AN ANALYSIS OF THE EFFECTS OF INSTITUTIONAL, BIOLOGICAL AND ECONOMIC FORCES ON THE VIRGINIA OYSTER FISHERY

by

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(Abstract)

The Virginia oyster industry changed markedly in the period between 1950 and the present. This change has been the result of a variety of forces which can be conveniently classified as economic, biological and institutional. In general, biological forces initiated a series of changes in the fishery which have had economic impacts and impacts on the institutional structure of the fishery. The biological forces have had a much more severe impact on the seed-planting, or private grounds, sector than on the public grounds sector. The dependence of the seed-planting sector on public seed beds and the different regulatory regimes applicable to the public and private grounds makes it difficult to draw firm conclusions on the relative merits of alternative tenure structures. The magnitudes of economic, biological and public policy forces as contributing factors to the decline of the oyster fishery are estimated and it is concluded that the biological forces have played the dominant role in the decline of the Virginia oyster fishery.

It is suggested that attention be focused on the physical and management inputs to the production of oysters and on methods for bringing forth an appropriate resource mix. It is argued that either a predominantly private grounds fishery, a predominantly public grounds

fishery, with appropriate institutional modifications to allow efficient harvest technologies to be used without threatening the viability of the resource base, or a mixed tenure system could be used and with appropriate management could result in substantial revitalization of the Virginia oyster industry. However, because of the biological changes which have occurred, management, whether public or private, takes on a much more important role in determining the future of the Virginia oyster fishery.

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

The oyster industry in Virginia has been the topic of considerable recent concern to public officials. In 1977 the Joint Legislative Audit and Review Commission of the Virginia General Assembly issues a report, Marine Resource Management in Virginia (JLARC, 1977), which documented the decline of the Virginia oyster harvest and cited the need to consider policy alternatives to enhance the production from the oyster fishery. Implementation of such policies would, however, require an expanded role for management of both the oyster itself and harvesters. Such management cannot be undertaken without an understanding of the forces affecting the fishery.

In 1978, scientists at the Virginia Institute of Marine Science (VIMS) issued a comprehensive study of the oyster industry in Virginia (Haven, et al, 1978) but despite its scope, the study called for detailed economic analyses of the oyster industry. Economic analyses have been conducted at the College of William and Mary (see Baker, Harris, and Moody, 1977, Garrett and Schifrin, 1977), however, these analyses have usually been narrowly focused on one specific problem, such as the evaluation of the effects of repletion (Baker, Harris, and Moody, 1977) or the assessment of the effects of a natural disaster, such as Tropical Storm Agnes (Garrett and Schifrin, 1977).

In addition to concern in Virginia over oyster production levels, there has been concern over the status of the oyster fisheries in nearby states (see for example Gracey, Keith and Rhodes, 1976, Kennedy and Breisch, 1981) and at the national level (see National Marine Fisheries Service, 1977a and 1977b). Although the specific problems of the oyster fishery may vary from state to state, the problems can generally be classified into three broad categories first delineated by Agnello and Donnelley, (1975a): economic, biological and legal, including public policy. In 1981 the Virginia General Assembly adopted House Joint Resolution 59 which called upon the Joint Legislative Audit and Review Commission (JLARC) to assess the economic potential and management of the industry and to make policy recommendations for State action to foster the State's competitive position, preserve the socio-economic well-being of those whose livelihood depends on the industry, and enhance State management and regulation.

The present study attempts to develop a theoretical framework and empirical model to improve the understanding of the changing performance of the Virginia oyster fishery. In particular, the relative importance of economic, biological and public policy forces in the historical production and price patterns observed in the Virginia oyster fishery from 1950 to 1980 will be assessed. Also, the potential effects of selected changes in the public sectors management programs for the Virginia oyster fishery are discussed.

1.2 PRODUCTION, EMPLOYMENT AND PRICE TRENDS IN THE VIRGINIA OYSTER FISHERY

The oyster fishery has long been an important part of the economy of the Virginia coastal region. In 1980, almost 8,500,000 pounds of oysters were harvested in Virginia with a dockside value of almost $8,800,000. This value of harvest is 10.4% of the total value of food, fish and shellfish landings in Virginia. This level of harvest is down significantly from levels achieved in the late 1950's. In 1958, almost 30,000,000 pounds of oysters were harvested in Virginia.

Since the peak period of 1958 nominal oyster prices increased from $2.48 per Virginia bushel to $5.43 per Virginia bushel, an increase of 119%. In the same time period the rate of inflation as measured by the consumer price index, rose 208%. Therefore declining harvest levels and declining prices relative to the general price level have put severe constraints on the income producing potential of the fishery. This is clearly reflected in the employment pattern in the oyster industry since 1958. For example, in 1958 there were over 4,500 licensed tong harvest gear units operating in Virginia, compared to around 2,500 units in 1982.

1.3 HISTORICAL DEVELOPMENT OF THE MANAGEMENT STRUCTURE IN THE VIRGINIA OYSTER FISHERY

The public management of the oyster beds of the Commonwealth defines two types of oyster grounds: public or Baylor grounds, and private or leased grounds. The management structure dates back to the last part of the 19th century, another period in which there was concern over the declining production of the Virginia oyster fishery. At that time the fishery was based upon an unmanaged wild stock from which any person could harvest oysters by any means desired.

The first studies of the fishery were based upon surveys to assess systematically the condition of the oyster beds in the Chesapeake Bay in Maryland and portions of Virginia. Between 1881 and 1884 Lieutenant Francis Winslow documented the decline of the oyster stocks in Pocomoke and Tangier Sounds and in the James River. (See discussion in Breisch and Kennedy, 1981 and Brooks, 1891.) Winslow found that in areas subject to fishing pressure for oysters the oyster populations were being depleted. A follow-up survey by W. R. Brooks concluded that "...the oyster property of the State (Maryland) is in imminent danger of complete destruction unless radical changes in the methods of managing the beds are made at once. (Brooks, 1891, p. 152.)"

The Winslow and Brooks studies proposed programs to enhance the productivity of the Maryland oyster beds which were equally applicable to the condition of the Virginia oyster beds in the late 1800's. They identified a need to:

1. protect young oysters from disease, predators, etc.
2. maintain and adequate level of cultch (hard material on the subaqueous bottoms on which oysters set) to promote the setting of oysters; and
3. protect and expand natural seed areas.

Artificial enhancement of oyster population through private leasing and cultivation was recommended. It was believed that such leasing and cultivation could have the same beneficial effects in the Chesapeake region as had been observed in other states (notably Connecticut) which had encouraged private cultivation.

At about the same time, similar concerns were being voiced by observers of the Virginia oyster industry. In 1891, Virginia Governor P. W. McKinney proposed that properly surveyed ground be leased to private planters for the cultivation of oysters. In 1892, the General Assembly mandated a survey to determine the location and extent of the natural oyster beds, rocks and shoals of the Commonwealth. The natural oyster grounds, those areas where oysters are found in abundance without human intervention, are generally areas where the bottoms are firm with a layer of oyster shells or other hard material (cultch) on which the oysters can set. In general the salinity levels on the natural oyster grounds range for 5 parts per thousand (ppt) to 15 parts per thousand (ppt). In 1894, Lieutenant James Baylor of the U.S. Coast and Geodetic

Survey delineated 210,477 acres of natural oyster grounds. Since the time of the Baylor survey there have been a number of additions to the public grounds and at present some 243,000 acres are contained within the public grounds. The extent of the public oyster grounds is set by statutory law. (Va. Code Ann., Secs. 28.1-100, 28.1-149 to 28.1-159, 1982, Supp.) The natural oyster rocks of the state are managed according to the language of Article XI, Sec. 3 of the Virginia Constitution which provides that: "The natural oyster beds, rocks and shoals in the waters of the Commonwealth shall be held in trust for the benefit of the people of the commonwealth, subject to such regulations and restrictions as the General Assembly may prescribe, but the General Assembly may, from time to time, define and determine such natural beds, rocks, or shoals by surveys or otherwise." (Va. Constitution, Article XI, Sec. 3.) Maryland and most other coastal states provide similar exemption from leasing to natural oyster bars. (See Md. Ann. Code., Nat. Res. Art, Secs. 4-1102 and 4-1108 (c).) For a summary of provisions in other coastal states, (see Haven, et al, 1978, pp. 864-879).

At the same time as the Baylor survey was conducted, provision was made for the leasing of naturally unproductive grounds suitable for cultivation of oysters. In 1900, the first year for which reasonably accurate data are available, there were 47,803 acres under lease for oyster cultivation. (Haven, et al, 1978, p. 67.) This acreage increased regularly until the late 1950's when leased acreage levelled off at around 130,000 acres. The all-time high in leased acreage was reached in 1967 when this figure was 134,492 acres. In the last fifteen years leased acreage has declined to around 100,000 acres. In 1982, leased acreage was 107,307 acres. However, it is impossible to determine the number of leased acres actively cultivated.

1.4 OBJECTIVES OF THIS STUDY

1. To describe the historical development of the oyster industry in Virginia with respect to:
   a. level of market oyster and seed oyster production
   b. employment in the tong harvest sector
   c. prices received by harvesters
   d. acreage of leased grounds
   e. productivity of the industry as measured by output per acre of leased grounds
   f. harvest and price of seed oysters
   g. mix of public grounds harvest and private grounds harvest
   h. importance of imported oysters to the Virginia oyster processing sector.
2. To analyze the relative historical importance of biological, economic and public policy forces on the output levels of the Virginia oyster industry.
3. To evaluate alternative public policies for the management of the Virginia oyster fishery in terms of impacts on public and private harvests and total revenue and on seed requirements.

1.5 PROCEDURES

Objective 1: Descriptive statistics on each of the variables will be presented and the implications discussed. The trends in Virginia will be discussed in the context of changes in the regional and national oyster fisheries.

Objective 2: Multiple regression analyses will be used to estimate public grounds harvest, private grounds harvest and seed harvest as functions of biological, economic and public policy variables. A regression model will be used to estimate ex-vessel oyster prices as a function of consumer demand, Virginia harvest, Maryland harvest, property rights, season and region. The theoretical justification for inclusion of each variable will be developed. Having developed equations to describe changes in the public and private grounds oyster harvest in the past these equations will be incorporated into a simulation model to isolate the separate effects of economic, biological and public policy forces on the Virginia oyster fishery.

Objective 3: The simulation model will be used to evaluate the existing public policies for management of the Virginia oyster fishery and the potential for expanded management to improve the performance of the industry.

The particular policy options to be examined include:

1. Expanding consumer demand, which is reflected as an exogenous increase in retail price

2. Increasing public repletion efforts while maintaining the historic patterns with respect to location of planting and the mix of shell and seed planting

3. Reducing the cost of seed to the private seed planting sector, which could result from the use of more efficient seed harvest technologies

4. Increasing the productivity of public oyster grounds through more intensive management. This option is similar to option 2, however option 2 is essentially incremental in nature, while this option involves more fundamental changes in the structure of the industry. This option covers both leasing portions of the public grounds to private parties and greatly expanded public management efforts; and

5. A combination of policy options 1-4 above.

CHAPTER II

OVERVIEW OF THE VIRGINIA OYSTER INDUSTRY

2.1 INTRODUCTION

In this chapter the recent history and the institutional structure of the Virginia oyster industry will be presented. The material presented in this chapter will serve as background for the economic model to be developed in Chapter III. In order to understand the development of the Virginia oyster industry, it will be necessary to present basic background on the biology of the oyster and the relationship between environmental conditions and oyster abundance.

2.2 BIOLOGY OF THE OYSTER

The Eastern Oyster, Crassostrea Virginica, is sensitive to a number of environmental factors. These factors include:

1. water temperature
2. salinity
3. rainfall
4. nutrition
5. pollution
6. condition of the underwater bottoms for setting spat
7. predators, parasites and pests; and
8. disease.

These environmental factors are not independent, but interact in omplex ways which are only partly understood. These environmental factors affect the public grounds sector (which is essentially a wild stock supplemented by a public replenishment or repletion program), the seed sector (which is a wild stock supplemented by a public repletion program) and the private grounds sector (which consists primarily of naturally barren grounds which are leased to private parties for the cultivation of oysters) in different ways.

