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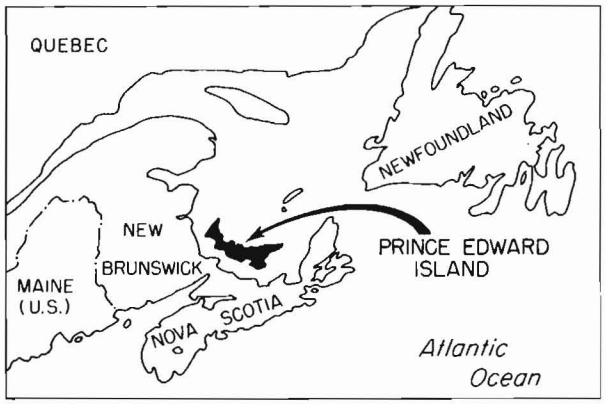
Transplanting oysters to good quality barren ground can increase their number and quality.



Development of a Program to Rehabilitate the Oyster Industry of Prince Edward Island

CLYDE L. MacKENZIE, JR.

ABSTRACT—The author developed and implemented an oyster industry rehabilitation program for Prince Edward Island in which large vessels are to transplant oysters from unharvested stocks and shells from buried deposits and spread them over otherwise barren public grounds. Great biological and ecological potentials exist for increasing oyster production because of: (1) regular annual spat-fall (reproduction), (2) high survival rates of oysters, (3) adequate growth rates, (4) existence of more than 200,000 boxes of unharvested stocks of small oysters in either deep water or on poor grounds as well as several million bushels of oyster shells, and (5) availability of at least 1,000 acres of otherwise barren public grounds possessing ecological features that produce high-quality oysters. After a few years, oyster production should more than double; earnings of the 200 public fishermen should rise steadily from an annual average of $2,300 to $4,550; and earnings of other industry sectors should also rise. The ratio of program costs to monetary benefits for the fishermen should eventually exceed 1 to 20.

INTRODUCTION

Prince Edward Island (P.E.I.), Canada, lies near the northern end of the range of the American oyster (*Crassostrea virginica* Gmelin), which extends from northern New Brunswick southward along the Eastern and Gulf Coasts of the United States to Mexico and also the West Indies (Galtsoff, 1964). In spite of the northern latitude, the environment on the Island is excellent for oysters, partly because estuarine water temperatures range from 70° to 75°F during the summer. The oyster industry has been an important part of the Island's tradition and economy since the mid-1800's. In recent years, however, annual production of oysters has been 20,000 to 30,000 boxes[1] (25,000 to 37,500 bushels), about one-third the peak years of 1880 to 1900, and the trend is downward (Fig. 1). This harvest has an annual value of about $400,000 (Morse, 1971). Virtually all oysters are exported from the Island to be sold in the cities of eastern Canada, where they are eaten raw on the half shell.

Oysters are harvested from both public and leased grounds, but most from the former during two seasons. About 200 men and women are engaged in the public fishery. Harvesting from public grounds and most leases is by means of tongs from dories. The oyster industry is labor-intensive and of low productivity and earnings; capital inputs and expenses are high in relation to earnings.

After 1890, the decline in oyster production seems to have been mainly the result of: harvesting oysters of all age groups until the early 1900's; an increasingly degraded habitat caused by silting from land erosion; and a disease that killed most stocks between 1915 and 1954. Virtually no effort has been made on public or leased grounds to increase the quantity or quality of oysters by such measures as spreading cultch shells, transplanting oyster stocks, or reducing mortalities.

Oyster beds in P.E.I. were discovered in most estuaries in the mid-1800's, and an oyster fishery developed as the human population and consequently the demand for food rose. The oysters were harvested with tongs from fishing dories. Since most oysters were shipped off the Island, the oyster industry was important as a means of employment. Production reached 70,000 boxes in 1890, the peak year. Eventually, the virgin beds were fished down and production declined. The fishermen's practice of including small oysters attached to those of market size in the harvest was a significant cause of the decline (Needler, 1931). In the early 1900's, however, various regulations and policing required fishermen to return these to the grounds (Found, 1927). The development of agriculture and consequent severe erosion caused sediment deposition on oyster grounds (Kemp, 1916). Later construction of roads caused additional deposition (de Belle, 1971) which further degraded the environment for oysters and added to the decline.

A disease known as "Malpeque Disease" first struck the oysters of

[1]A P.E.I. "box" = 5 pecks or 1.25 U.S. standard bushels.

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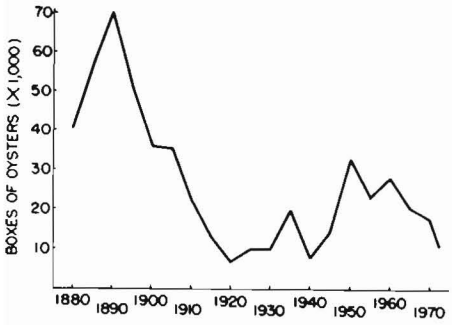

Figure 1.—Oyster landings on Prince Edward Island, 1880 to 1972 (Morse, 1971).

remained nearly barren. Leased grounds do play an important role in oyster production, however, since all oysters harvested from contaminated public beds during the spring season are held on the uncontaminated leased grounds over summer before they are marketed. Termed relay oysters, they have amounted to about 60 percent of total production (about 12,000 boxes) in recent years. Most

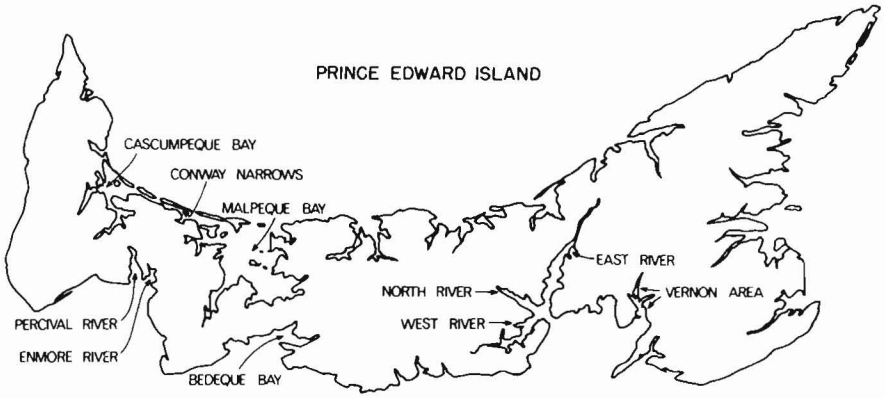

Figure 2.—Prince Edward Island showing estuaries where most oysters occur.

Malpeque Bay in 1915, and eventually killed nearly all oysters in the area. Gradually, this disease spread to other estuaries. It nearly destroyed the oyster industry since oysters suffered heavy mortalities (Needler, 1931, 1940, 1941; Needler and Logie, 1947; Logie, 1956; Found and Logie, 1957 Medcof, 1961; Drinnan and Medcof, 1961). A disease-resistant stock was propagated in some original areas until production rose again to reach a level of 30,000 boxes in 1950, but afterward it began to decline again. Presumably, the endemic oyster populations are now resistant to Malpeque Disease, since no outbreaks of disease have occurred since 1954.

A system of leasing grounds to individuals started about 1912 (Patton, 1913). The granting of a lease was intended to give an individual the right to protect the oysters he had either raised on the site or transplanted from public beds. Leased grounds averaged 4 acres. The areas granted for leasing had virtually no oysters on them, suggesting that the environment in those areas was unsuitable or marginal for oyster culture.

This leasing system has never worked well and most leased grounds have relays are held on the few larger leased grounds of from 8 to 20 acres.

P.E.I. has many estuaries, some of which penetrate deeply into its coastline (Fig. 2). Oyster beds varying in size from scattered individuals to extensive commercial-size stocks occur in most of these. The largest bed occurs along a 10-mile segment of the upper East River where some 132,000 boxes of oysters cover about 210 acres. (Most lie on grounds under water too deep for tonging.) The next largest beds occur in Bedeque Bay, where three beds hold a combined total of about 125,000 boxes of oysters and cover about 400 acres. All these oysters grow on grounds sufficiently shallow for harvesting, but their quality is poor. After these areas, the most significant beds occur in Cascumpeque Bay, northwest sections of Malpeque Bay, and West, North, Enmore-Percival, and Vernon Rivers. In all estuaries, oysters grow in clusters consisting of several age groups. Deposits of buried shells line the channels and banks of rivers and form reefs and cones that rise as high as 20 feet above bay bottoms. Such formations prove that extensive oyster beds once existed in most estuaries.

OBJECTIVES OF INVESTIGATION

A few years ago, the Provincial Department of Fisheries, P.E.I., charged me with developing, and if possible, implementing a management program to increase both production of oysters and earnings of the industry. My investigation lasted 12 months, from August 1972 to July 1973.

Except for literature references, the information presented in this report was gathered from direct observations and surveys, including scuba diving.

BIOLOGY OF OYSTERS

During this investigation, some biological features directly related to production were studied. They included: setting frequency, growth rates, and causes of mortality.

