THE SOFT-SHELL CLAM INDUSTRY

OF MAINE

Circular 110

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

UNITED STATES DEPARTMENT OF THE INTERIOR, Stewart L. Udall, *Secretary*
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by

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Department of Sea and Shore Fisheries
Augusta, Maine

United States Fish and Wildlife Service
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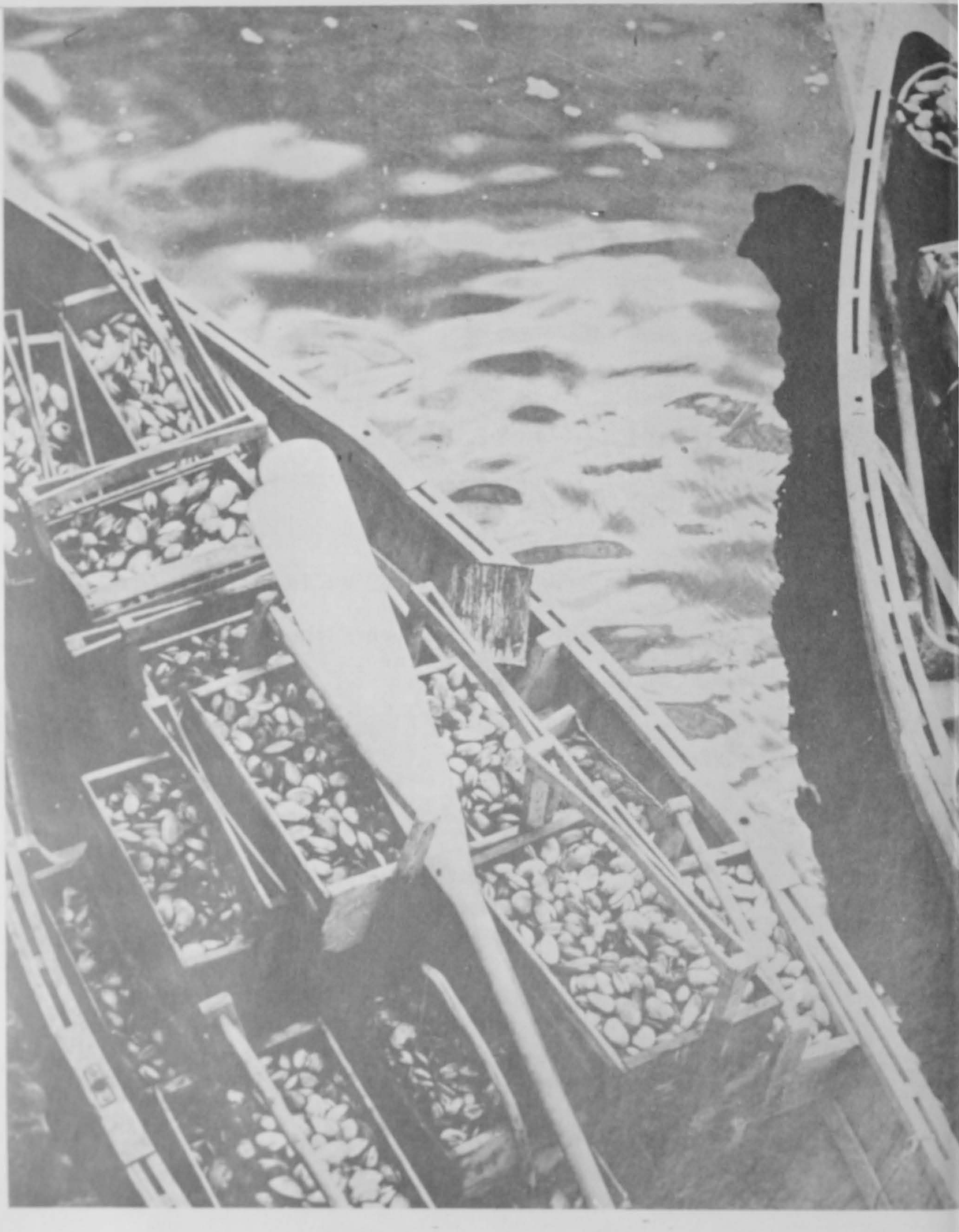

Freshly dug clams ready for pickup by the buyers.

FOREWORD

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Robert L. Dow and Dana E. Wallace, Department of Sea and Shore Fisheries of the State of Maine, conducted the research for the project and prepared the report.

Alton T. Murray, Economist, Branch of Economics, Bureau of Commercial Fisheries, edited and prepared the report for publication. He was assisted by Keith Brouillard and Mrs. Harriet Denton of that Branch.

FOREWORD

[illegible] This report [illegible] conducted by the [illegible]

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ABSTRACT

This report examines the organization and problems of the Maine soft-shell clam industry as well as the physical factors which limit market supplies from this public resource. The influence of public opinion, conservation legislation, and current management practices upon the industry are discussed in detail.

Private management of the clam flats is recommended to encourage adequate managerial practices for increased production and to conserve the resource. The effect of hydrographical, geological, and meteorological conditions upon the clam flats and the problems of predation are discussed and illustrated by photographs.

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EARLY HISTORY AND DEVELOPMENT OF THE INDUSTRY

Early man's dependence on shellfish for food is indicated by finds of shells in kitchen middens. When man first made use of soft clams in Maine is not known exactly, but fragments of shells found on the Glidden Farm at Newcastle show a Carbon 14 age of some 1,700 years.

The first white settlers made use of the clam resource, but only in time of dire need. Elder Brewster of the Plymouth Colony wrote that during the winter of 1620-21 he often had only clams to eat. Northern New England settlers appear to have considered the eating of clams a last resort in order to keep alive. Perhaps they were familiar with the species in northwestern Europe and in England and did not consider that species edible. They may also have known the blue mussel, *Mytilus edulis*, but their experience with New England blue mussels was unfortunate for colonial records contain frequent complaints of extreme illness from eating them. With lobsters and fish unavailable during the winter and mussels unpredictable, colonists were forced to eat clams. In his Journal of Maine History, Sprague wrote: "In 1781 food was scarce with many at the Kennebec. Mr. Baily knew families without bread for three months at a time, many even twenty miles inland sought the clam banks."

The association of hard times and privation with the clam resource appears to have retarded commercial development. The concept of a public resource has discouraged initiative, and no great concern for harvesting methods or the purposes of use has been evidenced as long as the clam supply has been available. The principal concern for conservation has always been associated with the need for clams as subsistence.

In the Biennial Report of 1907-08, the Commissioner of Sea and Shore Fisheries wrote: "The success of the clam industry directly or indirectly affects more citizens of this State than that of any other of the fisheries." Today this statement is still true. The clam resource, out of proportion to the value or the amount harvested, has always had an important role in the State of Maine's coastal economy.

For purposes of historical summary, the dominant commercial use of soft-shell clams and the periods of such uses are as follows:

Dominant Use	Years
Salt bait	1850 - 1875
Steamers (small clams steamed in shell)	1875 - 1900
Canned	1900 - 1940
Fresh market (shucked)	1940 to date

Although these dates should not be considered as exact, they indicate the shift from one major use of the resource to another.

Soft-shell clams were a source of food and of bait until 1850, but no one bought or sold them commercially. They were generally available and were dug without regulation.

The industry began with the use of clams for bait. They were dug, shucked, and salted in barrels for use by Grand Bank fishermen during the summer fishery. The digging of clams lasted from October through March and was a welcome source of income for those needing employment during the winter.

After 1875 when Bank fishermen began using fresh bait, the salt-bait industry declined. An export market of some importance developed, however, and continued until 1912 when several thousand barrels of clams were shipped to Portugal. Today fresh-bait clams are used in small amounts for commercial fishing purposes, and in some resort centers, small but profitable businesses have developed to supply bait for salt-water sport fishermen.

About the time that the salt-bait industry began to decline, a demand evolved for steamed clams in the shell. Clambakes and shore dinners during the summer months became increasingly popular. This market is still important to the industry.

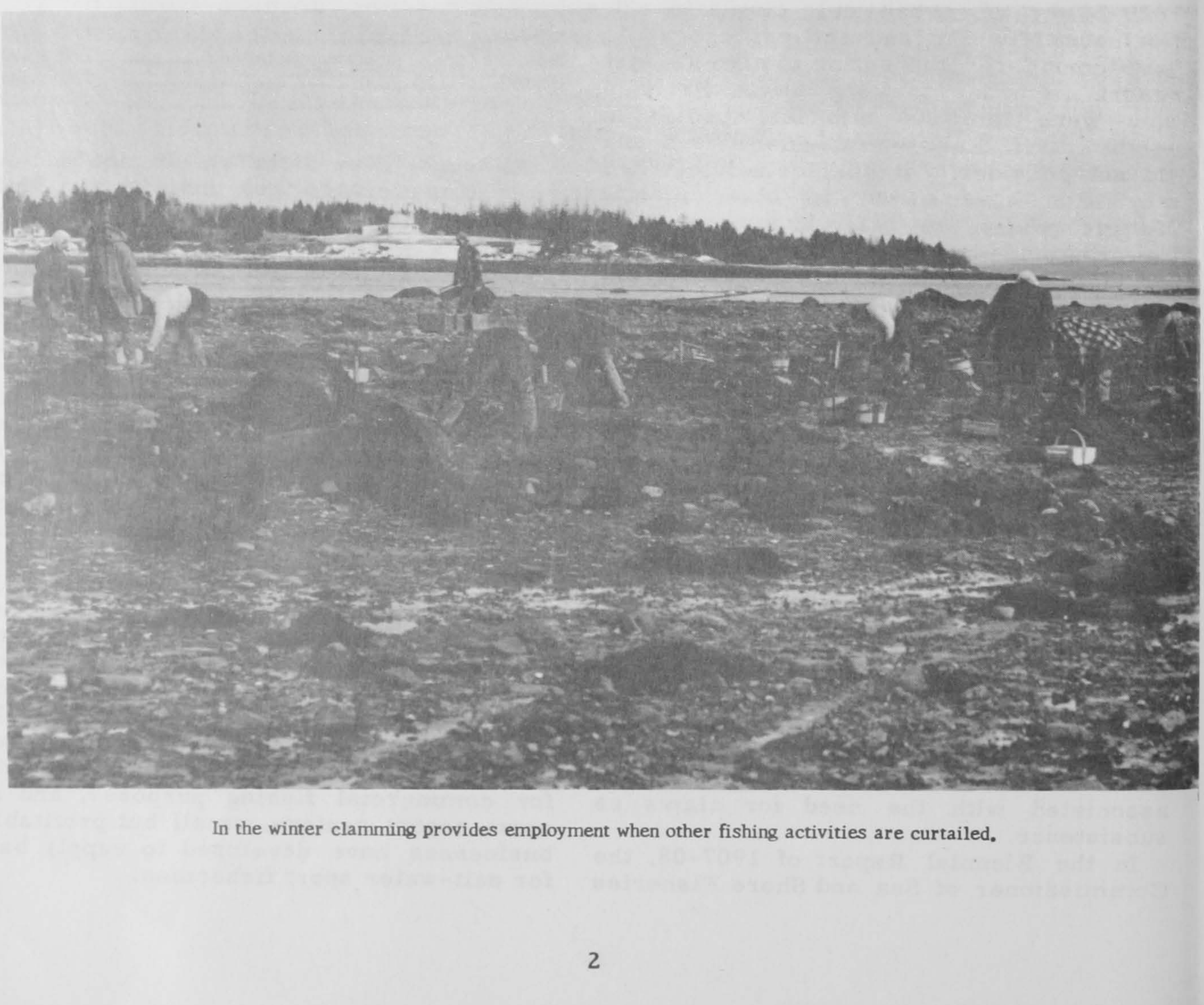
It is not known exactly when clams were first canned in significant quantities. By the end of the 19th century, however, canned clam production amounted to some 60,000 cases annually.

