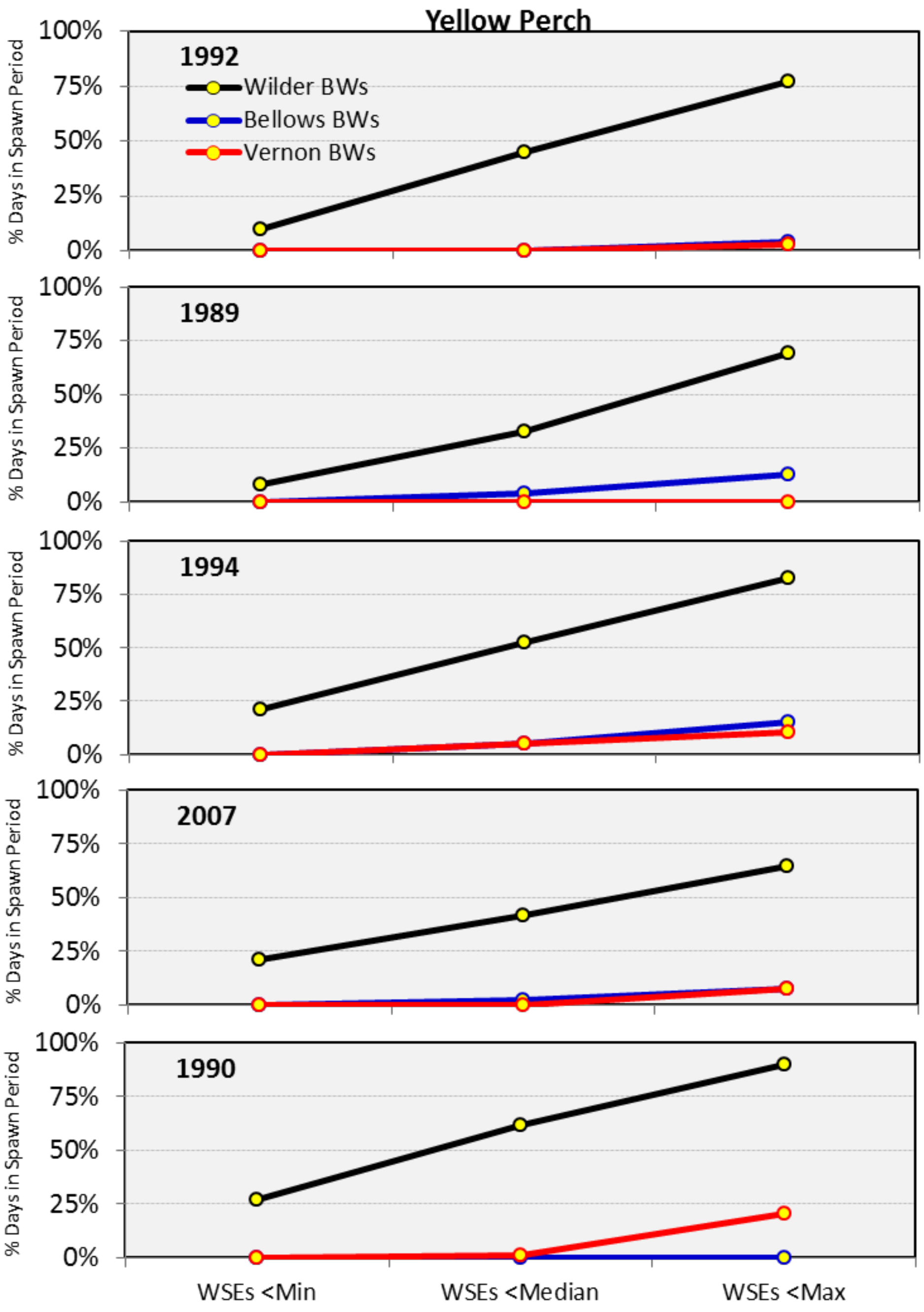

Figure 6.4-1. Mean proportion of days within the spawning period that WSEs dropped below minimum, median, and maximum spawning elevation criteria according to species, habitat type and hydrologic year.

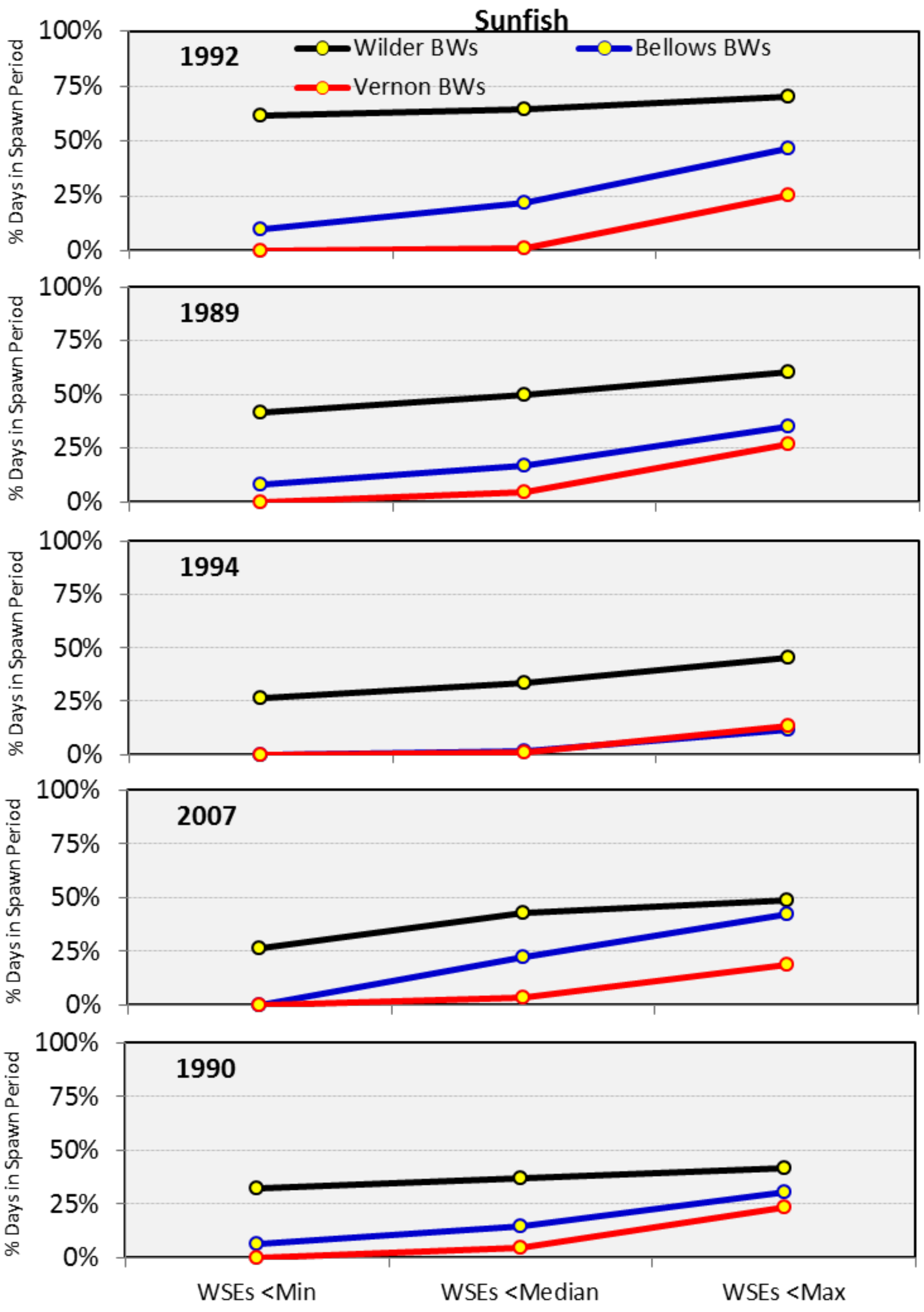

Figure 6.4-1 (continued).

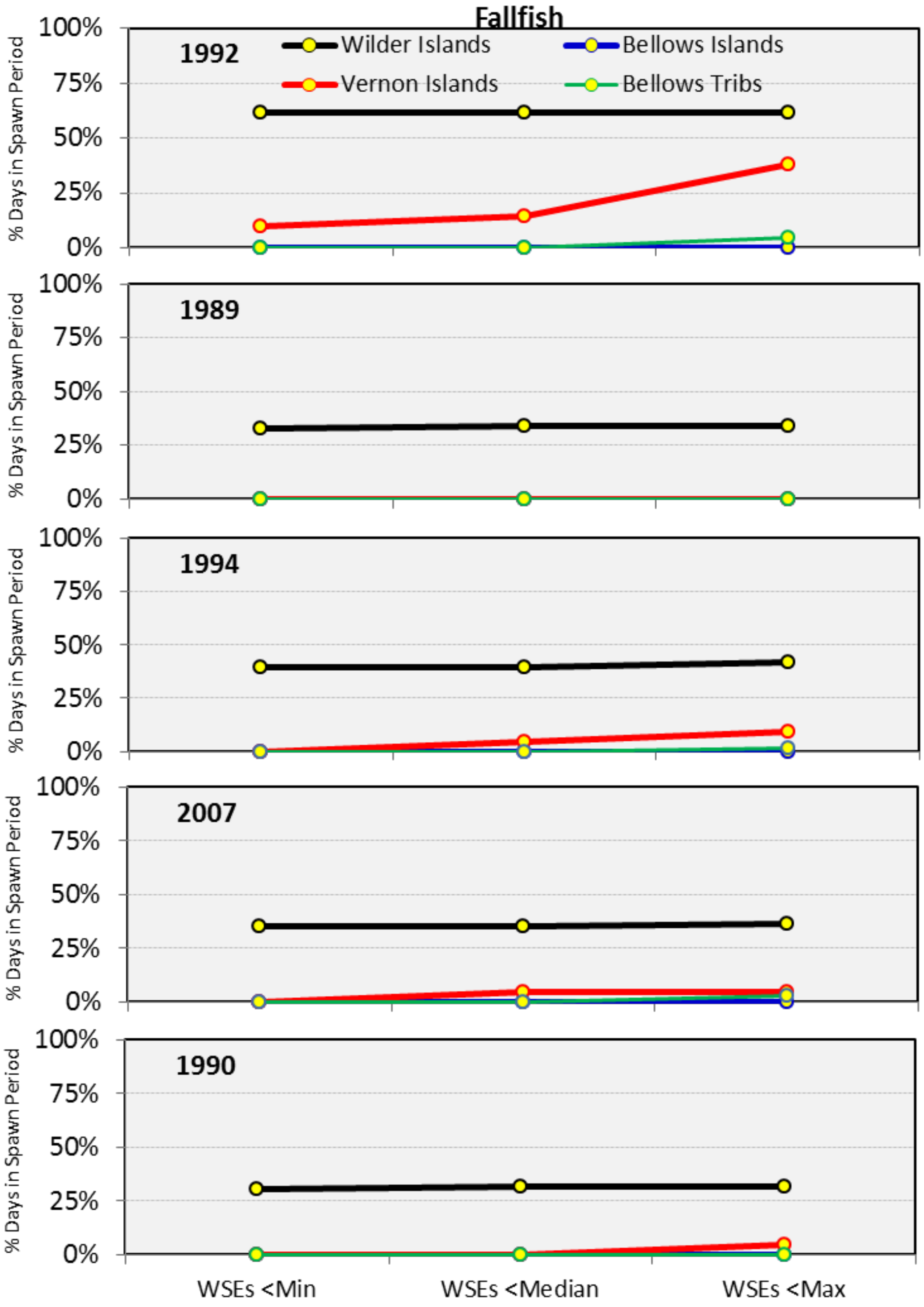

Figure 6.4-1 Revised (continued).

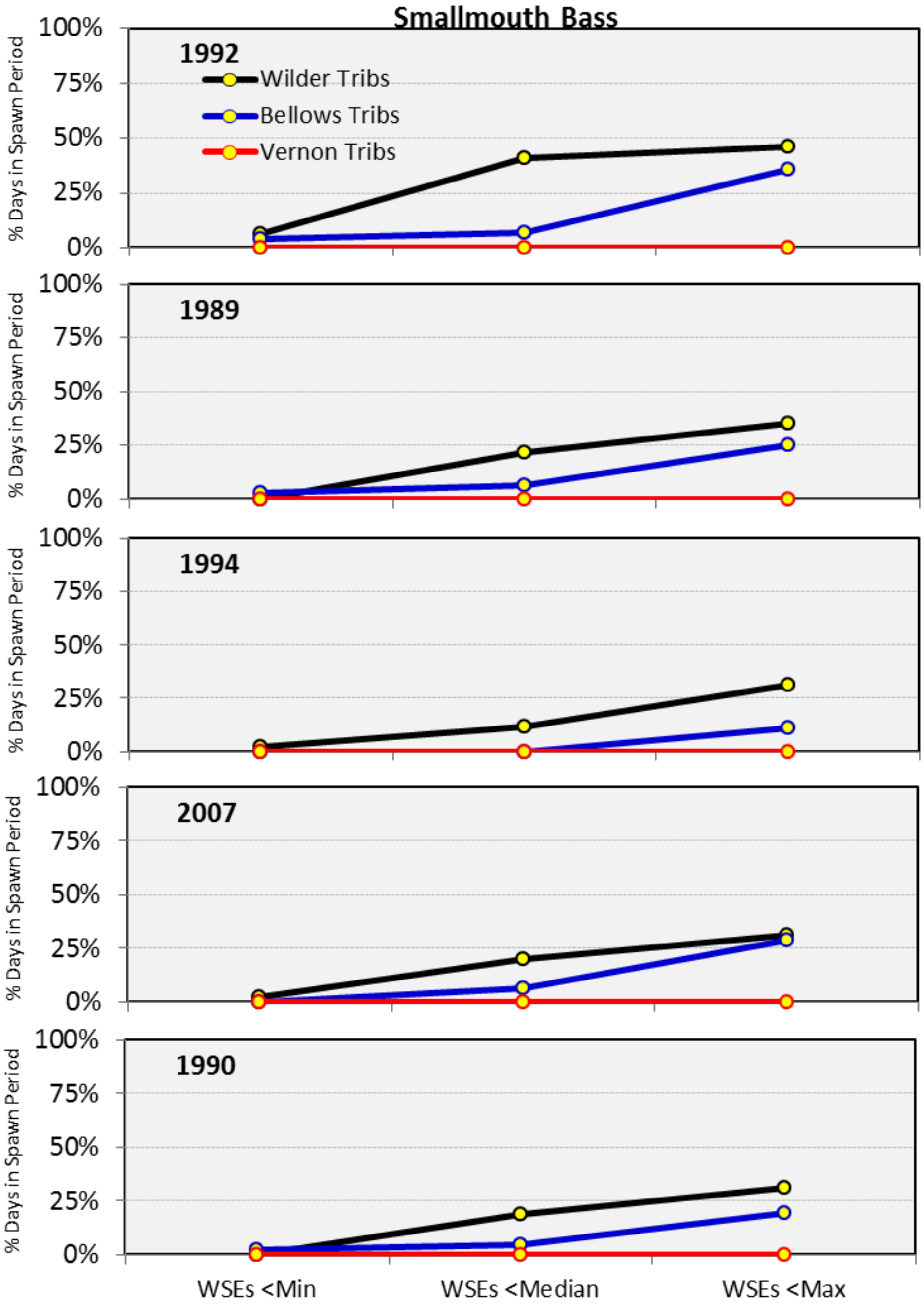

Figure 6.4-1 (continued).

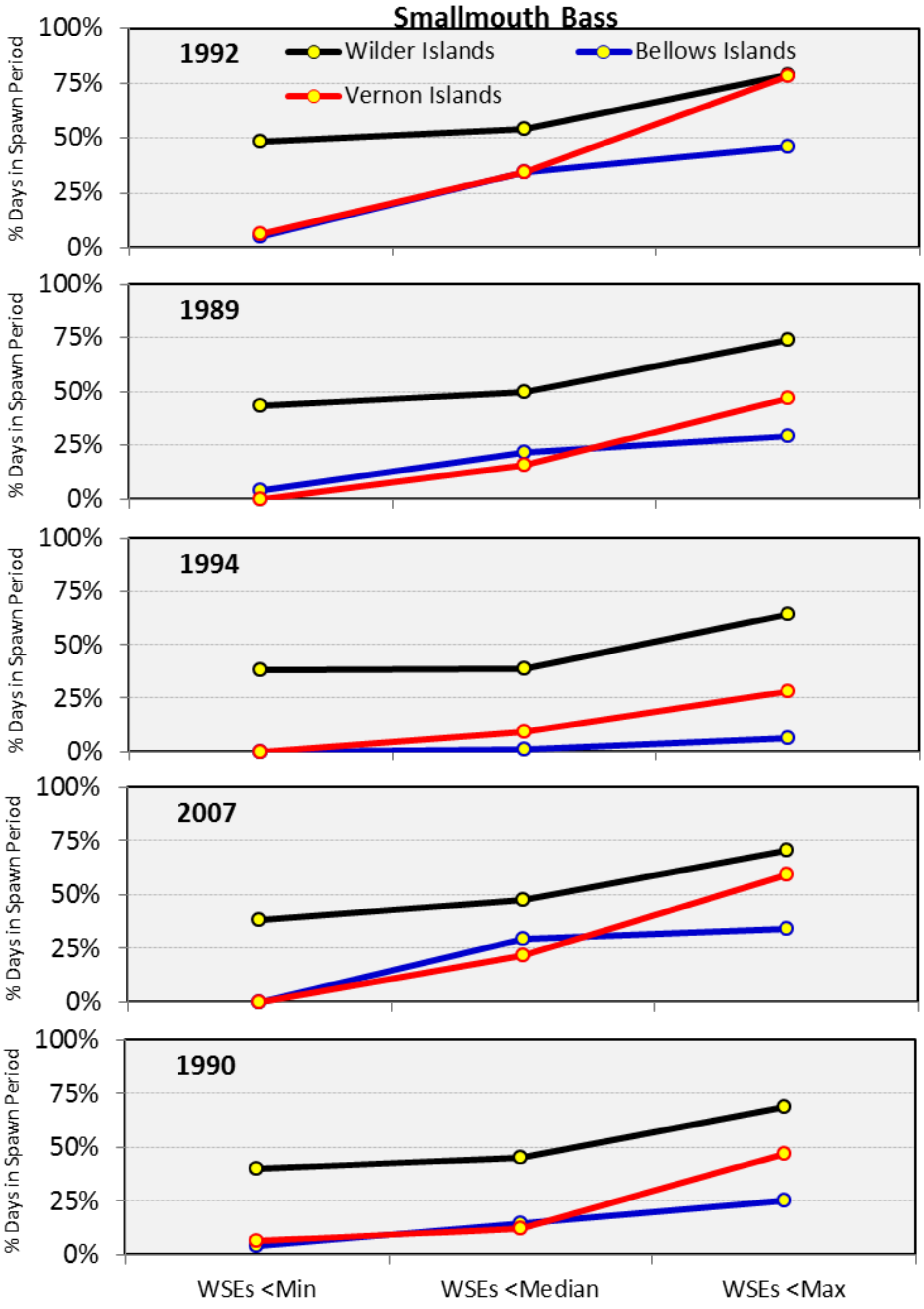

Figure 6.4-1 (continued).

7.0 STUDY CONCLUSIONS

Comparison of species spawning locations with WSEs measured in 2015 revealed some species and habitats appear to be relatively unaffected and others that appear to be regularly susceptible to dewatering of eggs or nests. Many of the dewatering events in impoundments appeared to be associated with high flow events either through spawning at particularly high WSEs (e.g., early season Yellow Perch egg masses), or through association with special operations procedures which drew dam WSEs below normal minimums (e.g., Smallmouth Bass nests at lower impoundment tributary sites).

Overall, the 2015 data suggested that 0-100% (overall 71%) of perch egg masses may have been dewatered in project-affected backwater habitats, along with 0-30% (overall 23%) of sunfish nests. Impoundment spawning by Fallfish and Smallmouth Bass were less impacted, with 0% of Fallfish nests and 13% of bass nests subject to dewatering or insufficient water depths. Dewatering events appear to be most notable in riverine reaches, particularly in areas proximal to the upstream dams. In riverine reaches, 36% of Fallfish nests and 32% of Smallmouth Bass nests were vulnerable to project-related WSE fluctuations in 2015.

Comparison of elevations selected by spawning fish in 2015 with predicted WSEs during five different hydrologic years showed similar patterns, with greater frequency of egg or nest dewatering during normal operations or high flow operations in the Wilder impoundment than in the Bellows Falls or Vernon impoundments, and greater proportions of dewatering events in riverine habitats than in impoundment habitats.

Yellow Perch

The estimated mean proportion of days in Wilder backwater habitats over the Yellow Perch spawning season (lasting 26 days) when WSEs dropped below the median spawning elevation criteria, or the elevation where one-half of the 2015 egg mass observations were lower (deeper) and one-half were higher (shallower), ranged from 33% to 62% over each of the five modeled hydrologic years. The comparative proportions for Yellow Perch spawning in Bellows Falls and Vernon backwater habitats ranged from 0% to 5% of days. Despite the high proportion of spawning days when WSEs exceeded spawning WSE criteria, Yellow Perch appear to remain at high abundance in all project reaches (e.g., first in abundance in the Wilder impoundment, Study 10 [Normandeau, 2016b]), and consequently the population of Yellow Perch does not appear to be adversely affected by either normal project operations or high flow operations.

Yellow Perch appear to be highly opportunistic spawners and deposit their eggs over a wide variety of elevations and substrate types. WSE levels that keep the lowermost foot of riparian branches inundated may be the most beneficial to Yellow Perch, as branches appear to be their preferred spawning habitat and likely helps to protect the egg masses from benthic predators (e.g., crayfish, suckers, bullhead, etc.) or from deposition of silt over the egg mass. However, it is also likely that existing branch elevations are determined in part by the current range of normal WSE fluctuations, and changes that produce more consistent inundation of branches may lead to decomposition of such branches and a return to a state of diurnal inundation of terrestrial vegetation.

Sunfish

For sunfish, estimated WSEs dropped below the median elevation criteria in Wilder backwaters over the 40-day spawning period for an average of 33% to 64% of days, depending on the modeled hydrologic year. In comparison, WSEs below the median elevation were estimated to occur an average of 2% to 22% of days in Bellows Falls backwaters, and an average of 1% to 5% of days in Vernon backwaters. It is likely that the short duration of sunfish egg incubation and nest-dependent fry rearing limits the effects of low impoundment elevations for these species, which appear to remain abundant in most backwater habitats.

