Great River Hydro

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August 18, 2019

VIA ELECTRONIC FILING
Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, D.C. 20426

Re: Great River Hydro, LLC
FERC Project Nos. P-1892-026, 1855-045, and 1904-073
May 20, 2019 ILP Study Report Addenda – Response to Comments, Disagreements and Requests to Amend Study Plans

Dear Secretary Bose:

Great River Hydro, LLC ("Great River Hydro" or "GRH") is the owner and licensee of the Wilder Hydroelectric Project (FERC No. 1892), the Bellows Falls Hydroelectric Project (FERC No. 1855), and the Vernon Hydroelectric Project (FERC No. 1904). On October 31, 2012, TransCanada (the previous licensee) initiated the Integrated Licensing Process ("ILP") by filing with the Federal Energy Regulatory Commission ("FERC" or "Commission") its Notice of Intent to seek new licenses for each project, along with a separate Pre-Application Document for each project. On May 9, 2019 the Commission issued a "Notice of Authorization for Continued Project Operation" for each of the three Projects. The Notices extend the conditions of the current licenses for one year or until the issuance of new licenses, whichever comes first; and, unless otherwise ordered by the Commission, automatically renew annual licenses should new licenses not be issued by April 30, 2020.

As required by 18 C.F.R. §5.15(f) and in accordance with the Revised Process Plan and Schedule issued February 19, 2019 by the Commission, Great River Hydro submitted Revised Final Study Report for ILP study 9 (Instream Flow) on May 20, 2019. As discussed in that filing, no changes were made to the Study 24 (Dwarf Wedgemussel) report filed on March 22, 2017 and therefore no filing was made for that study. However, a supplemental study report for ILP Study 18 (American Eel Upstream Passage Assessment) reporting on 2018 fieldwork was provided in the May 20, 2019 filing. A study report meeting was held on June 4, 2019 and a meeting summary was filed June 18, 2019. On July 18, 2019 the Vermont Agency of Natural Resources (VANR) and the Connecticut River Conservancy (CRC) filed comment letters addressing the May 20, 2019 filing. With this filing, and as per 18 C.F.R. §5.15(c)(5), Great River Hydro submits responses to comments and specifically to Disagreements and Requests to Amend Study Plans regarding the Study 9, Instream Flow Revised Final Study Report, and comments on the supplement report for Study 18. Our responses are indicated in the attached table entitled Response to Comments, Study Reports filed May 20, 2019.

As stated in the Revised Study Plan filed on August 14, 2013, the overall objective of the Instream Flow Study (Study 9) was to assess the relationship between stream flow and resultant habitat of key aquatic species in riverine reaches downstream of project dams. Specific objectives were to:

- compute a habitat index versus flow relationship for key aquatic species in each project reach; and
- use the habitat index versus flow relationship to develop a habitat duration time-series analysis over the range of current operational flows.

These objectives were met and study plan methods were followed. Several of the comments made did not address the study scope, study plan, or study report and did not specifically request additional studies; as those comments are outside the scope of this filing, Great River Hydro offers no response.

If there are any questions regarding the information provided in this filing, please contact John Ragonese at 603-498-2851 or by emailingjragonese@greatriverhydro.com.

Sincerely,

John L. Ragonese

FERC License Manager

cc: Interested Parties List (distribution through email notification of availability and download from Great River Hydro's relicensing web site www.greatriverhydro-relicensing.com).

Attachments:

(1) Response to May 20, 2019 USR Comments
(2) Appendix A: Habitat Suitability Criteria, to ILP Study 9 - Instream Flow Revised Final Study Report

Study 9 – Instream Flow Assessment

Comment #	Source	Comment	Response
1	VANR	Regarding Tables 6.3.1-1, 6.3.1-2, 6.3.1-5, and 6.3.1-6, what is meant by the highlighted rows (e.g., Walleye fry on page 167)? **Request**: Please revise the table caption to indicate what highlighted rows are meant to communicate, or if colored in error, revise the tables accordingly.	See pages 166 and 171 where the tables are introduced and discussed in the text. For tables 6.3.1-1 and 6.3.1-2, the text on page 166 states, "Examples highlighted in Tables 6.3.1-1 and 6.3.1-2 are Walleye adult, juvenile and fry, all of which have low velocity thresholds and are normally associated with pools, habitat that is rare under the CR analysis. For these life stages AWS values under the CR are appreciably lower and fluctuate erratically compared to total AWS." The text explains highlighted rows within the tables, no revisions are necessary.
2	VANR	Regarding Figure 6.3.2-6, the Agency recommends updating Appendix A to include the final updated Sea Lamprey spawning HSC in both graphical and tabular form to ensure they have a final, documented home. This will improve the likelihood that ongoing and future assessments of hydraulic-habitat conditions for Sea Lamprey at the projects are informed by common habitat suitability assumptions.	Appendix A has been updated as recommended and is included with this filing.
3	VANR, CRC	Section 6.3.3 'Time Series'. VANR: "Because essentially no information is provided on (a) the hydrologic and operational details of the 'strawman' scenario or (b) the sequencing and chronology of different habitat offerings (i.e., time series vs. duration curves), it is not clear what the habitat time series/habitat duration curve results mean relative to current operations/relicensing proposal. Additionally, the comment by GRH that 'Lacking any specific alternative proposals from the Aquatics Working Group…' does not reflect the discussions had between the Aquatic Working Group and GRH during	GRH participated in numerous consultation meetings where: 1.) It presented additional analyses as requested by AWG; 2.) Attended analytical presentations by members of the AWG; 3.) Provided data and recompiled data as requested by the AWG; 4.) Responded to a model scenario request designed to understand the hydrology associated with current inflows to the projects;

		the consultation process (e.g., the August 7, 2018 consultation meeting, at which GRH indicated a willingness to advance a new operations proposal). **Request**: Please clarify what the operational conditions underlying the 'strawman' proposal analyzed in the report, including base and generation flows, ramping rates, impoundment levels, etc. (e.g., operations model inputs). Additionally, please clarify if this proposal is what GRH intends to advance as its formal relicensing proposal. CRC: "Much of the conclusion relies on relating information about a "strawman" scenario where no details were provided as to the parameters used. It is quite difficult to understand the effects of a change of operational scenario without knowing what that change was. Additionally, the conclusions when comparing the baseline to the strawman seem to cherry pick only those that would indicate that an increase in minimum flow (having no idea what minimum flow was used) would be detrimental to or have no effect on available habitat. For instance, "an increase in minimum flows during the summer results in lower AWS for White Sucker and Smallmouth Bass fry,"5 but what about the other species under consideration?"	5.) Presented an overview of the energy generation markets and where these projects play a critical role. All with the intent of examining the results of Study 9 through the lens of a potential operational alternatives that the AWG would be interested in examining through the use of a time series analysis dependent on the Study 5 Operations Model. The goal of Study 9 in the final Study Plan states: "The overall objective of this study is to assess the relationship between stream flow and resultant habitat of key aquatic species in riverine reaches downstream of project dams. Specific objectives of this study are to: • compute a habitat index versus flow relationship for key aquatic species in each project reach; and • use the habitat index versus flow relationship to develop a habitat duration time-series analysis over the range of current operational flows." Under the Analysis Section of the Study Methodology, the Study Plan states: "Hydrology and flow scenarios to be assessed will be determined from results of the operations model (Study 5) and with input from the working group." GRH did not receive input from the AWG relative to a proposed operating scenario to be examined. Therefore, in order to provide some information to the AWG about the sensitivity and habitat response to a potential change in operations, GRH ran a "strawman" operational scenario that was outlined, but not specified, to the AWG. The intent was to illustrate and observe how habitat might shift given the two outlined characteristics of the "strawman" scenario which GRH described to the AWG as: 1) a

			significant increases above current year-round requirements in minimum flows that were seasonally adjusted over the course of a year as Spring, Summer and Fall-Winter flows, and 2) a substantial ramping rate that could not be exceeded, applied to both upward and downward adjustments in generation. Although GRH provided a full data set of the habitat changes to the AWG, GRH did not and will not provide the specific operational scenario to the AWG because that was not the intent of this exercise. It was not intended to quantify, only to illustrate general habitat sensitivity to operational changes such as increasing minimum flows and ramping rates in order to guide the AWG in development of potential operational scenarios.
4	VANR	Section 6.3.4 'Species and Life Stage Reduction', the Agency has independently explored opportunities to reduce the number of species/life stages represented in the data and agrees to the recommended groupings. However, it should be noted that these 'multi-species' curves should be appropriately weighted/considered in subsequent analyses that might otherwise view such results as representing 'one species.'	GRH recognizes VANR's concern regarding the grouping of species curves. At the point in time where an analysis indicates sensitivity among those species within a grouping such that weighting or single species differentiation is necessary, we will make that clear.
5	CRC	During the aquatic workgroup meetings over the last year stakeholders requested that Great River Hydro conduct an inflow equals outflow model run in order to evaluate the effect of that possible operational scenario on habitat. Great River Hydro executed that request but CRC notes that there was no habitat analysis conducted in coordination with that model run and no information from this model run was included in the study report, so the stakeholders and FERC cannot benefit from any information that might have been gleaned from that example.	CRC has mis-represented the discussion and rationale presented to GRH for requesting the inflow-equals-outflow model run and further, failed to mention GRH's presentation of the results of that model run. The AWG did request GRH to run an inflow-equals-outflow model run (aka steady-state model run). A significant portion of the October 5, 2017 consultation meetings was devoted to clarifying what was meant by this request. Inflow to the project at the head of the reservoir (?) vs inflow at the dam (?) was one such discussion point to be

			clarified. Additionally, GRH expressed concerns that the AWG did not fully comprehend that given significant river miles associate with each reservoir, inflow at the dam would potentially result in increases to the reservoir elevation and range of fluctuation at points upstream of the dam in comparison to current operations. During these discussions it was never suggested by the AWG that GRH perform and present a habitat time series analysis nor was it ever GRH's intent to do such. GRH stated repeatedly that an inflow-equals-outflow operating scenario was nothing they would consider as a viable operational alternative due to upstream reservoir management impacts. The AWG specifically informed GRH that the intent of the inflow vs. outflow model run was only to help inform them of the available water or hydrology that such a scenario might indicate as discharges from each dam. GRH was willing to perform the model run, present the results and provide the data set on that basis of understanding alone. Hydrology and reservoir elevation results from the steady-state operation model run were presented at the June 8, 2018 meeting and discussed in other Study 9 consultation meetings but was never intended to be a part of the Study 9 alternatives analysis. CRC's statement that "stakeholders requested that Great River Hydro conduct an inflow equals outflow model run in order to evaluate the effect of that possible operational scenario on habitat" is inaccurate.

Study 18 – American Eel Upstream Passage - Supplement

Comment #	Source	Comment	Response
1	VANR, CRC	Both VANR and CRC suggest GRH investigate and consider alternative means for counting eels. They	Currently, dedicated monitoring of the fishway is part of the VTFWD fishway monitoring program. The modifications

		identify that SalmonSoft was not designed for eel enumeration and the resulting data increasingly appear to be unreliable.	undertaken by GRH were intended to improve the capability and effectiveness of VTFWD's monitoring system in hopes of better detection and directional identification of passing eels with the goal of improving the count accuracy of eels in the Vernon fish ladder. Results for the 2019 migration season at Vernon, provided by VTFWD, show a positive upstream migration of eels in a year when the number of eels migrating up the river, as indicated by numbers passed at Holyoke and Turners Falls, was very low. The positive upstream count suggests the modifications made may be improving count accuracy and additional data points (i.e., additional monitoring with SalmonSoft) combined with results of the PIT tag study being conducted this year should be evaluated.

Appendix A

Habitat Suitability Criteria

Updated August 2019

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HSC sources and references for the Wilder, Bellows Falls and Vernon projects.

Species	Life Stage	Variable	Original Source	Identified Source	Note:
American Shad	Juvenile	Velocity	Stier and Crance, 1985	Stier and Crance, 1985	
		Depth	Stier and Crance, 1985	Excelon, 2012 (Conowingo IFIM)	Based on Greene et al. 2009
		Substrate	Stier and Crance, 1985	Stier and Crance, 1985	Not Stier and Crance 1985, source?
	Adult	Velocity	Stier and Crance, 1985	Stier and Crance, 1985	
		Depth	Stier and Crance, 1985	Stier and Crance, 1985	
		Substrate	Stier and Crance, 1985	Stier and Crance, 1985	Not Stier and Crance 1985, source?
	Spawning	Velocity	Stier and Crance, 1985	Hightower et al., 2012	Modified based on review of data
		Depth	Stier and Crance, 1985	Hightower et al., 2012	Used original Stier and Crance, 1985 endpoint of 50 feet.
		Substrate	Stier and Crance, 1985	Stier and Crance, 1985	
Walleye	Fry	Velocity	McMahon et al., 1984	McMahon et al., 1984	
		Depth	McMahon et al., 1984	McMahon et al., 1984	
		Substrate	McMahon et al., 1984	McMahon et al., 1984	
	Juvenile	Velocity	McMahon et al., 1984	McMahon et al., 1984	
		Depth	McMahon et al., 1984	McMahon et al., 1984	
		Substrate	McMahon et al., 1984	McMahon et al., 1984	
	Adult	Velocity	McMahon et al., 1984	McMahon et al., 1984	
		Depth	McMahon et al., 1984	McMahon et al., 1984	
		Substrate	McMahon et al., 1984	McMahon et al., 1984	
	Spawning/ Incubation	Velocity	McMahon et al., 1984	Bozek et al., 2011	Based on reanalysis of Bozek et al., 2011
		Depth	McMahon et al., 1984	Bozek et al., 2011	From Turners Falls project
		Substrate	McMahon et al., 1984	McMahon et al., 1984	
Fallfish	Fry	Velocity	NA	Gomez and Sullivan, 2007	Velocity and depth based on brook trout fry and juvenile HSC curves developed as part of a Delphi Process for the Deerfield River.
		Depth	NA	Gomez and Sullivan, 2007	
		Substrate	NA	Gomez and Sullivan, 2007	
	Juvenile	Velocity	NA	Gomez and Sullivan, 2007	
		Depth	NA	Gomez and Sullivan, 2007	
		Substrate	NA	Gomez and Sullivan, 2007	
	Adult	Velocity	None identified	Gomez and Sullivan, 2007	Developed in consultation with the New York Department of Environmental Conservation
		Depth	None identified	Gomez and Sullivan, 2007	
		Substrate	None identified	Gomez and Sullivan, 2007	
	Spawning/ Incubation	Velocity	None identified	Gomez and Sullivan, 2007	
		Depth	None identified	Gomez and Sullivan, 2007	
		Substrate	None identified	Gomez and Sullivan, 2007	

