Corbicula fluminea

The Asian clam

Phylum: Mollusca

Class: Bivalvia, Heterodonta, Euheterodonta

Order: Imparidentia, Venerida

Family: Cyrenoidea, Cyrenidae

Taxonomy: *Corbicula fluminea* was originally described as one of three species in the genus *Tellina* (Araujo et al. 1993). The taxonomy of this group was based on shell morphology and color, which are variable characters (Sousa et al. 2008a), and has lead to the synonymization of several previously described species that were found to display intraspecific variation (Araujo et al. et al. 1993). *Corbicula fluminea* was synonymized with *C. fluviatilis* by Prashad in 1929, *C. manilensis* in 1933 (Talvera and Faustino in Britton and Morton 1979) and *C. leana* by Morton (1977). This synonymization lead to two *Corbicula* species with widespread distribution: *C. fluminea* (a freshwater species) and *C. fluminalis* (an estuarine species) (Araujo et al. et al. 1993 but see Sousa et al. 2008a). These species can be further distinguished by geographic location and characters of biology and morphology, as all North American populations were determined to be only *C. fluminea* (see Britton and Morton 1979; Morton 1982; Araujo et al. et al. 1993).

Description

Size: Individuals range in size from less than 2.5– 6.4 cm in length, and are rarely over 5.0 cm (Ward and Whipple 1963). Individuals over 40 mm in length are often found in canal bottoms (Eng 1979). The illustrated specimen (from the Columbia River) is 14 mm in length. Mean wet weight for *C. fluminea* from the Potomac River were estimated for year classes 1, 2, 3, and 4 to be 0.48, 1.47, 4.30, and 10.37 grams, respectively (Cohen et al. 1984).

Color: Tan exterior; the shell interior is white, smooth, polished, and is sometimes with purple markings (Britton and Morton 1979). A periostracum is present and thick (Coan and Valentich-Scott 2007), particularly in canal specimens; specimens from earth-lined habitats may lack periostracum (Eng 1979).

General Morphology: Bivalve mollusks are bilaterally symmetrical with two lateral valves or **shells** that are hinged dorsally and surround a mantle, head, **foot** and viscera (see Plate 393B, Coan and Valentich-Scott 2007). The Veneroida is a large and diverse bivalve heterodont order that is characterized by well developed hinge teeth. There are 22 local families, and members of the Corbiculidae have an elongated hinge and serrate teeth laterally, *C. fluminea* is common in freshwater habitats and has a conspicuous triangular shape with low commarginal ridges (see Plate 398B, 415E, Coan and Valentich-Scott 2007).

Body:

Color:

Interior: The ligament is thick and strong, and is entirely external and posterior to the beaks (Fig. 2).
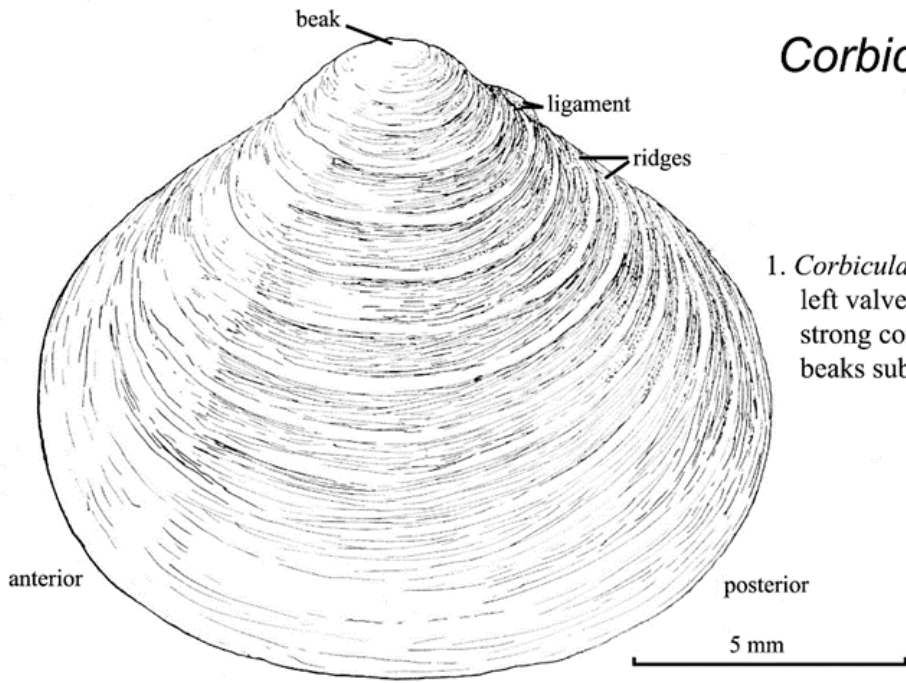
Exterior:

