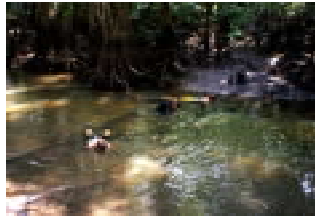
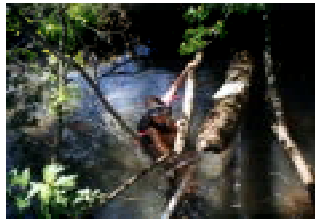


Mussels (Family: Unionidae) of the Lower Flint River Basin with 1999 Stream Habitat and Mussel Community Survey Methods



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Introduction

Freshwater mussel communities of the Flint River Basin (FRB) comprise one of the richest mussel assemblages in the world. Historically, 29 species of freshwater mussels occurred in the FRB, which is near the center of unionid species origin. Mussels are filter feeders, dependent on high water quality, good physical habitat, and an environment that will support host fish populations. The sandy and gravelly substrates of streams within the FRB provide ideal habitat for these species. Because of their dependence on high quality stream habitat, mussels are considered good indicators of aquatic ecosystem health (Williams et al. 1992).

Over the past century, land use changes, river impoundments, and declines in native fish species have severely affected mussel diversity and abundance. Currently, about 7% of the 300 mussel species that formerly occurred in the southeastern U.S. are presumed extinct (Williams and Neves 1995). Of the remaining species, 40% are endangered or threatened, 24% are of special concern, 24% are stable, and 5% are undetermined (Williams and Neves 1995).

Surveys conducted from 1991 to 1993 found that many Flint River tributaries within the Coastal Plain Province (lower FRB) continue to harbor diverse mussel faunas (from 9 to 16 species, including several endangered species; Brim-Box et al. 2000). However, only 22 of the 29 species originally found in the FRB were observed during the 1991-1993 survey. The Flint River system remains a viable home to many mussel species, but human activities continues to impair and degrade this ecosystem, thereby severely threatening mussel persistence.

Our mussel survey in the lower FRB (1999) was initiated in hopes that we could begin to gather important information about mussel habitat, species' life history requirements, factors contributing to species' declines, and unionid conservation needs. We hope that the work we have started will provide a foundation that can be built upon for years to come. Toward this end, we prepared this manual as an aid to future survey teams, a metadata manual for data collected during the 1999 surveys of mussel and stream habitat in lower Flint tributary streams, and a field guide for the amateur musseler.

Mussel Survey Methods

During the summer of 1999 mussel surveys were conducted at 45 sites on 12 tributary streams in the Coastal Plain portion of the Flint River basin. Bridge crossings at intervals along the longitudinal progression from headwaters to the Flint River confluence on each stream were selected for survey sites. Each mussel survey reach extended from 100 m to 200 m upstream from the road crossing. The survey reach was demarcated by stretching a tape measure down the center of the stream, starting from the bridge crossing. Permanent markers were placed on a large tree at the start point of each survey reach.

In small streams, the entire bed surface within the 100 m survey reach was grubbed (surface sediments were sieved with fingers) or visually searched for live and dead unionid mussels. In large streams (4th order or larger; greater than 12 m wide), visual and tactile searches for live and dead mussels were conducted along six transects, each 100 m in length, placed parallel to stream flow. Transects were two meters wide and evenly spaced across the width of the stream, with one transect on each bank.

All native live mussels were identified as they were found, and put back into place after identification. If more than 1000 specimens of any species were found before reaching the end of the survey reach, the extent of bed area searched was determined and recorded, and additional specimens of that species in the remaining survey stretch were not counted. Unionids were identified to species level, except *Elliptio complanata* and *Elliptio icterina*, which were grouped together as *Elliptio complanata/icterina* because of the difficulty of distinguishing between them in the field. All data were recorded on a waterproof plexiglass data board. Dead shells were collected and later identified in the lab.

After completion of the survey, mussel data were transferred from the plexiglass data board to a data sheet (See Appendix 1). Technicians' names, water temperature, survey start and stop time, major substrate types, water velocity, estimated stream width, and any additional survey notes were also recorded. Site diagrams were drawn on the back of the data sheet for each stream.

Following are accounts for mussel species found during the 1999 mussel surveys in the Lower Flint tributaries with diagnostic characteristics used in identifying each species. Italicized portions of the species' descriptions indicate key features to use in identification.

***Elliptio arctata* (Delicate Spike)**

Elliptio arctata historically was found in the main channel and tributaries of the Apalachicola, Chattahoochee, Chipola, and Flint Rivers. Presently, *E. arctata* is found only in the main channels of the Apalachicola and Chipola Rivers and in the mainstem and tributaries of the Flint and Chattahoochee Rivers. This mussel inhabits substrates of sand and limestone rock in areas of moderate to fast current.

The delicate spike has a small subelliptical shell that rarely exceeds 60 mm in length. Its form is highly variable, but is usually distinguished from other *Elliptio* by its arcuate, compressed valves. The posterior end is broadly rounded, somewhat biangulate, and extends below the base line. The anterior end is rounded. The posterior ridge is low and rounded with a faint second ridge above. The posterior slope is smooth and slightly concave. The periostracum can vary from yellowish to greenish to dark burnt-brown. Green rays cover the shell and become more prominent posteriorly. The left valve has two low, vestigial, triangular pseudocardinal teeth, and a short and narrow hinge line with two low, short, straight lateral teeth. The right valve has one lateral tooth and one low, chunky pseudocardinal tooth. Beak cavities are very shallow. The nacre is iridescent and dirty white or purplish with yellowish splotches. Incurrent papillae are unusually long, darkly pigmented, and thinly distributed. The excurrent chamber is heavily packed with dark prominent papillae.

Host species- Unknown.

Conservation status- Special concern.

Sources: Brim-Box and Williams 2000, Burch 1975, Johnson 1970.

***Elliptio complanata* (Eastern Elliptio)**



Elliptio complanata was historically found in the main channels of the Apalachicola, Chipola, Flint, and Chattahoochee Rivers. It presently is found in the main channel and tributaries of the Flint and Chipola Rivers, the mainstem of the Apalachicola River, and tributaries of the Chattahoochee River. This mussel is widely found in

almost any habitat; it lives in small creeks, large rivers, ponds, lakes, and reservoirs. It inhabits sand, silt, mud, and rocky substrates in slow, moderate and fast currents.

The eastern elliptio is highly variable in shell size, thickness, and shape. It can range in size from 20-110 mm in length, but usually is a medium-sized mussel, around 60 mm in length. Valves can be thick or thin, rough or smooth, rayed or unrayed. The periostracum is usually rayed, dull, and yellowish-green to black. It has parallel dorsal and ventral margins with a biangulated posterior point. The hinge ligament is prominent. The posterior slope is broad and unsculptured, and the umbo is low and uninflated. The left valve has two stumpy pseudocardinal teeth, with the anterior tooth more triangular in shape. The right valve has one lateral tooth and one chunky, serrated pseudocardinal tooth posterior to a vestigial tooth. Beak cavities are shallow. The nacre is iridescent and often purple, white, or orange. Marsupia occupy the entire length of the outer gill. The incurrent aperture is heavily pigmented with a purple to red color. Incurrent papillae are usually singular and occur in two rows.

Host species- *Perca flavescens* (yellow perch), *Fundulus diaphanus* (banded killifish).

Conservation status- Stable.

Sources: Brim-Box and Williams 2000, Burch 1975, Johnson 1970.

***Elliptio crassidens* (Elephant-ear)**



Elliptio crassidens was historically found in the main channel of the Apalachicola River, Mosquito Creek (a tributary of the Apalachicola River), and the Chattahoochee, Chipola, and Flint Rivers. It presently is found in the main channel of the

Apalachicola River and the main channel and tributaries of the Flint and Chipola Rivers. The elephant-ear is found in large creeks, rivers, and reservoirs. It inhabits muddy sand, sand, and rock substrates with a wide range of current velocities.