Species	Life Stage	Variable	Original Source	Identified Source	Note:
Longnose dace	Fry	Velocity	USGS HSC Library	Gomez and Sullivan, 2007	
		Depth	USGS HSC Library	Gomez and Sullivan, 2007	
		Substrate	USGS HSC Library	Gomez and Sullivan, 2007	
	Juvenile	Velocity	USGS HSC Library	Gomez and Sullivan, 2000	Modified by Vermont Department of Fish and Wildlife
		Depth	USGS HSC Library	Gomez and Sullivan, 2000	
		Substrate	USGS HSC Library	Gomez and Sullivan, 2000	
	Adult	Velocity	USGS HSC Library	Gomez and Sullivan, 2000	
		Depth	USGS HSC Library	Gomez and Sullivan, 2000	
		Substrate	USGS HSC Library	Gomez and Sullivan, 2007	
White sucker	Fry	Velocity	Twomey et al., 1984	Twomey et al., 1984	
		Depth	Twomey et al., 1984	Twomey et al., 1984	
		Substrate	Twomey et al., 1984	Twomey et al., 1984	
	Juvenile/Adult	Velocity	Twomey et al., 1984	Twomey et al., 1984	
		Depth	Twomey et al., 1984	Twomey et al., 1984	
		Substrate	Twomey et al., 1984	Twomey et al., 1984	
	Spawning/ Incubation	Velocity	Twomey et al., 1984	Twomey et al., 1984	
		Depth	Twomey et al., 1984	Twomey et al., 1984	
		Substrate	Twomey et al., 1984	Gomez and Sullivan, 2007	Modified from original source
Tessellated darter	Adult	Velocity	Warner et al. 2006	Warner et al. 2006 & Aadland and Kuitunen 2006	Modified by VTDFW-2015
		Depth	Warner et al. 2006		
		Substrate	Aadland and Kuitunen 2006	Aadland and Kuitunen 2006	Jhonny darter as surrogate
Sea lamprey	Spawning	Velocity	Kynard and Horgan, 2013	Kynard and Horgan, 2013	Modified by FWS based on Yergeau, 1983 (depth and substrate); Depth modified by NAI Feb. 2017
		Depth	Kynard and Horgan, 2013	Kynard and Horgan, 2013	
		Substrate	Kynard and Horgan, 2013	Kynard and Horgan, 2013	
Smallmouth bass	Fry	Velocity	NA	Leonard et al., 1986	HSC source for this project
		Depth	NA	Leonard et al., 1986	HSC source for this project
		Substrate	NA	Leonard et al., 1986	HSC source for this project
	Juvenile	Velocity	NA	Groshens and Orth, 1994	HSC source for this project
		Depth	NA	Leonard et al., 1986	HSC source for this project
		Substrate	NA	Leonard et al., 1986	HSC source for this project
	Adult	Velocity	NA	Groshens and Orth, 1994	HSC source for this project
		Depth	NA	Leonard et al., 1986	HSC source for this project
		Substrate	NA	Leonard et al., 1986	HSC source for this project
	Spawning	Velocity	NA	Allen, 1996	HSC source for this project
		Depth	NA	Edwards et al., 1983	HSC source for this project
		Substrate	NA	Allen, 1996	HSC source for this project
Macro-invetebrates	nymphs	Velocity	Unknown	Gomez and Sullivan, 2000	VTDFW modified
		Depth	Unknown	Gomez and Sullivan, 2000	NMPC curve
		Substrate	Unknown	Gomez and Sullivan, 2000	

Species	Variable	Original Source	Identified Source	Note:
Dwarf Wedgemussel	Velocity	Normandeau &Biodrawverity 2016	Normandeau &Biodrawverity 2016	Delphi process
	Depth	Normandeau &Biodrawverity 2016	Normandeau &Biodrawverity 2016	
	Substrate	Normandeau &Biodrawverity 2016	Normandeau &Biodrawverity 2016	
	Shear Velocity	Normandeau &Biodrawverity 2016	Normandeau &Biodrawverity 2016	
	Bed Shear Stress	Normandeau &Biodrawverity 2016	Normandeau &Biodrawverity 2016	
	Relative Shear Stress	Normandeau &Biodrawverity 2016	Normandeau &Biodrawverity 2016	
	Benthic Velocity	Normandeau &Biodrawverity 2016	Normandeau &Biodrawverity 2016	
Co-occurring Mussels	Velocity	Normandeau &Biodrawverity 2017	Normandeau &Biodrawverity 2017	
	Depth	Normandeau &Biodrawverity 2017	Normandeau &Biodrawverity 2017	
	Substrate	Normandeau &Biodrawverity 2017	Normandeau &Biodrawverity 2017	
	Bed Shear Stress	Normandeau &Biodrawverity 2017	Normandeau &Biodrawverity 2017	
	Relative Shear Stress	Normandeau &Biodrawverity 2017	Normandeau &Biodrawverity 2017	
	Benthic Velocity	Normandeau &Biodrawverity 2017	Normandeau &Biodrawverity 2017	

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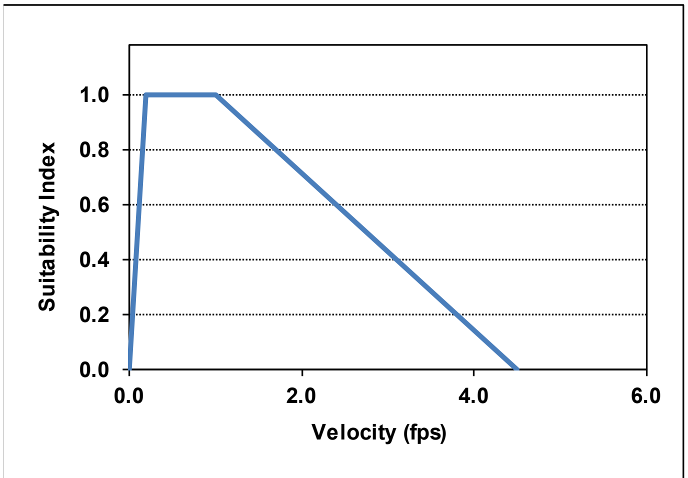
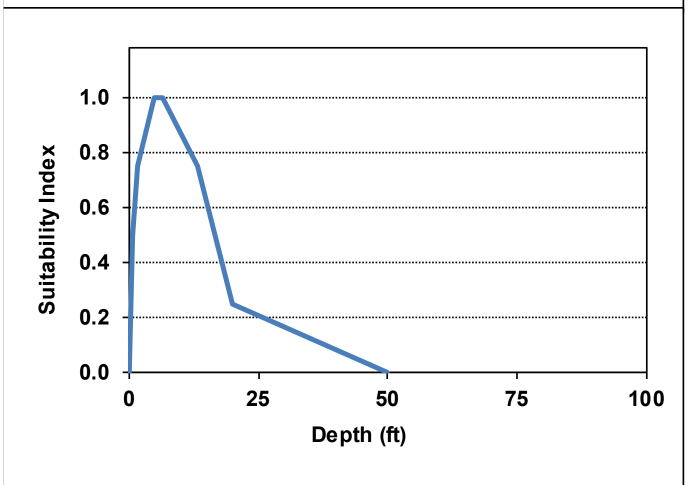
American Shad Juvenile

Source:



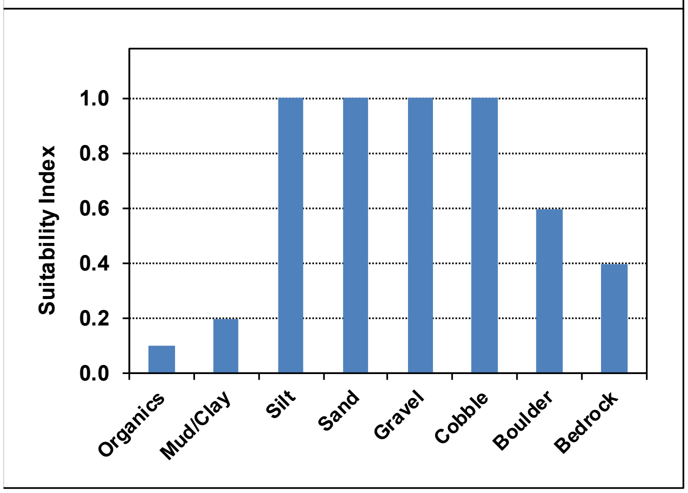
Stier and Crance, 1985

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



Greene et al., 2009

Depth (ft)	SI
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

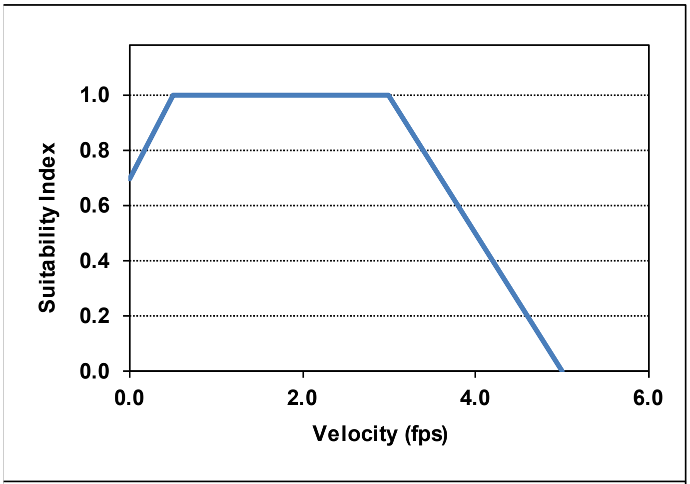


Conowingo IFIM

Substrate	SI
Organics	0.10
Mud/Clay	0.20
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	0.60
Bedrock	0.40

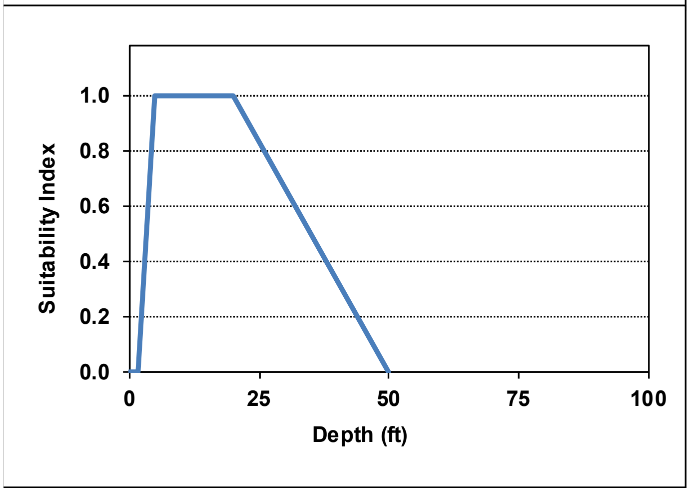
American Shad Adult

Source:



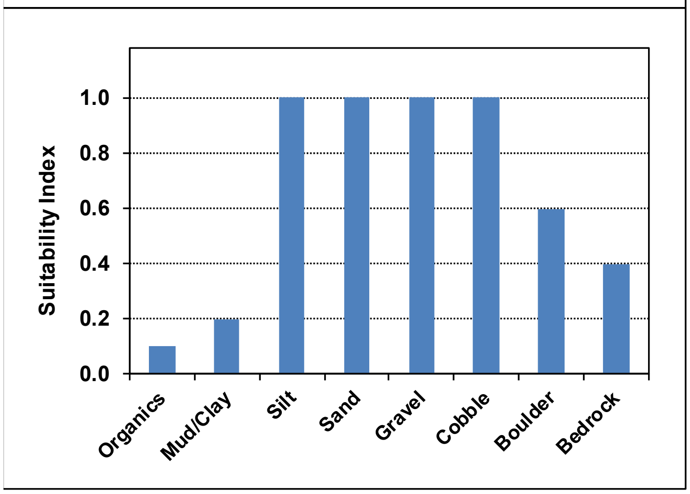
Stier and Crance, 1985

Velocity (ft/s)	SI
0.00	0.70
0.50	1.00
3.00	1.00
5.00	0.00



Stier and Crance, 1985

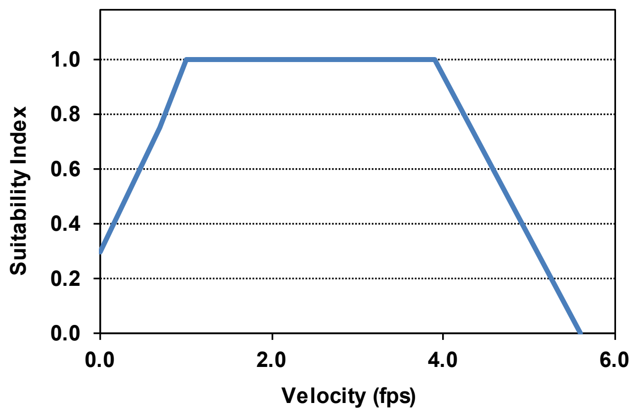
Depth (ft)	SI
0.00	0.00
1.50	0.00
5.00	1.00
20.00	1.00
50.00	0.00



Conowingo IFIM

Substrate	SI
Organics	0.10
Mud/Clay	0.20
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	0.60
Bedrock	0.40

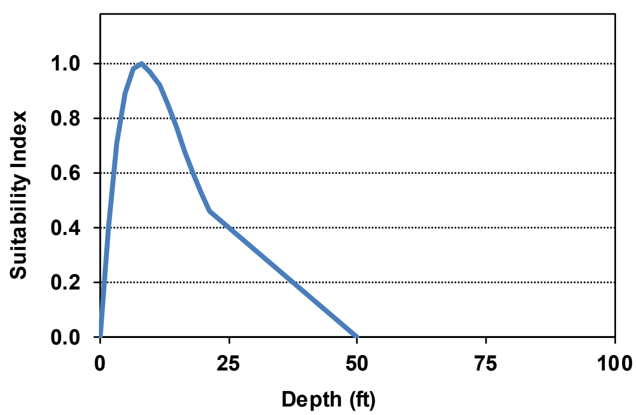
American Shad Spawning



Source:

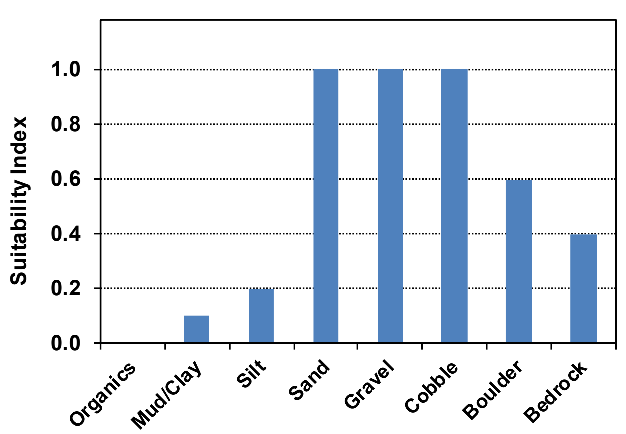
Velocity based on data from Hightower et al., 2012

Velocity (ft/s)	SI
0.00	0.30
0.70	0.75
1.00	1.00
3.00	1.00
3.90	1.00
5.60	0.00



Hightower et al., 2012 and Stier and Crance, 1985

Depth (ft)	SI
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
50.00	0.00

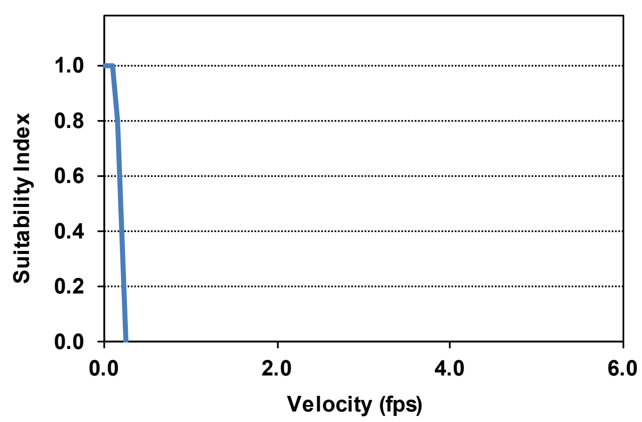


Stier and Crance, 1985

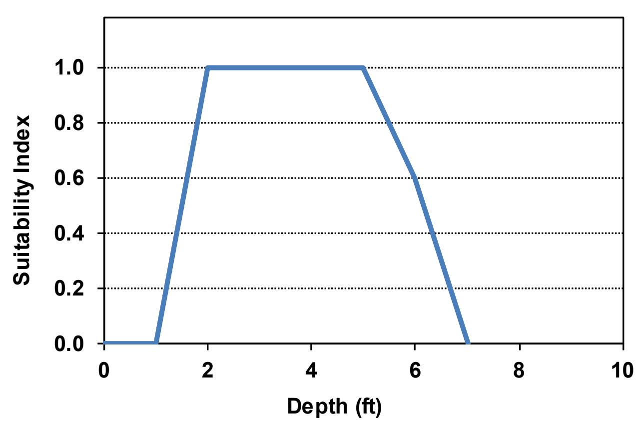
Substrate	SI
Organics	0.00
Mud/Clay	0.10
Silt	0.20
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	0.60
Bedrock	0.40