Setting Frequency

No previous records describing annual frequency of oyster setting on public or leased beds existed. The following direct procedure was used to determine reproductive frequency and estimate relative success: 1) make standard collections of oysters from various sites on beds; 2) determine the number in each age group; and 3) compare the total number of oysters among age groups. If the numbers of an age group within the total is relatively large, this reflects a good reproduction season. Spat counts on older oysters and shells were made in late fall because earlier counts are unreliable (some spat die after they set and others may be overlooked because of their small size).

During November 1972, this procedure was followed on beds in six estuaries that support oyster fishing. One of these was the bed in the deep channel of East River. Collections of oysters and shells were made by either scuba divers or with tongs. It was possible to identify five age groups of oysters on the basis of both annual shell growth rings and size. These were spat to 4-year-olds. Oysters that were 5 or more years old were counted with 4-year-olds. Accordingly, relative reproductive success was estimated from 1968 to 1972. The data showed that oysters set in commercial quanities

in these estuaries practically every year (Fig. 3). For example, in the two most important areas. Bedeque Bay and East River, the oyster set was successful in all 5 years, and in West River, there was poor reproduction of the 1972 class, but it was successful in all previous years.

Growth Rates

There were again no historical records available listing annual increments of oyster growth. I determined these by measuring the widths of growth bands on oysters from various beds after growth had ceased in November 1972. The average width of these bands from most beds, e.g., those in East River, was 0.75 inch. Accordingly, oysters became legal size, 3.0 inches, on most beds in 4 years after setting. In most sections of Bedeque Bay oyster beds, however, growth bands averaged about 1.5 inches wide, and in Conway Narrows and Malpeque Bay, they averaged only 0.4 inch wide.

Causes of Mortality

No previous studies of causes of oyster mortalities had been made on any beds, with the exception of those losses caused by Malpeque Disease.

Oyster beds in several estuaries were examined to detect causes of mortality from August to late November 1972. In monthly surveys divers examined oyster beds for potential predators and excessive sedimentation. Collections of oysters were then examined for extent of mortality from each cause. Because of ice cover, examinations were not made from December 1972 to April 1973 but were continued during May, June, and July 1973 to verify earlier estimates.

Oysters of P.E.I. have few natural enemies. The main causes of mortality are suffocation in silt, predation by starfish, ice, and extreme cold. Relatively few oysters are killed by oyster drills, mussels, or possibly, mud crabs.

Suffocation by silt kills oysters in the upper East River Channel, but not on most other grounds that are shallow because on the latter, wave action clears silt deposits. In East River and some other estuaries, silt washes off farm land and onto oyster beds lying in the channel bottom. The silt flood

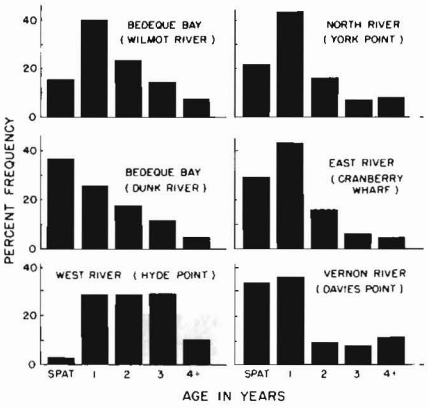

Figure 3.—Bar heights show relative numbers of oyster age groups collected randomly from six grounds, in fall 1972.

occurs during thaws in winter and in spring when temperatures range between about 32° and 40°F and the oysters are dormant. While dormant, oysters cannot clear silt deposits by pumping. Consequently, when temperatures rise and oyster metabolism increases, those covered by silt die. Usually the older oysters are at the bottom of clusters.

Starfish *(Asterias vulgaris)* do not occur within any major oyster beds, such as those in Bedeque Bay or East River. Nevertheless, scattered starfish destroy oysters along edges of beds there. They consume the smaller oysters in clusters (Needler, 1932). For example, in an isolated sample from Bedeque Bay, they destroyed 33 percent of the spat, and a few yearlings, but no older oysters.

Ice covers estuaries from mid-December to late April and kills oysters in shallow zones. Thickness varies from about 1 to 3 feet, depending on velocity of water currents and temperatures. At low tide, ice lies on the bottom in intertidal and shallow zones. Some oysters are forced into the bottom and killed. In rivers where currents are strong, no oysters lie along the shorelines since drifting ice scours these in spring.

In those years when air temperatures fall far below 0°F for several days before ice has formed in the fall, oysters are killed in intertidal zones. There is one record available of the frequency of oyster mortalities resulting from extreme cold. In Vernon River, intertidal oysters were killed three times in 20 years before 1972-73.

Oyster drills *(Urosalpinx cinerea)* are unimportant predators, since they occur in low densities and isolated patches. In Bedeque Bay, drills occur along the western edge of Wilmot River, but not in Dunk River. Where they were encountered, mortalities of oysters were about 2 percent; only spat and yearlings were killed.

Oysters smothered by dense growth of mussels *(Mytilus edulis)* were not found, but Medcof (1961) and fishermen report this has occurred in the past.

Fishermen cause most preharvest mortality. They kill many seed oysters in the cleaning process of knocking them from market-size oysters. This cause of mortality is unavoidable.

In sum, it has been established that oysters set regularly, and both grow and survive well on P.E.I. Morse (1971) was not accurate in stating, without presenting any evidence, that oysters fail to reproduce, i.e., they do not set frequently, nor grow and survive well.

ECOLOGY OF OYSTER GROUNDS

The distribution, abundance, availability, and quality of oysters in the commercial fishery on P.E.I. depend on several physical factors, especially the size of estuaries, bottom type, water depth, temperature, salinity, and the distribution and abundance of various animals and plants. Many ecological factors must be considered in developing a management program to enlarge and increase the number of oyster beds.

Physical Characteristics

The large size of P.E.I. estuaries is one of the most significant reasons that oyster populations thrive, since not only are oyster larvae easily detained during their period of development, but the shallow waters become warm during summer. The greatest length in miles for estuaries supporting significant oyster beds, including lengths of confluent rivers, is: East River, 17; Malpeque Bay, 13; Cascumpeque Bay, 7; West River, 7; North River, 6; Enmore River, 5; Vernon River, 5; and Bedeque Bay, 3.

The firmness of estuarine bottoms on P.E.I. varies widely. Oysters grow on sand, clay, shell deposits, and also mud that is barely firm enough to support them, although in many areas the soft bottom cannot support oysters. A significant factor that influences oyster quality, particularly shape of shell, is bottom hardness. Single oysters growing on hard bottoms have a round shape with a deep cup (fancy and choice grades), while oysters growing on soft bottoms tend to have a long and narrow shape (standard and commercial grades).

The estuaries are characterized by broad, flat grounds and narrow, deep channels. Oysters inhabit grounds that range from intertidal to a 35-foot-deep channel (East River). Most oysters grow on grounds that are covered by from 1 to 12 feet of water at low tide. The usual tidal range is from 2.5 to 6 feet.

In July and August, water temperatures in estuaries usually range from 70° and 75°F (Needler, 1931). Temperatures become that high because the rivers and bays have extensive shallow zones and broad intertidal flats which are a deep red color and absorb much radiant energy. These temperatures make it possible for oysters to reproduce regularly and grow well.

Water salinity is another basic factor affecting oyster abundance. In large sections of Bedeque Bay and East River, it is high enough to permit the growth of oysters, but sufficiently low (< 15 ppt) during the spring run-off period to exclude starfish, the only significant oyster predator.

Siltation of oyster beds appears to be a primary reason for the oyster production decline from 1890 to 1915 and its slow recovery during the disease-free period from 1955 to 1972. Deposits of silt not only suffocate oysters but also cover hard surfaces and thereby prevent setting of young oysters (MacKenzie, 1970). Quantities of silt flowed into the estuaries during the forest-cutting and shipbuilding period and farmland increased from 7 to 85 percent of the Island's area from 1830 to 1900 (Clark, 1959). The forests were cut and farmland was plowed to the banks of rivers and streams. Presently, run-off and consequent siltation are greatest during the thaw and rainy spring period. The rivers become a brick red color when waters become heavily laden with silt and long tongues of red water extend into blue-green water at their mouths. The construction of causeways across some rivers in the 1950's resulted in reduced flow rates and also increased the siltation rate. Deposits of silt were observed overlying shell deposits in several estuaries. For example, in parts of Bedeque Bay, East River, and Vernon River, shell deposits were covered by silt as thick as 2 feet. Presumably, the silt accumulated during the past 30 to 40 years following oyster mortalities caused by Malpeque Disease.

Associated Fauna and Flora

Starfish are the most serious oyster predators. They inhabit sections of most estuaries, and appear to limit the distribution of oysters in some. Oyster beds that occur in the upper reaches of estuaries where salinities become low are essentially free of starfish and other predators, but starfish do occur, especially in channels, in higher salinity zones.

Two phases of starfish biology were studied at the Biological Laboratory, Fisheries Research Board of Canada, on Bideford River, at Ellerslie. To develop a management program for oysters, there was a need for information on rates of oyster predation by starfish, and on the minimal salinity tolerance of starfish. We needed to know the maximum starfish density allowable for survival of most seed oysters spread over otherwise barren ground, and if absence of starfish is a result of periodic low salinities.