The elephant-ear is a large mussel, usually ranging from 60-100 mm in length. Shell shape can vary widely among and within drainages. Most variable among the shell features is the ventral edge, which may be convex or concave. The shell is normally very thick and heavy, subrhomboidal or quadratic in outline. The anterior end is broadly rounded and *the posterior end is rounded and somewhat pointed or biangulated. The posterior ridge is sharp and angular. The posterior slope has a few wrinkles that radiate from the posterior ridge to the dorsal margin.* Umbos are low, full, and located in the anterior third of the shell. Umbo sculpture consists of a few coarse ridges running parallel to growth lines. The periostracum is reddish brown, chestnut, black, or yellow with green rays. The left valve has two heavy, rough pseudocardinal teeth with a short, broad hinge line and two short, slightly curved lateral teeth. The right valve has one chunky serrated pseudocardinal tooth and one lateral tooth. The nacre is purple, salmon, or yellow, and is posteriorly iridescent. Branchial papillae occupy two rows: papillae of the inner row are long, slender, and usually bifid. The color of the mantle margins, brachial opening, super-anal, and anal openings are a dark orange to purple color.

Host species- *Alosa chrysochloris* (skipjack herring), *Alosa alabamae* (Alabama shad).

Conservation status- Stable.

Sources: Brim-Box and Williams 2000, Burch 1975, Clench and Turner 1956, Johnson 1970.

***Elliptio icterina* (Variable Spike)**



Elliptio icterina was historically found in the main channel and tributaries of the Chipola, Apalachicola, Flint, and Chattahoochee Rivers. It presently is found in the main channel and tributaries of the Apalachicola and Flint Rivers, the mainstem of the Chipola River, and tributaries of the Chattahoochee River. The variable spike inhabits streams, lakes, reservoirs, ponds, and rivers with slight to moderate current in

sand, silt, gravel, and rocky substrates.

The variable spike is a medium-sized mussel, usually ranging from 30 to 80 mm in length. Shell form is inconstant, described variously as subquadrangle to subelliptical to pointed in shape. The anterior end is rounded and the posterior end is usually biangulate near the base. It can have a rather pronounced and pointed posterior end with a rounded posterior ridge and flat to slightly concave posterior slope. Umbos are low, broad, full, and consist of several double-looped ridges. The periostracum ranges from fine and shiny to heavy and rough, with black, brownish-black, yellowish brown, bright yellow, or chestnut color. It often has numerous fine green rays. The left valve has two stumpy pseudocardinal teeth equal in size. The hinge line is short and narrow with two long straight lateral teeth. The right valve has two roughly parallel pseudocardinal teeth. The posterior tooth is serrated and chunky; the anterior tooth is low and vestigial. There is one lateral tooth. Beak cavities are shallow with iridescent purple, salmon, bluish white, or pinkish colored nacre. *The brachial and anal papillae are lightly to moderately pigmented with a reddish tinge, unlike the darkly pigmented papillae of other *Elliptio*.* Differences in marsupia and conglutinates are the most reliable diagnostic characters distinguishing *Elliptio icterina* from its congeners.

Host species- *Lepomis macrochirus* (bluegill sunfish).

Conservation status- Stable.

Sources: Brim-Box and Williams 2000, Burch 1975, Johnson 1970.

***Elliptio purpurella* (Inflated Spike)**



Elliptio purpurella is endemic to the Appalachian-Chattahoochee-Flint River Basin, historically found in the mainstems of the Flint, Chattahoochee, and Chipola Rivers. It presently is found in tributaries of the Flint River. It inhabits streams with sand, clay, and limestone rock substrates.



The inflated spike is a small species, usually only 40-50 mm in length. It is marked by a greatly *inflated shell, with an arcuate ventral margin*. The periostracum is sometimes covered with broad, green rays. This mussel has long, curved lateral teeth and two small, pointed pseudocardinal teeth in each valve. The nacre is usually purple. The mantle margin at the branchial and anal apertures is moderately

pigmented. Branchial papillae occur in two intermingled rows of short, singular projections. Anal papillae are also short, but occur in only one row. The branchial, anal, and supra-anal openings are roughly the same size.

Host species- Unknown.

Conservation status- Special concern.

Sources: Brim-Box and Williams 2000.

***Elliptoideus sloatianus* (Purple Bankclimber)**



Elliptoideus sloatianus historically was found in the mainstems of the Flint, Chattahoochee, Chipola, and Apalachicola Rivers. It presently is found in the Apalachicola and Flint Rivers. It inhabits large rivers and streams that

have a moderate current. It is found in fine gravel, sand, and muddy sand in water that is often more than 3 m deep.

The purple bankclimber is the second largest mussel in the FRB. It has a large, heavy shell, usually between 100 and 140 mm in length. The posterior end is slightly biangulate. The posterior ridge and slope are undefined, obscured by a lumpy and pustulated shell surface. The periostracum is a dull grey to black color. This mussel has a shallow umbo pocket and purple nacre along the shell margins. *It is the only mussel that has arborescent branchial papillae.* The branchial and anal apertures are darkly pigmented. *Elliptoideus sloatianus* has no mantle suture separating its supra-anal and anal portions of the excurrent aperture.

Host species- *Gambusia affinis* (mosquitofish), *Poecilia reticulata* (guppy), and *Percina nigrofasciata* (blackbanded darter).

Conservation status- Federally Threatened.

Sources: Brim-Box and Williams 2000, Burch 1975, Clench and Turner 1956.

***Lampsilis straminea claibornensis* (Southern Fatmucket)**



Lampsilis straminea claibornensis was historically found in the mainstem and tributaries of the Apalachicola, Chipola, and Flint Rivers, and the mainstem of the Chattahoochee River. It presently is found in the mainstem of the Apalachicola River, and the mainstem and tributaries of the Chipola and Flint Rivers. This mussel inhabits the mainstems of large creeks and rivers in the Coastal Plain. It

is found in sand and sandy mud in slow to moderate current.

The southern fatmucket has a moderately thick, inflated, and oval-shaped shell that usually reaches lengths of about 60-80 mm. The shell may be inflated posteriorly in females, distorting its normally oval shape. The periostracum is rayless and smooth, light to dark yellowish brown in color. The posterior slope is concave, and the posterior ridge is rounded, tapering to a broad and blunt posterior margin. The umbo is broad, moderately high, and anterior to center. The hinge ligament is long and fairly thick. The nacre is a highly iridescent bluish white to light pink color. The right valve has one small, thin and one large, thick pseudocardinal tooth. The left valve has equally thick pseudocardinal teeth. This mussel has elaborate, enlarged mantel flaps that have clear eye spots.

Host species- *Micropterus salmoides* (largemouth bass), *Lepomis macrochirus* (bluegill sunfish), *Gambusia holbrooki* (eastern mosquitofish), *Notemigonus crysoleucas* (golden shiner).

Conservation status- Special concern.

Sources: Brim-Box and Williams 2000, Clench and Turner 1956.

***Lampsilis subangulata* (Shiny-rayed Pocketbook)**



Lampsilis subangulata was historically found in the main channel and tributaries of the Chattahoochee River, the main channel of the Flint and Chipola Rivers, and Mosquito Creek (a tributary of the Apalachicola River). It presently is found in the main channel and tributaries of the Flint River, tributaries of the Chattahoochee River, and the

mainstem of the Chipola River. This mussel inhabits medium-sized creeks and rivers with slow to moderate current. It is found in silty sand, muddy sand, and clay substrates.

The shiny-rayed pocketbook is a medium-sized mussel reaching 85 mm. There is pronounced sexual dimorphism in shell shape. Males are pointed posteriorly, females are broader and rounder in the posterior end. *The ventral shell margin is convex, ending posteriorly at or above the midline.* This mussel has a thin, strong, smooth, subelliptical, inflated shell. The posterior slope is concave and the ridge is rounded. *It has a shiny, light yellowish brown periostracum with bright emerald green rays over the entire length of the shell.* The umbo is broad, low, rather full, and anterior to the center. The right valve has one large and one small, somewhat spatulate pseudocardinal tooth. The larger of the two is finely serrate. The left valve has two equally thickened and serrate pseudocardinals. The nacre is white, but some individuals may be salmon-tinted near the umbo cavity. The mantle margin is a rosy brown color and has small dark spots, giving it a peppered appearance. Villi extend along one-third of the ventral margin. Branchial papillae occur in two rows. During early spring through mid-summer, gravid females release a fish-like lure attached to a long, transparent, fibrous strand (superconglutinate).

