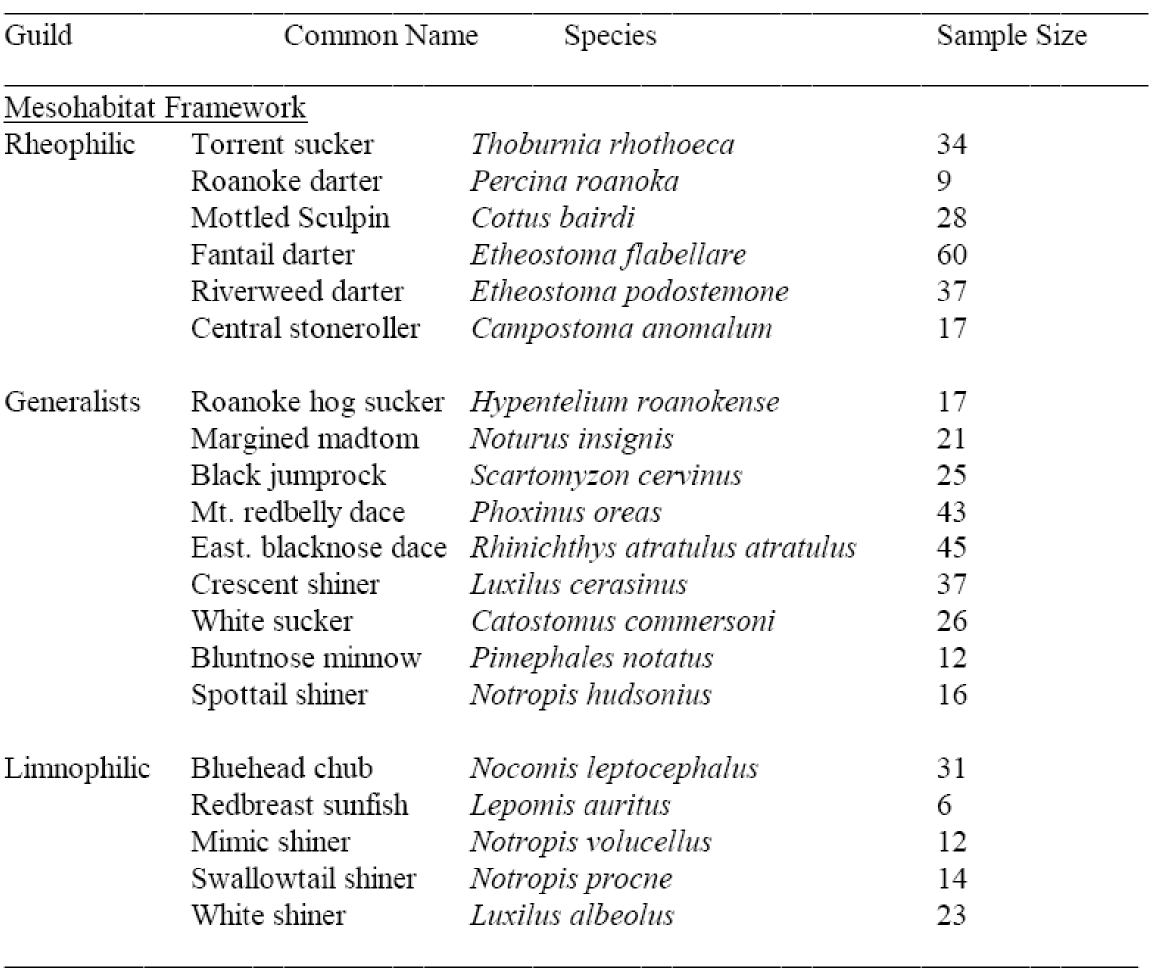
Ecomorphology of fishes

Ecomorpholoy is the correlation between an animal's ecological niche hypervolume, and its form. These correlations come about because animals adapt to, or specialize in, specific habitat types. Put another way, habitat type selects for certain body forms. Individuals with the best fit between phenotype and habitat are competitively superior to individuals that are less well matching thus natural selection promotes habitat-specific morphs independent of phylogeny.