1. Water Temperature - Oysters are found in waters from the Gulf of St. Lawrence in Canada to the Gulf of Mexico, so it is clear that oysters can survive a range of different temperatures. Galtsoff (1964) reports that feeding activity is greatest at a temperature of 25° - 26° centigrade (77° - 79°F). Davis and Calabrese (1964) suggest that the optimal temperature for larval development is somewhat higher between 30° and 32.5° centigrade (86° - 90°F). The spawning of oysters is also sensitive to temperature. Price and Mauer have formulated a relationship between degree-days of temperature above a certain critical level (12°C) and the onset of spawning.

2. Salinity - Just as oysters can survive under a wide range of temperatures, oysters are also found in waters of widely different salinities. In general, within the range of salinities found in the Chesapeake Bay (5 ppt - 28 ppt), and Bayside oyster grounds of

Virginia, the higher the salinity, the more rapid is oyster growth, ceteris paribus. The effect of salinity on oyster population and harvest is complicated, however, because of the interaction between salinity and the prevalence of oyster diseases and parasites; many of these diseases and parasites are most prevalent under those conditions which are most favorable for the growth of oysters in the absence of these diseases and predators. These interactions are discussed in the sections on disease and predators below. The specifications of the effect of salinity on oysters is complicated by the ability of oysters to adapt to changes in salinity, if the change occurs over time, while rapid changes in salinity, particularly from high salinity to lower salinity, may have adverse effects on oysters and result in increased mortality. (See discussion in Kennedy and Breisch, pp. 5-10.)

3. Rainfall - The effects of rainfall on oyster abundance and harvest are closely inter-related with the effects of salinity, since periods of high rainfall tend to be associated with lowered salinity levels. Although periods of heavy rainfall tend to be associated with higher mortality, there is also evidence linking increased rainfall with higher rates of oyster growth. Beaven (1955) and Kennedy and Breisch (1981) suggest a link between periods of increased rainfall and resultant increases in nutrient loads from runoff and subsequent increases in spat settlement.

4. Nutrition - Oysters feed primarily on algae and diatoms. As oyster culture under controlled environmental conditions has been explored, there has been increased interest in the formulation of rations to be fed to oysters under such conditions. Since oysters are filter feeders, any factor which influences the abundance of algae and diatoms in the waters in which the oysters grown will alter the amount of food potentially available to oysters. The links between the abundance of food sources and the harvest of oysters is unclear. As more intensive forms of oyster culture are developed, the study of oyster nutrition and the formulation of optional food supplement may become increasingly important.

5. Pollution - The shellfish growing areas of Virginia, like much of the rest of the Chesapeake Bay and its tributaries, have been subject to pollution from a variety of sources. The primary public policy response to water pollution, as it affects the Virginia oyster fishery, has been the designation of certain grounds as "condemned."

State law provides that: "When from examination of or analysis of the shellfish in a shellfish growing area, or the bottom in/or adjacent to or in the near proximity to a shellfish growing area," the State Health Commissioner determines that the shellfish growing in such area is unfit for market, he shall, after notifying the Commissioner of Fisheries, cause limits or boundaries of such area upon which such shellfish are planted to be fixed, which area shall be condemned, and remain so until such time as the Health Commissioner shall find such shellfish or area sanitary and not polluted. (Virginia Code Ann. Sec. 28.1-176 (1984).)

The regulation of shellfish growing areas by the State Health Department is conducted under the auspices of the National Shellfish Sanitation Program which operates under a cooperative arrangement between the industry, the Public Health Service and the State.

The general effects of pollutants on the Chesapeake oyster fishery have been summarized by Kennedy and Breisch (1981): "With (1) the post-war growth of the chemical industry, (2) greater reliance on petroleum products for transportation, fertilizers, and consumer goods, and (3) increased use of pesticides for health and agricultural purposes output of chemical materials has increased and diversified immensely. Dumping or leaking of chemicals into sewage systems, runoff from irrigation or drainage ditches, and spillage during ship transportation all contribute to disposition of increasing amounts of chemicals into estuaries."

"When these anthropogenic materials contact oysters, they may be lethal; they may exert sublethal effects; they may be concentrated in amounts dangerous to human health when oysters are eaten; or they may have a mix of influences. (Kennedy and Breisch, 1981, pp.

23-24.)" Among the major chemical pollutants which are believed to have had an effect on the Virginia oyster fishery are chlorine and a variety of heavy metals including copper, mercury, silver and zinc. These major classes of pollutants affecting the oyster fishery are petroleum hydrocarbons and pesticides. Oysters feeding and breathing in waters polluted by petroleum hydrocarbons concentrate these chemicals in their tissues, with a variety of sublethal and potentially lethal effects.

Pesticides are another type of pollutant which may have significant adverse effects on oysters. In the mid-1970's the highly toxic pesticide Kepone was found in the James River, with significant adverse consequences on the oyster fishery, as well as other fisheries in the James River and the Chesapeake Bay.

Significant portions of the oyster grounds of Virginia have been condemned for the harvest of oysters. In 1975, 178,732 acres of public and private oyster grounds were condemned. This compares to 100,662 acres of leased oyster grounds and 243,271 acres of public oyster grounds. However, the impact of this condemned acreage is probably less than proportional to the area of the bottoms condemned. Haven, et al, (1978) note that "condemned areas... frequently include many sites or locations which have never produced market oysters, hard clams, soft clams, or brackish water clams.

This fact must be considered when evaluating the impact of condemnation on the Virginia oyster... industry. Certain closed areas or portions of condemned areas do not produce oysters... and have not for a long time. (Haven, et al, (1978), pp. 734-735.)"

The above discussion has indicated that pollution has been a factor in the decline of the Virginia oyster fishery. However, Haven, et al, point out that: "Many of the once productive tributaries in the York, James, Rappahanock, and Potomac contain acreage classed as restricted and are essentially "out of production." While the loss of these areas is a serious matter, causing economic damage to the oyster industry, condemnation because of pollution has not been the principle cause of the major decline in oyster production which took place in Virginia... Hampton Roads is the only area now condemned where oysters were grown in any quantity prior to 1960 and this location was producing only a small fraction of the total market landings just prior to the start of the major decline. (Haven, et al, pp. 765-766.)"

6. Conditions of the underwater bottoms - In order for oysters to set, they must have a layer of firm substrate on which to attach and grow. Much of the difference in natural productivity between various areas in Virginia is due to differences in the nature of the substrate; in addition, dredging of the bottom of the rivers and Bay has increased in recent years. Such dredging can increase

turbidity in the water, as well as covering up natural oyster rocks with silt which interferes with the natural setting of oysters.

7. Predators, parasites and pests - Oysters share the underwater ecosystem with a wide variety of other species. Many of these other species are either direct predators on oysters or spat, or compete with oysters for limited supplies of nutrients. The management and control of these predators and pests assumes a much more important role under private oyster culture then in exploitation of a commonproperty resource, unless the control program is operated by a public agency. Public agencies, including the Virginia Marine Resources Commission and the Virginia Institute of Marine Science, conduct ongoing research and public education programs to control predators, parasites and pests affecting the Virginia oyster fishery.

8. Disease - The susceptibility of oysters to a variety of disease is widely cited as a dominant factor in the development of the Virginia oyster industry. (See Andrews and Wood, 1967 and Andrews, 1979.)

Diseases to which oysters in Virginia are particularly susceptible include MSX (Minchinia Nelsoni), Dermocystidiumn Marinum, and Seaside organism (SSO or Minchinia Costalis.) MSX has been widely blamed for a major portion of the decline in the Virginia oyster fisher. Haven, et al, (1978) stated: "We recognize that MSX is responsible for the initiation of the serious decline in Virginia's oyster production and is partially responsible for its current condition and for the continuation of some of the reduction in productivity. (Haven, et al, 1978, p. 677.)" Haven, (1982) notes: "The drastic reduction in landings of oysters after 1961 is now associated with many factors. The initial decline is attributed to the disease caused by the parasite Minchinia Nelsoni (MSX.) (Haven, 1982, p. 3.)" Similarly Haven, Hargis, and Kendall concluded: "A disease of major importance in Virginia has been caused by the Pathogen Minchinia Nelsoni (or MSX), which entered or became apparent in Chesapeake Bay about 1959. The effect of this organism was catastrophic, since it killed most of the oysters in the high-salinity regions of the Bay. Since 1959-60 MSX, more than any other single factor, has been responsible for the decline in yields from these public and private beds, formerly the mainstay of production in the Commonwealth. (Haven, et al, 1978, p. 324.)"

2.3 TRENDS IN VIRGINIA OYSTER HARVEST, EMPLOYMENT AND PRICES

The effects of MSX on the Virginia oyster industry are not limited to biological effects on the market oyster sector, but have included other impacts such as:

1. Declines in setting of small oysters in the James River seed beds.

2. Reduced willingness of planters of oysters on the private grounds to plant seed.

3. Changes in the amount and type of labor and capital inputs utilized in the Virginia oyster fishery.

Scientists at the Virginia Institute of Marine Science delineated four types of areas based on the prevalence of MSX. These areas are closely related to salinity patterns. The 15 ppt isohaline in late fall is reported to divide high MSX mortality areas from low MSX areas, with MSX prevalent in the high salinity areas and largely absent, or if present resulting in low mortalities in the lower salinity areas. In waters above 22 ppt salinity, MSX is report to be less prevalent than in the waters of salinity in the 15 ppt - 28 ppt range. The geographic location of the four types of grounds, on the basis of MSX susceptibility is shown in Figure II-1 below; the salinity patterns in these waters are shown in Figure II-2 below. The effects of MSX on oyster production in each of the four types of areas, as reported by Haven, et al, (1978), is summarized below.

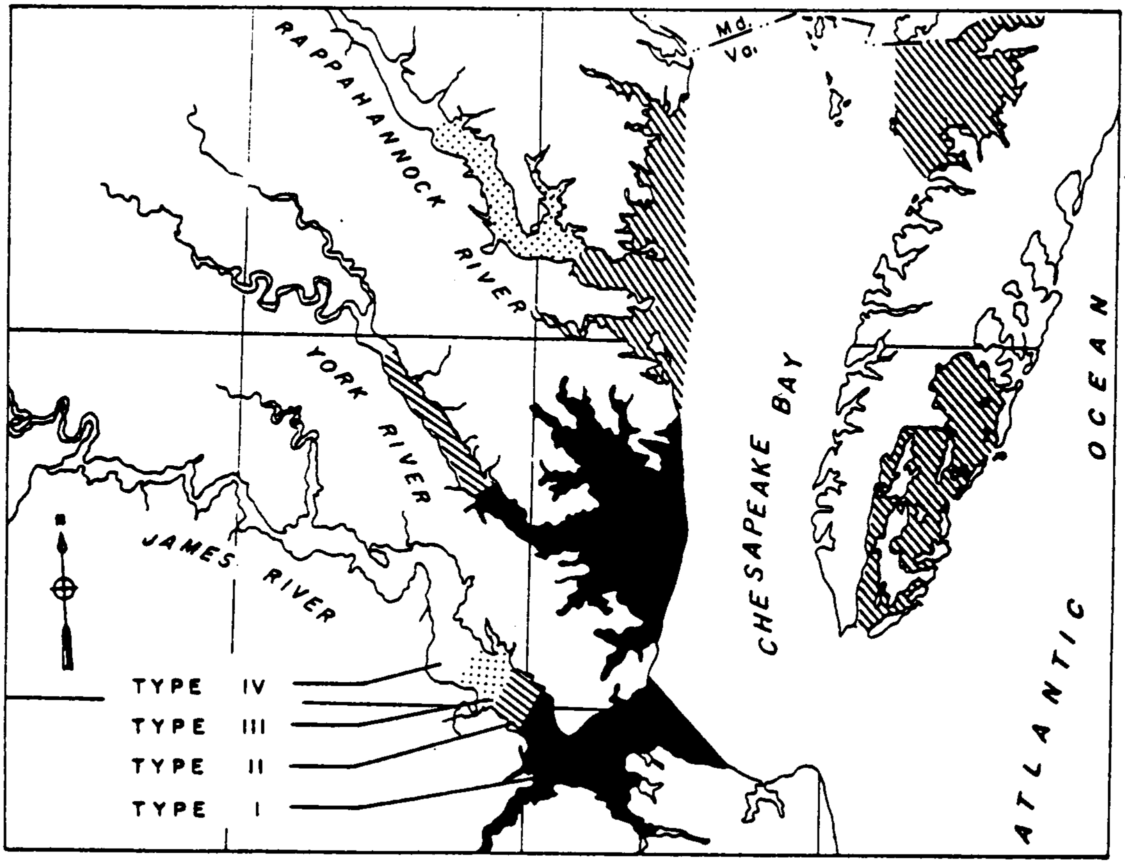

Figure II-1 Location of Different Types of Oyster Grounds Based on MSX Susceptibility