Walleye Fry

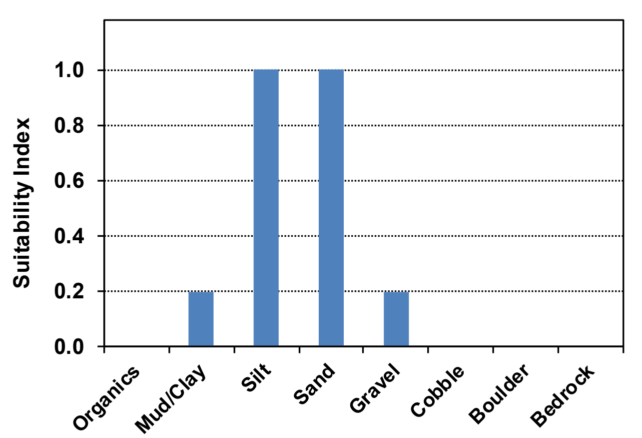
Source:
McMahon et al., 1984



Velocity (ft/s)	SI
0.00	1.00
0.10	1.00
0.15	0.80
0.25	0.00
2.00	0.00



Depth (ft)	SI
0.00	0.00
1.00	0.00
2.00	1.00
5.00	1.00
6.00	0.60
7.00	0.00

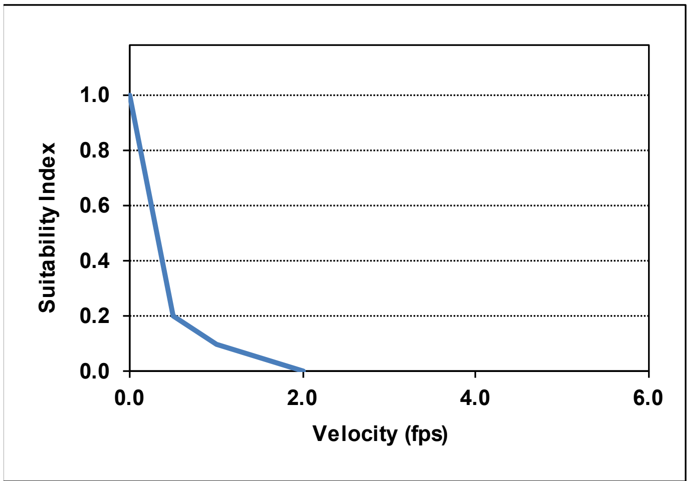


Substrate	SI
Organics	0.00
Mud/Clay	0.20
Silt	1.00
Sand	1.00
Gravel	0.20
Cobble	0.00
Boulder	0.00
Bedrock	0.00

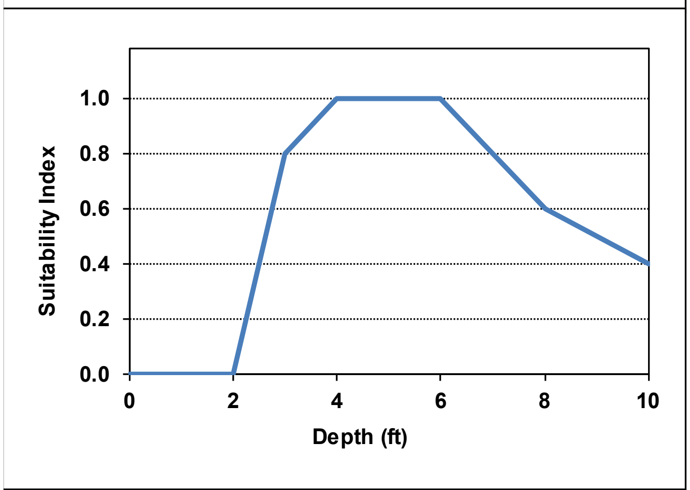
Walleye Juvenile

Source:

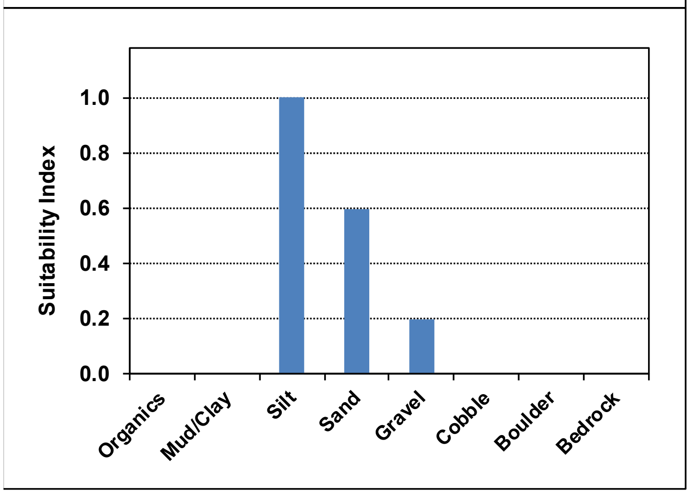
McMahon et al., 1984



Velocity (ft/s)	SI
0.00	1.00
0.50	0.20
1.00	0.10
2.00	0.00



Depth (ft)	SI
0.00	0.00
2.00	0.00
3.00	0.80
4.00	1.00
6.00	1.00
8.00	0.60
10.00	0.40
50.00	0.40

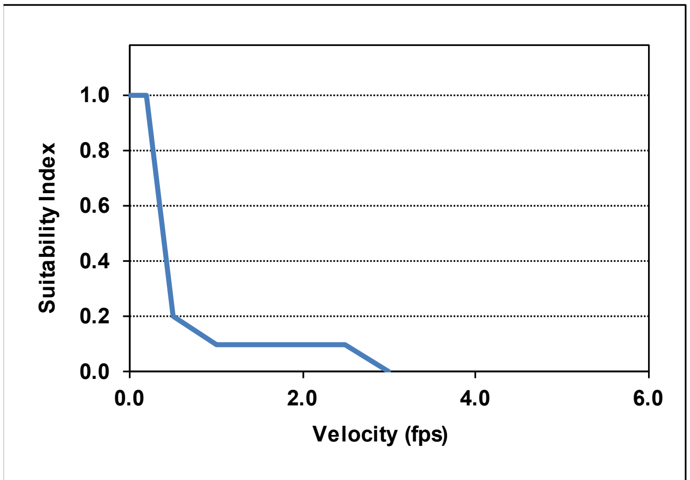


Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	1.00
Sand	0.60
Gravel	0.20
Cobble	0.00
Boulder	0.00
Bedrock	0.00

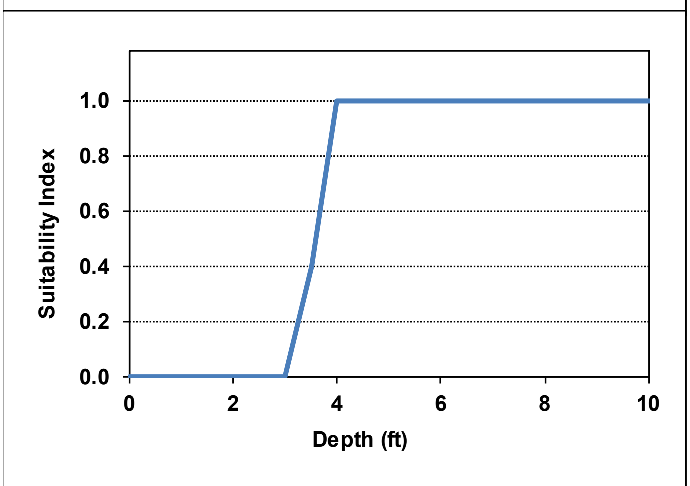
Walleye Adult

Source:

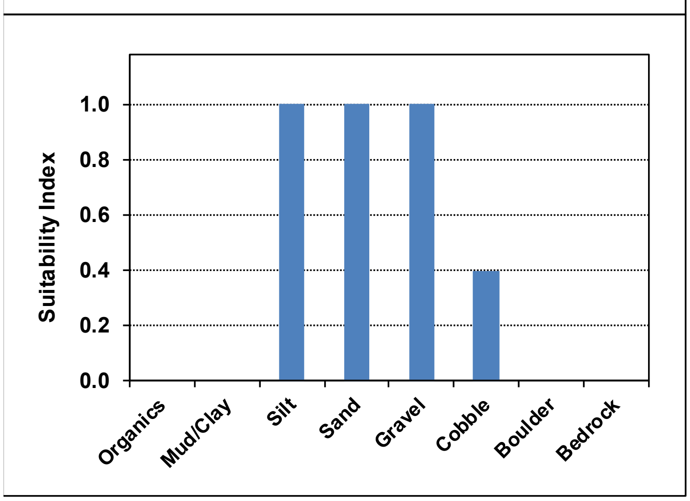
McMahon et al., 1984



Velocity (ft/s)	SI
0.00	1.00
0.20	1.00
0.50	0.20
1.00	0.10
2.50	0.10
3.00	0.00



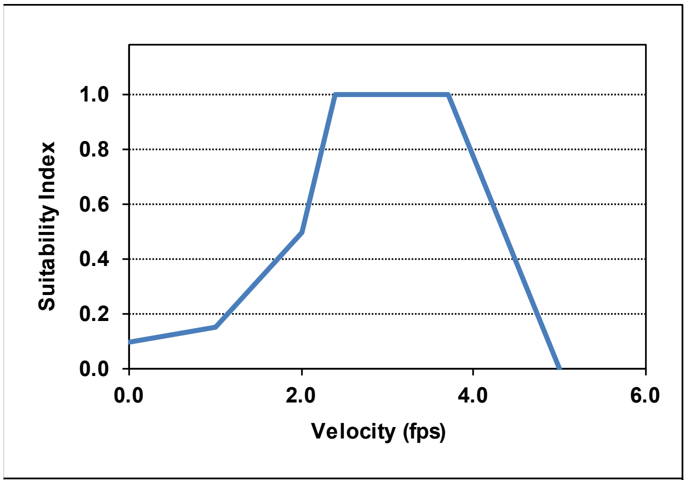
Depth (ft)	SI
0.00	0.00
3.00	0.00
3.50	0.40
4.00	1.00
50.00	1.00



Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	0.40
Boulder	0.00
Bedrock	0.00

Walleye Spawning & Incubation

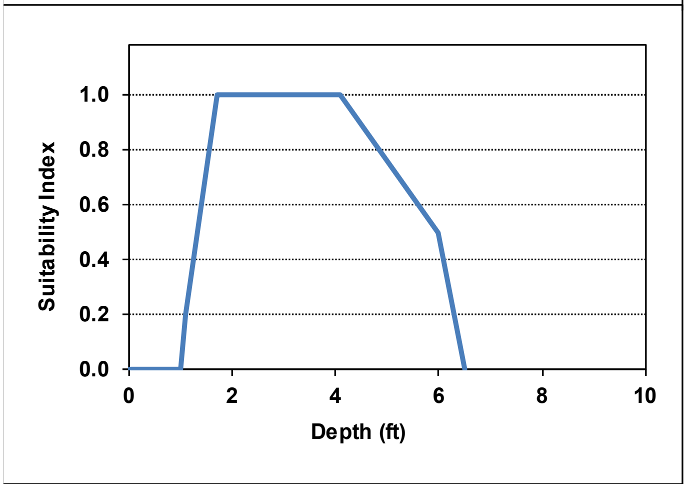
Source:



Based on Bozek et al., 2011

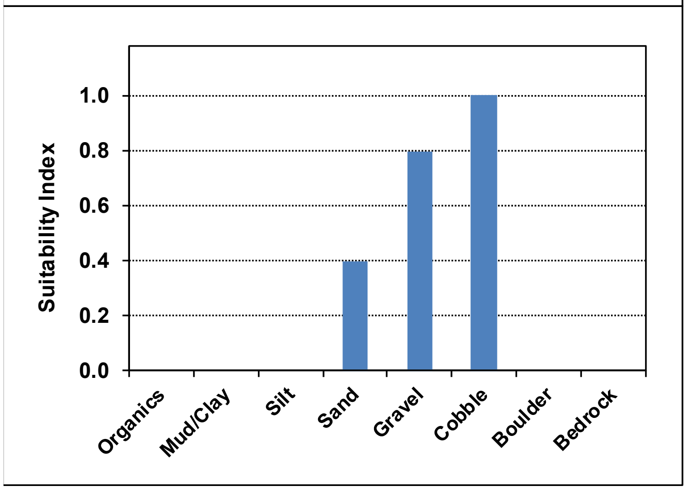
Velocity (ft/s)	SI
0.00	0.10
1.00	0.15
2.00	0.50
2.40	1.00
3.70	1.00
5.00	0.00

endpoint hypothetical



Turners Falls based on Bozek et al., 2011

Depth (ft)	SI
0.00	0.00
1.00	0.00
1.10	0.20
1.70	1.00
4.10	1.00
6.00	0.50
6.50	0.00



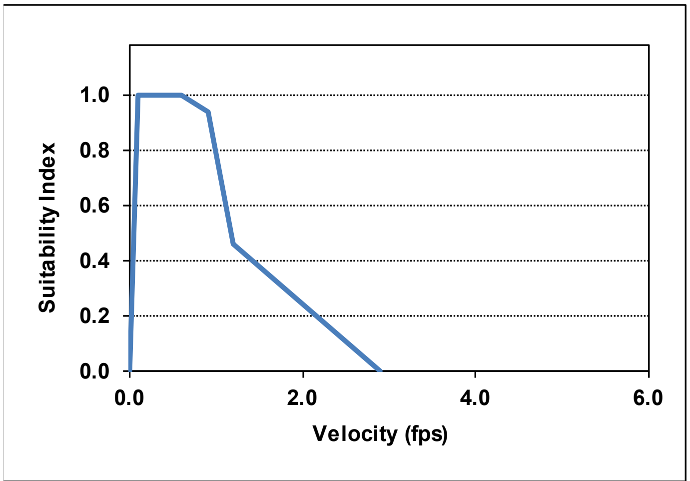
McMahon et al., 1984

Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.40
Gravel	0.80
Cobble	1.00
Boulder	0.00
Bedrock	0.00

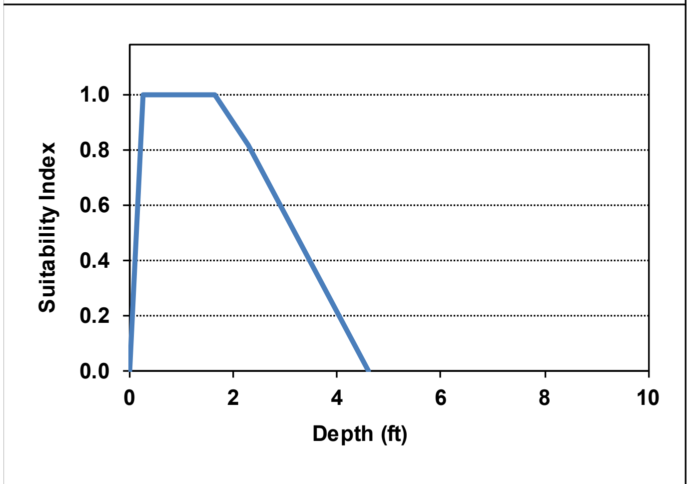
Fallfish Fry

Velocity and depth from brook trout fry curves (Deerfield River)
Substrate developed by Charles Ritzi

