Lopas, Sarah

From: Palmrose, Donald
Sent: Friday, September 24, 2010 2:53 PM
To: Kuntzleman, Nancy; Doub, Peyton; Masnik, Michael; Barnhurst, Daniel; Lopas, Sarah
Subject: FW: HAR Project In-stream Flow Studies - Final Habitat Suitability Criteria (HSC) Technical Memo
Attachments: HAR Instream Flow Study_HSC Information_Revised 09-15-10.doc; DWQ_BenthicColl_CFR.xls; COLA_macroinvertebrate species list.doc; COLA_macroinvertebrate species list.docx

Checking my email for important messages while I am out and thought this would be of interest to you all. If it has information of importance to your PNNL counterpart, please forward to them and let Sarah know.

Please note, I am just forwarding the files and have not opened them. So please let Sarah know if they need to go into ADAMS.

Thanks,
Don

From: Hickok, Linda [mailto:Linda.Hickok@pgnmail.com]
Sent: Wednesday, September 22, 2010 3:18 PM
To: 'Jim Mead (jim.mead@ncdenr.gov)'; 'Tarver, Fred'; 'John_Ellis@fws.gov [John_Ellis@fws.gov]'; ' (mark_bowers@fws.gov)'; 'Vann F. Stancil (vann.stancil@ncwildlife.org)'; 'Goudreau, Chris J. [chris.goudreau@ncwildlife.org]'; Thompson, Thomas; 'Ziegler, Ty'
Cc: Snead, Paul; Kapur, Arun; Palmrose, Donald; Crutchfield, John; 'Matthews, Monte K SAW'
Subject: HAR Project In-stream Flow Studies - Final Habitat Suitability Criteria (HSC) Technical Memo

Greetings - Please find attached the revised Habitat Suitability Criteria (HSC) Technical Memo for the Harris Advanced Reactor In-stream Flow Study per the study group's recommendations at the meeting on August 24, 2010. The following modifications and/or additions have been incorporated into the HSC Technical Memo:

Table 1 – Representative Guilds:

- Clarified/corrected footnotes describing guild criteria
- Added black bullhead (adult, spawning, embryo) to shallow-slow guild
  Note the black bullhead HSC data (Stuber 1982) was compared to the representative guilds and it appears that the shallow-slow guild type 1 (redbreast sunfish spawning) will cover black bullhead preferred summer velocities (assumed to be adult, of which velocity was the only curve available) and spawning/early life stage requirements (only substrate curve available)
- Added notes to indicate HSC curves that are not available for a particular guild/life stage (e.g., cover curves may not be available)

Table 2 – Individual Species / Life stages:

- Clarified which species / life stages would be modeled in each study reach (e.g., added American shad juvenile to Buckhorn Creek reach)
- Switched the second and third columns in table
- Condensed/clarified the reference material for the Carolina redhorse HSC curves
- Added notes to indicate HSC curves that are not available for a particular species/life stage (e.g., cover curves may not be available)

Table 4 – Fish Species Known / Potentially Present:

- Deleted 2009/2010 catch data

Tables 5 & 6 (new) – Breakout of Table 4 into Buckhorn Creek / Cape Fear River Specific Tables:

- Tables include species and numbers collected by Progress Energy (2009-2010) in Buckhorn Creek and the Cape Fear River side channels

Table 7 (new) – Substrate and Cover Information

- Table provides coding system used in the field to identify substrate and cover

Attachment 1:

- Added black bullhead HSC curves
- Added striped bass juvenile HSC curves
- Added Cape Fear shiner HSC curves
- Added notes in Tables 1 and 2 to indicate HSC curves that are not available for a particular guild or species/life stage (e.g., cover curves may not be available)

Attachment 2:

- Extended spawning and early life stage periodicity for American shad;

In addition, per a request during our meeting, we are providing summary results of the macroinvertebrate sampling from 2009/2010. The Word document (COLA macroinvertebrate species list.docx (also provided in .doc format)) contains four tables summarizing the mussel and benthic macroinvertebrate surveys conducted by PEC/NCWRC biologist during 2009. Table 1 list the mussel species observed in Buckhorn Creek and the Cape Fear River. Table 2 compares the mussel species observed during our surveys to extant species in the Cape Fear River basin and their conservation status. Table 3 list the benthic macroinvertebrate taxa collected in Buckhorn Creek and Table 4 summarizes the NCDWQ bioclassification scores we obtained for that data set.

Most benthic macroinvertebrate surveys conducted by NCDWQ were conducted in the tributaries of the Cape Fear River. However, there have been a few surveys conducted in the main channel. The closest to our study area was near the Highway 401 bridge at Lillington, NC. The Excel document summarizes existing benthic macroinvertebrate surveys conducted by DWQ in the main channel of the Cape Fear River at this location. The most recent surveys were conducted during 2002 and 2003.

We think we have captured all of the recommendations and changes requested at our August 24 meeting in this revised HSC Technical Memo. If, after reviewing, you have additional questions please let us know. We'd appreciate a response by September 30, 2010 either requesting additional clarifications or confirming that we have accurately captured your comments from the meeting. We are moving forward with the modeling phase of the study using the information presented in this Technical Memo.
As always, we appreciate your continued interest and participation in these studies.

Thanks!
Linda

Linda Drisko Hickok
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Memo

To:	Linda Hickok Lead Environmental Specialist, Progress Energy Carolinas		
From:	Matt McKinney Fisheries Scientist, HDR|DTA	Project:	Buckhorn Creek and Cape Fear River Instream Flow Studies
CC:	Tom Thompson, Fisheries Scientist, Progress Energy Carolinas Ty Ziegler, Environmental Engineering Manager, HDR|DTA		
Date:	September 15, 2010	Job No:	109480

RE: Buckhorn Creek and Cape Fear River Instream Flow Studies
Fish Species List, Proposed Guilds, Habitat Suitability Criteria, and Supporting Information

The following package of information contains Progress Energy's revised proposal for habitat suitability criteria (HSC) for Buckhorn Creek and Cape Fear River species-habitat guilds and target species/life stages. Based on requests made by the Harris Advanced Reactor (HAR) Instream Flow Study Team at the May 20, 2010 and August 24, 2010 meetings, this package was prepared to aide in selection and approval of proposed species-habitat guilds and target species/life stages to be modeled using 1-D PHABSIM. Selected HSC will become the basis for evaluation of the effects of project flow management scenarios on the aquatic habitat of Buckhorn Creek downstream from Harris Lake and Cape Fear River side channels immediately downstream from Buckhorn Dam. Species-habitat guilds and several of the stand-alone species HSC provided in this package were taken directly from Progress Energy's Pee Dee River Instream Flow Study associated with the relicensing of the Blewett and Tillery Hydroelectric Projects. Tables 1 and 2 provide the proposed species-habitat use guilds and target stand-alone fish species to model. Table 3 provides HSC reference information for the source rivers and creeks on which the original HSC were created. This may aide in assessing transferability of HSC to Buckhorn Creek and Cape Fear River side channels. Table 4 provides a complete list of fish species occurring or potentially occurring in the upper Cape Fear River Basin and whether or not HSC are available. Life stages for each species have been assigned to one of the four habitat-use guilds based on scientific literature and previous instream flow reports for potential incorporation into the proposed guilds. Fish species requested to be modeled without stand-alone HSC would be incorporated into a guild using these criteria or those recommended by the IF Study Team. Tables 5 and 6 include those species collected by Progress Energy during 2009-2010 sampling in Buckhorn Creek and Cape Fear River side channels, respectively. Table 7 compares the substrate and cover codes used in the HSC from the associated references. Attachments include the HSC curves referenced in Tables 1 and 2, spawning and early life stage periodicities for fish groups and target species, consultation records for selection of HSC on two other instream flow studies, and references.

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Table 1. Proposed guild breakdown and species' representation for Buckhorn Creek and Cape Fear River; modified from the Pee Dee River Instream Flow Study (Progress Energy 2006). This table is provided as a proposed list of guild representative species for a large river, with revisions/additions to be determined by the Shearon-Harris Instream Flow Study Group necessary for smaller lotic systems (e.g., Buckhorn Creek and Cape Fear River side channels). Descriptions of the HSC origin/reference streams provided in Table 3 may aide in this discussion.

Table 2. Stand-alone target species/life stages and HSC sources for Buckhorn Creek and Cape Fear River instream flow studies.

Table 3. HSC origin/reference stream and river descriptions for transferability considerations to Buckhorn Creek and Cape Fear River side channels.

Table 4. Fish species occurring, or potentially occurring in the upper Cape Fear River basin and those collected by Progress Energy from 2009-2010 in Buckhorn Creek (BHC - grey shading), Cape Fear River side channels (CFR - green shading), or both (yellow shading). Species with no shading were not collected from either water body during 2009-2010 sampling by Progress Energy. Species collected from the mainstem river immediately downstream from Buckhorn Dam are provided in Progress Energy's fish collection report. General riverine habitat guild assignments are based on previous regional instream flow studies and/or scientific literature. Although some species life stages fall into more than one guild, only one will be modeled (e.g., redbreast sunfish spawning shallow-slow in Table 1).

Table 5. Fish species collected by Progress Energy from 2009-2010 in Buckhorn Creek.

Table 6. Fish species collected by Progress Energy from 2009-2010 in the Cape Fear River side channels.

Table 7. Substrate and cover codes utilized in the HSC curves (Attachment 1).

Attachment 1. HSC for Proposed Guild Representatives and Stand-Alone Species (Progress Energy 2006; Duke Power 2005; Thomas R. Payne and Associates, Inc. 2007)

Attachment 2. Spawning and Early Life Stage Periodicities of Proposed Target Cape Fear River-Buckhorn Creek Fishes

Attachment 3. Related Communications and Consultation (Progress Energy 2006; Duke Power 2005)

Attachment 4. References

Table 1. Proposed guild breakdown and species' representation for Buckhorn Creek and Cape Fear River; modified from the Pee Dee River Instream Flow Study (Progress Energy 2006). This table is provided as a proposed list of guild representative species for a large river, with revisions/additions to be determined by the HAR Instream Flow Study Team as necessary for smaller lotic systems (e.g., Buckhorn Creek and Cape Fear River side channels). Descriptions of the HSC origin/reference streams provided in Table 3 may aide in this discussion.

Guild*	Types	Representative Species/Life Stage	References
Shallow Slow	1-Fine substrate without cover	Redbreast Sunfish/spawning	[1]EA (1990) cited in ENTRIX (2002); provided by P. Leonard in 4/4/04 e-mail. [2,3,4]EA (1990) cited in ENTRIX (2002); provided by P. Leonard in 4/4/04 e-mail, modified by Pee Dee Instream Flow Relicensing Subgroup, June 2004.
		Black Bullhead adult and spawning/embryo	[1]Adult only (Stuber 1982); [3]Spawning and embryo only (Stuber 1982). No depth or cover curves available.
	2-Woody debris cover	Silver Redhorse/young of year (surrogate for Notchlip Redhorse)	[1,2]MN DNR (2004). [3,4]Modification of mndnrprefcurves.xls as cited in ENTRIX (2003), provided by P. Leonard in 10/11/03 memo, modified by Pee Dee Instream Flow Relicensing Subgroup, June 2004.
	3-Aquatic vegetation cover	Silver Redhorse/young of year (surrogate for Notchlip Redhorse)	[1,2]MN DNR (2004). [3,4]Modification of mndnrprefcurves.xls as cited in ENTRIX (2003), provided by P. Leonard in 10/11/03 memo, modified by Pee Dee Instream Flow Relicensing Subgroup, June 2004.
	4-Coarse substrate	Generic shallow slow guild	[1,4]Aadland (1993), provided by P. Leonard in 10/11/03 memo. [2,3]Aadland (1993), provided by P. Leonard in 10/11/03 memo, modified by Pee Dee Instream Flow Relicensing Subgroup, June 2004.
	5-Early life stage	Bluehead Chub larval/fry	[1,2]EA (1990). [3,4]Developed by Pee Dee Instream Flow Relicensing Subgroup, June 2004.
Shallow Fast	1-Lower velocity	Margined Madtom/adult	[1,2]EA (1990). [3]EA 1990, modified by Pee Dee Instream Flow Relicensing Subgroup, June 2004. No cover curve available.
	2-Moderate velocity	Generic shallow fast	[1]EDAW (1998) cited in ENTRIX (2002); provided by P. Leonard in 4/4/04 e-mail. [2,3]EDAW (1998) cited in ENTRIX (2002); provided by P. Leonard in 4/4/04 e-mail, modified by Pee Dee Instream Flow Relicensing Subgroup, June 2004. No cover curve available.
	3-High velocity	Fantail Darter/adult (surrogate for Piedmont Darter)	[1,2,3]MN DNR (2004). [4]Developed by Pee Dee Instream Flow Relicensing Subgroup, June 2004.
Deep Slow	1-No cover	Generic deep slow	[1,2,3]Provided by P. Leonard in 10/11/03 memo. [4]Developed by Pee Dee Instream Flow Relicensing Subgroup, June 2004.
	2-Cover	Generic deep slow	[1,2,3]Provided by P. Leonard in 10/11/03 memo. [4]Developed by Pee Dee Instream Flow Relicensing Subgroup, June 2004.
	3-Cover	Redbreast Sunfish/adult	[1,2]Provided by P. Leonard in 10/11/03 memo. [3,4]EA (1991) cited in ENTRIX (2002); provided by P. Leonard in 4/4/04 e-mail.

Guild*	Types	Representative Species/Life Stage	References
Deep Fast	1-Fine substrate	Silver Redhorse/adult (surrogate for Notchlip Redhorse)	[1,2,3]EA (1990) as modified by ENTRIX (2002). No cover curve available.
	2-Gravel-small cobble substrate	White Bass/spawning	[1]Developed by Pee Dee Instream Flow Relicensing Subgroup, June 2004 (modeled after American Shad spawning – modification of Stier and Crance (1985); developed for Swift Creek – 10/11/03 memo from P. Leonard). [2,3]Hamilton and Nelson (1984) as cited in Progress Energy (2006). No cover curve available.
	3-Coarse mixed substrate	Shorthead Redhorse/adult	[1,2,3]MN DNR (2004). No cover curve available.

* Shallow Slow = < 2 ft deep and < 1 ft/s velocity; Shallow Fast = < 2 ft and > 1 ft/s; Deep Slow = > 2 ft deep and < 1 ft/s velocity; and Deep Fast = > 2 ft deep and > 1 ft/s velocity

[1] Velocity HSC

[2] Depth HSC

[3] Substrate HSC

[4] Cover HSC; Note from Pee Dee Instream Flow Study (Progress Energy [2006]): taxonomy of the redhorse group, especially *Moxostoma anisurum*, *M. collapsum*, and *M. pappillosum*, has been very fluid over recent years; however, habitat preferences of these species are very similar and silver redhorse habitat HSC should adequately represent this group.

Table 2. Stand-alone target species/life stages and HSC sources for Buckhorn Creek and Cape Fear River instream flow studies.

Species	Available HSC/ Life Stage*	Target Life Stage*	Applicable Water Body (BHC=Buckhorn Creek; CFR=Cape Fear River)	References
Carolina Redhorse	J,A (will use golden redhorse as surrogate)	J,A	BHC and CFR	[1,2]MN DNR (2004). [3]Adult developed by Pee Dee Instream Flow Relicensing Subgroup, June 2004; juvenile by MN DNR (2004); [4]Adult developed by MN DNR (2004); juvenile by Pee Dee Instream Flow Relicensing Subgroup, June 2004
American Shad	L,J,O,S,I	L,J,O,S,I	CFR	[1,2,3,4]Modification of Stier and Crance (1985); developed for Swift Creek – 10/11/03 memo from P. Leonard).
		J	BHC	
Striped Bass	L,I,J,S	L,I,S	CFR	[1,2]Larval, incubation, and spawning (EA 1994); [3]Larval and incubation (EA 1994 and Pee Dee Instream Flow Relicensing Subgroup, July 2004). No cover curve available.
		J	CFR	[2]Crance (1984); Velocity, substrate, and cover curves not available.
Cape Fear Shiner	A,S	A,S	BHC and CFR	[1,2,3,4]Hewitt et al. (2009)
Composite Chub	A,S	A,S	BHC and CFR	[1,2,3,4]Thomas R. Payne and Associates 2007)
Channel Catfish	J,A,S	J,A,S	CFR	[1,2,3,4]Herricks et al. 1980; Thomas R. Payne and Associates (2007)
Native Mussels	N/A	A	BHC and CFR	N/A - will use wetted perimeter as a measure of habitat availability
Insects	L (EPT)	L	BHC and CFR	[1,2,3]Developed by Jim Gore, provided by Jim Mead, NCDWR in 6/11/04 e-mail. No cover curve available.

[1] Velocity HSC
[2] Depth HSC
[3] Substrate HSC
[4] Cover HSC
* A=adult; J=juvenile; Y=young of year; F=fry; L=larval; D=drift; I=incubation; S=spawning; O=outmigration

Table 3. HSC origin/reference stream and river descriptions for transferability considerations to Buckhorn Creek and Cape Fear River side channels.

Species/Guild	Reference	Comments	Source Stream/River	Drainage Area (mi^2)	Estimated Mean Stream Width (ft)
All guilds and American shad	ENTRIX 2003	Depth and velocity criteria for all habitat-use guilds derived from the Swift Creek Instream Flow Study – ENTRIX 2003 modified Stier and Crance 1985 for American shad	Swift Creek (NC)	270	60
All guilds and certain species representatives	Aadland 1993; MNDNR 2004	Original guild/HSC sources modified by ENTRIX 2003 for Swift Creek Instream Flow Study	Minnesota Otter Tail St. Louis Snake Yellow Medicine Zumbro	7,990 1,830 3,400 960 650 1,135	200 140 330 150 72 140
Buckhorn Creek				80	50
Cape Fear River Mainstem				3,460 (Lillington)	400
Cape Fear River Side Channels				NA	115

Table 4. Fish species occurring, or potentially occurring in the upper Cape Fear River basin and those collected by Progress Energy from 2009-2010 in Buckhorn Creek (BHC - grey shading), Cape Fear River side channels (CFR - green shading), or both (yellow shading). Species with no shading were not collected from either water body during 2009-2010 sampling by Progress Energy. Species collected from the mainstem river immediately downstream from Buckhorn Dam are provided in Progress Energy's fish collection report. General riverine habitat guild assignments are based on previous regional instream flow studies and/or scientific literature. Although some species life stages fall into more than one guild, only one will be modeled (e.g., redbreast sunfish spawning shallow-slow in Table 1).

Scientific Name	Common Name	HSC Available	Habitat Guild and Life Stage[1,2]			
			Shallow Slow	Shallow Fast	Deep Slow	Deep Fast
Amiidae	**Bowfin**					
Amia calva	Bowfin	N			A, S	
Anguillidae	**Freshwater eels**					
Anguilla rostrata	American Eel	N	J		A, J	J
Aphredoderidae	**Pirate Perch**					
Aphredoderus sayanus	Pirate Perch	N	A		A	
Catostomidae	**Suckers**					
Minytrema melanops	Spotted Sucker	N	J	S	A	
Moxostoma collapsum	Notchlip Redhorse	N	J	S	J,A	
M. macrolepidotum	Shorthead Redhorse	Y	J	S	A	A[3]
M. pappillosum	V-Lip Redhorse	N	J	S	A	
Moxostoma sp.	Carolina Redhorse[4]	N		S	A, J	
Erimyzon oblongus	Creek Chubsucker	N	S		A, J, S	
Centrarchidae	**Sunfishes**					
Enneacanthus gloriosus	Bluespotted Sunfish	N	A		A	
Lepomis auritus	Redbreast Sunfish	Y	J, S		A, J, S	
L. cyanellus	Green Sunfish	Y			A, J, S	
L. gibbosus	Pumpkinseed	N	J, S		A, J, S	
L. gulosus	Warmouth	Y	A, J, S			
L. macrochirus	Bluegill	Y	J, S		A, J, S	
L. microlophus	Redear Sunfish	Y			A, J, S	
Lepomis sp.	Sunfish hybrid	N	J, S		A, J, S	
Micropterus salmoides	Largemouth Bass	Y	J, S		A, J, S	
M. punctulatus	Spotted Bass	Y	J, S		A, J, S	
Pomoxis annularis	White Crappie	Y	A, J, S		A,J	
P. nigromaculatus	Black Crappie	Y			A, J, S	
Clupeidae	**Herrings**					
Dorosoma cepedianum	Gizzard Shad	N	A, J		A, J, S	
D. petenense	Threadfin Shad	N	A, J		A, J, S	
Alosa sapidissima	American Shad	Y			J	J, S
Cyprinidae	**Carps and Minnows**					
Clinostomus funduloides	Rosyside Dace	N	A,J			
Cyprinus carpio	Common Carp	Y	J, S		A, J, S	
Luxilus albeolus	White Shiner	N	J	S	A, J	

Scientific Name	Common Name	HSC Available	Habitat Guild and Life Stage[1,2]			
			Shallow Slow	Shallow Fast	Deep Slow	Deep Fast
Notemigonus crysoleucas	Golden Shiner	N	A, J, S		A, J, S	
Hybognathus regius	E. Silvery Minnow	N	J, S		A, J, S	
Nocomis leptocephalus	Bluehead Chub	N		A, S		
Cyprinella analostana	Satinfin Shiner	N	A, J, S		A, J, S	
C. nivea	Whitefin Shiner	N	A, J	S	A	
Notropis altipinnis	Highfin Shiner	N	J, S		A	
N. alborus	Whitemouth Shiner	N	A,J	S	A,J	
N. amoenus	Comely Shiner	N	A, J	S	A, J	
N. procne	Swallowtail Shiner	N	A,J	S	A	
N. hudsonius	Spottail Shiner	N	A, J	S	A, J	
N. mekistocholas	Cape Fear Shiner	Y	A, J, S[5]			
N. petersoni	Coastal Shiner	N	A, J	S	A	
N. scepticus	Sandbar Shiner	N	A, J	S	A	
Semotilus atromaculatus	Creek Chub	Y	A	S		
Esocidae	**Pikes**					
Esox americanus	Redfin Pickerel	N			A, J, S	
E. niger	Chain Pickerel	N			A, J, S	
Fundulidae	**Killifishes**					
Fundulus rathbuni	Speckled Killifish	N	A		A	
Ictaluridae	**Catfishes**					
Ictalurus punctatus	Channel Catfish	Y			A, J	J
Ameiurus catus	White Catfish	N			A	A, J
A. brunneus	Snail Bullhead	N			A	A
A. natalis	Yellow Bullhead	N			A	
A. nebulosus	Brown Bullhead	N			A	
A. platycephalus	Flat Bullhead	N			A	
Pylodictis olivaris	Flathead Catfish	Y	J		A, J, S	
Noturus insignis	Margined Madtom	Y	S	A,J,S		
N. gyrinus	Tadpole Madtom	N	A			
Lepisosteidae	**Gars**					
Lepisosteus osseus	Longnose Gar	N	A, J		A, J	
Moronidae	**Temperate basses**					
Morone americana	White Perch	N	J	S	A, J	S
M. saxatilis	Striped Bass	Y				A,S
M. saxatilis x *M. chrysops*	Hybrid Striped Bass	N				A,S
M. chrysops	White Bass	Y				A,S
Percidae	**Perches**					
Etheostoma fusiforme	Swamp Darter	N	A,J,S		A,J,S	
E. flabellare	Fantail Darter	Y		A,J,S		
E. olmstedi	Tessellated Darter	N	A, J	S	A	

Scientific Name	Common Name	HSC Available	Habitat Guild and Life Stage[1,2]			
			Shallow Slow	Shallow Fast	Deep Slow	Deep Fast
E. serrifer	Sawcheek Darter	N	A	A		
Percina crassa	Piedmont darter	N		A, S		
Perca flavescens	Yellow Perch	Y			A, J, S	
Poeciliidae	**Livebearers**					
Gambusia holbrooki	E. Mosquitofish	N			A, J, S	
Umbridae	**Mudminnows**					
Umbra pygmaea	E. Mudminnow	N			A, J, S	

[1] Life stages: A = adult; J = juvenile, including young of year; S = spawning
[2] Classification of species and life stages into habitat types based on Becker (1983), Hamilton and Nelson (1984), Aadland (1993), Jenkins and Burkhead (1993), Rhode et al. (1994), Leonard and Dilts (2003), and Progress Energy (2006)
[3] Foraging adults based on Jenkins and Burkhead (1993)
[4] One individual collected by Progress Energy immediately upstream from Buckhorn Dam on the Cape Fear River in 2010;
[5] Hewitt et al. (2009)

Table 5. Fish species collected by Progress Energy from 2009-2010 in Buckhorn Creek.

