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PROTECTED INSTREAM FLOW STUDY REPORT

COLD RIVER

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List of Abbreviations

AEFOC	Alberta Environment Fisheries and Oceans Canada
cfs	cubic feet per second
cfsm	cubic per second per square mile
CRLAC	Cold River Local Advisory Committee
CWA	Clean Water Act
EPA	Environmental Protection Agency
°F	degrees Fahrenheit
ft	feet
ft^2	square feet
FTM	Floodplain Transect Method
GIS	Geographic Information System
GPS	Global Positioning System
HSI	Habitat Suitability Index
IFIM	Instream Flow Incremental Methodology
IPaC	Information for Planning and Consultation
MVP	Merrimack Valley Paddlers
NH	New Hampshire
NHB	Natural Heritage Bureau
NHDAMF	New Hampshire Department of Agriculture, Markets, and Food
NHDES	New Hampshire Department of Environmental Services
NHDFL	New Hampshire Division of Forests and Lands
PHABSIM	Physical Habitat Simulation
RMPP	Rivers Management and Protection Program
RTE	Rare, Threatened, or Endangered
SI	suitability index
TFC	Target Fish Community
UCUT	Uniform Continuous Under Threshold
USDOI	United States Department of the Interior
USFWS	United States Fish and Wildlife Services
USGS	United States Geological Survey
USGS Gage	USGS Gage No. 01154950 Cold River at High Street, at Alstead, NH
WSE	water surface elevation
WUA	Weighted Usable Area
YOY	young-of-year

Executive Summary

The New Hampshire Legislature created the Instream Flow Program in 1990, applying instream flow protections to the state's Designated Rivers. The goals of the Instream Flow Program are to maintain water for instream public uses, protect the resources for which the river or segment is designated, and regulate the quantity and quality of instream flow along designated rivers to conserve and protect outstanding characteristics.

To implement the program, the New Hampshire Department of Environmental Services (NHDES) determines the flow conditions in a stream that will protect the resources that are dependent on flow. New Hampshire has adopted regulations for the protection of instream flow on Designated Rivers (Env-Wq 1900). These regulations specify standards, criteria and procedures by which Protected Instream Flows shall be established and enforced. In accordance with the regulations, NHDES conducted a Protected Instream Flow Study on the Cold River and developed this study report, which includes proposed Protected Instream Flows. The Protected Instream Flows identified in these studies will inform the Water Management Plan for the Cold River, which will describe how water users will operate to satisfy their water use needs while also maintaining protected flow conditions.

The Protected Instream Flow Study was completed by documenting instream public uses that could be affected by potential alterations in the flow regime of the river and by performing scientific assessments to determine the flows that are needed to protect the public uses. The studies were performed within the context of the Natural Flow Paradigm, which suggests that variability of flows within and between years, as related to the natural magnitude, timing, duration, frequency and rate of change of flows, is necessary to maintain or restore the native integrity of aquatic ecosystems.

The results of three primary assessments, including aquatic habitat, riparian habitat and recreation, provided the proposed Protected Instream Flows for the Cold River. The aquatic habitat study included a stratified-random study design, which was a robust and unbiased design, for evaluating the habitat needs of prominent fish species that make up the Target Fish Community identified for the river. The riparian habitat assessment was performed using the Floodplain Transect Method, whereby the riparian communities along the river were surveyed and their frequency of inundation evaluated. Lastly, the needs of flow-dependent recreation were identified by performing surveys and interviews of recreationalists, along with online research.

In general, the habitat needs of various species within the Target Fish Community were the primary factor for low-flow protection throughout the year, whereas the needs of riparian habitat provided more general guidelines for maintaining the frequency of higher flows. Flow-dependent recreation was extremely limited on the Cold River, though protection of a combination of aquatic and riparian flows under the Natural Flow Paradigm would protect the flows for flow-dependent recreational resources on the Cold River. The Protected Instream Flows developed for the Cold River based on the studies are included in Table 1.

Table 1: Protected Instream Flows for the Cold River

Date Range	Common Flow				Critical Flow				Rare Flow			
	Common Flow (cfs)	Common Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)	Critical Flow (cfs)	Critical Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)	Rare Flow (cfs)	Rare Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)
December 1 – February 28/29	136.0	1.82	50	74	36.5	0.49	27	43	16.0	0.21	11	15
March 1 – April 15	480.0	6.43	21	37	63.0	0.84	13	21	39.0	0.52	8	12
April 16 – May 15	94.5	1.27	14	20	61.0	0.82	10	16	55.5	0.74	4	7
May 16 – July 7	125.0	1.68	24	48	16.0	0.21	9	14	10.0	0.13	6	8
July 8 – September 21	31.0	0.42	40	63	7.0	0.09	15	22	4.0	0.05	10	17
September 22 – November 30	76.5	1.03	28	64	15.5	0.21	15	27	7.5	0.10	6	10

Retain Flow Event Frequencies:

- >3,730 cfs, every 10 to 25 years
- 3,490 to 3,710 cfs every 10 years
- 1,080 cfs to 1,920 cfs every 2 years

Note: Flows provided are for the USGS gage in Alstead, NH (USGS Gage No. 01154950)

1 Introduction

1.1 New Hampshire Instream Flow Program

The New Hampshire Legislature created the Instream Flow Program in 1990, applying instream flow protections to the state's Designated Rivers. The goals of the Instream Flow Program are to maintain water for instream public uses and to protect the resources for which the river or segment is designated and to regulate the quantity and quality of instream flow along designated rivers to conserve and protect outstanding characteristics.

To implement the program, NHDES determines the flow conditions in a stream that will protect aquatic life, riparian ecosystems and recreational uses. New Hampshire has adopted regulations for the protection of instream flow on Designated Rivers (Env-Wq 1900). These regulations specify standards, criteria and procedures by which Protected Instream Flows shall be established and enforced. According to the regulation, NHDES shall conduct a Protected Instream Flow study and develop a study report that includes proposed Protected Instream Flows. The proposed flows are provided to the public for review and a public hearing is held on the study report and proposed flow before the commissioner issues a decision establishing the Protected Instream Flows for the Designated River. The Protected Instream Flow Study will:

- Identify and catalog all flow-dependent instream public uses on the Designated River listed under RSA 483:9-c, I and all designated uses under the federal Clean Water Act (CWA).
- Include an on-the-water stream survey of all flow-dependent instream public uses and designated uses under the CWA. The survey would directly observe, identify and catalog fish, wildlife, macroinvertebrates, plant and recreational uses.
- Be based upon scientific analyses using methods described in the Report of the Instream Flow Pilot Program (NHDES, 2015).

After the Protected Instream Flows are developed, management plans are drafted that describe how water users will operate to satisfy their water use needs while also maintaining protected flow conditions and how dam owners will manage their dams to maintain flow downstream.

Protected Instream Flows were developed for the Cold River by following the regulations discussed above to protect instream flows on the Cold River for future aquatic, riparian, and human uses.

1.2 Natural Flow Paradigm

Protected Instream Flow rates were developed for the Cold River within the context of the Natural Flow Paradigm (Poff et al. 1997). This concept is based on evidence suggesting that variability of flows within and between years, as related to the natural magnitude, timing, duration, frequency and rate of change of flows, is necessary to maintain or restore the native integrity of aquatic ecosystems.

1.3 Cold River Background

1.3.1 Designation

The New Hampshire Legislature created the Rivers Management and Protection Program (RMPP) within NHDES in 1988. The RMPP helps New Hampshire communities and towns protect a river. It allows for a wide range of uses for the river without adversely affecting the resources of the river. The Cold River was accepted into the RMPP as a Designated River in 1999. It is recognized for its significant statewide natural, cultural, scenic and scientific resources. The Cold River is protected under the RMPP from the outlet at the Crescent Lake Dam in Acworth to its confluence with the Connecticut River in Walpole, making the Designated portion of the river its full 23 miles. From the outlet of Crescent Lake to the Langdon/Walpole town line, which is approximately 20.3 miles downstream of Crescent Lake, the river is classified as a Rural River. From the Langdon/Walpole town line to the confluence with the Connecticut River, the river is classified as a Community River.

1.3.2 General Description

Cold River near Route 123A in Acworth

The Cold River flows for approximately 23 miles from its headwaters at Crescent Lake, through the towns of Unity, Acworth, Lempster, Alstead and Langdon to its confluence with the Connecticut River in Walpole, where it has a drainage area of approximately 102 square miles (Figure 1.3.2-1). Downstream of Crescent Lake, the river increases quickly in size as it is joined by many small tributaries, including Dodge Brook near East Acworth. Other major tributaries include Honey Brook, Bowers Brook, Great Brook (Acworth), Warren Brook and Great Brook (Langdon). The river gradient is moderately steep, with a change in elevation of 975 feet along its course. There are several areas where the water flows swiftly over ledges and waterfalls. Runoff from heavy rainfall or snowmelt in the watershed can move quickly downstream due to steep slopes, an abundance of relatively impermeable geologic deposits and a lack of flood control structures. It was impacted to a great degree during a major flood in 2005 and subsequent recovery, restoration and stabilization efforts.

There are currently 13 active or historic dams on the Cold River, 11 of which have been breached. Of the two remaining dams, one is located at the outlet of Crescent Lake and the other at Vilas Pool. The dam at Crescent Lake is 3 feet-high and impounds the 128-acre Crescent Lake. The dam at Vilas pool is 35 feet tall and impounds approximately 6 acres. It is used primarily for recreation and as a source of water for firefighting. Lake Warren, on Warren Brook, is the largest lake in the watershed at approximately 185 acres and was first dammed in 1770 to provide a reservoir for downstream mills, which are no longer in existence. There are no active hydroelectric projects on the river today. There is one active stream gage located on the river, USGS Gage No. 01154950 at High Street in Alstead, NH (USGS gage). The gage has a drainage area of 74.6 square miles and a period of record from 2009 to present. The only registered water withdrawal in the Cold River and in the watershed is Cold River Materials, a large gravel and aggregate operation in Walpole (CRLAC, 2009) (Figure 1.3.2-1).

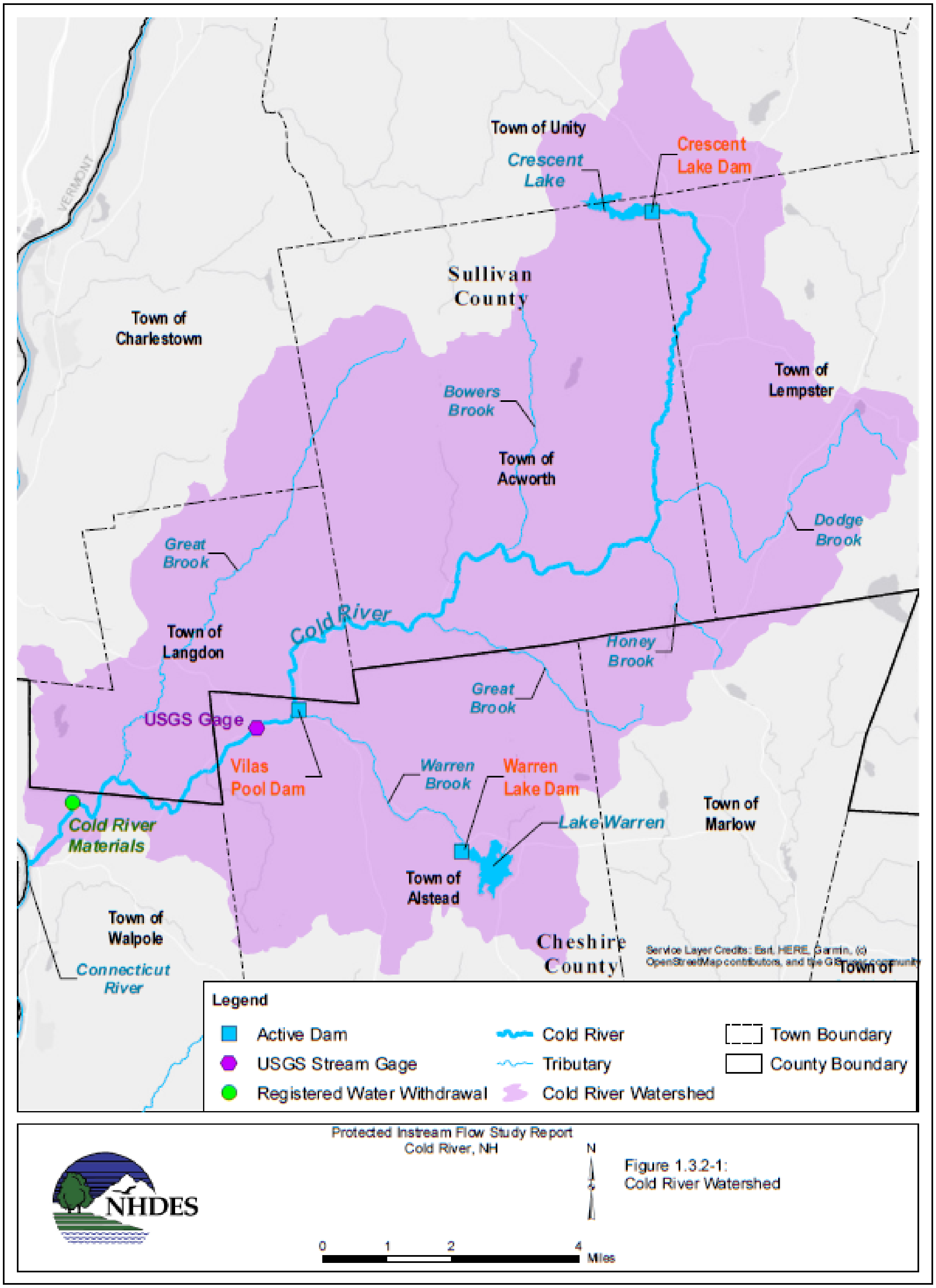

Floodplain Forest on the Cold River

The river supports a diverse habitat, composed of wetlands, forest and agricultural open space that harbors a variety of wildlife, including protected species such as bald eagle, peregrine falcon, Cooper's hawk, osprey, sedge wren, timber rattlesnake and several endangered plant species (NHDES, 2019). Three exemplary natural communities are supported by the river and river corridor environment, including the Southern New England Acidic Rocky Summit/Rock Outcrop, Central New England Dry Transitional Forest on Acidic Bedrock and Till and the Southern New England Floodplain Forest. Multiple, relatively large wetlands are present along the river, especially in the town of Lempster, downstream to East Acworth and several other stretches of the river contain smaller wetland systems.

Fish species in the river include a mixture of coldwater and warmwater species and it is stocked annually with salmonids. Fish community samples collected along the stream indicate that Blacknose Dace dominate the fish community (Gomez and Sullivan, 2018). Historically, the river was considered nursery and rearing habitat for juvenile Atlantic salmon, a federally endangered anadromous species; however, the restoration efforts for salmon in the Connecticut River watershed are no longer on-going. The only known documentation of Sea Lamprey presence is the capture of one larval ammocoete in 2021 by NHDES while electrofishing in the reach of river downstream of Drewsville Gorge.

In the Cold River Corridor Survey and Cold River Area Landowner Survey, both performed by the Upper Valley Lake Sunapee Regional Planning Commission in 1999, a variety of recreational uses were identified, including: fishing, swimming, skiing, bird and wildlife observation, walks, canoeing/kayaking, admiring natural scenic views, biking, hunting, photography and snowmobiling. Though there is little formal public access to the Cold River, there are several informal access points.

Figure 1.3.2-1: Cold River Watershed



2 Occurrence of Protected Entities on the Cold Designated River

The protection goals of the Instream Flow Program are to maintain water for flow-dependent instream public uses and protect the resources for which the river or segment is designated and to regulate water quality and quantity in designated rivers to conserve and protect the river's outstanding characteristics. Specific categories of the instream public uses and outstanding characteristics and resources (collectively called protected entities in the Instream Flow Program) are described in RSA 483.

The Cold River's protected entities were identified by gathering readily available information and data, performing an on-stream reconnaissance survey and through various data collection efforts along the river.

2.1 Aquatic Organisms

The Cold River is known as an important coldwater fishery that provides habitat for approximately 13 resident species. Many pools and undercuts in the river provide ideal conditions for coldwater fish. The importance of the Cold River for fish habitat is highlighted by its designation as a Special Focus Area within the Silvio O. Conte National Fish and Wildlife Refuge of the Connecticut River watershed. The diverse range of mesohabitats on the Cold River provide important habitat to several different aquatic species, which rely on sufficient instream flows to survive.

2.1.1 Target Fish Community

The Target Fish Community (TFC) for the Cold River was developed using fish community data from the best available reference rivers that would characterize a feasible and currently relevant fish community (Bain and Meixler, 2005). As such, the TFC model does not represent a historically "natural" community, but instead represents a community that would be expected to exist in the present time given relatively low direct anthropogenic impact on instream habitat. The TFC developed for the Cold River (Figure 2.1.1-1) was used for the development of protected instream flows for aquatic habitat on the river. Details on the development of the TFC on the Cold River are documented in Gomez and Sullivan Engineers (2018).

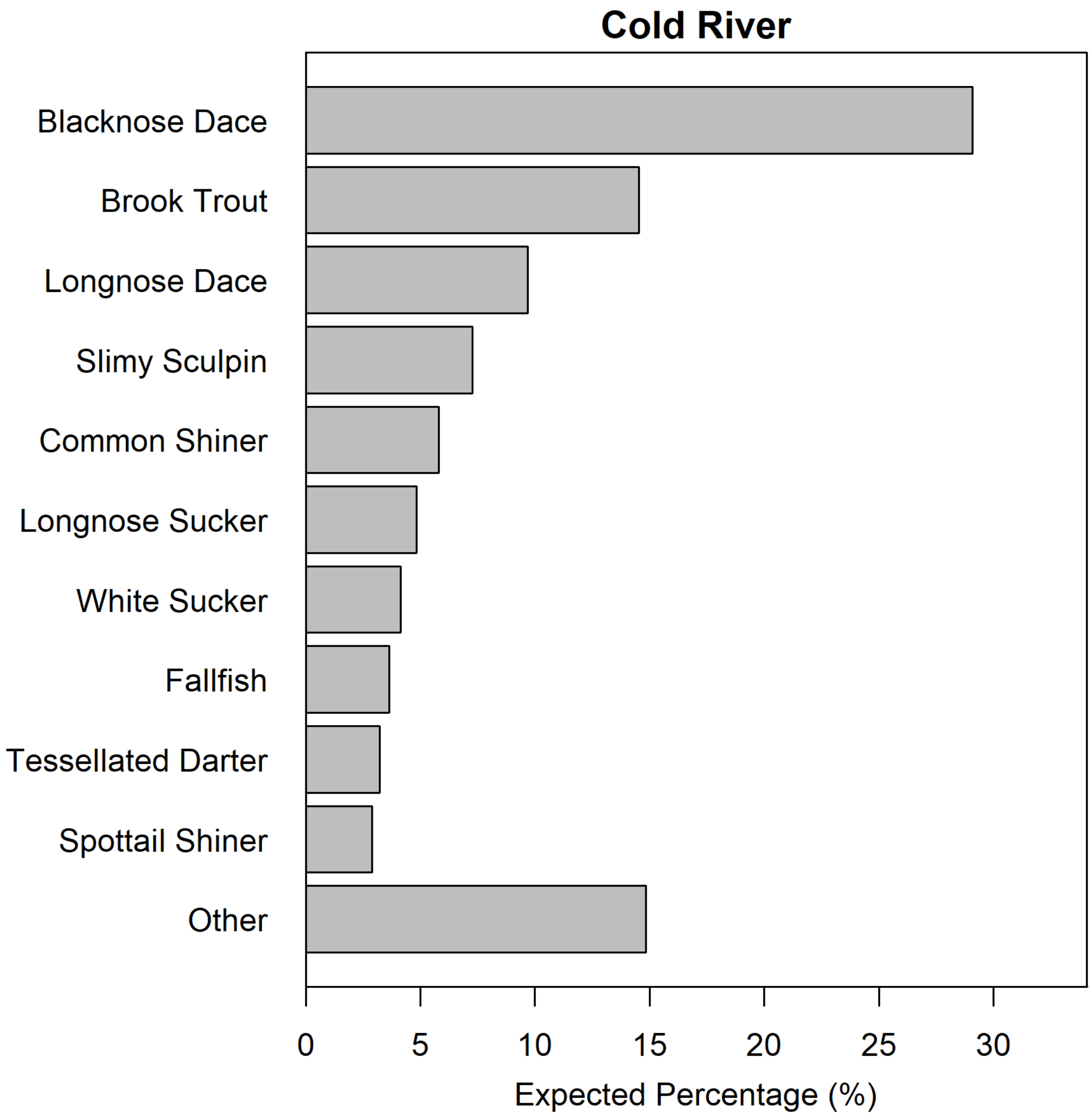


Figure 2.1.1-1: Target Fish Community for the Cold River

2.1.2 Aquatic Species

As part of development of the TFC, a comprehensive list of fish species native to the Cold River was developed (Table 2.1.2-1). In addition to the native fish species, non-native species have also been documented in fisheries surveys conducted by the State of New Hampshire. Smallmouth bass (*Micropterus dolomieu*) are introduced and have been documented in the furthest downstream reaches and brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta)* and rainbow trout (*Onchorynchus mykiss*) are currently stocked in the river.

It should be noted that the variety of aquatic species in the river are not likely to be evenly distributed. They will typically occur in areas of suitable habitat but may also distribute themselves based on interactions with other species and their environment. One major factor in the distribution of coldwater species such as brook trout, one of the prominent species in the TFC, includes the location of coldwater thermal refugia. In general, water temperatures above 70°F can be lethal to brook trout, particularly if those temperatures occur over long periods of time. Based on water temperature data collected in 2020, average monthly temperatures along most of the Cold River exceed 70°F during the summer, with maximum temperatures exceeding 80°F in most areas (Figure 2.1.2-1). However, water temperatures did not steadily increase with distance downstream, suggesting the presence of coldwater inflows (e.g., tributaries, springs) that could provide refugia to coldwater fish during the summer.

Table 2.1.2-1: Comprehensive List of Species Native to the Cold River

Species	Habitat Use Classification	Pollution Tolerance	Thermal Regime
American eel (*Anguilla rostrata*)	MG	T	Eurythermal
Atlantic salmon (*Salmo salar*)	FD	I	Cold
blacknose dace (*Rhinichthys atratulus*)	FS	T	Eurythermal
brook trout (*Salvelinus fontinalis*)	FS	I	Cold
brown bullhead (*Ameiurus nebulosus*)	MG	T	Warm
burbot (*Lota lota*)	FD	S	Cold
chain pickerel (*Esox niger*)	MG	M	Warm
common shiner (*Luxilus cornutus*)	FD	M	Eurythermal
creek chub (*Semotilus atromaculatus*)	FS	T	Eurythermal
eastern silvery minnow (*Hybognathus regius*)	[FS]	[I]	[Eurythermal]
fallfish (*Semotilus corporalis*)	FS	M	Eurythermal
finescale dace (*Phoxinus neogaeus*)	FD	I	Warm
golden shiner (*Notemigonus crysoleucas*)	MG	T	Eurythermal
lake chub (*Couesius plumbeus*)	FD	I	Cold
longnose dace (*Rhinichthys cataractae*)	FS	M	Eurythermal
longnose sucker (*Catostomus catostomus*)	FD	I	Cold
northern redbelly dace (*Phoxinus eos*)	MG	I	Warm
pumpkinseed (*Lepomis gibbosus*)	MG	M	Warm
slimy sculpin (*Cottus cognatus*)	FS	I	Cold
spottail shiner (*Notropis hudsonius*)	MG	M	Eurythermal
tessellated darter (*Etheostoma olmstedi*)	FS	M	[Eurythermal]
white sucker (*Catostomus commersonii*)	FD	T	Eurythermal
yellow perch (*Perca flavescens*)	MG	M	Eurythermal

*Note: For Habitat Use Classification – MG = Macrohabitat Generalist; FD = Fluvial Dependent; FS = Fluvial Specialist. For Pollution Tolerance – I = Intolerant; S = Sensitive (Moderately Intolerant); M = Moderate Tolerance; T = Tolerant. Information in brackets was not found in reliable literature and was inserted based on relevant species information.

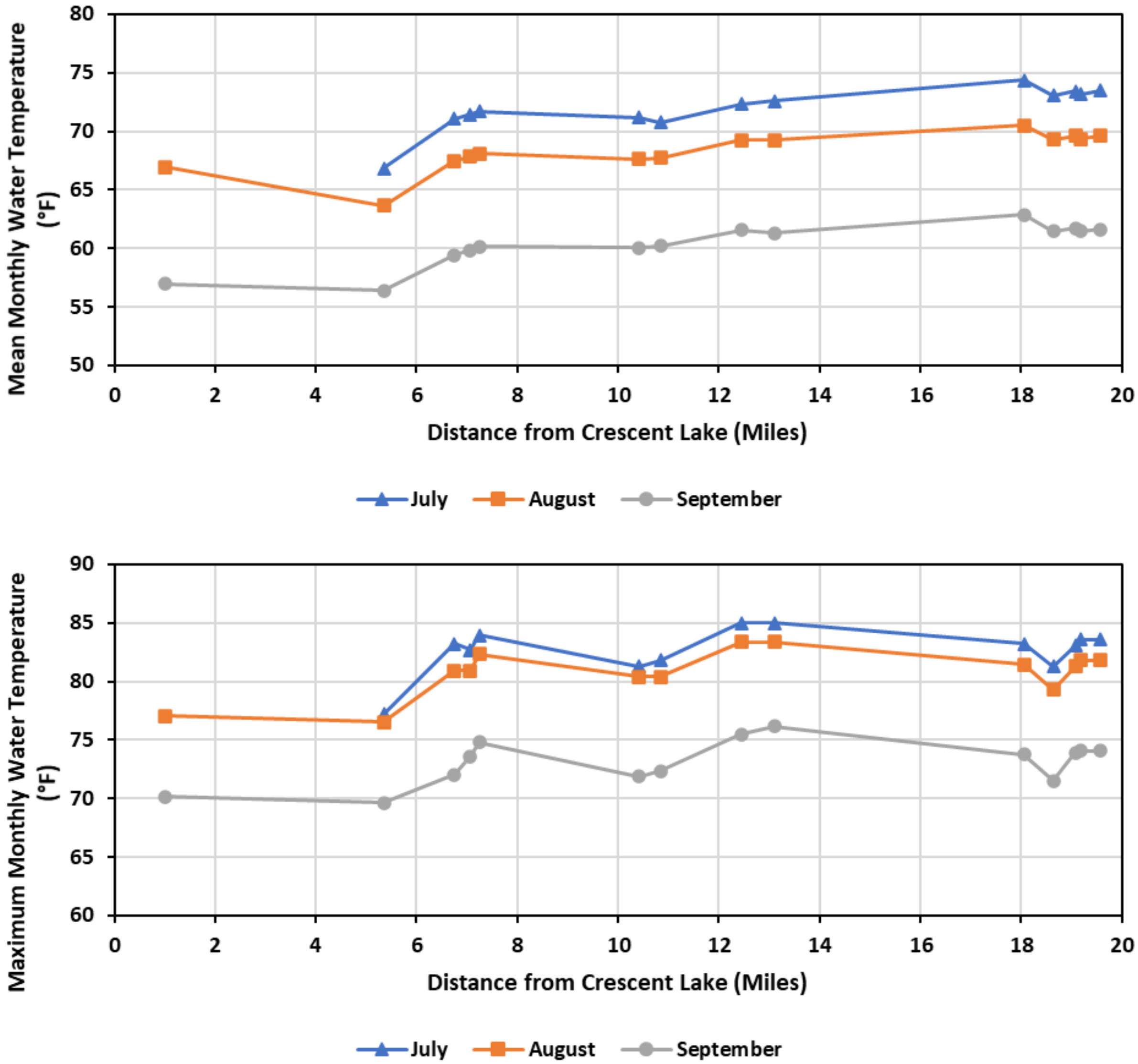


Figure 2.1.2-1: Mean and maximum monthly water temperatures measured along the Cold River in 2020.

2.2 Riparian Habitat

The Cold River watershed supports a diverse range of habitats comprised of wetlands, forests and agriculture. Each of these habitats contains a wide variety of flora and fauna. The river corridor is largely undeveloped and primarily contains hemlock-hardwood-pine forests, dominated by white pine and eastern hemlock. The upper portion of the river corridor is home to many wet meadows and shrub wetlands, while the lower portions contain more grasslands, floodplain forests and small villages along the river. Several natural communities and habitats for rare, threatened and endangered species can be found in the riparian zone of the Cold River, many of which are dependent on flood flows from the Cold River periodically inundating the floodplain to provide these species with nutrients and rich soils.

2.2.1 Riparian Communities

2.2.1.1 Wetlands

Emergent Wetland on the Cold River

The abundance of wetlands in the Cold River watershed is a key feature of significant value to the local ecosystem. Wetlands serve as important wildlife habitat that provide food, shelter, breeding areas and migration corridors for terrestrial and aquatic animals. Wetlands also serve as important recharge and discharge zones for stratified drift and bedrock aquifers and perform a variety of other key hydrologic functions including the filtration of pollutants and reduction of flooding and storm damage (Why are Wetlands Important? | US EPA, 2021).

Wetlands found in the Cold River riparian zone[1] and their total acreage are included in Table 2.2.1.1-1. Definitions for wetland classifications are included in Appendix A (Cowardin, et al., 1979). The most common types of riparian wetlands on the Cold River are shrub-scrub wetlands and emergent wetlands.

A major wetland complex exists approximately 0.26 miles downstream of Crescent Lake. This complex includes a 4.35-acre PSS1/EM1Eb wetland, a 3.72-acre PUBFb wetland and several PSS1 and PFO4 wetlands. PSS1, PEM1 and PFO4 wetlands are also present both upstream and downstream of Keyes Hollow. The Town of Acworth contains the next large area of wetlands, including 27 acres of PSS1/EM1E. The lower portions of the river corridor contain smaller areas of shrub-scrub, emergent and forested wetlands as well as riverine wetlands, such as the Vilas Pool impoundment and other seasonally-flooded side channels.

[1] 1,500-foot buffer around the Designated Cold River.

Table 2.2.1.1-1: Riparian Wetlands on the Cold River

Wetland Classification	Description[2]	Area (acres)
PSS1/EM1E	Palustrine Shrub-Scrub Broad Leaved Deciduous and Palustrine Emergent Persistent	86
R3UBH	Riverine Upper Perennial Unconsolidated Bottom	19
PSS1Eb	Palustrine Shrub-Scrub Broad Leaved Deciduous	17
R2UBH	Riverine Lower Perennial Unconsolidated Bottom	17
PSS1E	Palustrine Shrub-Scrub Broad Leaved Deciduous	13
PFO4E	Palustrine Forested Needle-Leaved Evergreen	12
R3USA	Riverine Upper Perennial Unconsolidated Shore	10
PUBHh	Palustrine Unconsolidated Bottom	10
PSS1C	Palustrine Shrub-Scrub Broad Leaved Deciduous	9
PFO4B	Palustrine Forested Needle-Leaved Evergreen	8
PEM1E	Palustrine Emergent Persistent	7
PUBFb	Palustrine Unconsolidated Bottom	6
PFO5Eb	Palustrine Forested Dead	5
PFO5Fb	Palustrine Forested - Dead	5
PFO1E	Palustrine Forested Broad Leaved Deciduous	5
PSS1/EM1Eb	Palustrine Shrub-Scrub Broad Leaved Deciduous and Palustrine Emergent Persistent	4
PUBHx	Palustrine Unconsolidated Bottom	4
PEM1/SS1E	Palustrine Emergent Persistent and Palustrine Shrub-Scrub Broad Leaved Deciduous	3
PFO1A	Palustrine Forested Broad Leaved Deciduous	2
PUBH	Palustrine Unconsolidated Bottom	2
PFO4/SS1E	Palustrine Forested Needle-Leaved Evergreen	1
PEM1Eb	Palustrine Emergent Persistent	1
PEM1Eh	Palustrine Emergent Persistent	1
PUBFx	Palustrine Unconsolidated Bottom	1
PFO1/SS1E	Palustrine Forested Broad-Leaved Deciduous and Palustrine Shrub-Scrub Broad Leaved-Deciduous	<1
PEM1/SS1Eb	Palustrine Forested Broad-Leaved Deciduous and Palustrine Shrub-Scrub Broad Leaved-Deciduous	<1
PUBF	Palustrine Unconsolidated Bottom	<1

2.2.1.2 Exemplary Natural Communities

Because the Cold River watershed contains a variety of habitats, from mountain tops to valley wetlands, a large array of plant life can be found on land and in the ponds, streams and within the riverine habitat. Some of these plants species and communities are listed by the New Hampshire Natural Heritage Bureau (NHB). NHB gives conservation priority to “exemplary” natural communities with rare species or excellent examples of common community types.

[2] See Appendix A for full description including modifiers. See Cowardin et. al., 1979 for full description of wetland classifications.

Three exemplary natural communities are documented on the Cold River according to NHB:

- Southern New England Acidic Rocky Summer/Rock Outcrop Community.
- Central New England Dry Transitional Forest on Acidic Bedrock.
- Southern New England Floodplain Forest Community.

Southern New England Acidic Rocky Summit/Rock Outcrop is dominated by oaks, pines, shagbark hickory, ironwood and eastern red cedar. Shrubs include scrub oak, early low blueberry, late low blueberry, bush honeysuckle, black huckleberry and bearberry. The community supports a variety of herbaceous species, including sedges, ferns, Solomon's seal and many lichens and mosses. Central New England Dry Transitional Forest on Acidic Bedrock is dominated by red oak and white pine. Southern New England Floodplain Forest Community are located in regularly flooded alluvial terraces along the banks of rivers. Floodplain forests are characterized by silver maples, eastern cottonwood, boxelder, American elm with herbaceous species including ferns and nettles (Sperduto and Nichols, 2012).

2.2.1.3 Observed Communities

Several wetlands and exemplary natural communities were observed on the Cold River during the on-stream reconnaissance survey. Shrub-scrub and emergent wetlands in the upper portion of the watershed were observed to have significant influence from beaver dams. More than a dozen active beaver dams were observed on the main channel of the Cold River. Moving further downstream several forested floodplains were observed, as well as emergent and shrub-scrub islands within the channel of the river. In the lower portion of the watershed, several Southern New England Floodplain Forest Communities were identified that included tree species such as sycamore, maples and American elm.

Beaver Dam on the Cold River

2.2.2 Riparian Species

2.2.2.1 Rare, Threatened and Endangered Species

Rare, threatened and endangered riparian plant species documented to occur in the Cold River watershed are primarily herbaceous. The NHB has documented the occurrence of several state-listed threatened or endangered riparian plant species in the Cold River watershed, including four-leaved milkweed (*Asclepias quadrifolia*), black maple (*Acer nigrum*), eastern waterleaf (*Hydrophyllum virginianum*), northeastern bulrush (*Scirpus ancistrochaetus*), Fogg's goosefoot (*Chenopodium foggii*), licorice goldenrod (*Solidago odora*) and Virginia stickseed (*Hackelia virginiana*) (NHDES, 2019).

The USFWS Information for Planning and Consultation tool (IPaC) identified northeastern bulrush as a federally endangered flowering plant present along the Cold River.

2.2.2.2 Observed Species


Mikania scandens (Source: Mikania scandens page, 2021)

One state-listed endangered species was observed on the Cold River during the on-stream reconnaissance survey, climbing hempvine (*Mikania scandens*). Climbing hempvine is a terrestrial plant that typically inhabits riparian and lakeside forests, thickets and floodplains in eastern North America, but is generally confined to coastal areas in New England (Go Botany: Native Plant Trust, 2021). Climbing hempvine was identified in a PEM1E wetland located in the upper portion of the Cold River. The wetland was an emergent mid-channel bar dominated by spotted joe pye weed (*Eutrochium maculatum*), tussock sedge (*Carex stricta*), cardinal flower (*Lobelia cardinalis*) and reed canary grass (*Phalaris arundinacea*).

No federally listed species were identified during the on-stream reconnaissance or subsequent field surveys. Several genera were identified that have state-listed rare, threatened, or endangered species including bur-reed (*Sparganium sp.*), goldenrod (*Solidago sp.*), honeysuckle (*Lonicera sp.*), spikesedge (*Eleocharis sp.*), willow-herb (*Epilobium sp.*), avens (*Geum sp.*), St. John's-wort (*Hypericum sp.),* horsetail (*Equisetum sp.*), shinleaf (*Pyrola sp.*) and violets (*Viola sp.*) (NHDFL, 2020).


Tufted Sedge (Carex elata) on the Banks of the Cold River

The tree stratum in the Cold River riparian zone was observed to be dominated by hemlock (*Tsuga canadensis*), black spruce (*Picea mariana*), red maple (*Acer rubrum*), yellow birch (*Betula alleghaniensis*), American beech (*Fagus grandifolia*), ash (*Fraxinus sp*.), sugar maple (*Acer saccharum*) and sycamore (*Platanus occidentalis*). The shrub stratum was dominated by hazelnut (*Corylus americana*), willow (*Salix sp.*), alder (*Alnus sp.*), hobblebush (*Viburnum lantanoides*) and honeysuckle (*Lonicera sp.*). The herb stratum was dominated by goldenrod (*Solidago sp.*), sensitive fern (*Onoclea sensibilis*), joe-pye weed, tall meadow-rue (*Thalictrum pubescens*), virgin's bower (*Clematis virginiana*), tussock sedge, jewelweed (*Impatiens capensis*) and tufted sedge (*Carex elata*).

Several invasive species were also identified including Asian bittersweet (*Celastrus orbiculatus*), common barberry (*Berberis vulgaris*), creeping yellow-loosestrife (*Lysimachia nummularia)*, glossy false buckthorn (*Frangula alnus)*, Japanese knotweed (*Reynoutria japonica)*, Japanese stiltgrass (*Microstegium vimineum)*, rambler rose (*Rosa multiflora)*, spotted knapweed (*Centaurea stoebe)*, yellow iris (*Iris pseudacorus)* and autumn-olive (*Elaeagnus umbellate)* (NHDAMF, 2017). Japanese knotweed was the most prevalent invasive observed on the river and though mostly absent from upper reaches of the river, lower reaches contain large growths in the riparian zone of the river.

A comprehensive list of all plant species identified on the Cold River during the on-stream reconnaissance and subsequent field surveys is included in Appendix B.

2.3 Recreation

2.3.1 Methods for Documenting Occurrence of Recreation

Occurrence of flow-dependent instream human uses, including boating, fishing and swimming, were assessed using a combination of recreational surveys, online outreach and field observations. Recreational sites on the Cold River were identified during the onstream reconnaissance. Most recreational sites were informal pull-offs and trails along the river. More heavily visited recreational areas on the Cold River include Vilas Pool in Alstead, the Bragg Lane Park in Alstead and the Cold River Road trail in Walpole.

Recreational surveys were performed five times along the length of the river, with visits to all sites identified during the onstream reconnaissance (Table 2.3.1-1). Survey dates were chosen to capture several river flow conditions and different seasons, when possible. Surveys were conducted to document the occurrence of boating, fishing, and swimming on the Cold River, as well as to determine flow preferences for each recreation type. It should be noted that the COVID-19 pandemic limited the ability to do surveys during the spring of 2020 and very low flows were present for most of summer/fall 2020.

Table 2.3.1-1: Recreational Survey Dates and Flow Conditions

Date	Day	Weather	Air Temp (°F)	Flow at USGS Gage (cfs)	Gage Height (ft)
11/30/2019	Saturday	Sunny	30	191	3.26
2/16/2020	Sunday	Cloudy	40	61.9	2.82
6/20/2020	Saturday	Sunny	85	8.75	1.99
10/18/2020	Sunday	Partly Sunny	53	92.9	2.80
12/3/2020	Thursday	Sunny	42	255	3.46

In addition to formal recreational surveys, any instances of boating, swimming, and fishing that were observed on the Cold River during aquatic and riparian habitat assessment field efforts were documented during various field visits seasonally and under different flow conditions.

Online outreach to document the occurrence of whitewater boating and the presence of angling guide services on the Cold River was conducted. A post was made on Facebook in the Merrimack Valley Paddlers (MVP) group to determine the occurrence of paddling on the river. The post asked if anyone in the group boats on the Cold River and whether they have flow preferences. In addition, the American Whitewater website was searched for any documented whitewater runs on the Cold River.

2.3.2 Documented Occurrences of Recreation

2.3.2.1 Boating

Despite several recreation surveys targeted at whitewater boating and flow events, along with substantial online information gathering (e.g., websites, whitewater boating groups and message boards), boating activities are uncommon on the Cold River. Boaters were never encountered during the recreational surveys, nor were any cars observed at pull-offs for the whitewater sections described by American Whitewater during any of the field efforts on the Cold River, suggesting that these runs may be anecdotal and not commonly paddled. The Facebook post on the MVP group generated some discussion amongst members of the paddling community. A few paddlers responded to the post stating that they had paddled the Cold River, but not in recent years (e.g., prior to 2011). They stated that they had run several sections of the river, but not Drewsville Gorge, as it is unsafe for boating.

2.3.2.2 Fishing

Angling occurs on the Cold River, though it is not as popular as some other fishing destinations in New Hampshire. Several angling guide services were identified that include the Cold River as a destination for catching brook trout and rainbow trout. Several anglers were observed fishing from shore at Vilas Pool over the course of this study. Angling was also observed at various pull-offs on Cold River Road in Acworth. Though angling occurs on the Cold River, it was not identified as a flow-dependent resource given that anglers would typically be targeting specific species during times of the year when fishing is typically best for those species. It is also anticipated that, under the natural flow paradigm, protected flows that provide habitat for a variety of game and forage fish species would also satisfy the needs of anglers.

2.3.2.3 Swimming

Swimming occurs most commonly at Vilas Pool, but evidence of swimming was also identified at other locations along the Cold River. Swimming was observed off the Cold River Road trail in Walpole, off of Cold River Road in Acworth and off Route 123A in Langdon. Swimming occurs during warm, low-flow periods in deep, slow, or impounded areas that are not substantially affected by changes in flow conditions. Therefore, swimming was not considered to be a flow-dependent resource on the Cold River.

3 Methods for Determining Protected Instream Flows

Protected flows were developed for specific flow-dependent instream uses, including aquatic organisms that reside in the river, riparian wildlife and vegetation and human recreational uses. Each of these three groupings were assessed using different methods. Aquatic organism habitat was assessed using the Instream Flow Incremental Methodology (IFIM). The Floodplain Transect Method (FTM) was utilized to assess riparian habitat. Recreational uses were identified using surveys and online research.

3.1 Aquatic Habitat

Aquatic habitat in a river can be described using a combination of macrohabitat, mesohabitat and microhabitat variables. Macrohabitat refers to broad river characteristics impacting fish survival and movement such as food supply, predation and water temperature and quality. Mesohabitat refers to habitat types such as pools, riffles and runs. Microhabitat represents specific physical characteristics of a location within a river, such as slope, width, substrate, cover and the variation of depth and velocity with flow. In general, a fish species or life stage prefers a particular mesohabitat type because of the microhabitat characteristics that make-up the mesohabitat are within its preferred range for a given species and life stage. For example, one species may prefer faster water with a rocky substrate, such as a boulder run, while another species prefers slower water with silt or mud substrates, such as a pool. These microhabitat conditions of depth and velocity are not static; they vary with streamflow. Too much or too little flow through the riffle or pool may push the velocities and depths outside the preferred limits or tolerances of a particular species or life stage.

The IFIM is a process for analyzing instream flows using field-measured microhabitat variables within several mesohabitats and hydraulic engineering models to derive habitat versus flow functions for certain aquatic organisms and life stages. The methodology is based on the premise that aquatic organisms prefer a certain range of depths, velocities, substrates and cover types, which are dependent upon the species and life stage and that the availability of these preferred habitat conditions varies with streamflow. The IFIM was developed in the late 1970s to quantify available habitat based the relationship between incremental changes in water flow and habitat (Bovee, 1982). The Physical Habitat Simulation (PHABSIM) model was developed in conjunction with the IFIM to complete the necessary hydraulic and habitat calculations required for IFIM analyses (USDOI and USGS, 2001). Field data were collected on the Cold River to obtain the necessary measurements required for the PHABSIM model to determine protected instream flows for aquatic habitat in the river.

In general, protected instream flows for aquatic habitat were developed by:

- Mapping mesohabitats along the entire Designated River.
- Identifying reaches that contain similar characteristics.
- Selecting study transects based on a stratified-random design.
- Collecting microhabitat and hydraulic data at study transects.
- Selecting evaluation species and Habitat Suitability Indices (HSI).
- Developing hydraulic-habitat models for the Designated River.
- Analyzing habitat timeseries data for each species and life stage within relevant bioperiods.

Each of these steps are outlined below in greater detail.

3.1.1 Mesohabitat Mapping

Aquatic mesohabitats, including pools, riffles and runs, were mapped for the entire Designated Cold River. Each mesohabitat unit was delineated using a field tablet with the ArcCollector application and an internal GPS. For each habitat unit, additional field data such as dominant substrate, secondary substrate, maximum depth, average depth and wetted width were collected. Extensive photographic documentation was also collected throughout the on-stream reconnaissance survey.

3.1.2 Reach Identification

The mesohabitat data collected in the field were processed in ArcGIS to determine the length of each mesohabitat segment. Reaches of the river containing different habitat characteristics were identified based on locations where abrupt and/or substantial changes occurred in the frequency of certain mesohabitat types, substrates, and the size of the stream channel.

3.1.3 Study Design and Transect Selection

Reaches appropriate for aquatic habitat were identified based on their potential to provide meaningful results to the Protected Instream Flow Study. These reaches generally a high proportion of free-flowing (e.g., non-impounded) habitats. Reaches with a high proportion of backwatered areas were not considered to be suitable given that impounded habitats would not be as sensitive to changes in flow relative to free-flowing reaches.