Host species- *Micropterus salmoides* (largemouth bass), *Micropterus punctulatus* (spotted bass).

Conservation status- Federally Endangered.

Sources: Brim-Box and Williams 2000, Burch 1975, Clench and Turner 1956.

***Lampsilis teres* (Yellow sandshell)**



Lampsilis teres was historically found in the mainstems and tributaries of the Flint, Chattahoochee, Chipola, and Apalachicola Rivers. It is presently found in the main channels and reservoirs of the Flint, Chattahoochee, Chipola, and Apalachicola Rivers. It appears to be restricted

mainly to the Coastal Plain. This mussel inhabits medium to large-sized rivers with slight to moderate current. It is found in sand and muddy sand.

The yellow sandshell usually reaches 60-110 mm in length, but sometimes attains lengths approaching 190 mm. The shell is smooth, thin to moderately thick, elongate, and light yellow to yellowish brown in color. The periostracum of younger specimens may have a few fine green rays over a portion of the shell. The posterior ridge is high and terminates in a sharp point above the shell midline. Branchial papillae occur in multiple, poorly defined rows. They can be single, bifid, and sometimes dendritic. Anal papillae appear as short crenulations. Mantle margins at the branchial and anal apertures are rosy brown and peppered with small dark spots. Pigmentation along ventral margins appears as brown striations. Female *L. teres* display fleshy, striated mantle flaps lacking eyespots.

Host species- *Lepisosteus platostomus* (shortnose gar), *Atractosteus spatula* (alligator gar), *Lepisosteus osseus* (longnose gar), *Scaphirhynchus platorynchus* (shovelnose sturgeon), *Lepomis humilis* (orangespotted sunfish), *Lepomis cyanellus* (green sunfish), *Lepomis gulosus* (warmouth), *Micropterus salmoides* (largemouth bass), *Pomoxis annularis* (white crappie), and *Pomoxis nigromaculatus* (black crappie).

Conservation status- Stable.

Sources: Brim-Box and Williams 2000, Burch 1975.

***Medionidus penicillatus* (Gulf Moccasinshell)**



Medionidus penicillatus is an endemic of the Appalachian-Chattahoochee-Flint River Basin, and was historically found in the main channel and tributaries of the Chattahoochee, Flint, and Chipola Rivers. A single specimen has been found in the Apalachicola River. At the present time, this mussel is found in the Flint River drainage, a Chattahoochee River tributary, and a Chipola River tributary. The gulf moccasinshell inhabits streams and rivers with slight to moderate current with sand, gravel, and mud substrates.

The gulf moccasinshell is a small species, rarely larger than 50 mm in length. *It is distinguished from other small mussels by a parallel series of thin plications along the length of the posterior slope.* The shell is subelliptical in outline and the periostracum is smooth, yellowish to greenish-brown, and has fine, interrupted green rays. The rounded posterior slope tapers to a blunt point on the posterior margin. The umbo is fairly broad, low, and anterior to center. There is one small pseudocardinal tooth in the right valve, where the hinge ligament is short and narrow. The left valve has one small and one fairly large pseudocardinal tooth and a very small hinge plate. The nacre is an iridescent bluish white or pale pink. The ventral mantle margin is darkly pigmented with well-defined villi extending across three-fourths of the mantle margin. Branchial papillae are long, slender, and occur in two rows. The mantle margin at the branchial, anal, and supra-anal apertures has a dark reddish-purple tint.

Host species- *Percina nigrofasciata* (blackbanded darter), *Etheostoma edwini* (brown darter).

Conservation status- Federally Endangered.

Sources: Brim-Box and Williams 2000, Burch 1975, Clench and Turner 1956.

***Megalonaias nervosa* (Washboard)**



Megalonaias nervosa historically was found in the main channels of the Flint, Chipola, Chattahoochee, and Apalachicola Rivers, as well as the lower ends of several tributaries to these rivers. The washboard is presently found in the mainstems of the

Apalachicola, Chattahoochee and Flint Rivers, and the lower end of the Chipola River. This mussel inhabits large rivers with moderate current. It is found in substrates ranging from mud to sand to limestone rock.

The washboard is the largest freshwater mussel in the FRB. Lengths normally range from 90-200 mm. The mussel has a heavy shell with deep umbo cavities. The periostracum is dull gray to black. There is a series of large ridges radiating from the umbo, and fanning across the posterior end from the slope to the ventral margin. Nacre color is bluish-white to iridescent-white. The branchial aperture is large and extends around the posterior end to the ventral margin. Branchial papillae are short, stubby, and may be singular or dendritic. Anal papillae appear only as fine crenulations. Branchial and anal apertures are pigmented dark brown.

Host species- *Amia calva* (bowfin), *Anguilla rostrata* (American eel), *Alosa chrysochloris* (skipjack herring), *Dorosoma cepedianum* (gizzard shad), *Carpionodes velifer* (highfin carpsucker), *Ictalurus punctatus* (channel catfish), *Ameiurus nebulosus* (brown bullhead), *Ameiurus melas* (black bullhead), *Noturus gyrinus* (tadpole madtom), *Pylodictis olivaris* (flathead catfish), *Morone chrysops* (white bass), *Pomoxis annularis* (white crappie), *Pomoxis nigromaculatus* (black crappie), *Micropterus salmoides* (largemouth bass), *Lepomis macrochirus* (bluegill), *Lepomis cyanellus* (green sunfish), *Stizostedion canadense* (sauger).

Conservation status- Stable.

Sources: Brim-Box and Williams 2000.

***Pleurobema pyriforme* (Oval Pigtoe)**



Pleurobema pyriforme was historically found in the main channel of the Apalachicola River, and the main channel and tributaries of the Chipola, Chattahoochee, and Flint Rivers. This mussel presently is found in tributaries of the Chattahoochee, Flint, and Chipola Rivers, and in the mainstem of the Chipola River. It inhabits small to large streams with moderate current. It is found in sand, silty sand, gravel, clay, and rock substrates.



The oval pigtoe is highly variable, but shell size usually measures 35-55 mm in length. Individuals range from having a compressed shell, low umbo, and yellow periostracum, to having an inflated shell, higher umbo, and dark periostracum. Young individuals may have faint green rays. There is usually a prominent posterior ridge on the shell surface. The posterior slope is slightly concave. The shell tapers to a blunt point posteriorly. The umbo is usually rather full, broad, low, and anterior to the center. The hinge plate is long, narrow, and arched in the central region. The right valve has one large irregular pseudocardinal tooth. The left valve has two subequal pseudocardinal teeth. The nacre is white or salmon. Branchial papillae are arranged in two parallel rows. The outer row consists of well-defined, singular papillae. The inner row consists of dendritic, unevenly spaced papillae. The anal papillae are short, singular and well-defined. Mantle margins are generally unpigmented, except for light pigmentation at the branchial and anal apertures.

Host species- *Pteronotropis hypselopterus* (sailfin shiner), *Gambusia holbrooki* (eastern mosquitofish).

Conservation status- Federally Endangered.

Sources: Brim-Box and Williams 2000, Clench and Turner 1956.

***Pyganodon grandis* (Giant Floater)**



Pyganodon grandis historically was found in the mainstem and a single tributary of both the Apalachicola and Chipola Rivers, and from the mainstem and tributaries of the

Chattahoochee and Flint Rivers. This mussel is currently found in the main channel of the Chipola River and in the main channel and tributaries of the Apalachicola River, and the impoundments, main channels, and tributaries of the Chattahoochee, and Flint Rivers. The Giant floater inhabits quiet waters with little current in mud and sand substrates.