Byssus: A small byssus is present only in first year (Morton 1979a) (not figured).

Gills:

Shell: The overrall shell shape is triangular (Coan and Valentich-Scott 2007) to subcircular. Both valves are similar and regular, and the shell is thick.
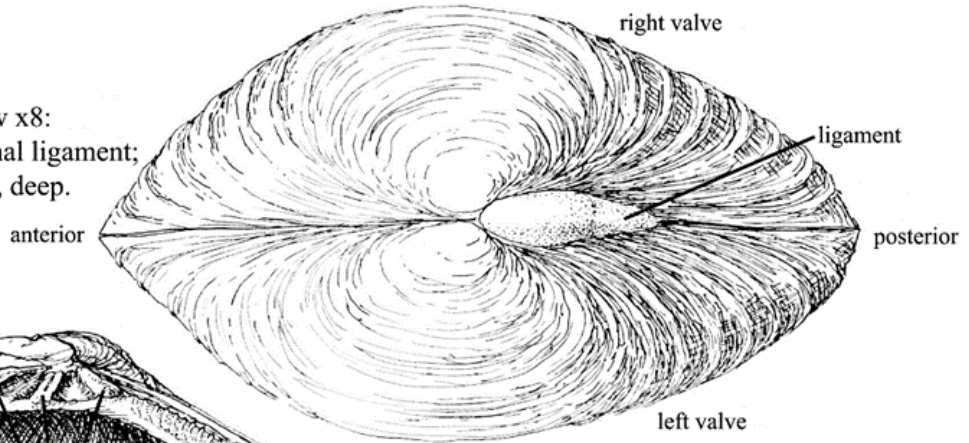
Interior: The adductor muscle scars are approximately equal (Coan and Valentich-Scott 2007) (Fig. 3). The pallial line is incomplete anteriorly (Corbiculidae, Britton and Morton 1979).

Corbicula fluminea

beak

ligament

ridges

1. *Corbicula fluminea* (14x12x5.5mm) x8:
left valve; regular, thick, triangular valves;
strong concentric ridges; external ligament
beaks subcentral.

anterior

posterior

5 mm

right valve

2. Dorsal view x8:
large external ligament;
shell heavy, deep.

anterior

ligament

posterior

left valve

ligament

cardinal
teeth

adductor
scar

lateral teeth

3. Interior, left valve:
3 cardinal teeth (each valve); elongate hinge,
serrate lateral teeth; chalky surface; subequal
adductor muscle scars.