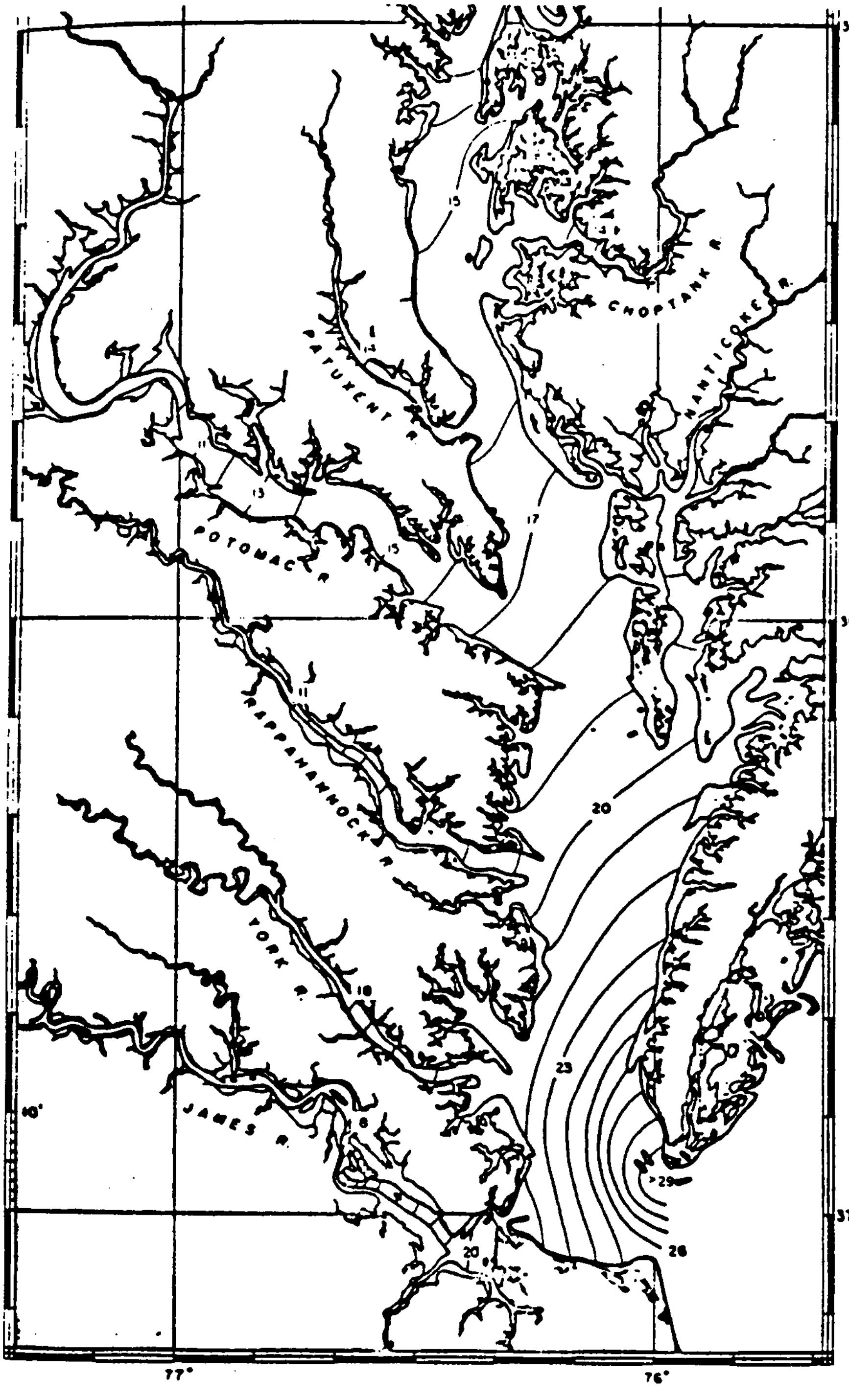

Figure II-2 Salinity Patterns on Virginia Oyster Grounds

In Type I MSX areas oyster culture is widely thought to be economically impossible. Haven, et al, (1978), report that: "...no oyster grower today is attempting to grow oysters from seed to full maturity (which requires two or three growing seasons) in such high disease areas. (Haven, et al, 1978 p. 643.)" Type II MSX areas are a transition zone between the Type I area where oyster culture has been severely restricted because of MSX-related factors and Type III areas where oyster culture, as well as harvest of oysters from natural oyster rocks, continues much as it did prior to the onset of MSX. Given the fact that the prevalence of MSX varies with salinity, which is affected by rainfall, the oyster culture in Type II areas involves a high degree of risk. While MSX will almost always pose severe problems in Type I areas and will rarely cause insurmountable problems in Type III and IV areas, the severity of MSX in Type II areas is reported to vary with rainfall and other climatic conditions. Consequently, a high degree of risk is associated with the culture of oysters in Type II MSX areas. Haven, et al, have summarized the conditions for oyster culture in Type II MSX areas: "Perhaps the best statement which can be made about Type II areas is that oysters may be cultured to market size in the upper parts (lower salinity.) The lower sections, where salinities might approach levels associated with excessive mortalities during certain years, are now avoided by growers. If growers so desired, many of the highersalinity Type II areas could be more widely used to culture oysters for one growing season. (Haven, et al, 1978, pp. 645-646.)"

One of the major indirect effects of MSX is a decline in leased acreage in areas susceptible to MSX. Table II-1 below shows the acreage of leased oyster grounds in Virginia from 1950 to 1984.

Although MSX became widespread in the Virginia oyster grounds in the 1959-60 season,leased acreage did not decline until Fiscal 1968. In 1962 the Virginia General Assembly passed a rent remission program which provided rent relief for designated disaster areas including, but not explicitly limited to, areas affected by MSX. The rent remission programs remained in effect until June, 1967. When the rent remission program ended there was a rapid drop in leased acreage from over 134,000 in 1967 to approximately 100,000 acres in 1974. Beginning in 1980, there was a gradual increase in leased acreage to about 110,000 acres in 1984. Haven, et al, attribute the decline in leased acreage after 1967 to: "...the abandonment of leases in regions where MSX made oyster culture unprofitable (p. 72)" and note that elimination of the rent remission provisions caused grounds which had been held in MSX-affected areas without the payment of rent to be abandoned when the rentremission ended. The rent-remission provisions affected between 34,000 and 49,000 acres, or roughly 30 percent of total leased acreage.

TABLE II-1

Acreage of Leased Oyster Grounds in Virginia, 1950 - 1984 (fiscal years)

YEAR	LEASED ACREAGE
1950	103,132
1951	105,464
1952	110,523
1953	115,023
1954	124,384
1955	126,927
1956	126,183
1957	128,217
1958	129,471
1959	127,816
1960	130,107
1961	132,847
1962	132,993
1963	133,528
1964	133,786
1965	133,665
1966	132,438
1967	134,492
1968	119,182
1969	114,371
1970	111,911
1971	109,143
1972	105,373
1973	101,614
1974	100,230
1975	100,662
1976	99,071
1977	98,781
1978	99,104
1979	98,564
1980	103,522
1981	105,215
1982	107,307
1983	108,602
1984	110,257

A major change in the Virginia oyster fishery in the aftermath of the appearance of MSX was the increased share of harvest from public oyster grounds. This resulted from a severe decline in private grounds harvest in relation to a relatively stable public grounds harvest. Table II-2 shows the relative share of oyster harvest from public grounds, private grounds, and the Potomac River by Virginians. The oyster fishery in the Potomac River is operated as a public grounds fishery under the authority of the Potomac River Fisheries Commission, which was formed under an interstate compact between the District of Columbia, Maryland and Virginia.

Accompanying the declines in private grounds harvest, there has been a significant decline in the seed oyster fishery. Unlike the market oyster sector, the seed oyster fishery is almost entirely a public grounds fishery. Table II-3 below shows the production of seed oysters from the public grounds in Virginia. Table II-3 indicates that there has been a major decline in Virginia public seed oyster harvest. Like the decline in harvest of market oysters, the decline in seed oyster harvest has been attributed to a complex mixture of biological, economic and institutional factors. A major question with respect to the economic forces is the importance of shifts in seed supply relative to shifts in seed demand. Table II-3 shows that there has been a long-term downward trend in Virginia public seed oyster production.

TABLE II-2

Share of Virginia Harvest from Public Grounds, Private Grounds and Potomac River.

YEAR	SHARE OF HARVEST FROM PUBLIC GROUNDS	SHARE OF HARVEST FROM PRIVATE GROUNDS	SHARE OF HARVEST FROM POTOMAC
1950	22.4%	77.6%	---
1951	18.4%	81.6%	---
1952	14.2%	85.8%	---
1953	15.0%	85.0%	---
1954	14.7%	85.3%	---
1955	15.8%	84.2%	---
1956	20.2%	79.8%	---
1957	16.6%	83.4%	---
1958	16.9%	83.1%	---
1959	18.7%	81.3%	---
1960	24.7%	75.3%	---
1961	18.4%	81.6%	---
1962	12.0%	88.0%	---
1963	9.8%	81.6%	8.6%
1964	16.9%	77.8%	5.3%
1965	37.2%	56.7%	6.1%
1966	21.6%	53.0%	25.4%
1967	7.6%	57.9%	34.5%
1968	26.5%	51.2%	18.2%
1969	33.8%	45.5%	20.7%
1970	24.7%	61.3%	13.9%
1971	21.2%	65.7%	13.1%
1972	30.2%	62.4%	7.4%
1973	39.5%	53.8%	6.7%
1974	37.8%	57.2%	5.0%
1975	45.0%	51.9%	3.1%
1976	43.9%	54.5%	1.6%
1977	43.6%	47.0%	9.4%
1978	53.8%	34.7%	11.5%
1979	51.9%	40.7%	7.4%
1980	54.7%	39.8%	5.5%
1981	52.2%	42.5%	5.3%
1982	48.0%	44.0%	8.0%
1983	37.1%	51.9%	11.0%

TABLE II-3

Seed Oyster Production from Virginia Public Oyster Grounds and Seed Prices

MARKET YEAR	SEED PRICE	PUBLIC GROUND SEED HARVEST (VIRGINIA BUSHELS)
1949-50	$0.68	2,188,092
1950-51	$0.83	2,461,289
1951-52	$1.10	2,079,550
1952-53	$1.05	1,944,513
1953-54	$1.18	2,216,951
1954-55	$1.15	2,743,479
1955-56	$0.99	2,230,777
1956-57	$1.22	2,245,426
1957-58	$0.89	2,321,954
1958-59	$1.02	1,850,231
1959-60	$0.42	2,480,450
1960-61	$0.93	1,428,580
1961-62	$0.88	1,557,234
1962-63	$1.29	1,040,707
1963-64	$1.48	766,577
1964-65	$1.49	634,725
1965-66	$1.23	988,970
1966-67	$1.25	818,310
1967-68	$1.26	943,929
1968-69	$1.49	587,109
1969-70	$1.62	488,970
1970-71	$1.51	722,791
1971-72	$1.88	532,276
1972-73	$2.04	440,136
1973-74	$2.35	527,818
1974-75	$1.88	379,470
1975-76	$1.86	536,202
1976-77	$1.49	454,402
1977-78	$1.94	402,378
1978-79	$2.11	514,810
1979-80	$2.34	397,300
1980-81	$2.12	298,881
1981-82	$2.22	424,586
1982-83	$2.10	505,888
1983-84	$2.10	385,086

TABLE II-4

Hand Tong Licenses Fiscal Issued, 1955-1982

YEAR	NUMBER OF HAND TONG LICENSES
1955	3322
1956	3264
1957	3412
1958	4191
1959	4242
1960	4117
1961	3510
1962	2857
1963	2722
1964	3166
1965	3116
1966	3255
1967	2061
1968	2277
1969	1890
1970	1698
1971	1690
1972	1181
1973	1248
1974	1557
1975	1703
1976	1691
1977	1550
1978	2072
1979	2155
1980	2100
1981	2040
1982	1934

While leased acreage and seed plantings represent measures of resource utilization in the private oyster sector, a measurement of resource utilization in the public grounds sector is more difficult to define. The number of hand tong licenses is one measure of capital and labor input (effort in the terminology of fisheries economics theory) in the public grounds sector. However, variability in intensity of fishing activity by different licensees, who are dependent to different degrees upon the public grounds fishery, makes license data only an imperfect measure of fishing effort. Table II-4 above shows the number of hand tong licenses issued during the period 1955-1982.

