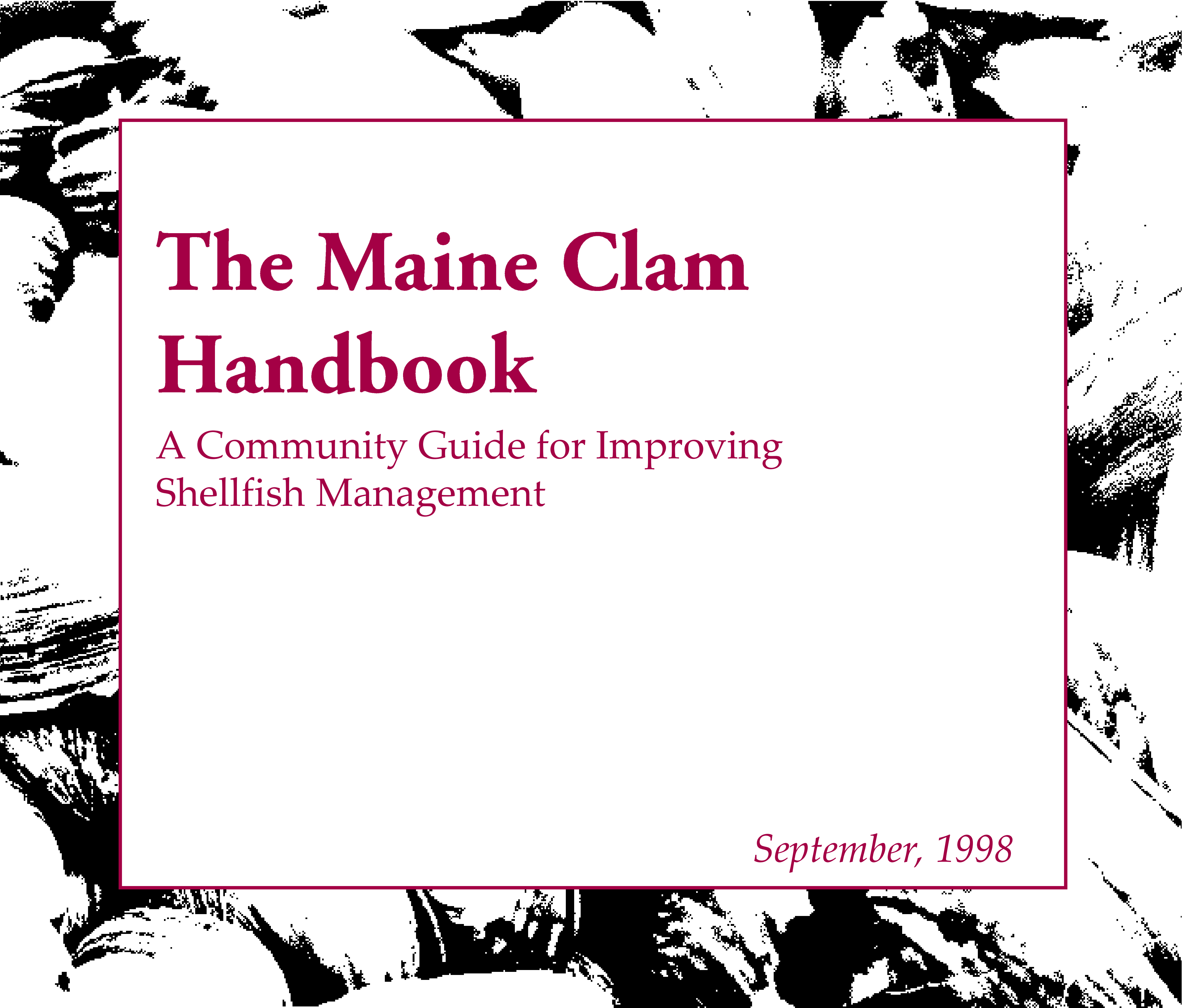

# The Maine Clam Handbook

A Community Guide for Improving Shellfish Management

*September, 1998*

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September 1998

Produced by Maine/New Hampshire Sea Grant College Program
Maine Coastal Program/Maine State Planning Office and
Maine Department of Marine Resources

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September 1998

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## Introduction

This handbook was developed to provide important information for community shellfish management programs. We hope this material will assist individuals and coastal towns in developing soft-shell clam (*Mya arenaria*) management programs that encourage stewardship by participants in the fishery.

The clam fishery is the only commercial fishery in Maine that is managed at the community level, with municipalities working in partnership with the State. The intent of this publication is to help individuals and towns develop stewardship-based clam management programs for their communities. Hopefully, this may bring about a new period of sustainable production and job security for the Maine clam industry.

This handbook contains information on the history of the soft-shell clam fishery, clam biology, clam aquaculture, and related legal issues. Expanded sections on public health and water quality requirements for shellfish harvesting have been added, as well as information on the social context of the clam fishery in Maine.

The section on clam management incorporates findings and recommendations produced by working groups—consisting of clammers and representatives of state agencies and non-profit organizations—which convened in December 1995 at a statewide clam management conference. The recommendations were presented to the industry at the Maine Fishermen's Forum in 1996.

Current thinking recognizes that effective fisheries management includes consideration of the social context of any fishery as well as the scientific status of the fish stock. Therefore, this handbook includes, descriptions of the social context of the soft-shell clam fishery in Maine. Specific discussions of community participation in management of the clam fishery, referred to as "co-management," are included in the clam management section.

## The Importance of the Maine Clam Industry

The Maine soft-shell clam fishery is a traditional, low-capital-entry fishery that employs hundreds of harvesters along the coast. Clams have been Maine's second or third most valuable commercial fisheries species in 36 of the past 56 years. In 1996, with clam landings and harvester jobs at historic lows, clams were the eighth most valuable marine species in the state.

Clams have historically provided income to more Maine people than any other marine species. In the past, during good clamming years in some coastal communities, half of the households included at least one member with a commercial clam license.

## Recent Developments

At this time (1998), large areas of historically productive clam flats remain closed to harvest, are poorly managed, or are not managed at all. Towns are frequently overwhelmed with the work required to satisfy water quality mandates, control harvester effort, and enhance wild clam stocks with aquaculture techniques. Meanwhile, statewide landings continue to decline.

In response to these trends, supporters of the Maine clam industry have initiated projects that offer hope for rebuilding the fishery. These efforts include:

- The Clean Water/Partners in Monitoring and the Shore Stewards Program (supported by the University of Maine Cooperative Extension, Maine Department of Marine Resources, and the Maine State Planning Office) have teamed up with municipalities and schools to organize and fund an effective statewide network of water quality monitoring volunteer groups. They have helped to re-open thousands of acres of clam flat habitat previously closed due to pollution.
- Techniques of spawning and culturing soft-shell clams in the laboratory were developed in 1977 at the University of Maine's Ira C. Darling Marine Center. This technology was consequently adapted and improved in the 1980s by the Beals Island Regional Shellfish Hatchery. Hatchery-raised clams offer the clam industry a chance to supplement wild populations to increase commercial landings with community-supported public aquaculture projects.
- Regional efforts have focused on restoring clam habitat and improving clam management along the coast. These efforts include the Friends of Casco Bay Clam Project in Cumberland County, Georges River Clam Project in Knox County, and Cobscook Bay Clam Project in Washington County.
- Three statewide clam industry conferences, initiated by the Penobscot Bay Network, have been held since December 1995. Volunteers and resource managers spent countless hours discussing the major issues concerning clam management in Maine.
- In 1997, the first Maine Soft-shell Clam Council and the first Maine Clammers' Association was organized to strengthen the link between municipalities that manage clam resources and clam harvesters with the Maine Department of Marine Resources and the Maine State Legislature.
- In the spring of 1997, the Beals Island Regional Shellfish Hatchery began a three-year project to test and demonstrate methods designed to improve clam harvests by involving municipalities in public clam aquaculture efforts.
- The perception of clam harvesting as "the employer of last resort" is gradually being replaced by a new professionalism and sophistication in the industry. The success of private shellfish aquaculture enterprises in Maine and the aquaculture industry's support of improving the management of the wild soft-shell clam fishery has helped create the current climate for positive change, unique in the history of the industry.

# Chapter 1. Clam Management in Maine

Commercial marine fisheries management in New England and the Canadian Maritimes is currently undergoing an historic and exciting transition. For the past 50 years, government-run fisheries management councils have focused on management of individual species. Recently, however, this narrow approach has been challenged as overfishing and habitat destruction have reduced commercial stocks of many fish and shellfish species.

Fisheries management today considers the relationship between marine species and their habitat as well as the social and economic situation of harvestors. In addition, the more traditional assessments of species' populations are still used.

To understand the many complex biological and sociological issues involved in modern clam management in Maine, it is useful to separate information into 1) social issues (including an assessment of fishery participants, the economics of the fishery, fishing technology and practices); and 2) scientific issues (including biological and habitat assessments and ecosystem modeling).

## • A History of Market Changes and Fishing Practices

Soft-shell clams are among Maine's most valuable commercial fisheries species, and little capital investment is needed to enter the fishery. Historically, clams have provided income to more Maine people than any other marine species. The following brief review of the history of the Maine clam fishery provides insight into the current state of the industry.

Traditionally, Maine clam harvesters, or "clammers," have worked the flats on a seasonal cycle—digging clams during spring, summer, and fall and finding other employment during the winter months. Winter clammers moved to traditional areas that remained ice-free after other areas were frozen.

(Photo: Dana Wallace.)

Clammers moved along the length of the coast, digging wherever clams were abundant and weather, tide, and local harvesting restrictions allowed. Family and friends worked together, often setting daily production goals and moving frequently to maintain that level of production. Today, access to flats is limited by public health-related restrictions and town management ordinances that limit clam harvests on local flats primarily to local residents.

Before World War II, most soft-shell clams were harvested for canneries. Commercial harvesting occurred in fall and winter when other resources were scarce and canneries needed to keep their production lines operating. Fewer than 1500 licensed harvesters worked professionally in the Maine fishery, although many clams were dug for personal consumption. Low volumes of fresh product were shipped out of Maine to other New England markets, and, until 1949, clams could not be shipped out of state from Hancock and Washingtn counties from June to September.

During this period, clammers measured their daily production in "barrels" (three bushels/barrel). The harvest of two or three barrels per tide per clammer was commonplace. Clammers often delivered their clams directly to canneries by boat, with dories filled to capacity with one or two clammers' daily production. At that time, clams were plentiful and low in value relative to other seafood in Maine, and shucking houses flourished all along the coast. Before 1945, annual production for a typical professional harvester exceeded 1,000 bushels. By comparison, full-time clammers today harvest approximately 300 to 500 bushels of clams annually.

In 1947, state clam licenses for commercial harvest were first issued to 2,474 harvesters. State licensing was initiated to satisfy federal public health requirements for interstate trade in shellfish and allowed Maine's Department of Sea and Shore Fisheries to gather more reliable statistics on the clam fishery. The first closure of flats due to pollution occurred in the 1930s in southern Maine. However, before 1947 no program for controlling shellfish harvesting to protect the public from polluted shellfish existed in Maine.

Record landings of clams occurred in the late 1940s and early 1950s (Table 1/Fig. A), with one four-year period producing annually over a half-million bushels. Landings decreased by as much as 75 percent during the late 1950s and early 1960s. In addition, between 2,000 to 3,000 state commercial shellfish licenses were sold per year until the early 1970s.

In 1957, the Maine legislature restricted clam harvesting to hand implements only. Hand harvesters in Maine traditionally use a steel-tined hoe (also called "fork") to dig in the coarser clam flat sediments or pick by hand (called "pulling" Down East) in the softer mudflats.

By the late 1960s, the canned market for Maine clams declined steadily and disappeared. Maine clams were replaced by the mid-Atlantic surf clam (*Spisula solidissima*) fishery which produced plenty of low-cost clam meat for southern canneries. The invention of the deep fat "fryolater" in the 1930s increased restaurant demand for fresh clam meats and shell stock for use as "steamers." Most Maine clams went to two markets: the smaller clams were sold as steamers and the larger clams shucked for fried clams. During the post-war period, the booming New England economy supported a rapid increase in the number of restaurants, and the market for fresh clams, both shucked meats and steamers, increased. In addition, soldiers returning home after World War II entered the fishery in large numbers, usually until they could find employment elsewhere.

*In the past, to circumvent the residency/taxpayer requirements of "town laws," some enterprising clammers purchased postage stamp-sized lots of land in coastal towns. These "clam- digger lots" can still be found on tax maps in St. George and other coastal towns.*

Prices paid for soft-shell clams remained relatively stable through the early 1970s and then began to increase rapidly in the mid-1970s. Clam and other seafood prices increased dramatically during the 1980s, but clam prices increased at a faster rate than those for other seafood. This sudden price increase, combined with high densities of wild clams statewide, quickly attracted a large number of harvesters into the fishery. From 1968 to 1973, the number of state commercial clam licenses increased more than 300 percent, from around 2,000 to 6,000 licenses. In 1973, annual state clam landings reached 484,000 bushels with 5,927 licensed harvesters, as compared to the nearly comparable 460,000 bushel level of 1950 with only 2,281 harvesters.

During this period, harvesters could earn a good living digging clams. A hard-working clammer could enjoy the independence of self-employment and also earn a yearly income equal to that of other fisheries, such as lobster and groundfish, and with much less capital investment. During this period of prosperity, many clammers built houses, bought new vehicles, invested in larger boats to go into higher-profile fisheries or financed a higher education, allowing them to move into other professions. This boom lasted until the mid-1980s when landings and license numbers began to decline sharply. The decline in landings continues today (Table 1/Fig A), although

Graphic Omitted

license numbers have stabilized at less than 1,700. Today, less than 20 percent of commercially licensed clammers work in the fishery year round.

Clamming has a strong town-based, territorial tradition in Maine. In the past, local clammers discouraged non-residents from working "their" town flats without the legal sanction of a "town law" or municipal ordinance. Clammers from towns with local clam ordinances may harvest flats in towns without local ordinances when pollution or "red tide" closures shut down their flats. When the temporary closures are lifted, these so-called "town law" clammers return to their town flats—protected from "out-of-towners" whose flats they have just been working.

**Table 1 Maine Clam Landings 1941-1996, Thousands of Pounds of Meats** ***(One bushel of clams = 15 lbs. of meats)***

| | | | | COUNTIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR | YORK | CUMB | SAG | LINCOLN | KNOX | WALDO | HANCOCK | WASH | TOTAL |
| 41 | 283 | 1800 | 873 | 37 | 563 | | 986 | 2272 | 6814 |
| 42 | 243 | 2304 | 290 | 8 | 763 | | 567 | 1859 | 6034 |
| 43 | 0 | 2331 | 59 | 22 | 205 | | 755 | 1356 | 4728 |
| 44 | 179 | 1431 | 482 | 239 | 149 | | 1504 | 1000 | 4984 |
| 45 | 198 | 2372 | 399 | 53 | 399 | | 1540 | 861 | 5822 |
| 46 | 118 | 2257 | 974 | 2320 | 625 | | 1685 | 1830 | 9809 |
| 47 | 47 | 970 | 445 | 3190 | 977 | | 1316 | 952 | 7897 |
| 48 | 47 | 668 | 310 | 3064 | 1664 | | 1185 | 2032 | 8970 |
| 49 | 23 | 296 | 155 | 1754 | 1816 | | 928 | 3651 | 8623 |
| 50 | 15 | 257 | 94 | 595 | 1149 | | 360 | 4407 | 6877 |
| 51 | 34 | 242 | 9 | 255 | 846 | | 380 | 3355 | 5121 |
| 52 | 31 | 271 | 25 | 400 | 1014 | | 532 | 3250 | 5523 |
| 53 | 7 | 88 | 29 | 410 | 607 | | 612 | 2396 | 4149 |
| 54 | 6 | 72 | 89 | 409 | 579 | | 447 | 2119 | 3721 |
| 55 | 0 | 86 | 14 | 176 | 378 | | 326 | 1642 | 2622 |
| 56 | 0 | 82 | 5 | 148 | 283 | | 224 | 1486 | 2228 |
| 57 | 0 | 99 | 7 | 184 | 257 | | 154 | 1263 | 1964 |
| 58 | 0 | 70 | 15 | 170 | 215 | | 137 | 1207 | 1814 |
| 59 | 35 | 32 | 42 | 286 | 282 | | 121 | 653 | 1451 |
| 60 | 23 | 167 | 94 | 367 | 546 | | 194 | 651 | 2072 |
| 61 | 34 | 164 | 76 | 308 | 404 | | 209 | 649 | 1844 |
| 62 | 21 | 138 | 35 | 496 | 417 | | 242 | 631 | 1980 |
| 63 | 11 | 110 | 29 | 324 | 346 | | 252 | 759 | 1831 |
| 64 | 33 | 261 | 51 | 274 | 336 | | 228 | 616 | 1799 |
| 65 | 85 | 226 | 87 | 235 | 365 | | 209 | 757 | 1964 |
| 66 | 181 | 465 | 94 | 495 | 470 | | 469 | 834 | 3008 |
| 67 | 146 | 651 | 93 | 576 | 484 | | 366 | 869 | 3185 |
| 68 | 36 | 421 | 90 | 420 | 524 | | 406 | 1434 | 3331 |
| 69 | 6 | 550 | 30 | 505 | 525 | | 578 | 1941 | 4135 |
| 70 | 107 | 643 | 57 | 683 | 515 | | 1011 | 2243 | 5259 |

Residents of inland towns have limited access to the public clam resource, even though towns with clam ordinances are required to set aside 10 percent of the licenses for sale to non-residents. There is a history of conflict between clammers in towns with plentiful clam resources and clammers from towns with scarce or no clam resources. This conflict has created strong feelings among clammers about fairness and equity of access to the public clam resource, and these feelings continue to influence the management of clams today.

Maine statute and regulations allow clamming year-round. Clamming, however, is seasonal in nature with many areas experiencing most of the total fishing effort during the late spring and summer months. The

**Table 1.**
**(continued)**

| | | | | | COUNTIES | | | | |
|---|---|---|---|---|---|---|---|---|---|
| YEAR | YORK | CUMB | SAG | LINCOLN | KNOX | WALDO | HANCOCK | WASH | TOTAL |
| 71 | 64 | 458 | 21 | 633 | 579 | | 947 | 2548 | 5250 |
| 72 | 103 | 463 | 19 | 689 | 543 | | 1578 | 2748 | 6143 |
| 73 | 69 | 495 | 16 | 852 | 764 | | 2383 | 2682 | 7261 |
| 74 | 37 | 276 | 5 | 550 | 624 | | 1792 | 2619 | 5903 |
| 75 | 26 | 496 | 17 | 768 | 1022 | | 1743 | 2675 | 6747 |
| 76 | 43 | 430 | 13 | 996 | 839 | | 2218 | 2830 | 7369 |
| 77 | 15 | 296 | 166 | 544 | 857 | | 2096 | 3661 | 7635 |
| 78 | 212 | 653 | 86 | 429 | 567 | | 1494 | 2567 | 6008 |
| 79 | 32 | 309 | 64 | 335 | 380 | | 1356 | 2718 | 5194 |
| 80 | 7 | 592 | 28 | 465 | 606 | | 1077 | 2902 | 5677 |
| 81 | 5 | 489 | 55 | 644 | 847 | 15 | 1049 | 2085 | 5189 |
| 82 | 9 | 789 | 33 | 378 | 868 | 20 | 1028 | 3595 | 6720 |
| 83 | 3 | 916 | 25 | 450 | 944 | 15 | 869 | 2514 | 5736 |
| 84 | 0 | 540 | 37 | 650 | 932 | | 644 | 2395 | 5198 |
| 85 | 4 | 566 | 2 | 629 | 592 | 28 | 559 | 1861 | 4241 |
| 86 | 29 | 519 | 21 | 484 | 252 | 25 | 482 | 1573 | 3385 |
| 87 | 6 | 410 | 4 | 474 | 276 | 4 | 287 | 1185 | 2646 |
| 88 | 3 | 454 | 18 | 546 | 331 | 25 | 269 | 664 | 2310 |
| 89 | 5 | 467 | 88 | 442 | 314 | 25 | 179 | 984 | 2586 |
| 90 | 4 | 611 | 39 | 415 | 241 | 0 | 301 | 854 | 2518 |
| 91 | 0 | 458 | 56 | 402 | 133 | 0 | 86 | 355 | 1546 |
| 92 | 61 | 645 | 138 | 690 | 162 | 0 | 68 | 437 | 2201 |
| 93 | 0 | 727 | 110 | 811 | 110 | 1 | 75 | 359 | 2193 |
| 94 | 7 | 795 | 97 | 780 | 210 | 0 | 153 | 396 | 2438 |
| 95 | 1 | 482 | 114 | 501 | 206 | 0 | 89 | 474 | 1866 |
| 96 | 37 | 462 | 98 | 375 | 81 | 0 | 83 | 421 | 1558 |
| AVE.LBS | 49 | 595 | 115 | 595 | 553 | | 729 | 1733 | [illegible] |
| AVE.BU | 3.5 | 39.7 | 7.6 | 39.6 | 39.9 | | 48 | 115 | [illegible] |

Source: NATIONAL MARINE FISHERIES SERVICE and Assessment and Statistics Div. ME DMR.
Data arranged by W.S. Foster, Assessment and Statistics Div. ME DMR.

opening of the Maine sea urchin fishery in September entices many clammers to leave the flats as the market price for clams drops with the end of the summer tourist season. This seasonal shift of clamming effort varies from one community to another, and, regionally, it depends on the local employment options available to clammers.