adductor
muscle scar

anterior

posterior

pallial line
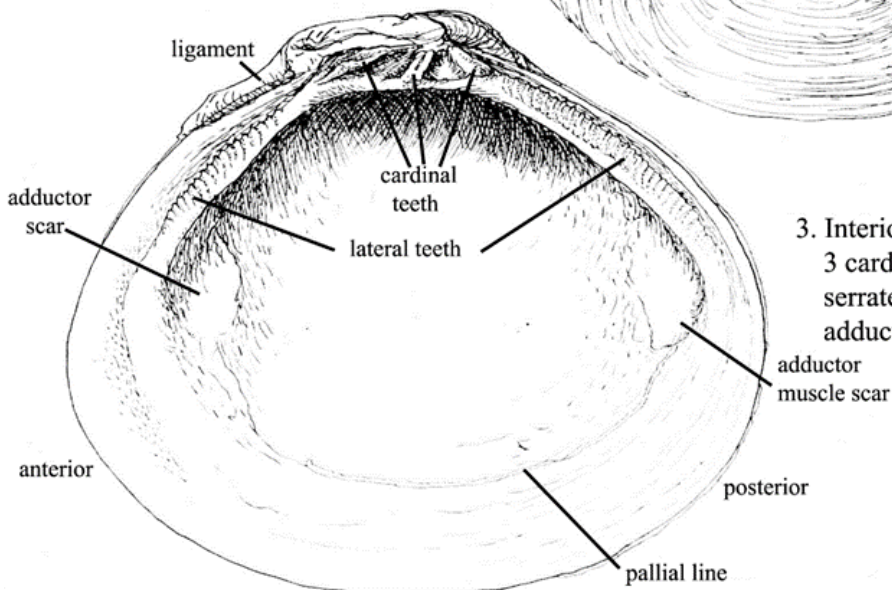
Exterior: The exterior sculpture has heavy concentric ridges and faint growth rings (Britton and Morton 1979) (Fig. 1).

Hinge: The hinge is very elongate, with anterior and posterior serrate lateral teeth (Corbiculidae, Burch 1975) (Fig. 3). There are three hinge teeth on each valve, which are "divergent, pseudocardinals" (Clarke1981) (Fig. 3). A long row of serrate hinge teeth are present both anteriorly and posteriorly (Fig. 3) (Corbiculidae, Burch 1975). (Note: Ward and Whipple 1963 lists two teeth in each valve, which is a possible error.) The beaks are subcentral (Ward and Whipple 1963), heavy, and inflated (Britton and Morton 1979). The umbones are often eroded, especially in acidic waters (Britton and Morton 1979).

Eyes:

Foot: The foot is rather large (Clarke 1981) (not figured).

Siphons: Siphons are of similar size and shape (Britton and Morton 1979) (not figured).

Burrow:

Possible Misidentifications

The Corbiculidae, of which *Corbicula* is the only North American genus (Burch 1975), are noted for a heavy shell, strong concentric sculpture, a hinge ligament that is internal, and with a peg-shaped chondrophore on the left valve (Coan and Valentich-Scott 2007). *Corbicula fluminea* is characterized by a thick, triangular shell with commarginal ridges and dark brown-black periostracum. There are three other freshwater bivalve families in the Pacific Northwest. The Unionidae are represented by two genera: the monotypic *Gonidea (angulata)* has a smooth but irregular elongate subtriangular shell, with a distinctive high sharp ridge. *Anodonta,* the second genus, has a thin smooth elliptical inflated shell, sometimes winged at the posterior end. It has fine parallel ridges (not deep heavy ones as in Corbiculidae) and its hinges lack teeth. The third family, the Sphaeriidae, belongs to the same superfamily (Sphaeriacea) as the Corbiculidae (Burch 1975). There are several genera, including *Sphaerium, Musculium,* and *Pisidium.* Sphaeridae can have regular valves, subcentral beaks and radial sculpture as do Corbiculidae. The lateral hinge teeth in Sphaeriidae are smooth, however, not serrate as in *Corbicula.*

A great number of species of *Corbicula* have been named worldwide, many of them superfluous. The **taxonomy** of the genus remains unclear, and there is still uncertainty as to how many species have been introduced into North America from Asia and elsewhere (Britton and Morton 1979). It is possible that only *C. fluminea* exists here: M.H. Smith et al. 1979 have suggested, on the basis of electrophoresis, that specimens from 5 major U.S. populations (California, Texas, Arkansas, Tennessee and South Carolina) are all of the same species. There is, however, a great deal of variation in shell shape, sculpture, etc. Although *C. fluminea* has been synonymized with *C. manilensis,* there are still a few questions about its reproductive habits and longevity (Morton 1979a). *Corbicula fluminalis,* may be larger than *C. fluminea,* could live longer (to 8 years), and seems to occupy river mouths rather than streams (Britton and Morton 1979) (see **taxonomy**).