Although sunfish were frequently observed to spawn in relatively discrete clusters, and often appeared to clean out and spawn in old nests from prior years, most backwaters contained an abundance of shallow, low-sloped margin habitat that was vegetated and appeared to provide suitable spawning habitat.

Fallfish

Fallfish nests associated with impoundment tributaries were only observed in the Bellows Falls impoundment, where WSEs in 0% of days over the 21-day spawning period were estimated to drop below median nest elevations in each of the five modeled hydrologic years. In contrast, estimated WSEs in riverine island/bar habitats were estimated to drop below median elevations for an average of 32% to 61% of days in the Wilder riverine reach. No Fallfish nests were predicted to be dewatered in the Bellows Falls riverine reach, and only 0% to 14% of days in the Vernon riverine reach were estimated to drop below median spawning elevations, although nest dewatering was evident in 2015. Because the Turners Falls impoundment downstream of the Vernon riverine reach appears to contain few larger tributaries or island-related gravel bars suitable for Fallfish nesting, continued exposure of Fallfish spawning habitat at Stebbins Island could have an effect on successful recruitment of this species between Vernon and Turners Falls dams. Despite these potential effects, Fallfish were among the top four most abundant species in five of the six project reaches according to Study 10 (Normandeau 2016b), with the exception being in the Vernon riverine reach.

Unlike the preceding two species, Fallfish have fairly rigid spawning requirements, particularly in relation to the availability of appropriately sized gravel and small cobbles that the adult fish can use to construct their nests. Nests also require water currents to ensure intra-gravel flow for the developing eggs and larvae (see Appendix A). In the riverine reaches, many of the available gravel bars that remain wetted and flowing at low flows are subject to high velocities during peaking flows, which may limit the ability of adult fish to construct nests in those locations. Perhaps for these reasons most of the Fallfish nests observed in the riverine reaches were generally located nearer the bank rather than in mid-channel areas. For Fallfish residing in impoundments, most spawning was observed in larger tributaries.

Smallmouth Bass

Smallmouth Bass nests were likewise less susceptible to dewatering in tributaries to the impoundments compared to riverine habitats, especially in the Bellows Falls and Vernon impoundments. In the Wilder impoundment, estimated WSEs over the five years of model data dropped below median nest elevations an average of 11% to 41% of days in the 32-day spawning period. One half of Smallmouth Bass nests were estimated to be susceptible to dewatering for less than 10% of spawning days in all years in the Bellows Falls impoundment, and were estimated to fall below the median spawning elevation 0% of days in Vernon tributary sites. Potential for dewatering was more frequent in the three riverine reaches, where WSEs were estimated to drop below median spawning elevations for an average of 39% to 54% of days in Wilder island/bar habitats. Estimates for Bellows Falls island/bar habitats were lowest at an average of 1% to 34% and intermediate at 9% to 34% of days in the Vernon riverine reach. As noted above, the riverine estimates are inflated by high proportions in the island/bar habitats closer to the project dams, whereas habitats near the downstream end of the Bellows Falls and Wilder riverine reaches generally showed lower estimated proportions of WSEs capable of dewatering bass nests.

In contrast to Fallfish, Smallmouth Bass are capable of spawning in protected eddies with slower water and do not require large quantities of clean gravel for successful spawning (e.g., they can excavate through thin layers of fines - see Figures 5.3-10 and 5.4-2); consequently there is likely more suitable habitat for bass spawning below project dams than for Fallfish. Although observed and potential effects on Smallmouth Bass are most apparent in the three riverine reaches, this species made up 17% to 30% of all fish captures in the three reaches in 2015, and were either first or second in abundance in each reach (Study 10 [Normandeau, 2016b]). These relatively robust fish composition percentages suggest that Smallmouth Bass are capable of maintaining significant abundance even in the more fluctuating riverine environments, whether due to successful riverine spawning or due to immigration from downstream impoundments. Large woody debris or other large instream structures were also found to be important features in riverine bass nests (Figures 5.3-10 and 5.4-2), likely due in part to the structures' effects on reducing velocities over the downstream nests.

For Smallmouth Bass in impoundment reaches, many of the observed bass nests occurred within the shallow, gravel-dominated deltas formed at tributary mouths. Because much of the mainstem habitat in impoundments consists of steeply sloped banks with fine substrates, the tributary deltas appeared to be productive locations for spawning bass, particularly on the downstream side of the main delta (Figure 5.3-5, upper image).

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APPENDIX A

Spawning Habitat Characteristics of Target Species

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Spawning Habitat Characteristics for Target Species

*** Peak** - if not specified in document, peak defined as range in means from multiple locations/years, or derived from HSC curves as suitabilities >0.5*

Species Group	Species	Periodicity Range	Periodicity Peak	W Temps °C Range	W Temps °C Peak	Velocity fps Range	Velocity fps Peak	Depth ft Range	Depth ft Peak	Substrate Type in Range	Substrate Type in Peak	Instream Cover	Data Location	Source Citation
	White Sucker	**Apr-June**	**April to May**	**6-18**	**9-17**	**<3**	**0.5-2**	**0.25-3.3**	**0.8-2.0**	**sand, gravel, rock**	**gravel**	**none**		**Summary of Information Listed Below**
		mid-May to early-June	-	-	-	-	-	-	-	-	-	-	Muskellunge Lake, WI	Spoor 1938 (only noted as a source of lake spawning observations)
		late-Mar to mid-June	-	-	-	-	-	-	-	-	-	-	inlets to NY lakes	various cited in Raney & Webster 1942
		March-mid May	-	6+	-	-	-	-	-	-	-	-	St.John R, NB	Doherty et al. 2010
		-	-	-	-	-	-	-	-	-	boulders	-	trib to Gouin Res, Quebec	Dion et al. 1994
		mid-Apr to	late-Apr	6.2-16.8	15.2-16.8	-	-	<3.28	-	sand, gravel, rock	-	-	Jack Lake trib, ON	Corbett & Powles 1983
		mid-April to	late-Apr	3.5-16.6	8.8-16.6	-	-	1-3.28	-	-	-	-	Apsley Cr, ON	Corbett & Powles 1986
		-	early-May to early-June	>10	-	-	-	-	-	-	gravel	-	rivers and lakes in Canada	Scott & Crossman 1998
		March to mid-Apr	early-Apr	11.5-13.0	-	0.16-1.77	-	0.26-1.12	-	0.08-1.54	-	-	small pond outflow, VA	McManamay et al. 2012
		early-Apr to late-May	-	-	-	-	-	-	-	-	-	-	Lake Taneycomo tribs, MO	Wakefield & Beckman 2005

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	White Sucker	-	-	10-22.5	-	1.64-1.93	-	0.66-0.82	-	-	med gravel	-	Deer Cr, IN	Curry & Spacie 1984
		early-May to early-June	late-May	-	12.2-15.5	-	-	<0.5	-	-	gravel	-	tribs to BC lakes	Geen 1958
		-	-	-	-	0.0-2.52	0.26-2.02	0.60-3.04	0.84-2.07	sand thru boulder	gravel & cobble	-	U.S rivers	Bovee 1978
		-	-	10-18	-	0.0-3.0	0.58-2.5	>0.0-2.0	0.25-1.38	0.001+	0.01-0.63	-	U.S rivers	Twomey et al. 1984
Species Group	**Species**	**Periodicity**		**W Temps °C**		**Velocity fps**		**Depth ft**		**Substrate Type in**		**Instream Cover**	**Data Location**	**Source Citation**
		Range	**Peak**	**Range**	**Peak**	**Range**	**Peak**	**Range**	**Peak**	**Range**	**Peak**			
Early-Spring Riffle and Tributary	**Walleye**	**April to May**	**April**	**4-16**	**6-12**	**<1-7**	**1-4**	**0.2-7**	**1-6**	**sand, gravel, cobble**	**gravel**	**none**		**Summary of Information Listed Below**
		-	-	-	5.0-8.9	n/a	n/a	<3.0	-	-	-	-	New York lakes	Festa et al. 1987 in Bozek et al. 2011
		-	-	2.0-9.0	4.0-6.0	n/a	n/a	-	-	-	-	-	Up Rideau Lk, ON	Environ Applications Group 1980 in Bozek et al. 2011
		-	-	-	-	n/a	n/a	0.66-3.94	-	-	-	-	5 ON lakes	W McCormick (pers comm) in Bozek et al. 2011
		-	-	7.0-10.0	-	n/a	n/a	0.82-3.28	-	-	-	-	Minesing Swamp,ON	Minor 1984 in Bozek et al. 2011
		-	-	-	-	n/a	n/a	<8.2	<3.94	-	-	-	ON lakes	Hartley & Kelso 1991 in Bozek et al. 2011

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Walleye	-	-	5.5-9.5	-	n/a	n/a	-	-	-	-	-	Lower & Upper Chemung Lk,ON	Wood 1985 in Bozek et al. 2011
		early-Apr to late-June	-	6.7-11.1	-	-	-	-	-	coarse gravel to boulder	-	-	rivers and lakes in Canada	Scott & Crossman 1998
		-	-	-	-	-	-	0.16-4.0	1.0-2.5	sand, gravel, rock	gravel	-	Lk Winnibigoshish, MN	Johnson 1961
		mid-Apr to mid-May	late-Apr	5.3-7.2	9.1-10.0	n/a	n/a	0.26-2.62	-	sand to sml boulder	6.4-149.9 (unembedded)	spawned near shoreline	Big Crooked Lk,WI	Raabe 2006 in Bozek et al. 2011
		-	-	-	7.0-10.0	n/a	n/a	<5.0	-	-	gravel, cobble, rubble	-	Gogebic Lk,MI	Eschemeyer 1950 in Bozek et al. 2011
		-	-	-	5.0-11.7	n/a	n/a	<30	-	-	-	-	Great Lakes	USFWS 1982 in Bozek et al. 2011
		-	-	2.2-15.5	5.6-7.8	n/a	n/a	0.17-2.49	-	incl emerg aquatic veg	gravel, cobble, rubble	-	Winnebago Lk region,WI	Priegel 1970 in Bozek et al. 2011
		-	-	7.8-8.9	-	n/a	n/a	-	-	-	6.4-149.9	-	Beaver Dam & Red Cedar lakes,WI	Williamson 2008 in Bozek et al. 2011
		-	-	-	7.2-11.1	n/a	n/a	-	-	-	-	-	Lk Osakis,MN	Newburg 1975 in Bozek et al. 2011
		-	-	-	7.8	n/a	n/a	-	-	-	-	-	Lil Cut Food Sioux Lk,MN	Johnson 1971 in Bozek et al. 2011
		-	-	5.6-11.1	6.7-8.9	n/a	n/a	-	-	-	-	-	Canadian lakes	Scott & Crossman 1973 in Bozek et al. 2011

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Walleye	-	-	-	-	n/a	n/a	-	-	incl roots & emerg aquatic veg	-	-	Tumas Lk, WI	Niemuth et al. 1972
		-	-	-	-	n/a	n/a	<3.28	-	-	-	-	Lk Francis Case,SD	Michaletz 1984 in Bozek et al. 2011
		-	-	6.0-11.0	7.0-9.0	n/a	n/a	0.16-15.08	-	-	-	-	Manitoba lakes	Newbury & Gaboury 1993 in Bozek et al. 2011
		-	-	3.3-11.1	7.2-10.0	n/a	n/a	-	-	-	-	-	Lac La Ronge,SAS	Rawson 1957 in Bozek et al. 2011
		-	-	4.4-9.0	7.2-8.9	n/a	n/a	-	-	-	-	-	Lonetree Res,CO	Weber & Imler 1974 in Bozek et al. 2011
		-	-	6.0-8.0	-	n/a	n/a	-	-	-	-	-	Alberta lakes	ADFLW 1986 in Bozek et al. 2011
		-	-	8.9-14.5	-	n/a	n/a	-	-	-	-	-	Alabama lakes	Colby et al. 1979 in Bozek et al. 2011
		-	-	2.2-15.6	-	n/a	n/a	-	-	-	-	-	misc lakes ?	Hokanson 1977 in Bozek et al. 2011
		-	-	3.3-10.0	5.6-6.7	n/a	n/a	-	-	-	-	-	misc lakes ?	Meisenheimer 1988 in Bozek et al. 2011
		April to early-May	-	4.4-13+	~8-10	-	-		-	-	-	-	Up Conn & Mississquoi Rs, NH	Gabe Gries, NHDFG, pers comm
		-	-	4.0-9.0	-	5.58-9.51	-	<5.74	-	-	-	-	Oswegatchie R, NY	LaPan & Klindt 1995 in Bozek et al. 2011
		-	-	6.1-16.6	9.0-15.0	-	-	-	-	-	-	-	Brandy Br,NY	LaPan 1992 in Bozek et al. 2011

Species		Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream	Data	Source
Group	Species	Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak	Cover	Location	Citation
	Walleye	-	mid to late-Apr	3.5-16.6	4.0-16.6	-	-	0.8-6.5	-	organics, mud, sand, gravel	gravel	-	Apsley Cr & Redmond Cr,ON	Corbett & Powles 1986
		-	-	4.0-14.0	9.0-14.0	3.28-6.56	-	-	-	-	-	-	Consecon & Melville Cr, ON	Schraeder 1980 in Bozek et al. 2011
		-	-	4.5-12.0	8.0-11.0	3.28-4.92	-	0.66-1.64	-	-	-	-	Hoople Cr & Raisin R,ON	Cholmodeley 1985 & Eckersley 1986 in Bozek et al. 2011
		-	-	-	-	0.16-0.66	-	-	-	-	-	-	Minesing, ON	Minor 1984 in Bozek et al. 2011
		-	-	-	-	<3.28	-	-	-	-	-	-	Ontario streams	Ontario MNR in Bozek et al. 2011
		-	-	-	-	-	-	<2.98	-	-	-	-	Georgian Bay tribs,ON	E. McIntyre (pers comm) in Bozek et al. 2011
		-	-	-	-	-	-	<2.49	-	-	-	-	Napanee R,ON	P. Mabee (pers comm) in Bozek et al. 2011
		-	-	-	-	-	-	0.66-6.56	-	-	-	-	Spanish R,ON	W. Selinger (pers comm) in Bozek et al. 2011
		-	-	-	-	-	-	0.66-2.95	-	-	-	-	Talbot R,ON	MacCrimmon & Skobe 1970 in Bozek et al. 2011
		-	-	-	-	-	-	1.97-2.49	-	-	-	-	Tay R,ON	W. McCormick (pers comm) in Bozek et al. 2011

Species		Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream	Data	Source
Group	Species	Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak	Cover	Location	Citation
	Walleye	-	-	3.3-10.0	8.0-9.0	-	-	-	-	-	-	-	Quinte Bay tribs,ON	Payne 1964 in Bozek et al. 2011
		-	-	4.4-10.0	6.1-8.3	-	-	-	-	-	-	-	Bobcaygeon R,ON	Bradshaw & Muir 1960,Wood 1985 in Bozek et al. 2011
		-	-	-	6.0-7.0	-	-	-	-	-	-	-	Constan Cr,ON	Anonymous 1979 in Bozek et al. 2011
		-	-	4.0-13.0	6.0-8.0	-	-	-	-	-	-	-	E Georgian Bay tribs,ON	Kujala 1979 in Bozek et al. 2011
		-	-	-	5.0-7.0	-	-	-	-	-	-	-	Madawaska R,ON	Anonymous 1979 in Bozek et al. 2011
		-	-	7.5-15.0	-	-	-	-	-	-	-	-	Nith R,ON	Timmerman 1995 in Bozek et al. 2011
		-	-	-	6.8-7.5	-	-	-	-	-	-	-	Otonabee R,ON	Maraldo 1986 in Bozek et al. 2011
		-	-	5.0-11.7	7.0-7.8	-	-	-	-	-	-	-	S Nation R,ON	Eckersley 1980 in Bozek et al. 2011
		-	-	4.0-10.0	6.0-8.0	-	-	-	-	-	-	-	Spanish R,ON	W Selinger (pers comm) in Bozek et al. 2011
		early-Apr to late-June	-	6.7-11.1	-	-	-	-	-	coarse gravel to boulder	-	-	rivers and lakes in Canada	Scott & Crossman 1998
		-	-	-	-	0.0-4.66	0.92-2.65	0.30-4.56	1.18-2.49	<0.002-20	0.002-2.5	-	MN rivers	Aadland & Kuitunen 2006

Species Group	Species	Periodicity Range	Periodicity Peak	W Temps ºC Range	W Temps ºC Peak	Velocity fps Range	Velocity fps Peak	Depth ft Range	Depth ft Peak	Substrate Type in Range	Substrate Type in Peak	Instream Cover	Data Location	Source Citation
	Walleye	-	-	7.0-8.5	-	1.15-2.46	-	0.42-2.26	-	-	0.08-10.0	-	WI stream	Stevens 1990 in Bozek et al. 2011
		-	-	-	-	-	-	<3.0	-	-	-	-	Muskegon R,MI	Eschmeyer 1950 in Bozek et al. 2011
		-	-	4.8-10.0	7.7	-	-	-	-	-	-	-	Tittabawassee R,MI	Jude 1992 in Bozek et al. 2011
		-	-	5-24	6-11	0.0-3.6	2.0-3.5	1.0-6.5	1.8-6.0	>0.002	-	-	Yellowstone & Missouri rivers	McMahon et al. 1984
		-	-	-	-	1.97-4.92	-	-	-	-	-	-	Cedar Cr,IA	Paragamian 1989 in Bozek et al. 2011
		-	-	-	8.9-13.9	0.69-1.61	-	-	-	-	-	-	Hamilton Cr, Man	Gibson & Hughes 1977 in Bozek et al. 2011
		-	-	5.0-15.0	8.3-12.2	1.41-3.80	-	1.96-20.0	2.03	incl mussel beds	gravel,rubble	-	Mississippi R, IA	Pitlo 1989 & 2002 in Bozek et al. 2011
		-	-	-	-	-	-	0.98-2.0	-	-	-	-	Hamilton Cr,MAN	Ellis & Giles 1965 in Bozek et al. 2011
		-	-	-	-	-	-	1.97	-	-	-	-	Provo R,UT	Arnold 1961 in Bozek et al. 2011
		-	-	-	-	2.3-10.5	-	0.66-2.95	-	-	-	-	Manitoba rivers	Newbury & Gaboury 1993 in Bozek et al. 2011
		-	-	-	-	-	-	-	-	-	-	-	-	Bovee 1978
		-	-	-	-	0.98-11.48	-	-	-	-	-	-	N.Amer streams	Ich Assoc 1996 in Bozek et al. 2011

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream	Data	Source
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak	Cover	Location	Citation
	Walleye	-	-	11	-	-	-	-	-	-	-	-	Cedar R,IA	Paragamian 1989 in Bozek et al. 2011
		-	-	-	-	-	-	-	-	-	gravel, cobble	-	-	Ivan et al. 2010 in Bozek et al. 2011
		-	-	-	-	-	-	-	-	-	gravel	-	-	Chalupnicki et al. 2010 in Bozek et al. 2011
		-	-	-	-	0.0-5.0	1.34-4.4	0.43-6.5	0.67-6.0	-	-	-	see above	geometric mean HSC based on Bozek et al. 2011 datasets (Normandeau pers comm)

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream	Data	Source
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak	Cover	Location	Citation
Early-Spring Backwater	**Yellow Perch**	**Apr to early-May**	**April**	**7-15**	**-**	**0.0-0.5**	**0**	**>0.5**	**1-5**	**sand, gravel, rock if veg is absent**	**rooted or woody vegetation**	**-**		**Summary of Information Listed Below**
		April	-	11-14	-	-	-		-	-	-	-	Waits R, NH	Gabe Gries, NHDFG, pers comm
		mid to late-Apr	-	-	-	-	-	5-12	-	sand, gravel, rock, or veg	-	-	Oneida Lk, NY	Clady & Hutchinson 1975
		mid-Apr to early-May	-	6.7-12.2	-	-	-	-	-	may incl open sand or gravel	rooted or woody vegetation	-	lakes in Canada	Scott & Crossman 1998
		March	-	-	-	-	-	-	-	-	-	-	Chesapeake Bay, MD	Muncy 1962

Species Group	Species	Periodicity		W Temps ºC		Velocity fps		Depth ft		Substrate Type in		Instream	Data	Source
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak	Cover	Location	Citation
	Yellow Perch	-	-	-	-	-	-	<1-46	<1-23	-	-	-	2 lakes in NE PA	Huff et al. 2004
		Apr to June	-	7-13	-	<0.16	-	3.3-12.1	-	-	-	-	U.S. lakes and rivers	Krieger et al. 1983
		-	-	-	-	0.0-0.51	0.0-0.43	0.56-5.55	0.83-4.5	mud, silt, sand	-	-	U.S. lakes and rivers	Bovee 1978
		mid-May to late-June		>6									Lk Michigan, MI	Brazo et al. 1975
		-	-	-	-	-	-	-	-	sand, gravel, cobble	cobble (if veg not present)	-	Lk Michigan, MI	Robillard & Marsden 2001
		Apr to early-May		6.7-11.1	-	-	-	-	-	sand, gravel, rock, or veg	SAV or woody debris	-	lakes in WI	Wisconsin DNR species summary
		early to late-May	-	>7.2	-	-	-	-	-	sandy w organic debris or vegetation	-	-	lakes in MN	Eddy & Underhill 1974
		Apr to May	-	12-14	-	-	-	-	-	-	-	-	Ohio?	Kolkovske & Dabrowski 1998
		-	-	11-15	-	-	-	-	-	-	-	-	Lake Erie, OH	Collinsworth & Marschall 2011
		late-Apr to early-June	early to mid-May	6.9-14.4	9-11	-	-	3-22	-	-	woody debris	-	2 reservoirs in MT	EA 1992