## • The Need for Management

Clam landings and numbers of licensed commercial harvesters have declined since the early 1980s. Statewide, clam populations are at historic lows and commercial landings have decreased by 75 percent since the high production years of the 1970s and early 1980s (Fig. 1). As an example of the decline, the average number of bushels of clams harvested in eastern Maine each year during the period from 1972 to 1982 was 296,000. The average number of bushels harvested in eastern Maine from 1990 to 1994 was 40,000. This difference represents an 86 percent decline in landings.

Over 4,000 clam harvester and processing jobs worth at least $20 million have disappeared from Maine's coastal communities since the mid-1980s. Coastal Washington and Hancock County communities have been the hardest hit. Landings in Washington and Hancock counties have dropped from 45 to 60 percent of the state total, to less than 25 percent in the past 20 years. While the exact causes of the decline are unknown, natural factors—such as lack of wild set and predation—and overharvesting have contributed to the loss of landings.

Local clam management programs can increase the sustainable harvest of area clam flats. In 1985, Ralph Townsend, a natural resource economist at the University of Maine, concluded that managed flats typically produce 15 percent more clams than unmanaged flats. Furthermore, a 1993 Maine Aquaculture Innovation Center report, "An Evaluation of Strategies to Restore *Mya arenaria* Production in Maine," concludes that "Restoration efforts must progress hand-in-hand with the development of more sophisticated local management."

## • Municipal and State Responsibilities: A Community Co-managed Fishery

The soft-shell clam fishery is unique among Maine fisheries because management authority over the resource has been shared or co-managed between the state and communities for more than 170 years. In 1821, one year after Maine separated from Massachusetts and became a state, the Maine legislature granted coastal municipalities the authority to issue permits for taking shellfish and imposed a standard penalty for violation of the permit conditions. "Private and Special Laws" for particular towns were passed by the Maine legislature from 1895 until 1963 and continued the tradition of shared responsibility for clam management. In 1962, 78 of the 105 coastal towns had such laws. In 1963, the

> The section in this handbook on the Georges River regional clam management program (page 21) and the Phippsburg clam management program (page 19) discusses two specific "bottom-up" clam co-management programs being tried in Maine. In a co-management model for a local soft-shell clam fishery, all stakeholders are actively and fairly represented, including resident and non-resident harvesters and the non-clamming public as well as representatives of the Maine Department of Marine Resources (DMR).

Maine State Legislature passed legislation which permitted towns to establish local ordinances regulating the harvest of soft-shell clams.

Traditionally, the Maine clam fishery has relied on top-down co-management with authority shared equally between the State and coastal municipalities. In exchange for this management authority granted by the State, towns accept enforcement and other specific management responsibilities, thus relieving the State of these duties and related costs.

- **The State Role**

State involvement in clam management includes regulatory control through regulations written by the Maine DMR and statutory control through laws written and passed by the Maine State Legislature.

The DMR and the Maine Legislature manage the soft-shell clam fishery as a wild resource in trust for the people of the state. While landowners along the shore own the flats to the low-tide mark (or 1,650 feet from the high-tide mark in areas of extensive intertidal flats), the public has the right to access the shore for fishing, fowling, or navigation purposes. The public can also use private shorelands for skating, salt-ice cutting, mooring boats, and worm and shellfish digging. The people of Maine own the submerged lands below low tide and the waters. These rights were established by the Colonial Ordinance enacted by the Massachusetts Bay Colony in the 1640s, and they were legally adopted by Maine when it became a state in 1820.

State fishery laws are passed by the Maine Legislature and regulations are written and enforced by the DMR. The Joint Standing Committee on Marine Resources reviews all proposed legislation related to marine resources. Proposed legislation affecting clam management legislation is presented to this committee for their review and recommendation to the full Legislature.

Maine law requires commercial clam harvesters to purchase a state shellfish license and to limit the harvest of soft-shell clams to animals over two inches in shell length (with a 10 percent tolerance per bushel). Maine DMR regulations detail the standards that local shellfish ordinances must meet in order to be approved. With these statewide standards, the DMR oversees local municipal clam management programs. Most of the regulations concerning shellfish management are detailed in chapters four and seven of the DMR regulations. The regulations are included in a Compilation of Shellfish Laws and Regulations, available from state Marine Patrol Officers and DMR offices.

The DMR offers clam management assistance to municipalities with shellfish management ordinances. Three regional biologists advise communities with shellfish management programs along the Maine coast. They offer assistance with clam population surveys, stock assessment, predator control, and restoration efforts. Marine Patrol officers of the DMR enforce state laws such as the two-inch minimum-size restriction and prohibition of harvesting from closed (restricted) areas. Towns with clam ordinances are responsible for enforcement of their own local regulations.

The DMR also has responsibility to protect the public from contaminated shellfish. To protect public health, the federal Food and Drug Administration's (FDA) National Shellfish Sanitation Program establishes water quality standards that shellfish-growing areas must meet if shippers from one state wish to transport and sell shellfish in another state. With the assistance of many local water quality monitoring groups, the DMR works to fulfill the mandates of the federal program by 1) sampling and analyzing water in shellfish-growing areas for bacteria and 2) surveying shorelines of growing areas to identify pollution sources. Following this process, the DMR then classifies shellfish-growing areas based on these water quality tests.

In addition, the DMR also tests shellfish species for the presence of paralytic shellfish poison (PSP) from toxic dinoflagellates (phytoplankton known as "red tide"). The DMR has the authority to close areas to shellfish harvesting because of pollution or red tide and to embargo shellfish products when the public health is endangered. Shucking and packing houses, as well as the facilities and trucks of shellfish shippers, are also inspected by the DMR.

## • Town Role

Coastal towns in Maine have a long tradition of community involvement in clam management. Diverse approaches to clam management have evolved that reflect the particular social, economic, and political characteristics of each community. Maine municipalities can have a shellfish management program with or without a local ordinance. In 1997, all towns with shellfish management programs also had local shellfish ordinances.

• *Town Jurisdiction Over Other Shellfish Species*

State law permits towns to assume management of shellfish stocks other than soft-shell clams, such as oysters (*Crassostrea virginica*) and quahogs (*Mercenaria mercenaria*) except for mahoghany quahogs (*Artica islandica*) within intertidal areas of the town. A town's shellfish ordinance can cover several species provided that the town has DMR-approved management plans for each species. The Town of Brunswick, for example, manages intertidal European oyster stocks as well as soft-shell clams and quahogs.

• *Areas without Local Clam Ordinances*

About half the coastal municipalities in Maine choose not to manage clams and leave clam management up to the DMR and the state legislature. These towns either lack sufficient commercial clam resources or prefer to leave access to the fishery open and assume no local management responsibilities. The Marine Patrol of the DMR enforces state shellfish laws and regulations in these areas.

• *The Maine Soft-shell Clam Advisory Council*

In 1997, the first Maine Soft-shell Clam Advisory Council (MSSCAC) was formed as a direct result of the efforts by working groups formed at two statewide conferences on improving municipal clam management. These conferences and work groups were a collaborative effort of clammers, state agencies, and non-profit organizations. Responding to the request from this effort for a clam council, the DMR Commissioner authorized formation of the Clam Council.

The purpose of the Council is to provide a forum where issues and policies relating to soft-shell clam management can be discussed openly and freely among all stakeholders. The objectives of the MSSCAC are to collect information at the local level, recommend policy, and redistribute information back to the local level.

The MSSCAC provides a forum for problem solving that has not existed previously in the Maine clam fishery. The MSSCAC is also responsible for organizing the "clam management day" at the Maine Fishermen's Forum with updates on improvements in clam management. In addition, the MSSCAC is charged with improving the marketing of clams and helping set priorities for scientific research.

For more information about the MSSCAC, contact the Maine Department of Marine Resources at 207-624-6550.

# Chapter 2. Establishing a Local Shellfish Management Program

The Maine clam fishery has followed typical "boom-and-bust" landings cycles, and natural ecological factors appear to have overshadowed human efforts to establish predictable and sustainable clam production. Consequently, Maine's 40-year effort in local clam management has given us much information about the challenges of managing the resource.

One of the challenges of clam management is the traditional public attitude toward the fishery from both industry-insiders and the general public. Until recently, the clam resource was considered "the employer of last resort," and many coastal and inland residents still consider clam harvesting a source of income they can fall back on if other employment fails.

In fact, many municipal programs in Maine seek to manage the local clam resources in order to provide a living wage to as many harvesters as possible. Other goals are to provide recreational clamming opportunities for residents, provide incentives for the removal of overboard discharges (OBDs) into marine waters, or simply maintain the clam resource.

## Implementing a Community Clam Management Plan

Effective design and implementation of a community clam management plan depends on integrating the social and economic information about clam fishery participants with scientific information about the clam population and habitat.

The clam fishery of each municipality or group of towns has unique social and economic characteristics which must be understood before effective clam management policies can be created at the local level. These characteristics may include:

- social and economic characteristics of fishery participants
- number of commercial and recreational harvesters (current and historic)
- number of full-time 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 of harvester production daily, monthly, and annually, including numbers of "powerful diggers" (high liners)
- number of commercial clam buyers (wholesale and retail)
- current market conditions, including price and demand
- estimates of effects of market changes on fishing effort
- seasonal shifts of clammers to other fisheries

Clam management efforts need to use scientific information about the biological status of the clam population within the management area. Basic biological information includes:

- standing crop estimates based on population surveys
- recruitment of "young of the year" clams into the population
- landings data, including individual harvester hod surveys and flat-specific total landings data by the week, month, and year.

Although many clam harvesters have little contact with municipally-appointed shellfish management committees, they should try to include themselves in local management decisions. In the long run, sustainable, stewardship-based clam management requires active participation in decision making by clam harvesters.

## Maintaining Sustainable Harvests: The Challenge of Clam Management

Communities can develop effective clam management programs, and the following steps are typically taken by most clam management efforts.

### Step 1. Build Support: Identify Incentives for Local Management

Managing shellfish resources at the local level requires commitment by many individuals and funding. Communities are motivated to undertake shellfish management for many reasons.

Often towns adopt municipal ordinances to protect their stocks of clams from intensive harvesting by large numbers of both resident and non-resident clammers. Without the adoption of local municipal ordinances restricting access, all state-licensed commercial clammers (and recreational diggers who dig less than one bushel per day) can access flats within a town. The adoption of ordinances by neighboring towns may produce a "domino effect" in which towns without ordinances feel they need their own ordinance to protect their town flats from neighbors who have legally excluded them.

A sudden decline in the wild clam supply, a desire to control access to the resource, and public health closures of clam flats may set up local "crisis" conditions that favor the adoption of a municipal clam management ordinance in a coastal town.

When clams are naturally scarce and relatively small areas of productive flats are ready to be reclassified or "opened" or market prices for clams are high, harvesters and municipalities see an obvious advantage to trying the local management option, because it protects suddenly vulnerable local clam populations from harvesters outside the town area.

In some coastal communities, clam flats have long been recognized as economic resources, providing millions of dollars over the years in earnings to local diggers and the local economy. Because of the value of the flats in Maquoit and Middle Bays, Brunswick has had a clam management ordinance since 1964. In 1989, the Town of Brunswick estimated the value of their clam resources and realized that they had a nearly $2 million-a-year industry in their midst. Brunswick recently passed land-use controls designed to protect the coastal water quality essential to the survival of the soft-shell clam industry.

Clam population surveys and economic assessments of the wild clam resource may help build public support for local shellfish management ordinances. Often the threat of losing the clam resource to oil spills or other catastrophic pollution events provides additional incentive for economic assessments. Population surveys provide scientific samples of flats to estimate stocks of clams, while economic assessments estimate the total value of the clam resource to the local economy based on current market conditions at the time of the survey. See Chapter 4, "Clam Management Toolbox," for details on population surveys.

Whatever the initial motivation, the adoption of a clam management ordinance and accompanying program allows a town to manage the clam resources within its boundaries as a sustainable resource, while providing employment to diggers and recreational digging opportunities for residents.

## Step 2. Create & Keep a 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 soft-shell clam management programs are directed by dedicated community volunteers. Sustaining an effective volunteer Shellfish Management Committee is one of the major challenges facing a municipal clam management program.

The commercial and recreational harvesters have the most to gain and the most to lose from the success or failure of any community clam management program. A local clammers' association may serve as a key source of ideas and volunteer energy to run the clam management program over the long term. At minimum, an informal mailing list of clam harvesters can be used to keep in touch with the harvesting community, alert them of changes to the clam management program, and/or solicit help with seeding and other flat stewardship efforts.

Often, volunteer committees are energized by "key" individuals—selectmen, harvesters, or members of the general public—who provide leadership and many hours of volunteer time to run the clam management program. Without them, the programs often languish. In some towns, the clam harvesters participate in making management decisions as members of the shellfish committee and are involved in management activities, such as stock surveys and re-seeding projects.

It is important to maintain communication between municipal officers and the shellfish committee. The shellfish committee must be supported and guided by municipal government officers and staff, so the committee chair needs to check in with members and selectmen from time to time. The shellfish warden should also attend all meetings and report his or her activities. In addition, newsletters help create group solidarity and keep everyone informed about committee activities and events.

## Step 3. Develop a Shellfish Management Plan/Clam Ordinance

Once a shellfish committee is established, one of the first tasks is usually the development of a shellfish management plan. These plans usually include an inventory or description of the shellfish resource, a statement of general goals, and a description of what steps will be taken to accomplish the goals. The description of the clam resource should include:

- a description of the current status of shellfish harvesting in the area
- surveys of the clam populations, and
- interviews with harvesters (more on inventories in Chapter 4).

Management goals may include, for example, the reopening of certain closed flats or the improvement of the wild clam population in another flat to allow increased harvests. Additional goals may involve obtaining projections for number of bushels of clams harvested per year, number of licenses issued for commercial and recreational harvesters, and number of flats open for shellfishing. Others goals may include the removal of pollution sources that close certain flats, and providing a certain level of employment in the local clam fishery. The plan needs to describe how goals will be achieved by detailing specific actions that need to be undertaken, a timetable, and estimated costs.

Maine DMR biologists are available to assist with the development of a shellfish management plan. Chapters 1 and 4 describe general requirements for local shellfish programs and ordinances. Chapter 1 outlines DMR management goals for shellfish management plans and management measures.

## Step 4. Establish Funding

Adequate funding of a shellfish program will increase the program's likelihood of success. Among the possible expenses for a shellfish program are the shellfish warden's salary (full- or part-time), the

*The following are examples of responsibilities that can be overseen by the shellfish committee:*

- monitor water quality conditions in cooperation with DMR staff, local water monitoring volunteer groups, and municipal employees
- assess clam population using all available resources—scientific surveys, landings data, anecdotal reports of abundance, and size distribution
- hire and help supervise a professional shellfish warden
- plan and fund a budget for all program operations
- purchase and maintain equipment
- supervise and organize volunteers to maximize use of their time
- enhance wild clam populations with cultured and/or wild seed
- successfully resolve conflicts with other resource-user groups
- maintain public access to the flats
- seek technical assistance from resources within the community or state
- network with other municipal clam management programs
- determine numbers and categories of commercial and recreational licenses
- develop a specific clam management plan

purchase of seed for restocking flats, the warden's boat expenses, and costs associated with water quality monitoring and clam flat assessment.

Some towns rely solely on the income from shellfish license (recreational and commercial) fees and ordinance violation fines to fund the expenses of a shellfish program. Other towns allot considerably more resources. For example, the 1997 budget for the Town of Harpswell included approximately $83,000 for shellfish management as well as an additional $8,000 for shoreline surveys and water quality testing program. Of the $83,000 for shellfish management, about $50,000 was allocated from general funds. Of the remaining $33,000, $15,000 was carried forward from the previous year, $10,000 was generated from license fees, and $7,000 from collection of fines.

Local seafood dealers and related businesses have stepped forward in some towns to provide funding for their clam management programs. Undoubtedly, the success of the management program directly benefits those businesses.

### Sample Budget for Clamville, Maine

| | |
|---|---|
| Income: | |
| License sales | |
| (10 recreational licenses @ $30, 60 @ $100) | $6,300 |
| Town budget appropriation | $10,000 |
| Shellfish fines collected | $800 |
| 50 percent of boat excise taxes | $1,700 |
| Grant from Shore Stewards Partnership for water quality monitoring | $2,000 |
| Total: $21,500 | |
| Expenses: | |
| Part-time shellfish warden (16hrs/wk @$10/hr) | $8,320 |
| Contribution to health insurance for warden | $1,000 |
| Town boat expenses | $1,500 |
| Seed Clams purchased for Broad Cove Restoration Project | $1,000 |
| Netting to protect clams | $250 |
| Total: $11,670 | |

## Step 5. Craft a Shellfish Ordinance/ Management Plan

If a town (or group of towns) has allocated money for a shellfish management program within the previous two years and obtained approval of the Commissioner of Marine Resources for its specific program, the municipality can adopt a clam management ordinance which allows the town (or towns) to:

- issue municipal shellfish harvesting licenses
- establish qualifications, application, and fees for the town shellfish harvesting licenses (non-residents/ resident categories)
- regulate or prohibit the possession of shellfish within the municipal boundaries
- set limits on the amount of soft-shell clams harvested
- provide for and evaluate the effectiveness of a green crab fencing program
- open and close flats to the harvest of clams
- regulate the time of harvesting
- transplant wild seed or plant hatchery seed for stock enhancement efforts

*The local shellfish ordinance*

At minimum, local ordinances must include provisions for periodic clam surveys and an annual report to the DMR, summarizing the status of the clam resource, which is used to justify the number of shellfish licenses allocated.

The DMR makes available a model shellfish ordinance which may be used and amended by a municipality. The model ordinance includes the minimum criteria for a shellfish management ordinance. Many towns use the model ordinance as a framework on which to build an ordinance that suits local conditions. The DMR Commissioner must approve a shellfish management ordinance before it is adopted by the town. Town ordinances, management plans, and programs are reviewed every three years by the DMR Commissioner. In practice, however, shellfish ordinances and programs are rarely revoked.

*Determining the number of licenses*

Clam management committees annually allocate clam resources by determining the number of licenses to be issued. License numbers are, at best, based on estimates of the volume of harvestable clams in a given area. In towns with minimal town funding of clam management programs, license allocations and fees tend to be based more on economic needs of the clammers and less on the biological status of the clam resource. In these towns, licenses are allocated to residents and nonresidents, based on the numbers of harvesters in the town from previous years and other local conditions. State law (as of 1990) requires that at least 10 percent of the shellfish licenses issued by a town be issued to non-residents.

## Step 6. How to Enforce the Local Ordinance

Enforcement of local clam laws was the responsibility of the state until 1959 when the Legislature shifted enforcement responsibility to the towns. State regulations require towns to enforce their own town shellfish ordinance if they adopt one. The DMR Commissioner can revoke a local shellfish ordinance if the town fails to provide for enforcement. Towns may choose to hire a shellfish warden, either in cooperation with a neighboring town or on their own.

*Changes in shoreline ownership over the past several decades have limited clam harvesters' access to the flats. (Photo: Maine Coastal Program)*

*Municipal shellfish warden*

Finding and keeping a municipal shellfish warden is often one of the most difficult parts of running a successful clam management program. Candidates with law enforcement experience often use the municipal warden's position as a career advancement step up into a local police, county sheriff, or DMR position. Therefore, salary and benefits must be competitive with these other employers to attract and keep a top-quality professional warden.