Pyganodon grandis is a large mussel, usually ranging from 50-120 mm in length. The shell is oval to subelliptical, very inflated, and thin on the margins, gradually growing thicker toward the hinge line. Periostracum color ranges from brownish yellow to dark brown. Beaks are swollen and elevated above the hinge line. Umbos are sculptured with four to five double loops. *The Giant floater lacks teeth in both valves.* Branchial papillae occur in two distinct rows. The inner row consists of long, discontinuously spaced branchial papillae. The outer row of papillae are short, slender, and more evenly and closely spaced than the inner row. The branchial, anal, and supra-anal apertures are weakly pigmented, giving them a peppered appearance.

Host species- Unknown.

Conservation status- Stable.

Sources: Brim-Box and Williams 2000, Burch 1975.

***Quincuncina infucata* (Sculptured pigtoe)**



Quincuncina infucata was historically found in the main channel and tributaries of the Chipola, Chattahoochee, and Flint Rivers, and the mainstem and a single tributary (Mosquito Creek) of the Apalachicola River. It is presently found in the mainstem and tributaries of the Apalachicola and Flint Rivers and in the mainstem of the Chipola River. The Sculptured pigtoe inhabits large creeks and rivers that have moderate to swift current. It is found in

sand, mud, gravel, and sandy mud substrates.

Specimens of *Quincuncina infucata* usually range from 30 -55 mm in length. The shell color is dull to metallic brown-black, and the shape is normally subcircular to quadrate. Sculpturing is variable, but specimens usually have pronounced, chevron-like ridges extending across the umbo and dorsal portion of the posterior slope. The posterior slope is flat to slightly concave. The posterior ridge is poorly defined, tapering to a blunt and rounded point at the margin. The umbo is broad, low, and anterior to center. The hinge ligament is short and thick. The hinge plate is thick and wide. Each valve holds two pseudocardinal teeth. Nacre is bluish white, grading into an iridescent sheen toward the posterior end. The branchial aperture is lined with one row of dendritic papillae. The anal aperture margin is barely crenulate. The mantle margins are light brown near the branchial and anal apertures, and are generally unpigmented for the remainder of their length.

Host species- Unknown.

Conservation status- Special concern.

Sources: Brim-Box and Williams 2000, Burch 1975, Clench and Turner 1956.

***Strophitus subvexus* (Southern Creekmussel)**



Strophitus subvexus was historically found in the main channel of the Apalachicola River and the main channel and tributaries of the Chipola, Chattahoochee, and Flint Rivers. At the present time, this mussel is found in tributaries of the Flint River (Kinchafoonee, Line, and Whitewater Creeks) and in Uchee Creek, a tributary of the

Chattahoochee River. This mussel inhabits small to large creeks having slight to moderate current. It is found in sand, sandy mud, and rock substrates.

The southern creekmussel is a medium-sized mussel rarely exceeding 100 mm in length. The shell is smooth, rayless and usually yellow to yellow brown, grading to dark brown toward the anterior end. The posterior ridge is broadly rounded, and the posterior slope is slightly concave. The umbo is inflated, below the hinge line, and slightly anterior to center. *It has no lateral teeth* and only a single low, stumpy pseudocardinal tooth in each valve. Branchial papillae are singular and occur in two or three intermingled rows. The anal aperture is crenulate. The inner mantle margin at the anal and branchial apertures is pigmented with red and black striations. The outer mantle margin is lightly peppered.

Host species- *Hypentelium etowanum* (Alabama hogsucker) and *Etheostoma douglasi* (Tuskaloosa darter).

Conservation status- Endangered.

Sources: Brim-Box and Williams 2000, Burch 1975.

***Toxolasma paulus* (Iridescent Lilliput)**



Toxolasma paulus is endemic to the Appalachian-Chattahoochee-Flint River Basin, and was historically found in the main channel and tributaries of the Flint, Chattahoochee, Chipola, and Apalachicola Rivers. It presently is found in the mainstem and tributaries of the Flint River and in the main channel of the Chattahoochee River. This mussel inhabits lakes and small to large creeks and rivers with slight current. It is found in mud, sand, silt, rock, and clay substrates.

The iridescent lilliput is a small species, generally not exceeding 30 mm in length. Individuals of the species are extremely inflated and truncated posteriorly. Shell color ranges from green to burgundy to black. The umbo is flush with the hinge line and very inflated. Individuals are sexually dimorphic: females have caruncles in the mantle margin below the branchial opening, while males lack caruncles. Caruncles are pin-head sized, spherical projections that are white, reddish brown, or black in color. Branchial papillae are situated in two intermingled rows and are typically long and slender. Anal papillae are short and stubby and occur in a single row. The mantle margins have a dark reddish purple pigment at the apertures.

Host species- Unknown.

Conservation status- Stable.

Sources: Brim-Box and Williams 2000.

***Uniomerus carolinianus* (Florida Pondhorn)**



Uniomerus carolinianus historically was found in the main channel and tributaries of the Apalachicola, Chipola, Flint, and Chattahoochee Rivers. At the present time, this species is found in the main channel and tributaries of the Apalachicola, Chipola, and Flint Rivers, and from a single tributary (Halawakee Creek) of the Chattahoochee River. It inhabits streams and lakes with slight current. It is found in muddy

sand, sand, clay, and limestone rock substrates. It can live from three to six months at a time without water.

The Florida pondhorn is a medium to large mussel that reaches 114 mm in length. The shell has a rhomboid or long rhomboidal shape. The anterior end is slightly truncated or rounded. The posterior end is usually somewhat pronounced. *Periostracum is generally a satiny black-brown and very rough, but can be yellowish brown in color. The hinge ligament is upturned posterior to the umbo and is long, compressed and unusually high.* The posterior ridge is rounded and ends in a slight biangulation at the base of the shell. Older specimens are a bit arcuate. The umbo is low to slightly elevated, sculptured with five or six heavy ridges that form a rounded angle on the posterior ridge. The left valve has two subequal, ragged pseudocardinal teeth and two straight lateral teeth. The right valve has one triangular pseudocardinal tooth that often has a vestigial tooth in front of it. This mussel has one lateral tooth on the right valve. The nacre can be white, bluish white, pink, or purple. It has short, dendritic branchial papillae. Anal papillae are absent or appear as slight crenulations.

Host species- Unknown.

Conservation status- Stable.

Sources: Brim-Box and Williams 2000, Burch 1975, Johnson 1970.

***Utterbackia imbecillis* (Paper Pondshell)**



Utterbackia imbecillis historically was found in the main channel and tributaries of the Chattahoochee, Flint, Chipola, and Apalachicola Rivers. It presently is found in the main channel and tributaries of the Chattahoochee, Flint, Chipola, and Apalachicola Rivers. This mussel inhabits ponds, creeks, and large rivers with slow current. It is found in muddy sand, mud, and sand substrates.

The paper pondshell is a medium to large-sized mussel, usually 50 -110 mm long, with a thin, smooth subelliptical shell. Valves are compressed when young and inflate with age. The anterior end is rounded and the posterior end is somewhat pointed. The posterior ridge is broadly rounded, and the posterior slope is slightly concave. The umbo is very low, broad, and anterior to the center. *The periostracum is rayless, smooth and shiny, with a yellow to vivid green or blue green to a dark greenish brown color. U. imbecillis* is distinguished from *Utterbackia peggyae* by the former's flatter ventral margin and rayless periostracum. *There are no shell teeth.* The nacre is an iridescent bluish white. Incurrent papillae are long, singular, and arranged roughly in two parallel rows. The inner row of papillae is spaced unevenly and farther apart than the outer row of papillae. The anal aperture is smooth, lacks papillae or crenulations, and is striated with reddish brown pigment on the inner surface. Branchial and anal apertures are generally darkly pigmented.

Host species- *Fundulus diaphanus* (banded killifish), *Ambloplites rupestris* (rock bass), *Micropterus salmoides* (largemouth bass), *Lepomis cyanellus* (green sunfish), and *Lepomis gibbosus* (pumpkinseed sunfish).

Conservation status- Stable.

Sources: Brim-Box and Williams 2000, Clench and Turner 1956, Johnson 1970.