Species Group	Species	Periodicity Range	Periodicity Peak	W Temps °C Range	W Temps °C Peak	Velocity fps Range	Velocity fps Peak	Depth ft Range	Depth ft Peak	Substrate Type in Range	Substrate Type in Peak	Instream Cover	Data Location	Source Citation
Early-Spring Backwater	**Northern Pike**	**Apr to May**	**-**	**5-17**	**7-12**	**<0.3**	**<0.3**	**0.2-12**	**0.6-4.8**	**dense submerged vegetation**	**flooded grasses or sedges**	**-**		**Summary of Information Listed Below**
		late-Apr to late-May	mid-May	5-13	7-12	-	-	<4.9-8.5	-	SAV & algae (shallow marsh veg unavailable)	-	-	marsh off St Lawrence R, NY	Farrell et al. 1996
		late-Apr to early-June	late-Apr	7.0-13.2	7.0	-	-	<4.9-12.1	-	inundated veg forming a mat over sediments, avoided pure cattails	-	-	bay on St Lawrence R, NY	Farrell 2001
		-	-	-	-	<0.3	-	<3.28	-	-	-	-	St Lawrence R, NY	Osterberg 1985 in Farrell et al. 1996
		-	-	-	-	-	<0.3	-	-	including cattails	inundated marsh not dominated by cattails	-	4 floodplains on St Lawrence R, Quebec	Mingelbier et al. 2008
		April	-	>4.4	9	-	-	>0.6	-	-	-	-	rivers and lakes in Canada	Scott & Crossman 1998
		following ice-out	-	-	-	-		-	-	-	inundated vegetation	-	lakes in NW CAN	McPhail & Lindsey 1970
		-	-	-	-	0.0-1.5	0.0-0.41	0.38-6.0	0.63-4.77	-	-	-	U.S. lakes and rivers	Bovee 1978
		following ice-out	-	>5	-	zero	-	-	-	mud	inundated vegetation	-	lakes in Alaska	Morrow 1980

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Northern Pike	-	-	-	-	-	-	<1.7	<0.8	-	marsh vegetation	-	Lake Erie bay, tribs, and pond, OH	Clark 1950
		-	-	-	-	-	-	0.5-1.5	-	-	-	-	-	Williamson 1942, cited in Clark 1950
		late-March to late-Apr	mid-Apr	6.7-16.7	-	-	-	-	-	-	-	-	Green Lk, MN	Bennett 1948
		following ice-out	-	8-13	-	zero	-	0.33-1.48	<01.64	may also use organic debris	dense mat of short vegetation	-	U.S. & Canada	Inskip 1982
		early to late-Apr	-	11.1-17.2	-	-	-	-	-	avoided cattails, also did not utilize SAV	most spawned over dense carex clumps	-	Lake George, MN	Franklin & Smith 1963
		Mar-Apr	-	6.1-8.9	-	-	-	0.2-1.0	-	-	-	-	Lk Chemung, MI	McNamara 1936
		early-Apr to early-May	-	-	-	-	-	-	-	-	-	-	Ball Club Lk, MN	Johnson 1957
		Mar to Apr	-	-	-	-	-	-	-	SAV and algae also used	flooded prairie grass	-	9 lakes and ponds in NE	McCarraher & Thomas 1972
Species Group	**Species**	**Periodicity**		**W Temps °C**		**Velocity fps**		**Depth ft**		**Substrate Type in**		**Instream Cover**	**Data Location**	**Source Citation**
		Range	**Peak**	**Range**	**Peak**	**Range**	**Peak**	**Range**	**Peak**	**Range**	**Peak**			
Early-Spring Backwater	**Chain Pickerel**	**Apr to May**	**-**	**7-13**	**-**	**-**	**-**	**1-10**	**-**	**inundated vegetation**	**-**	**-**		**Summary of Information Listed Below**
		May	-	-	-	-	-	-	-	-	-	-	lakes in Maine	Warner 1973

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Chain Pickerel	Apr to May	-	>8.3	-	-	-	3-10	-	inundated vegetation	-	-	rivers and lakes in Canada	Scott & Crossman 1998
		April	-	7-13	-	-	-	-	-	inundated vegetation	-	-	Patterson Cr, WV	Lewis 1974
		-	-	-	-	-	-	1-2	-	inundated vegetation	-	-	-	VA Dept Game & Inland Fisheries website
		Mar to April	-	2.2-22.2	-	-	-	-	-	-	-	-	Long Lk, OH	Armbruster 1959
		Mar to Apr	-	7.2-	-	-	-	-	-	inundated vegetation	-	-	-	South Carolina Dept Natural Resources website
Species Group	**Species**	**Periodicity**		**W Temps °C**		**Velocity fps**		**Depth ft**		**Substrate Type in**		**Instream Cover**	**Data Location**	**Source Citation**
		Range	**Peak**	**Range**	**Peak**	**Range**	**Peak**	**Range**	**Peak**	**Range**	**Peak**			
Late-Spring Backwater	**Largemouth Bass**	**May to July**	**early to mid-June**	**13-29**	**17-18**	**<0.3**	**<0.13**	**<20**	**1-7**	**any firm bottom type w veg**	**gravel**	**nearby object & wave protection**		**Summary of Information Listed Below**
		-	early to mid-June	>15.6	16.7-18.3	-	-	1-4	-	mud, sand, gravel, veg	-	-	rivers and lakes in Canada	Scott & Crossman 1998
		-	-	11.5-29	16-22	<0.3	<0.13	0.5-27	0.98-2.95	mud, sand, gravel, cobble, veg	gravel	protection from wave action	U.S. lakes	Stuber et al. 1982
		-	-	15-24	-	-	-	0.5-18.0	1.1-4.4	all types	gravel	prefers proximty to cover and protection from waves	lakes in U.S.	Heidinger 1976

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Largemouth Bass	-	-	-	16.7-18.3	-	-	-	-	any firm bottom type incl veg	gravel	-	WI lakes & ponds	Mraz 1964
		late-May to mid-June	-	-	-	-	-	0.7-4.26	-	-	-	prefer proximity to wood cover	WI lakes & ponds	Lawson et al. 2011
		-	-	-	-	-	-	-	-	remaining nests in sand, gravel or rocks	68% of nests were in SAV	60% of nests were w/in 4ft of rock or wood cover	2 WI lakes	Weis & Sass 2011.
			-	-	-	-	-	1.05-9.8	-	-	-	-	3 MN lakes	Reed & Pereira 2009
		mid-Apr to late-May	late-Apr	-	-	-	-	2.95-13.1	5.9-6.9	-	-	most nests near woody cover	Bull Shoals, MO	Vogele & Rainwater 1975
		mid-Apr to early June	-	-	-	calm & w/o wave action	0	<1-15+	-	any firm bottom type incl veg	gravel or rock	-	MO lakes	Pflieger 1975
		mid-May to late-June	late-June	15.5-18.3	-	-	-	<8	1-4	sand, gravel, rubble	-	-	lakes in WA	Wydoski & Whitney 2003
		late-Apr to early-June	-	12-20	-	-	-	-	-	-	-	-	Lake Shelbyville, IL	Miller & Storck 1984
		Mar to May	-	-	-	-	-	-	-	mud, gravel, or rock	-	-	Imperial Res, AZ	Weaver 1971
		Apr to early-July	-	-	-	-	-	-	0.5-4.0	any firm bottom type incl veg	-	-	AL ponds	Swingle & Smith 1943

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Largemouth Bass	Apr to June	-	14-24	-	-	-	-	3.2-6.5	sand, gravel, organic debris	-	prefers nearby object	CA lakes	Moyle 1976
		-	-	-	-	0.0-0.56	0.0-0.49	>0.0-15+	0.64-15+	mud, sand, gravel, cobble	gravel	-	U.S. lakes and rivers	Bovee 1978
		May	-	16.7-20.5	-	-	-	0.5-3.6	-	some nests in silt and sand	gravel & rock	73% of nests near SAV	Hudson R estuary, NY	Nack et al. 1993
		late-May to late-June	-	19.5-23	-	0.0-0.05	avg 0.02	0.92-5.74		silt to rock	sand, gravel	near SAV	Hudson R estuary, NY	Nack 1986

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
Late-Spring Backwater	**Bluegill**	**May to Aug**	**June**	**17-31**	**19-27**	**0.0-1.0**	**<0.25**	**1.5-15**	**0.5-5.0**	**any firm bottom type w veg**	**sand & gravel**	**protection from waves**		**Summary of Information Listed Below**
		-	early-July	<24.5	-	-	-	-	2.5	mud, sand, gravel	-	-	rivers and lakes in Canada	Scott & Crossman 1998
		-	-	17-31	24-27	<0.98	<0.25	3.28-9.8	-	any type	sand & gravel	-	U.S. lakes	Stuber et al. 1982
		-	early-June to early-July	-	19-23	-	-	1.64-16.4	3.28-14.8	-	-	-	Lake Giles, PA	Olson et al. 2008
		-	-	-	-	0.0-1.15	0.0-0.71	1.5-6.5	2.47-5.19	-	silt, sand, gravel	-	-	Bovee 1978

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Bluegill	mid-May to mid-Aug	-	-	-	-	-	<6	-	-	-	-	8 lakes in MI	Beyerle & Williams 1967
		late-May to early-Aug	June	-	-	-	-	-	1-2	any firm bottom type incl veg	gravel	-	MO lakes	Pflieger 1975
		late-May to early-July	-	-	-	-	-	3-6	-	sand	-	-	lakes in MN	Eddy & Underhill 1974
									avg 3.28	firm substrate type	gravel	short, low density aquatic veg	SD lake	Gosch et al. 2006
				>17.2	>26.6					clay, mud, sand, gravel, organics	sand & fine gravel		OH farm ponds	Stevenson et al. 1969
		-	-	19-	-	-	-	-	-	sand	-	-	lakes in WA	Wydoski & Whitney 2003
		Apr to October	-	-	-	-	-	<10	0.5-4.0	any firm bottom type incl veg	gravel	-	AL ponds	Swingle & Smith 1943
		May to Aug	-	-	-	-	-	-	-	mud, gravel, or rock	-	-	Imperial Res, AZ	Weaver 1971
			-	18-	-	-	-	-	0.16-0.50	sand, gravel, organic debris	-	-	CA lakes	Moyle 1976

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
Late-Spring Backwater	**Pumpkinseed**	**May to Aug**	**June**	**>20**	**-**	**-**	**0**	**0.5-6.0**	**0.8-1.7**	**all types of firm bottom**	**sand & gravel**	**SAV w wave protection**		**Summary of Information Listed Below**
		late-spring to mid-July	-	20.0-27.8	-	-	-	0.5-1.0	-	all types of firm bottom w SAV	-	SAV	rivers and lakes in Canada	Scott & Crossman 1998
		May to Aug	-	-	-	-	-	-	-	mud & clay (pumpkinseed)	-	-	Hudson River, NY	Orringer 1991
		mid-June to mid-July	-	-	-	-	-	0.6-1.9	0.8-1.7	-	gravel & sml rocks	preferred locations w emergent or aquatic veg	Lincoln Pond, NY	Ingram & Odum 1941
		mid-June to late-July	-	>23	-	-	-	0.65-2.6	avg 1.48	-	pebbles 0.6-1.25"	most nests w/in 1m of cover (but not SAV)	Otsego Lk, NY	Hakala 1994
		early June to early July	-	>20	-	-	-	-	-	-	-	-	Cranberry Pond, MA	Reed 1971
		-	-	-	-	-	-	-	-	all types of firm bottom	sand & gravel	-	-	Danylchuk & Fox 1996
		late-May to June	-	-	-	-	-	3-6	-	sand	-	-	lakes in MN	Eddy & Underhill 1974
			-	>20	-	-	-	<3.3	0.16-0.50	sand, gravel, organic debris	-	-	CA lakes	Moyle 1976

Species		Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream	Data	Source
Group	Species	Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak	Cover	Location	Citation
Late-Spring Backwater	**Black Crappie**	**May to July**	**June**	**13-21**	**18-20**	**-**	**0**	**0.5-6.0**	**0.9-3.3**	**mud, sand, gravel w SAV**	**firm substrate**	**SAV, emergent veg, woody debris, wave protection**		**Summary of Information Listed Below**
		-	late-May to mid-July	>19	-	-	-	0.8-2.0	-	mud, sand, gravel w SAV	-	-	rivers and lakes in Canada	Scott & Crossman 1998
		-	-	13-21	17.8-20	-	-	-	-	mud, sand, gravel w cover	-	SAV or woody debris	U.S. lakes	Edwards et al. 1982
		-	-	-	avg 21.3	-	-	1.64-3.28	avg 2.79	firm substrates	clay or sand	low density of short SAV	Campus Lk, IL	Phelps et al. 2009
		May to June	-	-	-	-	-	3-6	-	mud	-	-	lakes in MN	Eddy & Underhill 1974
			-	-	-	-	-	0.82-4.92	-	avoided SAV	-	prefered nearby bulrush	3 MN lakes	Reed & Pereira 2009
		-	-	-	-	-	-	1.3-2.6	-	mud, sand, gravel	mud	cattails and woody debris preferred w/o wave action	2 lakes in SD	Pope & Willis 1997
		late-Apr to late-June	mid-June	-	-	-	-	-	-	silt, clay	-	protection from waves	Rathburn Lake, Iowa	Mitzner 1991
		late-Apr to mid-July	late-May	13.4-21.0	18-20	-	-	0.6-32	6.8-15.1	gravel to bedrock	gravel & cobble	-	Brownlee Res, ID	Richter 2001

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Black Crappie	May to early-June	-	14.4-17.8	-	-	-	-	-	mud	-	-	lakes in WA	Wydoski & Whitney 2003
		Mar to July	-	14-	-	-	-	<3.3	0.16-0.50	mud or gravel w SAV	-	SAV	CA lakes	Moyle 1976
		-	-	-	-	0.0-1.98	0.0-1.47	0.73-5.0	0.89-3.24	mud, sand, gravel, cobble	-	-	U.S. lakes and rivers	Bovee 1978
Species Group	**Species**	**Periodicity**		**W Temps °C**		**Velocity fps**		**Depth ft**		**Substrate Type in**		**Instream Cover**	**Data Location**	**Source Citation**
		Range	**Peak**	**Range**	**Peak**	**Range**	**Peak**	**Range**	**Peak**	**Range**	**Peak**			
Late-Spring Backwater	**Golden Shiner**	**May to July**	**-**	**20-27**	**-**	**-**	**-**	**-**	**-**	**SAV, EAV, sand, organics**	**SAV & algae**	**-**		**Summary of Information Listed Below**
		May to Aug	-	>20	-	-	-	-	-	SAV & algae	-	-	lakes and rivers in NY	Smith 1985
		May to July	-	-	-	-	-	-	-	SAV & algae	-	-	lakes and rivers in NY	Kraft et al. 2006
		May to July	-	>20	-	-	-	same as LMB (use old nests)	-	SAV & algae	-	-	lakes in Canada	Scott & Crossman 1998
		summer	-	-	-	-	-	-	-	SAV	-	-	lakes in MN	Eddy & Underhill 1974
			-	20-27	-	-	-	may spawn in bass nests	-	SAV, sand, organic debris, emergent veg	SAV	-	lakes and rivers in WI	Becker 1983

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Golden Shiner	late-Apr to early-June	-	21.1-26.7	-	-	-	-	-	SAV & algae	-	-	lakes in MO	Pflieger 1975
		Mar to Aug	-	>15	>20	-	-	-	-	SAV and organic debris	-	-	lakes in CA	Moyle 1976

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
Late-Spring Backwater or Island/Bar & Tributary	**Spottail Shiner**	**June to July**	**-**	**>18**	**-**	**-**	**-**	**<30**	**3-4**	**sand & gravel shoals**	**-**	**-**		**Summary of Information Listed Below**
		June to July	-	-	-	-	-	-	-	sand & gravel at trib mouths	-	-	lakes and rivers in NH	NH Fish & Game species summaries (web)
		June to July	-	-	-	-	-	-	-	sand at trib mouths	-	-	lakes and rivers in NY	Smith 1985
		June to July	-	-	-	-	-	-	-	sand at trib mouths	-	-	lakes and rivers in NY	Kraft et al. 2006
		May to July	-	-	-	-	-	3-4	-	sandy shoals	-	-	lakes in Canada	Scott & Crossman 1998
		late-Apr to Sep	late-May to early-June	+/--18.3	-	-	-	up to 15	-	gravel or sandy shoals, algae	-	-	lakes and rivers in WI (often at trib mouths)	Becker 1983

		June to Sep	mid-June to late-July	-	-	-	-	<30	<18 (most gravid fish)	-	sand	-	great lakes & Kalamazoo R, MI	Wells & House 1974

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Spottail Shiner	late-June to early-July	-	-	-	-	-	-	-	sand and gravel	-	-	lakes in MN	Eddy & Underhill 1974
		May to early-June	-	-	-	-	-	-	-	-	-	-	lakes in MO	Pflieger 1975
		-	May	-	-	-	-	-	-	sand & sml gravel	-	-	Clear Lake, IA	McCann 1959
		June to July	-	-	-	-	-	-	-	sandy shoals	-	-	lakes in NW CAN	McPhail & Lindsey 1970

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
Late-Spring Island/Bar & Tributary	**Smallmouth Bass**	**May-June**	**mid-May to mid-June**	**13-25**	**15-20**	**0.0-1.0**	**<0.5**	**>0.5**	**1.5-4.0**	**coarse sand, gravel, cobble**	**gravel**	**prefers proximity to rock or wood cover**		**Summary of Information Listed Below**
		late-May to mid-June	late-May	15.5-20.0	-	-	-	2.2-3.3	avg 2.75	gravel & rubble	-	most nests near rocks or logs & protected from waves	S Branch Lk, ME	Neves 1975
		late-May to early-July	-	>16	-	-	-	-	avg 1.8-4.26	silt to gravel	-	>76% of nests near boulders or wood cover	Nova Scotia lakes	McNeill 1995
		-	-	-	-	-	-	-	-	-	-	-	Lk Erie & 2 ON lakes	Ridgeway et al. 1989

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Smallmouth Bass	-	early to mid-June	-	15-18	-	-	-	-	-	-	w/in 8 ft of shore	Tadenac Lk, ON	Turner & MacCrimmon 1970
		-	-	-	-	-	-	3-4	-	incl some short aquatic veg	"small rock"	most had boulders, rock ledges, or woody debris nearby	Georgian Bay & Lk Nippising, ON	Tester 1930
		-	late-May to early-July	12.8-20.0	16.1-18.3	-	-	2-20	-	sand, gravel, rock	-	prefers near cover	rivers and lakes in Canada	Scott & Crossman 1998
		late-Apr to late-June	-	>15	-	-	-	-	<6.5	coarse sand, all rock, roots, shells, sticks	0.4-3.1 gravel	prefers proximal rock or wood cover & shelter from waves	WI lakes, lit review	Forbes 1981
		-	-	-	-	-	-	<20	6-10	-	gravel	prefers nearby cover object	WI lakes & ponds	Mraz 1964
		mid-Apr to late-May	-	13.3-22.5	-	-	-	3.6-17.1	7.9-10.5 (range of means)	gravel to rubble	-	80% had rock or woody cover nearby	Bull Shoals Lk, AK	Vogele 1981
		late-Apr to mid-July	-	12.9-22.3	15-18	-	-	>0.0-14.0	2.44-10.0	0.002-10	0.1-3	-	Brownlee Res, ID	Richter 2003
		early-June into July	-	17-21	-	-	-	1.5-3.0	-	-	gravel	-	St. Lawrence R, NY	Stone et al. 1954

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
	Smallmouth Bass	early-May to mid-June	-	17-?	-	-	<0.07	-	avg 1.2	gravel-bedrock	pea gravel	most nests close to boulders, roots, or woody cover	Indian Cr, OH	Winemiller & Taylor 1982
		late-Mar to mid-Apr	mid to late-Apr	-	17.6	-	-	-	-	-	-	-	channels along Tenn R, AL	Wrenn 1984
		-	-	-	12.7-15.5	-	-	-	-	-	-	-	Columbia R, WA	Henderson & Foster 1957
		-	-	12-26	14-19	0.0-2.75	0.0-1.5	>0.22	>1.56	>0.002	0.1-2.5	-	-	Bovee 1978

Species Group	Species	Periodicity		W Temps °C		Velocity fps		Depth ft		Substrate Type in		Instream Cover	Data Location	Source Citation
		Range	Peak	Range	Peak	Range	Peak	Range	Peak	Range	Peak			
Late-Spring Island/Bar & Tributary	**Fallfish**	**Apr-June**	**-**	**13-19**	**15-18**	**<3**	**<2**	**0.4-4.5**	**0.5-3.4**	**-**	**gravel & cobble**	**none**		**Summary of Information Listed Below**
		Apr to June	-	>14.4	-	-	-	-	-	-	-	-	lakes and rivers in NY	Smith 1985
		-	mid-May	>12.0	-	-	-	-	-	-	-	-	rivers and lakes in Canada	Scott & Crossman 1998
		-	-	-	-	0.0-0.66	-	>0.0-3.26	-	-	-	-	Lamprey R, NH	Normandeau 2009
		-	-	-	-	0.0-3.0	0.05-2.15	0.4-4.5	0.52-3.4	-	-	-	Merrimack R, NH	Normandeau (date?)
		Apr to June	-	>14.4	-	-	-	-	-	-	-	-	lakes and rivers in NY	Smith 1985

Species Group	Species	Periodicity Range	Periodicity Peak	W Temps ºC Range	W Temps ºC Peak	Velocity fps Range	Velocity fps Peak	Depth ft Range	Depth ft Peak	Substrate Type in Range	Substrate Type in Peak	Instream Cover	Data Location	Source Citation
	Fallfish	-	-	13.5-18.5	15.5-18.0	-	-	-	0.33-1.64	-	0.002-2.52	prefers nearby instream cover, overhead cover, or deep water	Mill R, MA (D)	Trial et al. 1983
		late-Apr to mid-June in MA	-	>14.4	-	-	-	-	-	-	pebbles & stones (1-168g wt)	-	Mill & WB Swift rivers, MA	Reed 1971
		mid-Apr to early-June	-	15	-	-	-	-	>1.64	-	-	-	Mill R, MA	Ross & Reed 1978
		early-Apr & mid-May	-	16.2 & 17.9	-	-	-	-	-	-	-	-	Genito Cr, VA & Mill R, MA	Maurakis & Woolcott 1992
		May-June	-	14-19	-	-	-	-	-	-	-	-	Ontario rivers	http://www.ontariofishes.ca/fish_detail.php?FID=58
		-	mid-May	>12.0	-	-	-	-	-	-	-	-	rivers and lakes in Canada	Scott & Crossman 1998

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APPENDIX B

Maps of Egg Block Locations

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WT-007

WT-010

WT-011

WT-015


N
300 ft
14-WT-054
B
C
D
E
F
H
J

WT-054


N
1000 ft
14-WT-058
21
3
4
J
B A E
91
5
132
Old Bridge Rd
Kendall Station
River Edge

