Fish Passage Through Road Culverts in the Piedmont of North Carolina

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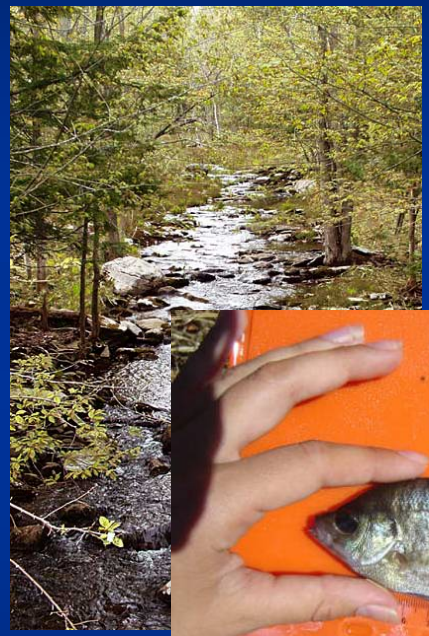
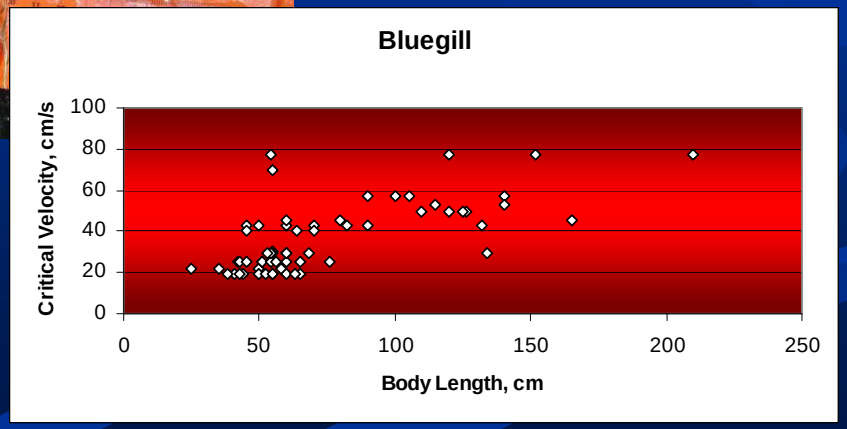
This presentation will cover the following:



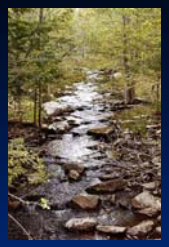
Project need

Materials and Methods



Results

In periods of rapid development the need for a new infrastructure often overshadows concerns of potential environmental impacts.



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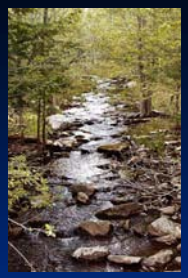
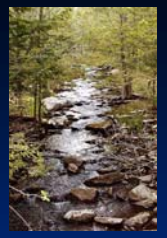
“A culvert is a rigid body set into a dynamic stream environment.” (WDFW 2003)



Existing culverts are often unable to accommodate changes in hydrology due to land development, instead they become barriers to fish movement.

There are both federal and state regulations regarding the building of culverts, and their effects on water bodies.



US Army Corps of Engineers

- Final Regional Conditions for Nationwide Permits: Section 2 # 5
- NWP # 14 Part 5, Part 11a

NC Division of Water Quality:

- General Certification Conditions (GC3375) Section 9

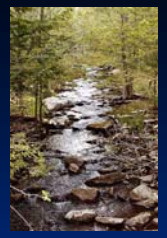
North Carolina's "Redbook"- administrative codes for surface waters and wetlands