Table II-4 shows that Virginia hand tong licenses peaked at about 4200 in 1959 just before the appearance of MSX on the Virginia oyster grounds. By 1962 tong licenses had declined to less than 3000, and a low of less than 1200 licenses was reached in 1972. Since 1972 the number of hand tong licenses has increased to approximately 2000. However, the number of tong licenses purchased is still far below the level of licenses which prevailed in the pre-1960 period.

In addition to labor and capital, major inputs to the Virginia public oyster harvest are the shell and seed planted by the Virginia Marine Resources Commission in its repletion program. For many years the Commonwealth has had a policy of promoting the development of the public grounds oyster fishery. The first official program for the repletion of the Virginia public oyster grounds was undertaken in 1928 under the Oyster Repletion Act.

The repletion program consists of two primary elements; planting of oysters shell and planting of seed oysters. Haven, et al, (1978), note three primary purposes for planting oyster shell: "1. To receive a strike of oysters on the shell to provide seed oysters for use by the VMRC and the public, i.e. harvest by watermen for sale as seed to growers or for use on their own growing grounds; 2. To receive a set of sufficient intensity to provide a later catch of market oysters; and 3. Political considerations, which at times seem to require some planting of shell in each district. (Haven, et al, 1978, p. 497.)"

The seed planting activity conducted under the repletion program is designed to achieve multiple purposes including:

1. to increase the total oyster population
2. to establish new seed oyster grounds in the Great Wicomico and Piankatank Rivers and the seaside of the eastern shore to supplement the James River seed oyster grounds; and
3. to develop MSX-resistant strains of seed oysters by transplanting seed form MSX-affected areas which have acquired some resistance to MSX to other public oyster growing grounds. Research by Andrews (1967) found that oysters grown from larvae setting in MSX affected areas are more resistant to MSX than are those setting in non-affected areas.

Table II-5 shows the plantings of seed and shell under the repletion program and the expenditures and implicit prices of seed and shell planted. Implicit prices were computed by dividing total expenditures on seed and shell by the respective quantities used in the program.

Table II-5 shows that there was a sharp increase in repletion activity between 1962 and 1965. This increase was composed of both and increase in the level of shell planted and an increase and a restarting of the planting of seed oysters. Between fiscal year 1947 and fiscal year 1961 there was no planting of seed oysters in connection with the repletion program. During this period the Virginia oyster fishery was dominated by private grounds production and there was an abundant supply of relatively inexpensive seed from the James River seed beds for planting on the leased grounds. With the increased importance of the public oyster grounds in Virginia, the planting of seed under the repletion program has become increasingly important. The resumption of seed planting was authorized under the Special Repletion Act of 1962.

TABLE II-5

Seed and Shell Planting Under the Virginia Oyster Repletion Program, Expenditures and Implicit Prices

FISCAL YEAR	QUANTITY PLANTED (bu.)	SHELL COST ($)	SHELL COST ($/bu.)	QUANTITY PLANTED (bu.)	SEED COST ($)	SEED COST ($/bu.)
1950	701,499	79,516	.11	0	0	---
1951	495,373	59,399	.12	0	0	---
1952	504,290	71,008	.14	0	0	---
1953	508,344	68,584	.13	0	0	---
1954	509,534	76,471	.14	0	0	---
1955	792,165	114,931	.14	0	0	---
1956	775,034	112,271	.14	0	0	---
1957	550,451	84,763	.15	0	0	---
1958	987,551	151,450	.18	0	0	---
1959	774,867	142,038	.18	0	0	---
1960	889,697	164,889	.16	0	0	---
1961	950,106	152,005	.16	0	0	0
1962	421,871	77,442	.18	96,460	93,996	.97
1963	1,054,819	153,029	.14	23,408	15,244	.65
1964	2,318,379	282,930	.12	82,350	28,772	.34
1965	4,148,702	494,482	.12	9,577	2,067	.22
1966	2,978,088	358,888	.12	95,425	32,122	.34
1967	2,241,563	294,644	.13	37,500	9,750	.26
1968	2,884,580	469,376	.16	53,418	27,283	.51
1969	1,032,944	190,729	.18	57,366	39,309	.68
1970	944,897	179,243	.19	114,613	87,117	.76
1971	1,488,494	288,589	.19	129,122	98,156	.76
1972	964,826	190,156	.20	114,866	90,744	.79
1973	1,885,718	413,769	.22	0	0	---
1974	2,256,007	525,252	.23	118,950	106,407	.89
1975	3,481,727	803,353	.23	50,379	48,508	.96
1976	3,608,737	860,961	.24	90,273	87,278	.97
1977	1,471,791	367,104	.25	50,702	94,133	1.86
1978	762,061	201,268	.26	80,837	97,277	1.23
1979	1,153,165	387,596	.31	33,822	54,473	1.71
1980	1,193,057	423,833	.36	65,483	106,371	1.62
1981	1,474,432	517,530	.35	61,291	99,818	1.63
1982	1,443,080	552,513	.38	12,321	115,650	1.27
1983	1,437,441	589,585	.41	33,245	54,952	1.65
1984	1,297,148	552,185	.43	11,824	35,472	3.00

In economic terms, the repletion program represents a form of public subsidy for the oyster industry. Haven, et al, (1978), note that: "Since its beginning the Repletion Program has been a partial State subsidy for the entire oyster industry. It benefits the watermen who work the Baylor Survey Grounds and the processors, shippers and private growers. The program has not been self sustaining for the Commission since the costs for planting shell and transplanting seed exceeds the return in taxes. (Haven, et al, 1978, p. 555.)" Similar conclusions were reached in a study by Baker, et al, (1977).

The interdependence between the public grounds sector and the private grounds sector is emphasized by Haven, et al, (1978): "One aspect basic to our entire repletion effort that must be fully realized is the relationship between the public and private sector of the industry. As it is now constituted, the private sector is not self-sustaining. It is dependent on the public sector for seed. The private sector has always been indirectly subsidized by the State with respect to its seed supply. Since the beginning of the industry many years ago the Baylor Grounds (managed and controlled by State funds and personnel) supplied all or most of the seed oysters planted on private bottoms..."

"Today State beds are almost the sole source of seed for private growers and are necessity rather than a choice of industry. (Haven, et al, 1978, p. 565, emphasis in the original.)"

TABLE II-6

Imports as a Percent of Total Shucking Oysters Processed in Virginia

CALENDAR YEAR	IMPORTS AS A PRESENT OF TOTAL PROCESSED
1962	4.4%
1963	13.7%
1964	10.0%
1965	13.0%
1966	31.0%
1967	51.7%
1968	59.9%
1969	56.9%
1970	54.4%
1971	53.3%
1972	69.9%
1973	71.0%
1974	62.7%
1975	58.4%
1976	60.2%
1977	60.5%
1978	51.8%
1979	51.0%
1980	51.0%
1981	54.2%
1982	55.0%
1983	55.4%

Another important change in the Virginia oyster fishery is the increased importance of oysters harvested outside the State (usually in Maryland) to the shucking, packing and processing operations in Virginia. Table II-6 shows the percentage of total handlings of shucking oysters processed by Virginia processors which were imported from out of state and the total handlings.

Table II-6 shows that the share of state handling accounted for by imported oysters increased rapidly in the middle to late 1960's. In 1967 for the first time more than half of the total handlings reported by Virginia processors was accounted for by imported oysters. The increase in imports roughly paralleled the decline in the Virginia private grounds oyster fishery; consequently the variability in handlings by Virginia processors has been much less than the variability in Virginia oyster harvest.

2.4 MANAGEMENT OF THE VIRGINIA OYSTER FISHERY

In order to develop a framework within which to analyze and compare recent trends in harvest and efficiency on the public grounds and private grounds, it will be helpful to analyze the institutional setting within which the public grounds and private grounds portions of the Virginia oyster industry operate. In addition, because of the increasing importance of Maryland as a source of shucking oysters for the processing sector of the Virginia oyster industry; a brief examination of the institutional structure of the Maryland oyster fishery will be presented.

A major difference between the Maryland and Virginia oyster fisheries is the relative importance of the public and private grounds fisheries in the two states. Alford (1975) notes that: "Historically most Maryland oyster production comes from public grounds, whereas in Virginia most of the harvest is taken from private productions. (Alford, 1975, p. 233.)" However, in recent years, except for 1983, public grounds oyster production has exceeded private grounds harvest.

Both the Maryland Department of Natural Resources and the Virginia Marine Resources Commission engage in a variety of fishery management activities in relation to the oyster fishery. These efforts include, but are not limited to:

1. Establishing fishing seasons, catch limits and harvesting gear.
2. Granting licenses for harvesting from the public grounds and leasing plots for private planting.
3. Resolving conflicts among oyster harvesters, between oyster harvesters and those harvesting other species, and between oyster harvesters and other users of the area's marine resources.
4. Keeping records on annual harvests and on recruitment of new oysters on public fishing grounds seed areas, and private planting plots.

5. Reviewing with appropriate agencies charged with the protection of public health the suitability for human consumption of oysters from shellfish beds.

6. Transporting oysters from shellfish grounds closed because of potential pollution to unpolluted growing and harvesting areas.

7. Organizing seeding and shell planting programs to rehabilitate the fishing grounds.

8. Planning and participating in research efforts designed to improve efficiency and harvest productivity. (See Kennedy and Breisch, 1981, pp. 109-110.)

Although the same management tools are utilized in Maryland and Virginia, the importance which has been given to each aspect of oyster resource management has differed marketedly in the two states. Alford (1975) has offered the following explanation for the development of different tenure systems for oyster production in Maryland and Virginia: "A combination of social, political and ecologic factors are responsible for continuing the common property tenure system within the Bay. Maryland's oystermen or watermen as they are called locally, have always opposed private oyster culture. They feel that and expansion of the system will lead to the public grounds being turned over to private control. They also feel that private culture would lead to over-production and lower market prices..."

"Although Virginia watermen have similar attitudes, ecological difference have made private culture more palatable in Virginia. The inherent inferiority and relatively low yield of the oyster have in the southern half of the Bay made private enterprise relatively more attractive in Virginia. Much of the seed of the lower half of the Bay is taken from public bars and is harvested and sold by watermen. Since private planters are the primary market for this seed it has also been to the watermen's advantage not to be totally antagonistic to the planting industry. (Alford, 1975, p. 235.)"

Because of the fact that access to the public oyster grounds is much more open than access to oyster grounds under lease, a variety of restrictions are placed on harvest from the public grounds. Because these restrictions limit who may lawfully harvest oysters from the public grounds and the gear used for harvest the public grounds oyster fishery is not a true "open access" resource.

The most obvious restriction on access to the Virginia oyster beds is the licensure requirement. Under Virginia law only Virginia residents may plant or take oysters from Virginia waters. This state residency requirement was upheld by the U.S Supreme Court in McCready v. Virginia (94 U.S. 391 (1877).) However, the validity of state statutes which prohibit the commercial utilization of a natural resource by non-residents has been called into question by a number of recent Supreme Court ruling, in particular Douglas v. Seacoast Products, Inc.

(431 U.S. 265 (1977).) (For a discussion of this case see Strand and Lewis, 1978.) In addition to residency requirements there are a number of other provisions of Virginia law designed to restrict fishing effort applied to the public grounds. Because of the existence of private property rights on the leased oyster grounds, there are fewer legal restrictions applied to restrict effort on leased grounds.

In addition to licensure, other measures used to restrict effort on the public grounds include: season restrictions, gear restrictions, minimum size for oysters (other than seed) harvested and a variety of taxes. The regulatory structure of the Virginia public grounds oyster fishery is described below.