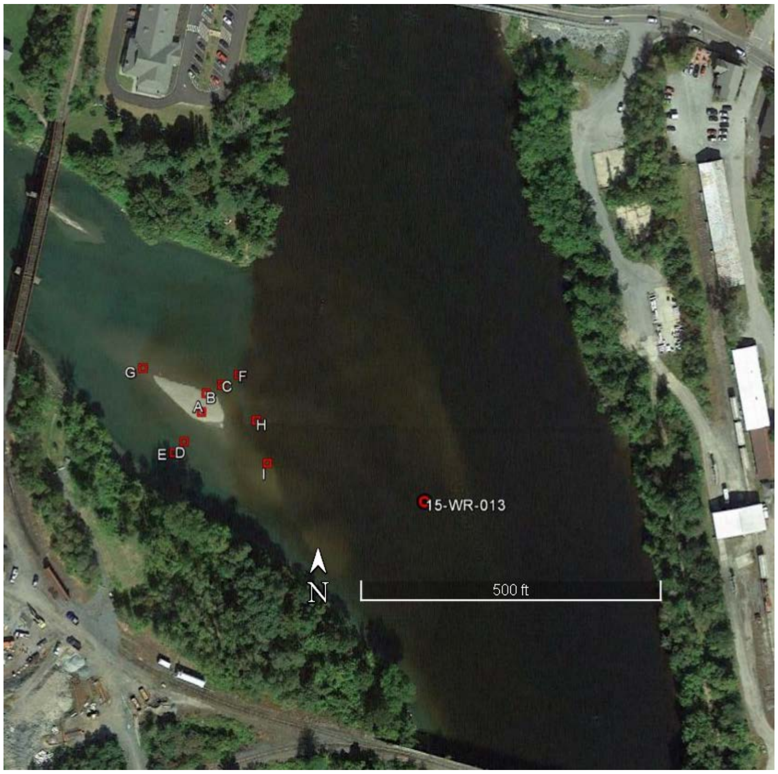
WT-058


14-WT-074
A
B
D
H
G
F
E
N
1000 ft
River Trail
Esker
Spencer Rd

WT-074


G
A
B
E
D
C
H
F
N
500 ft
15-WR-002

WR-002



WR-013

WR-026

WR-061

WR-069

WR-080

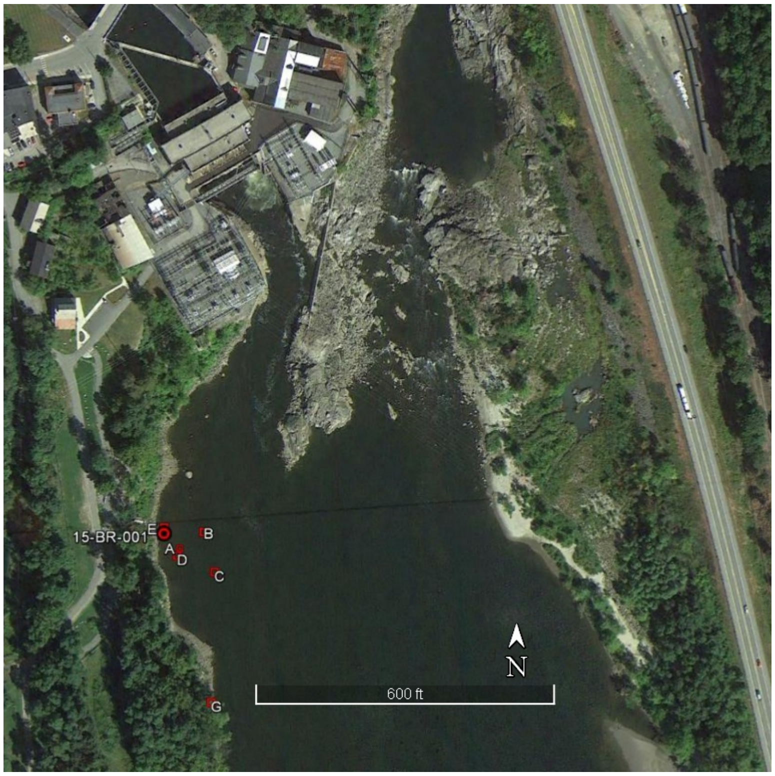
WR-100

BT-002,004

BT-013

BT-018

BT-031


15-BR-001
E
A
B
D
C
G
600 ft
N

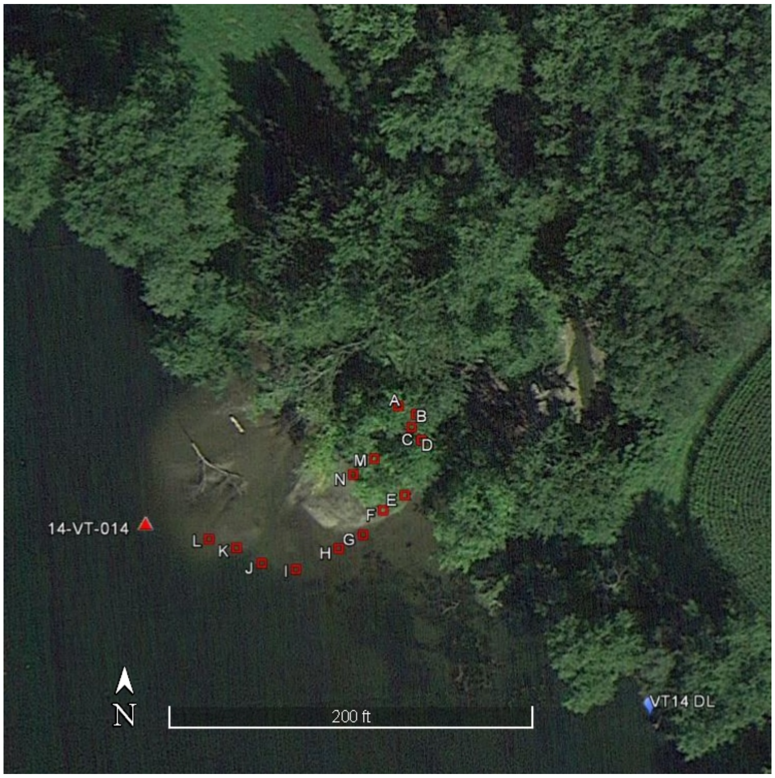
BR-001


A2
C2
B2
D2
E2
J
K
L
M
2
BR06 DL
1
15-BR-005
H
E
G
D
C
B
BR05 DL
600 ft
N

BR-005


L
K
J
I
BR07 DL
D
C
B
A
H
G
F
E
15-BR-007
N
300 ft

BR-007


A
B
C
D
M
N
E
F
14-VT-014
L
K
J
I
H
G
N
200 ft
VT14 DL

VT-014


14-VT-016
E
F
D
C
B
A
VT16-2 DL
VT16-1 DL
200 ft
N

VT-016


14-VT-018 X
G
H
C
A
B
F
E
D
200 ft
N

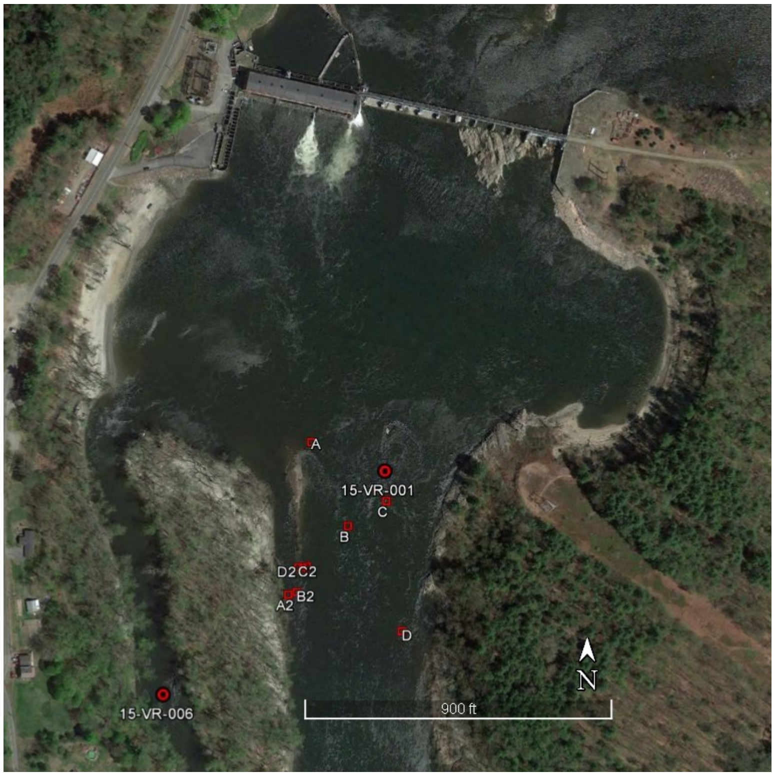
VT-018


BB
AA
GG
FF
DD
14-VT-040
E
H
A
C
N
1000 ft

VT-040


VT46 DL
14-VT-046
EE
DD
FF
CC
BB
AA
E
C
D
A
N
300 ft

VT-046


A
15-VR-001
C
B
D2
C2
B2
A2
D
N
900 ft
15-VR-006

VR-001


D
C
B
A
E
F
VI02 DL
N
700 ft

VR-002

APPENDIX C

Larval Fish Trawl Capture Data

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Study Reaches are WI-Wilder Impoundment, WR-Wilder Riverine, BI-Bellows Falls Impoundment, BR-Bellows Falls Riverine, VI-Vernon Impoundment, VR-Vernon Riverine

Species	Date	Study Reach	Study Site	No. Larvae
White Sucker	5/21/2015	BI	BB-30	1
	5/21/2015	VI	VB-40	103
	5/21/2015	VI	VB-45	5
	5/21/2015	VI	VB-50	10
	5/26/2015	VI	VB-40	1
	5/29/2015	BR	BI-003	14
	5/29/2015	BR	-[1]	21
	5/31/2015	VR	-[1]	1
	5/31/2015	VR	-[1]	1
	6/1/2015	VR	-[1]	4
	6/2/2015	VI	-[1]	1
	6/9/2015	WI	WB-16	7
	6/9/2015	WI	WB-32	16
	6/9/2015	BR	-[1]	2
	6/9/2015	VI	-[1]	1
	6/10/2015	VI	-[1]	6
	6/10/2015	VI	VT-014	17
	6/10/2015	VI	VT-018	21
	6/13/2015	BR	-[1]	1
	6/16/2015	VI	-[1]	4
	6/17/2015	BR	-[1]	2
	6/17/2015	VI	VT-016	7
	6/18/2015	WI	WB-060	8
	6/20/2015	BR	-[1]	1
	6/23/2015	VI	-[1]	5
	6/25/2015	BR	-[1]	1
	6/26/2015	BR	-[1]	1
Yellow Perch	5/18/2015	WI	WB-51	2
	5/19/2015	WI	WB-12	33
	5/19/2015	WI	WB-16	44
	5/19/2015	WI	WB-28	210
	5/19/2015	WI	WB-32	6
	5/19/2015	BI	BB-30	12
	5/19/2015	BI	BB-33	2
	5/21/2015	WI	WB-28	3
	5/21/2015	WI	WB-32	41
	5/21/2015	WI	WB-60	33
	5/21/2015	BI	BB-30	3
	5/21/2015	BI	BB-33	5

	5/21/2015	VI	VB-45	30
	5/21/2015	VI	VB-50	2
	5/31/2015	VR	-[1]	2
	6/1/2015	VR	-[1]	1
	6/4/2015	VI	-[1]	1
	6/10/2015	VI	VT-024	1
	6/11/2015	VR	-[1]	2
	6/13/2015	BR	-[1]	2
	6/14/2015	BR	-[1]	1
	6/17/2015	BR	-[1]	2
	6/24/2015	BR	-[1]	2
	6/30/2015	BR	-[1]	3
Chain Pickerel	5/19/2015	WI	WB-16	1
Largemouth Bass	5/26/2015	VI	VB-50	3
	6/9/2015	VI	VB-040	11
	6/10/2015	VI	VT-024	3
	6/18/2015	WI	WB-016	11
	6/18/2015	WI	WB-051	5
Lepomis spp.	5/19/2015	BI	BB-30	4
	5/21/2015	BI	BB-19	1
	6/9/2015	WI	WB-16	4
Golden Shiner	5/21/2015	WI	WB-51	1
	6/13/2015	BR	-[1]	1
	6/16/2015	VI	VB-050	10
	6/17/2015	VI	VT-016	1
Spottail Shiner	6/23/2015	VI	-[1]	1
	6/30/2015	BR	-[1]	1
	7/1/2015	VR	-[1]	1
Cyprinid spp.	5/19/2015	BI	BB-19	39
	5/19/2015	BI	BB-30	19
	5/19/2015	BI	BB-33	1
	5/21/2015	BI	BB-19	51
	5/21/2015	BI	BB-30	8
	5/21/2015	BI	BB-33	123
	5/21/2015	VI	VB-40	2
	5/21/2015	VI	VB-45	16
	6/1/2015	VR	-[1]	1
	6/10/2015	VI	-[1]	1
	6/11/2015	VR	-[1]	3
	6/13/2015	BR	-[1]	2
	6/16/2015	VI	-[1]	8
	6/22/2015	VI	-[1]	3
	6/23/2015	VI	-[1]	2

	7/2/2015	BR	-[1]	1
Fallfish	6/9/2015	WI	WB-32	112
	6/9/2015	VI	VB-040	12
	6/9/2015	VI	VB-045	12
	6/9/2015	VI	-[1]	12
	6/10/2015	VI	VT-018	11
	6/10/2015	VI	VT-024	8
Smallmouth Bass	5/21/2015	VI	VB-45	16
	6/3/2015	WR	-[1]	1
	6/3/2015	VR	-[1]	1
	6/4/2015	WI	WB-51	24
	6/9/2015	WI	WB-16	4
	6/9/2015	VI	VB-045	1
	6/18/2015	WI	WB-016	1

[1] data from shad trawls (all other from spawning trawls)

Study Reaches are WI-Wilder Impoundment, WR-Wilder Riverine, BI-Bellows Falls Impoundment, BR-Bellows Falls Riverine, VI-Vernon Impoundment, VR-Vernon Riverine

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APPENDIX D

[3]Maps of Fish Spawning Locations

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[3] All Northern Pike and Chain Pickerel locations are non-spawning observations (i.e., adult rearing or angling capture locations)

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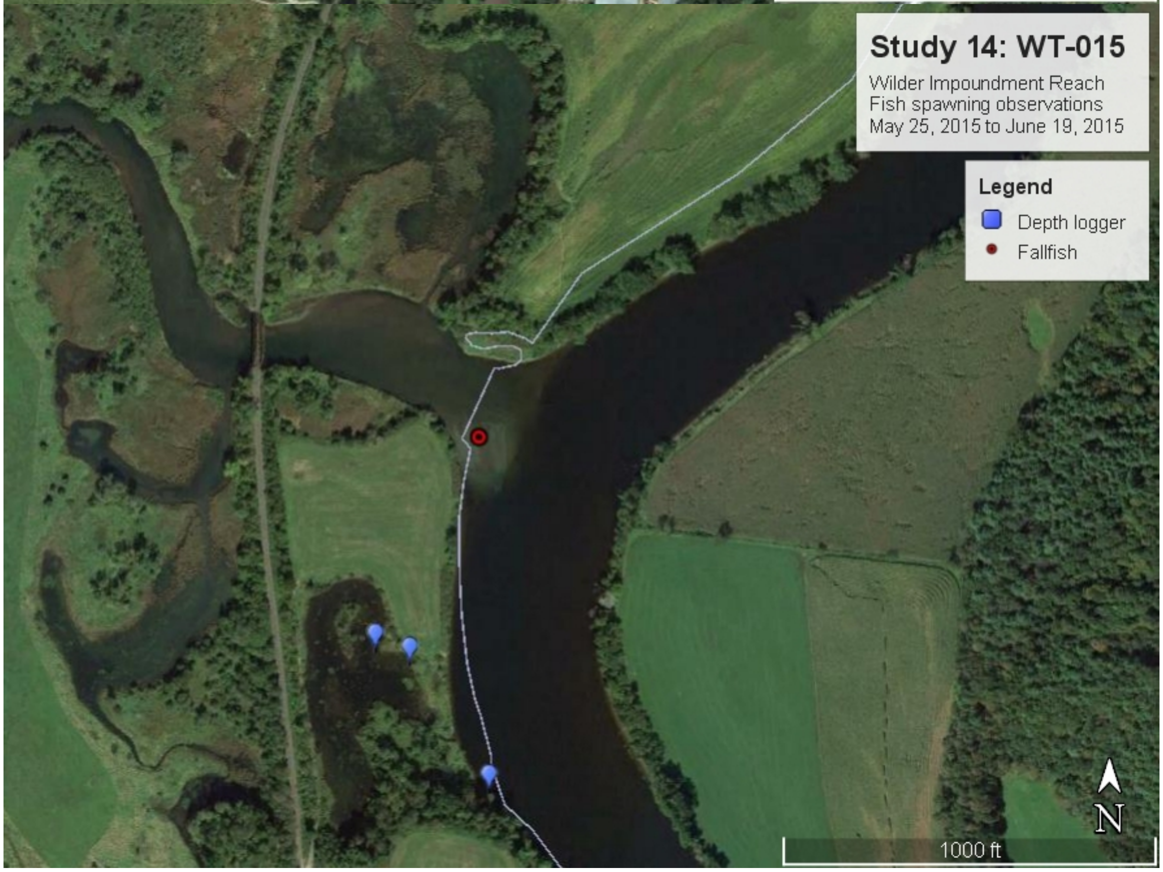
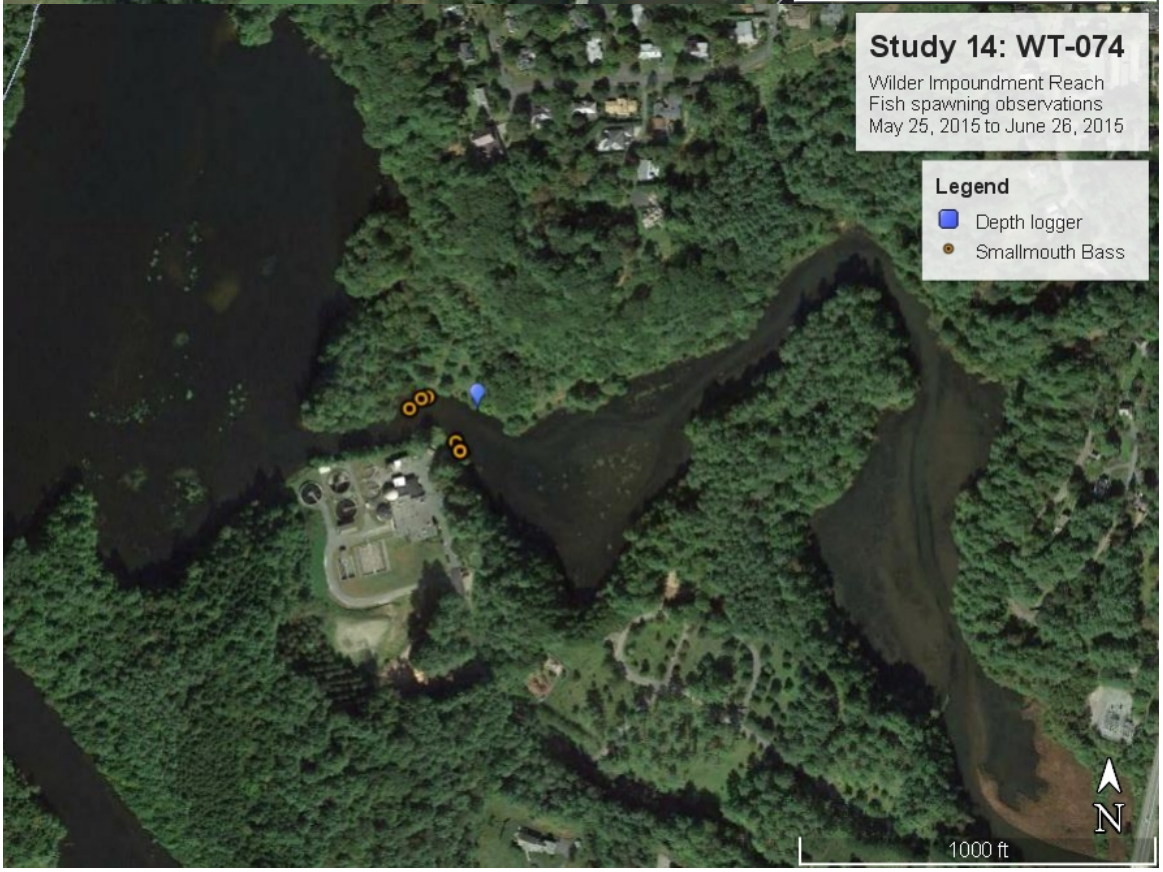
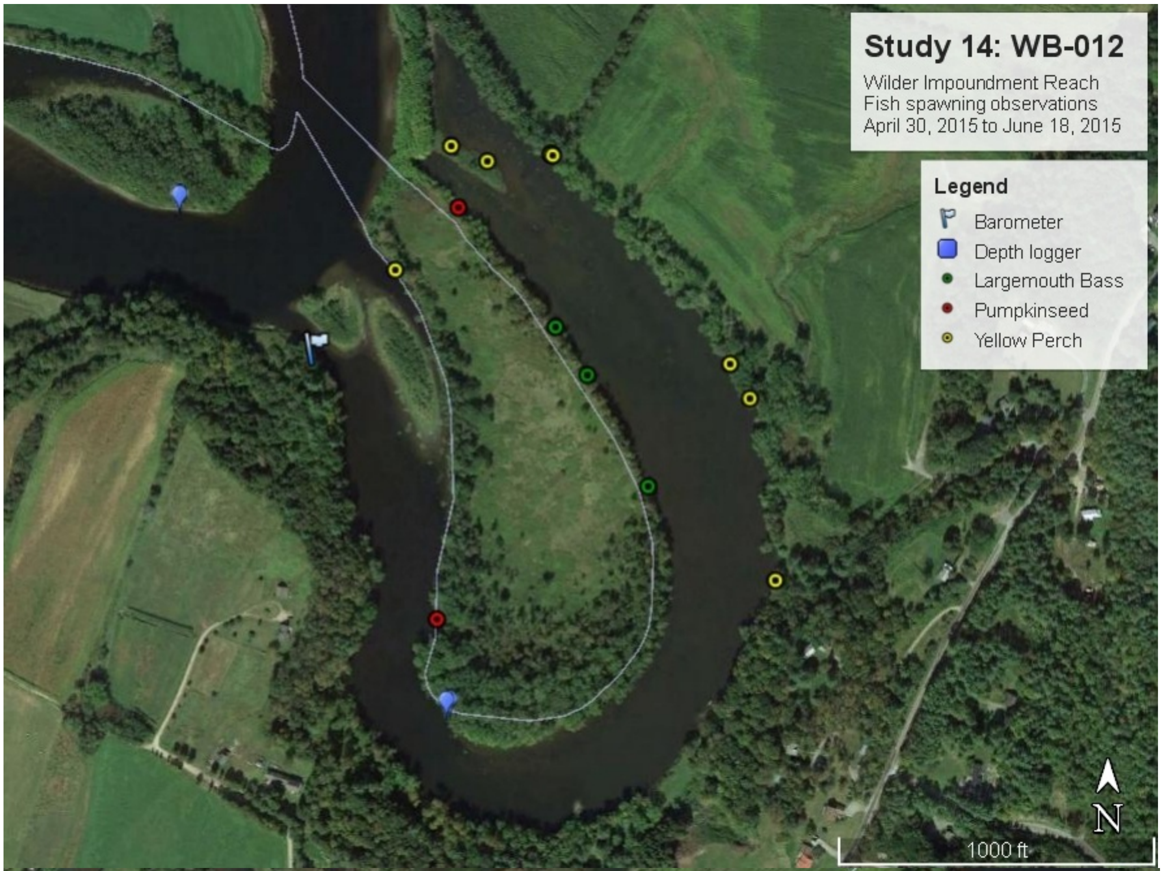
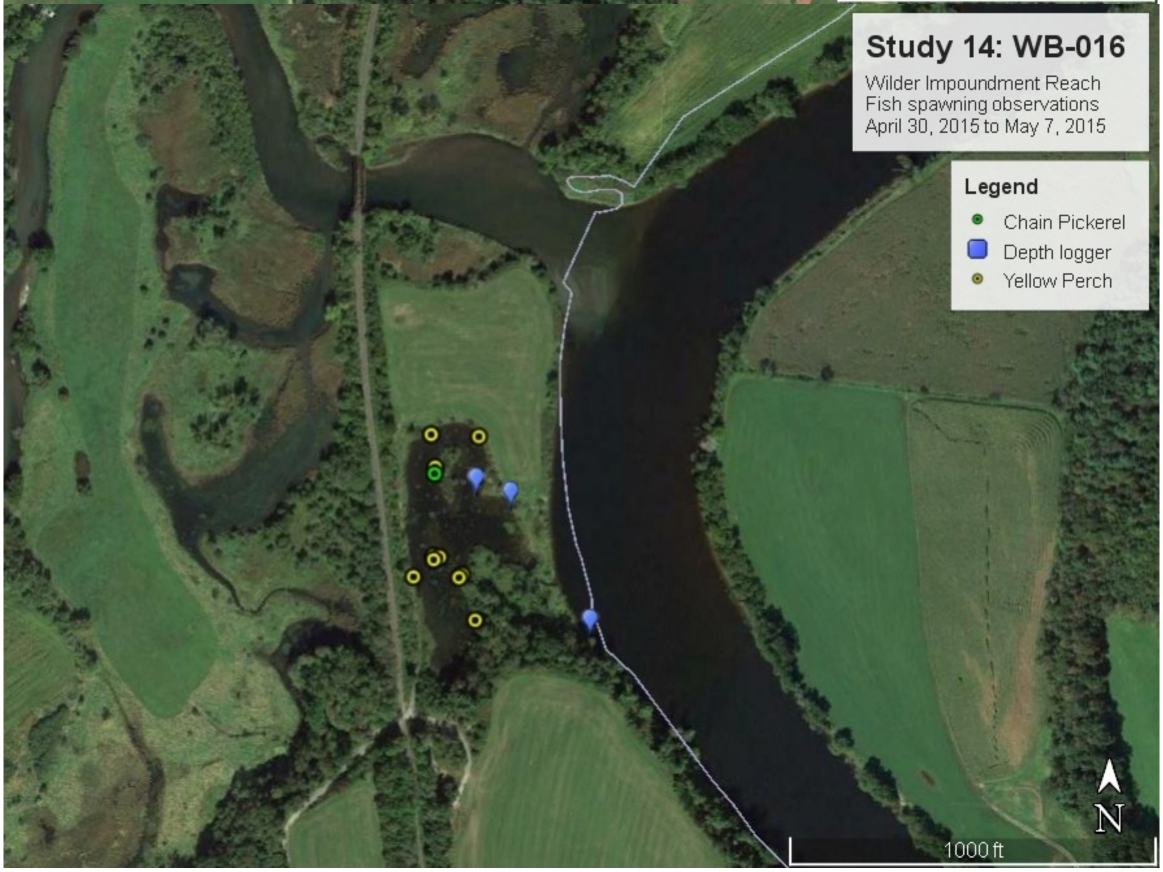
Study 14: WT-010
Wilder Impoundment Reach
Fish spawning observations
May 27, 2015 to June 8, 2015
Legend
🟦 Depth logger
● Smallmouth Bass
N
1000 ft