Ecological Information

Range: Type locality is the Artemovka River in Russia (Kantor et al. 2009) and is endemic to southeast Asia (Morton 1979b). *Corbicula fluminea* is a widespread species with a history of invasion that is well documented; it is a non-native invasive species and, where present, leads to considerable ecological and economic impacts in many aquatic systems (e.g., hydrology, biogeochemistry, biodiversi-

ty, Sousa et al. 2008a; Sousa et al. 2008b; Crespo et al. 2015 and references therein). It has been transported (e.g., via ballast water, as bait, etc.; Sousa et al. 2008a) to North America in (first half of 20th century) and South America in the 1960–70s, Europe in the 1980s (see Fig. 1, Crespo et al. 2015). This species was introduced to North America from southeast Asia in the 1930s and is now present in all major U.S. drainages (in the Pacific and Atlantic) below 40° latitude (Britton and Morton 1979; McMahon 1982). Its range in the Pacific Northwest includes Washington, Idaho, Oregon to northern California and it also occurs in the Imperial Valley, California, and in Arizona. There were likely two "epicenters" of human mediated introductions in North America; the first to the northwest from southeast Asia and the second a population in the Ohio River (see Fig. 1, McMahon 1982). On the eastern coast of North America, *C. fluminea* was first observed in Potomac River in 1977 (Cohen et al. 1984; Phelps 1994). Outside of North America, established populations were reported in the Negro River Basin in Patagonia, Argentina, which is the southernmost reach if the species distribution to date worldwide (Molina et al. 2015) and the Iberian Peninsula (Spain and Portugal, Araujo et al. 1993). Potentially high genetic diversity exists within populations, which is observed molecularly (e.g., Hongze Lake, China, Li et al. 1994) and morphologically (a dark morph observed in southwestern United States, Nichols and Black 1994) (Sousa et al. 2008a).

Local Distribution: Local distribution includes the Columbia River system (from which the illustrated specimen originated), Siuslaw River at Florence, and possibly in the Umpqua River (Carlton 1979).

Habitat: An opportunist, *C. fluminea* can live in quiet or fast moving water, in streams, rivers, canals, lakes and reservoirs. It can uti-

lize either an "r" or a "k" reproductive strategy, and its only limiting factor seems to be space (Britton and Morton 1979). It has expanded geographically very successfully in 50 years, especially into irrigation canals in northern California, where it is considered a pest. In canals, it finds a nursery in the incrustation formed of corophiid amphipod tubes and colonial hydroids on the concrete walls. Locally, the densely packed individuals accumulate as a solid layer (sometimes up to 92 cm thick) composed of clams, fine silt, and mucus. Individuals become so dominant that they have the capacity to change their environment radically. In the Columbia River system, they live in stream bottoms. Prolonged exposure to air can cause death by accumulation of metabolic wastes (rather than desiccation as the clam shell can close tightly). Mean survival is 26.8 days at 20 °C, at high relative humidity (r.h.); 13.9 days at 20 °C., at low r.h.; 8.3 days at 30 °C., at high r.h.; 6.7 days at 30 °C., at low r.h (McMahon 1979). Mortality rate increases with increased turbidity (e.g., 150 nephelometric turbidity units, Avelar et al. 2015). Bioturbation from *C. fluminea* increases soluble and labile phosphorus within sediment (up to 64 mm depths, Chen et al. 2016). Individuals prefer oxygenated, sandy sediment (Crespo et al. 2015). *Corbicula fluminea* is a common bioindicator (e.g., lead contamination, Clarke et al 1979; potassium, Daum et al. 1979; Sousa et al. 2008a) and experiment species (e.g., Baudrimont et al. 1997; Basack et al. 1998; Cataldo et al. 2001; Miller et al. 2005; Vale et al. 2014; Erdogan and Erdogan 2015; Rosa et al. 2015; caffeine, Aguirre-Martinez et al. 2015; Oliveira et al. 2015; metals Bonnail et al. 2016; Oliveria et al. 2016).