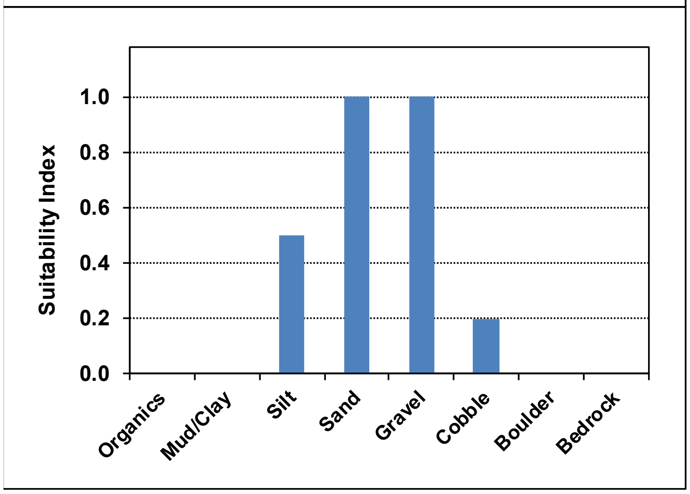
Source:
Gomez and Sullivan, 2007



Velocity (ft/s)	SI
0.00	0.00
0.10	1.00
0.60	1.00
0.90	0.94
1.20	0.46
2.90	0.00



Depth (ft)	SI
0.00	0.00
0.25	1.00
1.65	1.00
2.30	0.82
4.60	0.00
100.00	0.00

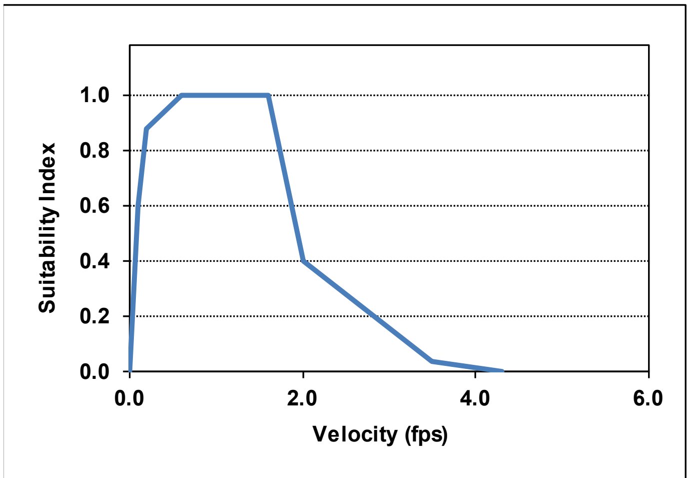


Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.50
Sand	1.00
Gravel	1.00
Cobble	0.20
Boulder	0.00
Bedrock	0.00

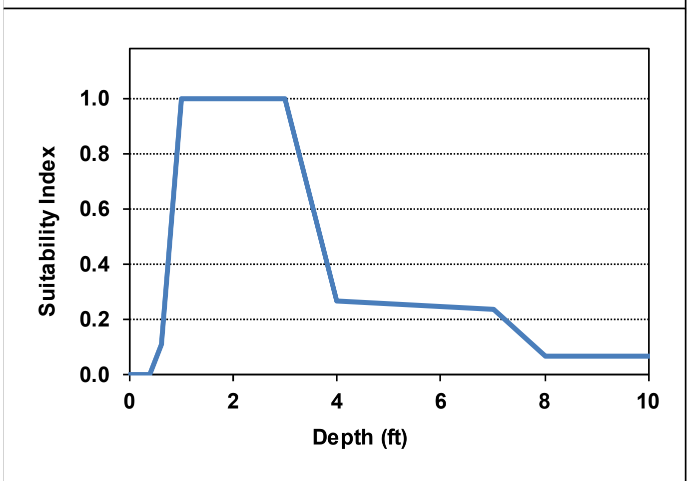
Fallfish Juvenile

Velocity and depth from brook trout fry curves (Deerfield River)
Substrate developed by Charles Ritzi

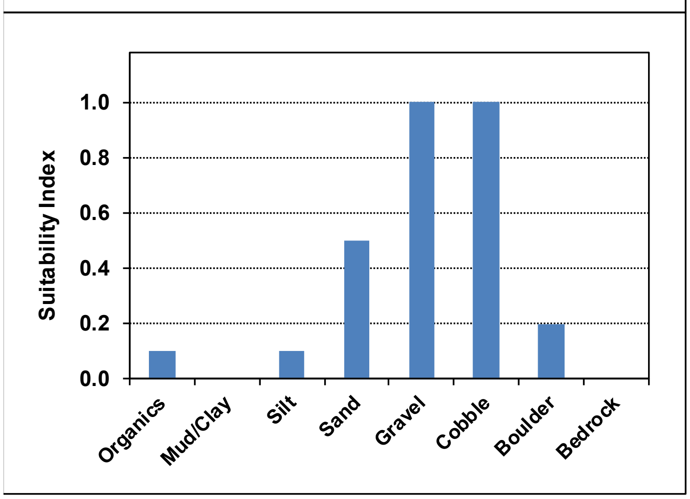
Source:
Gomez and Sullivan, 2007



Velocity (ft/s)	SI
0.00	0.00
0.10	0.60
0.20	0.88
0.60	1.00
1.60	1.00
2.00	0.40
3.50	0.04
4.30	0.00



Depth (ft)	SI
0.00	0.00
0.40	0.00
0.60	0.11
1.00	1.00
3.00	1.00
4.00	0.27
7.00	0.24
8.00	0.07
20.00	0.07
100.00	0.07

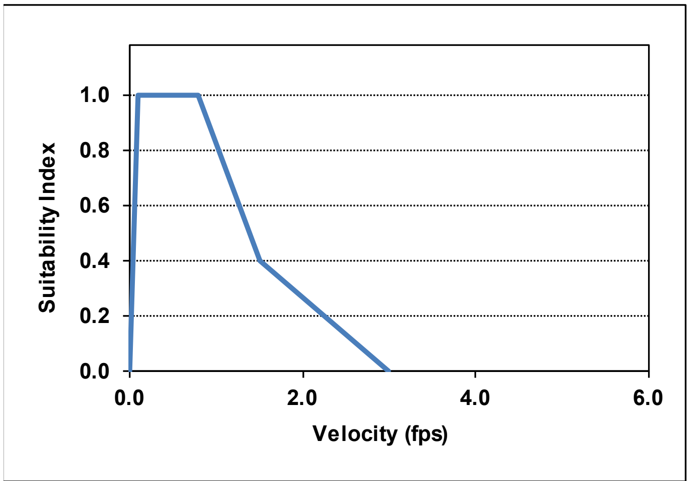


Substrate	SI
Organics	0.10
Mud/Clay	0.00
Silt	0.10
Sand	0.50
Gravel	1.00
Cobble	1.00
Boulder	0.20
Bedrock	0.00

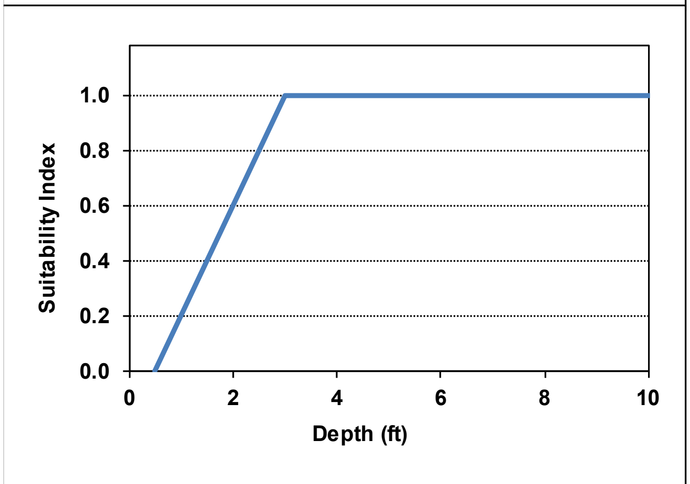
Fallfish Adult

Developed from consultation with NYSDEC
(New York Dept. of Environmental Conservation)

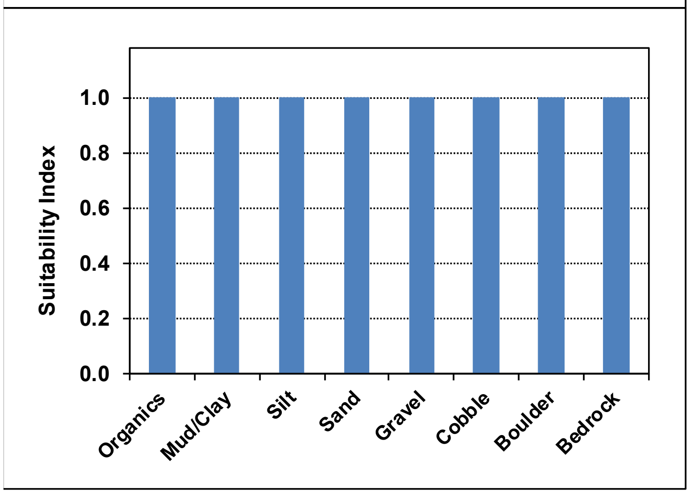
Source:
Gomez and Sullivan, 2007



Velocity (ft/s)	SI
0.00	0.00
0.10	1.00
0.80	1.00
1.50	0.40
3.00	0.00



Depth (ft)	SI
0.00	0.00
0.50	0.00
3.00	1.00
100.00	1.00

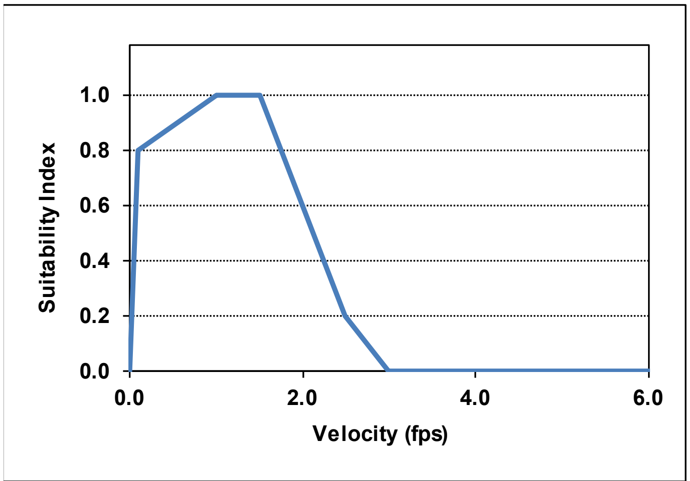


Substrate	SI
Organics	1.00
Mud/Clay	1.00
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	1.00
Bedrock	1.00

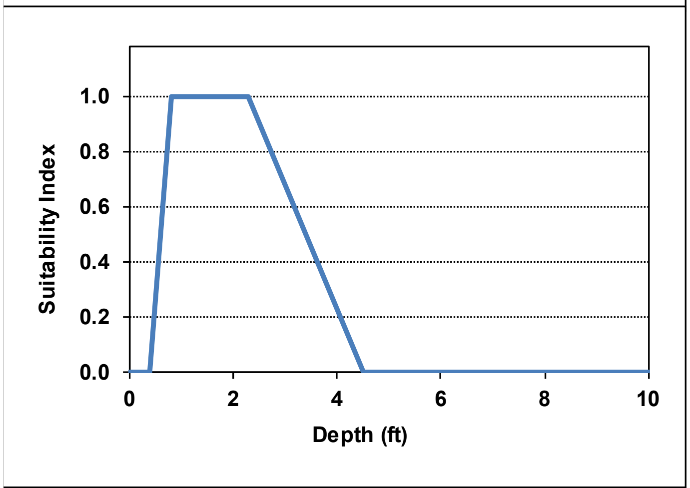
Fallfish Spawning & Incubation

Developed from consultation with NYSDEC
(New York Dept. of Environmental Conservation)

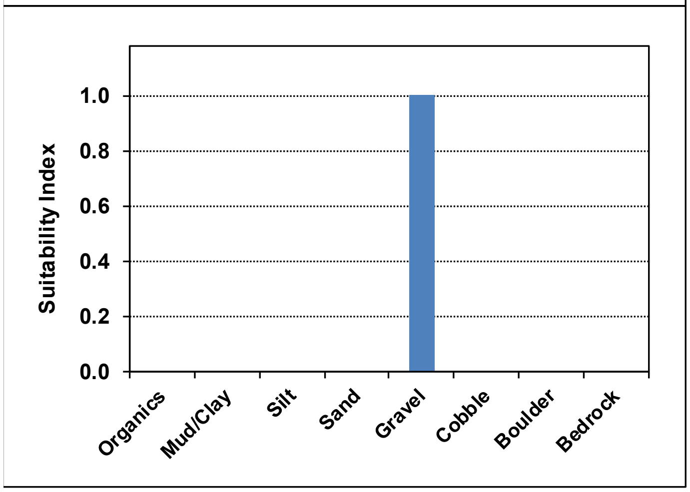
Source:
Gomez and Sullivan, 2007



Velocity (ft/s)	SI
0.00	0.00
0.10	0.80
1.00	1.00
1.50	1.00
2.50	0.20
3.00	0.00
100.00	0.00



Depth (ft)	SI
0.00	0.00
0.40	0.00
0.80	1.00
2.30	1.00
4.50	0.00
100.00	0.00

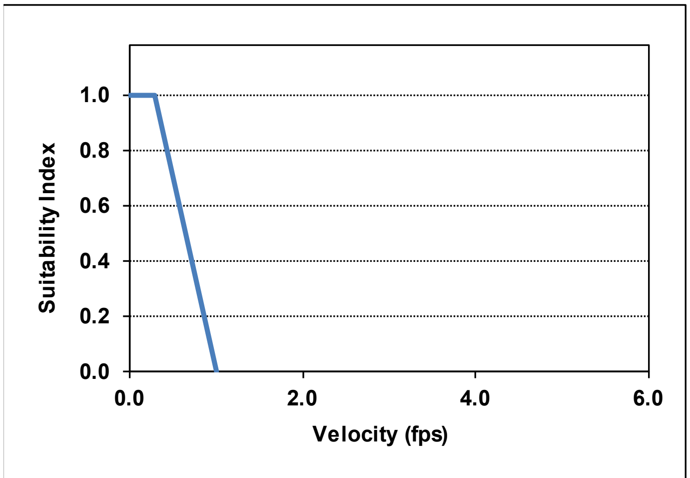


Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.00
Gravel	1.00
Cobble	0.00
Boulder	0.00
Bedrock	0.00

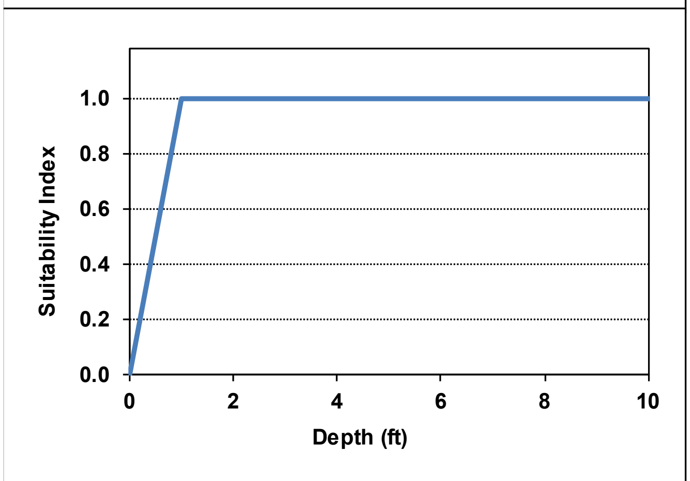
White Sucker Fry

Source:

