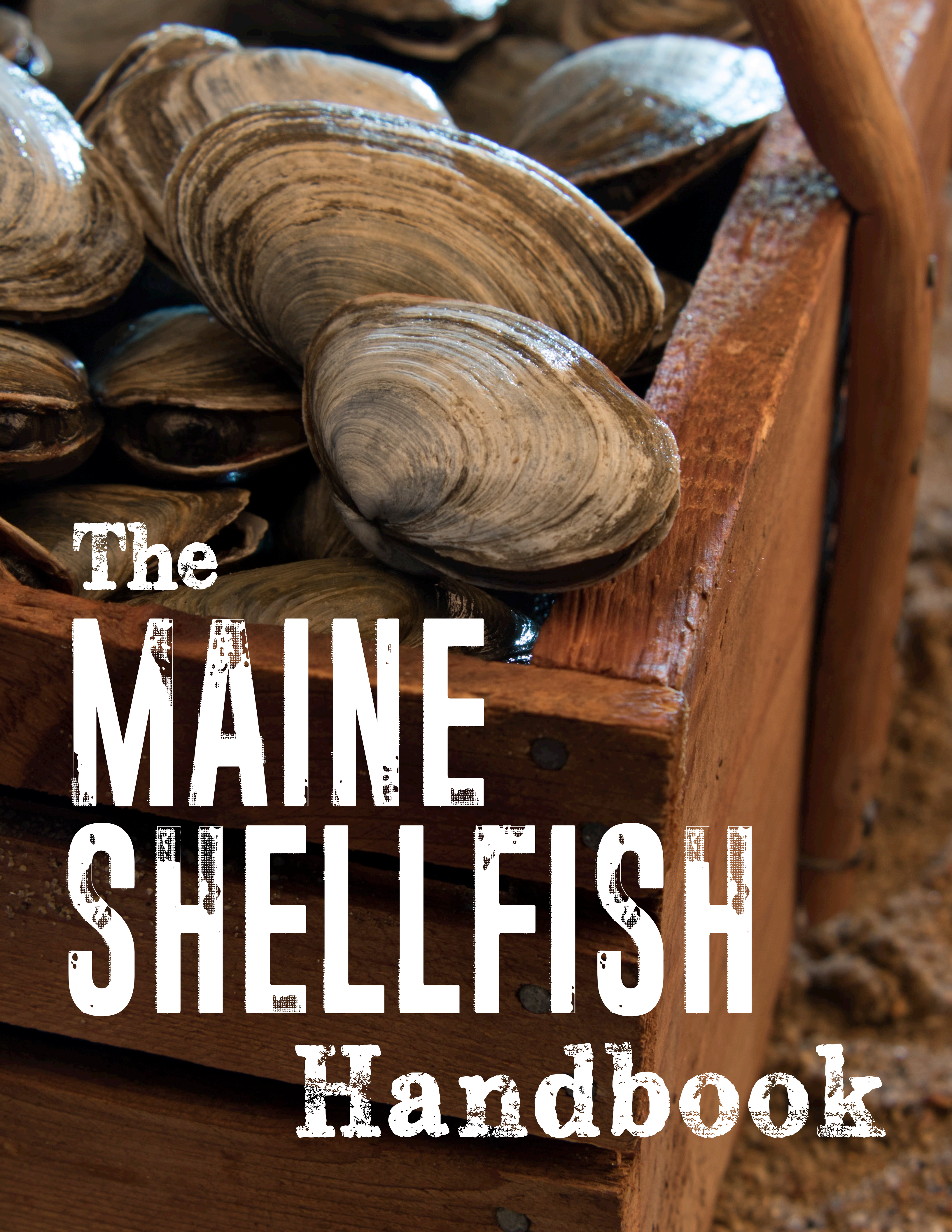
The MAINE SHELLFISH Handbook



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Introduction

This handbook updates ***The Maine Clam Handbook*** (1998), which was based on ***Increasing Clam Harvests in Maine*** (1983). The material included in this edition has been selected with the purpose of assisting individuals and coastal towns in the development of shellfish management programs that encourage stewardship of local resources and promote sustainable coastal communities.

This publication contains information on the history and biology of the soft-shell clam, northern quahog, American and European oysters, and blue mussels. Expanded sections on state resources to address water quality issues and predatory species have been added, as well as information about tools that municipalities can use to preserve or increase their intertidal shellfish resources. This handbook is organized into five chapters, beginning with a summary of the need for and history of shellfish management in the state. The second chapter provides guidance on establishing a municipal shellfish program and recommendations for communicating the value of shellfishing in local communities. The third chapter describes relevant aspects of shellfish biology, and the fourth chapter outlines a municipal shellfish toolbox with advice about how to conduct shellfish surveys and enhance shellfish stocks. The fifth chapter offers some next steps for getting involved in shellfish co-management and diversifying Maine's bivalve fishery.


B. McGreavy

Chapter 1 | The Management System

The need for effective management of Maine's bivalve shellfish has never been greater. In the decades since the first version of this handbook was published, the pressures on intertidal mudflats, shellfish species, harvesters, and communities who rely on bivalve shellfish species have increased. Coastal communities in Maine and around the world are working to adapt to changes in ocean temperatures, shellfish predation, land use, markets, and more. In different ways, Maine's shellfish industry and coastal communities are confronting these problems and advancing solutions. Throughout the state, there are many examples from dozens of towns where harvesters, civic leaders, managers, scientists, and others are organizing conservation programs, protecting juvenile clams from predators by using netting, collecting data about shellfish population trends, identifying and addressing pollution sources, educating their communities and younger generations about the value of shellfish, and innovating to strengthen the fishery.

The species addressed in this handbook are those defined as "shellfish" under Maine Statute 6601(6): "shellstock clams, quahogs other than mahogany quahogs, and oyster shellstock." Blue mussels are also included in this handbook because, although not managed by shellfish ordinances, towns can work with Department of Marine Resources (DMR) to develop management plans addressing harvest in areas where wild mussel and soft-shell clam habitat overlap.

Defining co-management

The municipal shellfish co-management program is a key piece of the puzzle for confronting current and future challenges. Studies from around the world show that "co-management" approaches, where those invested in a fishery have shared responsibility for management, can allow communities and industry to sustain a resource, such as shellfish, and adapt over time (Pinkerton 1989). Co-management arrangements can improve sustainability, cost efficiency, and management effectiveness. Management authority for soft-shell clams has been shared between the state government (through the DMR) and Maine communities for more than 170 years. The state does not currently have the capacity to manage populations of wild soft-shell clams and other shellfish species throughout the thousands of miles of Maine coastline. Working together, the state and coastal communities manage the soft-shell clam fishery as a wild resource in trust for the people of Maine.

Co-managed clam fisheries are more productive, have more institutional support to engage resources users, and have a greater capacity to respond to change than their state-managed counterparts. As a result, Maine's co-managed soft-shell clam fisheries are well-positioned to address challenges and better prepared to adapt to environmental change than conventionally managed fisheries (McClenachan et al. 2015).

Coastal communities in Maine have a long tradition of soft-shell clam management with diverse approaches that reflect their particular social, economic, and political characteristics. Towns manage their shellfish resources in the intertidal zone, which is defined as the shores, flats or other land below the high-water mark and above subtidal lands (that is, above extreme low water). While landowners along the shore may have deeds that show ownership to the low-tide mark (or 1,650 feet from the high-tide mark in areas of extensive intertidal flats), the public maintains the right to access the intertidal zone for "fishing, fowling, and navigation" purposes. The definition of "fishing" includes the harvest of wild bivalve shellfish. These rights were established by the Colonial Ordinance enacted by the Massachusetts Bay Colony in the 1600s and legally adopted by Maine when it became a state in 1820 (Hanna 2000).


K. Tenga-González

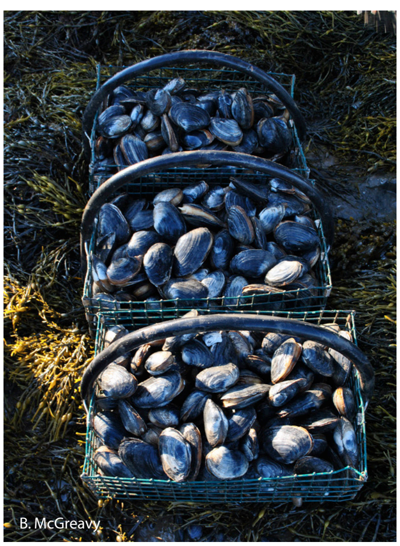
State responsibilities

The Maine Department of Marine Resources (DMR) ensures that municipalities assuming the responsibility of managing shellfish resources do so in a manner consistent with the state's goal of balancing use of the resource and conservation. State involvement in soft-shell clam management includes regulations, written by the DMR, and statutes or laws written and passed by the legislature after review by the Joint Standing Committee on Marine Resources.

In 1963, Maine approved legislation that authorized municipalities to enact shellfish ordinances, subject to the approval of the DMR Commissioner. DMR Resources Regulations chapters 4 and 7 detail the criteria by which municipal programs are evaluated, including approval of municipal shellfish ordinances and minimum qualifications and certification of municipal shellfish wardens. The DMR offers management assistance to municipalities with shellfish ordinances through the Shellfish Management Program within the Bureau of Public Health. Area biologists serve an important role in this process by working with municipalities in a variety of ways, including: assisting in the drafting of new ordinances or ordinance amendments, population survey training and stock assessments, predator control strategies, and other conservation and restoration activities.

State restrictions on harvest

Maine law requires commercial shellfish harvesters to purchase and carry a state shellfish license in order to sell to a shellfish dealer. Recreational harvesters are not required to purchase a state license, but may need to purchase a municipal license if harvesting within boundaries of a municipal program (see section on municipal responsibilities). All commercial and recreational harvest must abide by minimum size regulations, daily limits (where appropriate), and gear restrictions.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Refer to the DMR website for current regulations and harvest restrictions: *maine.gov/dmr.*

Shellfish Growing Area Classification Program

Because shellfish are sometimes consumed raw or lightly cooked, they pose a unique risk to consumers. Bivalve shellfish such as soft-shell clams, northern quahogs, oysters, and mussels are filter feeders, siphoning seawater and "filtering out" phytoplankton and other particulate matter. In areas polluted with sewage, shellfish can become contaminated with bacterial, viral, and parasitic organisms that can cause illness in consumers. When certain types of phytoplankton bloom in coastal waters, they produce toxins that shellfish ingest and concentrate, leading to foodborne sickness or even death.

Maine, along with all other shellfish-producing states, administers a Shellfish Sanitation Program that follows the guidelines of the National Shellfish Sanitation Program (NSSP). The NSSP was created and is maintained by the Interstate Shellfish Sanitation Conference (ISSC) that meets biennially to deliberate technical issues related to public health. The intent of the ISSC is to create minimum regulatory criteria to protect public health and provide guidance to the shellfish industry for best harvest and handling practices.

Under statutory authority, the Maine DMR administers key elements of the NSSP, including the Shellfish Growing Area Classification Program. This program is primarily concerned with two types of contamination: 1) potentially pathogenic organisms associated with sewage pollution, and 2) marine biotoxins associated with harmful algal blooms (e.g., "red tide").

The Maine Shellfish Growing Area Classification Program monitors water quality at almost 1,500 stations throughout the coast. This effort includes shoreline surveys conducted once every 12 years for each growing area, water sampling, and analysis of environmental conditions such as weather, tides, and currents. The results of the evaluation process are used to assign a "classification" to the growing area. These classifications include: Approved, Conditionally Approved, Restricted, Conditionally Restricted, or Prohibited.

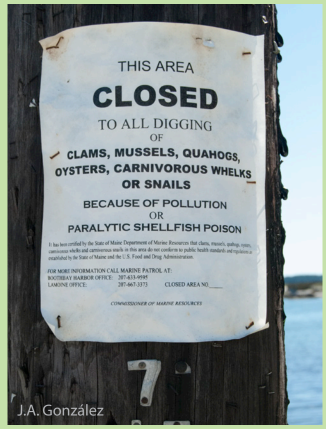
Water quality stations have been established within each growing area. These stations are sampled a minimum of six times per year. Samples are tested for levels of fecal coliform, an indicator of fecal contamination in the water.

Details about this program can be found on the DMR website: *maine.gov/dmr/shellfish-sanitation-management/programs/growingareas*

Marine Biotoxin Monitoring Program

The Marine Biotoxin Monitoring Program surveys coastal waters for levels of potentially toxic phytoplankton and evaluates toxin levels in shellfish. The most prevalent harmful algal species in Maine is the single-celled dinoflagellate *Alexandrium sp*., which contains a biological toxin (saxitoxin) that causes paralytic shellfish poisoning (PSP). *Alexandrium* is common in the waters of Maine, and shellfish closures often occur between May and July for “red tide” events. Other biotoxin challenges in Maine include blooms of the phytoplankton *Pseudo-nitzschia* and *Dinophysis*, which can cause Amnesic Shellfish Poisoning (ASP) and Diarrhetic Shellfish Poisoning (DSP), respectively. Through the Marine Biotoxin Monitoring Program, shellfish are collected weekly and their tissues are analyzed to determine the levels of each toxin present. Different shellfish species concentrate toxins at different rates. Mussels, soft-shell clams, northern quahogs, and oysters are analyzed separately, resulting in species-specific closures.

Monitoring is crucial because toxic shellfish do not look or taste any different from non-toxic shellfish. Commercial and recreational harvesters are responsible for checking whether harvest areas are open or closed.



J.A. González

Closure updates for Maine shellfish harvest areas are available online and from the Shellfish Sanitation Hotline: 800.232.4733 or 207.624.7727. DMR also provides an email and text alert service. Interested individuals can subscribe to this service through DMR’s website.

Shellfish Closures webpage: ***maine.gov/dmr/shellfish-sanitation-management/closures***

Shellfish Advisory Council

The Maine Shellfish Advisory Council was created in 2008 and is composed of harvesters, aquaculture leaseholders, certified shellfish dealers, municipal shellfish wardens, representatives from municipal wastewater treatment facilities and other industries, and interested citizens. The Council works on matters concerning how to best utilize state agencies, municipal governments, the shellfish industry, and citizen groups to make improvements to and maintain the quality of the state’s coastal waters, and to expedite the opening of closed shellfish flats. In addition, the Council examines matters of interest to the state’s shellfish industry, including, but not limited to, shellfish resource management, public health protection, and the activities and recommendations of the Interstate Shellfish Sanitation Conference (ISSC), a multistate organization that promotes shellfish sanitation. In recent years, small seed grants have become available to towns, and the Council has played an important role in shaping the structure and priorities for these funds. Links to available funding sources and programs can be found on the Council website. The Council makes recommendations to the DMR Commissioner and Joint Standing Committee on Marine Resources and helps disseminate information to the shellfish industry. The Council also contributes to planning the yearly Shellfish Focus Day at the Maine Fishermen’s Forum, which is usually held the first weekend of March in Rockport, Maine. Council meetings are held on a quarterly basis and are open to the public. Attending Council meetings and the Shellfish Focus Day is a good way to learn about statewide shellfish issues, scientific studies, municipal program activities, and shellfish policy initiatives. Council meeting minutes, schedule, and locations are available on the Council website and video recordings of presentations at previous Shellfish Focus Days are available on YouTube.

Shellfish Advisory Council: *maine.gov/dmr/about/councils/shellfish/index.html*

Shellfish Focus Day Videos: *youtube.com/channel/UCMr--C1OPJVhMQIIL5b4pHw/playlists*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Municipal responsibilities

Maine Statute Title 12, Chapter 623, Article 4 §6671 permits towns to assume management of other shellfish in addition soft-shell clams within intertidal areas of the town, including American and European oysters, northern quahogs, razor clams, and surf clams. A municipal shellfish ordinance can include multiple shellfish species, but is limited to managing intertidal harvest. The procedures used by municipalities to manage a shellfish conservation program are detailed in DMR Regulations Chapter 7.

Municipal shellfish management ordinances must meet several requirements in order to be approved by the DMR Commissioner. These requirements include:

- A minimum size limit of 2 inches for soft-shell clams harvested
- Adequate enforcement through the hiring of a certified municipal shellfish conservation warden
- A minimum number of non-resident licenses based on 10% of resident licenses sold, and the ordinance may not discriminate between resident and non-resident license holders

A municipal shellfish warden who is active on the flats can ensure that harvesters carry current licenses, are not harvesting over their limit, and are harvesting only in open areas. The warden can also serve as an important communication link between the harvesters and the municipal shellfish committee. In many towns, wardens are key leaders in implementing the ordinance and advancing town priorities for shellfish management and conservation.

Some coastal municipalities in Maine choose to not manage their shellfish resources either because they lack sufficient commercial shellfish resources or because they prefer to leave access to the fishery open and assume no local management responsibilities. In this case, management is overseen by the state through the DMR Marine Patrol, and a state shellfish license is the only requirement for commercial harvest.

Blue mussels are not included in the statutory definition of shellfish (Title 12, Chapter 623, Article 1, §6601(6)). However, Maine Statute §6671 and DMR Regulations Chapter 7 allows for municipalities to work with DMR to determine locations that should be managed with regard to intertidal mussel dragging in order to protect other shellfish resources. Intertidal areas where blue mussels are harvested must be designated in a DMR-approved Intertidal Mussel Management Plan (see website link below). When determining whether to approve an Intertidal Mussel Management Plan, DMR considers the status of the resource, comments from the municipality (required with application), whether the municipal performance has met expectations, and the likelihood of the requested activity impacting shellfish resources other than mussels. Individuals who wish to harvest mussels in towns that have included mussels in their intertidal shellfish management plan must obtain an intertidal mussel harvest permit from the DMR.

Intertidal Mussel Management Plans can be found on this website: *maine.gov/dmr/shellfish-sanitation-management/programs/municipal/forms/*

Municipal restrictions on harvest

Municipal Management Programs may choose to limit the number of commercial and recreational licenses available each year and charge associated fees. In most cases, commercial licenses are required for harvesting within the town boundaries and must be purchased from the town in addition to the required state license. There is wide variation in the types of commercial and recreational licenses available, and examples include special designations for students and seniors. All license types must be available for non-resident purchase (at least 10% of resident licenses over five total). The non-resident fee may not exceed twice the resident fee if it is set at $200 or less and not more than 1 ½ times the resident fee if the cost is over $200. Fees collected from license sales often contribute to funding program expenses, such as warden salary or conservation activities.

Municipal shellfish aquaculture

Municipalities with an established shellfish conservation program may lease up to 25% of the intertidal zone within their borders that is open to the taking of shellfish, provided they have a DMR-approved municipal shellfish aquaculture permit ordinance. A DMR-approved ordinance would essentially have to mirror the same process the state uses to grant aquaculture leases, including riparian landowner approval, consideration of utilization of existing resources, and impacts to navigation. As of January 2019, no municipality has enacted such an ordinance, but the process is described in Maine Statute Title 12, Chapter 623, Article 3, §6673. Maine Statute Title 12, Chapter 623, Article 3, §6674 makes it illegal for a person to knowingly interfere with the activities of a municipal shellfish aquaculture permit holder. Interference includes taking, disturbing, or molesting shellfish within the municipal aquaculture permitted area.

A brief history of managed species

Soft-shell clams

For millennia, Wabanaki people have used soft-shell clams for food, trade, and cultural purposes, and continue to do so today. Historian George Neptune describes how the area around Mount Desert Island was an important gathering place for clamming and how soft-shell clams shaped human relationships with the place:

> We came to Pesamkuk as a place in the summer to meet with other Wabanaki. People came from the south and down from Nova Scotia, all the way from Massachusetts, all the way to Newfoundland was our traditional territory. They would come from all over to meet and trade with each other, and hunt all over the island, and maybe get married in the summer because you were going to find somebody who wasn't from your tribe or from your clan. And it was very much a thriving summertime metropolis almost in the way it is now, with smaller year-round communities, so the island has kept its history in that way. And the sand bar itself [from which Bar Harbor draws its name] we called Moneskatik, [which] means 'the clam-digging place.' So 'ess' is a clam and 'moneskat' means to gather clams, and then the ending 'ik' denotes a place, so Moneskatik. We would come here and gather clams off the sand bar. (Clark and Neptune 2014)

Large shell middens, or piles of leftover shells, provide evidence of how clams, mussels, and oysters have sustained coastal communities for thousands of years. Over 2,000 shell middens occur along the Maine coast and provide evidence that between 2,200 and 1,000 years ago, Native Americans visiting the coast throughout the Gulf of Maine consumed oysters, clams, and other seafood as an important component in their seasonal diet (late winter and spring). Middens not only provide insight into past cultures and behaviors, but also can be used to learn about climate change, sea-level rise, and other pre-historic abiotic and biotic conditions that regulated ancient shellfish populations (Sanger and Sanger 1997). Researchers are also studying these middens to learn more about the history of shellfishing and are trying to find ways to protect these historic artifacts from sea-level rise (Carpenter 2017).


Courtesy of the Peabody Museum of Archaeology and Ethnology, Harvard University, 2004.24.3148

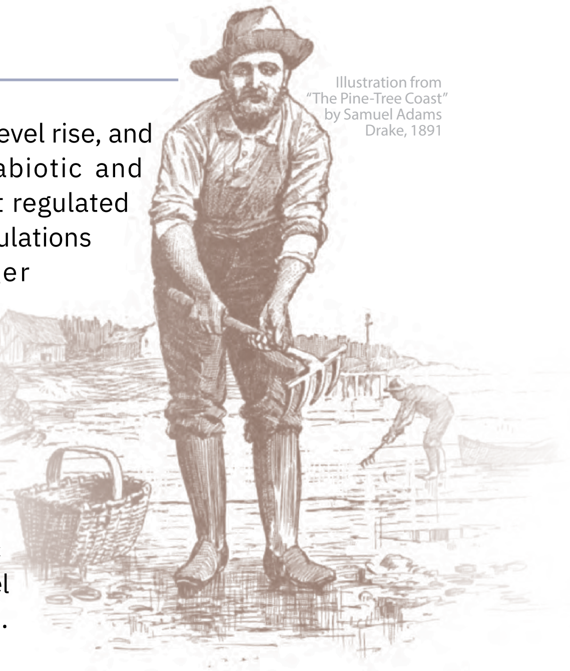


Illustration from "The Pine-Tree Coast" by Samuel Adams Drake, 1891

Soft-shell clams also provided food for European colonists. Traditionally, harvesters worked the intertidal flats on a seasonal cycle, digging or hand-pulling soft-shell clams spring through fall and moving along the coast and digging wherever soft-shell clams were abundant and weather, tide, and local harvesting restrictions allowed. Family and friends worked together, often setting daily production goals. In the winter, some harvesters would move to areas that remained ice-free, while others would find alternative employment.