The ideal municipal shellfish warden has a background and personal interest in both the law enforcement and clam management aspects of the job. There is a wide range of expectations and job descriptions for local municipal wardens. Specific qualifications and a job description need to be written by each municipality based on its actual program and needs.

A two-day Municipal Warden Training program offered by the DMR provides both law enforcement and clam management training. The DMR also has a certification program for shellfish wardens, which may encourage an enhanced level of competence and professionalism for these important positions.

Marine Patrol Officers (MPO) enforce regulations on clam harvesting in classified areas. The regulations allow no harvesting of any kind in state-designated "Prohibited" areas and depuration harvesting only in "Restricted" areas. In "Approved" areas, where harvesting is allowed, MPO's enforce the two-inch minimum size and the state commercial license requirement. They are not required to enforce any municipal regulations such as possession of town licenses or compliance with specific restrictions on harvesting effort.

It benefits a municipal clam management program if the municipal shellfish warden and the MPO assigned to the area are able to work effectively together. Efforts should be made to foster good communication and build a working relationship between the two officers. Ideally, the town shellfish warden should be able to rely on support from a local town police officer or sheriff's deputy who has been cross-trained in shellfish enforcement duty. More specific and up-to-date information on both Marine Patrol and Municipal Shellfish Warden responsibilities can be obtained from the DMR.

## Step 7. Maintain Access to Flats

Residents of the State of Maine have long enjoyed a tradition of public access over public land. In many coastal areas, well-worn paths leading from town roads to the tidal flats have provided access for recreational and commercial clammers and for others wishing to access the coast. As coastal properties escalate in price and change ownership, traditional accessways and shortcuts to the shore are occasionally blocked with "No Trespassing" signs.

Clammers often depend on these traditional access routes, and clam management committees can help to establish informal or formal agreements with landowners to allow continued use. For example, the towns cooperating to manage clams in the Damariscotta River area recently inventoried shore paths and posted shellfish regulations at the head of each path. The shellfish warden, working with the committee contacted the landowners and tried to address their concerns. The most common concern voiced by landowners was that litter was left on their property from visitors.

Towns may actually own right-of-ways to the shore that have been forgotten over the years. The Maine State Planning Office/Maine Coastal Program provides small grants to towns to investigate their legal title to historical right-of-ways.

# Chapter 3. Clam Management Programs in Maine

In 1997, 56 coastal towns in Maine managed their local shellfish resources with a municipal ordinance. Table 2 lists Maine towns with clam ordinances and wardens.

**Table 2.**

**Maine Towns with Clam Ordinances and Wardens**

Washington County:
Addison
Beals
Cutler
East Machias
Eastport
Edmunds/Trescott
Harrington
Jonesboro
Jonesport
Lubec
Machiasport
Pembroke
Perry
Roque Bluffs
Steuben
Whiting

Hancock County:
Bar Harbor
Brooklin
Surry
Swans Island

Waldo County:
Islesboro
Searsport

Knox County:
Cushing
Friendship
Rockport
South Thomaston
St. George
Thomaston
Warren

Lincoln County:
Bremen
Bristol
Boothbay
Boothbay Harbor
Damariscotta
Edgecomb
Newcastle
South Bristol
Waldoboro
Wiscasset
Westport

Sagadahoc County:
Georgetown
Phippsburg
Woolwich
West Bath

Cumberland County:
Brunswick
Cumberland
Falmouth
Freeport
Harpswell
Scarborough
Yarmouth
North Yarmouth (no warden)

York County:
Kennebunkport
Kittery (no warden)
Ogunquit
Wells
York

## • Municipal Programs (Town-funded; some professional management)

Programs that hire both clam management and enforcement expertise require substantial funding beyond the income derived from license sales and fines for violation of the ordinance. Maine towns typically spend under $50,000 per year on clam management programs. In contrast, coastal towns in Massachusetts typically budget $200,000 to $500,000 annually for their municipal shellfish management programs, which usually involve management of several shellfish species.

Several southern Maine coastal towns fund clam management programs with municipal funds, supplemented by monies from grants, license fees, and collected fines. The volunteer shellfish management committee, appointed by the municipal officers, works with a professional manager and shellfish warden to manage the area's clam resources. Scientific information about the clam resource may be collected by a professional consultant hired to survey a specific area. These towns periodically assess and publicize the value of the clam resource to the local economy in order to maintain continued taxpayer support for the clam management program. Towns with centralized, municipally funded clam management programs include Harpswell, Freeport, Scarborough, and Brunswick.

### Brunswick

Brunswick's clam management program is often cited as the best in Maine. A volunteer Marine Resources Committee, appointed by the city government, works with a natural resources planner and a part-time and full-time shellfish warden. Management tools used by Brunswick include management closures of specific flats, closed seasons, reseeding flats with hatchery seed, and surveys of estimated commercial standing crop and harvester effort. There were 69 commercial clam licenses issued in 1997.

### Freeport

The town of Freeport manages its clam resource with a shellfish program coordinator, a part-time municipal employee who works with the Freeport Shellfish Commission. Population surveys are performed by a consulting firm which conducts surveys and resource enhancement studies with the volunteer assistance of Freeport harvesters. The Freeport shellfish ordinance requires license holders to spend volunteer time in resource assessment and enhancement activities. Harvesting effort is controlled by varying license numbers, according to recommendations of a professional biologist/consultant. In 1997, 59 commercial licenses were issued, including six issued to non-residents.

## • Municipal Programs (Self-supporting)

Most Maine towns with shellfish ordinances have clam management programs run by a municipally-appointed volunteer shellfish committee, and minimal general town funds are budgeted for operating the program. Funding comes from grants, license fees and fines collected for violations, or private sources.

A professional shellfish warden is hired primarily for enforcement and may or may not perform any stock assessment or enhancement work. Most or all management activities are done by volunteers. Harvesters often do stock assessment or stock enhancement work as part of their qualification for a commercial license. East of the Kennebec River, the Maine coastal towns with municipal clam management ordinances (as of 1997) all run clam management programs with minimal funds.

### Phippsburg

Phippsburg manages its clam resource with a volunteer Shellfish Committee under the active leadership of one "key" harvester. Phippsburg clammers actively participate in decision making at their monthly shellfish committee meetings. These meetings are regularly attended by most licensed clammers.

The committee focuses most of their management efforts on an aggressive re-seeding program using wild seed. This effort is carried out by commercial harvester volunteers and specific re-seeding time requirements for licensing are written into the Phippsburg shellfish ordinance. Management closures of specific flats are used as management tools. In 1997, 35 five commercial licenses were issued.

## • Shared Access among Towns with Reciprocal Agreements

Formal, written interlocal agreements on clam management, describing the details of administration and sharing of tasks, common property ownership, and withdrawal procedures, are usually not attempted by towns and are seldom used to strengthen the reciprocal harvest arrangement.

Graphic Omitted

(Figure: Maine Coastal Program)

To maintain the traditional mobility of the clam fishery, clammers often have urged their municipality to arrange reciprocal harvesting agreements with neighboring towns. Under such an agreement, the municipal license from the resident's town is honored by the other town(s) in the agreement. Often this is accomplished by simply writing the reciprocating towns' names into each municipal ordinance to sanction shared harvesting rights.

Traditionally, towns have been able to share harvesting rights, but they have been much less successful sharing resource management responsibilities. Prior to 1996, towns with reciprocal harvesting agreements were required by statute to operate separate Shellfish Management Committees for each town. With separate shellfish management committees, each municipality could run its clam management program differently than its neighbors, while they attempted to equally share a common resource and the responsibilities of management over a multi-town area.

Statute changes in 1996, initiated by the Georges River Clam Project, allow several towns to cooperate in regional management by forming a single regional shellfish management committee with equal representation from each municipality. This allows a single, regional management plan with management practices applied uniformly to the whole regional habitat and clam resource (see section on Georges River on page 21).

## Damariscotta River Regional Management Program

Five municipalities—Boothbay, Boothbay Harbor, Damariscotta, Edgecomb, and Newcastle—share their clam resources on the Damariscotta River estuary through reciprocal harvesting agreements included in each town's clam management ordinance, adopted independently by each town in 1991.

The clam management program is administered solely by a designated "lead town" which in 1998 was Newcastle. A Newcastle selectman and a Regional Shellfish Committee, with representation from each of the five municipalities, oversee administration of the program, and a shellfish warden is hired on a part-time basis. Population surveys and re-seeding efforts are carried out, while bushel limits and management closures are also used as management tools. Each municipality determines and issues its own number of commercial licenses using a uniform fee schedule for the five towns. A total of 141 commercial licenses were issued in 1997.

## • Cooperative Management

### Georges River Clam Project (formal interlocal agreement)

In June 1996, the Joint Board and the Shellfish Management Committee created the Georges River Shellfish Management Plan, which defines and describes management actions that can be taken to prevent overfishing.

Five municipalities—Cushing, Warren, Thomaston, South Thomaston, and St. George—share and manage their clam resources on the St. George River estuary with a written interlocal agreement adopted by each town's voters. The interlocal agreement formalizes the administrative procedures and is intended to minimize conflict between towns over management issues. In 1996, a five-member Joint Board of Selectmen was formed to serve as the legal entity administering the interlocal agreement.

One town acts as the "administrative town," handling the funds, keeping the financial records, hiring the shellfish warden, and owning any common property for the purposes of licensing and insurance liability. The program is funded by license sales, grants, fines, and fundraising activities.

Daily clam management decisions are made by the Georges River Shellfish Management Committee, with three commercial harvester representatives from each of the five towns. A full-time shellfish warden is employed to work with the committee on stock assessment and enhancement activities, as well as enforce shellfish laws and regulations. The Georges River Clammers' Association has approximately 50 members, and this informal local harvesters association provides a source of volunteers to serve on the Shellfish Management Committee.

The University of Maine Cooperative Extension (UMCE)provided start-up facilitation for the Georges River regional clam management program and continues to serve in an advisory capacity to the Shellfish Management Committee and the Joint Board. Future changes to the management plan may involve setting specific production goals and modifying the definition of overfishing. In July 1996, 128 commercial clam licenses were issued.

### Cobscook Bay Clam Restoration Project

In easternmost Washington County, nine municipalities share the shores of Cobscook Bay: Lubec, Trescott, Whiting, Edmunds, Dennysville, Pembroke, Perry, Pleasant Point, and Eastport. With the facilitation and coordination of The Cobscook Bay Clam Restoration Project, these towns are managing their clam resources. Begun in 1995, the Clam Project addresses the decline in the local clam industry by targeting four broad goals: 1) to improve the health of Cobscook Bay,

2) to increase productivity of the flats, 3) to create a regional approach to clam management, and 4) to increase access to education in resource management.

A regional newsletter, Cobscook Clam News, is produced by the Cobscook Bay Clam Restoration Project for networking and building a regional identity around the clam fishery. All nine communities, including those two without shellfish ordinances or committees, participated in re-seeding efforts in 1995, using both wild and cultured seed. Over 2,000 acres of flats were reclassified "Approved" for open harvesting in 1996. In addition, a clam management plan was written for all Eastport flats.

The Cobscook Regional Clam Association was created to coordinate clam management around the Cobscook Bay and evolved from cooperation between the Clam Project and the UMCE. This community partnership includes municipal officers, shellfish committee members, wardens, shellfish buyers, and harvesters.

A total of 146 commercial licenses were issued in 1996-1997 for the seven Cobscook Bay towns with municipal shellfish ordinances.

# Chapter 4. Clam Management Toolbox

The following section describes tools for building an effective, sustainable clam management program at the local level. Results should not be expected overnight, since improving sustainable harvests of clams is a slow process that may take three years or longer.

## • Stock Assessment

### Clam Population Surveys

When combined with growth-rate studies, clam surveys may be used to predict future commercial crops for the next year, with indications for possible future harvests. Since wild clam populations are dynamic, a survey is a snapshot estimate of the clam population. Surveys estimate the "standing crop" volumes of legal clams at one time and the size distribution of all clams. One must keep in mind, however, that predation rates are higher for the smaller clams and clams under one inch are mobile and may rapidly appear or disappear from flats unless protected with netting.

Survey information may be used to set license numbers, set production goals for particular flats or the 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 efforts.

### Standard Survey Method

The method described here to survey clam populations in the field is the "best available" at the time of publication. Clam population surveys give scientific information that is helpful in making informed management decisions. Surveys are a waste of time if they are not conducted seriously and with every effort to give credible results or if they are not used as the basis of management decisions.

### *Planning the Survey*

The quality of the survey depends on how carefully all clams are removed and measured. The standard survey method is to remove, count, and measure the length of clams of all sizes from small, representative sample plots in a clam flat and then use this information to estimate the abundance of clams in the entire flat.

Tables have been developed so that the number of bushels of clams per acre can be estimated once the numbers of clams harvested from representative plots are sorted and counted according to size class (Tables 3 and 4).

Sediment type and special features of the flat such as islands, ledges, or drainage channels should be noted and a map of sample plot locations and the extent of the survey made. Use this map to estimate the acreage of the survey area.

**Table 3 . Sample Standing Crop and Size Frequency Calculations**

TOWN: DYERTOWN
FLAT: BACK COVE

DATE: JUNE 23, 1980

TEAM: BEAL AND GRAY
PLOT INTERVAL: 30

PLOT SIZE: 0.2
CLAM LENGTH INTERVALS (mm)

| Plot No. | Sediment | Spat | 15-19 | 20-24 | 25-29 | 30-34 | 35-39 | 40-44 | 45-49 | 50-54 | 55-59 | 60-64 | 65-69 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S | 8 | 3 | 3 | 2 | | 2 | 1 | 1 | 2 | | | 1 | 15 |
| 2 | S | - | 2 | 2 | 2 | | | | | | | | | 6 |
| 3 | S | - | | | | | | | | | | | | 0 |
| 4 | S | - | 3 | 2 | 2 | 8 | 3 | 1 | 1 | | | | | 20 |
| 5 | S | 14 | 5 | | 3 | 9 | | 1 | 1 | | 2 | 2 | 1 | 24 |
| 6 | C | - | 7 | 1 | 7 | 2 | 1 | | | | | | | 18 |
| 7 | C | - | 1 | 2 | 2 | | 2 | 1 | 2 | 2 | 3 | | | 15 |
| 8 | G | - | 1 | 1 | 3 | 5 | 1 | 1 | | 1 | 2 | | | 15 |
| 9 | G | - | 1 | | 2 | 1 | | 1 | | | | | | 5 |
| 10 | S | 3 | 3 | 4 | 1 | | 2 | 1 | | 1 | | | | 12 |
| | | | 26 | 15 | 24 | 25 | 11 | 7 | 5 | 8 | 7 | 1 | 1 | 130 |
| Percent of Total | | | | 20.0 | 11.5 | 18.5 | 19.2 | 8.5 | 5.4 | 3.8 | 6.2 | 5.4 | 0.8 | 0.8 |
| BU/Acre | | | | 14.3 | 18.0 | 53.1 | 92.0 | 62.6 | 58.3 | 58.4 | 126.4 | 145.7 | 26.8 | 33.8 |

Average Density of Clams >40 mm = 442.4 bu/acre/10 plots

= 44.2 bu/acre

For Area of 6 Acres, Standing Crop = 265 bu.

Sediment types: Sand = S, Clay = C, Gravel = G

Sample plots may be located either randomly or systematically. Samples of random plots (the locations determined with a random number table) are taken from the entire flat area and show relative abundance. Systematic sample plots are taken usually at 100-foot intervals, in a measured grid. Systematic sampling is used for standing crop estimates.

For systematic surveys, an initial walk-over of the flat is recommended, with occasional plots dug, so that those areas with virtually no clams can be excluded from the survey. Often the best distance between plots is 30 meters or about 100 feet. For surveys used to estimate standing crop, care is taken to ensure that the size of the area populated by clams is clearly defined on the map or aerial photo.

The numbers and sizes of all clams in each plot are recorded on a data sheet (Table 3). Lengths are recorded in 1/4-inch or 6-mm intervals. Data analysis generally includes calculating a mean population density in bushels per acre and summarizing all length data in a size-frequency distribution graph.

Graphic Omitted

*Town of Yarmouth sampling survey map. (Figure: Brian Beal)*

### *Clam Sampling Tasks*

Ideally the survey team has two surveyors. One person (the digger/measurer) outlines the plot with a screen frame, typically a one-foot-square frame (placed twice), digs up the clams, and measures the sizes of clams in the sample by quickly setting each clam into the corner of the frame where a scale is painted onto the inside corner.

The second person, the recorder, records the number of clams found in each size class and the location of the sample on a map of the shellfish area. With an 100-foot length of rope, either the digger or the recorder then goes to the next sample plot along a transect. To maintain consistency, it is best to have the surveyers maintain one job during the survey and avoid switching tasks.

Surveys may be accomplished by one digger/measurer who collects all the clam samples in pre-labeled, one-gallon poly bags and then measures the clams on shore. Plot numbers should be marked on the bags in advance. This technique saves time on large expansive flats where several people can work along parallel transects.

If only totals are used in the data analysis, there is no need to keep the samples separate. Pace off 100 feet (or another pre-selected distance between plots), dig samples, and then put them in the bucket to be sorted later. Keep track of and record the total number of samples taken.

### *Sample Procedure*

Begin sampling from the landward side of the flat and follow the tide out and then sample back toward shore as the tide comes in.

*Mapping and Other Recorder Tasks*

1. Use a large-scale topographic map (1:6000 scale) or aerial photograph (1:500) for field notes. Aerial photos are available at most town offices and can be reproduced.

2. Carefully record the number of the plot on the map and try to keep the location of the plots accurate by referencing the map and sighting with a compass or head toward landmarks in each traverse of the flats. Locate the first sample site by referencing an obvious landmark.

***IMPORTANT:*** *Before surveying a "prohibited" or "restricted" flat, the DMR area biologist and Marine Patrol officer for the area must be notified and DMR approval obtained in writing.*

Graphic Omitted

*A sampling frame is easy to build and crucial to estimating clam populations. (Photo: Brian Beal)*

3. Align the plots 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.

**The Survey Team**

*Surveys are best performed with a team which at minimum includes a recorder and a digger/measurer. The recorder designates where the samples will be dug; maps the area and location of the plots; records clam lengths, plot size, and distance between plots; records other field observations; and assists in finding all the clams in the sediment sample.*

*Professional survey consultants, shellfish wardens, volunteer harvesters, or community volunteers can be used to perform flat surveys. Maine Department of Marine Resources area biologists can help organize a survey or analyze data and are available for technical assistance.*

*Because commercial clammers are practiced at working fast and seeing legal-size clams, they often must be instructed to find small clams in the sediment when they do a survey.*

*Harvesters bring important practical skills to the survey process. They are familiar with particular flats and hazards such as "honey pots" or deep, watery mud holes that unsuspecting surveyors may step into. Harvesters can provide boats and information about access to the flats. If not actually conducting the surveys, diggers should at least be consulted as advisors. Clam harvesters usually know the relative abundance of clams on specific parts of flats, and they can help in laying out the survey on a map or aerial photo and identifying areas where there are relatively few clams.*

*Citizens are often very willing to help manage a community marine resource. The use of volunteers is being tried in a few clam management programs, and it seems to hold promise.*

4. Measure the distance from the plots high on the shore to the high water mark. Record this distance on the map. This information will be used to define the boundaries and size of the area populated with clams.

5. Record the sediment type at each site—boulder, gravel, sand, silt, or clay. Record landmarks at each site, such as drainages and streams, the width of the clam belt, and other observations. 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 the distribution of the clams. Evidence of predation or shell damage should also be noted.

6. Record the number of clams in each size class per sample.

7. If no clams are found, enter a zero on the data sheet. Take care to count and record all values accurately.

*Digger/Sampler Tasks*

1. Drop the sample frame on the ground at the exact site marked by the measuring line. (Make no effort to place the frame on a visible concentration of clam holes.)

2. 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.

3. Prior to digging the plot, clean the sediment and clams away from the outside of one edge of the plot to make access to the plot easier.

4. Dig all the clams larger than spat 15 mm (5/8 inch) from the sample plot to a depth where no more clams are found. This depth will vary with sediment type and from sample to sample, but should be at least eight inches.