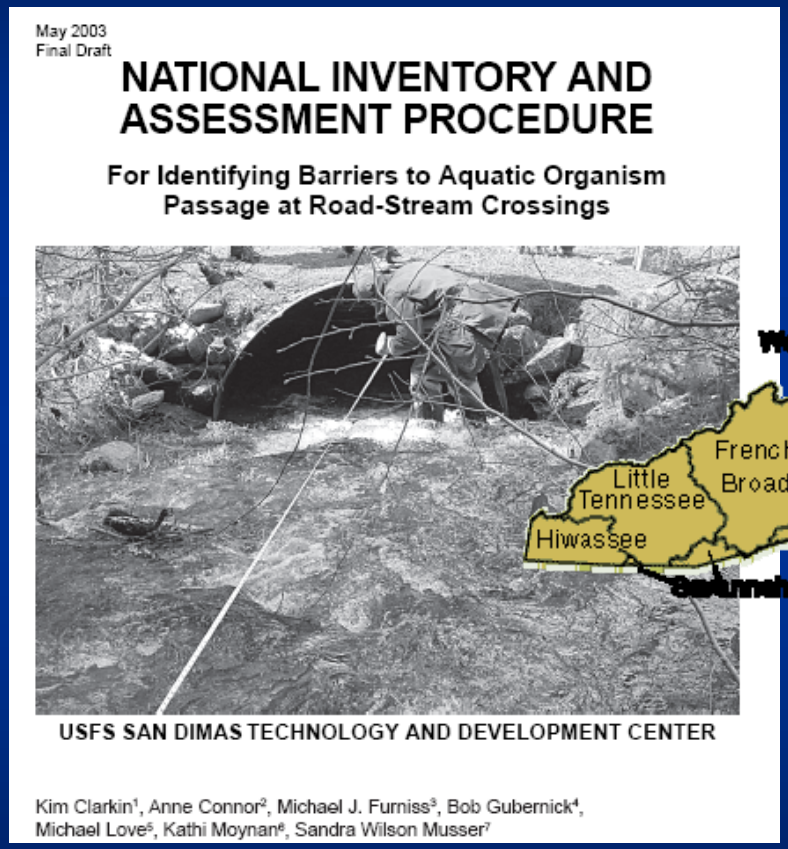
- Section 15A NCAC 02B.0231, b.5.d

North Carolina State BMP manual

- Chapter 4

Regional criteria need to be developed that reflect movement capabilities North Carolina fish.





May 2003
Final Draft

NATIONAL INVENTORY AND ASSESSMENT PROCEDURE

For Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings

USFS SAN DIMAS TECHNOLOGY AND DEVELOPMENT CENTER

Kim Clarkin[1], Anne Connor[2], Michael J. Furniss[3], Bob Gubernick[4], Michael Love[5], Kathi Moynan[6], Sandra Wilson Musser[7]

Six species were chosen for the experiment based on input from the NC Division of Water Quality and the NC Wildlife Resource Commission

Swallowtail shiner

Notropisprocne

Margined madtom

Noturus insignis

Redbreast sunfish

Lepomis auritus

Johnny darter

Etheostoma nigrum

Bluehead chub

Nocomis leptocephalus

Bluegill

Lepomis macrochirus

Goal: To find the Critical Velocities for each of the six species

Critical velocity is defined as “the maximum sustained speed a fish can maintain for 10 minutes, which is considered comparable to the passage velocity of a fish through long culverts up to 100m (328ft)” (Clancy 1990)

Test Hypothesis 1:

The critical velocities will not be the same for each species

Test Hypothesis 2:

The critical velocities will be functions of body length for each species

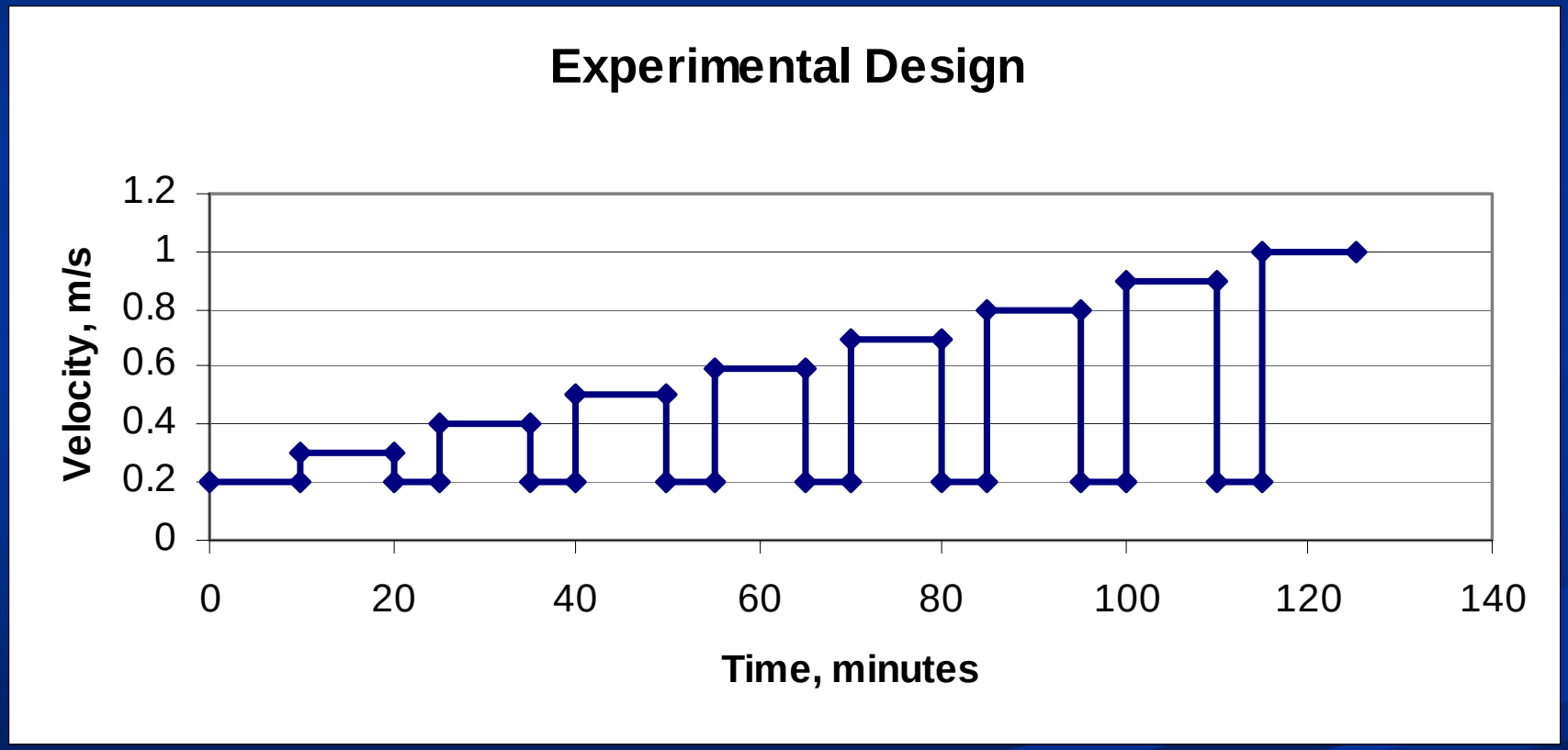
Fish were collected from Crabtree Creek and Rocky Branch using an electrofisher.

The data collection site was located on the Lake Wheeler Road Field Laboratory, operated by NCSU

A flume was constructed in a basin at the Lake Wheeler Field Laboratory.

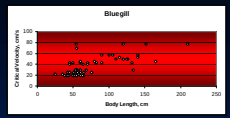
Materials included: Lumber, Cinderblock, Wire Mesh, Synthetic fabric, and Soft Mesh fabric.