Once the study reaches were identified, a stratified-random design was implemented to select study sites in an unbiased manner. Transects for microhabitat measurements representing the primary mesohabitats within each reach were selected randomly, with the most transects selected in the most abundant mesohabitats.

3.1.4 Microhabitat and Hydraulic Data Collection

Microhabitat measurements, including depth, velocity, substrate type[3], instream cover[4], percent embeddedness[5] and bed elevations were collected across the river at the representative transects. The slope of the river at each transect was measured by surveying a longitudinal profile (up-and-down river) in the vicinity of the transect. Water level recorders set to record depth on 15-minute intervals were installed and surveyed at all transects and remained in place through a range of flow conditions.

Pre-marked ropes were extended along each transect and were anchored at fixed permanent locations on the riverbanks, above the estimated bankfull elevation where possible. The relative positions of these anchor points and temporary benchmarks were surveyed using a Total Station. Channel characteristics

[3] Substrate refers to the material armoring the channel such as sand, gravel, boulder, etc. Substrate is an important variable as certain species and life stages of fish prefer different substrate types.

[4] Instream cover includes velocity refuges such as large or small boulders allow fish to seek refuge from high water velocities.

[5] Percent embeddedness refers to the amount of fine material in interstitial spaces between the dominant substrate.

that are not flow-dependent, including substrate, instream cover, percent embeddedness, slope, bankfull elevation, and bed elevation were measured once, during the first field effort. Channel bed and bank elevations (to the nearest 0.01 ft) were collected at a series of points 1 foot apart (referred to as verticals) along each transect to develop stream cross-sectional profiles, using a Total Station referenced to the local transect datum. Substrate, percent embeddedness, and cover data were also collected at the same verticals as the bed elevations. Channel slope was estimated by measuring several bed elevations with the Total Station approximately 500 feet up and downstream of each transect.

Depth, velocity, and water surface elevation, which are flow-dependent, were measured during four different flow conditions so that the PHABSIM hydraulic models could accurately characterize a wide range of flows. Table 3.1.4-1 shows a summary of the dates and flow conditions of the field measurement efforts. Field data for each event was collected over a 2- to 3-day range.

Table 3.1.4-1: Summary of Field Data Collection River Flows

Field Data Collection Dates	Range of River Flow at USGS Gage	Average River Flow (cfs)
06/24/2020 to 06/26/2020	15.1 cfs to 7.9 cfs	11.4
09/09/2020 to 09/10/2020	4.4 cfs to 3.6 cfs	3.9
10/21/2020 to 10/22/2020	32.9 cfs to 24.2 cfs	28.8
12/07/2020 to 12/08/2020	139.0 cfs to 99.8 cfs	120.8

Flow measurement dates were largely chosen due to what flow events were available during the field season. Because the Cold River is flashy and unregulated, choosing specific target flows for field measurement efforts was not possible. However, the field-measured flows provide an overall good range of calibration flows to be input into the hydraulic model. While total river flow changed over the course of each field effort, the river was stable during measurements at each transect. Depth and velocity were measured using a digital flow meter and wading rod set-up, at the same verticals as substrate and bed elevation. These measurements were used as inputs into the hydraulic and habitat model as well as to estimate streamflow during the measurement. Water surface elevation was measured both using a rod and level and obtained from the water level recorders, which were both referenced to the local transect datum.

3.1.5 Habitat Suitability Indices for the Target Fish Community

Evaluation species for the PHABSIM habitat model were selected based on the TFC for the Cold River (Figure 2.1.1-1). Additionally, some anadromous fish species of interest were selected for evaluation.

Microhabitat suitability and preferences have been documented for several aquatic species in various studies over the last 40 years. Using the results of these studies, Habitat Suitability Index (HSI) curves have been developed for depth, velocity, substrate, and in some cases, cover. HSI curves describe suitability on a scale from 0 to 1 (called suitability index value). An HSI index value of 0 indicates no habitat value, whereas an HSI value of 1 indicates optimal habitat value. The HSI curves assign a range of velocities (ft/s) and depths (ft) a suitability index (SI) value between 0 and 1 to indicate a species/life stages preference for certain depths and velocities. HSI curves are also available for substrate preferences. Because substrate is a qualitative field determination (i.e., cobble, boulder, bedrock, etc.) a substrate coding system has been adopted to assign a numeric value to certain substrate, embeddedness and cover conditions (Table 3.1.5-1).

HSI curves that were used for the Cold River habitat model and the references for the studies they were obtained from are included in Appendix C.

Table 3.1.5-1: Substrate Coding System

Substrate Code		Embeddedness Code		Cover Code	
1	Roots, Snags, Undercut Banks	0.2	0-25%	0.03	Few Velocity Refuges
2	Clay	0.5	26-50%	0.06	Abundant Velocity Refuges
3	Silt	0.7	51-75%		
4	Sand	0.9	76-100%		
5	Small Gravel (<2")				
6	Gravel (2"-4")				
7	Cobble (4"-10")				
8	Small Boulder (10"-2')				
9	Large Boulder (>2')				
10	Bedrock				
11	Organic Detritus				

Example Field Code: 5.53 = Small Gravel (5), 26-50% Embedded (0.5), with Few Velocity Refuges (0.03)

3.1.6 Hydraulic Modeling

To develop habitat-flow relationships that capture a wide range of flows and to account for differing drainage areas and total flows measured in the field at each transect, a hydraulic model using MANSQ from the PHABSIM model was used to simulate hydraulic conditions for each transect using calibration data collected in the field. MANSQ is a modeling approach that utilizes Manning's equation to predict water surface elevations, depths, and mean column velocities across each transect as a function of flow (USDOI and USGS, 2001). For each transect, the field data were input into the model and used to compute depth, velocity, and wetted width at 26 additional flows not measured in the field, all standardized to the USGS gage.

3.1.7 Habitat Modeling

3.1.7.1 PHABSIM HABTAE Model

The results of the hydraulic model and the selected HSI curves for each evaluation species and life stage were used in the PHABSIM HABTAE model to develop habitat versus flow relationships. Each habitat cell at each simulated streamflow is evaluated for its habitat suitability for a particular species/life stage based on the HSI curves, fixed characteristics (substrate and cover), and the variable characteristics of the cell (depth and velocity). The PHABSIM methodology expresses habitat versus flow relationships as Weighted Usable Area (WUA) curves described in square feet of available habitat versus cfs of streamflow (USDOI and USGS, 2001).

The following equation was used to calculate WUA:

$$WUA = \frac{\sum_{i=1}^{n} WUA(I)}{L} \times L_{mac}$$

where: WUA(I) = Weighted Usable Area in cell (I);
n = Total number of cells in the reach;
L = Total length of the study reach; and
L_{mac} = Length of stream, which is represented by the reach, with suitable macrohabitat conditions.

The individual cell WUA(I) is calculated as follows:

$$WUA(I) = CF(I) \times Area(I)$$

where: Area(I) = Surface area of cell(I); and
CF(I) = Compound Function Index for cell(I)

The Compound Function Index, CF(I), is calculated as follows:

$$CF(I) = SI_V \times SI_D \times SI_S$$

where: SI_V = Suitability Index for Velocity;
SI_D = Suitability Index for Depth; and
SI_S = Suitability Index for Substrate/Cover.

The WUA is then computed for each cell and summed for each transect at each flow. The transects that were chosen within each type of mesohabitat were averaged separately for Reach 2 and Reach 3. The average WUA from the representative transects within each reach were then multiplied by the length of the river that they were chosen to represent. Habitat for anadromous fish species, including sea lamprey, American shad, Atlantic salmon, and river herring was only modeled in Reach 3, given the falls in Drewsville Gorge that would have historically blocked upstream passage. Habitat for the remainder of the resident species was modeled for both Reach 2 and 3, given that these species could reside in any of the river sections.

3.1.7.2 Winter Habitat Assessment

Habitat for fish and aquatic life during the winter does not typically conform to the HSI curves developed, which typically apply to warmer-water and spawning periods. However, wetted area is often considered to be a suitable habitat metric for winter aquatic habitat (AEFOC, 2007). Wetted width for each modeled flow at each transect was averaged for each mesohabitat that the transect represented. Average wetted width for each mesohabitat was then multiplied by length of that mesohabitat to develop wetted area versus flow relationships.

Even in the absence of detailed species-specific habitat data, maintaining wetted area consistent with the natural flow regime will be protective of aquatic species during the winter months. This method is also advantageous as the relationship between wetted area and discharge remains constant assuming consistent channel morphology over time.

3.1.8 Habitat Timeseries Analyses

3.1.8.1 Evaluation of Long-Term Flow Dataset

Daily flow data for the Cold River were compiled by NHDES from 1950 to 2017.[6] The dataset was evaluated to determine whether any modifications were necessary to avoid historical effects that would have been inconsistent with the natural flow paradigm (e.g., were there any flow modifications to the river that would have affected the data on a daily time step). Given the lack of large storage dams, or major withdrawals that would have affected the gage data historically and currently, no modifications to the flow dataset were needed for further analysis.

3.1.8.2 Establishment of Bioperiods and Representative Species/Life Stages

The boundaries of bioperiods were determined from hydrologic patterns that occur over the course of a year, based on statistics (e.g., percentiles) from a long-term flow dataset. The representative species and life stages for each bioperiod were chosen based on the life history of prominent species from the TFC along with diadromous fish with historical habitat in the river. For bioperiods without specific

[6] Note: Data from the Drewsville Gage (USGS Gage No. 01155000) were included in the dataset from 10/1/1950 through 9/30/1978, data from the Alstead Gage (USGS Gage No. 01154950) were included in the dataset from 10/1/2009 through 9/30/2017, and the gap in the dataset (10/1/1978-9/30/2009) was filled by NHDES using the QPPQ Transform Method (Fennessey, 2019; Fennessey, 2018a; Fennessey 2018b).

species, appropriate metrics such as wetted area (winter) and water level (spring freshet) were chosen to be representative of habitat for those bioperiods.

3.1.8.3 Development of Habitat Timeseries

Within each bioperiod, the flow timeseries was converted to habitat for each of the target species and life stages (or other habitat parameters) using the habitat versus flow relationships from the habitat models.

3.1.8.4 Identification of Habitat Stressor Thresholds

Habitat stressor thresholds can be defined by evaluating the magnitude and duration of habitat limitation events. A habitat limitation event occurs when a specific quantity of habitat remains below a predefined threshold for a continuous period. Habitat limitation events that occur over longer periods have greater impacts on aquatic species and communities; these types of extended events occur at a lower frequency than brief periods when habitat may be limited. To evaluate both magnitude and duration of habitat limitation events, Uniform Continuous Under Threshold (UCUT) curves were developed for each habitat timeseries developed for each bioperiod. The UCUT method was developed as a modification to CUT curves (Capra, Breil and Souchon, 1995). The primary difference between the UCUT and CUT curves, is that the UCUT curves include points along the lines for all continuous durations, which results in vertical portions of the curves where specific durations did not occur in the timeseries. For habitat metrics that were a measure of area (e.g., WUA), the curves were standardized to the percentage of maximum habitat available based on the habitat models.

From the UCUT plots, which contain a series of curves, common and less common habitat limitation events can be distinguished based on the cumulative durations, the shape, and distances between the curves. Interpretation of these patterns can be generalized as follows:

- The curves in the left portion of the graph depict rare events.
- The horizontal distance between curves indicate the change in frequency of events associated with changes in habitat amounts.
- Steep curves represent little change in event frequency given differences in continuous durations, whereas inflection points reflect a rapid change in frequency of continuous durations.

Rare, critical, and common habitat levels were identified using the following set of rules:

- Rare: The first curve to contain portions that stand out from vertical. This may or may not be the first curve on the plot. This threshold would be exceeded most of the time within the timeseries dataset.
- Critical: The first curve that occurs beyond (to the right side of the plot) a gap in the curves. Below this point, if habitat were to become more limited, it would descend relatively rapidly to the rare level.

- Common: The first curve beyond the next gap in the curves, to the right of the critical level. This level may also be identified as curves that are no longer exhibiting the vertical nature that the rare and critical levels tend to exhibit, particularly at longer continuous durations.

For each threshold level, continuous durations were identified as:

- Persistent: The lowest convex inflection point along the curves. The curves begin to steepen above this point, which indicates a low frequency of longer-duration events.

- Catastrophic: A higher inflection point, above which the curve becomes primarily vertical. Above this point, durations are so high that they occur extremely infrequently, on a decadal scale.

3.2 Riparian Habitat

3.2.1 Floodplain Transect Method for Riparian Wildlife and Vegetation

Protected instream flows for riparian flora and fauna and exemplary communities found in the floodplain and channel of the Cold River were assessed using the Floodplain Transect Method (FTM). This method involves surveying representative transects across the river channel and floodplain for resident flora and botanical species and evaluating inundation at various water levels to determine the flows that inundate these species or communities.

3.2.1.1 Transect Selection

The locations of the transects were chosen based on the presence of key wetland habitats and riparian species that were found during the reconnaissance. The transects spanned the entire river channel and much of the floodplain, to develop flow requirements for wetlands, floodplains and channel habitats and their associated flora.

3.2.1.2 Field Data Collection

Headpins were placed at both ends of the transect, and a topographic survey of the transect was conducted using a Total Station. Primary vegetation types and species along each transect were documented using protocols consistent with NHDES survey methodologies (e.g., herbaceous stratum within a 1.5-meter swath along the transect, sapling/shrub stratum within a 5-meter swath along the transect, and tree stratum within a 10-meter swath along the transect). Breakpoints in vegetation type were surveyed along the transect using a Total Station, which provided both the location and elevation of the breakpoints.

Water level loggers were placed at each transect and were surveyed into each local transect datum using a Total Station. Water level was recorded continuously, on 15-minute intervals, across a timespan that allowed the documentation of water levels at a variety of flow rates. Additionally, the transects were visited multiple times at various flow rates to confirm the levels of inundation.

3.2.1.3 Transect Analysis

Vegetation and topographic survey data were used to create cross-sectional profiles of each transect. The elevation of each breakpoint between vegetation types were denoted on the profiles.

A continuous time series of water level logger data was used in conjunction with streamflow data from the USGS gage[7] to determine the flow at which each different vegetation type is inundated. The elevation of the vegetation type breakpoint was identified in the water level logger dataset and the corresponding discharge measured at the USGS gage during flow events were identified.

[7] Note: USGS data from November 1 through the present were still marked as provisional.

3.3 Recreation

The results of the recreation surveys and online research were evaluated to determine flow preferences for boating, fishing, and swimming. Surveys were tailored to each type of recreation and included questions on frequency and timing of visits to the Cold River, what sections are visited, how flows are monitored and flow preferences.

4 Protected Instream Flow Study Results

4.1 Aquatic Habitat

4.1.1 Study Design

4.1.1.1 Mesohabitat Mapping Results

Mesohabitat mapping of the Cold Designated River was completed during the on-stream reconnaissance survey from September 9 through 13, 2019. River flow at the USGS gage averaged at 6.8 cfs during the survey. Approximately 21 miles of the Designated River were mapped during the on-stream reconnaissance survey, including 249 pools, 274 riffles and 170 runs. Riffles comprised over nine miles of the river, while pools made up approximately five miles and runs approximately four miles. The remaining two miles were primarily backwatered habitats (e.g., beaver dams).

4.1.1.2 River Reaches

Four reaches were delineated based on the mesohabitat mapping results (Figure 4.1.1.2-1). Reaches were developed to divide the river into segments with similar habitat characteristics, for habitat-hydraulic modeling purposes.

Reach 1

Abundant Overhead Cover in Reach 1

Reach 1 began at the outflow of Crescent Lake, where the drainage area is 5.8 square miles, and ended above the Dodge Brook confluence, where the drainage area is approximately 20 square miles. Reach 1 was characterized by a narrow channel (approximately 12 feet of wetted width during the survey), abundant overhead cover in flowing sections, and large, open areas backwatered by beaver activity. This reach contained 6.34 miles of mapped habitat, of which only 2.8 miles was non-backwatered. Habitat was relatively diverse, with riffles, step-pool runs, pools and runs as the dominant mesohabitats. Pools were generally small and shallow, exhibiting a variety of dominant substrates, with rubble being most dominant. Riffles were dominated by cobble, runs were dominated by small boulders and cobble and step-pool runs were dominated by small boulders. Large boulders were documented as a substrate component (primary, secondary, or tertiary) along nearly 18% of the non-backwatered habitat in the reach.

Reach 2

Typical Riffle in Reach 2

Reach 2 began at the Dodge Brook confluence where the drainage area is approximately 30 square miles and ended at Vilas Pool, where the drainage area is approximately 61 square miles. At the confluence of Dodge Brook, the drainage area increases by over 55%, resulting in a significant widening of the channel width in Reach 2 (approximately 31 feet of wetted width during the survey). Reach 2 was characterized by riffle habitats with interspersed pools and runs and less overhead tree cover than Reach 1. Reach 2 was the longest, containing 9.9 miles of mapped habitat, of which most (9.6 miles) was non-backwatered. The dominant substrate in riffles and runs was cobble while pools were more diverse, with a mix of rubble, cobble, small boulder, and small gravel. Though primary substrates were slightly smaller than Reach 1, large boulders were documented as a substrate component (primary, secondary, or tertiary) along nearly 20% of the non-backwatered habitat in the reach.

Reach 3

Reach 3 was further divided into Reach 3A and Reach 3B. Reach 3A began just below Vilas Pool and extended down to the second Route 123 bridge in the village of Drewsville in Walpole, where the drainage area is approximately 83 square miles. In Reach 3A, the river flows through the village of Alstead, where restoration occurred after historical flooding in 2005, and then the Drewsville Gorge which is steep and contains bedrock waterfalls. Reach 3B began at the second Route 123 bridge in Drewsville and extended downstream until approximately 0.95 miles upstream of the confluence with the Connecticut River, where the drainage area is approximately 101 square miles.

Deep Run and Cobble Bar in Reach 3

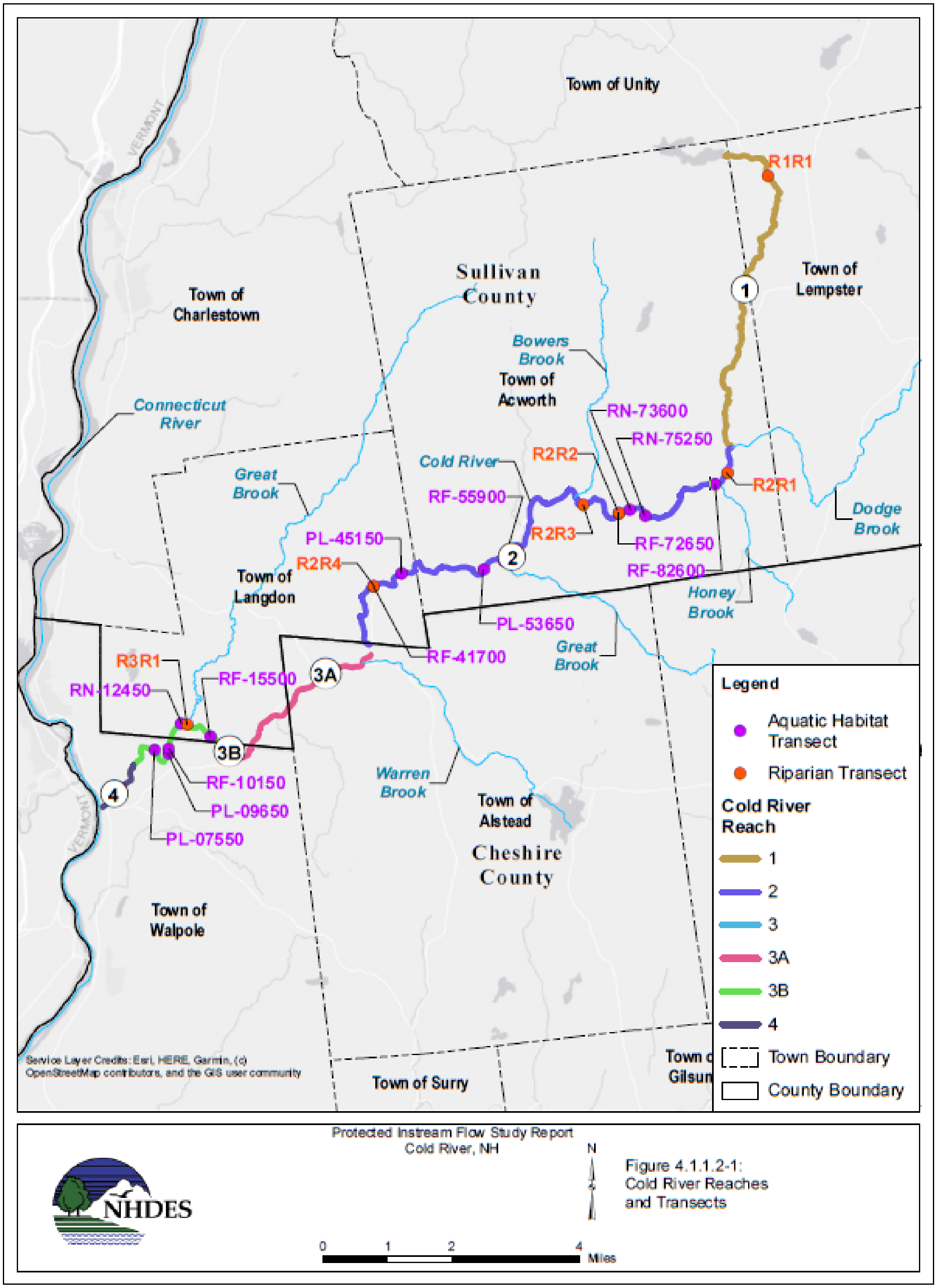
Reach 3 was characterized by wide bankfull widths with large cobble bars that are periodically inundated during high flows but are not wetted during low flows, limiting overhead cover of the main channel. Reach 3 was 5.87 miles long, with 5.85 miles of non-backwatered habitats. Though riffles were the dominant habitat in Reach 3, pools were more prevalent than in Reach 2. Pools were also different in character, often being relatively long and deep. Large boulders were the dominant substrate in this reach, providing instream cover to aquatic species.

Reach 4

Wide Channel Width in Reach 4

Reach 4 began approximately 0.95 miles upstream of the confluence with the Connecticut River and extended to the mouth of the Cold River. One area of this section was backwatered by beaver activity, though most of the reach was not backwatered. This reach was highly alluvial, with a very wide bankfull channel, and could be considered part of the Connecticut River floodplain. Wetted channel habitats were shallow and primarily consisted of wide riffles with cobble and gravel substrates. Under high flow conditions, this reach is often backwatered from the Connecticut River. Large boulders were documented as a substrate component in less than 15% of the reach; as such, shelter for fish during low flows would be very limited given the few boulders and lack of overhead cover.

Figure 4.1.1.2-1: Cold River Reaches and Transects



4.1.1.3 Representative Transect Selection

Representative aquatic habitat transects were selected in Reach 2 (n=8) and Reach 3 (n=5), such that 16 miles (80%) of the river length was represented by the habitat-hydraulic models (Table 4.1.1.3-1 and Figure 4.1.1.2-1). These reaches were identified as being most appropriate for habitat-hydraulic model development and subsequent analyses because they represented the greatest amount of free-flowing habitat in the river and were not affected substantially by beaver dams or historic stream rehabilitation efforts.8

Table 4.1.1.3-1: Summary of Representative Aquatic Habitat Transects

Transect	Mesohabitat Represented	Reach	River Miles from Mouth	Drainage Area (mi^2)
RF-82600	Riffle	2	15.6	33.0
RN-75250	Run	2	14.3	34.8
RN-73600	Run	2	13.9	35.4
RF-72650	Riffle	2	13.8	35.5
RF-55900	Riffle	2	10.6	46.5
PL-53650	Pool	2	10.2	54.1
PL-45150	Pool	2	8.6	59.1
RF-41700	Riffle	2	7.9	59.9
RF-15500	Riffle	3B	2.9	83.7
RN-12450	Run	3B	2.4	98.7
RF-10150	Riffle	3B	1.9	98.9
PL-09650	Pool	3B	1.8	99.0
PL-07550	Pool	3B	1.4	99.2

Photographs of each transect were also collected (Appendix D).

4.1.2 Habitat versus Flow Relationships

Habitat versus flow relationships for each species/life stage are expressed as weighted usable area (WUA) measured in square feet versus flow (cfs) at the USGS gage. Habitat versus flow relationships for all species/life stages for the winter survival bioperiod are expressed as wetted area (ft^2) versus flow (cfs) at USGS Gage No. 01154950 in Alstead which has a drainage area of 74.6 mi^2. These relationships show available habitat on the Cold River as it related to flow in the river.

[8] No aquatic habitat transects were chosen from the following reaches:

- Reach 1, which would not have been a substantial driver of flowing habitat, given its small size and high proportion of beaver-affected habitats.
- Reach 3A, which contains habitats that were substantially affected by stream restoration construction and streambank stabilization efforts.
- Reach 4, which represents a very small portion of the riverine habitat, and is substantially affected by backwatering from the Connecticut River

4.1.2.1 Species-Specific Relationships

WUA curves for each species/life stage evaluated in the IFIM study are included in Appendix E. Flows that were modeled ranged from 2 cfs to 255 cfs. WUA for most species/life stages peaked within this range, though some species such as American shad continue to increase with flows beyond 255 cfs. WUA for several species/life stages are limited by available substrate, such as the spawning and incubation life stages of white suckers, sea lamprey, brook trout, common shiner, longnose suckers, and Atlantic salmon. The spawning and incubation life stages for these species have a strong preference for gravel substrates, which are not abundant on the Cold River (See Appendix C for Habitat Suitability Curves). Overall, the Cold River provides the most preferable habitat for brook trout, longnose dace, white suckers, blacknose dace, and sculpins, due to a prevalence of cobble and small boulder, as well as suitable depths and velocities. It provides the least preferable habitat for common shiner and river herring due to substrate limitations (lack of sand and gravel).

4.1.2.2 Wetted Area

Wetted area versus flow curves for Reach 2, Reach 3, and both combined are shown in Figure 4.1.2.2-1. The Reach 3 curve was used for habitat analyses for anadromous species while both Reach 2 and 3B were used for all resident species. In general, the curves rise sharply from 2 cfs to 15 cfs, then become asymptotic. Wetted area continues to increase as flow increases and will never decrease like weighted usable area. However, increases in wetted area become marginal at the high range of modeled flows.

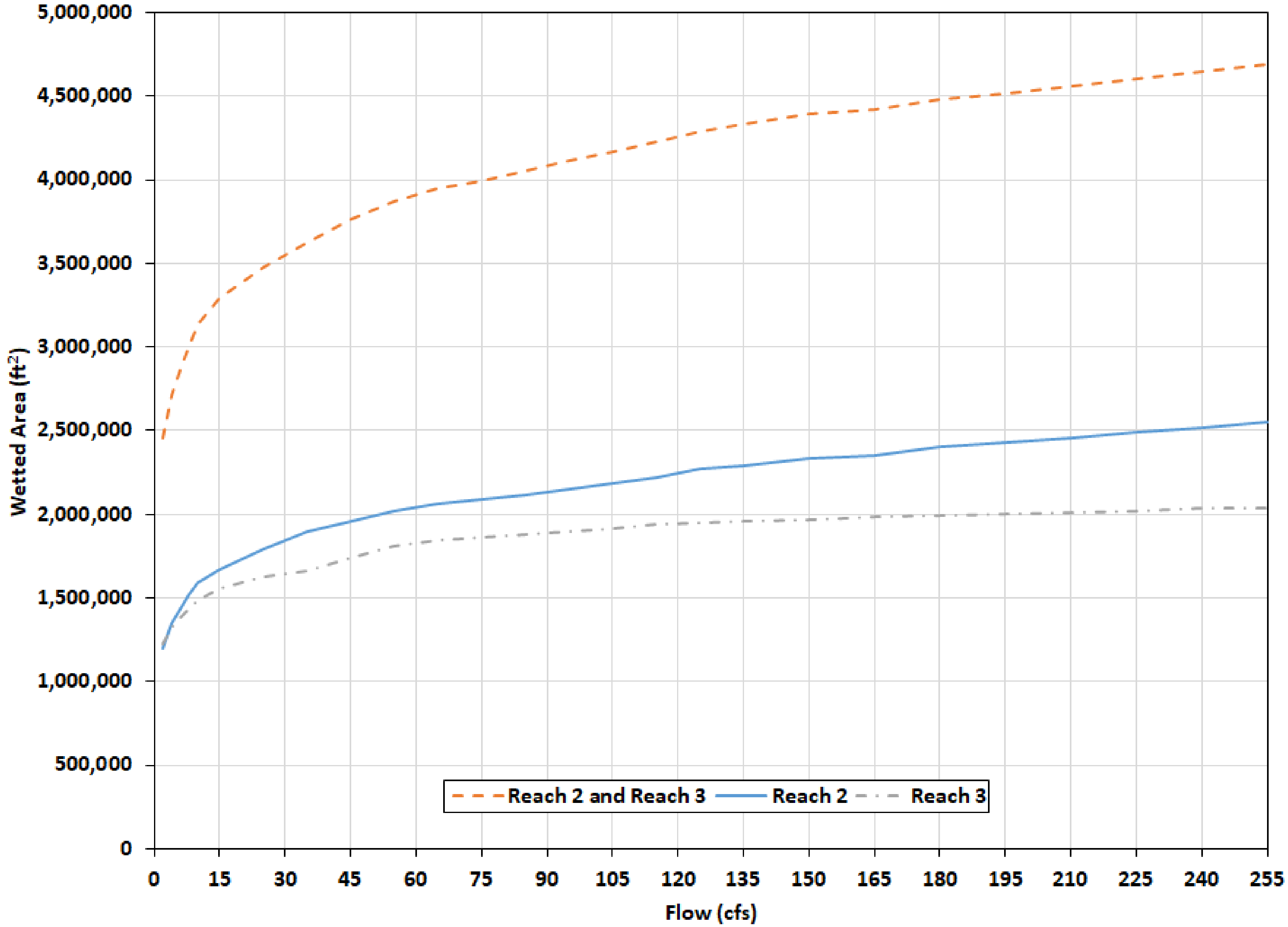


Figure 4.1.2.2-1: Wetted Area Curve

4.1.3 Habitat Timeseries Analyses

4.1.3.1 Bioperiods

Six bioperiods were identified on the Cold River based on the hydrology and the needs of the target aquatic species and life stages (Figure 4.1.3.1-1). Though the activities of each target species and life stage are variable and could expand beyond the dates delineating specific bioperiods, the date ranges described for each bioperiod would be expected to encompass their primary needs (Figure 4.1.3.1-1 and Table 4.1.3.1-1). The aquatic habitat needs within each bioperiod were assessed as follows:

Winter Survival

Flows during the winter on the Cold River tend to be moderately low, with most precipitation in the watershed consisting of snow that only periodically thaws to provide brief higher-flow periods. Relatively little is known about winter habitat use by aquatic organisms, however wetted area is generally considered to be important for a variety of aquatic life (AEFOC, 2007). Therefore, habitat timeseries analyses were performed on wetted area provided by the habitat-hydraulic model.

Freshet

Springtime snowmelt and rains result in high flows during the freshet. The freshet bioperiod would therefore not typically be limited by low flows. During this period, most aquatic species would be seeking velocity refugia, and some would begin moving toward spawning areas. High flows and associated inundation during the freshet are also important for riparian and wetland habitats. Habitat timeseries analyses during the freshet were performed using the water level at the USGS gage, which was back calculated for the full timeseries based on a rating curve developed for the gage.

Sucker Spawning

There are two native, resident sucker species that, when combined, are expected to represent approximately 10% of the TFC. These species spawn during the spring as flows recede from the freshet. Their spawning would typically occur prior to peak spawning of anadromous fish and cyprinid target species on the Cold River.

Springtime Anadromous Fish and Resident Cyprinid Spawning

During the later portion of the declining hydrograph from the freshet, water temperatures are typically warming enough that suckers would finish spawning, but species that prefer slightly warmer temperatures would begin spawning. Springtime-spawning anadromous fish would typically arrive in the river around mid-May and spawning could occur through the month of June and potentially into early July. This spawning period also coincides with resident cyprinid species that prefer similar water temperatures and conditions for spawning, such as common shiner.

Rearing and Growth

Adult and juvenile resident fish, along with juvenile diadromous fish, would typically feed and grow during the summer period when flows are relatively low. Habitat timeseries analyses were performed on a variety of relevant species and life stages.

Fall Salmonid Spawning

Brook trout and Atlantic salmon[9] are the only native salmonids to the Cold River. These species spawn in the fall, with brook trout typically spawning in late September and October, and Atlantic salmon spawning in October and November.

Table 4.1.3.1-1: Cold River Bioperiod Date Ranges

Bioperiod	Start Date	End Date	Days in Period
Winter Survival	12/1	2/28*	90
Freshet	3/1	4/15	46
Sucker Spawning	4/16	5/15	30
Springtime Anadromous Fish and Resident Cyprinid Spawning	5/16	7/7	53
Rearing and Growth	7/8	9/21	76
Fall Salmonid Spawning	9/22	11/30	70

* The winter survival period would end on February 29 and would span 91 days during leap years. Additionally, if the spring freshet occurs late, the flows needed for the Winter Survival period could be continued until flows increase due to the freshet.

[9] Though Atlantic Salmon no longer utilize the Cold River, they were included in this assessment because the flows they required could also be used by other species as part of the natural flow paradigm.

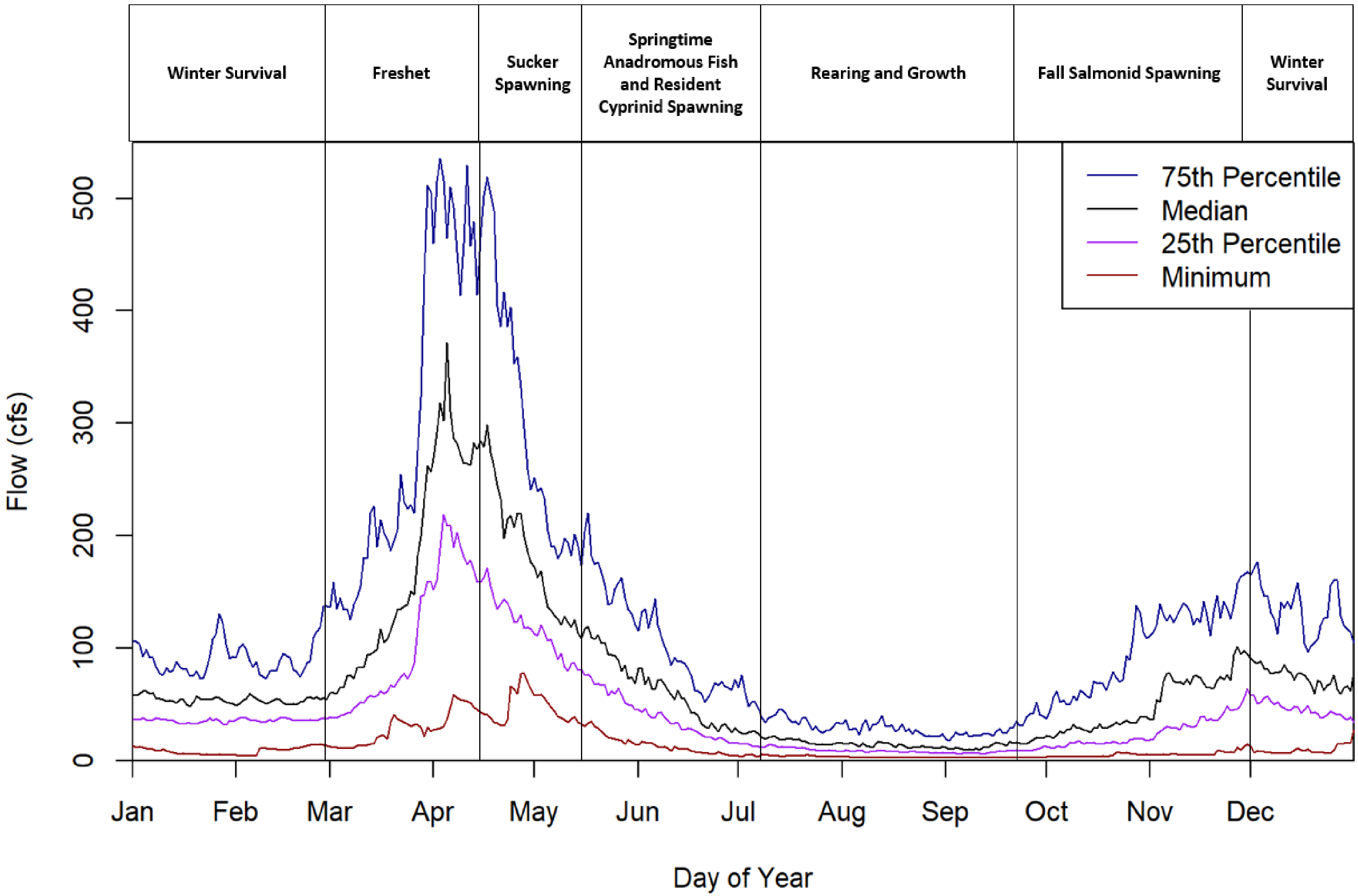


Figure 4.1.3.1-1: Cold River Flow Statistics and Bioperiods

4.1.3.2 UCUT Analyses

UCUT curves were developed based on the habitat-flow relationships and the flow timeseries. UCUT curves for most of the species and lifestages from the TFC were considered suitable for the Protected Instream Flow analysis (Table 4.1.3.2-1). However, some were excluded from further analysis because they were either not low-flow limited during the bioperiod that they were selected to represent (e.g., White Sucker Spawning, Common Shiner Spawning, Young-of-Year (YOY) and Fry) or did not fit well within the bioperiod boundaries (e.g., Longnose Dace Spawning). The UCUT curves are included in Appendix F. The results of the UCUT analyses for each species and bioperiod are shown in Tables 4.1.3.2-1 to 4.1.3.2-7.

Each of the tables provides habitat stressor thresholds derived from the UCUT curves. These thresholds include the magnitude (e.g., % wetted area, % WUA, gage height) of common, critical and rare habitat limitation events, along with their persistent and catastrophic durations, as defined in Section 3.1.8.4. The corresponding flows associated with the habitat stressor thresholds are also included for each threshold. After analysis of individual species, the habitat stressor thresholds were consolidated for the various species in each bioperiod (see Section 4.1.4).

Table 4.1.3.2-1: Summary of UCUT Analyses

Applicable Bioperiod	Target Species or Parameter	Life Stage	UCUT Results Evaluated	Comments
Winter	Wetted Area	Aquatic Habitats	Yes	
Freshet	Gage Height	Riparian Habitats	Yes	
Sucker Spawning	longnose sucker	Spawning	Yes	
	white sucker	Spawning	No	High flow limited during this bioperiod based on WUA curves
None selected	longnose dace	Spawning	No	Spans late sucker and early anadromous bioperiods, does not fit into a single bioperiod and is therefore not suitable for UCUT within the defined bioperiods.
Springtime Anadromous and Resident Cyprinid Fish Spawning	American shad	Spawning	Yes	
	river herring	Spawning	Yes	
	sea lamprey	Spawning	Yes	
	common shiner	Spawning	No	High flow limited during this bioperiod based on WUA curves
Rearing/Growth	blacknose dace	Adult	Yes	
	longnose dace	Adult	Yes	
	longnose dace	Juvenile	Yes	
	common shiner	Juvenile	Yes	
	mottled sculpin	Adult/Juvenile	Yes	
	brook trout	Adult	Yes	
	brook trout	Juvenile	Yes	
	Atlantic salmon	Juvenile	Yes	
	American shad	Juvenile	Yes	
	white sucker	Adult/Juvenile	Yes	
Salmonid Spawning	brook trout	Spawning	Yes	
	Atlantic Salmon	Spawning	Yes	
Note: WUA curves were developed for YOY/Fry for some of the target species. These life stages were not included in this assessment because their habitat was not typically limited by low flows. Further, fry develop into YOY/juvenile fish relatively quickly and any applicable bioperiod would be too short (and variable in time) for effective management.				

Table 4.1.3.2-2: UCUT Results for Winter Bioperiod

Threshold	Reach 2 Wetted Area	Reach 3 Wetted Area
Common Habitat (% Wetted Area)	90%	96%
Persistent Duration (days)	50	50
Catastrophic Duration (days)	74	73
Corresponding Flow (cfs)	136	136
Critical Habitat (% Wetted Area)	72%	82%
Persistent Duration (days)	22	27
Catastrophic Duration (days)	32	43
Corresponding Flow (cfs)	29	36.5
Rare Habitat (% Wetted Area)	66%	76%
Persistent Duration (days)	11	10
Catastrophic Duration (days)	15	14
Corresponding Flow (cfs)	16	14.5

Table 4.1.3.2-3: UCUT Results for Freshet Bioperiod

Threshold	USGS Gage
Common Habitat (ft)	4.0
Persistent Duration (days)	21
Catastrophic Duration (days)	37
Corresponding Flow (cfs)	480
Critical Habitat (ft)	2.6
Persistent Duration (days)	13
Catastrophic Duration (days)	21
Corresponding Flow (cfs)	63
Rare Habitat (ft)	2.4
Persistent Duration (days)	8
Catastrophic Duration (days)	12
Corresponding Flow (cfs)	39

Table 4.1.3.2-4: UCUT Results for Sucker Spawning Bioperiod

Threshold	Longnose Sucker Spawning
Common Habitat (%WUA)	98%
Persistent Duration (days)	14
Catastrophic Duration (days)	20
Corresponding Flow (cfs)	94.5
Critical Habitat (%WUA)	90%
Persistent Duration (days)	10
Catastrophic Duration (days)	16
Corresponding Flow (cfs)	61
Rare Habitat (%WUA)	88%
Persistent Duration (days)	4
Catastrophic Duration (days)	7
Corresponding Flow (cfs)	55.5

Table 4.1.3.2-5: UCUT Results for Springtime Anadromous Fish and Resident Cyprinid Spawing

Threshold	American Shad Spawning	River Herring Spawning	Sea Lamprey Spawning
Common Habitat (%WUA)	88%	80%	98%
Persistent Duration (days)	24	34	27
Catastrophic Duration (days)	48	48	47
Corresponding Flow (cfs)	125	125	102.5
Critical Habitat (%WUA)	32%	74%	34%
Persistent Duration (days)	9	10	9
Catastrophic Duration (days)	14	12	14
Corresponding Flow (cfs)	16	15	15
Rare Habitat (%WUA)	24%	64%	26%
Persistent Duration (days)	5	5	6
Catastrophic Duration (days)	8	8	8
Corresponding Flow (cfs)	9	8.5	10

Table 4.1.3.2-6: UCUT Results for Rearing and Growth Bioperiod

Threshold	Blacknose Dace Adult	Longnose Dace Adult	Longnose Dace Juvenile	Common Shiner Juvenile	Mottled Sculpin Adult/ Juvenile	Brook Trout Adult	Brook Trout Juvenile	Atlantic Salmon Juvenile	American Shad Juvenile	White Sucker Adult/J uvenile
Common Habitat (%WUA)	52%	74%	90%	84%	78%	88%	86%	98%	88%	98%
Persistent Duration (days)	44	44	40	39	36	36	36	37	36	39
Catastrophic Duration (days)	65	63	63	63	64	65	65	63	63	61
Corresponding Flow (cfs)	30	28.5	31	30.5	29.5	29.5	29.5	28.5	29	24.5
Critical Habitat (%WUA)	20%	24%	34%	40%	30%	44%	44%	76%	54%	54%
Persistent Duration (days)	15	14	14	14	14	14	14	14	15	14
Catastrophic Duration (days)	22	28	27	27	28	28	28	28	28	28
Corresponding Flow (cfs)	7	6	6.5	6	6	6	6.5	7	6.5	6
Rare Habitat (%WUA)	14%	14%	20%	30%	20%	30%	34%	62%	38%	36%
Persistent Duration (days)	10	10	10	10	10	10	10	10	10	10
Catastrophic Duration (days)	17	17	17	17	17	17	17	17	17	17
Corresponding Flow (cfs)	4	4	3.5	3.5	3.5	3	4	3	4	4

Table 4.1.3.2-7: UCUT Results for Fall Salmonid Spawning Bioperiod

Threshold	Brook Trout Spawning	Atlantic Salmon Spawning
Common Habitat (%WUA)	98%	90%
Persistent Duration (days)	40	28
Catastrophic Duration (days)	64	64
Corresponding Flow (cfs)	30.5	76.5
Critical Habitat (%WUA)	44%	12%
Persistent Duration (days)	11	15
Catastrophic Duration (days)	16	27
Corresponding Flow (cfs)	10	15.5
Rare Habitat (%WUA)	32%	2%
Persistent Duration (days)	6	9
Catastrophic Duration (days)	10	11
Corresponding Flow (cfs)	7.5	7

4.1.4 Protected Instream Flow Recommendations for Aquatic Habitat

Based on the UCUT results in Section 4.1.3.2, Protected Instream Flow thresholds and durations were determined by selecting the values that would be protective of habitat for most or all species assigned to a bioperiod (Table 4.1.4-1). The most protective habitat thresholds were represented by higher flows and/or lower durations of habitat limitation events for the species in a bioperiod. The protected instream flows for aquatic habitat are provided in Table 4.1.4-2.