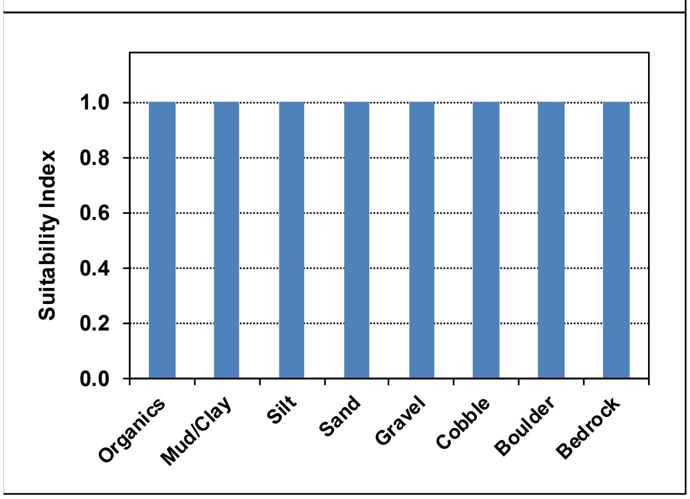
Twomey et al., 1984



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



Depth (ft)	SI
0.00	0.00
1.00	1.00
100.00	1.00

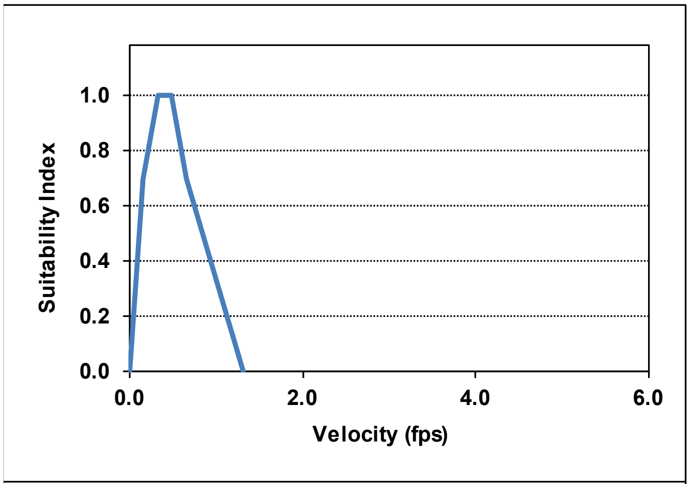


Substrate	SI
Organics	1.00
Mud/Clay	1.00
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	1.00
Bedrock	1.00

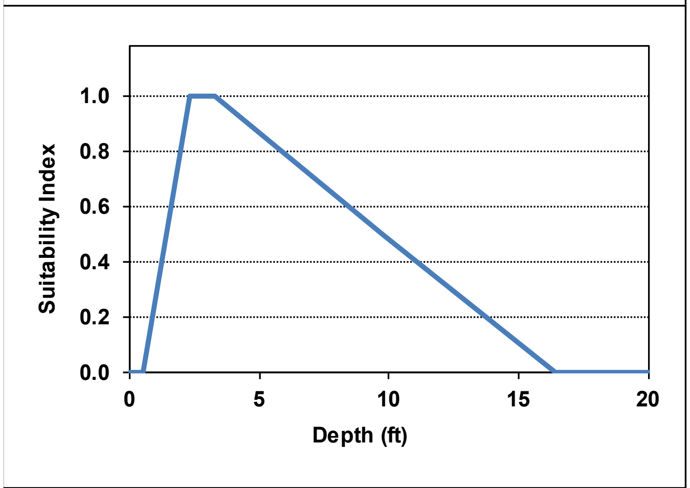
White Sucker Adult/Juvenile

Source:

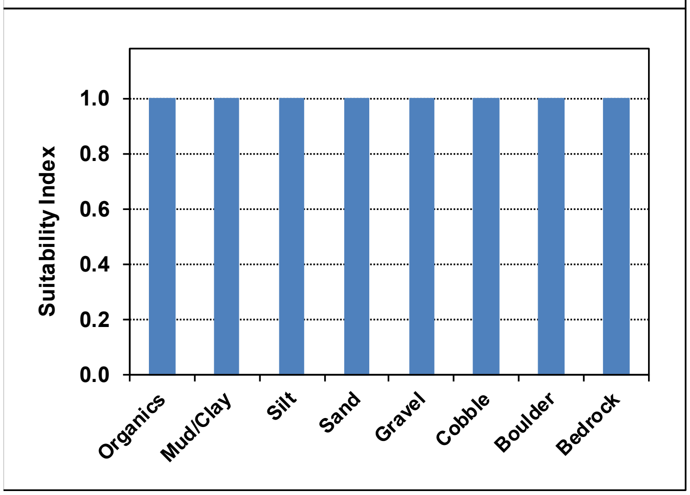
Twomey et al., 1984



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



Depth (ft)	SI
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

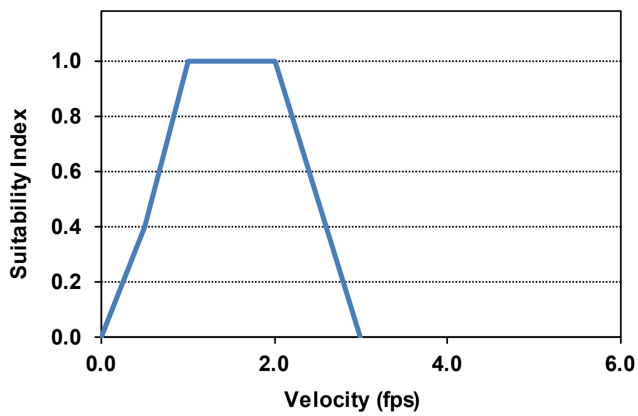


Substrate	SI
Organics	1.00
Mud/Clay	1.00
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	1.00
Bedrock	1.00

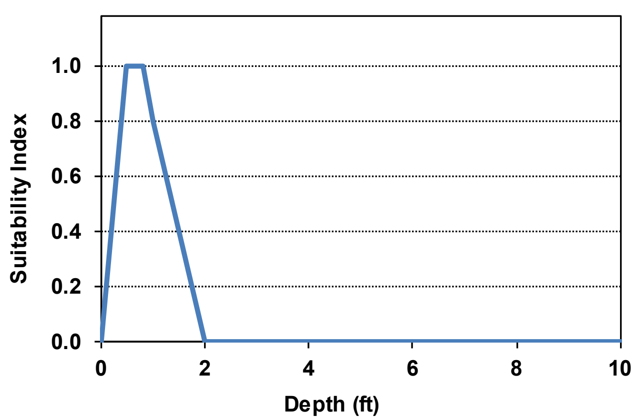
White Sucker Spawning & Incubation

Source:

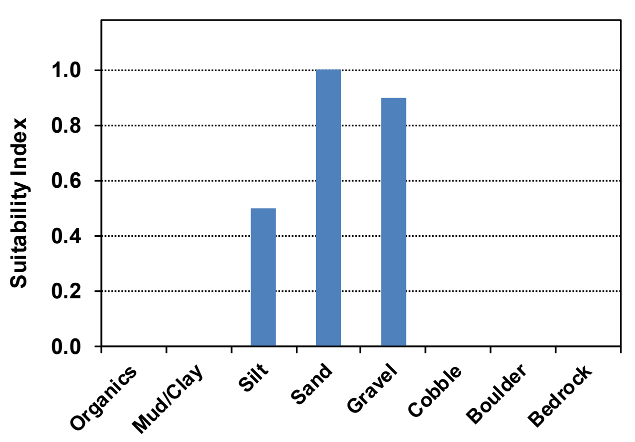
Twomey et al., 1984



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



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



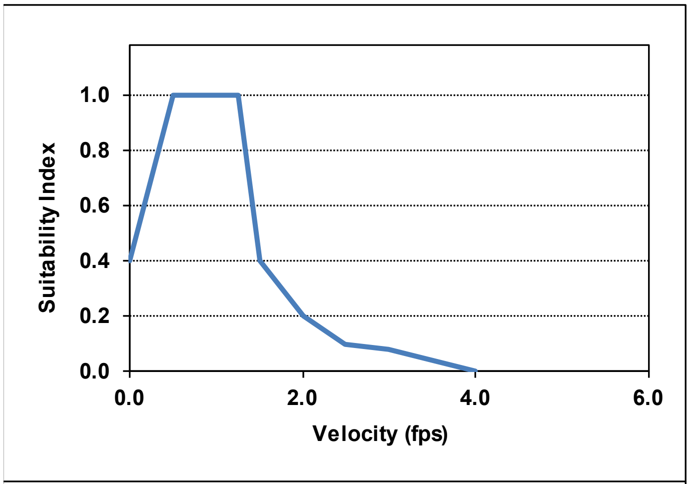
Substrate Source:
Gomez and Sullivan, 2007

Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.50
Sand	1.00
Gravel	0.90
Cobble	0.00
Boulder	0.00
Bedrock	0.00

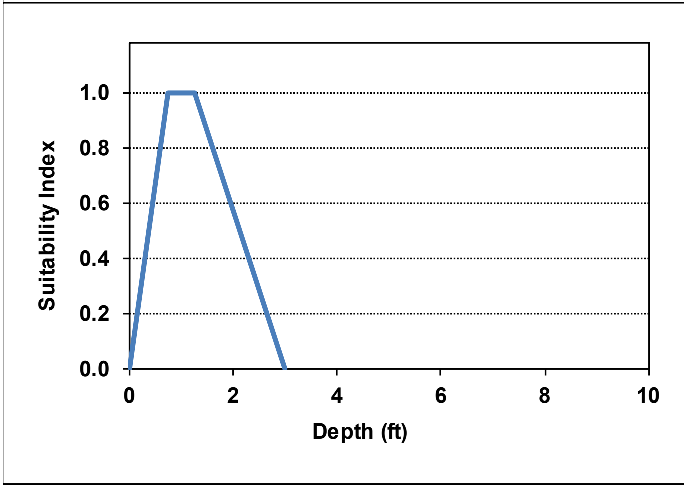
Longnose Dace Fry

Original curve identified as from USFWS HSC library
Modified by VDFW for the Lamoille River IFS (Gomez and Sullivan, 2000)

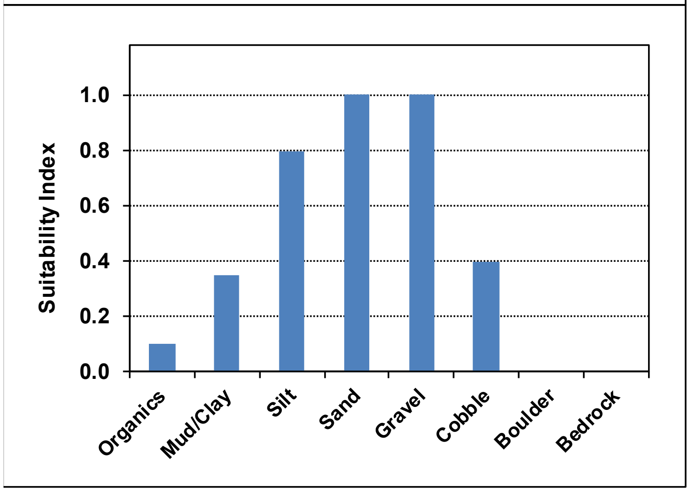
Source:
Gomez and Sullivan, 2007



Velocity (ft/s)	SI
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



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

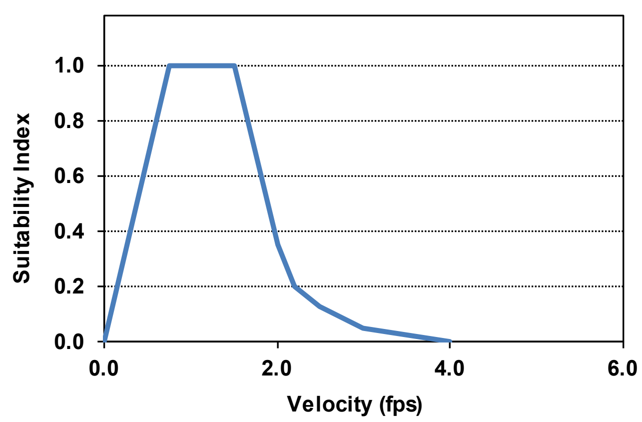


Substrate	SI
Organics	0.10
Mud/Clay	0.35
Silt	0.80
Sand	1.00
Gravel	1.00
Cobble	0.40
Boulder	0.00
Bedrock	0.00

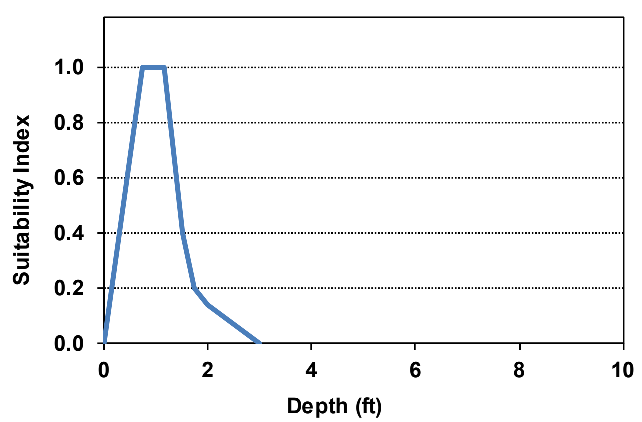
Longnose Dace Juvenile

Original curve identified as from USFWS HSC library
Modified by VDFW for the Lamoille River IFS (Gomez and Sullivan, 2000)

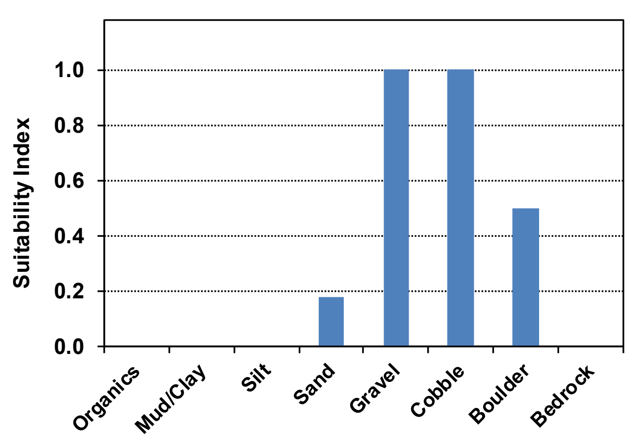
Source:
Gomez and Sullivan, 2000



Velocity (ft/s)	SI
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



Depth (ft)	SI
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

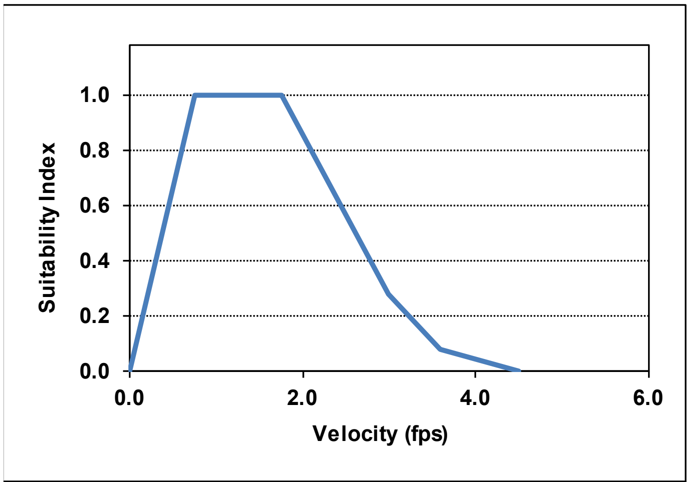


Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.18
Gravel	1.00
Cobble	1.00
Boulder	0.50
Bedrock	0.00