From 1900 to 1940 the canneries took the major portion of all clams produced in Maine. Canning was confined to the winter months when there was little competition from other activities. Laws were passed prohibiting canning, packing, and barreling of clams, either fresh or salt, and the digging of clams for these purposes between June 1st and September 15th. Parellel legislation prohibited shipping or transporting of clams, in any, manner, beyond the State limits except those which had been canned, packed, or barreled during the winter season. Those engaged in the steamer-clam trade were sufficiently influential to obtain waivers of these laws during the summer, to permit digging and barreling of clams in the shell for consumption within the State.

Today canners provide only a limited outlet for Maine soft-shell clams. In recent years Maryland soft-shell clams and surf clams have been canned in increasing quantities and have greatly reduced the market for canned Maine clams. Large clams, unacceptable for the shucked clam market, are generally used for canning.

The peak of the canning season is in the spring for several reasons: Increased siphoning activity by the clams makes them more easily found by the diggers; excellent tide conditions uncover the large clams growing below mean low water; prices are lower in spring than in summer; and meat quality is higher in spring than in summer.

The fresh-clam industry is reported to have begun shortly after the Civil War,



In the winter clamming provides employment when other fishing activities are curtailed.

Gulls follow clam diggers to pick up sublegal clams left on the surface of the flats by the digging operations.

when shucked meats were shipped to Boston to be used in chowders and as fried clams. For a long time, however, the summer restrictions on clam digging limited the development of a trade in the fresh product.

In 1937 summer restrictions were repealed on clams in the western coastal counties of York, Cumberland, and Sagadahoc, and in Lincoln County, restrictions were repealed in 1941. The influence of the canning industry remained sufficiently strong to retain summer-digging restrictions in the eastern coastal counties until 1949.

Fried clams had been sold for many years by restaurants and various small eating places in New England, but the rapid growth in popularity outside of New England greatly improved the fresh-clam market. Just prior to World War II a large restaurant chain introduced fried clams, made from fresh-shucked clam meats, and their new specialty had wide acceptance. Moreover, this innovation is credited with the increase in demand for shucked clams from other growing areas in New England as well as Canada.

During World War II the number of diggers drastically declined, and the clam population increased substantially. At the close of World War II, however, discharged military personnel found clam digging a highly profitable occupation. For many, clam digging was interim work until more permanent employment could be found. The increased demand for protein foods, the abundance of clams, and the enhanced work force brought high production levels.

Many clams were exported in the shell to the shucking houses of eastern Massachusetts. Shucking facilities in Maine were rapidly expanded, and production of clams during the 1946-49 period reached the highest level since 1912.

As the clam population of the western, or "open counties," declined, the loose wording of the law and the increase in illegal summer digging made enforcement of regulations in the eastern, or "closed counties," impossible during 1946 through 1948. Resentment increased among diggers who respected the law, and in 1949 the legislature repealed the remaining summer-digging restrictions.

ORGANIZATION OF THE INDUSTRY

The Maine clam fishery is a hand-labor industry and requires only a small investment in gear and equipment. Clams are dug with four-tined short-handled hoes from the intertidal areas of coves, bays, and estuaries when the flats are exposed at ebb tide.

Soft-shell clams live in sediments varying from compacted marine blue clay to coarse sand-cobble mixtures, in a zone extending from below extreme low water nearly to mean high water. The term "flat" applies to that part of ocean bottom exposed during low tide, and which may extend seaward a mile or more depending on the gradient of the bottom and the range of the tide. Flats that are not accessible by motor vehicles are reached by boats, either oared or equipped with outboard motors.

Diggers deliver their catch at some convenient place--the shore, dock, canning plant, shucking house, or fish stand. At one time clams were sold by the barrel; more recently sales are made by the bushel or fraction thereof.

Buyers pay the diggers a going price for clams on an ungraded basis. The price paid allows for the amount of debris and the small or broken clams which have to be discarded at the processing plant. For ungraded clams, the loss in volume after sorting varies but may sometimes exceed 50 percent. Some buyers pay particular diggers a premium for washed or graded clams, although this practice is limited and especially so in areas where canning is important.

Clams are picked up by buyers at some convenient place.

This horse and woods scoot provided an extra service in picking up clams from diggers as they worked on the flats.

The majority of diggers harvest clams as a part-time occupation, and very few dig on a year-round basis. The availability of various kinds of work in a community affects production as other industries that use unskilled manual labor are competing for the diggers' time and services. Early autumn potato picking in Aroostook County draws numerous eastern diggers. Blueberry picking is considered a fall interlude by many commercial diggers. November is traditionally the month to go deer hunting, so clam production declines then. In November and December the Christmas-tree harvest and coastal pulp and lumbering operations attract diggers to work in the woods. Commercial diggers participate in other fisheries at various seasons.

After the buyer has completed his daily purchases, he delivers the clams to the processing plant where he collects a commission based on the number of bushels bought. Since he deals directly with the digger, the size of the geographical area a buyer can cover is limited. For this reason larger processing plants require the services of several buyers. Buyers may be associated with one processor, or be independent in operation and serve several plants and dealers.

Processing plants may have as many as 50 employees or be quite small. Operators of small shucking plants must function as their own buyers and purchase clams directly from the diggers or make use of independent buyers who supply several shucking plants or canneries.

Processing may consist of shucking and canning or simply culling and washing for resale as steamers. At the shucking plants, clams are washed and debris is removed.

Many clams are "home shucked" for local sale, a practice which is legal in Maine. Although sanitary restrictions on shucking plants theoretically prevent the sale of home-shucked clams in interstate commerce, this is more an ideal than a fact.

The shucking at the plants is done by women who are paid on the basis of number of gallons shucked, and therefore they discard small or broken clams which require extra time.

After shucking, clams are washed in a large air-agitated water bath or another large container. The washing time varies in different plants according to the wishes of the manager or owner. Some processors believe that prolonged washing or soaking increases the apparent volume of shucked meats. This belief was disproved in 1950 by Harriman, who showed that the amount of water absorbed by the meats that could be drained from packed clams depended more upon the method of washing than upon the length of time of washing.

When excess water has been drained from the shucked clams, the meats are packed in gallon cans with friction covers and held in a cold room for several hours. Then the packed cans are put in iced barrels for shipment to market.

Demand for clams varies seasonally and reaches its peak during the summer. The principal markets for shucked clams are the diners, roadside stands, and restaurants featuring fried clams. Although these

Production and value of the Maine soft-shell clam industry, 1948 - 1958.

eating establishments offer this specialty all year, the demand during the tourist peak in July and August is at least three times as great as in any other season.

All retail outlets, whether fish markets or eating places, must be supplied on a continuous basis since the processors have not developed satisfactory methods of accumulating or holding whole clams or clam meats longer than a few days. Dealers, therefore, cannot supply regular customers with quantities in excess of the rather low level of dependable daily production. Consequently, the prospect for expanding the market is limited by the problem of obtaining a dependable daily supply to meet the minimum year-round requirements of the trade.

Before the development of the Maryland fishery, some Maine dealers quickfroze shucked clam meats during the spring glut to help meet the demand during July and August, but the quality was inferior to that of fresh clams, and in time the supply from the Maryland fishery reduced the need. In recent years the Maryland fishery has dominated the soft-clam market because it can produce a dependable daily supply during the period of peak demand. The Maryland fishery was developed initially from the need of the New England clam dealers for new sources of supply to compensate for declining resources in New England and Canada.

Prior to World War II when canning still dominated the industry, the processor was often favored by a buyer's market. In the immediate postwar period, however, the fresh-clam processor became important and the producer-processor relationship changed. Digging operations commenced on a year-round basis, and seasonally high prices encouraged repeated digging of areas that were formerly dug only occasionally. As the clam population declined and the price increased, diggers deliberately curtailed their efforts. The feeling was that dealers would pay even better prices if fewer clams were offered them. The market became a seller's market. Clams were in such demand, irrespective of quality, that rival buyers bid vigorously in order to obtain a local monopoly of clams and diggers.

Dealers and processors have since tried various methods to regain the initiative, or restore the buyer's market. Before the development of the Maryland soft-clam fishery, a wider use of surf clams, *Spisula solidissima*, was attempted. Results were so successful that nearly all commercial clam chowder is now made from this species. Similarly, surf clams were processed for frying and soon became an important competitor of soft-shell clams for the fried-clam market.

With the advent of a reliable supply of soft-shell clams from Maryland, Maine dealers could make use of this new source whenever local producers failed to meet requirements of quantity, price, and quality. As both Maryland clams and surf clams are plentiful, the Maine producer's favored economic position has deteriorated.

Declines in the production of soft clams throughout the northeastern states and Canada have not been compensated for by Maryland production. Although the surf clam is a competitor of the soft clam, in the sense that all shellfish are competitors, it is not entirely a substitute since they are different species with different flavor and acceptability characteristics.

There are seasonal and real variations in clam quality. Maine will have to give serious consideration to quality if it expects to compete successfully with the more efficient Maryland fishery. Dealers should encourage production of a better product by paying a price differential for washed, culled, and unbroken clams.

Processors refer to quality of the processed product in general terms. Size of individual clams, dryness of the pack, color, and dry solid content are factors. The Maryland clam fishery provides a product which can easily be graded according to size. This phase of quality control has not been carried on in Maine except in a very general way. Large clams dug during the spring tides are not acceptable as steamers and generally are not acceptable for frying purposes. The large clams are used chiefly by canners. A marked price premium favors clams under 3 inches in diameter.

Dealers have a limited seasonal steamer market for small clams, particularly those just under 2 inches in diameter. However, during the remainder of the year and for shucking or canning purposes, they do not wish to handle sublegal sizes. Some dealers and processors admit that they wish to retain the minimum 2-inch restriction when they do not have a market for undersized clams, as the legal restriction protects them from the necessity of purchasing any and all clams which the producer may deliver. The dealers fear that refusal to buy small clams, when steamer demand is low, will result in loss of the digger's services. The influence of the dealers was sufficient to defeat repeal of the minimum-size law.[1]

One of the quality problems is breakage caused by the digging process. There is bacteriological evidence that broken and unwashed clams are a health and sanitation hazard. When diggers are paid a premium price for unbroken and washed clams, they do less damage to the residual population in the flats because of greater care in harvesting.

Processors publicly admit that quality control is vital to the industry but at the same time insist that they can do nothing about the problem because of intense competition among themselves for the clams. Some dealers have shown interest in quality standards backed by adequate laws, while expressing no confidence in voluntary standards because of competition. With quality standards in effect, competent and capable diggers would not have their efforts penalized by poor quality clams and dealers would not be forced to downgrade prices.

Various criteria of quality have evolved in recent years. Several became of recognized importance by the industry in 1960 during the period of temporary repeal of the minimum-size regulation.

(1) Meat yield is the most important consideration as far as the shucking house operator is concerned. Yield varies seasonally and according to geological conditions.
(2) Shell appearance and color is important in the steamer market. Aesthetically more acceptable color offsets poor meat yield. This criterion became increasingly important in 1960.
(3) Washed and unbroken clams are important steamer quality factors which have been accorded industry consideration only within recent years.
(4) Uniformity of size and shape of the clams influences price.
(5) High quality clam meats possess uniformity of size and color. These factors have become increasingly important in 1960 and are the most important consideration in the recent expansion of a quality market.
(6) For shucked-clam processors and steamer-clam dealers, retracted siphons and immediate response to touch indicate that the clam is alive.
(7) Flavor appears to be important only for those discerning consumers who prefer clams from highly saline waters.

