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Softshell Clam Culture: Basic Biology and General Culture Considerations

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The softshell clam, *Mya arenaria*, (Figure 1) is an ecologically important bivalve mollusk that is harvested recreationally and commercially from coastal waters of the western North Atlantic. As with all bivalve mollusks, they possess two valves or shells that are connected by a hinge. The pair of whitish/gray shells surrounds and protects a **mantle**, **visceral mass** and **muscular foot**. The elongate shells are relatively thin and brittle, leading to the name "softshell." Unlike hard clams and oysters, the softshell clam cannot close its shells completely, resulting in a gape most notable at the **anterior** and **posterior** ends. As such, softshell clams are damaged more readily and can have a shorter shelf-life than do similar-size oysters or hard clams. A shelf-life of 7 to 10 days can be expected when the animal is kept cool, approximately 3 to 4^{o}C, and moist.

The softshell clam may exceed 10 cm in **shell length** (SL) and lives burrowed in sediments. The clam moves by using its relatively small, muscular foot. Clams less than 25 mm SL use the muscular foot to burrow and to move laterally on the sediment surface; larger clams, which tend to be sedentary, use the muscular foot to move vertically in the sediments. Softshell clams possess a single long, fleshy siphon composed of a fused, larger incurrent and a smaller excurrent tube. The fused siphon extends through the sediments to the sediment/water interface. Cilia associated with the gills move oxygenated water with microscopic food, such as phytoplankton, bacteria and small organic particles,

Figure 1. Softshell clams are typically white or gray and cannot close completely. (Photo: Joe Buttner)

through the incurrent tube into the visceral mass. The gills sieve out or filter food and other particles, and send it to the **labial palps**. The palps sort food items, directing some to the mouth for ingestion. Other food items and non-food items are bundled in mucus expelled through the excurrent tube as **pseudofeces**. Metabolic wastes and feces are also expelled via the excurrent tube. Large clams may filter 50 L of water per day depending on seawater temperatures. When disturbed, the siphon can be retracted quickly and a squirt of water is emitted.

Distribution

The softshell clam naturally ranges in coastal waters of the western North Atlantic from Labrador and the Canadian Maritimes south along the Atlantic shore to North Carolina, but is not common in waters south of Maryland. Outside its natural range, the clam is often considered a nuisance species. Softshell clams were first observed on the U.S. Pacific coast in San Francisco in 1874. They have subsequently spread northward into Oregon, Washington, British Columbia and Alaska waters. In Europe, this species has become established from Norway to Portugal and has been introduced into the Mediterranean Sea with reports of its existence along the northern Adriatic, western Sicily, and the Saronikos Gulf in Greece.

Habitat

To protect their thin and brittle shells, softshell clams are normally found buried in a wide variety of sediment types in protected bays and estuaries. The clam grows best in substrates of mixed sand and silt. It will colonize and can attain high densities in clay, mud, silt and gravel sediments. Clams in coarse sediments, such as gravel, typically have thicker and more deformed shells compared to clams in finer sediments. Densities can exceed 100 market-size individuals (≥ 51 mm SL)/m^2.

The **eurythermal** and **euryhaline** softshell clam tolerates temperatures from -2 to 28ºC and salinities between 4 to 33 ppt. They prefer cooler temperatures, with an optimum temperature of 17 to 23ºC. North of Cape Cod, Massachusetts the clam is predominantly intertidal in distribution, burrowing in the sediments to a depth of 30 cm or more. South of Cape Cod the clam becomes increasingly subtidal and burrows deep in the substratum to avoid elevated temperatures. They can be found in waters ≥ 200 m deep.

Life Cycle

Softshell clams in nature routinely live for 10 to 12 years and have been documented to live for 28 years. Sexes are typically separate, but a small percentage of a population may be **hermaphroditic**. Male and female clams are identical externally. The only non-intrusive way to determine the sex of an individual is to observe its **gametes** released at **spawning**. Clams can develop gametes at ~20 mm SL; by 30 mm SL most are able to reproduce. As water warms in the spring, gametes start to ripen or mature. This process can take 8 or more weeks. Spawning generally occurs after inshore water temperature reaches at least 10ºC. A second spawn may occur in the late summer or early fall in more southerly waters of the western North Atlantic, as water temperature drops below 25ºC. One female can produce and release in excess of one million eggs per spawn. Eggs are round and typically 40 to 50 μm (0.04 to 0.05 mm) in diameter. Sperm are 2 to 3 μm in length.