Fish diversity in warm water streams is a challenge to habitat management, particularly when attempting to predict potential impacts caused by changes to instream flow regimes. Habitat "guilds" can facilitate analysis of discharge-habitat relationships and are increasingly being applied to instream flow studies. Ecomorphological relationships are one approach to predicting habitat guild membership, and therefore, stream management.

There are 3 general habitat categories: rheophilic (current-loving), limnophilic (slow-water loving), and generalists (jack of all trades, master of none). The first two are further subdivided into three subcategories (Table).



Guild	Common Name	Species	Sample Size
Mesohabitat Framework			
Rheophilic	Torrent sucker	*Thoburnia rhothoeca*	34
	Roanoke darter	*Percina roanoka*	9
	Mottled Sculpin	*Cottus bairdi*	28
	Fantail darter	*Etheostoma flabellare*	60
	Riverweed darter	*Etheostoma podostemone*	37
	Central stoneroller	*Campostoma anomalum*	17
Generalists	Roanoke hog sucker	*Hypentelium roanokense*	17
	Margined madtom	*Noturus insignis*	21
	Black jumprock	*Scartomyzon cervinus*	25
	Mt. redbelly dace	*Phoxinus oreas*	43
	East. blacknose dace	*Rhinichthys atratulus atratulus*	45
	Crescent shiner	*Luxilus cerasinus*	37
	White sucker	*Catostomus commersoni*	26
	Bluntnose minnow	*Pimephales notatus*	12
	Spottail shiner	*Notropis hudsonius*	16
Limnophilic	Bluehead chub	*Nocomis leptocephalus*	31
	Redbreast sunfish	*Lepomis auritus*	6
	Mimic shiner	*Notropis volucellus*	12
	Swallowtail shiner	*Notropis procne*	14
	White shiner	*Luxilus albeolus*	23