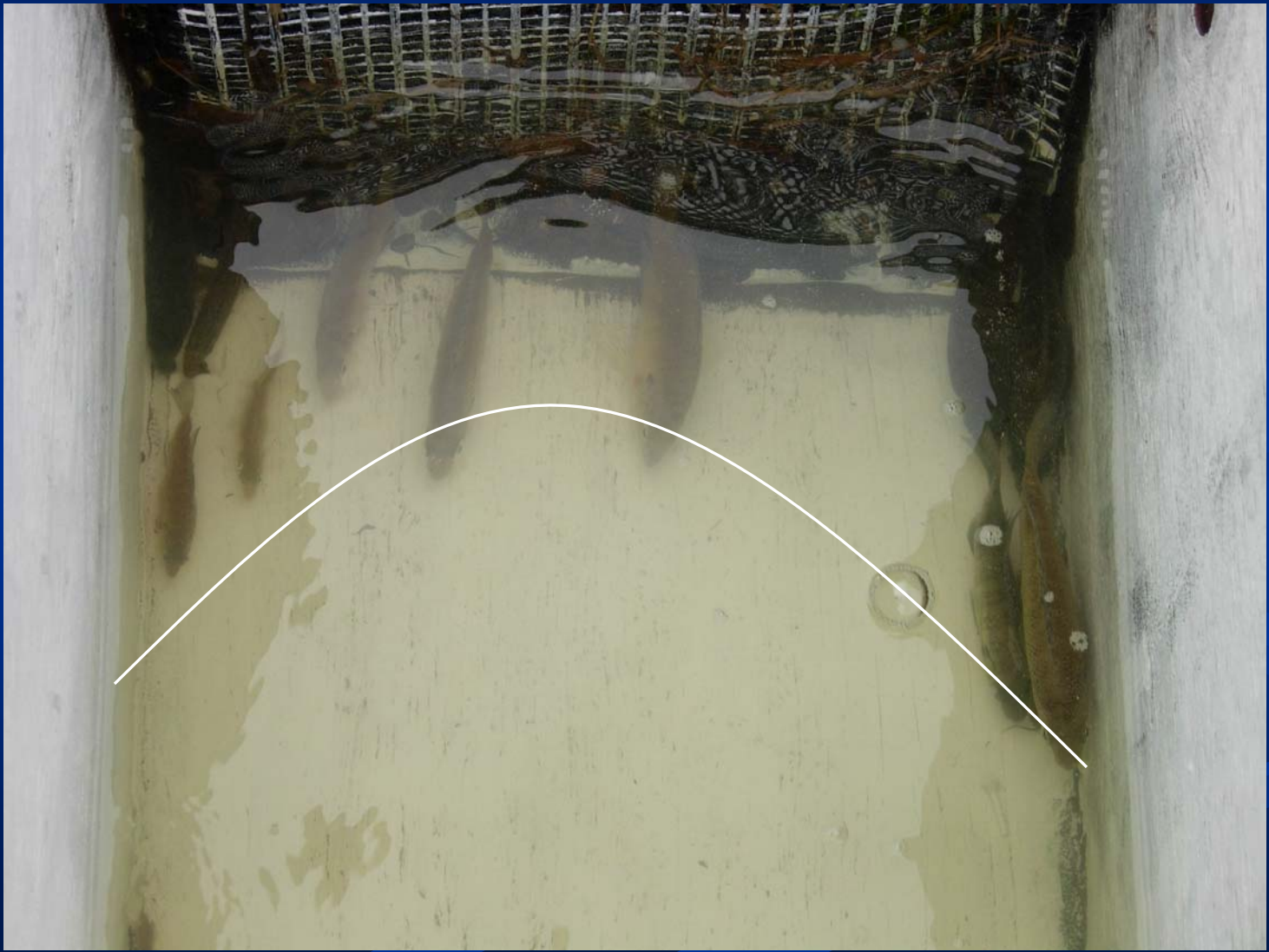
In the experiment the velocity of water in the flume was increased in 10 minute intervals, with a five minute "rest" in between.

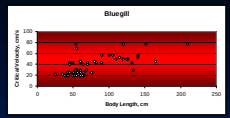


A fish was considered exhausted when it could not swim off of the mesh after a gentle prod.

The sunfish and chubs often swam in an arc pattern, with the largest fish at the center of the flume, and the smaller ones along the sides.

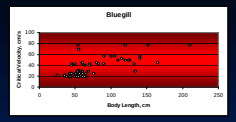





Bluegill
Critical Velocity, cm/s
Body Length, cm
0
20
40
60
80
100
0
50
100
150
200
250

F
Does not play well with others
Does not participate

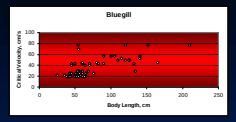
The mean critical velocities for a species ranged from 37cm/s to 86 cm/s, with the overall mean across species being 54cm/s.



Species		Individuals Tested	Mean Critical Velocity cm/s
Overall Mean		**202**	**53.57**
Bluegill		61	37.05
Bluehead	chub	33	85.56
Johnny	darter	21	67.76
Margined	madtom	9	48.67
Redbreast	sunfish	52	43.89
Swallowtail	shiner	26	61.42

A GLM for the data showed that critical velocity is significantly different between species.

A second GLM was used to test the significance of Body Length on Critical Velocity within each species. (Hypothesis 2)

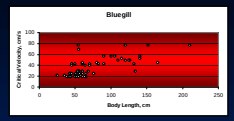


Species	Estimate of Intercept cm/s	Standard Error	P-value	Significant
Bluegill	14.479	4.63	0.002	Yes
Bluehead chub	61.611	12.215	<0.0001	Yes
Johnny darter	72.929	22.95	0.0017	Yes
Margined madtom	49.778	33.201	0.1355	No
Redbreast sunfish	28.957	6.06	<0.0001	Yes
Swallowtail shiner	79.866	20.522	0.0001	Yes

Species	Estimate of Slope cm/s/mm	Standard Error	P-value	Significant
Bluegill	0.2998	0.055	<0.0001	Yes
Bluehead chub	0.2145	0.107	0.0456	Yes
Johnny darter	-0.0971	0.426	0.8200	No
Margined madtom	-0.0148	0.437	0.9730	No
Redbreast sunfish	0.2054	0.078	0.0088	Yes
Swallowtail shiner	-0.3311	0.364	0.3643	No

Table 3.3 p 54

Contrasts were performed to test if the relationship between body length and critical velocity varied among species.