Graphic Omitted

Mya arenaria *(left) and* Macoma balthica *(right). (Figure: Andrea Sulzer, from* A Guide to Common Marine Organisms Along the Coast of Maine*)*

Use the clam hoe to take small slices (approximately 1 inch) from the sample sediment to be sure all clams are found. Commercial harvesters typically will take four-to six-inch slices and are looking only for clams 2 inches and more in length.

5. Measure the clams using the measure on the inside of the screen frame. Call out the measurements to the recorder.

6. Put clams back in sediment and cover to aid survival.

Observations and surveys of the abundance of spat (young clams under 15 mm (5/8 inch) in length) serve to indicate where spat settle from year to year, which flats have the most spat settlement, relative survival rates of clams on different flats, and which flats are the best sources of wild seed for transplanting efforts. The number of soft-shell clam spat should be recorded with approximate location

Graphic Omitted

*Designed by the University of Maine Bio-Resource Engineering Department and the Beals Island Regional Shellfish Hatchery, the dredge uses sprays of water to uncover hidden clams. (Photo: Brian Beal)*

and date sampled. These observations should be collected by the shellfish warden or shellfish committee. After a number of years, the observations and surveys provide a useful profile of the flat.

To specifically sample spat, remove sediment from one-eighth of the plot to an estimated depth of one to two inches and place the sediment in the screen frame. Screen the sediment with water, count the spat and measure, or save the spat in labeled bags for measuring later on shore. Protect spat from the sun and wind. Clams in plastic bags can “cook” if left exposed to the sun.

It is important to measure and count only soft-shell clams (*Mya arenaria*) when sampling spat. Other species of clams may be found in the sediment sample and must be distinguished from the soft-shell clam. The “two-headed” clam (*Macoma balthica*) is a small oval clam that resembles juvenile soft-shell clams. Samplers must be trained to distinguish the two to avoid errors in collecting spat data. A hand lens is useful for distinguishing the two species in the spat samples.

Mechanical hydraulic dredging of seed clams has been done most successfully in sandy sediments. Mechanical-hydraulic dredges have been used in softer mud sediments to collect spat (young-of-the-year clams under 5 mm). Specific information on mechanical dredges can be obtained from the Maine Department of Marine Resources, the University of Maine (School of Engineering Technology), or the Beals Island Regional Shellfish Hatchery.

### *Sampling Clams to Estimate Clam Growth Rates*

Once the clams in a sample are sorted according to size and the size distribution of clams in the flat is known, then growth rates must be determined. This information has implications for shellfish management, since clams on a flat with very slow growth rates might not recover from harvesting as soon as clams in a fast-growing area. Also, areas with fast-growing clams may be more suitable for seeding efforts than slow-growth areas.

Maine DMR area biologists or private professional shellfish biologists can assist with the determination of growth rates.

To establish growth rates, the shell with the hinge projection should be shucked from live clams taken from representative areas of each flat at high-, mid-, and low-tide ranges. Each sample should consist of a “large” clam (2 to 3 inches or 50 to 75 mm); a “medium” clam (1 to 1-1/4 inches or 25 to 30 mm) and a “small” clam (1/2 to 3/4 inch or 13 to 19 mm).

Place the shells in a plastic bag labeled with flat name, plot number, location on the flat, name of town, and date. These shell samples and a copy of the field map are needed to estimate growth. See Appendix III for detailed information on marking and measuring clams for growth rate determinations.

## Estimating Standing Crop

The estimate of the standing crop of clams in a flat is an approximation of the total bushels of clams per acre in the surveyed area. It is important to realize that "standing crop" estimates apply only for the time of the survey and represent a "snapshot" estimate of the clam population which is dynamic and constantly changing. Subsequent growth, harvesting, and natural events can change the numbers substantially.

Take the following steps to estimate standing crop. Maine DMR area biologists can perform or assist with the calculations.

1. For all plots, count and record the total number of clams in each size range. If only totals are used in the data analysis, there is no need to keep the samples separate. Pace off 100 feet (or whatever dis-

**Table 4. Bushels per Acre/Number of Clams per 2 ft.2 Plot.**

| | BUSHELS PER ACRE<br>Number of Clams per 2 ft.2 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 >10 clams per plot in a given length interval, add bu/acre estimates, e.g., for 14, 2.50-2.74 inch clams, 141.4-353.5=494.9 bu/acre or for 26, 1.50-1.74 inch clams, 66+66+82.4=214.4 bu/acre.

tance between plots), dig, and put the samples in the bucket to be sorted later. Keep track of and record the total number of samples taken.

2. Calculate the total number of clams removed in the entire survey (disregard spat).

3. Calculate the percentage of each size class represented, i.e., the total number of one size class divided by the total number of clams measured x 100.

4. Construct a size frequency graph or table (See Table 3 on page 24).

5. Calculate the density of commercial-size clams in bushels per acre for each plot (See Table 4 on page 29).

6. Add density estimates for all plots and divide by the total number of plots to obtain the average density (bushels/acre) of commercial-size clams in the survey area.

7. Calculate total standing crop (bushels) of market-size clams at the time of the survey by multiplying the average density (bushels/acre) by the survey area (in acres).

**Table 5. Size/Volume Conversion**

| Length/Interval | Volume Per Clam (cc) | Number of Clams Per Bushel | Number of Bushels Per Acre* |
|---|---|---|---|
| 15-19 | 1.0 | 36648 | 0.55 |
| 20-24 | 2.1 | 16910 | 1.20 |
| 25-29 | 3.9 | 9148 | 2.21 |
| 30-34 | 6.4 | 5495 | 3.68 |
| 35-39 | 9.9 | 3555 | 5.69 |
| 40-44 | 14.5 | 2430 | 8.33 |
| 45-49 | 20.3 | 1734 | 11.67 |
| 50-54 | 27.5 | 1281 | 15.80 |
| 55-59 | 36.3 | 972 | 20.82 |
| 60-64 | 46.7 | 755 | 26.80 |
| 65-69 | 58.8 | 599 | 33.78 |
| 70-74 | 73.1 | 482 | 41.98 |
| 75-79 | 89.4 | 394 | 51.36 |
| 80-84 | 107.8 | 327 | 61.88 |
| 85-89 | 129.1 | 273 | 74.12 |
| 90-94 | 152.5 | 231 | 87.60 |
| 95-99 | 178.9 | 197 | 102.72 |
| 100-104 | 207.3 | 170 | 119.03 |
| 105-109 | 239.7 | 147 | 137.65 |
| 110-114 | 275.3 | 128 | 158.09 |
| 115-119 | 314.6 | 112 | 180.67 |

*For one clam per $0.2m^2$ plot; for more than one clam, multiply the number in this column times the total number of clams in that length interval.

Graphic Omitted

*(Illustration: Majo Keleshian)*

## Estimating Clam Flat Growth Area

To estimate clam flat growth area, place a sheet of tracing paper with 10 squares to the inch over the scaled map of the entire flat on which the field notes have been transcribed. Then count the squares or portion of squares covering the clam-producing area and record on the map. The area in acres represented by each square is then multiplied by the number of squares recorded. The area represented by the squares is determined by its size relative to the scale of the map.

## Collecting Landings Data

Landings can give information about real production, actual economic value of the local clam resource, relative productivity of specific flats, and fishing-effort levels. Landings information is often hard to collect, complicated by issues of privacy and cooperation. The regulations require all shellfish to be tagged by the harvester with the place of origin noted.

Hod surveys (see sample form below) collect information from harvesters as they return off the flats, and they can be collected by shellfish wardens or

Table 6. Volume Increments

| Initial Size | 1" | 11/4" | 11/2" | 13/4" | 2" | 21/4" | 21/2" | 23/4" | 3" |
|---|---|---|---|---|---|---|---|---|---|
| 1" | - | | | | | | | | |
| 11/4" | 1.96 | - | | | | | | | |
| 11/2" | 3.40 | 1.73 | - | | | | | | |
| 13/4" | 5.41 | 2.76 | 1.59 | - | | | | | |
| 2" | 7.99 | 4.08 | 2.35 | 1.48 | - | | | | |
| 21/4" | 11.41 | 5.82 | 3.36 | 2.11 | 1.43 | - | | | |
| 21/2" | 15.69 | 8.00 | 4.62 | 2.90 | 1.96 | 1.37 | - | | |
| 23/4" | 20.91 | 10.67 | 6.15 | 3.87 | 2.62 | 1.83 | 1.33 | - | |
| 3" | 26.98 | 13.77 | 7.94 | 4.99 | 3.37 | 2.36 | 1.72 | 1.29 | - |

volunteers. Landings from a particular flat can be tracked and used to decide on restricting or prohibiting harvesting effort in an area.

## • Increasing Clam Stocks and Value of the Harvest

### Natural Cycle

Many municipalities in Maine base their entire clam management program on the hope that the plankton will deliver to their flats an abundant supply of post-larval individuals that will metamorphose into juvenile clams. The arrival, survival, and establishment of commercial quantities of young-of-the-year clams on a particular clam flat is essential if good digging is to be maintained from year to year.

The goal of managing clam flats is straightforward: maximize the number of clams that attain harvestable size. This seemingly simple goal requires many insights into the processes and dynamics that influence spawning, larval survival and transport, settlement, recruitment, post-settlement mortality, and growth. Unfortunately, no one completely understands all of these complex processes that involve the interaction of biological as well as environmental factors. One thing is certain: a failure of any of the factors of the life cycle of the clam will result in a failure to produce clams in commercial quantities.

### Worming and Clamming: Does digging of worms or clams have an effect on clam survival and growth?

Clams and worms (both bloodworms and sandworms) co-exist within the mudflats of our coast. These organisms are harvested commercially from flats in a similar manner: both wormers and clammers use short-handled, tined hoes to excavate the sediment to expose the catch. In the process, the small piles of sediment are turned over, leaving the flat with the appearance of a garden that has been plowed or tilled.

The depth to which the mud or sand is turned depends on at least three factors: 1) time of year (organisms generally burrow deeper in fall and winter than in spring and summer), 2) the size of the animals (3-inch clams burrow deeper than 2-inch clams and the same is generally true for worms), and 3) commercial-size sandworms live deeper in the sediments than bloodworms. Therefore, the hoe that a sandworm digger uses has longer tines (9 to 14 inches) and is more similar to a clam hoe than one used by bloodworm digger (tine length of 8 to 10 inches).

At least three investigations since the 1950s have asked the question: "Does clamming affect the survival of clams that are not harvested?" The answer is: Yes! Although direct mortality of clams from hoes or forks varies with sediment type, clam size, clam density, and sediment compaction, these studies concluded that incidental mortality of clams due to harvesting could significantly decrease clam yields.

Recently, numerous shellfish conservation groups in Maine have questioned whether the harvesting of bloodworms has similar indirect and negative effects on clam stocks. A 12-week field study was conducted during the summer of 1996 at an intertidal flat in the town of Brunswick to investigate the effect of blood worming and clam digging on the growth and survival of wild and cultured juvenile soft-shell clams. The study concluded that both types of harvesting can affect the survival of remaining clams by exposing them to predators.

These results indicate that towns that wish to manage the resource must be aware of the effects of predators on small clams even when netting is employed. Secondly, both clamming and worming can be harmful to the survival of small clams. If a community wishes to protect its cultured or wild juveniles, netting should be used and no harvesting beneath the protected areas should be permitted.

## Natural Set Enhancement

Usually, along an estuary or bay, there are certain flats which naturally seem to favor the setting of young clams. In Casco Bay, for example, soft-shell clams generally settle more heavily in the north-northeastern sections of the finger bays, in areas such as Maquoit Bay, Thomas Point Beach, Rich Cove, Orr's Cove, Brickyard Cove, and Upper Middle Bay at Crow Island. Warmer south-facing flats may also encourage settlement of larvae.

For at least the past 75 years, there have been energetic attempts to grow seed clams in selected areas of Maine's bays and coves. The sediment surface of the flats has been modified by turning it over with hoes or plows and by modifying prevailing current flow by placing snow fencing or cut brush onto the flats.

Generally these exercises produce inconclusive results, because their success depends on an abundant supply of larvae or post-settlement clams. Since supply can depend on the size of the spawning stock, predation of larvae and post-settlement juveniles, as well as weather-related effects, it is not surprising that the success of these exercises varies from one year to the next. Enough anecdotal harvester observations exist and continue to be brought up to keep the desire to carry on these activities alive in communities with commercial quantities of soft-shell clams.

Recently, a series of experiments were completed that support the idea that clam seed positively respond to surface or current modification by setting in desired modified areas. One experiment, involving the placement of standardized fence barriers at different tidal heights, demonstrated an increase of clam seed settling in localized "eddy" areas adjacent to the fences.

This may support the observations by harvesters that seed tend to set in well-dug areas and to the creation of many "eddy" areas across the clam flat surface. In another experiment looking at clam seed survival and growth with and without protective netting, natural seed set and survival under the protective netting was three to five times that found in experimental areas without nets. The netted areas were covered with quarter-inch plastic mesh that was buoyed off the sediment with small toggle floats when the tide covered them.

This netting configuration has been observed to accumulate sediment over time. This suggests that those conditions that allow sediment to settle also influence clam seed to settle, grow, and burrow into the sediment. The presence of the netting prevents much of the predation which occurs on open flats and may provide small microscopic clams with protection from scouring waves and currents.

Collectively, these recent experiments strongly indicate that natural clam seed can be influenced to set and grow in specified locations. What is now needed are additional trials to refine the manipulations in order to make their application in a larger setting both practical and economical.

## Clam Pounding

For many years, the Maine lobster industry has used lobster pounds to stockpile lobsters when prices are especially low in the fall. The lobsters are held in these tidal impoundments into the winter when trapping effort is much reduced. As wintertime prices for lobsters increase, the stockpiled lobsters are sold from the pounds at a profit. This pound industry provides jobs and product stability in the marketplace.

The same technique has been proposed for the clam industry and recently tested in the Jonesport and Wiscasset areas. Traditionally, clammers experience low prices in the spring. As demand increases over the summer, the price per bushel typically rises between 100 and 150 percent of the winter market price. Small-scale trials involving approximately 20 bushels of market-size clams placed back in the flats, either in wire cages or under protective netting, have demonstrated that greater than 90 percent can survive from April to August.

## Depuration Digging

Depuration clam harvesting is strictly regulated by the DMR to protect public health. A processing facility called a "depuration plant" is licensed to hold and treat clams from mildly polluted shellfish growing areas classified "restricted" by DMR's Shellfish Sanitation Program. Clams harvested by special crews under strict supervision of Marine Patrol Officers are held in an ultraviolet-treated, flowing seawater system which kills pathogens flushed from the clams' digestive systems. Testing of the water and meats is required to assure that public health is protected.

Depuration digging can be a contentious issue because it allows outsiders or non-residents to take clams in large quantities from local flats closed for public health reasons. Municipal officials and clammers often oppose depuration digging particularly if water quality improvements seem imminent, which would allow the DMR to reclassify the site for open or "approved digging."

### *Looking Back: Efforts to Keep Maine's Clams Clean*

Because many polluted flats were closed in the post-World War II period, it was necessary to find a way to utilize clams from moderately polluted flats and waters.An exploratory experiment was conducted in the summer of 1946 at Lamoine that indicated that polluted clams would cleanse themselves when held in cages in clean seawater. Testing for coliform bacteria was done in the agricultural experimental station at the University of Maine in Orono, because the state's Sea and Shore Fisheries Department (now DMR) had no bacteriological laboratory.

In 1949, laboratory facilities were constructed at Boothbay Harbor for the Department of Sea and Shore Fisheries to process coastal water samples to assess pollution levels. In the following years, Philip Goggins and John Hurst experimented with the depuration process.

These activities led to efforts with the U.S. Public Health Service to develop a model using ultraviolet light to sterilize water that could flow into tanks and be siphoned by the clams in the feeding process. This model of U.V. bulbs and a box-like arrangement directed a thin flow of water beneath the bulbs for its sterilization.

This model was further tested in Maine, along with the parameters of its use. Environmental factors such as temperature, oxygen, and salinity were evaluated as well as the relation of the water flow to shellfish volumes and the levels of pollution in clams and waters. Efficient methods had to be devised to handle and purify shellfish on a commercial scale. It was necessary to develop and test a public health control scheme for the depuration process and shell cleaning, and to monitor the harvesting, transportation, and holding of clams.

For several years, state funds were not available to build and operate a commercial-scale plant to work out the details of operation and control prior to making recommendations to the clam industry for industrial use.

Finally, federal funds were procured to establish an experimental commercial scale plant at Biddeford Pool in York County. Procedures of operations and controls were later applied to depuration plants in Phippsburg, Scarborough (three plants), Stockton Springs, Eliot, and Waldoboro.

Clams were dug in designated depuration areas all along the coast, and production reached a level of about 25,000 bushels a year for a few years in the 1970s. There has always been a need for a dependable supply of clams for depuration, and this is becoming a more acute issue as pollution abatement is successful. Today, only the Eliot plant at Spinney Creek operates as a shellfish depuration facility in Maine.

Depuration digging does allow unharvestable clams to be harvested and marketed and has direct economic benefit to the diggers and operator of the depuration facility. It also provides the clam market with a dependable and safe product. There are those who believe that closed flats with a high volume of very old clams can benefit from depuration digging, prior to opening, because the older clams (which have a lower market value) will be removed and smaller clams can resettle.

The availability of depuration digging may, however, hinder efforts at improving water quality on particular flats since towns are paid a set fee by the depuration company for clams removed from their flats.

## Seeding the Clam Flats

During the past decade, our knowledge about juvenile clam ecology has improved considerably, thanks, in part, to a statewide stock enhancement program using clam seed cultured at the Beals Island Regional Shellfish Hatchery. 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 behave similarly to wild seed. This implies that cultured clam seed can be used to accurately estimate and predict the fate of wild populations of juvenile clams.

To maximize growth and survival, hatchery seed should be planted in the spring (April/May) at densities of 20 to 40 clams per square foot and protected from predators using 1/4-inch flexible plastic netting. Before embarking on a seeding effort, the re-seeding site should be carefully selected.

### *Site Selection*

When seed are planted, the clam manager has the option of choosing where the clams are planted. A good site determines how well the seed will survive and grow, and a carefully planned testing program to determine the suitability of the site should precede any major investment in time or money.

The following factors should be considered in site selection for planting the seed:

- Abundance of a natural population of clams with fast growth rates
- Intertidal height
- Sediment type
- Current
- Location in a cove (mouth vs. head)
- Seasonal changes in water temperature, salinity, and icing
- Protection from wind and waves

Graphic Omitted

*Clam depuration was once conducted in several plants along the Maine coast. (Photo: Dana Wallace)*

- Predators
- Accessibility and visibility to clam wardens for enforcement of flat closures

The status of the existing clam population is an important first 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 contribute to the knowledge concerning predator activity.

Note that green crabs are especially abundant in warmer estuarine sites adjacent to salt marshes. Large, expansive flats which drain over a long distance at low tide (such as Maquoit Bay, Brunswick) tend to be low in green crab abundance, but these areas have, at times, high populations of another predator, horseshoe crabs (*Limulus polyphemus*). In towns where high numbers of predators are common, larger seed can be planted or seed can be protected under plastic mesh netting.

Clams feed on microscopic algae, detritus, and other microorganisms. 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 is also more severe in coastal inlets and salt ponds. Low salinities can also be a problem during the spring runoff season. Salinities as low as two to three parts per thousand (30 ppt is normal for coastal waters) are common in the runoff streams.

In general, seeded plots will likely do better at mid-intertidal heights even though growth may be greater lower in the intertidal. For example, a recent study on a Jonesport clam flat indicated that seed clams near the extreme low-water mark grew 54 percent faster than those near high water and 14 percent faster than those near the mid-intertidal. However, survival typically is 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.

*Within the cage and suspended from the bottom, juvenile clams can overwinter safe from ice scour and predation. (Photo: Brian Beal)*

### *Seed Sources*

Currently, clam seed used in planting is obtained either from a shellfish hatchery or by digging wild seed and transplanting it to managed flats. Hatcheries have been a dependable source of known age and uniform-sized clam seed for more than 10 years. Its availability has allowed researchers to investigate clam growth in a manner that has greatly increased our understanding of clam biology and survival in the clam flat. Dependable supplies of millions of clam seed have allowed communities the opportunity to experiment with seeding flats as a part of a structured clam management program.