Study 14: WT-015
Wilder Impoundment Reach
Fish spawning observations
May 25, 2015 to June 19, 2015
Legend
🟦 Depth logger
● Fallfish
N
1000 ft

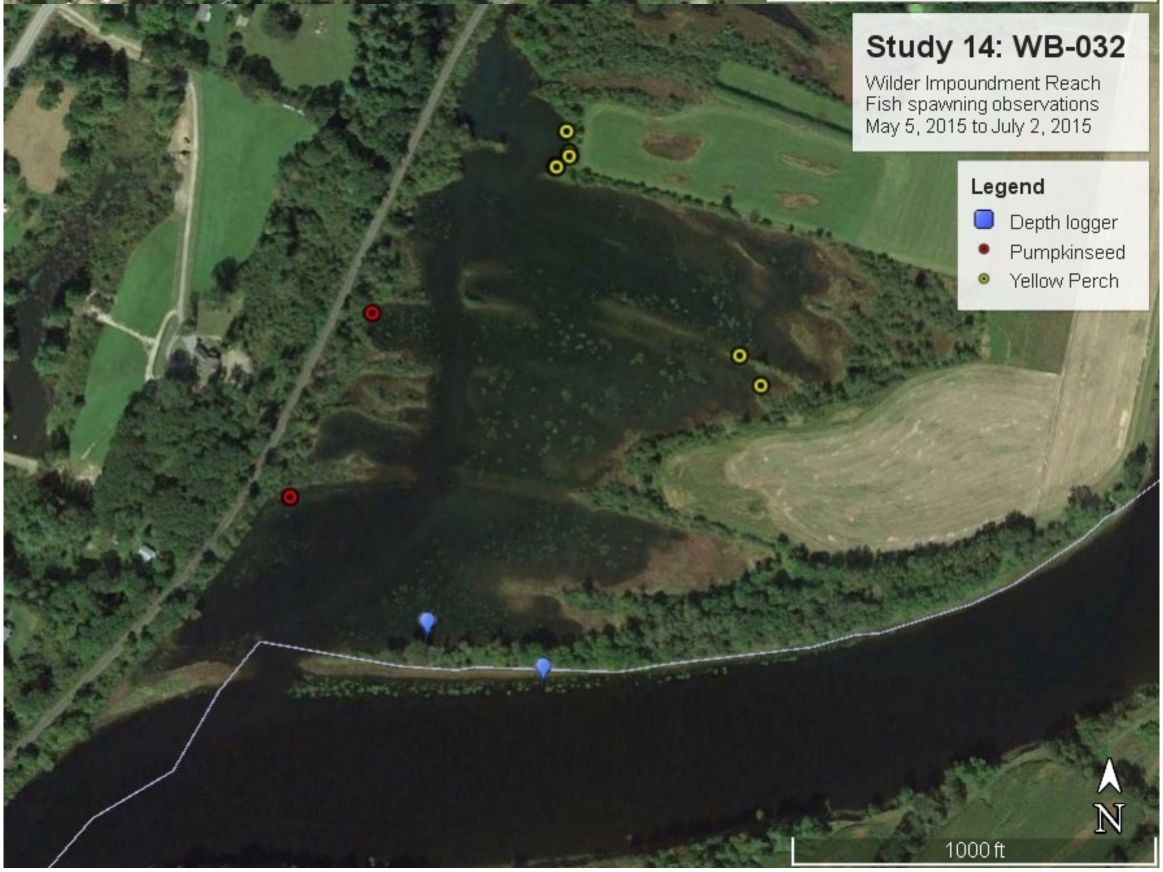

Study 14: WT-058
Wilder Impoundment Reach
Fish spawning observations
May 25, 2015 to June 8, 2015
Legend
Depth logger
Smallmouth Bass
N
1000 ft

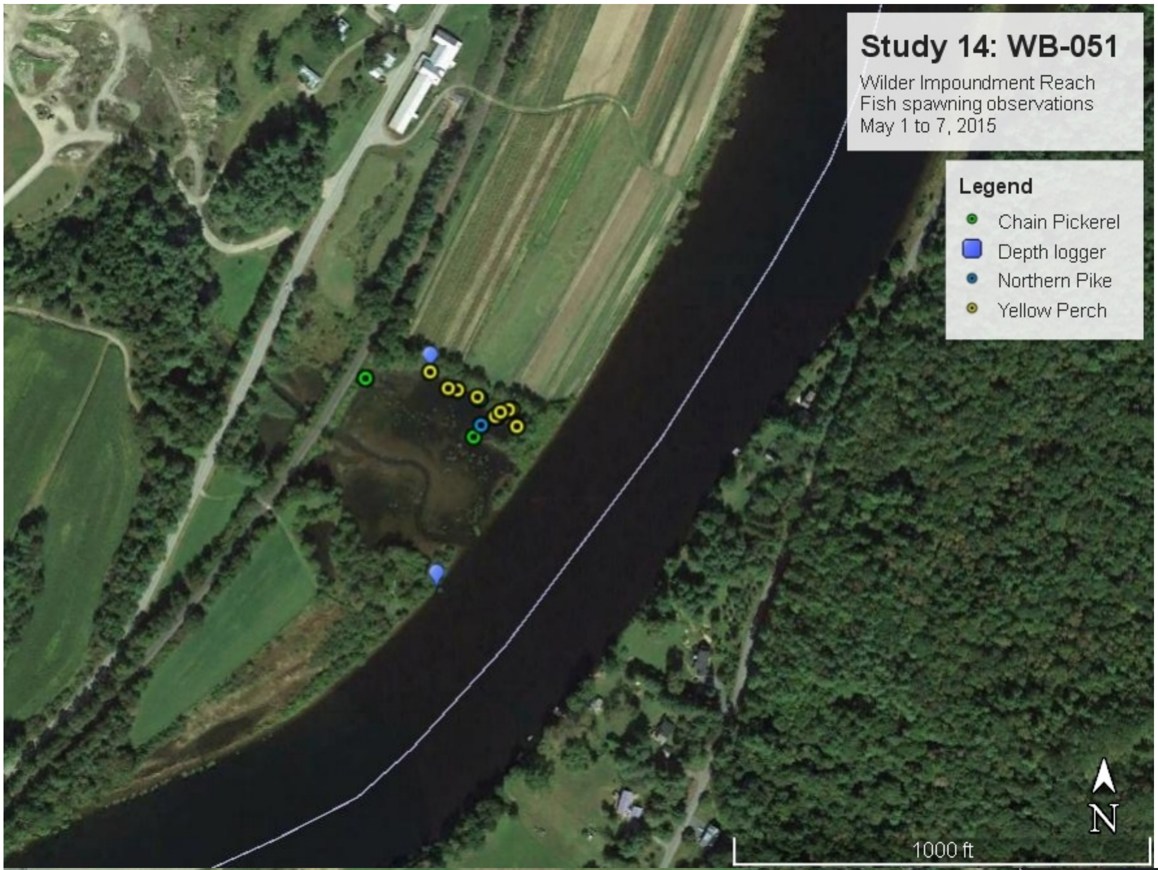

Study 14: WT-074
Wilder Impoundment Reach
Fish spawning observations
May 25, 2015 to June 26, 2015
Legend
Depth logger
Smallmouth Bass
N
1000 ft

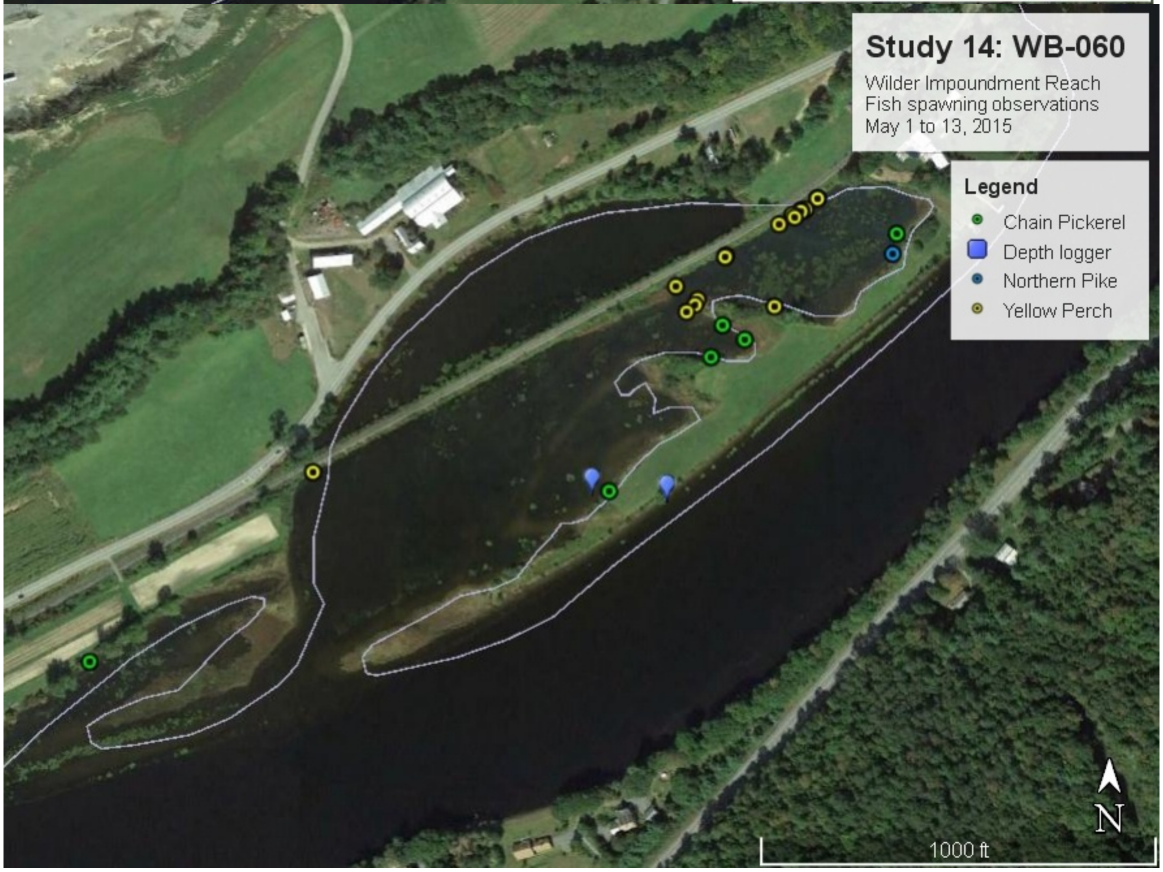

Study 14: WB-012
Wilder Impoundment Reach
Fish spawning observations
April 30, 2015 to June 18, 2015
Legend
Barometer
Depth logger
Largemouth Bass
Pumpkinseed
Yellow Perch
N
1000 ft

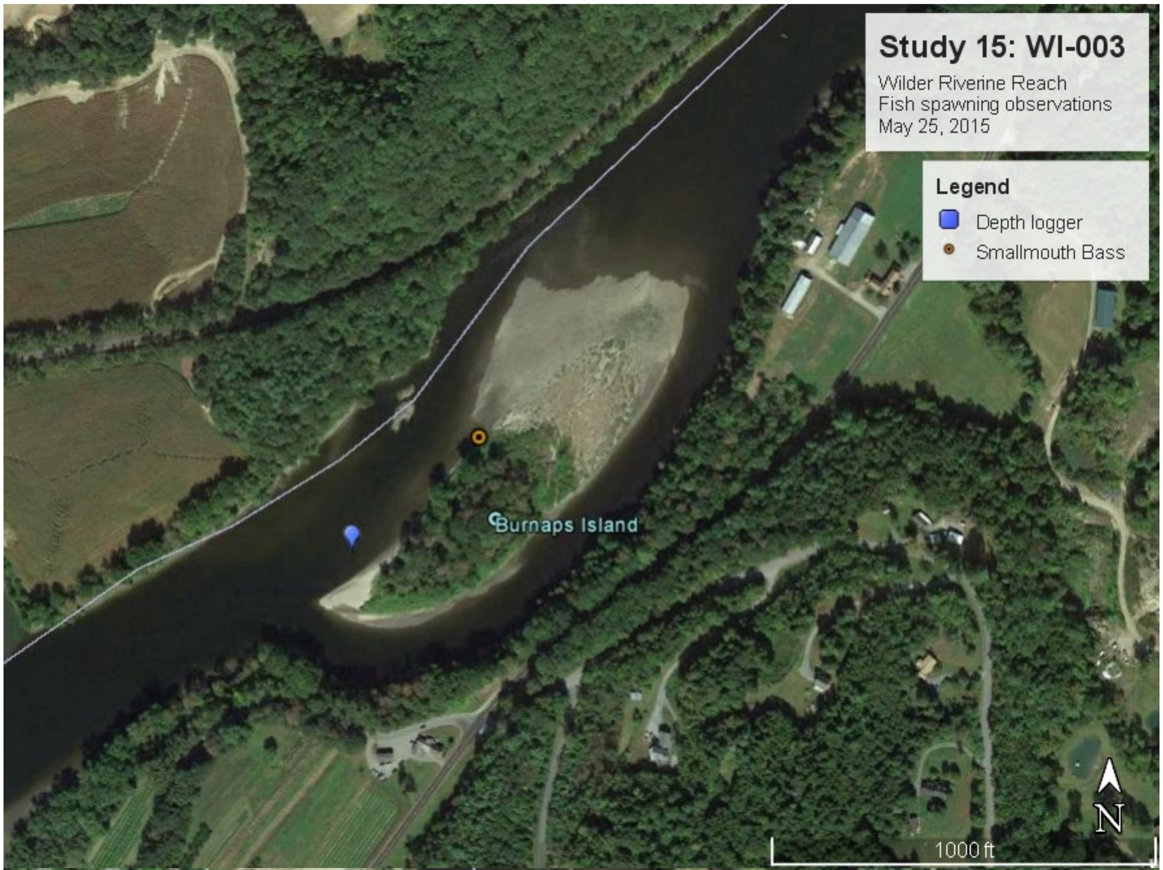

Study 14: WB-016
Wilder Impoundment Reach
Fish spawning observations
April 30, 2015 to May 7, 2015
Legend
Chain Pickerel
Depth logger
Yellow Perch
N
1000 ft

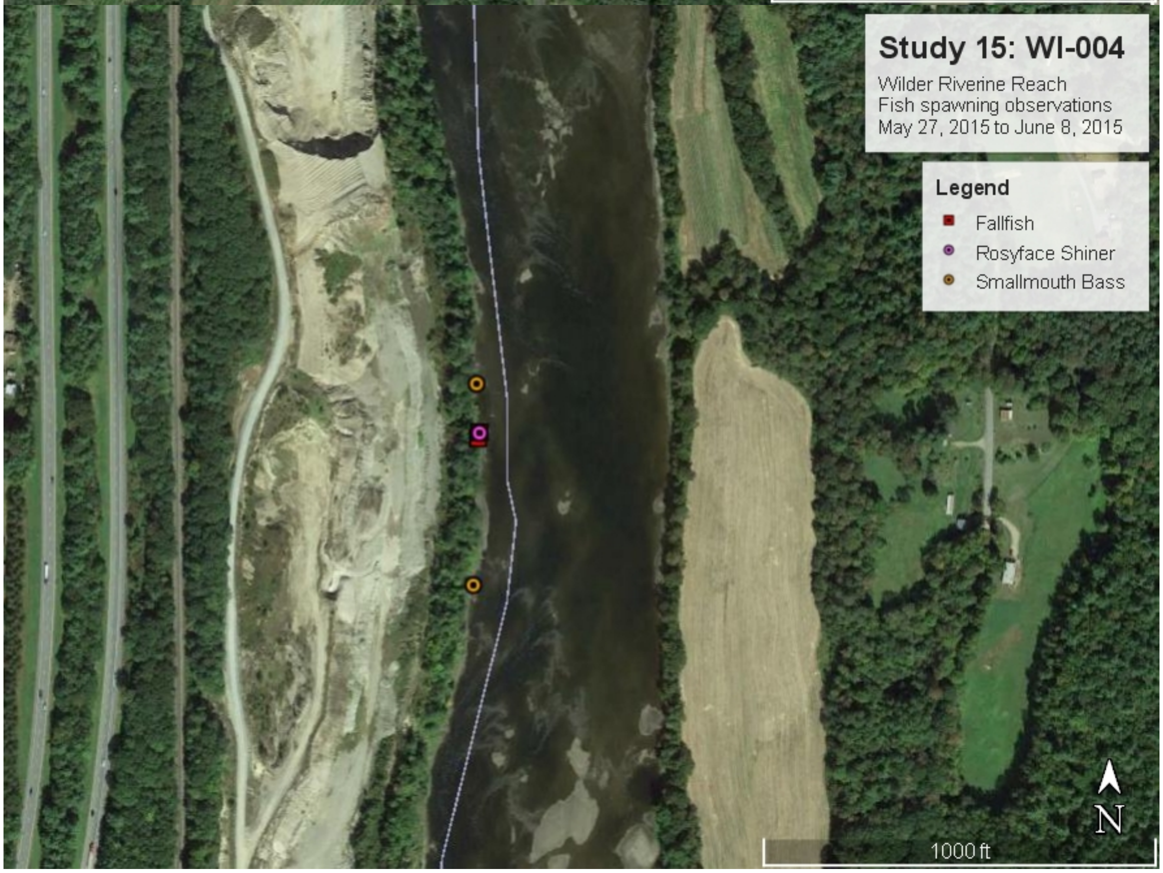

Study 14: WB-028
Wilder Impoundment Reach
Fish spawning observations
April 30, 2015 to May 12, 2015
Legend
Depth logger
Yellow Perch
N
1000 ft