Season - The open season for the harvest of oysters from the public grounds is October 1 to June 1, on all public grounds except those on the Seaside of the Eastern Shore. On the Seaside of the Eastern Shore the open season is from November 1 to April 1. Haven, et al, note that: "The closed season corresponds to or encompasses the local spawning season. There is little evidence from a biological viewpoint to support the concept of a closed season if the crop is to be harvested at the time of maximum biomass or even maximum economic yield (Haven, et al, 1978, p. 884)."

Cull size - In most areas only oysters three inches or longer may be harvested from the public grounds. In certain designated areas, notably the James River seed areas and areas from which "soups," oysters less than three inches in size which are used in soups, stews and similar processed products, are harvested, there is no minimum size for harvest. Haven, et al, have noted possible economic inefficiencies associate with cull size regulation: "The most powerful and perhaps valid reason for the three-inch cull law is that it is wasteful in terms of biomass to harvest an oyster when it is growing rapidly and on the average, three inches is the time when growth begins to "level off." However, the concept of harvest at the point of maximum biomass might not be as valid as harvest at the point of maximum economic return. (Haven, et al, 1983, pp. 885-886.)"

Since there is no restriction on minimum cull size on the private grounds the private lessee has greater flexibility with respect to harvesting oysters at the optimal size for maximizing profits. In addition because oysters on private grounds are private property and are not subject to common property externalities, the private lessee is not in a position of having either to harvest and oyster or risk having that oyster harvested by another.

Daily catch limits - Virginia places no explicit catch limit on the quantity of oysters which and individual may harvest from the public grounds. However, the restrictions on allowable harvest technology on most of the public grounds places a practical limit on the daily harvest attainable from the public grounds. Maryland which in contrast to

Virginia permits the use of more efficient harvest technologies, places daily harvest limits on those harvesting oysters from the public grounds (25 bushels per day per person; 75 bushels per day per tong boat; 150 bushels per day per dredge boat.)

Permitted gear - On most of the public oyster grounds in Virginia only hand tongs may legally be used. In certain areas too deep for the effective use of hand tongs, patent tongs may legally be used. In addition certain areas of the public grounds have been designated a Fishery Management Areas in which dredges may legally be used on public oyster grounds.

To a certain extent daily catch limits and gear restrictions serve the same purpose, that is to restrict harvest either directly, as daily catch limits do, or indirectly, as gear restrictions do. However, gear restrictions have the effect of mandating a certain amount of technical inefficiency in the harvest of oysters, while daily catch limits do not of necessity require technical inefficiency.

Taxes - Three types of taxes are potentially applicable to oyster harvested from Virginia public grounds: (1) repletion tax, (2) inspection tax; and (3) export tax.

The only tax, other than the rental fee, for oysters harvested off the private grounds is the inspection tax. As noted above several studies of the Virginia oyster repletion program have indicated that there is a considerable subsidy element involved in the Virginia repletion program. These studies indicate that the subsidies accrue not only to the public grounds and seed sectors of the fishery, but to the private grounds and processing sectors and, indirectly, to the consumers of oysters.

2.5 SUMMARY

In this chapter the major forces influencing the Virginia oyster fishery and related sectors of the Virginia economy have been summarized. Following Agnello and Donnelley (1975a) these forces may be classified as legal, economic and biological. In this chapter the underlying inter-relations between these three types of forces have been laid out. In the chapters which follow an effort will be made to quantify the forces identified here and to estimate a statistical model to explain the influence of various forces affecting the Virginia oyster fishery. The model developed to explain the influence of various factors on the Virginia oyster fishery will then be utilized to simulate the effects of alternative policy options on the performance of the output and prices of the public and private grounds oyster fisheries.

CHAPTER III

MODEL DEVELOPMENT

3.1 INTRODUCTION

In order to understand the forces which have resulted in the decline of the Virginia oyster fishery it will be helpful to isolate the legal, biological and economic forces affecting the fishery. In the current study, legal forces are described by the dichotomy between private leased oyster grounds and public grounds and by the regulatory structure governing the taking of oysters from these grounds. Biological forces represent factors that change the quantity of oysters available for harvest. Economic forces represent the costs and returns to the factors of production from the oyster fishery.

The model developed here will be used to accomplish two of the objectives set forth in Chapter I.

1. the isolation and analysis of the effects of economic and biological forces on the decline of the Virginia oyster industry; and
2. the analysis of projected effects of public management alternatives on the future direction of the fishery.

In order to accomplish these objectives, a five equation system was developed. The model is depicted in Figure (III-1) and Equations (3.1) through (3.6).

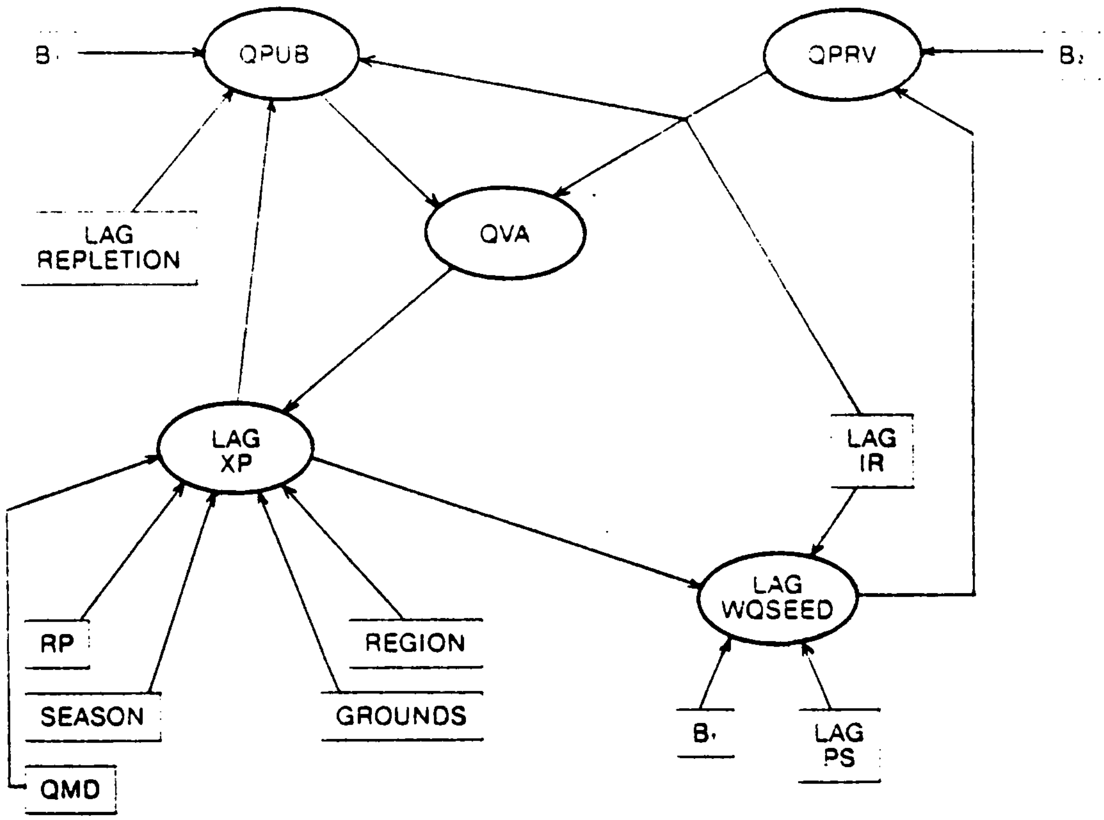

Figure III-1 Structure of the Virginia Oyster Industry Model

$$XP = F,(RP, QVA, QMD, S, R, G) \quad (3.1)$$

$$QVA = QPUB + QPRV \quad (3.2)$$

$$QPRV = f_2 \ (WQSEED, B_2) \quad (3.3)$$

$$QSEED = f_4 \ (XP\text{-}PS, B_1) \quad (3.4)$$

$$QPUB = f_1 \ (\frac{XP_{t-n}}{IR_{t-n}}, Rep_{t-n} \ Bio_t) \quad (3.5)$$

$$WQSEED = .25 * QSEED_{t-2} + .50 * QSEED_{t-3} + .25 * QSEED_{t-4} \quad (3.6)$$

where:

XP = ex-vessel price of oysters.

RP = retail price of oysters.

QVA = total quantity of oysters harvested in Virginia.

QMD = total quantity of oysters harvested in Maryland.

S = a 0-1 dichotomous variable representing season of year.

R = a set of 0-1 dichotomous variables representing regions of Virginia oyster grounds.

G = a 0-1 dichotomous property rights variable.

QPUB = Virginia public grounds oyster harvest.

QPRV = Virginia private grounds oyster harvest.

WQSEED = a weighted average of past seed plantings.

B_1 = a measure of the abandonment of private leased oyster grounds affecting the willingness of private planters to plant seed oysters.

B_2 = a biological variable representing the productivity of planted seed oysters.

IR = interest rate index (a measure of the opportunity cost of production inputs).

Rep = a measure of expenditures by the Virginia Marine Resources Commission on repletion - adjusted to account for changes in prices paid by the VMRC.

Bio = a measure of biological productivity of natural oyster grounds.

PS = the price of seed oysters \$/va bushel.

t = year.

3.2 OVERVIEW OF THE MODEL

The model shown in Figure III-1 and Equations (3.1) - (3.6), represents the oyster industry as a recursive system. Current oyster price at the ex-vessel level (XP) is determined by retail price, Virginia harvest, Maryland harvest, and a series of dichotomous variables representing regional, seasonal and grounds (public vs. private) effects (Equation (3.1)). Current ex-vessel price enters into the seed planting equation (Equation (3.4)); current and lagged price enters into the public grounds harvest equation (Equation (3.5)). Lagged seed planting enters into the private grounds harvest equation (Equation (3.3)). Private grounds harvest and public ground harvest sum to total harvest (Equation (3.2)). Total harvest then enters back into the ex-vessel price equation (Equation (3.1)).

The individual components of the model will now be discussed. First, the demand model will be discussed. Then the standard theoretical model of production from a fishery will be presented. This theory will then be applied to the Virginia oyster fishery by the estimation of equations to represent; (1) the harvest of oysters from the natural or public oyster grounds; (2) the planting of seed oysters on privately leased oysters grounds; and (3) the harvest of market oysters from private grounds following the planting of seed.

3.3 DEMAND COMPONENT

The demand component of this model consists of an estimated equation which expresses ex-vessel price as a function of retail price, Virginia quantity, Maryland quantity and seasonal, regional, and property rights dichotomous variables. The rationale for the inclusion of each of these variables will be briefly discussed.

The demand for oysters at the ex-vessel level is a derived demand depending upon the consumer demand for oysters and oyster-related products. The theoretical rational for the inclusion of retail price follows from the assumption that there is a certain relationship between the ex-vessel price of oysters and the retail price of oysters. This is a fairly standard approach to the estimation of price determination models, particularly in the food and agriculture sections, of the economy (see Waugh, 1954). The retail price may be defined by the identity:

Retail Price = ex-vessel price + "marketing margin,"

where marketing margin is defined as the difference between ex-vessel and retail price. The inclusion of retail price in the ex-vessel price equation in a linear form assumes a certain relationship between marketing margin and ex-vessel price.[1]

The other variables included in the price determination model represent factors which are hypothesized to affect the marginal value of Virginia oysters to consumers and processors. Virginia harvest is expected to exert a slight negative effect on ex-vessel price. In general, the more of a commodity that is available for sales, the lower the price will have to be in order for the market to clear.

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[1]Formally, if one collapses all other terms into the intercept, the price equation XP = a + b RP may be re-written as:

$$M = \frac{1 + b\ XP_b}{b} - \frac{a}{b}.$$

where:
XP = ex-vessel price.
M = retail ex-vessel price spread.
RP = retail price.

The expected sign on Maryland harvest in the Virginia price equation is indeterminate. Maryland oysters, like Virginia oysters, represent an increase in total Chesapeake regional oyster harvest which, *ceteris paribus*, is expected to depress Virginia price. The Virginia oyster processing sector has come to rely increasingly upon imported oysters, primarily from Maryland. Since 1967 over half of the oysters handled by Virginia processors have come from outside of Virginia. As the share of imported oysters processed by Virginia processors increases, the price paid by processors would be expected to approximate Maryland price plus transportation cost.