Before World War II, many people harvested soft-shell clams for personal consumption. During that period, fewer than 1,500 locally licensed harvesters worked professionally, and they sold mostly to canneries. Commercial harvesting took place mostly in fall and winter when other resources were scarce, and canneries needed to keep their production lines operating. Small volumes of fresh product were shipped out of Maine to other New England markets. The cold temperatures common to winter harvesting were thought to prevent pathogens and other health risks associated with pollution from untreated sewage, industrial waste, and household garbage. The first closure of flats due to pollution occurred in the 1930s in southern Maine.


Courtesy Penobscot Marine Museum

Like today, harvesters typically measured their daily production in "barrels" (three bushels to a barrel, or about 150 pounds) and could land two or three barrels per tide. Harvesters often delivered their soft-shell clams directly

to canneries with dories that were filled to capacity. At that time, soft-shell clams were plentiful and low in value relative to other seafood in Maine, and shucking houses flourished all along the coast. Before 1945, production for a typical harvester exceeded 1,000 bushels per year. Today, full-time harvesters land approximately 300 to 500 bushels of soft-shell clams annually.

In 1947, the state issued the first commercial shellfish licenses to 2,474 harvesters. State licensing was initiated to satisfy federal public health requirements for interstate trade in shellfish and to allow the state to gather more reliable statistics on the soft-shell clam fishery. In 1957, the Maine legislature restricted soft-shell clam harvesting to hand implements only, such as a steel-tined hoe (also called a "fork") or picking by hand (sometimes called "pulling"), in softer mudflats.

Techniques to spawn adult soft-shell clams and culture larvae and juveniles in the laboratory were developed in 1977 at the University of Maine's Ira C. Darling Marine Center in Walpole. This technology was adapted and improved in the mid-1980s at the Beals Island Regional Shellfish Hatchery (BIRSH), a project associated with the University of Maine at Machias. In 2001, BIRSH became the Downeast Institute (DEI), and today the organization continues to operate the state's only public shellfish hatchery and production center that produces juvenile soft-shell clams and seed for other commercial shellfish.

After 1990, improvements in water quality, among other factors, allowed for harvesters to fish year-round. Now, many areas experience the heaviest fishing effort during late spring and summer when temperatures, demand, and price are highest.

Today, the Maine soft-shell clam fishery remains one with low costs to entry. Since 2010, soft-shell clams have been Maine's second or third most valuable commercially harvested marine species. In 2019, 7.8 million pounds of soft-shell clams were landed with a dockside value of $18.2 million, making the fishery tied with elver as the second most valuable fishery in the state behind lobster. It was also second in fishery employment behind lobster. In 2018, the industry employed more than fifteen hundred harvesters along the coast. When including activities such as shucking, transporting, and wholesale, retail, and restaurant sales, the industry yields an estimated total economic benefit of $67.5 million. Maine is a major contributor to overall soft-shell clam landings nationwide, contributing 62.2% to the total U.S. soft-shell landings and 65% of the total value of the U.S. fishery (Evans et al. 2016).

Still, the fishery faces challenges. Dockside landings in 2017 were the lowest recorded since the 1920's (Johnson et al. 2014), and in the last forty years, state clam landings have decreased by nearly 75% (Beal et al. 2016, Figure 1). Current research conducted in Maine (Beal et al. 2018, 2020a, 2020b), as well as other intertidal locations in downeast and midcoast Maine suggest that warming seawater temperatures in the Gulf of Maine over the past decade (Pershing et al. 2015) have coincided with increases in predator populations, such as the invasive green crab (*Carcinus maenas*) and the native milky ribbon worm (*Cerebratulus lacteus*).

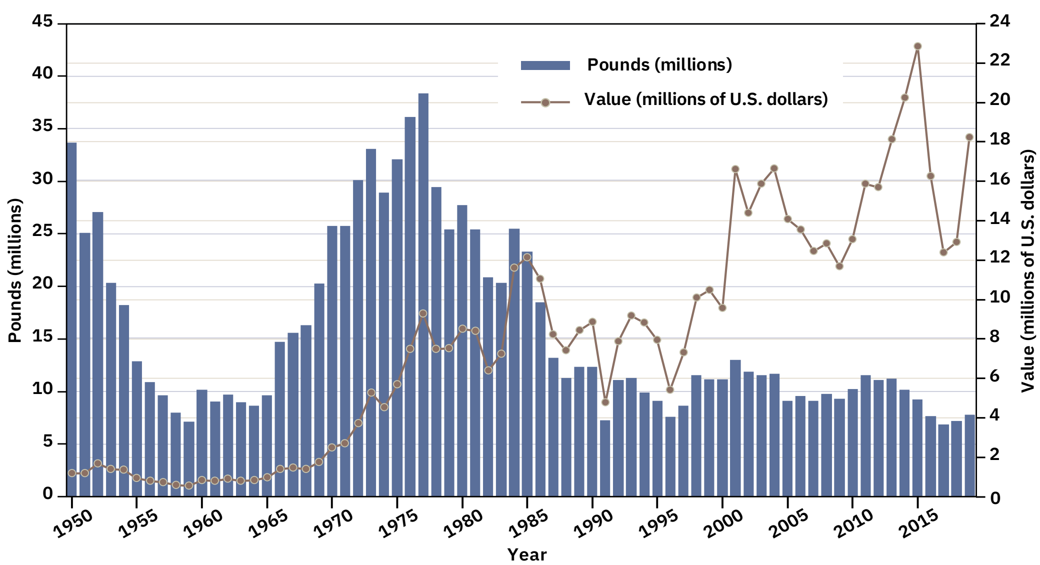


Figure 1: Dockside values in millions of pounds (bars) and millions of dollars (line) of the Maine soft-shell clam fishery (1950–2019).

Hard clams or northern quahogs

Northern quahogs (*Mercenaria mercenaria)*, also called hard clams are growing in commercial importance. Although the fishery is not as large as that of soft-shell clams, it provides some additional income to harvesters, and quahogs may be an important species in the future. Larvae (Davis and Calabrese 1964) and juveniles (Savage 1975) are physiologically more tolerant of higher ocean temperatures than soft-shell clams. The quahog harvest increased from 17,265 pounds in 1964 to more than 1.3 million pounds in 2017, worth nearly $1.8 million.


B. McGreavy

Quahogs have several market names, depending on size. These include (smallest to largest): littlenecks, cherrystones, and chowders. In Maine, it is unlawful to take, possess, buy, or sell quahogs that are one inch thick or less as measured across the hinge width, except for those holding an aquaculture lease or a limited-purpose aquaculture license, as established in DMR Regulations Chapter 10.

In shallow subtidal areas, quahogs are harvested by hand with "scratch" or "basket" rakes, or from a boat with wooden-handled tongs or heavier "bull" or "mud" rakes. Dredges or drags are also used, subject to size and location restrictions. Additionally, quahogs are harvested in some areas by hand rakes (hoes) similar to how soft-shell clams are harvested.

Maine Statute Title 12, Chapter 623, Article 1 §6601(4) allows the harvest of up to one peck of quahogs per day for personal use without a license, unless municipal ordinances or public health closures further limit or restrict harvesting. This allowance does not apply to those people whose ability to obtain a shellfish license has been suspended by the DMR Commissioner.

Oysters


D. Morse

Two species of oysters can be found in Maine waters: the Eastern oyster (*Crassostrea virginica*) and the European or Belon oyster (*Ostrea edulis*). The Eastern oyster is native to Maine waters. As the middens described above and other research have shown, they grew in abundance along the entire northeastern coast, helping to protect the coast from storm surges by forming reefs (Matcher 2018). While landings of Eastern oysters were around 22.5 thousand pounds in 1964, the 2017 landings were almost 2.7 million pounds and were worth $6.4 million. The majority of these landings were from aquaculture production. However, increasing populations of wild Eastern oysters are being observed in areas near active oyster aquaculture operations, and wild commercial harvest is allowed. Several towns have added this species to their shellfish ordinance in order to include it in their management activities.

European oysters were first introduced to the state as a candidate for aquaculture in 1948 in West Boothbay Harbor, where the DMR Laboratory is currently located. However, disease and seed production challenges impeded the success of aquaculture operations. After the initial introduction, European oysters did survive in small pockets of wild stock and are now quite common in several areas from Southport Island to Casco Bay. European oysters are primarily a wild harvest fishery, although there is some aquaculture production.

D. Morse

Both wild product harvesters and aquaculturists collect oysters by hand through picking or diving, and dragging, or both. A wild harvested American oyster usually has a cultch mark, or cultch scar created on the shell when a wild oyster cements itself to the substrate or oyster reef. A cultchless oyster has no shell scar, and is therefore usually presumed to be the product of aquaculture activities.

Maine Statute Title 12, Chapter 623, Article 1 §6601(4) allows for the harvest of up to one-peck of oysters per day for personal use without a license, unless municipal ordinances or public health closures further limit and restrict harvesting. American and European oysters have a minimum size of 2 ½ inches in shell length (SL) and 3 inches SL, respectively. A closed season for European oysters is in place from June 15 to September 15 annually. General information on oyster harvest can be found in DMR Regulations Chapter 14.

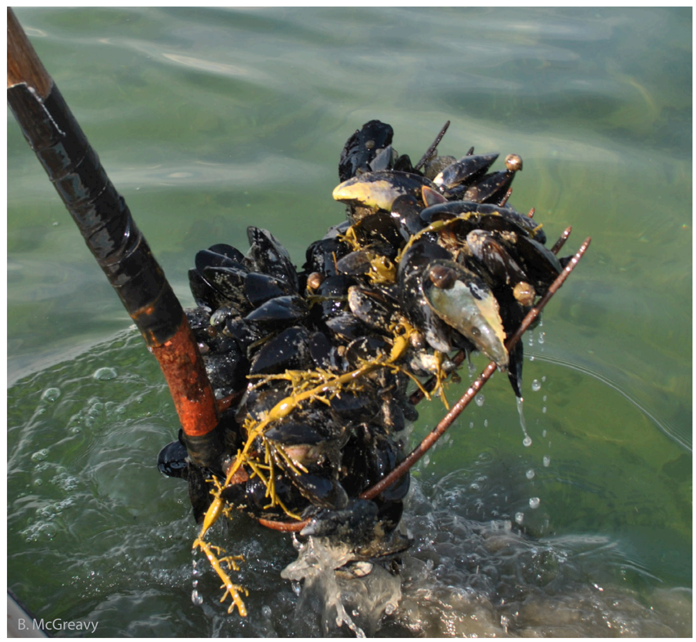
Blue mussels

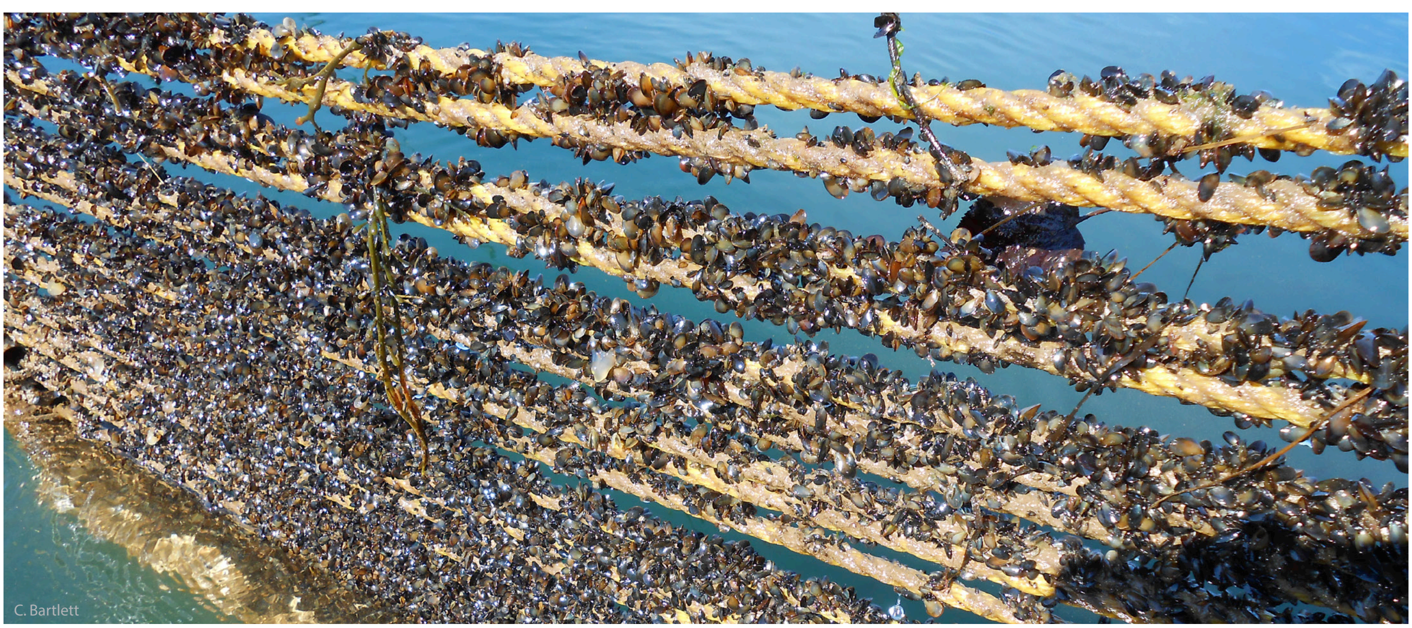
Mussels have been harvested for food for thousands of years. The reported harvests of blue mussels in the last decade have varied between 28 million pounds in 2002 and 7.1 million pounds in 2017. The 2017 mussel harvest was worth just over $2 million.

In the past, DMR used aerial photography and on-site sampling of mussel beds to develop estimates of mussel density. Recent survey efforts have paired drone technology with on-the-ground sampling. The commercial quality of mussel beds depends on weight and flavor of meats, absence of pearls, and shell appearance. Meat quality varies seasonally, depending on where the mussel is in its spawning cycle.

Wild mussels are harvested by hand using a rake or by boat using a drag. Either method requires a license from DMR. After mussels are landed, they are typically tumbled to separate the animals. Mussels are primarily sold whole and in the shell. There is a growing mussel aquaculture industry in Maine that employs either rope or bottom culture techniques.

State law allows individuals to take or possess a maximum of two bushels of mussels in one day for personal use without a license. Mussels cannot be taken from an area that is closed or restricted to harvest due to pollution or the presence of biotoxins. General information on blue mussel harvest (including seed mussels) can be found in DMR Regulations Chapter 12.





Chapter 2 | Strategies for Municipal Shellfish Programs

Build local support and engage harvesters

Managing shellfish resources at the local level requires commitment by many individuals as well as funding to manage a resource that defies political borders. Working across town lines with neighbors who share a cove or bay can improve harvests for everyone. Similarly, shellfish committees comprised of individuals who are not commercial or active harvesters should consider partnering with the harvester community and supporting civic leadership.

Although the shellfish industry has historically favored minimal management efforts, harvesters have recognized the changing conditions along Maine's coast. A changing climate, increasing human population, and a dwindling wild resource (Figure 1, Chapter 1) are several of the factors encouraging harvesters to play a more active role in managing the shellfish resource. Sustainable, stewardship-based shellfish management requires participation by harvesters on local and regional committees, active involvement in making decisions, and follow-through in the field with projects, programs, and activities that are designed to boost yield.

Develop a shellfish management plan

Municipalities that wish to implement conservation measures and manage their shellfish resources must have a DMR-approved shellfish management plan, as required in DMR Regulations Chapter 7 and Maine Statute 6671. The municipality may appoint or elect a shellfish committee to assist with developing and implementing the plan.

The shellfish fishery in each municipality or group of towns has unique characteristics that must be understood before effective management policies can be created at the local level. These characteristics include:

- Demographics and the community's cultural values regarding shellfish
- Number of commercial and recreational harvesters (current and historic)
- Number of full and part-time commercial harvesters (current and historic)
- Estimates of fishing effort based on numbers of digger days or tides per month and year; estimates of production per harvester and range or harvester production daily, monthly, and annually
- Number of commercial buyers
- Current and projected market conditions
- Marketing efforts at local, state, and national levels

The DMR Shellfish Management Program staff members are available to assist with development of shellfish management plans. Successful municipal shellfish management plans typically include:

A statement of general goals. Goals may include increasing clam harvests through the reopening of certain closed flats or enhancing wild soft-shell clam populations on a particular flat. Other goals may include the removal of pollution sources or providing a certain level of employment in the shellfish industry through the issuance of licenses.

An inventory of the shellfish resource. This may include an estimation of the size-specific standing stock for one or more species that are gathered through population surveys and interviews with harvesters.

A description of various conservation measures to be used to reach stated goals, such as the number and type of licenses, establishing conservation areas, clam flat restoration, or predator control. Specific actions should be detailed, such as when the conservation measure was put into effect and what will be measured to determine its efficacy. A timetable, list of responsible parties, and costs will help guide the scope and extent of future activities.

Establish funding

Adequate funding of a shellfish program will increase the program's likelihood of success. Salary for one or more shellfish wardens is, in many cases, the single highest expense of a shellfish program. Other expenses may include purchase of seed, netting, or other equipment needed for conservation activities. Some towns rely solely on the income from shellfish license fees and ordinance violation fines to fund the expenses of a shellfish program. Other towns devote considerably more resources from town budgets.

Craft a shellfish ordinance

If a town (or region) has allocated money for a shellfish plan and DMR has approved the plan, the municipality can adopt a shellfish conservation ordinance. According to Title 12, Chapter 623, Article 4, §6671 "Municipal Shellfish Conservation Programs," adoption of a shellfish conservation ordinance allows the town to:

- Regulate or prohibit the possession of shellfish
- Fix (limit) the amount of shellfish that can be taken
- Provide protection from shellfish predators
- Authorize municipal officials to open and close flats under specified conditions
- Specify areas of the intertidal zone in which the dragging of mussels may be limited to the degree necessary to support a municipal shellfish conservation program
- Establish a minimum size limit for possession of shellfish regulated in the ordinance, as long as those size limits are as strict or stricter than any minimum size limit set in this chapter, or by rule, except that an ordinance must establish minimum size limits for possession of soft-shell clams that are at least as strict as those limits established in section 6681
- Establish a maximum size limit for possession of shellfish regulated in the ordinance, as long as those size limits are as strict or stricter than any maximum size limit set in this chapter, or by rule


K. Tenga-González

The DMR provides a model shellfish ordinance with minimum criteria, which a municipality may use and amend. Shellfish population surveys and economic assessments of the wild shellfish resource may help build local support for shellfish management ordinances. The DMR Commissioner must approve the shellfish conservation ordinance and any further amendments before the town can adopt the ordinance. State regulations require towns to enforce their own shellfish ordinance. The DMR Commissioner can revoke a local shellfish ordinance if the town fails to provide enforcement.

Hire a municipal shellfish warden. Recruiting and supporting a municipal shellfish warden is one of the most important and challenging parts of running a successful shellfish management program. The ideal municipal shellfish warden has a background and personal interest in both the law enforcement and shellfish management aspects of the job. The DMR offers an annual municipal warden training and certification that provides both law enforcement and shellfish management training. Expectations and job descriptions vary greatly between communities for municipal wardens.

Courtesy Waldoboro Shellfish Warden

Municipal wardens are responsible for enforcing all provisions governing a shellfish conservation ordinance as well as the two-inch minimum size law. State-employed Marine Patrol officers enforce state regulations on harvesting in classified (e.g., prohibited or restricted) areas. In areas approved for harvesting, Marine Patrol officers enforce the two-inch minimum size law for soft-shell clams and state commercial license requirements, but do not enforce local regulations.

It benefits a municipal shellfish management program if the municipal shellfish warden and the Marine Patrol officer assigned to the area work together effectively. Efforts should be made to foster good communication and build a working relationship between the two officers. Ideally, the municipal shellfish warden should also be able to rely on support from a local police officer or sheriff's deputy who is cross-trained in shellfish enforcement duties.


Courtesy Harpswell Marine Resources & Harbor Management

Form a shellfish management committee

A municipality or group of municipalities adopting a shellfish ordinance is not required by law or regulation to form and operate a shellfish management committee. However, the most successful management programs are directed by dedicated and diverse community volunteers operating in the context of a shellfish committee. Sustaining an effective shellfish committee is one of the major challenges facing a municipal shellfish program. Effective and inclusive communication is important, and there are many ways to strengthen communication. At minimum, maintaining an informal mailing list of harvesters can help to keep in touch with the harvesting community, alert them of changes to the shellfish management program, and solicit help with seeding and other stewardship efforts.

Shellfish committee members are volunteers and should be selected deliberately. A diversity of representatives can contribute different expertise and perspectives: harvesters understand the resource; municipal representatives and select-board members are familiar with local politics; residents can be charged with civic responsibilities, such as taking minutes; local organizations bring knowledge of watershed and water quality issues as well as planning and economic development; and scientists can help to assess the resource, or work with harvesters and committee members to carry out field activities to test hypotheses about how to best enhance the resource.

Often, "key" individuals who provide leadership and many hours of volunteer time energize committees (McGreavy et al. 2018). Without this leadership element, programs may struggle to get things done. In some towns, as members of the shellfish committee, shellfish harvesters participate in making management decisions and are involved in management activities, such as stock assessment surveys and re-seeding projects. In the end, the commercial and recreational harvesters have the most to gain and the most to lose from the success or failure of a municipal shellfish program.

Shellfish committees should connect with and make full use of existing municipal resources to function in an effective, efficient, and inclusive way. Municipal officers and staff need to support and help guide the shellfish committee in a way that is consistent with other town committees, such as select-boards, planning boards, and conservation commissions. Establishing regular communication between committee members, town clerks and related employees, select-board members, and others in the town who have a stake in the management is essential so that the shellfish committee functions as one of a set of town-based committees and has access to the resources needed to fulfill its civic role. Making these connections can be the shared responsibility of the shellfish committee chair, the shellfish warden, the town clerk, and/or designated shellfish leaders in the town or region.