Table 4.1.4-1: Summary of Species/Parameters that Defined the Protected Instream Flows

Bioperiod	Common	Critical	Rare
Winter Survival	Wetted Area - Reach 3	Wetted Area - Reach 3	Wetted Area - Reach 2
Freshet	USGS Gage Height		
Sucker Spawning	Longnose Sucker Spawning		
Anadromous and Resident Cyprinid Spawning	American Shad Spawning	American Shad Spawning	Sea Lamprey Spawning
Rearing and Growth	Longnose Dace Juvenile	Blacknose Dace Adult	Several Species
Fall Salmonid Spawning	Atlantic Salmon Spawning	Atlantic Salmon Spawning	Brook Trout Spawning

Table 4.1.4-2: Protected Instream Flows for Aquatic Habitat in the Cold River

Bioperiod	Common Flow				Critical Flow				Rare Flow			
	Common Flow (cfs)	Common Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)	Critical Flow (cfs)	Critical Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)	Rare Flow (cfs)	Rare Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)
Winter Survival	136	1.82	50	74	36.5	0.49	27	43	16	0.21	11	15
Freshet	480	6.43	21	37	63	0.84	13	21	39	0.52	8	12
Sucker Spawning	94.5[10]	1.27	14	20	61	0.82	10	16	55.5	0.74	4	7
Springtime Anadromous Fish	125	1.68	24	48	16	0.21	9	14	10	0.13	6	8
Rearing and Growth	31	0.42	40	63	7	0.09	15	22	4	0.05	10	17
Fall Salmonid Spawning	76.5	1.03	28	64	15.5	0.21	15	27	7.5	0.10	6	10

Note: Flows provided are for the USGS gage in Alstead, NH (USGS Gage No. 01154950)

[10] Note: Though higher flows are more common in the Sucker Spawning bioperiod than the Springtime Anadromous Fish bioperiod, Longnose Sucker do not require as high of common flows as Springtime Anadromous Fish due to the habitat-flow relationship for this species and the flows that commonly occur during the sucker spawning season.

4.2 Riparian Habitat

4.2.1 Floodplain Transect Method Results

A total of six transects (Table 4.2.1-1 and Figure 4.1.1.2-1) were evaluated using the FTM. Riparian transects were surveyed from July 22 - 23, 2020, when river flow at the USGS gage was between 7 cfs and 16 cfs. Water level loggers were installed during the initial survey in July 2020 and were removed in April 2021. Individual measurements of water surface elevation were made in July 2020, October 2020, December 2020, and April 2021 using a Total Station to calibrate and verify data from the loggers.

Table 4.2.1-2 shows the relationship between flows at the USGS gage and the observed inundation of plant communities in the river channel and riparian floodplain at the six transect locations. Cross-section plots are included in Appendix G.

Table 4.2.1-1: Summary of Transects for the Floodplain Transect Method

Transect	Transect Location	Reach	Protected Entities Represented
R1R1	1 mile downstream of Crescent Lake Dam.	1	PFO4, PFO3, PFO1, Floodplain Forests including hemlock, red maple, yellow birch, black spruce, sugar maple, balsam fir, yellow birch.
R2R1	0.5 miles downstream of confluence of Dodge Brook and 1,200 feet upstream of Cold River Road intersection with NH Route 123A.	2	PEM1, PSS1, emergent and shrub-scrub islands within the river channel including sedges, goldenrod, ferns, silky dogwood, willow, hazelnut, speckled alder, and striped maple.
R2R2	0.6 miles downstream of Echo Valley Road bridge and 400 feet upstream of NH Route 123A bridge.	2	PFO1, PEM1, PSS1, emergent and shrub-scrub island including ferns, goldenrod, dark-green bulrush, sedges, striped maple, silky dogwood, and speckled alder. Floodplain forest including hemlock, red maple, sugar maple, American elm, yellow birch, black spruce.
R2R3	1,500 feet upstream of Beryl Mountain Road Bridge.	2	PEM1/PSS1, shrub-scrub island and multiple side channels including goldenrod, ferns, hazelnut, sedges, joe-pye weed, aster, bur-reed, speckled alder, and basswood.
R2R4	530 feet downstream of McDermott Covered Bridge.	2	Riverine wetland containing an emergent bar including sedges, ferns, goldenrod, spikesedge, jewelweed, and mint. Floodplain forest including red oak, black cherry, and green ash.
R3R1	1 mile downstream of Drewsville Gorge and 2.5 miles upstream of the confluence with the Connecticut River.	3	Sycamore Floodplain Forest (PFO1) and PEM1/PSS1 wetlands including goldenrod, sedges, Allegheny monkey-flower and sycamore saplings and trees.

Table 4.2.1-2: Flows Associated with Observed Inundation of Community Types

Plant Community in Order by Descending Elevation[11]	Flow (cfs) that Inundates Community	Percent of time flow is equaled or exceeded[12]
Transect R1R1		
PFO1, PFO2, PFO3	≥3,730	<1%
PFO4	3,490	<1%
PEM1 (Mid Channel Bar)	265	10%
R3UB1 (Channel)	≤30	22%
Transect R2R1		
Upland	≥3,730	<1%
PEM1, R3UB3, PEM1/PSS1 (SideCh)	1,080	<1%
Right Bank PEM1/PSS1	806	1%
Left Bank PEM1/PSS1	189	16%
PFO3	146	22%
PEM1 (Mid Channel Bar)	28	69%
R3UB1 (Channel)	≤8	93%
Transect R2R2		
Left Bank PFO1, Upland	≥3730	<1%
Right Bank PFO1	3,550	<1%
PSS1, R3UB3 (Side Ch and Bar)	1,060	<1%
PEM1	86	36%
R3UB1 (Channel)	≤22	76%
Transect R2R3		
PFO4, Left Bank PEM1, PSS1	≥3,730	<1%
PEM1/PSS1 (R Bank & Mid Ch Bar)	1,920	<1%
PEM1	74	41%
R3UB1 (Channel and Side Ch)	≤20	78%
Transect R2R4		
PFO1/PSS1 (Left and Right Bank)	≥3,730	<1%
PSS1	2,520	<1%
PEM1 (Mid Ch Bar and Right Bank)	475	4%
R3UB1 (Channel)	≤62.6	46%
Transect R3R1		
PFO1/PSS1 (Sycamore Forest & RB)	3,710	<1%
PEM1 (Left and Right Bank)	1,860	<1%
R3UB1 (Channel)	≤45.3	57%

[11] See Appendix A for wetland classifications definitions.
[12] Annual flow duration statistics calculated from the Cold River mean daily flow data time series extended from 1950 to 2017 using the QPPQ method.

4.2.2 Protected Instream Flow Recommendations for Riparian/Wetland Habitats

The wetland classification of R3UB1 seen in Table 4.2.1-1 corresponds to the channel of the Cold River (riverine upper perennial unconsolidated bottom cobble-gravel). The channel was generally delineated as where the streambed met vegetated banks and did not necessarily correspond to the bankfull width/elevation. The channel of the Cold River was fully inundated between flows of 8 cfs and 62.6 cfs at the six transects. These flows are equaled or exceeded between 78% and 46% of the time on an annual basis on the Cold River, indicating that throughout the watershed the natural stream channel of the Cold River is fully wetted at least 46% of the time.

Table 4.2.2-1 shows the flow for selected flow event frequency intervals on the Cold River at the USGS gage. These flows were estimated using regression equations for New Hampshire published by the USGS (Olson, 2009).

Table 4.2.2-1: Flow Event Frequency Estimates for the Cold River at the USGS Gage

Recurrence Interval (years)	Annual Exceedance Probability (%)	Flow (cfs)
2	50	1,930
5	20	2,900
10	10	3,670
25	4	4,650

Most floodplain forests at the six transects were not observed to be inundated at the highest flow (3,730 cfs) that occurred during the study period, indicating that these floodplain forests are inundated at flows higher than the 10-year event. Floodplain forests that were lower in elevation and closer to the channel of the Cold River, including the sycamore floodplain forest at Transect R3R1, the floodplain forest at Transect R2R2, and the floodplain forest at Transect R1R1, were inundated during the study period at flows between 3,490 cfs and 3,710 cfs, which corresponds approximately to the 10-year event. Emergent and shrub-scrub communities, which were lower in elevation, rely more heavily on periodic inundation from the Cold River. These communities were observed to be inundated between 1,080 cfs and 1,920 cfs, which corresponds approximately to a 2-year event. Most side channels and mid channel bars would be inundated annually, or multiple times per year.

4.3 Recreation

Though whitewater boaters are common on some New Hampshire rivers, none were observed or surveyed during the study. Posts on the MVP Facebook page indicated that one whitewater boater who has utilized the Cold River in the past did so at flows of approximately 700 cfs, which provided difficult/advanced whitewater conditions. Many paddlers also indicated that the lack of regulated flow releases on the river deterred them from utilizing the Cold River. Given the very limited whitewater use on the Cold River, typical boating flows were not apparent, and no recommendations were developed. Alternatively, high spring flows and protected instream flows (flow event frequencies) for riparian habitat would occur at higher levels than those needed for whitewater boating. The rise and fall of the hydrograph during these events will provide recreational opportunities to potential future paddlers on the Cold River.

All swimming and angling that was observed on the Cold River happened during low flow conditions in summer and fall. Generally, both swimmers and anglers identified the months of April and May as generally having flows that are too high for angling and swimming. Based on the results of the recreational surveys, swimming was not determined to be a flow-dependent resource on the Cold River. One angler that was surveyed stated that flows lower than around 10 cfs would be too low to fish on the Cold River because the water levels in the pools become too low. This would indicate some degree of flow dependency on angling resources; however, flows below this level frequently occur during summer low flows in the river. During these periods, habitat for aquatic species is likely more of a limiting factor to longer-term angling success than the needs of anglers. Given the substantial data on aquatic habitat, and the relatively limited information on flow needs for angling, no protected instream flow recommendations were provided for angling. Instead, flow recommendations during the summer period were derived from the needs of aquatic habitat. The natural flow paradigm will provide the necessary aquatic habitat to allow angling activities to occur on the Cold River.

5 Discussion

Based on this study, Protected Instream Flows for the Cold River (Table 5-1) are based on the needs of aquatic and riparian habitat. Other public uses of the stream are either not flow-dependent, or their needs would be satisfied by the recommendations for aquatic and riparian habitat. Protected instream flows for aquatic habitat would protect against extended periods of low flows, which could be exacerbated by water withdrawals or diversions during low flow periods. Additionally, protected instream flows for riparian habitat recommend that flow event frequencies in accordance with the natural flow paradigm are maintained.

Table 5-1: Protected Instream Flows for the Cold River

Date Range	Common Flow				Critical Flow				Rare Flow			
	Common Flow (cfs)	Common Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)	Critical Flow (cfs)	Critical Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)	Rare Flow (cfs)	Rare Flow (cfsm)	Allowable Duration Under (days)	Catastrophic Duration (days)
December 1 – February 28/29	136.0	1.82	50	74	36.5	0.49	27	43	16.0.	0.21	11	15
March 1 – April 15	480.0	6.43	21	37	63.0	0.84	13	21	39.0	0.52	8	12
April 16 – May 15	94.5	1.27	14	20	61.0	0.82	10	16	55.5	0.74	4	7
May 16 – July 7	125.0	1.68	24	48	16.0	0.21	9	14	10.0	0.13	6	8
July 8 – September 21	31.0	0.42	40	63	7.0	0.09	15	22	4.0	0.05	10	17
September 22 – November 30	76.5	1.03	28	64	15.5	0.21	15	27	7.5	0.10	6	10

Retain Flood Frequencies:

- >3,730 cfs, every 10 to 25 years
- 3,490 cfs to 3,710 every 10 years
- 1,080 cfs to 1,920 cfs every 2 years

Note: Flows provided are for the USGS gage in Alstead, NH (USGS Gage No. 01154950)

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Appendices

Appendix A: Wetlands and Deepwater Habitat Classification

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

System: M - Marine

Subsystem	Class	Subclass
1 - Subtidal	RB – Rock Bottom	1 Bedrock 2 Rubble
1 - Subtidal	UB – Unconsolidated Bottom	1 Cobble-Gravel 2 Sand 3 Mud
1 - Subtidal	AB – Aquatic Bed	1 Algal 3 Rooted Vascular
1 - Subtidal	RF – Reef	1 Coral 3 Worm
2 - Intertidal	AB – Aquatic Bed	1 Algal 3 Rooted Vascular
2 - Intertidal	RF – Reef	1 Coral 3 Worm
2 - Intertidal	RS – Rocky Shore	1 Bedrock 2 Rubble
2 - Intertidal	US – Unconsolidated Shore	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic

System: E - Estuarine

Subsystem	Class	Subclass
1 - Subtidal	RB – Rock Bottom	1 Bedrock 2 Rubble
1 - Subtidal	UB – Unconsolidated Bottom	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
1 - Subtidal	AB – Aquatic Bed	1 Algal 3 Rooted Vascular 4 Floating Vascular
1 - Subtidal	RF – Reef	2 Mollusk 3 Worm
2 - Intertidal	AB – Aquatic Bed	1 Algal 3 Rooted Vascular 4 Floating Vascular
2 - Intertidal	RF – Reef	2 Mollusk 3 Worm
2 - Intertidal	SB – Streambed	1 Bedrock 2 Rubble 3 Cobble-Gravel 4 Sand 5 Mud 6 Organic
2 - Intertidal	RS – Rocky Shore	1 Bedrock 2 Rubble
2 - Intertidal	US – Unconsolidated Shore	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
2 - Intertidal	EM – Emergent	1 Persistent 2 Non-persistent 5 *Phragmites australis*
2 - Intertidal	SS – Scrub-Shrub	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen
2 - Intertidal	FO – Forested	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen

System: R - Riverine

Subsystem: 1 - Tidal; 2 – Lower Perennial; 3 – Upper Perennial; 4* - Intermittent; 5* – Unknown Perennial

Class	Subclass
RB** – Rock Bottom	1 Bedrock 2 Rubble
UB – Unconsolidated Bottom	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
SB** – Streambed	1 Bedrock 2 Rubble 3 Cobble-Gravel 4 Sand 5 Mud 6 Organic 7 Vegetated
AB – Aquatic Bed	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular
RS – Rocky Shore	1 Bedrock 2 Rubble
US – Unconsolidated Shore	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated
EM – Emergent	2 Nonpersistent

* **Intermittent** is limited to the **Streambed** Class;
Unknown Perennial is limited to **Unconsolidated Bottom** Class code **R5UB** only

** **Rock Bottom** is not permitted for the **Lower Perennial** Subsystem;
Streambed is limited to **Tidal** and **Intermittent** Subsystems

Classification of Wetlands and Deepwater Habitats of the United States, Cowardin *et al.* 1979

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

System: L - Lacustrine

Subsystem: 1 - Limnetic

Class	RB – Rock Bottom	UB – Unconsolidated Bottom	AB – Aquatic Bed
Subclass	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular

Subsystem: 2 - Littoral

Class	RB – Rock Bottom	UB – Unconsolidated Bottom	AB – Aquatic Bed	RS – Rocky Shore	US – Unconsolidated Shore	EM – Emergent
Subclass	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	2 Nonpersistent

System: P - Palustrine

Class	RB – Rock Bottom	UB – Unconsolidated Bottom	AB – Aquatic Bed	US – Unconsolidated Shore	ML – Moss-Lichen	EM – Emergent	SS – Scrub-Shrub	FO – Forested
Subclass	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	1 Moss 2 Lichen	1 Persistent 2 Nonpersistent 5 *Phragmites australis*	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen

MODIFIERS

In order to more adequately describe the wetland and deepwater habitats, one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

Water Regime			Special Modifiers	Water Chemistry			Soil
Nontidal	**Saltwater Tidal**	**Freshwater Tidal**		**Coastal Halinity**	**Inland Salinity**	**pH Modifiers for all Fresh Water**	
A Temporarily Flooded	L Subtidal	S Temporarily Flooded-Tidal	b Beaver	1 Hyperhaline	7 Hypersaline	a Acid	g Organic
B Saturated	M Irregularly Exposed	R Seasonally Flooded-Tidal	d Partly Drained/Ditched	2 Euhaline	8 Eusaline	t Circumneutral	n Mineral
C Seasonally Flooded	N Regularly Flooded	T Semipermanently Flooded-Tidal	f Farmed	3 Mixohaline (Brackish)	9 Mixosaline	i Alkaline	
E Seasonally Flooded/ Saturated	P Irregularly Flooded	V Permanently Flooded-Tidal	h Diked/Impounded	4 Polyhaline	0 Fresh		
			r Artificial	5 Mesohaline			
F Semipermanently Flooded			s Spoil	6 Oligohaline			
G Intermittently Exposed			x Excavated	0 Fresh			
H Permanently Flooded							
J Intermittently Flooded							
K Artificially Flooded							

Appendix B: Plant Species List

Common Name	Scientific Name	Status
balsam fir	*Abies balsamea*	Native
red maple	*Acer rubrum*	Native
mountain maple	*Acer spicatum*	Native
striped maple	*Acer pensylvanicum*	Native
silver maple	*Acer saccharinum*	Native
sugar maple	*Acer saccharum*	Native
bugle	*Ajuga sp.*	Non-Native
speckled alder	*Alnus incana*	Native
alder	*Alnus sp.*	Native
Canada serviceberry	*Amelanchier canadensis*	Native
hemp dogbane	*Apocynum cannabinum*	Native
wild sarsaparilla	*Aralia nudicaulis*	Native
common burdock	*Arctium minus*	Non-Native
Jack-in-the-pulpit	*Arisaema triphyllum*	Native
swamp milkweed	*Asclepias incarnata*	Native
common barberry	*Berberis vulgaris*	Non-Native - Invasive
yellow birch	*Betula alleghaniensis*	Native
cherry birch	*Betula lenta*	Native
paper birch	*Betula papyrifera*	Native
beggar-ticks	*Bidens sp.*	Native/Non-Native sp.
river tuber-bulrush	*Bolboschoenus fluviatilis*	Native
bluejoint	*Calamagrostis canadensis*	Native
hedge false bindweed	*Calystegia sepium*	Native
tufted sedge	*Carex elata*	Native
nodding sedge	*Carex gynandra*	Native
common fox sedge	*Carex vulpinoidea*	Native
tussock sedge	*Carex stricta*	Native
American hornbeam	*Carpinus caroliniana*	Native
Asian bittersweet	*Celastrus orbiculatus*	Non-Native - Invasive
spotted knapweed	*Centaurea stoebe*	Non-Native - Invasive
white turtlehead	*Chelone glabra*	Native
water-hemlock	*Cicuta sp.*	Native
enchanter's-nightshade	*Circaea sp.*	Native
Virginia virgin's-bower	*Clematis virginiana*	Native
field bindweed	*Convolvulus arvensis*	Non-Native
three-leaved goldthread	*Coptis trifolia*	Native
alternate-leaved dogwood	*Cornus alternifolia*	Native
Canadian bunchberry	*Cornus canadense*	Native
American hazelnut	*Corylus americana*	Native
beaked hazelnut	*Corylus cornuta*	Native
eastern hay-scented fern	*Dennstaedtia punctilobula*	Native
deer-tongue rosette-panicgrass	*Dichanthelium clandestinum*	Native
tall white-aster	*Doellingeria umbellata*	Native
spinulose wood fern	*Dryopteris carthusiana*	Native
autumn-olive	*Elaeagnus umbellata*	Non-Native - Invasive

Common Name	Scientific Name	Status
spikesedge	*Eleocharis sp.*	Native
downy wild-rye	*Elymus villosus*	Native
willow-herb	*Epilobium sp.*	Native
horsetail	*Equisetum sp.*	Native
boneset thoroughwort	*Eupatorium perfoliatum*	Native
white wood-aster	*Eurybia divaricata*	Native
common grass-leaved-goldenrod	*Euthamia graminifolia*	Native
spotted Joe-Pye weed	*Eutrochium maculatum*	Native
American beech	*Fagus grandifolia*	Native
glossy false buckthorn	*Frangula alnus*	Non-Native - Invasive
ash	*Fraxinus sp.*	Native
green ash	*Fraxinus pennsylvanica*	Native
marsh bedstraw	*Galium palustre*	Native
rough bedstraw	*Galium asprellum*	Native
closed gentian	*Gentiana clausa*	Native
avens	*Geum sp.*	Native
rattlesnake manna grass	*Glyceria canadensis*	Native
American witch-hazel	*Hamamelis virginiana*	Native
pale St. John's-wort	*Hypericum ellipticum*	Native
St. John's-wort	*Hypericum sp.*	Native
common winterberry	*Ilex verticillata*	Native
jewelweed	*Impatiens capensis*	Native
yellow iris	*Iris pseudacorus*	Non-Native - Invasive
blue iris	*Iris versicolor*	Native
common soft rush	*Juncus effusus*	Native
rice cut grass	*Leersia oryzoides*	Native
Canada lily	*Lilium canadense*	Native
cardinal-flower	*Lobelia cardinalis*	Native
honeysuckle	*Lonicera sp.*	Native/Non-Native sp.
common wood rush	*Luzula multiflora*	Native
maleberry	*Lyonia ligustrina*	Native
fringed yellow-loosestrife	*Lysimachia ciliata*	Native
creeping yellow-loosestrife	*Lysimachia nummularia*	Non-Native - Invasive
swamp yellow-loosestrife	*Lysimachia terrestris*	Native
purple loosestrife	*Lythrum salicaria*	Non-Native
false solomon's-seal	*Maianthemum sp.*	Native
Canada-mayflower	*Maianthemum canadense*	Native
cultivated apple	*Malus pumila*	Non-Native
ostrich fern	*Matteuccia struthiopteris*	Native
Indian cucumber root	*Medeola virginiana*	Native
white sweet-clover	*Melilotus albus*	Non-Native
mint	*Mentha sp.*	Native/Non-Native sp.
Japanese stiltgrass	*Microstegium vimineum*	Non-Native - Invasive
climbing hempvine	*Mikania scandens*	Native - RTE
Allegheny monkey-flower	*Mimulus ringens*	Native

Common Name	Scientific Name	Status
partridge-berry	*Mitchella repens*	Native
wild bergamot	*Monarda fistulosa*	Native
white mulberry	*Morus alba*	Non-Native
water forget-me-not	*Myosotis scorpioides*	Non-Native
sweetgale	*Myrica gale*	Native
tall rattlesnake-root	*Nabalus altissimus*	Native
sensitive fern	*Onoclea sensibilis*	Native
marjoram	*Origanum sp.*	Non-Native
royal fern	*Osmunda regalis*	Native
cinnamon fern	*Osmundastrum cinnamomeum*	Native
hop-hornbeam	*Ostrya virginiana*	Native
common yellow wood sorrel	*Oxalis stricta*	Native
switch panicgrass	*Panicum virgatum*	Native
New York fern	*Parathelypteris noveboracensis*	Native
Virginia-creeper	*Parthenocissus quinquefolia*	Native
halberd-leaved smartweed	*Persicaria arifolia*	Native
Pennsylvania smartweed	*Persicaria pensylvanica*	Native
arrow-leaved tearthumb	*Persicaria sagittata*	Native
reed canary grass	*Phalaris arundinacea*	Native
long beech fern	*Phegopteris connectilis*	Native
garden phlox	*Phlox paniculata*	Non-Native
black spruce	*Picea mariana*	Native
red spruce	*Picea rubens*	Native
Canada clearweed	*Pilea pumila*	Native
eastern white pine	*Pinus strobus*	Native
American sycamore	*Platanus occidentalis*	Native
hairy Solomon's-seal	*Polygonatum pubescens*	Native
Christmas fern	*Polystichum acrostichoide*	Native
eastern cottonwood	*Populus deltoides*	Native
choke cherry	*Prunus virginiana*	Native
black cherry	*Prunus serotina*	Native
bracken fern	*Pteridium aquilinum*	Native
shinleaf	*Pyrola sp.*	Native
northern red oak	*Quercus rubra*	Native
Japanese knotweed	*Reynoutria japonica*	Non-Native - Invasive
staghorn sumac	*Rhus hirta*	Native
black locust	*Robinia pseudoacacia*	Non-Native
rambler rose	*Rosa multiflora*	Non-Native - Invasive
blackberry	*Rubus sp.*	Native
green-headed coneflower	*Rudbeckia laciniata*	Native
common arrowhead	*Sagittaria latifolia*	Native
willow	*Salix sp.*	Native/Non-Native sp.
black elderberry	*Sambucus nigra*	Native
three-square club-bulrush	*Schoenoplectus pungens*	Native
soft-stemmed club-bulrush	*Schoenoplectus tabernaemontani*	Native

Common Name	Scientific Name	Status
dark-green bulrush	*Scirpus atrovirens*	Native
woolgrass	*Scirpus cyperinus*	Native
purple crown-vetch	*Securigera varia*	Non-Native
stonecrop	*Sedum sp.*	Non-Native
water-parsnip	*Sium suave*	Native
carrion-flower	*Smilax herbacea*	Native
climbing nightshade	*Solanum dulcamara*	Non-Native
Canada goldenrod	*Solidago canadensis*	Native
goldenrod	*Solidago sp.*	Native
large-leaved goldenrod	*Solidago macrophylla*	Native
common wrinkle-leaved goldenrod	*Solidago rugosa*	Native
bur-reed	*Sparganium sp.*	Native
white meadowsweet	*Spiraea alba*	Native
silky dogwood	*Swida amomum*	Native
red-osier dogwood	*Swida sericea*	Native
New England American-aster	*Symphyotrichum novae-angliae*	Native
New York American-aster	*Symphyotrichum novi-belgii*	Native
American yew	*Taxus canadensis*	Native
tall meadow-rue	*Thalictrum pubescens*	Native
marsh fern	*Thelypteris palustris*	Native
northern white-cedar	*Thuja occidentalis*	Native
American linden	*Tilia americana*	Native
poison-ivy	*Toxicodendron radicans*	Native
Virginia marsh-St. John's-wort	*Triadenum virginicum*	Native
eastern hemlock	*Tsuga canadensis*	Native
broad-leaved cat-tail	*Typha latifolia*	Native
slippery elm	*Ulmus rubra*	Native
American elm	*Ulmus americana*	Native
stinging nettle	*Urtica dioic*	Native
highbush blueberry	*Vaccinium corymbosum*	Native
blue vervain	*Verbena hastata*	Native
New York ironweed	*Vernonia noveboracensis*	Native
hobblebush	*Viburnum lantanoides*	Native
smooth arrowwood	*Viburnum dentatum*	Native
withe-rod	*Viburnum nudum*	Native
violet	*Viola sp.*	Native/Non-Native sp.
river grape	*Vitis riparia*	Native
balsam fir	*Abies balsamea*	Native
red maple	*Acer rubrum*	Native
mountain maple	*Acer spicatum*	Native

Appendix C: Habitat Suitability Curves

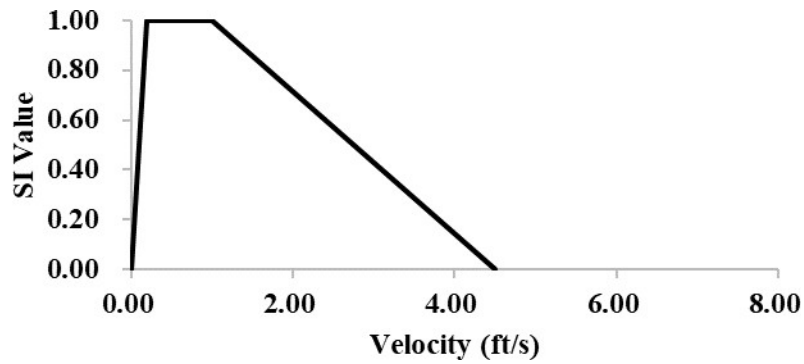
Substrate Coding System

Substrate Code		Embeddedness Code		Cover Code	
1	Roots, Snags, Undercut Banks	0.2	0-25%	0.03	Few Velocity Refuges
2	Clay	0.5	26-50%	0.06	Abundant Velocity Refuges
3	Silt	0.7	51-75%		
4	Sand	0.9	76-100%		
5	Small Gravel (<2")				
6	Gravel (2"-4")				
7	Cobble (4"-10")				
8	Small Boulder (10"-2')				
9	Large Boulder (>2')				
10	Bedrock				
11	Organic Detritus				

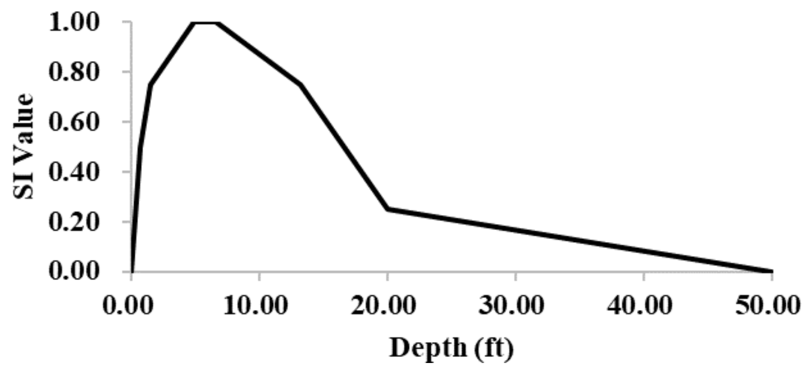
Example Field Code: 5.53 = Small Gravel (5), 26-50% Embedded (0.5), with Few Velocity Refuges (0.03)

Species: American Shad
Lifestage: Juvenile

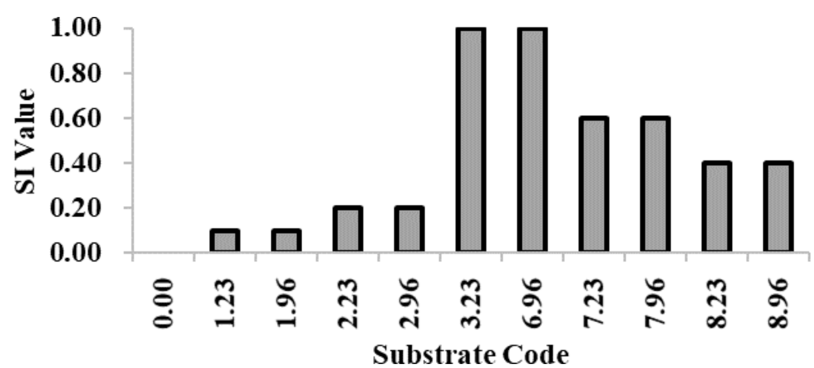
Velocity (ft/s)	SI value
0.00	0.00
0.20	1.00
1.00	1.00
4.50	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.66	0.50
1.50	0.75
4.90	1.00
6.60	1.00
13.20	0.75
20.00	0.25
50.00	0.00



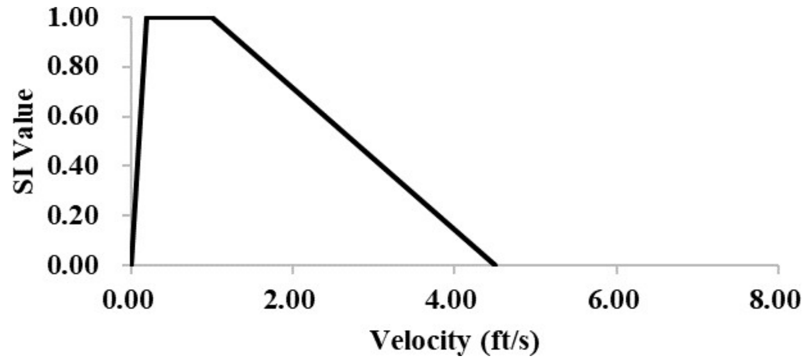
Code	SI value
0.00	0.00
1.23	0.10
1.96	0.10
2.23	0.20
2.96	0.20
3.23	1.00
6.96	1.00
7.23	0.60
7.96	0.60
8.23	0.40
8.96	0.40
100.00	0.00



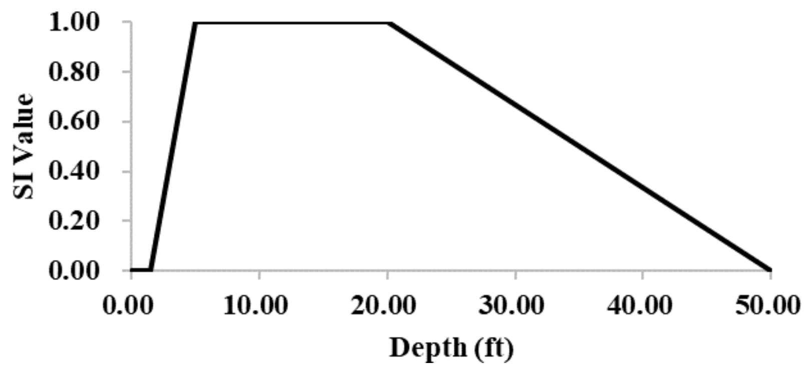
Stier, D.J., Crance, J.H. (1985). *Habitat Suitability Index Models and Instream Flow Suitability Curves: American Shad*. USFWS Bluebook.

Species: American Shad
Lifestage: Fry

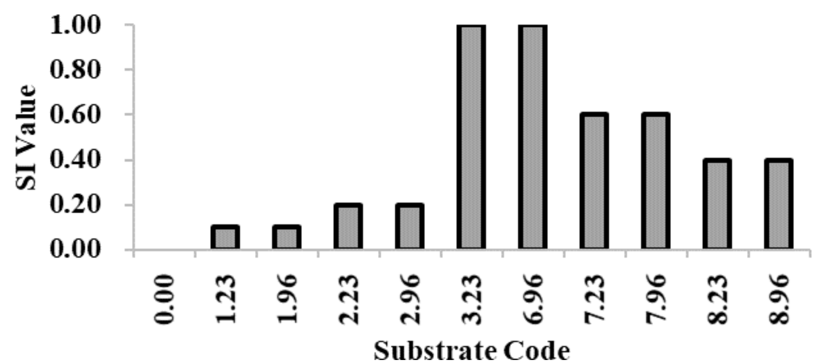
Velocity (ft/s)	SI value
0.00	0.00
0.20	1.00
1.00	1.00
4.50	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
1.50	0.00
5.00	1.00
20.00	1.00
50.00	0.00



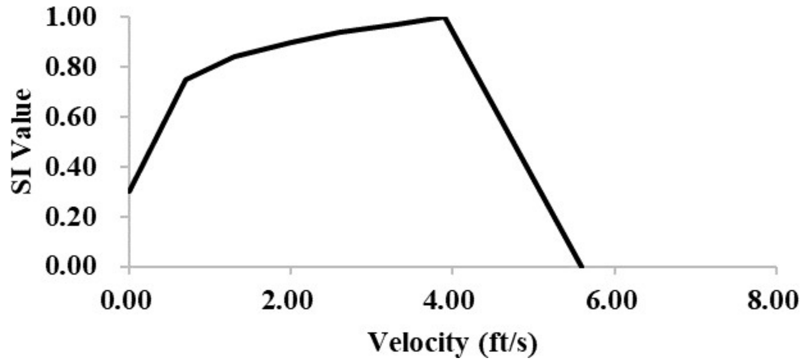
Code	SI value
0.00	0.00
1.23	0.10
1.96	0.10
2.23	0.20
2.96	0.20
3.23	1.00
6.96	1.00
7.23	0.60
7.96	0.60
8.23	0.40
8.96	0.40
100.00	0.00



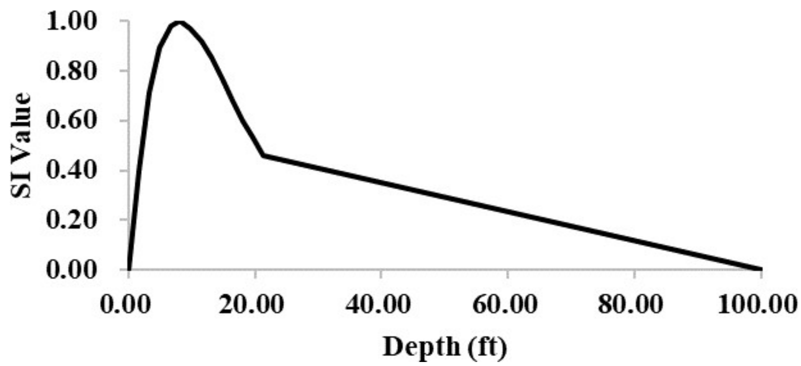
Source: Stier, D.J., Crance, J.H. (1985). *Habitat Suitability Index Models and Instream Flow Suitability Curves: American Shad*. USFWS Bluebook.

Species: American Shad
Lifestage: Spawning and Incubation

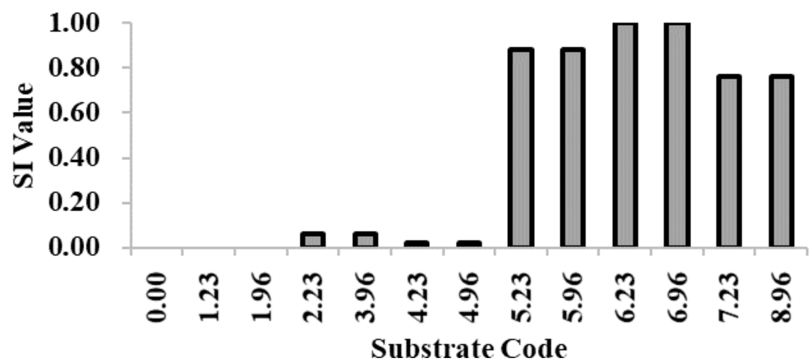
Velocity (ft/s)	SI value
0.00	0.30
0.70	0.75
1.30	0.84
2.00	0.90
2.60	0.94
3.30	0.97
3.90	1.00
5.60	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
1.60	0.40
3.30	0.71
4.90	0.89
6.60	0.98
8.20	1.00
9.80	0.97
11.50	0.92
13.10	0.85
14.80	0.77
16.40	0.68
18.00	0.60
19.70	0.53
21.30	0.46
100.00	0.00



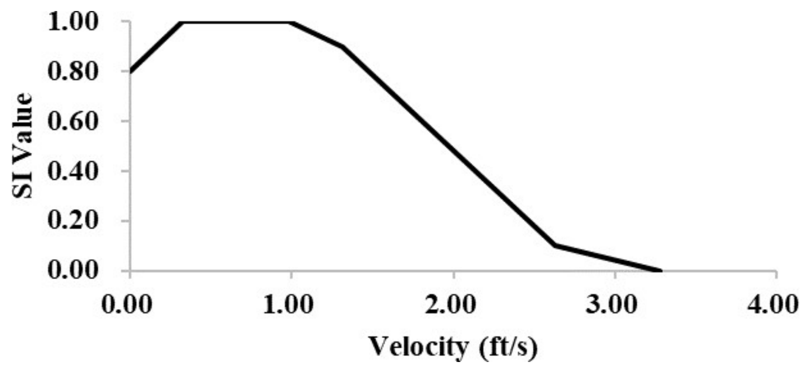
Code	SI value
0.00	0.00
1.23	0.00
1.96	0.00
2.23	0.06
3.96	0.06
4.23	0.02
4.96	0.02
5.23	0.88
5.96	0.88
6.23	1.00
6.96	1.00
7.23	0.76
8.96	0.76
100.00	0.00



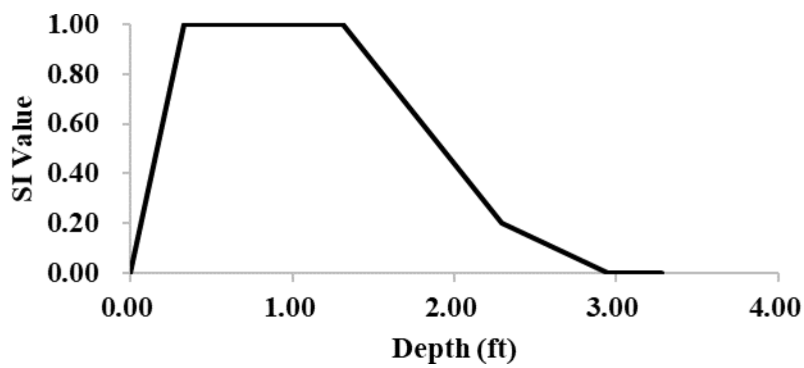
Source: Stier, D.J., Crance, J.H. (1985). *Habitat Suitability Index Models and Instream Flow Suitability Curves: American Shad*. USFWS Bluebook.

Species: Atlantic Salmon
Lifestage: Fry

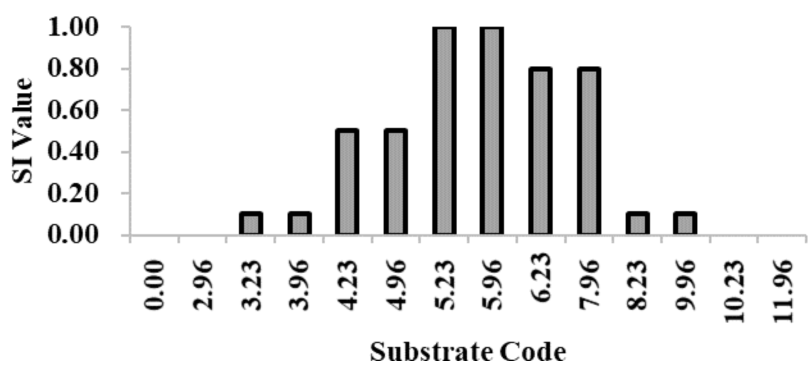
Velocity (ft/s)	SI value
0.00	0.80
0.33	1.00
0.98	1.00
1.31	0.90
2.62	0.10
3.28	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.33	1.00
1.31	1.00
2.30	0.20
2.95	0.00
3.28	0.00
100.00	0.00



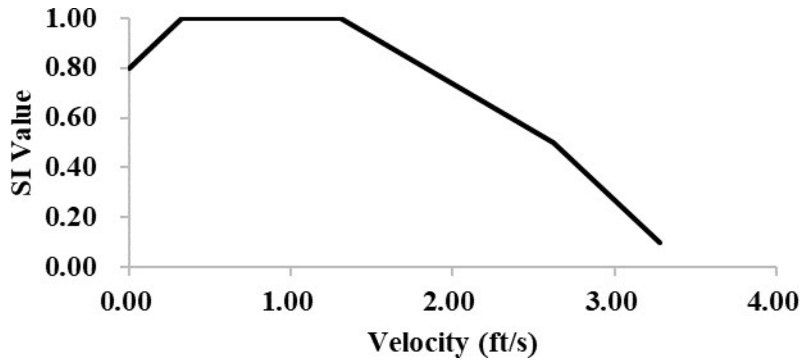
Code	SI value
0.00	0.00
2.96	0.00
3.23	0.10
3.96	0.10
4.23	0.50
4.96	0.50
5.23	1.00
5.96	1.00
6.23	0.80
7.96	0.80
8.23	0.10
9.96	0.10
10.23	0.00
11.96	0.00
100.00	0.00



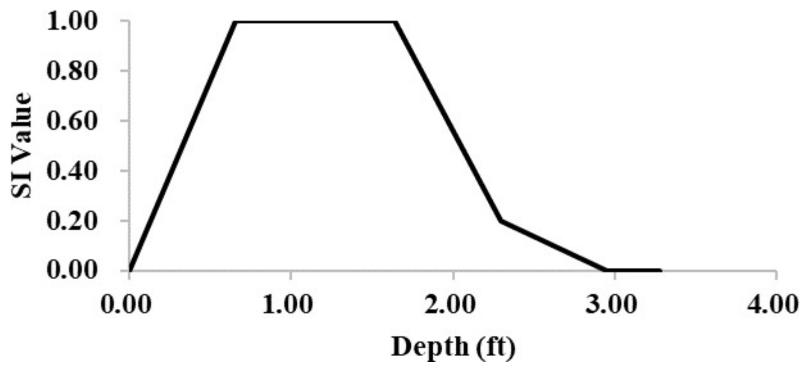
Source: Stanley, J.G., Trial, J.G., (1995). *Habitat Suitability Index Models: Nonmigratory Freshwater Life Stages of Atlantic Salmon*. National Biological Service Biological Science Report 3.

Species: Atlantic Salmon
Lifestage: Parr

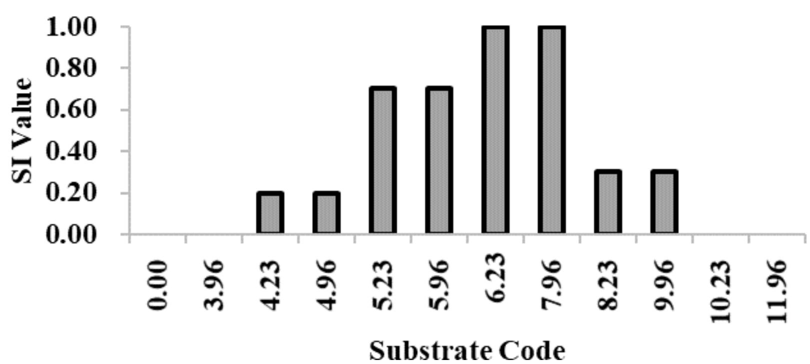
Velocity (ft/s)	SI value
0.00	0.80
0.33	1.00
1.31	1.00
2.62	0.50
3.28	0.10
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.66	1.00
1.64	1.00
2.30	0.20
2.95	0.00
3.28	0.00
100.00	0.00



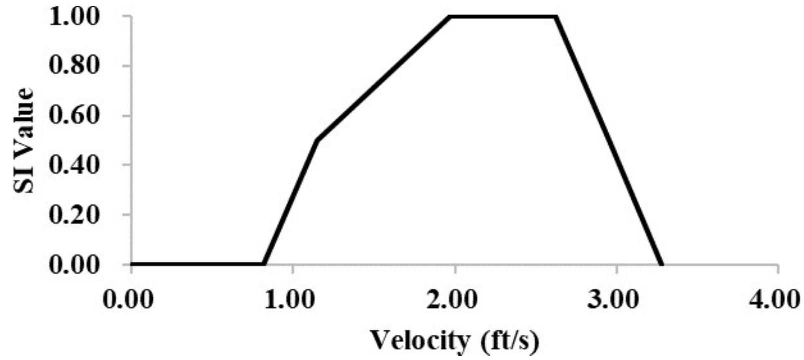
Code	SI value
0.00	0.00
3.96	0.00
4.23	0.20
4.96	0.20
5.23	0.70
5.96	0.70
6.23	1.00
7.96	1.00
8.23	0.30
9.96	0.30
10.23	0.00
11.96	0.00
100.00	0.00



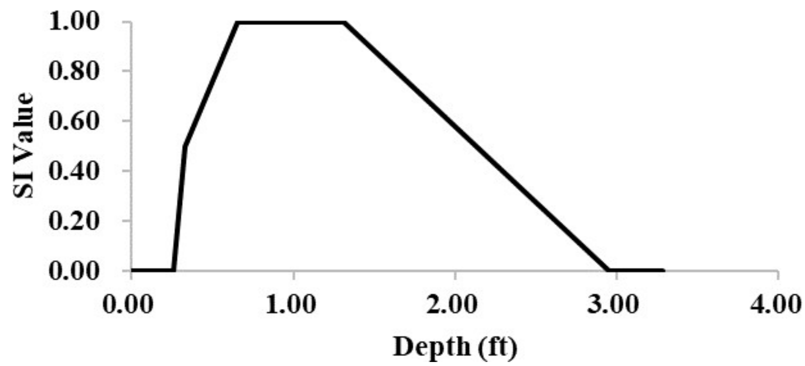
Source: Stanley, J.G., Trial, J.G., (1995). *Habitat Suitability Index Models: Nonmigratory Freshwater Life Stages of Atlantic Salmon*. National Biological Service Biological Science Report 3.