***Utterbackia peggyae* (Florida Floater)**



Utterbackia peggyae historically was found in the mainstem and tributaries of the Chipola and Flint Rivers, as well as in Mosquito Creek (a tributary of the Apalachicola River). It presently is found in the main channel and tributaries of the Flint River and in the main channel and one tributary of the Apalachicola River. This mussel inhabits sluggish streams and ponds with slow current. It is

found in sand and mud substrates.

Specimens of *Utterbackia peggyae* generally range from 30 to 90 mm in length. The Florida floater is extremely similar in size, shape and internal anatomy to *Utterbackia imbecillis*. The anterior end is rounded and the posterior end is somewhat pointed. The posterior ridge is broadly rounded, and the posterior slope is slightly concave. The umbo is very low, broad, and anterior to the center. *The shell has a round appearance, and is usually yellow to green to dark greenish brown in color, with fine green rays on the ventral margin. There are no shell teeth.* Incurrent papillae are long, singular, and arranged roughly in two parallel rows. The inner row of papillae is spaced unevenly and farther apart than the outer row of papillae. The anal aperture is smooth, lacking papillae or crenulations. The outside margins of the branchial, anal, and supra-anal apertures are pigmented with small dark spots that give the mantle a peppered appearance. Although sometimes difficult to distinguish, *U. peggyae* has a rounder ventral margin and has rays on the periostracum, while *U. imbecillis* has a more elongate body and is normally rayless.

Host species- Unknown.

Conservation status- Stable.

Sources: Brim-Box and Williams 2000.

***Villosa lienosa* (Little Spectaclecase)**



Villosa lienosa historically was found in the main channel and tributaries of the Apalachicola, Chipola, Chattahoochee, and Flint Rivers. It presently is found in the main channel and tributaries of the Apalachicola, Chipola, Chattahoochee, and Flint Rivers. It inhabits small creeks with moderate to fast current. It is found in mud, sand, clay, and limestone rock substrates.



The little spectaclecase is a medium-sized mussel, reaching 75 mm in length. The shell is thin, strong, smooth, inflated, and subelliptical in outline. Color varies from dark brownish black to chestnut brown to greenish brown. Some specimens exhibit faint green rays. The posterior slope is flattened with a poorly defined posterior ridge. This species is sexually dimorphic. The female shell is greatly inflated and angulated posteriorly. The male shell is bluntly pointed posteriorly. The umbo

is broad, full, low, and anterior to the center. The ligament is long and narrow. The hinge plate is long and narrow. The right valve has one large and one small coarsely crenulated pseudocardinal teeth. The left valve has one large and one small slightly crenulated pseudocardinal teeth. Nacre varies from white to salmon to purple and is highly iridescent posteriorly. *The mantle margins on the ventral side are characterized by a brownish pigmentation extending midway to the anterior end from the posterior end.* The pattern of pigmentation on the mantle margin distinguishes this species from congeners. Branchial papillae are fine, singular, and occur in two rows. Anal papillae are well-defined, long, and singular.

Host species- *Micropterus salmoides* (largemouth bass), *Lepomis macrochirus* (bluegill sunfish).

Conservation status- Stable.

Sources: Brim-Box and Williams 2000, Burch 1975, Clench and Turner 1956.

***Villosa vibex* (Southern Rainbow)**



Villosa vibex historically was found in the tributaries of the Apalachicola River and the main channel and tributaries of the Chipola, Chattahoochee, and Flint Rivers. It presently is found in tributaries of the Apalachicola and Chattahoochee rivers and in the mainstem and tributaries of the Chipola and Flint Rivers. It inhabits small rivers, lakes, and creeks with slight to moderate current. It is found in mud, detritus, soft sand, and clay substrates.

The southern rainbow is a medium sized mussel reaching up to 100 mm in length. The shell is thin, inflated, smooth, and subelliptical in outline. Valves are subinflated, thin, and translucent. The anterior end is rounded, and the posterior margin is broadly rounded in females and moderately rounded in males. The posterior ridge is broadly rounded and the posterior slope is moderately concave. Umbos are broad, full, low, and anterior to the center, usually with several fine, low, slightly double-looped ridges in younger specimens. The periostracum is smooth on the disc, and roughened on the ventral margin and posterior slope. Color ranges from a light yellowish brown to black, with numerous broad greenish rays. The left valve has two delicate pseudocardinal teeth, two short, straight lateral teeth and a long, narrow hinge line. The right valve has two triangular, narrow, parallel pseudocardinal teeth separated by a narrow pit, and one lateral tooth. Beak cavities are shallow and nacre is bluish white to pink and purple. *The mantle has dark solid or mottled pigmentation which extends along most of the ventral margin.* The inner mantle posterior of the branchial opening is papillate in females, and usually nonpapillate in males. Mantle margins have eyespots in some females. The pattern of pigmentation on the ventral margin, the presence of green rays on the posterior shell, and its relatively thin pseudocardinal teeth distinguish this species from congeners.

Host species- *Micropterus salmoides* (largemouth bass), *Lepomis macrochirus* (bluegill).

Conservation status- Stable.

Sources: Brim-Box and Williams 2000, Burch 1975, Clench and Turner 1956, Johnson 1970.

***Villosa villosa* (Downy Rainbow)**



Villosa villosa historically was found in the mainstem of the Chattahoochee River and in the mainstem and tributaries of the Apalachicola, Chipola, and Flint Rivers. It presently is found in the mainstem and tributaries of the Chipola and Flint Rivers, the mainstem of the Apalachicola River, and two tributaries of the Chattahoochee River. It inhabits reservoirs, creeks, and rivers with slow to moderate

current. It is found in mud, sand, vegetation, and silt.

The downy rainbow rarely exceeds 60 mm in length. Valves are subinflated, thin, and translucent, with rounded anterior ends. The species is sexually dimorphic, with females having a broadly rounded posterior end, and males having more pointed, high posterior ends (like those of *Lampsilis subangulata*). The posterior ridge is rounded, and the posterior slope is slightly concave. Umbos are moderately swollen, slightly elevated above the hinge line, located in the anterior of the shell and sculptured with several fine, low, slightly double-looped ridges. The shell is greenish yellow, dark green, or brownish black. The periostracum is sometimes smooth and shiny, but frequently has a cloth-like appearance. Faint blue, green, or yellow rays are sometimes seen on the shell. The left valve has two delicate pseudocardinal teeth, and a short, narrow hinge line with two short, straight lateral teeth. The right valve has two triangular, narrow, parallel pseudocardinal teeth separated by a narrow pit. The nacre is bluish white and highly iridescent. Branchial papillae appear as little crenulations and occur in poorly defined rows. The ventral mantle margins have dark solid or mottled pigmentation, similar to *Villosa vibex*.

Host species- *Micropterus salmoides* (largemouth bass), *Lepomis macrochirus* (bluegill sunfish).

Conservation status- Special concern.

Sources: Brim-Box and Williams 2000, Burch 1975, Clench and Turner 1956, Johnson 1970.

Stream Habitat Survey Methods

Stream habitat surveys consisted of recording general site information, including upland habitat and channel roughness; determining channel slope; diagramming longitudinal and cross-sectional profiles of the survey reach; and recording habitat conditions along each of the profiles. Methods and data recording conventions used for the 1999 survey are described in the order in which they appear on the Habitat Survey Data Sheet (Appendix 2).

Site Information

- Site ID# - [Consists of a two-digit number (the last two digits of the year that a mussel survey was first conducted at the site) followed by a dash and a three-digit number (indicating the site number assigned during the first survey year)]
- Location Description – Stream name, road number, county, and location from nearest town.
- Date
- Technicians – Initials of each crew member and code for task performed:
T = Transit reader; PH = Leveling rod holder and substrate classifier;
WT = Water chemistry tester; SC = Sediment corer; LP = Longitudinal profile; SD = Spherical densiometer reader; DR = Data recorder
- Bridge Photo Numbers – Film number and photo number of the bridge photos. Up = Upstream; Down = Downstream.
- Upland Vegetation – Predominant landcover type in upland areas on each side of the stream. An “X” next to a category indicates the predominant landuse in the zone between the riparian area and approximately 0.5 km upland from the riparian area. (“Right” bank refers to right side of stream as you look downstream.) One individual made these determinations at all sites.
- Channel Roughness – Parameters relating to channel resistance to flow. Parameters were visually estimated using Manning’s *n* table (Appendix 3). One individual made these estimates at all sites.