Shellfish stakeholders include commercial and recreational license holders, certified shellfish dealers, shellfish committee members, municipal shellfish wardens, select board members and town officials, DMR scientists including area biologists and water quality experts, coastal landowners, citizens in the town and region, and non-profit, academic, and scientific organizations. Given this diversity, a one-size-fits-all approach is not going to work for most programs.


B. McGreavy

Best practices for collaboration for new and established groups

While the primary goal of any municipal conservation program is to sustain and/or enhance healthy and viable shellfish populations, membership within a shellfish committee provides other opportunities to access information, build relationships, find ways to respond to changes, and innovate for effective stewardship of intertidal resources. That is, shellfish committee members can share and create knowledge about fisheries, build community, and celebrate the culture of shellfishing that will help sustain this way of life now and into the future.

This section describes a set of best practices for collaborations between local stakeholders. These suggestions draw from multiple research projects conducted on shellfish management in Maine in the last fifteen years (Hanna 2000, MacLagan 2014, McGreavy et al. 2018), which demonstrated that shellfish programs have diverse needs and priorities that depend on:

- program size
- status of the resource
- geographic location
- socio-economic characteristics of a region

The most successful programs:

- run effective, efficient, and inclusive meetings
- connect science and local knowledge with management
- celebrate the resource and its culture

Running shellfish committee meetings

In a shared management and public decision-making context, meetings should allow people to have access to the information they may need to participate, ask questions, and contribute their ideas. Most towns have functioning communication systems and technology, such as websites to archive program information, platforms to advertise upcoming meetings, and meeting procedures that are generally used in town committees. It is the town's responsibility to give the shellfish committee access to these types of resources to support the ordinance.

Develop and share an agenda. Before holding the meeting, identify what people might need to know in advance to be able to participate, and create a way for people to access that information. Making an agenda available in advance helps people know when important issues are going to be discussed. The basic components of an agenda include the title of the committee, the date and location of the meeting, a list of the basic objectives (such as "Discuss changes to the conservation closure schedule" and "Warden's Report"). Plan at least one hour for shellfish meetings to ensure that the committee can address multiple issues and have enough time for public dialogue and comment. Inform potential attendees about the meeting by setting a time at the previous meeting, and posting the meeting date and time on the town website, at shellfish dealers, and/or in the newspaper.

Set convenient meeting times and location. Try to hold the meeting at a time and place that works for the most people. Shellfish committee meetings tend to take place in municipal buildings like town halls, fire station meeting rooms, public libraries, local schools, and related spaces. Most municipal meetings happen at a regularly scheduled time, such as on the last Wednesday of every month. Evening meetings tend to be generally well-attended, as they are outside of regular work hours. However, tides are an important factor to consider when scheduling meetings, as tide stage may affect harvesters' ability to attend meetings. When the low tide is at the same time of the shellfish meeting, only those harvesters who can miss a tide will be able to attend the meeting. This is especially true in summer months when it stays light later and the price of soft-shell clams is usually higher. Programs that prioritize and require participation in the monthly meetings may want to consult the tide chart in advance and have a more flexible approach to scheduling meetings to align with a tidal stage and size to help increase meeting attendance.

Run an effective meeting. It is important to make the most of the time you set aside by identifying the major objectives of the meeting and keeping the group moving through the agenda items. Giving committee members clearly-defined roles, like chair, vice chair, and secretary can help make meetings run more smoothly. The following are some questions to ask of your group to help identify the roles and responsibilities for running a meeting:

- What is the role of the chair? Does this person have good facilitation skills and, if so, can s/he run the meeting?
- What is the role of the warden? Does this person have the ability to contribute to the shellfish meetings, help prepare the agenda, take meeting minutes, or serve other supporting roles?

- Are there any other paid municipal staff or volunteers in the town or on related committees, such as the select board, planning board, conservation commissions, who could help run and/or staff the meeting?
- Who will be responsible for keeping the group on time and on track? Who will record and share the meeting minutes?

The shellfish warden should attend all committee meetings and report their activities. Remember that in many cases, the town's shellfish warden is the program's only paid staff member. All others are volunteers. It is advisable to include basic meeting administration and support as part of this person's job description, especially if s/he is already going to be attending the meetings. There are other resources available for learning basic group facilitation. For example, the University of Maine Cooperative Extension has a 5-session facilitation training program in Bangor and southern Maine for those who want to develop skills for working in groups and facilitating meetings. In addition, the Maine Municipal Association offers a broad array of training, publications, manuals, and online resources.

Facilitation training: *extension.umaine.edu/community/strengthening-your-facilitation*

Maine Municipal Association resources: *memun.org/Training-Resources*

Take and archive minutes. Minutes provide a record of the major points of discussion and actions that a committee takes in meetings, helping the group make progress towards goals and avoid covering the same ground again and again. It can be helpful for meeting attendees to have access to minutes from the previous meeting in handout form. This way, attendees can determine if and how much progress has been made since the last meeting, and if there are any outstanding items that still need to be discussed. When minutes and any other handouts are brought to a meeting, creating extra copies to provide to each attendee can help ensure that the information is as open and accessible as possible. Minutes and handouts can be scanned to a digital PDF format and stored on town websites. Hard copies can be kept in a file in the town office to be indexed and arranged by date. Paid municipal staff, such as the shellfish warden, can be assigned this task to ensure it is completed.

Address conflict. Conflict is an inevitable and sometimes necessary part of shared decision-making. Shellfish stakeholders have differing perspectives about management and sometimes these differences collide. Understanding that some level of conflict is inevitable and having a way to work through conflict when it does happen can help committees navigate the rough seas. For example, when differences of opinion come up, give people an opportunity share their views, talk about the range of options, and then use a decision-making process like coming to consensus or taking a vote to help resolve the issue. As a committee, it is important to actively listen to people by being transparent about how public comments influence any decision.

In the early stages of a conflict situation, it may be important to simply learn about the diverse perspectives to be able to clarify the multiple factors that are contributing to a disagreement. First, set aside time in the meeting to respectfully discuss the differences in opinion. Having working agreements that emphasize listening and respect can help set the tone for this type of dialogue. Second, once the group has a better understanding of the diverse perspectives, there may be a need to seek out additional information related to the issue at hand. Using visuals like maps, photographs, videos, or other ways of displaying information can be particularly helpful. Third, some conflicts are more complicated than others depending on the number of people involved, the uncertainty in the information that is available, the severity of what is at stake (livelihoods, identities, a sense of security, etc.), and the level of trust within the group. In some cases, collaboration may not be the answer and legislative measures may be required. However, when non-regulatory collaboration is possible, recognizing that it takes time and a commitment to keep coming back to the table to find ways to work through conflict is essential. In cases where there are real power differences, for example unequal levels of authority or access to financial resources, it is very important to pay attention to how these differences are affecting the conflict and whether the power can be distributed more evenly for all of the people involved.


B. McGreavy

Connect science, local knowledge, and decision-making

Finding ways to connect with science and local knowledge can help towns identify changes in mudflats and shellfishing, and determine what to do about these changes. Scientific information and harvesters' in-depth knowledge about the mudflats are used to support decision making about conservation, resource management, and public health.

Friendly and respectful relationships that are based on adequate trust can facilitate the sharing and use of scientific information. In a statewide study that conducted interviews to find ways to strengthen shellfish co-management (McGreavy et al. 2018), one marine scientist who has been involved in shellfish management for more than a decade said he tries to build good relationships by "listening a lot. I try to listen more than I talk ... and always be respectful of the local knowledge." For those who have scientific information to share, recognizing the importance of listening and having genuine conversation is essential to the success of efforts to link science with management.

There are many ways for communities to connect with scientists working at academic, governmental, and nonprofit organizations throughout the state of Maine. For example, though Maine receives less funding than other places in the United States for scientific research, it does have a Land Grant and Sea Grant institution, the University of Maine, with a long history of connecting academic research with community needs. The Maine Sea Grant and UMaine Cooperative Extension Marine Extension Team works extensively with communities on a range of coastal issues, including shellfishing. See References for a list of publications connected to these efforts and those of other scientists from academic and research institutions across New England who have relevant expertise in ecological, economic, and social issues related to shellfishing who can potentially serve as a resource for shellfish management.

K.Tenga-Gonzalez

In addition to inviting shellfish biologists to meetings, committees can benefit from inviting scientists and local experts with a range of expertise who can support different aspects of decision-making. Some experts to consider include marine and freshwater ecologists, oceanographers, water quality technicians and chemists, economists, communication researchers, sociologists, historians, and more.

Scientific studies can provide information useful to decision makers, especially if others have had an opportunity to provide input about what questions matter and need to be addressed. Collaborating with scientists can help to interpret results with a local perspective so that the results can be applied to management. These types of partnerships can facilitate the trading of knowledge and expertise: those involved in the industry can train in scientific methods and, conversely, scientists can gain the opportunity to spend time on the mudflat with harvesters to learn more about their local knowledge and methods (Beal et al. 2016).

Harvesters are constantly innovating to find ways to improve and grow the resource. As one harvester said in an interview, "if I see a good sized rock, like a boulder, and it has a lot of seeds hooked to it, I'll take it and I'll drag it out to the middle of the spot where I'm digging after I've already dug it. And I'll move all the seed and all the dirt from it and I'll put it in the hole, and then put all the seeds and just leave it there to let the mud go over the rock or let the mud surround it and all the seed will grow around it. The seaweed will protect [the seed]." The observations and knowledge come with being out on the mudflats every day, in all seasons, and year after year. Noticing patterns helps harvesters keep track of where to dig on any given day and these observations can be useful for helping other shellfish stakeholders understand what is going on in the intertidal zone.

It can be hard to sort through the diverse perspectives about what is going on with the resource and what is needed to sustain and grow it in the future. One committee member said, "sometimes the hardest thing for a DMR person at one of those meetings is when there's 15 clammers and there's a lot of different voices, and they're trying to filter that and get both information out and trying to understand how to best help and how to inform."

Use consistent and diverse approaches to communicate scientific information. In addition to talking to each other, harvesters access information about water quality closures by using DMR's hotline, website, and closure maps (Johnson et al. 2019). In some regions, sending text messages is also an effective way to rapidly share information about prices and shellfish closures.

Documenting, celebrating, and sustaining shellfishing as a culture, livelihood, and way of life

Sustaining intertidal shellfish harvesting also means ensuring that harvesters can access the resource. Maine residents have long enjoyed a tradition of public access to the sea. In many coastal areas, well-worn paths leading from town roads to the tidal flats have provided access for recreational and commercial harvesters and for others wishing to access the coast. As coastal properties change ownership, traditional access and short-cuts to the shore are sometimes lost. The most common concerns voiced by landowners who restrict access across their property involve littering or damage to roads and property. Grants and guidance are available to help towns preserve and enhance access to the shore and local working waterfronts. For more information, visit: *accessingthemainecoast.com.*

K Tenga-González

People have long worked the tides, digging and pulling softshell clams as a source of healthy and abundant food. In more recent times, shellfish have become a vital source of income for individuals and coastal communities. Across Maine, individuals, towns, and organizations are celebrating and preserving the culture of clamming.

Yarmouth Clam Festival (*clamfestival.com*)

The Yarmouth Clam Festival began in 1965 and has become the largest yearly celebration of clamming. It usually starts on the 3rd Friday of July, and admission to the festival is free. Local non-profits organize the event. In addition to featuring many clam dishes (including more than 6,000 pounds of clams!), the festival offers a parade, road race, live music, fireworks, and related activities.

Photo courtesy of Yarmouth Clam Festival/Michael Leonard

Downeast Fisheries Trail (*downeastfisheriestrail.org*)

DOWNEAST FISHERIES TRAIL

The Downeast Fisheries Trail connects 45 locations from Penobscot Bay, Maine, to Passamaquoddy Bay, New Brunswick, that illustrate the region's maritime heritage, including fish hatcheries, aquaculture facilities, fishing harbors, clam flats, processing plants, historical societies, community centers, and parks, as well as sites that highlight the cultural value of shellfishing. For a printed map-brochure of the Trail, please call 207.581.1435 or visit the website to download a map of the trail (*downeastfisheriestrail.org/wp-content/uploads/2012/05/DowneastFisheriesTrail2014.pdf*).

Clam Cam (*nest.maine.edu/clamcam*)

Researchers at the University of Maine and harvesters partnered to create Clam Cam to help raise awareness about what it takes to get clams from mud to market to plate. For example, a series of Clam Cam videos shows clamming practices and differences in mud type in southern, mid-coast, and downeast Maine:

Digging in Freeport, soft mud, southern

Picking in Waldoboro, soft mud, mid-coast

Pulling in Gouldsboro, pulling mud (soft), downeast

Digging in Gouldsboro, shelly mud, downeast

Digging in Gouldsboro, rocky mud, downeast

Digging in Roque Bluffs soft mud over hard pan, downeast

Abbe Museum (*abbemuseum.org*)

Based in downtown Bar Harbor, Maine, the Abbe Museum acknowledges Indigenous land and that we are living in the "homeland of the Wabanaki, the People of the Dawn." The Abbe Museum honors and celebrates the rich histories and vibrant communities of the Abenaki, Maliseet,

M. Panciroli

Micmac, Passamaquoddy, and Penobscot Nations and seeks to educate people about all of the Native communities who have lived here for thousands of generations in the region that is now known as Maine, New England, and the Canadian Maritimes. Through exhibits, outreach, cultural programs, and related efforts, the museum acknowledges the "continual violations of water, territorial rights, and sacred sites in the Wabanaki homeland. The Abbe is honored to collaborate with the Wabanaki as they share their stories." The Wabanaki people continue to rely on fisheries such as clams, mussels and oysters for food, trade, and cultural traditions.

The Super Hod

To highlight harvesters in parades and other community celebrations, industry leaders and Waldoboro harvesters Abden Simmons and Glen Melvin built an oversized clam hod on wheels, called The Super Hod. More than 12 feet long, the Super Hod has frequented parades from Freeport to Waldoboro. For now, the Super Hod resides in Waldoboro behind the town office for those who want to check it out.

Portland Mural

Painted on the side of 223 Congress Street in Portland, a 15-by-60-foot mural features clammers digging on a mudflat. Artist Susan Barlett Rice from Walpole portrays the beauty, as well as the grit, of clamming. For more information, check out the article here (Bennett 2016): *portland.bangordailynews.com/2016/09/26/news/giant-clammers-come-to-life-outside-a-portland-bar*


S. Bartlett Rice

At Low Tide

At Low Tide is an ethnographic film produced by Anna Grimshaw documenting clamming in Machiasport. In this documentary, Grimshaw follows and records a harvester across the seasons in a way that gives a sense of the rhythms and poetry of clamming.


A. Grimshaw

Downeast Institute (*downeastinstitute.org*)

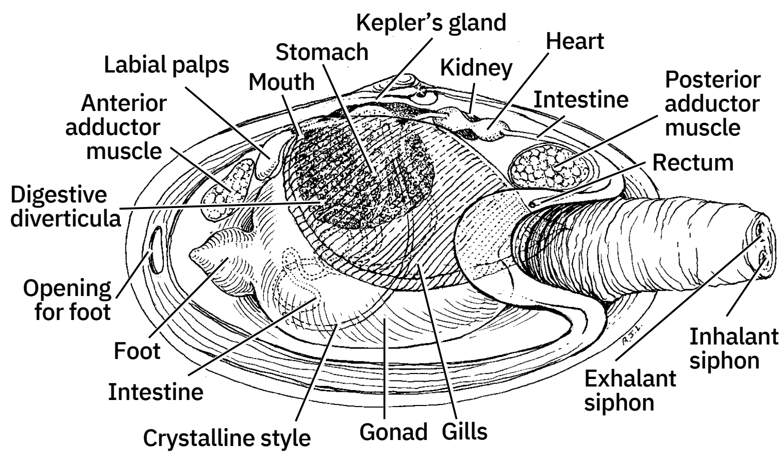
DEI and its predecessor, the Beals Island Regional Shellfish Hatchery, has celebrated the soft-shell clam since 1987 through its activities to: enhance flats along the Maine coast with hatchery seed; educate the public by working hand-in-hand in the field with community stewards; and, conduct applied research to generate new knowledge to better manage clam populations.

Chapter 3 | Biology

Soft-Shell Clam

Soft-shell clams (*Mya arenaria*) are ubiquitous soft-bottom invertebrates that live in mud, sand, and gravel sediments in intertidal flats and shallow subtidal regions from the Arctic to Cape Hatteras, North Carolina. The soft-shell clam belongs to a group of bottom-dwelling marine bivalves known as suspension or filter feeders. These animals get food by filtering microscopic particles of organic material out of seawater. Living and dead plant cells (phytoplankton) are the most important food source for clams, but clams also consume microscopic animals (zooplankton) and bacteria. Soft-shell clams grow and build their shell by secreting calcium carbonate and aragonite from the mantle (a sheet-like, translucent membrane that extends across the inside of both valves). Clams live in burrows and orient themselves upside down in the sediment. A muscular foot extends outside the shell through an opening in the mantle. This foot allows the clam to burrow into soft sediments. If removed from its burrow, a clam can reposition itself by pumping seawater into its foot and swelling to 6–7 times its normal size. Then, it can squirt the seawater jet-like into the sediment, softening the area and creating a hole into which the clam can fall. The clam will repeat this activity until it reaches a threshold depth where the clam's body is fully buried, but its siphons still protrude above the sediment by approximately ¼ to ½ inches when fully extended. The siphon (a long, fleshy, blackish tube with two openings) transports seawater. The larger opening is the inhalant siphon, which pulls seawater into the clam and over the sheet-like gills. The smaller opening is the exhalant siphon, which serves as a path for water, feces, pseudofeces, and gametes (during the reproductive season) to exit from the animal.

The space enclosed by the mantle is the mantle cavity. This area contains the main part of the clam's body including: the stomach, digestive glands, intestine, heart, kidneys, and reproductive tissue. At the anterior end is a small mouth and below the mouth is the foot. Just in front of the mouth are two pairs of labial palps, one pair on each side. The inside faces of these two flaps are covered with rows of tiny hairs called cilia. When feeding, rows of cilia on the gills move to generate current, carrying seawater into the inhalant siphon and chambers, through holes in the gills and the exhalant chamber, and back out through the exhalant siphon. As the water passes through the holes, the cilia strain out the suspended particles. The palps press closely together when the clam is feeding and accept food or reject particles. Mucus coats unaccepted food particles (typically particles that are too large for the clam to digest), and the particles exit into the water column via the exhalant siphon as pseudofeces (Bacon et al. 1998). Labial palps sort the accepted food particles, and those particles move along to the stomach, where a clear, spinning, flexible rod called the crystalline style grinds and partially digests them. Further digestion takes place in a darkened region called the digestive gland. Waste material collected in the rectum forms into elongated pellets that exit the animal through the exhalant siphon.



A.J. Lippson-NOAA

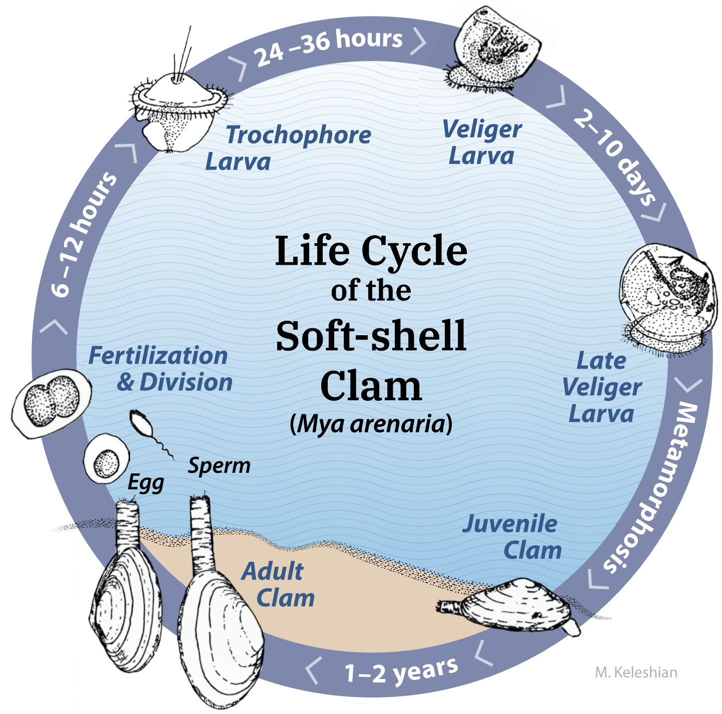
Clams are capable of pumping and filtering a large amount of seawater. Clams approximately 25–32 mm long (1 to 1 ¼ inches) can filter as much as 3.4 liters (3.6 quarts) per hour in the summer (Riisgard and Seerup 2003), while clams as large as 66 mm (2 ½ inches) can filter up to 7.4 liters (7.8 quarts) at temperatures close to 66° F (Du Clos et al. 2017).

Capable of distinguishing different food types and sizes of particles, clams preferentially ingest food-rich particles over food-poor particles. As phytoplankton concentrations become higher during algal blooms, the number of algae filtered become too great to swallow. Because this food cannot be used efficiently, much of it is expelled as pseudofeces. As an alternative, a clam may slow down the rate at which it pumps and filters water so as to remove fewer particles.

Clams grow faster when consuming phytoplankton in the water column rather than phytoplankton resuspended in mud. While benthic plankton, such as diatoms, may become suspended from mudflats and serve as food for clams, the additional mud in suspension may increase the production of pseudofeces. Phytoplankton abundance increases in early spring as days lengthen and seawater temperatures rise. These plankton blooms correspond with the greatest percentage of annual shell growth that occurs between early June and mid-August. Clams cannot process food as efficiently in cold winter water as they can during summer months; therefore, in Maine, shell growth typically ceases around the first of November and resumes in mid-April (Beal et al. 2001).