In spite of relatively high levels of imports, the total quantity of oysters processed in Virginia is less than the quantity processed in the pre-MSX period. Consequently, Maryland harvest may act to stabilize the total supply available to Virginia processors. Further, Maryland may be acting as a price leader, so that increases in Maryland harvest may strengthen Maryland's leadership position. Thus, it is impossible to specify *a priori* an expected sign on Maryland harvest.

The seasonal dummy variable accounts for the tendency for fall demand to be greater than spring demand, thus resulting in higher fall harvest. The effect on price is indeterminate.

The regional dummy variable is a proxy for transportation cost from the point of harvest to the point of processing. Oyster processing in

Virginia is concentrated in the Northern Neck area of Virginia. The processors in this area are in close proximity to Maryland oyster grounds, so that oysters from both states can be utilized. One would expect the price paid to oyster harvesters to decline as distance from the processor increases. Maryland public grounds harvest increased shortly after the dramatic decline in Virginia private grounds harvest. As production in the MSX-affected areas of the lower Western shore of Virginia fell, there was a need for processors to seek alternative sources of supply.

The property rights variable, unlike the other variables in the price model which flow from standard derived demand theory of price formation, pertains to features unique to the oyster fishery. As discussed in Chapter II, the Virginia oyster fishery is composed of two segments, a public grounds portion on which the resource is managed under a system of common property and a private grounds portions which is managed under a system of exclusive use rights. Virginia law holds that the interest which a lessee has in leased oyster ground "shall be construed as a chattel real." (Va. Code Ann., Sec. 28.1-109 (12), 1982 Supp.) In Blake v. United States (181 F. Supp. 584, (1960), affirmed at 295 F. 2nd 91 (1961)) the U. S. District Court held that an oyster lease "constitutes 'private property' in the lessee (at 587)."

Because private grounds harvest represents utilization of a privately held and controlled resource, while public grounds harvest represents utilization of a resource to which access is less restricted, the public grounds harvester has less control (and less certainty) over the stock available for harvest. The common property externality is expected to alter the temporal distribution of public grounds harvest and to limit the ability of those utilizing public grounds to take advantage of higher prices during periods of expanded demand. Agnello and Donelley (1976b) tested the hypothesis that there was no difference between ex-vessel prices for oysters harvested off private grounds and ex-vessel prices for oysters harvested off public grounds. The data set used to test this hypothesis consisted of pooled time-series and cross-sectional data for sixteen Atlantic and Gulf Coast states for the period 1962 to 1969. The mean price for private grounds oysters was higher than the mean price for public grounds oysters; this difference was statistically significant at the .05 level.

Next, Agnello and Donelley tested the hypothesis that there was no significant difference between the seasonal pattern of harvest on public grounds and the seasonal pattern on private harvests. Agnello and Donnelley found that the ratio of fall harvest to spring harvest was 1.35 on public grounds and 1.01 on private grounds. At the .01 level of significance, the hypothesis that the seasonal mix of harvest from private grounds is the same as the seasonal mix of harvest from public grounds is rejected.

The above discussion had developed a method of depicting the forces which affect market oyster prices. A variety of forces including oyster price affect the decision to harvest oysters. The property rights variable is included because the oyster fishery in Virginia consists of two components, a private grounds sector which is, in essence, engaged in a primitive form of farming the sea and a public grounds sector which is engaged in gathering a wild stock augmented by stock attributable to the management efforts of public agencies.

County data from the National Marine Fisheries Service on oyster landings by month was aggregated into seasonal and regional categories. The seasons are fall, from September through March, and spring, from April through August. This choice of seasons is designed to correspond with natural events in the life cycle of the oyster, primarily spawning, which affect the performance of the industry. The regions in the model are the Eastern Shore, the upper Western Shore (Northern Neck), and the lower Western Shore (mouth of the James). These regions are delineated to reflect differences in transport costs to the main concentration of processing plants in the Northern Neck area.

3.4 THE HARVEST EQUATIONS

3.4.1 Overview

The general framework within which the harvest models (Equations (3.3), (3.4) and (3.5)) are developed represents a modification of standard production economics models and fisheries economics models to fit the unique biological and institutional characteristics of the oyster fishery. The harvest from a fishery may be viewed as a function of population size and effort applied to that given population. This maybe expressed as:

$$C = D * F \tag{3.7}$$

where:

C = harvest per unit time.

D = stock abundance or density.

F = effective fishing effort, that is, the percentage of the mean population which is caught per unit time.

There exists some relationship by which nominal effort, however measured, is translated in effective effort. This relationship may be hypothesized to be linear in which case the relationship between nominal and effective fishing efforts maybe expressed as $F = qf$

where:

f = nominal fishing effort.

q = the catchability coefficient, that is, the proportion of harvestable population which is harvested by one unit of nominal effort.

If one assumes that stock abundance is independent of nominal fishing effort and of the catchability coefficient, then Equation (3.7) may be re-written as:

$$C = Dqf \tag{3.8}$$

It should be noted that if q is a constant then Equation (3.8) implies constant returns to scale, while if q is variable, Equation (3.8) is consistent with increasing or decreasing returns to scale.

It is reasonable to assume that private grounds oyster populations and public grounds oyster populations are distinct and do not directly affect one another. Therefore, it is possible to re-formulate Equation (3.8) in terms of two harvest components, private grounds harvest and public grounds harvest, as shown in Equations (3.9) and (3.10) below.

$$C_{pri} = D_{pri} * q_{pri} * f_{pri} \tag{3.9}$$

$$C_{pub} = D_{pub} * q_{pub} * f_{pub} \tag{3.10}$$

Where the subscript pri refers to the value of C, D, q and f for the private oyster ground and the subscript pub refers to the values of C, D, q and f on the public oyster grounds.

Equations (3.9) and (3.10) may be transformed by considering the system shown in Equations (3.11) through (3.14) below.

$$C_{gt} = D_{gt} * q_{gt} * f_{gt} \tag{3.11}$$

$$D_{gt} = f_1 (X_{rt}) \tag{3.12}$$

$$q_{gt} = f_2 (X_{jt}) \tag{3.13}$$

$$f_{gt} = f_3 (X_{gt}) \tag{3.14}$$

where:

C_{gt} = harvest from grounds g (public or private) in time t.

D_{gt} = the oyster population on grounds g in time t.

q_{gt} = the catchability coefficient on grounds g in time t.

f_{gt} = nominal effort employed on grounds g in time t.

X_i = a vector of variables related to oyster population.

X_j = a vector of variables affecting the catchability coefficient.

X_k = a vector of variables affecting the level of nominal effort employed.

Substituting relations (3.12), (3.13) and (3.14) into relation (3.11) yields Equation (3.15).

$$C_{gt} = f_4(X_{it},X_{jt},X_{kt}) \tag{3.15}$$

In order to formulate Equation (3.15) in a manner which can be estimated empirically it will be helpful to look at the specification of the private grounds and public grounds harvest sectors separately.

3.4.2 The Private Grounds Portion of the Model

The private grounds fishery is a managed fishery; this implies that the population available for harvest is functionally related to natural oyster population plus oyster population attributable to human augmentation. Human augmentation of private grounds oyster populations takes the form of seed planting, shell planting, and various management practices to control predators, or otherwise enhance the survivability of oysters. For the purposes of the current study, it will be assumed that seed planting is a suitable proxy for inputs to augment oyster population. This implies that other inputs designed to increase harvestable population are used in fixed proportion to seed.

The private grounds side of the model may therefore be broken down in two components expressed by Equations (3.3) and (3.4), a seed oyster transformation relationship and a seed oyster planting equation. The seed oyster-market oyster relationship reflects a purely technical biological relationship, while the seed planting equation is designed to capture the response of seed planters to changed biological and economic conditions.

3.4.3 The Seed Planting Decision

In order to model the seed planting decision the theory of derived input demand will be utilized. Under perfect competition a producer will employ an input up to the point where the marginal value product of this input is equal to its price. Thus, the demand for seed oysters will depend upon the price of seed oysters, the price of shuck oysters and the marginal productivity of seed oysters in producing shuck oysters. Since a period of two or more years is necessary for oysters to reach marketable size, increases in seed planting do not show up as increases in private market harvest for two or more years. Because of the existence of private property rights on the leased oyster beds, harvest decisions can be modified on the basis of expected prices in future time periods more readily than they can be on public oyster beds. That is, it is possible to think of the planting of seed as a decision to add to inventories of marketable oysters two or more years in the future, and the harvesting of market oysters may be thought an immediate reduction of market oyster inventories. If the private oyster planter is viewed as having, in the long run, a desired inventory level (and, implicitly, a desired age mix of oysters) then the quantity of market oysters harvested by this planter is affected by current market oyster prices and current, and perhaps anticipated, seed oyster prices. The quantity of seed oysters planted is affected by current seed oyster prices and anticipated market oyster prices.

Baker, Harris and Moody (1977) and Harris (1978) have formulated a model which specified that the quantity of seed demanded is a function of current price of seed oysters, current prices of shuck oysters and variables related to the productivity of seed. Baker, Harris and Moody express the equilibrium condition of the utilization of seed and other inputs in the market oyster fishery assuming perfect competition.

$$P_{market} = MC_{market} = \frac{P_{labor}}{MPP_{labor}} = \frac{P_{capital}}{MPP_{capital}} = \frac{P_{seed}}{MPP_{seed}} \qquad (3.16)$$

where:

P_{market} is the price of one unit of market oysters.

MC_{market} is the marginal cost of one unit of market oysters.

P_{labor} is the cost of one unit of labor.

MPP_{labor} is the marginal physical product of one unit of labor.

$P_{capital}$ is the cost of one unit of capital.

$MPP_{capital}$ is the marginal physical product of one unit of capital.

P_{seed} is the price of seed.

MPP_{seed} is the marginal physical product of seed.

In the model to be developed here, the price of seed is exogenous. Therefore, the equilibrium condition in Equation (3.16) may be rewritten as:

$$MPP_{seed} * P_{market} = P_{seed} \tag{3.17}$$

The variables P_{labor}, $P_{capital}$, act to shift the profitability of planting seed. From Equation (3.17) it is clear that P_{market}, P_{seed}, and a measure of MPP_{seed} should appear in the seed planting equation. Allowing the costs of non-seed inputs to change, changes the profit-maximizing level of seed planting. In general form, then, the following arguments should appear in the seed planting model:

1. price of market oysters
2. price of seed oysters
3. a measure of the expected yield from planted oysters; and
4. costs of other non-seed inputs.

The appearance of MSX in the Virginia Chesapeake Bay caused major changes in the expected yield of planted seed. The effects of MSX on the seed planting decision have been described by Andrews (1979 and 1974) and by Andrews and Frierman (1974). Andrews and Frierman (1974) stated: "Twelve years after its sudden appearance, the pathogen called MSX, the common name for Minchinia Nelsoni, continued to caused unabated epizootics in isolated populations of introduced oysters in lower Chesapeake Bay. The ravaged areas did not recover, and they remain barren and unplanted. Nearly half of Virginia's pre-epizootic rented oyster grounds are no longer planted" (Andrews and Frierman, 1974, p. 127). It is apparent that seed-planting declined significantly because of the biological effects of MSX. As a relatively "pure" measure of the biological effects of MSX the difference in private grounds harvest immediately before the onset of MSX is compared to the harvest immediately after the onset of MSX.

There is some evidence that MSX caused a decline in seed harvest soon after MSX hit; however, mortalities in the seed areas were relatively low compared to mortalities experienced by private planters (Andrews 1964). Andrews noted that "...(D)amage to the seed area will probably be reflected in quality of seed rather than direct mortality" (Andrews, 1964, p. 65). Consequently an index variable of planter willingness to plant is used to represent planters perception of the physical productivity of planted seed.

Empirically the equation to be estimated expresses the level of seed planting as a function of: (1) the price of seed; (2) the anticipated price of the market oysters to be harvested from the planted seed; (3) the anticipated physical productivity of the planted seed; and (4) actual costs of planting seed and the anticipated costs of harvesting market oysters.

The price of seed is calculated from data in the Fisheries Statistics of the United States for 1948-1976 and from data reported the annual reports of the Virginia Marine Resource Commission for the period 1977-1980. The same data sources were used for the price of private grounds market oysters. The costs of planting and harvesting oysters are represented by an interest rate index (interest rate on the smallest denomination long-term commercial loans) constructed such that 1958 equals 1. This variable is designed to capture the effects of changes in economic conditions, other than seed cost, affecting the seed planting decision. Ideally, one would like to use a measure which captures all the relevant factors entering the harvester's decision to enter or exist from the oyster fishery. Alternative measures of the cost of production were tried; most of these indices tended to move with the interest rate index.