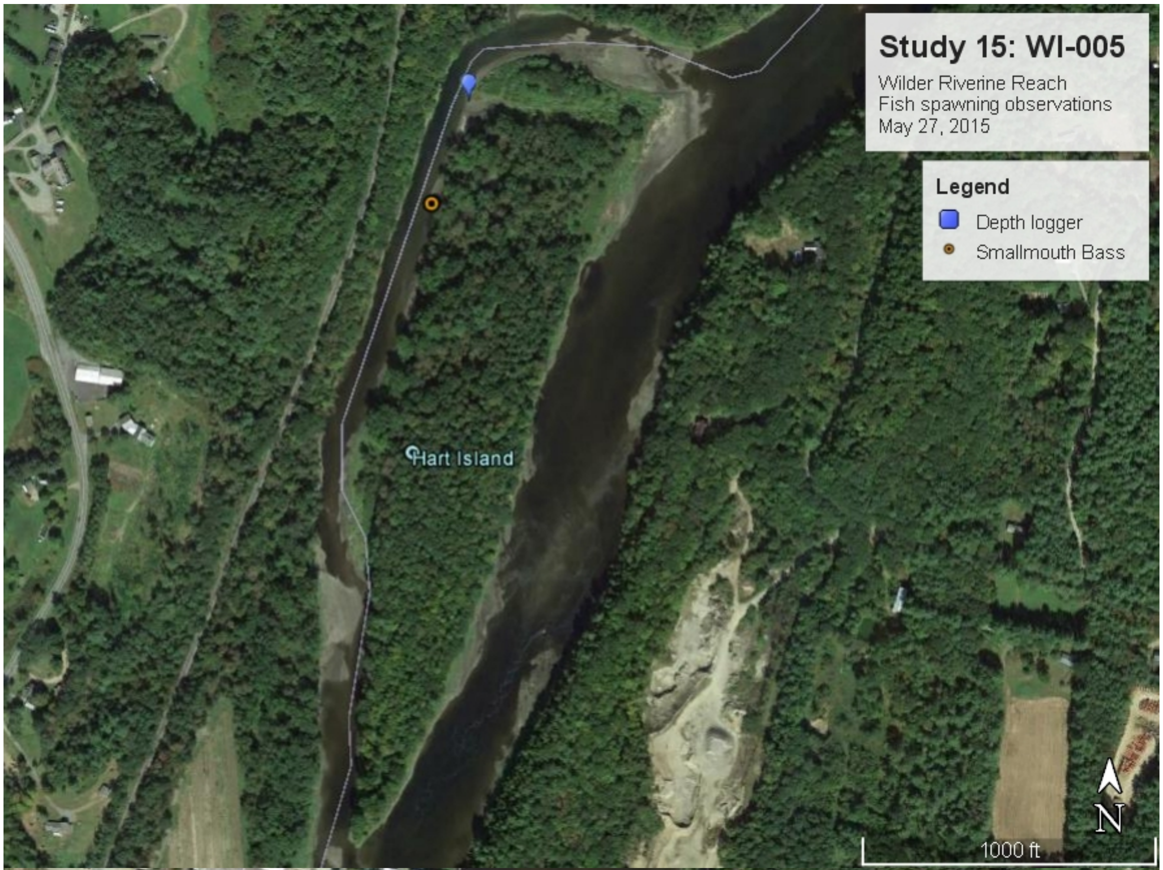

Study 14: WB-032
Wilder Impoundment Reach
Fish spawning observations
May 5, 2015 to July 2, 2015
Legend
Depth logger
Pumpkinseed
Yellow Perch
N
1000 ft

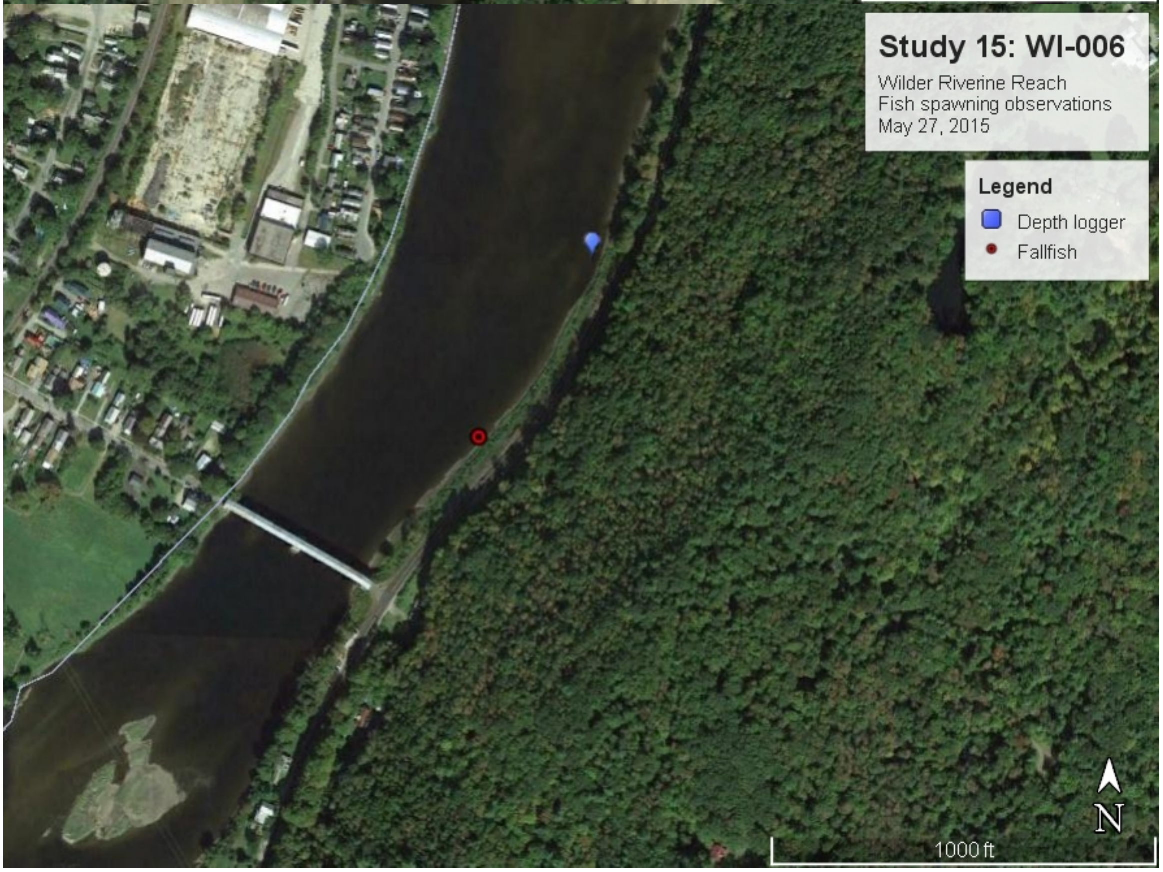

Study 14: WB-051
Wilder Impoundment Reach
Fish spawning observations
May 1 to 7, 2015
Legend
● Chain Pickerel
🟦 Depth logger
● Northern Pike
● Yellow Perch
N
1000 ft

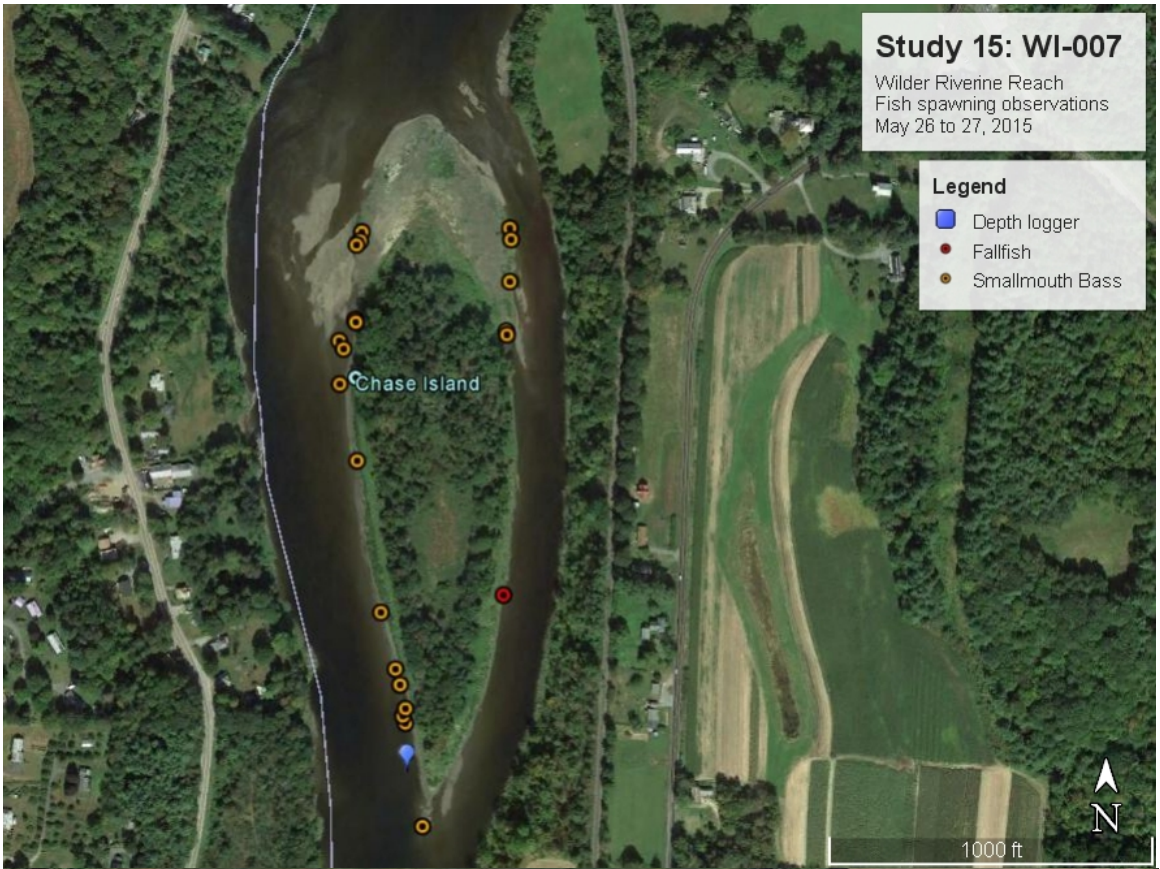

Study 14: WB-060
Wilder Impoundment Reach
Fish spawning observations
May 1 to 13, 2015
Legend
● Chain Pickerel
🟦 Depth logger
● Northern Pike
● Yellow Perch
N
1000 ft

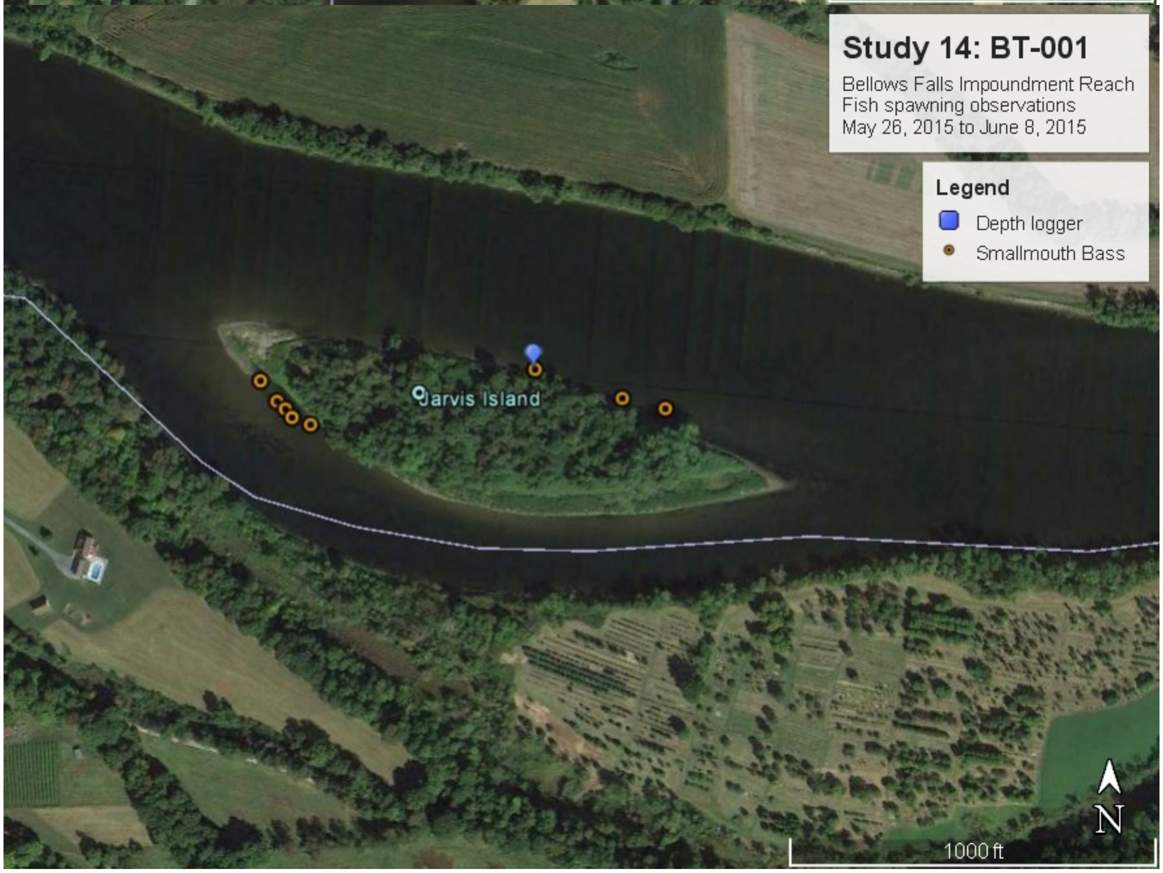

Study 15: WI-003
Wilder Riverine Reach
Fish spawning observations
May 25, 2015
Legend
Depth logger
Smallmouth Bass
Burnaps Island
N
1000 ft

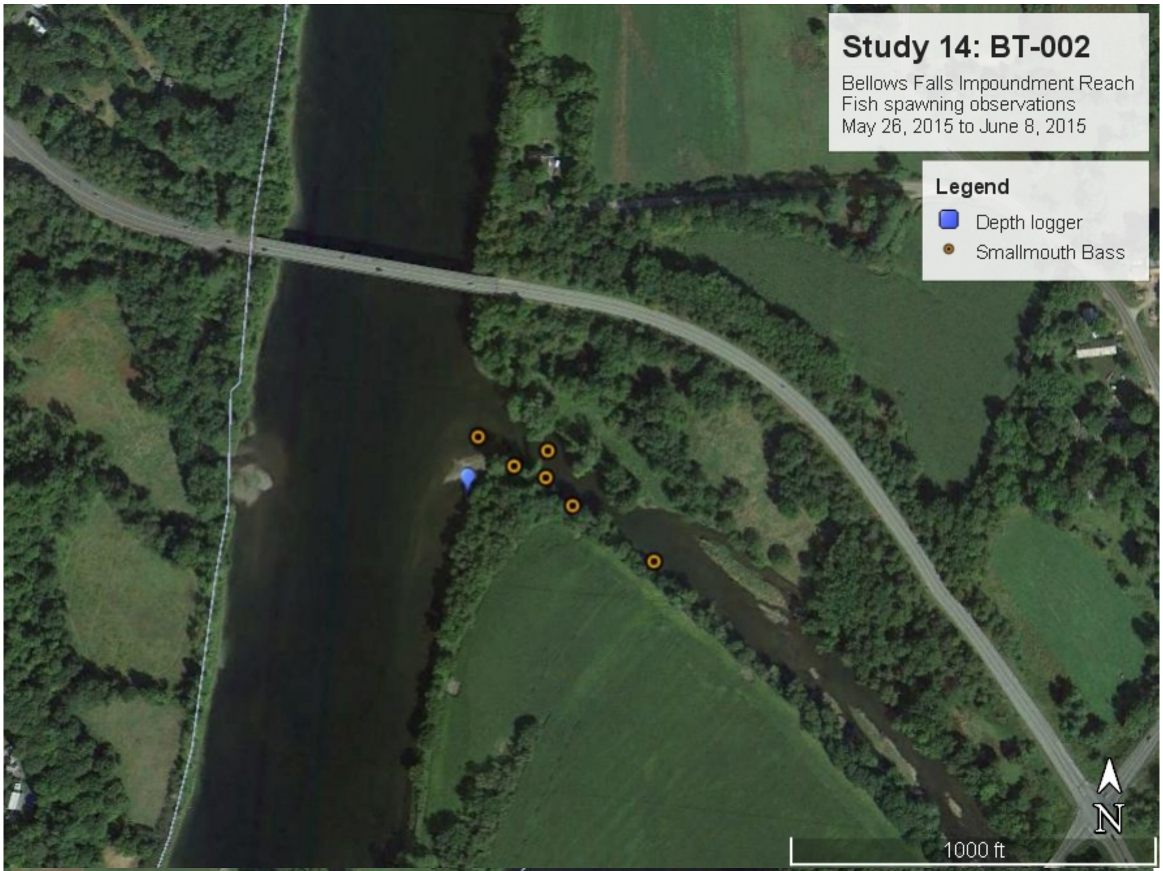

Study 15: WI-004
Wilder Riverine Reach
Fish spawning observations
May 27, 2015 to June 8, 2015
Legend
Fallfish
Rosyface Shiner
Smallmouth Bass
N
1000 ft

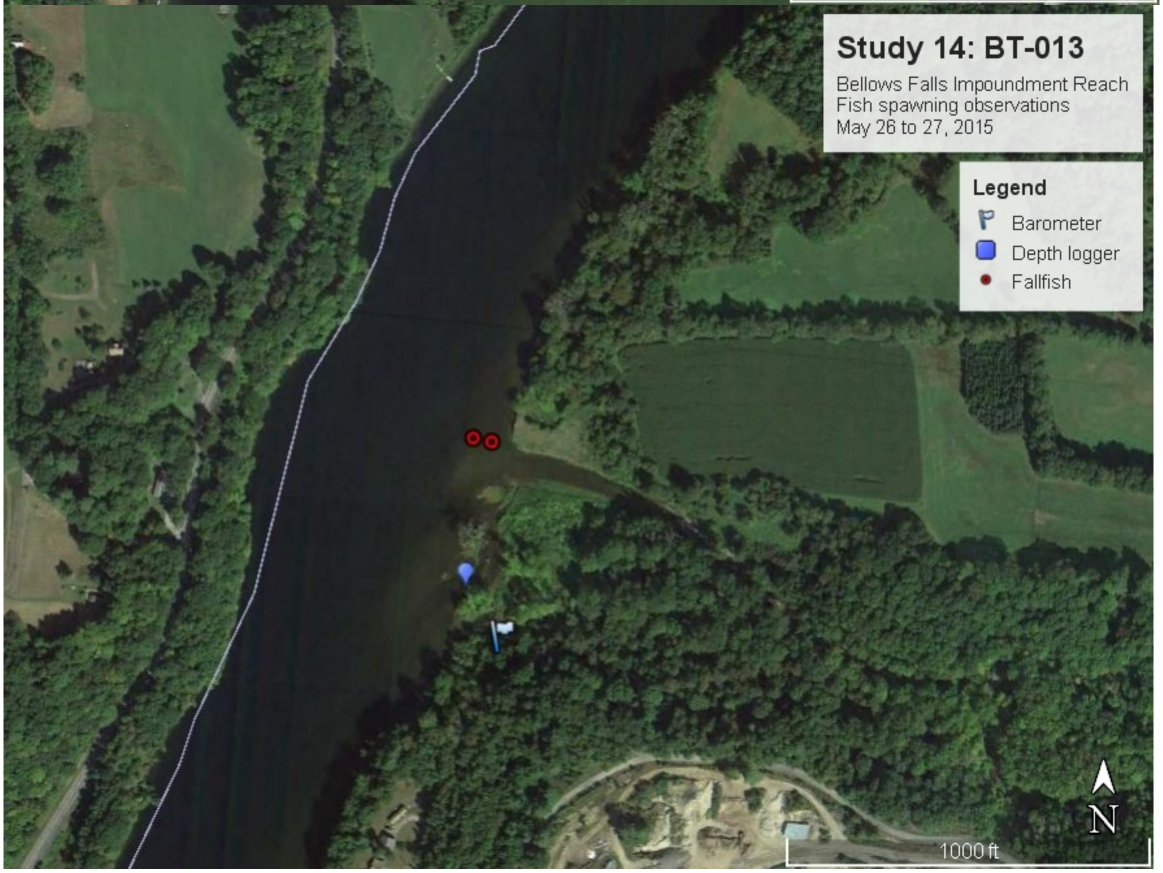

Study 15: WI-005
Wilder Riverine Reach
Fish spawning observations
May 27, 2015
Legend
Depth logger
Smallmouth Bass
Hart Island
N
1000 ft