Species: Atlantic Salmon
Lifestage: Spawning and Incubation

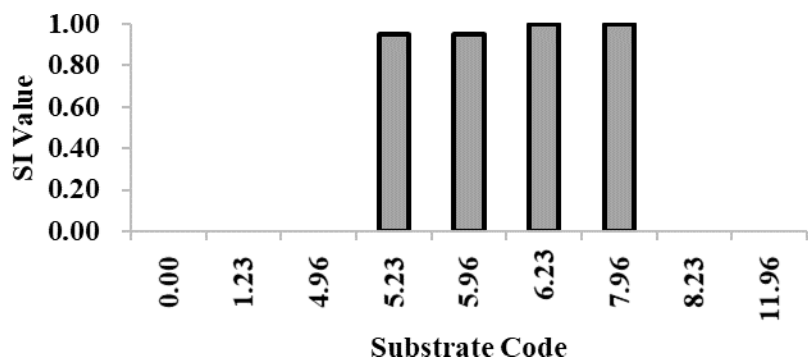
Velocity (ft/s)	SI value
0.00	0.00
0.82	0.00
1.15	0.50
1.97	1.00
2.62	1.00
2.95	0.50
3.28	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.26	0.00
0.33	0.50
0.66	1.00
1.31	1.00
2.95	0.00
3.28	0.00
100.00	0.00



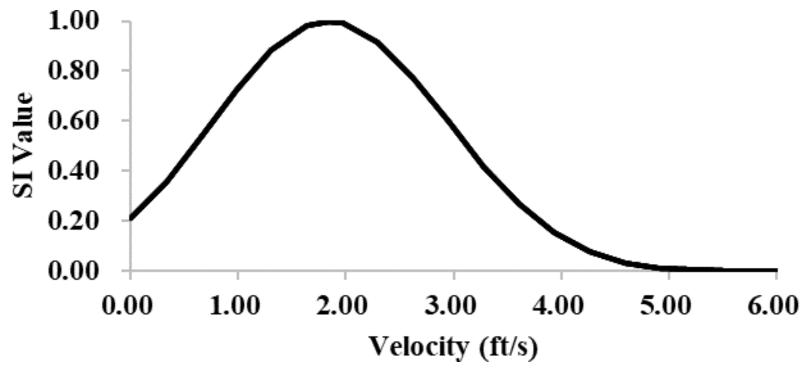
Code	SI value
0.00	0.00
1.23	0.00
4.96	0.00
5.23	0.95
5.96	0.95
6.23	1.00
7.96	1.00
8.23	0.00
11.96	0.00
100.00	0.00



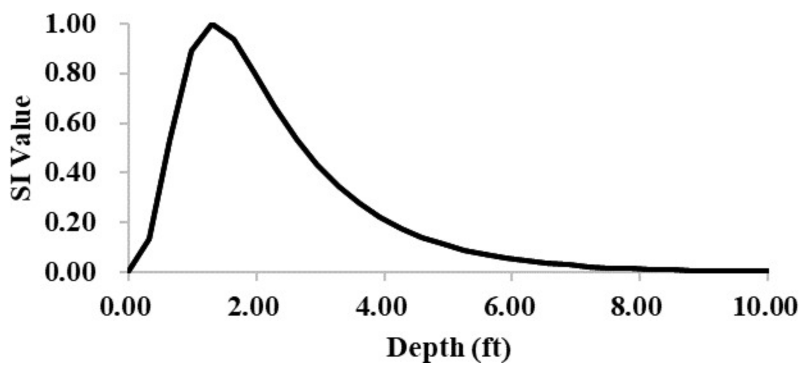
Source: Stanley, J.G., Trial, J.G., (1995). *Habitat Suitability Index Models: Nonmigratory Freshwater Life Stages of Atlantic Salmon*. National Biological Service Biological Science Report 3.

Species: Blacknose Dace
Lifestage: Adult

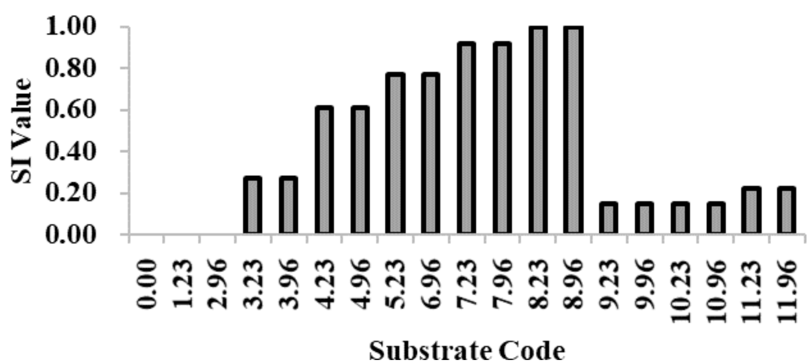
Velocity (ft/s)	SI value	Velocity (ft/s)	SI value
0.00	0.21	3.28	0.42
0.33	0.36	3.61	0.27
0.66	0.54	3.94	0.15
0.98	0.72	4.27	0.08
1.31	0.89	4.59	0.03
1.64	0.98	4.92	0.01
1.84	1.00	5.25	0.00
1.97	0.99	5.58	0.00
2.30	0.92	5.91	0.00
2.62	0.77	100.00	0.00
2.95	0.60		



Depth (ft)	SI value	Depth (ft)	SI value
0.00	0.01	5.25	0.09
0.33	0.13	5.58	0.07
0.66	0.53	5.91	0.06
0.98	0.89	6.23	0.05
1.31	1.00	6.56	0.04
1.64	0.94	6.89	0.03
1.97	0.80	7.22	0.02
2.30	0.66	7.55	0.02
2.62	0.54	7.87	0.01
2.95	0.43	8.20	0.01
3.28	0.35	8.53	0.01
3.61	0.28	8.86	0.01
3.94	0.22	9.19	0.01
4.27	0.18	9.51	0.00
4.59	0.14	9.84	0.00
4.92	0.11	100.00	0.00



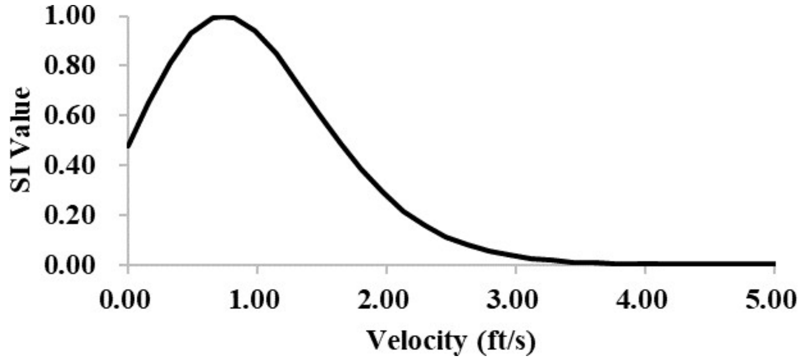
Code	SI value	Code	SI value
0.00	0.00	7.96	0.92
1.23	0.00	8.23	1.00
2.96	0.00	8.96	1.00
3.23	0.27	9.23	0.15
3.96	0.27	9.96	0.15
4.23	0.61	10.23	0.15
4.96	0.61	10.96	0.15
5.23	0.77	11.23	0.22
6.96	0.77	11.96	0.22
7.23	0.92	100.00	0.00



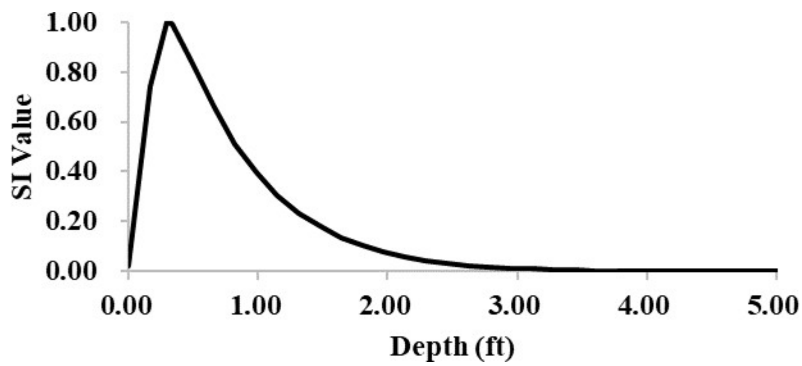
Source: Aadland, L.P., Kuitunen, A. (1991). *Habitat Suitability Criteria for Stream Fishes and Mussels of Minnesota*. Minnesota Department of Natural Resources Ecological Services Division.

Species: Blacknose Dace
Lifestage: Young-of-Year

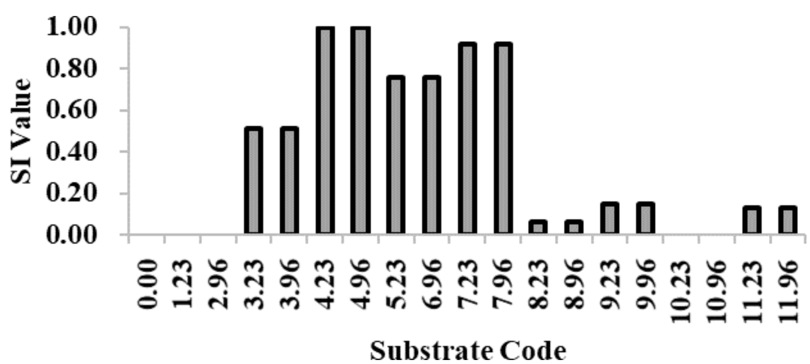
Velocity (ft/s)	SI value	Velocity (ft/s)	SI value
0.00	0.48	2.13	0.22
0.16	0.65	2.30	0.16
0.33	0.81	2.46	0.11
0.49	0.93	2.62	0.08
0.66	0.99	2.79	0.06
0.74	1.00	2.95	0.04
0.82	0.99	3.12	0.03
0.98	0.94	3.28	0.02
1.15	0.85	3.44	0.01
1.31	0.73	3.61	0.01
1.48	0.61	3.77	0.01
1.64	0.49	3.94	0.00
1.80	0.38	4.10	0.00
1.97	0.29	100.00	0.00



Depth (ft)	SI value	Depth (ft)	SI value
0.00	0.02	2.13	0.06
0.16	0.74	2.30	0.04
0.30	1.00	2.46	0.03
0.33	0.99	2.62	0.02
0.49	0.83	2.79	0.02
0.66	0.66	2.95	0.01
0.82	0.51	3.12	0.01
0.98	0.40	3.28	0.01
1.15	0.31	3.44	0.00
1.31	0.23	3.61	0.00
1.48	0.18	3.77	0.00
1.64	0.14	3.94	0.00
1.80	0.10	4.10	0.00
1.97	0.08	100.00	0.00



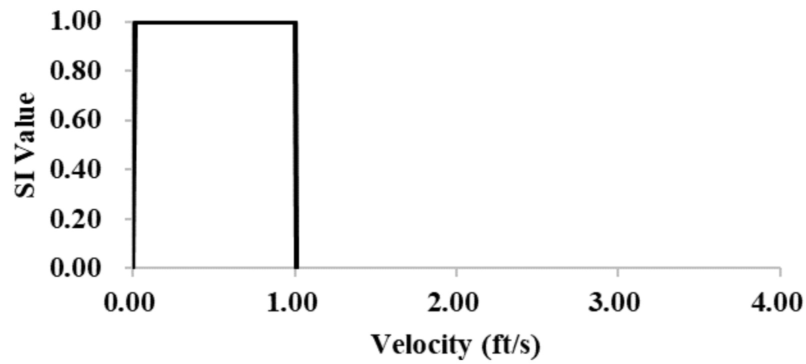
Code	SI value	Code	SI value
0.00	0.00	7.96	0.92
1.23	0.00	8.23	0.06
2.96	0.00	8.96	0.06
3.23	0.51	9.23	0.15
3.96	0.51	9.96	0.15
4.23	1.00	10.23	0.00
4.96	1.00	10.96	0.00
5.23	0.76	11.23	0.13
6.96	0.76	11.96	0.13
7.23	0.92	100.00	0.00



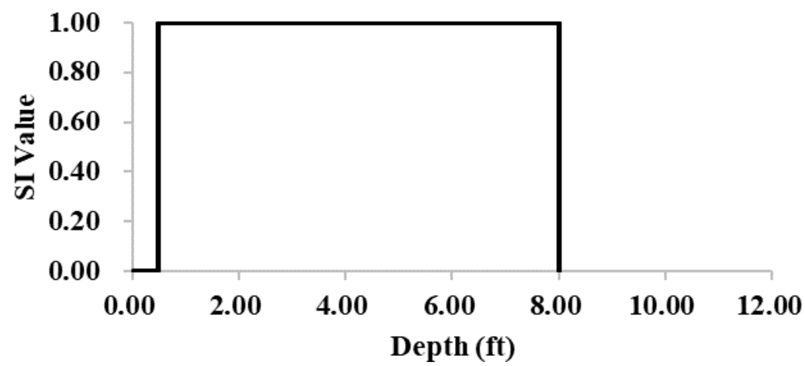
Source: Aadland, L.P., Kuitunen, A. (1991). *Habitat Suitability Criteria for Stream Fishes and Mussels of Minnesota*. Minnesota Department of Natural Resources Ecological Services Division.

Species: Blueback Herring
Lifestage: Spawning and Incubation

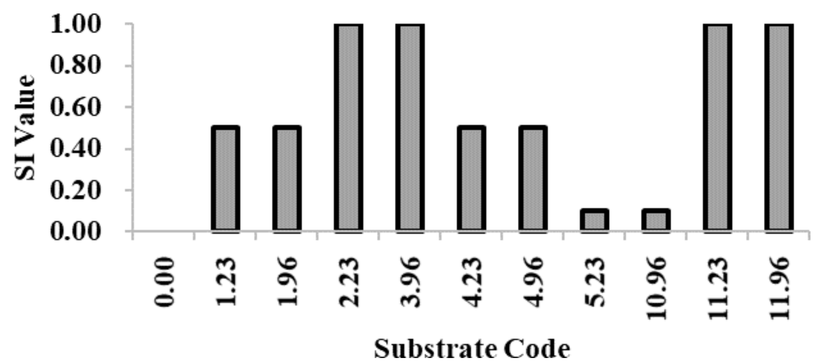
Velocity (ft/s)	SI value
0.00	0.00
0.01	1.00
1.00	1.00
1.01	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.48	0.00
0.49	1.00
8.00	1.00
8.01	0.00
100.00	0.00



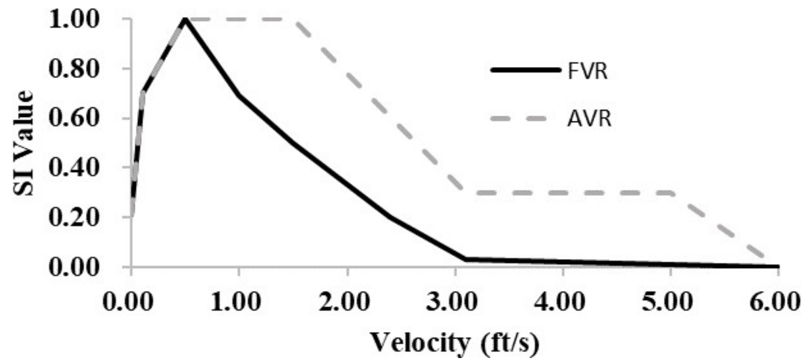
Code	SI value
0.00	0.00
1.23	0.50
1.96	0.50
2.23	1.00
3.96	1.00
4.23	0.50
4.96	0.50
5.23	0.10
10.96	0.10
11.23	1.00
11.96	1.00
100.00	0.00



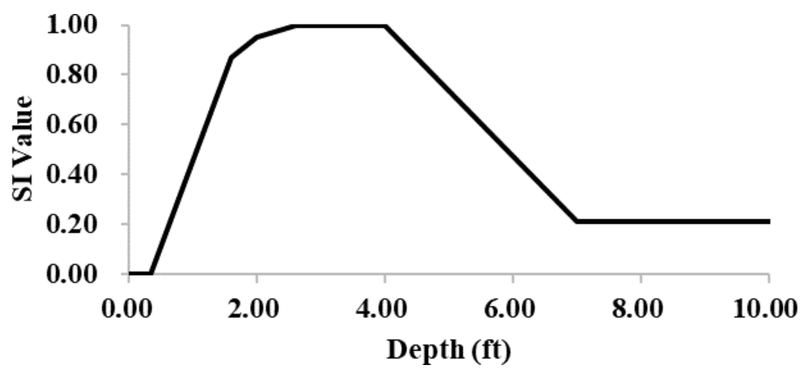
Source: Pardue, G.B. (1983). *Habitat Suitability Index Models: Alewife and Blueback Herring*. USFWS Bluebook.

Species: Brook Trout
Lifestage: Adult

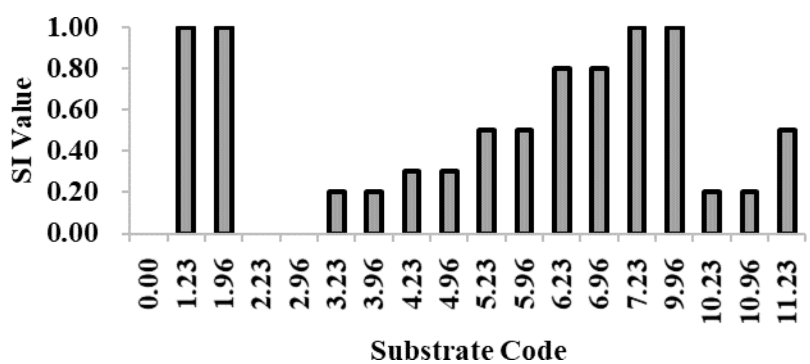
Few Velocity Refuge		Abundant Velocity Refuge	
Velocity (ft/s)	SI value	Velocity (ft/s)	SI value
0.00	0.21	0.00	0.21
0.10	0.70	0.10	0.70
0.50	1.00	0.50	1.00
1.00	0.69	1.50	1.00
1.50	0.50	3.10	0.30
2.40	0.20	5.00	0.30
3.10	0.03	6.00	0.00
6.00	0.00	100.00	0.00
100.00	0.00		



Depth (ft)	SI value
0.00	0.00
0.33	0.00
1.60	0.87
2.00	0.95
2.60	1.00
4.00	1.00
7.00	0.21
100.00	0.21



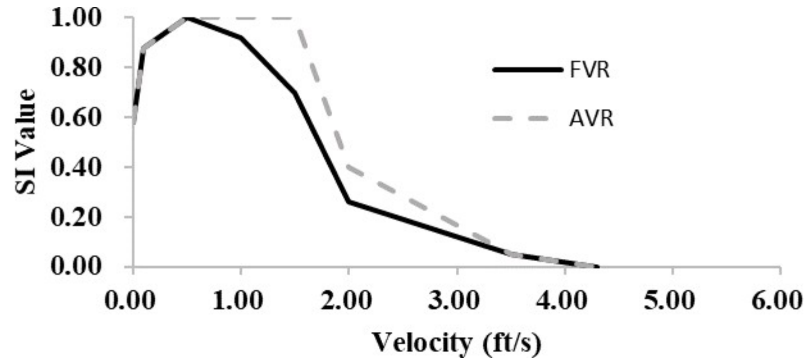
Code	SI value	Code	SI value
0.00	0.00	5.90	0.50
1.20	1.00	6.20	0.80
1.90	1.00	6.90	0.80
2.20	0.00	7.20	1.00
2.90	0.00	9.90	1.00
3.20	0.20	10.20	0.20
3.90	0.20	10.90	0.20
4.20	0.30	11.20	0.50
4.90	0.30	100.00	0.50
5.20	0.50		



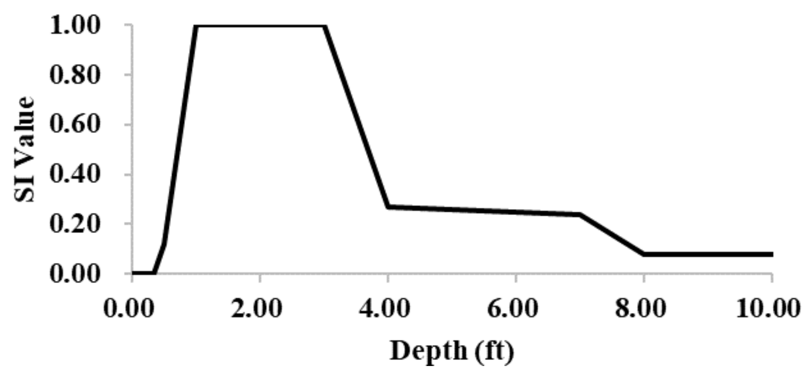
Source: Raleigh, R.F. (1982). *Habitat Suitability Index Models: Brook Trout*. USFWS Bluebook. Modified by GSE in 1991.

Species: Brook Trout
Lifestage: Juvenile

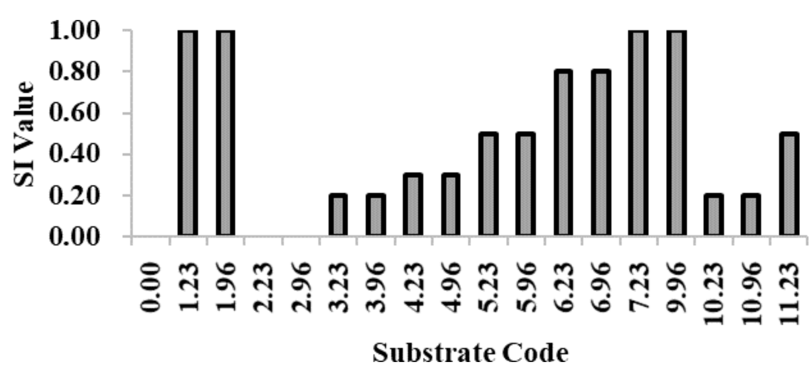
Few Velocity Refuge		Abundant Velocity Refuge	
Velocity (ft/s)	SI value	Velocity (ft/s)	SI value
0.00	0.58	0.00	0.58
0.10	0.88	0.10	0.88
0.50	1.00	0.50	1.00
1.00	0.92	1.00	1.00
1.50	0.70	1.50	1.00
2.00	0.26	2.00	0.40
3.50	0.05	3.50	0.05
4.30	0.00	4.30	0.00
100.00	0.00	100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.33	0.00
0.50	0.12
1.00	1.00
3.00	1.00
4.00	0.27
7.00	0.24
8.00	0.08
100.00	0.08



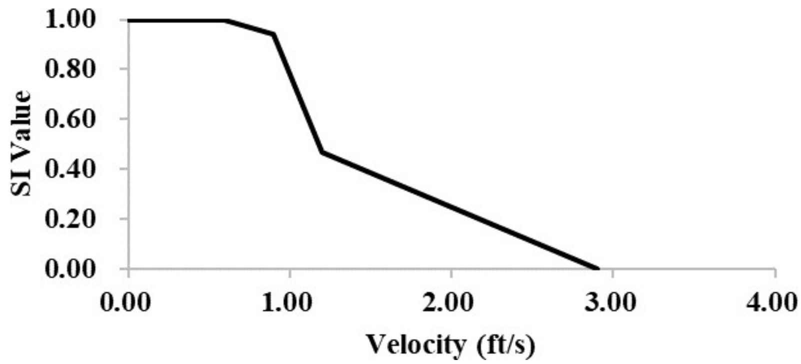
Code	SI value	Code	SI value
0.00	0.00	5.90	0.50
1.20	1.00	6.20	0.80
1.90	1.00	6.90	0.80
2.20	0.00	7.20	1.00
2.90	0.00	9.90	1.00
3.20	0.20	10.20	0.20
3.90	0.20	10.90	0.20
4.20	0.30	11.20	0.50
4.90	0.30	100.00	0.50
5.20	0.50		



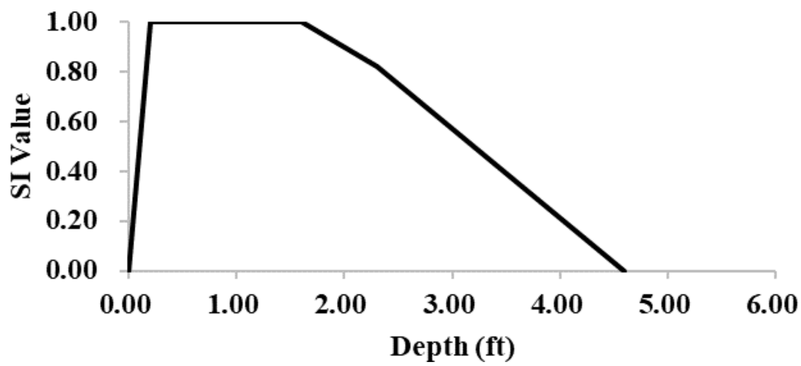
Source: Raleigh, R.F. (1982). *Habitat Suitability Index Models: Brook Trout*. USFWS Bluebook.
Modified by GSE in 1991.

Species: Brook Trout
Lifestage: Fry

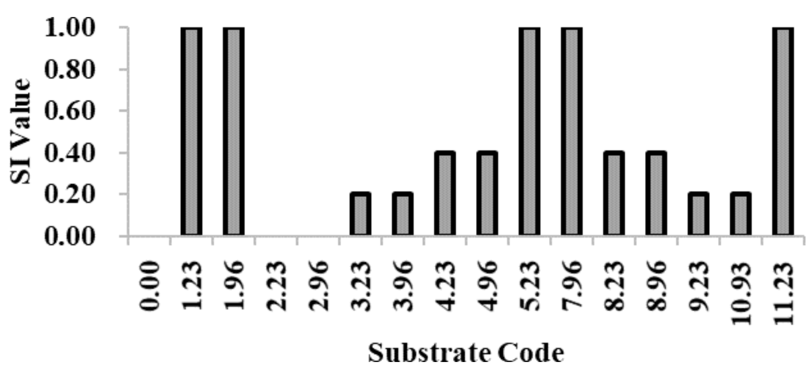
Velocity (ft/s)	SI value
0.00	1.00
0.60	1.00
0.90	0.94
1.20	0.47
2.90	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.20	1.00
1.61	1.00
2.30	0.82
4.60	0.00
100.00	0.00



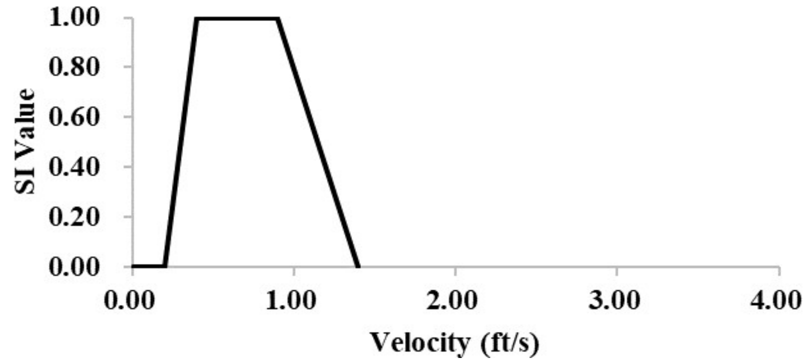
Code	SI value
1.20	1.00
1.90	1.00
2.20	0.00
2.90	0.00
3.20	0.20
3.90	0.20
4.20	0.40
4.90	0.40
5.20	1.00
7.90	1.00
8.20	0.40
8.90	0.40
9.20	0.20
10.90	0.20
11.20	1.00
100.00	1.00



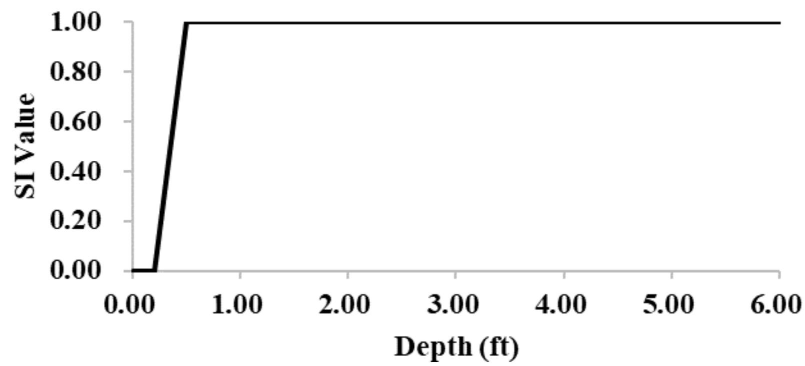
Source: Raleigh, R.F. (1982). *Habitat Suitability Index Models: Brook Trout*. USFWS Bluebook.
Modified by GSE in 1991.

Species: Brook Trout
Lifestage: Spawning and Incubation

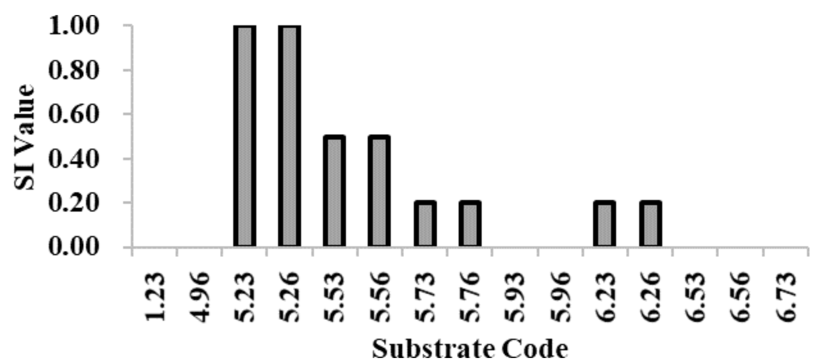
Velocity (ft/s)	SI value
0.00	0.00
0.20	0.00
0.40	1.00
0.90	1.00
1.40	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.20	0.00
0.50	1.00
100.00	1.00



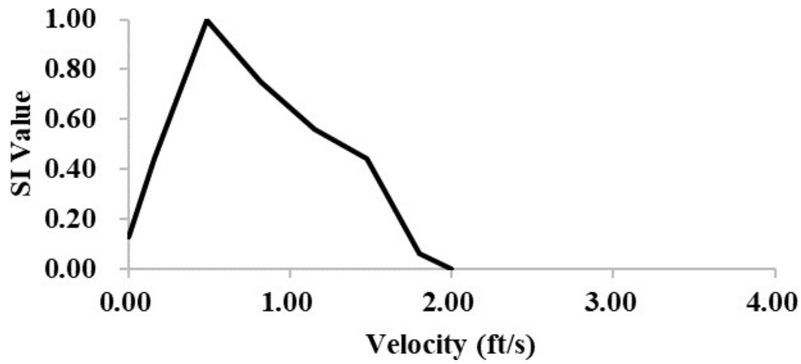
Code	SI value
1.20	0.00
4.90	0.00
5.20	1.00
5.50	0.50
5.70	0.20
5.90	0.00
6.20	0.20
6.50	0.00
100.00	0.00



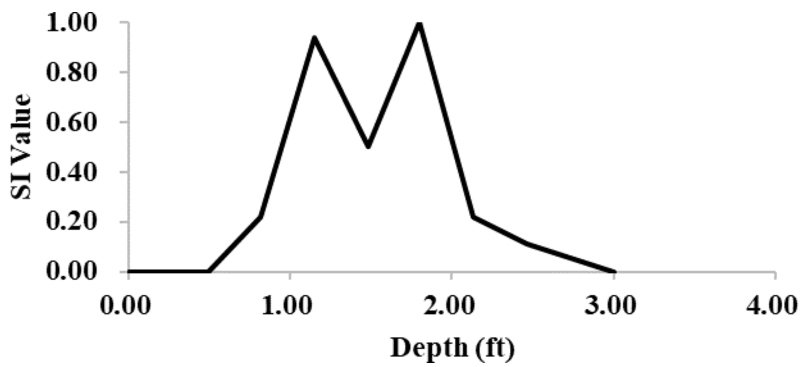
Source: Raleigh, R.F. (1982). *Habitat Suitability Index Models: Brook Trout*. USFWS Bluebook.
Modified by GSE in 1991.

Species: Common Shiner
Lifestage: Juvenile

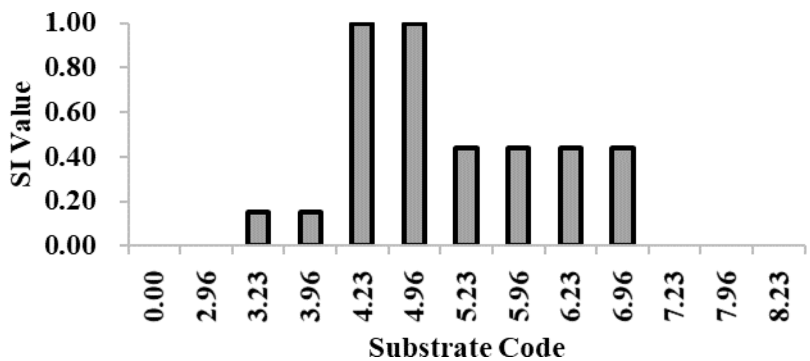
Velocity (ft/s)	SI value
0.00	0.13
0.16	0.44
0.49	1.00
0.82	0.75
1.15	0.56
1.48	0.44
1.80	0.06
2.00	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.16	0.00
0.49	0.00
0.82	0.22
1.15	0.94
1.48	0.50
1.80	1.00
2.13	0.22
2.46	0.11
3.00	0.00
100.00	0.00



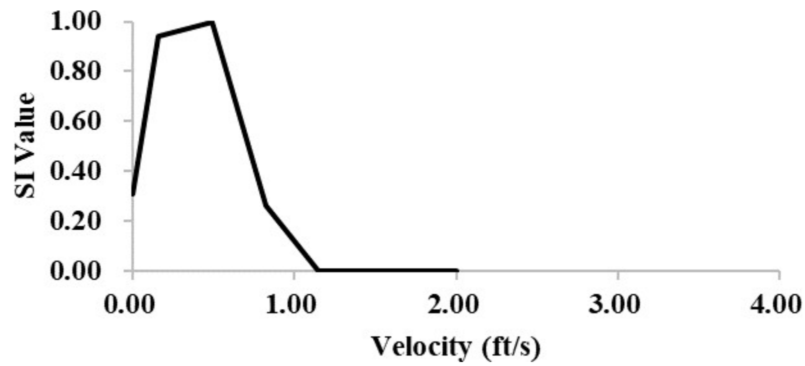
Code	SI value
0.00	0.00
2.96	0.00
3.23	0.15
3.96	0.15
4.23	1.00
4.96	1.00
5.23	0.44
5.96	0.44
6.23	0.44
6.96	0.44
7.23	0.00
7.96	0.00
8.23	0.00
100.00	0.00



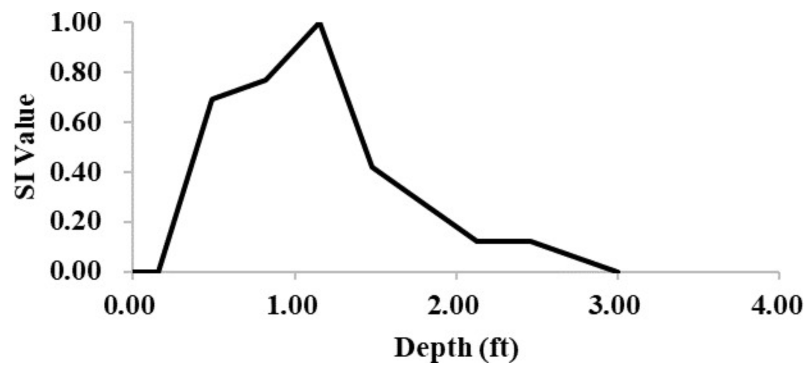
Source: Moody, R.C. (1989). *Habitat Use, Availability, and Preference for Johnny Darter, White Sucker, Northern Hog Sucker, Common Shiner, and Creek Chub in Streams in Central Wisconsin*. MS Thesis. University of Wisconsin, Stevens Point.

Species: Common Shiner
Lifestage: Fry

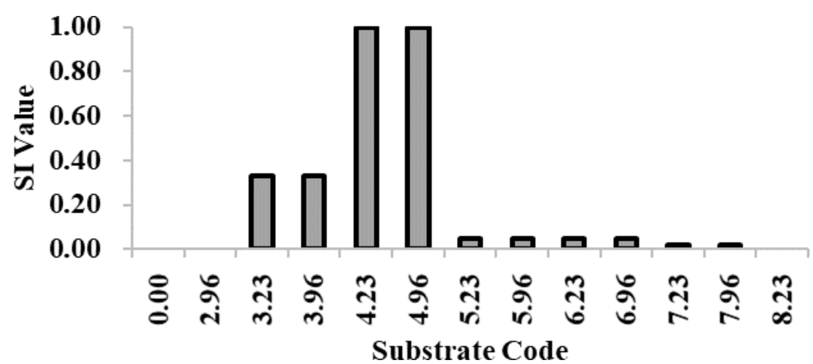
Velocity (ft/s)	SI value
0.00	0.31
0.16	0.94
0.49	1.00
0.82	0.26
1.15	0.00
2.00	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.16	0.00
0.49	0.69
0.82	0.77
1.15	1.00
1.48	0.42
1.80	0.27
2.13	0.12
2.46	0.12
3.00	0.00
100.00	0.00



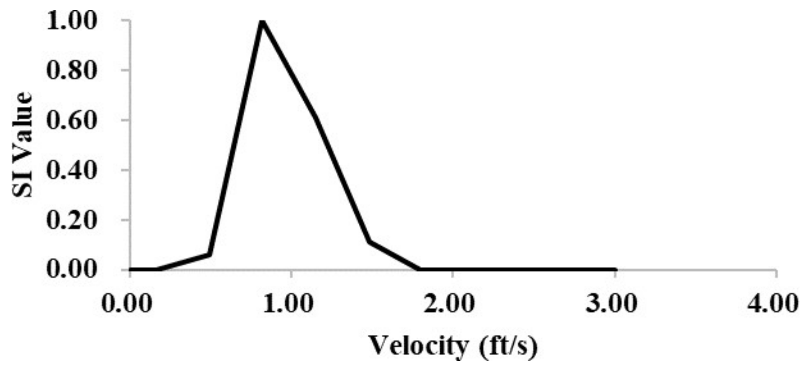
Code	SI value
0.00	0.00
2.96	0.00
3.23	0.33
3.96	0.33
4.23	1.00
4.96	1.00
5.23	0.05
5.96	0.05
6.23	0.05
6.96	0.05
7.23	0.02
7.96	0.02
8.23	0.00
100.00	0.00



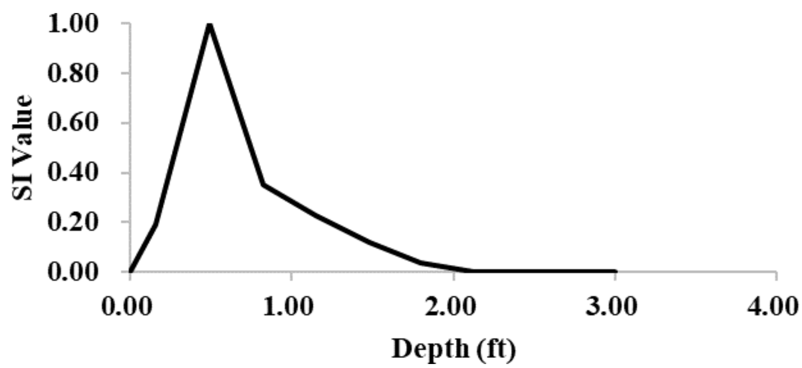
Source: Moody, R.C. (1989). *Habitat Use, Availability, and Preference for Johnny Darter, White Sucker, Northern Hog Sucker, Common Shiner, and Creek Chub in Streams in Central Wisconsin*. MS Thesis. University of Wisconsin, Stevens Point.

Species: Common Shiner
Lifestage: Spawning and Incubation

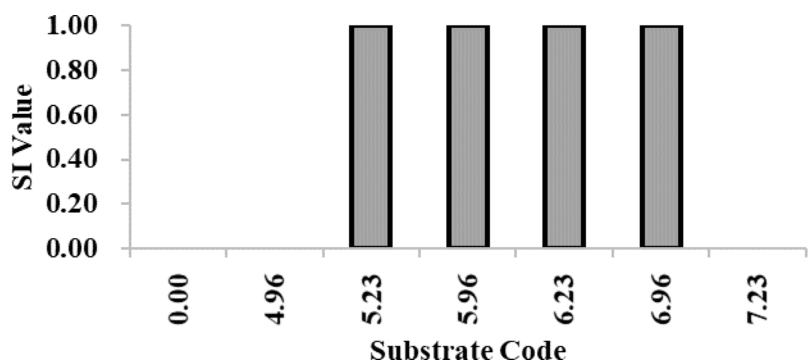
Velocity (ft/s)	SI value
0.00	0.00
0.16	0.00
0.49	0.06
0.82	1.00
1.15	0.61
1.48	0.11
1.80	0.00
2.13	0.00
3.00	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.16	0.19
0.49	1.00
0.82	0.35
1.15	0.23
1.48	0.12
1.80	0.04
2.13	0.00
3.00	0.00
100.00	0.00



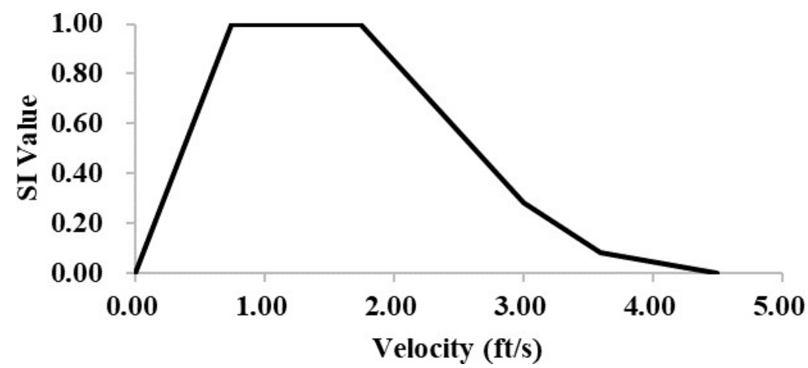
Code	SI value
0.00	0.00
4.96	0.00
5.23	1.00
5.96	1.00
6.23	1.00
6.96	1.00
7.23	0.00
100.00	0.00



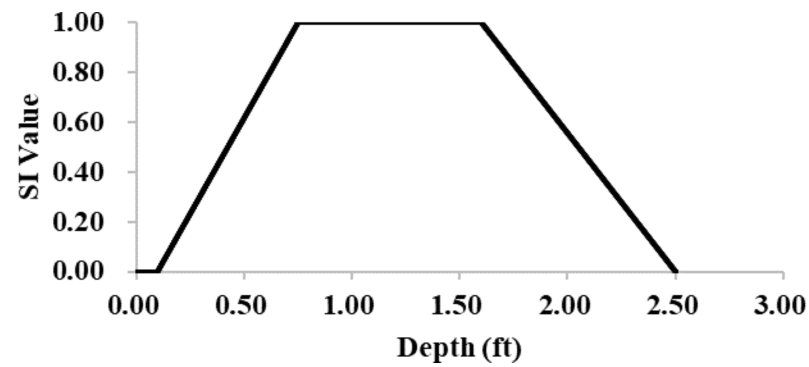
Source: Moody, R.C. (1989). *Habitat Use, Availability, and Preference for Johnny Darter, White Sucker, Northern Hog Sucker, Common Shiner, and Creek Chub in Streams in Central Wisconsin*. MS Thesis. University of Wisconsin, Stevens Point.