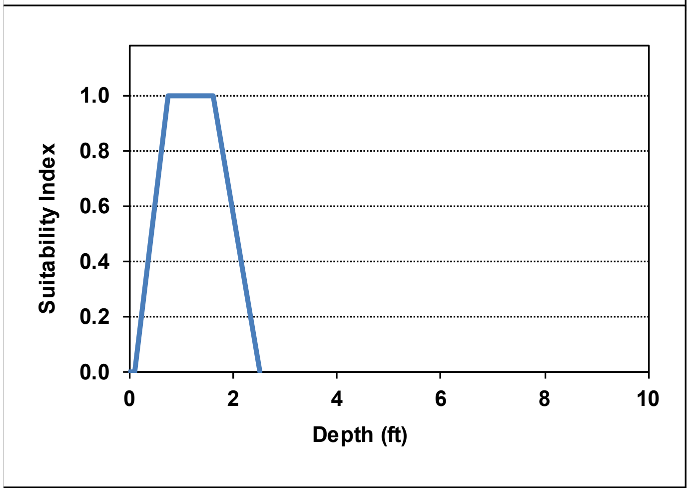
Longnose Dace Adult

Original curve identified as from USGS HSC library
Modified by VDFW for the Lamoille River IFS (Gomez and Sullivan, 2000)

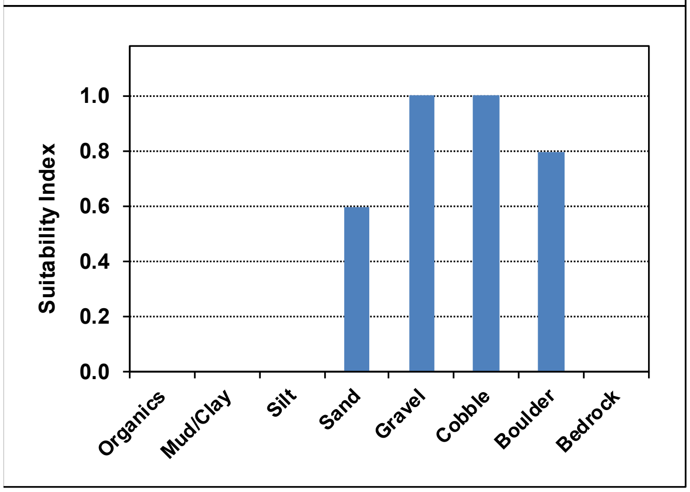
Source:
Gomez and Sullivan, 2000



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



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



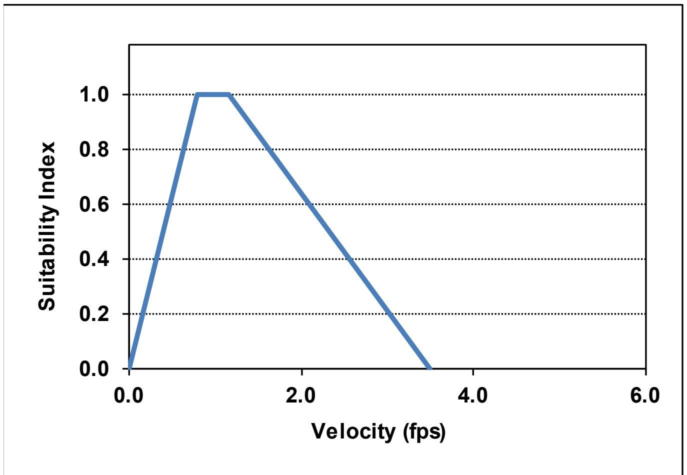
Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.60
Gravel	1.00
Cobble	1.00
Boulder	0.80
Bedrock	0.00

Tessellated Darter Adult

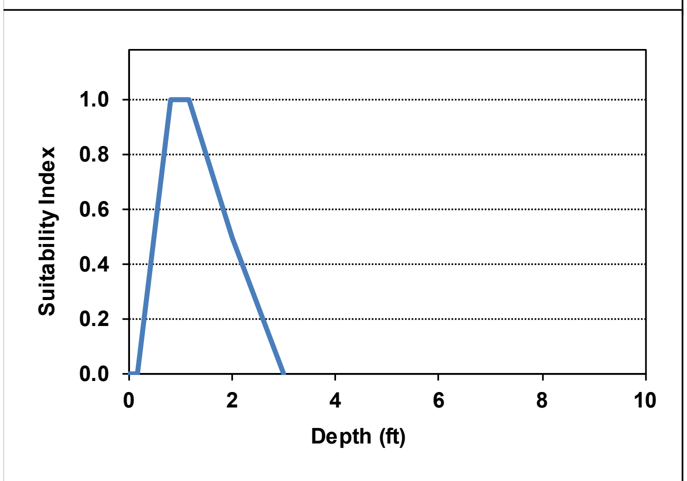
Modified by VDFW (2015) using sources

Source:

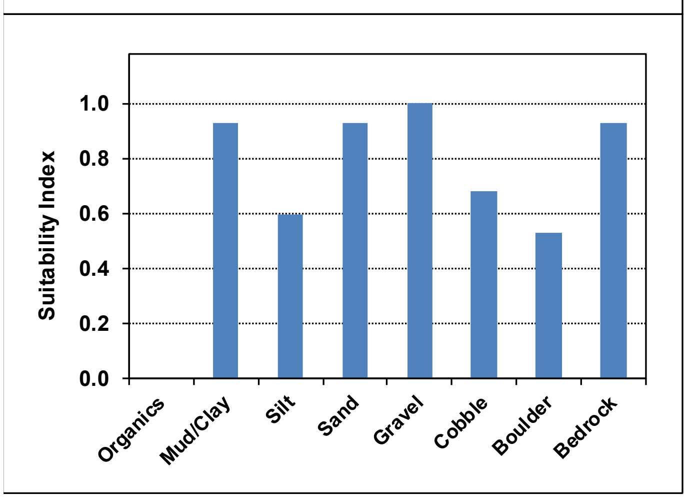
Warner et al. 2006,
Aadland and Kuitunen 2006



Velocity (ft/s)	SI
0.00	0.00
0.80	1.00
1.15	1.00
3.50	0.00



Depth (ft)	SI
0.00	0.00
0.16	0.00
0.80	1.00
1.15	1.00
2.00	0.50
3.00	0.00



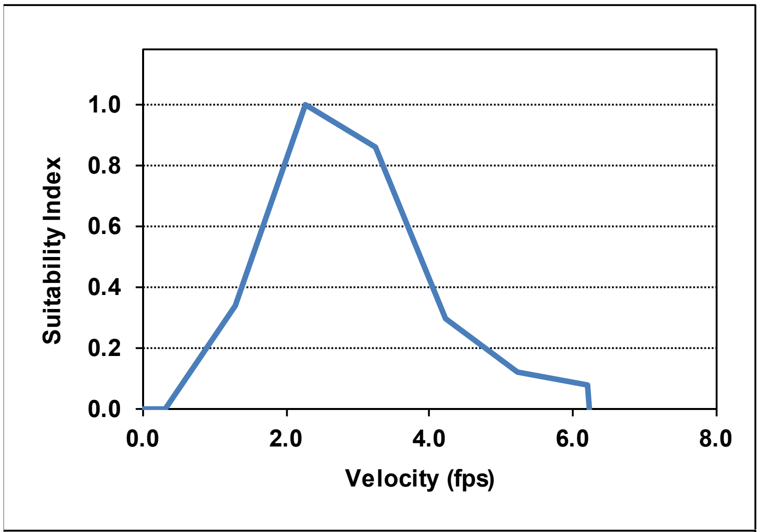
Substrate Source: Aadland and Kuitunen, 2006
Johnny Darter- Surrogate for Tessellated Darter
(PPL Bell Bend 2012)

Substrate	SI
Organics	0.00
Mud/Clay	0.93
Silt	0.60
Sand	0.93
Gravel	1.00
Cobble	0.68
Boulder	0.53
Bedrock	0.93

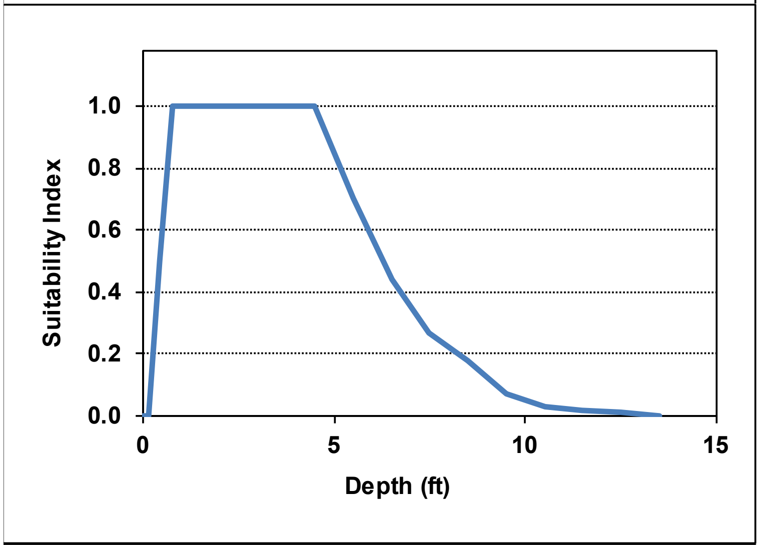
Sea Lamprey Spawning & Incubation

Modified by USFWS (2014) based on Yergeau 1983 (substrate)
Modified by NAI (2017) based on observations (depth)

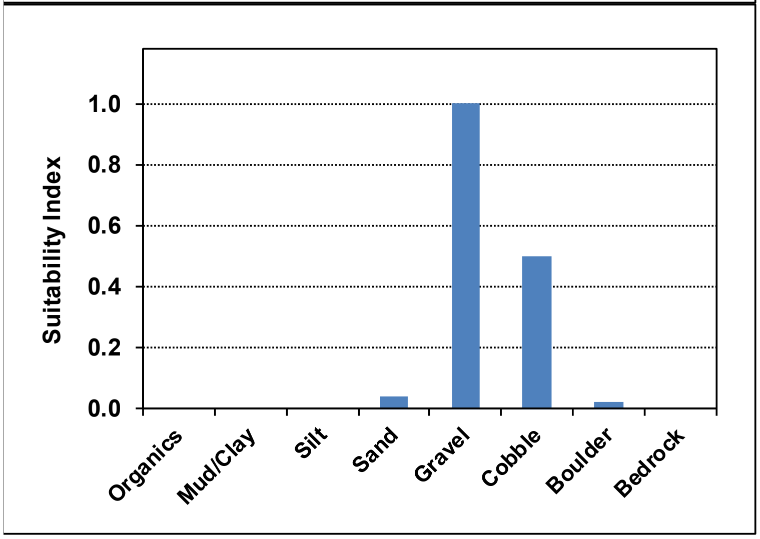
Source:
Kynard and Horgan, 2013
Yergeau, 1983



Velocity (ft/s)	SI
0.00	0.00
0.30	0.00
1.28	0.34
2.26	1.00
3.25	0.86
4.23	0.30
5.22	0.12
6.20	0.08
6.23	0.00



Depth (ft)	SI
0.00	0.00
0.13	0.00
0.46	0.50
0.79	1.00
4.50	1.00
5.50	0.70
6.50	0.44
7.50	0.27
8.50	0.18
9.50	0.07
10.50	0.03
11.50	0.02
12.50	0.01
13.50	0.00

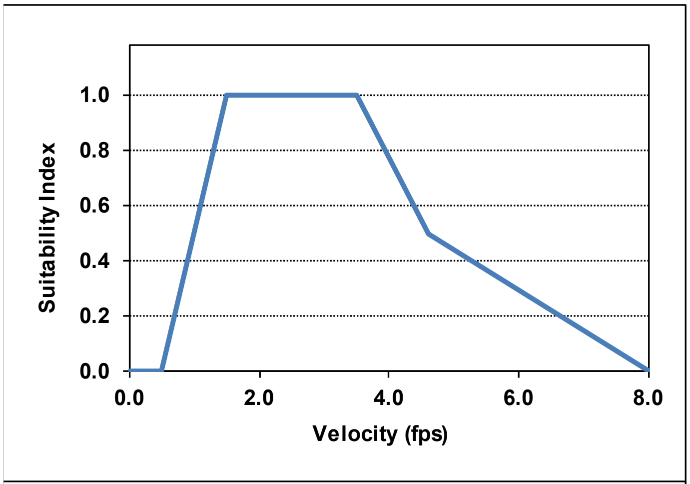


Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.04
Gravel	1.00
Cobble	0.50
Boulder	0.02
Bedrock	0.00

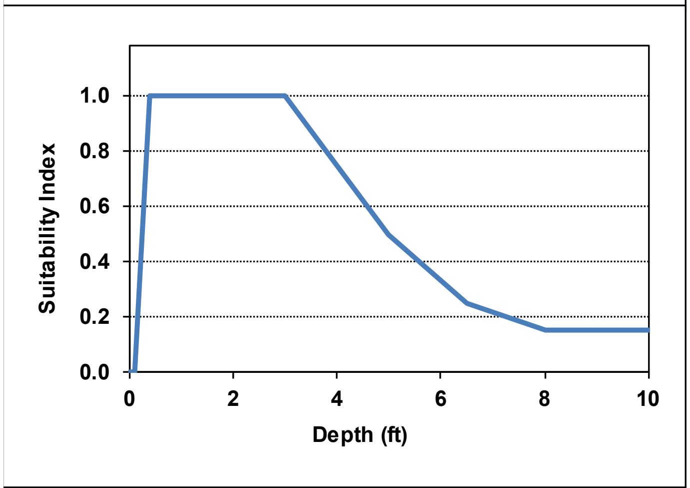
Macroinvertebrates

Source:

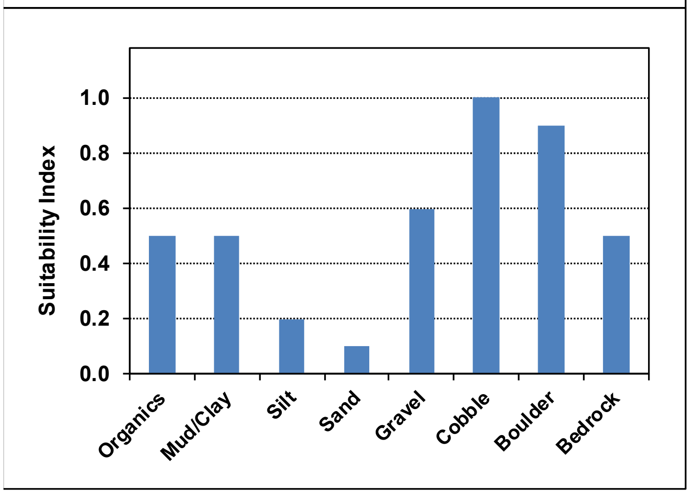
Gomez and Sullivan, 2000



Velocity (ft/s)	SI
0.00	0.00
0.50	0.00
1.50	1.00
3.50	1.00
4.60	0.50
8.00	0.00



Depth (ft)	SI
0.00	0.00
0.10	0.00
0.40	1.00
3.00	1.00
5.00	0.50
6.50	0.25
8.00	0.15
10.00	0.15
100.00	0.00