Swallowtail shiner vs Bluehead chub

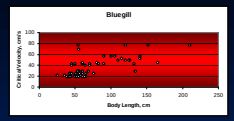
Swallowtail shiner vs Johnny Darter

Bluegill vs Redbreast sunfish

Bluegill vs Johnny Darter

And it’s a Tie!!!!!!!

Using results from the two hypothesis tests, a final GLM was created.



Critical Velocity (Bluegill) = 0.247BL + 18.456

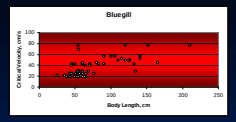
Critical Velocity (Bluehead Chub) = 0.247BL + 57.97

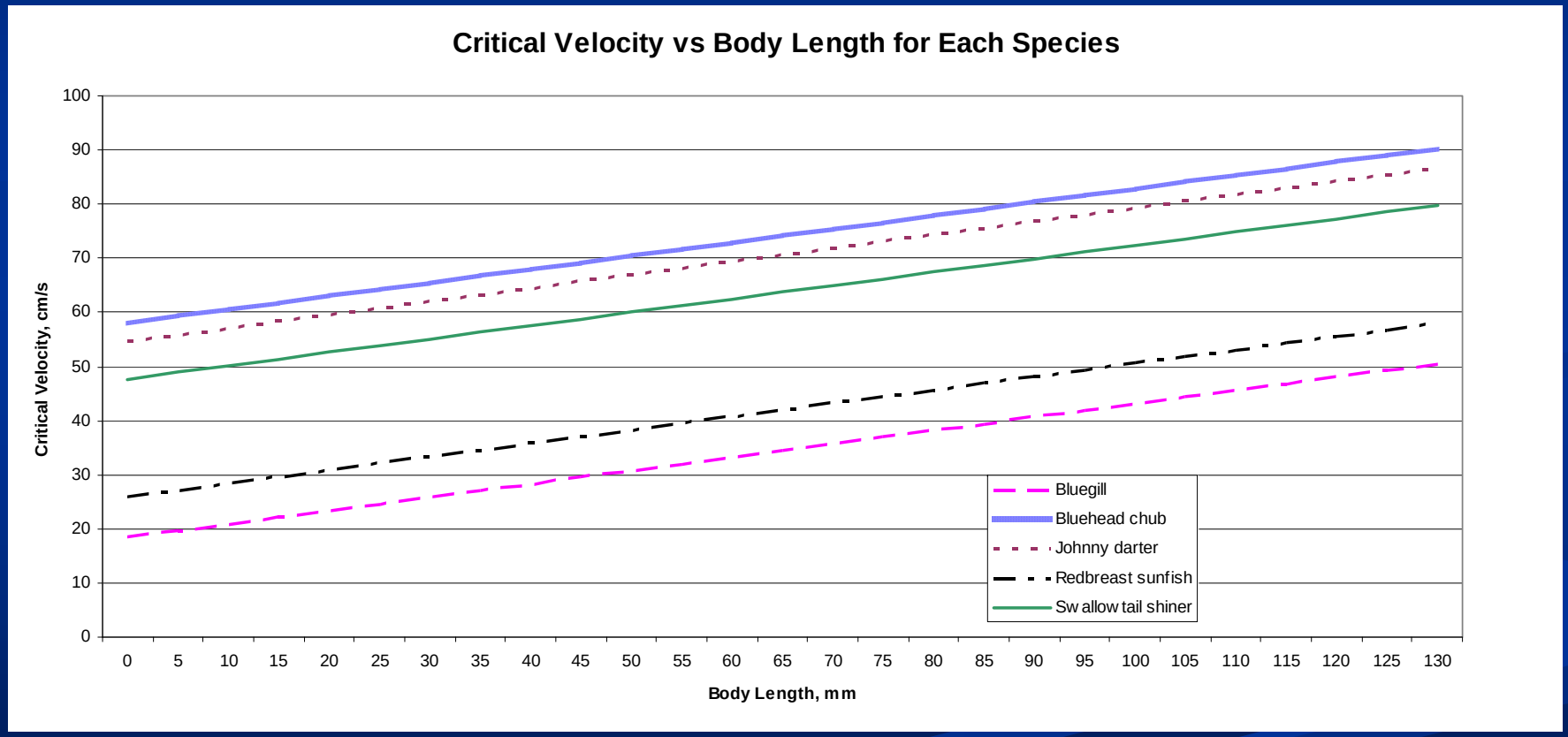
Critical Velocity (Johnny Darter) = 0.247BL + 54.61