Scientific Name	Common Name	Number Collected
Anguillidae	**Freshwater eels**	
Anguilla rostrata	American Eel	54
Aphredoderidae	**Pirate Perch**	
Aphredoderus sayanus	Pirate Perch	61
Catostomidae	**Suckers**	
Erimyzon oblongus	Creek Chubsucker	6
Centrarchidae	**Sunfishes**	
Lepomis auritus	Redbreast Sunfish	284
L. cyanellus	Green Sunfish	7
L. gibbosus	Pumpkinseed	5
L. gulosus	Warmouth	13
L. macrochirus	Bluegill	133
L. microlophus	Redear Sunfish	22
Micropterus salmoides	Largemouth Bass	15
Cyprinidae	**Carps and Minnows**	
Luxilus albeolus	White Shiner	65
Notemigonus crysoleucas	Golden Shiner	1
Nocomis leptocephalus	Bluehead Chub	15
C. nivea	Whitefin Shiner	6
N. procne	Swallowtail Shiner	197
N. petersoni	Coastal Shiner	23
N. scepticus	Sandbar Shiner	3
Semotilus atromaculatus	Creek Chub	28
Esocidae	**Pikes**	
E. niger	Chain Pickerel	1
Fundulidae	**Killifishes**	
Fundulus rathbuni	Speckled Killifish	7
Ictaluridae	**Catfishes**	
A. brunneus	Snail Bullhead	40
A. natalis	Yellow Bullhead	2
A. platycephalus	Flat Bullhead	7
Noturus insignis	Margined Madtom	18
N. gyrinus	Tadpole Madtom	12
Percidae	**Perches**	
E. olmstedi	Tessellated Darter	118
Percina crassa	Piedmont darter	18
Poeciliidae	**Livebearers**	
Gambusia holbrooki	E. Mosquitofish	146

Table 6. Fish species collected by Progress Energy from 2009-2010 in the Cape Fear River side channels.

Scientific Name	Common Name	Number Collected
Anguillidae	**Freshwater eels**	
Anguilla rostrata	American Eel	114
Catostomidae	**Suckers**	
Moxostoma collapsum	Notchlip Redhorse	1
M. macrolepidotum	Shorthead Redhorse	12
Erimyzon oblongus	Creek Chubsucker	1
Centrarchidae	**Sunfishes**	
Lepomis auritus	Redbreast Sunfish	309
L. cyanellus	Green Sunfish	9
L. gibbosus	Pumpkinseed	3
L. macrochirus	Bluegill	489
L. microlophus	Redear Sunfish	3
Micropterus salmoides	Largemouth Bass	6
M. punctulatus	Spotted Bass	169
Clupeidae	**Herrings**	
Dorosoma cepedianum	Gizzard Shad	8
Cyprinidae	**Carps and Minnows**	
Cyprinus carpio	Common Carp	49
Luxilus albeolus	White Shiner	1
Nocomis leptocephalus	Bluehead Chub	9
Cyprinella analostana	Satinfin Shiner	361
C. nivea	Whitefin Shiner	250
N. alborus	Whitemouth Shiner	4
N. amoenus	Comely Shiner	4
N. procne	Swallowtail Shiner	10
N. hudsonius	Spottail Shiner	67
N. mekistocholas	Cape Fear Shiner	1
N. scepticus	Sandbar Shin	178
Fundulidae	**Killifishes**	
Fundulus rathbuni	Speckled Killifish	2
Ictaluridae	**Catfishes**	
Ictalurus punctatus	Channel Catfish	67
Pylodictis olivaris	Flathead Catfish	29
Moronidae	**Temperate basses**	
Morone americana	White Perch	3
Percidae	**Perches**	
E. flabellare	Fantail Darter	2
E. olmstedi	Tessellated Darter	26
Percina crassa	Piedmont darter	19
Perca flavescens	Yellow Perch	3

Table 7. Substrate and cover codes utilized in the HSC curves (Attachment 1).

Code	Stand Alone Species and Guilds from Progress Energy (2006)			Stand Alone Species from TRPA (2007) [1]		
	Substrate		Cover	Substrate		Cover [2]
	Type	Size (in)		Type	Size (in)	
0	detritus	NA	none	-	-	-
1	silt/clay	<0.1	boulder	silt or terrestrial vegetation	<0.1	no cover
2	sand	<0.1	ledge	sand	<0.1	no cover
3	small gravel	0.1-0.5	undercut	gravel	0.1-3.0	no cover
4	medium gravel	0.5-1.5	overhang	cobble	3.0-12.0	no cover
5	large gravel	1.5-3.0	log	small boulder	12.0-36.0	no cover
6	small cobble	3.0-6.0	log complex	boulder, angled bedrock, or woody debris	NA	no cover
7	large cobble	6.0-12.0	aquatic vegetation attached to rocks	mud or flat bedrock	NA	no cover
8	small boulder	12.0-36.0	aquatic vegetation rooted in substrate	terrestrial vegetation	NA	overhead vegetation
9	large boulder	>36.0	-	gravel	0.1-3.0	overhead vegetation
10	smooth bedrock	NA	-	cobble	3.0-12.0	overhead vegetation
11	irregular bedrock	NA	-	small boulder, boulder, angled bedrock, or woody debris	NA	overhead vegetation
12	-	-	-	small boulder, boulder, angled bedrock, or woody debris	NA	instream

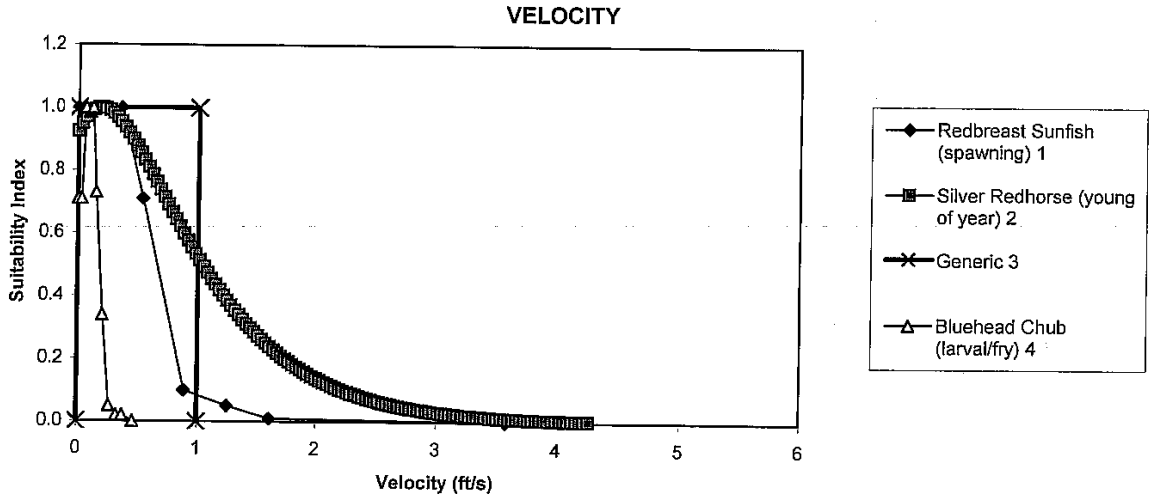
13	-	-	-	small boulder, boulder, angled bedrock, or woody debris	NA	instream
14	-	-	-	cobble	3.0-12.0	proximal
15	-	-	-	small boulder, boulder, angled bedrock, or woody debris	NA	proximal
16	-	-	-	gravel	0.1-3.0	instream or proximal
17	-	-	-	silt or sand	<0.1	overhead, instream, or proximal
18	-	-	-	aquatic vegetation - macrophytes	NA	aquatic vegetation

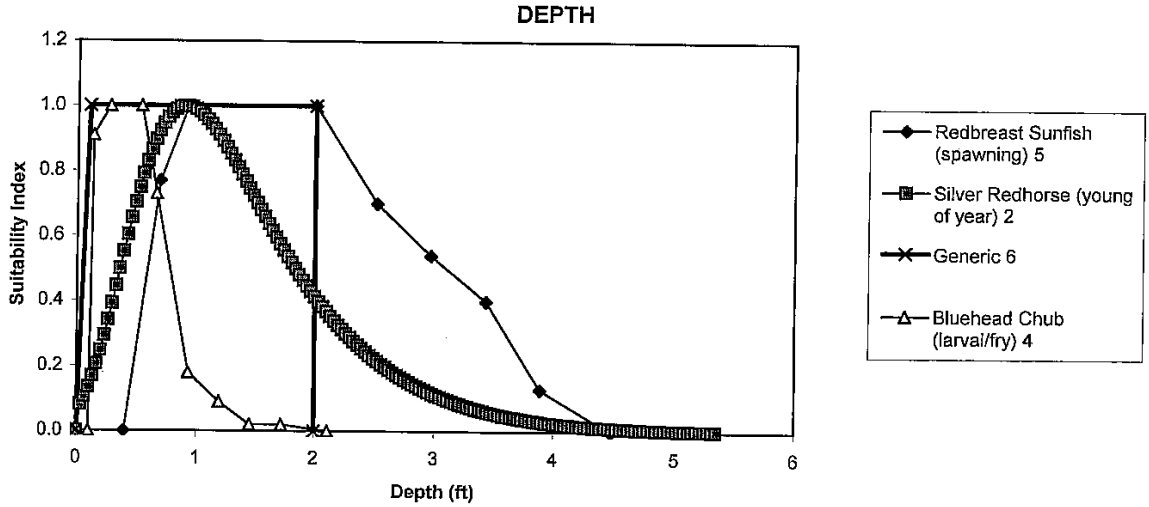
[1] HSC curves referenced from TRPA (2007) include both substrate and cover combined for a given code where those from Progress Energy (2006) are separate. [2] Proximal cover - within 4 feet upstream or downstream.

Attachment 1

HSC for Proposed Guild Representatives and Stand-Alone Species (Progress Energy 2006; Duke Power 2005; Thomas R. Payne and Associates, Inc. 2007)

Shallow Slow Guild - Habitat Suitability





Citations:

[1]EA 1990 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email.

[2]MN DNR 2004.

[3]Aadland 1993, provided by P. Leonard in 10/11/03 memo.

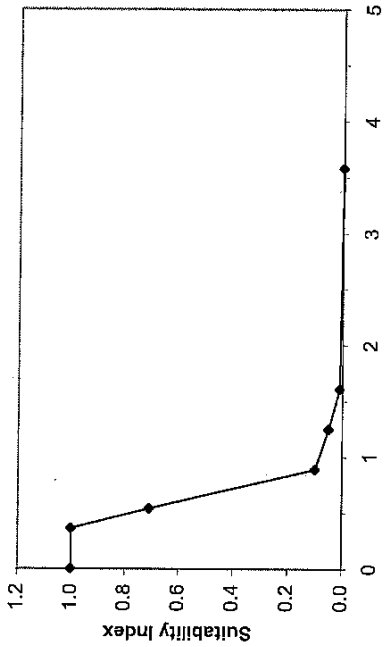
[4]EA 1990.

[5]EA 1990 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email, modified by Pee Dee Instream Flow Subgroup, June 2004.

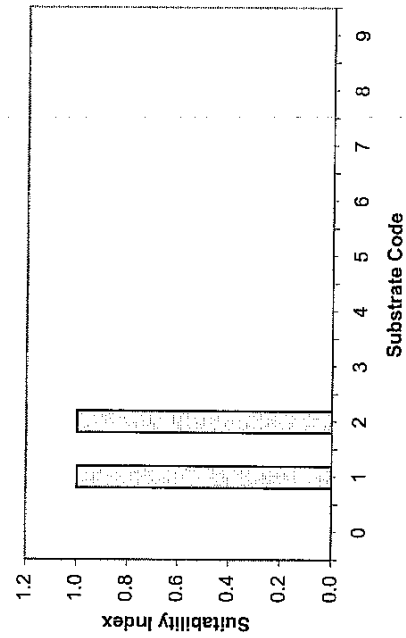
[6]Aadland 1993, provided by P. Leonard in 10/11/03 memo, modified by Pee Dee Instream Flow Subgroup, June 2004.

Shallow Slow Guild, Fine Substrate Without Cover

Redbreast sunfish spawning habitat suitability

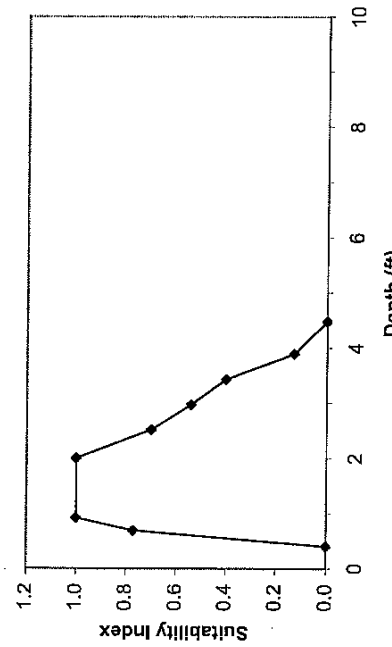


(EA 1990 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email)

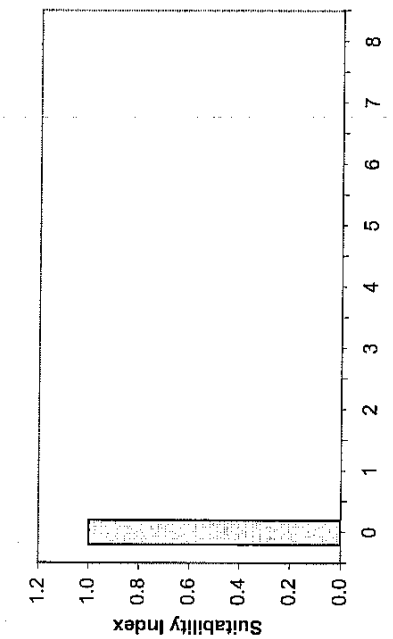


(EA 1990 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email, modified by Pee Dee Instream Flow Subgroup, June 2004)

Substrate Codes	
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Smooth Bedrock
9	Irregular Bedrock



(EA 1990 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email, modified by Pee Dee Instream Flow Subgroup, June 2004)

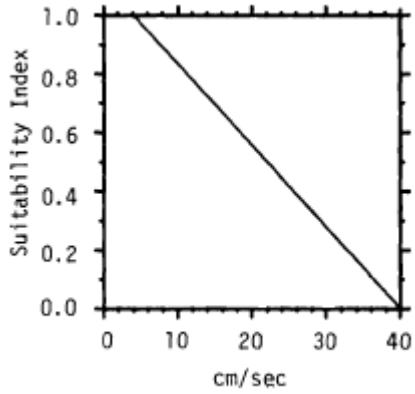


(EA 1990 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email, modified by Pee Dee Instream Flow Subgroup, June 2004)

Cover Codes	
0	None
1	Boulder
2	Ledge
3	Undercut
4	Overhang
5	Log
6	Log Complex
7	Att Veg
8	Rt Veg

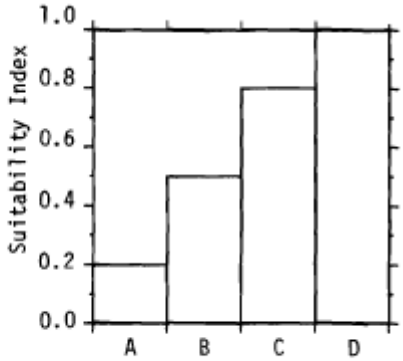
BLACK BULLHEAD (Stuber 1982)

Average current velocity at 0.6 depth during average summer flow.



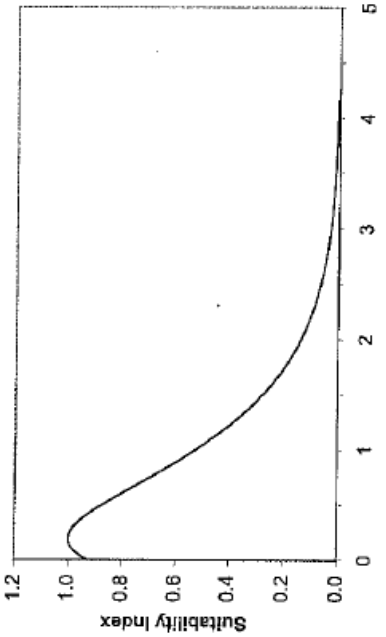
Dominant substrate type within pools, backwaters, or littoral areas for spawning (embryo).

A) Fines (< 2 mm diameter) and gravel insignificant (≤ 10%)
B) Fines noticeable (> 10 - ≤ 25%)
C) Fines and gravel present in equal amounts, combined (> 25 - ≤ 50%)
D) Fines dominant (> 50%)

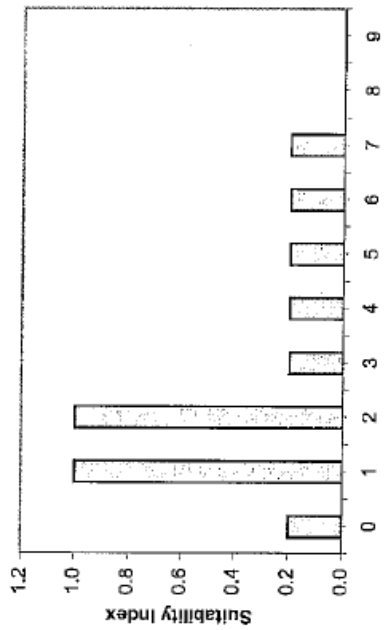


Shallow Slow Guild, Woody Debris Cover

Silver redhorse young of year habitat suitability

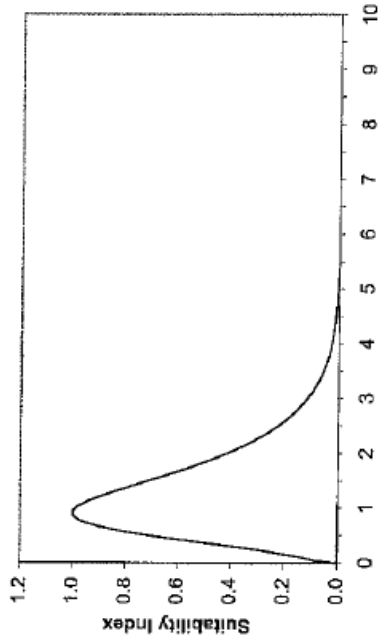


(MN DNR 2004)

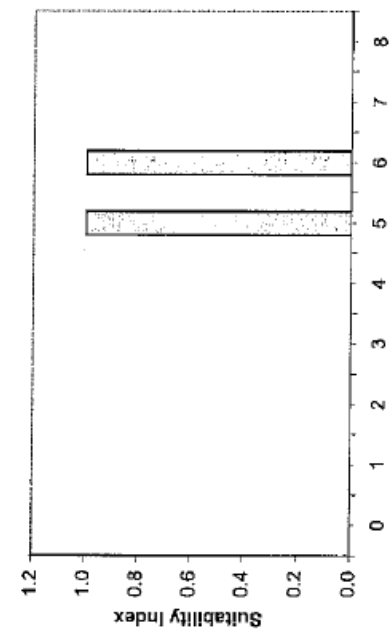


(modification of mndnrprefcurves.xls as cited in ENTRIX 2003, provided by P. Leonard in 10/11/03 memo; modified by Pee Dee Instream Flow Subgroup, June 2004)

Substrate Codes	
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Smooth Bedrock
9	Irregular Bedrock



(MN DNR 2004)

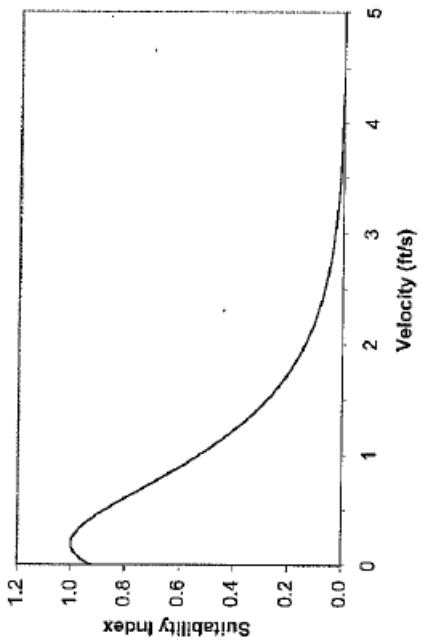


(modification of mndnrprefcurves.xls as cited in ENTRIX 2003, provided by P. Leonard in 10/11/03 memo; modified by Pee Dee Instream Flow Subgroup.

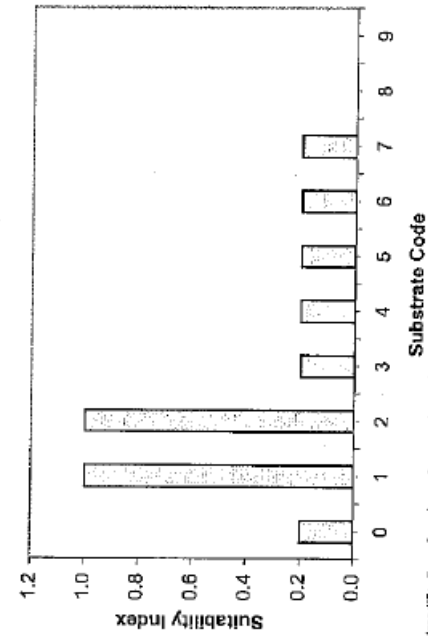
Cover Codes	
0	None
1	Boulder
2	Ledge
3	Undercut
4	Overhang
5	Log
6	Log Complex
7	Att Veg
8	Rt Veg

Shallow Slow Guild, Aquatic Vegetation Cover

Silver redhorse young of year habitat suitability

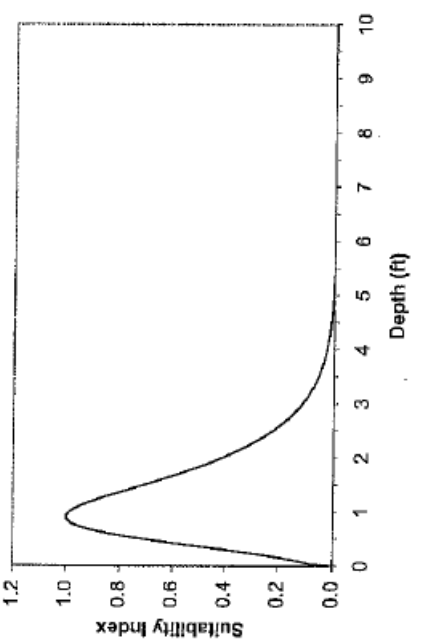


(MN DNR 2004)



(modification of mndnrprefcurves.xls as cited in ENTRIX 2003, provided by P. Leonard in 10/11/03 memo; modified by Pes Des Instream Flow Subgroup, June 2004)

Substrate Codes
0 Detritus
1 Fines
2 Sm Gravel
3 Lg Gravel
4 Sm Cobble
5 Lg Cobble
6 Sm Boulder
7 Lg Boulder
8 Smooth Bedrock
9 Irregular Bedrock



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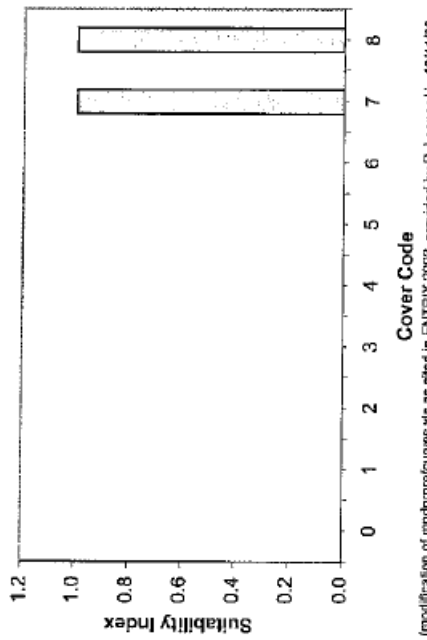
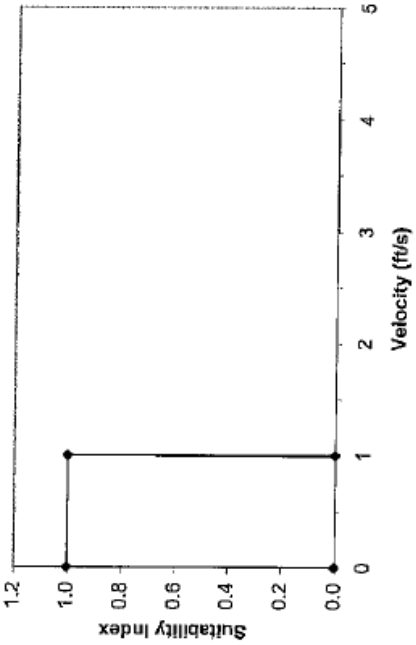


(modification of mndnrprefcurves.xls as cited in ENTRIX 2003, provided by P. Leonard in 10/11/03 memo; modified by Pes Des Instream Flow Subgroup, June 2004)

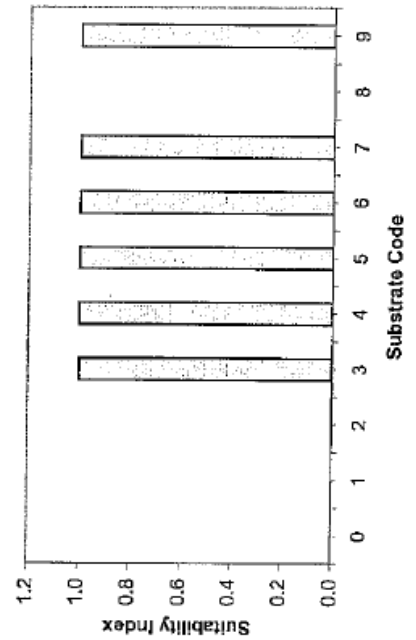
Cover Codes
0 None
1 Boulder
2 Ledge
3 Undercut
4 Overhang
5 Log
6 Log Complex
7 Alt Veg
8 Rt Veg