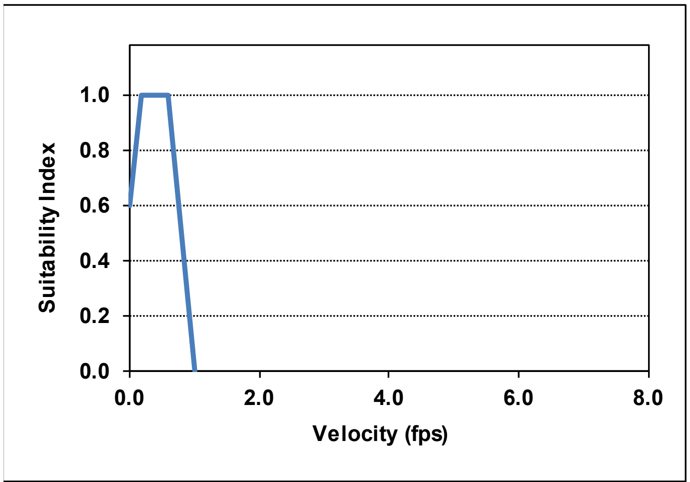


Substrate	SI
Organics	0.50
Mud/Clay	0.50
Silt	0.20
Sand	0.10
Gravel	0.60
Cobble	1.00
Boulder	0.90
Bedrock	0.50

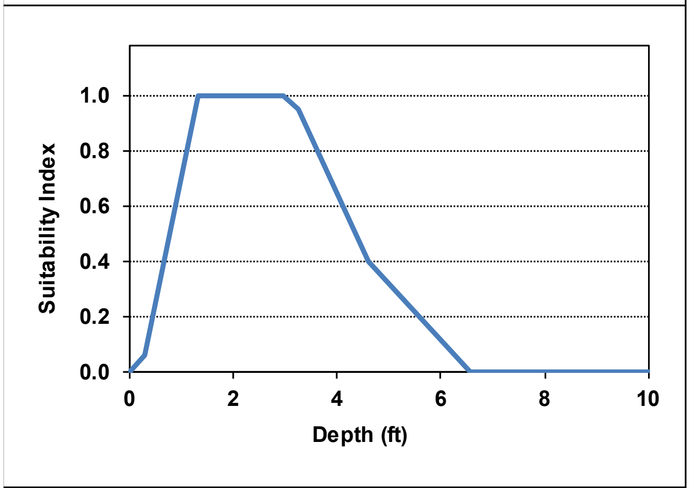
Smallmouth Bass Fry

Source:

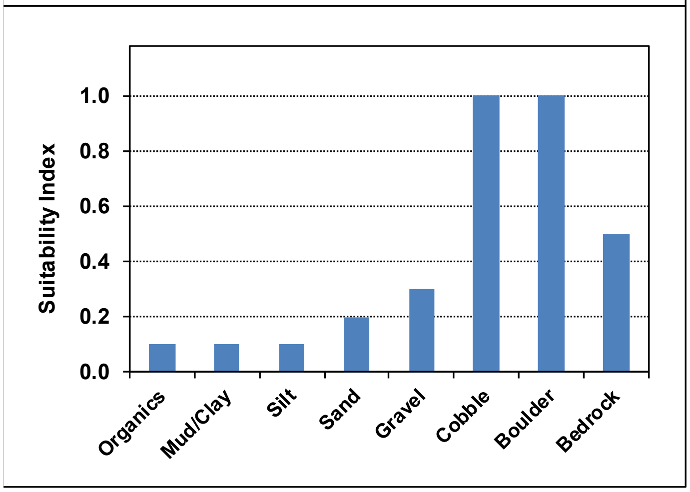
Leonard et al, 1986



Velocity (ft/s)	SI
0.00	0.60
0.19	1.00
0.59	1.00
1.00	0.00

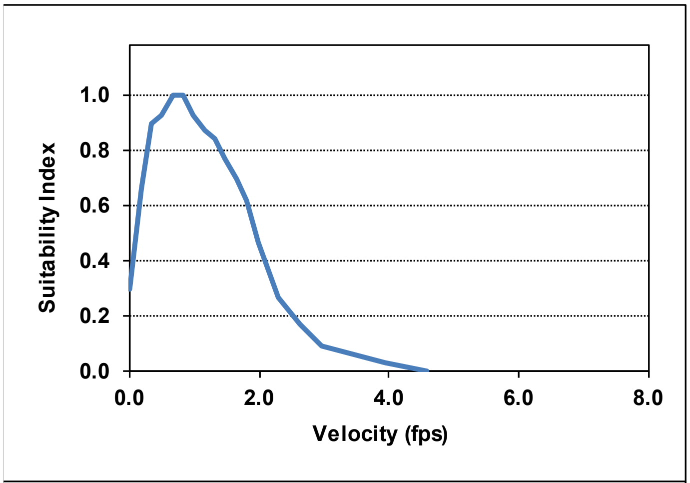


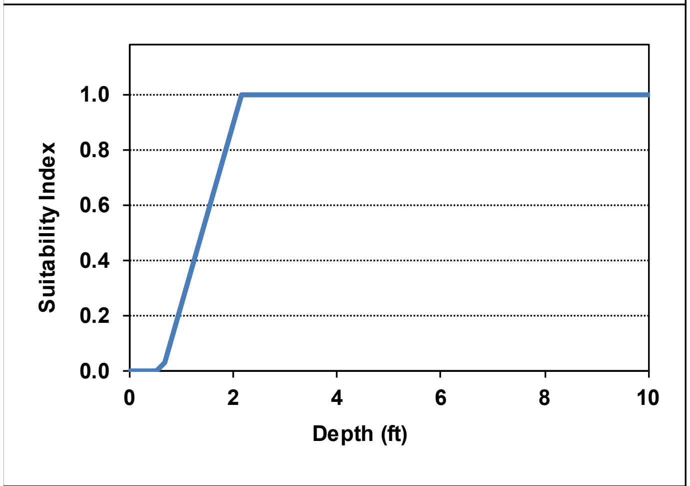
Depth (ft)	SI
0.00	0.00
0.28	0.06
1.31	1.00
2.95	1.00
3.25	0.95
4.59	0.40
6.56	0.00
10.00	0.00

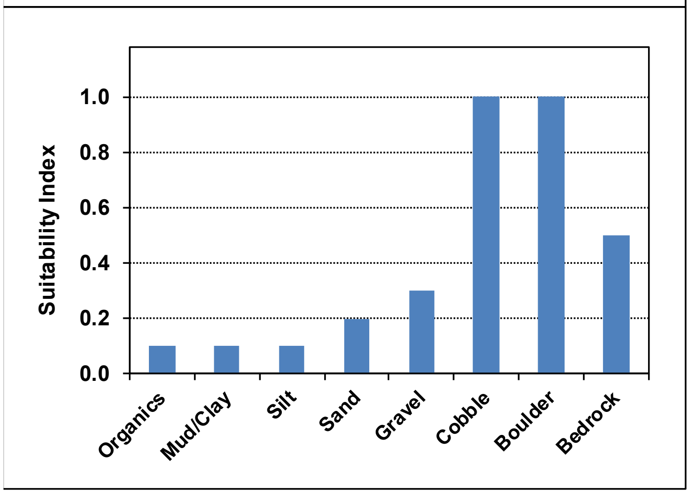


Substrate	SI
Organics	0.10
Mud/Clay	0.10
Silt	0.10
Sand	0.20
Gravel	0.30
Cobble	1.00
Boulder	1.00
Bedrock	0.50

Smallmouth Bass Juvenile







Source:

Groshens and Orth 1994

Velocity (ft/s)	SI
0.00	0.30
0.17	0.66
0.33	0.90
0.50	0.93
0.66	1.00
0.83	1.00
0.98	0.93
1.15	0.87
1.31	0.84
1.47	0.77
1.64	0.70
1.81	0.62
1.98	0.47
2.30	0.27
2.62	0.17
2.95	0.09
3.94	0.03
4.59	0.00

Leonard et al, 1986

Depth (ft)	SI
0.00	0.00
0.52	0.00
0.67	0.03
2.15	1.00
10.00	1.00

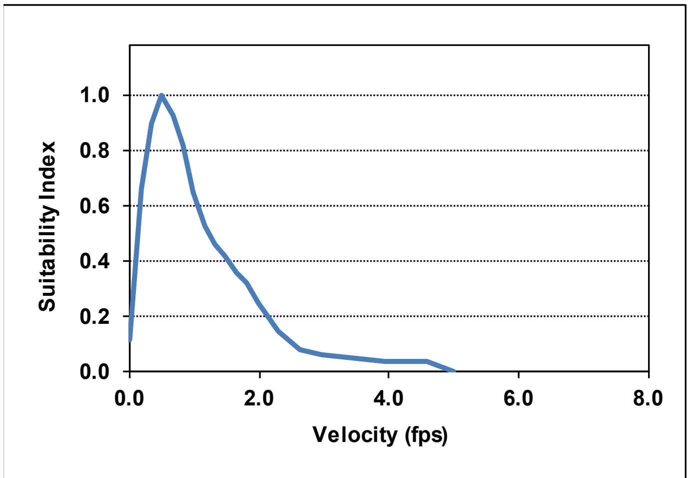
Leonard et al, 1986

Substrate	SI
Organics	0.10
Mud/Clay	0.10
Silt	0.10
Sand	0.20
Gravel	0.30
Cobble	1.00
Boulder	1.00
Bedrock	0.50

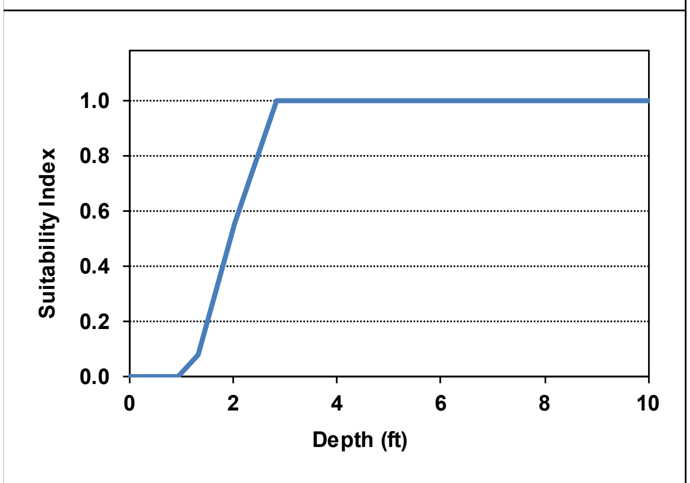
Smallmouth Bass Adult

Source:

Groshens and Orth 1994

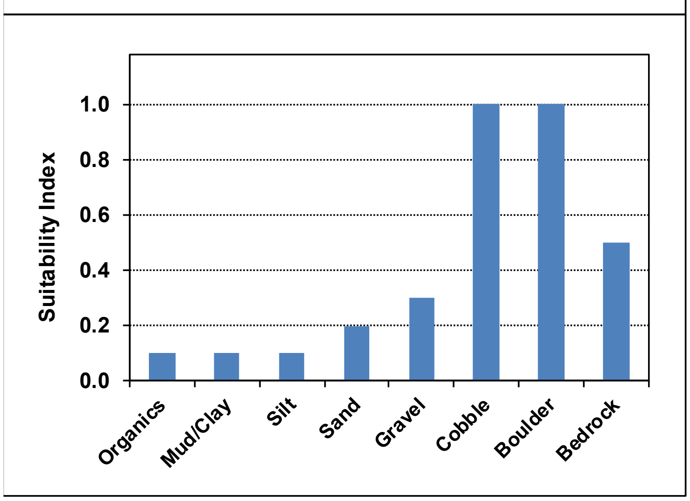


Velocity (ft/s)	SI
0.00	0.12
0.17	0.66
0.33	0.90
0.50	1.00
0.66	0.93
0.83	0.82
0.98	0.65
1.15	0.53
1.31	0.46
1.47	0.42
1.64	0.36
1.81	0.32
1.98	0.25
2.30	0.15
2.62	0.08
2.95	0.06
3.94	0.04
4.59	0.04
5.00	0.00



Leonard et al, 1986

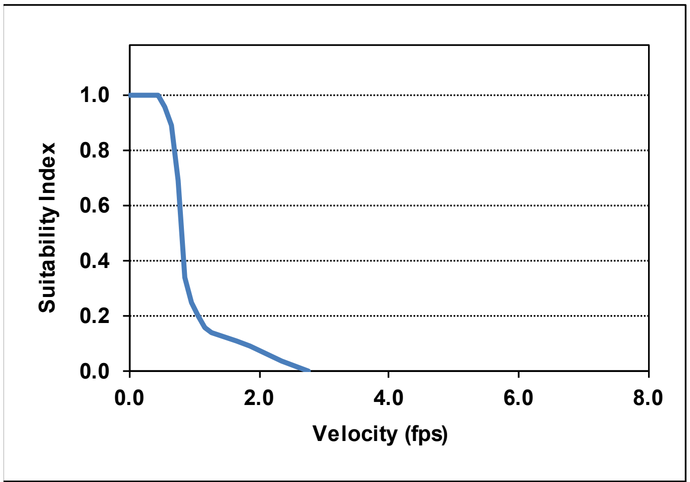
Depth (ft)	SI
0.00	0.00
0.92	0.00
1.31	0.08
2.03	0.56
2.82	1.00
6.00	1.00
10.00	1.00

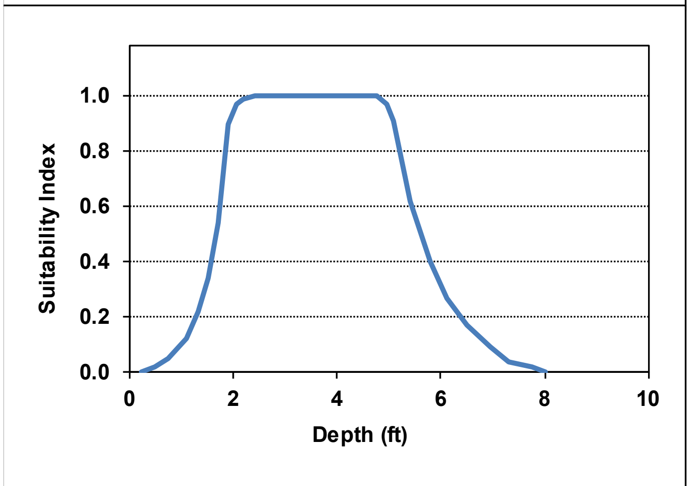


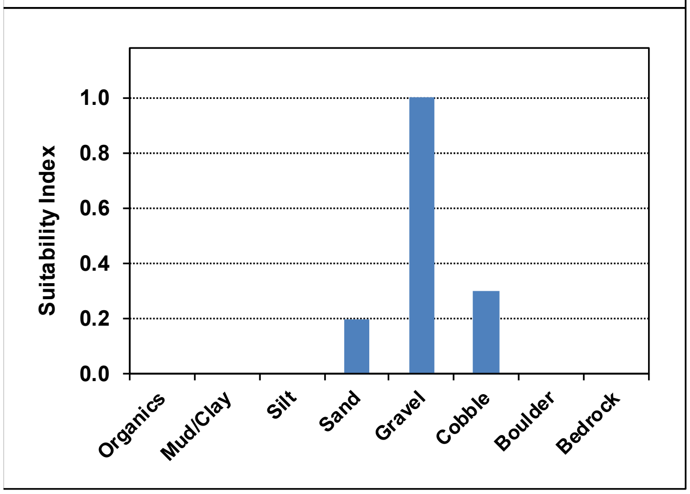
Leonard et al, 1986

Substrate	SI
Organics	0.10
Mud/Clay	0.10
Silt	0.10
Sand	0.20
Gravel	0.30
Cobble	1.00
Boulder	1.00
Bedrock	0.50