Salinity: Considered a freshwater species, but can survive a gradual increase of salinity, i.e., up to salinity of 22 for 80 days. Salinity range reported for *C. fluminea* is 10–14 (Crespo et al. 2015). In shock tests, however, mortality was 50% within 10 days of salinity

over 10, and individual sodium uptake was measured 50% sodium at salinity of 4.5 (Evans et al. 1979). The closely related species *C. fluminalis,* is differentiated from *C. fluminea* by some authors as an estuarine, where C. fluminea is exclusively freshwater (Araujo et al. et al. 1993 but see Sousa et al. 2008a).

Temperature: Individuals cannot survive cold temperatures (i.e., one severe winter can kill a population, Horning and Keup 1964). Short warm water periods may be a limiting factor in the northern range (Eng 1979). The distribution of this species seems to be limited by low temperatures (Crespo et al. 2015; Gama et al. 2016), as individuals are negatively effected by high temperatures (temperature range 2–34.8°C, Crespo et al. 2015). Growth occurs only at temperatures over 14°C, and spawning takes place only at 13–16 °C. (California, Eng 1979).

Tidal Level: Usually a shallow water or near-shore species.

Associates: Individuals become very dominant and outcompete native bivalves within whose communities it can live (Morton 1979a; Crespo et al. 2015). In canals, the amphipod *Corophium spinicorne* provides tubes that harbor recently settled clams; the colonial hydrozoan *Cordylophora lacustris* also provides habitat (Eng 1979). The oligochaete, *Chaetogaster limnaei,* can sometimes be found within the mantle cavity of *C. fluminea* (Eng 1976).

Abundance: Often more than 1,000 individuals per square meter (McMahon 2000; Majdi et al. 2014). Maximum densities in fall, winter, summer were up to 4,500 clams per ~1 square meter in the Delta-Mendota Canal, California (Eng 1979); mean density range was 173–2,990 clams per square meter in a river near Charlottesville, Virginia (Hornback 1992); and up to 525 individuals per square meter in the Negro River Basin (Molina et al. 2015).

Life-History Information

Reproduction: The reproductive organs are composed of an anterior testis and posterior ovary, which both discharge into a common gonoduct (Britton and Morton 1979). (For oocyte and sperm morphology see, Fig. 4 Kraemer and Galloway 1986.) Early reproduction and high fecundity contribute to the success of this species (see **Range**). Both a protogynous and a protandric consecutive hermaphrodite (Britton and Morton 1979), it can also function as a simultaneous hermaphrodite (Crespo et al. 2015), making it highly successful reproductively (Sousa et al. 2008a). Individuals are also capable of androgenetic self-fertilization (Crespo et al. 2015). *Corbicula fluminea* incubates its young for about one month in the inner demibranch of each ctenidium (Morton 1979a) i.e., the branchial water tubes (see Fig. 1, Sousa et al. 2008a). There are two reproductive peaks in California: April to May and August to September and fall and spring peaks were reported in Arkansas, the former lasting longer than the latter in Arkansas (Kraemer and Galloway 1986). (In Kentucky, a cooler climate, there was only but one peak per year.) Cleavage is via a coeloblastula that is 175 µm in diameter at 24 hours post fertilization and development proceeds with cone-shaped gastrulae by 30 hr (175–180 µm); trochophore larvae (180 µm in length); veliger larvae at 24–48 hrs (190–250 µm).