Shallow Slow Guild, Coarse Substrate

Generic guild habitat suitability

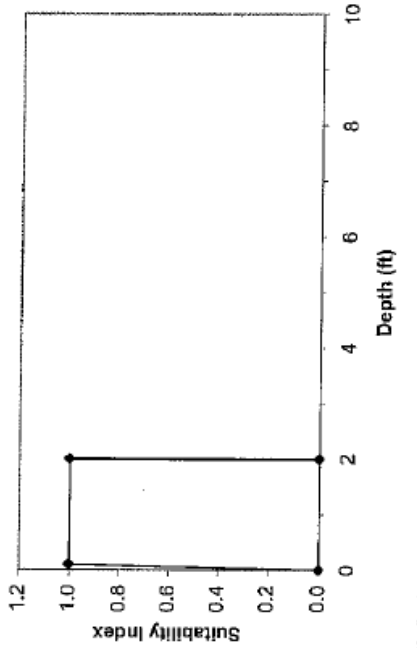


(Aadland 1993, provided by P. Leonard in 10/11/03 memo)

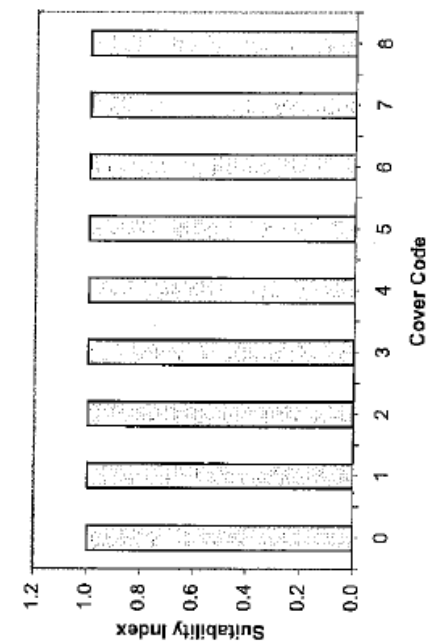


(Aadland 1993, provided by P. Leonard in 10/11/03 memo, modified by Pee Dee Instream Flow Subgroup, June and July 2004)

Substrate Codes	
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Smooth Bedrock
9	Irregular Bedrock



(Aadland 1993, provided by P. Leonard in 10/11/03 memo, modified by Pee Dee Instream Flow Subgroup, June 2004)

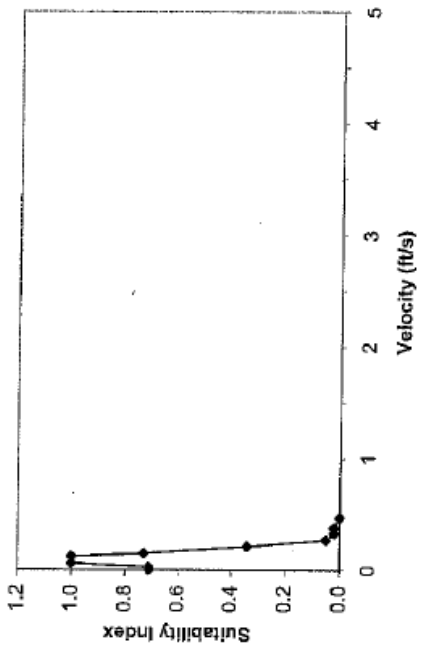


(Aadland 1993, provided by P. Leonard in 10/11/03 memo)

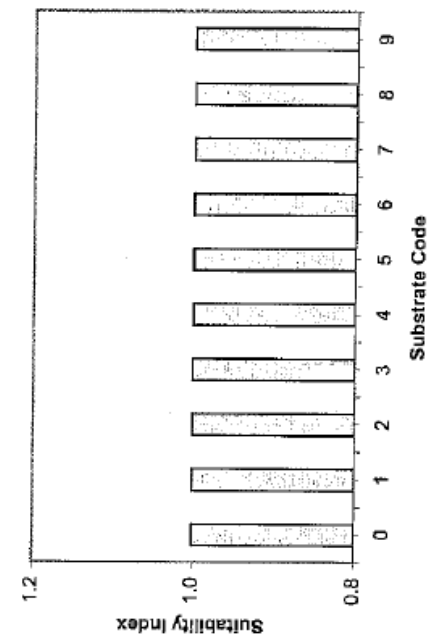
Cover Codes	
0	None
1	Boulder
2	Ledge
3	Undercut
4	Overhang
5	Log
6	Log Complex
7	Alt Veg
8	Rt Veg

Shallow Slow Guild, Early Life Stage

Bluehead chub larval/fry habitat suitability

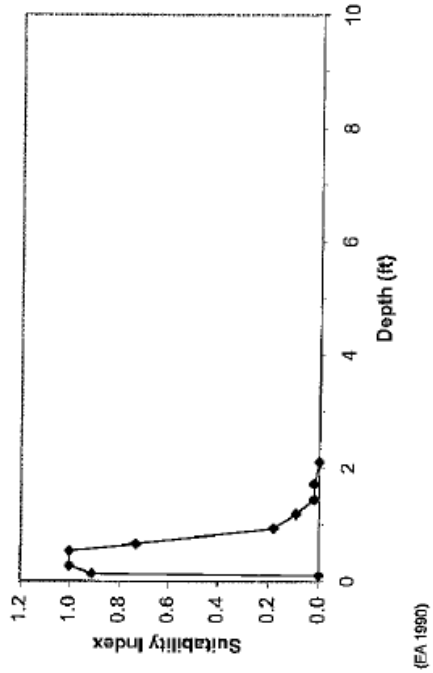


(EA 1990)

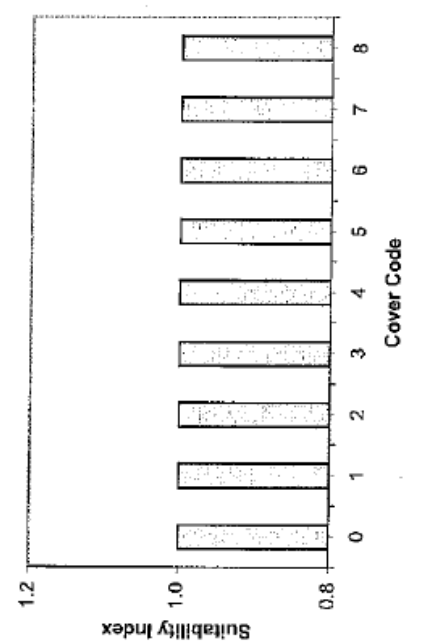


(Developed by Pee Dee Instream Flow Subgroup, June 2004)

Substrate Codes	
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Smooth Bedrock
9	Irregular Bedrock



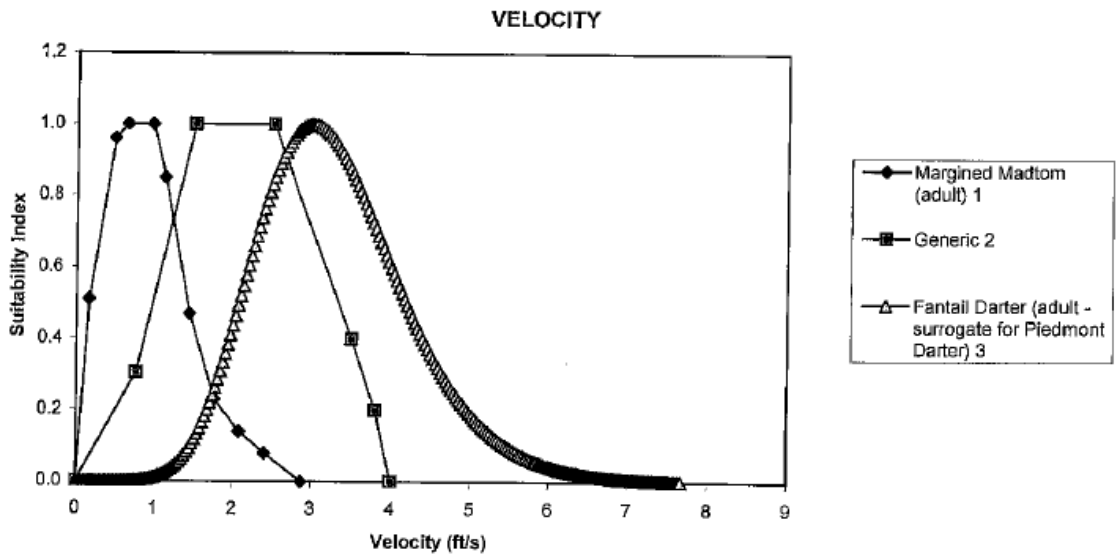
(EA 1990)

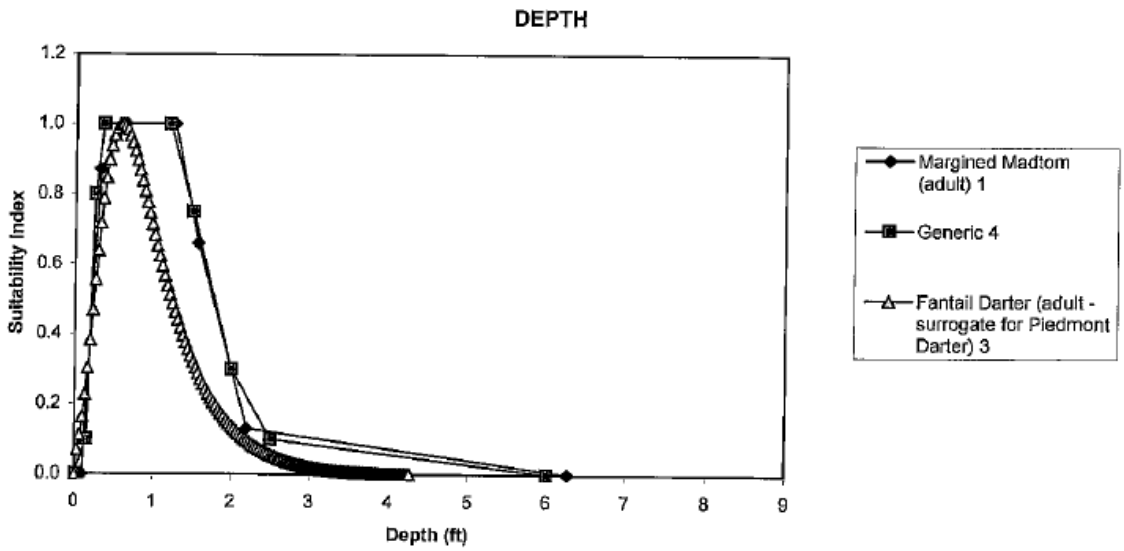


(Developed by Pee Dee Instream Flow Subgroup, June 2004)

Cover Codes	
0	None
1	Boulder
2	Ledge
3	Undercut
4	Overhang
5	Log
6	Log Complex
7	Att Veg
8	Rt Veg

Shallow Fast Guild - Habitat Suitability





Citations:

[1]EA 1990.

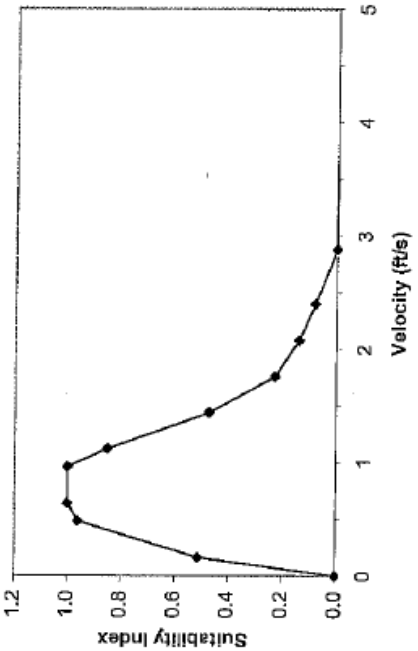
[2]EDAW 1998 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email.

[3]MN DNR 2004.

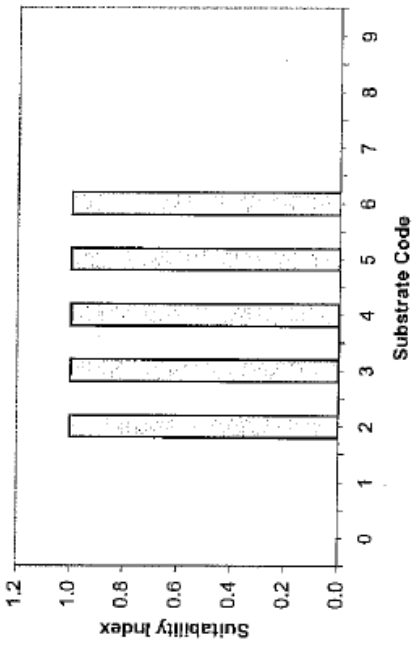
[4]EDAW 1998 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email, modified by Pee Dee Instream Flow Subgroup, June 2004.

Shallow Fast Guild, Lower Velocity

Margined madtom adult habitat suitability

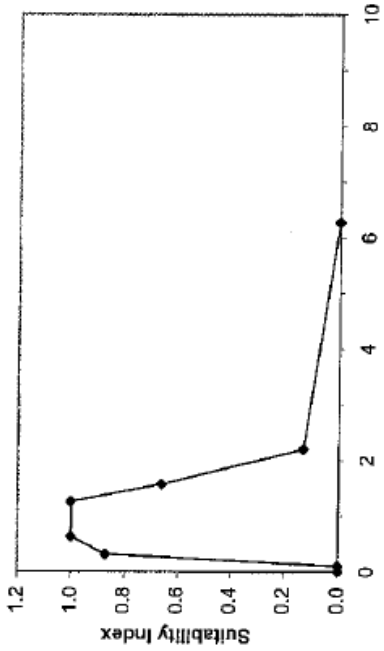


(EA 1990)



(EA 1990, modified by Pee Dee Instream Flow Subgroup, June 2004)

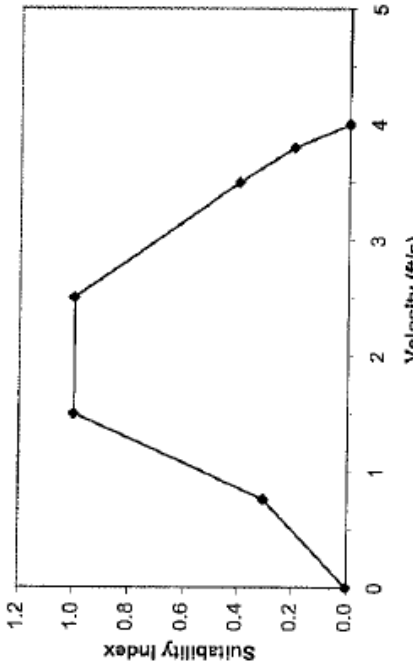
Substrate Codes
0 Detritus
1 Fines
2 Sm Gravel
3 Lg Gravel
4 Sm Cobble
5 Lg Cobble
6 Sm Boulder
7 Lg Boulder
8 Smooth Bedrock
9 Irregular Bedrock



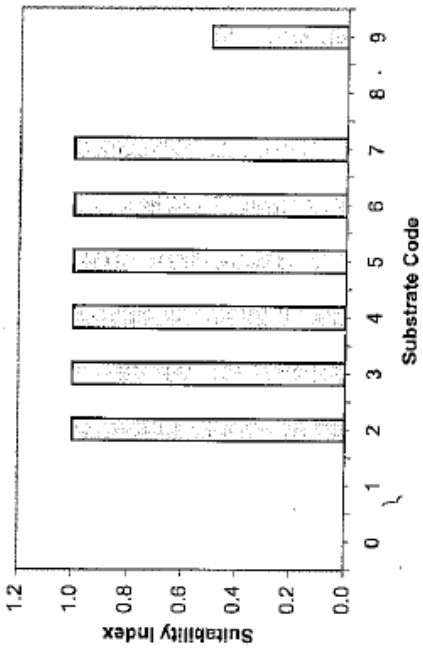
(EA 1990)

Shallow Fast Guild, Moderate Velocity

Shallow-fast generic guild habitat suitability

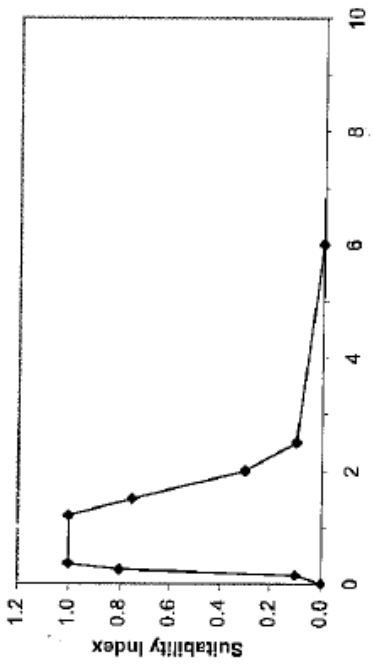


(EDAW 1998 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email)



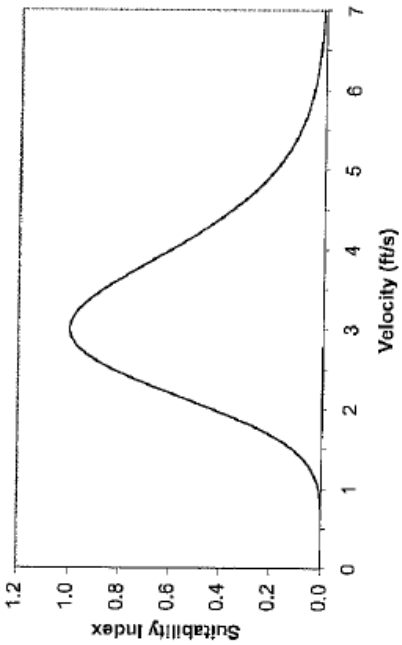
Substrate Codes	
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Smooth Bedrock
9	Irregular Bedrock

(EDAW 1998 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email, modified by Pee Dee Instream Flow Subgroup, June 2004)

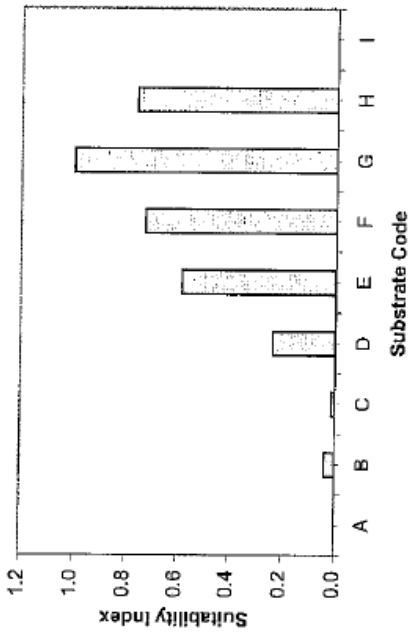


(EDAW 1998 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email, modified by Pee Dee Instream Flow Subgroup, June 2004)

Shallow Fast Guild, High Velocity
Fantail darter adult habitat suitability
(Surrogate for Piedmont darter)

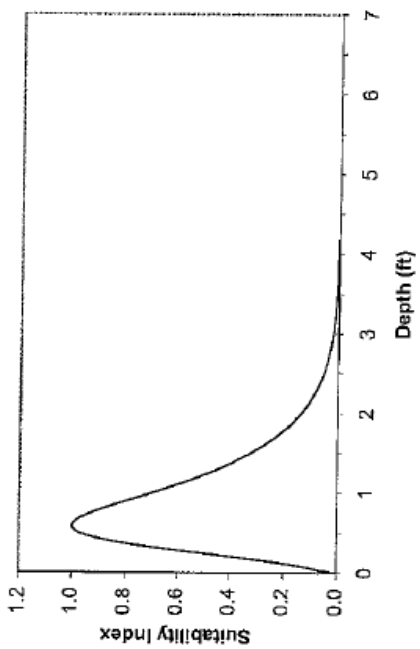


(MN DNR 2004)

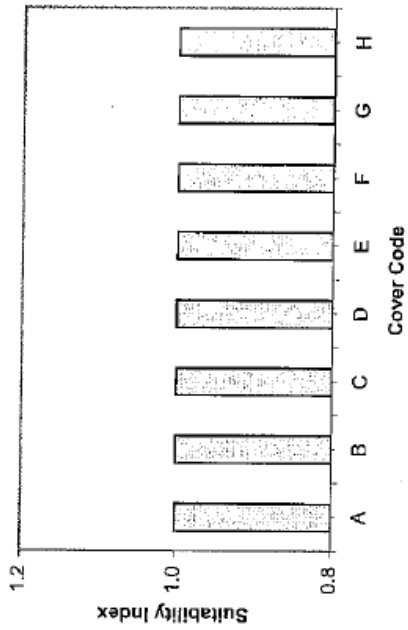


(MN DNR 2004)

Substrate Codes	
A	Detritus
B	Silt
C	Sand
D	Gravel
E	Cobble
F	Rubble
G	Sm Boulder
H	Lg Boulder
I	Sm Bedrock



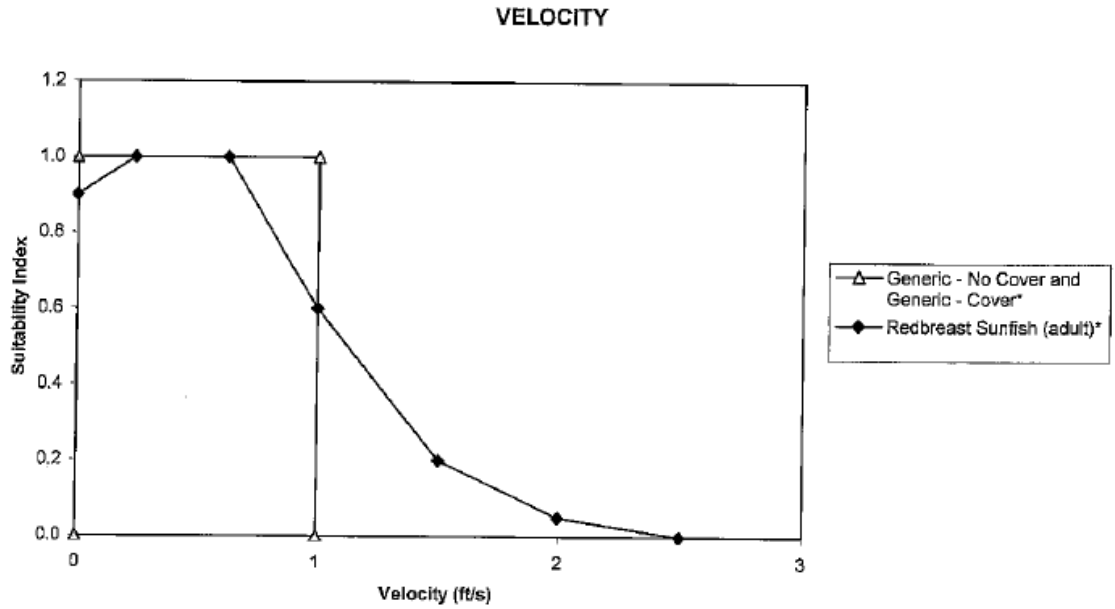
(MN DNR 2004)

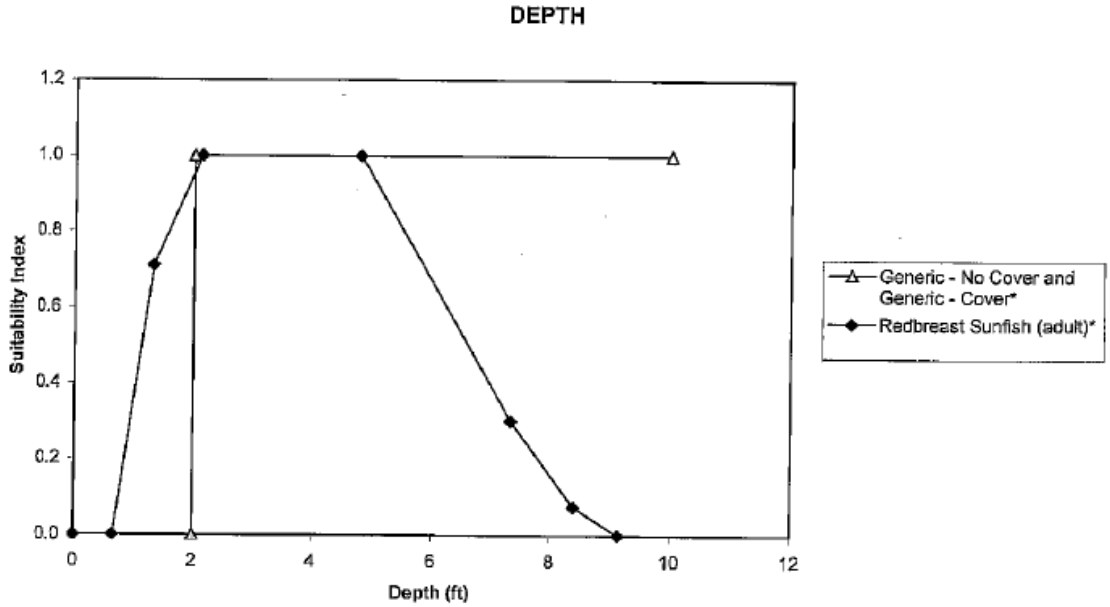


(Developed by Pee Dee Instream Flow Subgroup, June 2004)

Cover Codes	
A	None
B	Undercut
C	Veg
D	Wood
E	Boulder
F	Flotsam
G	Canopy
H	Edge

Deep Slow Guild - Habitat Suitability

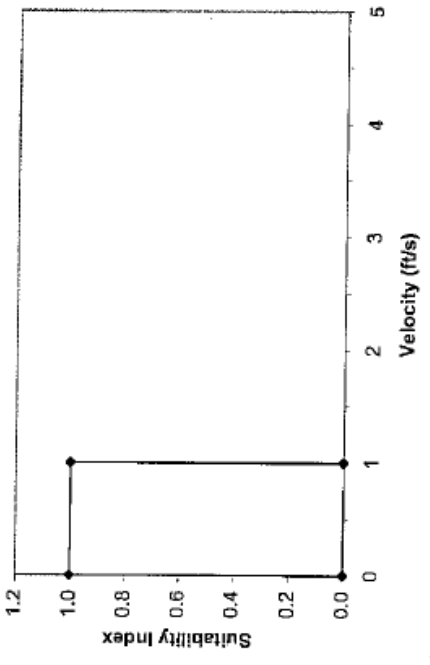




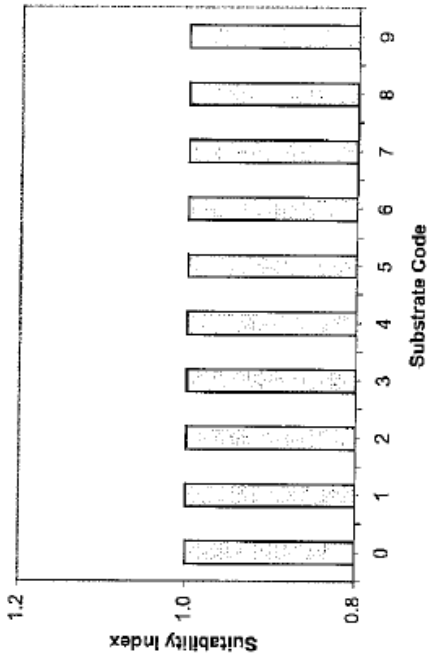
Citations:
*Provided by P. Leonard in 10/11/03 memo.