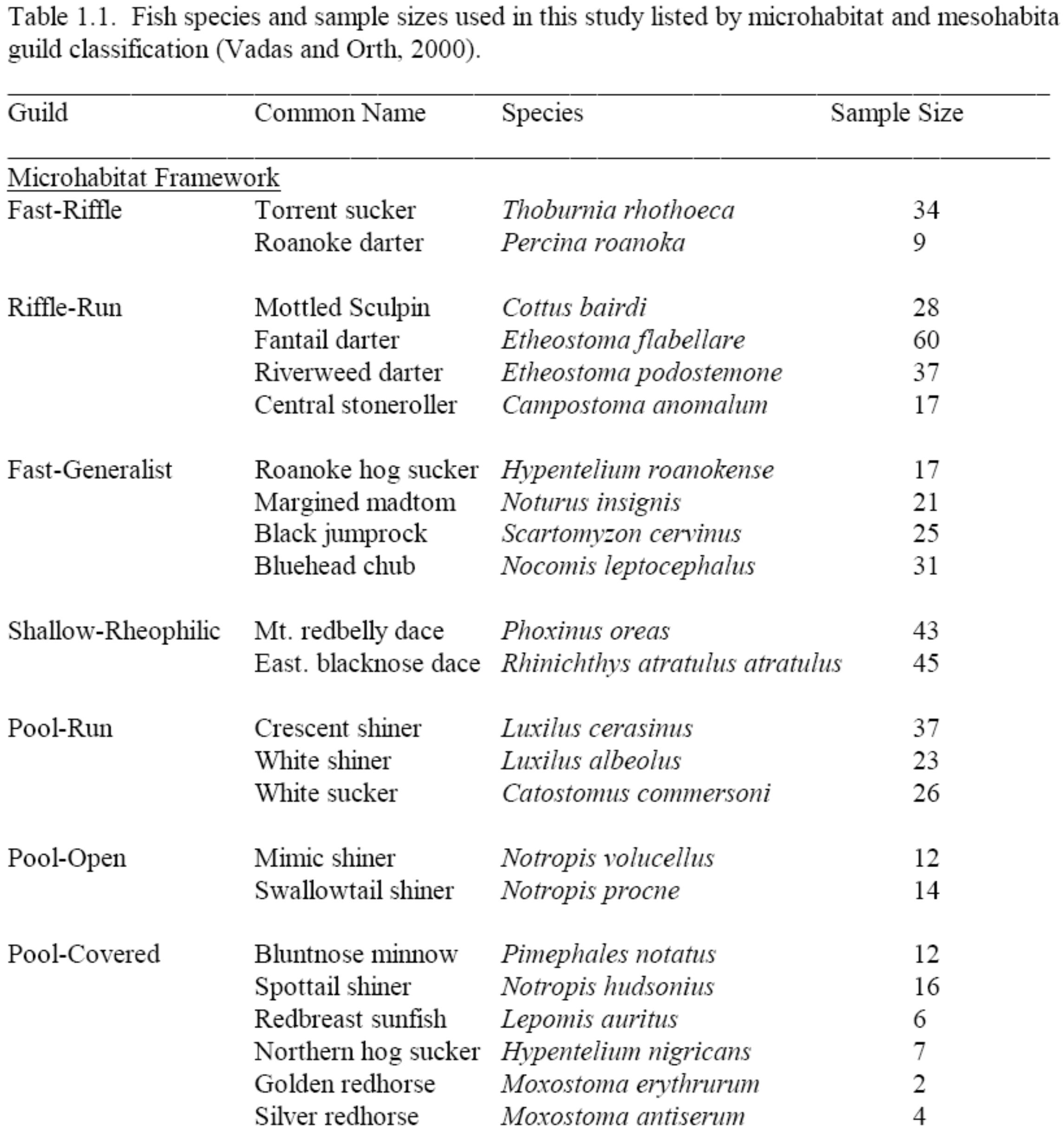


Table 1.1. Fish species and sample sizes used in this study listed by microhabitat and mesohabita guild classification (Vadas and Orth, 2000).

Guild	Common Name	Species	Sample Size
Microhabitat Framework			
Fast-Riffle	Torrent sucker	*Thoburnia rhothoeca*	34
	Roanoke darter	*Percina roanoka*	9
Riffle-Run	Mottled Sculpin	*Cottus bairdi*	28
	Fantail darter	*Etheostoma flabellare*	60
	Riverweed darter	*Etheostoma podostemone*	37
	Central stoneroller	*Campostoma anomalum*	17
Fast-Generalist	Roanoke hog sucker	*Hypentelium roanokense*	17
	Margined madtom	*Noturus insignis*	21
	Black jumprock	*Scartomyzon cervinus*	25
	Bluehead chub	*Nocomis leptocephalus*	31
Shallow-Rheophilic	Mt. redbelly dace	*Phoxinus oreas*	43
	East. blacknose dace	*Rhinichthys atratulus atratulus*	45
Pool-Run	Crescent shiner	*Luxilus cerasinus*	37
	White shiner	*Luxilus albeolus*	23
	White sucker	*Catostomus commersoni*	26
Pool-Open	Mimic shiner	*Notropis volucellus*	12
	Swallowtail shiner	*Notropis procne*	14
Pool-Covered	Bluntnose minnow	*Pimephales notatus*	12
	Spottail shiner	*Notropis hudsonius*	16
	Redbreast sunfish	*Lepomis auritus*	6
	Northern hog sucker	*Hypentelium nigricans*	7
	Golden redhorse	*Moxostoma erythrurum*	2
	Silver redhorse	*Moxostoma antiserum*	4

A full measurement of morphology is a complex and time-consuming process. Measures that are most important are those that relate directly to current: frictional drag and access to the low-flow zone at the boundary layer next to the substratum:
Body length (1), maximum body depth (10), caudal fin shape (4, 15), pectoral fin shape (19, 20), dorsal fin shape (6, 29), anal fin shape (A, B), head shape (13, 28)