Fertilization occurs externally as eggs and sperm are released into the water column and encounter each other. After fertilization, the eggs pass through three **planktonic** larval stages: the short-duration **trochophore**, the **veliger** and finally the **pediveliger** (Figure 2). Trochophore larvae are characterized by the presence of relatively large apical cilia. A mouth, gut, and anus are present at this developmental stage, but no valves or shells occur. Veliger larvae are characterized by the presence of a **velum** and very thin valves. The ciliated velum enables larval clams to swim and capture food. The pediveliger is the last larval stage before the animal settles to the bottom. It can be quite variable in duration as the young clam may **metamorphose** quickly or remain planktonic for several weeks depending on various environmental and biological cues. Temperature, salinity and food availability affect duration and success of the larval stage. Typically, the larval stage is 8 to 21 days in duration. The stage ends as planktonic larvae metamorphose into benthic, juvenile clams, which lack a velum and possess a single-chambered siphon as well as a functional muscular foot as the sole means of locomotion. Recently metamorphosed benthic clams are small with a shell length of ~200 μm (0.2 mm).

Both the pediveliger and recently-metamorphosed clams produce elastic **byssal threads** in a gland within the foot. Byssal threads attach the clams to small objects such as sand grains in the substrate. Young clams can also detach from their byssal threads if necessary and can move along the surface of the sediment pushed by tidal or wind-driven currents. Softshell clams lose their

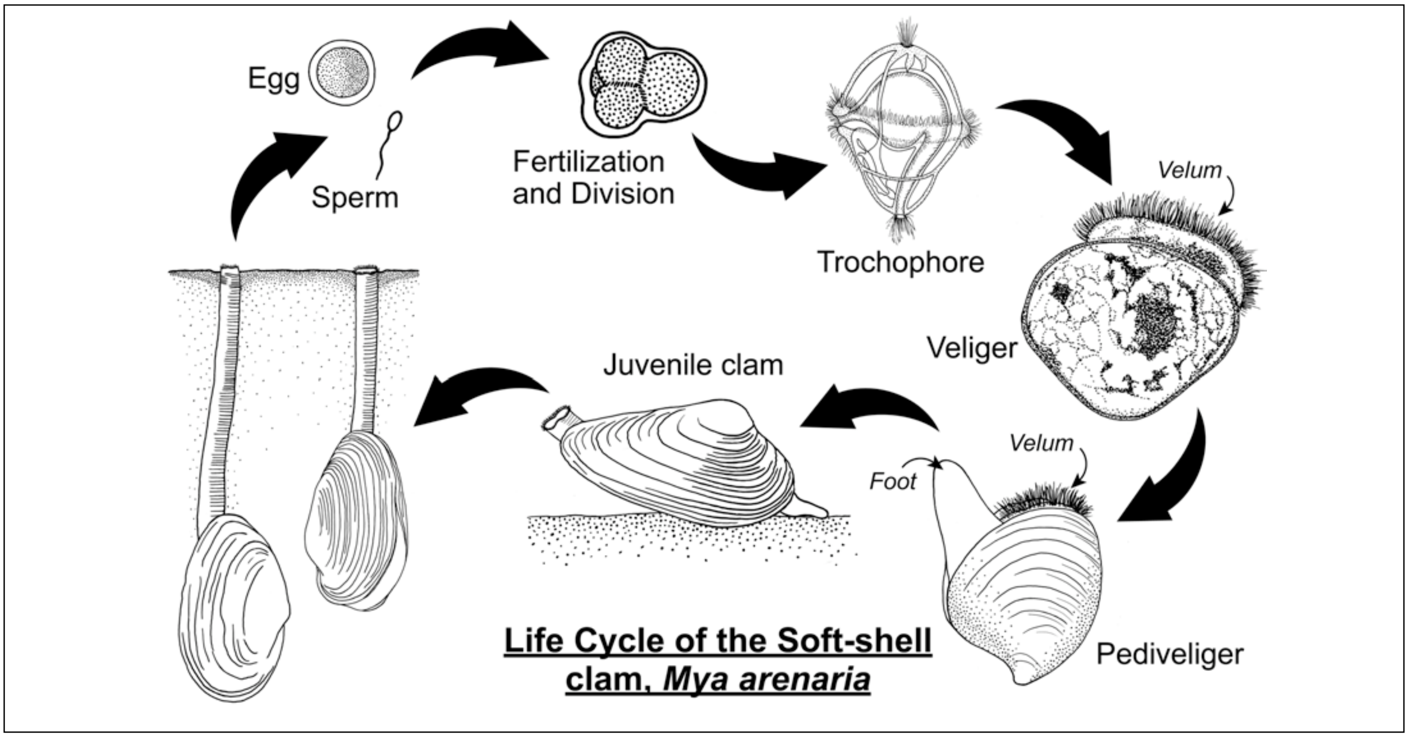

Figure 2. Life cycle of softshell clam. (Drawing by Virge Kask, UConn Biological Illustration.)

ability to produce byssal threads as they approach 20 mm SL. Juvenile clams up to ~20 mm SL are lightweight and do not bury deeply, which means they may be disrupted and transported by waves or currents, despite being attached to sand grains by byssal threads. Sometimes, clams appear at the sediment surface to avoid predators, **anoxic** conditions, or for other reasons. If this occurs on sunny days during periods when the tide is low, the valve that is exposed to the sun may dry. When the tide returns, the clam will float because of trapped air or increased water tension associated with drying out. The clam may be transported toward the upper intertidal area. This action tends to help clams establish themselves near the upper intertidal zone of some flats.