Slope – Determination of the slope of the water level over the length of the 100 m survey reach. Methods described in Harrelson et al. (1994) were used for determining slope. Stream slope was measured by one of two methods. In the profile leveling method, the transit was placed midway between the start point and end point of the 100 m survey reach and the vertical distance between transit level and water level was determined for both the start point and the end point. Slope was calculated as the difference in water level between these two points. In the differential leveling method, the relative water level elevations at 0 and 100 m were determined by multiple transit setups and measurement of elevation changes between consecutive transit levels. If vegetation or flow prevented use of a transit, an eye level was substituted, and the differential leveling method was employed. The data sheet is set up for data recording using the differential leveling method.

- Station - Transit setup number.
- Backsight (BS) - Actual vertical distance from water level at 0 m to a horizontal line (the line of sight) projected by the transit, which was set up 10-20 m upstream. The backsight reading was taken as the rod was held steady with its base contacting the water surface, but not above or below the water surface. Because actual water surface elevation was not known for the survey sites, water level elevation at 0 m was always designated as 100 m above sea level. The sum of the BS reading and water level elevation at the start point (100 meters) equals the height of the transit (HI).
- Height of Instrument (HI) - Elevation of the line of sight projected by the instrument (transit). It is found by adding the backsight rod reading to the designated elevation of water level at 0 m (100 m).
- Foresight (FS) - Rod reading taken on the water surface upstream of the transit. The foresight was subtracted from the HI to determine the water surface elevation at the location of the rod upstream (ELEV).
- Elevation (ELEV) - Water surface elevation where the rod was held in place for the backsight and foresight readings. It was calculated as the difference between the HI and the FS rod readings.
- After backsight and foresight readings were recorded for the first transit setup, transit was moved 10-20 m upstream of the foresight rod location, and a backsight reading of the rod from the new transit location was taken. (The rod was placed in EXACTLY the same location as it was held during the previous foresight reading.) After recording the backsight, the rod was moved 10-20 m upstream of the transit and another foresight reading was taken. This process was repeated until the water surface elevation at 100 m was calculated. The slope is the difference between the 100 m water surface elevation and the 0 m water surface elevation.

Longitudinal Profile – Characterization of the channel habitat types, density of coarse woody debris, and canopy cover within the survey reach. Starting at 0 m on the survey reach, one individual moved upstream in the middle of the channel (keeping equal distance from both sides) and recorded channel depth, canopy cover (with a spherical densiometer), channel unit type, and number of logs encountered at 10 m intervals.

- Distance – Location along 100 m longitudinal transect (0, 10, 20, 30, 40 m, etc.). Distances other than 10 m interval stops were recorded to denote additional habitat characteristics (mid-channel islands, debris dams, etc.). These habitat forms were recorded in the "other" column.
- Level – Depth of water in the center of the channel at each 10 m interval.

- Channel Unit Type – Channel unit type at each 10 m interval:
 - RI = Riffle – (*white*) water flowing over exposed rocks
 - RU = Run – water flowing over non-exposed bed surface
 - SPO = Shallow Pool – water relatively stationary over pool < 1 m deep
 - DPO = Deep Pool – water stationary over pool > 1 m deep
- Coarse Woody Debris – Number of logs in each size category encountered by the surveyor as s/he walked up the center of the channel to the next 10 m interval. Logs partially buried in sediment or treefalls below the level of bankful were included.
 - Small : 5-10 cm in diameter
 - Med : < 50 cm in diameter
 - Large : > 50 cm in diameter
- Canopy cover – Spherical densiometer readings (number of vertices in which sky is visible). Upstream, downstream, left and right bank readings were recorded. Canopy cover measurements were made only at 20 m intervals, starting at 0 m. One individual read the spherical densiometer at all sites.
- Other – Length and location of mid-channel islands, log jams, or other major features within stream.

Cross-Section Profile – Diagram of a channel cross-section and characterization of the substrate, organic matter and mussel densities found across a representative width of stream. Cross section(s) were located within the 100 m mussel survey reach. A relatively uniform, straight stretch within the reach was selected. Features such as large boulders, big deadfalls, abrupt changes in slope, and meander bends that have altered the extent and form of the channel were avoided. At the selected cross-section location, non-stretch rope (marked and flagged to indicate m intervals) was tied between two large trees on the first terrace level above the stream. The rope was stretched tight and level above the water. Permanent markers (numbered aluminum tags) were placed at transit level on the trees to which the cross-section rope was tied. Starting at or near bankful level on either bank, level height, cross section distance, bed material and bed organic matter type were recorded at 1 m intervals. These data were also recorded at water level and bankful on both sides of stream. Mussel data were recorded at selected points along each transect.

- Site ID #
- X-section Location – Cross-section location on the 100 m survey reach transect.
- Distance – Interval along the cross-section rope.
- Level – Depth of bed from transit horizontal at each 1 m interval.
- Bed Material – Primary and secondary bed material at bed surface (top 10 cm of substrate). Determination was made by gathering a handful of the sediment at each 1 m interval and visually estimating relative proportions of sediment sizes.

MU = Mud (clay-sized particles mixed with fine organic matter)
CL = Clay (<0.62 mm particles --- usually very cohesive)
SA = Sand (< 2.0 mm particle diameter)
GR = Gravel (2 mm - 6.5 cm)
CO = Cobble (6.5 cm – 25 cm)
BO = Boulder (25 cm – 400 cm)
BE = Bedrock (>400 cm)
NO = No substrate at the surface (top 10 cm of bed surface covered by thick layer of detritus or other substance)

- Water – Location of water level and bankful on both sides of the stream
- Bed Organic Matter – Primary organic matter type found at the bed surface.
 - D = Leaf and Twig Detritus
 - CWD = Coarse Woody Debris (logs > 5 cm in diameter)
 - RK = Large hardwood roots and cypress knees
 - FR = Fine roots
 - EV = Emergent vegetation
 - SV = Submergent vegetation
 - 0- = No organic matter at bed surface
- Mussels – Number of *Corbicula* and unionids in 0.25 m² quadrat centered at three or more locations along x-section rope. In large streams quadrats were placed at five-meter intervals, starting at water level on one side of the stream; in small creeks, three quadrats were placed at equal intervals across the width of the stream.

Cross-Section Habitat Conditions

- Tree tags – Location and numbers of tree tag monuments. Stream, banks and tree tag locations were diagramed. Direction of survey was indicated (R→L = right bank to left bank; L→R = left bank to right bank). The numbers of the tree tags that were set to transit horizontal were indicated (e.g., BM = tag# or tag#).
- Canopy Cover – Mid-channel spherical densiometer readings upstream, downstream, and toward left and right banks. One person read the spherical densiometer at all sites.
- Photo Numbers – Photos numbers upstream and downstream of the cross-section.
- Water Chemistry / Physical parameters -
 - Water Temperature – Recorded in degrees Celsius.
 - Dissolved Oxygen –Recorded in ppm. (Sentry Oxygen Monitor)
 - Conductivity – Recorded in μMHOS. (YSI Meter)
 - Nitrate – Nitrogen – Recorded in ppm. (CHEMets test kit)
 - Phosphate – Recorded in ppm. (CHEMets test kit)
 - Ammonia – Nitrogen – Recorded in ppm. (La Motte test kit)

Field Sample Collections

Sediment Cores – A 4.7 cm-diameter (1½ inch) PVC pipe was inserted to a depth of 8.5 cm in bed substrate at mid-channel near the start of the 100 m transect. Substrate was extracted from corer and placed in plastic bag labeled with site ID. Three substrate core samples were taken at each site. If substrate could not be cored at mid-channel (e.g., substrate was bedrock, boulder or cobble), we moved upstream midchannel until we encountered a patch of sediment that can be cored. Samples were brought back to the lab for sediment analysis.