Species: Longnose Dace
Lifestage: Adult

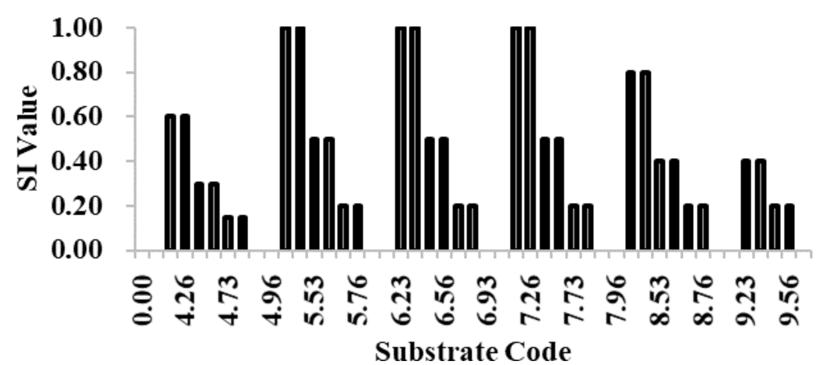
Velocity (ft/s)	SI value
0.00	0.00
0.75	1.00
1.75	1.00
3.00	0.28
3.60	0.08
4.50	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.10	0.00
0.75	1.00
1.60	1.00
2.50	0.00
100.00	0.00



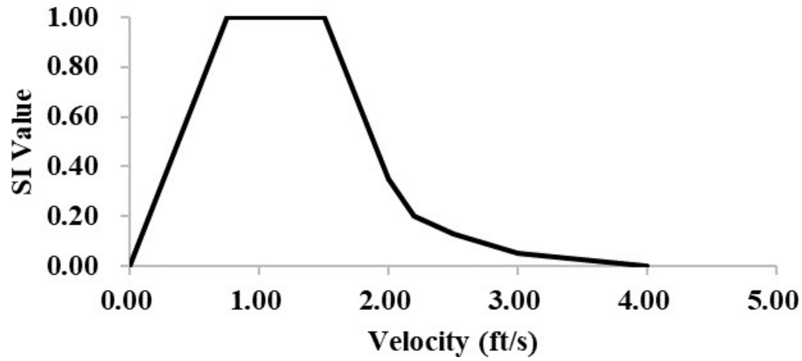
Code	SI value	Code	SI value
0.00	0.00	6.93	0.00
3.96	0.00	6.96	0.00
4.23	0.60	7.23	1.00
4.26	0.60	7.26	1.00
4.53	0.30	7.53	0.50
4.56	0.30	7.56	0.50
4.73	0.15	7.73	0.20
4.76	0.15	7.76	0.20
4.93	0.00	7.93	0.00
4.96	0.00	7.96	0.00
5.23	1.00	8.23	0.80
5.26	1.00	8.26	0.80
5.53	0.50	8.53	0.40
5.56	0.50	8.56	0.40
5.73	0.20	8.73	0.20
5.76	0.20	8.76	0.20
5.93	0.00	8.93	0.00
5.96	0.00	8.96	0.00
6.23	1.00	9.23	0.40
6.26	1.00	9.26	0.40
6.53	0.50	9.53	0.20
6.56	0.50	9.56	0.20
6.73	0.20	9.73	0.00
6.76	0.20	100.00	0.00



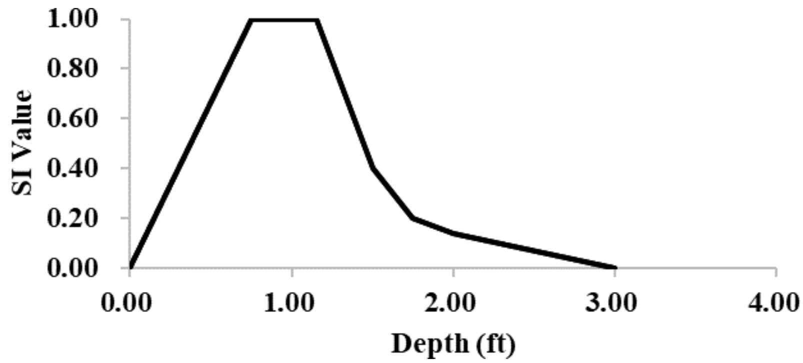
Source: Edwards, E.A. (1983). *Habitat Suitability Index Models: Longnose Dace*. USFWS Bluebook. Modified by VDFW.

Species: Longnose Dace
Lifestage: Juvenile

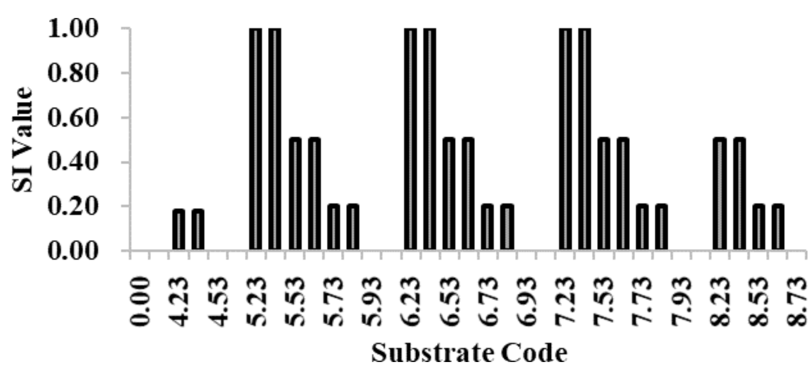
Velocity (ft/s)	SI value
0.00	0.00
0.75	1.00
1.50	1.00
2.00	0.35
2.20	0.20
2.50	0.13
3.00	0.05
4.00	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.75	1.00
1.15	1.00
1.50	0.40
1.75	0.20
2.00	0.14
3.00	0.00
100.00	0.00



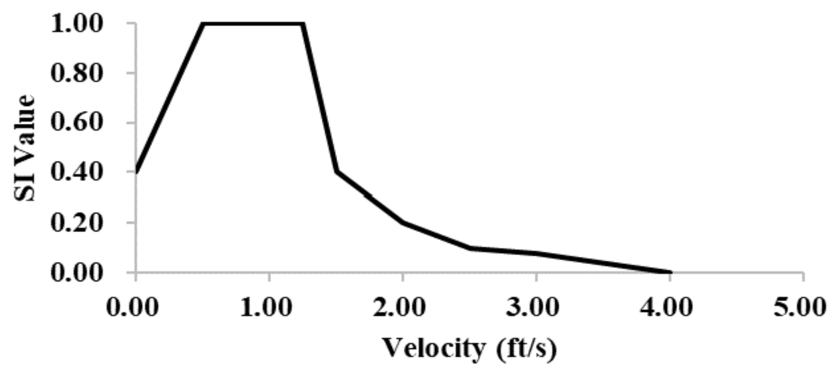
Code	SI value	Code	SI value
0.00	0.00	6.73	0.20
3.96	0.00	6.76	0.20
4.23	0.18	6.93	0.00
4.26	0.18	6.96	0.00
4.53	0.00	7.23	1.00
4.96	0.00	7.26	1.00
5.23	1.00	7.53	0.50
5.26	1.00	7.56	0.50
5.53	0.50	7.73	0.20
5.56	0.50	7.76	0.20
5.73	0.20	7.93	0.00
5.76	0.20	7.96	0.00
5.93	0.00	8.23	0.50
5.96	0.00	8.26	0.50
6.23	1.00	8.53	0.20
6.26	1.00	8.56	0.20
6.53	0.50	8.73	0.00
6.56	0.50	100.00	0.00



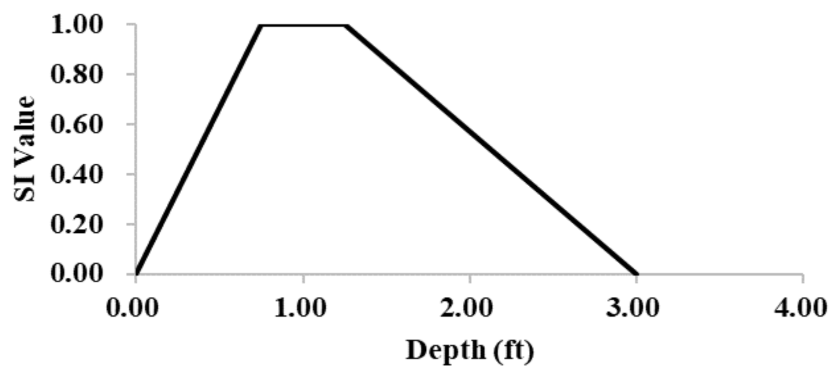
Edwards, E.A. (1983). *Habitat Suitability Index Models: Longnose Dace*. USFWS Bluebook. Modified by VDFW.

Species: Longnose Dace
Lifestage: Fry

Velocity (ft/s)	SI value
0.00	0.40
0.50	1.00
1.25	1.00
1.50	0.40
2.00	0.20
2.50	0.10
3.00	0.08
4.00	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.75	1.00
1.25	1.00
3.00	0.00
100.00	0.00

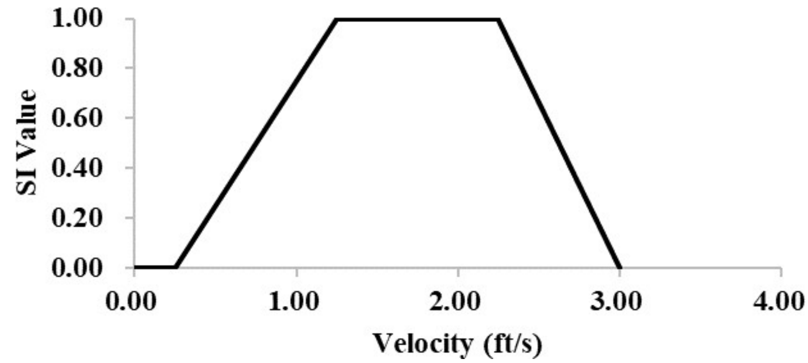


Code	SI value	Code	SI value
0.00	0.00	5.23	1.00
1.23	0.10	5.26	1.00
1.26	0.10	5.53	0.90
1.53	0.00	5.56	0.90
1.96	0.00	5.73	0.85
2.23	0.35	5.76	0.85
2.26	0.35	5.93	0.80
2.93	0.35	5.96	0.80
2.96	0.35	6.93	0.80
3.23	0.80	6.96	0.80
3.26	0.80	7.23	0.40
3.93	0.80	7.26	0.40
3.96	0.80	7.93	0.40
4.23	1.00	7.96	0.40
4.26	1.00	8.23	0.00
4.53	0.90	8.26	0.00
4.56	0.90	11.23	0.10
4.73	0.85	11.26	0.10
4.76	0.85	11.93	0.10
4.93	0.80	11.96	0.10
4.96	0.80	100.00	0.00

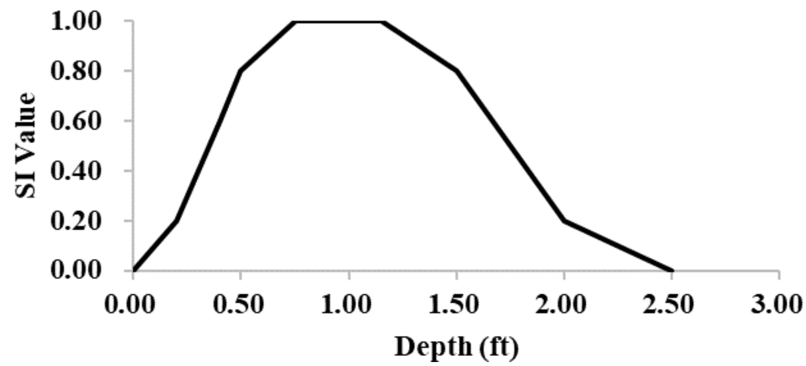
Edwards, E.A. (1983). *Habitat Suitability Index Models: Longnose Dace*. USFWS Bluebook. Modified by VDFW.

Species: Longnose Dace
Lifestage: Spawning and Incubation

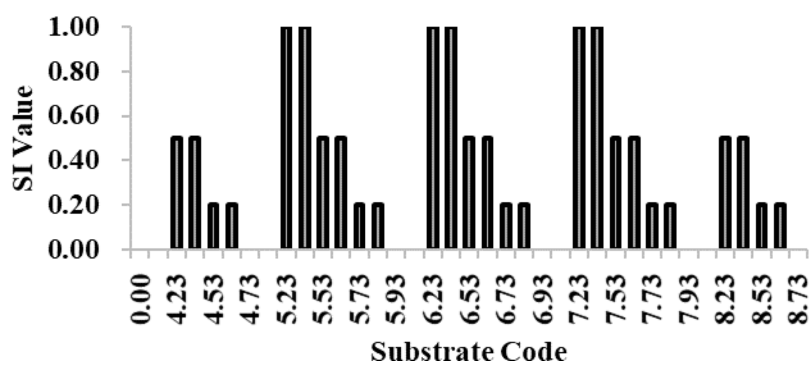
Velocity (ft/s)	SI value
0.00	0.00
0.25	0.00
1.25	1.00
2.25	1.00
3.00	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.20	0.20
0.40	0.60
0.50	0.80
0.75	1.00
1.15	1.00
1.50	0.80
2.00	0.20
2.50	0.00
100.00	0.00



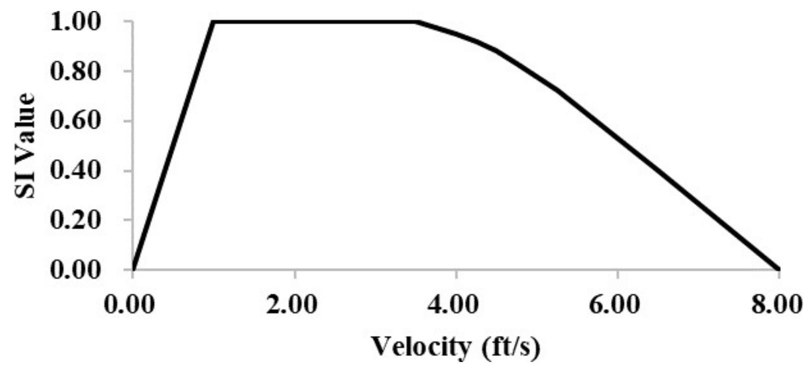
Code	SI value	Code	SI value
0.00	0.00	6.56	0.50
3.96	0.00	6.73	0.20
4.23	0.50	6.76	0.20
4.26	0.50	6.93	0.00
4.53	0.20	6.96	0.00
4.56	0.20	7.23	1.00
4.73	0.00	7.26	1.00
4.96	0.00	7.53	0.50
5.23	1.00	7.56	0.50
5.26	1.00	7.73	0.20
5.53	0.50	7.76	0.20
5.56	0.50	7.93	0.00
5.73	0.20	7.96	0.00
5.76	0.20	8.23	0.50
5.93	0.00	8.26	0.50
5.96	0.00	8.53	0.20
6.23	1.00	8.56	0.20
6.26	1.00	8.73	0.00
6.53	0.50	100.00	0.00



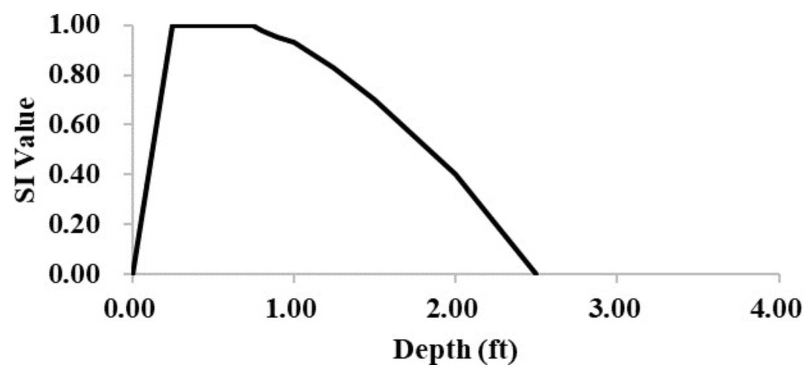
Edwards, E.A. (1983). *Habitat Suitability Index Models: Longnose Dace*. USFWS Bluebook. Modified by VDFW

Species: Longnose Sucker
Lifestage: Spawning and Incubation

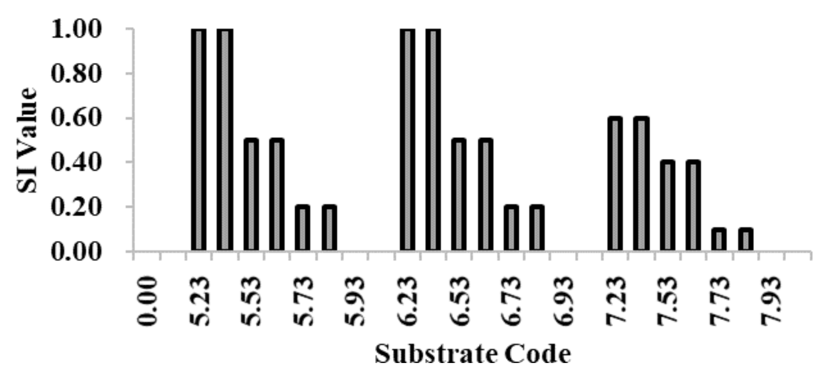
Velocity (ft/s)	SI value
0.00	0.00
1.00	1.00
3.50	1.00
4.00	0.95
4.25	0.92
4.50	0.88
4.75	0.83
5.25	0.72
6.50	0.40
8.00	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.25	1.00
0.75	1.00
0.80	0.98
0.90	0.95
1.00	0.93
1.25	0.83
1.50	0.70
2.00	0.40
2.50	0.00
100.00	0.00



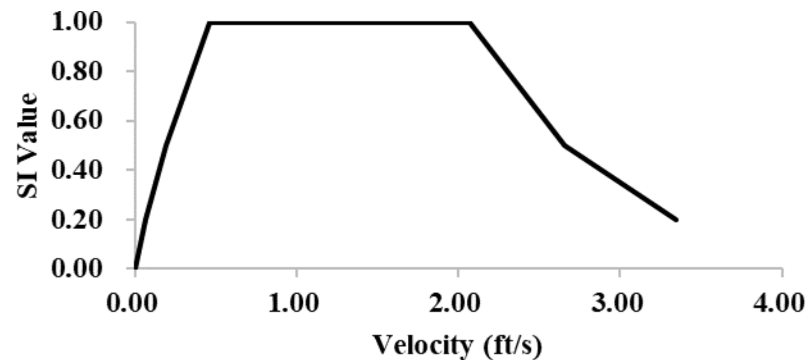
Code	SI value
0.00	0.00
4.90	0.00
5.20	1.00
5.50	0.50
5.70	0.20
5.90	0.00
6.20	1.00
6.50	0.50
6.70	0.20
6.90	0.00
7.20	0.60
7.50	0.40
7.70	0.10
7.90	0.00
100.00	0.00



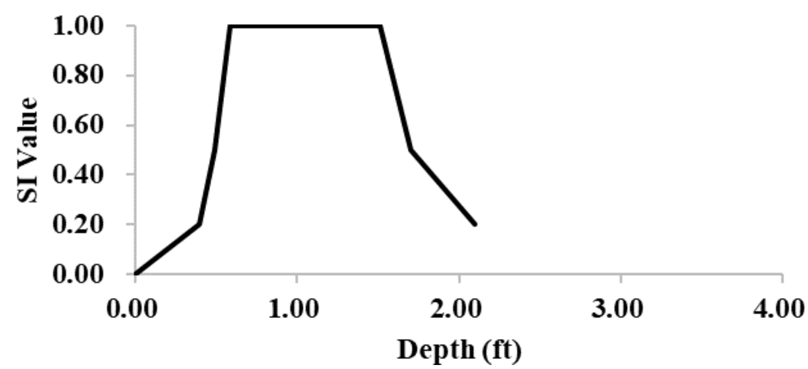
Source: Edwards, E.A. (1983). *Habitat Suitability Index Models: Longnose Sucker*. USFWS Bluebook.

Species: Mottled Sculpin
Lifestage: Adult/Juvenile

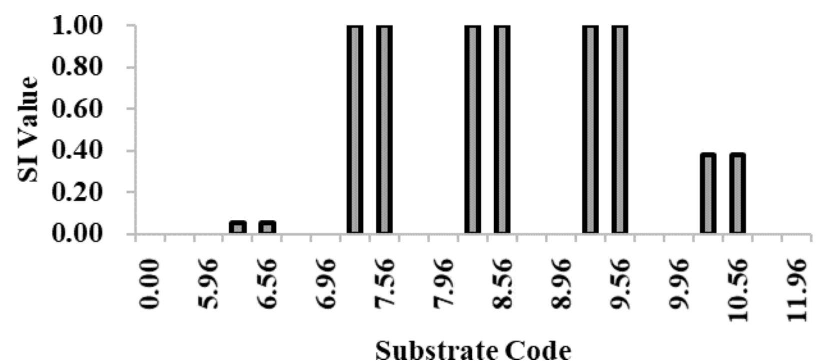
Velocity (ft/s)	SI value
0.00	0.00
0.07	0.20
0.20	0.50
0.46	1.00
2.07	1.00
2.66	0.50
3.35	0.20
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.39	0.20
0.49	0.50
0.59	1.00
1.51	1.00
1.71	0.50
2.10	0.20
100.00	0.00



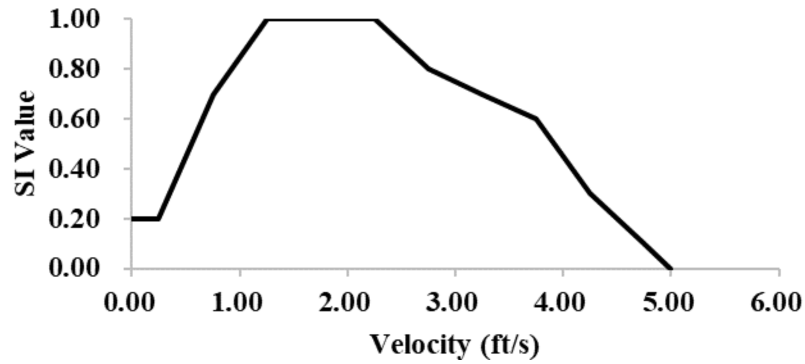
Code	SI value
0.00	0.00
1.23	0.00
5.96	0.00
6.23	0.05
6.56	0.05
6.73	0.00
6.96	0.00
7.23	1.00
7.56	1.00
7.73	0.00
7.96	0.00
8.23	1.00
8.56	1.00
8.73	0.00
8.96	0.00
9.23	1.00
9.56	1.00
9.73	0.00
9.96	0.00
10.23	0.38
10.56	0.38
10.73	0.00
11.96	0.00
100.00	0.00



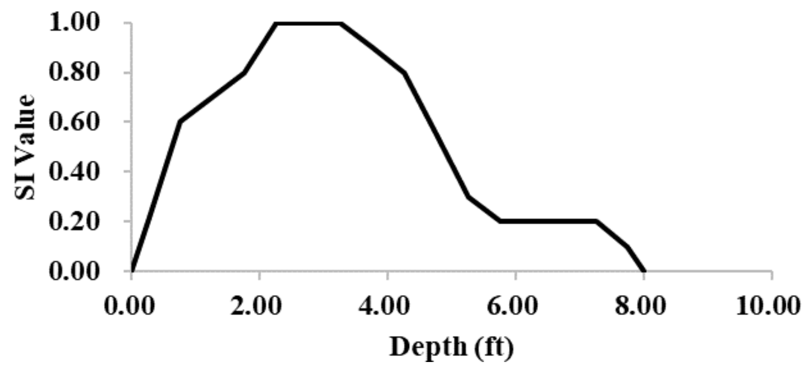
Source: Persinger, J.W. (2003). *Developing Habitat Suitability Criteria for Individual Species Habitat Guilds in the Shenandoah River Basin.* Virginia Polytechnic Institute and State University MS Thesis.

Species: Sea Lamprey
Lifestage: Spawning and Incubation

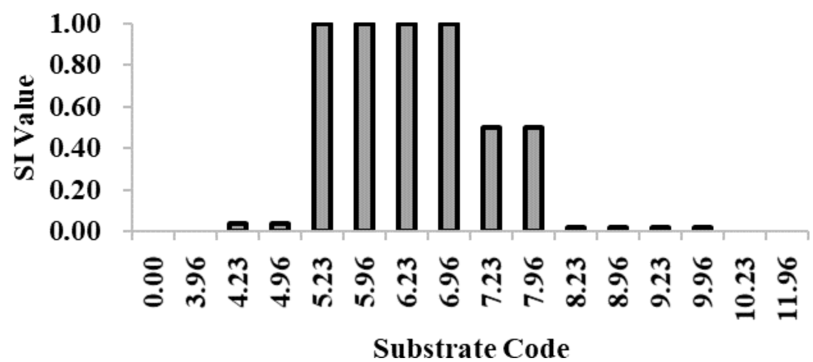
Velocity (ft/s)	SI value
0.00	0.20
0.25	0.20
0.75	0.70
1.25	1.00
2.25	1.00
2.75	0.80
3.25	0.70
3.75	0.60
4.25	0.30
4.75	0.10
5.00	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.25	0.20
0.75	0.60
1.25	0.70
1.75	0.80
2.25	1.00
3.25	1.00
3.75	0.90
4.25	0.80
4.75	0.55
5.25	0.30
5.75	0.20
7.25	0.20
7.75	0.10
8.00	0.00
100.00	0.00



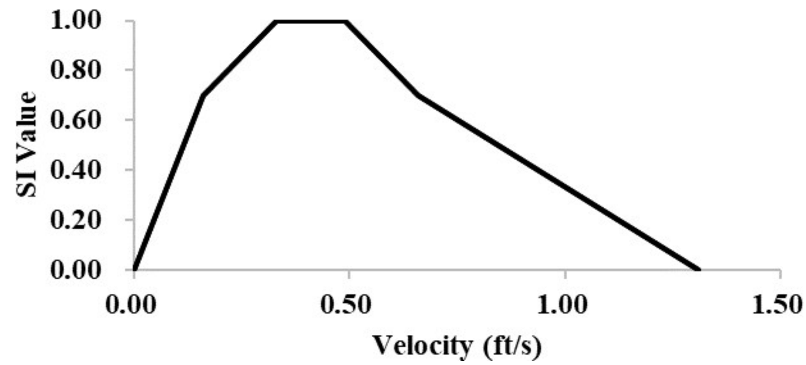
Code	SI value	Code	SI value
0.00	0.00	7.96	0.50
3.96	0.00	8.23	0.02
4.23	0.04	8.96	0.02
4.96	0.04	9.23	0.02
5.23	1.00	9.96	0.02
5.96	1.00	10.23	0.00
6.23	1.00	11.96	0.00
6.96	1.00	100.00	0.00
7.23	0.50		



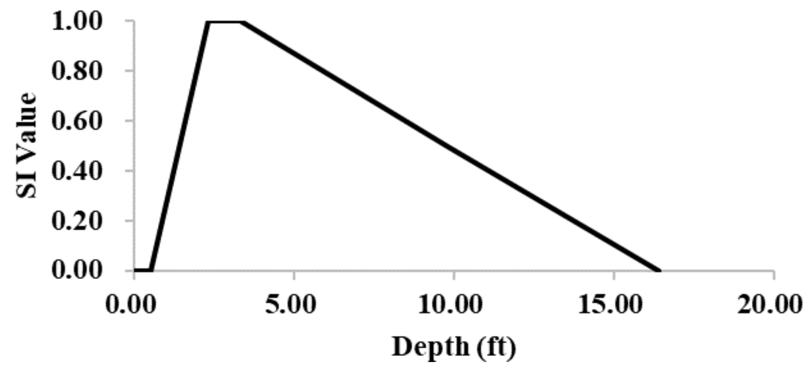
Source: Kynard, B., Horgan, M. (2013). *Habitat Suitability Index for Sea Lamprey Redds*. BK-Riverfish, LLC. Modified per USFWS in 2014.

Species: White Sucker
Lifestage: Adult/Juvenile

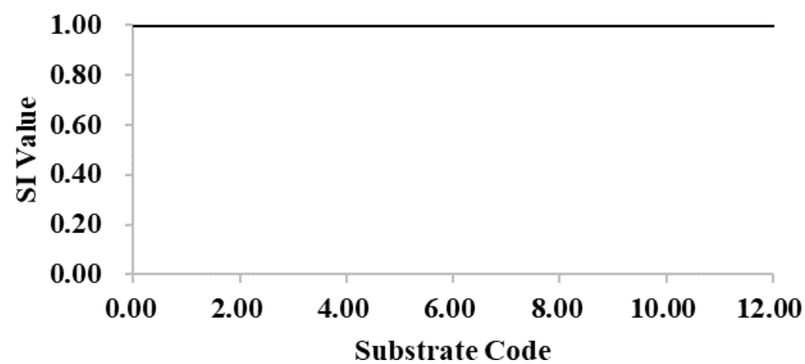
Velocity (ft/s)	SI value
0.00	0.00
0.16	0.70
0.33	1.00
0.49	1.00
0.66	0.70
1.31	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
0.50	0.00
2.30	1.00
3.30	1.00
9.80	0.50
16.40	0.00
100.00	0.00



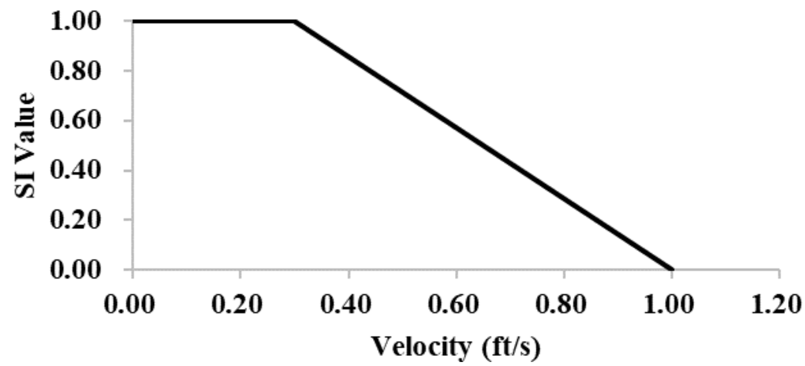
Code	SI value
0.00	1.00
100.00	1.00[1]



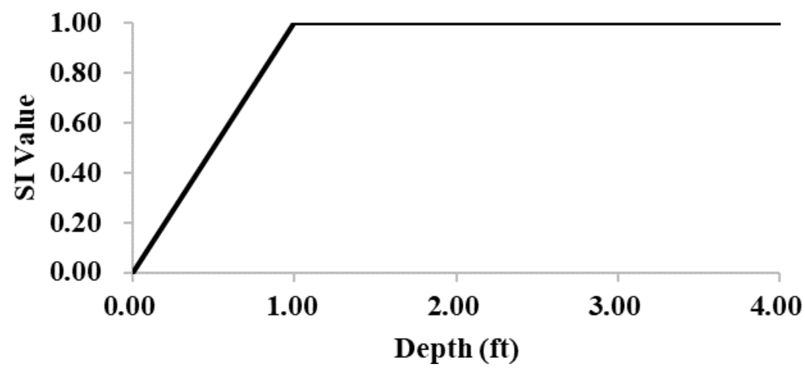
Source: Twomey, K.A. et al. (1984). *Habitat Suitability Index Models and Instream Flow Suitability Curves: White Sucker*. USFWS Bluebook.

[1] All substrates assumed to be suitable for white sucker adults and juveniles

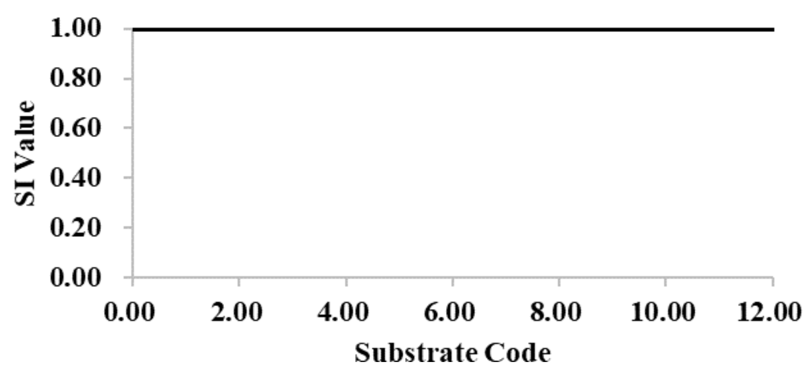
Velocity (ft/s)	SI value
0.00	1.00
0.30	1.00
1.00	0.00
100.00	0.00



Depth (ft)	SI value
0.00	0.00
1.00	1.00
100.00	1.00

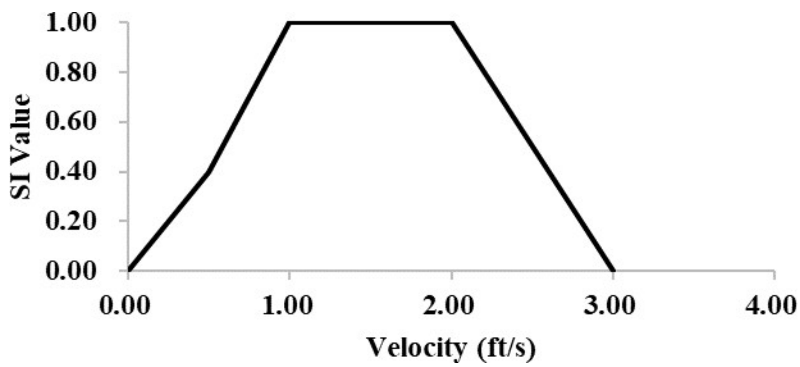


Code	SI value
0.00	1.00
100.00	1.00[2]



Source: Twomey, K.A. et al. (1984). *Habitat Suitability Index Models and Instream Flow Suitability Curves: White Sucker*. USFWS Bluebook.

Velocity (ft/s)	SI value
0.00	0.00
0.50	0.40
1.00	1.00
2.00	1.00
3.00	0.00
100.00	0.00



Depth (ft)	SI value
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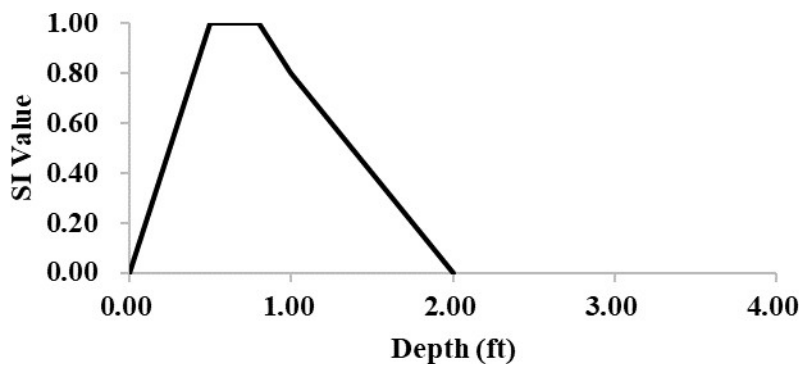
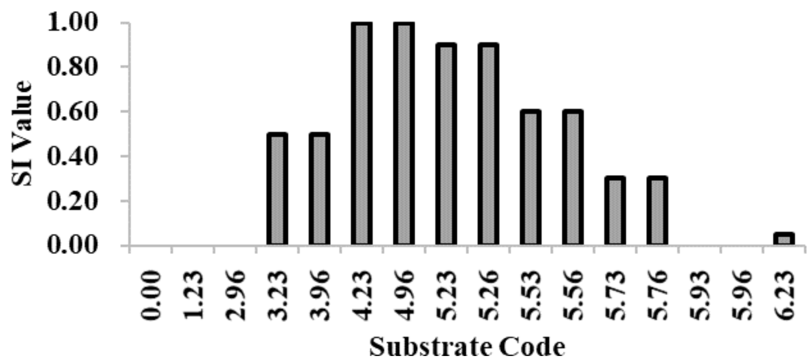
0.50	1.00
0.80	1.00
1.00	0.80
2.00	0.00
100.00	0.00



Code	SI value
0.00	0.00
1.23	0.00
2.96	0.00
3.23	0.50
3.96	0.50
4.23	1.00
4.96	1.00
5.23	0.90
5.26	0.90
5.53	0.60
5.56	0.60
5.73	0.30
5.76	0.30
5.93	0.00
5.96	0.00
6.23	0.05
100.00	0.05



Source: USFWS Bluebook, Twomey et al, *Habitat Suitability Index Models and Instream Flow Suitability Curves: White Sucker*, 1984

Appendix D: Transect Photographs

Transect: RF-82600, From Left Bank, Flow = 14.6 cfs at USGS gage

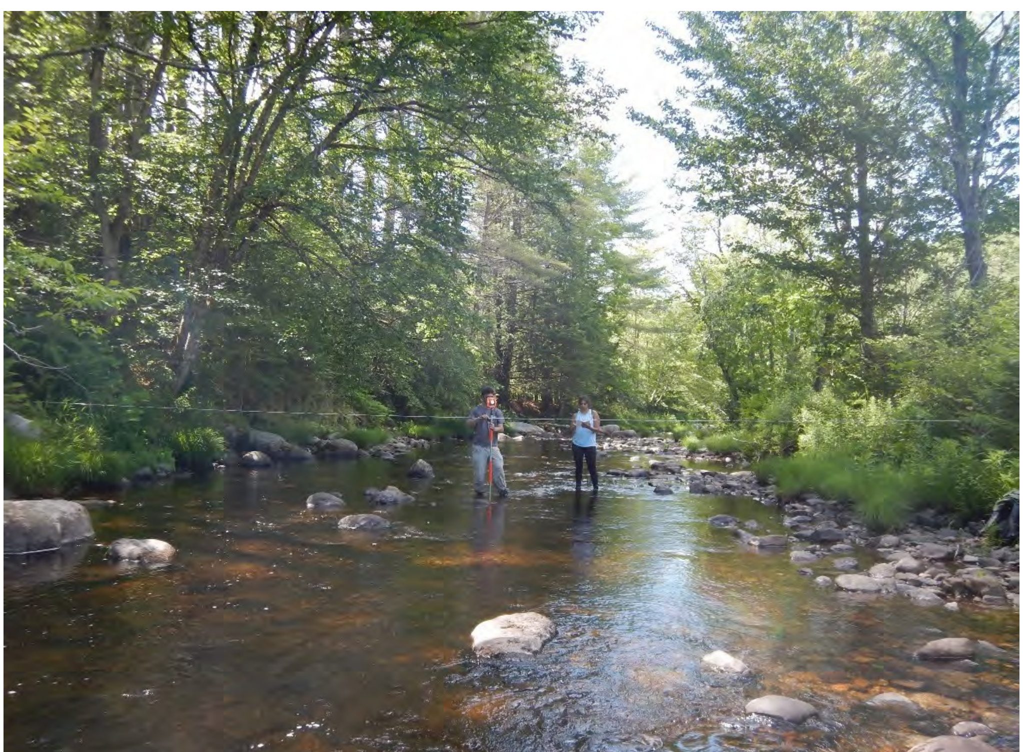
Transect: RF-82600, Looking Upstream, Flow = 14.6 cfs at USGS gage

Transect: RF-82600, Looking Downstream, Flow = 14.6 cfs at USGS gage

Transect: RF-82600, From Right Bank, Flow = 14.6 cfs at USGS gage

Transect: RN-75250, From Right Bank, Flow = 14.6 cfs at USGS gage

Transect: RN-75250, Looking Downstream, Flow = 14.6 at USGS gage



Transect: RN-75250, From Left Bank, Flow = 14.6 at USGS gage

Transect: RN-75250, Looking Upstream, Flow = 14.6 at USGS gage

Transect: RN-73600, From Left Bank, Flow = 14.6 cfs at USGS gage

Transect: RN-73600, Looking Upstream, Flow = 14.6 cfs at USGS gage

Transect: RN-73600, From Right Bank, Flow = 14.6 cfs at USGS gage

Transect: RN-73600, Looking Downstream, Flow = 14.6 cfs at USGS gage

Transect: RF-72650, From Left Bank, Flow = 11.5 cfs at USGS gage

Transect: RF-72650, Looking Downstream, Flow = 11.5 cfs at USGS gage

Transect: RF-72650, Looking Upstream, Flow = 11.5 cfs at USGS gage

Transect: RF-72650, From Right Bank, Flow = 11.5 cfs at USGS gage

Transect: RF-55900, Looking Upstream, Flow = 11 cfs at USGS gage

Transect: RF-55900, From Left Bank, Flow = 11 cfs at USGS gage

Transect: RF-55900, Looking Downstream, Flow = 11 cfs at USGS gage

Transect: RF-55900, From Right Bank, Flow = 11 cfs at USGS gage

Transect: PL-53650, Looking Upstream, Flow = 11 cfs at USGS gage

Transect: PL-53650, From Left Bank, Flow = 11 cfs at the USGS gage

Transect: PL-53650, Looking Downstream, Flow = 11 cfs at the USGS gage

Transect: PL-53650, From Right Bank, Flow = 11 cfs at USGS gage

Transect: PL-45150, Looking Downstream, Flow = 10.5 cfs at USGS gage

Transect: PL-45150, From Right Bank, Flow = 10.5 cfs at USGS gage

Transect: PL-45150, Looking Upstream, Flow = 10.5 cfs at USGS gage

Transect: PL-45150, From Left Bank, Flow = 10.5 cfs at USGS gage

Transect: RF-41700, From Left Bank, Flow = 10.5 cfs at USGS gage

Transect: RF-41700, Looking Downstream, Flow = 10.5 cfs at USGS gage

Transect: RF-41700, Looking Upstream, Flow = 10.5 cfs at USGS gage

Transect: RF-41700, From Right Bank, Flow = 10.5 cfs at USGS gage

Transect: RF-15500, From Right Bank, Flow = 8.77 cfs at USGS gage

Transect: RF-15500, Looking Upstream, Flow = 8.77 cfs at USGS gage

Transect: RF-15500, From Left Bank, Flow = 8.77 cfs at USGS gage

Transect: RF-15500, Looking Downstream, Flow = 8.77 cfs at USGS gage

Transect: RN-12450, From Left Bank, Flow = 8.77 cfs at USGS gage

Transect: RN-12450, Looking Upstream, Flow = 8.77 cfs at USGS gage

Transect: RN-12450, From Right Bank, Flow = 8.77 cfs at USGS gage

Transect: RN-12450, Looking Downstream, Flow = 8.77 cfs at USGS gage

Transect: RF-10150, Looking Upstream, Flow = 8.77 cfs at USGS gage

Transect: RF-10150, From Left Bank, Flow = 8.77 cfs at USGS gage

Transect: RF-10150, Looking Downstream, Flow = 8.77 cfs at USGS gage

Transect: RF-10150, From Right Bank, Flow = 8.77 cfs at USGS gage

Transect: PL-09650, From Right Bank, Flow = 8.77 cfs at USGS gage

Transect: PL-09650, Looking Upstream, Flow = 8.77 cfs at USGS gage

Transect: PL-09650, From Left Bank, Flow = 8.77 at USGS gage

Transect: PL-09650, Looking Downstream, Flow = 8.77 at USGS gage

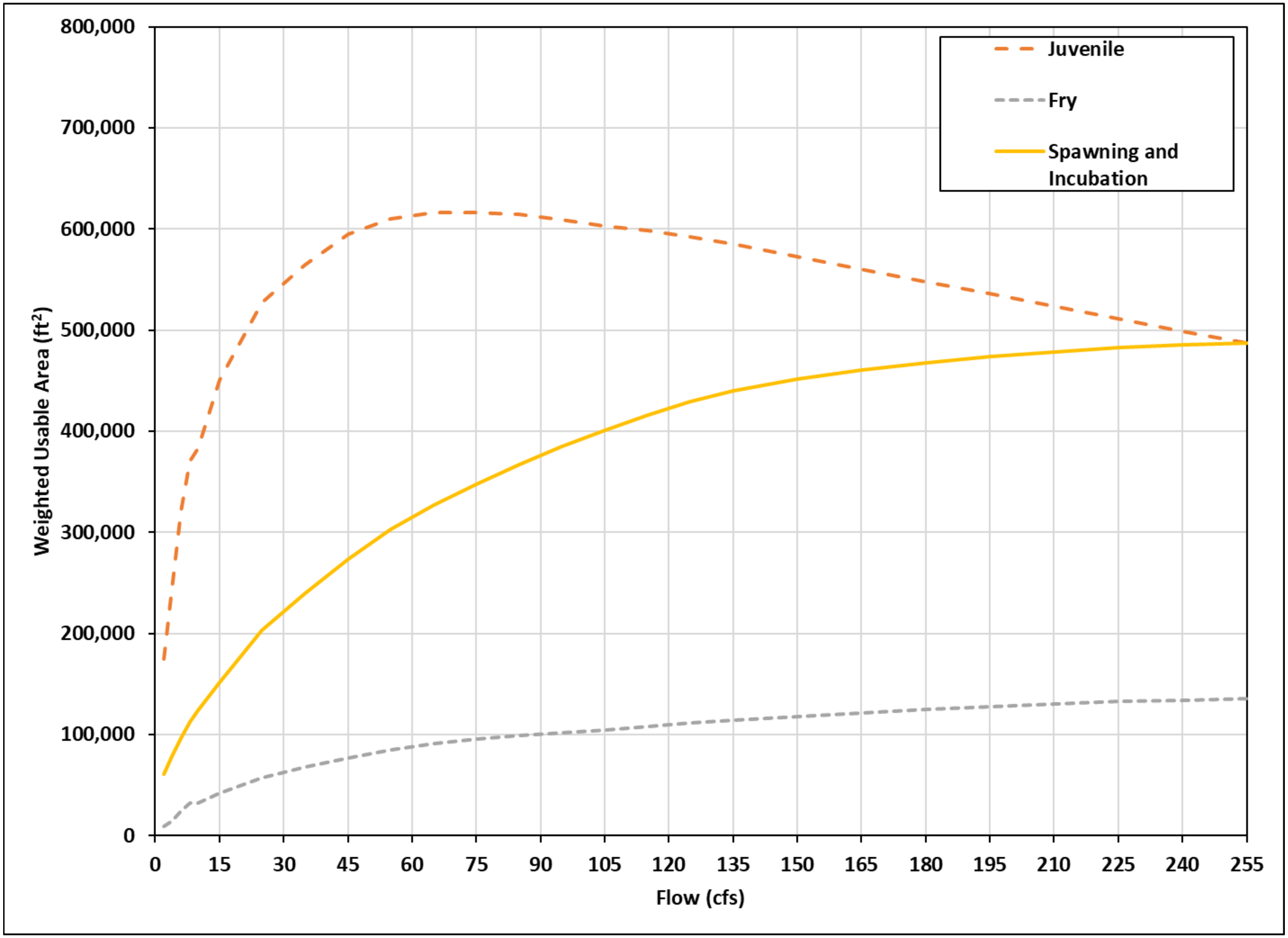
Transect: PL-07550, Looking Upstream, Flow = 8.78 cfs at USGS gage