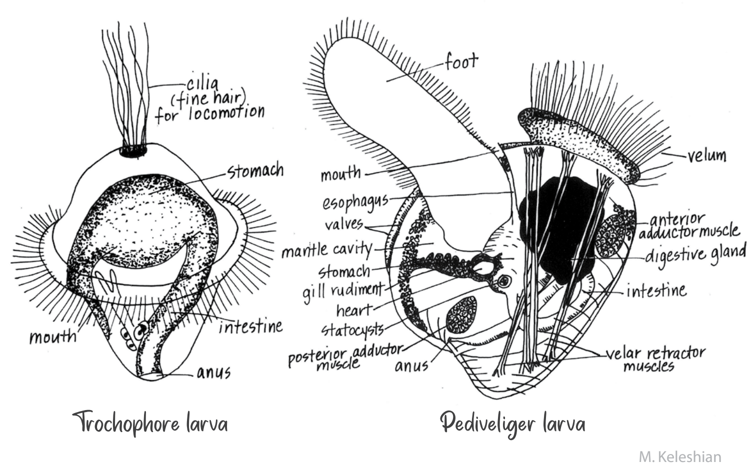
Food availability is not the only factor affecting clam growth. Metabolic rate (the amount of energy used for basic life functions) varies seasonally in the soft-shell clam. The rate is typically highest in the summer, partly due to elevated environmental temperatures. Other factors affecting clam growth may include density of adults or juveniles, mud flat topography, tidal level, sediment pH, and presence of predators. Clams tend to grow faster in sandy or muddy flats since these sediments are more easily penetrated than coarse gravel or hard clay. As a general rule, clam growth is related to position in the intertidal zone. Clams can grow faster in the lower intertidal zone because they are covered with water for a longer period during the tidal cycle and thus have a longer time during which they can access food. Clams grow more slowly as they get older, because they are less efficient and lose a greater percentage of their body weight each year due to spawning. During December and January, clams that are about two years or older begin redirecting energy into reproduction. From February to mid-May (prior to spawning), the meat of a shucked clam appears plump and is a solid, creamy-white color. This plumpness is due primarily to the production of eggs (in females) or sperm (in males). This period is typically the best time of year for clam processors to produce a shucked product because it takes fewer clams to fill a volume than it does during summer and fall months.

Once water temperatures exceed 10°C (about 50°F), clams begin to spawn. This activity is gradual for soft-shell clams, taking perhaps as long as a month or more to release gametes into the water column. Once clams have released most of their gametes, their meat appears translucent and watery. Spawning usually occurs between early May and the end of June depending on geographic location. Clams in the southwestern part of Maine spawn about six weeks earlier than clams in eastern Maine. Depending on water temperature, spawning may extend through July.



Similar to other bivalve mollusks that release their gametes into the water column, clams have adapted to produce a high number of gametes. One 2 ½-inch female can produce between about one and two million eggs. Only a small percentage of eggs will be fertilized, and an even smaller percentage (<0.1%) will eventually settle to the intertidal zone. A fertilized egg rapidly develops into a small (40–60 micron) swimming trochophore and then into a two-shelled veliger larva (80–100 microns) within the first two weeks of its planktonic life. The larvae feed on phytoplankton and grow for three to six weeks, depending on seawater temperatures, before developing a muscular foot and settling out from the water column and onto the mudflat where it begins life as a juvenile (around 200–230 microns, or $\frac{1}{125}$ inch).

At this point, the clams are in the pediveliger stage and have the capacity to both swim, using the velum (swim-



ming organ), and to crawl. This ability may last for up to a week while the clam searches for habitat. When it finds a suitable bottom, settling occurs and the clam quickly loses its velum and metamorphoses into its adult form.

The foot remains an important organ for clams from the time they settle to the time they approach one inch in size. A gland in the foot produces a thin, sticky strand, called a byssal thread, which helps to anchor the clam to the sediment. Then, the byssal gland disappears and the ability to produce a byssal thread ceases. For comparison, the blue mussel retains the byssal thread throughout its entire life.

Small clams live within the top one inch of sediment and are extremely vulnerable to storm surges, waves, ice floes, and a range of predators, from crabs to ducks. Ice and storms may push clams towards the upper portion of intertidal flats, where growth tends to be slower, or remove juveniles from the intertidal and deposit them into subtidal areas.

Adult clams in any given flat are not necessarily the source of local juvenile clams. Clam larvae typically spend between three and six weeks drifting in the water column. Since ocean currents along Maine's coast generally flow from the northeast to southwest, larvae generally settle somewhere to the westward of where their parents were located. This information underscores the importance of a regional approach to managing soft-shell clams.

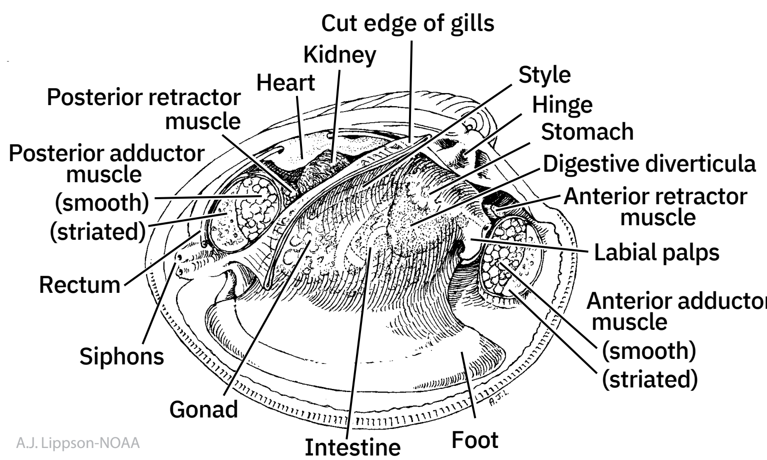
Clam recruitment is highly variable from year-to-year for a number of reasons, including spawning effort, current patterns, and predation. A failure during of any one of the life stages leading up to and including the settling process can result in an entire year-class perishing.

Hard Clams

Northern quahogs (*Mercenaria mercenaria*) are similar in physical body plan and larval development to the soft-shell clam. Both are infaunal bivalve mollusks that are harvested commercially and recreationally in Maine. Quahogs range from the southern Gulf of St. Lawrence in Canada to the central coast of eastern Florida and occur where salinities range from around 10 parts per thousand (ppt) to about 35 ppt. Adult quahogs have shorter siphons than soft-shell clams and burrow shallowly in sediments, about 1 to 1 ½ inches deep (Doering 1982). Quahogs bury deeper in sandy sediments than muddy sediments, and are more abundant in the lower estuary than the upper estuary (Stanley and DeWitt 1983). In Maine, quahogs are more abundant in the lower intertidal zone than in the upper intertidal.


NOAA

Studies indicate that major areas of quahog abundance in Maine are from the New Meadows River west to the Harraseeket River. However, a GIS survey of molluscan species abundance along the Maine coast in 2009 and 2010, using data provided by town officials, harvesters, and Marine Patrol officers, revealed that northern quahogs in Maine are located in spotty locations from Kittery to Frenchman Bay. Quahogs are commercially dug in the lower intertidal at Goose Cove in Trenton (Beal et al. 2009), which is the easternmost extent of commercial populations of quahogs in Maine.



A.J. Lippson-NOAA

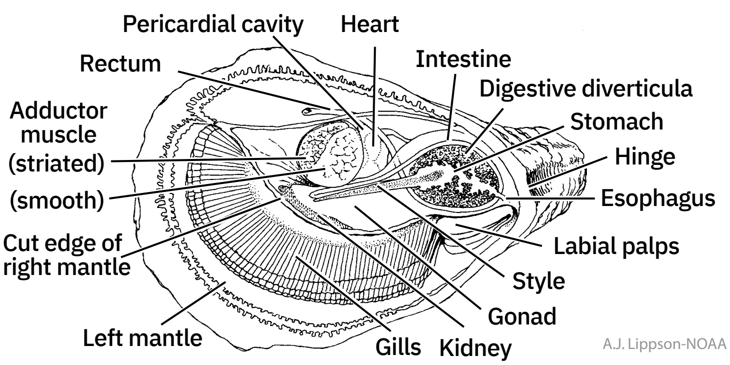
Similar to soft-shell clams, quahog sexes are separate, adults are broadcast spawners (releasing gametes into the water column), and young quahogs use byssal threads to attach to objects while in the crawling stage (Gustafson 1977). The spawning season extends from May through August, depending on latitude and temperature, and individuals become sexually mature around 2 or 3 years old.

The shells of all bivalve mollusks, including quahogs, have "hinge teeth" along the inside edge nearest the area where the two valves come together (the hinge, or "umbo"). The arrangement and morphology of teeth near the hinge that helps keep the valves shut are species specific. The inside of the quahog shell is shaded from white at the edge to purple near the ventral margin, and its foot is robust and muscular.

Juvenile quahogs are shallow burrowers and have the ability to move around on the flats; however, they are highly susceptible to predators such as crabs (Malinowski 1985) and starfish (Doering 1982) within the intertidal zone. Malinowski reported that a single green crab (*Carcinus maenas*) consumed 200 5-mm quahog seed in one hour. In another study, MacKenzie and Stehlik (1988) seeded one thousand 2–3 mm hard clam juveniles in July 1986 at four sites near Barnegat Bay, New Jersey. Because they were interested in natural predation rates, they did not cover the clams with any protective netting. At one site, crabs had consumed 96% of the clams within four days and no live clams were recovered after two months. In that same study, the researchers offered 50 clams with a shell length (SL) of 1 mm to adults of the seven-spined sand shrimp (*Crangon septemspinosa*) within a laboratory setting, and the sand shrimp consumed all clams within 24 hours. The sand shrimp is a common invertebrate predator that grows up to 3 inches in length and is present throughout Maine's intertidal zone, especially during periods of tidal inundation. As quahogs grow, they may reach a size refuge from crabs and other predators around 30-mm SL (Bricelj 1993). However, unlike soft-shell clams that can find refuge by burrowing deep in the sediments, quahogs reach a refuge size by adding new shell that increases in thickness with increasing size. This harder, thicker shell helps deter predators.

Oysters

The American, or Eastern oyster (*Crassostrea virginica*) is a species of bivalve mollusk that lives on top of sediments or attached to hard surfaces, such as rocks and ledges. This species of oyster ranges along the east coast of North America from the southern Gulf of St. Lawrence to the Gulf of Mexico, the Caribbean, Brazil, and Argentina. Like blue mussels, oysters are ecosystem engineers, creating new habitats as they grow and become an important component of the intertidal and subtidal epifaunal community. While oysters have become an iconic symbol of clean water due to the ecosystem services they provide by filtering massive



amounts of seawater (an adult can filter up to 8.3 quarts per hour), their shells provide habitat for a variety of invertebrates, from small amphipods and polychaete worms to mud snails and barnacles. In turn, these organisms provide habitat and foraging opportunities for organisms higher up the food web such as fish, crabs, shrimp, and shorebirds.

Like hard clams and soft-shell clams, oysters have separate sexes and reproduce by releasing their gametes into the water column via their exhalant siphon. Oysters are highly fecund with large females (110 mm, or 4.3 inches) producing 100–120 million eggs. The relationship between fecundity and oyster size is exponential, meaning that smaller individuals produce disproportionately fewer eggs and sperm than larger individuals (Mann et al. 2004). A similar exponential relationship between size and fecundity occurs in other marine invertebrates, including clams, sea urchins, lobsters, snails, and polychaete worms.

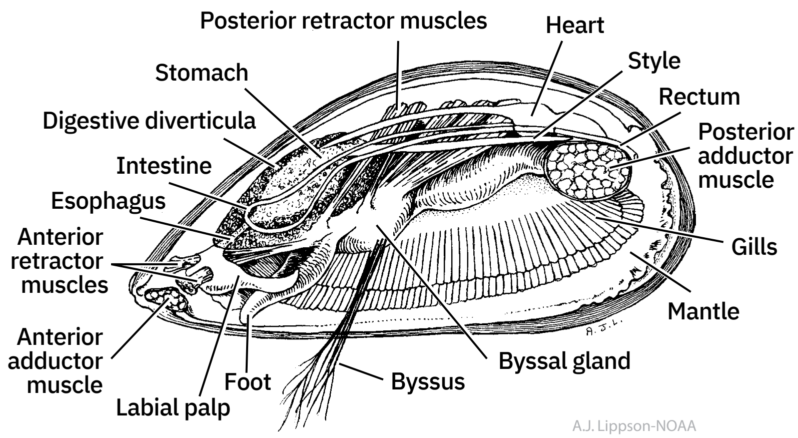
Oyster larvae, like hard clams, soft-shell clams, and blue mussels, swim in the water column for a period of 2–3 weeks depending on food and seawater temperatures. At settlement, oysters must find a clean, solid surface upon which they can cement themselves. One of the best surfaces for settlement is oyster shell, if it is not covered in silt or fouled with other organisms. A regular practice in states south of Maine is to spread clean shell (cultch) to "catch a set," which is then transferred to areas with favorable conditions that allow oysters to grow quickly.

Oysters are resilient animals that can survive extremes in temperatures ranging from below freezing to above 85°F, and grow in locations with salinities ranging from 5 to 40 ppt. As with other bivalves, predation during the one- to two-week period immediately after settlement is a crucial factor in the structure of wild eastern oyster populations (Newell et al. 2000). In Maine, few studies have been conducted on wild oyster populations. Rather, the majority of oysters harvested commercially are cultured and sold within 2–3 years (depending on temperature and other local conditions). Wild oysters are rare, but have been successful in populating hard bottom areas south of Sagadahoc County. The origin of these "wild" oysters remains unknown. Presumably, the parents are from nearby aquaculture sites. As long as the oysters occur in the intertidal zone, it is possible for shellfish committees to include wild Eastern oysters (or even wild European oysters, *Ostrea edulis*) in the list of species that fall under the auspices of a town's shellfish conservation ordinance. This would increase the diversity of shellfish managed by the municipality and harvested locally by clammers and other shellfishermen.

Blue Mussels

Atlantic blue mussels (*Mytilus edulis*) like oysters, are epifaunal bivalve mollusks found in the intertidal and subtidal zones from the Canadian Maritimes to Cape Hatteras, North Carolina (Jones et al. 2009). A sibling species, the bay mussel (*Mytilus trossulus*), has overlapping geographic distributions, and may hybridize the Atlantic blue mussel. The blue mussel has a wide temperature tolerance (Aunaas et al. 1988). They can withstand winter temperatures as cold as -16°C (3.2°F), and summer temperatures as high as 29°C (84°F). Blue mussels are also able to adapt to a wide range of salinities, from brackish (4.5 ppt) to oceanic conditions (> 35 ppt) (Westerbom et al. 2002, West et al. 2016).

Blue mussels have separate sexes and become reproductively active around one year old (around 2 inches SL). Mussel spawning cycles can vary greatly depending on latitude, water temperature, and availability of food. Planktonic mussel larvae spend about three weeks in the water column and then settle and attach themselves to the hard substrates with byssal threads, a biopolymer formed by glands in the foot of the mussel. This initial action is considered "primary" settlement, and the larvae remain in place until they have grown to about 1 to 1.5 mm SL. After reaching 1.5 mm SL, the larvae release byssal threads and float in the water column until stimulated to produce new byssal threads and attach to a second surface (Newell 1989). These two settlement phases make it difficult to predict exactly when mussel recruitment will take place in an area.



Mussels can adjust their filtration rate depending on the concentration of phytoplankton in the surrounding seawater. Because mussels pump greater volumes of seawater through their systems than soft-shell clams, they may concentrate harmful levels of algae containing biotoxins more quickly than nearby clams. The DMR uses mussels as an indicator species to determine if biotoxins are present in water quality sample locations.

Mussels are susceptible to predation from several species of crabs. Green crabs prefer juvenile mussels to most other prey items (Ropes 1968). Eider ducks and starfish also consume first year mussels, but mussels outgrow the threat when they reach a refuge in size (Clime and Hamill 1979). Once mussels reach 4–5 cm in length, they are vulnerable only to attack by large starfish, crabs, and some birds (Newell 1989). Most mussel growth occurs between April and November in Maine; however, raft-grown mussels can grow slowly throughout the winter months (Clime and Hamill 1979). Location on the shore generally influences the life span of blue mussels. Mussels growing low on the shore may survive for only 2–3 years, compared to up to 20 years at upper shore levels (Bayne 1976).

Chapter 4 | Shellfish Management Toolbox

This chapter describes common and traditional management tools used by municipal shellfish programs, as well as new tools that have been field-tested and used with some success. Results should not be expected overnight, since improving sustainable harvests can be a slow process that may take years.

Most municipal shellfish management is focused on soft-shell clams, and successful management efforts incorporate both scientific information and local knowledge about shellfish populations, such as:

- Stock assessment that provides standing crop estimates based on population surveys
- Recruitment estimates (recent settlers, i.e., 0-year class individuals) and tracking these "young-of-the-year" into the population
- Landings data, including individual harvester surveys
- Harvester observations about mudflat conditions

Harvesters spend more time on the mudflats than most scientists or natural resource managers, as they work in the intertidal habitat and make daily observations about the resource and the environment and how these change across time and space. This knowledge can be valuable in identifying patterns and making decisions about management, especially when used in combination with formal scientific processes.

Water quality also impacts the harvesters access to productive flats and can be managed and mitigated to an extent. Water quality issues are addressed in the last section of this chapter.

Methods for gathering data about the resource

Soft-shell clam population surveys

Communities can use population surveys to understand the location, density, and distribution of sizes of commercial and non-commercial clam populations. Surveys can also help identify areas of consistently high numbers of young-of-the-year clams (also called seed, recruits, or 0-year class individuals). Surveys can be used to estimate the "standing crop" volumes of legal or sublegal clams and size distribution of all clams at a given point in time. Because of this, surveys can provide guidance for future harvest targets, though should only be viewed as estimates since predation and other factors may affect clam populations.

If conducted consistently over a number of years, population surveys provide a useful profile of the flat. Consistent and comprehensive survey information along with other factors, such as effort and social considerations, may be used to manage license numbers, establish production goals for particular flats or an entire management area, identify flats with high populations of juvenile clams that may warrant protection, identify recruitment patterns, and locate sources of wild seed for transplanting.

It is possible, using inexpensive equipment, to make predictions about the fate and growth of clams of various sizes in the surveyed flats that could help estimate future number of commercial-size clams in the area. This information can help managers and local shellfish committees determine appropriate harvest levels.

Process for conducting soft-shell clam population survey

Surveys are most effective when conducted in a systematic and structured manner, and with every effort to obtain objective results. The municipal shellfish warden or a shellfish committee member should be the primary individual responsible for collecting observations. Professional survey consultants, harvesters, or community volunteers can all assist with planning and performing the surveys. DMR Shellfish Management staff may be available to help organize a survey or analyze data, and can provide technical assistance. Even if they are not actively participating in the survey, local harvesters should be consulted in the process. Harvesters bring important practical and technical skills because of their knowledge of the local flats. They are familiar with features and hazards (such as deep, watery mud holes, called "honey pots," that unsuspecting surveyors may step into), may provide boats or information about accessing specific flats, and usually know the relative abundance of clams in local areas.

Harvesters may assist during the planning process by providing input on the survey location and can identify areas where there are relatively few clams. When harvesters do participate in survey itself, they may need to be reminded that the small clams also need to be captured since their typical harvest habits focus on working fast and targeting legal-size clams.

IMPORTANT: Before surveying a Prohibited or Restricted flat, written approval must be obtained from DMR.

Planning the survey

The standard survey method is to remove, count, and measure the shell length of soft-shell clams of all sizes from representative sample plots in a clam flat. This information is then used to estimate the abundance of clams across the entire flat. The quality of the survey depends on how carefully surveyors remove and measure clams. A consistent plan and methodology are crucial to accurately represent the resources of a flat. Record the location of the sampling transect and/or the sample plots on a map and estimate the acreage of the survey area. The size of the flat will influence the number of samples, i.e. a large cove will require more sample plots or transects. Note sediment type (rocky, sandy, soft) and special features of the flat (islands, ledges, drainage channels) on the data sheet as well.

Sample plots may be located either randomly or systematically. To sample from random plots, determine locations across the entire flat with a random table and show relative abundance. For systematic surveys, do an initial walkover of the flat, digging the occasional plot, in order to identify those areas with virtually no clams and exclude them from the survey. Use a large-scale topographic map (1:6000 scale) or aerial photograph (1:500) to determine where to sample and how far apart to space transects or plots. Aerial photos are available at most town offices and can be reproduced. GIS maps are also useful. Based on the size of the area and the time available to survey it, determine the appropriate number of plots and transects to assess the quantity and distribution of clams. Often the best distance between plots is 50 feet, although larger flats may be adequately sampled at 100-foot intervals or greater. For surveys used to estimate standing crop, ensure that the size of the area populated by clams is clearly defined on the map or aerial photo.

Pre-determine the transect length or distance between plots before the survey and indicate it on the survey data sheets. Transects should be parallel to each other but not necessarily parallel to the shoreline. Cove size and shape, tide stage, and the number of participants will determine the survey approach. For example, start at the upper intertidal and follow the tide out, or if the tide is low, start the survey at low water and proceed toward shore staying ahead of the incoming tide. Record the numbers and sizes of all clams in each plot on the data sheet.

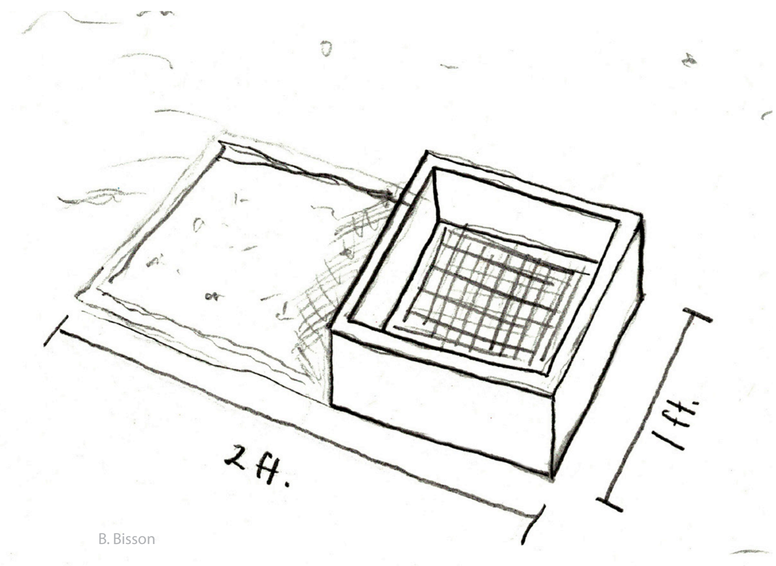

B. McGreavy

Conducting the survey

The standard DMR sampling method involves a team of at least two surveyors. One person (the digger) digs and measures the clams. The other person (the recorder) keeps track of the location and size of the plots, notes distance between plots, records clam lengths on a data sheet, records other field observations, and assists in finding all the clams in the sediment. To maintain consistency, it is best to have the surveyors maintain one job during the survey and avoid switching tasks.