Data on starfish feeding rates were obtained from laboratory and field cage studies. In the laboratory, starfish 3.0 inches in diameter were held in running water pans with an ample supply of oysters 1.0 inch in diameter. Because of time limits only two water temperatures were tested. In 7 days, individual starfish consumed an average of 9.4 oysters (1.3/day) at 40°F, and 17.0 oysters (2.4/day) at 50°F. In field cages suspended in water (32°F) under the ice, individual starfish consumed about three oysters in 7 days (0.4/day). These laboratory and cage feeding studies establish that starfish can consume small oysters rapidly and that some predation occurs in winter. Significant mortalities of seed oysters would take place where densities of adult starfish exceeded about 1 individual per 10 square yards.

The salinity death point of adult starfish was determined by holding individuals at a series of constant salinities for 39 days. Starfish held in water at 14 ppt and below, and 1 of 2 starfish held at 16 ppt, died, while those held in water at higher salinities survived. Relating this to oyster management, starfish cannot inhabit grounds where water salinities fall below 15 ppt but they can inhabit those which remain above this point, if other environmental factors are favorable.

Adult starfish do not generally inhabit grounds less than 4 feet deep at low water. Probably, fresh water flowing under the ice during winter ebb tides kills them.

The tube worm *(Polydora websteri)* grows abundantly on oysters in certain areas. I found that it plays an important role in oyster harvesting. It forms a weak bond between oysters in clusters. A cover of tube worms prevents oysters from cementing themselves to adjacent oysters as they grow (Fig. 4). Not only can fishermen clean market-size oysters faster, but also the under-size oysters are separated into smaller clusters when returned to the bottom and grow into a better shape or grade. Also, fishermen kill fewer seed oysters in cleaning market-size oysters. Tube worms are abundant along the western edges of oyster beds in Bedeque Bay and on most beds in East River, but are scarce in other sections. Tube worms do not tend to burrow holes in live oyster shells, and accordingly market oysters do not have mud blisters which reduce their aesthetic appeal.

Various animals, such as boring sponges *(Cliona* sp.) (Needler, 1941; Worburten, 1958; Medcof, 1961); flatworms *(Stylochus* sp.), calcareous bryozoans *(Electra crustulenta);* oyster drills *(U. cinerea)* (Medcof, 1961; Medcof and Thomas, 1969); slipper limpets *(Crepidula fornicata, Crepidula plana)* (Needler, 1941); mussels *(M. edulis)* (Needler, 1932, 1941; Medcof,

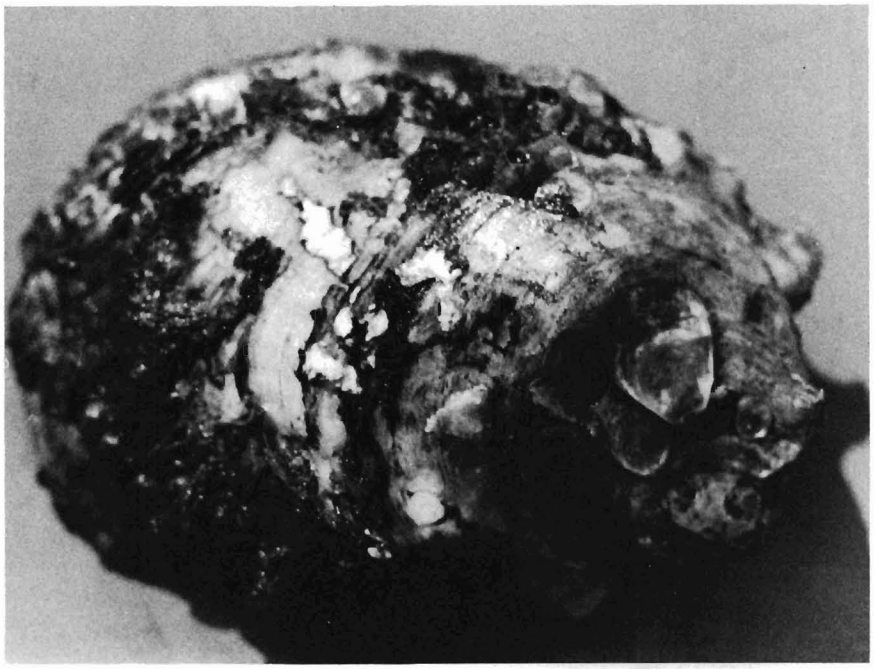

Figure 4.—A market-size oyster from Bedeque Bay. This oyster was easy to clean because numerous attached worm tubes (dark zone in center of oyster) weakened the bond between adjoining oysters.

1961); barnacles (species not determined); and mud crabs *(Neopanope texana)* (Needler, 1941; Medcof, 1961) inhabit oyster beds, but the impact of each on the oyster fishery is small.

Two types of plants have some impact. Sea lettuce *(Ulva lactuca)* thrives in Wilmot River where solid patches of it cover most oysters and hinder harvesting. Eelgrass *(Zostera marina)* is generally beneficial as its roots stabilize the bottom; its short and sparse leaves do not interfere with oyster harvesting (Medcof, 1961).

Characteristics of Bedeque Bay and East River

Bedeque Bay and East River produce about 83 percent of the Island's oysters and are where the pilot projects later described were conducted. Oysters at the heads of these two estuaries are of poor quality, but they improve towards the mouths. Needler (1932) believed this to be generally true for oysters in all estuaries of P.E.I.

Bedeque Bay is fed by two rivers, Wilmot and Dunk, both of which contain large oyster beds (Fig. 5). A single bed occurs between Hilson Point and Wilmot Point and extends toward a highway bridge crossing Wilmot River, where an estimated 25,000 boxes of oysters grow on about 100 acres of ground. Three beds occur between Hurd Point, Oyster Point, and Murray Island in Dunk River, where an estimated 100,000 boxes of oysters grow on about 300 acres of ground. Most of these oysters are not harvested because they are of poor quality.

Reproduction and growth of oysters are excellent. Oysters set over the entire extent of the oysters beds practically every year. During the setting season, from one to three spat are caught on virtually all oysters. Oysters grow about 1.5 inches per year. This regular annual setting and rapid growth result in the formation of clusters that may consist of 100 or more individuals of several age groups. Even before the oysters attain a size of about 3 inches, they grow only in length owing to lateral crowding. Consequently, most market-size oysters are long and narrow and are graded commercial. The moderate quality oysters, choice and standard grades, grow along the western edges of the beds, where harvesting takes place.

About 600 acres of grounds possessing excellent environmental conditions for oysters are available for expanding these oyster beds westward: 100 acres in Wilmot River and 500 acres in Dunk River. The grounds are protected from storms by land relief. Water depths of from 3 to 4 feet at low tide prevent ice and cold from killing the oysters yet allow easy harvesting. Starfish do not generally occupy these grounds. Young-of-the-year starfish inhabiting them during the summer of 1972 were absent the following spring, probably killed by fresh water flowing under the ice during winter ebb tides. A tube worm cover on oysters would work to the advantage of oystermen by speeding up harvesting rates and improving the average grade. Some ecological features of the bay are summarized in Table 1.

The East River is 17 miles long. During this investigation, a virgin oyster bed was discovered growing in the channel along a 10-mile section in the upper river (Fig. 6). An inventory showed that the bed covers 210 acres and consists of about 132,000 boxes of oysters (283,000,000 individuals). An estimated 106,000 boxes of oysters covering 140 acres in a band from 400 to 600 feet wide lie under water too deep for harvesting. Some oysters within the upper part of the zone are too poor in quality for harvesting. A shell deposit ranging from several inches to 5 feet thick underlies the entire bed.

Regular annual oyster setting results in clusters containing at least five age groups. In the deep beds the smallest oysters are well shaped, but

Table 1.—Comparison of features between virgin oyster beds and barren grounds in Bedeque Bay and East River.

	Bedeque Bay		East River	
Bottom type	Virgin bed (firm)	Barren ground (firm)	Virgin bed (firm)	Barren ground (firm)
Depth at low water (feet)	1-2	3-4	10-35	3-10
Salinity (ppt)[1]	4.1-14.1	22.6-22.7	6.9-15.6	18.0-22.3
Reproduction	annual	annual	annual	probably annual
Starfish	absent	few juveniles	absent	few
Tube worms	few	many	many	many
Annual growth (inches)	1.5	1	0.75	0.75