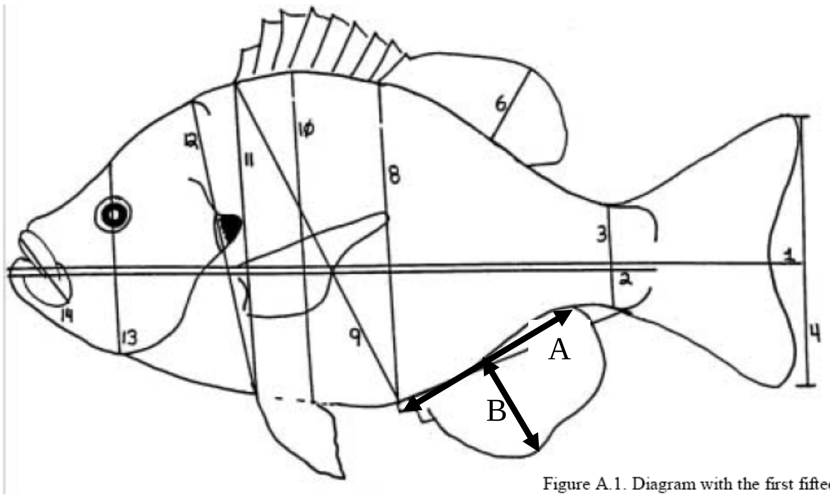


Figure A.1. Diagram with the first fifteen morphology measurements used in this study (the remainder are illustrated in Figure A.2): 1) total length (TL), 2) standard length (SL), 3) anterior caudal fin depth (VMCFDMCF), 4) posterior caudal fin depth (CFD), 5) distance from anal fin to caudal fin (AFVMCF), 6) maximum dorsal fin span (MDFS), 7) maximum body width (not shown) (MBW), 8) distance from posterior of dorsal fin to anal fin (PDFAF), 9) distance from dorsal fin to anal fin (ADFAF), 10) maximum body depth (MBD), 11) distance from dorsal fin to pelvic fin (ADFPEL), 12) distance from posterior of neurocranium to pelvic fin (PNERPEL), 13) head depth (HD), and 14) upper jaw length (JMAX). References for measurements are as follows: 1, 2, 4, 6, 10 (Bandyopadhyay et al., 1997); 7, 13 (Watson and Balon, 1984); and 3, 5, 8, 9, 11, 12, 14 (Wood and Bain, 1995).