Larva: Larvae are brooded until they are 210 µm and released as spat with very straight umbo (see Fig. 4, Brink 2001) (see **Reproduction**). Pediveligers develop after 3–5 days (230 µm) at which point the velum is shed metamorphosis occurs into a straight-hinge juvenile (see Fig. 11 and for full description of development see Kraemer and Galloway 1986 and for list of life-history characters, see Table 1, Sousa et al. 2008a). Larvae

have a sloping posterior shoulder with rounded posterior end that is slightly shorter than the anterior end. "Larvae" collected in plankton are likely thread drifting (see *Macoma balthica, Nutricola tantilla, Hiatella arctica,* descriptions in this guide) juveniles that have settled to the benthos and exhibit secondary settlement by riding currents (i.e., not true larvae) (Brink 2001). Larvae are released (as juveniles or late pediveligers, Kraemer and Galloway 1986) into the plankton, and this species is the only freshwater bivalve that does this (Eng 1979; Crespo et al. 2015). Both primary and secondary growth lines give larval shell a "pleated appearance" (Nichols and Black 1994). (For larval identification key for *C. fluminea*, *Driessena polymorpha*, and *D. rosteriformis bugensis* see Nichols and Black 1994).

Juvenile: Like other bivalve species (e.g. *Mytilus edulis, Macoma balthica*), post-larval (i.e., juvenile) *C. fluminea* may exploit two dispersal periods. The initial larval dispersal and settlement into the benthos, is followed by potential dispersal from the benthos by thread drifting on water currents via mucous threads by juveniles (i.e., "thread drifting", Martel and Chia 1991). Clams produce these mucous threads (see Fig. 2, Prezant and Chalermwat 1984) in response to water current stimuli via ctenidial mucocytes (Prezant and Chalermwat 1984). Juvenile settlement flexibility greatly aids in dispersal potential.

Longevity: Two to 4 years (Britton and Morton 1979) or one to 5 years (Sousa et al. 2008a), with large animals in canal bottoms living longest. Two to 3 years were estimated for individuals collected near Charlottesville, Virginia (Hornback 1992).

Growth Rate: Rapid growth is one of the successful strategies of *C. fluminea* (Sousa et al. 2008a). Clams primarily grow from March to October, when temperatures are over 14°C. (Eng 1979). In central California,

outside canals, clams grow to a mean of 12 mm the first season, and 15 mm the second (Heinsohn 1958), with two growth rings formed each year (Britton and Morton 1979). Growth varies with depth, with specimens at 8 m deep are longer than those at 12 m (Abbott 1979). Growth of individuals collected in a river near Charlottesville, Virginia was 11.1 mm in the first year, 17.6 mm in the second year (Hornback 1992).

Food: A non-selective filter feeder (Boltovskoy et al. 1995) that also pedal feeds. Diet consists primarily of diatoms (Hanna 1966) and possibly flagellates (i.e., phytoplankton, Foe and Knight 1985). *Corbicula fluminea* removes chlorophyll *a* from river water with filtration rates that ranged from 13.8–33.9 ml per hour per gram (wet weight) clam (Cohen et al. 1984). Filtration rates measured in three riverine habitats (Tombigbee and Tangipahoa, Mississippi, and Ouachita, Louisiana) ranged from 4–145 ml per hour per gram clam (Way et al. 1990). Increased abundance of *C. fluminea* reduced abundance of benthic bacteria and flagellates (Hakenkamp et al. 2001; Majdi et al. 2014). However, large populations do not necessarily effect food consumption by competition (Eng 1979).

Predators: Humans use *C. fluminea* for fish bait, and occasionally for food. Other predators include fish (Robinson and Wellborn 1988) and waterfowl (Sinclair and Isom 1963).

Behavior: A burrower and pest in dredged sands that are used to make concrete (Morton 1979a).

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