[1]Determined at low water, late May 1972

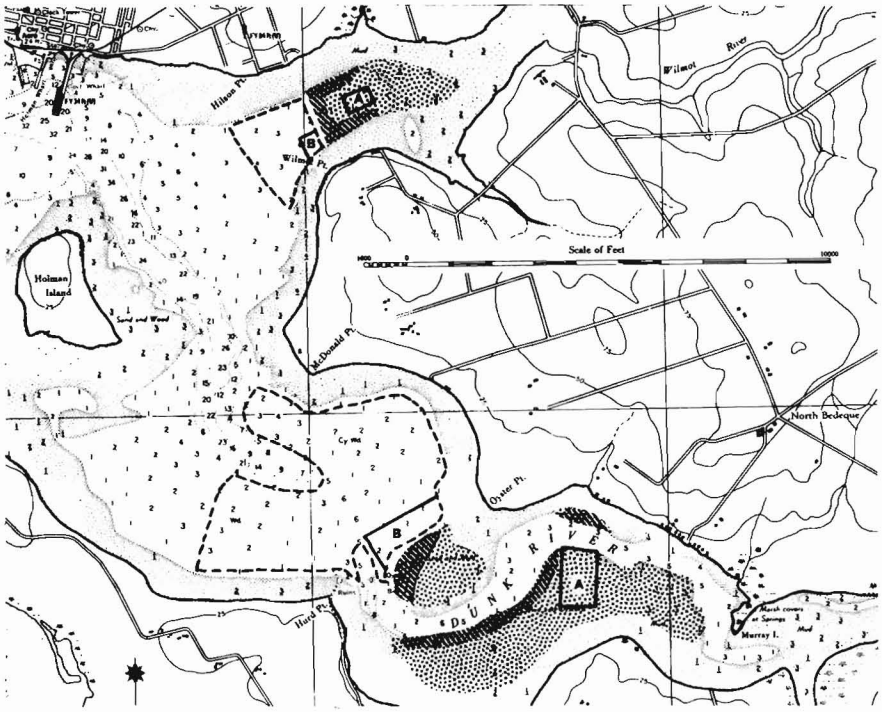

Figure 5.—Chart of Bedeque Bay showing general areas of oyster population (dotted) and oyster harvesting (lined). In 1973 oysters were transplanted from A to B sections. Barren areas outlined by broken lines produce oysters of high market value. Depths are shown at lowest normal tides. Usual low tides are about 1 foot deeper than indicated.

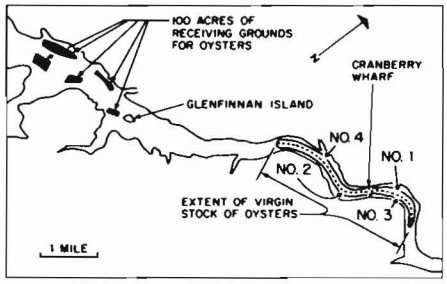

Figure 6.—Portion of East River showing the locations of 140 acres of virgin oyster bed (divided into four sections for management purposes), and 100 acres of otherwise barren grounds that can produce oysters of high value, within the designated fall fishing section.

most oysters over 3 inches are long and narrow due to overcrowding.

About 100 acres of grounds within the uncontaminated section and several hundred acres below it in the contaminated section, possessing excellent environmental conditions for oysters, are available for establishing new beds. The grounds are well protected from storms by land relief and the water is 3 to 10 feet deep at low tide, offering protection from ice and cold. Starfish cannot generally inhabit the shallow grounds (<4 feet) but they might invade the deeper ones. If starfish become numerous on a bed and kill the small oysters before they can be controlled, the ground might require periodic replenishment by transplants from the upriver virgin bed. It is anticipated that worm tubes will cover oysters.

The contaminated grounds in the lower river were not thoroughly studied, but they appear to have about the same environmental features for oysters as those immediately below Glenfinnan Island. Some river features are included in Table 1.

Characteristics of Leased Grounds

An examination was made of the environment of some typical leased grounds to determine their suitability for cultivating oysters. Leases had been granted in areas barren of oysters. The examination revealed that these grounds had more than one of the following undesirable conditions: Intertidal, soft bottom, infrequent setting of young oysters, slow growth, or many starfish. Because of these poor environmental conditions, it would be virtually impossible to grow seed oysters to market size on them as a profitable enterprise.

Morse (1971) and others have recommended that industry management be oriented towards cultivating oysters on leased grounds, with a deemphasis of the public fishery. They probably did not consider the poor environment of these grounds as well as some other negative features (see below) for cultivating oysters by individual fishermen.

Impact of Domestic Pollution

Over half the areas where public oyster beds occur are contaminated by domestic pollution. As a consequence, the Federal Government has closed them for the direct marketing of oysters for human consumption. Nevertheless, oysters can be harvested for relaying onto leased grounds which are in uncontaminated waters. Oysters from uncontaminated beds can be harvested directly for market. The contaminated areas include the entire extent of Bedeque Bay, part of West River, both the north and south parts of East River, North River, and other smaller areas. The uncontaminated areas include most of West River, the middle part of East River, and some smaller areas.

FUNCTIONAL OPERATIONS OF INDUSTRY

The oyster industry on P.E.I., including the public fishery and the buying and handling of relay oysters, is labor-intensive, with low productivity and earnings. Capital inputs and expenses are high in relation to earnings. This industry is traditional in the sense that few changes have been made since it began in the 1800's. The oyster fishermen and buyers function efficiently because they make maximum use of the equipment and resources available; little money, labor, and time are wasted. As individuals, the fishermen value their independence and enjoy their work when earnings are adequate. Besides oystering, some also fish for lobsters and smelts and some farm.

The Public Fishery

About 90 percent of the oysters are harvested from public beds; approximately 60 percent are from beds contaminated by pollution during the

spring oyster season, which extends from 1 May to 15 July. Most spring beds are in Bedeque Bay, but some are in parts of East River, North River, and elsewhere. Oysters harvested from contaminated beds are relaid onto leased grounds in clean waters where they cleanse themselves, and they are sold during the fall marketing season that begins in September and ends in early winter. The remaining 40 percent are harvested from public beds free of pollution during the fall oyster season, which extends from 1 October to 30 November. Most beds are in West and East Rivers. Fall production from West River has averaged about 1,600 boxes, and from East River about 3,200 boxes per season. The final 10 percent of oysters harvested originate from natural reproduction and growth on leased grounds.

Bedeque Bay and the East River produce 83 percent of P.E.I.'s oysters. About 50 percent of the oyster harvest, or 9,000 boxes, is from Bedeque Bay, and about 33 percent or 6,000 boxes, is from East River.

Usually, there are about 200 public fishermen, but when the economy is depressed, this number increases. Most live in Prince County in the western part of the Island, a considerable distance from the oyster grounds. For example, the average traveling distance for most fishermen to Bedeque Bay is about 35 miles, and to West and East River, about 90 miles. Rather than commuting daily, the fishermen live at the shore in one- or two-man trailers during the week[2] (Fig. 7); they deliver their oysters to buyers and return home on weekends.

The public fishermen are highly mobile. They move their dories and trailers from one oyster-producing estuary to another without losing harvesting time. The dories are trucked and the trailers towed. When fishermen get word of good oyster fishing on grounds in either New Brunswick or Cape Breton, a few may even travel there to harvest oysters for a short period.

Figure 7.—A fishermen's settlement along East River, showing a permanent building where oysters are graded and packed, and trailers in which fishermen live.

All public fishermen use similar equipment to harvest oysters, including a dory about 14 feet long, fitted with a 6- × 18-inch tonging board on which oysters are cleaned at the bow. Usually the boat is powered by an 18 or 20 horsepower outboard motor and has an anchor and dory cable. Most fishermen use two pairs of tongs with 8- or 10-foot handles in Bedeque Bay and three pairs with 8-, 10-, and 12-foot handles in the fall fishing areas, where the water is deeper. Sometimes even longer handles are used. Fishermen also carry three or four oyster boxes in their dories. They wear boots, oilcloths, and rubber gloves, besides their underclothing. At low tide fishermen harvest oysters with tongs from dories (Fig. 8). An average of three marketable oysters are tonged up every four dips, but this number ranges from zero to 10 and higher.

The harvest rate per day averages two boxes in the spring season, and one and one-half at the beginning and one at the end of the fall season. The harvest rate per hour is the same at the beginning of the fall season as it is during the spring season, but the fishermen do not work as long because of the shorter daylight period.

Another means of harvesting is by picking along the shore at low tide. This is done either by hand or by using a short-handled rake with about five small tines.

In Bedeque Bay, fishermen find the good quality oysters (fancy and choice grades) are too sparsely scattered along the western edges of oyster beds; the moderate quality oysters (choice and standard grades) grow on only about 35 acres of the beds; and poor quality oysters (commercial grade) in large, difficult-to-separate clusters grow on the majority of the beds. The average fisherman harvests about 10 boxes of oysters per week, a rate that remains constant, except for a slight dip in June, during the entire 10-week season (Fig. 9).

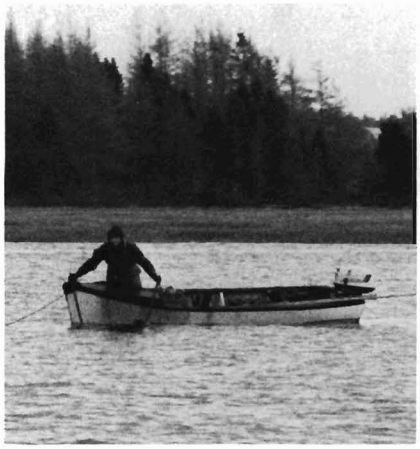

Figure 8.—Most oysters are harvested from shallow grounds by fishermen using tongs from a dory.

In East River, in the section open for fall fishing, public fishermen find that oysters grow on only about 20 acres of ground. The grade of oysters averages about half standard, half choice. The average fisherman harvests eight boxes of oysters during the first week of the season and this gradually falls off to about six boxes near the season's end. Since about 100 fishermen begin the fall season in that river, however, the bulk of market-size oysters are harvested off these grounds within the first 2-3 weeks of the 9-week season (Fig. 10, 11).