Transect: PL-07550, From Left Bank, Flow = 8.78 cfs at USGS gage

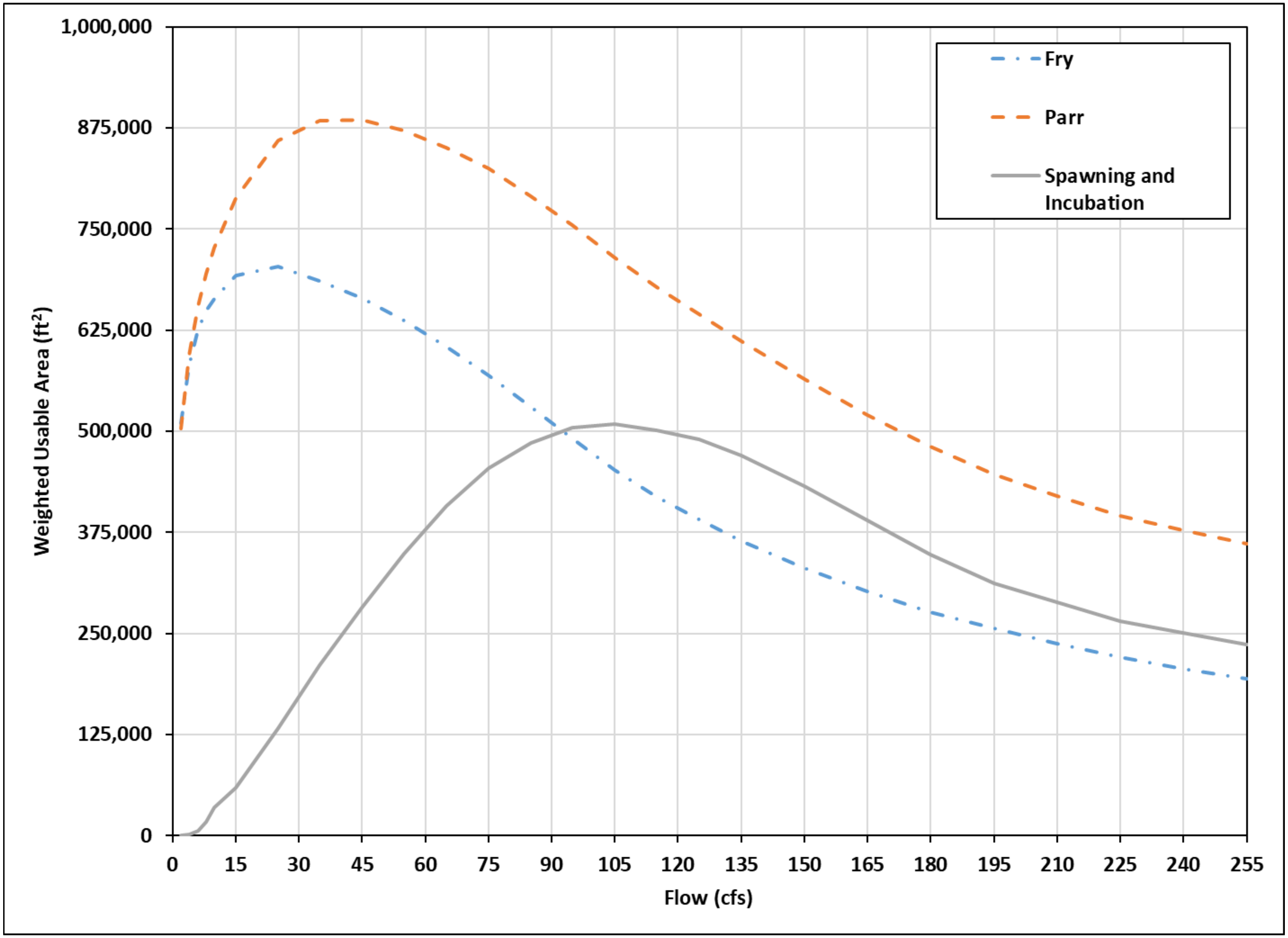
Transect: PL-07550, Looking Downstream, Flow = 8.78 cfs at USGS gage

Transect: PL-07550, From Right Bank, Flow = 8.78 cfs at USGS gage

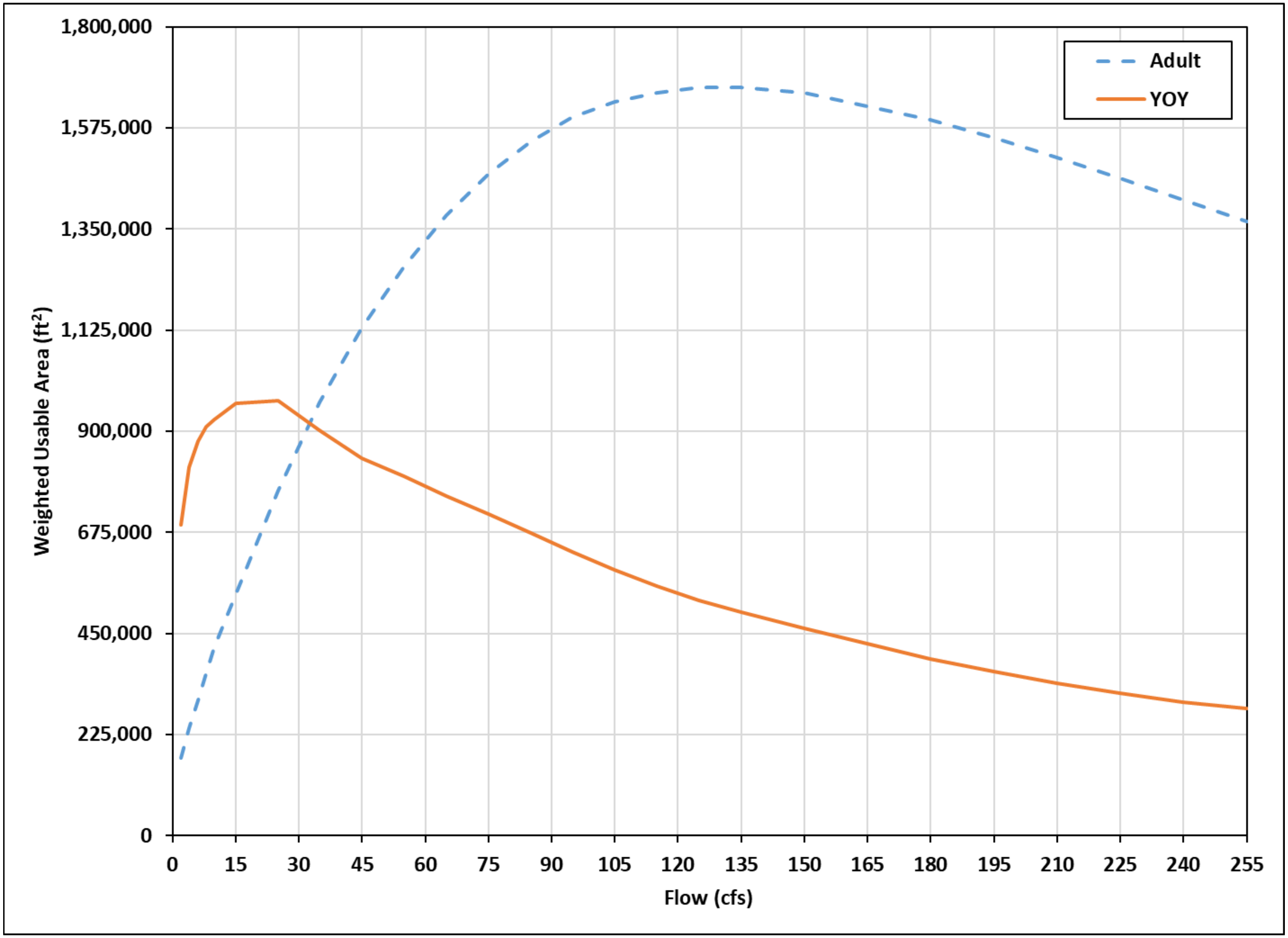
Appendix E: WUA Curves



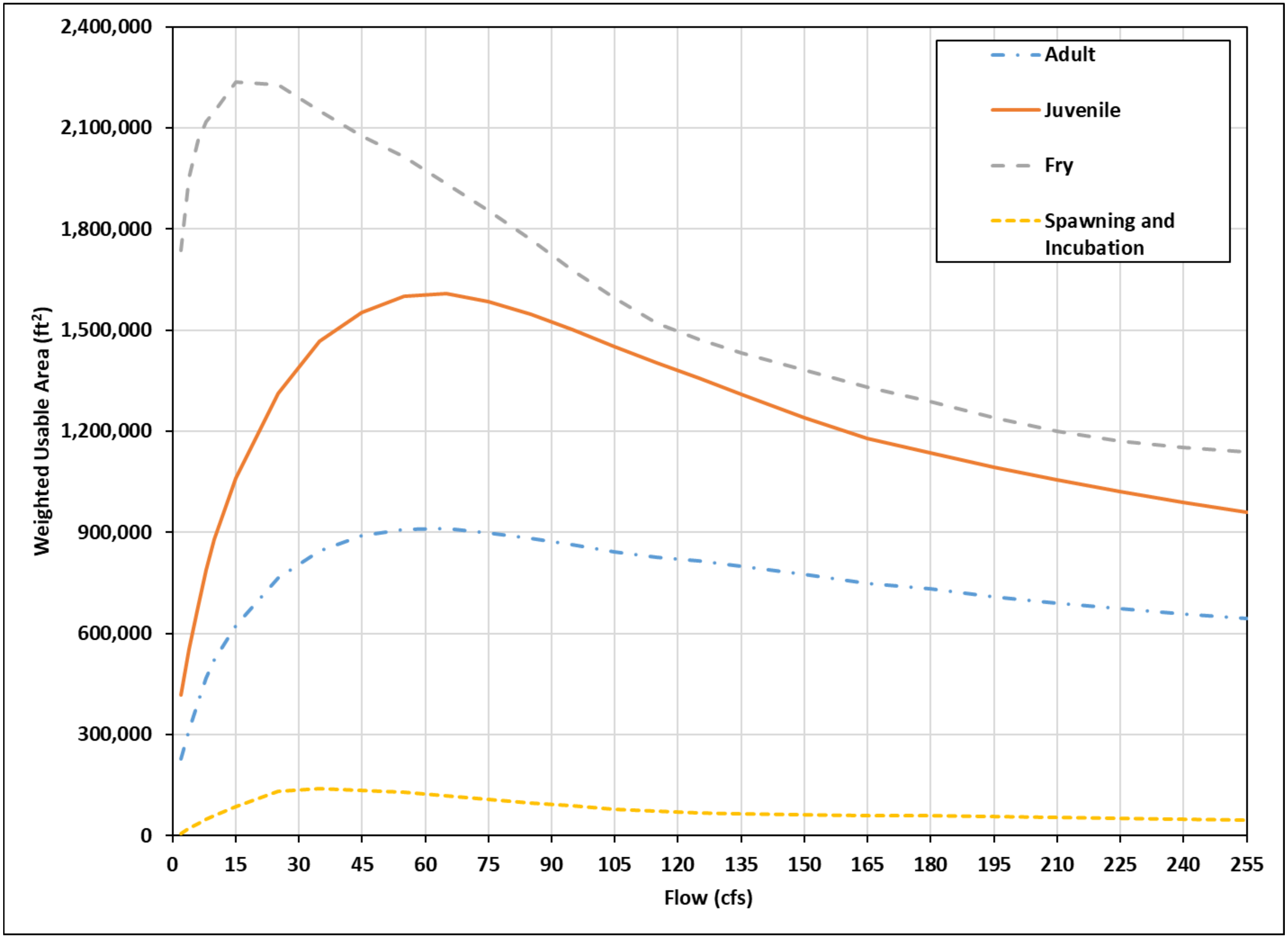
American Shad WUA Curves



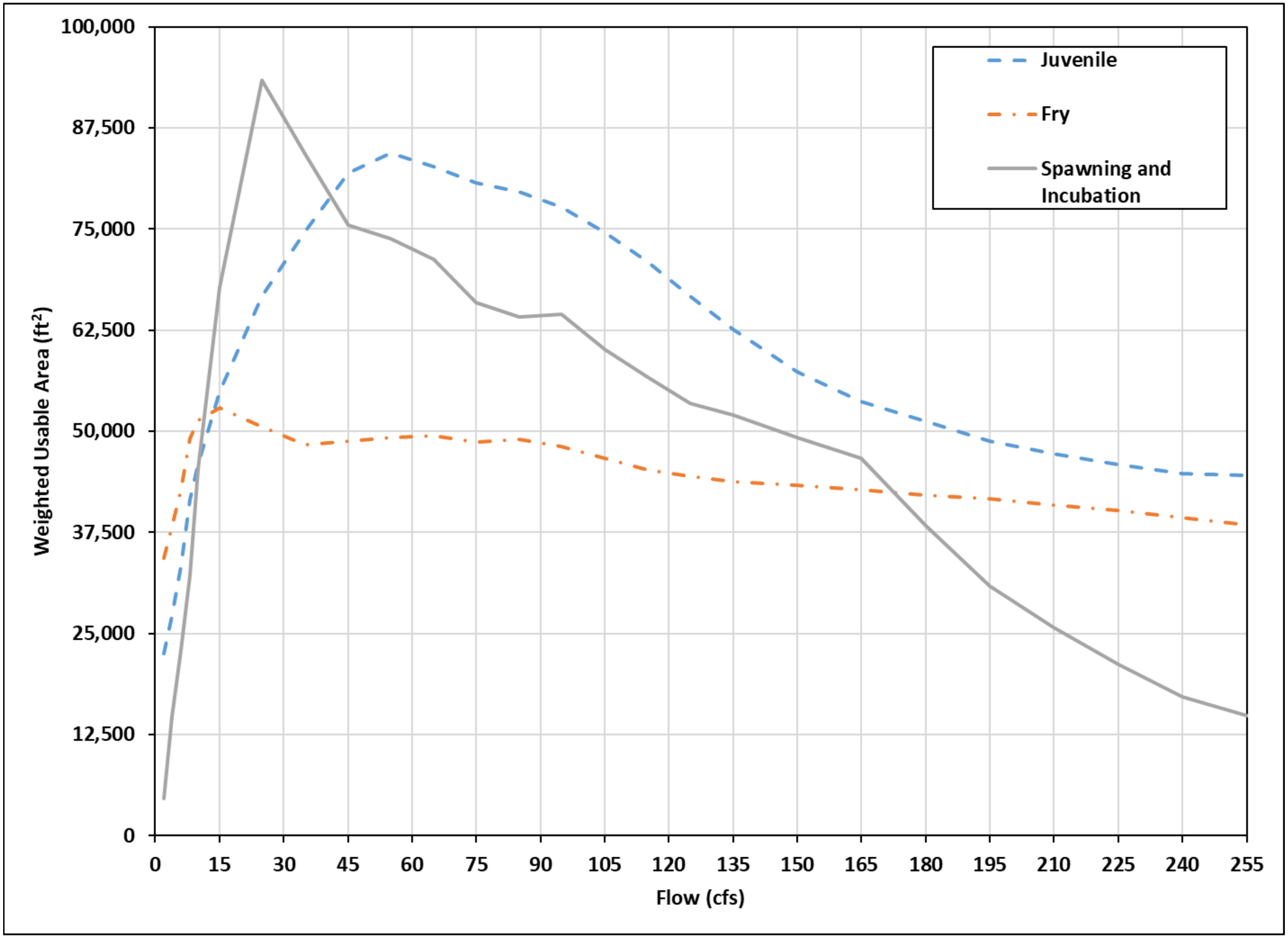
Atlantic Salmon WUA Curves



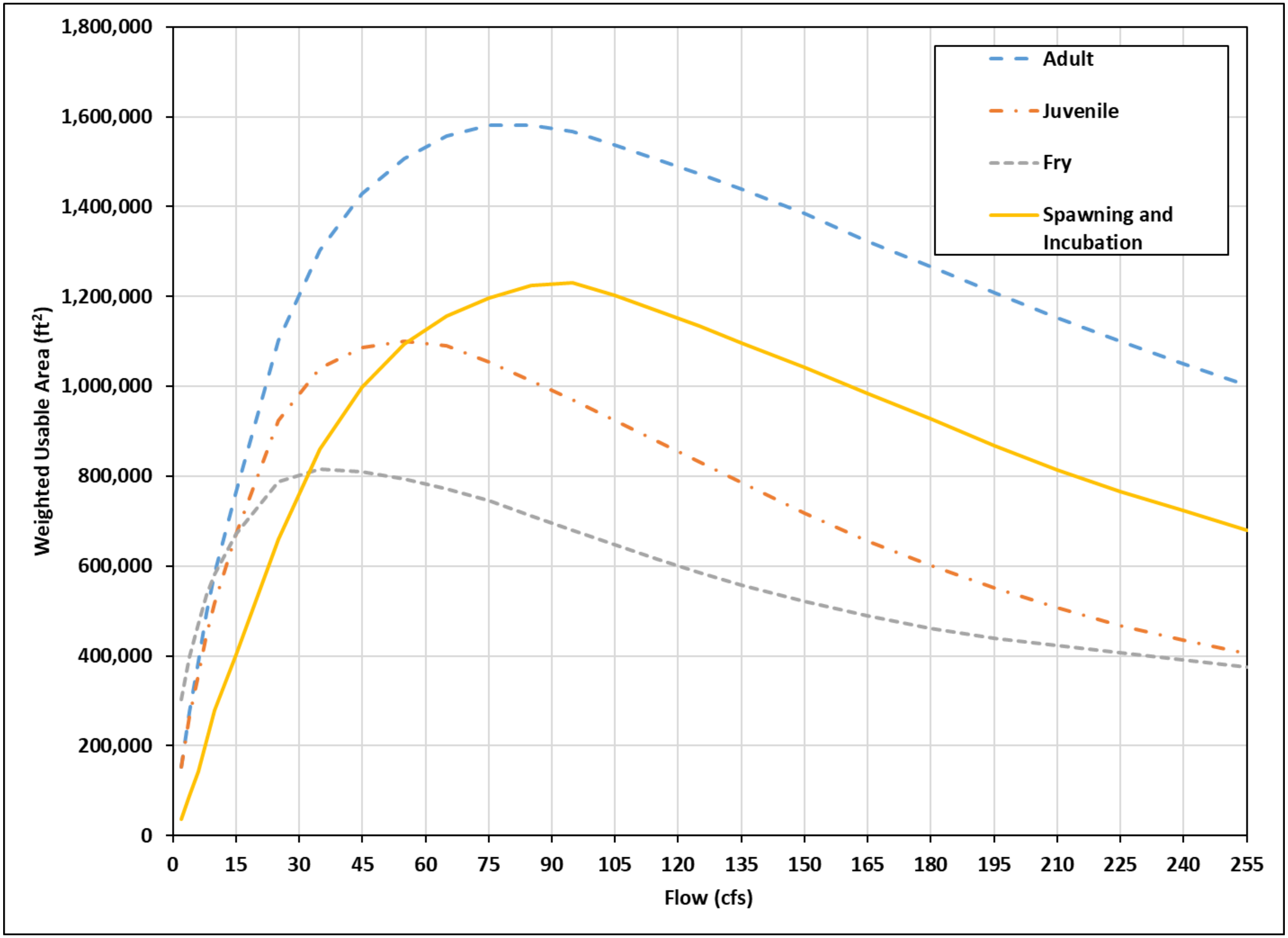
Blacknose Dace WUA Curves



Brook Trout WUA Curves

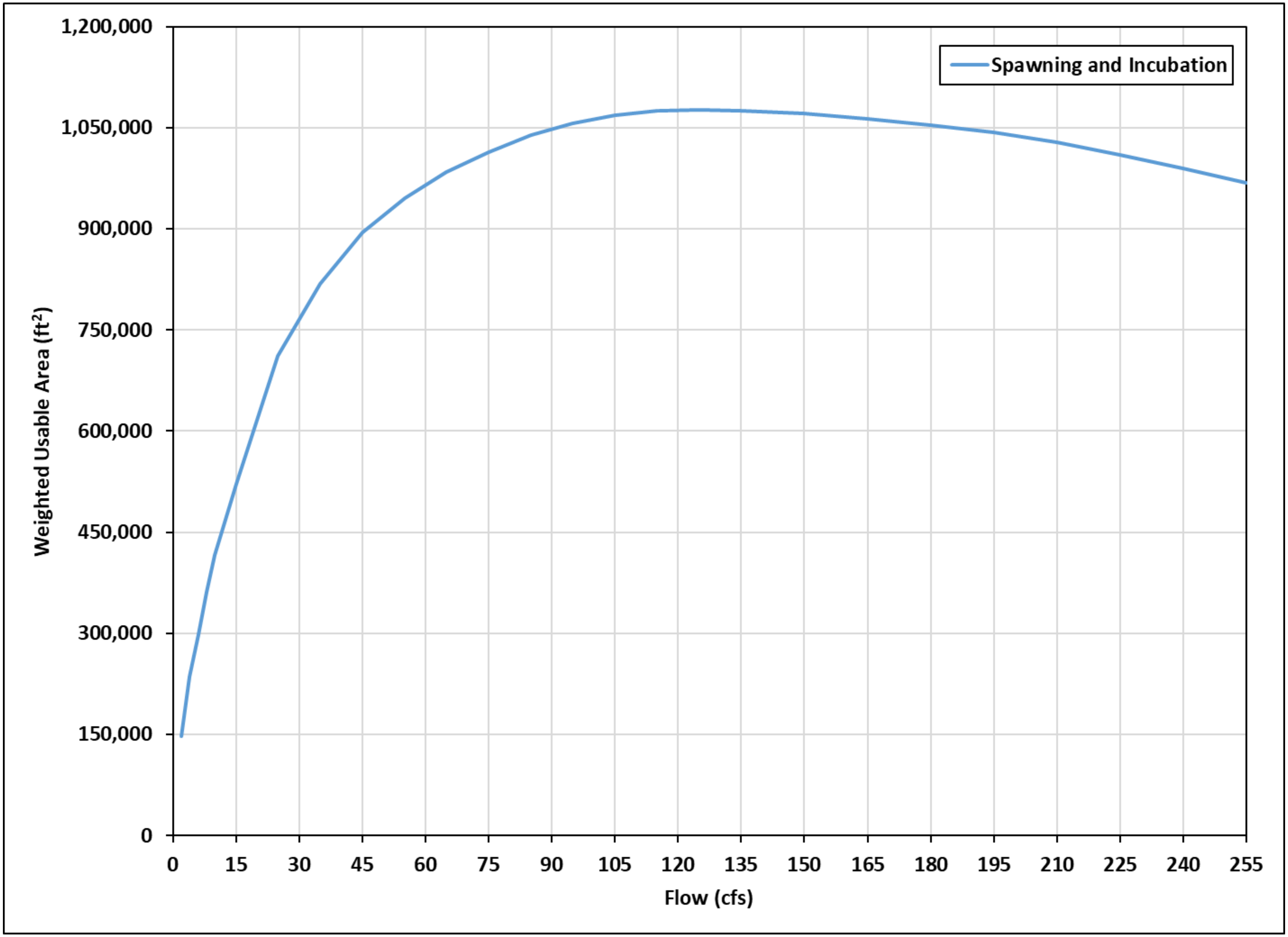


Common Shiner WUA Curves

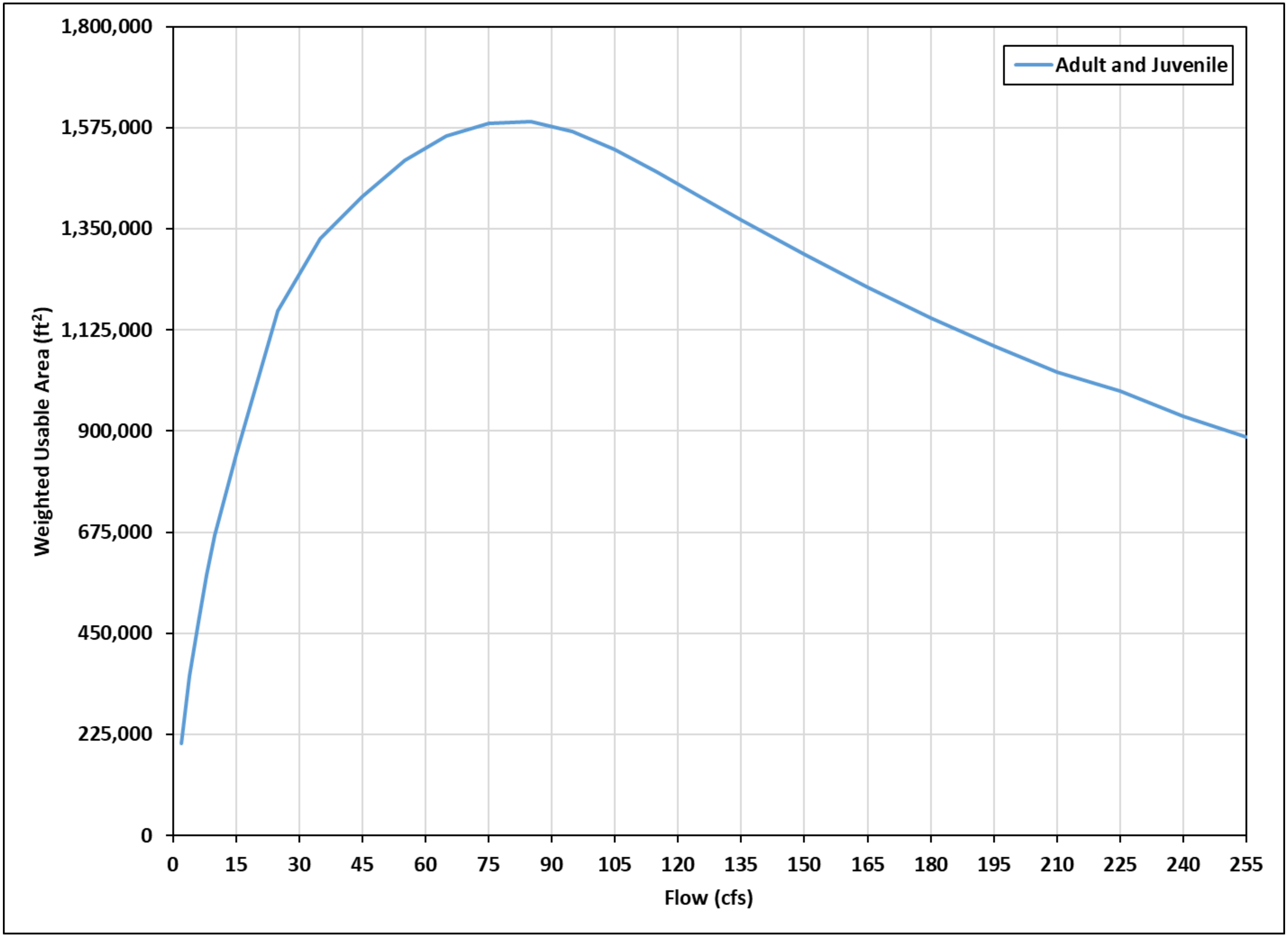


Longnose Dace WUA Curves[13]

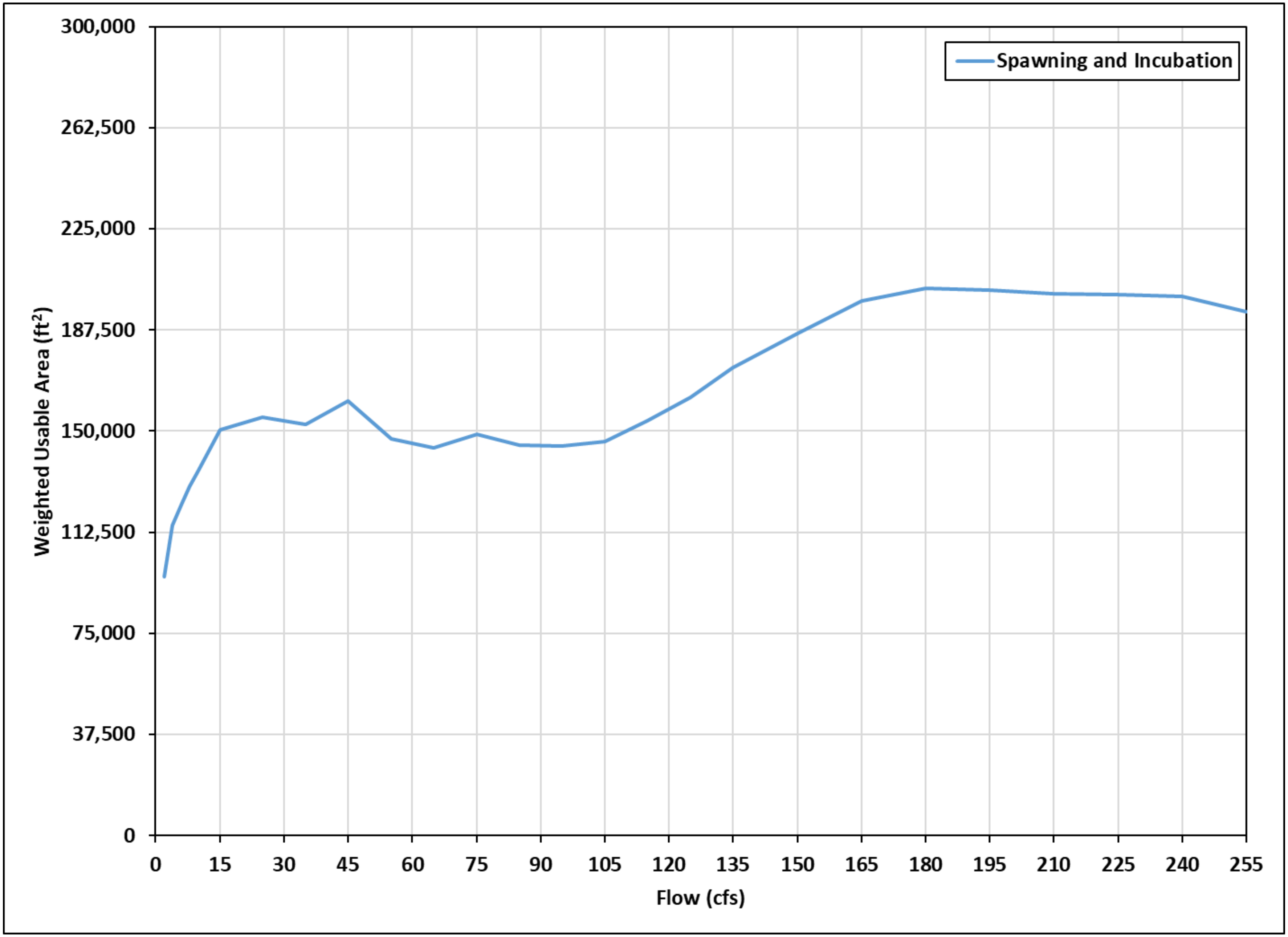
[13] The vertical axes in these figures have been modified to show the appropriate range details for each species WUA curves and are therefore not identical.