The price of the seed from any hatchery depends on the size of the seed. In 1997, for instance, a Maine community could purchase one million seed clams from the Beals Island Regional Shellfish Hatchery at prices ranging from $1,500 to $25,000, depending on the clam size.

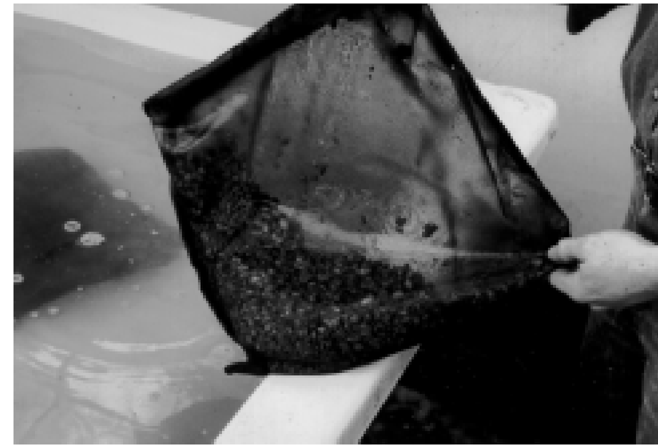
Certain clam flats periodically produce tremendous seed sets that clump together and result in stunted clam growth and poor survival. Seeds can be harvested from these sites and broadcast over more favorable areas. Many diggers are not accustomed to focusing on small clams under one inch in length and care must be taken on their part to look for smaller clams or their effort will be wasted. Unfortunately, no quantitative estimates of survival of transplanted wild seed exists.

In the 1980s, the DMR commissioned the University of Maine Agricultural Engineering Department to build a floating, mobile, hydraulic clam seed harvester. A mechanical seed harvester designed to operate in a variety of sediments would enable communities to thin and transplant from areas of heavy natural seed clam set to commercially depleted flats.

Recently, researchers from the University of Maine at Orono, University of Maine at Machias, and Maine Maritime Academy, developed (with funding from the Maine Aquaculture Innovation Center) and used successfully a spat dredge that hydraulically removes clams between 6-15 mm in all sediments. In 1997, the dredge was used in three Maine communities participating in a community clam culture program. In Prince Edward Island, Canada, hydraulic dredges are used to soften sediments on flats before seeding.

### *Collecting and Overwintering Clam Spat*

Juvenile clams are very mobile. In fact, simply because a set of clams is observed in the fall does not mean that it will be there (or anywhere on a flat) 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 need not occur with a little planning, sampling, and a few tides in late October or early November devoted to capturing the small seed. 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 begins with finding dense enough sets to make the investment of time worthwhile.



*Clam spat bags are easy to construct from simple window screening. (Photo: Brian Beal)*

Communities with low wild populations of market-size clams may wish to attempt collecting and overwintering young-of-the-year clams that settle as spat in summer and grow to between 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.

A technique for overwintering wild spat in the subtidal has been developed by the Beals Island Regional Shellfish Hatchery using hatchery-raised spat. This technique brings 85 to 95 percent of the spat through the winter alive and ready for spring planting in May.

In mid- to late fall, locate sources of wild spat where densities are high enough to allow hand collection. Mechanical dredging may be tried with the assistance of the Maine DMR and university researchers who have experimented with specific dredging equipment on numerous flats.

Spat may be collected manually by skimming and washing the upper quarter- to half-inch layer of the sediment, because spat are generally not found deeper than one inch in the sediment. The collected sediment can be sieved and the clam spat washed. The spat are then placed into window screen bags and stacked 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 bags of 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 during the following May, but they should be protected by plastic mesh netting.

## Transplanting Wild "Seed" Clams

Seed clams are collected by hand or mechanically dredged. One should locate a flat with low numbers of predators such as ducks, horseshoe crabs, moon snails, green crabs or milky ribbon worms. Next, broadcast seed into rectangular plots (typically 14 x 20-30 feet long). Once seed is on the flat with the plot, cover with protective 1/4-inch netting and floats to protect the freshly planted spat from predators during the growing season. Managers may want to try planting in some areas without netting and some with netting. Netting should be removed in the late fall to avoid ice damage or loss.

Planting clams is like broadcasting grass seed on a lawn. One should try to attain a planting density of 20 to 40 clams/square foot. 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 reburrowing rates depend on clam size, and larger individuals may take three to four tides to completely reburrow.

Once seeded, the flat should be protected from all harvesting by clammers and marine wormers for at least one growing season. Harvesting should be allowed when 60 to 70 percent of the clams in the seeded area are legal size.

Seed clams may be removed from Prohibited areas and re-seeded into Approved areas, although a minimum six-month closure to harvest must be imposed on any flat where that is done (see Appendix II). In the past, communities with large supplies of wild seed have sold or bartered seed with other communities lacking wild seed.

A large-scale (15 to 20 bushels transplanted per day, four to six times a season) seeding method has been used by the Phippsburg shellfish committee for the past eight years. They have produced a one-page instruction sheet explaining the steps they follow when transplanting. Phippsburg clammers have helped teach other communities and produced a video describing their re-seeding methods.

Because re-seeding involves temporary gathering and possession of illegal, undersize clams, special permission must be obtained from the Maine DMR for each seeding event. A description of steps required by the DMR for conducting a seeding day are included in Appendix II.

### Planting Hatchery Seed Clams

If adequate supplies of wild seed clams are lacking, hatchery-reared seed may be used to enhance production on flats.

Since small soft-shell clams under a quarter-inch in size are mobile and can leave a flat and float to other areas where they re-settle into the sediment, seed clams from 1/2- to 1/4-inch are best for transplanting. Spat-size seed from a shellfish hatchery should be grown to this transplanting size in a nursery area after they leave the hatchery. Seeding larger clams costs the community in dollars paid directly for the larger clams or in equipment for nursery grow-out or in volunteer time to tend the clams during the nursery period, but it is well worth the effort because of the increased success of the seeding effort.

Nursery grow-out of clams usually involves raft-based, tidal upwellers or floating bags of clams in trays or cages at the surface in a protected cove with warm water (to enhance growth) and an abundant planktonic food supply until the clams reach 1/2- to 3/4 inch long. Refer to Chapter 5 on clam hatchery operation for more information on nursery grow-out techniques.

In Maine, soft-shell clams generally reach the harvestable size of two inches within three to four years; however, growth is directly related to water temperature and position on the flat with respect to the tide.

## • Predation and Protection

Soft-shell clams are a food source for many predators including sandworms, bloodworms, milky ribbon worms, moon snails, gulls, ducks, green crabs, horseshoe crabs, mummichogs, flounder, shrimp, and other bottom-feeding fishes. The list of predators changes, however, depending on the size of the clams. When clams first settle to mudflats, they are smaller than grains of sand. In the flats are also predators that, as adults, are about the size of a sand grain. These organisms are called meiofauna (animals less than 1/2 mm or 0.02 inches) and contain such groups as harpacticoid copepods, turbellarians, nematodes, kinorhynchs, etc.

Several field studies have shown that predators can decrease abundances of recently settled shellfish. As clams grow from the size of sand grains to about 1 mm (0.04 inch), they encounter more predators. These predators include juvenile worms, amphipods, snails, and crabs. There is little we can do about these small predators.

### Green Crabs

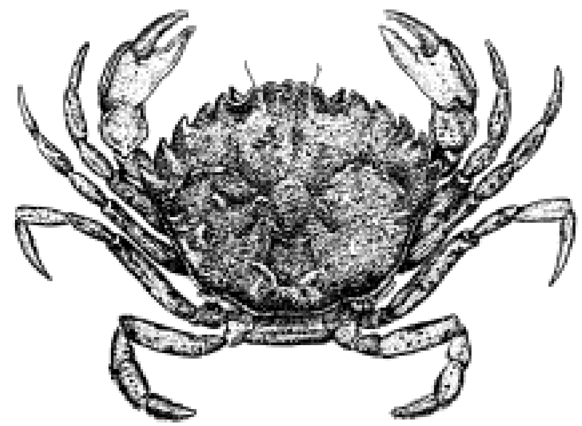
Green crabs, *Carcinus maenas*, are related to swimming crabs such as the blue crab of the Chesapeake and are classified in the Family *Portunidae*. Although green crabs are perhaps the most important predator of clams along the Maine coast today, they were not always here and, in fact, they are not even native to the United States. They are a European species (as is the common periwinkle) accidentally introduced to the Long Island Sound region around the time of the Civil War (1865). They began extending their range north and south soon after their arrival 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. Green crabs were not present in Washington County in 1942 but by 1951, they were common in lobster traps and on flats in Jonesport and Bucks Harbor. Green crab predation is thought to be largely responsible for the major decline in clam landings in eastern Maine from 1950 through the early 1960s. For example, in 1950, 294,000 bushels of clams were harvested from Washington County shores. By 1962, only 42,000 bushels were harvested, representing a loss in productivity of 85 percent over that 13-year period.

It appears that green crab populations are largely controlled by temperature. After particularly severe winters, green crab population densities are not as high, as after a mild winter. There has been an upswing in the population recently, although there are no continuous records kept of their abundance.

Due to slightly warmer temperatures and more available inshore cover, green crab predation is most severe in southern Maine. Some adult green crabs migrate offshore in the fall and return in late April or May when water temperatures reach 7 ºC-8 ºC (44½-46½F). First-year crabs will attain a size of about 10-12 mm (1/2 inch) by their first winter and overwinter in tidal or subtidal flats or marsh banks. These juveniles are more susceptible to winter mortality than adults. 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 (May to October, but especially in July and August).

Smaller clams are the most susceptible to crab attack, since their shells are thin and they are not burrowed very deeply in the sediments. Clams less than 12 mm (about 1/2 inch) in length can usually be eaten whole, while larger ones are chipped apart and the meats picked out. Clams over 60 mm (2-3/8 inch) become resistant to predation, partly due to a heavier and thicker shell, but primarily due to the ability to



Carcinus maenas, *the green crab. (Figure: Andrea Sulzer, from* A Guide to Common Marine Organisms Along the Coast of Maine*)*

burrow more deeply into the sediment. Unfortunately for clams, green crabs can dig pits as deep as nine or 10 inches in certain sediments.

Most predators in the intertidal zone prey on juvenile soft-shell clams (i.e., animals less than 32 mm (1-1/4 inch) in length, so clams of this size must be effectively protected in any stock enhancement effort. Attempts to avoid high mortalities of juvenile clams by planting seed in late November (since green crabs don't actively feed below 7ºC (44½F) have had mixed results. Crab predation is very low from November through March, but because winter storms and ice can have serious impacts on the movement of small clams, some fall seeding efforts have resulted in complete failure.

Planting seed clams in the spring and protecting them from crabs and other predators using netting is the preferred method today.

The decimation of a clam flat does not take long, as one adult green crab can consume up to 15 clams per day. Stomach analyses from nearly 4,000 green crabs in Maine and Massachusetts in the mid-1960s showed that clams and mussels are the most 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 (such as newly seeded unprotected plots or flats that have received a heavy natural set).

Green crabs can be trapped, and some communities in Maine practice this form of control. When green crab densities are extremely high, however, trapping may remove only a small percent of animals. For instance, during the fall of 1952, Harlan Spear, a research biologist with the U.S. Fish and Wildlife Service, conducted an intensive green crab trapping program in Love's Cove near Southport Island. Traps with mesh screening were established in three series across the cove at low tide depths of approximately one, five, and nine feet. The traps were baited and fished daily for 35 days. Although the total average catch was nearly 1,000 green crabs a day, 1,400 were caught on the last day of trapping. Trapping the crabs seemed to be a futile effort. Crab traps can be useful, however, in determining the size distribution and the number of crabs in a given area.

Although chemical control was used in the past, use of poisons such as DDT, lindane, and other toxins is definitely to be avoided. These substances poison non-target species such as lobsters, shrimp, and most other invertebrates (including clams, fish, birds, and people who eat the tainted organisms).

Adult crabs can travel great distances, and since crab larvae are planktonic, any control measures must be continuous. The most effective control measure to date has been crab fencing and using nets to deter mobile predators. Fences were used with some success during the 1950s and 1960s, but their use has been somewhat limited during the past two decades. Fences typically were 18 inches high with sheets of wire mesh supported by stakes driven into the sediment.

A 3 to 6-inch flange of boards or aluminum flashing bent over the top of the fence deters crabs from climbing over the top. The mesh is buried a few inches into the sediment to prevent entrance via burrowing. Fencing can be effective in slowing down predators, but it is somewhat difficult and cumbersome to install.

*Green Crab Fencing Program*

There is a green crab fencing program established by statute to exclude green crabs from soft-shell clam growing areas. The program is administered by the Commissioner of the Department of Marine Resources (DMR) who may provide funds, materials, or expertise to a municipality for the construction and installation of fencing once he/she has determined that a soft-shell clam growing area is adversely affected by green crab predation. This program has been unfunded and inactive for more than 15 years.

*Netting*

It has been demonstrated that clams under one inch that are planted on open flats in the fall do not survive the winter season well due to ice scouring, sediment freezing, and predation by ducks. These same clams planted in early April exhibit greater survival rates, because they have a season to grow and burrow more deeply into the sediment. The survival of planted clams on open flats is very low from spring to fall due to high predation rates. Although no predator control measure is 100 percent effective, the use of plastic, flexible netting is used most often these days.

Survival can be greatly increased by planting seed under one inch under plastic (1/6- or 1/4-inch) mesh netting. Sections of mesh, 12 to14 by 22-feet in size, buried six inches in the mud on the edges and buoyed from the underside by nine, 4 by 4-inch plastic floats or styrofoam toggles, provide a good chance of survival for seed clams greater than 1/2 inch in size. The netting may be lifted off the surface of the flat using boards to enclose the clams, but the use of boards on a large scale is not cost effective.

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

Nets can be secured by walking on top of the outside edge and poking the edge into the flat. Or, a furrow can be dug around the edge of the seeded area and the edge of the net placed into the furrow, back-filled with the mud dug from the furrow. Netting does a good job of deterring green crabs, but it should be checked regularly for tearing and fouling. Netting generally is purchased in large, 14-foot wide rolls and can be easily cut to any length.

Nets should be applied at the same time clams are seeded and checked at regular (weekly or biweekly) intervals until the fall. Nets are set out on the flats in early spring and removed, cleaned, and stored in late November before any ice has a chance to build up on the flat. If nets are not removed prior to the winter, there is a likelihood that they will be lost due to ice or storms.

In the fall, if the average size of the clams on the re-seeded flat is greater than 30 mm (about 1-1/4 inches), it may be unnecessary to place nets on the same plots the next spring. As small clams grow within the sediments of flats, they burrow increasingly deeper until they achieve what is called a "refuge size" from most predators. At approximately 1-1/4 inches in length, clams become relatively safe from most predators and generally will sustain only modest losses from that size until market (2-inch) size.

The presence of mesh netting on the clam flat modifies the movement of water over the flat and may enhance the set and survival of wild seed clams. This effect may prove to be a valuable tool in a town's clam management plan as a mechanism to economically re-seed coves that have been unable to re-seed on their own.

Clam seed under mesh have enhanced growth rates. In one field experiment, clam seed under mesh grew 78 percent faster than similar seed planted adjacent to the mesh on open flats. The use of netting enhances natural set, increases growth rates, and increases survival from predation. Its efficacy has been demonstrated in several small, commercial-scale plantings. The techniques and machinery that would allow large tracts of flats to be seed-enhanced through the large scale use of netting, requires further development in Maine, but this has been done commercially on the West coast of North America as well as on the coasts of Ireland, France, and Spain.

Studies conducted in eastern Maine with hatchery-reared clams (8-12 mm or under 1/2 inch in length) in 1990-1991 indicated no difference in the protective ability between flexible and rigid plastic netting. In the same study, aperture size of netting was examined. There was no difference in survival between clams protected with 1/4 inch or 1/2 inch netting, but clams under 1/6 inch netting had reduced survival compared with the other two types due primarily to excessive fouling on the smaller aperture nets.

Although green crabs are the primary crustacean predator of juvenile clams, other crabs, such as the rock crab, *Cancer irroratus*, venture onto the flat when the tide covers the intertidal, especially at night. These crabs also prey on small clams and are deterred by nets.

*Moon Snails*

Along with the assortment of crabs present in Maine waters, moon snails, also known as clam drills, are another group of important predators on soft-shell clams.

In Maine, there are two species to contend with: *Euspira heros*, the northern moon snail, and *Euspira triseriata*, the banded moon snail. The northern moon snail 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 is smaller, reaching sizes no larger than about 20 mm. According to a recent study conducted in Whiting Bay near the town of Edmunds, moon snails can consume up to 60 percent of clams less than 20 mm during a summer. Snails attack clams that are similar to their size. By examining moon snail size, one should be able to predict quite accurately the size of clam that is susceptible to attack by this gastropod predator.

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 (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.

Moon snails devour soft-shell clams by drilling a countersunk hole in the clam shell usually near the hinge using a rasping organ (the radula) in conjunction with a hydrolytic acid that helps dissolve the shell. After the hole is complete, the moon snail secretes digestive enzymes that kill the clam. Then, the mouth-like proboscis is inserted through the hole and the clam tissue consumed. Drilling may take several hours to several days. Sometimes moon snails give up before they complete the drilling process, or they become disturbed by a clammer or predator such as a crab or gull. Often these snails will leave incomplete bore holes in the shell.

*Maine has two species of moon snails,* Euspira heros*, the northern moon snail and* Euspira triseriata*, the banded moon snail. (Photo: Brian Beal)*

An estimation of the actual number of snails present on the flats can be difficult because snails are attracted to high clam densities and will migrate considerable distances to a heavy clam set. In addition, the number of snails visible on the surface at any one time is an underestimate 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.

Clam consumption rates of snails have been estimated at 95 to100 clams per snail per year. Unlike green crabs, moon snails are strongly affected by low salinities and are not usually found in areas where freshwater runoff is significant.

Moon snail predation has been a major factor regulating soft-shell clam abundance Down East in the Cobscook Bay and Passamaquoddy Bay regions. Investigations at St. Andrews, New Brunswick during the late 1940s and early 1950s indicated that snails were a major threat to clam populations at that time. Control measures, even using nets, are largely ineffective because of the behavior of this animal. Since they live within the sediments, it is practically impossible to detect them when planting juvenile clams. Covering clams with netting has been tried, but these attempts have not yielded promising results. Snails must first be excluded from the seeded area. Then, they must not be allowed to migrate into the seeded areas. Intensive hand picking has been tried, but this was deemed only minimally effective at best.

Predation by moon snails on soft-shell clams can be intense. Clams averaging 38 mm (about 1-1/2 inches) were transplanted by Canadian researchers in June 1948 to each of three intertidal plots near St. Andrews and experienced 75, 90, and 100 percent mortalities from moon snails in the upper, mid, and low intertidal, respectively, within two weeks. During that time, 5,133 snails were collected. More recently, studies have shown that clams from 15 to 61 mm can be attacked, but that predation rates are higher on small clams.

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.

Graphic Omitted

Limulus polyphemus *also poses a hazard to clams. (Photo: Brian Beal)*

At this point in time, there appears to be no truly effective, economic control method for moon snails. Enhancement efforts should occur away from areas with 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.

### *Other Predators*

Many other marine animals eat clams, but due to their small size, they leave scant evidence of their presence and are generally overlooked. One of these "other" predators is the small benthic feeding bait fish, the mummichog (*Fundulus heteroclitus*). A study in Essex Bay, Massachusetts demonstrated that soft-shell clams are an important diet item in fish greater than 55 mm (2-1/4 inches) total length. A total of 154 mummichogs collected between May and September 1977 contained 1,150 soft-shell clams. The same study concluded that in areas of high mummichog density

(0.35 to 6.0 fish/$m^2$) that during peak predation periods, 880,650 soft-shell clams per mile of shoreline could be consumed in a single day!

Other efforts have revealed that sand worms (*Nereis virens*), sand shrimp (*Crangon septemspinosa*), and a tiny burrowing crustacean amphipod (*Corophium volutator*) will also devour tiny clams. These tiny predators may seem insignificant, but work on a Jonesboro mud flat revealed that one sand shrimp can eat over 100 tiny clams in three hours. With millions of sand shrimp on the flats, the resulting loss of tiny, newly set clams must be enormous. This high loss of the very early-stage clams appears very difficult to control. The very high reproductive capacity of the clam, however, insures that reasonable numbers of clams survive to become larger adult clams.