During a season, public fishermen harvest about half the market-size oysters that grow on a bed (Resource

[2]All fishermen cook their own meals in their trailers. Usually, meals are of low quality as they are often hastily prepared, high in starch, and low in protein and green vegetables. Trailers have no refrigeration; this limits the variety of food that can be prepared. When the tide is low during mid-day, fishermen eat a light lunch in their dory.

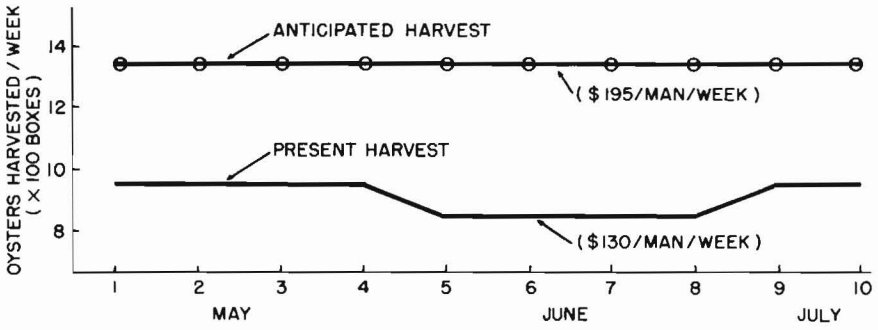

Figure 9.—Present and possible harvest yields of oysters during season in Bedeque Bay. The anticipated yield is that expected after recommended management program is conducted.

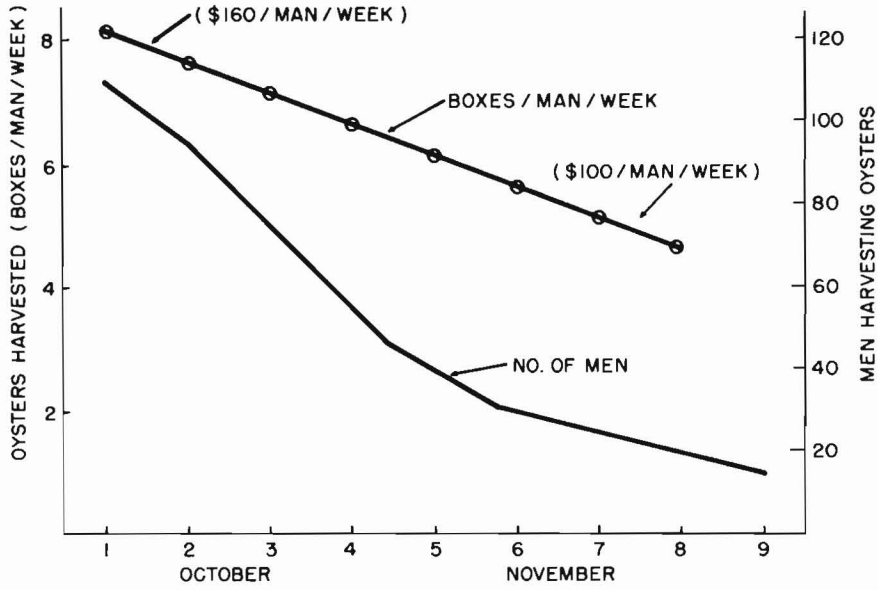

Figure 10.—Present harvest yields of oysters and number of fishermen during season in East River.

Development Branch, Fisheries Service, Environment Canada, pers. commun.). Oyster beds are self-perpetuating, i.e., a new crop of young oysters sets on them regularly to replace the market-size oysters harvested. Oysters have been harvested annually from the same beds for many years.

The public fisherman stores his oysters on the shore and usually sells them to a buyer on the weekend. Some fishermen have their own leased grounds and spread their harvest of relay oysters on them, rather than sell directly to buyers. Usually, fishermen harvest and sell these when oysters become scarce on the fall public beds.

Strict laws regulate oyster harvests by public fishermen. The most significant are: the only devices permitted on public grounds are hand tongs and picks; minimum marketable size limit is 3 inches across the longest part of the shell; harvesting from public grounds is allowable from 1 May to 15 July in areas contaminated by domestic pollution (with all oysters relayed on leased ground in uncontaminated areas) and from 1 October to 30 November in uncontaminated areas.

Oyster Buyers

About 10 buyers purchase oysters from public fishermen during the spring and fall seasons. In spring, the oyster buyers shovel relay oysters over their leased grounds at a concentration of 400 to 800 boxes per acre. The relay oysters remain there until the fall marketing season. Then they are harvested by either tonging, power dragging from a lobster boat, forking, or by hand. With tongs one can harvest about 20 boxes of relay oysters per day from a well-stocked leased ground, or about 10 times faster than oysters are harvested on public beds. This is because cleaning is unnecessary, as oysters are unclustered and have no seed oysters attached.

I designed a hand drag to enable fishermen to harvest oysters faster and easier on leased grounds with soft bottoms (Fig. 12). A special feature of the drag is a 1-inch diameter bar and side runners that keep it from sinking into the mud. The bar has a row of 3-inch teeth welded onto it that pulls oysters out of the mud as it is towed. The drag has a long, light-weight but strong bridle that makes it easy for a fisherman to pull it into his dory for dumping. The drag holds about 3 pecks of oysters. When it is used for harvesting oysters, a single fisherman harvests oysters

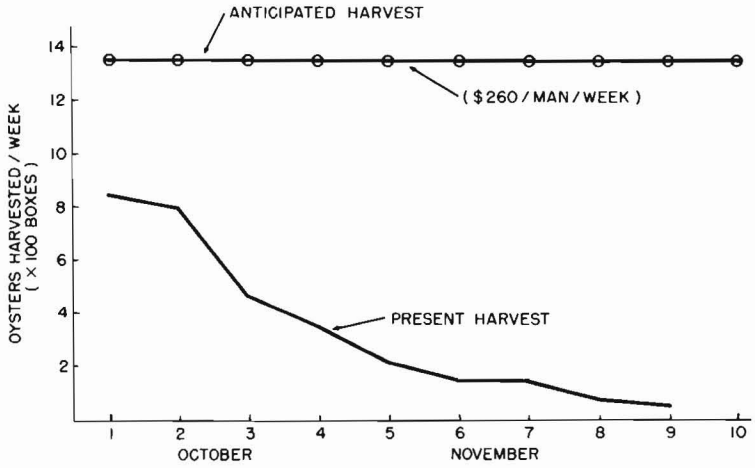

Figure 11.—Present harvest and possible harvest yields of oysters in East River. The anticipated yield is that expected after recommended management program is conducted.

about twice as fast as by tonging, and the work is easier.

Oysters sold for market are carefully graded according to shape into one of four categories, namely, fancy, choice, standard, and commercial, in order of descending value. Then, they are packed in individual 5-peck (1¼-bushel) wooden or cardboard boxes. Before it is sealed shut, every packed box is examined and stamped by an inspector of the Federal Fisheries Service, who visits each grading house about twice a week.

Economic Factors of Fishing and Buying

Expenses and Earnings of Public Fishermen

It might appear that the cost of entering the public oyster fishery is slight and gross earnings are virtually all profit, but actually the entering cost and expenses amount to a considerable proportion of gross earnings. Morse (1971) is not correct in stating that the entering cost and expenses are both low.

The cost of fishing can be broken down into three major categories: gear, habitation, and travel. The current cost of new gear necessary to enter the fishery is about $1,000 and the cost of a fitted trailer is about $500. Travel cost is extra (Table 2). Actually, few men purchase this gear new when they enter the oyster fishery but obtain much of it second-hand, especially more expensive items such as the outboard motor. An entering fisherman may share a trailer and travel between home and the fishing area with someone else. The cost per week of each is: owning and using gear, $25; habitation, $9.00; and travel, $13.50; or a total of about $47.50 (Table 2). The cost of food is about $15 extra.

Figure 12.—A hand drag designed for harvesting oysters on soft leased areas. The thick toothed bar and runners prevent the drag from sinking into mud as it is towed.

Table 2.—Weekly costs of a typical oyster fisherman during two seasons (10 weeks in spring, 9 weeks in fall).

	Item	Purchase cost ($)	Longevity	Cost/year ($)	Cost/week ($)
I.	GEAR				
	Dory	125.00	5 years	25.00	1.31
	Outboard motor	750.00	6 years	125.00	6.58
	Gas can	42.00	4 years	10.50	0.55
	Gas and oil	(0.72/gal)			1.68
	Dory cable (rope)	2.50	2 years	1.25	0.07
	Anchor	10.00	5 years	2.00	0.10
	Paint for dory/gal	10.00	½ year	20.00	1.05
	Tongs (3 pairs)	60.00	1 year	60.00	3.16
	Gloves/pair	1.50	1 day	118.20	7.88
	Oil clothing	24.00	coat: 3-4 seasons		
			pants: 1 season	15.00	0.79
	Boots	14.00	1 year	14.00	0.74
	Oyster boxes (12)	18.00	1 year	18.00	0.95
	Subtotal	1,057.00		Subtotal	24.86
II.	HABITATION				
	Trailer	425.00	10 years	42.50	2.24
	Heating stove	70.00	7 years	10.00	0.53
	Heating oil	(0.50/gal)	8 gal/week	60.00	4.00
	Cooking stove				1.00
	Cooking gas				1.00
	Trailer license	5.00	1 year	5.00	0.26
	Subtotal	500.00			9.03
III.	TRAVEL				
	1,825 miles year	gas, oil, tires		96.00 10.00	5.07 0.53
	Depreciation of vehicle	⅓ year		150.00	7.90
				Subtotal	13.50
				Grand total	$47.39

During the spring season, weekly earnings range from about $100 to $145 (depending upon the capability of the individual fisherman) averaging about $130 (Fig. 9). Earnings remain about constant during the entire season, except for a slight drop during June when oysters become scarce. Afterward, the harvest rate improves as the undersized oysters reach marketable size. The average fisherman who remains for the entire season earns about $1,300.