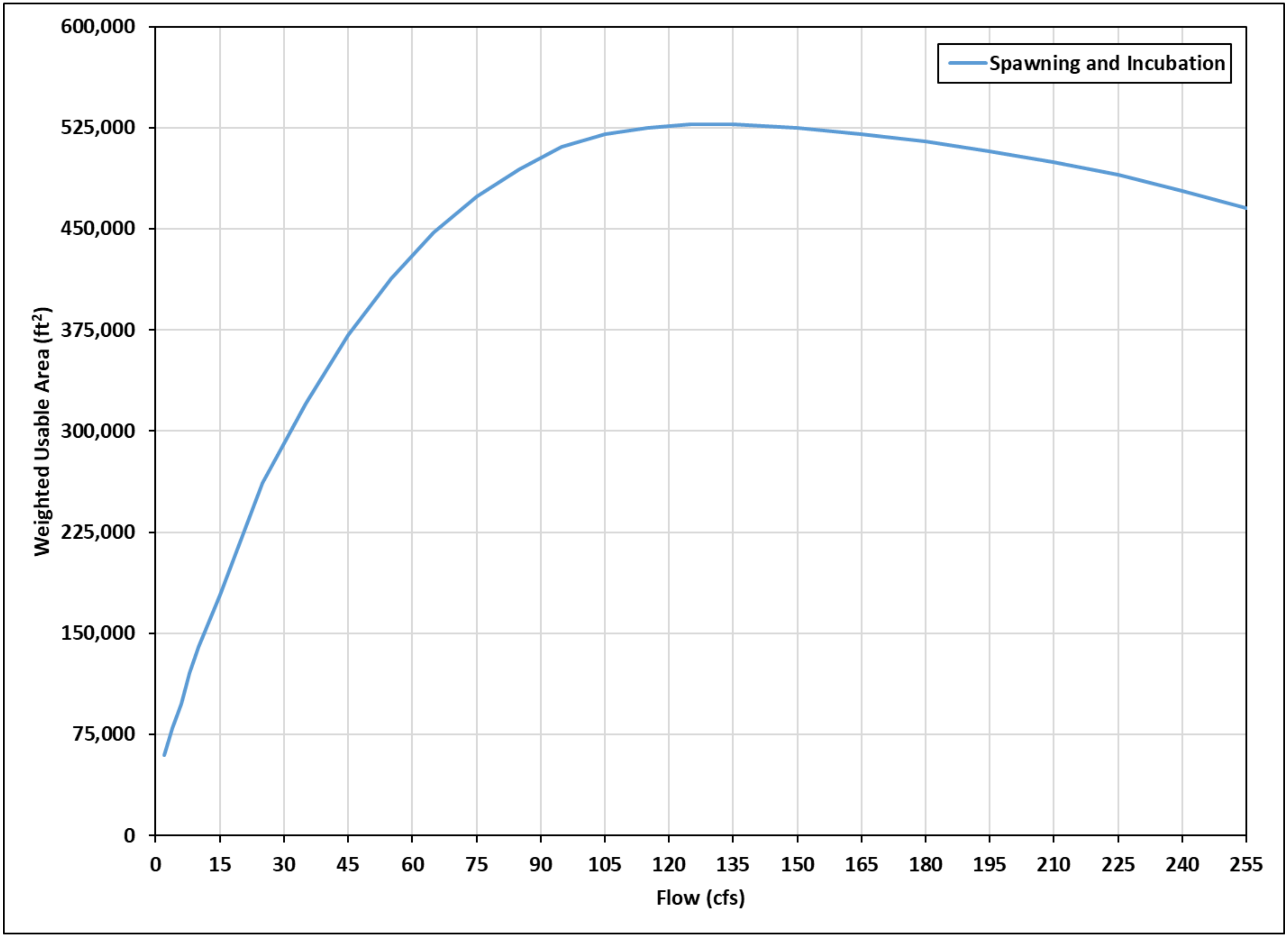
Longnose Sucker WUA Curves



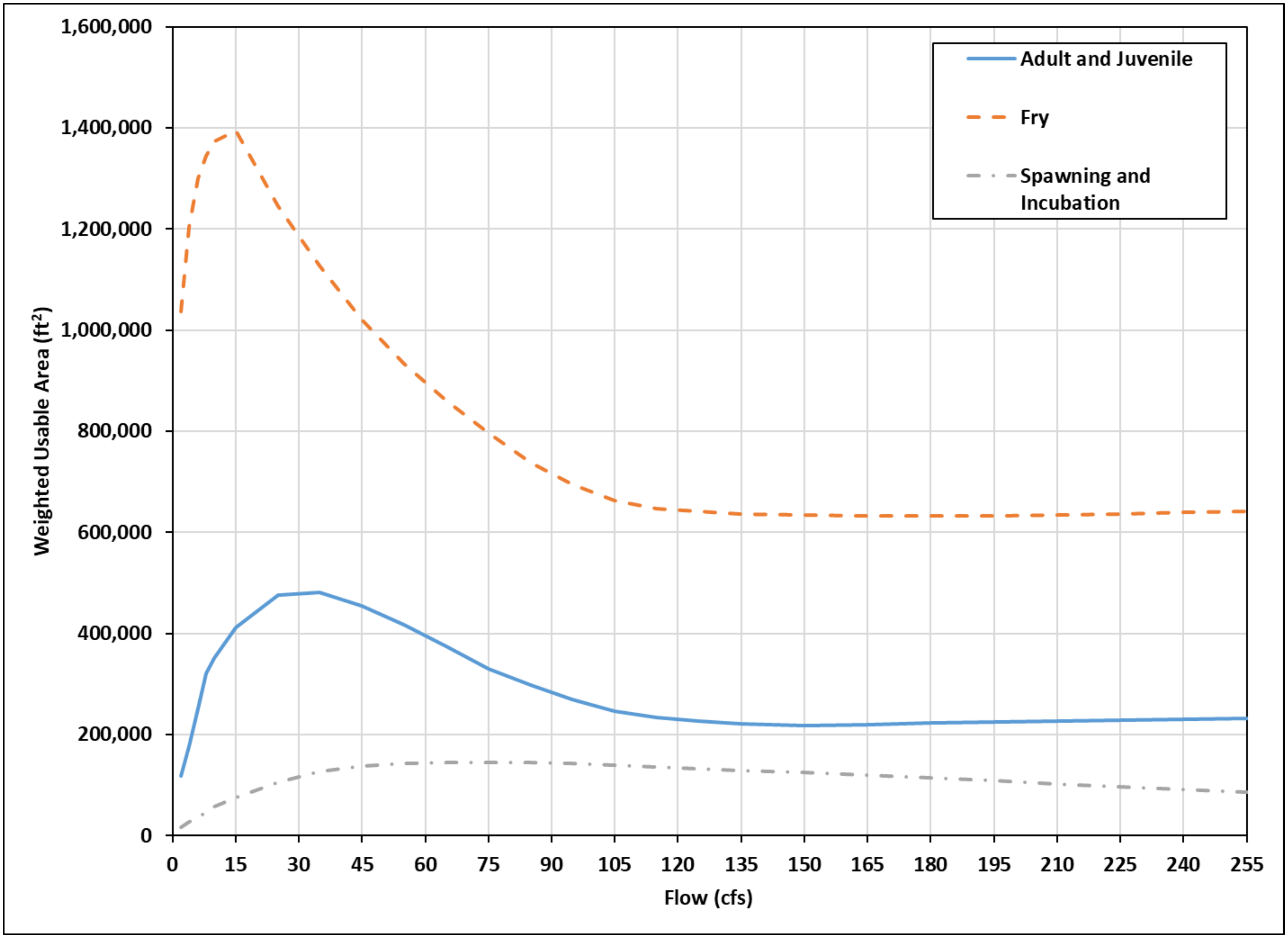
Mottled Sculpin WUA Curves



River Herring WUA Curves

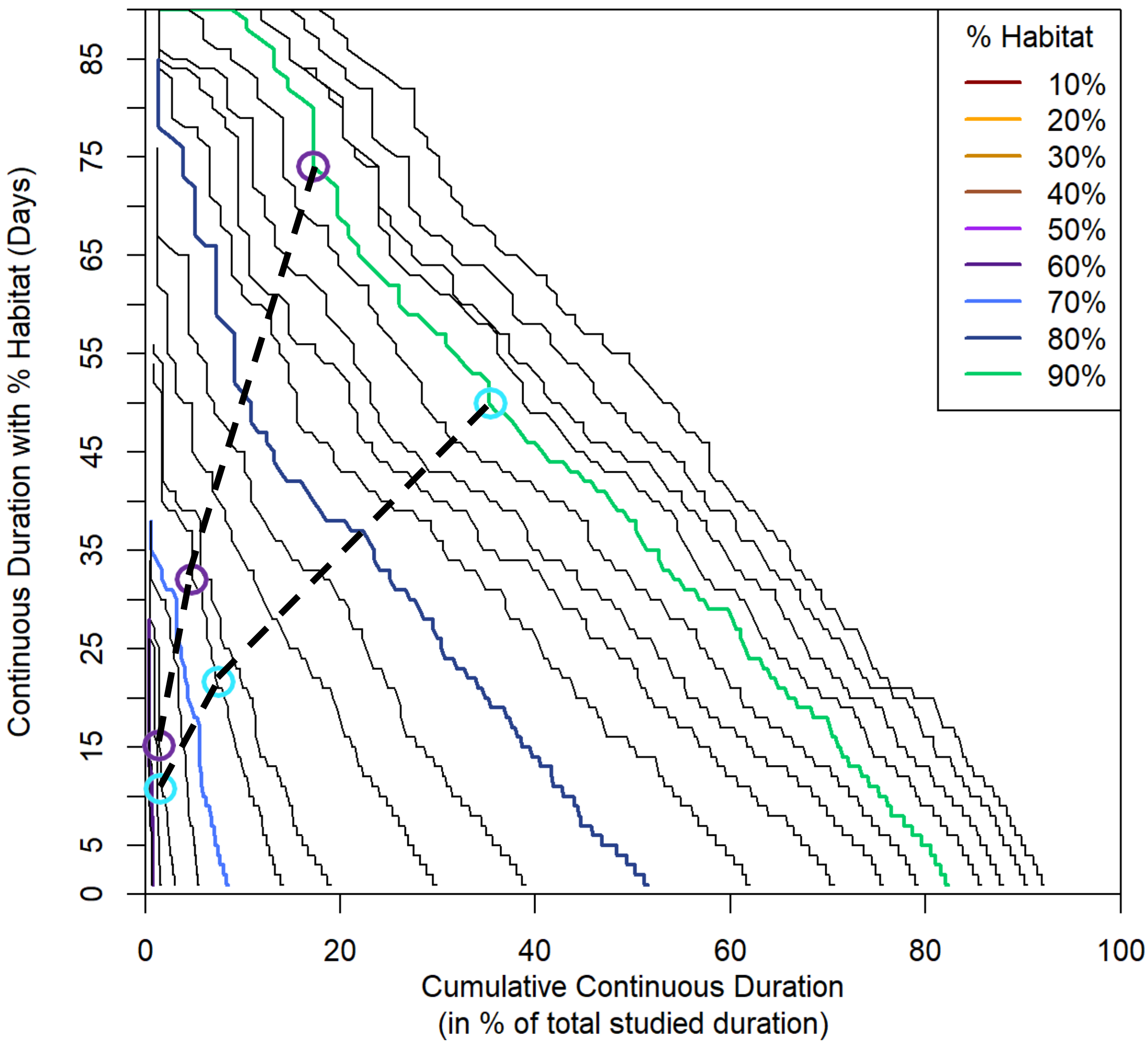


Sea Lamprey WUA Curves

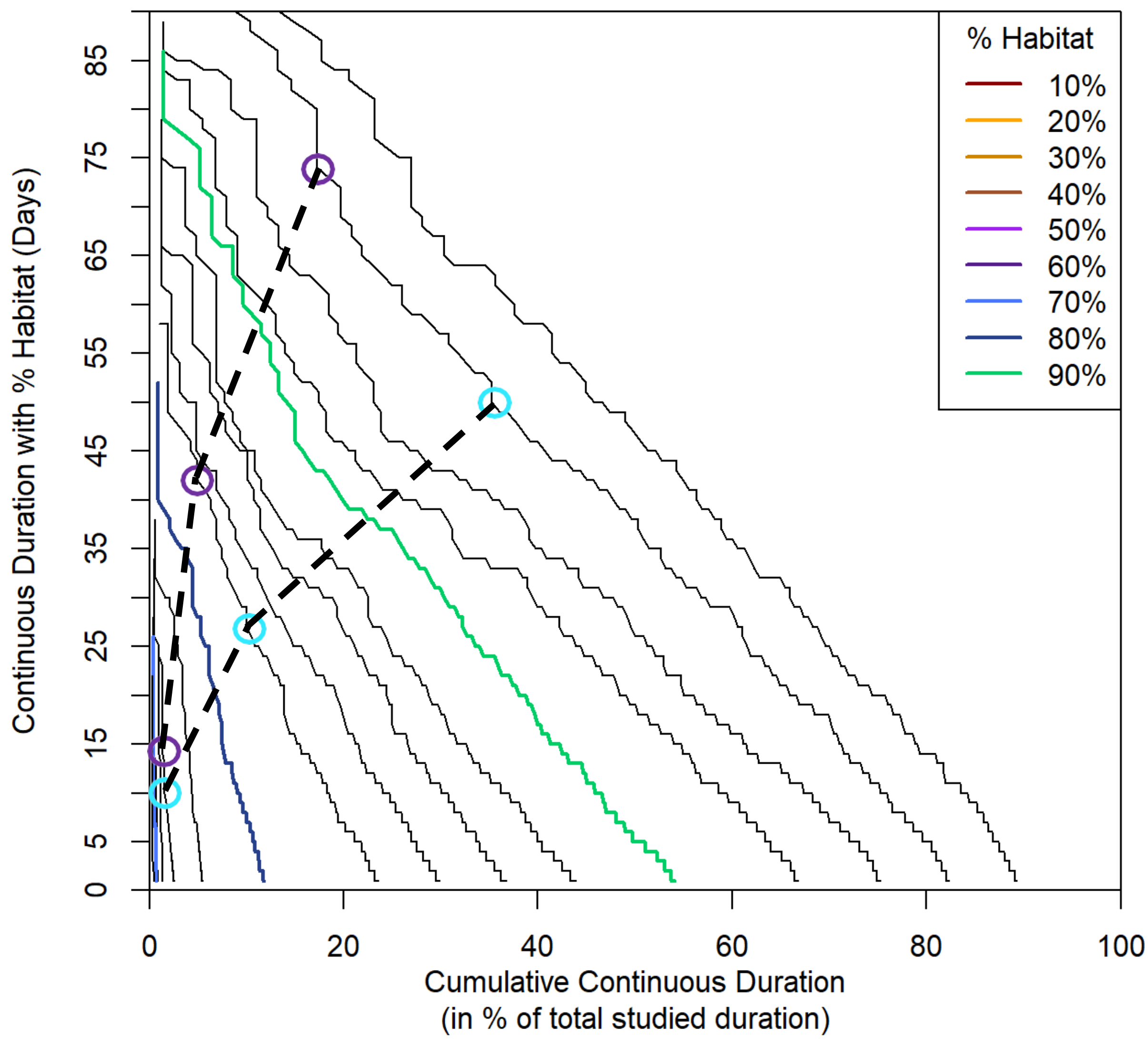


White Sucker WUA Curves

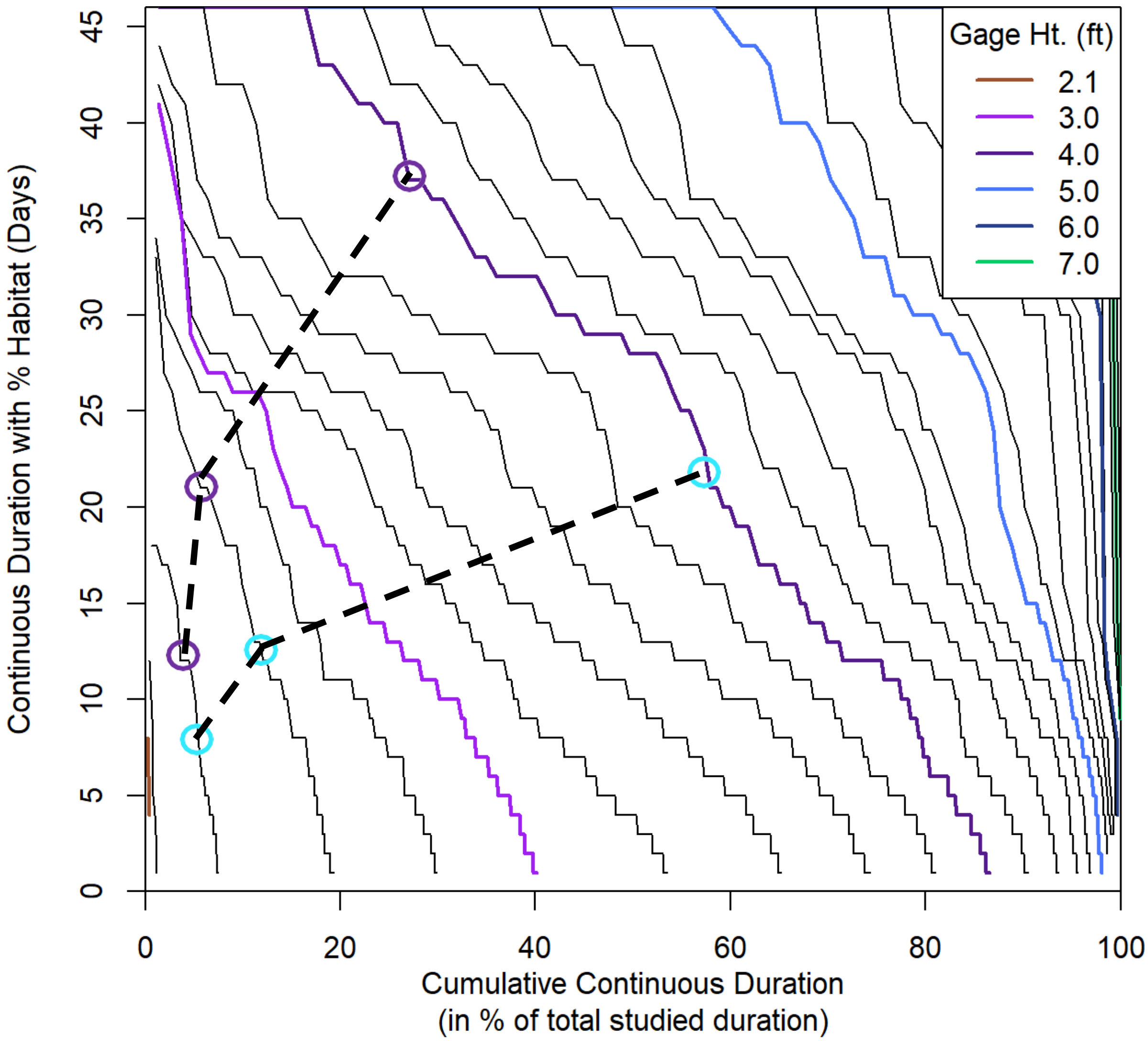
Appendix F: UCUT Curves



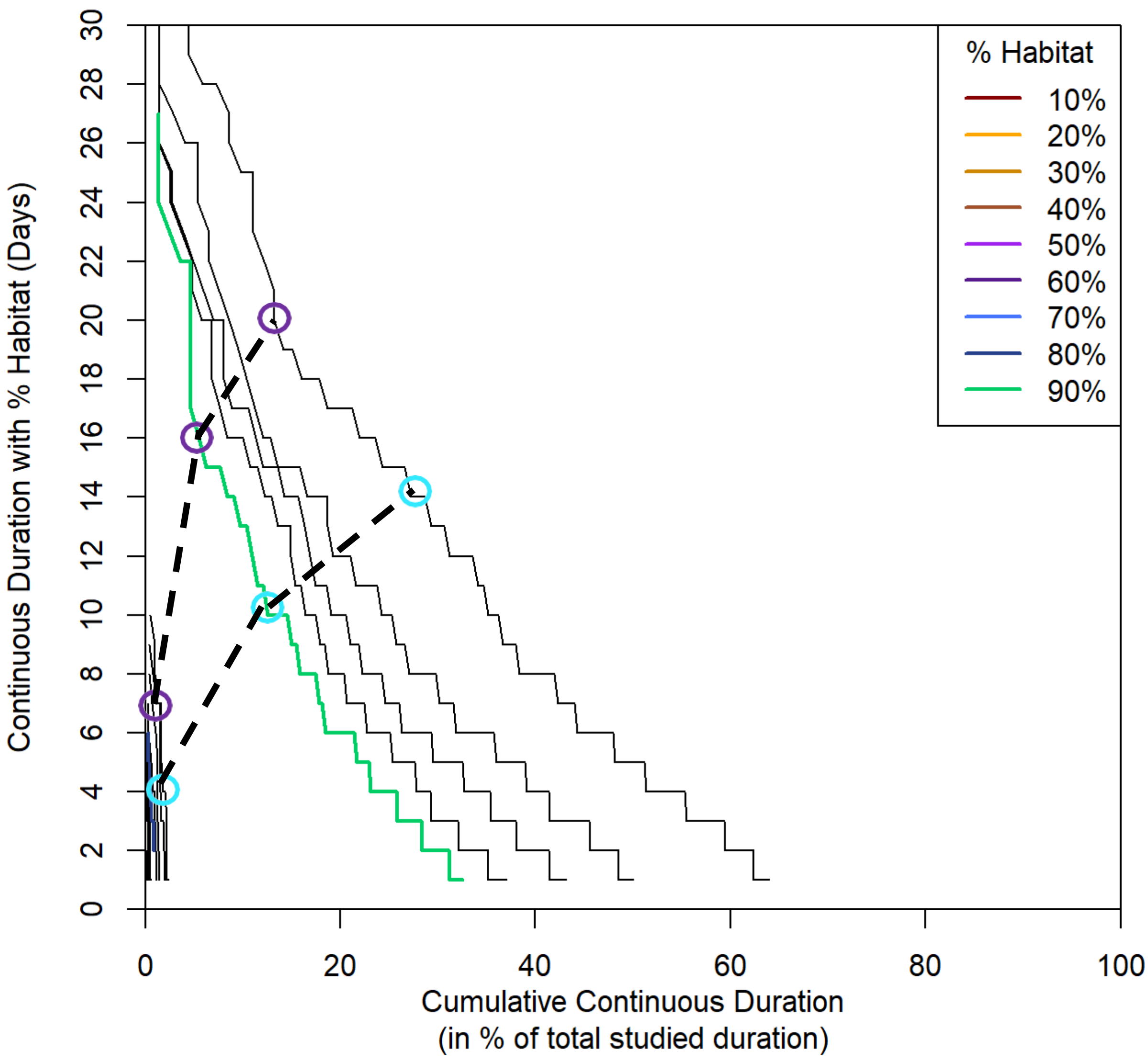
Wetted Area Reach 2 (Winter)



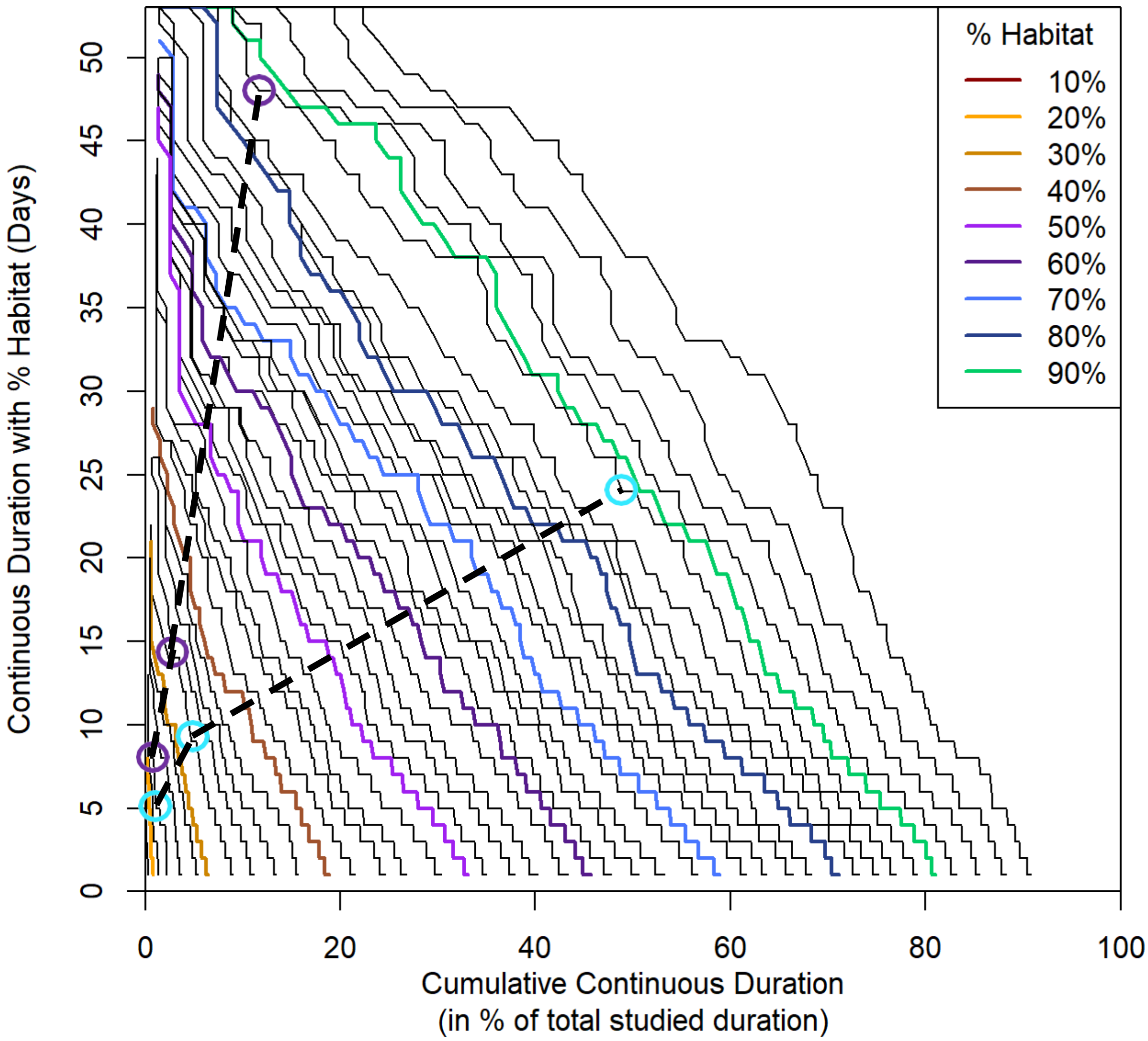
Wetted Area Reach 3 (Winter)



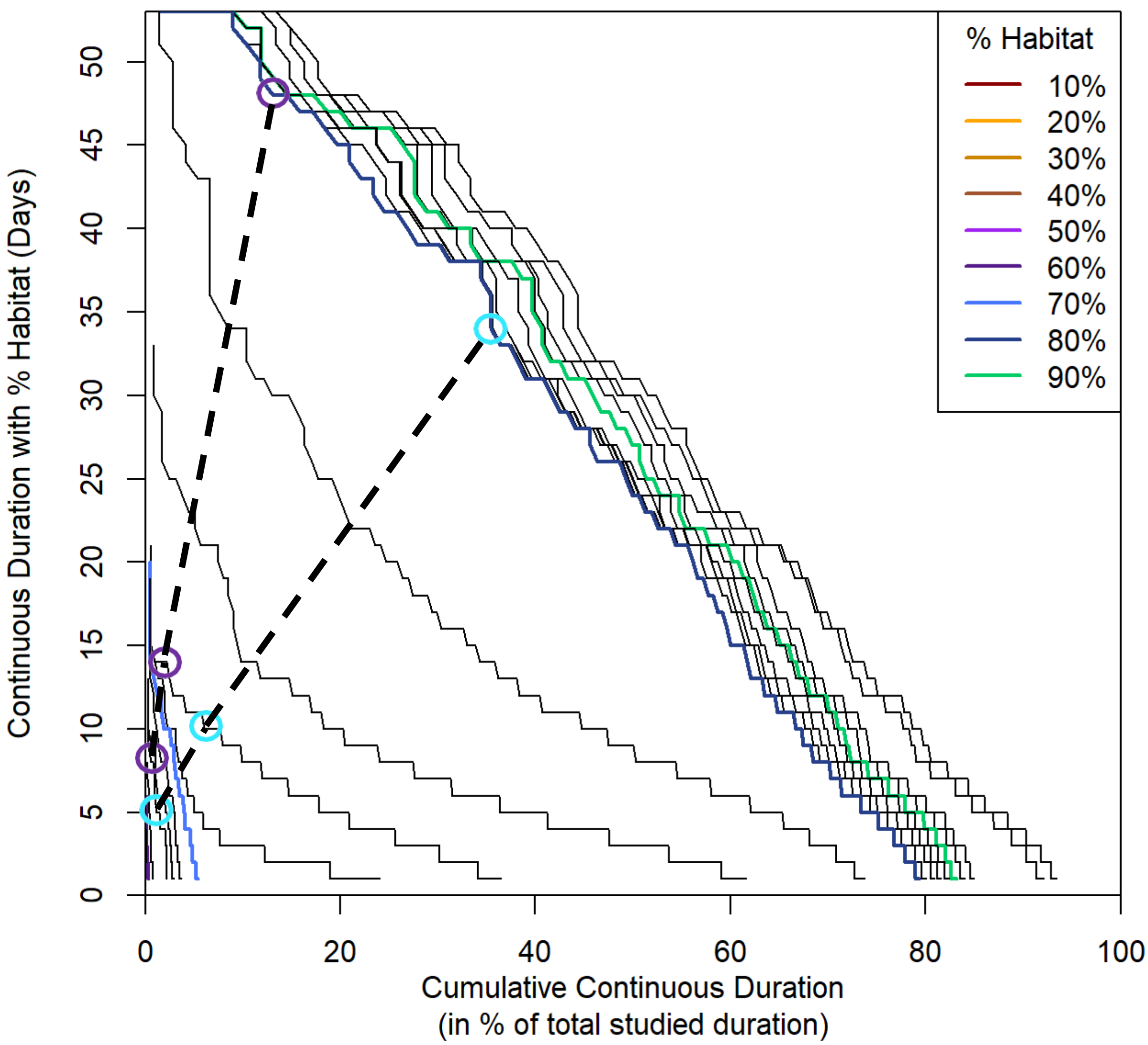
Gage Height (Freshet)