Smallmouth Bass Spawning







Source:

Allen, 1996

Velocity (ft/s)	SI
0.00	1.00
0.45	1.00
0.55	0.96
0.65	0.89
0.75	0.69
0.85	0.34
0.95	0.25
1.05	0.20
1.15	0.16
1.25	0.14
1.65	0.11
1.85	0.09
2.35	0.04
2.55	0.02
2.75	0.00

Edwards et al., 1983

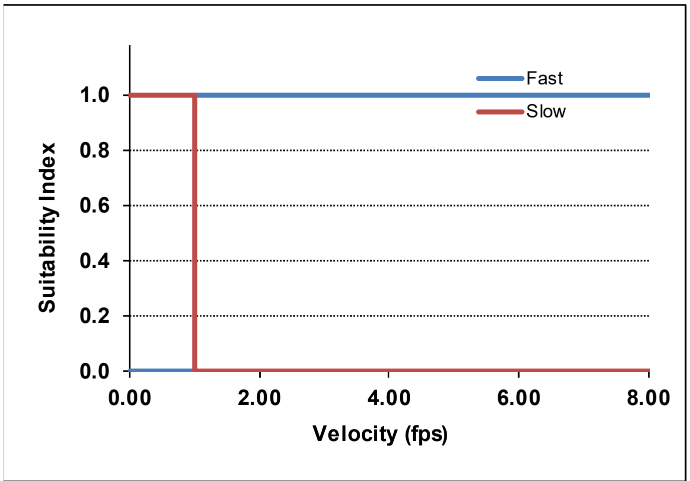
Depth (ft)	SI
0.22	0.00
0.50	0.02
0.74	0.05
1.10	0.12
1.32	0.22
1.53	0.34
1.70	0.54
1.90	0.90
2.05	0.97
2.18	0.99
2.40	1.00
4.75	1.00
4.95	0.97
5.10	0.91
5.40	0.62
5.80	0.40
6.10	0.27
6.50	0.17
6.95	0.09
7.30	0.04
7.75	0.02
8.00	0.00

Allen, 1996

Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.20
Gravel	1.00
Cobble	0.30
Boulder	0.00
Bedrock	0.00

Generalized Habitat Criteria (GHC)

Source:
VDFW

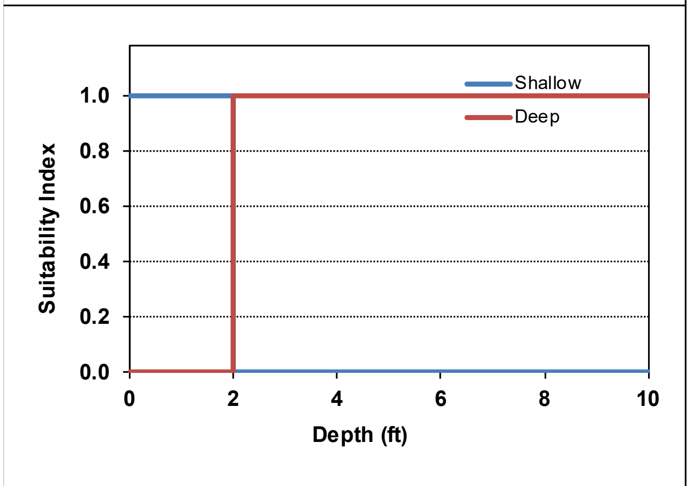


Fast

Velocity (ft/s)	SI
0.00	0.00
1.00	0.00
1.01	1.00
10.00	1.00

Slow

Velocity (ft/s)	SI
0.00	1.00
1.00	1.00
1.01	0.00
10.00	0.00

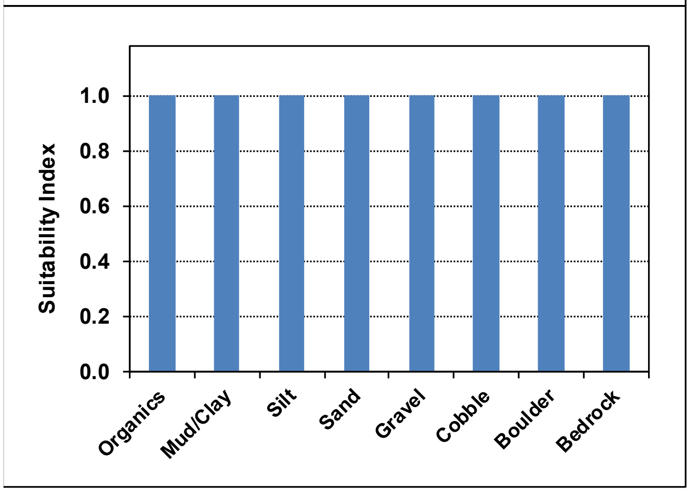


Shallow

Depth (ft)	SI
0.00	1.00
2.00	1.00
2.01	0.00
10.00	0.00

Deep

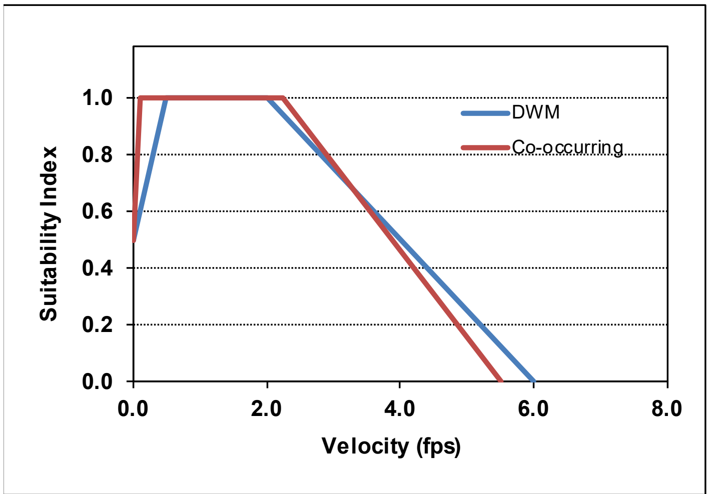
Depth (ft)	SI
0.00	0.00
2.00	0.00
2.01	1.00
100.00	1.00



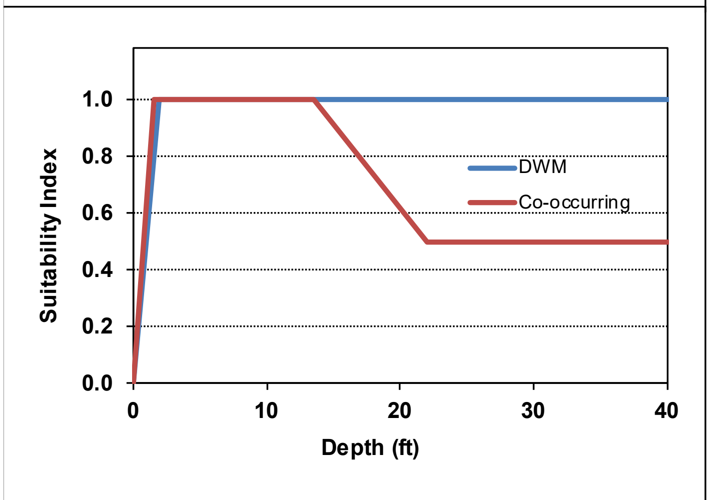
Substrate	SI
Organics	1.00
Mud/Clay	1.00
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	1.00
Bedrock	1.00

Mussels - Dwarf Wedgemussel (DWM)
Co-Occurring

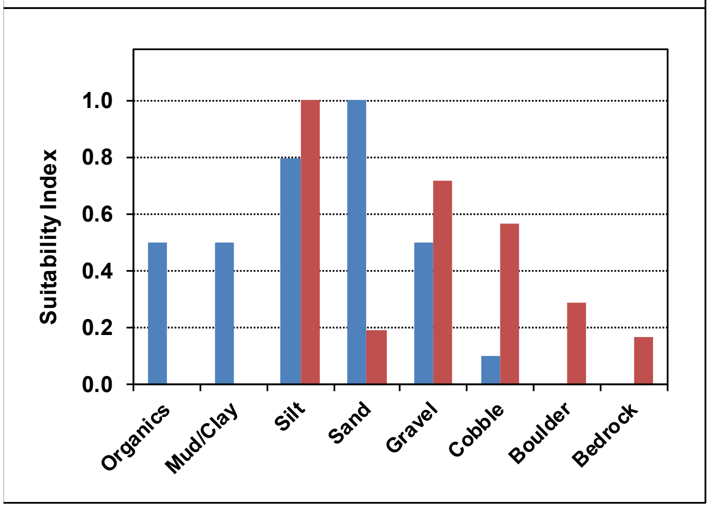
Source:	DWM	Co-0ccurring
	Normandeau and Biodrawversity 2016	Normandeau and Biodrawversity 2017



DWM		Co-occurring	
MCV (ft/s)	SI	MCV (ft/s)	SI
0.00	0.50	0.00	0.50
0.50	1.00	0.10	1.00
2.00	1.00	2.25	1.00
6.00	0.00	5.50	0.00



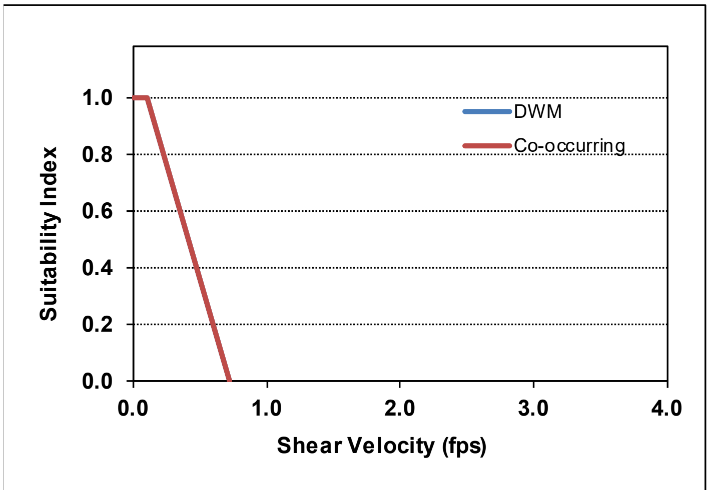
DWM		Co-occurring	
Depth (ft)	SI	Depth (ft)	SI
0.00	0.00	0.00	0.00
2.00	1.00	1.50	1.00
40.00	1.00	13.50	1.00
100.00	1.00	22.00	0.50
		30.00	0.50
		100	0.5



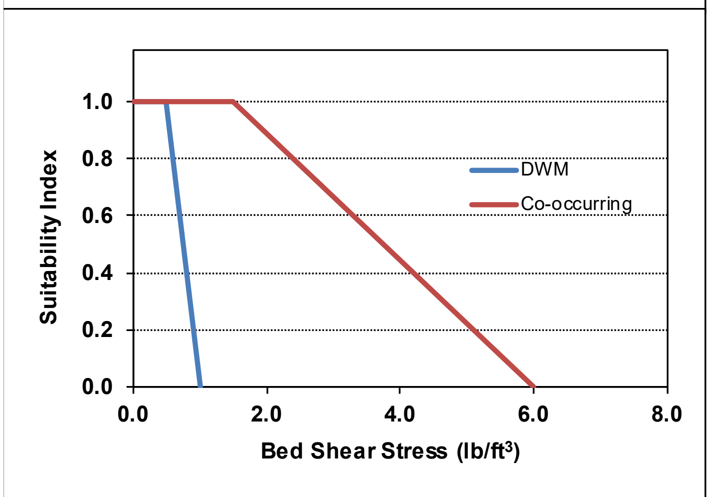
DWM		Co-occurring	
Substrate	SI	Substrate	SI
Organics	0.50	Organics	0.00
Mud/Clay	0.50	Mud/Clay	0.00
Silt	0.80	Silt	1.00
Sand	1.00	Sand	0.19
Gravel	0.50	Gravel	0.72
Cobble	0.10	Cobble	0.57
Boulder	0.00	Boulder	0.29
Bedrock	0.00	Bedrock	0.17

Mussels - Dwarf Wedgemussel (DWM)
Co-Occurring

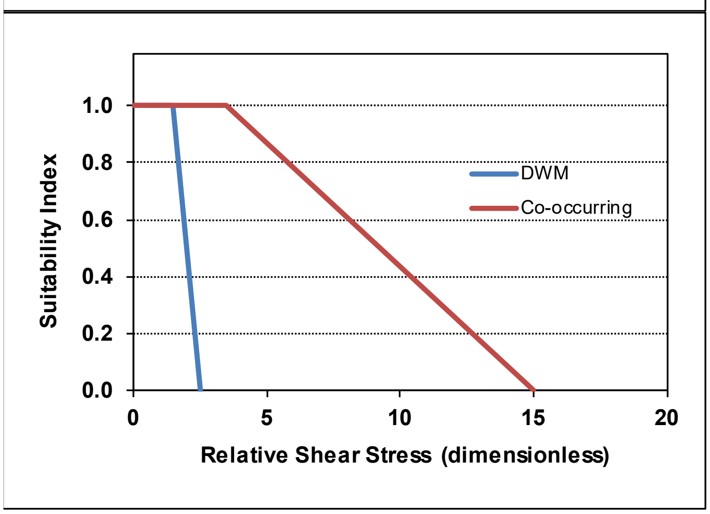
Source: DWM Normandeau and Biodrawversity 2016; Co-0ccurring Normandeau and Biodrawversity 2017



DWM		Co-occurring	
Velocity (ft/s)	SI	Velocity (ft/s)	SI
0.00	1.00	0.00	1.00
0.10	1.00	0.10	1.00
0.72	0.00	0.72	0.00

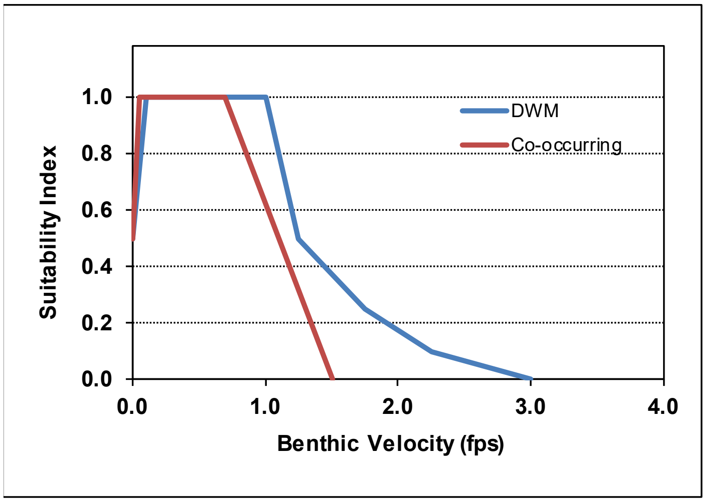


DWM		Co-occurring	
SS (lb/ft^3)	SI	SS (lb/ft^3)	SI
0.00	1.00	0.00	1.00
0.50	1.00	1.50	1.00
1.00	0.00	6.00	0.00



DWM		Co-occurring	
RSS	SI	RSS	SI
0	1.00	0	1.00
1.5	1.00	3.5	1.00
2.5	0.00	15	0.00

Mussels - Dwarf Wedgemussel (DWM)
Co-Occurring



Source:	DWM	Co-0ccurring
	Normandeau and Biodrawversity 2016	Normandeau and Biodrawversity 2017

DWM		Co-occurring	
Velocity (ft/s)	SI	Velocity (ft/s)	SI
0.00	0.50	0.00	0.50
0.10	1.00	0.05	1.00
1.00	1.00	0.70	1.00
1.25	0.50	1.50	0.00
1.75	0.25		
2.25	0.10		
3.00	0.00		

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