Deep Slow Guild, No Cover

Generic guild habitat suitability

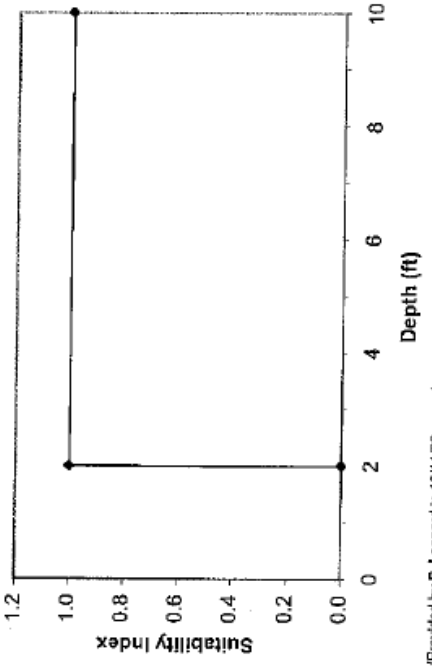


(Provided by P. Leonard in 10/11/03 memo)

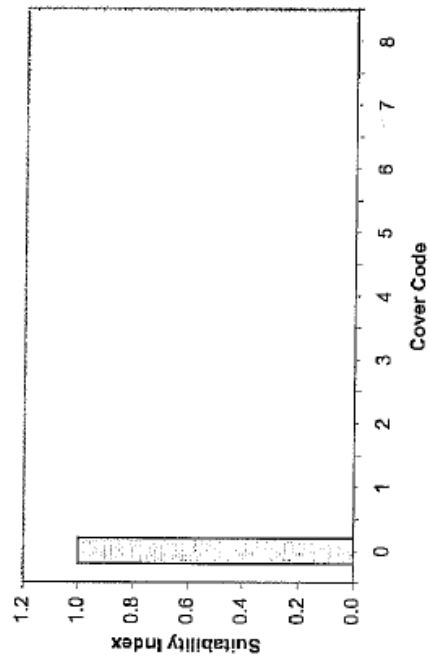


(Provided by P. Leonard in 10/11/03 memo)

Substrate Codes
0 Detritus
1 Fines
2 Sm Gravel
3 Lg Gravel
4 Sm Cobble
5 Lg Cobble
6 Sm Boulder
7 Lg Boulder
8 Smooth Bedrock
9 Irregular Bedrock



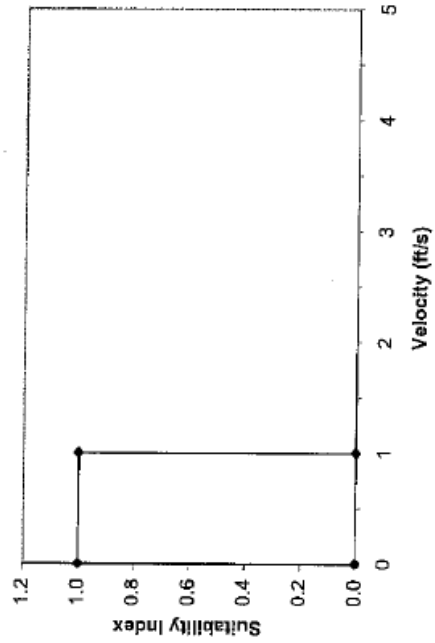
(Provided by P. Leonard in 10/11/03 memo)



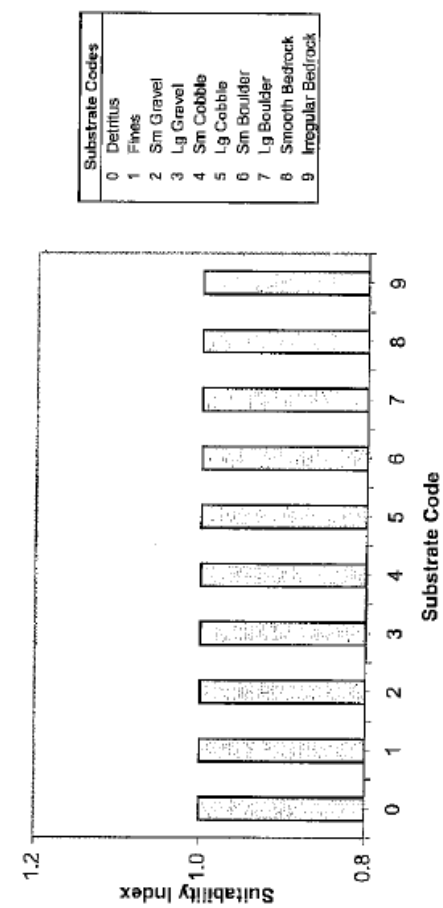
(Developed by Poe Dee Instream Flow Subgroup, June 2004)

Cover Codes
0 None
1 Boulder
2 Ledge
3 Undercut
4 Overhang
5 Log
6 Log Complex
7 Att Veg
8 Rt Veg

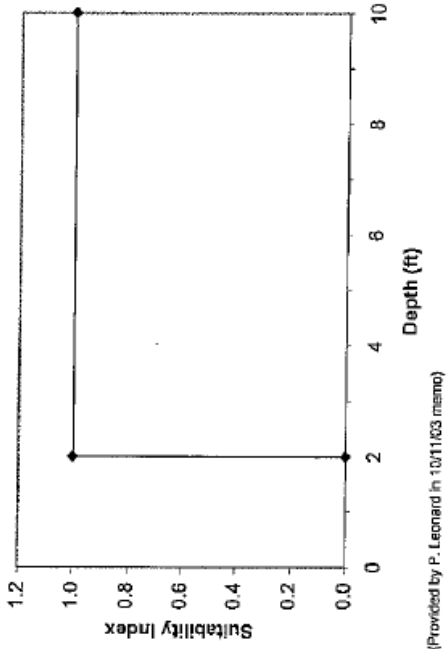
Deep Slow Guild, Cover
Generic guild habitat suitability



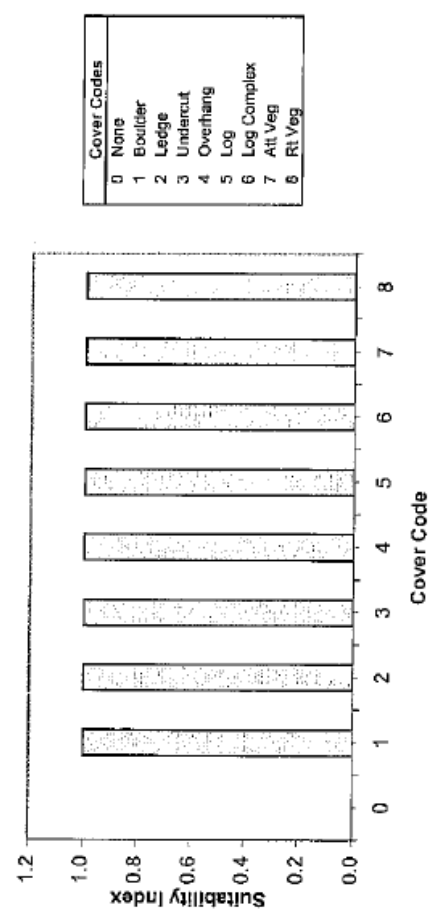
(Provided by P. Leonard in 10/11/03 memo)



(Provided by P. Leonard in 10/11/03 memo)



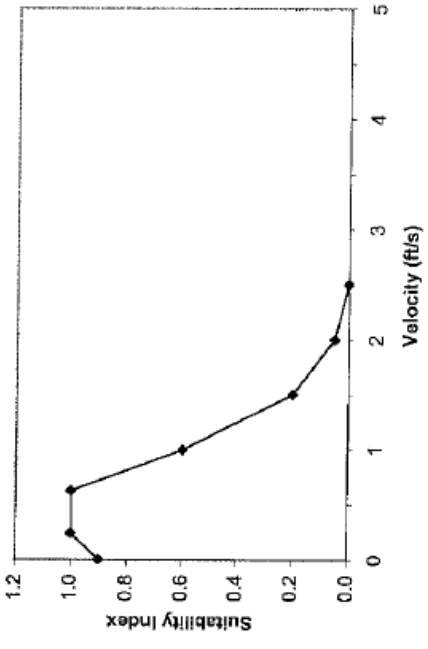
(Provided by P. Leonard in 10/11/03 memo)



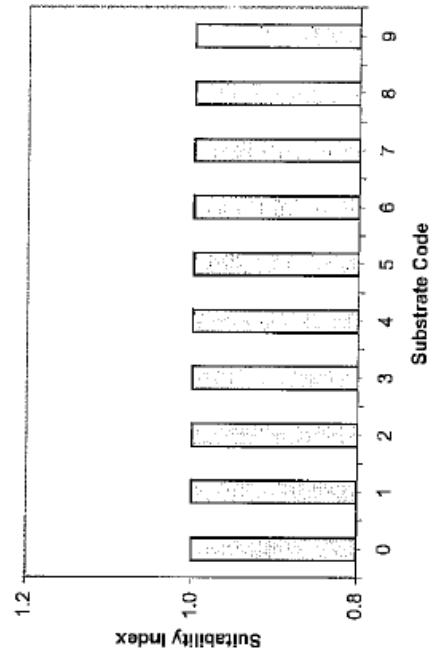
(Developed by Pee Dee Instream Flow Subgroup, June 2004)

Deep Slow Guild, Cover

Redbreast sunfish adult habitat suitability

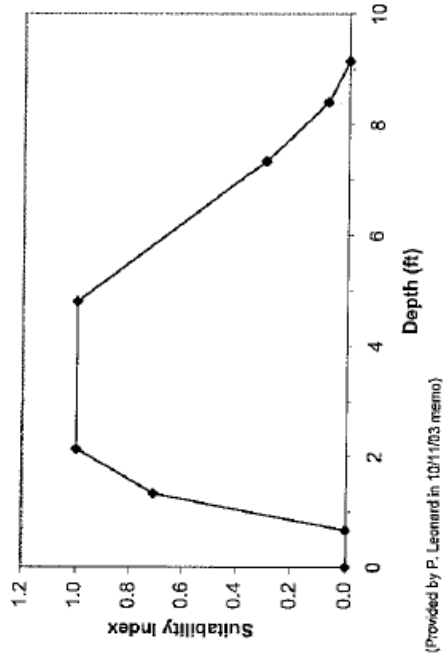


(Provided by P. Leonard in 10/11/03 memo)

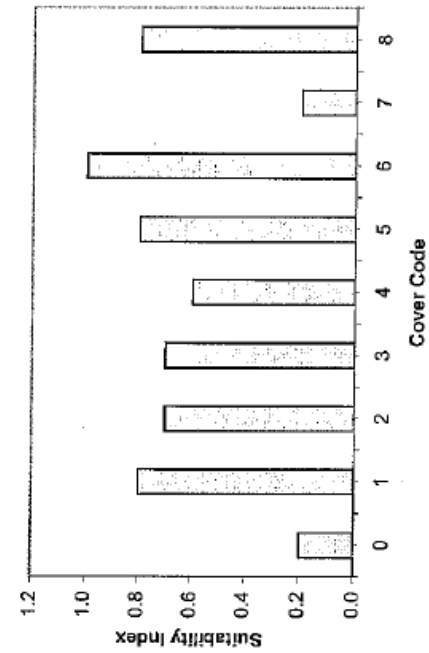


(EA 1991 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email)

Substrate Codes
0 Detritus
1 Fines
2 Sm Gravel
3 Lg Gravel
4 Sm Cobble
5 Lg Cobble
6 Sm Boulder
7 Lg Boulder
8 Smooth Bedrock
9 Irregular Bedrock



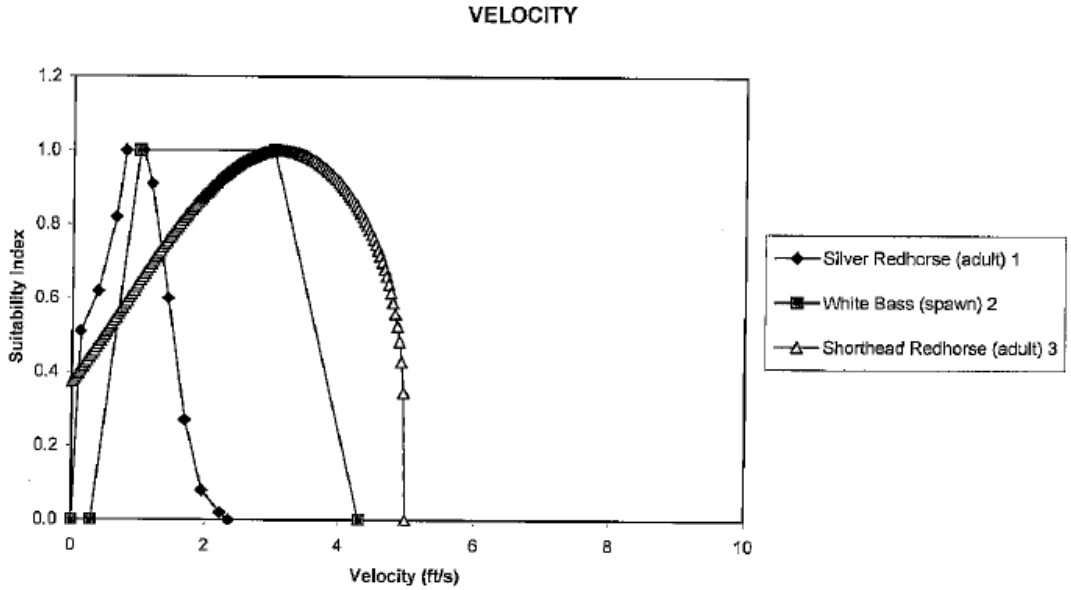
(Provided by P. Leonard in 10/11/03 memo)

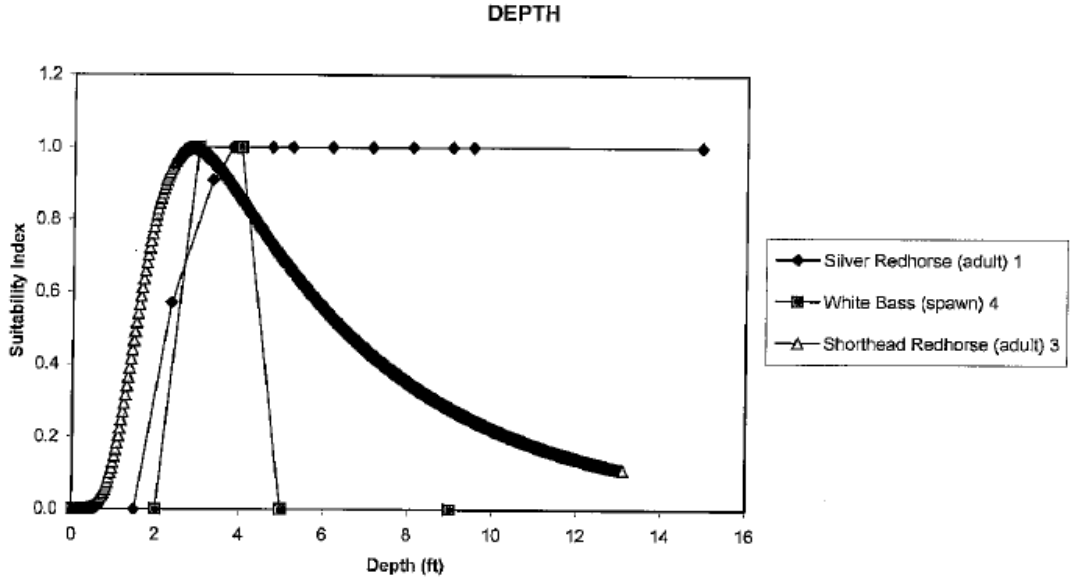


(EA 1991 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email)

Cover Codes
0 None
1 Boulder
2 Ledge
3 Undercut
4 Overhang
5 Log
6 Log Complex
7 Alt Veg
8 Rt Veg

Deep Fast Guild - Habitat Suitability





Citations:

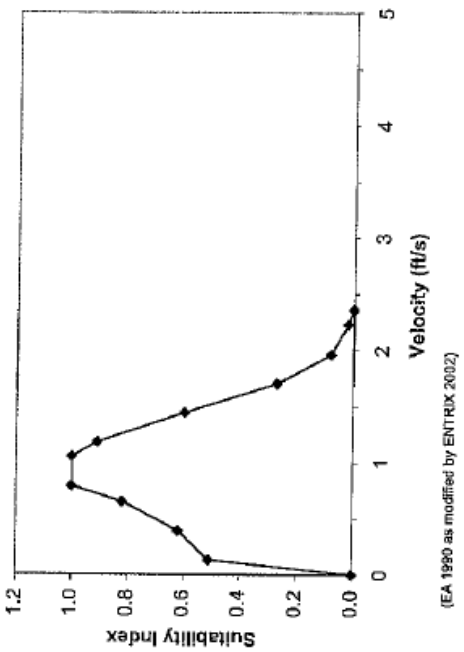
[1]EA 1990 cited in ENTRIX 2002; provided by P. Leonard in 4/4/04 email.

[2]Developed by Pee Dee Instream Flow Subgroup, June 2004 (modeled after American shad spawning - modification of Stier and Crance 1985; developed for Swift Creek - 10/11/03 memo from P. Leonard). 2,3Hamilton and Nelson 1984 as cited in Progress Energy 2004.

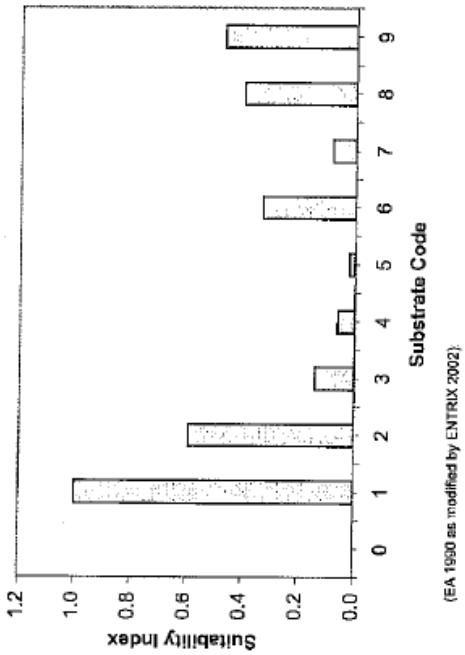
[3]MN DNR 2004.

[4]Hamilton and Nelson 1984 as cited in Progress Energy 2004.

Deep Fast Guild, Fine Substrate
Silver redhorse adult habitat suitability

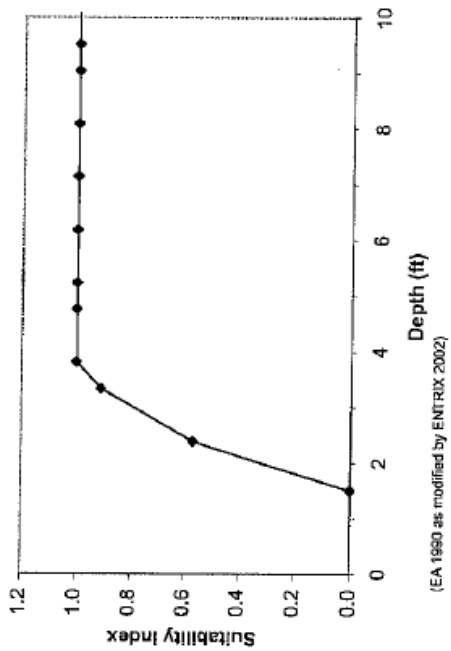


(EA 1990 as modified by ENTRIX 2002)



(EA 1990 as modified by ENTRIX 2002)

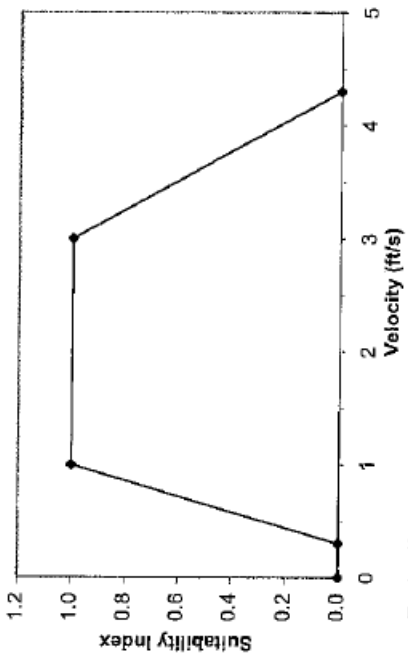
Substrate Codes	
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Smooth Bedrock
9	Irregular Bedrock



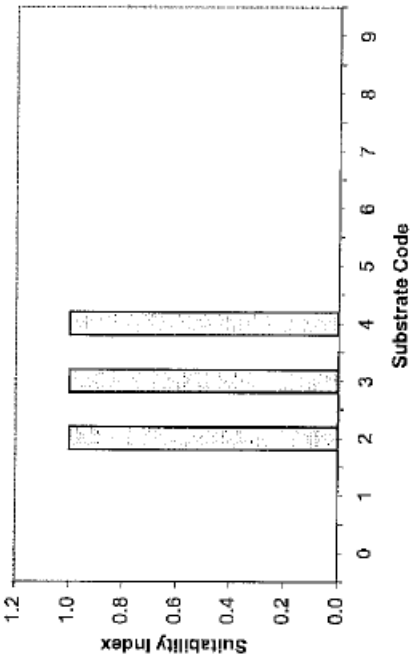
(EA 1990 as modified by ENTRIX 2002)

Deep Fast Guild, Gravel-Small Cobble Substrate

White bass spawning habitat suitability

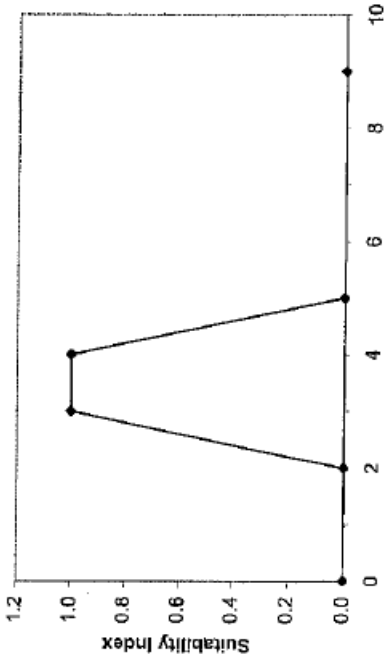


(Developed by Pee Dee Instream Flow Subgroup, June 2004 (Modeled after American shad spawning - modification of Stier and Crance 1985; developed for Swift Creek - 10/11/03 memo from P. Leonard))