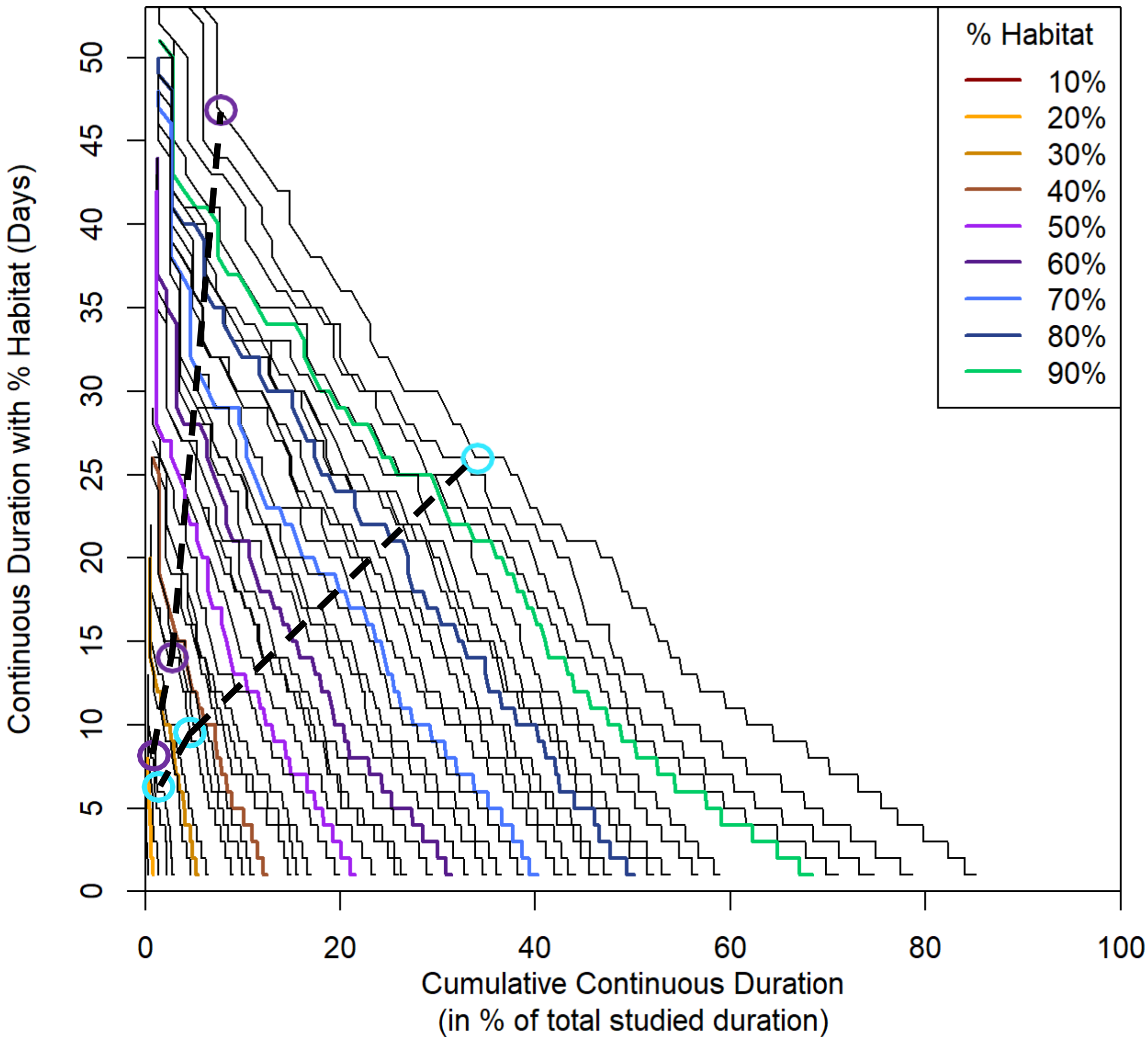
Longnose Sucker Spawning



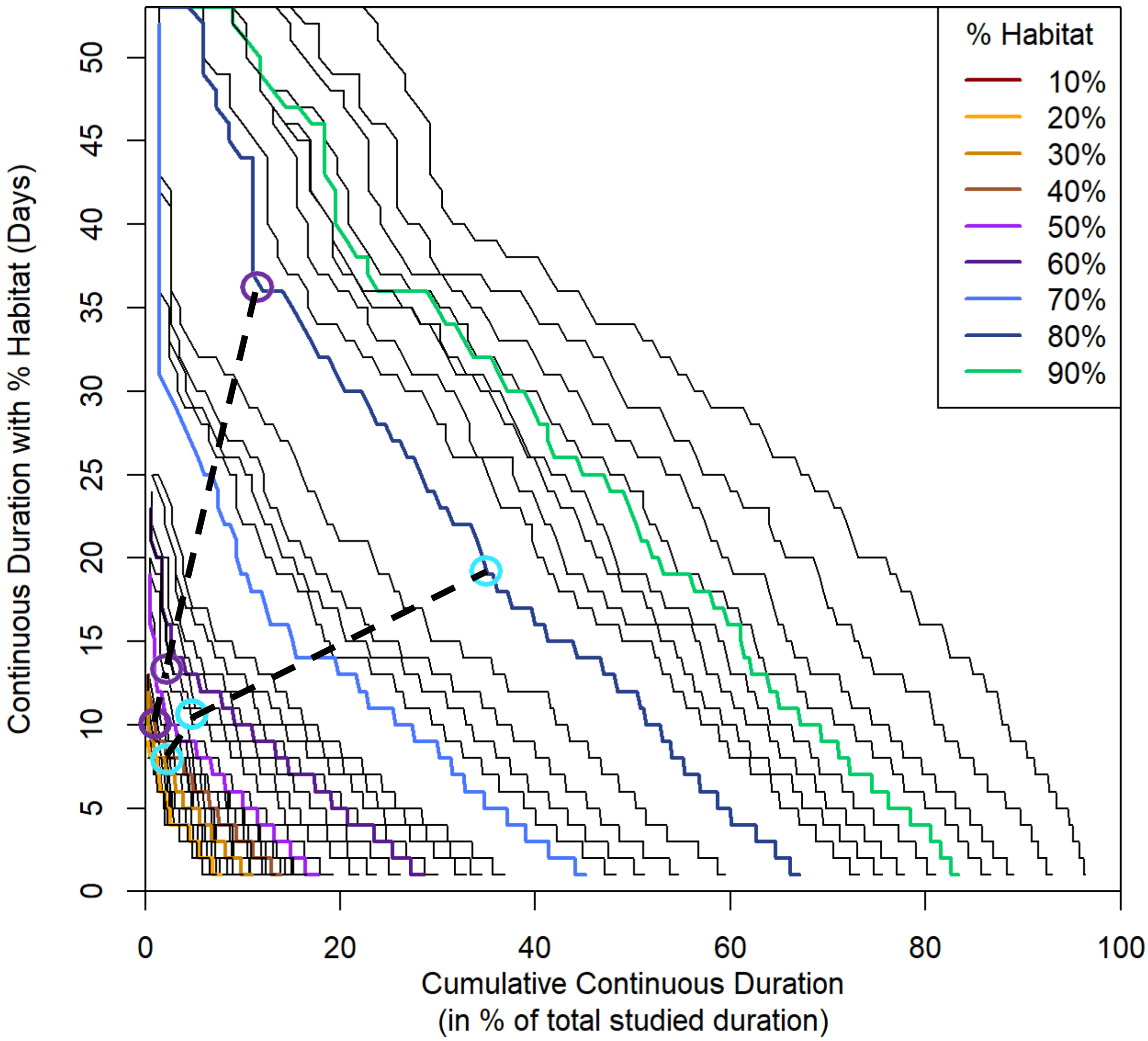
American Shad Spawning



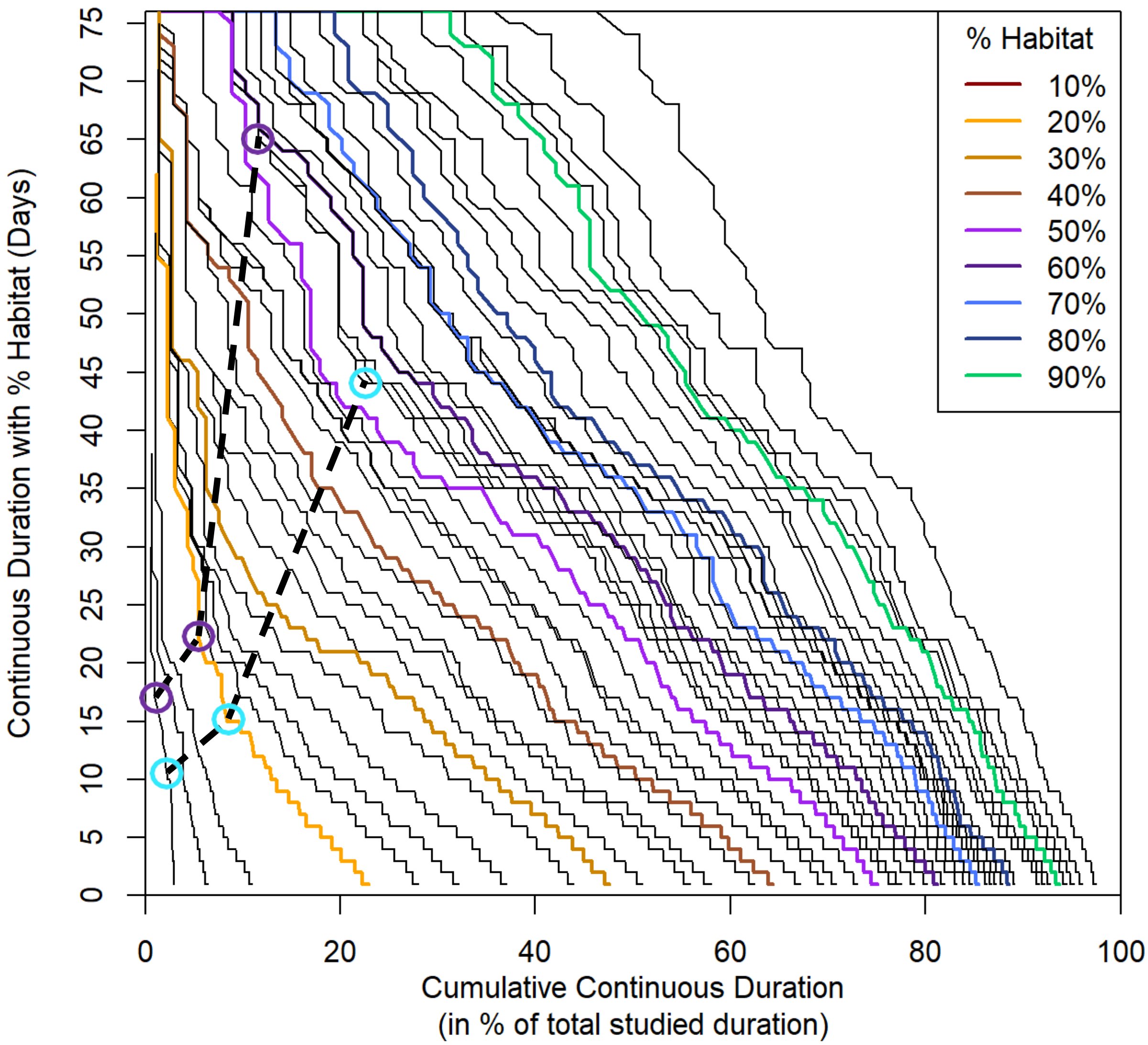
River herring spawning



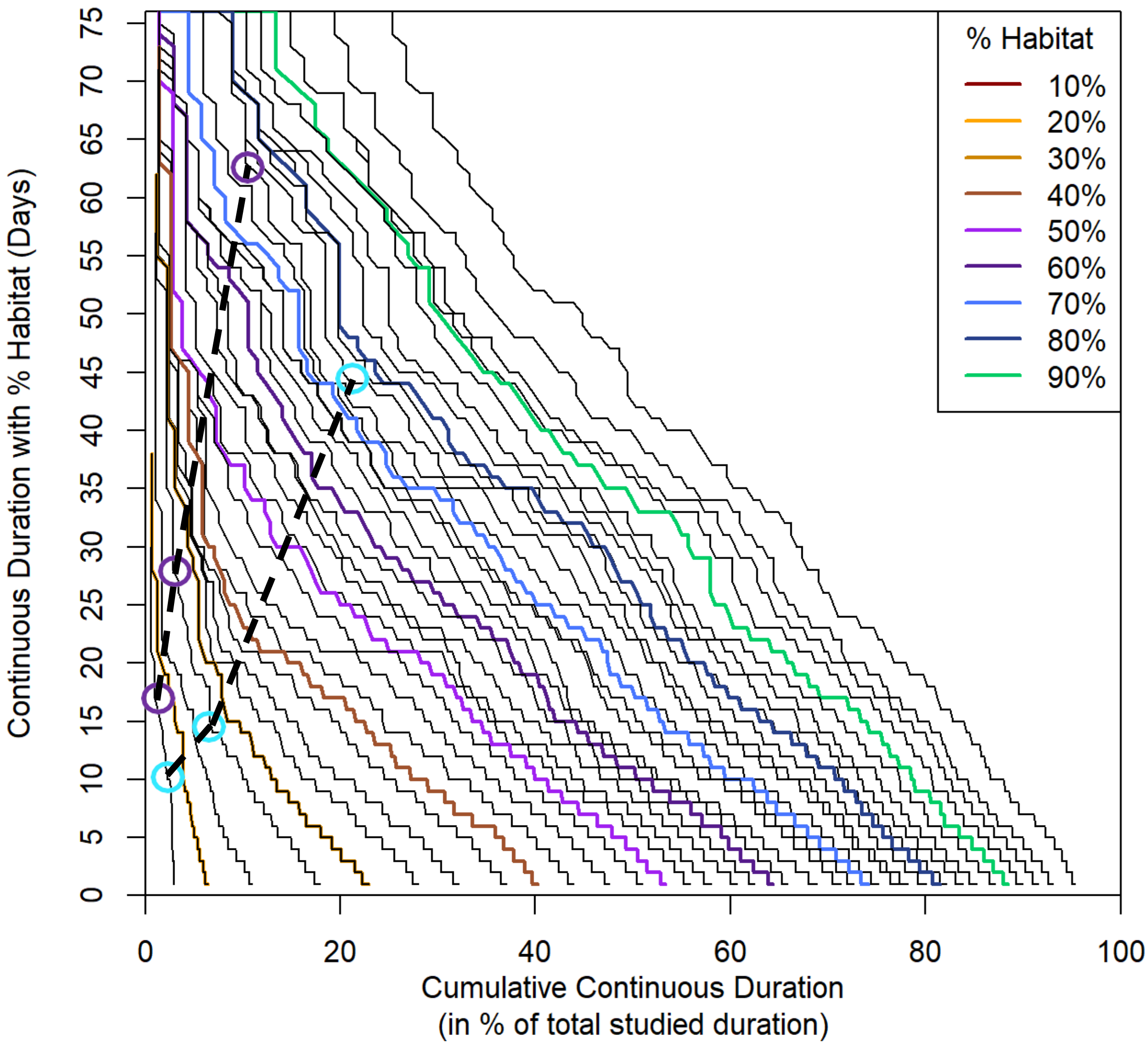
Sea Lamprey Spawning



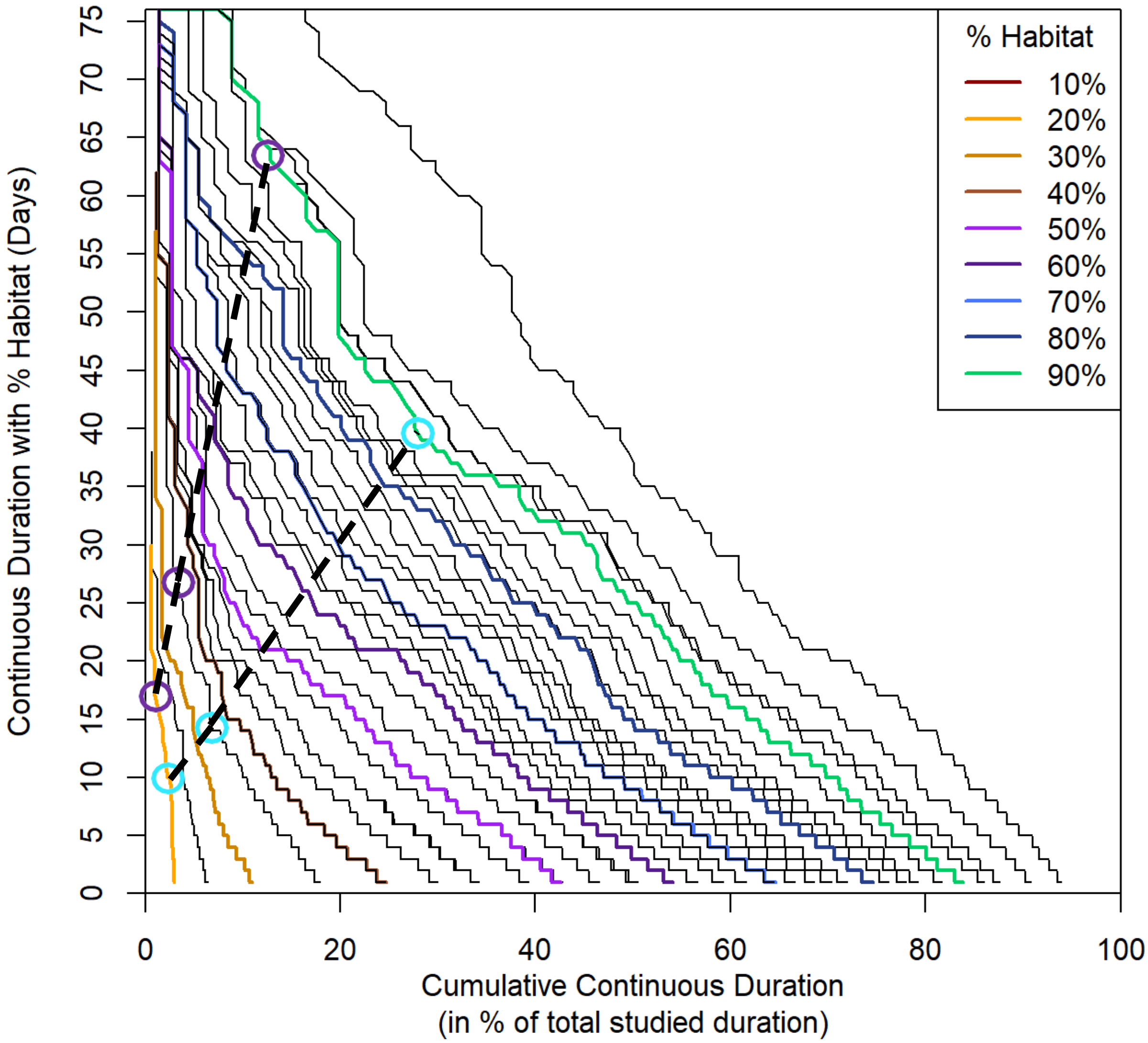
Common Shiner Spawning



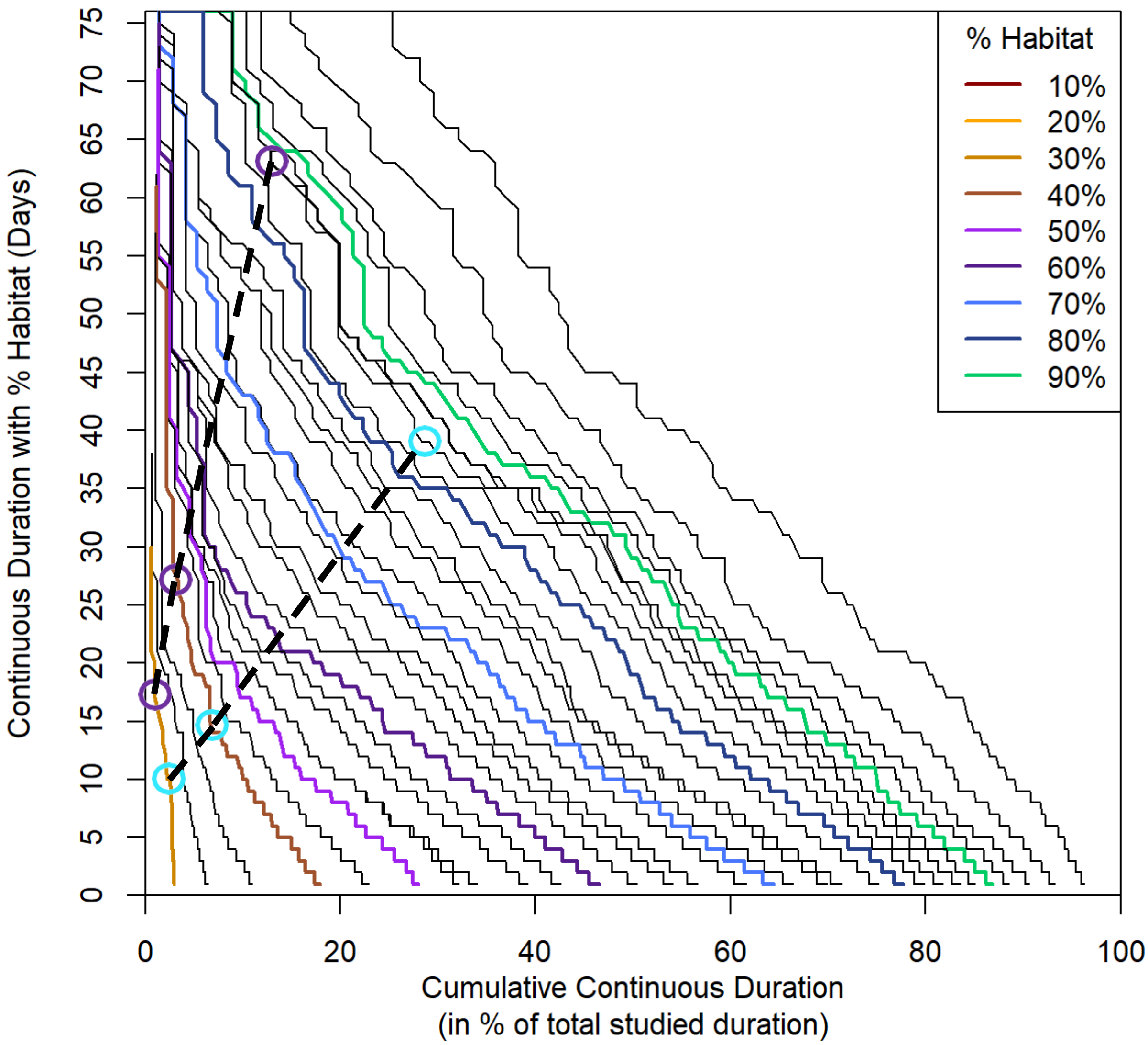
Blacknose Dace Adult



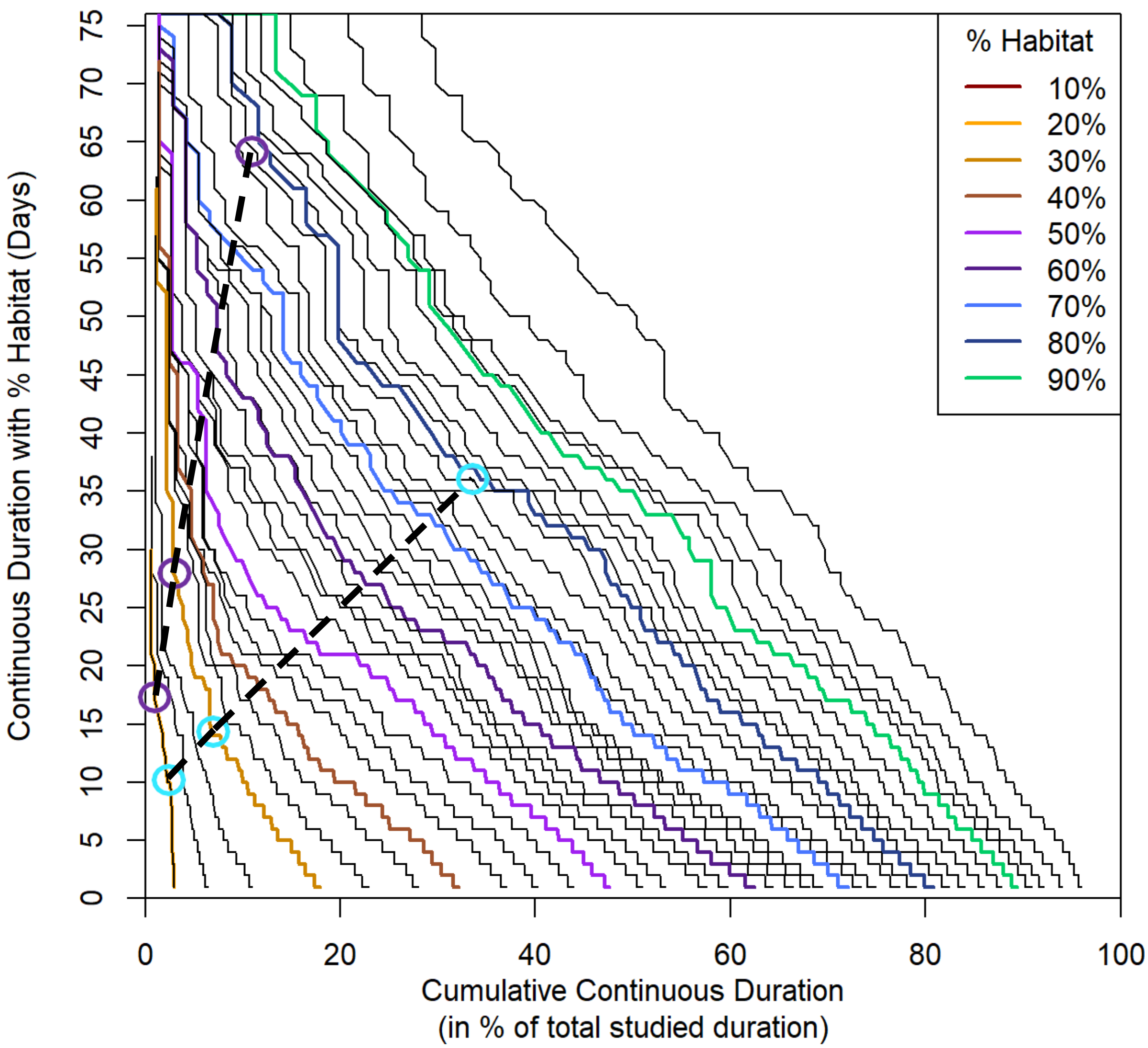
Longnose Dace Adult



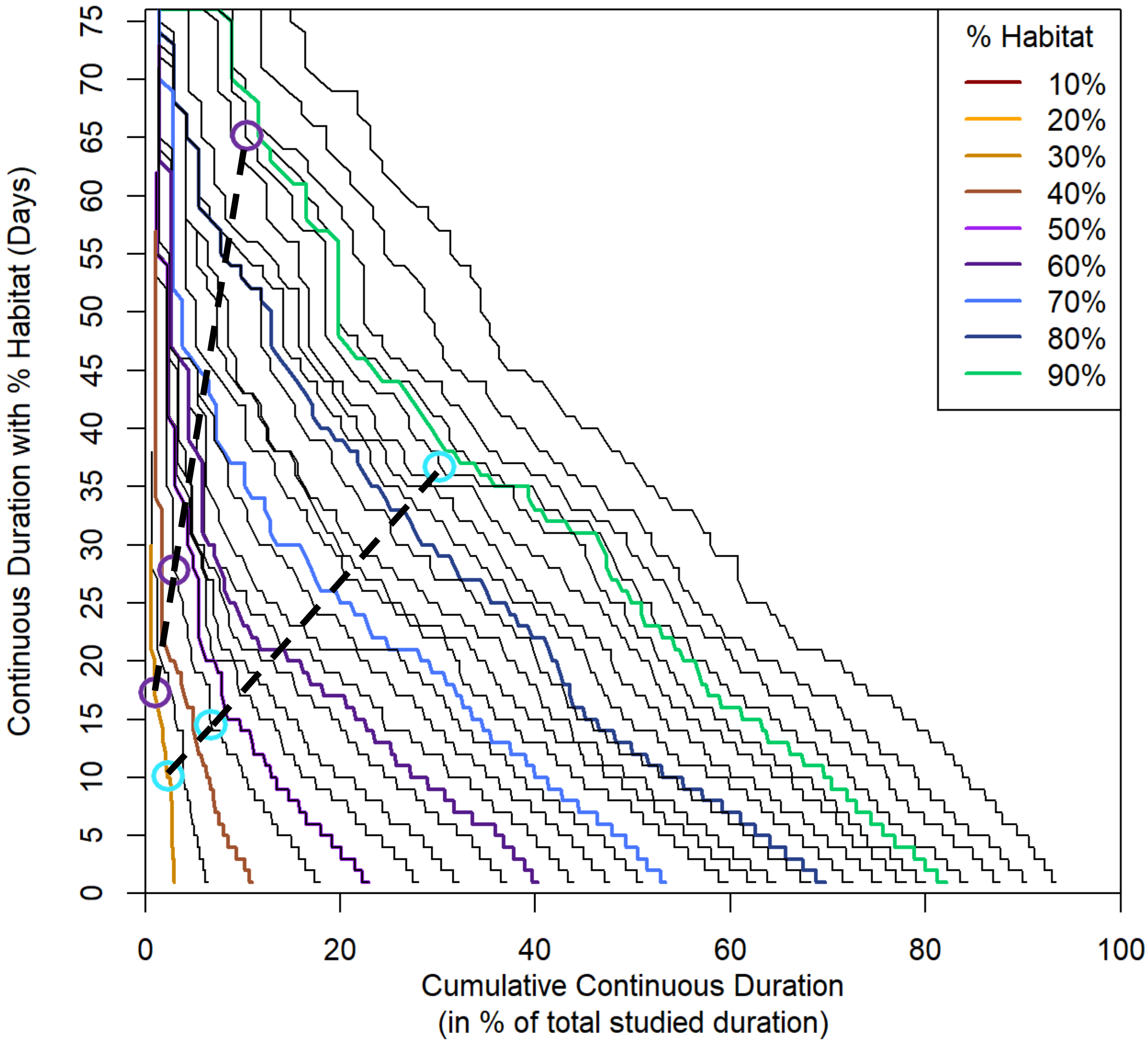
Longnose Dace Juvenile



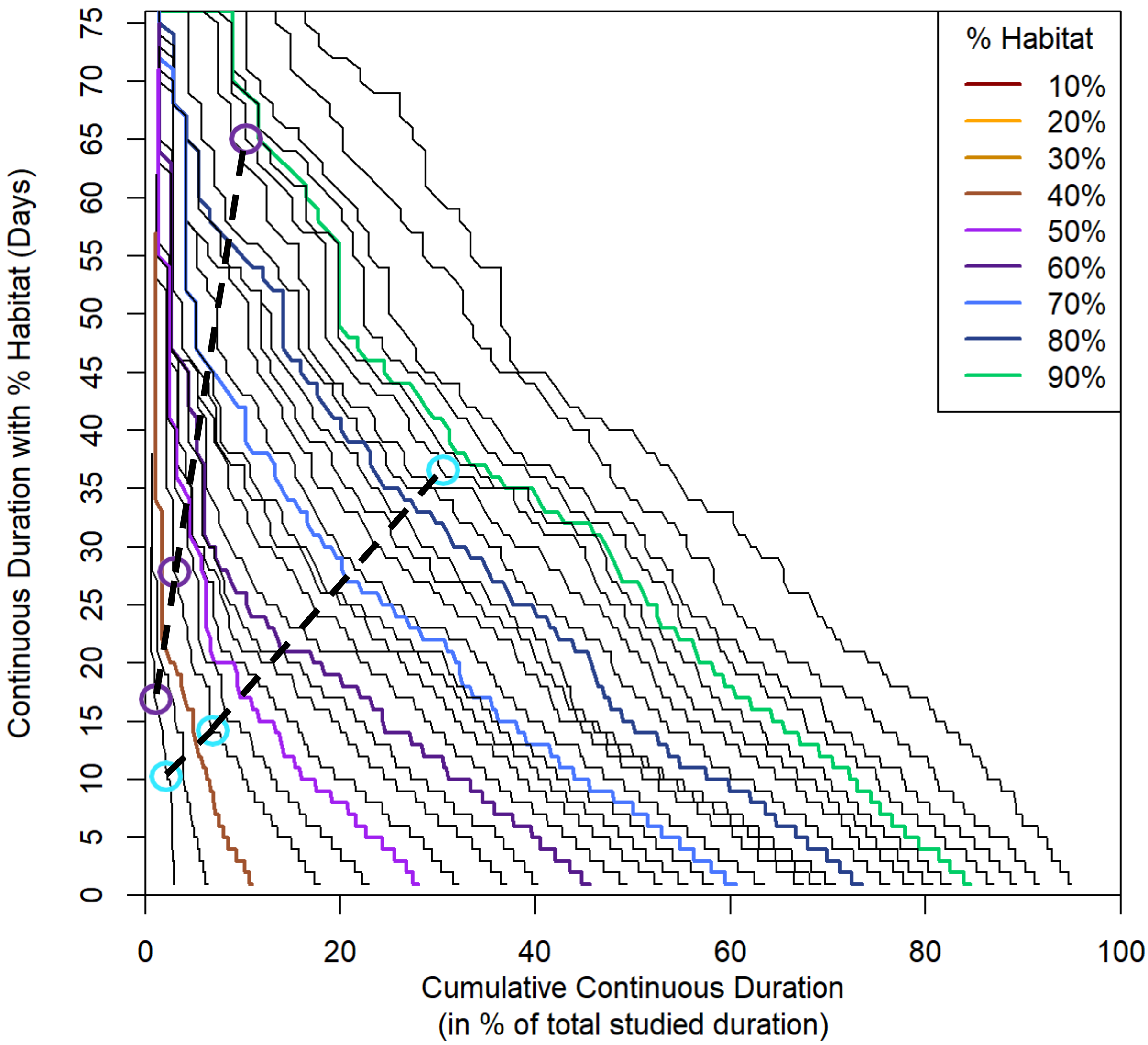
Common Shiner Juvenile



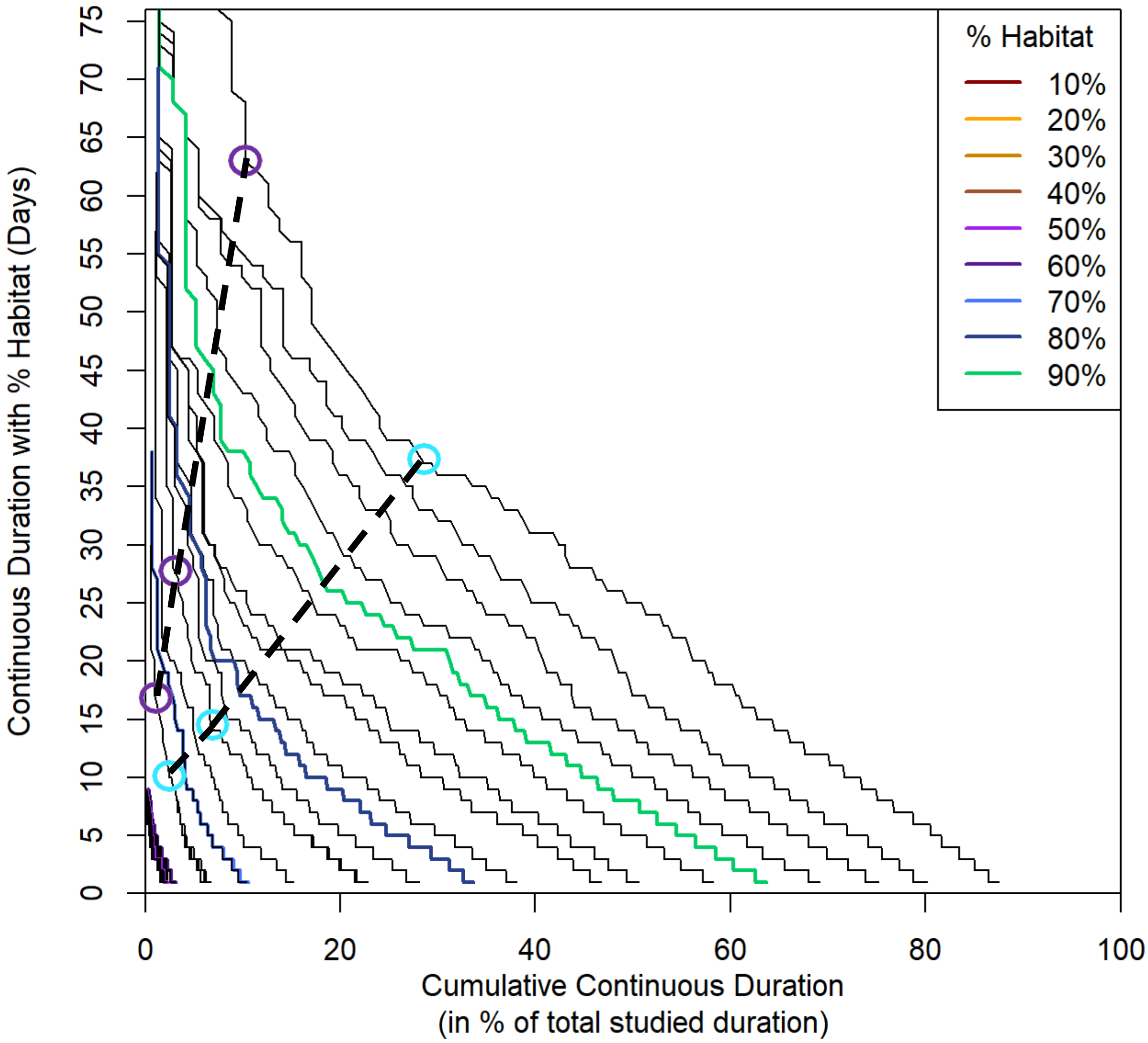
Mottled Sculpin Adult/Juv



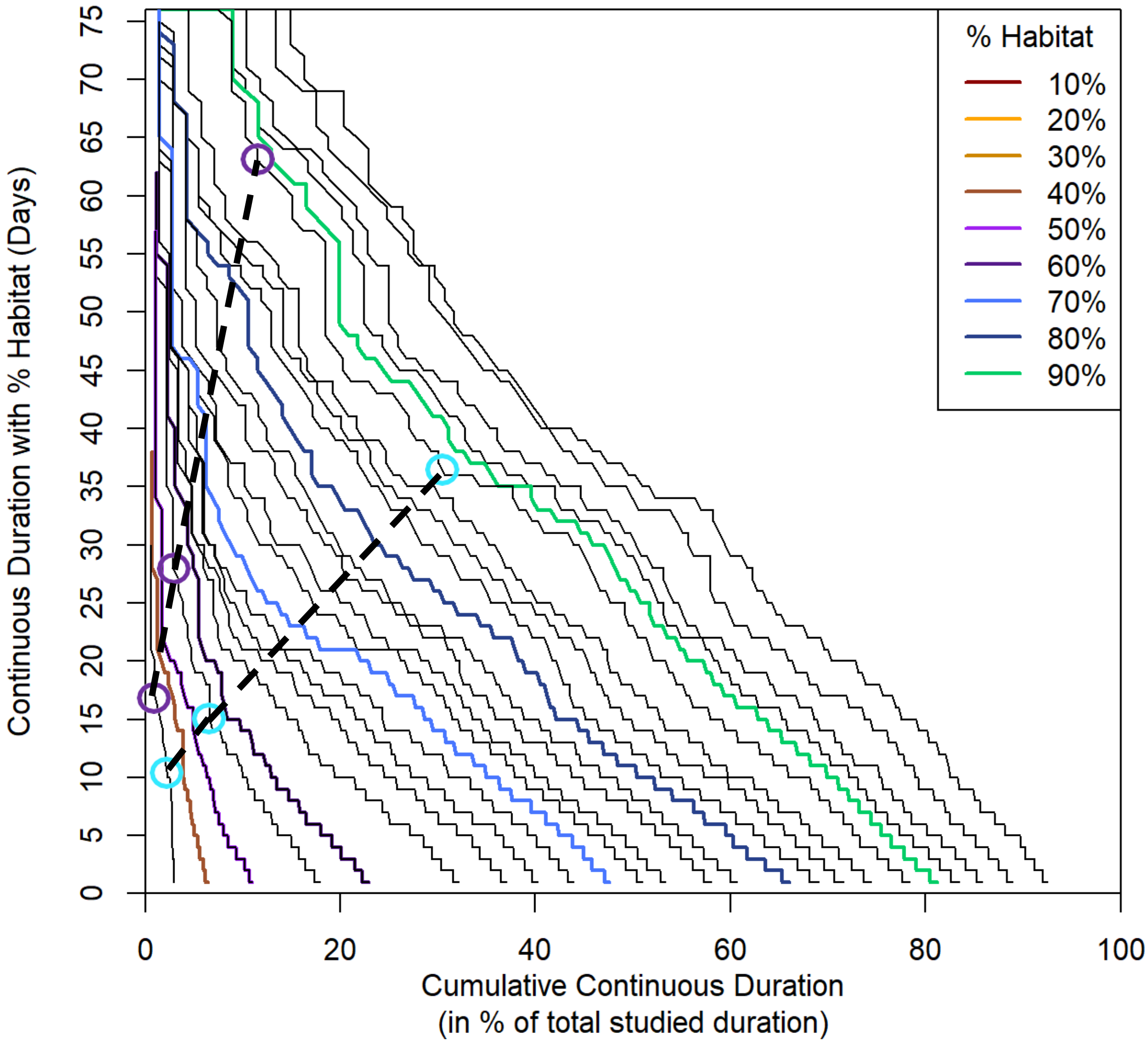
Brook Trout Adult



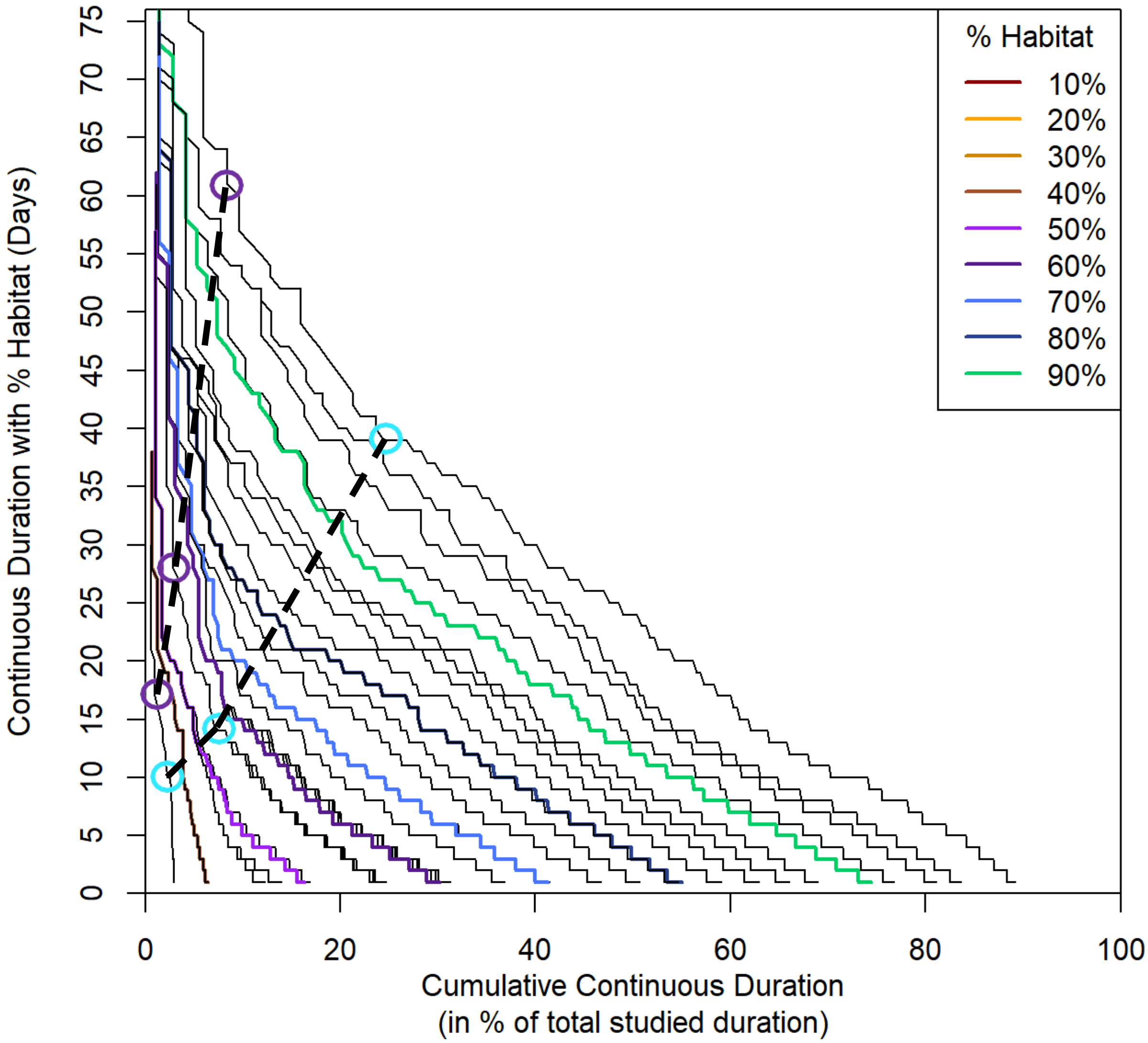
Brook Trout Juvenile



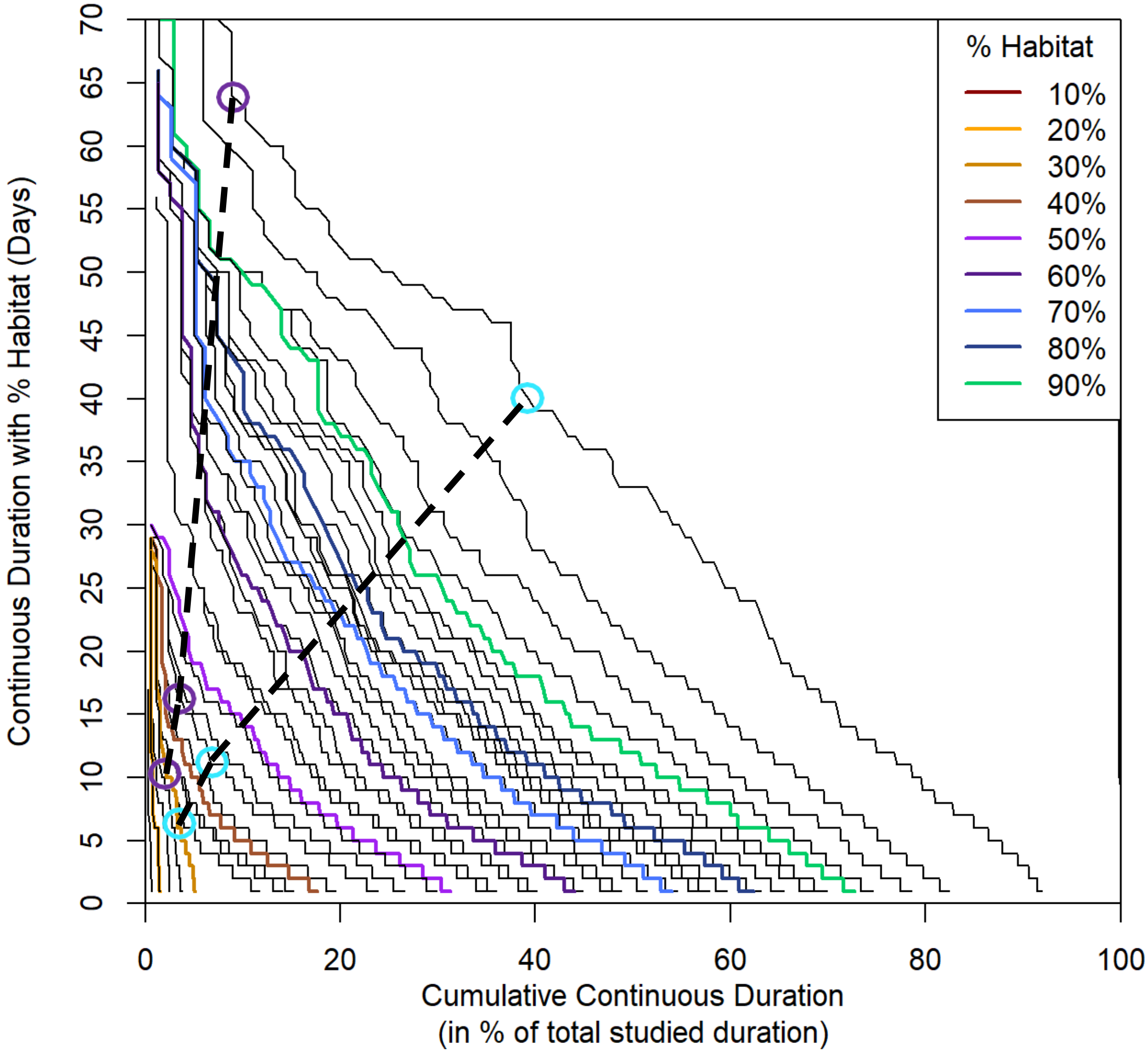
Atlantic Salmon Parr



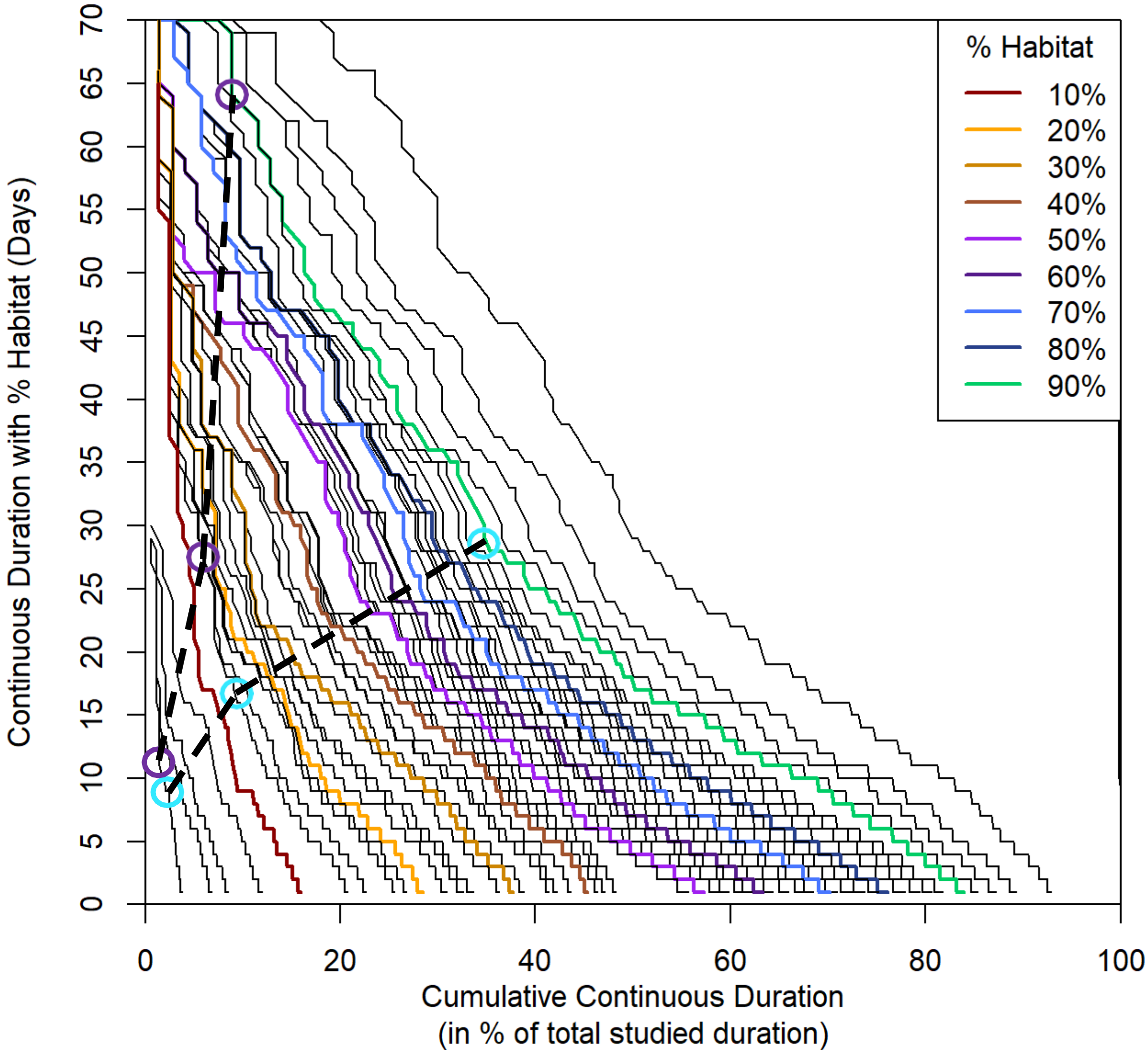
American Shad Juvenile



White Sucker Adult/Juv

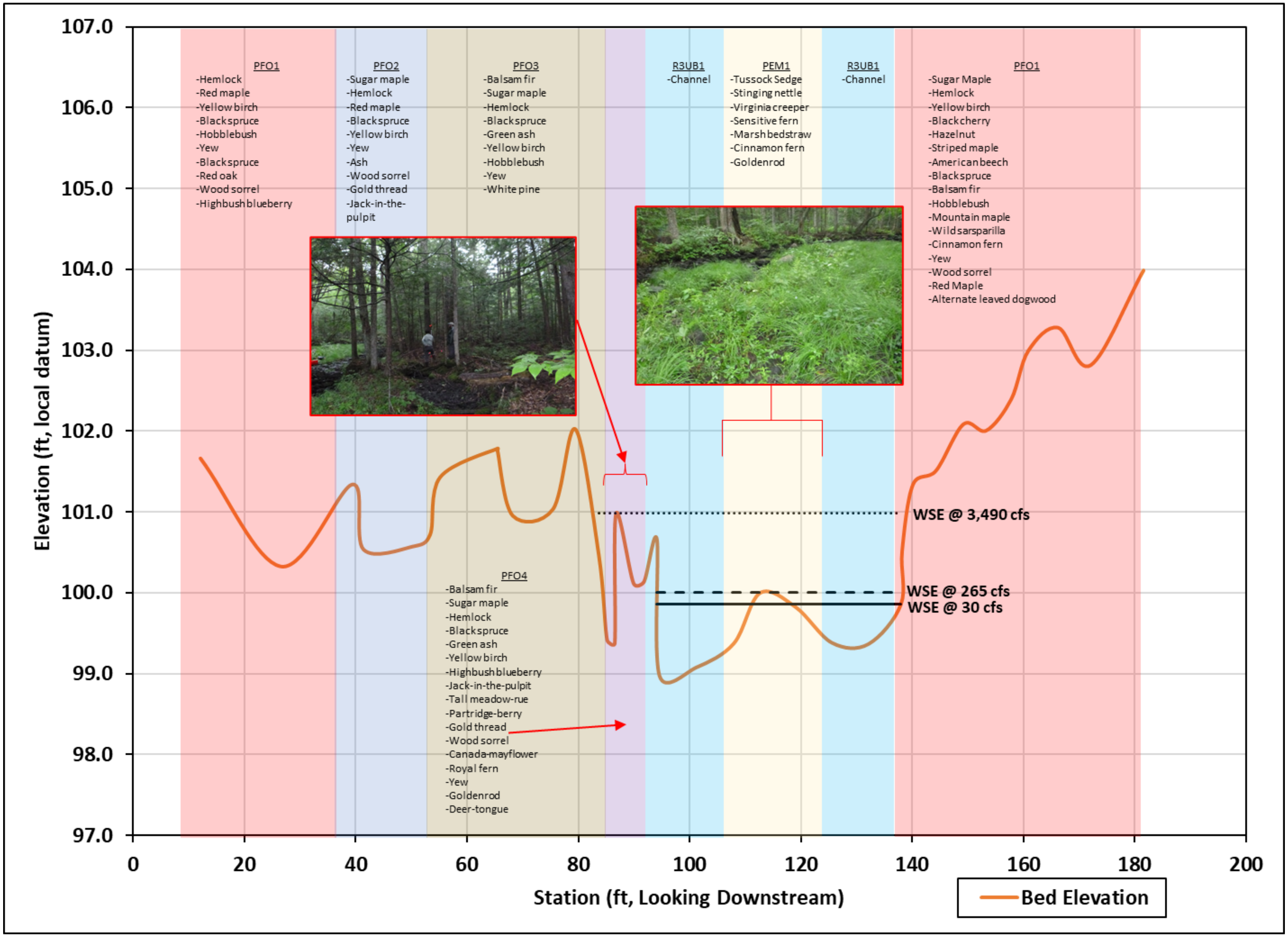


Brook Trout Spawning



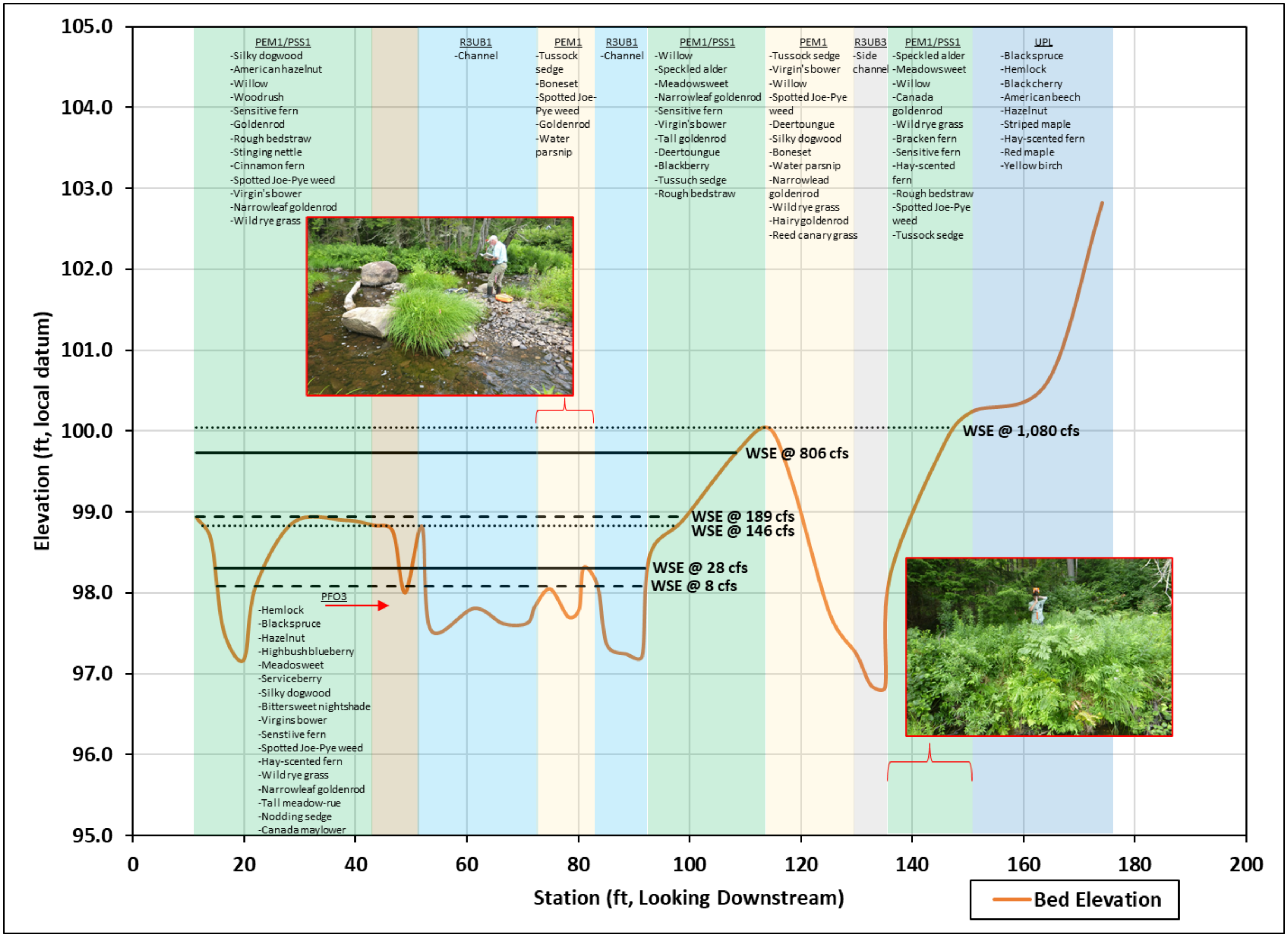
Atlantic Salmon Spawning

Appendix G: Riparian Transect Cross Sections

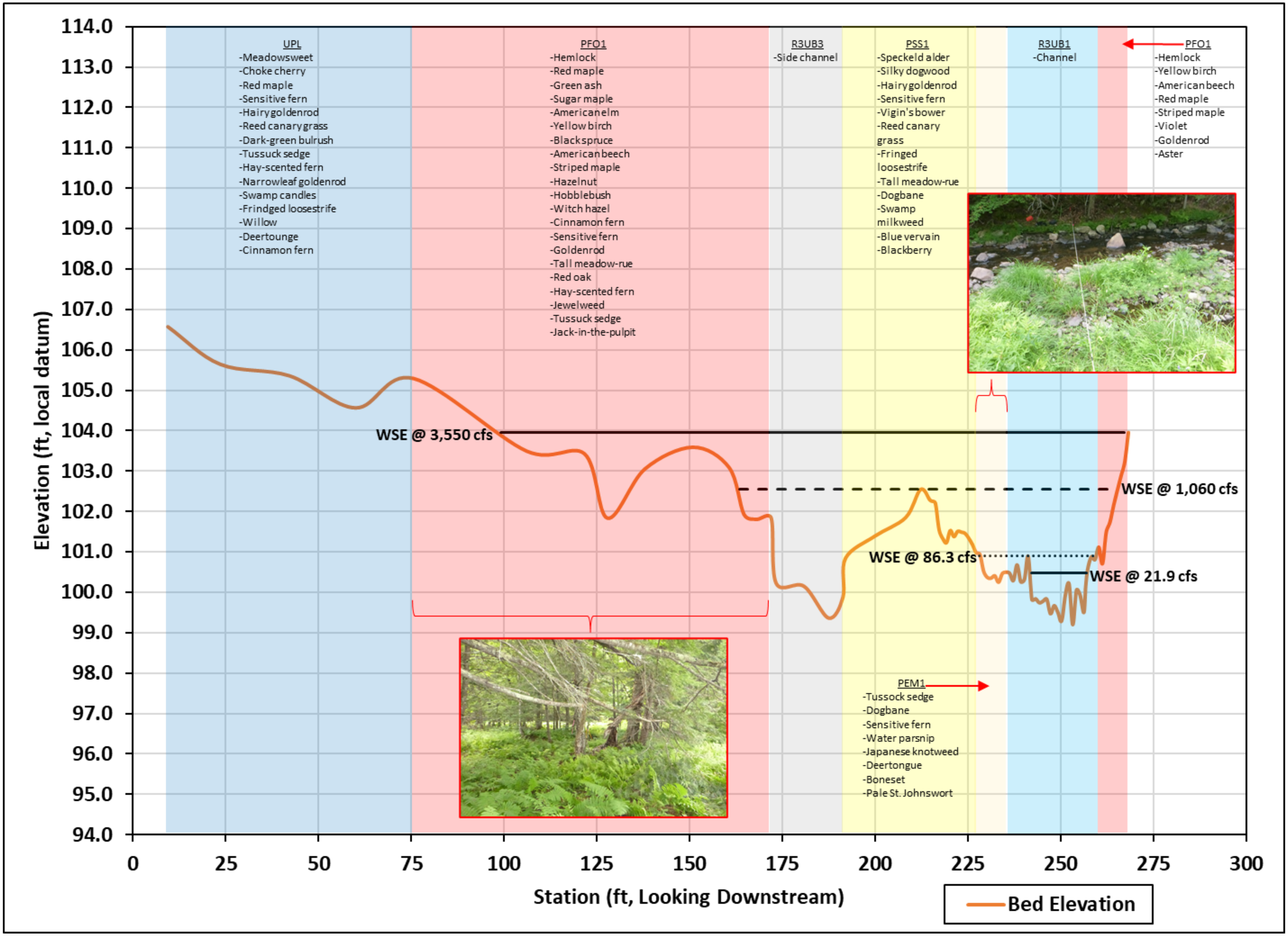


Transect R1R1[14]

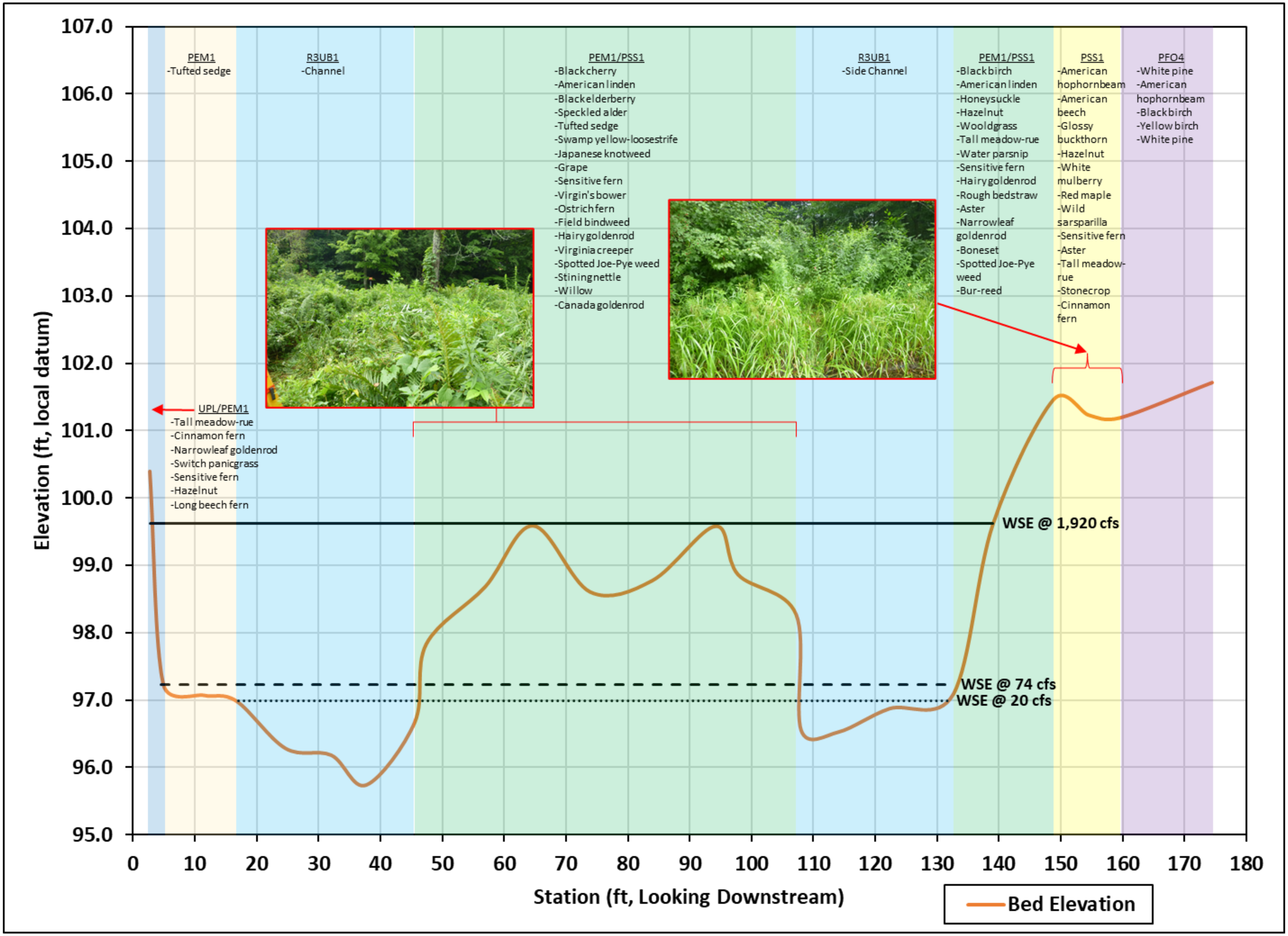
[14] Water surface elevations were obtained from water level recorders placed in the main channel of each transect. Water surface elevation in side channels at certain transects may vary from the water surface elevation in the main channel due to downstream backwater effects or other topographic differences in the channels.



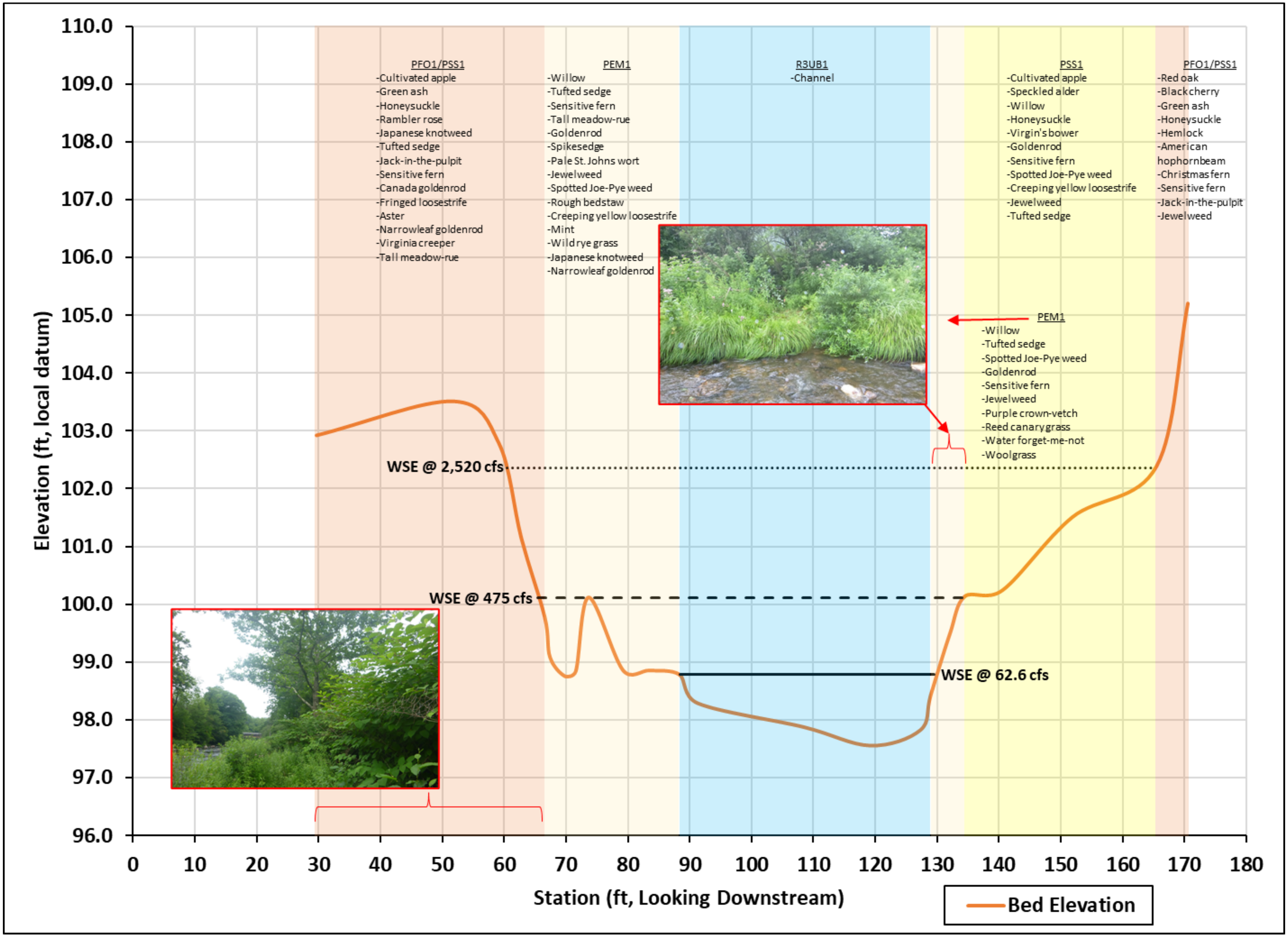
Transect R2R1



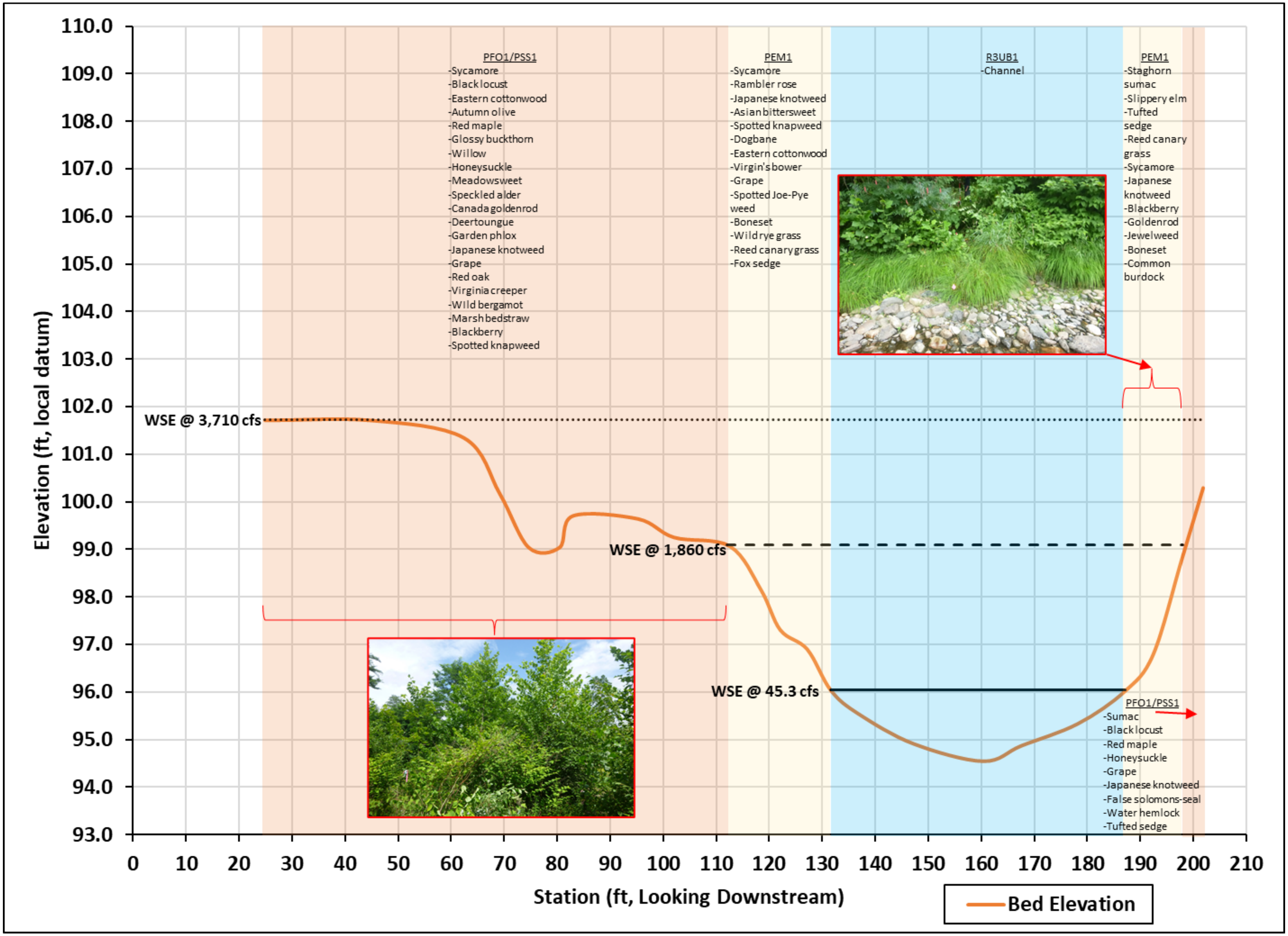
Transect R2R2



Transect R2R3



Transect R2R4



Transect R3R1

Appendix H: Comments and Comment Responses

A draft of this report was provided to the public for comment from August 31, 2021 through November 17, 2021. On September 27, 2021 at the Alstead, NH Town Hall, an informational meeting was held to describe the proposed protected instream flows for the Cold River and to answer any questions from in-person and remote attendees. A formal hearing was also held on October 18, 2021 at the Alstead, NH Town Hall, including a remote access option, to receive comments. Attendees at the hearing primarily asked technical questions similar to those discussed at the informational hearing. One informal comment was provided by one of the hearing attendees, who stated that the report was a good report. No formal comments were received at the hearing, and no written comments were received during the comment period.