Another clam predator that is difficult to control, even as an adult, is the nemertean milky ribbon worm, *Cerebratulus lacteus*. These animals can reach sizes of more than three feet in length. 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. This animal was largely responsible for the complete collapse of the clam fishery in the Annapolis Basin, Nova Scotia. Ribbon worms have been seen to attack clams through the siphons and ingest the clam without leaving any visible shell damage. Since the worms can vary their own diameter, they can easily crawl through mesh netting. As with moon snails, there seems to be no effective method to keep them from attacking clams of all sizes. Enhancement efforts should not take place in areas of high ribbon worm densities, which often correspond to areas of soupy mud.

## Shellfish Growing Area Classification

• *Approved*

Open to harvest of shellfish at all times. Sanitary Survey is complete with acceptable water quality results and shoreline survey indicates no significant pollution sources.

• *Conditionally Approved*

Open to harvest only when certain conditions are met. These areas are usually open depending on 1) proper function of a municipal wastewater treatment plant, 2) rainfall events, or 3) seasonal issues such as boating or habitation.

• *Restricted*

These areas are closed to general harvest, however they can be harvested for depuration. The Sanitary Survey indicates that the area is marginally polluted, but the shellfish can be treated by the process of depuration to make them safe.

• *Conditionally Restricted*

Harvest for depuration is allowed when certain conditions are met. Those conditions may be identical to the conditions listed above under Conditionally Approved.

• *Prohibited*

Closed to all harvest of shellfish. These areas are either grossly polluted, or the Sanitary Survey has yet to be completed.

## Maine's Shellfish Sanitation Program

Like all other shellfish-producing states, Maine administers a Shellfish Sanitation Program which follows the guidelines of the National Shellfish Sanitation Program (NSSP). The NSSP was created and is updated by the Interstate Shellfish Sanitation Conference which meets annually to deliberate technical issues related to shellfish sanitation. The intent of the ISSC is to create standardized regulatory criteria which will protect public health and provide guidance to the shellfish industry in harvest and handling practices.

The ISSC has three key participants: the USFDA, the state shellfish control authority, and the shellfish industry. Under statutory authority, the DMR administers three key elements as defined in the NSSP: the Shellfish Growing Area Classification Project, the Marine Biotoxin Monitoring Project, and the Shellfish Processing Plant Inspection Project.

## • Why Shellfish Can Be Unsafe

Shellfish (clams, quahogs, oysters, and mussels) are filter feeders. While feeding, shellfish siphon tremendous quantities of seawater and "filter out" particulate matter. In areas where the water is polluted, the shellfish can concentrate harmful contaminants in the gut, thereby becoming harmful to the public.

The state shellfish sanitation 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). In areas polluted with sewage, shellfish can become contaminated with bacterial, viral and parasitic organisms which can cause the consumer to become ill. When toxic phytoplankton are blooming, shellfish can become contaminated with biotoxins which cause sickness and, in extreme cases, death.

## • Shellfish Growing Area Classification

Shellfish growing areas are classified based on the sanitary condition of the overlying seawater. Areas may be classified *Approved, Conditionally Approved,*

Graphic Omitted

*The dinoflagellate* Alexandrium *is one of the toxic algae that bloom in Maine waters. (Photo: Laurie Bean, Department of Marine Resources)*

*Restricted, Conditionally Restricted,* or *Prohibited* (see page 45). The NSSP provides explicit guidelines to determine which classification is most appropriate for a shellfish-growing area. These guidelines include water quality testing procedures, water quality evaluation criteria, pollution source evaluation, and shoreline survey evaluation. The intent of the guidelines are 1) to determine the actual or potential level of sewage pollution in an area, and 2) to prohibit harvest of shellfish from areas where that risk is unacceptable.

Groups of boats moored in a shellfish-growing area may cause the area to be classified as Restricted or Prohibited under the NSSP rules because of the possibility of overboard discharge of untreated sewage. Local harbormasters should keep this in mind when allocating mooring permits in or near productive shellfish growing areas.

All shellfish growing areas which are harvested must have an up-to-date Sanitary Survey. The Sanitary Survey is compiled by DMR staff and includes three principal components: 1) water quality analysis, 2) shoreline survey and pollution source evaluation, and 3) hydrographic analysis.

The information which goes into the Sanitary Survey is collected by DMR staff and frequently involves the participation of volunteers. These volunteers are trained and certified in water quality sample collection and shoreline survey techniques by DMR staff and by the University of Maine Cooperative Extension. Volunteers are often members of management organizations, municipal shellfish committees, or school groups.

## • Water Quality Evaluation

The NSSP allows the state programs to select either total or fecal coliform bacteria as the indicator organism for monitoring sewage pollution in marine water. The DMR has selected fecal coliform as the indicator for evaluating the water quality in Maine's marine waters. Fecal coliform is a group of bacteria which are most typically associated with fecal matter from warm-blooded animals. It provides a convenient indicator of sewage pollution because 1) its presence is usually indicative of fecal contamination, 2) the methods for analysis are simple, and 3) the testing procedures are relatively inexpensive.

*During the late 1980s through the mid-1990s, tougher water quality mandates from the federal level and reduced staffing at the Maine DMR resulted in increased closures of clam flats. Some large estuaries in the midcoast, including the Sheepscot, Damariscotta, Medomak, and St. George rivers, were shut down to clamming almost entirely for several years or longer. The "prohibited" classification protected the clams, and wild populations thrived in the absence of harvesting, but it was a crisis for clam harvesters suddenly shut out of the local fishery. Clammers, town officials, aquaculture companies, school groups, and environmental organizations worked together to get flats approved for clam harvesting.*

DMR samples approximately 2,400 water stations statewide (1997 figures) a minimum of six times per year on a random schedule. By randomizing the sampling throughout the typical sample season of March through November, the data will provide some indication of variability of fecal contamination at different times of year under various meteorological conditions and at different tidal stages.

Samples are analyzed at either of the two DMR laboratories (Boothbay Harbor or Lamoine), and data is managed with a computer database system. DMR evaluates each water sampling station for trends and variability in fecal coliform in order to determine whether an area is subject to sewage pollution.

By late 1997, there were approximately 25 groups of volunteer water quality groups involved in checking coastal waters for bacteria. The work of volunteer water quality monitors helps the DMR gather the water quality information needed to monitor flats. Most of these groups are part of the Clean Waters/Partners in Monitoring Program and are funded in part with grants from the Shore Stewards Fund at the Maine Community Foundation. Recently, quality assurance programs have been instituted to assure consistent sampling methods, and standardized locations and data collection by volunteers. In addition to aiding the DMR in sample collecting, volunteers have worked to identify and eliminate pollution sources.

## • Shoreline Survey Project

All of the shoreline adjacent to shellfish harvest areas must be surveyed for potential pollution sources. This activity is conducted by DMR staff with assistance from volunteers. Shoreline surveys involve walking along the entire shoreline of the affected area, preferably at low tide, to observe any possible sources of bacterial pollution to the clam flats. Investigators conducting shoreline surveys look for straight pipes (indicating direct untreated sewage discharges from houses onto the flats), sources of pollution from animals (pastures, flocks of birds), overboard discharges, moorings, outhouses, streams, polluted ditches, and anything else that may impact water quality.

This information is collated and linked with the water quality evaluation in the Shoreline Survey. When pollution problems are identified which represent a violation of environmental law, corrective actions are sought through municipal or state mechanisms. In this manner, failed septic systems, improper sewage conveyances, or other inappropriate land uses are identified for correction.

Conducting a shoreline survey is the first step required to open a closed shellfish area. If there are no known sources of pollution, 30 random water samples taken over a five-year period which are "clean" (i.e., meet the standards of the NSSP), will allow the opening of a previously closed area for the taking of shellfish.

Areas can be opened sooner if water samples are taken under adverse conditions over a three-year period. Adverse samples are collected whenever pollution is expected to be the greatest, such as following storms, certain tide stages and other times. Fifteen adverse samples must be taken over a three-year period to meet the numerical standards of the NSSP.

*Through the efforts of water quality monitoring volunteers, clam flats are being reopened to harvesting (Photo: Carol Marsh)*

In addition to clean water, the DMR requires that a clean clam meat sample be taken from the area under review for opening, and that DMR personnel prepare a sanitary survey that summarizes all known pollution sources to the growing area, the results of the shoreline survey, and the results of the water quality and clam meat quality tests.

The final piece of the sanitary survey is to determine how the water quality and shoreline survey information might impact adjacent shellfish growing areas. This is done by evaluating the effect of adverse meteorological conditions and by evaluating currents and probable mixing or dilution of the pollution. Occasionally, the DMR might use dye studies or other mechanisms for tracking the poten-

> *For more information see* Steps to Opening Clam Flats, *a brochure published by the Friends of Casco Bay, Portland, ME (1996) and the* Volunteer Manual of the Shellfish Sanitation Program, *published by the Maine Department of Marine Resources (1997).*

tial movement of a plume of pollution. Dilution calculations are done around known point sources of pollution, such as wastewater treatment facilities, to determine the extent of the adjacent area which must be closed to harvest.

## • Marine Biotoxin Monitoring

DMR also monitors shellfish for marine biotoxins. The most common marine biotoxin in Maine waters is Paralytic Shellfish Poison (PSP), a problem associated with certain species of dinoflagellates (single-celled algae). When this dinoflagellate grows rapidly (blooms), it is ingested by shellfish resulting in their toxicity to human consumers. This bloom is commonly known as ",red tide."

Although red tide is a very serious concern and can cause severe illness and even death, Maine has had no significant illness outbreaks related to marine biotoxins. This is due primarily to the effectiveness of the monitoring program. The program for monitoring marine biotoxins has two laboratories (Boothbay and Lamoine) and uses a mouse bioassay for determining levels of PSP in shellfish tissue. All elements of this project are implemented following the guidance of the NSSP.

To assist DMR, volunteers are involved in the Marine Phytoplankton Monitoring Program. Started in 1997, this program is made up of a network of 22 groups statewide who collect plankton samples and make gross microscopic observations of the abundance of various potentially toxic phytoplankton. The field observations are sent to the DMR for incorporation into the database in hope that someday there can be either predictive models developed for toxic algal blooms or an early warning system to better protect public health from contaminated shellfish.

The current status of red tide closures in Maine is available on the "Red Tide Hotline" at 1-800-232-4733.

## • Shellfish Processing Plant Inspection

After shellfish are harvested, they continue to represent a potential hazardous food product. This is due, in part, to the fact that they are shipped live to the final consumer and because some shellfish (not necessarily soft-shell clams) are often consumed raw or partially cooked. The NSSP has developed standards for food handling and processing specific to the shellfish industry. Control measures are monitored by a DMR seafood technologist and include facility construction, shipping and handling conditions, and tagging and labeling of product. By implementing the standardized protocols under the NSSP, the DMR is able to assure the state's shellfish industry that their product is considered safe and that industry members from other states follow the same guidelines.

## • Grant Programs to Remove Pollution Sources

The Maine Department of Environmental Protection (DEP) manages grant programs that partially reimburse homeowners for the cost associated with the removal of overboard discharges and replacement with alternate wastewater treatment systems. Groups of faulty septic systems or community wastewater treatment facilities requiring upgrades may be eligible for the Small Community Grant Program administered by the DEP. For more information on the grant programs, call the DEP at 207-287-2111.

Marinas, boatyards and towns may apply to the Pump-out Grant program, presently administered by the DEP, to recover costs involved with the installation of boat pump-out or sewage disposal stations. For information on these grants, which are available for a limited time, contact the DEP at the number listed above.

The hatchery techniques developed for culturing soft-shell clams parallel many of the accepted methods used in rearing oysters, hard clams, and bay scallops. These techniques are very basic and require minimal training and equipment. For some, the technology involved, equipment used, and understanding of the biological functions of the soft-shell clam require no more expertise than is required in home canning.

The work in a clam or shellfish hatchery can be divided into six areas: food (algae) production, broodstock gathering and conditioning, spawning, larval care and setting, and juvenile clam care (inside and outside). More detailed and specific information regarding equipment and techniques, manpower requirements, and cost can be obtained from Brian Beal, University of Maine at Machias (207-255-1314).

## • Food Production

Clams feed by filtering algae (microscopic plants) from seawater. In order to work indoors with large numbers of clams in a confined space, large quantities of this food must be grown. Several types of algae are maintained in sterile tubes and small

# Chapter 5. Clam Hatchery Operation

flasks in a room modified to provide light and an even, cool temperature. The small jars of different types of algae are transferred to larger vessels of several liters and then into mass algal culture tubes containing tens of gallons.

Generally, several strains of algae are grown at once in order to provide a balanced diet for the clams. The larger tubes of cultured algae are then tapped to feed the animals in the hatchery. If one of these large tubes requires five days to grow before it can be used, it is obvious that in order to harvest one tube each day, a tube must be started every day for five days in order to begin a cycle of start-growth-harvest. After several types of algae are growing in large volumes, it is time to bring in and condition the broodstock clams.

## • Broodstock Gathering and Conditioning

In Maine, clam broodstock may be kept inside in the winter months in containers with sand, under flowing seawater conditions. Clams kept this way experience temperatures that are one to two degrees warmer than found outside in the mudflats, and they can be ready to spawn by early March in mid-coastal Maine.

Wild clams (2-1/2 to 3 inches) can be dug and brought into the hatchery and spawned easily from mid-May to early June. They may be harvested for spawning through the middle of July. After that, the natural population has mostly finished spawning. If more broodstock is needed, it should be collected in early April or May and held in the hatchery under cool conditions in order to retard the natural spawning process. This technique may be enhanced by taking advantage of the difference in water temperatures in the spring from western coastal to eastern coastal Maine. When the broodstock has been either conditioned inside or collected in season from natural populations, the spawning process may be attempted in the hatchery.

- **Spawning**

In order to obtain enough spawnable clams, as many as 100 clams should be selected, sprayed clean, and placed in a shallow tray with three to four inches of clear, filtered seawater over them. The clams are arranged in rows so that each siphon, or "neck," extends in the same direction as the one beside it. This makes the job of watching for a sperm or egg-release much easier. After a short time in the tray, the clams will begin to relax, extend their siphons, and start to pump water. The water with the clams in it is now slowly warmed up and some algae is added.

With clams in a ripe condition, it takes about an hour at a warmer temperature (18 º - 24 ºC) with ample food to trigger the spawning process. Usually, a male starts to release sperm into the tray water. The presence of the sperm triggers the females to release their eggs into the tray water. After several males and females have begun to spawn, they are removed to separate warm water containers and allowed to continue spawning. If this is not done, so much egg and sperm are released into the spawning tray that the water becomes milky" and makes separating the males from females impossible. Also, the eggs develop into larvae more successfully if they are removed from a strong sperm suspension.

When the females in the separate spawning containers have stopped releasing eggs, the eggs are all pooled into one large container and fertilized with a "thin" sperm suspension. After the eggs are observed under a microscope, an estimate is made of the number of eggs. At this point, they are divided and added to tanks (300-500 gallon) where the eggs develop into the larval form of the clam.

Sometimes clams are reluctant to respond to the above-described manipulation and provide eggs "on call." When this happens, another technique has been used with good success. Two- to three-dozen clams that have been through a "normal" spawning manipulation are placed in a floating tray in a 700-gallon warmwater (23 ºC) tank and left for 24 hours. This usually will produce a reasonable spawning of eggs. It is important that the container have sufficient volume to handle both the volume of eggs and sperm released.

Graphic Omitted

*Several strains of algae must be started sequentially in small flasks to provide a proper diet for hatchery-raised clams. (Photo: Brian Beal)*

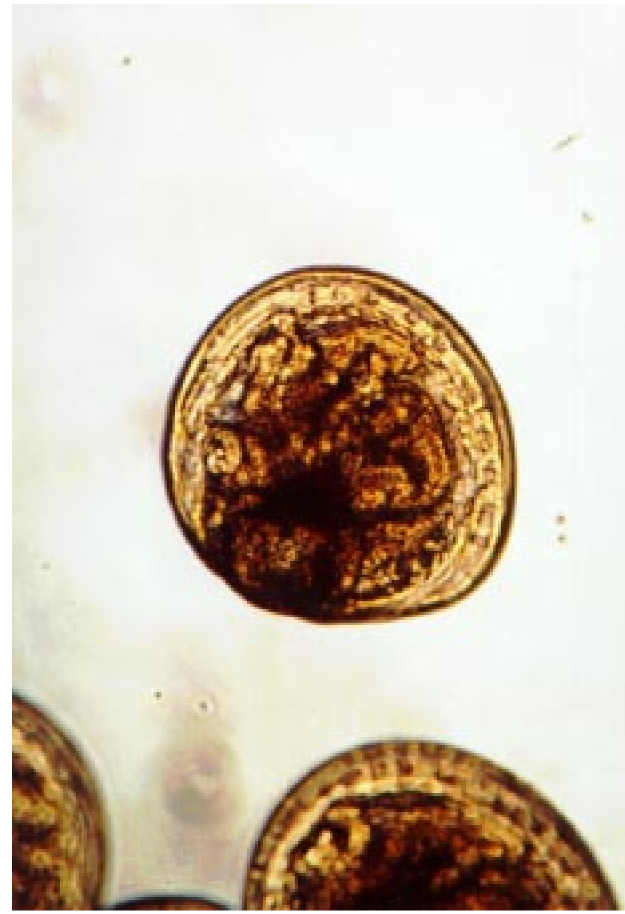
## • Larval Care and Setting

The fertilized eggs are put into plastic tanks (holding between 100 to 700 gallons of water) which drain from the bottom. The seawater they are grown in is filtered through fabric bags to remove other organisms, and the water is slightly warmed to 20 ºC (68 ºF). Within 24 hours of being fertilized, the eggs develop into a larva which has two shells and a swimming organ. Next, a dilute mixture of algae is added to each larval culture tank as food for the developing clam larvae.

Every other day, the swimming larvae are drained out of their tanks and caught on a very fine mesh sieve and placed in 35-gallon holding buckets. While they are in the barrels, the larval tanks are washed out with soap and hot water, rinsed well, and filled with 20 ºC filtered seawater. Algae is added to the freshly-filled tanks, followed by the clam larvae. A mixture of algae types is added to each larval culture tank in order to provide as nutritious a food as possible for the developing larvae.

Sometime after about 14 days of culture, the larva develops an organ called a foot. This foot is used by the larva as a means to attach to and crawl over solid surfaces. By sampling the larvae from their tanks and observing them under a microscope daily, one can determine when most of them have a foot and are ready to set. Set, or spat fall, refers to the phase where larvae settle out of the water, lose their ability to swim, and begin to develop the types of organs found in adult clams. The larvae are drained out of their tanks and placed on fine-mesh, floating screens in shallow tanks.

Some water in which adult clams have been covered for several hours is now added to the water the larvae are in, and this triggers the setting phase. Within minutes, the larvae stop swimming and start crawling about on the fine mesh. At the end of 24 hours, most of the larvae have lost their swimming organ and have started developing adult-type organs. Even though these recently settled clams are .006 of an inch, they are now called juvenile clams and will stay on screening until



*Within 24 hours of fertilization, eggs develop into larvae that have two shells and a swimming organ. (Photo: Brian Beal)*

Graphic Omitted

they are utilized in experiments or seeded into mudflats.

## • Juvenile Clam Care in the Hatchery

Juvenile clams are grown on floating screens in shallow trays after the setting phase. At this time, they are given all the cultured algae they can use in the course of a day. At regular intervals, the tank water is changed, the juvenile clams are removed from the system, cleaned, sized into different groups, and then placed back on their screens in the tank. This process continues either until the clam seed are large enough to go outside into floating screened trays or are removed at less than one-millimeter size and placed into upwellers.

### Upweller Nursery

In the upwelling process, clams are placed in a square or cylindrical container (silo) which has an appropriately sized mesh attached to the bottom. Unfiltered, food-laden seawater is forced up through the mesh and the clams, providing them with ample feed and carrying away their waste at the same time.

There are two types of upweller systems that currently are being used to grow clam seed. One is a land-based unit that is supplied with water from a pump. The other is a floating raft, anchored to face the flowing tide or powered by a pump. The energy of the flowing tidal water is captured in an open-end "scoop-box," and water is forced up through banks of upweller boxes attached to the inside of the box.