Water Sample – A 1L sample of water from a *flowing* section of stream was collected. The sample was placed in a plastic storage bottle and stored on ice until it could be refrigerated in the lab. All water samples were collected at base-flow levels during a three day period.

Laboratory Methods for Field Samples

Alkalinity - Alkalinity was determined within 7 days of collection using a Mettler DL12 titrator. Before beginning the alkalinity titration, 60 ml sub-samples of each water sample were allowed to equilibrate to room temperature. The meter was set to a constant of 100. After placing the sample in the meter, it was given 3 minutes to come to a stable pH reading before beginning the titration. A solution of 0.02 N H₂SO₄ was used as the titrant. The target endpoint pH was 4.5. Alkalinity, the pH reading before beginning the titration, the endpoint pH, and amount of titrant used were recorded.

Conductivity - Each water sample brought back to the lab was measured for conductivity at the same time alkalinity was determined. A YSI meter was used for conductivity measurements. Readings were recorded in µMHOS.

Sediment – Sediment samples were brought to the lab and dried in plastic bags for two months under ambient conditions. Samples were then placed on paper plates and dried for another 2 weeks under ambient conditions. Samples were weighed and returned to plastic bags for storage.

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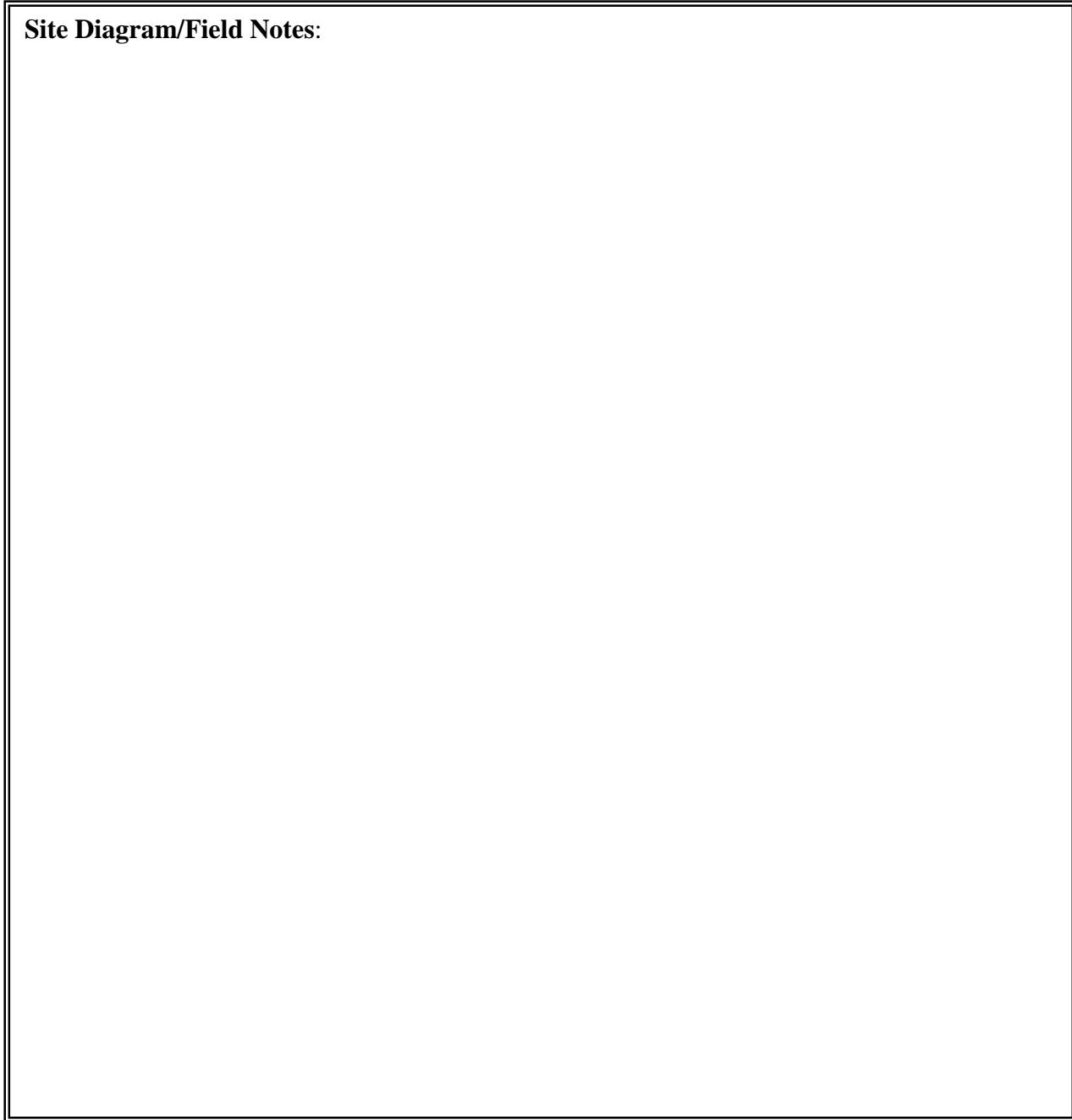
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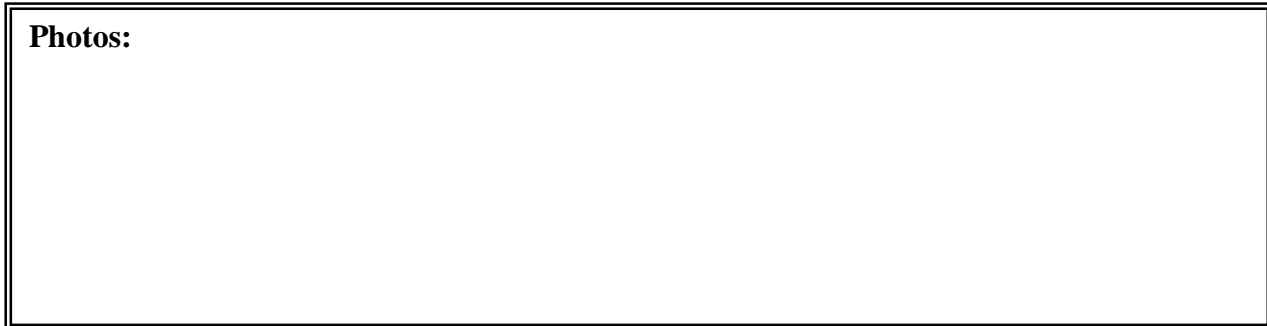
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Appendix 1 – Mussel Survey Data Sheet

Site Diagram/Field Notes:

A large, empty rectangular box with a double-line border, intended for drawing a site diagram or writing field notes.

Photos:

A smaller, empty rectangular box with a double-line border, intended for pasting or drawing photos.