The present research could be extended by conducting an in-depth study of the responsiveness of oyster harvesters to changes in prices, costs (or individual components of costs) and abundance (expected harvest) of oysters. In addition studies of the costs and returns from different types of oyster harvest technologies as well as from other fishing activities available to oyster harvesters would help in understanding the nature of supply response in the oyster fishery.

Preliminary analysis indicated that the capital-labor ratio for any single harvest technology is highly stable; the model as formulated here assumes that capital leads labor into or out of the fishery. Given that the decision process being modeled here is that of owner-operators rather than that of hired labor, the use of the cost of capital as a decision variable seems reasonable.

Market oyster price, seed oyster price and interest rate have tended to move together; because of the functional interdependence between seed prices and market prices, multicollinearity was observed when market price, seed price and interest rate were entered separately. The multicollinearity resulted in none of the variables listed having statistically significant coefficients (at the .10 level). In addition multicollinearity typically produced highly unstable parameter estimates. An attempt was made to combine these three factors (returns to market oysters, costs of seed oysters and opportunity costs of non-seed inputs) into a single measure of the profitability of planting seed. It is hypothesized that the decision to plant seed is based on the expected profitability of such planting. The measure used to represent the economic dimension of this decision is the differential between market system prices and seed oyster prices adjusted to take in account changes in on-seed harvest costs. This factor is measured by the variable E_t, which is defined:

$$E_t = \frac{PPRI_t - PS_t}{IRI_t}, \qquad (3.18)$$

where:

E_t = the economic factor in the seed planting equation in time t.

$PPRI_t$ = the price of private ground market oysters in time t.

PS = the price of seed oysters in time t.

IRI_t = the index of oysters harvest and seed planting opportunity costs, measured by interest rate on long term commercial loans under $5,000 in year t.

The biological variable in the seed planting equation is designed to capture the pure biological effect of MSX on willingness to plant seed. As a measure of this biological effect the immediate change between pre-MSX private ground harvest and post-MSX private ground harvest, during a period to short for planters to adjust their planting to perception of MSX, was observed and used as a measure of the pure biological effect of MSX on the productivity of MSX-affected private grounds. As planters observed mortalities in MSX-affected areas, the planting of oysters in these areas ceased and, what planting remained was concentrated in areas of lower potential productivity that the ground left unplanted because of MSX.

The biological effect of MSX on the seed planting decision is represented by a dichotomous variable. This variable takes on a value equal to the average annual harvest in the period immediately prior to the appearance of MSX (1957-58 and 1958-59) for the period 1947-48 to 1958-59, 19037, measured in thousands of pounds of meat per year. For the entire post-MSX period (1959-60 and after) the index variable takes on a value of 12688.5, which represents the average private grounds harvest, in thousands of pounds, in the period immediately following the appearance of MSX (1969-61 and 1961-62). Computationally, the biological index is a linear transformation of a 0,1 binary variable. The biological variable may be written as $12688.5 + 6348.5D_t$ where D_t takes on a value of 0 in the post - MSX period and a value of 1 in the pre-MSX period.

3.4.4 Private Harvest Equation

Having formulated a seed-planting equation, the next step in analyzing private market oyster harvest is to attempt to explain the transformation of seed planting into market oyster harvest. The simplest model to explain private market oyster harvests as a function of seed planting is a simple linear regression of the form shown in Equation (3.19) below.

$$QMPRI_t = f\ (WQSEED_{t-n}) \qquad (3.19)$$

where:

$QMPRI_t$ = quantity of market oysters harvested from private grounds in season t, measured in pounds.

$WQSEED_{t-n}$ = weighted quantity of seed planted in time period t-n, measured in Virginia bushels.

If all private grounds were naturally barren and if the "correct" lag structure for seed plantings were formulated, one would expect the intercept term in an estimated equation of the form $QMPRI_t = a + b$ $(WQSEED_{t-n})$ to be equal to 0.

Several points about the relationship specified in the equation stand out. First, the marginal physical product of a Virginia bushel of seed is assumed constant. The coefficient b will represent the marginal physical product of a Virginia bushel of seed if:

(i) a lag structure is used which assumes that all of the market oyster harvest comes from seed planted n years in the past, or,

(ii) a weighting scheme is used to construct a weighted measure of seed plantings 1, 2, ..., n years in the past such that $W_1 + W_2 + \ldots + W_n = 1$, where W_1 is the weight assigned to seed-plantings one year in the past, W_2 is the weight assigned to seed-plantings two years in the past, etc. It should be noted that some of the W_i's may be set to 0, implying that seed planted in year t-j is where W_j is equal to 0, make no contribution to market oysters harvest in year t. A second assumption of this formulation is that there is no response of private oyster harvest to seed plantings in any year k when $W_k = 0$. As formulated in Equation (3.19) the model assumes that the marginal physical product of seed in each year is identical in all years. However, one of the effects of MSX was to alter the nature of the seed oyster - market oyster relationship. With the onset of MSX, many of the aspects of the Virginia oyster industry changed.

There is some evidence the MSX caused a decline in seed harvest soon after it entered Virginia seed areas; however, mortality in the seed areas was relatively low compared to mortality experienced by private planters (Andrews, 1964). If, as Andrews (1964) suggests, the effects of MSX on the seed areas show up as a decline in seed quality, this effect can be represented as a shift in the seed oyster-market oyster relation.

The decline in seed quality, as well as a shift in the location of seed plantings, is hypothesized to have resulted in a decline in the productivity of planted seed. Between 1948 and 1970 there was, as demonstrated in Chapter II, a general decline in the market oyster - seed oyster ratio. This may represent a general shift in the location of seed plantings. Andrews (1979) has described the effects of MSX on the location of oyster plantings in the post-MSX period. "The appearance of Minchinia Nelsoni in 1959-60 changed the whole industry of oyster culture in Chesapeake Bay. No longer were planters able to tolerate loses as they had with D. Marinum kills. Only trial plantings were made after 1960 in high salinity waters (>15.0 ppt). MSX, as M. Nelsoni was called, replaced and displaced D. Marinum as the major cause of oyster mortalities." (Andrews, 1979, p. 47.) To test the hypothesis that the marginal physical product of seed was the same in the pre-MSX and the post-MSX period, a slope shifter was included in Equation (3.3) above.

On average it takes about three years for oysters to reach marketable size (Haven, et al, 1978, and Galtsoff, 1964). However, oysters grow and mature at different rates due to variations in biological conditions and other factors. Consequently, a weighted average of seed plantings was used to depict the harvestable stock of oysters on private grounds. As shown in Equation (3.6) this variable ($WQSEED_t$) was constructed by assigning and weight of .25 to seed planted two years in the past, a weight of .50 to seed planted three years in the past and .25 to oysters planted four years in the past. The implicit assumption of this weighting structure is that twenty-five percent of the harvestable population represents seed planted two years in the past, fifty percent represents seed planted three years in the past and twenty-five percent represents seed planted four years in the past.

Having developed an empirical model to estimate private grounds harvest, the next step is to develop an empirical model to estimate the harvest from the public oyster grounds. The same basic forces: prices, opportunity costs and biological conditions, which affect the private grounds fishery are hypothesized to affect the public grounds fishery. The model formulation differs however, to take into account the institutional differences between the cultivation of a managed resource (the private grounds), and the harvest of a wild stock (the public grounds).

3.4.5 The Public Grounds Portion of the Model

Equation (3.5) depicts oyster harvest from the public grounds as a function of current and past prices and costs, current and past repletion efforts and current natural productivity. Because direct observations of the oyster densities from selected natural oyster bars are available, these data can be used to provide a direct empirical measure of oyster population. Direct measures of repletion and prices are also available. The model developed here represents an application of standard fisheries economic theory where harvest is treated as a function of harvestable population and the factors which affect the effort applied to that population. The current model differs from standard models because of the existence of an extensive public program to artificially augment natural oyster populations. These economic and public policy forces do not have their entire effect immediately. Rather, these effects occur over a number of years. To account for these lagged impacts, the Almon polynomial distributed lag is used to account for the lagged response of public grounds harvest to economic and public policy forces.

3.4.6 The Almon Polynomial Lag

Because of the managed nature of the private grounds fishery, there is believed to be a fairly systematic relationship between seed plantings at specific times in the past (2, 3 and 4 years) and current harvest. For the public grounds fishery, which represents a less intensively managed wild stock fishery, a less rigid form of lag structure was believed to be appropriate. The Almon polynomial distributed lag form was chosen to represent the effects of lagged prices and repletion on the public grounds harvest. The general problem of the polynomial distributed lag is to estimate a set of weights, Wi's, to fit an equation:

$$Y_t = A + L\,(W_o\,X_t + W_1\,X_{t-1} + \ldots + W_k\,X_{t-k})$$
$$+ a_j\,X_{jt} + E_t \qquad (3.20)$$

Y_t = the value of the dependent variable at time t.

A = the estimated intercept for the equation.

L = an arbitrary parameter.

W_1 = a weight determined by Equation (3.21).

$$W_1 = C_0 + C_{1i} + C_{2i}{}^2 + C_{3i}{}^3 + \ldots + C_{Ni}{}^N \qquad (3.21)$$

where:

The C's are regression parameters to be estimated.

i = the lag term whose weight is to be determined.

N = the degree of the polynomial to be estimated.

K = the number of terms involved in the lag structure.

a_j = coefficients on variables not involved in the lag structure.

X_{jt} = the value of the variable X_j in period t.

E_t = the residual term in period t.

Substituting Equation (3.21) into Equation (3.20) yields:

$$Y_t = A + L\ C_0X_t + L\ (C_0 + C_1 + C_2 + \dots C_N)\ X_{t-1}$$

$$L\ (C_0 + 2\ C_1 + 4\ C_2 + 8C_3 + \dots 2^N\ C_N)\ X_{t-2} +$$

$$L\ (C_0 + 3C_1 + 9C_2 + 27C_3 + 3^NC_N)\ X_{t-3} + \dots +$$

$$L\ (C_0 + KC_1 + K^2C_2 + K^3C_3 + K^NC_N)\ X_{t-k} \qquad (3.22)$$

Equation (3.22) may be re-written as (3.23)

$$Y_t = A + LC_0X_t + LC_1\ (X_t + X_{t-1} + X_{t-2} + \dots + X_{t-k}) +$$

$$LC_2\ (X_{t-1} + 4\ X_{t-2} + 9\ X_{t-3} + \dots + K^2\ X_{t-k}) +$$

$$LC_3\ (X_{t-1} + 8\ X_{t-2} + 27\ X_{t-3} + \dots + K^3\ X_{t-k}) + \dots +$$

$$LC_N\ (X_{t-1} + 2^N\ X_{t-2} + 3^N\ X_{t-3} + \dots + K^N\ X_{t-k}) + E_t \qquad (3.23)$$

Equation (3.23) may be estimated directly using ordinary least squares regression. The estimated values of LC_k (K = 1 ... N) may be substituted back into Equation (3.22), and Equation (3.22) may be used to perform statistical tests on the C_i's and, indirectly, on the W's.

3.5 ESTIMATING THE MODEL AS A SYSTEM

Equations (3.1), (3.3), (3.4) and (3.6) are estimated using ordinary least squares. The model will be used to isolate the effects of economic, biological and institutional forces on private and public harvest using static backcasting techniques. In the static backcast model, price is taken as exogenous in order to permit simulation of industry harvest under alternative price conditions and to isolate the economic component of the changes in industry output and revenues. Conditions facing the oyster industry in the 1957-58 season are used as a base against which to compare actual and simulated conditions under alternative biological, economic and public policy conditions.

For purposes of forecasting the effects of future policies and conditions, price is treated as endogenous. That is, in response to an exogenous change, harvest changes resulting in price changes and changes in the other endogenous variables will be modeled. Attention will be focused on the values to which the endogenous variables converge as the system stabilizes.

CHAPTER IV

MODEL ESTIMATION AND APPLICATIONS

4.1 INTRODUCTION

In this chapter the estimates of the equations for the system developed in Chapter III will be presented. Then the results of these estimations will be combined to analyze alternative scenarios, either by altering conditions from those which historically existed or by projecting these conditions into the future under alternative assumptions regarding policy options or natural conditions.