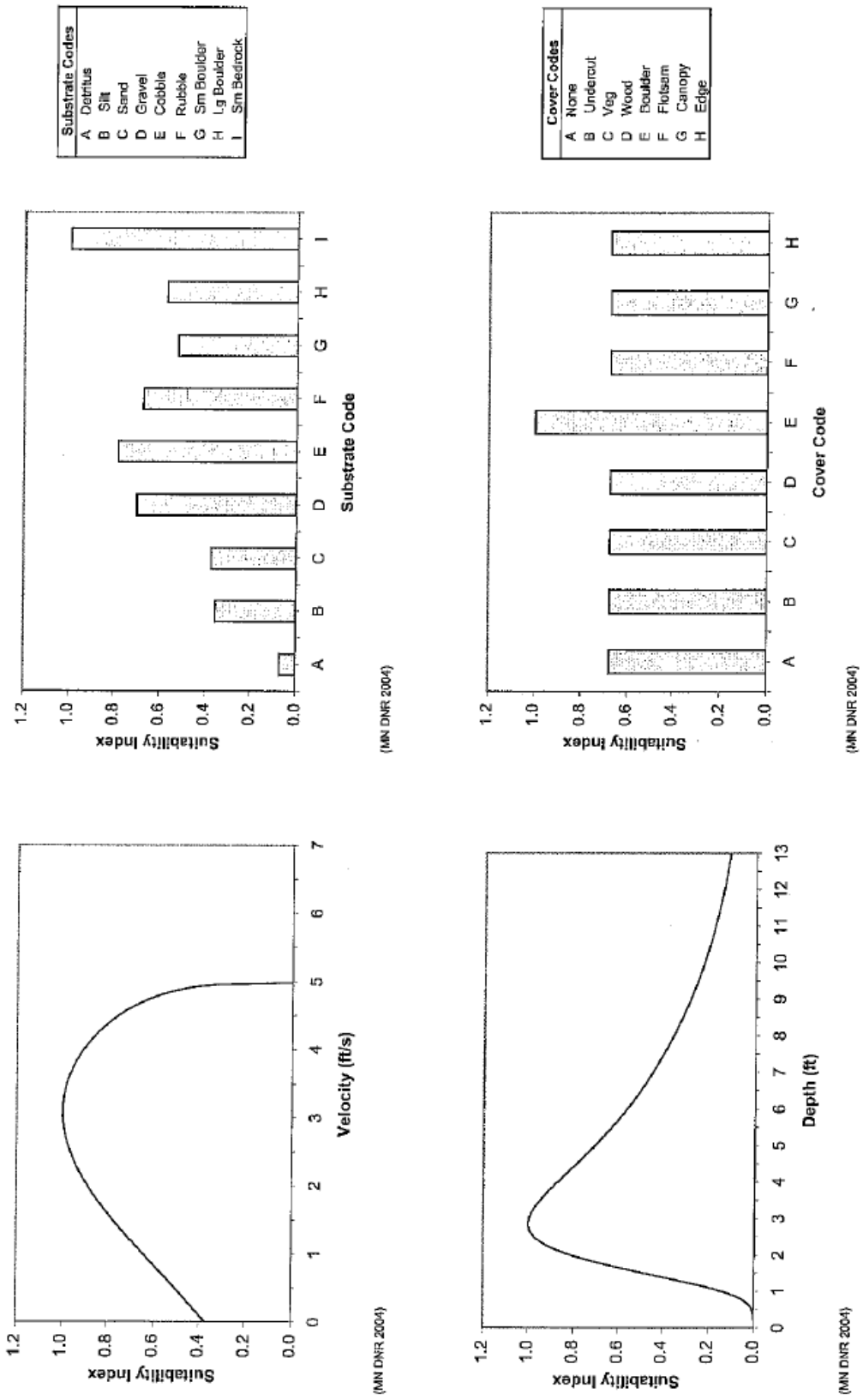
(Hamilton and Nelson 1984 as cited in Progress Energy 2004)

Substrate Codes	
0	Detritus
1	Fines
2	Sm Gravel
3	Lg Gravel
4	Sm Cobble
5	Lg Cobble
6	Sm Boulder
7	Lg Boulder
8	Smooth Bedrock
9	Irregular Bedrock



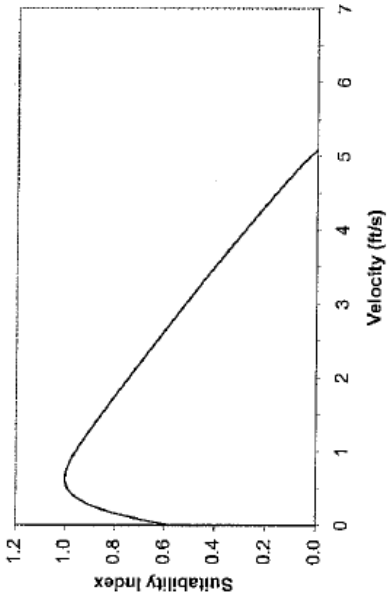
(Hamilton and Nelson 1984 as cited in Progress Energy 2004)

Deep Fast Guild, Coarse Mixed Substrate
Shorthead redhorse adult habitat suitability

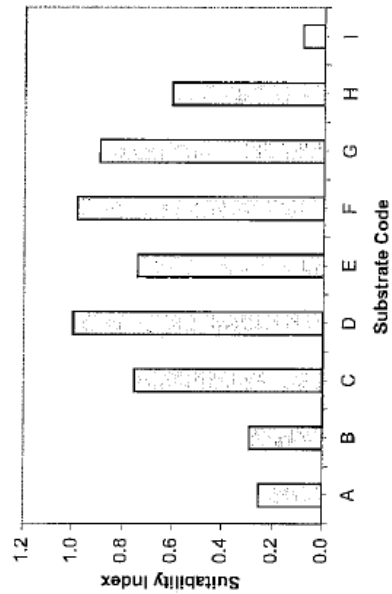


Stand Alone Target Species/Life Stages
HSC Curves

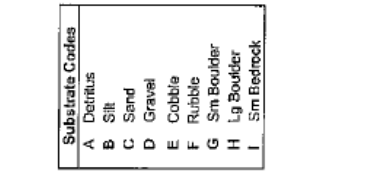
Golden Redhorse Adult Habitat Suitability
(Surrogate for Carolina Redhorse)

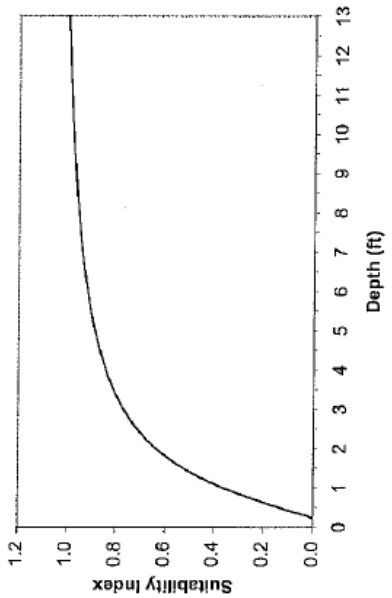


(MN DNR 2004)

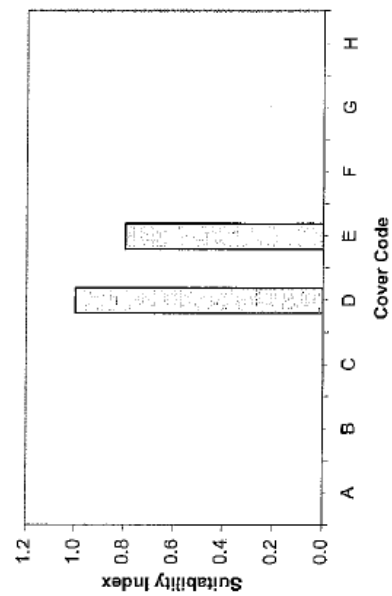


(MN DNR 2004 modified by Pee Dee Instream Flow Subgroup, June 2004)

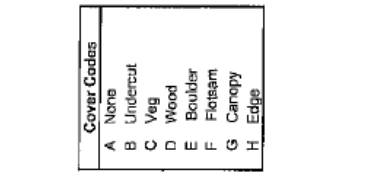




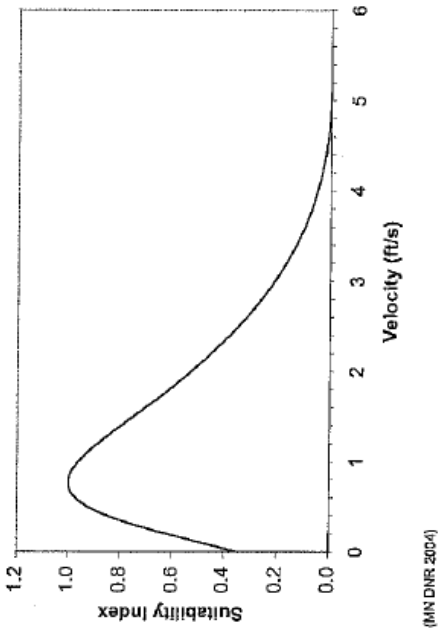
(MN DNR 2004)



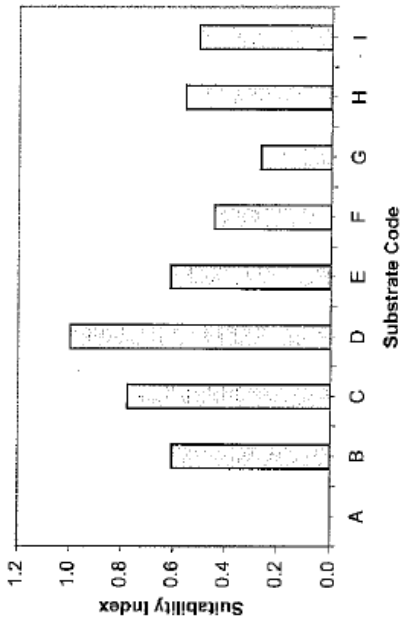
(MN DNR 2004)



Golden Redhorse Juvenile Habitat Suitability
(Surrogate for Carolina Redhorse)



(MN DNR 2004)



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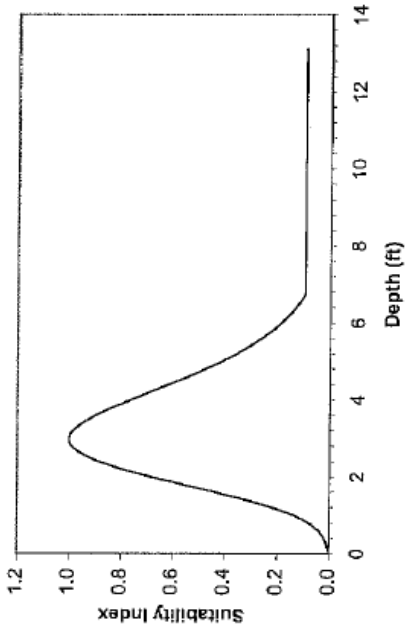
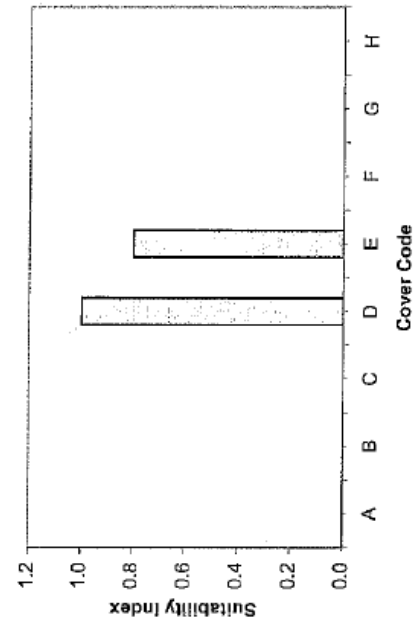
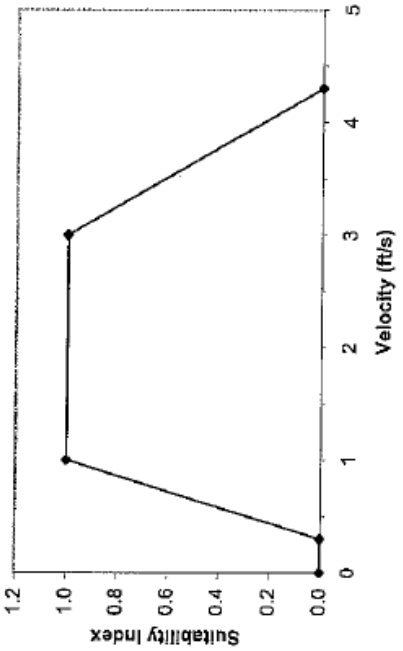


(MN DNR 2004)

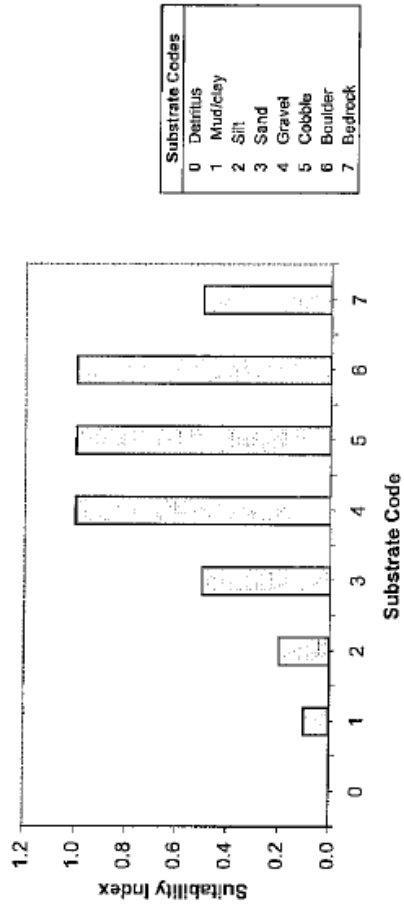


(Developed by Pee Dee Instream Flow Subgroup, June 2004)

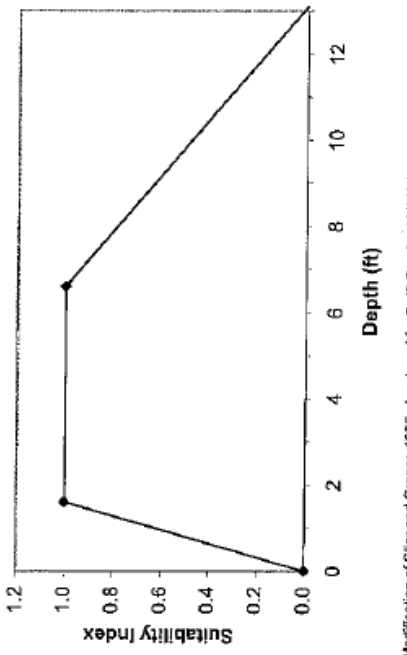
American Shad Spawning Habitat Suitability



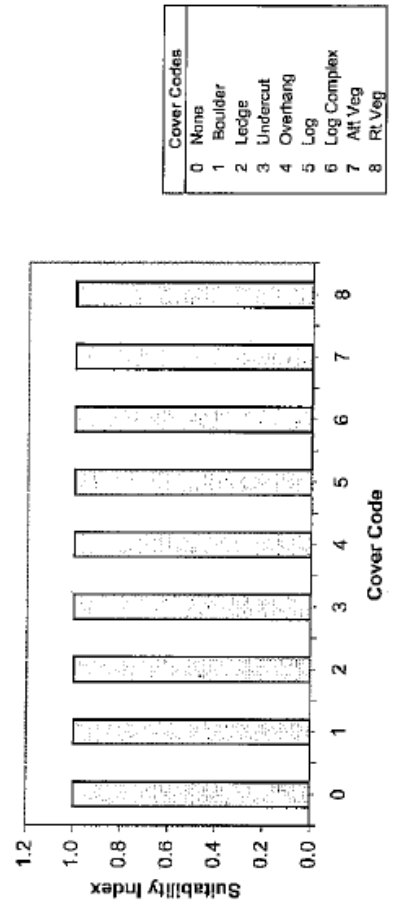
(Modification of Siler and Crance 1985; developed for Swift Creek - 10/11/03 memo from P. Leonard)



(Modification of Siler and Crance 1985; developed for Swift Creek - 10/11/03 memo from P. Leonard)



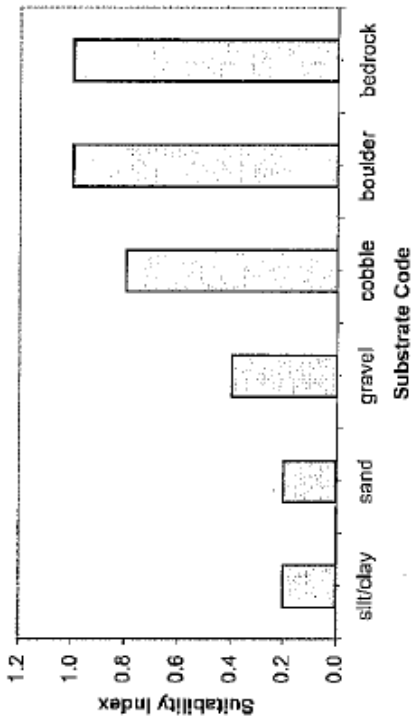
(Modification of Siler and Crance 1985; developed for Swift Creek - 10/11/03 memo from P. Leonard)



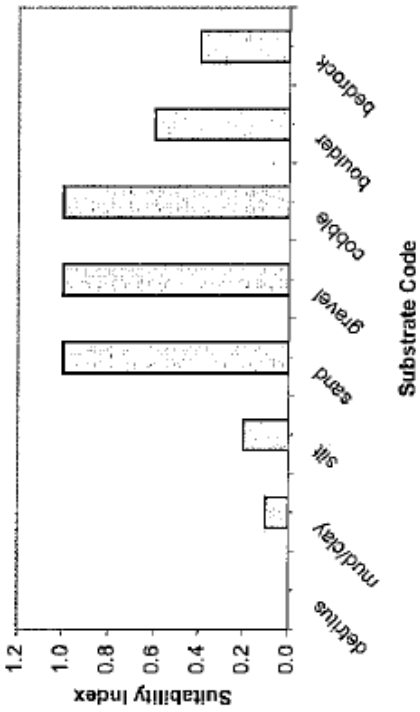
(Modification of Siler and Crance 1985; developed for Swift Creek - 10/11/03 memo from P. Leonard)

American Shad Spawning Substrate Habitat Suitability

(Hightower 2004, Stier and Crance 1985)

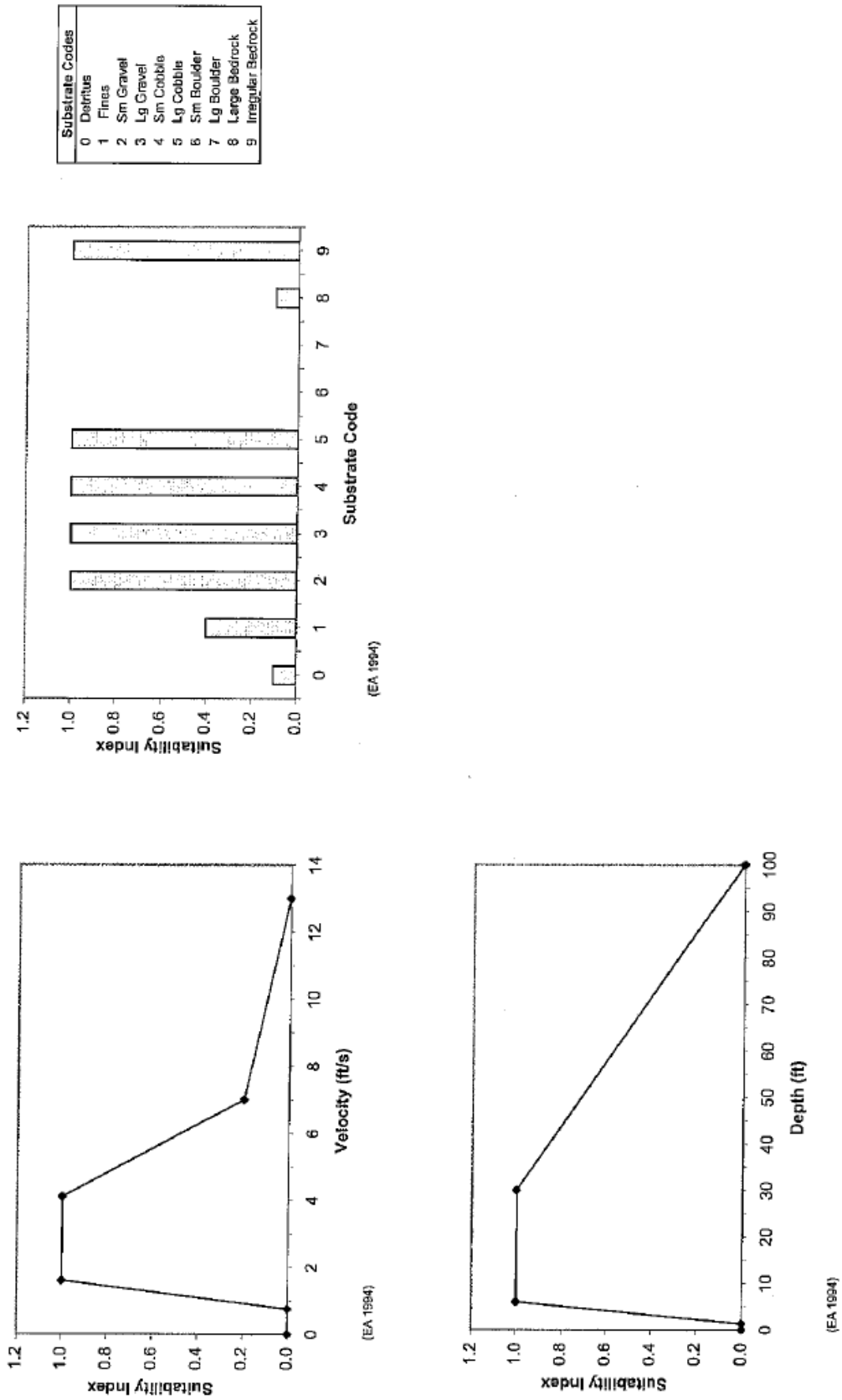


(Hightower 2004)

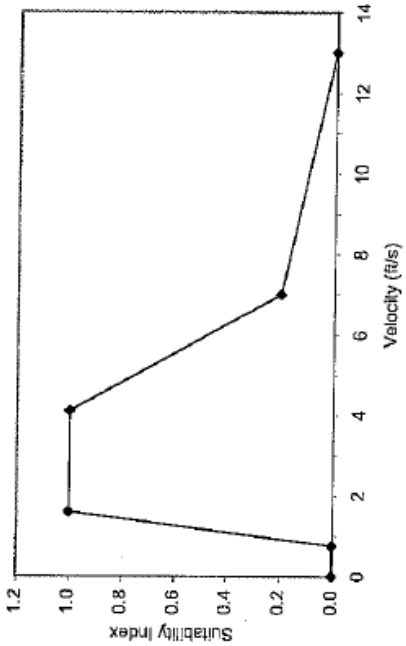


(Stier and Crance 1985)

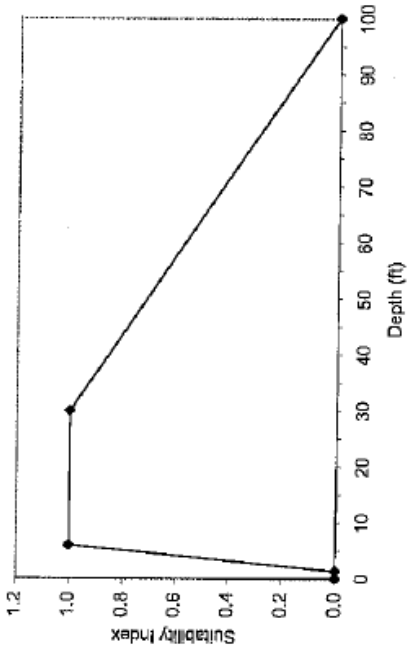
Striped Bass Spawning Habitat Suitability



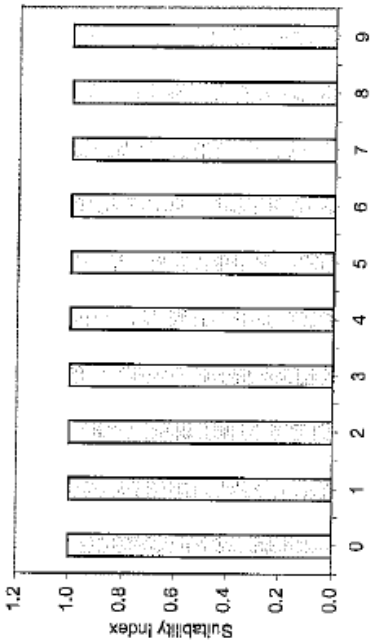
Striped Bass Larval and Incubation Habitat Suitability



(EA 1994)



(EA 1994)



(Pee Dee Instream Flow Subgroup, July 2004)

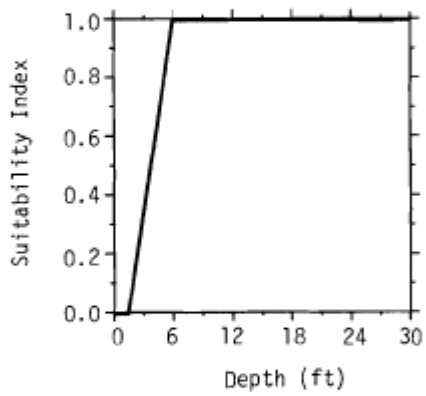
Substrate Codes
0 Detritus
1 Fines
2 Sm Gravel
3 Lg Gravel
4 Sm Cobble
5 Lg Cobble
6 Sm Boulder
7 Lg Boulder
8 Large Bedrock
9 Irregular Bedrock

STRIPED BASS JUVENILE (Crance 1984)

A velocity SI curve for juvenile striped bass is not available. Information on the relationship of the variable to juvenile habitat suitability was insufficient to develop a curve.