During the fall season, weekly earnings average $160 (range, $100 to $200) at the beginning, and $100 at the end (Fig. 10). Harvests and earnings vary considerably from week to week, however, owing to adverse weather. The average fisherman earns about $1,000 during this season.

The entry cost into the public oyster fishery is significantly greater than the gross earnings during either season, and weekly expenses consume about 35 percent of gross weekly earnings, leaving the fisherman with a net income of about $85 before meal costs.

Expenses and Profits of Oyster Buyers

Buyers, who purchase relay oysters during the spring oyster season for spreading on their leased grounds until fall season, pay about 70 percent as much as for fall oysters, but their profit margin is about the same in each season. In spring, the usual price paid for relay oysters is $11 to $12 per box. While oysters are carried on leased grounds, about 10 percent are lost through mortality. Accordingly, a recovered box actually costs the buyer about 11 percent more than the original price or about $13.30 for a $12 box. (These oysters improve slightly in grade, partially recovering this loss.) In addition, it costs the buyer about $5 to harvest, clean, grade, pack, and place the relay oysters in a truck (this includes the $1.25

box cost). The extra costs of spreading oysters, the boat, shovels, drags, tongs, and forks, telephone calls, transportation between home and the grading house are estimated to be $2.00 per box. Thus, the total cost of a box of relay oysters ready for shipping to market is $20.30. In 1971, the buyers received an average price of $24.60 per box of oysters, netting about $4.30 per box.

In fall 1972, the average price the buyers paid for oysters from public grounds was $17.50 per box. It costs $1.25 to grade and pack, and $1.25 for a box. Thus, the total cost for a box of oysters was $20.00. Since buyers sold these for the same price as relay oysters, $24.60 (average) per box, their gross profit was $4.60 before overhead, an estimated $1.00 per box. Therefore, the net profit was about $3.60 per box.

In 1972 the percentages of oysters sold in each grade were: fancy, 3; choice, 35; standard 43; and commercial, 19.

Nearly all oysters are shipped to cities of eastern Canada (the largest market is in Montreal) for consumption raw on the half shell. Although all grades of oysters have about the same meat content and excellent flavor, consumers place high value on shell shape. A small quantity of oysters is sold on the Island, both in the shell and shucked. Medcof (1961) reported that P.E.I. oysters have a dry storage life of approximately 4 months if held under proper conditions.

Leased Ground Fishery

In 1973, there were 1,038 leased grounds on P.E.I. that covered about 3,700 acres; they yielded about 2,000 boxes of oysters per year (0.5 box per acre, average). It is not feasible to culture oysters (to collect or buy seed oysters and grow them to market size) on most of these grounds for several reasons. Aside from the poor environment provided for oysters described above, procuring and rearing seed oysters to market size is risky and economically marginal; oyster poaching is extensive; and market demand is variable.

There are mixed opinions of advantages of private ownership. Morse (1971) states: "A shift in policy to convert the public beds to privately managed grounds probably would result in an increase in output, and in income earned, from these areas." However, some sections of public beds already produce high yields, near the maximum that can be produced, without any management. These yields could not be increased under private ownership. More importantly, only a few fishermen, the ones who obtained grounds with oysters on them, would stand to gain by such a shift; they could use a drag to harvest more market oysters off these grounds than they could with tongs. However, the remaining fishermen, those receiving barren grounds, would lose, since they would be excluded from the productive beds. Even though the environment is good for culturing oysters on the barren grounds in Bedeque Bay and East River especially, I believe it would be extremely difficult to begin a profitable enterprise on them for reasons described above.

Most leased grounds should be used to hold over summer market-size relay oysters that are harvested during the spring season for sale in the fall. This practice of purchasing and selling relay oysters is a good business proposition. Relay oysters will survive on nearly all leased grounds in spite of the generally poor environment.

DEVELOPMENT OF MANAGEMENT PROGRAM

The management program for the oyster industry was developed by identifying the needs within the three sectors, reviewing biological and ecological potentials for enlarging and increasing the number of oyster beds, and conducting pilot projects in which large vessels transplanted stocks of oysters and shells.

Identification of Needs Within Industry

Improvements in any production system, such as the oyster industry on P.E.I., should be designed to benefit all sectors. Basically, improvements should result in higher earnings, greater employment, lighter workloads, and improved health. A significant improvement in one sector will affect the others, and thus it must be examined for its effects before any implementation is made, to ensure that it will indeed be beneficial to the whole. If any one sector stands to lose by an improvement in another sector, doubtless that sector will not accept the change. The result would be that the improvement could not be implemented.

An essential step in the process of making improvements in a traditional system of oyster culture lies in acquiring a thorough understanding of the needs within each production sector and then finding and developing ways to satisfy those needs. One approach is to provide better alternatives to existing methods or policies, as recommended in the field of agriculture by Schultz (1964). All oyster industry sectors are marginal; thus, none can afford to invest money, labor, or time in new developments. Ideally then, improvements should provide sure and immediate gains.

There are three basic production sectors of the oyster industry; the public fishermen, the buyers (leaseholders), and the wholesalers. The basic needs of each follow.

Needs of Public Fishermen

Information for this section was obtained from interviews with fishermen. The public fishermen need: increasing harvests per unit time (larger and denser beds with reduction in cleaning time); more high grade oysters to bring higher prices; lighter workloads; and better living conditions. If all these needs were satisfied, fishermen would earn more, be healthier, and have longer effective working lives.

Needs of Buyers (Leaseholders)

Information for this section was obtained from buyer interviews. The buyers, whether they purchase relay oysters in the spring for holding on their leases until the fall marketing season, or purchase oysters from public fishermen in the fall, need: a larger volume of oysters to handle for higher incomes; more high-grade oysters to satisfy the stronger demand; better protection from poaching; and more efficient equipment for harvesting.

Needs of Wholesalers in Cities off P.E.I.

Information for this section was obtained by telephone interview with a Montreal wholesaler. The wholesalers need: a much larger, dependable supply of oysters to encourage and maintain consumer demand; and more high grade oysters, for which the demand is stronger.

It can be seen that a larger supply of oysters with higher quality on both spring and fall public oyster grounds would satisfy the basic needs of all three production sectors. Accordingly, my objectives focussed on devising a management program to expand the oysters on both types of grounds, and to improve the quality of oysters on those beds.

Biological and Ecological Potentials

The biological and ecological potentials for increasing the number and size of commercially valuable oyster beds in Bedeque Bay and East River are substantial. Virgin beds exist in both estuaries. Oysters could be transplanted from these beds, in an orderly way so as not to deplete them, and spread over good quality barren grounds towards the mouths of the estuaries. These oysters would reproduce regularly and grow rapidly, attaining market size in no more than 4 years. Little mortality on the newly-established beds would occur in Bedeque Bay, but starfish do inhabit some grounds in East River. Avoiding high concentrations of starfish or some predator control might be necessary when spreading oysters over barren river grounds.

Important factors in evaluating the attributes of vacant public grounds as adequate oyster environments include: protection from storms; ground firmness for inducing growth of a round, cupped shell (fancy or choice grade); water depths of 3 to 4 feet (low water) to prevent ice from killing oysters, to avoid starfish, and to enable fishermen to harvest easily; regular setting in order that a new oyster bed will be self-perpetuating (if setting were not regular, these grounds would require refilling periodically); and presence of tube worms. Almost 600 acres of good quality barren ground are available in Bedeque Bay, 100 acres in the fall harvesting zone, and several hundred acres in the East River spring fishing zone.

Finally, estuaries currently producing commercial quantities of oysters under no management have far greater potential for an increase in production than unproductive ones. Equal investment of effort in estuaries that do not produce many oysters would yield smaller returns. Therefore, in selecting estuaries for development, those that produced the most oysters, Bedeque Bay and East River, were given priority.

Shell deposits that can be mined and used as a cultch source occur in most estuaries. In Bedeque Bay, shell deposits occur near oyster beds. In East River, the shells would not have to be mined and respread; rather, they would be prepared in place when oysters are dragged from the channel beds.

Use of Large Vessels

The most efficient and rapid means of increasing oyster production and industry earnings is to use large oyster vessels to transplant oysters and shells within public grounds. Large vessels can transplant large volumes of oysters from harvested virgin beds to good quality barren bottoms, within a short time and at relatively low cost. The area of productive oyster beds in Bedeque Bay and East River could be increased fivefold within only a few years.