[1] The Maine Legislature repealed the minimum-size restriction on soft-shell clams for the period March 1, 1960, to January 1, 1962. Unless action is taken by the legislature (convening January 1, 1961), the restriction will once again be in force.

FACTORS LIMITING CLAM MARKET SUPPLIES

Fluctuations in the Abundance of Clams

Fluctuations in year-to-year production (table 2) appear to be caused by variations in the size of the clam population. It can be seen from the wide swings in production that general and widespread survival of clam sets rarely occurred. When those infrequent sets reached market size, they were so intensively exploited that high levels of production lasted only 2 or 3 years. Scarcity followed each intermittent period of abundance.

Records of the Department of Sea and Shore Fisheries of the State of Maine mention some special periods of clam scarcity. In the Biennial Report of 1903-04, the Commissioner of Sea and Shore Fisheries wrote--

> As in my last report, I am obliged to say that this important industry is very certainly decreasing, and has already got to the danger point, and unless there is something done I think that the present disparity between the demand (so rapidly extending) and the supply (so surely being exhausted) will be almost, if not quite, irreparable.
>
> The falling off in production, comparing this report with the two years covered by my last report, is startling and exceeds two million three hundred thousand pounds! And this in face of the fact that if our production for the present year was doubled the market demand would not be supplied. [2]

In the 1913-14 Biennial Report of the Department of Sea and Shore Fisheries, the Commissioner reported--

> realizing that our clams are fast decreasing, it is the intention of the Department to reserve more flats in 1915 for like purposes. [3]

Again, in the Biennial Report of 1919-20, the Commissioner reported--

> During the summer of 1919 the Commissioner of Sea and Shore Fisheries made an investigation of the condition of the clam fishery in different sections of the coast line, and in each case found adult clam life in point of numbers greatly depleted, which condition it is plain is the result of injudicious over fishing.[4]

In addition to overfishing, the following factors have longterm effects upon the abundance of clams or limit the resource.

[2] This period of relatively low production corresponds with the low period from 1902 to 1906 shown in table 2.

[3] This comment refers to the low production period of 1913 shown in table 2.

[4] Production in 1919, as shown by table 2, was the lowest on record until 1957.

Natural History

A general knowledge of the biology of the soft-shell clam is essential to understand the biological problems which limit the resource.

In Maine soft-shell clams are known simply as "clams." (Elsewhere they are known as soft-shell clams, long-necked clams, manninose, and steamer clams.) The scientific name for the species is *Mya arenaria*, and it belongs to the family Myacidae.

Distribution and Environment.--Clams live all along the Maine coast wherever there are tidal flats. They are found in tidal river systems and on the flats of islands miles at sea.

In Maine clams normally live in water of approximately ocean salinity (30-32 parts per thousand), but for a short time they will survive in water that is almost completely fresh (salinity of less than one part per thousand), occurring at certain stages of the tide.

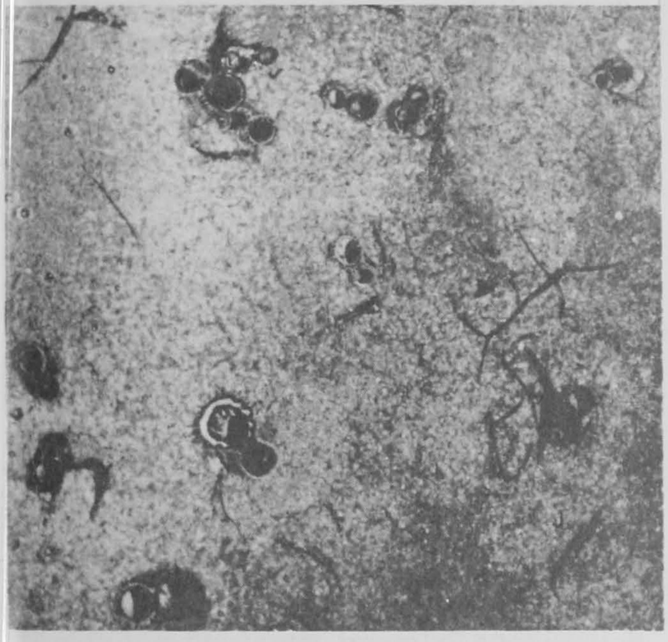
The growing areas are flats which slope from high water downward, well below even the lowest low tide. Some areas of the flats are more productive than others. Slow-growing clams live on the higher portions of the slope just below high water or near the top of high bars which are barely covered by the tide. The fastest growing live from near the mid-point between high and low tide to low water, and it is here that most of the clams are dug. But the largest and oldest clams live below low water, in that part of the flat uncovered only at the lowest low tides. These clams are seldom available to diggers, which accounts for their size.

Anatomy of the Clam.--The body of the clam is encased in two elongated valves or shells, hinged by an interlocking projection and ligament. The live clam can regulate the opening and closing of the valves with the adductor, or closing, muscles. When these valves relax, or the clam dies, the shells are forced apart by the elastic pad beneath the hinge.

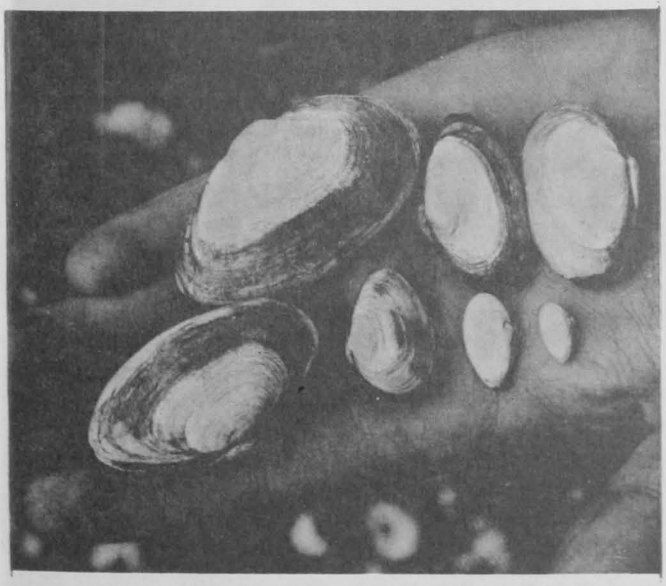
Retractable siphons, consisting of two muscular tubes, are extended to the surface of the flats during feeding. Food and oxygen-bearing water are drawn through the incurrent tube and from there enter the branchial chambers and pass through the paired gills on each side of the body cavity where the food is separated from the water and material that has no food value. Water and waste products are expelled through the smaller excurrent tube or through the opening around the foot.

Between the gills is the visceral mass (the so-called belly or stomach), which contains the digestive and reproductive organs. The digestive tract consists of the mouth, esophagus, stomach, so-called liver, intestine, and the crystalline style, which curves around the visceral mass from stomach to foot and assists in digesting starchy substances in the food. Recent studies of the crystalline style indicate that thin, weak clams (which fishermen call "water bellies") lack an important food-processing enzyme.

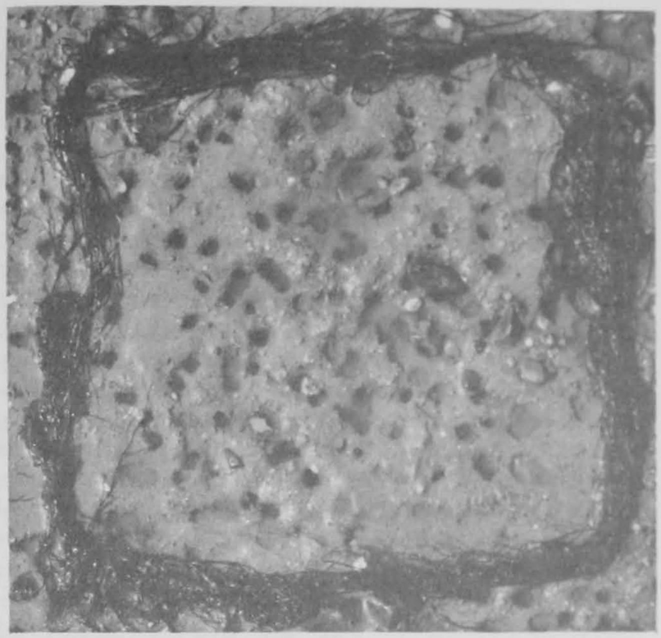
The heart pumps blood to the various organs and tissues, and during circulation



When the flooding tide brings water, food, and oxygen in over the flats, the clam extends its siphons upward and begins to draw food-bearing water into the larger incurrent tube.



Even when several clam year-classes are represented in a growing area, growth rate among individual clams will vary widely.



During warm weather months burrows reveal the presence of clams.

In the winter the burrows become covered because of decreased activity. This 15-inch plot contained more than 100 clams and corresponds in population density to that shown in the photograph above.

the blood is purified through kidneys and gills. The heart is wrapped around the intestine but does not connect with it.

At the lower end of the clam is a burrowing organ, the foot, which, when distended, is extruded between the shells through an opening in the mantle. Clams less than an inch in diameter use this foot to move about over the flats and to dig themselves holes. As the foot is expandable, the clam digs into the sediment by swelling the end and using it as an anchor while jetting water from around the foot opening. The clam burrows to varying depths, depending on the type and compaction of the sediments in the flats and the size and age of the clam. Generally clams burrow approximately two and one-half times their longest diameter.

The nervous system centers are above the mouth, near the foot, and below the posterior adductor muscle. The clam's so-called brain is primitive and compares with that of other animals of a low order.

The mantle, just inside the shell, covers the body of the clam and secretes a sticky substance that becomes impregnated with lime to form the shell. Two lime layers and a protective chitinous covering compose the shell, which varies in color, thickness, and shape according to the sediments of the flats and the growth rate of the clam. In sand flats clam shells grow white, brittle, and paper thin; in rocky flats the shells are dark gray to black, thick, and with rounded and blunt edges. Sometimes very slow-growing clams will have overlapping layers of shell growth.

Contrast in sediment size and distribution is shown by this photograph of Flake Point Bar, Jonesport, historically an excellent clam-growing area. Upper slopes are cobble, center section silt clay with scattered cobble, while lower portion is coarse sand and gravel. Clam population at time photograph was taken occupied sand-gravel area with densities of more than 100 per square foot. Only a few scattered clams were in the silt-clay area.

The rate of growth is shown by the width between the concentric growth interruption lines of the shell. A fast-growing shell will have wide bands between the lines, but in a slow-growing clam the interruption lines may be fused or run together.

During the past 10 years clams marked with opaque ink have been studied by the Department of Sea and Shore Fisheries of the State of Maine and by the U.S. Fish and Wildlife Service, and the resultant reliable growth information has established the annual lines in the shell as an index of age. Each winter, at the end of the growing season, a line of growth interruption is developed in the shell. Age can be fairly well determined by counting the winter check lines. If clams are disturbed by being dug, washed, or otherwise moved out of their burrows, they may cease to grow for a short period of time. When this happens, a false annual ring develops in the shell.

Life History.--Clams are male or female, and the sex can be determined by microscopic examination to distinguish the eggs of the female from the sperm of the male. A $2\frac{1}{2}$-inch female may spawn about 3 million eggs a year, and a male of the same size produces sperm numbering in the billions.

Spawning occurs primarily from June to September, when water temperatures are most favorable and conducive. Experiments have shown that the presence of eggs or sperm in the water also stimulates clams to spawn. Although favorable water temperatures affect spawning, clams spawn spasmodically--and in some years live larvae are present in Maine waters nearly the year around.