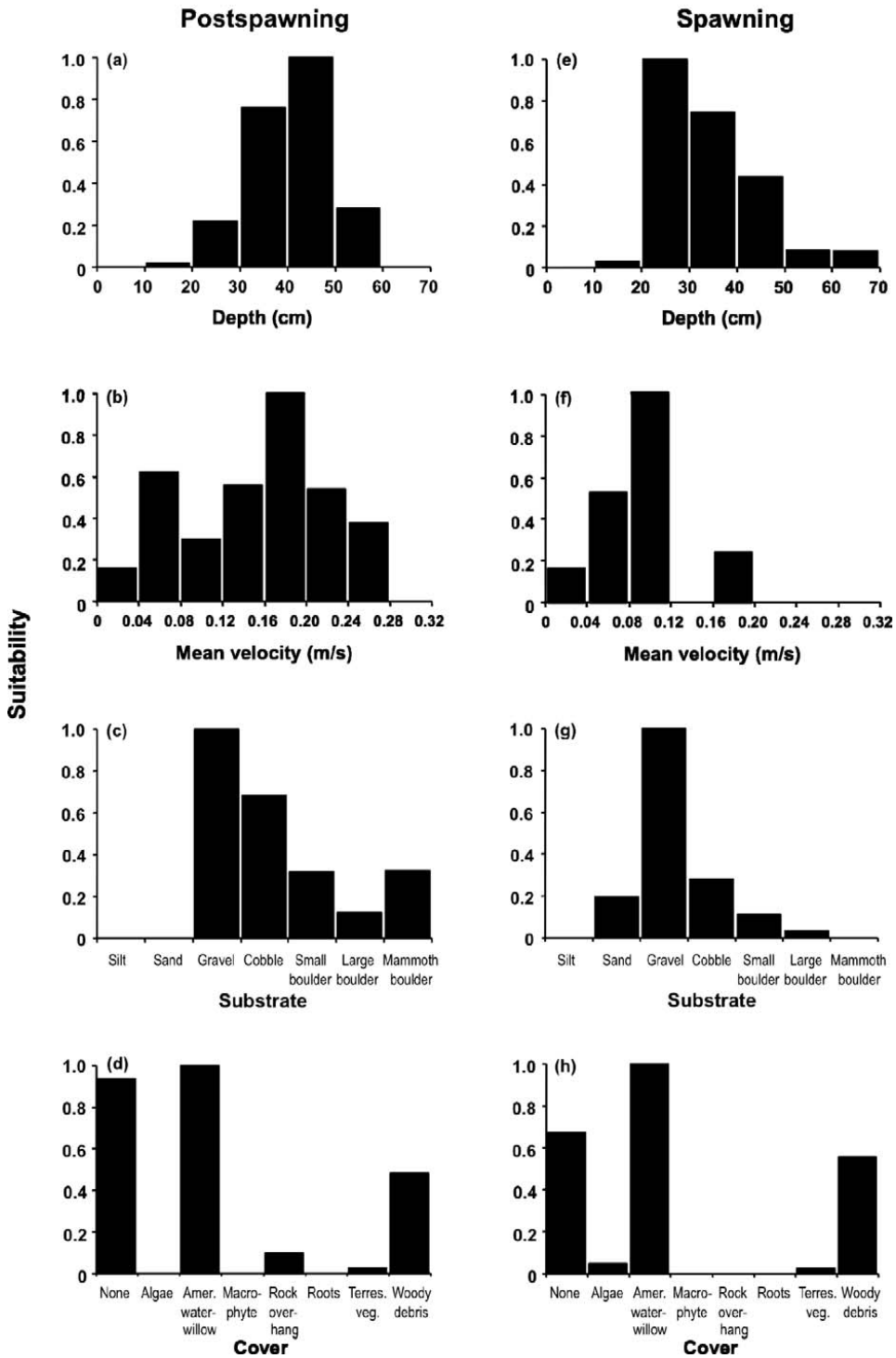
Coordinates

x (ft)	y (SI)
0.0	0.0
1.4	0.0
6.0	1.0
30.0	1.0
100.0	0.0



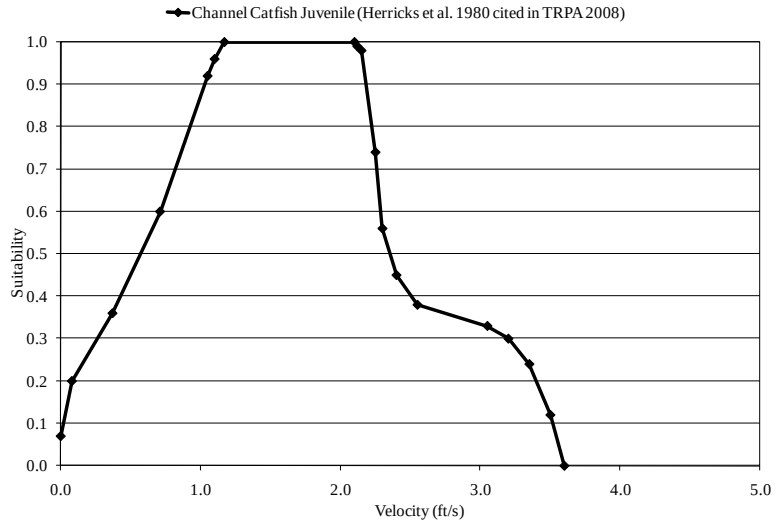
A substrate SI curve for juvenile striped bass is not available. Information on the relationship of the variable to juvenile habitat suitability was insufficient to develop a curve.

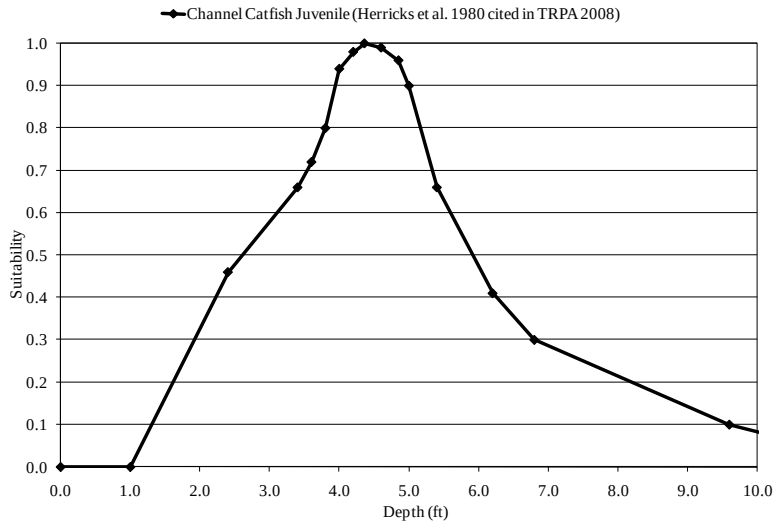
CAPE FEAR SHINER (Hewitt et al. 2009)

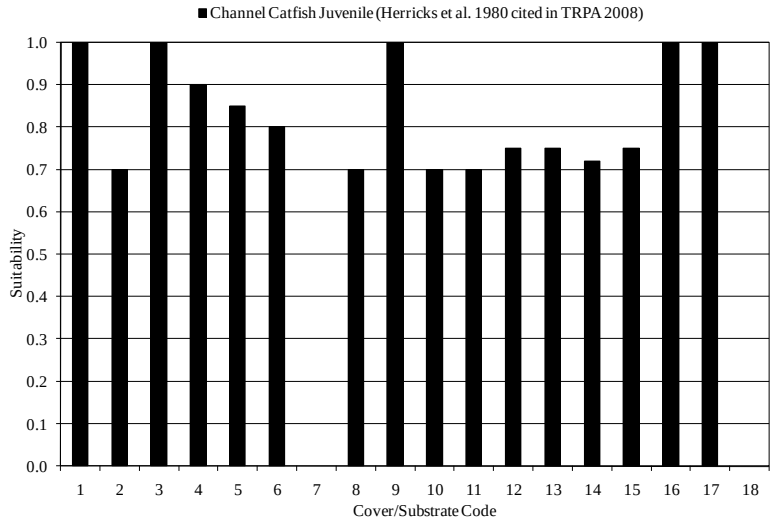


Silt (<0.02 in); Sand (0.02-0.08 in); Gravel (0.1-2.5 in); Cobble (2.5-10.0 in); Small Boulder (10.0-80.0 in); Large Boulder (80.0-160 in); Mammoth Boulder (>160 in)

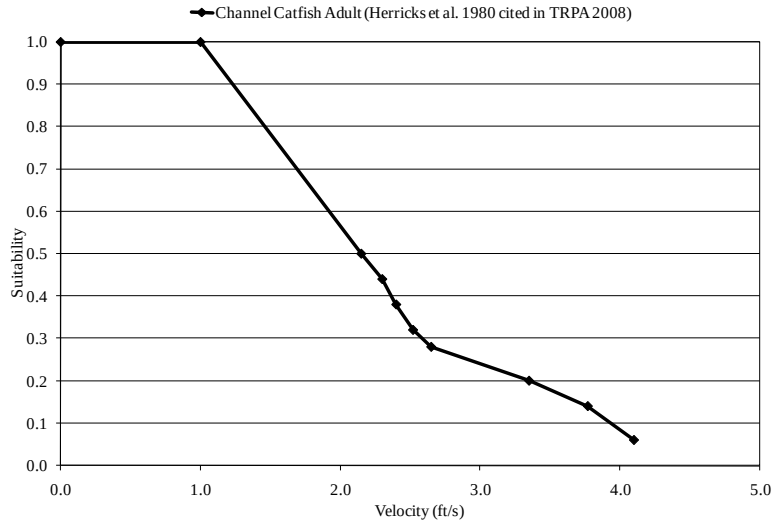
CHANNEL CATFISH JUVENILE

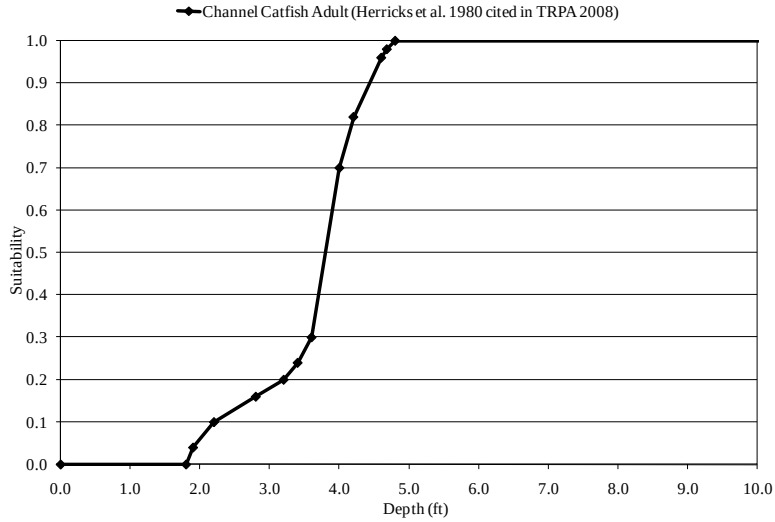


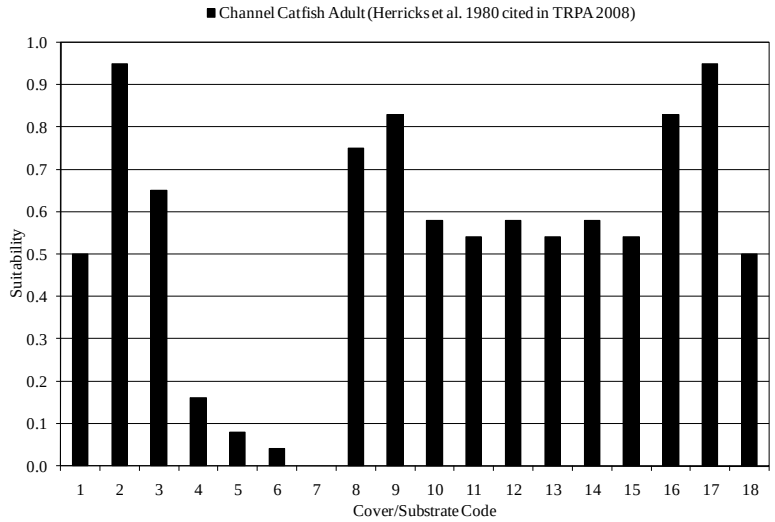




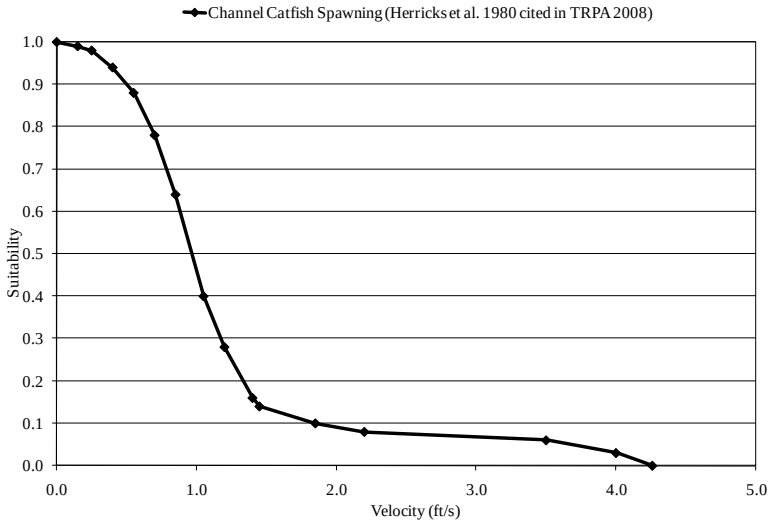
CHANNEL CATFISH ADULT

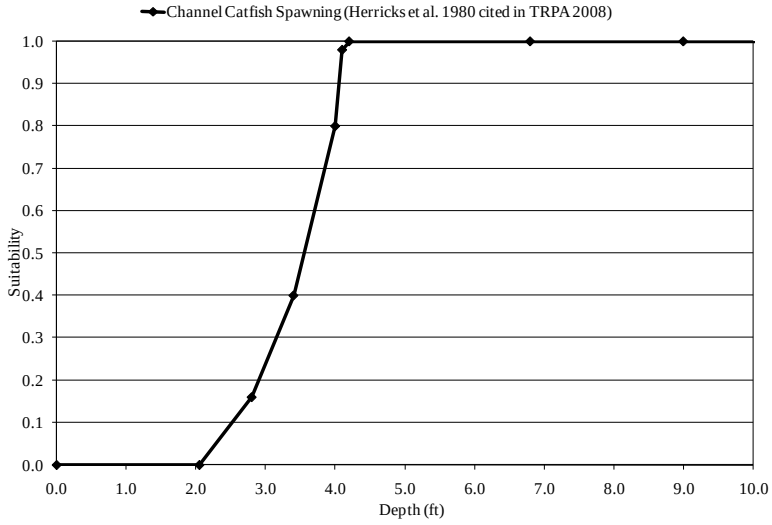


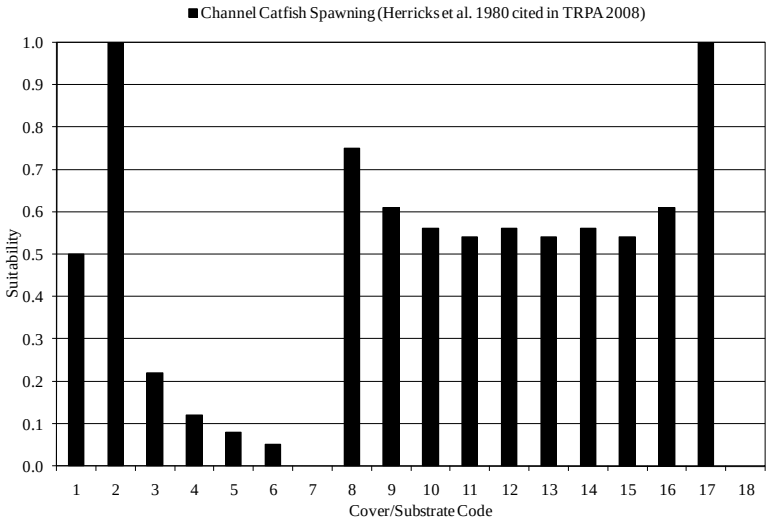




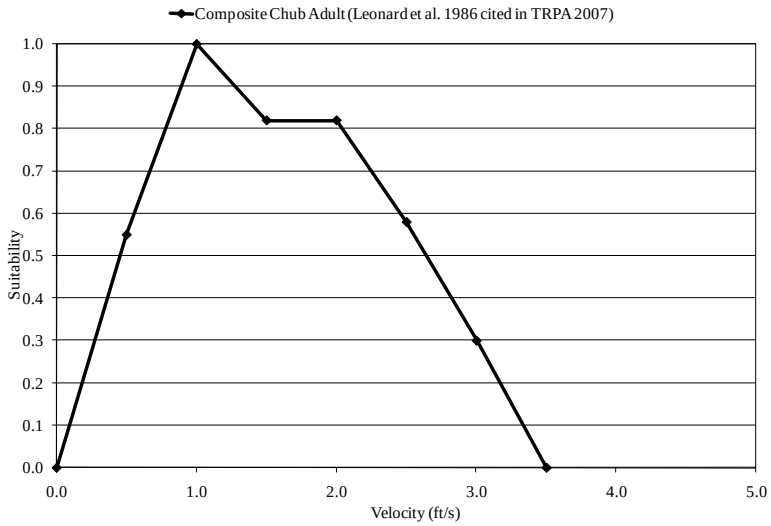
CHANNEL CATFISH SPAWNING

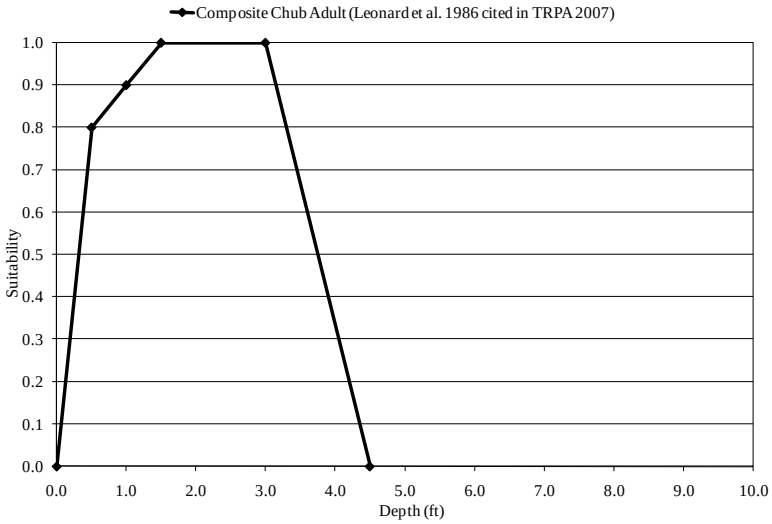


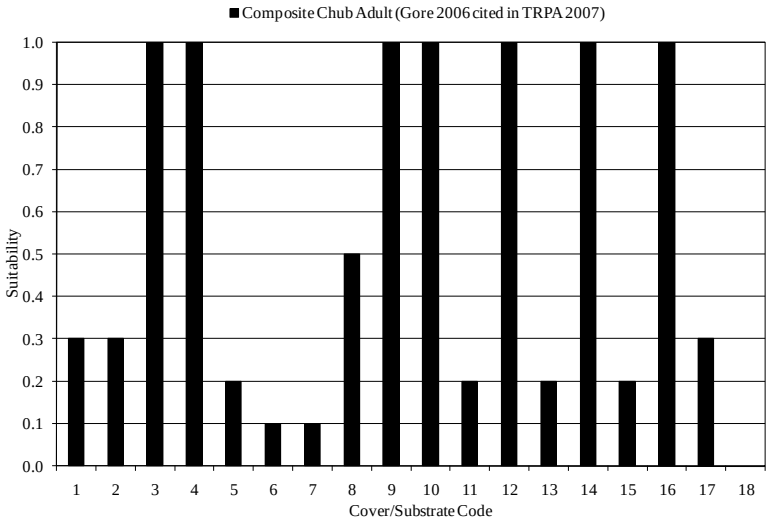




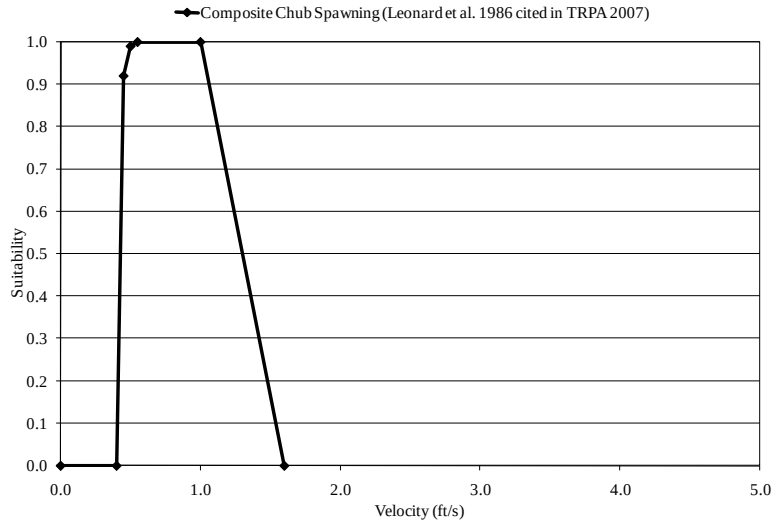
COMPOSITE CHUB ADULT

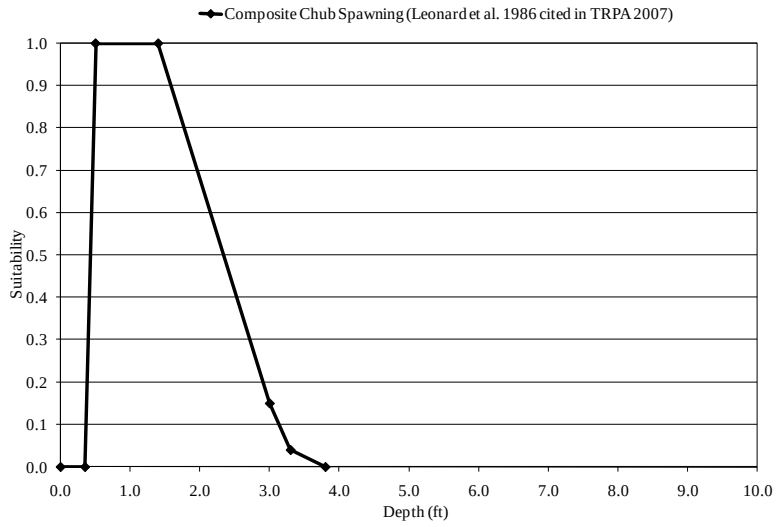


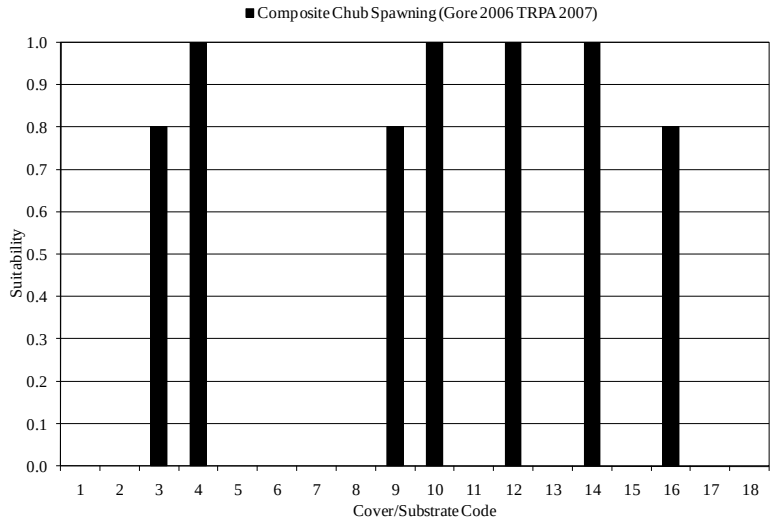




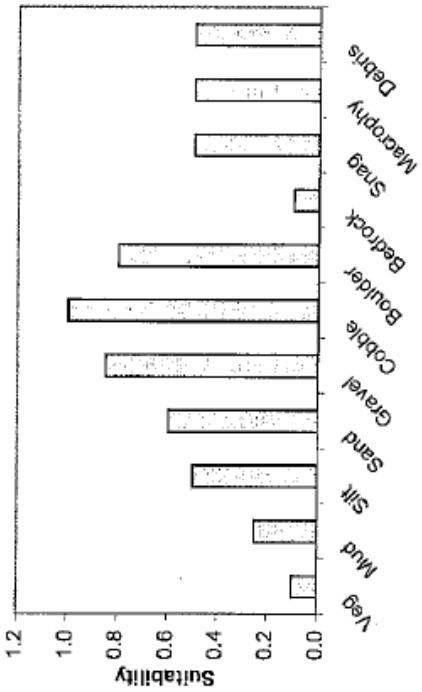
COMPOSITE CHUB SPAWNING



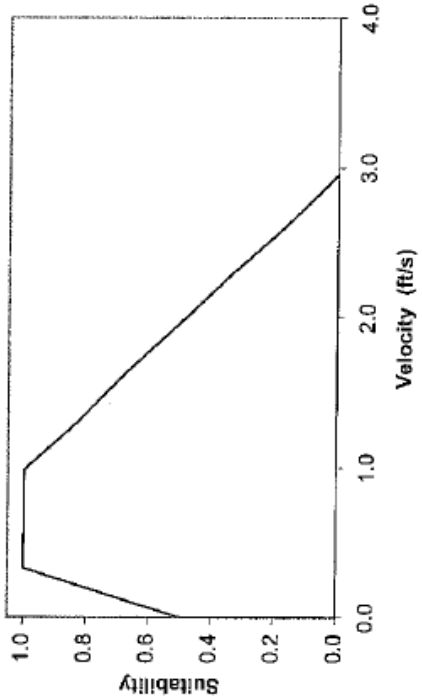




Ephemeroptera Habitat Suitability



(Developed by Jim Gore, provided by Jim Mead, NCDWR in 6/11/04 email)