A functional way to increase earnings of fishermen is to improve oyster quality, since the price differential between grades is wide (3.5 times). For example, in fall 1972, the price per box to public fishermen of fancy grade oysters was $28, choice grade $25, standard grade $15, and commercial grade $8. Transplantation of oysters by large vessels can significantly improve oyster quality and value as clusters are broken apart during this process. The separation not only enables oysters to grow into better shapes but also means that fishermen can harvest and clean them more rapidly. In Bedeque Bay, oysters will be transplanted from shallow flats, where tube worms are scarce, to hard grounds covered by 3 to 4 feet of water at low tide, where these worms are abundant. In East River, oysters will be transplanted from the channel to hard grounds where they can be harvested by fishermen and tube worms are abundant.

The costs of enlarging or establishing new oyster beds would be low in relation to the benefits as this involves only the transplantation of existing oysters. Similarly, costs of mining and spreading shells in Bedeque Bay to sustain the original oyster beds would also be low relative to benefits because annual oyster setting on shells is virtually certain. Undoubtedly, the stocks spread on most new grounds will be self-perpetuating, owing to regular natural setting. Accordingly, they would yield oyster harvests year after year, at no additional cost beyond that of the initial establishment of the beds.

The operation of large vessels on public grounds could be financed by public funds under the direction of a government fisheries agency. The general management program suggested is similar to those used by most coastal states in the United States. The large oyster producing states such as New Jersey, Delaware, Maryland, Virginia, Florida, Alabama, Mississippi, Louisiana, and others sponsor programs to maintain oyster beds on public grounds. Collectively, the programs involve the mining and spreading of several million bushels of shells to collect seed oysters, and transplanting of seed oysters with large vessels.

These programs produce large cost-benefit ratios. For example, Whitfield (1973) stated that man-established oyster beds in Florida that produce for 20 years, as some already have, result in a cost-benefit ratio at the fishermen's level of 1 to 100. He states further that oyster bed rehabilitation in Louisiana has resulted in cost-benefit ratios as high as 1 to 20.

PILOT PROJECTS CONDUCTED

Three pilot projects were begun during the investigative period. These were considered as pilot projects as no management plan had as yet been formalized; but the last two were effec-

tive enough already to have made significant improvements in the oyster industry.

The first project was conducted in East River, in which barren grounds were stocked with oysters that had been dragged from the virgin bed in the upper river, during fall 1972. A scallop boat fitted with an oyster drag was chartered to harvest the oysters. During an 18-day period, it harvested about 2,000 boxes of oysters. Approximately half were sold to East River leaseholders at low cost, while the remaining half were spread on public grounds. Review of this project showed that it would be of greater total benefit to spread all oysters dragged from the channel on public grounds. The environment for oysters was better on those grounds and the leaseholders would be spared from paying for the oysters—they could harvest them on public grounds.

The second project was a larger-scale transplantation in East River involving use of an oyster boat, a catamaran-type vessel constructed especially for these projects (Fig. 13). No existing vessels suitable for transplanting oysters were available in the Maritimes. The catamaran had a capacity of about 225 boxes of oysters. Its two drags could be raised 5 feet above its deck by booms and the oysters were dumped by releasing a door on the drag (Fig. 14). Oyster clusters were partially separated when they fell on the deck (Fig. 15). The oysters were spread overboard by hosing with water. During the summer of 1973, about 15,000 boxes of oysters were transplanted by the catamaran from section No. 1 in the virgin oyster bed in the upper river (Fig. 6) and spread on three good-quality barren grounds, whose combined areas totalled 30 acres, below Glenfinnan Island. Each box contained about 1,000 oysters of mixed ages and sizes. The rate of spreading was 500 boxes per acre. After the oysters had grown during the summer of 1973, the concentration was about 800 boxes per acre in the fall, a concentration optimum for harvesting. The oldest oysters were slightly smaller and they had poorer shell shapes than oysters on other public beds in the river, but clusters were broken apart to about twice the extent as the others. Accordingly, it is anticipated that they will eventually grow into better shapes than the others. The transplanted oysters were too small for harvesting in the fall of 1973, but by 1974 they were expected to provide an additional 30 acres of productive beds.

The virgin oyster bed in East River lies on a continuous deposit of oyster shells. During the oyster transplanting operation, mud was scoured off the bottom, and consequently the underlying shells were clean before the oyster setting season. During July the shells received a heavy set of oysters over an area of several acres where oysters had been harvested previously. After a few years, this ground should be replenished with a large bed of oysters of several age groups.

The third project was conducted in Bedeque Bay. It consisted of transplanting small, poor-quality oysters from plots within oyster beds, spreading them on barren grounds west of and adjacent to the harvesting areas, and then spreading mined shells over the dragged plots (Fig. 5). Some 1,600 boxes in Wilmot River and 17,000 boxes in Dunk River were transplanted to 4-acre and 34-acre plots respectively, alongside the western borders of the fishing areas. Each box contained an average of about 450 oysters of various age groups.

Some oysters were to have been harvested from this area in 1974, and it should reach full commercial productivity in 1975.

During the oyster setting season, some 3,500 boxes of shells that had been mined from a deposit about a mile away were spread over the two plots. Additional shells were not required because shells buried in the bottom within the dragged plots were lifted to the surface during the dragging operation. Most shells collected a heavy set of oysters.

With the use of the oyster catamaran, oysters and shells were transplanted at low cost. In Bedeque Bay, it costs an average of $0.85 to transplant a box of oysters, or $425 to spread 500 boxes of oysters over an acre; and in East River, an average of $0.65 to transplant a box of oysters, or $325 to spread 500 boxes over an acre. These costs approximate those for transplanting oysters in the United States. It costs about $1.25 to mine and transplant each box of shells in Bedeque Bay. Although this figure is higher than the usual cost for shelling grounds in the United States, the near certainty that spread shells will collect oyster spat still makes mining and transplanting of shells an excellent economic proposition.

Figure 13.—Catamaran with part of an oyster load on its deck in East River. Note booms that lift drags.

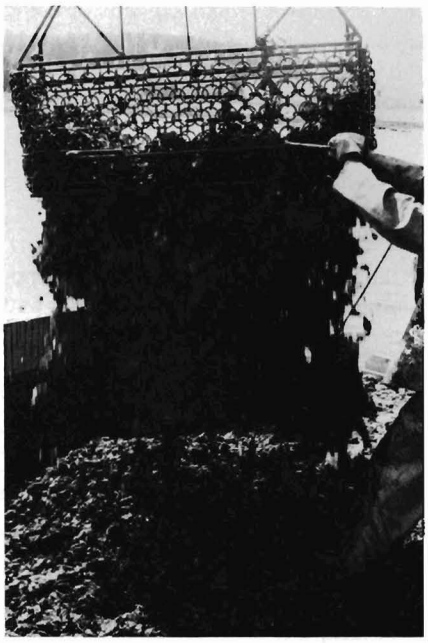

Figure 14.—Clusters of oysters dropped from the drag are partially separated when they hit the platform.

SPECIFIC MANAGEMENT PROGRAM

The management program for oysters is not complex, but involves transplanting sufficient oysters to cover and establish new beds on 70 or more acres of barren bottom each year.

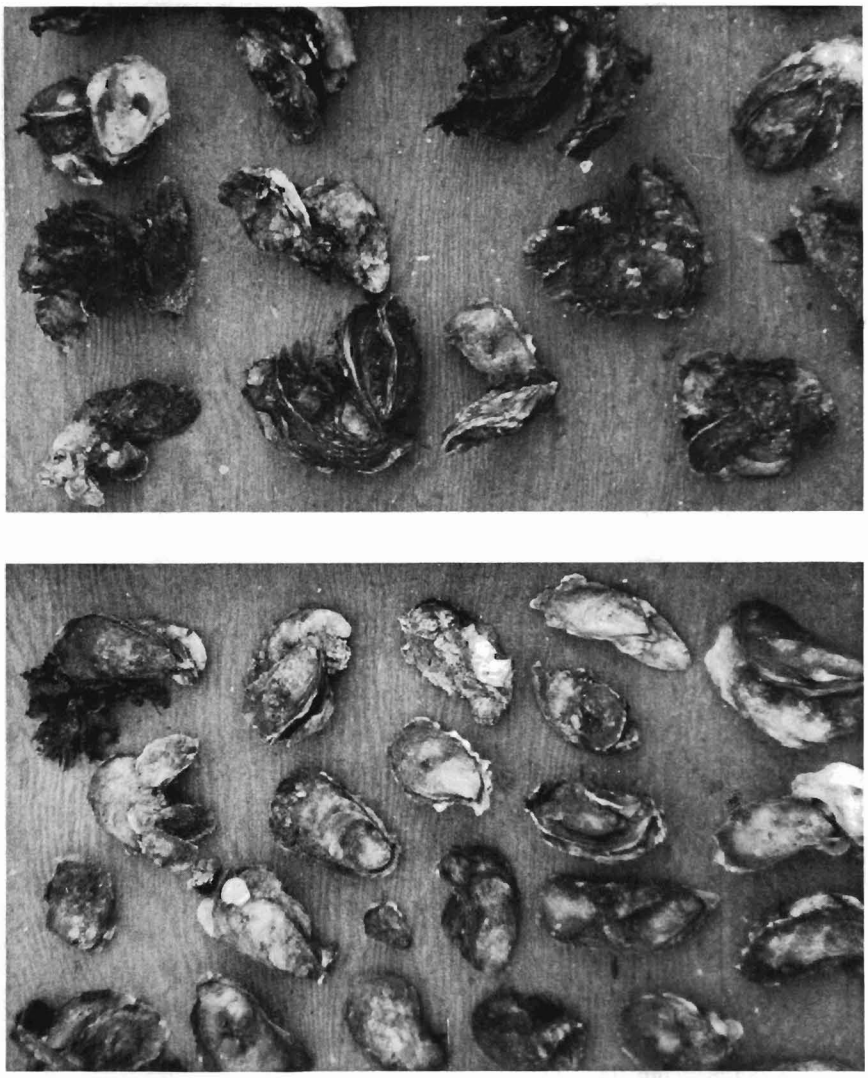

Figure 15.—Samples of oysters before (upper) and after (lower) drop onto catamaran, showing extent of cluster separation as a result of the drop.