Step 1

Digger At the exact site marked by the measuring line, press the screened frame into the flat to make an outline of the plot. Place and press the screen again to mark a plot adjacent to the first, so that the total sample area is two square feet in size. Do not make an effort to place the frame on a visible concentration of clam holes. Prior to digging the plot, clean the sediment and clams away from the outside of one edge of the plot to make access easier.



B. Bisson

Recorder Record the transect and plot number on the map and data sheet. The first plot of each transect is plot #1. Estimate the distance from the plots to the high water mark and record the distance on the map. This information will be used to define the boundaries and size of the area populated with clams.

Step 2

Digger If sampling for spat (clams smaller than 10 mm), use a clam hoe to collect sediment from one-eighth of the plot to an estimated depth between 1 and 2 inches deep.

Recorder On the map, record any landmarks at each site such as drainages and streams, the width of the clam belt, and other observations.


B. McGreavy

Step 3

Digger Place the sediment in a screen frame and sieve with water. Count the number of spat on the data sheet or save the spat in labeled bags for measuring later. It is important to measure and count only soft-shell clams (*Mya arenaria*) when sampling spat. Other species of clams may be in the sediment. The “two-headed” clam (*Limecola balthica*), for example, is a small oval clam that resembles juvenile soft-shell clams. Samplers learn to distinguish one from the other to avoid errors in collecting spat data. A hand lens is useful for distinguishing the two species in spat samples.

Recorder Assist in identifying species and record the number of spat.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Step 4

Digger Dig the rest of the plot edge-to-edge, removing clams and measuring each using the ruler attached to one side of the survey box. Use the ruler to measure the clams in millimeters and call out the measurements to the recorder.

Dig to a depth where no more clams are found. This depth will vary with sediment type and from plot to plot, but should be at least 8 inches. Using the clam hoe, take small slices (approximately 1 inch) from the sample sediment to be sure all clams are found. Commercial harvesters will typically take 4- to 6-inch slices and look only for clams 2 inches and more in length, so they must be careful to use this survey process when digging the plot.

Return clams to in the sediment and softly cover them with mud to aid their survival.


B. McGreavy

Alternatively, collect all the clam samples in pre-labeled, 1-gallon bags and then measure the clams on shore. Mark plot numbers on the bags in advance. This saves time on large, expansive flats where several people can work along parallel transects. Samples can be combined if only totals are used in the data analysis, with all clams placed in one bucket to be sorted later. Keep track of and record the total number of samples taken.

Recorder Record the number of clams of each size in each plot on the data sheet. If no clams are found, enter a zero on the data sheet for that plot. Note any evidence of predation or shell damage.

Step 5

Digger Move to the next plot, using a rope the length of the distance between plots (usually 10 feet). To make measuring easier, tie stakes to each end of the rope and stake the end into the mud and then walk along the transect line to the end of the rope to locate the appropriate distance for the next sample plot.

Recorder Align the plots on the transect line by sighting from one plot to another, both parallel to the shore and from high water to low water. Small sticks or stakes can be placed in the plots to aid in alignment. Try to keep the location of the plots accurate by referencing the map and sighting with a compass or heading toward landmarks in each traverse of the flats.

Step 6

Digger Start a new transect. If the next transect has not been previously marked by anchor and buoy, move on to the next transect by facing toward the water and turning to a right angle (90°) from the last plot of the first transect. Using the measuring stakes, measure 100 or 150 feet away from the last plot of the first transect. This point will be the beginning of a new transect.

Recorder If transects have not already been designated by anchor and buoy previously, locate a landmark to identify the starting plot and mark it with a stick or one of the measuring stakes. From here, align the plot transects by sighting and measuring from one plot to the next. Small sticks or stakes, GPS, and compass can all be used to aid in alignment.

Step 7

Supplemental plots may be dug in areas with heavy clam concentrations, such as at the edge of runoff streams, in order to provide more information about clam distribution.

Process for calculating growth rate

To begin, examine results of the survey and determine specific size distribution of clams from the survey site. Using this data, harvesters, the marine warden, community members, and/or students from a local school can set up a small field trial to examine growth and survival of the clams. Follow the example below:

Community Y conducts a clam survey at a specific intertidal flat at a particular tidal height that indicates there are 50 bushels of commercial clams per acre. The size range of clams in the survey shows that the majority of clams in the flat are less than 1 ¼ inches (60%), 20% are larger than 2 inches, and 20% are between 1 ¼ and 2 inches. By examining survival and growth of clams in these three size categories over some specified period of time at that tidal height, it would be possible to predict the future commercial clam harvest from the area of that flat. You will need 8-inch diameter by 6-inch deep plastic plant pots, several garden trowels, and clams from the three size classes.

Beginning in mid-April, collect clams from the surveyed site that represent the size classes from the survey (clams smaller than 1 ¼ inches; between 1 ¼ and 2 inches; larger than 2 inches). Take a plant pot and dig a hole in the flat that is slightly smaller than the diameter of the pot. Then push the plant pot into the hole so that the lip of the pot is even with the surface of the flat. Place the dug sediment back into the pot in such a manner so that the sediment that is near the bottom of the pot is the sediment that was from the level deepest in the hole. That is, replace the sediment into the pot so that sediment from the surface of the flat is the sediment that is near the top of the pot, and sediment that was from the bottom of the hole is near the bottom of the pot. In this example, you'll need about 15 pots (five for each of the three size classes). If you have more size classes, add five more pots for each additional class. Place the pots in one or two or three straight rows parallel to the low water mark and mark the ends of each row with painted wooden stakes. Spread the pots out so they are three feet from each other and place the wooden, painted stakes at the ends of each row, about six feet from the pots. The stakes may catch kelp or other seaweed, and if they are too close to the pots, could interfere with clam feeding or provide habitat for crabs and other clam consumers. After situating the pots, plant two clams from a single size class into each pot with the siphons pointing upwards toward the overlying water. Randomly assign a particular size class of clams to a particular pot prior to going to the flat. Write down this information and take a map (field schematic) with you.


B. Bisson


B. Bisson

By initiating the field trial in early April and allowing the trial to extend through at least mid-November, the clams will have added the maximum amount of shell they would normally, since nearly 100% of their annual growth occurs during that period of time. In November, remove pots from the flat and inspect the contents. It is easy to wash the contents of each pot through a sieve with ⅛-inch hardware cloth. Examine the fate of the clams and determine if there are any live 0-year class recruits (juvenile clams that settled into the pots and grew to a size that likely will be less than 1 inch). For each live clam, obtain a growth rate by measuring from the disturbance line the clam likely will lay down at the size it was at the beginning of the trial.

Alternatively, you can mark and measure each clam prior to placing them in the plant pots in April. To do so, wash the sediment off each clam shell with freshwater and allow the shell to dry completely. This should be done indoors, and will likely take 15–20 minutes from washing to drying. Once dried, use a Sharpie marker (black works best) to write a number or code on each clam. Then, measure the clam (either with a ruler or calipers). Write down the code and the clam size in a notebook so that you have a record of the size of each clam at the beginning of the trial.

To increase the amount and type of information from such an exercise, place pots in a similar array at another tidal height or increase the number of pots and encase half in protective netting to determine the effect of predators on clam fate and number of recruits.

The data collected from this field trial will give you size-specific growth and survival estimates that you can use to predict future volumes or densities of clams at that particular site and tidal height. For example, you may find that 90% of clams in the largest size class survived, and that they grew an average of ¾ of an inch. You would then return to results from the population survey, find the size-class of clams that matches the one used for the field trial, and use the field trial survival and growth rate as a predictor of how many bushels per acre you can expect in the surveyed area. If the population survey indicated that there were 30 bushels of clams in the largest size category, and your growth survey indicated that 90% of them survived and grew ¾ of an inch over the survey period, then you can use the table in Appendix II (p. 44) to calculate the total number of bushels per acre, based on the number of clams in the 2 ft. x 2 ft. population survey plots.

Additional techniques for measuring soft-shell clam growth are included in Appendix II.

Northern quahog (hard clam) population surveys

Many towns have not traditionally included quahogs in their stock assessments because most have had limited quahog resources. In recent years, the quahog resource has expanded, aided by warming ocean waters, especially in southern areas of the state. Since quahogs are gaining importance as a commercially valuable fishery, towns may want to start including quahogs in their population surveys. This can be accomplished using the same survey technique applied to soft-shell clams. In some communities, quahogs may be lower in the intertidal zone than soft-shell clams. If this is the case, surveys of quahog populations may need to be separate from soft-shell clam surveys.

Landings data

Data about shellfish landings can provide information about harvest production, ex-vessel (landed) economic value of the local shellfish resource, and relative productivity of specific flats. State regulations require all primary dealers, those that buy clams directly from the harvester, to report data at the harvester level (pounds harvested) and origin (flat or cove where the clams were taken). DMR collects and maintains this statewide data. However, confidentiality laws may prevent a municipal program from obtaining and using landings information on a small scale, such as for a single town. Municipal programs may choose to collect area-specific data, such as landings by flat and harvest effort, as a part of their program. A town could collect their own landings data by making reporting of landings data to the warden or shellfish committee part of a license condition within their municipal shellfish ordinance.

Fishing effort, or the amount of actual harvesting taking place, can be another important source of information for shellfish managers. This information can be obtained by recording the number of active harvesters in each flat on a daily or tide basis, and may be a part of the warden's responsibilities or members of the shellfish committee. Fishing effort data can be used to estimate the currently productive clamming areas, changes in productive areas over time, as well as the overall amount of actual harvest effort occurring in the town.

Deploying recruitment boxes and sampling the adjacent unprotected mud is also a survey method to predict future

year classes. This is done by placing at least 6 standard size boxes per tidal height prior to clam spawning season (May) and removing them in the fall at the end of clam growing season (Nov.) while taking adjacent 6-inch deep by 6-inch diameter core samples. Comparing the number and size of clam recruits in the core samples will be compared to what is found in the recruitment boxes. The difference in number per square foot and/or size distribution of clams between boxes and the core samples reflects the difference that this type of predator protection affords (aka the recruit "survival rate"). Knowing the survival rate provides information about why a flat is commercially productive or not. For more information, see page 29.

Conservation strategies

Protecting and enhancing shellfish stocks

Many municipalities in Maine rely on natural recruitment of shellfish to maintain their resource. The arrival, survival, and establishment of commercial quantities of young-of-the-year on a particular flat is essential if good digging is to be maintained from one year to the next.

One overarching goal of managing shellfish flats is to maximize the number of shellfish that attain harvestable size. While it sounds simple, this goal requires many insights into the processes and dynamics that influence spawning, larval survival and transport, settlement, post-settlement mortality, recruitment, and growth. Unfortunately, no one completely understands all of these complex processes. One thing is certain: disruption or mortality at any phase of the life cycle will result in a failure to produce shellfish in commercial quantities.

With these biological realities in mind, various approaches to management have evolved that reflect the particular social, economic, and political characteristics of each community. To manage the resources in their flats, municipalities may decide to limit license numbers, limit harvest times or dates, rotate conservation closures to protect small clams, conduct predator control, enhance natural seed set, transplant seed, or develop novel conservation techniques.

Harvest closures

Municipalities establish and use conservation closures for a number of reasons: to protect areas that have been seeded from harvest activity until the seed has reached legal size, to set aside an area that does not freeze up in the winter for digging, and to rotate with other conservation areas to distribute effort, particularly for areas prone to overharvesting. A municipality must submit a conservation closure request to DMR at least 20 days before the intended start of the closure. The municipality must provide a detailed description of the area to be closed, and must advertise the closure for five days prior to the intended start date to ensure people are aware that a closure is being implemented.

B. McGreavy

Enhancing natural settlement

There are techniques that communities use to encourage the settlement of juvenile clams in the hopes that it will increase clam harvests. One technique is called "roughing" and involves turning over the sediment with hoes.

Another technique is "brushing" and involves placing cut brush onto flats to modify currents. In 2019 identical studies were conducted in Gouldsboro, Bremen, and Harpswell over a 5-month period to assess the efficacy of brushing to enhance juvenile soft-shell clam recruitment. Results found that though all the sites did receive juvenile clam and quahog recruits, neither species were enhanced by brushing because brush creates habitat for predators such as the green crab. Clams that do settle near the brushed areas are eaten by predators that are using the brush as habitat. Brushing may have been effective in the past when seawater temperatures were cooler, but most areas of the coast will likely see no benefit from using this technique in the current warming marine environment (Beal et al. 2020b)

Another method to enhance clam harvests is protecting settled juvenile clams from predators. Adding mesh netting to a flat to protect soft-shell clam seed modifies the movement of water in and around the seeded area, especially when using Styrofoam floats or plastic toggles to raise the netting off of the bottom during periods of tidal inundation. The presence of netting creates eddies and modifies movements of tidal currents that may enhance settlement and survival of wild seed. This effect may prove to be a valuable tool in a town's management plan as a mechanism to economically re-seed coves that have been historically unable to re-seed on their own. Field trials conducted at two flats in communities in eastern, midcoast, and southern Maine during 2014 and 2015 demonstrated that putting netting in the intertidal to capture wild clam seed was only effective some of the time (Beal et al. 2016). Further, netting used to protect cultured seed clams varied widely due to site-specific conditions. At sites where siltation was heavy or mud snails (*Tritia obsoleta*) deposited massive numbers of egg capsules on the nets, anoxic conditions resulted and no wild recruitment were able to survive.

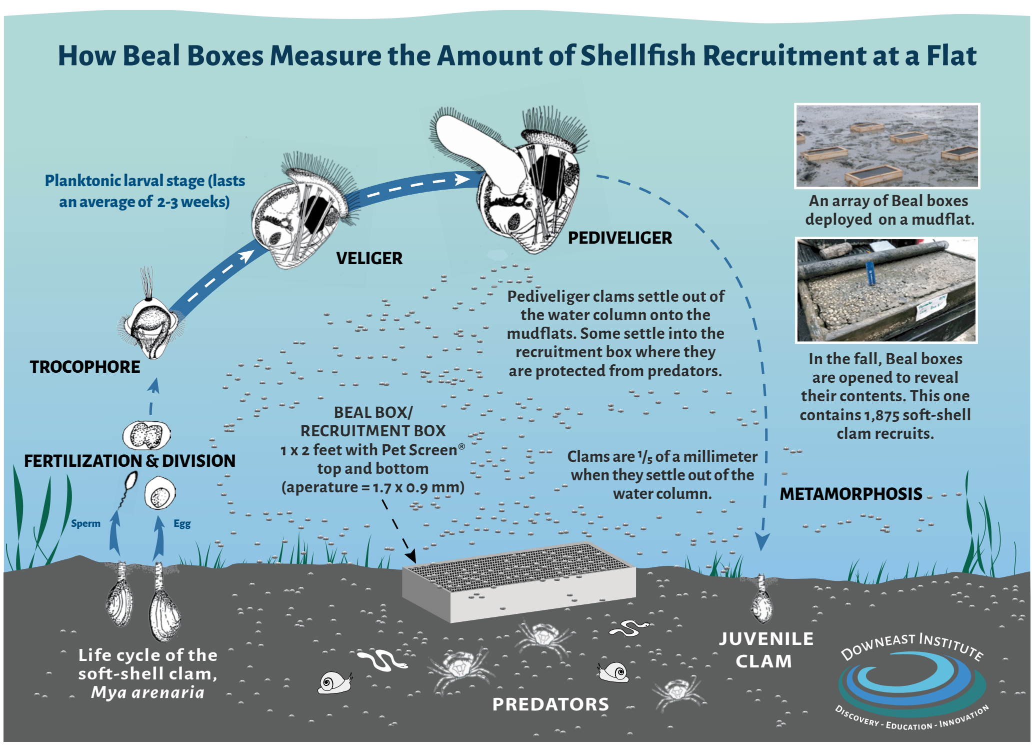
Recruitment box

Since 2015, a series of field experiments in twelve coastal communities from Freeport to Cutler have used a simple device—a recruitment box—to understand soft-shell clam settlement and recruitment processes. Information generated from these field trials is allowing communities to make more informed decisions about new measures to enhance wild clam populations and increase local soft-shell clam production.

Recruitment boxes are wooden, made of spruce strapping, and measure 1 foot long, by 2 feet wide, by 3 inches deep on the outside. The boxes are lined on top and bottom with a heavy-duty window screening that can be purchased at most hardware stores (*phifer.com/product/petscreen*; approximately 1.7 mm x 0.9 mm).

A 1 foot x 2 feet x 3 inch deep soft-shell clam recruitment box. The empty boxes were anchored to the mudflat surface during the last two weeks of May and remained in place until the first two weeks of November.

Empty boxes are placed directly on top of the mudflat surface and are anchored in place using two 20-inch wooden laths that are inserted into the sediments at each end of the box to a depth of 18 inches. Then, two or three galvanized trap nails are pounded through the lath and into the end of the recruitment box. Soft-shell clams and other bivalve species settle onto flats beginning in mid-May and continuing through mid-September, and the recruitment boxes act as passive collectors. To date, investigators have found boxes deployed in the lower intertidal zone to collect significantly more clams than those at higher tidal heights. In addition, as described, boxes do not perform as well in hard substrates (gravel, sand, cobble) because sediments around boxes in these environments tend to erode and sometimes leave the bottom of the box elevated 1 to 3 inches above the mudflat surface. Because settling clams are much smaller than the aperture of the protective screening (the area of the aperture is approximately 40x larger than a settling soft-shell clam larvae), they can pass easily through the screening and out of the box. Should boxes be deployed in erosional environments, the bottom screening should be replaced with a woven, UV-resistant polypropylene landscape fabric (ground cover) typically used in lawn and garden industries.



During the field studies, boxes are collected during the first two weeks of November. While the initial weight of each box is around 3 pounds, a single box can weigh as much as 30 pounds at the time of collection due to the accumulation of muddy sediments over time.

The contents of the box reveal the relative number of settling clams in an area and the wide variability of clam size. For example, boxes placed in the lower intertidal on both east and west sides of the Harraseeket River in Freeport in April 2015 (Beal et al. 2018) contained clams that were as large as 38 mm (1 ½ inches)

SL, and as small as 1.5 mm. Subsequent field trials demonstrated that the largest juveniles in a recruitment box settled in late May and early June, whereas the smallest juveniles settled as late as mid-September. A total of 1,875 juvenile clams were found in a recruitment box placed in the St. George River with sizes ranging from 3.9 mm to 22.1 mm (average size 9.0 mm). A total of five boxes were deployed at the St. George site in June, and the average number of juvenile soft-shell clams per box in December was 1,783, which equates to 1,097 clams per square foot.

A recruitment box deployed near the lower intertidal area of a mudflat in the St. George River in South Thomaston on June 3, 2018 and retrieved after 194 days on December 14, 2018.

Reseeding and stock seeding flats

Reseeding involves digging seed from one area of the flats and replanting them in another cove. Though commonly used, the effectiveness of reseeding has not been well documented. Any community that wishes to undertake reseeding should design the project and collect information in order to assess whether or not it was a success. An alternative to moving wild seed is to purchase cultured soft-shell clams from a hatchery. Currently, the only shellfish hatchery in Maine to produce soft-shell clam seed for sale is the Downeast Institute, which has been providing communities with clam seed since 1987. Unlike re-seeding, the efficacy of using cultured seed to enhance wild stocks is well-documented. Should communities consider seeding with cultured juveniles, installing nets to better protect small clams from predation is highly recommended. Studies conducted in eastern Maine (Beal et al. 2001, Beal, 2006) and elsewhere along the coast (Beal et al. 2016, Beal et al. 2018) have shown repeatedly that netting can increase clam survival during the first year by 7–8x (<10% survival in control plots without netting vs. 70–80% survival in plots protected with netting).

downeastinstitute.org/hatchery/soft-shell-clams

See Appendix III for additional information about seeding flats.

Protection from predators

Shellfish are eaten by a variety of predators, including sandworms (*Alitta virens*), bloodworms (*Glycera dibranchiata*), milky ribbon worms (*Cerebratulus lacteus*), moon snails (*Euspira heros* and *E. triseriata*), gulls (*Larus argentatus and L. marinus*), black ducks (*Anas rubripes*), green crabs (*Carcinus maenas*), horseshoe crabs (*Limulus polyphemus*), sand shrimp (*Crangon septemspinosa*), mummichogs (*Fundulus heteroclitus* and *F. majalis*), winter flounder (*Pseudopleuronectes americanus*), wrymouth fish (*Cryptacanthodes maculatus*), and other bottom-feeding fishes. The array of predators change depending on the size of the clams. When clams or quahogs first settle onto mudflats, they are approximately 250 microns (¼ mm, or ~ 0.01 inches). Tiny clam predators called meiofauna (animals less than 0.5 mm or 0.02 inches) that occur in the sediments on the flats are the size of sand grains as adults. These organisms contain such groups as harpacticoid copepods, turbellarians, and nematodes. Several field studies have shown that these predators can decrease abundances of recently settled shellfish. As shellfish grow from the size of sand grains to about 1 mm in length (0.04 inches), they encounter more predators. These predators include juvenile worms, amphipods, snails, and crabs.

Green crabs

Green crabs (*Carcinus maenas*) are a European species introduced to the Long Island Sound region around 1817. They began extending their range north and south soon after their arrival in North America, and by 1905 the first green crab was reported in Casco Bay. By 1922, they were observed swimming in the St. George River in Thomaston, and in September 1939 they were collected in Hancock County in the town of Winter Harbor. By 1951, they were common in lobster traps and on flats in Jonesport and Machiasport in Washington County. Green crab predation is thought to be largely responsible for the major decline in soft-shell clam landings in eastern Maine from 1950 through the early 1960s.