Appendix 3 – Manning’s N Table

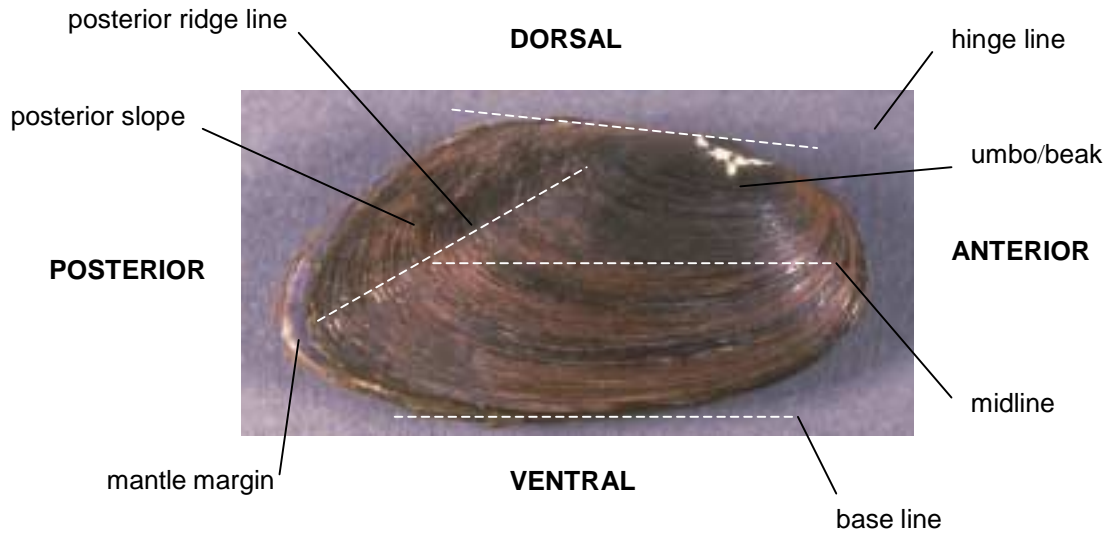
$$n = (n_0+n_1+n_2+n_3+n_4)m$$

Channel Condition	Value
Additive Factors	
Material involved	n_0
Earth	0.020
Rock cut	0.025
Fine gravel	0.024
Coarse gravel	0.028
Cobble	0.030-0.050
Boulder	0.040-0.070
Degree of Irregularity	n_1
Smooth	0.000
Minor (slight scour)	0.005
Moderate (slumping)	0.010
Severe (eroded banks)	0.020
Variation in Channel Cross Section (location of thalweg)	n_2
Gradual	0.000
Alternating occasionally	0.005
Alternating frequently	0.010-0.015
Effect of Obstructions	n_3
Negligible	0.000
Minor (15% of area)	0.010-0.015
Appreciable (up to 50%)	0.020-0.030
Severe (> 50% is turbulent)	0.040-0.060
Vegetation	n_4
None	0.000
Low (grass/weeds)	0.005-0.010
Medium (brush, none in streambed)	0.010-0.025
High (young trees)	0.025-0.050
Very high (brush in streams, full grown trees)	0.050-0.100
Multiplicative Factors	
Degree of Meandering	m
Minor	1.000
Appreciable	1.150
Severe	1.300

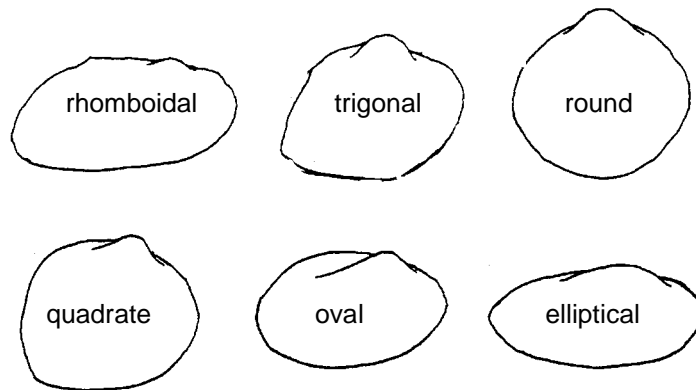
Note: adapted from Cowen, 1955

Appendix 4 -- Mussel identification terms

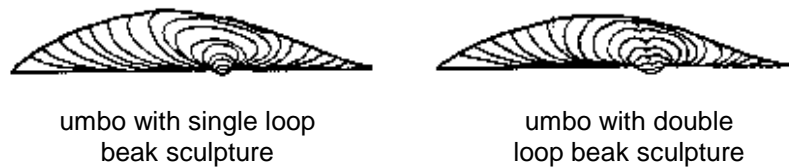
Shell anatomy



Shell shapes



Umbo sculpturing (dorsal view)



Exterior and interior shell structures

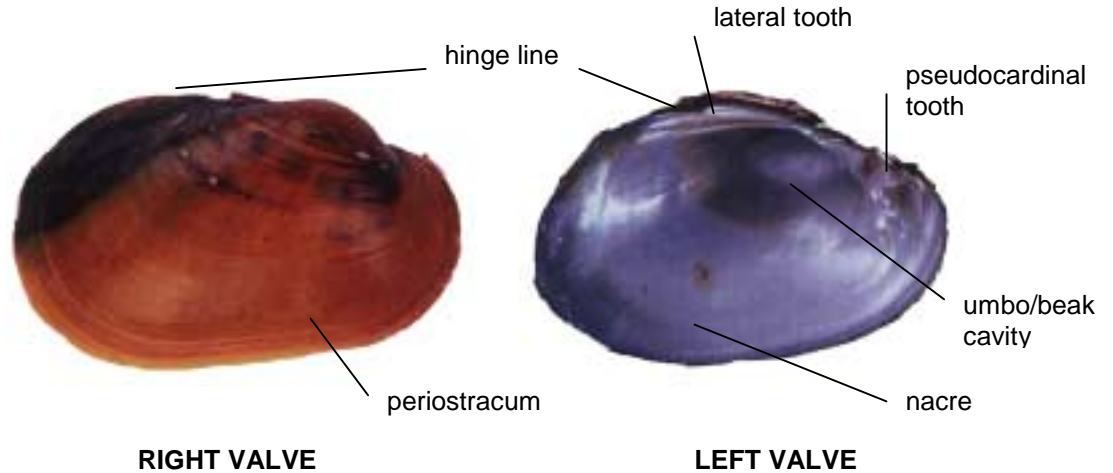
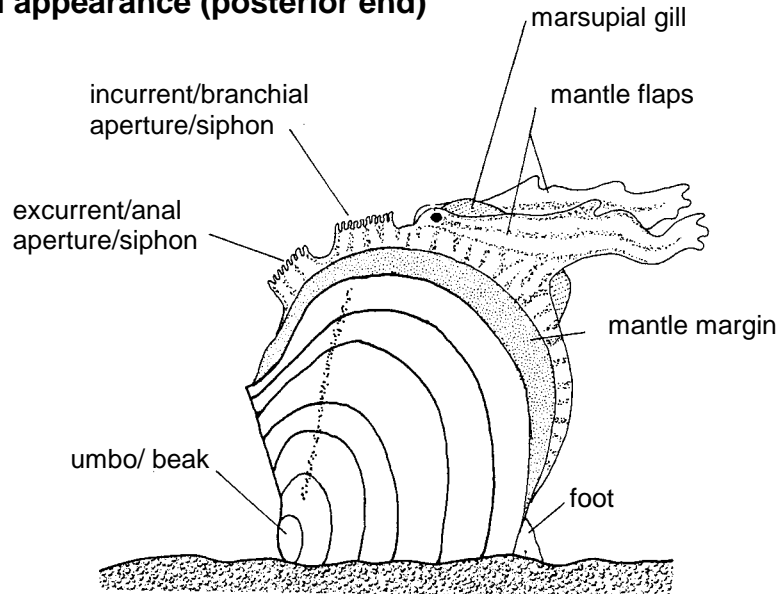


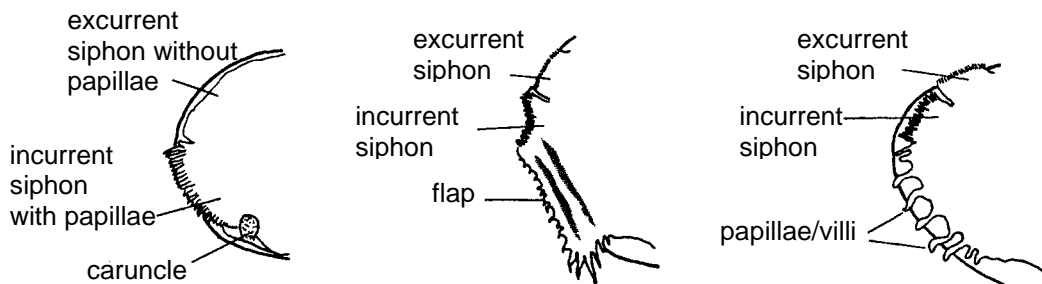
Photo courtesy of Jayne Brim-Box

External appearance (posterior end)



Adapted from McMahon (1991)

Posterior mantle margin specialized structures



Adapted from McMahon (1991)

Acknowledgements

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