Some additional suggestions for increasing production and earnings and industry development are listed below under the section on applied research.

Transplanting of Oysters and Shells

In Bedeque Bay, transplanting of oysters from harvested sections to good-quality barren grounds of Wilmot and Dunk Rivers should be continued each year. A total of 4,000 boxes in Wilmot River and 16,000 in Dunk River will be transplanted and spread over 40 acres. More oysters could be transplanted if two or more catamarans were available to do the work. Eventually, the barren 100 acres in the mouth of Wilmot River and the barren 500 acres in the mouth of Dunk River may be covered with oysters (Fig. 5). Ample shells will be spread on the cleared sections to sustain the original stocks.

In East River, transplanting oysters from the virgin bed in the upper river to good-quality barren grounds in the lower river should be continued each year. A total of 15,000 boxes of oysters from the bed will be transplanted and spread over 30 acres. Eventually, the barren 100 acres in the fall harvesting zone and an even larger area in the spring harvesting zone may be covered with oysters.

The bed contains about 106,000 boxes of oysters and covers 140 acres. It has been divided into four sections: the upper two sections each will have about 25 acres (25,000 boxes) and the lower two sections, 45 acres (28,000 boxes). From early May to mid-June, the boat will transplant 15,000 boxes from a section as designated in Figure 6. Oysters were transplanted from section No. 1 in 1973. The intention was also to transplant from section No. 2 in 1974, from section No. 3 in 1975, from section No. 4 in 1976, and section No. 1 again in 1977, etc. By transplanting as many oysters as possible before they begin pumping in spring, those that would be suffocated in silt deposits would be saved. After oysters are transplanted from a section, the entire bottom will consist of clean shells as well as the oysters that remain. It is anticipated that young oysters in adequate numbers will set on shells and oysters as they did in 1973 and, in later years, on growing oysters. Ultimately, the bed should consist of the same numbers and sizes of oysters it had before it was dragged. Accordingly, about 15,000 boxes of oysters could be dragged off each section every fourth year in rotation.

Anticipated Increases in Production

It is difficult to forecast production from oyster beds accurately as many factors are involved. A means of forecasting production of oysters from newly-established beds is to examine production from existing beds. The most productive public beds yield an estimated 150 boxes of oysters per acre per season. If we take a more conservative average yield of 100 boxes per acre per season, yields at that level from the new beds can be forecast. In Bedeque Bay, the oyster yield from 40 acres should be about 4,000 boxes, and in East River from 30 acres, about 3,000 boxes. Thus, if about 70 more acres of beds are added to the existing beds each year, oyster production would probably increase at an annual rate of about 7,000 boxes.

The potential for increasing oyster production, however, hinges on more than increasing available supplies. It also hinges on both fishing pressure and the ability of buyers and wholesalers to purchase sudden increases in production.

It is possible that the supply of oysters on public grounds might eventually outstrip the fishermen's harvesting

capacity after the management program has been underway for a few years. In that event, increased production could be attained by allowing fishermen to harvest oysters with hand drags (Fig. 12), instead of tongs. A limit could be placed on the number of days, or weeks, that drags could be used to control harvest rates, if warranted.

Anticipated Increases in Earnings

In Bedeque Bay, weekly harvests of individual fishermen should increase from 10 to 15 boxes and remain that high during the entire season. Accordingly, weekly earnings of individual fishermen should rise from $130 to $195, and seasonal earnings from $1,300 to $1,950 (Fig. 9).

In East River, weekly harvests of fishermen at the season's beginning should rise from 8 to 14 boxes, and remain that high during the entire season (Fig. 11). Accordingly, weekly earnings of individual fishermen should rise from $130 to $260, and seasonal earnings, from $1,000 to $2,600. (The fall season would be extended to 10 weeks.) In some years, poor weather will reduce these earnings.

It is anticipated that the quality of oysters in both Bedeque Bay and East River will increase by about half a grade, and lead to an increase in the price of about $4.50 (average) per box in the fall. This increase is not included in the projections listed above.

The earnings of the typical fisherman will increase from $1,300 to $1,950 during the spring season, and from $1,000 to $2,600 during the fall season, increasing combined earnings from $2,300 to $4,550. The two remaining industry sectors would also benefit: the buyers on P.E.I. would earn more money, since they would handle greater volumes of high-quality oysters; the wholesalers in off-Island cities would earn more money, since they, too, would have more high-grade oysters to handle and could rely on a dependable supply.

Possible Negative Aspect

It is likely that a significant increase in quantities of high-quality oysters on public grounds will lure into the oyster fishery many more men who will anticipate good earnings. Although this would have the effect of increasing the level of gainful employment on P.E.I., the additional number of men may be sufficiently large to effectively negate any potential gain in earnings intended for the regular fishermen. The new entrants might not only compete for the same oysters, but also increase production sufficiently to result in a drop in prices.

This rehabilitation program was intended to spread out the increased oyster quantities for the regular fishermen over an entire season. Accordingly, it is proposed that a limit be placed on the number of new entrants into the public oyster fishery, to ensure that the regular fishermen do, indeed, gain the projected increased harvests and earnings. Under a limited entry plan, a controlled number of men would be permitted to enter the oyster fishery if warranted by adequate supplies and market demand each year.

COST-BENEFIT RATIOS

The monetary benefits to be gained from stocking previously barren grounds with oysters to establish new beds should far exceed costs. Indeed, during each season the amount of money earned by fishermen from a newly established bed should far exceed initial costs. For example, the cost of stocking an acre in Bedeque Bay was $425, and the anticipated earnings from an acre are $1,200 per season ($12 per box of oysters × 100 boxes harvested); the cost of stocking an acre in East River was $325, and the anticipated earnings are $1,750 per season ($17.50 per box of oysters × 100 boxes harvested). On those beds that perpetuate themselves through natural setting, cost-benefit ratios may ultimately exceed those reported for the United States, 1 to 20 and as high as 1 to 100, as costs are about the same and the sale value of P.E.I. oysters is greater.

APPLIED RESEARCH NEEDED

A list is presented of some key studies that could be pursued further to develop the oyster industry.

I. Oyster biology and ecology
   a) Studies, more detailed than were made during this investigation, of causes of oyster mortalities during various seasons to refine management procedures.
   b) Studies of starfish biology, such as migration patterns, recruitment rates, seasonal feeding rates, food preferences, and factors affecting distribution.
   c) Studies of tube worm biology, such as seasonal recruitment, growth rates, longevity, and factors affecting distribution.
   d) Studies of oyster genetics to determine the extent that shell shape of parent oysters influences shape of offspring.
   e) Studies to determine both the sources and seasonal deposition rates of silt, its precise effects on oyster beds, and the feasibility of slowing its flow into estuaries.

II. Oyster culture
   a) Studies to determine the cost-benefit ratio of increasing grades of oysters on already productive public oyster beds by transplanting them every year, separating any clusters.
   b) Studies to ascertain whether oyster clusters can be separated by towing a device such as an agricultural cultivator over a ground. Separation of clusters to improve the quality of oysters would bring some beds into production where harvesting does not occur because oysters have poor quality.
   c) Studies to determine whether dormant shell deposits can be converted to productive oyster beds again by towing over them a device such as a toothed oyster drag that is 6 or more feet wide. The teeth would loosen the shells and the drag's pressure plate would scour silt off the ground.
   d) Studies to determine the feasibility of using quicklime (CaO) to control starfish, sea lettuce, and the biota on live oysters and exposed shells. Advantages of control of the first two types are obvious. Control of the latter before the setting season of oysters would provide more and better setting surface for oyster larvae, resulting in heavier sets.
   e) Studies to explore the feasibility of mining shells for storage

on land. Leaseholders with proper grounds need a convenient supply of shells for collecting seed oysters.

f) Studies to explore the means of extending the time that oysters are available for market. An extension is needed because, at present, the fresh supply is terminated when ice forms over the estuaries.

III. Social needs

a) Studies to determine the feasibility of providing temporary or mobile kitchens at shore sites near the major public beds, to provide better meals for fishermen.

b) Studies to determine whether bunk houses could be built at shore sites in order that men who do not own trailers might easily enter the public fishery.

IV. Economic needs

a) Studies to determine whether low cost government sponsored loans should be made available to oyster buyers during the spring oyster season. It is possible buyers may not have extra funds to purchase the projected increases in oyster harvest by fishermen. In that event, production increases would not take place, unless additional buyers were found.

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