At the time of spawning, the female discharges her eggs into the water through the excurrent siphon and the male discharges the sperm in the same manner. Fertilization takes place in the water.

Fertilized eggs develop into larvae, which drift or swim and grow in the water for several weeks. During this period water currents may distribute the larvae considerable distances. The length of the larval period depends upon water temperature, food, and other factors and may last 2 weeks or longer. After developing a swimming organ, the larva swims freely and feeds on food in the water.

Free-swimming larvae are subject to the vagaries of the tidal currents, to unfavorable winds, storms, and other meteorological conditions, and to changes of salinity, temperature, and food in ocean water and in surface water runoff in growing areas near river mouths. They are exposed to predation by fish and shellfish that feed on plankton and to the dangers of industrial contamination (dissolved toxic substances), oxygen-reducing pollutants, disease, and starvation.

At the end of the free-swimming period, the clam larva has undergone many physical changes, including the formation of the shell, and has acquired most of the organs characteristic of the adult. Without magnification, it is still too small to be seen by man and under the microscope somewhat resembles a small quahog. At this stage, the swimming organ begins to degenerate and the larva goes to the bottom to crawl about with its foot. It then attaches itself to some object by means of its byssus. The byssus is a threadlike substance, similar to that found in the adult mussel, and looks very much like the silken thread spun by certain moths and butterflies to attach their cocoons to twigs or leaves. The larva may attach to sand grains, seaweed, rocks, thatchgrass, or some other anchor. The young clam retains this power of attachment for some time and may move over the flats swinging by the threadlike byssus or float about by surface tension, or it may detach itself at any time and crawl short distances by using the foot.

If the young clam is washed out of the flats after it has grown to the burrowing stage, it may dig itself in again or, to find more favorable conditions, migrate short distances by means of its foot. By marking their shells with an ink number, it has been established that small clams may travel several hundred yards to a new home. As a rule the young clam is permanently established in its burrow before it is an inch long. The power to dig in, which lessens with increasing size, is retained even in the commercial-size clam.

Growth and Food.--The rate of growth in the clam is influenced by many conditions such as water temperatures, currents, time of submergence, degree of crowding, and availability of food. Other conditions being equal, differences in growth rate have been shown to depend on water temperatures alone. To a certain extent warm water favors rapid growth, but high water temperatures may be detrimental.

The growth rate of clams varies with environment. Clams transplanted from one

Juvenile clams attached by byssus to oak leaf.

Cluster of juvenile clams attached to bottom debris and to each other.

type of sediment to another assume the growth characteristics of the new area, showing that environment and not heredity is important in determining growth. In an area having a great amount of fresh water (e.g., tidal estuaries), they grow more slowly than those in salty water. In Maine, it has been found that clams will pump water only when salinities are in excess of 24 parts per thousand.

The slowest growing clams usually are high on the flats where they are covered at high tide for short periods. Clams near the low-tide level grow faster because they have more time to feed during each tidal cycle.

Recent studies show that the bulk of clam food consists of small plants and animals, clumps of bacteria, and decomposing fragments of larger organisms, but it is not known what foods the clam prefers nor what foods contribute to growth.

Strong water currents serve to bring in new food supplies and to remove waste products. When clam populations are crowded, growth may be inhibited by accumulation of wastes as well as by competition for food.

Mortality Factors

Many small clams are destroyed by harvesting operations. Shell breakage and burial occur each time a flat is turned over. The magnitude of this mortality was well demonstrated in one growing area where a large set of clams had survived and grown well during its first year. In the following year, however, one portion of the area was repeatedly worked by marine worm diggers; the clam population was destroyed. Typically, survival of clams with broken, crushed, or pierced shells is less than 1 percent.

Commercial digging operations leave undersized clams buried at depths of 1 to 9 inches; the deeper clams are buried, the poorer are their chances for survival. Those buried in upright or horizontal positions have a better chance than the ones in inverted positions, and survival chances are greater in silty sand than in either sand or silt. Average survival, taking into consideration all sediment types, seasons, sizes of clams, and positions of burial, can range from about 87 percent at 1-inch depth to about 4 percent at 9-inch depth. Each time a flat is dug, about half of the small clams are buried too deep to survive and others are broken by the digging operation and die.

Most growing areas are dug intermittently until the clams are too scarce for commercial diggers to make a living. It can be expected that portions of many growing areas will be dug at least once every 6 months, and in an area dug twice, the population will be reduced about 80 percent from a combination of breakage and other digging mortalities exclusive of any natural mortality or normal predation.

From time to time mass mortalities of clams have been observed by biologists and reported by commercial diggers, but all the causes of this widespread mortality are not known. Clam "graveyards" can be found in many growing areas.

Falls Cove, Sullivan, showing large clam "graveyard." Mass mortalities of clams occurred in this area during the years when "water belly" was prevalent.

A condition of watery, brownish- or blackish-colored meats is referred to by diggers as "water belly." Although the frequency of this condition varies, clams showing water belly symptoms can be found in some growing areas at any time. These clams are unacceptable for market because of the low meat yield and unattractive appearance. Chaet (1955), discussing his theory relating to this phenomenon, said--

> The results of these experiments indicate that excessive phosphorous utilization and absorption occurs within "water belly" clams; however, the significance of this high phosphorous uptake is still obscure. It is possible that this phosphorous uptake is an indirect measurement of glucose absorption by the diseased clam. If this were the case, one could theorize that the "water belly" clam is unable to split large carbohydrates, such as glycogen, into smaller glucose molecules.

This inability would result in a general glucose deficiency in clams. Animals experimentally fed glucose may absorb large quantities in an attempt to counteract the deficiency of their own digestive systems.

In one area where water belly had been prevalent for several years, approximately 100 bushels of small 8- to 10-year-old clams, less than 2 inches long, were transplanted to adjacent flats where growing conditions were known to be excellent. In this new area, many of the clams began to grow rapidly, and the meat quality improved. During the same period the residual population of stunted clams recovered; about half reached a growth rate normally associated with the best growing areas, and all clams improved greatly in meat quality.

These clams are all of the same year-class. Growth and meat quality were very poor during the first 8 to 10 years of their existence. Rapid recovery occurred when approximately half the population was moved to areas with favorable growing conditions.

Since growth had been extremely poor for the preceeding 8- to 10-year period and recovery was rapid in the transplanted area as well as in the source area, it is assumed that previous failure to grow can be attributed to nutritional deficiency. It cannot be assumed, however, that all cases of water belly are the same or occur for the same reason.

Green crab and 3-inch clam upon which it had been feeding.

Evidence of two clam predators, tracks of the herring gull and a 9 5/8-inch deep pit dug by a green crab to reach a soft clam.

The impact of predation varies geographically, seasonally, and periodically. Biologists of the Maine Department of Sea and Shore Fisheries and the U.S. Fish and Wildlife Service have found convincing evidence that predation has been one principal cause of mortality after the larvae have set. Harriman regularly sampled shellfish growing areas and found that large-scale green crab predation commenced when clams are between 2 and 3 millimeters in diameter. Since 1949 the green crab has been the most serious clam predator in Maine. In 1951 an experimental clam farm in Scarboro, operated by the Department of Sea and Shore Fisheries and the Fish and Wildlife Service, was completely destroyed in 3 weeks by green crabs. Entire populations of clams outside experimentally fenced areas in Islesboro, Wells, Bremen, Jonesport, and Searsport were destroyed by these crabs.

Drills, *Polynices heros*, lobsters, rock crabs, winter flounders, gulls, ducks, and various sea birds also prey upon clams to some extent, but their combined depredations appear insignificant compared to the damage done by green crabs.

A typical tidal estuary at low water showing pits made by green crabs. Green-crab burrows generally are more numerous near channels, marsh sod, or other features which furnish protection.

Many green crabs live in burrows in the marsh during cold weather.

Large-scale mortalities have occurred when flats are blanketed by deposits of marine algae, including *Ulva* and *Enteromorpha* as well as several of the brown algae.

In many growing areas the blue mussel, *Mytilus edulis*, is a competitor of the clam. The mussel is a surface dweller, and groups of them form colonies above the clam population, thus blanketing the flats and depriving the clams of food and oxygen. The mussel beds trap silt, feces, and other waterborne debris and gradually build up these deposits to a depth of several feet. Clams surviving the initial mussel blanket are eventually killed by the increasing depth of the bed.

Experimental efforts to control mussel encroachment have shown that effective methods are expensive. Destruction of the mussels is ineffective unless their shells and other accumulated debris are removed from the flats.

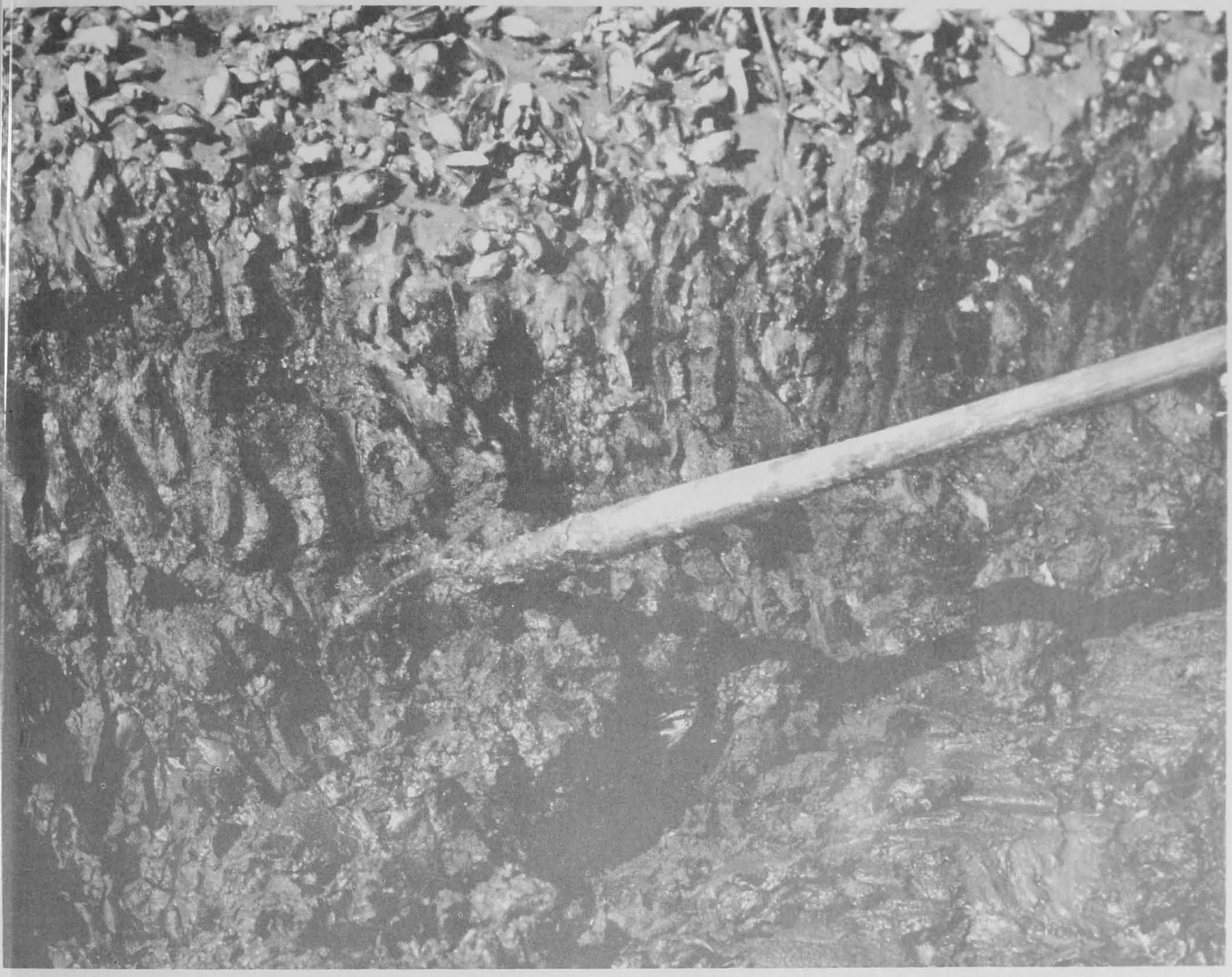
Pollution

Coastal pollution has caused reduction of the clam-growing areas available for use. Increasing unsanitary conditions by 1946 required the closure of some 40,606 acres of flats to the digging of shellfish. By 1960 the total had increased 15.6 percent, to 46,958 acres.