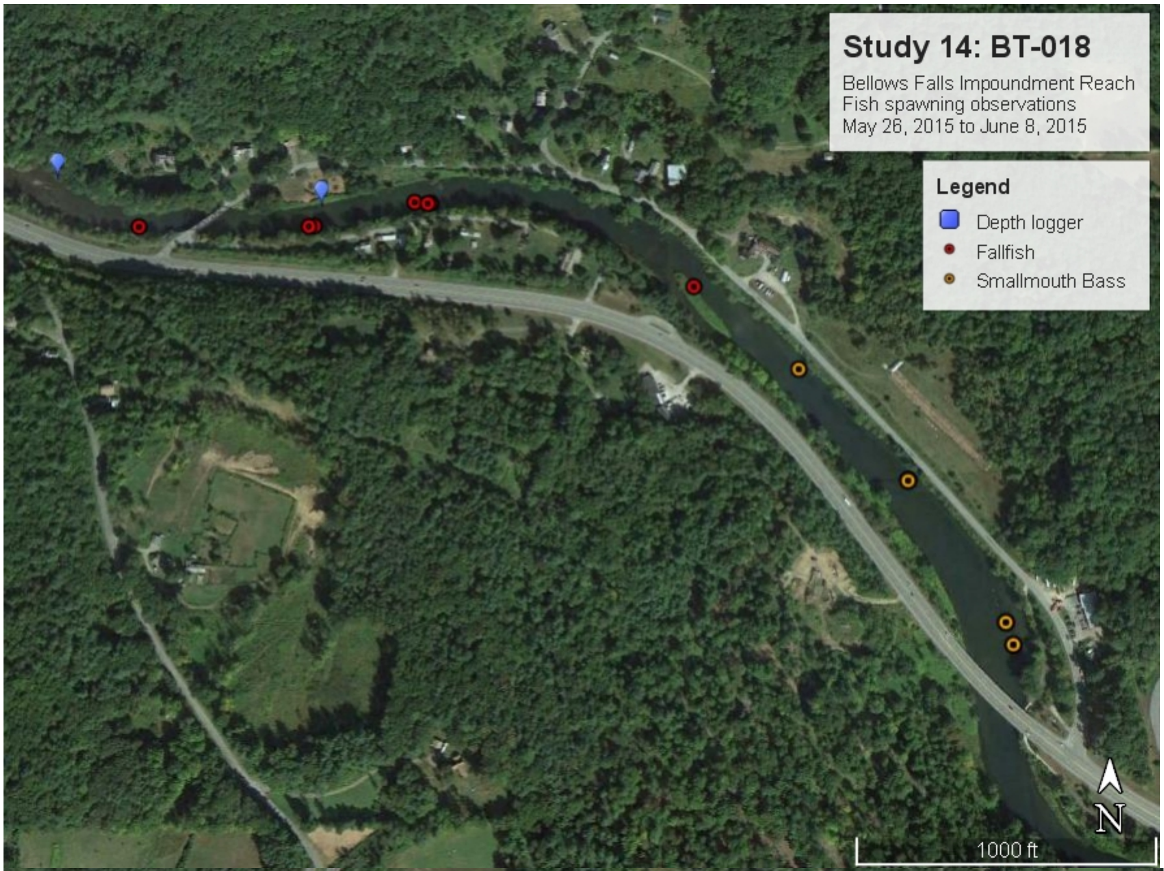

Study 15: WI-006
Wilder Riverine Reach
Fish spawning observations
May 27, 2015
Legend
Depth logger
Fallfish
N
1000 ft

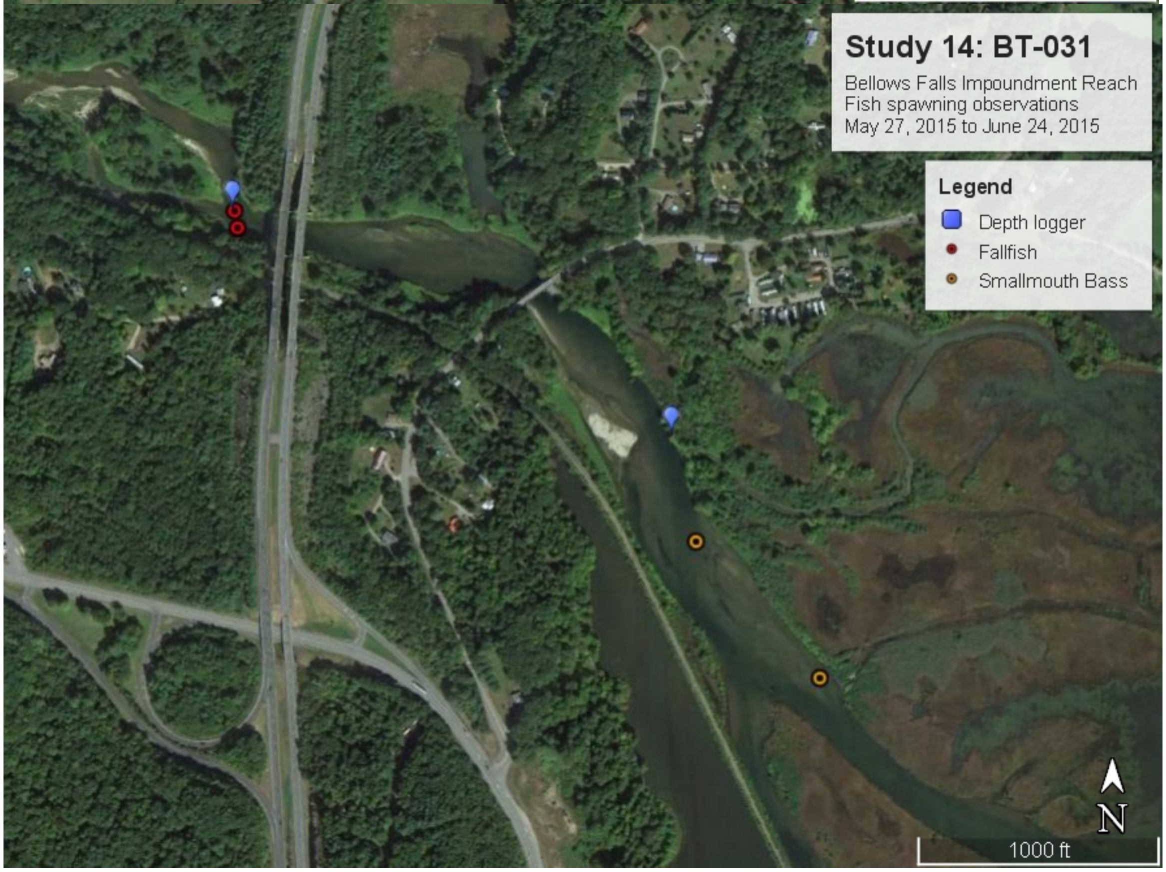

Study 15: WI-007
Wilder Riverine Reach
Fish spawning observations
May 26 to 27, 2015
Legend
🟦 Depth logger
● Fallfish
● Smallmouth Bass
Chase Island
N
1000 ft

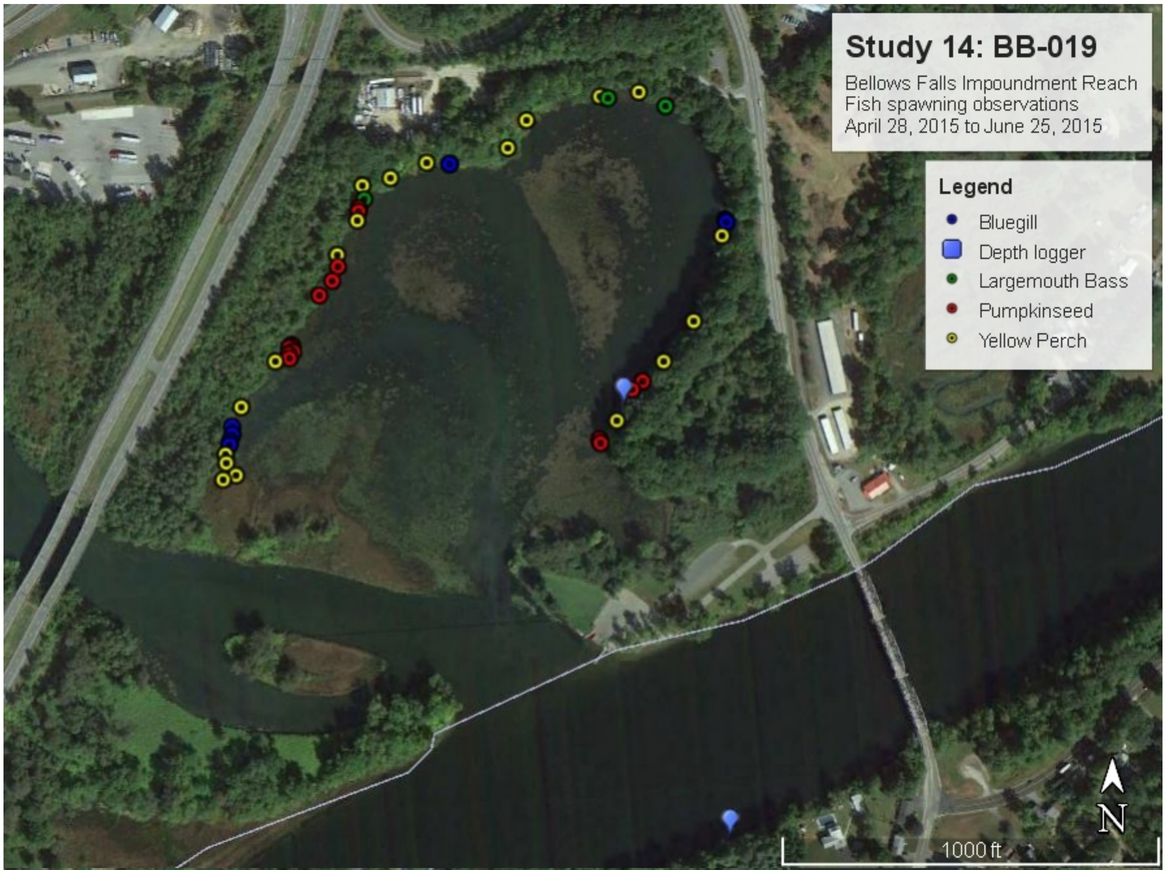

Study 14: BT-001
Bellows Falls Impoundment Reach
Fish spawning observations
May 26, 2015 to June 8, 2015
Legend
🟦 Depth logger
● Smallmouth Bass
Jarvis Island
N
1000 ft

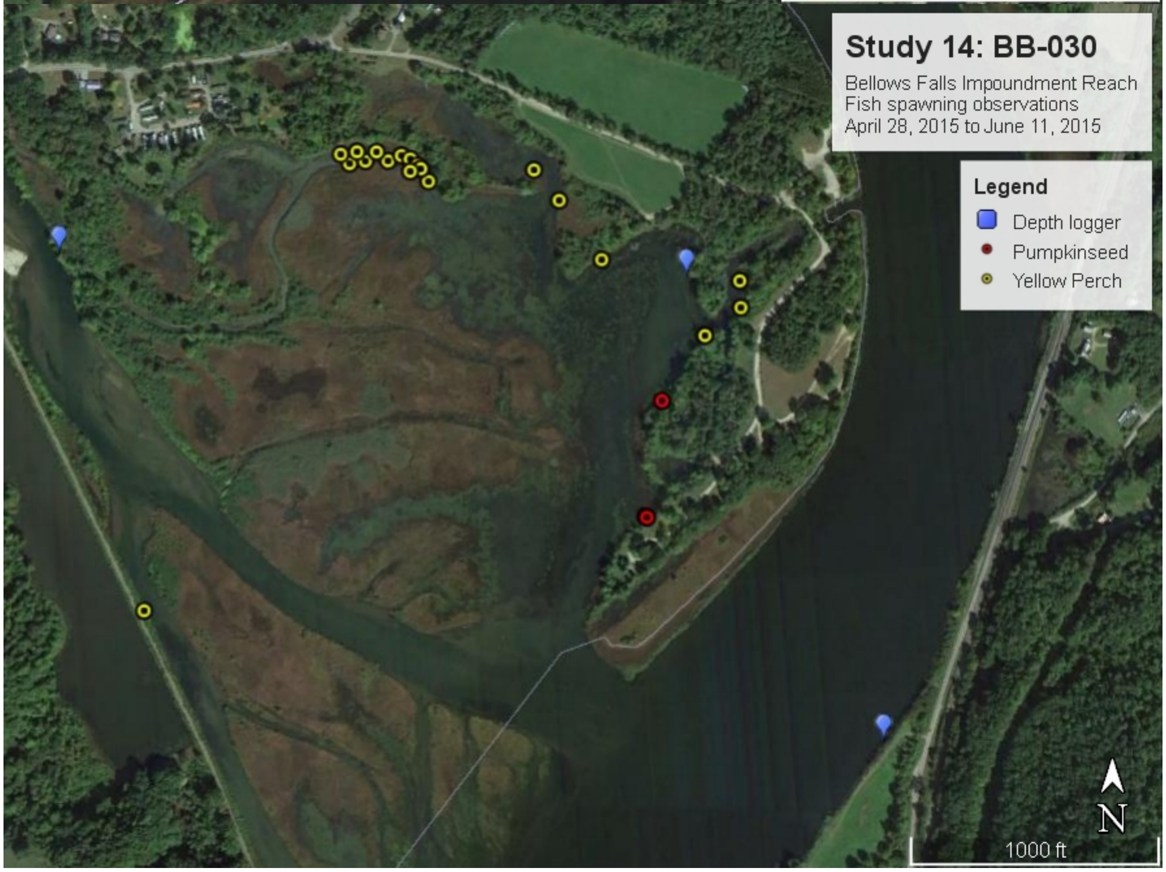

Study 14: BT-002
Bellows Falls Impoundment Reach
Fish spawning observations
May 26, 2015 to June 8, 2015
Legend
Depth logger
Smallmouth Bass
N
1000 ft

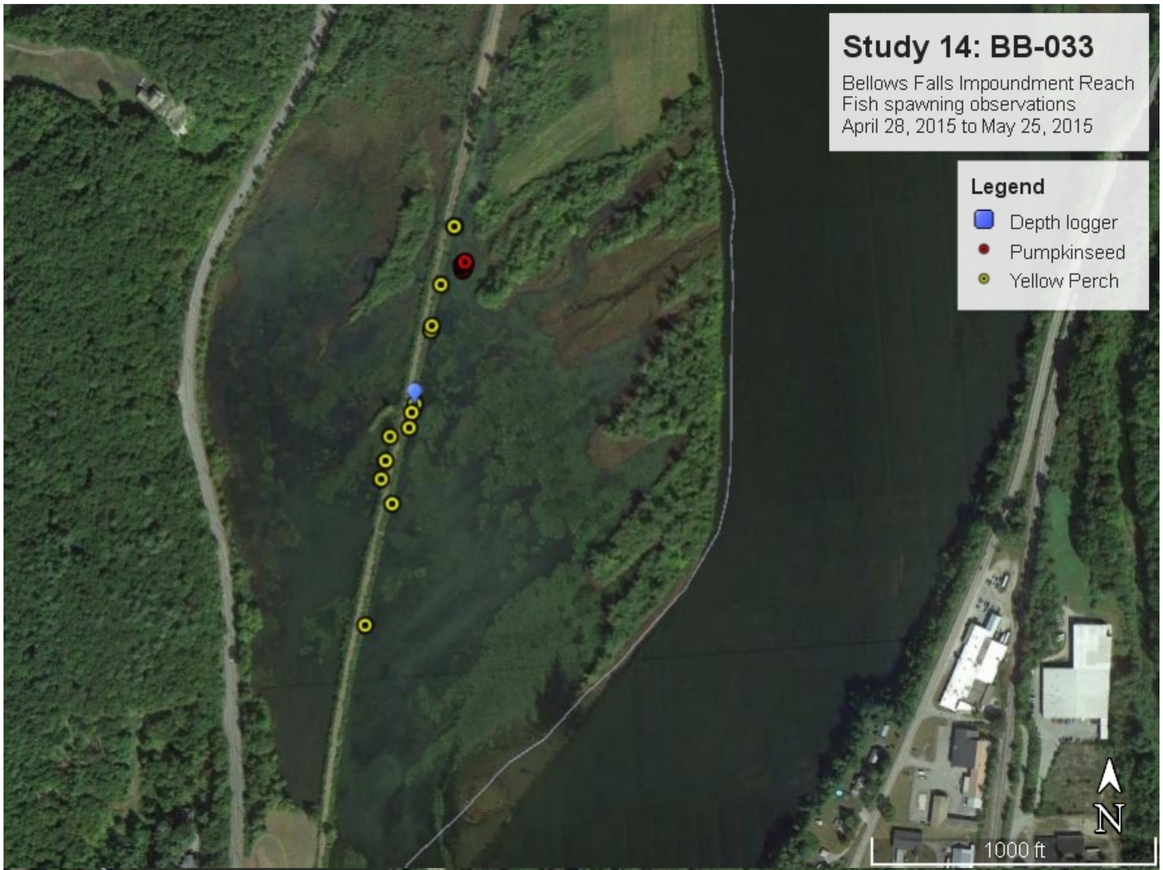

Study 14: BT-013
Bellows Falls Impoundment Reach
Fish spawning observations
May 26 to 27, 2015
Legend
Barometer
Depth logger
Fallfish
N
1000 ft

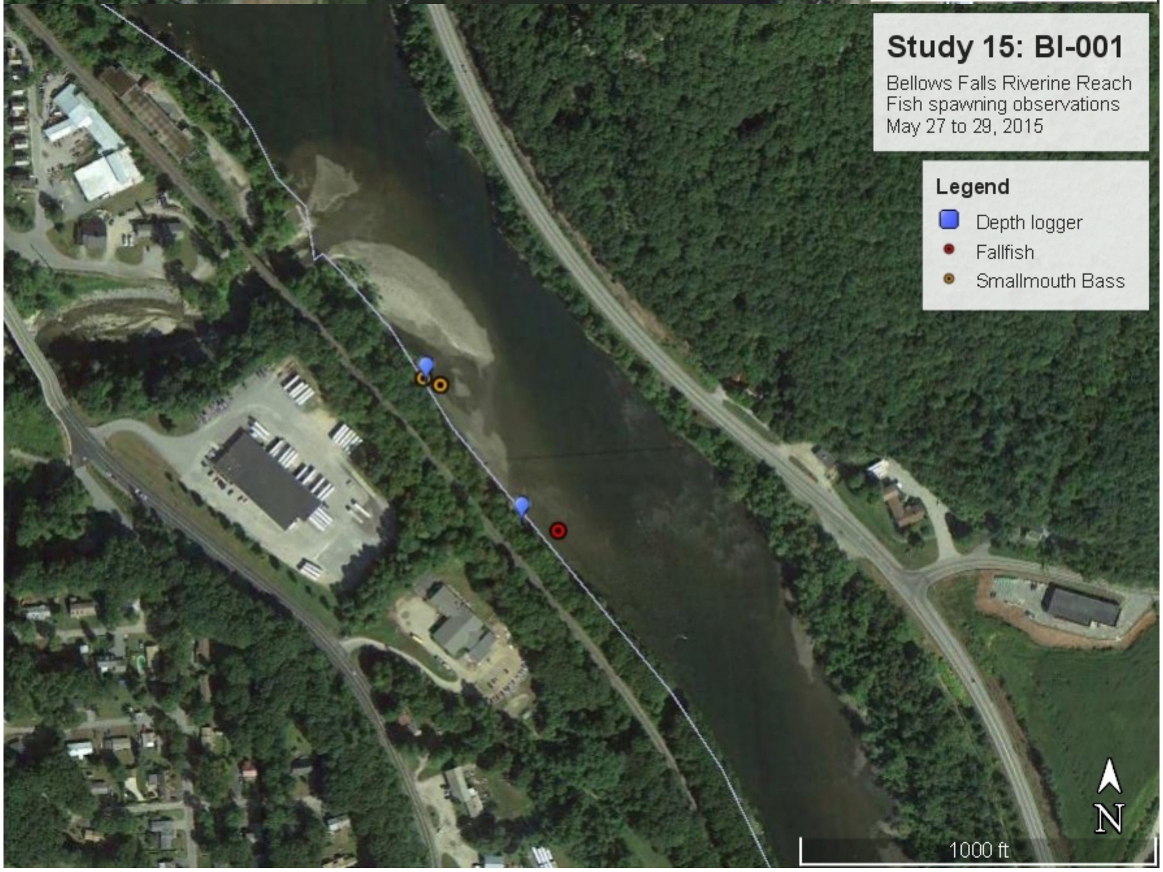

Study 14: BT-018
Bellows Falls Impoundment Reach
Fish spawning observations
May 26, 2015 to June 8, 2015
Legend
Depth logger
Fallfish
Smallmouth Bass
N
1000 ft

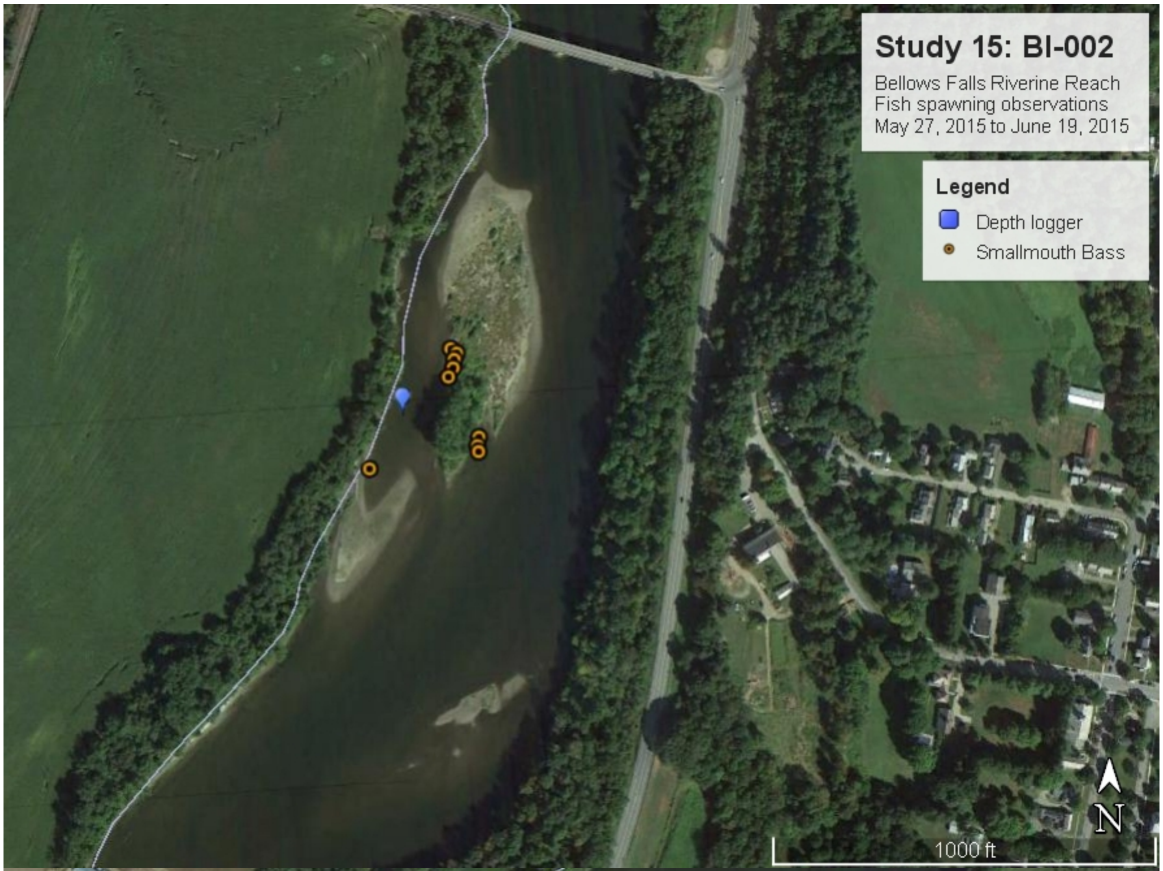

Study 14: BT-031
Bellows Falls Impoundment Reach
Fish spawning observations
May 27, 2015 to June 24, 2015
Legend
Depth logger
Fallfish
Smallmouth Bass
N
1000 ft