Softshell clams grow relatively fast. Under optimal conditions they can grow up to 8 mm in a month during their first summer. Growth is mainly determined by temperature, food supply, current, density and sediment type. Most growth occurs during the spring, summer and fall, with little to no growth in the winter, especially in Maine and eastern Canada. Some clams in more southerly waters may become sexually mature by the end of their first summer, and the vast majority of soft shell clams are ready to spawn the year after they settle into the sediment.

Predation and Disease

Softshell clam populations are adversely affected by predation, environmental stress and disease. Predators vary with life stage. Larval clams are preyed upon by plankton and fish, which if abundant can decimate a **cohort**. Post metamorphic clams are ingested by nemertean worms, segmented worms, fish, aquatic birds, crabs, horseshoe crabs, oyster drills, moon snails and **meiofauna**. Surviving clams minimize predation by growing large and by burrowing deeper into the sediments. Elevated temperatures during hot summers have been associated with mortalities in intertidal populations and even subtidally in Chesapeake Bay. Few diseases have been identified that directly affect softshell clams, unlike oysters and hard clams. Neoplasia, a leukemia-like disease, is relatively common but occurs at very low incidence levels (typically less than 5%). At times, however, neoplasia has been known to cause massive mortalities. Populations in Prince Edward Island, Canada and in Chesapeake Bay have experienced catastrophic die-offs due to neoplasia. *Perkinsus* spp., the causative agent of Dermo, has been identified in softshell clams, but its impact on clam health remains unclear.

Few human diseases have been attributed to ingestion of softshell clams. The clam may serve as a vector for bacteria or paralytic shellfish poisoning. Federal and state regulations reduce the likelihood of contacting disease if clams, or other commercial shellfish, are purchased from a reputable source.

Harvest

Throughout its western Atlantic range from the Quebec North Shore and Prince Edward Island to the Chesapeake Bay, softshell clams have historically been harvested commercially and recreationally. Pollution and inconsistent sets have restricted harvest. Outside its natural range, softshell clams supported modest commercial activities in the past (e.g. California, from 1880s to 1948; Oregon, 30 tons in 1980; Washington, 180 tons in 1985). Today, clams outside their natural range are harvested recreationally for food and bait, but little or no commercial harvest occurs. Clams are typically harvested from intertidal waters by hand forks, rakes, or hoes (Figure 3). Rakes, plungers, forks and hydraulic rigs, where legal (Figure 4), are used to harvest clams in subtidal sediments. According to the National Marine Fisheries Service (2009), approximately 3.8 million pounds were harvested in 2008 (worth in excess of $21 million).

Marketing

Softshell clams are marketed and consumed almost exclusively as a cooked product, either steamed or breaded and fried. Steamed clams are boiled or steamed in their shells, piled on a plate and ingested whole by the consumer, after removing the shells and tissue that surrounds the siphon. Commonly, clams are dipped in melted butter or other sauces before being consumed. Fried clams are shucked, breaded and deep-fried whole. Preferred size for steamed or fried clams is 63 to 76 mm SL. The edible portion of softshell clams (35% by weight) greatly exceeds that of other commonly consumed bivalve mollusks such as oysters (13%), scallops (18%), and hard clams (18%). Softshell clams are high in minerals, such as iron, zinc, magnesium, potassium, copper, and phosphorus. These minerals help build healthy blood cells, promote immune reactions, make proteins, promote muscular strength, healthy skin, and help build healthy bones. Twenty steamed clams without melted butter have 133 calories with 0.2 g of saturated fat, 23 g of protein and 60 mg of cholesterol.

Figure 3. Softshell clams are harvested from intertidal waters by hand rakes and stored in bags for transport to wholesalers. (Photo: Joe Buttner)

Figure 4. Hydraulic rigs are used to harvest softshell clams from subtidal waters. (Photo: Dale Leavitt)

Aquaculture

Little interest in **aquaculture** of softshell clams exists south of New York, but several private commercial and many public aquaculture initiatives exist in New England, particularly Maine and Massachusetts, and in Canada, particularly Quebec and New Brunswick. Public aquaculture targets restoration and enhancement of selected flats harvested by commercial shellfishers. Private aquaculture is typically pursued on modest-size leases, two acres or so in size.