In 1949 the Maine Legislature authorized the Department of Sea and Shore Fisheries to carry on a continuous sanitary survey of shellfish-growing areas closed because of light or moderate pollution. Bacteriological samples are taken and sanitary surveys made in these areas, and after it is determined that conditions conform to public health standards, the flats are opened for specified periods of time.

Pollution of the tidal flats is steadily worsening. In 1947 there were 8,831 acres in areas which were polluted for part of

Expanding mussel bed has almost completely blanketed a formerly productive clam flat. Shown at approximately two-thirds flood tide.



Depth of mussel bed is illustrated by difference of approximately 4 feet in level of surface and bottom of excavation. It was estimated that maximum depth of accumulated silt, organic material, and other debris was at least 8 feet. The area had been a highly productive clam flat before mussel encroachment.

the year and could be opened seasonally; by 1958 only 4,391 acres could be opened seasonally.

The effect of fuel oils, gasoline, and other liquid petroleum products on waters in tidal areas has been studied for the last several years by scientists of the Department of Sea and Shore Fisheries. In 1954 John W. Hurst, Jr., a departmental bacteriologist, wrote in a summary of this work--

> Minor oil pollution is regarded by many as unimportant, due to the expected dispersion of the oil over large areas. The work the Department of Sea and Shore Fisheries has done (chiefly in the intertidal zone) on oil pollution indicates that minor oil pollution must also be regarded as serious......In four localities on the coast of Maine, clams, *Mya arenaria*, exposed to minor oil pollution (in the form of spills) were found to have an oily flavor. In one instance in a good area, the oil flavor persisted for nearly four weeks.

In recent years one important clam-growing area became chronically affected by oil contamination. Although the contamination may have had no adverse effect on survival, the unpalatable oily flavor imparted to the clams made them unacceptable for market.

Departmental researchers have been concerned with the possible impact of oil contaminants upon shellfish-growing areas resulting in (1) direct mortality of fish and shellfish within the affected areas, (2) interference with normal feeding activity of shellfish, (3) destruction of food, (4) adverse

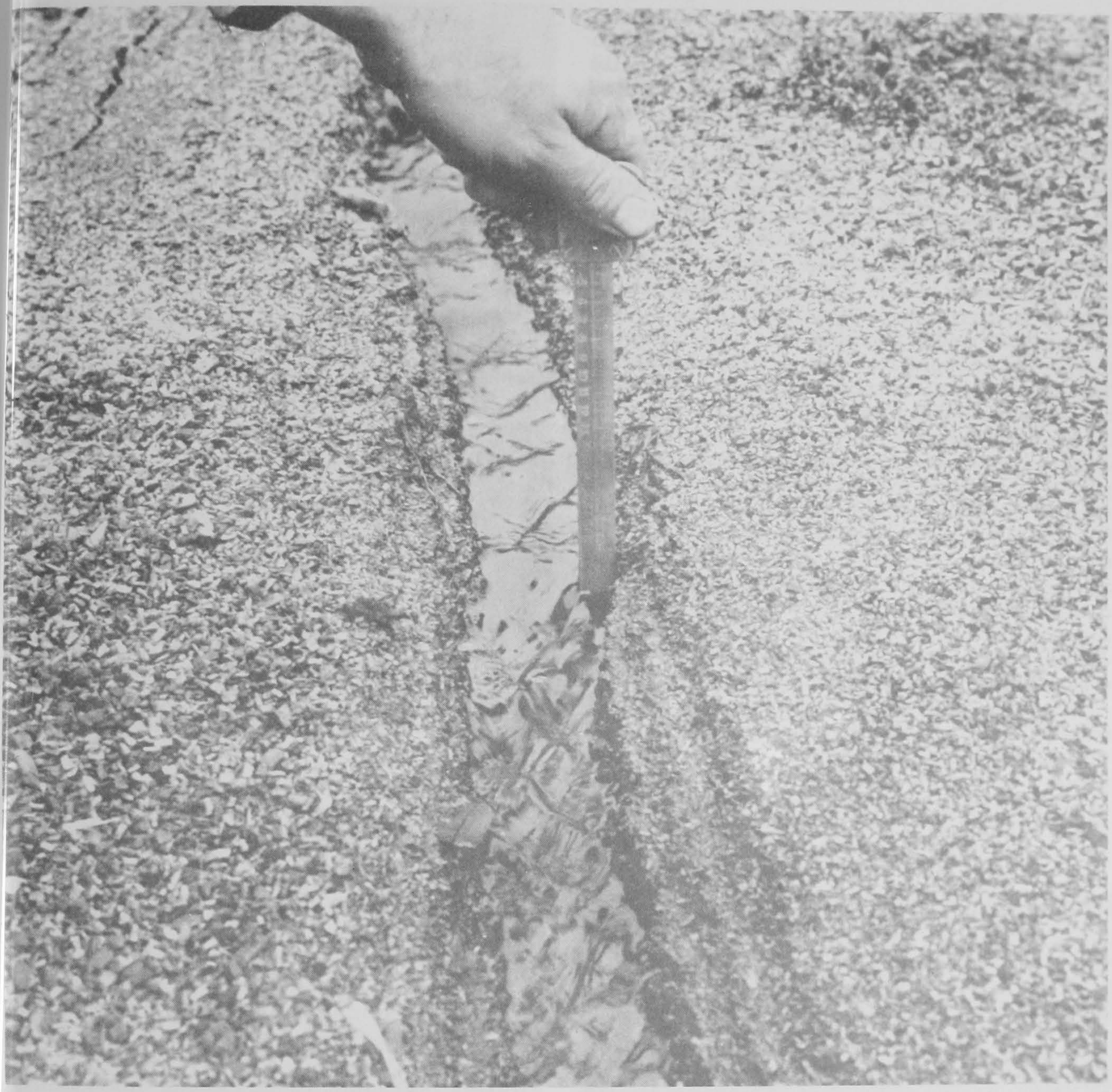
In addition to bacterial and chemical pollution contributed by man and industry, there is the problem of physical pollution of shellfish-growing areas. This former growing area has been buried under a deposit of sawdust.

effects upon shellfish larvae, and (5) unfavorable influences on larval foods.

Though it has not been definitely determined that chemical factors directly affect shellfish survival, high mortality rates and poor growth have occurred in growing areas where it was suspected that unfavorable chemical conditions were involved. The presence of hydrogen sulphide in the water is reflected in a lowered pH (acid-alkaline factor). The formation of hydrogen sulphide results from the decomposition of organic material on the surface, or mixed with the sediments, of the flats.

Even in areas where the presence of chemical factors is suspected, physical factors, such as the pattern of water currents and the particle size of sediments, obviously are important. Organic material other than that which is created within an area is transported by incoming tidal currents and surface-water runoff. After deposition and partial decomposition, the organic material--by cohesion with the sediments--reduces water percolation. Water exchange and tidal runoff are inadequate to remove accumulated substances which are detrimental to the clam populations.

It would appear, then, that chemical factors may adversely affect clam survival and growth but these chemical factors depend upon the existence of unfavorable physical factors such as poor drainage and inadequate water circulation.



Sawdust deposit has blanketed clam flat to average depth of 6 inches. In some areas clams have been found surviving well in sawdust. In other areas clam graveyards have been found beneath layer of sawdust.

Geological, Hydrographical, and Meteorological Conditions

The common sediment of the western Maine coast is sand, and it is in sand that the clam makes its best growth. The rapid growth of clams in favorable conditions results in a thin white shell, which brings a higher price in the steamer market.

Sand bottom is found only in well-washed areas, not in constricted coves where subsurface drainage is poor or where sea water tends to stagnate. Good water percolation, subsurface drainage, and ample water exchange are all characteristics of sand areas, and these physical attributes appear to have more influence upon growth than does temperature. A favorable hydrographic condition is associated with a favorable sediment size, whereas silt and clay are generally found where tidal currents are most restricted.

One drawback of sandy growing areas is the tendency toward scouring. The term scouring, as it is used here, differs only slightly from the term erosion and is used in reference to water passing over well-compacted sediments. Constricted mouths of coves, the exposed slopes of sandbars, and the ends of peninsulas are areas subject to scouring. The principal impact is upon postlarval clams, as the velocity of the water current makes it impossible for them to settle on the flats and attach themselves to surface material.

Erosion and scouring are the complements of deposition and redistribution in the total complex of change. Erosion may be a gradual process, in which sediments are slowly removed from a growing area over a period of years, or it may take place abruptly as the result of a severe storm or flood. Tidal action may erode bottom sediments and then redeposit them during later periods in the cycle. In such areas the net loss or gain of surface sediments may be insignificant, but the associated turbulence and turbidity can be a serious detriment to the settling of larval clams and the feeding of established clams.

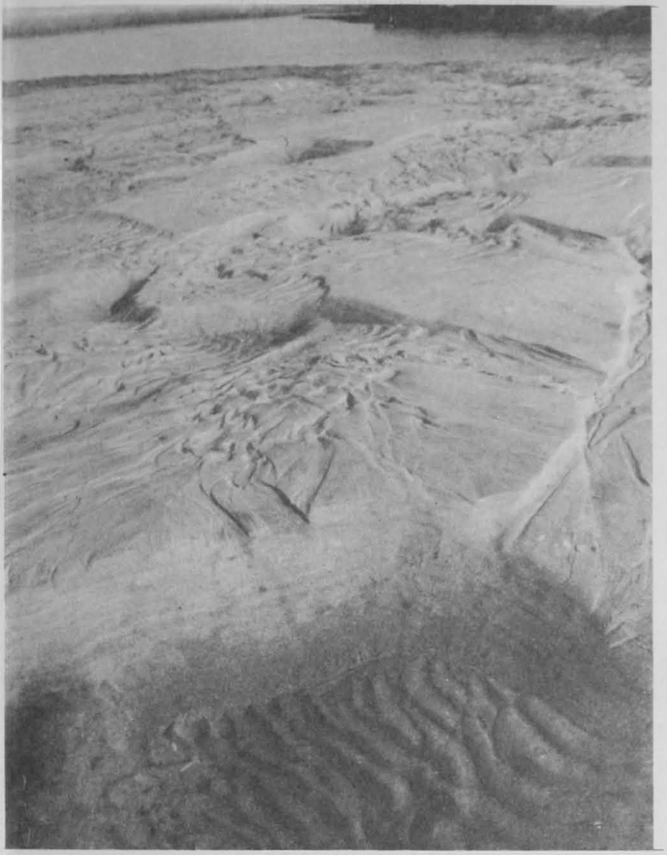
Erosion occurring above mean high water may have more serious consequences than erosion within the intertidal zone because a thin blanketing layer of clay, deposited on the surface of the flats, kills the clams. Commercial diggers refer to these areas as "dead flats."