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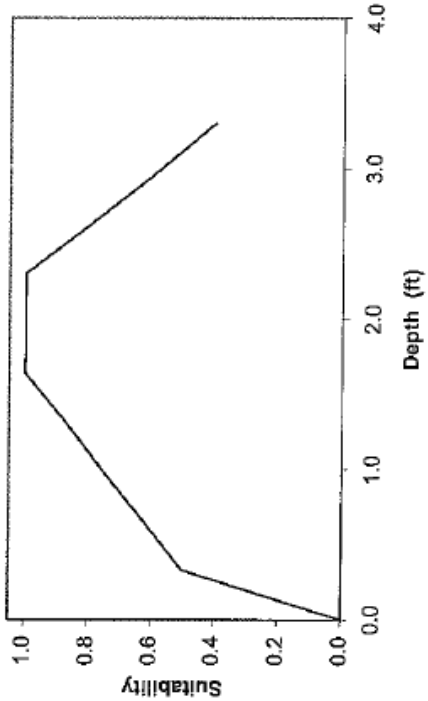
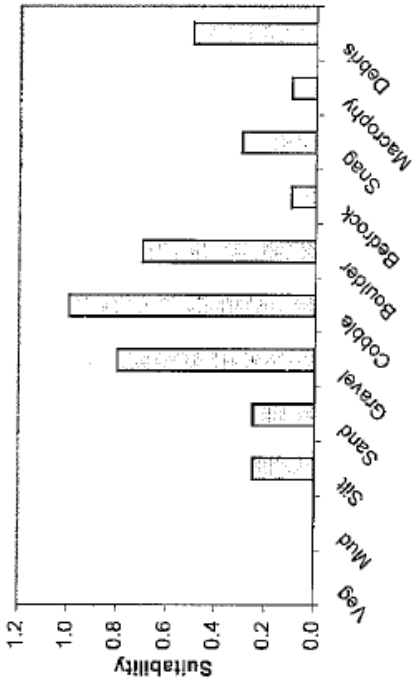


(Developed by Jim Gore, provided by Jim Mead, NCDWR in 6/11/04 email)

Plecoptera Habitat Suitability



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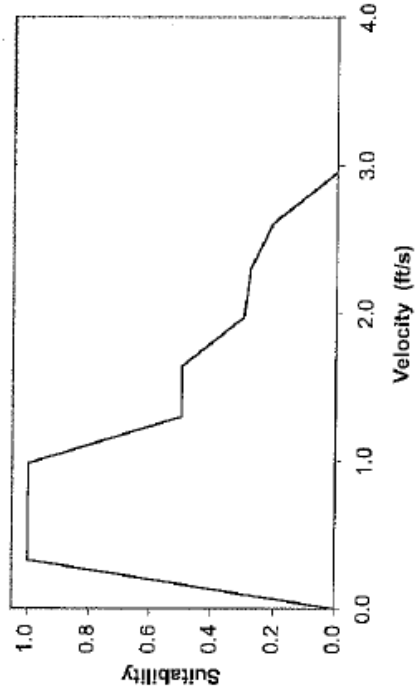

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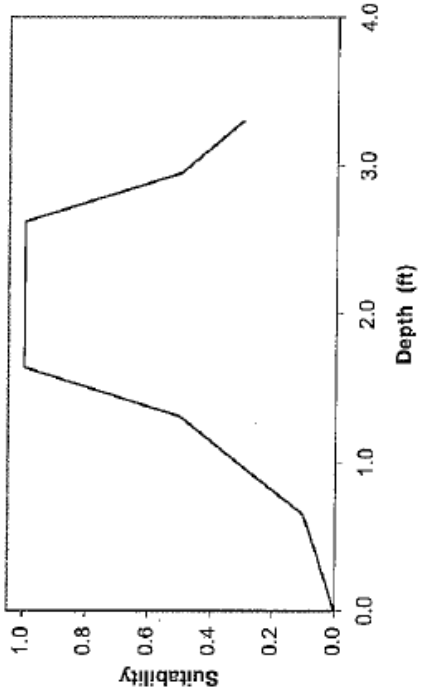
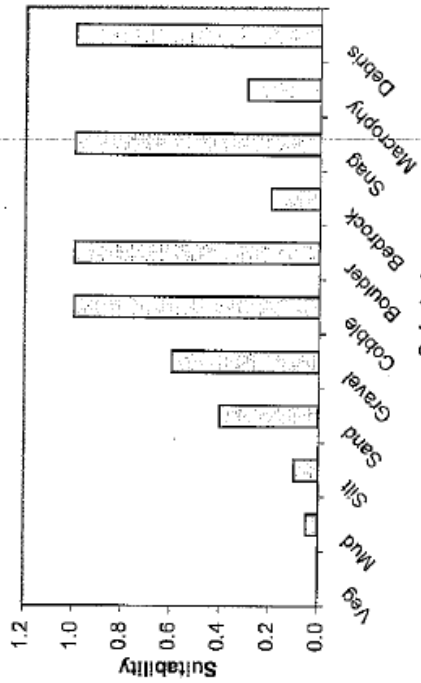
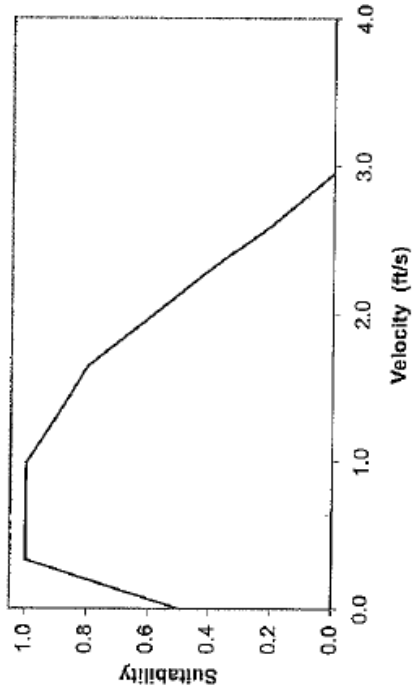


(Developed by Jim Gore, provided by Jim Mead, NCDWR in 6/11/04 email)

Trichoptera Habitat Suitability
Pee Dee River Reach 1



(Developed by Jim Gore, provided by Jim Mead, NCDWR in 6/11/04 email; modified by Instream Flow Subgroup July 2004)



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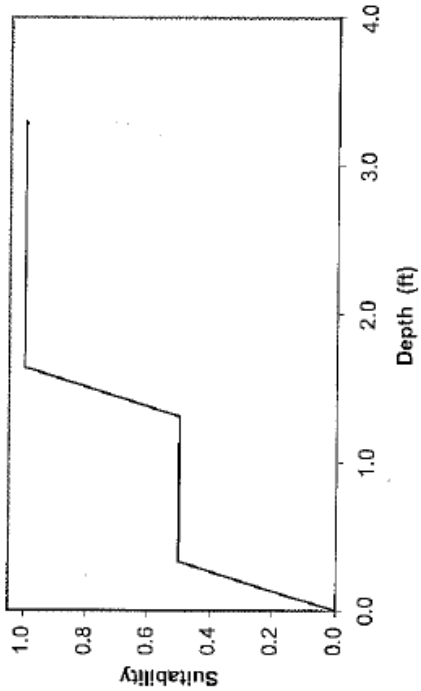
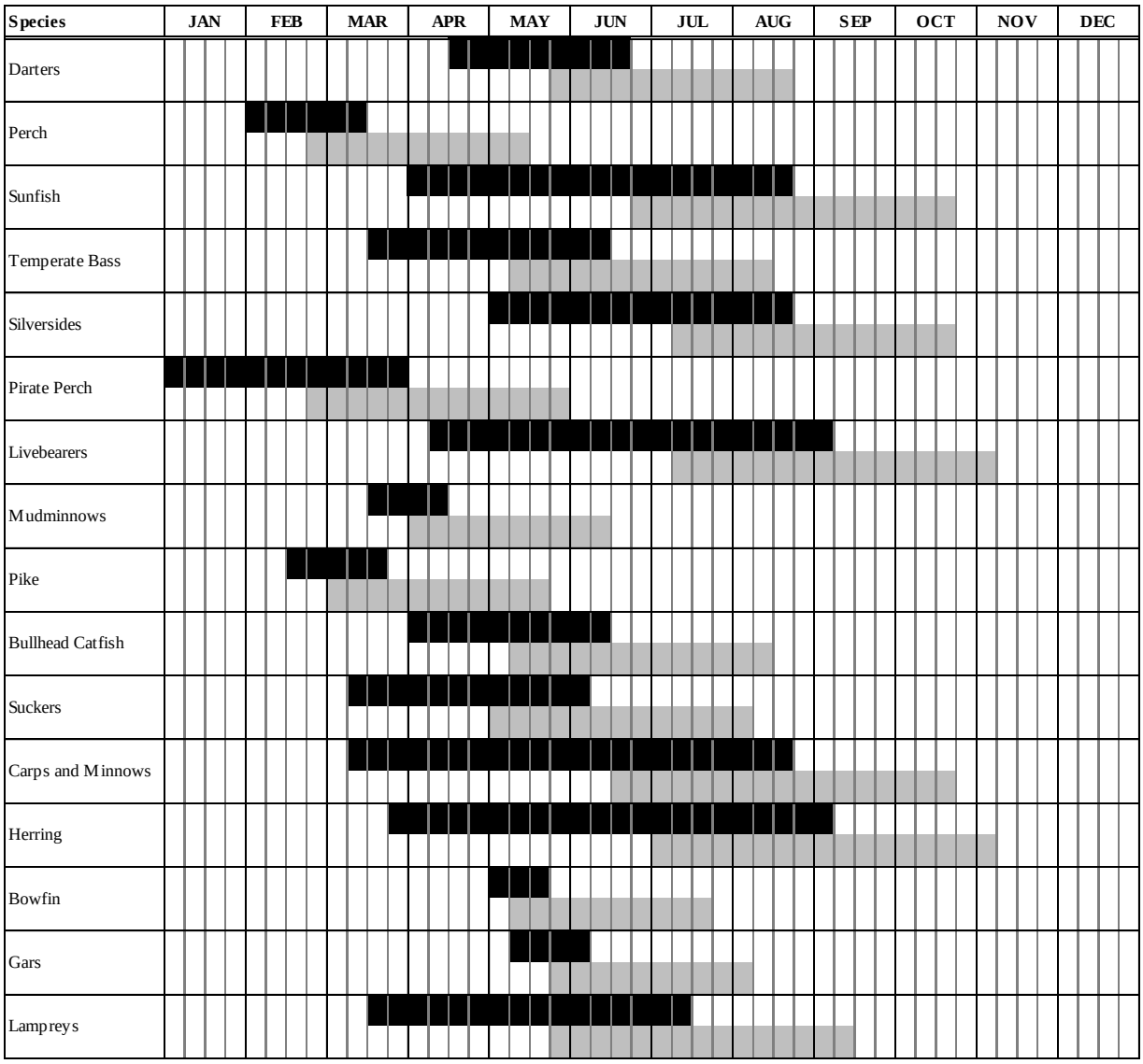


(Developed by Jim Gore, provided by Jim Mead, NCDWR in 6/11/04 email)

Attachment 2

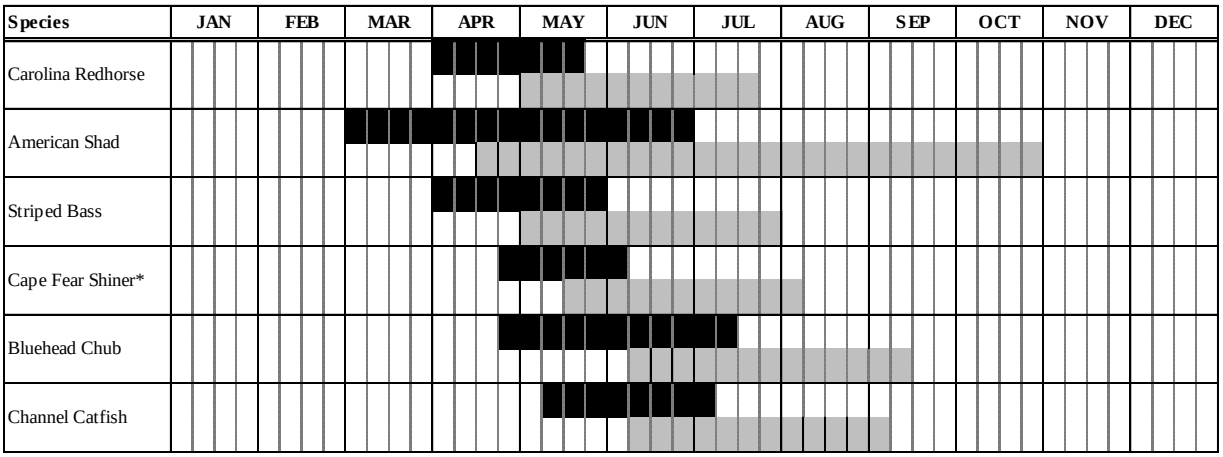
Spawning and Early Life Stage Periodicities of Proposed Target Cape Fear River-Buckhorn Creek Fishes

Periodicities for major fish groups, Cape Fear River-Buckhorn Creek



Spawning
Early Life Stage (estimated to begin two-thirds of the way through the spawning period and lasting 60 days post spawn)
Source: Jenkins and Burkhead (1993)

Periodicities for potential target stand-alone fish species, Cape Fear River-Buckhorn Creek



Spawning
Early Life Stage (estimated to begin two-thirds of the way through the spawning period and lasting 60 days post spawn; except for Cape Fear Shiner)

Source: Jenkins and Burkhead (1993)

* Cape Fear Shiner Source: Hewitt et al. (2009)

Attachment 3

Related Communications and Consultation
(Progress Energy 2006; Duke Power 2005)

Telephone Log and E-mails (Progress Energy 2006; Duke Power 2005)

Date:	May 4, 2004
Contact Person:	Robert Ross
Organization:	USGS, Northern Appalachian Research Lab, Pennsylvania
Phone Number:	(570) 724-3322 x239

Brief Details of Discussion:

I called Bob to ask him about HSI information for some anadromous fish species for the Pee Dee flow study. He said they are currently working on developing habitat suitability models for all alosids as part of an assessment of dam removal impacts on diadromous fish. He said VA Commonwealth and Pennsylvania have developed some models for blueback herring spawning. He said he would see what information he could gather regarding HSI models for blueback herring (spawning), American shad (juveniles), and striped bass (juveniles) and mail/email it to me.

I asked about a target date for their publishing of their results. He expected an in-house draft in the next 6 months and it was hard to say after that.

Employee's Name	Peter Browne

Date:	June 23, 2004
Contact Person:	Pete Kornegay, Anadromous Fisheries Coordinator
Organization:	North Carolina Wildlife Resources Commission
Phone Number:	252 338-3607

Brief Details of Discussion:

Wilson Laney (USFWS) recommended I call Pete regarding the suitability of using the Oconee River HSI curves for American shad (juvenile and outmigration) that Chris Goudreau (NCWRC) provided at the June 9-10, 2004 Instream Flow Subgroup meeting in Pinehurst. I reviewed that the in the curves, optimal depth and velocity values for juvenile shad was 5-20 feet and 0.2 to 1.0 feet/sec., respectively. He said juveniles experience a wide range of conditions during outmigration and he would recommend considering 1) in river and 2) estuary phases. He said, in the Roanoke, their was a diversity of habitats and that outmigration occurred from August to November, which represented a wide variety of water temperatures. He recommended I call Pres Brownell, who helped develop some of the shad curves, and Joe Hightower. I reviewed my call in early May with Joe and I said, considering the project location, we would probably focus on the river component of their outmigration.

He said they usually conduct electroshocking during sampling and he agreed with what Joe said, in that its not conducive to determining habitat preference.

Employee's Name	Peter Browne

Date:	June 23, 2004
Contact Person:	Pres Brownell
Organization:	NMFS
Phone Number:	843 762-8591

Brief Details of Discussion:

As recommended by my earlier conversation with Pete Kornegay (NCWRC), I called Pres regarding the suitability of using the Oconee River HSI curves for American shad (juvenile and outmigration) that Chris Goudreau (NCWRC) provided at the June 9-10, 2004 Instream Flow Subgroup meeting in Pinehurst. Pres said that he thought those curves were reasonable and he suggested that we make them available for the group to review. I told him that at the meeting, we discussed the Oconee curves and that Wilson Laney (USFWS) recommended we call some people, who were not present at the meeting, to see if the curves were suitable and that Pete Kornegay suggested I call Pres. Pres and I agreed that I would email him PDF copies of the curves and that he would review and get back to me regarding whether slight adjustments would be appropriate.

Pres recalled that the American shad spawning curves used in the Swift Creek flow study resulted from modifications he and Joe Hightower made to blue book information. While these curves had not been published, they have been used for a number of flow studies. He said that people involved with the Swift Creek study thought these curves were good. However, the people involved with the Augusta study, who weren't as familiar with flow studies, thought that the revised spawning models showed too much habitat at lower flows. He thought that it might be good to convey this context to the Pee Dee subgroup.

For clarification, I noted that we were using the Swift Creek curves for American shad spawning and that we had discussed these at the June subgroup meeting. I stated that we had a difficult time finding juvenile curves for shad, that I had called Joe Hightower (in early May), and that it wasn't until Chris provided the Oconee curves that we had any HSI information for juvenile shad. He stated that spawning was the key consideration for shad, but that he would be happy to review the juvenile curves that we have.

Employee's Name	Peter Browne

Date:	June 23, 2004
Contact Person:	Michael Odom
Organization:	USFWS, Harrison Lake National Fish Hatchery, VA
Phone Number:	804 829-2421

Brief Details of Discussion:

Wilson Laney (USFWS) recommended I called Mike regarding the suitability of using the Oconee River HSI curves for American shad (juvenile and outmigration) that Chris Goudreau (NCWRC) provided at the June 9-10, 2004 Instream Flow Subgroup meeting in Pinehurst. I mentioned the optimal depth criteria of 5 to 20 feet represented by the Oconee juvenile shad HSI curve. Mike said that is not what he sees – they are usually in shallow water. He said, one problem with existing shad curves is that a lot were developed for tidal rivers. He has done most of his work in the Piedmont of Virginia where he finds juvenile shad in water 6 inches to 3-4 feet. They are holding immediately above or below a riffle. The juveniles are closely associated with submerged aquatic vegetation (SAV). They often are holding in a velocity refugia (a feeding station) from where they will dart into a high velocity area. He said they are a fairly plastic species. He referred to Ross's work and how he said that shad are habitat generalists, though they are frequently associated with SAV. That is what he has seen. In sampling in the tidal part of the Potomac, he found juvenile shad along the edges of SAV. In the Pamonhee (sp?), they used push netting and found higher densities of juveniles in shallow areas and higher densities of blueback herring in mid-channel deeper waters. He said the bluebacks are more of a pelagic species. Juvenile shad are not filter feeding, but rather sight-feeding on terrestrial and aquatic insects in the shallow areas below the riffles. They find higher numbers of juvenile shad in areas having relatively high primary production (both periphyton and aquatic macrophytes), which in turn leads to higher secondary production. Mike thought that competition with other species also can be a factor with bass likely pushing juvenile shad into the shallows.

He said that he has been sampling shad for 10 years, mostly in the James River above the fall line and in the upper tidal portion of the Potomac. They had been measuring habitat variables in the James River in two dimensions. But they didn't get enough data points to reach any conclusions. He said they need to look at a system in three dimensions, but that is too difficult.

Employee's Name	Peter Browne

Arnold, Stephen

From: Crutchfield, John [john.crutchfield@pgnmail.com]
Sent: Tuesday, June 29, 2004 1:57 PM
To: Arnold, Stephen; Browne, Peter
Subject: FW: Carolina Redhorse Spawning Requirements

See Wayne's perspective on Carolina redhorse spawning-no concrete studies, just anecdotal, observational data.
Observed depths approximately 1.5-2.5
Estimated velocities during spawning approx. 2 ft/sec (certainly not slow, < 1 ft/sec)
Gravel substrate, 1.5-2.5 inches dia.
May orient towards Justicia clumps for cover during spawning, see Wayne's comment, he is unsure of sucker identity.

Probably could construct a curve on BPJ.

Will await to determine if Bob Jenkins has anything further to offer.

John Crutchfield
-----Original Message-----
From: Wayne Starnes [mailto:Wayne.Starnes@ncmail.net]
Sent: Monday, June 28, 2004 4:16 PM
To: Crutchfield, John
Cc: jenkins@roanoke.edu; Morgan Raley; Gabriela Hogue
Subject: Re: Carolina Redhorse Spawning Requirements

John--I believe Bob will be in Quebec (Copper Redhorse) for a few more days yet. I should think he'll have quite a bit of info on parameters of Golden spawning habitat. This may be the best source of detailed data.

As I think we mentioned before, the only direct evidence we have for Carolinas is the sighting of a male holding territory (and one possible spawning according to my notes) beneath the NC 22 bridge at High Falls (following which we actually managed to seine a female in the run just along side & below). Date was 9 May 1996, water temp 24, sunny weather; I believe the observation was near our arrival time which I have noted as 1330 (so high sun). I'd estimate water depth to be 20" or so at the holding spot w/ gravel substrate. I believe the gravel in this area of the riffle complex is of fairly large (maybe 1.5 - 2.5 " range) dimension but it's probably worth renoting on next visit (I think it's pretty stable but I've not been there in a year or two). I would guess velocity at 2'/sec or so in that area under the flow conditions at the time.

We also noted probably spawning activity in shallower runs upstream of the bridge in gravel chutes between Justicia clumps but these could not be seen clearly. Circumstantially, these may have also been Carolinas. I suppose it's also possible V-lips may have been spawning by then, too (or late Brassies or Shortheads) (I'll defer to Bob on this). We did not have a shocker at that time so didn't manage to sample any further redhorses. To my recollection, substrate is generally finer up there, and current is more gentle, perhaps 1 ft/sec. This really all should be better quantified someday but then there has never been another opportunity to view spawning despite a lot of return May visits to the site between '96 and 2000 or so.

The following year (1997), while shocking, Katey and I knocked up 3 males in spawning condition (in 3 different shock runs) just above that bridge in 2.5' depth water flowing fast over coarse gravel and

around large rocks. We did not observe any spawning activity before hand from above but visibility wouldn't have permitted it, really. That collection was on 18 May (1430-1730) and, though later than the '96 encounter, water was cooler at 19 C. It appeared these males had been banging around a bit so perhaps spawning had been underway for several days or more. Perhaps water had cooled off from a cool snap or something or maybe the 24 C in early May of '96 was atypical (and I'm beginning to wonder how much temp really has to do w/ spawning anyway?!).

I realize this is a bit anecdotal (and could be supplemented a bit as far as substrate info goes with a revisit to the site...again, assuming fair stability of the area) but it's all we have had the fortune to encounter. Bob struck out on Little R. this year despite a survey or two for spawning activity. Hopefully, he's got lots more to offer from the standpoint of Goldens. -W

"Crutchfield, John" wrote:

> Wayne and Bob:
> As part of our Pee Dee River relicensing work related to instream flow, we have a subgroup that is developing an instream study plan for the river below Blewett and Tillery plants. One of the target species is Carolina redhorse. In a previous e-mail, I asked about surrogate species that could be used for habitat suitability curve criteria as there is no such information known for Carolina redhorse. You suggested golden redhorse, which we have reviewed and incorporated.
>
> Specific questions at our June instream flow meeting concerned Carolina redhorse spawning requirements, i.e., depth, velocities, preferred substrate types, cover. I assume spawning habitat is shallow, fast runs on gravel bars. Do you guys have any perspectives on optimal depth, water velocities, substrate, that you could share in developing a suitability curve for spawning Carolilna redhorse.
>
> Any insights would be helpful.
>
> Thanks,
> John Crutchfield

--

Wayne C. Starnes, Ph.D., Research Curator of Fishes >^^^> >^^^>
North Carolina State Museum of Natural Sciences
wayne.starnes@ncmail.net Ph. 919-733-7450 x760; FAX 919-715-2294
Museum Web Site: http://www.naturalsciences.org

My lab & postal/shipping address location:
North Carolina State Museum of Natural Sciences
Research Laboratory
4301 Reedy Creek Rd., Raleigh, NC 27607 USA

Arnold, Stephen

From: Danny Johnson [johnsond@dnr.state.sc.us]
Sent: Wednesday, June 30, 2004 3:15 PM
To: Arnold, Stephen
Subject: Fw: Striped bass info.

Steve,
FYI.
Danny

----- Original Message -----
From: Dick Christie
To: Danny Johnson
Cc: Dan Crochet
Sent: Wednesday, June 30, 2004 2:39 PM
Subject: RE: Striped bass info.

Hi Danny - we did not place striped bass in any of the guilds for the Augusta Shoals Instream flow study. They were in a class of anadromous fish which included American shad spawning habitat, American shad larvae and juveniles, American shad outmigration, and striped bass egg/larval drift. The habitat suitability curves used in that study were presented in Figure 4-1 of the SRIFS report. I would think a similar approach could be used on the Pee Dee.