Clams do very well in upweller systems. In temperatures above 18ºC, 650-micron sized seed placed on 500-micron (.02 inch) mesh, at a density of 250/cm can grow into 1000-micron sized seed (.04 inch) in seven days. In the tidal-powered upweller, clams will grow from 1-5 mm (.04-.2 inch) in 30 days when water temperature is above 18ºC. The advantage of the tidal upweller is in utilizing free, food-laden water from the sea or estuary to grow clam seed at high density, replacing the costly shore-based algal culture and pumped water systems. Even more rapid growth may be obtained with pump-powered upwellers situated in marinas or other sheltered cove areas where electricity is available. Clam and other shellfish seed require tremendous amounts of food as growing juveniles, so the development of upwellers has made seed production less expensive.

The publication, *Guide to Construction of a Tidal Upweller* by William Mook, available through the Maine Aquaculture Innovation Center or Maine Science and Technology Foundation, has excellent diagrams and instructions on constructing an upweller nursery.

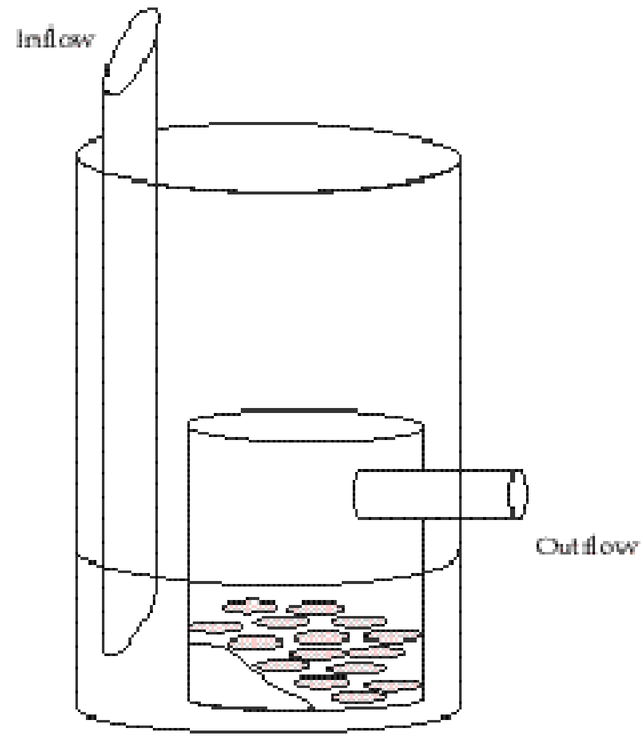
### Floating Tray Culture

When the seed reach a size of at least 4 mm(1/6 inch), they can be set out in floating trays. In this system, trays with mesh bottoms and tops that are covered with opaque (black) plastic sheeting are constructed and floated attached to each other in long rows on the water surface. The mesh can be sized to contain a desired size seed but the smaller the mesh, the more often it needs to be cleaned. In many instances, fiberglass window screening is used for the smaller mesh. Wave action, in conjunction with tidal flow, help in carrying water into the trays, while the natural algae and higher temperatures found at the surface promote good growth. Caution must be exercised in sizing clams to go onto the window screen mesh because the mesh openings tend to vary considerably. The possibility also exists that heavy wave action may retard seed growth.

Floating trays, as well as many other culture systems, have problems with bio-fouling on the mesh and tray sides. In most places along our coast, they need to be scrubbed weekly to prevent the fouling from growing into a mat that restricts water exchange and retards growth. Small periwinkle snails and hermit crabs placed inside the trays are useful to reduce mesh fouling and related labor costs.

If trays are floated in a cove where the waves come only from one direction, the clams inside will be forced into one end or corner. The resulting bunch of clams will have a much reduced growth rate, due to restricted food availability. The cleaning process usually redistributes the clams over the mesh screening. A 3' x 4' tray, depending on the grow-out site, will grow approximately 15,000, 4 mm to 8-15 mm (average size of 1/2 inch) seed over a growing season, a size which is large enough to be overwintered and then seeded directly on flats.

- **Grow-Out to Market Size**




*Clam nursery upweller sketch. (Recopied from John Manzi)*

The feasibility of culturing commercial quantities of soft-shell clams to the two-inch market size either in artificial substrate or in open trays has been studied. No suitable artificial medium has been located that sustains good clam growth economically. The growth of clams in open trays is rapid to about one inch

(12-14 months), then slows to an economically unacceptable rate, taking three to four years to reach less than two inches in length.

Two reasons have been proposed for this slow growth. First, as the clam grows out of sediment, an increasing amount of energy goes into the adductor muscles that keep the shell closed, at the expense of general meat and shell development. Secondly, the presence of bio-fouling organisms that colonize the shell surface interfere with the process that produces the new shell growth. Clams grown out of sediment develop a thick, football-shaped shell.

Clams harvested from the wild, with a musculature developed in the presence of sediment pressure and placed onto open trays, often die within a few weeks. This is due to the fact that they suddenly have to work to keep their shells closed and do not have the muscle mass or tone to do so and ultimately spread open and gape, which kills the clam.

### • Leasing Intertidal Flats

At present (1998), there is only one commercial aquaculture lease (on Swan's Island) used for the grow-out of soft-shell clams in an intertidal area in Maine. Other shellfish species, such as oysters and quahogs, have a higher market value than soft-shell clams and are more profitable to culture at this time. Intertidal areas may be leased by private individuals under Maine law but the process differs from that used to obtain subtidal tracts.

Under Maine law, one may obtain a shellfish aquaculture lease from the Maine Department of Marine Resources (DMR) or from a municipality, if the municipality in which a lease is to be located has an approved shellfish management program. The DMR reviews applications for aquaculture leases and grants leases provided that a number of conditions are met: the applicant has the permission of the shorefront owner; the lease will not interfere with the access of the shorefront owners to their property, fishing, or other uses of the area; and other conditions. Potential applicants are advised to contact the DMR for more information.

If the municipality in which a lease is to be located has an approved shellfish management program, DMR leases for sites over two acres in size must also be approved by the municipal officers. In general, leases cannot exceed 100 acres in size or exceed a term of 10 years.

Municipal leases may not exceed 25 percent of the intertidal area in the town that is open to the taking of shellfish. The approval of the Commissioner of the Department of Marine Resources is required for municipal leases.

# Chapter 6 Clam Biology

### • Anatomy and Feeding

Soft-shell clams, *Mya arenaria*, are found in mud and silt flats from the Arctic Ocean south to Cape Hatteras off the coast of North Carolina. The soft-shell clam is one of a group of benthic (bottom) infaunal

## Beals Island Regional Shellfish Hatchery

The Beals Island Regional Shellfish Hatchery (BIRSH) is located in eastern Maine in the island community of Beals. The Hatchery was created in 1987 to help coastal communities improve the management and sustainability of a traditional marine resource, the soft-shell clam, *Mya arenaria*.

The mission of BIRSH is to enhance Maine's soft-shell clam and other species through aquaculture, applied research, technology transfer, and public education. During the past 10 years, more than 60 million hatchery-reared clams have been seeded onto public, intertidal flats in 25 of the 56 Maine coastal communities with established shellfish management programs, ranging as far west in the state as Kittery and as far east as Eastport.

Although seeding flats is a major goal, so too is providing outreach to coastal communities. Outreach activities provide training on how to overwinter seed clams, where and when to transplant seed, how to deter predators, and how to grow clams to commercial size efficiently and economically. In addition, the hatchery staff works with volunteers in several communities to monitor water quality to increase the amount of commercial clam habitat.

BIRSH has been successful in promoting natural resource management at the town and state levels through combined outreach and extension programs targeted toward schools, clam harvesters, and shellfish management committees. The hatchery also works closely with the University of Maine at Machias (UMM) to provide opportunities for faculty research and hands-on experience for college students.

Originally organized under the auspices of UMM, the hatchery is now a non-profit corporation governed by a 16-member board of directors representing a cross-section of the clamming industry, education, and management interests. The staff, which includes a hatchery manager and an outreach coordinator, is augmented during the summer months of peak activity with university work-study interns.

BIRSH carries out its programs with the cooperation and support of clammers, shellfish committees, researchers, educators, and industry leaders. It has received support from the USDA AmeriCorps Program, the Sea Grant Program at the University of Maine, National Coastal Resources Research & Development Institute, Maine Aquaculture Innovation Center, Sunrise Economic Development Council, Maine State Planning Office Coastal Program, and the Maine State Legislature.

(living within the sediments) marine bivalves known as suspension feeders, filter feeders, or lamellibranchs. These animals obtain their food by filtering microscopic particles of organic material from suspension in seawater. These organic particles include plant cells, microscopic animals, bacteria, and dead plant material, or detritus. Of these, floating microscopic plant cells (phytoplankton) are considered their main food.

Most benthic suspension feeders are sedentary from the time they are juveniles throughout their adult life. As a result, they must wait for their food source to come to them. As larvae, however, they drift for four to six weeks at the mercy of winds and tidal currents. During this time, they still must rely on an abundance of phytoplankton and other floating sources of food. Once they have grown large enough to settle out of the water column (at about 150-175 microns in size, or 0.006-0.007 inches) and reach the bottom, they quickly change shape (metamorphose) from a circular (quahog-like) animal into a more elliptical shape typical of adults.

From this settlement size (smaller than a grain of sand) until they are about one inch in length, they are highly mobile and can crawl over the sediment surface using their foot. At these small sizes, they are extremely vulnerable to being moved about by currents, storms, and ice, but eventually they dig a permanent burrow and generally remain in one place for the rest of their lives.

The outermost portion of the clam's body is the mantle, a sheet-like, translucent membrane that extends across the insides of both valves. The mantle secretes the shell material (calcium carbonate and aragonite) as the animal grows. The edges of the mantle are also fused to each other across the space that separates the margins of the two valves. Thus, the clam is completely sealed off from the sediment that surrounds it, with the exception of three discrete openings. At the back (anterior) end, there is the opening for the foot which is used for digging and maintaining a position within the sediments. At the front (posterior) end, the mantle is elongated into a long, fleshy siphon, with two tubular openings. The larger opening (the inhalant siphon) allows seawater to enter the animal along the sheet-like gills, while the smaller opening (exhalant siphon) permits water, feces and, during the reproductive season, gametes to exit from the animal.

The space enclosed by the mantle is known as the mantle cavity. The main part of the clam's body—the belly, or visceral mass—includes the stomach, digestive glands, intestine, heart, kidneys, and reproductive tissue. At one end is the small mouth and the short esophagus leading to the stomach. 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, which are closely pressed together when the clam is feeding, are covered with muscular ridges and troughs, and these in turn are covered with rows of cilia.

The palps, which can best be seen under a microscope, are marvelously complex. All the cilia within a row beat in the same direction; different rows, however, beat in different directions. The palps accept food particles, carrying them to the mouth, or reject particles, discarding them on the surface of the mantle. There is a large paired gill on either side of the belly. The gills constitute a large surface area, and they effectively partition the mantle cavity into inhalant and exhalant chambers.

Clams feed by moving water through holes and past tiny hairs called cilia. Tracts of stiff, powerful cilia on the gills generate the feeding current, carrying seawater through the inhalant siphon and inhalant chambers, through the holes in the gills and the exhalant chamber, and back out through the exhalant siphon. As the water passes through the holes, large, branched cilia strain out the suspended particles. Particles as small as 5 microns (0.0002 inches) in length are efficiently captured. The particles are then caught in mucous swept into food grooves, and they are carried toward the mouth by cilia in the grooves.

The particles are sorted by the labial palps and are swallowed. The food is ground up and partially digested by the action of a clear, flexible rod in the stomach called the crystalline style. (This rod varies in length depending on the size of the clam. In animals about 2-1/2 inches in length, the crystalline style is nearly 1-1/4 inches.) Further digestion takes place in a darkened (usually deep green in color) region called the digestive gland. The anus is at the posterior end of the visceral mass and opens into the exhalant chamber. Feces are carried out the exhalant siphon on the normal feeding current.

## • Diet and Feeding

The food particles in a clam's stomach may include diatoms (phytoplankton cells encased in silica capsules or frustules), dinoflagellates (red tide-producing microalgae), other types of phytoplankton, bivalve larvae and other microscopic animals, sponge spicules, detritus, and mineral grains from resuspended sediments. Phytoplankton is considered the most important food item of clams and other two-shelled animals, called bivalves. It is nutritious, with a high nitrogen level and good caloric value. Clams do not have enough of the right kinds of enzymes to digest animal protein efficiently, but they do digest phytoplankton efficiently.

Laboratory studies of soft-shell clam feeding using cultured algal diets do not reflect accurately the conditions a clam encounters in an intertidal flat, but such studies provide insight into how clams live. For example, several studies have shown that as the concentration of phytoplankton in seawater increases, a clam's filtration rate (the rate at which it pumps water through its mantle cavity and filters out the particles) sooner or later decreases. This decrease can be quite sharp, especially in the spring when metabolic rates are slowly recovering from cold winter temperatures.

Feeding experiments have shown that soft-shell clams seem capable of incorporating into their diet some sediments that become resuspended near the sea bottom. Clams digest nutrients from this sediment, although it is a poor quality food compared to phytoplankton. In some instances, benthic diatoms may be attached to small sedimentary grains that clams ingest. Other bivalves have been shown to digest more phytoplankton when small amounts of silt are added to the algae, and this is probably true of soft-shell clams.

In this section, we have noted that clams have a fairly complex feeding behavior that is typical of other suspension-feeding bivalves. Clams respond differently to different kinds and different concentrations of particles on their labial palps. They can actually distinguish different food types and sizes of particles and, as a result, ingest more of the food-rich particles and reject more of the food-poor particles. They appear well adapted to handle resuspended intertidal sediments, although those sediments are typically lower in caloric value than phytoplankton. Detritus may be an important energy source in winter, when phytoplankton levels are particularly low, and in the spring right after the decline of the phytoplankton bloom.

As phytoplankton concentrations become higher during times of algal blooms, the amount of algae filtered from suspension and carried to labial palps and the mouth becomes too great to swallow. This food cannot be used efficiently, so much of it is wrapped in mucus and expelled through the exhalant siphon as pseudofeces. The only alternative is to slow down the rate at which water is pumped and filtered, so that fewer particles will be removed.

Graphic Omitted

*Anatomy of* Mya arenaria. *(Figure: Majo Keleshian)*

Clams are capable of pumping and filtering a large amount of seawater. Clams approximately 25-32 mm long (1 to 1-1/4 inches) can filter as much as 2.5 liters (2.6 quarts) per hour in the summer. Clams can filter and digest much more food per unit time in summer than they can in spring.

## • Clam Growth

In early spring, when light is no longer a limiting factor and there is an abundance of dissolved nutrients available in surface waters, phytoplankton begins to grow. The result is the annual spring phytoplankton bloom. High-quality food is readily available to clams and, at this time, they begin to grow after a period of about five months when they have added no additional shell, but have been placing energy into gametogenesis (the production of eggs or sperm).

Clams cannot handle food as efficiently in cold water as they can during summer months. As waters begin to warm, blooms of phytoplankton exhaust nutrients from the surface waters, and both phytoplankton growth and concentration in seawater decrease. Thus, in the summer, although clams and other shellfish can handle and digest more phytoplankton, there is less available.

Food availability is not the only factor in growth. The metabolic rate (the rate at which a clam burns off calories in carrying out its various activities and physiological functions) also affects growth. Metabolic rate varies seasonally in the soft-shell clam. The rate is typically highest in the summer, partly due to elevated environmental temperatures.

Summer is the time of most rapid clam growth in Maine coastal waters. Although there is a spring "bloom" of diatoms in the Gulf of Maine each year, the greatest percentage of annual shell growth occurs between early June to mid-August.

Field studies conducted in eastern, mid-coast, and southern Maine during the past decade indicate that in most years, clams begin to grow during mid- to late March. Shell growth from early spring to the first week of June represents approximately 15 percent of the annual growth; 65 percent occurs between early June and mid-August; 20 percent occurs between mid-August and mid-October, and no more than one percent occurs from mid-October to the following spring. Clams essentially cease adding to their shells during the winter months. However, this does not mean that clams are not growing.

During December or January, clams of both sexes that are about two years and older begin placing much of their metabolic energy into reproduction. From February to mid-May (before 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 or sperm. (Incidentally, this period is the best time of year for clam processors to produce a shucked product because it takes fewer clams to fill a certain volume container than it does during summer and fall months).

Graphic Omitted

*Percent annual growth for hatchery-raised soft-shell clams at two intertidal sites. (Figure: recopied fromBrian Beal)*

Once water temperatures exceed 10 ºC (about 50 ºF), clams begin to spawn. This activity does not always occur at once with the sudden release of all an animal's eggs or sperm. Rather, the process is more gradual, taking perhaps as long as a month or more. Once the animals have released most of their gametes, their meat appears translucent and watery looking. After spawning, the clam has lost a high proportion of its body tissue and is said to be in "poor" condition. Spawning usually occurs between the middle of May through June depending on geographic location. Clams in the southwestern part of Maine (Cumberland and York County) spawn about six weeks earlier than those in eastern Maine (Washington County). When summer seawater temperatures are lower than usual, spawning may extend through July.

## • Other Biotic and Abiotic Effects on Growth

As discussed in the previous section, the feeding and growth of clams is a complicated process, with variations due to such diverse factors as the seasonal availability of phytoplankton, water currents, and water temperature. Other factors affecting clam growth may include density of adults or juveniles, mud flat topography, tidal level, and presence of predators. Sediment type may also be important. 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 rule, clam growth is directly related to position in the intertidal zone.

Clams grow faster at lower intertidal levels than at upper levels due to the length of time they are inundated by the tide. Clams may reach two inches in one-and-a-half growing seasons near the low water mark whereas it may take eight to 10 years or more for clams to reach this size at high intertidal areas. Some clams, especially those downeast in the Cobscook Bay area, may never reach two inches if they remain at upper intertidal areas. Clams appear to grow best in areas with good current exchange, but protected from wave action.

The growth of bivalves such as clams can be predicted using what is called an energy budget. The positive terms of the budget include the energy produced by food ingestion. The negative terms include energy lost by feeding, respiring, moving, spawning, and other metabolic requirements. Clam growth is calculated as the difference between the positive and negative terms. Thus, for example, clams generally grow faster on the lower shore because on the lower shore they are covered with water for a longer period of time, have a longer time available for feeding, and more positive inputs in their energy budget. Similarly, clams grow better on phytoplankton than on resuspended mud, because there is a greater energy component to the phytoplankton. Clams grow more slowly as they get older because they lose a greater percentage of their body weight each year due to spawning, and become less efficient with age.

Appendix III describes various practical techniques used to measure and assess the growth rate of clams

## • Conditioning and Spawning Broodstock Clams

"Conditioning" is the conversion of the clam's food reserves to the eggs and sperm. In all bivalve mollusks (i.e., mussels, clams, scallops), the process depends on the interaction between water temperature and food availability. In the spring, phytoplankton are abundant, and water temperatures increase rapidly from a low of 2 ºto 3 ºC (35 ºF) in early March to about 10 ºC (50 ºF) by mid- to late May depending on geographic location. As clams filter sufficient food for growth and gonad development, harvesters and processors can observe the meats becoming progressively firmer, fatter, and creamier.

In early summer, most clams in a flat will achieve a high state of readiness to spawn. Some environmental change—for example, warm seawater flooding of the flat with the incoming tide—will trigger the initial spawning. (It has been observed that under laboratory conditions, male clams generally are the first to spawn.) The sperm in the water contains a pheromone, or chemical messenger, which then will stimulate a simultaneous spawning of all clams on the flat that are in a ready state. This is nature's way of insuring efficient fertilization of clam eggs.

## • Clam Larvae

Once a female has expelled her eggs into the water column, they must be fertilized by the sperm of a male within two to three hours or else the eggs will not develop. Clams, like other bivalve mollusks that release their gametes into the water column, are prolific organisms. For example, one 2-1/2-inch female can produce about one to two million eggs. Clam eggs range in size from about 35-50 microns (0.001 - 0.002 inches). The reason for producing so many eggs is, of course, that only a small percentage will actually become fertilized and that an even smaller percent (< 0.1 percent) will eventually settle to the intertidal zone.