Eroded clay bank contributing thin veneer to surface of mixed sand-gravel flat. Patchy areas where light colored clay has been deposited contain dead and dying clams. Adjacent unaffected areas still support living population.

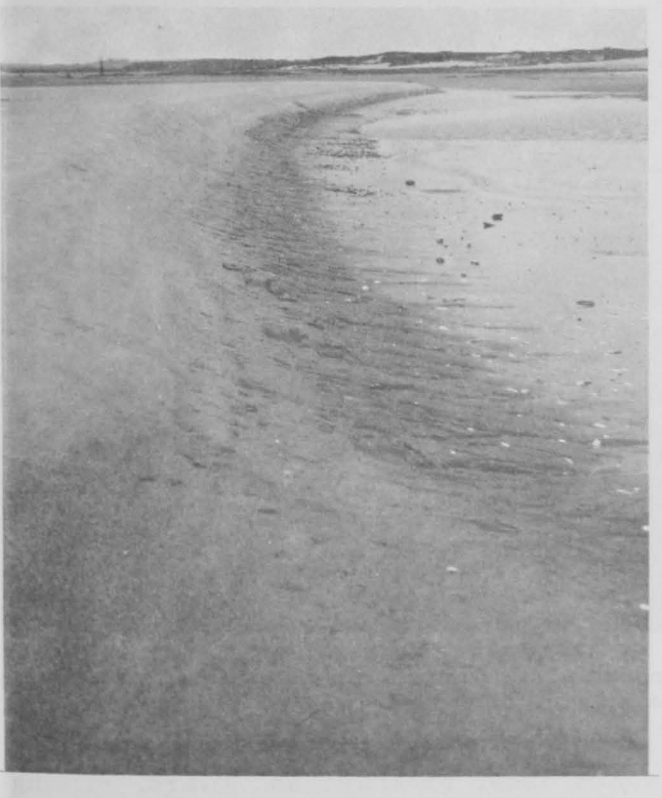
Bedrock frequently creates water stratification with lower level becoming stagnant as indicated by salinity and dissolved oxygen.

Occasionally, violent storms moving in the same direction as the tide will remove large quantities of protective surface sediment and expose the shellfish beneath. If this occurs during cold winter months, a large percentage of the clam population will die. In estuaries, flash floods may cause the drainage channels to be so altered that tidal coverage is appreciably reduced.

The shifting of surface sediments by wind and water has caused high mortality of clam populations. Wind-driven sediments during low water periods can result in elevation changes of several inches per hour, while sediments carried by water surface tension usually have a gradual building influence on clam flats. If the surface level is raised continuously, the flats will be covered for a shorter period of time by flood tide and the clams will have less time for feeding. Storms sometimes move sandbars shoreward, burying and smothering clams in the tidal flats.



Shifting sand has eliminated this area as a productive clam flat.



Shoreward migrating sand bar which destroyed all clams in its path.

During the winter the ice, as it rises and falls with the tide, picks up quantities of bottom sediment. Following a thaw or the spring ice breakup, these sediments are moved to other portions of the flats, and their deposition is comparable to the results of severe storms. By removal of their covering, some clams are exposed to freezing and others buried when the debris is redeposited. Ice can also undercut banks adjacent to growing areas, causing clay deposits, trees, and large rocks to be washed onto the flats when the banks collapse.

Winter survival of clams can be affected by slight differences in surface elevation. Shallow pockets, which retain water and surface sediments during low tide periods, protect the shellfish from freezing. A difference of as little as one-tenth of a foot in elevation can result in a great difference in survival.

During cold weather clams which have been dislodged from their burrows make very little effort to dig themselves in again. Repeated thawing and freezing on the surface of the flats results in their death because the pallial (mantle) muscle of the clam breaks away from the shell. Even though the clam may still be alive, it is unable to burrow into the flats.

Sills, dikes, and other coastal bedrock structures reduce water circulation and create stagnant conditions. (Lack of water percolation, surface impermeability, and low pH have already been discussed in terms of their biological influence.) Sometimes bedrock under the flats is sufficiently bowl-shaped so that fresh water comes in over but does not mix with the lower layer of stagnant water, and clams are deprived of both oxygen and food.

Although boulders strewn over a beach reduce the size of the area which supports clams, under certain conditions these boulders help to insure the survival of the clam population. When boulders are mixed with cobbles of assorted sizes, excellent protection is afforded against green crab predation. Crabs have difficulty burrowing into these flats to seek clams established in the finer sediments beneath. Successful penetration by green crabs depends upon favorable compaction. Burrows collapse when crabs dig in loose sediments which apparently discourages or prevents them from reaching their prey. Very compacted sediments also prevent burrowing.

PUBLIC OPINION, CONSERVATION LEGISLATION, AND MANAGEMENT OF THE CLAM RESOURCE

The public attitude toward the clam resource and legislation designed to solve the problems of the clam industry often reflects conflicting social, psychological, and economic conditions.

The need during colonial times for a readily available source of food determined the contents of free fishing and fowling ordinances, and this long tradition of subsistence further strengthened the concept of the clam as a noncommercial public resource. The 1641-47 colonial ordinance provided that--

> Every inhabitant that is an house holder shall have free fishing and fowling in any gre-t ponds and Bayes, Coves, and Rivers, so farre as the sea ebbes and flows within the presincts of the Towne where they dwell, unless the free men of the same Towne or the Generall Court have otherwise appropriated them, provided that this shall not be extended to give leave to any man to come upon others proprietie without there leave.

These provisions were later amended. In 1672 they became a part of our common law and are so recognized and enforced today. Under amendment the new version became--

> Every inhabitant who is an House Holder, shall have free Fishing and Fowling in any great ponds, Bayes, Coves and Rivers, so far as the Sea Ebbes and Flows within the presincts of the Town where they dwell, unless the Freemen of the same Town or the General Court have otherwise appropriated them.
>
> Provided that no Town shall appropriate to any particular person or persons, any great Pond, containing more than ten Acres of Land, and that no man shall come upon another's

Sorting action with respect to sediment sizes under storm conditions washes clams from burrows and leaves them exposed to freezing in troughs of ripples.

When clam flats are rippled, clam populations are either washed out or buried.

propriety without their leave, otherwise than as hereafter expressed.

The which clearly to determine:

It is Declared, That in all Creeks, Coves and other places about and upon Saltwater, where the Sea Ebbs and Flows, the Proprietor, or the Land adjoyning, shall have Propriety to the Low-water mark, where the Sea doth not Ebbe above a hundred Rods, and not more wheresoever it Ebbs further.

Provided that such Proprietor, shall not by this liberty have power to stop or hinder the passage of Boats and other Vessels, in or through any Sea, Creeks, or Coves, to other mens Houses or Lands.

And for great Ponds lying in Common, though within the Bounds of some Town, it shall be free for any man to fish and fowle there, and may pass and repass on foot through any man's propriety for that end, so they trespass not upon any man's Corn or Meadow."

The resource is considered by law to be a public one, but only for certain portions of the public. The Maine Legislature has confirmed the prevalent attitude among the residents of coastal communities that shellfish resources, and especially the clam flats, should be available only to the local residents of municipalities having these resources within their boundaries. The responsibility for the enforcement of this exclusive use rests with the public as a whole; the cost is paid by the public as a whole; and yet the benefits are limited to a minority of the general public.

Despite more than a century of commercialization, there still exists a strong belief that commercial use of the resource is of secondary importance to its noncommercial use by the public. Public attitude is that any coastal community resident has the traditional "right" to go down to the flats at any time (low water permitting) and dig a "mess" of clams and that the chronically indigent should be allowed limited commercial use as a source of cash income. This attitude may be the result of denying that the clam resource is a commercial one, and, by virtue of its legal sanctity, regarding it more as a municipal safeguard against pauperism--a sort of latter-day town poorfarm.

There appears to be growing opposition to the concept that the clam flats are the exclusive property of the municipality as granted by the legislature. In part this may be due to unrestricted operations of diggers in the marine worm fishery,[5] who dig anywhere in the tidal flats except in areas temporarily closed to all digging. Diggers who depend upon clamming for a significant part of their annual income are opposed to town laws that impede their operations. They, however, wish to exclude those casual diggers who leave other employment when clam market or supply conditions become attractive.

Legislation to conserve the clam resource stems from a belief, once widely held, that the majority of the small clams survive and reestablish themselves in their burrows after being dug or repeatedly exposed or buried by harvesting operations. Conservation laws are predicated on "saving the babies." The Biennial Report of the Maine Department of Sea and Shore Fisheries for 1915-16 commented that "clams are taken to such a small size that not seed enough is left in the flats to warrant the next crop." It was not until 1935, however, that a minimum-size law was established.

For years diggers and other coastal residents have been aware that the age of clams can be fairly well determined by counting the growth rings on the shell. However, false rings develop when the clams are disturbed. Errors in reading the rings have led to false estimates of productivity.

Misconception of the nature of the conservation problem has resulted in heavy mortality of clams by wasteful harvesting methods. This situation could be largely corrected by repealing the minimum-size law in favor of regulation of growing areas, so that harvesting would be undertaken only when most of the clams in a regulated area have attained market size.

Competition for the resource did not become critical until World War II. Since then competition has existed among seasonal, part-time, full-time, incidental, commercial, and noncommercial diggers; operators of eating establishments, canners, processors, bait and food dealers; coastal and noncoastal residents of adjacent or bordering municipalities; commercial fishermen using clams for bait purposes; and municipal officials and other interested citizens who wished to have clams available at all times for the unemployed.

In the past, efforts have been made to encourage individual initiative in the production of intertidal shellfish, and in 1905 legislation was passed enabling individuals to obtain grants to shellfish-growing areas. Impetus for this legislation came from the experimental findings of the Department of Sea and Shore Fisheries, reported in its Biennial Report of 1907-08 and in preceding and subsequent biennial reports--

> There is no reason why--if a system of leasing flats were adopted, putting in the hands of private individuals the cultivation of the flats, to whose interest it would be to improve the quality as well as to increase the quantity--this State should not compete with or excel any other of the New England States in the quality, quantity, and value of this industry.

Although enabling legislation has been in force since the earliest part of this century, within recent years there have been only five reservations. Some 30 years ago between 20 and 30 private grants were made, but there were two conditions which made private reservations unsuccessful. In the first place, available scientific knowledge was not used in the cultivation of these shellfish-growing areas, and in the second, legal provisions for obtaining seed stock were so involved that grant holders were discouraged from attempting to carry on a continuing program. Also, problems were encountered in enforcing private property rights on clam flats. At present in coastal communities, public opinion opposes private reservations, and this attitude is shared to a considerable extent by the clam industry.

Experiments in the management of public flats were carried on by the Department of Sea and Shore Fisheries in several areas in the early 1930's. Some of these efforts were quite successful, but others failed because of abrupt changes of environmental conditions which resulted in extensive clam mortalities. In 1946 research personnel were employed to establish a continuous

[5]Two species of marine worms (sandworm, *Nereis virens*, and bloodworm, *Glycera dibranchiata*) are dug from intertidal flats for salt-water fishing biat. In some areas clam diggers have turned to worm digging as a more profitable occupation. Total payments in 1959 amounted to $706,000 to diggers for these two species of marine worms.

management program and conduct investigations.

Records show that at one time there were 106 towns, cities, and plantations of the Maine coastal area producing shellfish. Many of these areas are no longer available for commercial shellfishing. At the present time only 78 of these political subdivisions have open areas of any commerical importance, and only 69 have three or more licensed diggers.