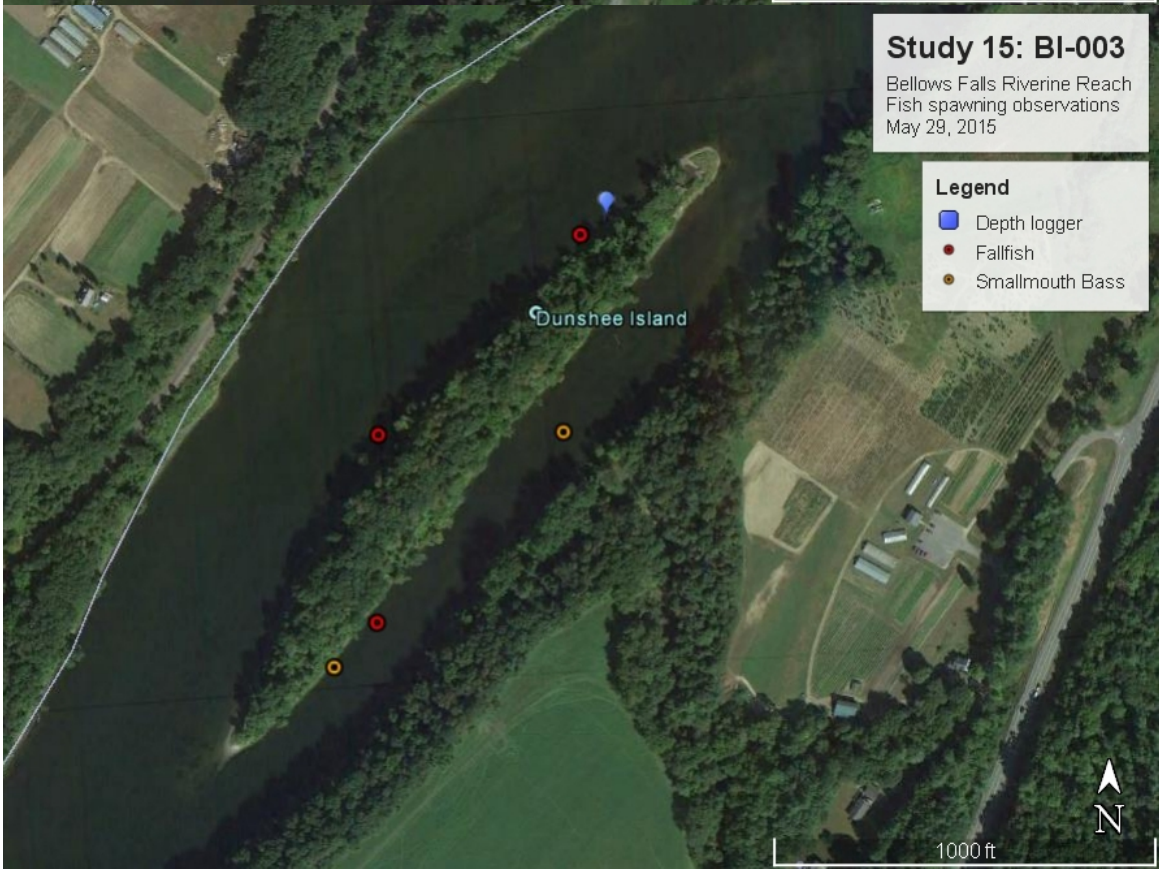

Study 14: BB-019
Bellows Falls Impoundment Reach
Fish spawning observations
April 28, 2015 to June 25, 2015
Legend
Bluegill
Depth logger
Largemouth Bass
Pumpkinseed
Yellow Perch
N
1000 ft


Study 14: BB-030
Bellows Falls Impoundment Reach
Fish spawning observations
April 28, 2015 to June 11, 2015
Legend
Depth logger
Pumpkinseed
Yellow Perch
N
1000 ft

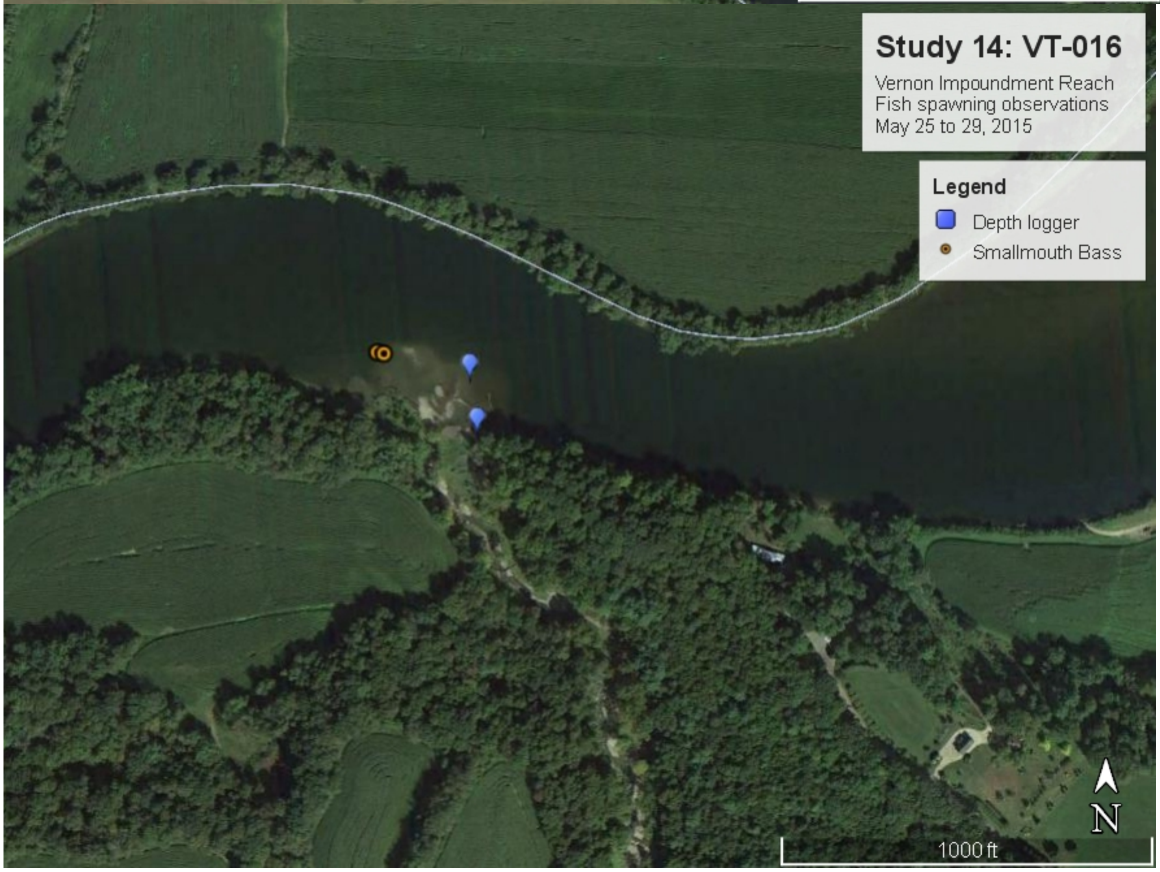

Study 14: BB-033
Bellows Falls Impoundment Reach
Fish spawning observations
April 28, 2015 to May 25, 2015
Legend
Depth logger
Pumpkinseed
Yellow Perch
N
1000 ft

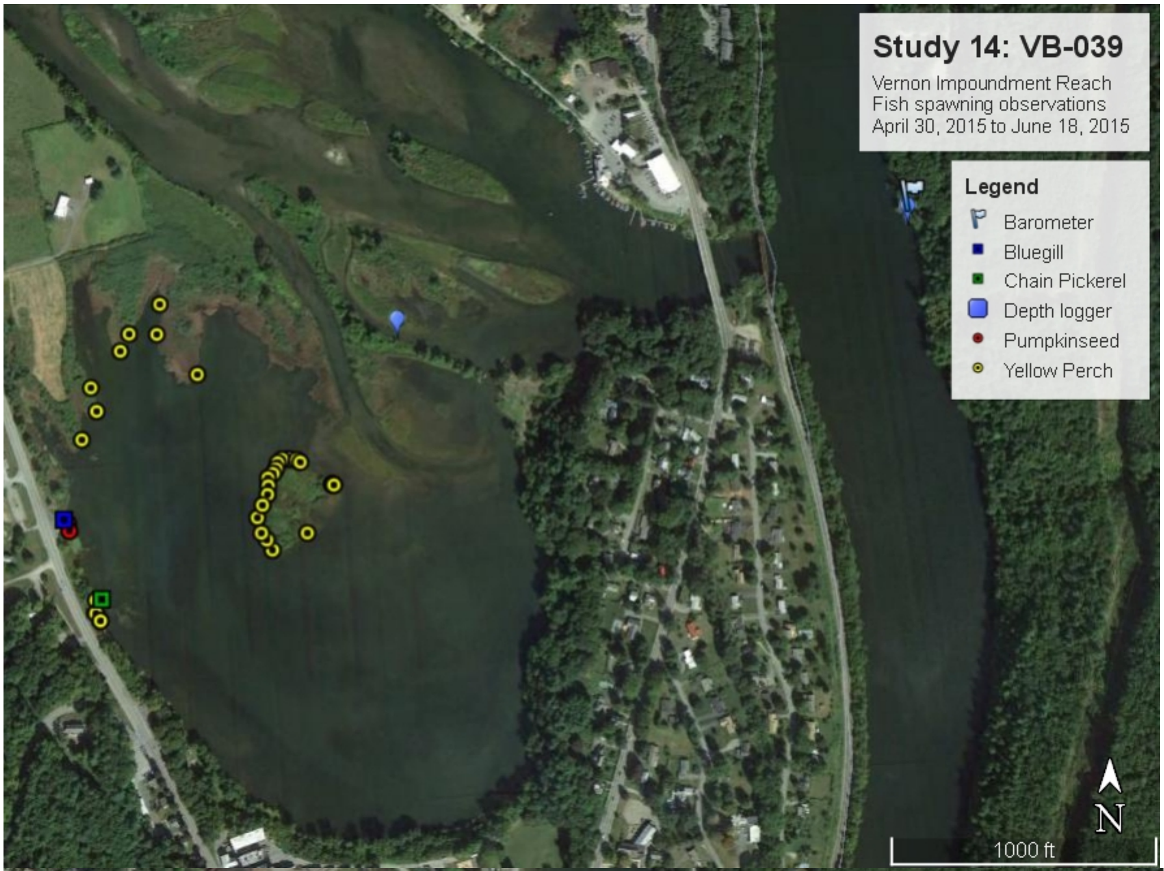

Study 15: BI-001
Bellows Falls Riverine Reach
Fish spawning observations
May 27 to 29, 2015
Legend
Depth logger
Fallfish
Smallmouth Bass
N
1000 ft

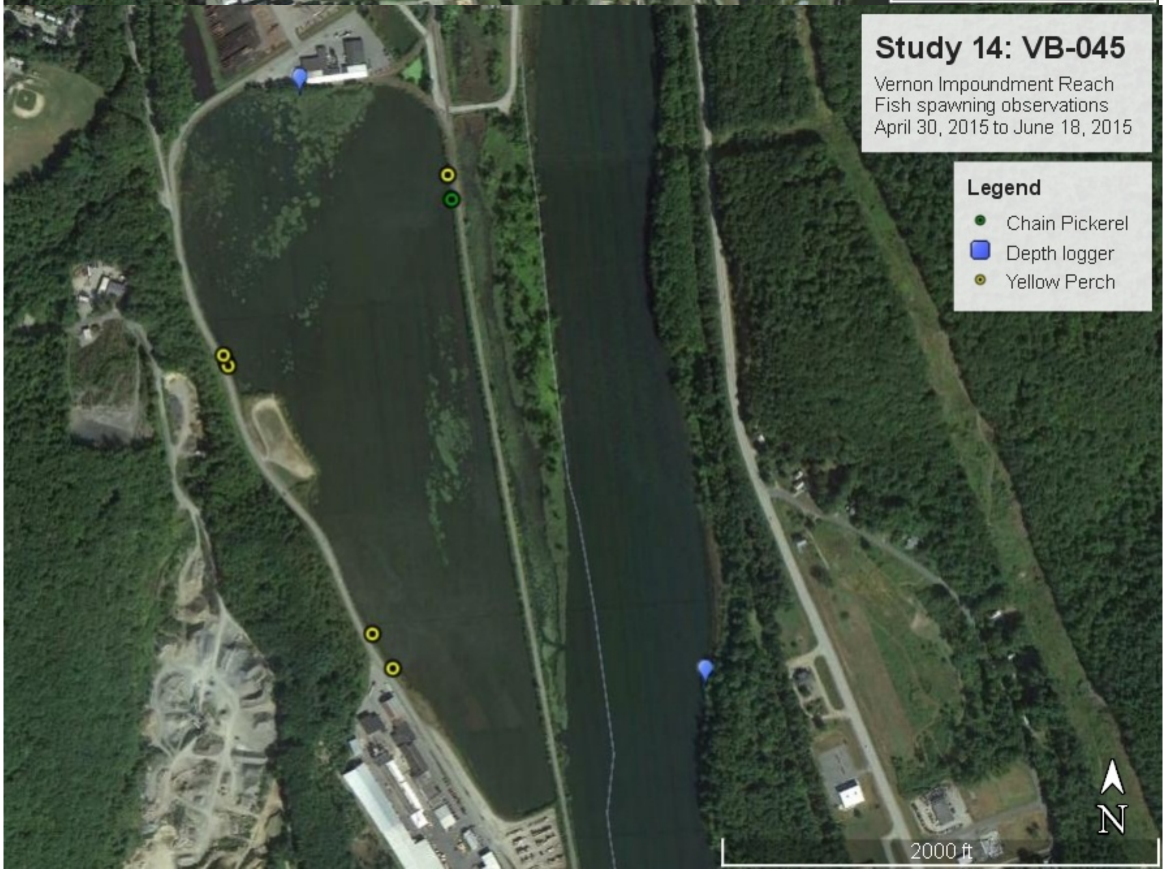

Study 15: BI-002
Bellows Falls Riverine Reach
Fish spawning observations
May 27, 2015 to June 19, 2015
Legend
Depth logger
Smallmouth Bass
N
1000 ft

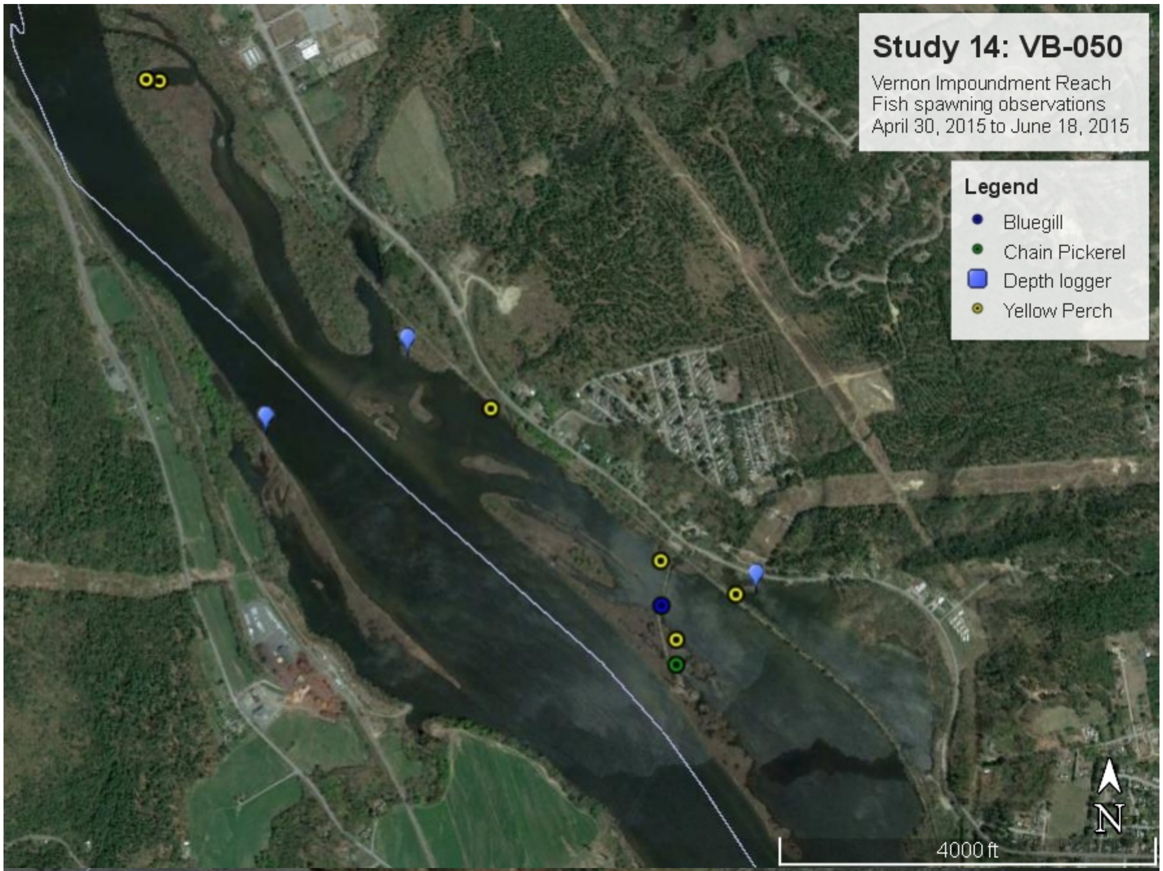

Study 15: BI-003
Bellows Falls Riverine Reach
Fish spawning observations
May 29, 2015
Legend
Depth logger
Fallfish
Smallmouth Bass
Dunshee Island
N
1000 ft

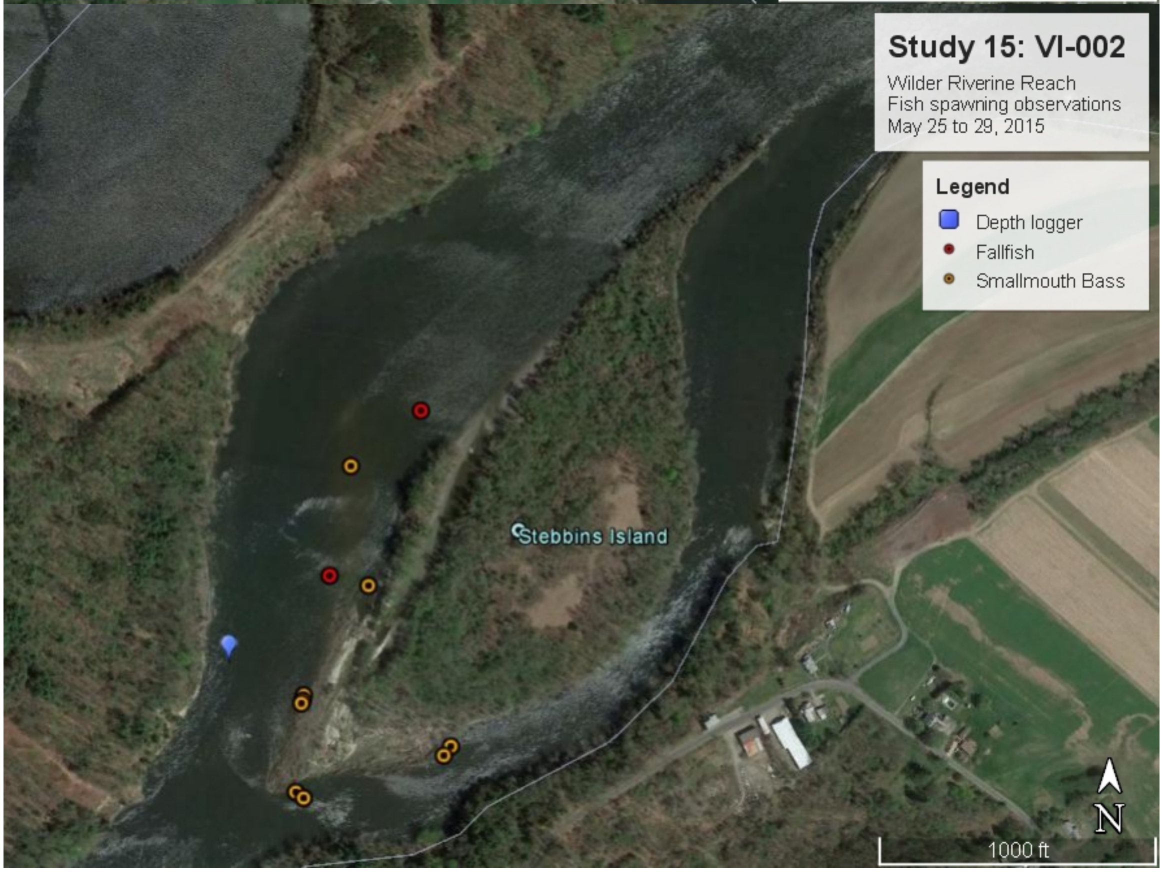

Study 14: VT-014
Vernon Impoundment Reach
Fish spawning observations
May 25, 2015 to June 19, 2015
Legend
Depth logger
Smallmouth Bass
N
1000 ft


Study 14: VT-016
Vernon Impoundment Reach
Fish spawning observations
May 25 to 29, 2015
Legend
Depth logger
Smallmouth Bass
N
1000 ft


Study 14: VB-039
Vernon Impoundment Reach
Fish spawning observations
April 30, 2015 to June 18, 2015
Legend
Barometer
Bluegill
Chain Pickerel
Depth logger
Pumpkinseed
Yellow Perch
N
1000 ft


Study 14: VB-045
Vernon Impoundment Reach
Fish spawning observations
April 30, 2015 to June 18, 2015
Legend
Chain Pickerel
Depth logger
Yellow Perch
N
2000 ft


Study 14: VB-050
Vernon Impoundment Reach
Fish spawning observations
April 30, 2015 to June 18, 2015
Legend
● Bluegill
● Chain Pickerel
■ Depth logger
● Yellow Perch
N
4000 ft


Study 15: VI-002
Wilder Riverine Reach
Fish spawning observations
May 25 to 29, 2015
Legend
■ Depth logger
● Fallfish
● Smallmouth Bass
Stebbins Island
N
1000 ft

Appendices Filed Separately in a single Excel workbook:

APPENDIX E: **Water Quality Data**

APPENDIX F: **Operations Model Analysis (revised)**