A fertilized egg in the water will rapidly develop in a day or two into a small, two-shelled swimming animal called a veliger larva . It feeds on tiny plant cells in the water and grows for a three- to six-week period before it develops a foot (pediveliger stage) and settles out of the water column and onto the mudflat where it begins life as a juvenile. (Keep in mind that since clam eggs develop in the water column, their movement is controlled mostly by tidal currents and prevailing winds. Only a small proportion of clam larvae presumably settle out within the intertidal zone. That is, a large percent probably settle into the subtidal zone where many are consumed by myriad predators there.) At the time of settlement, the clam measures less than 1/50 inch, which is smaller than a grain of sand.

If a single adult female clam releases a million or more eggs and it only takes two surviving young to eventually replace the original pair of spawners, the losses along the way, especially in the larvae, must be enormous. Clam larvae are planktonic swimmers, and therefore they are consumed by zooplankton and larval fish as well as adult fish that consume zooplankton (e.g., fishes in the herring family).

A common misconception about small clams is their origin. Because a flat may have an abundance of adult clams does not necessarily imply these are the parents of the juvenile clams found there. Because clam larvae typically spend four to six weeks as plankton and since currents generally flow from the northeast to southwest along the Maine coast, larvae (whose parents may reside in a Cutler flat, for example) might eventually settle in Harrington or Milbridge. This information underscores the importance of a regional approach to managing soft-shell clams.

In the past, scientists from Normandeau Associates monitored the presence of clam larvae in water samples collected one mile off the coast of New Hampshire at water depths ranging from 1to 17 meters (3 to 50 feet). In some samples, they found as many as 1,000 clams in a cubic meter of water. Highest numbers of clam larvae were found in the late summer. These results illustrate how widely distributed clam larvae are.

Predicting the eventual settlement site of a larval clam is not a simple matter. One would think that a patch of planktonic clam larvae could be modeled by tracing the movement of dye or neutrally buoyant spheres for a couple of weeks. While clam larvae have a very limited ability to travel on their own for any appreciable horizontal distance, they can, unlike an inert object, exercise control of their vertical position in seawater. Since most bottom waters in embayments have a net movement landward, a clam larva near the bottom could remain close to the embayment where its parents originated. Alternatively, it could fall to the bottom of an ebb tide and swim more actively on the flood tide, thus being retained in the same water body for its larval life. Such behavioral responses exist for oyster and mussel larvae, but these have not been as extensively studied for soft-shell clam larvae.

## • Setting

After several weeks of swimming in the plankton, clam larvae begin to develop a muscular foot. At this stage (pediveliger), clams have both the capacity to swim using the velum (swimming organ) and to crawl. Larvae may retract their velum into the mantle cavity and, because they are negatively buoyant, will sink, or settle, to the bottom. Once settled, a clam will evert its foot and begin to probe the substrate. Clam larvae have rows of cilia that rim the periphery of the foot. These cilia allow the clam to differentiate bottom types. Should the bottom be hard and impenetrable, the clam will retract its foot into the mantle cavity, open its valves exposing its velum, and swim away. This process is repeated until a suitable substrate is encountered. During this "swim-crawl" stage, the clam has the ability to delay its setting for up to a week while "choosing" its eventual benthic home. When setting occurs, the clam quickly loses its velum, metamorphosing 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. As with mussels and other bivalves, juvenile clams have a byssal gland in their foot that permits them to produce a thin, sticky strand, called a byssal thread, which is used to help anchor them to the bottom. At about 1 mm (1/25 inch) in size, clams, like mussels, produce a drifting byssal thread which allows them to move inshore on incoming tides. When conditions permit, the byssal thread can be severed so the clam can move about willingly by using its foot to crawl over the sediment surface. Juvenile clams can crawl and reburrow themselves until they reach about an inch in length. After that, the ability to produce a byssal thread disappears because the byssal gland disappears.

Observations of juveniles (clam spat) and associated physical and chemical conditions hopefully will improve our knowledge about the phenomenon of setting in field conditions. Concentrations of spat in sandy or gravelly areas, near river mouths, and around obstructions such as fish weirs indicate the importance of current patterns and substrate texture on settlement.

Clam recruitment is highly variable from year to year for a number of reasons, including low spawning effort, current patterns, and predation. A failure of any one of the stages leading up to and including the setting sequence will result in a failure of the entire growth system. Typically, we may expect good and bad years for setting success. One successful year may be followed by a series of unsuccessful years. This gives rise to a dominant "year class" of clams which, if carefully managed, should sustain digging for several seasons.

## • Juvenile Clam Ecology

Once larval clams have lost their ability to swim and settle to the benthos, they are referred to as juveniles. Juveniles undergo metamorphosis and quickly assume the form of an adult. In Maine, it will take two to ten years for a juvenile clam to reach a market size. The life of a juvenile clam up to an inch in size is very precarious. The tiny clams with delicate shells dwell very near the surface and are prey to a variety of animals. After settlement, juvenile clams grow quickly to a size between 3-10 mm (0.12 - 0.4 inches) by the end of October. They grow very little (1-2 mm at most) until the following spring and spend the entire winter buried at depths less than 3/4 inch below the mudflat surface. They are extremely susceptible to being moved by storm surges and ice floes.

Graphic Omitted

*Soft-shell clam trochophore (bottom) and pediveliger (top) larval stages. (Figures: Majo Keleshian)*

At an intertidal flat along the Damariscotta River in March, for example, it was noted that the surface sediment suddenly became populated with one-inch juvenile clams. These clams may have been deposited by ice rafting. During extremely cold winters, ice blocks that can be two to three feet thick will form on flats. The weight of the ice pushes down into the uppermost portion of the mudflat surface which freezes and adheres to the blocks. When warmer weather breaks up the ice, the floes, with their muddy bottoms, move in whichever direction wind and tidal currents take them.

Because small clams are living within the top inch of sediment, they too become moved about. Often, the ice is pushed toward the upper intertidal where a percentage of the clams that are not crushed in this ice-moving process are deposited onto the flat. This results in sets "appearing" in the spring when they were not there the previous fall. Conversely, complete sets may disappear either because ice or storms have deposited clams in the subtidal zone.

## • Where Have All the Clams Gone?

From the 1940s through the early 1980s, clam flats in the easternmost portion of Maine (Washington and Hancock County) annually produced between 45 to 75 percent of all clams harvested in this state. Several reasons may be responsible for this fact, including the presence of a larger harvesting population than elsewhere in the state and larger tides exposing more clamming habitat Down East.

Since 1982, however, landings in the eastern counties have fallen by nearly 70 percent, while the catch has increased in the southwestern portion of the coast. Investigators at the University of Maine at Machias and Maine Maritime Academy conducted a study during the summer of 1995 to determine whether the lack of clams northeast compared to the southwest was related either to a lack of larvae in the water column Down East or to a difference in mortality of post-larval clams between the two regions. In other words, they wondered whether clams were reaching the downeast flats at all or were dying off en route. They examined settlement and recruitment (the process of surviving to some determined size) patterns of clams at six intertidal flats both in Washington and Cumberland County.

The study concluded that, in 1995, nearly seven times the number of clams settled and survived to 2 mm (0.08 inches) at the southwestern sites than those Down East. A series of short-term field tests indicated that at peak settlement in the southwest (mid-July) as many as 85,875 settlers per square meter (approximately 8,000/ft.$^2$) settled out of the water column in a two-week period whereas peak settlement in eastern Maine was only 1,875/m$^2$ (175/ft.$^2$). These results indicate that in eastern Maine, larval supply, rather than post-settlement processes, may be more important in regulating clam populations.

# REFERENCES

*For further reading on soft-shell clams and clam aquaculture, please refer to the following publications.*

*A Compilation of Shellfish Laws and Regulations*. Maine Department of Marine Resources, revised October, 1995.

*An Evaluation of Strategies to Restore* Mya arenaria *Production in Maine*. Clime, R. and Townsend, R., for the Maine Aquaculture Innovation Center, December, 1993.

*Aquaculture in Maine*. Maine Aquaculture Innovation Center with the Maine Aquaculture Association and Maine Sea Grant, 1989.

*Aquaculture in Maine: A Curriculum Guide for Secondary School Teachers*. Bernhardt, P., Sucoff, K., White, S., et al., Maine Sea Grant, 1997.

Beals Island Regional Shellfish Hatchery brochure.

"Culture and Ecology of the Soft-Shelled Clam, *Mya arenaria*," Hidu, H. and Newell, C., in *Clam Mariculture in North America*, pp. 277-292, 1989.

*Steps to Opening Clam Flats*, published by Friends of Casco Bay, March, 1996.

*The Fate of Hatchery-reared Juveniles of* Mya arenaria L. *in the Field: How Predation and Competition are Affected by Initial Clam Size and Stocking Density*. Beal, B., Maine Sea Grant, 1992.

*The Soft-Shell Clam and its Environment: A Study in Jonesboro, Maine*. Arbuckle, J., Maine Sea Grant, 1982.

*The Soft-Shell Clam Industry of Maine*. Dow, R. and Wallace, D., U.S. Fish and Wildlife Service, Circular 110, Washington, D.C., June 1961.

*Volunteer Manual*, Maine Shellfish Sanitation Program, Department of Marine Resources, 1997.

# Appendix I

## List of Resource People

**Department of Marine Resources Shellfish Sanitation Program**

Boothbay Harbor Laboratory
PO Box 8
West Boothbay Harbor, ME 04575
Paul Anderson, Director
633-9554

Lamoine Laboratory
c/o Lamoine State Park
RFD 2
Ellsworth, ME 04605
667-3373

**Certification of Shellfish Dealers**
Amy Fitzpatrick, Senior Seafood Technologist
23 Marshall Ave.
Bath, ME 04530
443-1583

Jeffrey Armstrong, Seafood Technologist
18 Avon Rd.
Cape Elizabeth, ME 04107
799-7193

Bruce Chamberlain, Seafood Technologist
RFD 2 Box 252A
Ellsworth, ME 04605
667-4595

**Growing Area Classification Program**
**Boothbay**

Gail Parson, Microbiologist
633-9515
Jan Barter, Specialist II
633-9501
Fran Pierce, Specialist
633-9511
Laura Livingston, Specialist
633-9533
Nancy Hurst, Technician
633-9552
Jason Bartlett, Technician
633-9546

Lamoine
Mercuria Cumbo, Microbiologist
Bob Goodwin, Specialist
John Fendl, Specialist
David Dennison, Specialist
667-5654

*For help with scheduling, equipment needs, or other technical assistance related to water quality and shoreline survey work, contact the Specialist responsible for your area.*

**Marine Biotoxin Monitoring Program**
**Boothbay**

John Hurst, Supervisor
633-9570
Laurie Bean, Specialist II
633-9555

Lamoine
Jay McGowan, Specialist II
667-2418

*For help with the phytoplankton monitoring program, contact the Specialist from your region.*

**Watershed Management Division**

Hal Winters, Supervisor
624-6550

Don Card, Area Biologist for southern Maine, Portsmouth to the Kennebec River
443-6559
Ron Aho, Area Biologist for midcoast Maine, Kennebec River to Searsport
586-5572
David Clifford, Area Biologist for eastern Maine, Searsport to Calais
255-3926

*For questions about shellfish management, municipal shellfish ordinances, coastal development, permitting and other technical information related to coastal land use, contact the Area Biologist for your region.*

Red Tide Hotline, for updates on PSP openings/closings and rainfall closures: 1-800-232-4733

Shellfish Landings
Walter Foster
PO Box 8
West Boothbay Harbor, ME 04575
633-9524

**Other Agencies and Organizations**

Beals Island Regional Shellfish Hatchery
PO Box 83
Beals, Maine 04611
497-5769

Kathleen Leyden
Shore Stewards Coordinator
Maine Coastal program
Station 38
Augusta, ME 04333
287-3144

Esperanza Stancioff
Univ. of Maine Cooperative Extension
PO Box 309
Waldoboro, ME 04572-0309
1-800-244-2104

David Achorn
Dept. of Environmental Protection
Bureau of Land and Water Quality
Station 17
Augusta, ME 04333-0017
287-7766 *OR*
Richard Green
287-7765

Maine Aquaculture Innovation Center
141 N. Main St.
Brewer, ME 04412
989-5310

Maine Soft-Shell Clam Advisory Council
c/o DMR
Hallowell, Maine
624-6550

# Appendix II

## Maine Department of Marine Resources Requirements for transplanting clams within the Municipal Shellfish Program

A community must have a permit from the Maine Department of Marine Resources (DMR) to process undersized soft shell clams (*Mya arenaria*). This permit will allow the municipality to possess sub legal clams for the purpose of reseeding shellfish areas. Without such a permit, the diggers may be in violation of state law.

The following guidelines should be followed while transplanting clams from all sources:

1. The activity will take place during daylight hours.
2. The activity will take place on designated days.
3. The activity should take place under the supervision of the town's shellfish officer or a designee of the Shellfish Committee.

The following guidelines must be followed when taking seed clams from a Closed or Restricted area.

1. All clams harvested must be less than 2" in the longest diameter. This is a no tolerance policy.
2. The harvest area must be marked by orange flags.
3. There must be a designated landing point for product that is included in the application.
4. During harvesting activities, harvest crew diggers shall remain in the same area, close enough for immediate supervision of all diggers at all times by the representative of the shellfish committee. The period of harvesting activity will be considered the time from

which the names of the diggers are taken by the representative of the shellfish committee until the clams are landed at the designated landing point.
5.The method and route of the transportation of product to the receiving area must be submitted to DMR at the time off application.

**NOTE: Areas seeded with clams taken from Depuration or Prohibited (Closed) areas must be closed for a period of at least six months.**

## PROCEDURE

In order to obtain a permit the Shellfish Conservation Committee (SFC) must do the following:

1. Fill out the attached application.

2. Send the completed form, at least a week prior to the requested date, to:

Commissioner, Dept. of Marine Resources
21 State House Station
Augusta, ME 04333-0021

3. Marine Patrol in either W. Boothbay Harbor at Division I (207-633-9595) or Lamoine at Division II (207-667-3373) must be notified on the morning of the activity, or if the activity is initiated prior to the start of the normal business day or occurring on a weekend, the previous business day, of the name of the following:

A) The name of the supervisor

B) The area of the activity

i)The name of the supervisor
ii)The number of diggers involved
iii)The area of the activity.

4. The supervisor of the activity will have in his possession a copy of the permit from the Department for the activity and a list of names of diggers involved.

5. Questions and comments should be addressed to the following:

York, Cumberland and Sagadahoc Counties
Donald Card
Telephone: 207-386-0035
HCR 32 Box 252
W. Bath, ME 04530

Lincoln, Knox and Waldo Counties
Ron Aho
Telephone: 207-586-5572
118 Kings Highway
Newcastle, ME 04553

Hancock and Washington Counties
David Clifford
Telephone: 207-255-3926
PO Box 37
E. Machias, ME 04630

To: Commissioner, Department of
Marine Resources
21 State House Station
Augusta, ME 04333-0021

From: The Town of ______________________________
requests to possess undersized clams for the purpose of transplanting.

Contact Person of the town:

Name
_______________________________Title______________

Address
________________________________________________

________________________________________________

Telephone
________________________Fax______________________

Please answer the following:

1. Who will be the supervisor of the seeding operation?_______________________________

Title____________________Telephone #_______________Fax#____________

2. What is the source of seed clams? (Please mark one)
Natural _____ (Go to #3)
Hatchery _____ (Go to #6)
Other _____ (Go to #6) Describe:
_______________________________________

3. Please name the source area and attach a map showing the source area.

4. Please indicate the State classification of the seed source area:
Approved (Open) _____ (Go to #5)
Prohibited (Closed) _____ (Go to #11)
Restricted (Depuration) _____ (Go to #11)

5. What day and time will the seed clams be harvested? Date:_______Time:_______

6. What is the destination of seed clams? (Please attach a map of the area)

7. What day and time will the seed clams be planted? Date:_______ Time:_______

8. How will the success of this project be monitored?

9. Is the seeded area being closed to harvest of clams?

10. Are predator controls being used? ______ If yes, please describe:

If Hatchery seed or Open area clams are used, no further questions need to be answered. If Closed Area clams are used, please go to #11.

**CLOSED/RESTRICTED AREA SOURCE SEED CLAMS**

***Please Note:***

**Closed/Restricted Harvest Area must be marked by orange flags.**

11. What day and time will the seed clams be harvested? Date:_______Time:_______

12. What is the destination of the seed clams? (Please attach a map of the area)

13. How will the seed clams be moved to the planting site?______________________

14. If seed clams are transported by car, where will the clams be landed? (Please note that clams from Closed and Restricted areas must be planted immediately. No storage is allowed.)

15. What day and time will the seed clams be planted? Date:_______Time:_______

16. How will the success of this project be monitored?__________________________

17. Is the seeded area being closed to harvest of clams?

NOTE: Areas seeded with clams taken from Depuration or Prohibited (Closed) areas must be closed for a period of at least 6 months.

18. Are predator controls being used?_______ If yes, please describe:

# Appendix III

## Advanced Clam Measurement Techniques

### How to Assess Where Clams Grow Fastest

Two factors contribute to the difficulty in measuring the growth of clams under natural conditions. Clams grow more slowly as they get larger. Therefore, for comparative growth rate estimations, clams of the same initial size should be used. In addition, growth may be slower at high densities. Follow growth rate during the period from late March/early April to 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 1/2 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., 1/2-inch, 3/4-inch to 1-inch, 2-3/4-inch 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 use one size class of the smallest clams available (that is, do not vary the size of the clams you use). Since small clams will grow faster, they can be used to quickly assess the best growing areas since you can remove them from the sediments at three- to four-week intervals.

## Growth Measurement: Two 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 upon 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 remeasured 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.

### • Changes in Size Frequency Distribution—Counting the numbers of individual clams within each size class

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 1-1/2 inches in March may measure two 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.

### • Annual Lines (How Old Is that Clam?)

In New England, soft-shell clams generally exhibit seasonal differences in shell growth which result in 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 Lf (final length) and Li (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), false annual checks are formed called disturbance lines. Depending on the severity of the disturbance, these lines may sometimes be as distinct as the annual checks.

Annual growth increments using the shell margin of larger animals are more difficult to interpret because the distance between annual checks is quite narrow. One can hold the shell up to a light (candling) to aid in aging the animal, but a more accurate age can be determined by examining growth lines in the inner shell layer. Although fairly accurate, this technique is laborious and more costly than other methods. Using this technique, shells are cut perpendicular to the anterior-posterior axis from the chondrophore to the outer margin using a slow-speed saw equipped with a diamond-edge sawblade. One half of the shell is embedded in an epoxy resin.

After the resin hardens, the resin is sanded to expose the clam, and then the clam and resin are polished using fine grit and water. Next, a weak solution of hydrochloric acid (HCl) is poured over the resin and polished clam. This etches the shell and helps expose the annual lines. Finally, the clam and resin are placed flat down on a piece of clear acetate that is flooded with acetone. After a few moments of drying, the acetate is peeled away from the resin and shell and an impression of the shell is left on the acetate. These thin slices of the shell are examined under a microscope. Annual growth lines in the inner shell get deposited early in the spring in Maine, when growth first begins.

### • Mark and Recapture Techniques (Marking Clams)

Mark and recapture techniques are probably the most accurate methods to estimate growth rates of clams. They involve digging wild clams or obtaining hatchery seed, marking and/or measuring them, recording the measurements, planting them in locations of interest at constant densities, returning after some period of time, digging them up, and measuring growth increments. The advantage of mark and recapture is that the investigator can choose clams of the same initial size (making growth rates comparable) and plant them at constant densities (some fixed number per unit area).

### • Notching

The edge of the shell may be notched with a small file. This produces a check line which records the initial clam size. However, notching might cause an interruption of growth and not reflect true growth rates.

Graphic Omitted

*The use of annual shell checks to calculate growth. Growth equals final length (Lf) minus initial length (Li). (Figure: Majo Keleshian)*

### • 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 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

Clams may also be marked 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.

- **Using Hatchery-reared Clams**

Perhaps the easiest method of all for determining the rate of growth of soft-shell clams to assess which flat or area of a flat is best suited for growth is to use hatchery-reared animals (1/2-inch to 3/4-inch). These animals are reared in a sediment-free environment. Once they are placed in any substrate (sand, gravel, or mud), the new shell that is added is usually a much different color than the old shell (typically whiter). This difference in coloration is so dramatic that growth rates for periods as short as two weeks or as long as one year are easily observed and measured. One should measure the total length of the clam with calipers. Next, measure the darker, older portion of the shell which was the size of the clam when placed in the flat. To estimate growth rate, use the following equation: growth rate = (final length — initial length)/time (in days, months, years).

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