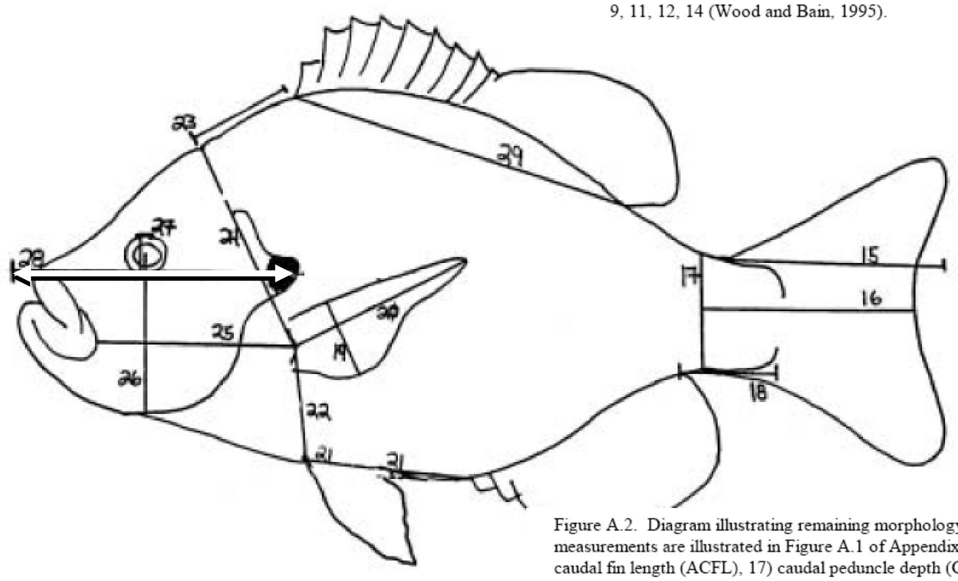
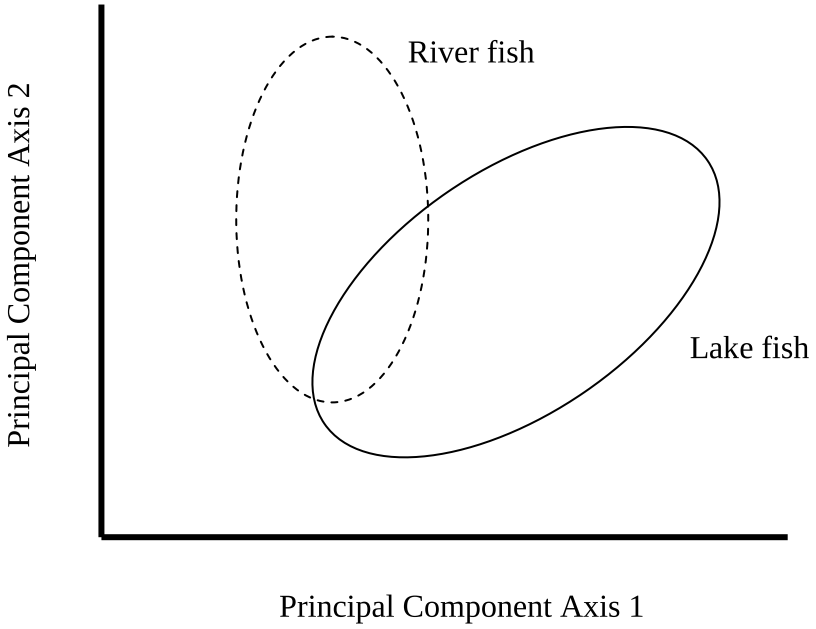


Figure A.2. Diagram illustrating remaining morphology measurements taken for this study (other measurements are illustrated in Figure A.1 of Appendix A): 15) caudal fin length (CFL), 16) axial caudal fin length (ACFL), 17) caudal peduncle depth (CPD), 18) caudal peduncle length (CPL), 19) pectoral fin width (PFW), 20) pectoral fin length (PFL), 21) distance from pelvic fin to anal fin (PELAF), 22) distance from pectoral fin to pelvic fin (PECPEL), 23) pre-dorsal fin length (PNERDF), 24) distance from posterior of neurocranium to pectoral fin (PNERPEC), 25) distance from jaw to pectoral fin (MAXPEC), 26) eye position (EP), 27) eye diameter (EYESIZ), 28) distance from most anterior point of body to the point of greatest body depth (ALEEVY), 29) total length of dorsal fins (TLDF), and 30) caudal peduncle width (not shown) (CPW). References for measurements are as follows: 16, 29 (Bandyopadhyay et al., 1997); 15, 17, 18, 19, 20, 26, 30 (Watson and Balon, 1984); 21, 22, 23, 24, 25 (Wood and Bain, 1995); 28 (Aleev, 1969); and 27 (Gatz, 1979b).

We will analyze these data using principle components analysis. This technique finds the variables in a complex data set that explain the greatest amount of the variation in that data set. The data are plotted in *n*-dimensional space, where *n* is the number of variables in the matrix. A new axis is created that aligns with maximum variation in the data cloud. This is the Principle Components Axis 1. Then, a second axis is created that is perpendicular (orthogonal) to PC1 that best aligns with the maximum remaining variation in the data cloud. This is PC2. This process can be continued until *n* axes have been created, but the first two axes explain most of the variation in the data, so these two can be plotted against each other for each fish measured.

If lotic and lentic habitats select for fishes of different form, then fishes from these habitats should fall out in different regions of a graph of PC1 versus PC2, such as in the figure below.



Another useful output of this method is that it will reveal which of the variables contributes most to each PCA. This will allow us to reveal which aspects of body form are selected by habitat type.