The decimation of a soft-shell clam flat does not take long, as one adult green crab can consume up to 15 soft-shell clams per day. Stomach analyses from nearly 4,000 green crabs in Maine and Massachusetts in the mid-1950s showed that soft-shell clams and mussels are preferred foods. However, crabs will eat almost anything available; their diets are strongly influenced by whatever happens to be abundant at the time. This predation becomes important in areas of high densities of soft-shell clams. Since feeding rates of these and other invertebrate predators increase in response to temperature, green crab foraging on soft-shell clams occurs mainly during the warmer months. Attempts to avoid high mortalities of juvenile soft-shell clams by planting seed in late November have had mixed results.

Soft-shell clam shell showing damage likely due to green crab predation.

Smaller soft-shell clams are the most susceptible to crab attack, since their shells are thin and they cannot burrow very deep. Crabs eat smaller soft-shell clams (less than 12 mm, about ½ inch) whole, but they chip apart and then pick the meat out of larger clams. Soft-shell clams over 60 mm (2 ⅜ inch) reach a size refuge from predation, partly due to a heavier and thicker shell, but primarily due to their ability to burrow deeper into the sediment. Unfortunately for soft-shell clams, green crabs can dig pits as deep as 9 or 10 inches in certain types of sediments.

It appears that green crab populations in the past were largely controlled by temperature, with densities declining after particularly severe winters. To avoid cold temperatures, some adult green crabs migrate offshore into deeper water in the fall and return in late April or May when water temperatures reach 7–8°C (44.5°–46.5°F). First-year crabs will attain a size of about 10–12 mm (½ inch) by their first winter and often overwinter in tidal or subtidal flats or marsh banks by burrowing into mudbanks.

In recent years, the population of green crabs along the Maine coast appears to have increased, although no continuous records of their abundance are available. Seawater temperatures in the Gulf of Maine during 2014–2018 were similar to those observed during the early 1950s when green crab populations exploded along the Maine coast and clam populations declined precipitously (Glude 1955). A second invasion route has recently been identified. A new green crab genotype from northern Europe has migrated through Canada into eastern Maine and appears to be able to withstand colder weather than the genotype that has existed in Maine since the beginning of the 20th century (Blakeslee 2013).

Adult crabs can travel great distances, and, since crab larvae are planktonic and settle to the flats at sizes of about 1 mm (1/25 inch), settling green crabs can fit through predator protection mesh. Once clams reach a half-inch size, the most effective green crab control measures to date have been predator exclusion netting or boxes lined on both top and bottom with ⅙- or ⅛-inch netting, or Petscreen (1.7 mm aperture).

During the 1950s and 1960s, fences were used to deter green crabs, but their efficacy was never assessed. Fences are difficult and cumbersome to install and maintain. Recent field studies in Freeport (2013–2014), tested the effects of fencing on survival of juvenile clams, and found that it is less effective than using plastic netting alone. Considering labor and maintenance costs, fencing should not be considered an effective tool to exclude predators from small clams (Beal et al. 2016). An Army Corps of Engineers permit is required to place fencing or other structures on mudflats.

Green crabs can be trapped, although the method removes only a small percentage of animals when densities are high. In the 1950s, the U.S. Fish and Wildlife Service conducted an intensive 35-day green crab-trapping program in Love's Cove near Southport Island. Although the average daily catch was nearly 1,000 green crabs, 1,400 total crabs were caught on the last day of trapping.

Some communities in Maine are now trapping crabs to remove them from their flats or determine the size distribution and the number of crabs in a given area. In a five-month study in Freeport, 300 trap hauls resulted in 13,065 landed pounds of crabs. A related study found no difference in total crabs caught in traps fished for one, two or three days before being hauled. Trapping crabs over a summer and fall can provide information on crab abundance, which municipalities can use to help make efficient decisions on future attempts to capture crabs (Beal 2014). During another study conducted in Freeport during 2014, investigators placed crab traps near plots containing juvenile soft-shell clam seed protected with netting (⅙-inch aperture), while netted plots without adjacent crab traps served as controls. The results showed that traps did not provide additional protection to wild clam recruits or planted seed (Beal et al. 2016).

Moon snails

Moon snails, also known as clam drills, are another group of important soft-shell clam predators. The northern moon snail, *Euspira heros*, can be found throughout the intertidal zone where it typically reaches sizes no larger than 30 mm, although some in Cobscook and Passamaquoddy Bay have been observed as large as 60 mm. The banded moon snail, *Euspira triseriata*, is smaller, reaching sizes typically no larger than about 20 mm.


B. Bisson

Moon snails are easily recognized by their rounded, almost spherical shell, which has a low spire and a large opening for an enormous foot. The foot is modified for burrowing and has a well-developed flap, called a propodium, which covers and protects the head as the snail moves within the sediments. These snails are scavengers and will feed on a variety of mollusks and other organisms; however, they have a distinct preference for soft-shell clams over other species, even if trained on other diets. Unlike green crabs, moon snails are strongly affected by low salinities and are not usually found in areas with significant freshwater runoff.

Moon snails drill a countersunk hole in the clam shell, usually near the hinge (umbo), using a rasping organ (the radula) in conjunction with hydrochloric acid that helps dissolve the shell. After the hole is complete, the moon snail secretes digestive enzymes that kill the clam. Then, the snail inserts a mouth-like proboscis through the hole and consumes the clam tissue. Drilling may take several hours to several days depending on the size of the snail and the size of its prey. Typically, the size of the prey is slightly smaller than the moon snail itself. When a snail drills on a clam that is larger than it, often the drill hole occurs away from the hinge and toward the edge of the shell. Sometimes moon snails give up before they complete the drilling process, leaving incomplete bore holes in the shell.


B. Beal

Soft-shell clam showing a hole characteristic of moon snail predation.

Predation by moon snails on soft-shell clams can be intense. Clam consumption rates have been estimated at 95 to 100 clams per snail per year. A study conducted in eastern Maine (Beal 2006) and another in Cape Breton, Nova Scotia (Clements 2011) determined that the size of the borehole created by a moon snail increased with the size of the snails: larger snails drilled larger boreholes and this relationship was consistent no matter the prey size. Both studies also determined that an increase in snail size led to a corresponding increase in the size range of their prey.


B. Beal

Even very small soft-shell clams (~3 mm) shown here on the edge of a penny show evidence of moon snail predation.

An estimation of the actual number of snails present on the flats can be difficult to determine because snails are attracted to high clam densities and will migrate considerable distances to a heavy clam set. Additionally, the number of snails visible on the surface at any one time is an underestimation of true population density, since snails live under the mud or sand. Searching for moon snails on a flat at night using lights will give a much more realistic estimate of the true population density.

Control measures, even using nets, are difficult because of this animal's behavior. Since they live within the sediments, moon snails are practically impossible to detect when planting juvenile clams. Snails must first be excluded from the seeded area and then kept from migrating back into the area. Attempts to cover clams with netting have not yielded promising results. Intensive hand picking has been deemed only minimally effective at best. Collecting and destroying the characteristic egg cases, or sand collars, also seems to be an ineffective approach because the larvae of the northern moon snail are planktonic and will continually resettle cleared areas.


B. McGreavy

Moon snail egg cases, often called sand collars, are signs of soft-shell clam predators in the area.

At this point in time, there appears to be no truly effective economic control method for moon snails other than planting clams in areas near freshwater runoff. Enhancement efforts should occur in areas that do not have high moon snail densities. If that is not possible, then the size of seed transplanted should be larger than the size of moon snails in the area, the seed should be protected with netting, and routine maintenance should be performed on the net to remove silt accumulation. Additionally, if the area has a high population of mud snails (*Tritia obsoleta*), it is advisable to wait until after egg deposition to deploy nets (the month of July in certain areas) as mud snail eggs weigh down netting and prevent it from operating properly (Beal et al. 2016).

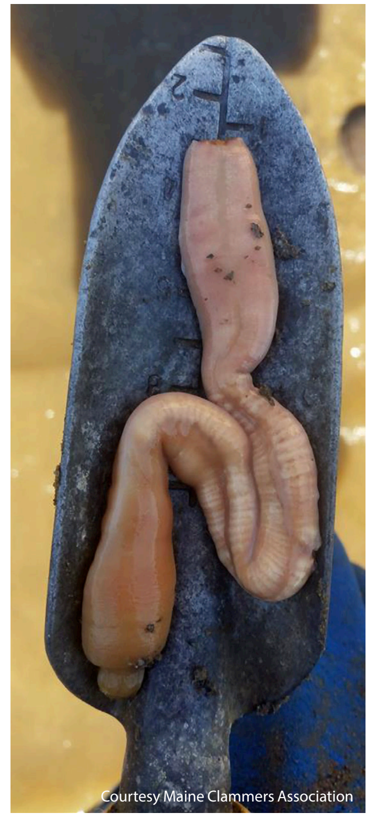
Milky ribbon worm

Another soft-shell clam predator that is difficult to control is the nemertean milky ribbon worm (*Cerebratulus lacteus*). These animals can reach lengths of more than six feet. Ribbon worms, sometimes called tapeworms, attack soft-shell clams through the siphons and can ingest a soft-shell clam without leaving any visible shell damage (Kalin 1984). Since the worms can vary their own diameter, they can easily crawl through mesh netting.

B. Beal

The first experimental evidence that milky ribbon worms prey on soft-shell clams came from a study conducted in Nova Scotia during the late 1980s. Environmental changes in the Annapolis Basin, Nova Scotia, combined with predation by milky ribbon worms, are thought to have led to the complete collapse of the soft-shell clam fishery (Rowell and Woo 1990). Further study is needed to understand why these worms tend to group together on flats and if interactions between worms could limit how often individual worms kill clams (Bourque et al. 2001). Some researchers have theorized that worms clustered together are the result of a feeding-induced response, and soft-shell clams may be a preferred food item.

As with moon snails, there seems to be no effective method to keep ribbon worms from attacking soft-shell clams of all sizes. Enhancement efforts should not take place in areas of high ribbon worm densities.



Courtesy Maine Clammers Association

Environmental challenges

Ocean and coastal acidification

Ocean and coastal acidification is a threat to shellfish survival and growth. As the concentration of atmospheric carbon dioxide (CO_2) increases, more CO_2 is absorbed into ocean waters. As that happens, a chemical reaction creates carbonic acid, which splits into bicarbonate ions and hydrogen ions, lowering pH and making seawater more acidic. Reduced pH makes it more difficult for shellfish larvae and spat to add calcium carbonate ($CaCO_3$) to their shells as they grow. The animal has to use more energy to create shell, which means less energy is available for growth and survival. There is a concern that the marine environment could get acidic enough to dissolve shells of shellfish larvae and spat to the point that it starts to kill them. As a result, fewer shellfish would grow to a harvestable size and fewer would reproduce.

Measurements of pH in intertidal sediments can be taken with a handheld pH meter, though it is important to know that pH varies by time of year, location, length of sediment exposure to air, and depth of the measurement taken. It is not unusual for intertidal sediments to be more acidic than overlying seawater (Jansen et al., 2009). Aragonite saturation state is commonly used to track ocean acidification, because it is a measure of carbonate ion concentration. When saturation state is less than 1, shells and other aragonite structures begin to dissolve.

It has been suggested that adding crushed bivalve shells ($CaCO_3$) to the mudflats may act to balance or mitigate the impacts of corrosive sediments ("sediment buffering") and therefore improve chemistry conditions for settling bivalves. The effects of sediment buffering on settling bivalves has been tested in Washington state and also locally in Casco Bay over the last decade with various results. Two short-term field experiments conducted over 16 days and 35 days in West Bath and Portland found that sediment buffering initially may tend to increase clam recruits (Green et al. 2009, 2013). However, the results of eight experiments which looked at recruit survival in sediment buffered plots vs. predator protected plots found that spreading crushed clam and oyster shells on the mudflats to counteract the effects of

S. Randall

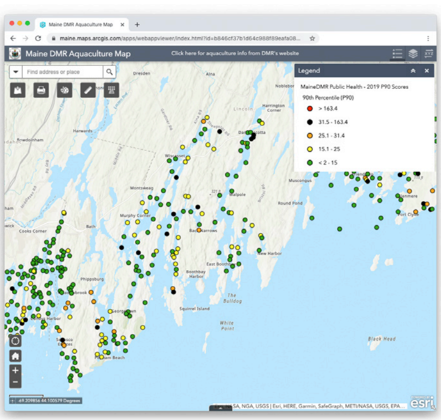
coastal acidification does not increase numbers of juvenile clams and quahogs (Beal et al. 2020a). Instead, excluding predators dramatically increases abundance of juvenile clams, suggesting that deterring predators from eating recently settled bivalves is a more effective tool to enhance clam and quahog recruits than returning crushed shells to intertidal sediments.

Two permits are needed if towns wish to distribute shell on flats, one from the Maine Department of Environmental Protection (DEP) for a Permit by Rule under the Natural Resources Protection Act, and one from the Army Corps of Engineers. To assist municipalities with obtaining these permits, towns can request a letter of support from the DMR to include with their applications to the DEP and Army Corps of Engineers.

Pollution: Growing Area Classification Program

Shellfish growing areas are classified based on the sanitary condition of the overlying seawater. Areas may be classified Approved, Conditionally Approved, Restricted, Conditionally Restricted, or Prohibited. The National Shellfish Sanitation Program provides explicit guidelines to determine which classification is most appropriate for a shellfish growing area based on fecal coliform results of seawater samples. DMR staff collects most seawater samples; however, some municipal shellfish wardens or other trained volunteers provide samples for testing at the DMR labs in Lamoine and Boothbay Harbor. Every water quality station must be sampled six times a year and some stations require up to 12 samples a year.

DMR provides an *interactive web map* where municipal officials and harvesters can access the current classifications of growing areas and the associated 90th percentile (P90) score for each water quality station. The P90 score is calculated based on the most recent 30 samples for a given station, and the value dictates the station's classification barring any known, active pollution sources in proximity. Approved or Conditionally Approved in the open status growing areas allow harvested shellfish to be marketed directly. Restricted or Conditionally Restricted in the open status growing areas require shellfish to be relayed or depurated before marketing. Aquaculturists may only use Prohibited growing areas for seed production. Restricted, Conditionally Restricted and Prohibited areas are always under the jurisdiction of the state and not the municipality.



All shellfish growing areas that are harvested must have an up-to-date Sanitary Survey. The Sanitary Survey is compiled by DMR staff and includes three main parts: shoreline survey and pollution source evaluation, water quality evaluation, and hydrographic analysis. DMR staff collect the information that goes into the Sanitary Survey and may involve the participation of municipal officials, especially in resolving identified pollution sources. DMR uses a problem form process whereby any identified pollution point source, such as a malfunctioning septic system, is reported directly to the town. The town, generally through the Licensed Plumbing Inspector, then has the responsibility to resolve the pollution point source with the homeowner and the appropriate state agency, such as the Department of Health and Human Services. A mandatory Prohibited area is implemented around any pollution point source until the problem is resolved and documented. DMR frequently refers shellfish committees to their town office to discuss and resolve pollution point sources located in their towns.

Municipalities should consider the impact to water quality and shellfish harvest areas when planning land-based development and creating or expanding vessel mooring areas. Town planners and harbormasters should keep in mind the impact of development and use when making decisions that could affect productive shellfish growing areas. Managers of public recreational lands located on coastal waters should consider pet waste management. Occasionally, wildlife management considerations are important to towns if, for example, large flocks of Canada geese have taken up year-round residence or beaver dams are impacting water quality.

DMR growing area staff are available to present current water quality data to towns and describe known pollution sources impacting intertidal flats. Shellfish committees are encouraged to request the growing area manager of their town to come to one of their meetings and provide a presentation on water quality and growing area classifications.

Depuration digging

Depuration harvesting from Restricted or Conditionally Restricted areas is strictly regulated by the DMR to protect public health. Depuration facilities are licensed and certified to hold and treat shellfish from mildly polluted growing areas. Special crews under the strict supervision of Authorized Representatives and Marine Patrol Officers harvest the shellfish, which are treated by purging them in clean water. The U.S. Food & Drug Administration (FDA) requires testing of the water and meats to verify process effectiveness.

Depuration companies are required to include local licensed harvesters in any activity within a municipality with a shellfish ordinance. They may also utilize state-only licensed harvesters. The depuration companies are required to notify the town clerk, municipal warden, and the shellfish committee chair of any scheduled harvests at least 48 hours prior to starting the activity. Please refer to Maine Statute Title 12, Chapter 625, §6856(3-D) for more information on depuration harvesting within municipalities.

DMR notifies towns when a growing area is going to be downgraded from Approved or Conditionally Approved to Restricted or Conditionally Restricted. This notification is designed to provide an opportunity for the town to request a pollution abatement closure. To qualify for an abatement closure, the town must identify the pollution sources impacting the growing area. The pollution sources must be reasonably likely to be successfully mitigated, and resources to resolve the problem must be available. DMR evaluates the application, and if it meets the criteria laid out in Title 12, Chapter 625, §6846 (3-D) then a closure of the area is granted and depuration harvest cannot occur. The pollution abatement closure application, along with guidance for submission, can be found on the DMR website.

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Chapter 5 | Conclusion

This handbook demonstrates the diverse value of Maine's bivalve shellfish resource. This is a fishery that has been sustained for at least 5,000 years, and it is also one that can be sustained far into the future. However, the information in this handbook also highlights the challenges that the fishery currently faces, and outlines some of what it will take to ensure that the fishery is still here for future generations. The good news is that many people involved in this fishery, from harvesters to civic leaders to managers, scientists, and beyond, are working diligently to strengthen the fishery so it can survive and thrive.

Becoming involved in shellfish co-management helps strengthen this fishery. There are many examples of projects and programs that help build community and support the fishery. These include, but are not limited to: keeping long-term records of clam resources and linking this information with license sales, conducting field trials to enhance wild seed recruitment or survival, developing school programs to teach children about shellfish science, conducting studies that are useful for management, and testing out new approaches to prevent and mitigate pollution. Municipal shellfish programs that are able to initiate effective and innovative activities all seem to have one main thing in common: these programs have strong partnerships with people of diverse backgrounds who care about and are invested in the shellfish resource. This handbook is designed to help encourage new partnerships, and to serve as a resource for getting involved and helping to sustain this vital fishery.


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References

Peer-reviewed publications

Aunaas, T., Denstad, J. P., & Zachariassen, K. E. (1988). Ecophysiological importance of the isolation response of hibernating blue mussels (*Mytilus edulis*). *Marine Biology, 98*, 415–419.

Bacon, G. S., MacDonald, B. A., & Ward, J. E. (1998). Physiological responses of infaunal (*Mya arenaria*) and epifaunal (*Placopecten magellanicus*) bivalves to variations in the concentration and quality of suspended particles I. Feeding activity and selection. *Journal of Experimental Marine Biology and Ecology, 219*, 105–125.

Beal, B., Coffin., C., Randall, S., Goodenow, C., Pepperman, K., and B. Ellis. 2020a. Interactive effects of shell hash and predator exclusion on 0-year class recruits of two infaunal intertidal bivalve species in Maine, USA. Journal of Experimental Marine Biology & Ecology 530–531, 151441. https://doi.org/10.1016/j. jembe.2020.151441.

Beal, B. F. (2006). Biotic and abiotic factors influencing growth and survival of wild and cultured individuals of the softshell clam (*Mya arenaria* L.) in Eastern Maine. *Journal of Shellfish Research, 25*, 461–474.

Beal, B. F., Bayer, R., Kraus, M. G., & Chapman, S. R. (1999). A unique shell marker in juvenile, hatchery-reared individuals of the softshell clam, *Mya arenaria* L. *Fishery Bulletin, 97*, 380–386.

Beal, B. F., Coffin, C. R., Randall, S. F., Goodenow, C. A., Pepperman, K. E., Ellis, B. W., Jourdet, C. B., & Protopopescu, G. C. (2018). Spatial variability in recruitment of an infaunal bivalve: experimental effects of predator exclusion on the softshell clam (*Mya arenaria* L.) along three tidal estuaries in southern Maine, USA. *Journal of Shellfish Research, 37* (1), 1–27.

Beal, B. F., Nault, M., Annis, H., Thayer, P., Leighton, H., & Ellis, B. (2016). Comparative, large-scale field trials along the Maine coast to assess management options to enhance populations of the commercially important softshell clam, *Mya arenaria* L. *Journal of Shellfish Research, 35* (4), 1–17.

Beal, B. F., Parker, M. R., & Vencile, K. W. (2001). Seasonal effects of intraspecific density and predator exclusion along a shore-level gradient on survival and growth of juveniles of the soft-shell clam, *Mya arenaria* L., in Maine, USA. *Journal of Experimental Marine Biology and Ecology, 264*, 133–169.

Beal, B. F., Protopopescu, G., Yeats, K., & Porada, J. (2009). Experimental trials on the nursery culture, overwintering, and field grow-out of hatchery-reared northern quahogs (hard clams), *Mercenaria mercenaria* (L.), in eastern Maine. *Journal of Shellfish Research, 28*, 763–776.

Beal, B.F., Randall, S.F., and K. Pepperman. 2020b. Comparative field trials to examine the efficacy of a traditional management tool—brushing—to enhance local densities of 0-year class recruits in the soft-shell clam, Mya arenaria L., fishery in Maine, USA. *Journal of Shellfish Research* 39(3).

Blakeslee, 2013; *Maine Sea Grant Green Crab Summit*

Bourque, D., Miron, G., & Landry, T. (2001). Predation on soft-shell clams (*Mya arenaria*) by the nemertean *Cerebratulus lacteus* in Atlantic Canada: implications for control measures. *Hydrobiologia*, *456,* 33–44.

Bricelj, V. M. (1993). Aspects of the biology of the northern quahog, *Mercenaria mercenaria*, with emphasis on growth and survival during early life history. In *Proceedings of the Second Rhode Island Shellfish Industry Conference. Rhode Island Sea Grant, Univ. Rhode Island, Narragansett*, 29–48.

Commito, J. A. (1982). Effects of *Lunatia heros* predation on the population dynamics of *Mya arenaria* and *Macoma balthica* in Maine, USA. *Marine Biology, 69*, 187–193.