Critical Velocity (Redbreast Sunfish) = 0.247BL + 25.94

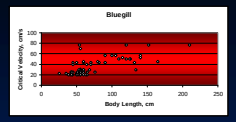
Critical Velocity (Swallowtail Shiner) = 0.247BL + 47.66

The figure below illustrates the equations for each fish species developed from the final GLM





Results indicate that culverts designed to facilitate anadromous fish may be acting as barriers to other native species.



Trout, salmon, adult chinook, coho, sockeye and steelhead

60.96cm/s (2 ft/s) to 182.88cm/s (6ft/s) (Bates 2003)

Trout 67- 96 cm/s (2.2 – 3.15 ft/s) (Belford and Gould 1989)

Commonwealth of Virginia's guideline for trout waters

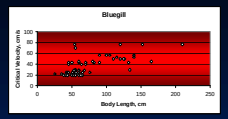
36.58cm/s (1.2 ft/s)

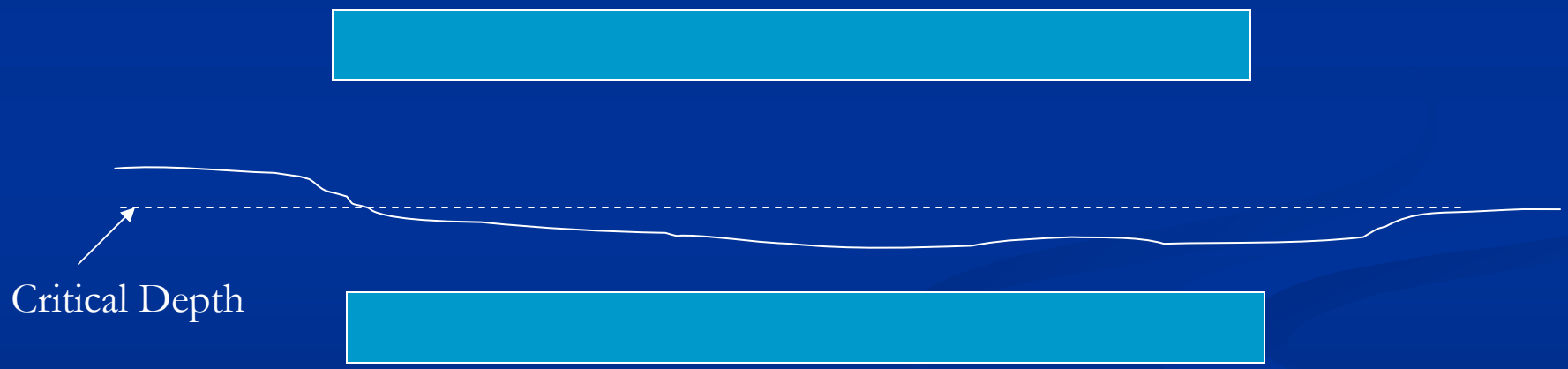
Variety of 26 species: 30-40cm/s (1-1.3ft/s) (Warren and Pardew 1996)

Burbot, Broad whitefish, Mountain whitefish, Arctic char, and Arctic cisco

42.5-100.2 cm/s (1.39-3.29 ft/s) (Jones 1974)

An Excel model was developed to calculate flow through box, circular, and sunken circular culverts.





Velocity was calculated using Flow Type 1, and Manning's Equation

Design recommendations:

- Maximum velocities should be kept under 55cm/s during 90% of the fish migration season.

- Culverts should be installed as per instructions in the NC BMP manual

This study is the first step in developing a regional screen for the state of North Carolina.

A special thank you to…

- Dr Greg Jennings, Dr. Jim Gilliam, Dr. Bill Hunt
- David Godley, Mike Shaffer, Paige Puckett, Will Clayton
- Bryn Tracy and the whole fish crew at NC DWQ