Striped bass are not considered to be truly anadromous in the Pee Dee, but I assume that they do make upstream and downstream migrations as they do in other SE coastal rivers. According to theBig Pee Dee River management plan, striped bass support a commercial and sport fishery in this river. Maybe Dan can shed some more light on this.

Hope this helps.

-----Original Message-----
From: Danny Johnson [mailto:johnsond@dnr.state.sc.us]
Sent: Wednesday, June 30, 2004 11:22 AM
To: dick christie
Subject: Fw: Striped bass info.

Dick,
Please refer to my 6/15/04 email to you on this. Do you have any thoughts I could pass along on this?
Thanks,
Danny

----- Original Message -----
From: Arnold, Stephen
To: Danny Johnson
Cc: john.crutchfield@pgnmail.com
Sent: Wednesday, June 30, 2004 11:37 AM
Subject: RE: Striped bass info.

Hi Danny,

Just checking in to see if you were able to discuss our striped bass questions with Dick and Dan.
Thanks for your help.

Steve

-----Original Message-----
From: Danny Johnson [mailto:johnsond@dnr.state.sc.us]
Sent: Tuesday, June 15, 2004 3:24 PM
To: Arnold, Stephen
Subject: Re: Striped bass info.

Thanks, Steve. I'll see what our guys can come up with.
Danny

----- Original Message -----
From: Arnold, Stephen
To: Danny Johnson
Cc: john.crutchfield@pgnmail.com ; Browne, Peter
Sent: Tuesday, June 15, 2004 2:28 PM
Subject: RE: Striped bass info.

Danny

I was checking my notes today to answer your question. My notes indicate you were going to check with Dick Christie and Dan Crochet to find out which guild(s) they would place striped bass juveniles, and striped bass adults into. Also, any insight they may have on the life history of Pee Dee River striped bass (ie., confirmation of non-migratory status, seasonal movement patterns, etc.) would be helpful too.

Thanks for your help,
Steve

-----Original Message-----
From: Danny Johnson [mailto:johnsond@dnr.state.sc.us]
Sent: Tuesday, June 15, 2004 2:08 PM
To: Arnold, Stephen
Subject: Striped bass info.

Steve,
At the end of our recent Instream Flow Study Team meeting on June 9-10, I was asked to consult with our fisheries biologists and obtain some info on Pee Dee striped bass for the group. When I reviewed my notes on this I found them less that exact on the specific info I was to obtain. I guess I was getting a little groggy by meeting's end. Can you enlighten me on what I need to get for the Team?
Thanks,
Danny

Browne, Peter

From: Arnold, Stephen
Sent: Wednesday, September 22, 2004 8:09 PM
To: Ty Ziegler (E-mail); Amanda Hill (E-mail); Besler, Doug (E-mail); Chris Goudreau (E-mail); Dave Coughlan (E-mail); Dick Christie (E-mail); Donley Hill (E-mail); Ed Luttrell (E-mail); Ewing, Todd (E-mail); Gene Vaughan (E-mail); Gerrit Jobsis (E-mail); Greg Kozak; Hall, Joe (E-mail); Harden, Wayne (E-mail); Huff, Jennifer (E-mail); Hugh Barwick (E-mail); Jim Mead (E-mail); Kathi Peacock (E-mail); Ken Kearns (kkearns@kearnswest.com); Mark Cantrell (E-mail); Michael Barclay (E-mail); Oakley, Mark (E-mail); Prescott Brownell (E-mail); Scott Fletcher (E-mail); Steve Johnson (E-mail); Steve Reed (E-mail); Harland, Bryan
Cc: Browne, Peter
Subject: FW: review of eel paper recommended by USFWS for HSI curve development

To Catawba-Wateree Instream Flow Study Team:

As a follow up to our IFST discussion last week regarding HSC development for American eel, I thought I'd pass along comments from one of our biologists regarding recent literature and it's application to the development of HSC for the American eel.

Steve

Stephen H. Arnold
Senior Aquatic Scientist
Devine, Tarbell & Associates, Inc.
970 Baxter Blvd.
Portland, ME 04103
207-775-4495
stephen.arnold@devinetarbell.com

-----Original Message-----
From: Browne, Peter
Sent: Wednesday, June 23, 2004 8:47 AM
To: Arnold, Stephen; John Crutchfield (E-mail); Barclay, Michael
Subject: review of eel paper recommended by USFWS for HSI curve development

I reviewed Wiley et al. (2004), *Relation between Physical Habitat and American Eel Abundance in Fiver River Basins in Maryland*. Wilson Laney had recommended this paper as a possible source for HSI information for American eel.

The study results indicate that eels don't associate with a particular habitat type. The authors stated that the failure of the study to find eel-habitat relations was consistent with other studies: Bain et al. (1988) found that eels "... use habitat broadly and did not find the presence or absence of eels to be associated with specific habitat features such as depth, water velocity, and substrate..."; in SC Meffe and Sheldon (1988) "found no consistent patterns of habitat use by American eels with respect to 15 habitat variables ..."; and Huish and Pardue (1978) found no differences in eel abundance in NC streams having varying width, substrate, flow, and depth.

Wiley et al. conclude that it is therefore difficult to develop habitat models for eels which "...appear to be (a) generalist species that (is) highly tolerant of and adaptable to a broad variety of habitats under a wide range of conditions."

Of note, of the 17 variables Wiley et al. evaluated, the variable *velocity-depth diversity* was most closely linked to the parameters for which we are searching for the Pee Dee curve development. For this parameter, Wiley et al. considered 1) shallow-slow, 2) shallow-fast, 3) deep-slow, and 4) deep-fast conditions. They determined that optimal conditions occurred when all four of these habitats were present and that suboptimal, marginal, and poor conditions occurred when only 3, 2, and 1 of these habitats were present, respectively. So basically, optimal conditions for eels are rivers or streams having a variety of habitats. As such, I think our analysis for the other selected species (representatives for each guild and the stand alone species) should adequately cover eel habitat needs.

1

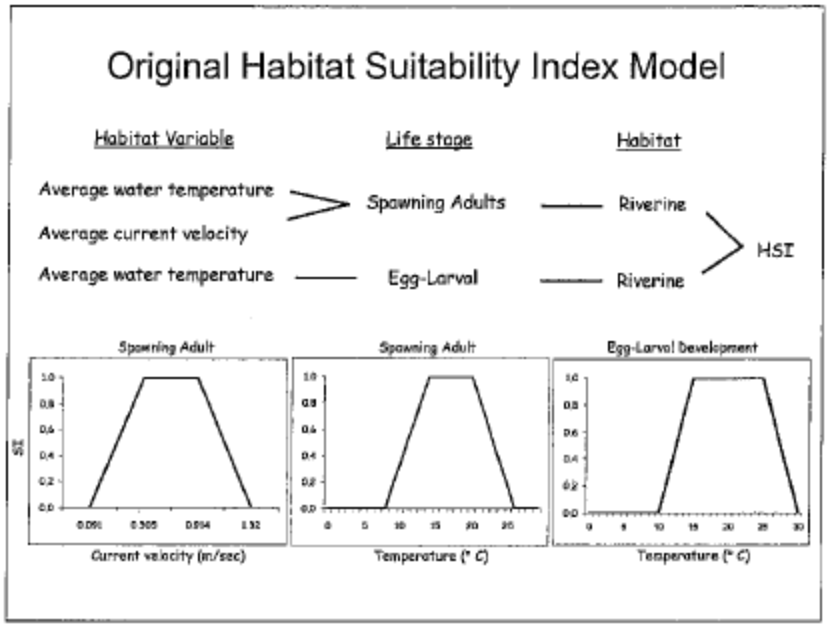
From: Mark_A_Cantrell@fws.gov [mailto:Mark_A_Cantrell@fws.gov]
Sent: Friday, October 29, 2004 10:16 AM
To: Ziegler, Ty; Amanda Hill (E-mail); Besler, Doug (E-mail); bmharland@yahoo.com; Chris Goudreau (E-mail); Dave Coughlan (E-mail); Dick Christie (E-mail); Donley Hill (E-mail); Luttrell, Ed; Ewing, Todd (E-mail); Gene Vaughan (E-mail); Gerrit Jobsis (E-mail); Greg Kozak; Hall, Joe (E-mail); Harden, Wayne (E-mail); Huff, Jennifer (E-mail); Hugh Barwick (E-mail); Jim Mead (E-mail); Peacock, Kathi; kkearns@kearnswest.com; Mark Cantrell (E-mail); Barclay, Michael; Oakley, Mark (E-mail); Prescott Brownell (E-mail); Ron Ahle; Fletcher, Scott; Steve Johnson (E-mail); Steve Reed (E-mail)
Cc: McCann, Mary
Subject: American shad - modified HSI curve from Hightower

Here is information from Joe Hightower regarding HSI for American shad:

The default HSI model for spawning adults defined by Stier and Crance (1985), using an optimal range of 14-20°C for temperature and 0.31-0.91 m/s for current velocity. The model for egg and larval development uses water temperature only and has an optimal range of 15 to 26. The lower HSI value from the two models is assumed to be the overall HSI value.

The modified HSI model uses the current velocity range as defined by Stier and Crance (1985) but uses a single temperature range rather than separate temperature ranges for spawning and egg/larval development. The new temperature component assumes that the range of 14.5-1-24.5 °C is optimal for both spawning adults and egg and larval development (Ross et al. 1993a; Bilkovic et al. 2002). The other modification to the model is to include a suitability curve for bottom substrate. The suitability values were estimated based on used and available habitat for spawning American shad in the Neuse River (Beasley and Hightower 2000; Bowman and Hightower 2001).

(See attached file: ModifiedAShadHSI_Model.ppt)



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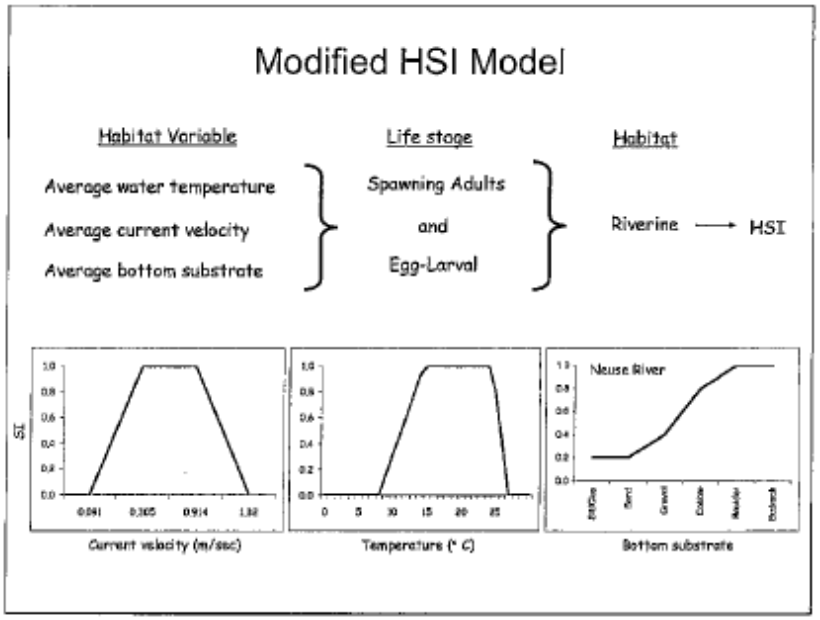

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Attachment 4

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Table 1. Freshwater mussel species found, the number of each species collected (n) at each sample location, the total number per station and the total number per taxa in the Buckhorn Creek and Cape Fear River surveys[+].

	Buckhorn Creek					Cape Fear River					
Common Name Species Name	**BK4**	**BK5**	**BK6**	**BK6 Below Dam**		**Reach 1 Upper**	**Reach 1 Middle**	**Reach 2**	**Reach 3 Main-stem**	**Reach 3**	**Total number per taxa**
Eastern Elliptio *Elliptio complanata*	18	236	274	54		139	543	551	3	2	1820
Carolina Slabshell *Elliptio congaraea*						4		23			27
Atlantic Spike *Elliptio producta*			1	1		9	19	9			39
Variable Spike *Elliptio icterina*		11	2					8		1	22
Roanoke Slabshell *Elliptio roanokensis*						39	72	16	2	6	135
Yellow Lampmussel *Lampsilis cariosa*							2				2
Florida Pondhorn *Uniomerus carolinianus*		10									10
Paper Pondshell *Utterbackia imbecilis*				1		1	1	1		1	5
Eastern Creekshell *Villosa delumbis*		2	1								3
Total number	**18**	**259**	**278**	**56**		**192**	**637**	**608**	**5**	**10**	

Total number of mussels collected from Buckhorn Creek = 611
Total number of mussels collected from Cape Fear River = 1452
Total number of mussels collected =2063

[+] Mussel surveys were conducted in Buckhorn Creek on September 29, 2009 and in the Cape Fear River on October 1-2, 2009.

Table 2. Extant Freshwater Mussel Species in the Cape Fear River Basin in North Carolina and their Conservation Status Listing[+]. NCE=North Carolina Endangered; NCT=North Carolina Threatened, FSC=Federal Species of Concern; NCSC= North Carolina Species of Concern; NCSC= North Carolina Significantly Rare

Common Name	Scientific Name	Listing Status[¶]	2009 PEC Surveys
Eastern Floater	*Pyganodon cataracta*		
Paper Pondshell	*Utterbackia imbecilis*		X
Creeper	*Strophitus undulatus*	NCT	
Triangle Floater	*Alasmidonta undulata*	NCT	
Brook Floater	*Alasmidonta varicosa*	NCE, FSC	
Atlantic Pigtoe	*Fusconaia masoni*	NCE, FSC	
Eastern Elliptio	*Elliptio complanata*		X
Box Spike	*Elliptio cistellaeformis*		
Cape Fear Spike	*Elliptio marsupiobesa*	NCSC	
Carolina Slabshell	*Elliptio congarea*		X
Carolina Spike	*Elliptio raveneli*		
Variable Spike	*Elliptio icterina*		X
Carolina Lance	*Elliptio angustata*		
Atlantic Spike	*Elliptio producta*		X
Pod Lance	*Elliptio folliculata*	NCSC	
Roanoke Slabshell	*Elliptio roanokensis*	NCT	X
Green Lance	*Elliptio viridula*		
Florida Pondhorn	*Uniomerus carolinianus*		X
Savannah Lilliput	*Toxolasma pullus*	NCE, FSC	
Eastern Pondmussel	*Ligumia nasuta*	NCT	
Eastern Creekshell	*Villosa delumbis*	NCSR	X
Notched Rainbow	*Villosa constricta*	NCSC	
Carolina Creekshell	*Villosa vaughaniana*	NCE, FSC	
Southern Rainbow	*Villosa vibex*		
Eastern Lampmussel	*Lampsilis radiata*[2]	NCT	
Yellow Lampmussel	*Lampsilis cariosa* [1]	NCE, FSC	X
Rayed Pink Fatmucket	*Lampsilis splendida*		

[+] Bogan, A.E. 2002. Workbook and key to the freshwater bivalves of North Carolina.
[¶] Natural Heritage Program List of the Rare Species of North Carolina; 2008.

Table 3. Taxonomic listing of benthic invertebrates collected from Stations BK4, BK5 and BK6 in Buckhorn Creek, August 25-27, 2009 and the taxon's associated Biotic Index tolerance value.[+]

Order	Family	Genus/Species	Tolerance Value[+]	BK4	BK5	BK6
Oligochaeta						
	Naididae					
		Nais spp	8.9		C	R
		Pristinella spp.	7.1			R
	Lumbriculidae		7.0	C	C	A
	Tubificidae					
		Ilyodrilus templetoni	9.3		R	
		Isochaetes curvisetosus	6.8		R	
		Limnodrilus spp.	9.5	R	R	
	Megadriles		9.0	R		
Bivalvia						
	Corbiculidae					
		Corbicula fluminea	6.1	C	R	A
	Sphaeriidae					
		Pisidium spp.	6.5		A	
		Sphaerium spp.	7.6	R	A	C
	Unionidae					
		Elliptio complanata	5.1		A	A
Gastropoda						
	Ancylidae					
		Ferrisia spp.	6.6		C	R
	Hydrobiidae					
		Somatogyrus spp.	6.4		A	
	Lymnaeidae					
		Pseudosuccinea columella	7.7	R	R	
	Physidae					
		Physella spp.	8.8		A	R
	Planorbidae					
		Helisoma anceps anceps	6.2	R	A	A
	Viviparidae					
		Campeloma decisum	6.5		A	A
Amphipoda						
	Crangonyctidae					
		Crangonyx spp.	7.9	C		
	Talitridae					
		Hyallela azteca	7.8	C	A	A

Table 3 (continued)

Order	Family	Genus/Species	Tolerance Value+	BK4	BK5	BK6
Decapoda						
	Cambaridae		7.5			C
	Palaeomonidae					
		Palaeomonetes paludosus	7.1	R		R
Isopoda						
	Asellidae					
		Caecidotea spp.	9.1	A	C	R
Ephemeroptera						
	Baetidae					
		Baetis flavistriga	7.0		A	
		B intercalaris	7.0		C	
		B. pluto	4.3		R	
		Callibaetis spp.	9.8		R	C
		Centroptilum spp.	6.6			R
		Procloeon viridoculare	5.0	R		
		Pseudocloeon propinquus	5.8			R
	Baetiscidae					
		Baetisca spp.	3.4		R	
	Caenidae					
		Caenis spp.	7.4	C	R	A
	Heptageniidae					
		Stenonema modestum	5.5	A	A	A
		Stenacron interpunctatum	6.9	C		C
	Leptophlebiidae					
		Paraleptophlebia spp.	0.9	R	R	
	Oligoneuriidae					
		Isonychia spp.	3.5	A	C	
	Tricorythidae					
		Tricorythodes spp.	5.1		C	R
Odonata						
Anispotera						
	Aeshnidae					
		Boyeria vinosa	5.9			R
		Basiaescha janata	7.4	R	C	C
	Corduliidae					
		Epicordulia spp.	5.6		R	C
	Cordulegasteridae					
		Cordulegaster spp.	5.7	R		
		Neurocordulia obsoleta	5.2		C	C
		Tetragoneuria spp.	8.6	R	C	C
	Libellulidae					
		Libellula spp..	9.6	R	C	
		Pachydiplax longipennis	9.9		C	
	Gomphiidae					
		Hagenius brevistylus	4.0			R
		Gomphus spp.	5.8	R	A	A
		Progomphus obscures	8.2		R	A
	Macromiidae					
		Didymops transversa	2.4	R		
		Macromia spp.	6.2	R	R	

Table 3 (continued)

Order	Family	Genus/Species	Tolerance Value[+]	BK4	BK5	BK6
Zygoptera						
	Coenagrionidae	*Argia* spp.	8.2	A	C	
		Ischnura spp.	9.5	A	C	
	Calopterygidae					
		Calopteryx spp.	7.8		C	R
Megaloptera						
	Corydalidae					
		Corydalis cornutus	5.2	C	C	
		Nigronia serricornis	5.0	R	A	C
	Sialidae					
		Sialis spp.	7.2	C	R	C
Trichoptera						
	Dipseudopsidae					
		Phylocentropus spp.	6.2	R		
	Hydropsychidae					
		Cheumatopsyche spp.	6.2	A	A	C
		Hydropsyche betteni	7.8		R	
		Macrostemum spp.	3.5	R		
	Leptoceridae					
		Ceraclea ancylus	2.3	R		
		Mystacides sepulchralis	2.7	R	R	C
		Oecetis sp A (Floyd)	2.0		R	R
		O. nocturna	4.1	R		
		O. persimilis	4.7	R		R
		Triaenodes ignitus	4.6			R
		T. perna	4.1		R	A
	Limnephilidae					
		Pycnopsyche spp.	2.5	R	R	C
	Philopotamidae					
		Chimarra spp.	2.8	A	C	
Coleoptera						
	Dytiscidae					
		Lioporeus spp.	3.0	R		R
		Neoporus spp.	8.6	R		
	Dryopidae					
		Helichus spp.	4.6	C	A	A
	Elmidae					
		Ancyronyx variegatus	6.5	R	R	A
		Dubiraphia spp.	5.9	C	A	A
		Macronychus glabratus	4.6	C	C	C
		Stenelmis crenata	7.0		C	R
	Gyrinidae					
		Dineutus spp.	5.5			C
	Haliplidae					
		Peltodytes spp.	8.7			R
	Hydrophilidae					
		Berosus spp.	8.4		R	R
		Tropisternus spp.	9.7			R

Table 3 (continued)

Order	Family	Genus/Species	Tolerance Value[+]	BK4	BK5	BK6
Diptera						
	Ceratopogonidae					
		Atrichopogon	6.5	R		
		Palpomyia complex	6.9	C	C	
	Chironomidae					
	Chironomini					
		Chironomus spp.	9.6			A
		Cladopelma spp.	3.5		R	
		Cryptotendipes spp.	6.2		R	
		Cryptochironomus spp.	6.4		R	
		Dicrotendipes fumidus	8.1		C	
		D. modestus	8.7			A
		D. simpsoni	10.0		R	
		Polypedilum aviceps	3.7		R	
		P. beckae	¶			R
		P. illinoense	9.0	C		
		P. scalaenum	8.4	R	R	
		Parachironomus spp.	9.4		R	
		Paratendipes spp.	5.1		R	
		Phaenopsectra sp. 3[¥]	6.6	R	R	
		Pseudochironomus spp.	5.4			R
		Rheotanytarsus spp.	5.9		R	
		Stenochironomus spp.	6.5	C	C	C
		*Tanytarsus*spp.	6.8		C	C
		Tribelos jucundus	6.3	A	A	A
	Orthocladiini					
		Cricotopus politus	¶		R	
		Nanocladius alternantherae	7.1		R	R
		Rheocricotopus robacki	7.3		C	
	Tanypodinae					
		Ablabesmyia mallochi	7.2	R	C	A
		A. janta/parajanta	7.4			C
		Clinotanypus pinguis	8.7	R	R	R
		Labrundinia spp.	5.9		R	
		Labrundinia johansseni	¶			R
		Pentaneura spp.	4.7	R	C	R
		Procladius spp.	9.1	C	C	A
	Culicidae					
		Anopheles spp.	8.6	R		
	Simuliidae					
		Similium spp.	6.0		R	
	Tabanidae					
		Chrysops spp.	6.7			R
		Tabanus spp.	9.2			R
	Tipulidae					
		Tipula spp.	7.3	R	C	
Nemertea						
		Prostoma graecense	6.1		A	

Table 3 (continued)

Order	Family	Genus/Species	Tolerance Value[+]	BK4	BK5	BK6
Pharyngobdellida						
	Glossiphoniidae					
		Helobdella triserialis	9.2		R	
Hydracarina			5.5	A	A	A
Tricladida						
	Planariidae					
		Dugesia tigrina	7.2		A	R
		Hydrolimax grisea	[¶]		A	C

[+]Tolerance values were adopted from NCDWQ (2006) where
R = Rare (1-2 individuals collected),
C = Common (3-9 individuals collected), and
A = Abundant (10 or more individuals collected).
[¶]Tolerance value not assigned.
[¥]Refers to NCDWQ naming nomenclature for Family Orthocladiini midges.

Table 4. Benthic invertebrate taxa richness, EPT and BI scores, and NCDWQ BI bioclassification ratings collected from Stations BK4, BK5 and BK6 in Buckhorn Creek, August 25-27, 2009[+].

Station	Number of Taxa	Number of EPT Taxa	EPT Score	BI Value	BI Score	Metric Average	NCDWQ Bioclassification
BK4	57	15	2.4	6.2	3.0	2.7	Good-Fair
BK5	85	17	2.6	6.5	2.4	2.5	Fair
BK6	70	14	2.4	6.6	2.0	2.2	Fair

[+]The acronym BI means Biotic Index.

Waterbody	Location	Date	Collection Number	Site ID	County	Basin	Subbasin
CAPE FEAR R	US 401	1/21/2003	8876	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	10/2/2002	9027	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	7/8/1998	7643	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	8/23/1993	6343	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	9/12/1990	5344	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	7/12/1988	4620	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	7/11/1988	4600	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	7/8/1986	3827	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	8/1/1985	3531	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	9/25/1984	3350	BB437	HARNETT	CPF	7
CAPE FEAR R	US 401	7/14/1983	3127	BB437	HARNETT	CPF	7

Eight Digit HUC	el 4 Ecoreg	Latitude	Longitude	Sample Type	Bioclass	luctivity (µS	pH (SU)
03030004	65m	35.40833	-78.8133	EPT	Good-Fair	110	7.6
03030004	65m	35.40833	-78.8133	EPT	Not Rated	185	7.3
03030004	65m	35.40833	-78.8133	Full Scale	Good	180	7.4
03030004	65m	35.40833	-78.8133	Full Scale	Good	0	0
03030004	65m	35.40833	-78.8133	Full Scale	Good	0	0
03030004	65m	35.40833	-78.8133	Full Scale	Good	0	0
03030004	65m	35.40833	-78.8133	EPT	Good	0	0
03030004	65m	35.40833	-78.8133	Full Scale	Good	0	0
03030004	65m	35.40833	-78.8133	Full Scale	Good	0	0
03030004	65m	35.40833	-78.8133	Full Scale	Good-Fair	0	0
03030004	65m	35.40833	-78.8133	Full Scale	Good	0	0

mperature	ved Oxygen (mg/L)
5.8	12.8
25	6.9
28	7
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0