Davis, H. C., & Calabrese, A. (1964). Combined effects of temperature and salinity on development of eggs and growth of larvae of *M. mercenaria* and *C. virginica. Fishery Bulletin, 63* (3), 643–655.

Doering, P. H. (1982). Reduction of sea star predation by the burrowing response of the hard clam *Mercenaria mercenaria* (Mollusca: Bivalvia). *Estuaries, 5* (4), 310–315.

Du Clos, K. T., Jones, I. A., Carrier, T. J., Brady, D. C., & Jumars, P. A. (2017). Model-assisted measurements of suspension-feeding flow velocities. *Journal of Experimental Biology, 220*, 2096–2107.

Evans, K. S., Athearn, K., Chen, X., Bell, K. P., & Johnson, T. (2016). Measuring the impact of pollution closures on commercial shellfish harvest: the cast of soft-shell clams in Machias Bay, Maine. *Ocean and Coastal Management, 130*, 196–204.

Glude, J. B. (1955). The effects of temperature and predators on the abundance of the soft-shell clam, *Mya arenaria*, in New England. *Transactions of the American Fisheries Society, 84*, 13–26.

Green, M. A., Waldbusser, G. G., Reilly, S. L., Emerson, K., & O'Donnell, S. (2009). Death by dissolution: Sediment saturation state as a mortality factor for juvenile bivalves. *Limnology & Oceanography, 54*, 1037–1047.

Hanna, S. S. (2000). Managing for human and ecological context in the Maine soft shell clam fishery. In F. Berkes and C. Folk (Eds.), *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*, second ed. Cambridge, UK: Cambridge University Press.

Jansen, S., Walpersdorf, E., Werner, U., Billerbeck, M., Bottcher, M.E., and D. de Beer. 2009. Functioning of intertidal flats inferred from temporal and spatial dynamics of O_2, H_2S and pH in their surface sediment. *Ocean Dynamics* 59, 317–332.

Johnson, M., O'Neil, C., Rizk, K., & Walsh, K. (2014). The State of coastal and island wildlife in Maine. *The State of Maine's Environment 2014*. Retrieved from: *web.colby.edu/stateofmaine2014/the-state-of-island-and-coastal-wildlife/*

Jones, S. J., Mieszowska, N., & Wethey, D. S. (2009). Linking thermal tolerances and biogeography: *Mytilus edulis* (L.) at its southern limit on the east coast of the United States. *Biological Bulletin, 217* (1), 73–85.

Kalin, R. J. (1984). Observations of a feeding method of the Atlantic ribbon worm, *Cerebratulus lacteus. Estuaries, 7*, 170–180.

MacKenzie Jr, C. L., Morrison, A., Taylor, D. L., Burrell Jr, V. G., Arnold, W. S., & Wakida-Kusunoki, A. T. (2002). Quahogs in eastern North America: part II, history by province and state. *Marine Fisheries Review, 64* (3), 1–64.

MacKenzie, C. L., & Stehlik, L. L. (1988). Aspects of predation on hard clam (*Mercenaria mercenaria*) populations in northeastern U.S.A. estuaries. *SHL Report #88-01*. U.S. Department of Commerce, NMFS-NOAA Northeast Fisheries Center, Highlands, New Jersey. 15 p. Retrieved from: *apps-nefsc.fisheries.noaa.gov/rcb/publications/series/shlr/shlr88-01.pdf*

Mann, R., Southworth, M., Carnegie, R. B., & Crockett, R. K. (2004). Temporal variation in fecundity and spawning in the eastern oyster, *Crassostrea virginica*, in the Piankatank River, Virginia. *Journal of Shellfish Research, 33* (1), 167–176.

McClenachan, L., O'Connor, G., & Reynolds, T. (2015). Adaptive capacity of co-management systems in the face of environmental change: the soft-shell clam fishery and invasive green crabs in Maine. *Marine Policy, 52*, 26–32.

McGreavy, B., Randall, S., Quiring, T., Hathaway, C., & Hillyer, G. (2018). Enhancing adaptive capacities in coastal communities through engaged communication research: Insights from a statewide study of shellfish co-management. *Ocean and Coastal Management, 163* (1), 240–253.

Morse, D., & Rice, M. A. (2010). Mussel aquaculture in the northeast. *Northeast Regional Aquaculture Center, 211*, 1–10.

Newell, R., Alspach, G., Kennedy, V. & Jacobs, D. (2000). Mortality of newly metamorphosed eastern oysters (*Crassostrea virginica* Gmelin) in mesohaline Chesapeake Bay. *Marine Biology, 136* (4) 665–676.

Newell, R.I.E. (1989). Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North and Mid-Atlantic)—blue mussel. U.S. Fish and Wildlife Service Biological Report 82(11.102). U.S. Army Corps of Engineers, TR El-82-4.1–25.

Pershing, A., Alexander, M., Hernandez, C., Kerr, L., Le Bris, A., Mills, K., Nye, J., Record, N., Scannell, H., Scott, J., Sherwood, G. & Thomas, A. (2015). Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery. *Science, 350* (6262), 809–812.

Pinkerton, E.W. (Ed.), 1989. Co-operative Management of Local Fisheries: New Directions for Improved Management and Community Development. University of British Columbia Press, Vancouver.

Riisgard, H. U., & Seerup, D.F. (2003). Filtration rates in the soft clam *Mya arenaria*: effects of temperature and body size. *Sarsia, 88*, 415–428.

Ropes, J.W. (1968). The feeding habits of the green crab, *Carcinus maenas* (L.). *Fishery Bulletin, 67* (2), 183–203.

Rowell, T. W. & Woo, P. (1990). Predation by the nemertean worm, *Cerebratulus lacteus* Verrill, on the soft-shell clam, *Mya arenaria* Linnaeus, 1758, and its apparent role in the destruction of a clam flat. *Journal of Shellfish Research, 9* (2), 291–297.

Sanger, D., & Sanger, M. J. (1997). The Damariscotta oyster shell heaps. *Northeastern Naturalist, 4* (2), 93–102.

Savage, N. B. (1975). Burrowing activity in *Mercenaria mercenaria* (L.) and *Spisula solidissima* (Dillwyn) as a function of temperature and dissolved oxygen. *Marine Behaviour and Physiology, 3* (4), 221–234.

Stanley, J. G., & DeWitt, R. (1983). Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)—hard clam. U.S. Fish and Wildlife Service Biological Report 82(11.18). U.S. Army Corps of Engineers, TR El-82-4.1–19.

West, F., Cubero-Leon, E., & Ciocan, C. (2016). Effects of environmental stressors affecting blue mussels *Mytilus edulis* Linnaeus, 1758 populations on the Sussex coast (UK). *Vie et Milieu, 66* (2), 219–226.

Westerbom, M., Kilipi, M., & Mustonen, O. (2002). Blue mussels, Mytilus edulis, at the edge of their range: population structure, growth and biomass along a salinity gradient in north-eastern Baltic Sea. *Marine Biology*, 140, 991–999.

Other references

Bayne, B. L. (1976). Marine mussels: their ecology and physiology. New York: Cambridge University Press. 506.

Beal, B. F. (2014). Green crab, *Carcinus maenas*, trapping studies in the Harraseeket River, and manipulative field trials to determine effects of green crabs on the fate and growth of wild and cultured individuals of soft-shell clams, *Mya arenaria* (May to November 2013). *Downeast Institute Final Report*.

Bennett, T. (2016). Giant clammers come to life outside a Portland bar. *Bangor Daily News Portland*. Retrieved from: *portland.bangordailynews.com*

Carpenter, M. (2017, October 19). Native American secrets lie buried in huge shell mounds. *New York Times*. Retrieved from: *nytimes.com*

Chenoweth, Stanley. n.d. The Blue Mussel in Maine. Maine Department of Marine Resources.

Clark, J., & Neptune, G. (2014, Spring). The Wabanaki and the Mount Desert Island Region before Colonization. *Friends of Acadia Journal.* Retrieved from: *friendsofacadia.org/news-publications/friends-of-acadia-journal/people-dawnland*

Clements, J. C. (2011). Feeding ecology of the northern moonsnail (*Euspira heros*)(Gastropoda: Naticidae) in Cape Breton, Nova Scotia. B.Sc. (Hons) Thesis. Cape Breton University, Canada. 55 p.

Clime, R., & Hamill, D. (1979). *Growing Oysters and Mussels in Maine.* Coastal Enterprises, Incorporated. 1–36.

Coleman, P. T., Deutsch, M., Marcus, E.C. Handbook of Conflict Resolution: Theory and Practice. Jossey-Bass, 2014.

Gustafson, A. H. (1977). Quahogs (*Mercenaria mercenaria*) in Maine and Their Relevance to the Critical Areas Program. *State Planning Office, 43*, 1–26.

Johnson, T., Morgan, R., & Pontbriand, K. (2019). *Shellfish mapping survey results*. Presentation at the DMR Shellfish Advisory Council meeting, Augusta, Maine.

Malinowski, S. M. (1985). The population ecology of the hard clam, *Mercenaria mercenaria*, in eastern Long Island. Ph.D. dissertation, University of Connecticut. 101.

Mason Webber, M. GIS data layer "Molluscan shellfish areas (10/12/2010)" available from the Maine Office of GIS website: *maine.gov/megis/catalog*. Accessed 25 February 2014.

Mason Webber, M. (2013). Results of the one-day green crab trapping survey conducted along the Maine coast from August 27 to 28, 2013. *Maine Department of Marine Resources*.

Matcher, E. (2018, January 10). As storms get bigger, oyster reefs can help protect shorelines. *Smithsonian Magazine*. Retrieved from: *smithsonianmag.com*

MacLagan, S. J. (2014). Managing natural resources at the intersection of economy, ecology and policy. (Master's thesis). Retrieved from: *digitalcommons.library.umaine.edu*

Maine Sea Grant. "Maine Green Crab Summit". University of Maine. 6 March 2014 *seagrant.umaine.edu/green-crab-summit*.

Mcdougall, P. (2009, October 6). Scientist studies the impact of ocean acidification on the Gulf of Maine. *Island Institute*. Retrieved from: *workingwaterfront.com*.

Maine Statutes

legislature.maine.gov/statutes/12/title12ch0sec0.html

Maine Legislature. Title 12: Conservation. Part 9: Marine Resources. Subpart 2: Licensing. Chapter 623: Shellfish, Scallops, Worms and Miscellaneous Licenses. Subchapter 1: Shellfish. Article 1: Licenses. Statute 6601: Commercial shellfish license.

Maine Legislature. Title 12: Conservation. Part 9: Marine Resources. Subpart 2: Licensing. Chapter 623: Shellfish, Scallops, Worms and Miscellaneous Licenses. Subchapter 1: Shellfish. Article 4: Municipal Conservation Programs. Statute 6671: Municipal shellfish conservation programs.

Maine Legislature. Title 12: Conservation. Part 9: Marine Resources. Subpart 2: Licensing. Chapter 623: Shellfish, Scallops, Worms and Miscellaneous Licenses. Subchapter 1: Shellfish. Article 4: Municipal Conservation Programs. Statute 6673: Municipal shellfish aquaculture permit.

Maine Legislature. Title 12: Conservation. Part 9: Marine Resources. Subpart 2: Licensing. Chapter 623: Shellfish, Scallops, Worms and Miscellaneous Licenses. Subchapter 1: Shellfish. Article 4: Municipal Conservation Programs. Statute 6674: Interference with municipal shellfish aquaculture permit.

Maine Legislature. Title 12: Conservation. Part 9: Marine Resources. Subpart 2: Licensing. Chapter 623: Shellfish, Scallops, Worms and Miscellaneous Licenses. Subchapter 1: Shellfish. Article 5: Soft-shell Clam Management. Statute 6681: Soft-shell clam management.

Maine Legislature. Title 12: Conservation. Part 9: Marine Resources. Subpart 2: Licensing. Chapter 625: Wholesale and Retail Licenses. Statute 6856: Shellfish sanitation; depuration certificate and permits. Section 3-D: Soft-shelled clam depuration harvesting in municipalities with municipal shellfish conservation programs.

Department of Marine Resources Regulations

maine.gov/dmr/laws-regulations/regulations/index.html

Chapter 4: Certification, Recertification, Revocation of Certification for Municipal Shellfish Conservation Warden.

Chapter 7: Requirements for Municipalities Having Shellfish Conservation Programs

Chapter 9: Harvester—Shellstock Harvesting, Handling and Sanitation

Chapter 10: Clams and Quahogs

Chapter 12: Mussels

Chapter 14: Oysters

Chapter 90: Conservation Areas

Chapter 94: Sanitary Control of Molluscan Shellfish

Chapter 95: Closed Pollution Areas

Chapter 96: Closed Areas—Marine Biotoxins

Chapter 115: *Vibrio parahaemolyticus* Control Plan

Glossary

Biotoxin: a poisonous or venomous substance produced by a living organism.

Bivalve: any of a class of mollusks (such as clams, oysters, mussels, or scallops) that have a 2-valved, hinged shell.

Broadcast spawning: when an organism releases gametes directly into the ocean for external fertilization.

Byssal thread: one of many thin, hairlike filaments secreted by certain mollusks for attachment to a substrate.

Co-management: an arrangement where people who are invested in a fishery have shared responsibility for management. In Maine, management authority for soft-shell clams has been shared between the state government and Maine communities for more than 170 years.

Depuration: a process that occurs when shellfish are moved to a depuration facility to cleanse themselves in sterile seawater under strict controls, and are tested before they are released to the market.

Fecal coliform bacteria: a sub-group of coliform bacteria, found in the intestinal wastes of humans and animals. If detected in water, this is an indication that the water has been contaminated by sewage or is improperly treated wastewater and therefore may contain disease-causing organisms.

Gametes: an organism's reproductive cells.

Intertidal zone: the shores, flats, or other land below the high-water mark and above subtidal lands.

Invertebrates: animals without a backbone.

Mantle: in shellfish—a sheet-like, internal organ that extends across the inside of both valves and secretes calcium carbonate to make new shell.

Mollusks: soft-bodied invertebrates of the phylum Mollusca, usually wholly or partly enclosed in a calcium carbonate shell secreted by a soft mantle covering the body. Clams, oysters, mussels, snails, octopuses, and squid are all mollusks.

Ocean acidification: a reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO_2) from the atmosphere.

Overboard discharge: a discharge to surface waters of the State of domestic pollutants (sanitary wastes or wastewater from household activities generated at residential or commercial locations) that are not conveyed to municipal or quasi-municipal sewerage treatment facilities.

Phytoplankton: microscopic marine algae. Phytoplankton are responsible for most of the photosynthetic activity in the ocean and are a major food source for shellfish.

Recruitment: the process of a young-of-the-year bivalve reaching a given size. Recruitment is the result of successful settlement followed by survival to a size discovered by an investigator.

Salinity: the concentration of salt in water, usually measured in parts per thousand (ppt).

Shellfish growing area classifications: determined by conducting a "sanitary survey."

Approved (Open)—Shellfish harvesting is allowed.

Conditionally Approved (Open)—Harvesting allowed except during specified conditions (rainfall, STP bypass or seasonal).

Conditionally (Closed)—Harvesting not allowed.

Restricted (Open)–Depuration and/or Relay harvesting only.

Conditionally Restricted (Open)—Depuration and/or Relay harvesting allowed except during specified conditions (rainfall, STP bypass or seasonal).

Conditionally Restricted (Closed)—Harvesting not allowed.

Prohibited (Closed)—No harvesting allowed or water use allowed for processing (administratively imposed precautionary closure).

Shoreline survey: part of a Sanitary Survey that identifies pollution sources that may impact water quality.

Siphon: a tube-like structure that pumps water into the body, over the gills, and back out so that shellfish can breathe, eat, and expel waste.

Appendix I | Guidance regarding intertidal mussel harvesting for municipalities with shellfish conservation programs

Law and regulations

12 M.R.S §6671 sub-§3A(5): Within any area of the municipality, a shellfish conservation ordinance may specify areas of the intertidal zone in which the dragging of mussels may be limited to the degree necessary to support a municipal shellfish conservation program.

12 M.R.S. §6671 sub-§12: With the advice of the municipality, the Commissioner may issue a permit that authorizes the permit holder to fish for and take mussels from an area designated by the municipality under the shellfish conservation program. The permit may specify limits on the amount of mussels taken, when the mussels may be taken and gear usage and any other conditions necessary for consistency with the shellfish conservation program.

DMR Procedural Rules, Chapter 7: Requirements for Municipalities Having Shellfish Conservation Programs; outlines the regulation of intertidal mussel harvest by drag or dredge in section 7.70. It states that a municipality with an approved shellfish conservation program may specify intertidal areas to be limited for mussel harvesting by drag.

Definitions

Intertidal Zone: the shores, flats or other land below the high-water mark and above subtidal lands.

Shellfish Conservation Program: requires a shellfish management plan, which consists of a written statement of goals and objectives and a description of the various conservation measures the town intends to employ to reach those goals.

Shellfish: shellstock clams, quahogs, other than mahogany quahogs, and oyster shellstock.

Municipal responsibilities

1. Municipalities must actively and vigorously pursue their shellfish conservation program. The municipality must establish the number of licenses to be issued annually, review the status of the resource annually, enforce municipal ordinances and submit annual reports to DMR.

   This means that if a municipality fails to meet these performance standards, the Commissioner may rescind approval of that municipality's shellfish conservation program.

2. Municipalities shall review the status of the resource affected prior to closing or opening an area to shellfish harvesting.

   For the purpose of this guidance document, this means that if an area is closed as a conservation measure and/ or an area specified by the municipality to be limited for mussel harvest by drag (to protect the shellfish resource), the status of the shellfish resource must be established prior to closing. The DMR Shellfish Management Program (Area Biologists) should be consulted for this process in order to ensure proper evaluation methods are being used.

3. Municipalities may request approval from the Commissioner for intertidal areas to be limited to mussel harvest by drag. When requesting an area to be limited to mussel harvest, the municipality must provide an explanation as to why they believe these areas require additional protections.

   DMR expects municipalities to include in their request detailed mapping of the specified areas, the explanation regarding the importance of the area(s), and supporting resource assessment documentation. Electronic maps should be developed that include GPS coordinates for the requested area. Mapping assistance can be requested from the staff of the DMR Shellfish Management Program.

4. Municipalities shall provide written recommendations to the applicant for Intertidal Mussel Harvest Permits within 21 days of the receipt of the application.

   An applicant that wishes to harvest mussels from an area that is specified in a municipal shellfish conservation program must obtain a permit from the DMR. When submitting their application, the applicant must include *the written comments of the municipality. In determining whether or not to issue the requested permit, the DMR will consider, but is not bound by, the municipal recommendation. Other Department considerations include if the status of the managed resource (e.g. soft-shell clams) has changed, if the municipal performance has not met expectations, the abundance of the mussel resource, and the likelihood of the requested activity impacting the resource. If competing permits are requested, DMR will allocate appropriate access.*

5. Municipalities may recommend mussel harvest controls for consideration by the Commissioner when a permit is requested, including but not limited to: gear used, time of harvest, area of harvest, and volume of harvest.

Recommendations regarding the amount of mussels taken should be defined by weight in pounds or bushels, and an explanation should accompany why limiting volume supports the shellfish conservation program. Time of harvest needs to be defined in seasons (months), not days or hours, and accompanied by an explanation how this supports the shellfish conservation program. Gear usage recommendations are limited to dragging (not hand harvest, etc.), and need to be clearly and precisely defined and be accompanied by an explanation of how this supports the shellfish conservation program. Any other conditions necessary must be consistent with other marine resources laws and regulations, and also provide an explanation of how they support the shellfish conservation program.

Permit applications

A standard permit application can be found on the DMR website: *maine.gov/dmr/shellfish-sanitation-management/programs/municipal/forms/index.html*

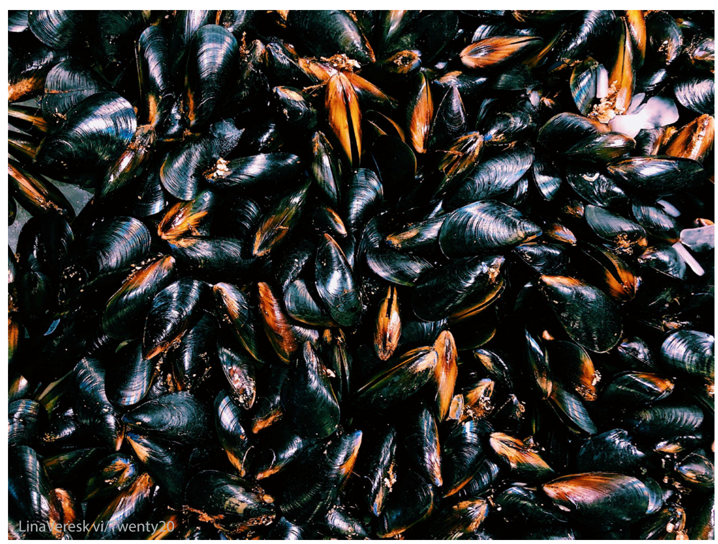
Request by mail: PO Box 8, West Boothbay Harbor, ME 045675

Request by email: *DMRPublicHealthDiv@maine.gov*

Request by phone: 207.633.9515

DMR evaluation of areas proposed for limitations on intertidal mussel harvesting

The DMR evaluation of areas requested by municipalities for limitations on intertidal mussel harvesting will include a review of the successful implementation of the overall municipal shellfish conservation program. Does the requesting municipality have adequate enforcement, are they actively pursuing conservation and management of their intertidal resources, do they regulate licensing properly, etc.? The specified areas must be part of the town's conservation program. The areas should be clearly established and explained so applicants can make appropriate requests. If approved, the areas will be posted online at the Department's website.



Appendix II | Techniques for measuring soft-shell clam growth

Assessing where soft-shell clams grow fastest

At least three factors contribute to the difficulty in measuring the growth of soft-shell clams under natural conditions. First, clams grow more slowly as they get larger. Therefore, for comparative growth rate estimations, clams of the same initial size should be used. Second, growth may be slower at high densities. Third, clams typically grow faster at lower intertidal heights versus upper intertidal heights. To estimate clam growth over an entire growing season, one should begin in late March/early April and continue into late October since this is the only time of year when new shell is formed. There are two different approaches one may take to estimate growth rates. The first is to use a variety of sizes of clams from ½- to 3-inch animals and plant them in marked plots (one square foot, two square feet, etc.). As long as five or more animals from each size class (i.e., ½-inch, ¾- to 1-inch, 2 ¾- to 3-inch) survive, you should be able to determine accurately the length of time it takes for a certain size clam to attain a given size. (You may wish to vary the number of clams in your plots to better understand how density affects growth rate).