Public and private aquaculturists either purchase and stock hatchery-produced juvenile clams or entice setting of small naturally produced clams under propylene netting commonly installed to prevent predation by crabs and birds. Small clams also can be collected from one location and transferred to another location. Growth rates can vary significantly even within a bed of clams. Time required to attain market size depends upon size of clam stocked, time stocked (before, during or after summer) and location. Typically, 1.5 to 2.5 years are required for 10 to 15 mm SL clams stocked in southern New England waters during late spring/early summer to attain market size. In Canada, where low temperatures and short growing seasons limit growth, the time required to attain maturity and market-size is increased to 4 to 6 years. Details on spawning and culturing softshell clams are described in NRAC publications 202-2010 *Softshell clam Culture: Hatchery Phase, Broodstock Care through Seed Production* and 203-2010 *Softshell Clam Culture: Nursery and Growout Methods*.

Glossary

Anoxic – Relating to or characterized by a severe deficiency of oxygen.

Anterior – Pertaining to or toward the mouth end of the body. In a softshell clam the mouth is located above the foot in the mantle cavity, at the opposite end of the siphon.

Aquaculture – The farming of aquatic organisms such as fish, crustaceans, mollusks and aquatic plants.

Byssal threads – Sticky threads or filaments of protein produced by mussels and clams used to attach themselves to substrates.

Cohort – A group of individuals in a larger population that are of similar age or size.

Euryhaline – References a mollusk or other organism that tolerates a wide range of salinities.

Eurythermal – References a mollusk or other organism that tolerates a wide range of temperatures.

Gametes – Reproductive cells that unite during sexual reproduction to form a new cell called a zygote. In clams, male gametes are sperm and female gametes are eggs (or ova).

Hermaphroditic – Able to produce both male and female gametes.

Labial palps – Paired ciliated triangular flaps on either side of the mouth in bivalves. They sort ingested material, passing it either to the mouth for digestion or expelling it via the excurrent siphon.

Mantle – One of three structures found in and used to characterize mollusks. The mantle is a thin cloak of tissue that surrounds the visceral mass and secretes the shell, if one is present. It is also involved in respiration, feeding and reproduction.

Meiofauna – Small animals that live in and on the sediments that typically range in size between 0.064 mm and 0.5 mm.

Metamorphosis – A complete or marked change in the form of an animal as it develops into an adult. In clam culture, metamorphosis refers to the period in which the veliger larvae gains a foot, becoming a pediveliger, then loses its swimming organ called the velum, and settles to become a miniature benthic clam.

Muscular foot – One of three structures found in and used to characterize mollusks. Composed primarily of muscle tissue, the muscular foot is used for locomotion. Softshell clams use the foot to move in and on sediments.

Pediveligers – Larval mollusks that have developed a small foot. The foot can be extended beyond the shell and used to travel along and probe the substrate.

Planktonic – Organisms, including algae and clam larvae, that float or drift in fresh or salt water. While some forms of plankton are capable of independent movement and can swim up to several hundreds of meters vertically in a single day, their horizontal position is primarily determined by currents in the body of water that they inhabit.

Posterior – Pertaining to or toward the anus end of the body. In a softshell clam, the anus connects to the excurrent tube of the siphon. Soft shell clams live in the sediments with their posterior end nearest the sediment/water interface.

Pseudofeces – The filtered, undigested material that is discharged because it is not food or the clam is full. The rejected particles are wrapped in mucus and expelled out of the siphon. In a hatchery it can be a sign of overfeeding clams.

Shell length (SL) – Measurement of the longest shell dimension in bivalve mollusks. In softshell clams shell length measures the distance from the anterior to posterior ends of the shell.

Spawning – The release of eggs or sperm into the water column for the purpose of reproduction.

Trochophores – The larval stage in bivalves that develops 12 to 20 hours after fertilization and lasts for 12 to 24 hours. They are 50 to 60 µm pear-shaped spheres surrounded by a girdle of cilia (fine hairs) with an apical tuft of cilia that is used to swim. Trochophores are equipped with a mouth, stomach and anus. This is the developmental phase that precedes the veliger.

Velum – A structure found in planktonic, larval mollusks. It is a swimming organ that can be retracted into the larval clam's transparent shell. The ciliated velum also enables larval clams to capture food.

Veligers – Larval, planktonic mollusks with shells and a swimming organ called a velum, which is replaced by the siphon(s) once they become benthic organisms. This is the developmental phase that follows the trochophore.

Visceral mass – One of three structures found in mollusks and used to characterize them. The visceral mass contains many important organs and systems including digestive, excretory and circulatory.

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