The decrease in the number of towns commercially producing shellfish can be attributed to four factors: (1) Decline in shellfish populations caused primarily by too frequent digging, (2) green crabs and other predators, (3) increases in pollution which have resulted in the closing of many growing areas, and (4) manmade and natural environmental (ecological) alterations damaging the clam flats.

Transplanting of clams has not been generally successful. Prior to 1950, experimental relaying of clams dug with conventional hoes into small plots gave discouraging results because of the high costs of hand labor and poor survival of the clams. It became apparent that in order to be economically sound, any transplanting program must be carried on by using mechanical or hydraulic methods to obtain clams of small size only.

A source of seed was found, and a hydraulic rake was developed, but cooperative State, town, and Federal clam farms failed because of the predation on clams by green crabs. Green-crab control then became a major project, and commercial applications were developed. Some of the local management programs have been successful in reducing predator damage by the use of fencing and insecticides.

In 1957 as a result of the department's findings and recommendations, supported by the findings of the United States Fish and Wildlife Service, the Maine Legislative Research Committee recommended--

> That the Sea and Shore Fisheries Laws be amended to provide for the repeal of the "town clam laws", so-called, that the Commissioner of the Department of Sea and Shore Fisheries be vested with authority to grant exclusive regulatory rights to such towns or combination of towns as express a willingness to accept the entire responsibility for enforcement and are willing to cooperate with the Department of Sea and Shore Fisheries in its conservation and clam management programs.

The committee in support of these recommendations said--

> The recommendation of the Committee, calling for the repeal of town laws, would tend to promote conditions of uniformity in the law, thereby eliminating present legal congestion, promoting uniformity in town shellfish regulations to biological conditions, promote flexibility in management and conservation programs in shellfish areas, and provide incentives for towns to actively manage and enforce shellfish regulations for the benefit of the town. The Committee feels that it is most desirable for regulation at the local level because urgent needs generate more prompt action and ultimately prove to be of the most value.

These recommendations were not accepted by the legislature primarily because of the stipulation that enforcement be the responsibility of the local area.[6]

Because of the doctrine of free fishing and fowling, or unmanaged public ownership, that has existed for more than 300 years, there is strong opposition to unrestricted commercial utilization of the resource except for those engaged in the industry. Efficient use and commercial development of the resource would require private management of the growing areas, aided and advised by competent marine scientists. Both industry and local municipalities lack trained personnel.

The advantages of private over public management are many. One of the difficulties in public management, which has helped prevent its effectiveness in the past, is the lack of public interest in and responsibility for the well-being of the resource. While commercial development might be a transitory stage in the long-range control and use of the resource, the enlightened self interest of the businessman could be an advantage under present conditions.

In this connection is the present problem of increasing pollution which is gradually eliminating many important shellfish-growing areas. It is doubtful if any abatement program will be initiated on the basis of the need for conservation of shellfish alone. Moreover, since the abatement of pollution requires public support, the protection of the clam resource is often subordinated to growing urban needs for disposing of untreated sewage. Private ownership and management, with its personal interest and economic survival at stake, could be more effective in bringing about corrections of pollution abuses.

Limited local control and inappropriate state regulations also have been contributing factors to ineffective public management. Private management would substantially reduce law enforcement costs. Under it,

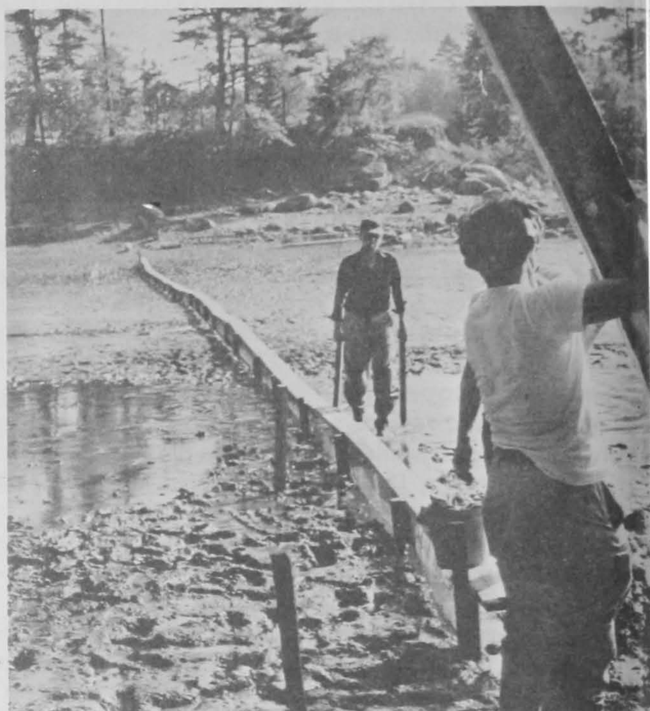
[6] See footnote 1 on p. 7.

production of the growing areas could be greatly increased by reducing the frequency of digging and by systematic removal of marketable clams when the flats are harvested. Research findings concerning the biological requirements of the species would be generally accepted. Moreover, the fishery would be established as a recognized commercial venture in place of its present vague status.

If individuals wish to control shellfish-producing flats, they must gain the approval of virtually everyone in the area. This is very difficult to do. Recently attempts were made by two clam diggers to gain management control of a few acres of flats. At public hearings held by the town, almost unanimous opposition was expressed toward granting the concession on the grounds that private reservations would infringe upon long-established rights to dig clams at any time or in any area for home consumption or for sale. To achieve an atmosphere suitable for the establishment of private management, years of public education will be required.

For many years political boundaries have been used as a basis for delineating the natural borders of the clam resource. Many municipal boundaries run through bays and coves or along river channels. Often the boundaries have no relation to biological or economic realities. Ecological factors affecting clams are local in character, and dividing growing areas by political boundaries is in contradiction to sound conservation and management. The establishment of boundaries for management purposes should be made on a scientific basis. Amalgamation of contiguous growing areas, under common management by groups of cooperating towns, would greatly assist conservation efforts.

Measurable progress in improving the management of clam flats can be made under a public control regime. Informal meetings with local authorities, dealers, and clam diggers sometimes lead to the establishment of experimental management programs. In this event, a thorough survey of the growing areas is undertaken, employing local diggers to work with the biological specialists of the Department of Sea and Shore Fisheries and in cooperation with a local shellfish committee. After the results of the survey are evaluated, details of a management plan involving the periodic harvesting of growing areas (taking into consideration biological, geological, and economic factors) are worked out jointly with the local committee and presented as recommendations to diggers and other interested residents.



Installing fence across the constricted mouth of a cove to protect clam set from green-crab predation.

CONCLUSIONS

There are many factors beyond the control of man which influence the abundance of clams. The future of the clam industry, however, depends upon making the best use of the available resource. If this resource is to be efficiently utilized, the industry has two possible courses of action: (1) The implementation of a comprehensive and well-planned public management program for the resource, in which scientific recommendations would be followed, or (2) private ownership or private management of the resource under which the individual would be responsible for the operation of growing areas.

More efficient harvesting methods would benefit the industry and conserve the resource. Researchers estimate a maximum hand-digging efficiency of about 85 percent even under ideal conditions of sediment size, compaction, clam-size distribution, and population density. The use of different hand tools under varying sediment and compaction conditions will reduce breakage loss as much as 50 percent. Systematic harvesting of growing areas, however, would reduce digging mortalities to a negligible level.

Harvesting in accordance with market demands would permit producers to increase their earnings. It would also allow processors to expand their market, which they cannot do under the present conditions of only supplying the dealers, and they in turn the retail outlets, with a dependable daily quantity of clams to meet the minimum year-round requirements. A continuous day-to-day supply for the dealers is necessary because the processors cannot keep whole clams or clam meats for more than a few days and, therefore, when diggers produce more, they cannot buy a large supply to hold over for the peak season. As most diggers harvest clams only part of the time, the available daily year-round supply is small and does not fulfill the demands of the retail outlets in the peak season. However, if diggers produced clams in accordance with the market demand, over the span of an entire year they would sell more and the processors could process and sell immediately to dealers as many clams as retail outlets needed at any time.

The repeal of the minimum-size law and private and special laws granting municipalities exclusive rights to shellfish resources would facilitate greater production. Harvesting at times when the clams had attained their optimum size would give maximum yield and greatly increase landings in most growing areas.

These conclusions are based on the assumption that the clam resource will continue to be a public one. Good management of the resource, either public or private, would encourage the development of the industry and increase efficiency, production, and resultant income.

The greatest handicap imposed upon a public fishery is the instability of production. The clam industry, in particular, is vulnerable to fluctuations since it is a seasonal and part-time activity and attracts very few professional workers. Cost of digging equipment is small and, consequently, when unemployment is prevalent in other industries, the number of clam diggers increases.

If the clam industry is to remain important in the Maine economy, ultimately it must be established on a basis of personal responsibility. The long tradition of public ownership is a serious handicap and restricts the potential development of the commercial resource.

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APPENDIX

TABLE 1.--United States production of soft-shell clams by States, 1954-58

[In thousands of pounds and thousands of dollars]

State	1954		1955		1956	
	Quantity	Value	Quantity	Value	Quantity	Value
Maine	3,722	1,360	2,622	948	2,228	808
Massachusetts	1,010	560	1,021	580	816	494
Rhode Island	9	4	11	5	4	2
Connecticut	-	-	1	([1])	([1])	([1])
Maryland	251	156	1,294	431	2,779	926
Virginia	-	-	16	9	38	16
Other	137	84	147	88	251	103
Total	5,129	2,164	5,112	2,061	6,116	2,349

State	1957		1958	
	Quantity	Value	Quantity	Value
Maine	1,964	738	1,634	600
Massachusetts	697	452	746	484
Rhode Island	3	1	1	([1])
Connecticut	([1])	([1])	([1])	([1])
Maryland	2,744	915	3,918	1,306
Virginia	23	8	7	3
Other	285	101	293	94
Total	5,716	2,215	6,599	2,487

[1] Less than 500 pounds or $500.

Source: U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries.

TABLE 2.--Production and price per pound of Maine soft-shell clams, 1887-1959

[In millions of pounds and millions of dollars]

Year	Quantity	Value	Average price per pound	Year	Quantity	Value	Average price per pound
1887..........	6.1	.2	$.038	1931...........	7.0	.2	$.034
1888..........	6.0	.2	.038	1932...........	7.3	.2	.032
1888..........	(1)	(1)	(1)	1933...........	6.5	.2	.034
1889-97.......	9.5	.3	.032	1934...........	(1)	(1)	(1)
1899..........	8.2	.3	.043	1935...........	7.0	.3	.041
1900..........	8.7	.4	.040	1936-38........	(1)	(1)	(1)
1901..........	7.6	.3	.043	1939...........	5.7	.2	.042
1902..........	5.5	.3	.044	1940...........	6.3	.3	.048
1903..........	6.6	.3	.050	1941...........	6.8	.4	.057
1904..........	6.4	.3	.050	1942...........	5.9	.5	.101
1905..........	3.7	.4	.108	1943...........	4.7	.6	.130
1906..........	7.7	.4	.049	1944...........	4.3	.6	.139
1907..........	9.1	.6	.066	1945...........	5.1	.8	.157
1908..........	5.1	.5	.098	1946...........	9.8	1.8	.185
1909..........	7.3	.5	.067	1947...........	7.9	1.5	.189
1910..........	9.4	.7	.078	1948...........	9.0	1.8	.201
1911..........	7.8	.6	.074	1949...........	8.6	1.4	.165
1912..........	9.5	.8	.081	1950...........	6.9	1.2	.172
1913..........	5.2	.3	.056	1951...........	5.1	1.2	.232
1914..........	6.2	.5	.077	1952...........	5.5	1.7	.303
1915-18.......	(1)	(1)	(1)	1953...........	4.1	1.4	.333
1919..........	2.1	.2	.078	1954...........	3.7	1.4	.366
1920-23.......	(1)	(1)	(1)	1955...........	2.6	.9	.362
1924..........	3.6	.2	.064	1956...........	2.2	.8	.363
1925-28.......	(1)	(1)	(1)	1957...........	2.0	.7	.376
1929..........	6.7	.5	.070	1958...........	1.6	.6	.367
1930..........	9.9	.3	.035	1959...........	1.4	.5	.378

[1] Data not available.