Another approach is to only use one size class of the smallest clams available. Since small clams will grow faster and you can remove them from the sediments at three- to four-week intervals, they can be used to quickly assess the best growing areas.

Growth measurement: Methods for measuring the changes in shell growth

Growth of clams is usually measured as the difference in shell length between the size at planting and the size at the time of sampling. The increase in shell length (the longest anterior-posterior dimension) can be estimated accurately using dial-type or Vernier calipers, or during survey work using a ruler affixed to the spat sieve. Growth may also be estimated by comparing the change in volume that occurs between planting and sampling date(s). Animals may be placed in a container with known volume at planting (e.g., dry volume–numbers of clams/liter; or as displacement volume using a graduated cylinder partially filled with water) and then re-measured using the same container or cylinder upon sampling. Clam growth may also be assessed in terms of mass by recording the difference in weight between planting and sampling date.

Another method of estimating clam growth is to use juvenile, cultured (hatchery) seed (4–15 mm in shell length). When hatchery-reared clams are placed in sediments, they immediately form a disturbance mark that delineates their shell length at that particular time. New shell growth is visually distinct, usually appearing whiter than the "older shell" (Beal et al. 1999). To estimate growth for an individual, take calipers and measure its final shell length and subtract its initial SL.

Size frequency distribution

If the same flat is surveyed periodically, the size-frequency distribution of the clams will change as the clams grow. Within a certain area, a certain percentage of clams that measured 1 ½ inches in March may measure 2 inches in August. This technique of measuring growth may be useful to municipal management programs; however, it is not as accurate as examining the growth of marked individuals because mortality may also influence changes in size-frequency distribution.

Hatchery-reared clams planted at Collins Cove, Freeport, Maine in April 2014. The disturbance line is visible here as a distinct white line, recorded in July 2014.

Annual growth lines

In New England, soft-shell clams generally exhibit seasonal differences in shell growth, with rapid shell growth during the warmer months and, at best, slow growth during the colder months. In some areas, if growth is not interrupted by digging, intense storms, or the activity of a predator (such as a green crab or horseshoe crab that may damage the shell but not kill the clam), annual lines are formed on the outer shell. Annual growth is most easily interpreted by digging clams in late fall and measuring shell growth from the last winter's check line to the ventral margin (outside edge).

The difference between final length and initial length is the amount of shell added during the period between late March and the date sampled. If clams of the same initial size are used, you need simply to calculate an average growth increment from each area. When growth is interrupted (as described above), or when planting clams that originated in a hatchery, a dark disturbance line forms. This is sometimes referred to as a "hatchery mark" (Beal et al. 1999). Depending on the severity of other types of disturbances, these lines may sometimes be only as distinct as the annual checks, making unambiguous estimates of clam age difficult. In contrast, hatchery marks are typically very visible to the human eye.

Alizarin staining

When wild or cultured clams are put in a seawater solution containing cultured algae and the red dye alizarin for about a week, a red line forms on the clam's shell. If these clams are then placed in the flats soon after, the mark can be useful for two reasons: first, it will mark the length of the clams at the beginning of the growth-testing period, and the alizarin will make it relatively easy to distinguish them from other clams that may have been in the transplant area.

Paint and ink

Mark clams by rinsing in fresh water, drying, and painting the shell with oil-base spray paint, an oil base artist ink (Mark-Tex Corporation), or by measuring and numbering the clams with drafting ink. The latter method works best if a clear enamel (fingernail polish) is used to cover the drafting ink. Spray paint is often eroded in the sediment, and marked and measured clams are often lost, resulting in wasted time. The artist ink works best and has been used with excellent results for periods of up to five years without any erosion on soft-shell clams, hard clams, and other infaunal bivalves.

BUSHELS PER ACRE / Number of Clams per 2 ft. x 2 ft. Survey Plot

Length (inches)	1	2	3	4	5	6	7	8	9	10
0.25–0.49	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6
0.50–0.74	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.7	4.1
0.75–0.99	1.2	2.4	3.6	4.8	6.0	7.3	8.5	9.7	10.9	12.1
1.00–1.24	2.7	5.3	8.0	10.6	13.3	16.0	18.6	21.3	23.9	26.6
1.25–1.49	4.9	9.9	14.8	19.8	24.7	29.7	34.6	39.5	44.5	49.4
1.50–1.74	8.2	16.5	24.7	33.0	41.2	49.5	57.7	66.0	74.2	82.4
1.75–1.99	12.8	25.5	38.3	51.0	63.8	76.5	89.3	102.0	114.8	127.5
2.00–2.24	18.6	37.3	55.9	74.6	93.2	111.9	130.5	149.2	167.8	186.5
2.25–2.49	26.1	52.2	78.4	104.5	130.6	156.7	182.8	208.9	235.1	261.2
2.50–2.74	35.4	70.7	106.1	141.4	176.8	212.1	247.5	282.8	318.2	353.5
2.75–2.99	46.5	93.1	139.6	186.1	232.7	279.2	325.7	372.3	418.8	465.3
3.00–3.24	59.8	119.7	179.5	239.4	299.2	359.1	418.9	478.8	538.6	598.5
3.25–3.49	75.5	151.0	226.4	301.9	377.4	452.9	528.4	603.9	679.3	754.8
3.50–3.74	93.6	187.2	280.9	374.5	468.1	561.7	655.3	749.0	842.6	936.2
3.75–3.99	114.4	228.9	343.4	457.8	572.3	686.7	801.2	915.6	1030.1	1144.5
4.00–4.24	138.2	276.3	414.5	552.6	690.8	828.9	967.1	1105.3	1243.4	1381.6
4.25–4.49	164.9	329.9	494.8	659.7	824.8	989.6	1154.5	1319.4	1484.3	1649.3
4.50–4.74	194.9	389.9	584.8	779.8	974.7	1169.7	1364.6	1559.6	1754.5	1949.5
4.75–4.99	228.4	456.8	685.2	913.6	1142.0	1370.4	1598.8	1827.2	2055.6	2284.0

Note: For more than 10 clams per plot in a given length interval, add bushels per acre estimates. For example, for 14 2.50″–2.74″ clams: 353.5 + 141.4=494.9 bushels per acre; or for 26 1.50″–1.74″ clams, 66+66+82.4=214.4 bushels per acre

Appendix III | Soft-shell clam seeding projects

Important notes

When using soft-shell clam seed under the regulated minimum size (two inches, or 50.8 mm), *a Shellfish Transplant Permit Application* must be submitted to the DMR Shellfish Management Program for each municipal seeding event. This permit applies both to wild seed and to seed purchased from a hatchery.

Special licenses or other permits held by researchers do not cover the town's activities unless they are specifically named in the license, so it is important to obtain the transplant permit before the activity starts.

If the clam seed is harvested from areas classified as Restricted by DMR's Shellfish Growing Area Program, the receiving flats need to be closed to harvest for at least 60 days.

Installing predator netting requires an Army Corps of Engineers permit.

There are various permitting requirements for this activity depending on the project specifications. It is important to consult with DMR during the planning phase to ensure that all requirements are met.

Site selection

Location determines how well the seed will survive and grow, and a carefully planned investigation to determine the suitability of the site should precede any major investment of time or money. The following factors should be considered in site selection for planting and protecting the seed:

- Abundance of a natural population of clams with fast growth rates
- Intertidal height and location
- Sediment type
- Water current
- Location in a waterway (mouth vs. head)
- Seasonal changes in water temperature, salinity, and icing
- Protection from wind and waves
- Number and type of predators present
- Accessibility for routine maintenance of netting or boxes and/or enforcement of flat closures

The status of the existing clam population is an important step in site selection. Areas with high natural abundance of green crabs and moon snails should be avoided. Examination of predator activity both at day and night during high tide, use of baited traps, and survival studies on protected and unprotected seed can help to evaluate predator activity. In areas where high numbers of predators are common, seed should be protected under mesh netting, which will need to be inspected and repaired throughout the growing season.

Clams feed on microscopic algae and other microorganisms, so areas characterized by an abundance of algae, warm temperatures, high salinities, and good current exchange generally result in the rapid growth of clams. In Maine, many locations often meet these characteristics. However, winter icing can be severe in coastal inlets and salt ponds, and low salinities can be a problem during the spring runoff season. Salinities as low as two to three parts per thousand (ppt) are common in the runoff streams (30–32 ppt is normal for coastal waters).

In general, seeded plots will likely do better at mid-intertidal heights even though growth may be greater lower in the intertidal zone. Survival is typically 10 to 20 percent less at lower tidal heights than at the mid-intertidal even in protected plots, because these areas are covered longer each tidal cycle and give predators such as green crabs longer times to burrow under the nets.

Seeding technique

To maximize growth and survival, plant seed in the spring (April or May). Broadcast seed by hand into rectangular plots (typically 14 x 20 or 14 x 30 feet) at densities of 20 to 40 clams per square foot. After seeding, cover the plot with ¼-inch or ⅙-inch plastic netting to protect the freshly planted seed from predators during the growing season. Netting generally is purchased in large, 14-foot wide rolls and can be easily cut to any length.

Bury the netting 6 inches into the mud on the edges and buoy from the underside with up to nine 4 x 4-inch floats. If sediments are soft enough, nets can be secured by walking on top of the outside edge and pushing the edge into the flat. In more sandy or gravelly substrates, dig a furrow around the edge of the seeded area and place the edge of the net into the trench, then fill back in. Netting effectively deters green crabs, but needs to be checked regularly for tearing and fouling.

Once the edge of the net is secured into the flat and the tide covers the seeded area, the net will bulge up off the flat at high tide because of the placement of the floats. This ensures that the net will not interfere with the clams as they feed and will also inhibit a gradual buildup of sediments on the net that could suffocate the animals. Setting out mesh netting is a team effort and may involve at least a dozen people to accomplish the planting of a million seed in one tide.

In November, remove, clean, and store the nets before any ice has a chance to build up on the flat. If nets are not removed before winter, there is a chance that they will be lost due to ice or storms.

If no netting is used, broadcast clams by hand onto the flat as the tide rises. While the tide covers the flats, the transplanted seed clams dig into the sediment and establish themselves in the new flat. Note that burrowing rates depend on clam size, and larger individuals may take three to four tides to completely burrow into the mud. Once seeded, the flat should be protected from all harvesting for at least one growing season. However, it must be emphasized that seeding without using nets to protect the small clams is not recommended, due to the fact that green crab predation has been so high during the past few years.

Harvesting can proceed when 60 to 70 percent of the clams in the seeded area are legal size. In Maine, soft-shell clams generally reach the harvestable size of 2 inches (50.8 mm) within two to four years; however, growth is directly related to water temperature and tidal position on the flat.

Seed sources

Soft-shell clam seed used in planting is obtained either from a shellfish hatchery or by digging wild seed and transplanting it to managed flats. Wild soft-shell clam seed are collected by hand, and, in the past, communities with large supplies of wild seed have sold or bartered seed with other communities lacking wild seed. Certain clam flats periodically produce tremendous seed sets that clump together and result in stunted clam growth and poor survival. Seed can be harvested from these sites and broadcast over more favorable areas. Unfortunately, no quantitative estimates of the survival of transplanted wild seed exist, because it is difficult to effectively mark wild seed before transplant in a way that will stay noticeable over time.

Hatchery-reared seed is also available, with prices varying depending on the size of the seed. Depending on the source of the seed, an import permit may be required from DMR under Chapter 24 regulations. Field experiments with hatchery-reared, soft-shell clam juveniles have resulted in information about the effects of planting season, stocking density, tidal height, clam size, and predator exclusion on growth and survival. In addition, studies have been conducted to determine how to overwinter seed clams so that animals can be planted in the spring when growth begins, rather than in the fall when growth ceases. These investigations have shown that hatchery seed behaves similarly to wild seed.

Since small soft-shell clams under ¼ inch in size are mobile and can float to other areas where they re-settle into the sediment, seed clams from ¼ to ½ inch (6 to 12 mm) are best for planting. Although a municipality may be tempted to buy small clam seed from a hatchery to reduce costs, the cost of equipment and the volunteer time needed for nursery grow-out of smaller clams may offset the savings. Clams can be grown to a transplantable size using various systems and techniques, including upwellers, floating trays, and floating bags. A Limited Purpose Aquaculture permit is the simplest and most expedient mechanism to start a municipal nursery site. A Standard or Experimental lease will be required for projects that exceed 400 square feet in size.


B. McGreavy

Seeding larger hatchery clams greater than ¼ inch (6 mm) costs the community more in dollars paid directly for the larger clams, but it may be worth it to the municipality if either the equipment or volunteers available for tending a nursery grow-out site are not available.

Collecting and overwintering wild soft-shell clam spat

Juvenile clams are very mobile. Just because a set of clams is observed in the fall does not mean that clams will be there the next spring: the loss of young-of-the-year clams in the 3–10 mm size range over the winter approaches 90 to 100 percent on many flats in Maine. This waste doesn't need to occur. With a little planning, sampling, and digging a few tides in late October or early November, survival of the wild soft-shell clam spat can be increased. The use of netting and the ability to overwinter seed clams enables clam managers and local shellfish committees to take advantage of naturally-occurring dense sets of clams in the fall. The key to enhancing the survival of wild seed clams is finding dense enough sets to make the investment of time worthwhile. Communities with low wild populations of market-size clams may wish to attempt collecting and overwintering young-of-the-year clams (6–12 mm) by late November. Sampling to determine the location and relative density of clam spat should occur during the last two weeks in October, when seawater temperatures are falling rapidly.

Wild spat can be overwintered in the subtidal area. In middle to late fall, locate sources of wild spat where densities are high enough to allow hand collection by skimming and washing the upper quarter- to half-inch layer of the sediment through a sieve. Place the spat into window screen bags and stack on wire shelves in wire lobster trap-type cages suspended off the bottom for the winter. These cages may be made neutrally buoyant and anchored deep enough in a protected cove to avoid ice damage, or they may be suspended to depths of 10 to 12 feet from pilings or large wooden rafts. In areas where tidal currents are strong, a weighted cage with a false bottom to keep the clams from smothering in bottom sediments may work best. Placing small hermit crabs outside the clam bags and putting a handful of periwinkles (*Littorina littorea*) inside the clam bags may prevent fouling of the screen mesh. These wild seed clams can be planted on flats during the following May.

K. Tenga-Gonzalez

Appendix IV | Support for municipal projects

Organizations who may support municipal water quality projects

Maine Department of Environmental Protection's Overboard Discharge (OBD) Program is responsible for regulating discharges of sanitary and household wastewater generated at residential or commercial locations to streams, rivers, bays, and the ocean. These discharges provide primary and secondary treatment of wastewater. All OBDs must be approved by the DEP through a licensing process. The DMR is required by the FDA National Shellfish Sanitation Program (NSSP) to close areas immediately around OBD outfall pipes to shellfish harvest, because harmful bacteria may enter the water if the system fails or isn't maintained properly. Where closures impact potential shellfish harvest areas, the DMR works with the DEP to identify overboard discharges, contact the town, and encourage discussions on whether the discharge can be removed.

Maine DEP Small Community Grant Program provides grants to towns to help replace malfunctioning septic systems that are polluting a water body or causing a public nuisance. The highest priority is given to problems that are polluting a public drinking water supply or a shellfish harvest area. Grant applications must be submitted by the municipality in which the property owner resides.

Maine DEP Pumpout Grant Program provides grants for the installation, operation, and maintenance of boat holding tank pumpout equipment to marinas, boatyards, and municipalities, through a non-competitive program. The discharge of untreated sewage from any vessel into the marine environment is prohibited by federal law within three miles of the coast. Additionally, Maine law requires pumpout stations at marinas, defined as any facility on coastal waters that provides services and has 18 or more slips or moorings for boats greater than 24 feet in length. Each marina must provide an easily accessible pumpout station that is functional during normal working hours and at all stages of tide or water level. This protects public health by providing boaters with facilities that can accept sewage from boat holding tanks. A marina in a shellfish-growing area may cause the area to be classified as "Restricted" or "Prohibited" permanently or seasonally under the NSSP rules because of the possibility of overboard discharge of untreated sewage.

Maine Department of Health and Human Services Subsurface Wastewater Unit within the Maine Centers for Disease Control and Prevention's Division of Environmental Health Drinking Water Program administers rules for subsurface wastewater disposal systems. The State Plumbing Inspector works with DEP and DMR staff to ensure septic malfunctions, straight pipe discharges, and other issues discovered during shoreline surveys that may impact water quality are resolved by the Licensed Plumbing Inspector for the town where the problem was found.

The Maine State Housing Authority Home Repair Program provides information about grants and loans available to low-income homeowners, which could be used for septic system repairs.

The United States Department of Agriculture's Rural Development Program offers direct loans and grants to develop water and waste disposal systems in rural areas and towns with a population not in excess of 10,000. The funds are available to public bodies, nonprofits, and Native American communities.

Local land trusts, watershed groups, and conservation organizations are often interested in working together to improve water quality. The following list of organizations is not comprehensive, but instead is intended to serve as a starting point. There are many other organizations throughout the state and region that may be able to assist or support the municipal management of shellfish.

Casco Bay Estuary Partnership
cascobayestuary.org

USM Muskie School of Public Service
PO Box 9300
Wishcamper Center #229
34 Bedford Street
Portland, ME 04104-9300
Phone: 207.780.4820
Fax: 207.228.8460
Email: cbep@maine.edu

Coastal Rivers Conservation Trust
Coastalrivers.org

P.O. Box 333
Damariscotta, ME 04543
Phone: 207.563.1393
Email: info@coastalrivers.org

Downeast Institute
downeastinstitute.org

39 Wildflower Lane
P.O. Box 83
Beals, Maine 04611
Phone: 207.497.5769
Email: info@downeastinstitute.org

Frenchman Bay Partners
frenchmanbaypartners.org

Jane E. Disney, President, Frenchman Bay Partners
MDI Biological Laboratory
PO Box 35
Salisbury Cove, ME 04672
Phone: 207.288.3605 x423
Email: jdisney@mdibl.org

Friends of Casco Bay
cascobay.org

43 Slocum Drive
South Portland, ME 04106
Phone: 207.799.8574
Fax: 207.799.7224
Email: keeper@cascobay.org

Friends of Merrymeeting Bay
friendsofmerrymeetingbay.org

Dup Crosson, Coordinator/Organizer
PO Box 233
Richmond, ME 04357
Phone: 207.666.1118
Email: fomb@comcast.net

Friends of Taunton Bay
friendsoftauntonbay.org

PO Box 411
Hancock, ME 04640
Phone: 207.565.3575
Email: info@friendsoftauntonbay.org

Maine Center for Coastal Fisheries
coastalfisheries.org

PO Box 27
13 Atlantic Avenue
Stonington, ME 04681
Phone: 207.367.2708
Fax: 207.367.2680
Email: info@coastalfisheries.org

Maine's Marine Extension Team (MET)
seagrant.umaine.edu/extension

Collaboration between Maine Sea Grant and University of Maine Cooperative Extension

Maine Land Trust Network
mltn.org/view_trusts-alphabetical.php

1 Bowdoin Mill Island, Suite 201
Topsham, ME 04086
Phone: 207.729.7366
Fax: 207.729.6863

Maine Soil and Water Conservation Districts
www.maine.gov/dacf/about/commissioners/soil_water/index.shtml

Midcoast Conservancy
midcoastconservancy.org

PO Box 439
Edgecomb, ME 04556
Phone: (207) 389-5150
Email: info@midcoastconservancy.org

University of Maine Cooperative Extension
extension.umaine.edu/county-offices

Wells National Estuarine Research Reserve
wellsreserve.org/research

342 Laudholm Farm Road
Wells, ME 04090
Phone: 207.646.1555

Organizations who may support municipal research projects

The Downeast Institute (DEI) is a public, non-profit organization whose mission is to improve the quality of life for the people of downeast and coastal Maine through marine research, marine science education, and innovations in wild and cultured fisheries. DEI was formerly the Beals Island Regional Shellfish Hatchery (1987–1999), and has been producing soft-shell clam seed for communities to enhance their wild populations for over three decades. In addition, researchers at DEI have undertaken many field-related projects over the years to examine various methods involving both cultured and wild clams to enhance clam numbers and the coastal economy. Many of these reports and findings (downeastinstitute.org/publications/), as well as scientific papers about soft-shell clams and other commercially-important shellfish are available on the DEI web site (*downeastinstitute.org/research*).

Maine Sea Grant (MSG) is a federal-state partnership program based at the University of Maine that supports marine and coastal research, education, and outreach via members of their Marine Extension Team (MET). MET members are jointly supported by Maine Sea Grant and University of Maine Cooperative Extension, and they are located in coastal communities from Wells to Eastport. Among other things, MSG supports projects and research that provide opportunities for wild harvesters and aquaculture producers to strengthen or diversify their seafood business, improve coastal and marine resources monitoring and management, and help communities identify and prioritize opportunities related to marine business and infrastructure. Find more information about MSG's research and extension efforts as well as funding opportunities on the MSG website. (*seagrant.umaine.edu*)

Manomet is a sustainability nonprofit grounded in science and named for the coastal village in New England where its headquarters have been since the Manomet Bird Observatory was founded in 1969. Manomet's projects include shellfish aquaculture and management, diversification of new fishing opportunities, and restoration of habitats and food webs to support existing fishing opportunities. Manomet works directly with land managers, grocery store managers, wetland managers, commercial foresters, and more to further its mission of applying science and engaging people to sustain our world. Find out more on the Manomet website. (*manomet.org/project/*)

Photo by George French, 1947/Maine State Archives

NOTE: Photographs of students and others not wearing masks were taken prior to the coronavirus pandemic. The University of Maine and University of Maine at Machias follow federal and state Centers for Disease Control and Prevention health and safety guidance, which includes social distancing and use of face coverings for the start of the 2020–21 academic year.

MSG-E-21-05 • 00M