Sources: U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries; Maine Department of Sea and Shore Fisheries.

TABLE 3.--Total landings of Maine soft-shell clams, pounds of meat canned, and percent canned, specified years

Year	Clam landings	Clam meats canned	Percent canned of total clam landings
	Thousands of pounds	*Thousands of pounds*	
1900-04 average	7,390	2,493	33.7
1945	5,122	4,380	85.5
1946	9,809	3,729	38.0
1949	8,623	3,472	40.3
1950	6,877	1,435	20.9
1951	5,121	1,289	25.2
1952	5,523	1,112	20.1
1953	4,148	701	16.9
1954	3,722	686	18.4
1955	2,621	632	24.1
1956	2,228	515	23.1
1957	1,964	472	24.0
1958	1,634	164	10.0

Source: Maine Department of Sea and Shore Fisheries, biennial reports and unpublished data.

TABLE 4.--Distribution of Maine clam production, within and outside of the State, 1950-59

[In thousands of pounds of clam meat]

Year	Total production	Sold for consumption within State		Sold for consumption outside of State		Canned
		In shell	Shucked	In shell	Shucked	
1950	6,877	821	1,909	966	1,746	1,435
1951	(1)	(1)	(1)	(1)	(1)	(1)
1952	5,523	457	916	715	2,323	1,112
1953	4,148	761	1,532	462	692	701
1954	3,722	567	604	500	1,365	686
1955	2,621	426	462	450	651	632
1956	2,228	497	376	503	337	515
1957	1,964	278	440	476	298	472
1958	1,634	246	544	167	513	164
1959	1,451	381	573	234	102	160

1 Data not available.

Source: Maine Department of Sea and Shore Fisheries.

TABLE 5.--Maine soft-shell clam fishery, by counties, 1940-59

Year	Cumberland County			Hancock County		
	Clam diggers	Landings	Value	Clam diggers	Landings	Value
	Number	*Pounds*	*Dollars*	*Number*	*Pounds*	*Dollars*
1940	(1)	2,945,403	116,874	(1)	953,886	37,793
1941	(1)	1,799,850	103,137	(1)	985,530	56,530
1942	92	2,303,540	179,442	400	567,195	44,185
1943	249	(1)	(1)	303	(1)	(1)
1944	289	994,917	122,695	399	1,045,982	128,991
1945	250	1,100,000	189,640	363	919,200	105,448
1946	307	2,257,400	417,596	343	1,685,449	311,788
1947	270	970,275	229,422	471	1,316,030	189,932
1948	407	667,529	171,084	819	1,185,315	212,076
1949	210	296,090	72,170	571	927,650	150,114
1950	263	257,312	61,219	322	359,735	61,439
1951	352	241,648	73,443	245	380,175	95,078
1952	437	271,144	123,213	400	532,141	175,165
1953	287	88,017	39,827	489	612,104	210,457
1954	303	72,087	37,131	480	447,035	171,250
1955	256	85,753	39,219	426	325,673	130,154
1956	297	82,145	42,168	416	224,330	87,345
1957	369	99,445	68,542	306	153,853	59,801
1958	362	70,090	38,624	215	137,193	50,360
1959	338	31,782	18,266	177	120,635	45,551

Year	Knox and Waldo Counties			Lincoln County		
	Clam diggers	Landings	Value	Clam diggers	Landings	Value
	Number	*Pounds*	*Dollars*	*Number*	*Pounds*	*Dollars*
1940	(1)	259,365	10,288	(1)	27,285	1,083
1941	(1)	562,905	32,258	(1)	36,540	2,092
1942	333	763,080	59,444	65	8,070	629
1943	75	(1)	(1)	78	(1)	(1)
1944	70	6,887	849	140	166,235	20,502
1945	82	320,200	54,527	130	1,355,500	232,072
1946	95	624,555	115,543	225	2,319,774	429,134
1947	154	977,345	146,559	484	3,190,034	650,971
1948	543	1,663,613	302,291	450	3,064,068	723,985
1949	528	1,816,065	292,855	306	1,754,388	356,148
1950	323	1,149,039	188,470	166	594,871	117,016
1951	306	846,346	205,592	129	254,497	65,582
1952	409	1,013,562	325,074	194	399,487	144,057
1953	368	606,941	215,548	197	409,497	151,376
1954	477	578,922	218,276	242	408,807	177,492
1955	363	378,085	142,773	199	175,681	75,588
1956	297	283,004	108,532	160	147,589	66,674
1957	272	256,875	111,377	215	183,783	87,070
1958	128	214,705	91,395	209	169,761	75,599
1959	233	281,790	113,232	269	286,031	124,044

See footnotes at end of table.

TABLE 5.--Maine soft-shell clam fishery, by counties, 1940-59--Continued

Year	Sagadahoc County			Washington County		
	Clam diggers	Landings	Value	Clam diggers	Landings	Value
	Number	*Pounds*	*Dollars*	*Number*	*Pounds*	*Dollars*
1940	([1])	74,854	2,970	([1])	1,713,709	68,08
1941	([1])	873,000	50,027	([1])	2,272,095	130,19
1942	35	289,620	22,561	340	1,959,175	144,83
1943	14	([1])	([1])	502	([1])	([1])
1944	31	334,911	41,313	532	695,079	85,73
1945	97	342,900	56,015	505	884,500	85,89
1946	90	973,584	180,113	671	1,830,347	388,59
1947	183	445,111	90,390	854	952,045	177,59
1948	150	309,912	74,175	936	2,031,549	303,56
1949	150	154,902	32,415	1,016	3,650,715	507,40
1950	130	94,168	18,622	1,056	4,407,275	731,34
1951	82	9,180	2,090	858	3,354,630	732,79
1952	153	24,675	10,470	783	3,250,092	878,56
1953	178	29,165	11,616	790	2,395,495	749,93
1954	157	89,395	40,440	876	2,119,165	712,34
1955	142	14,457	5,344	843	1,641,775	555,49
1956	158	4,575	2,749	766	1,486,265	500,39
1957	168	6,581	3,419	636	1,263,145	407,29
1958	201	14,835	6,988	487	1,027,439	336,66
1959	130	41,528	20,165	340	653,475	205,36

Year	York County			Total		
	Clam diggers	Landings	Value	Clam diggers	Landings	Value
	Number	*Pounds*	*Dollars*	*Number*	*Pounds*	*Dollars*
1940	([1])	([1])	([1])	([1])	5,974,502	237,09
1941	([1])	283,155	16,226	([1])	6,813,075	390,46
1942	27	242,835	18,917	1,292	6,133,515	470,00
1943	39	([1])	([1])	1,260	([1])	([1])
1944	26	124,224	15,327	1,487	3,368,235	415,41
1945	74	199,500	35,604	1,501	5,121,800	759,20
1946	106	118,308	21,887	1,837	9,809,417	1,864,65
1947	58	47,452	11,773	2,474	7,898,292	1,496,64
1948	21	47,376	14,030	3,326	8,969,362	1,801,20
1949	42	23,062	8,584	2,823	8,622,872	1,419,69

See footnotes at end of table.

TABLE 5.--Maine soft--shell clam fishery, by counties, 1940-59--Continued

Year	York County			Total		
	Clam diggers	Landings	Value	Clam diggers	Landings	Value
	Number	*Pounds*	*Dollars*	*Number*	*Pounds*	*Dollars*
1950	21	14,457	6,259	2,281	6,876,857	1,184,370
1951	34	34,093	12,359	2,006	5,120,569	1,186,937
1952	18	31,491	16,801	2,394	5,522,592	1,673,347
1953	32	6,694	3,405	2,341	4,147,913	1,382,161
1954	18	6,479	3,498	2,553	3,721,890	1,360,436
1955	10	64	17	2,239	2,621,488	948,592
1956	12	240	176	2,106	2,228,148	808,035
1957	10	30	16	1,976	1,963,712	737,518
1958	21	-	-	1,623	1,634,023	599,633
1959	36	35,386	21,167	[2] 1,554	1,450,627	547,789

[1] Data not available.
[2] Includes Androscoggin, Kennebec, Penobscot, and Somerset Counties which show 31 diggers in 1959. Previous years are not included.

Note: Information on the number of clam diggers for 1943-47 are estimated. 1948-59 data are from the files of the Department of Sea and Shore Fisheries, Commercial Shellfish Records.

Sources: U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries; Maine Department of Sea and Shore Fisheries.

TABLE 6.--Number of licensed clam diggers in Maine and period of seasonal operations, 1947-56

Year	Number of licensed diggers	Number of licensed diggers reporting	Period operating[1]				
			2 months or less	Between 3-5 months	Between 6-8 months	Between 9-11 months	Over 11 months
1947	2,474	1,507	32.7	38.6	21.2	3.8	3.7
1948	3,337	1,996	24.4	40.9	24.4	5.2	5.1
1949	2,840	1,803	23.4	41.0	23.7	5.1	6.8
1950	2,291	1,354	24.0	39.2	22.4	6.2	8.2
1951	2,016	1,034	28.4	37.8	22.8	4.2	6.8
1952	2,403	1,360	28.3	39.8	19.3	5.7	6.9
1953	2,356	1,300	33.4	35.1	19.7	5.1	6.7
1954	2,564	1,190	31.5	37.6	18.0	5.2	7.7
1955	2,244	1,041	33.0	37.7	18.1	4.0	7.2
1956	2,110	1,118	34.4	37.4	17.9	3.3	7.0

[1] Percent of licensed diggers reporting for that particular period of operation.

Sources: Maine Department of Sea and Shore Fisheries; Commercial Shellfish License Applications.

TABLE 7.--Average daily catch and income of commercial diggers, annual landings and value per pound, and number of fishing days of the Maine soft-shell clam fishery, 1947-59

Year	Average daily catch	Annual landings	Diggers	Annual fishing days	Average landed value per pound	Average daily income
	Pounds	*Pounds*	*Number*	*Number*	*Cents*	*Dollars*
1947............	38.3	7.90	2,474	83.4	18.9	7.24
1948............	39.1	9.00	3,337	92.6	20.1	5,85
1949............	30.9	8.62	2,840	98.2	16.5	5.10
1950............	30.5	6.88	2,291	98.4	17.2	5.25
1951............	27.8	5.12	2,016	91.4	23.2	6.45
1952............	26.1	5.52	2,403	88.0	30.3	7.91
1953............	19.6	4.15	2,356	90.0	33.3	6.53
1954............	16.3	3.72	2,564	89.0	36.6	5.97
1955............	13.7	2.62	2,244	85.2	36.2	4.96
1956............	12.9	2.28	2,110	83.6	36.3	4.68
1957............	11.8	1.96	1,983	83.4	37.6	4.44
1958............	11.5	1.63	1,623	87.6	36.7	4.22
1959............	11.0	1.45	1,554	85.0	37.8	4.16

Sources: U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries; Maine Department of Sea and Shore Fisheries (unpublished data).

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