4.2 EMPIRICAL ESTIMATION OF THE MODEL

4.2.1 Demand Component

As developed in Chapter III, Equation (3.1) ex-vessel oyster price is hypothesized to be a function of retail price, Virginia harvest, Maryland harvest, season, grounds and region. The estimated price response equations is shown in Equation (4.1).

$P_{gt} = .010 + .448\ RP_t + 3.22 \times 10^{-8}\ QMD_t$

*(.263) (26.4) (1.31)
(.787) (.0001) (.1966)

$-1X587 \times 10^{-8}\ QVA_t + .0224\ SEASON_t$

(-0.297) (1.40)
(.767) (.1508)

$+ .116\ GDS_i - .6\ REG1_j - 106REG2_j$

(7.73) (-11.5) (-6.24) (4.1)
(.0001) (.0001) (.0001)

$R^2 = .6386$ D - W = 1.431

F - Ratio = 118.899 Pr > F = .0001

*t - statistic and level of significance in parentheses.

where:

p^{ijt} = the ex-vessel price of oysters landed on grounds type i in county j in month t.

RP_t = the retail prices for oysters, ($/12 oz.) standards in Baltimore, in month t.

QMD_t = quantity of oysters landed in Maryland in month t.

QVA_t = quantity of oysters landed in Virginia in month t.

SEASON = a 0-1 dichotomous variables equal of 0 if month t is in the fall (Sept.-March) and equal to 1 if month t is in the spring (April-August).

GDS_i = a 0-1 dichotomous variable equal to 0 for public grounds and 1 for private grounds.

$REG1_j$ = 1 if county j is on the Eastern Shore, 0 otherwise.

$REG2_j$ = 1 if county j is in the Lower Bay, 0 otherwise.

*Since Equation (4.1) involves pooled time-series, cross-section data, the Durbin-Watson statistic is not unique and cannot be evaluated using standard tests for time series data.

It should be noted that neither Virginia quantity nor Maryland quantity is statistically significant at the .10 level. There is a high degree of multicollinearity between quantity produced in Maryland and quantity produced in Virginia. An alternative formulation incorporating total quantity in the Bay region and Maryland share of Bay harvest performs better in a single equation context. However, for simulation purposes it is impossible to simultaneously and independently vary Bay quantity and Maryland share. Equation (4.1) indicates that each increase of 1,000,000 pounds per year (83,333 pounds per month) in Virginia oyster harvest depresses ex-vessel price by 1.4 cents per pound.

4.2.2 Private Grounds Component

4.2.2.1 Seed Planting Equation

As developed in Chapter III, Equation (3.4) speed planting is hypothesized to be a function of: (1) the price of seed; (2) the anticipated price of the harvested oysters to be produced from the planted seed; (3) the anticipated productivity of the planted seed; and (4) actual costs of planting seed and anticipated costs of harvesting market oysters. When Equation (3.4) is estimated empirically the results shown in Equation (4.2) below were obtained.

$$QSP_t = \underset{\substack{(-5.11)\\(.0001)}}{1556636.12} + \underset{\substack{(10.11)\\(.0001)}}{195.218B_{1t}} + \underset{\substack{(3.56)\\(.0016)}}{92571.84\,E_t} \qquad (4.2)$$

$R^2 = .823 \quad F = 55.82 \quad Prob > F = .0001$

D. W. = 2.16

where:

QSP_t = Quantity of speed planted in year t.

B_{1t} = the value of the biological index (12688.5 or 19037) in year t.

E_t = the value of the economic index (the difference between the price of private grounds market oysters ($/pound) and the price of seed oysters ($/Va bushel) divided by the interest rate index) in years t.

The model performs reasonably well when evaluated in terms of explanatory power, significance of explanatory variables, and absence of serial correlation. The R^2 statistic would likely improve with the inclusion of variables which more accurately reflect biological conditions existing at any given point in time.

4.2.3 Seed Oyster - Market Oyster Relation

As shown in Equation (3.3), harvest of market oysters from private grounds is estimated as a function of lagged seed plantings and biological conditions on the seed planting grounds. Since it was argued in Chapter III that the main effect of MSX on the private market sector was reflected in the planting of seed on less productive oyster grounds, the biological variable B_2 is defined as a slope-shifter which changes the magnitude of the co-efficient on lagged seed planting. Consequently, B_2 was defined to have a value of 0 in the period prior to 1959-60 and a value equal to $WQSEED_t$ in the period 1959-60 and after. When this relationship was estimated the results shown in Equation (4.3) below were obtained.

$$QMPRI_t = 1010906 + 8.532WQSEED_t$$

$$\quad\quad (1.626) \quad\quad (20.493)$$
$$\quad\quad (.1170) \quad\quad (.0001)$$

$$-1.964B_{2t} \tag{4.3}$$

$$(-4.440)$$
$$(.0002)$$

R^2 = .9484 D-W = 1.3449

F = 220.34 Pr > F = .0001

where:

$QMPRI_t$ = Harvest of market oysters off private oyster grounds in ear t, (pounds).

$WQSEED_t$ = Weighted average of seed planted 2, 3 and 4 years in the past, with weights of .25 on seed planting 2 years in the past, .50 on seed planting 3 years in the past, and .25 on seed planting 4 years in the past, (Virginia bushels). B_{2t} = a biological variable equal to 0 in the period prior to 1959-60 and equal to $WQSEED_t$ in the period 1959-60 and thereafter.

Equation (4.3) implies that the marginal physical product of a bushel of seed was 8.532 pounds prior to 1959-60 and 6.563 pounds in the period 1959-60 and after. This result is obtained by adding the coefficient on the variable B_2 (-1.69) to the coefficient on the variable WQSEED (8.532).

Equation (4.3) exhibits generally good statistical properties with a high value of R^2 and statistically significant t values on the explanatory variables. The Durbin-Watson statistic is in the indeterminate range, which suggests that serial correlation of the error terms may exist.

4.2.4 Public Grounds Component

4.2.4.1 Background

The final harvest equation to be estimated is the model of public grounds harvest. An Almon polynomial lag structure, as discussed in Chapter III, is used to estimate weights on lagged repletion expenditures and lagged prices in the harvest equation for the public grounds. Two independent measures of public grounds oyster population available for harvest are used. One measure is the abundance of oyster on the natural, unreplenished oyster bars of Virginia; the second measure is the level of seed planting and shell planting under the repletion program conducted by the Virginia Marine Resources Commission.

Haven, et al, (1978) report oyster densities by year for twenty-three oyster bars in five river systems in Virginia. These data were used to construct a measure of oyster population on the unrepleted public oyster bars. (See Appendix A for a discussion of the construction of this index.) Since not all oysters are harvested at the same age, and since oyster harvests may respond to exceptionally favorable or exceptionally unfavorable biological conditions for a number of years, the index was constructed in discrete blocks of years, corresponding to major changes in environmental conditions, rather than to assign a unique value to each year. The logic of the index construction is such that one could assign a separate index value to each bar, each river system and each year.

The repletion program in Virginia, as discussed in Chapter I consists of the planting of dredge shell, fresh shell and seed oysters. Ideally one would like to identify the increment in production associated with the planting of a given quantity of each material at each location. However, for the aggregate analysis being conducted here, it was desirable to include a single value for repletion expenditure. Repletion, as a form of human action to increase available stocks of oysters plays the same role in the public grounds model that seed planting plays in the private grounds model.

Utilized Equation (4.4) below is obtained.

$$QPUB_t = -4373393 - 0.495112A_0$$
$$+0.594251A_1 - 0.044128A_2$$
$$-247060C_0 - 2494206C_1 + 1045948C_2 + 5434462\ Bio_t \tag{4.4}$$

where:

A_0, A_1, and A_2 represent the constant, linear, and quadratic portions respectively of the lag structure on repletion expenditures.

C_0, C_1, and C_2 represent the constant linear, and quadratic portions respectively of the lag structure on prices.

QPUB is the quantity of oysters harvested off public grounds; and Bio_t is the physical productivity index. (See Appendix)

Disentangling the Almon polynomial lag into its component parts Equation (4.4) can be expressed as:

$$QPUB_t = -4373393 + 5434462\ Bio_t - .495R_t + .055\ R_t-1 +$$
$$.517\ R_{t-2} + .890R_{t-3} + 1.176\ R_{t-4} - 247060\ P_t -$$
$$1695318\ P_{t-1} - 1051680\ P_{t-2} + 1683854\ P_{t\pm 3}$$
$$6511284\ P_{t-4} \tag{4.5}$$

In order to express the overall significance of the lagged repletion and lagged price effects, the weights determined from Equation (4.5) were used to form weighted lagged price and weighted lagged repletion variables as shown in Equation (4.6) and (4.7) below:

$$WLR_t = .495\ R_t + .055\ R_{t-1} + .517\ R_{t-2} + .890\ R_{t-3} + 1.176\ R_{t-4} \quad (4.6)$$

$$WLP_t = -247060\ P_t - 1695318\ P_{t-1} - 1051680\ P_{t-2} + 1683854\ P_{t-3} + 6511284\ P_{t-4} \quad (4.7)$$

where:

WLR_t = weighted lagged repletion.

WLP_t = weighted lagged price.

An equation was estimated to described the relationship of public grounds harvest to weighted lagged repletion, weighted lagged prices and the physical productivity index, as shown in Equation (4.8) below:

$$\underset{\substack{(-3.2489)\\(.0036)}}{QPUB_t = -4373393} + \underset{\substack{(2.0096)\\(.0569)}}{1.0\ WLR_t} + \underset{\substack{(4.6459)\\(.001)}}{1.0\ WLP_t} + \underset{\substack{(4.9268)\\(.0001)}}{5434464\ Bio_t} \quad (4.8)$$

$R^2 = .6227 \quad F = 12.10$

where all variables are defined as above.

The coefficients on the physical productivity index and weighted lagged price are both highly significant; the coefficient on weighted lagged repletion is significant at the .1 level and barely insignificant at the .05 level. Although the explanatory power of Equation (4.8) is somewhat low, this is not surprising given the wild stock nature of many of the public oyster grounds. The Durbin-Watson statistic is in the indeterminate range; the fact that Bio_t, the measure of biological productivity takes on a series of discrete values, when in fact the natural oyster population is constantly changing may explain some of this serial correlation. The large co-efficients on the earlier time periods for the repletion and economic effects indicates that the public grounds fishery responds slowly to inter-seasonal changes in economic and public policy forces.

4.3 APPLICATION OF THE MODEL

In this section the impact of a number of factors on the output, price, total revenues and seed requirements of the Virginia oyster fishery will be examined. These impacts will be disaggregated to show the changes predicted to occur in both the public grounds and private grounds sector of the oyster fishery in response to exogenous changes. The first technique to be used is to isolate these forces is static backcasting. In static backcasting, the analysis takes developed relationships between endogenous variables and selected exogenous variables and evaluates how observed levels of endogenous variables would have been different if the exogenous variables had taken on specified values, given the hypothesized model structure. In this technique the predicted values for public harvest, private harvest and seed harvest will be calculated using actual values for the exogenous variables and using baseline values (1957-1958) for prices and biological variables. Public policy effects are simulated by changing the expenditures on repletion in the public grounds model.

The second type of analysis to be conducted is a dynamic forecasting model to analyze projected effects of a variety of public policies on prices, outputs and revenues from the public and private grounds. The estimated equations from Chapter IV will be interfaced with the theoretical model outlined in Chapter III. The structure of this model is shown in Figure IV-1.

Equations estimated for the Virginia Oyster Model

$$WQSEED_t = .25*QSEED_{t-2} + .5*QSEED_{t-3} + .25*QSEED_{t-4} \quad (4.1)$$

$$QSEED_t = f_1 (E, B_1) \quad (4.2)$$

$$QPUB_t = f_2 (P_{t-n}/IR_{t-n}, Rep_{t-n}, Bio) \quad (4.3)$$

$$QPRV_t = f_3 (WQSEED_t, B_2) \quad (4.4)$$

$$QVA_t = QPUB_t + QPRV_t \quad (4.5)$$

$$XP = f_4 (RP_t, QVA_t, QMD_t, S, Reg, G) \quad (4.6)$$

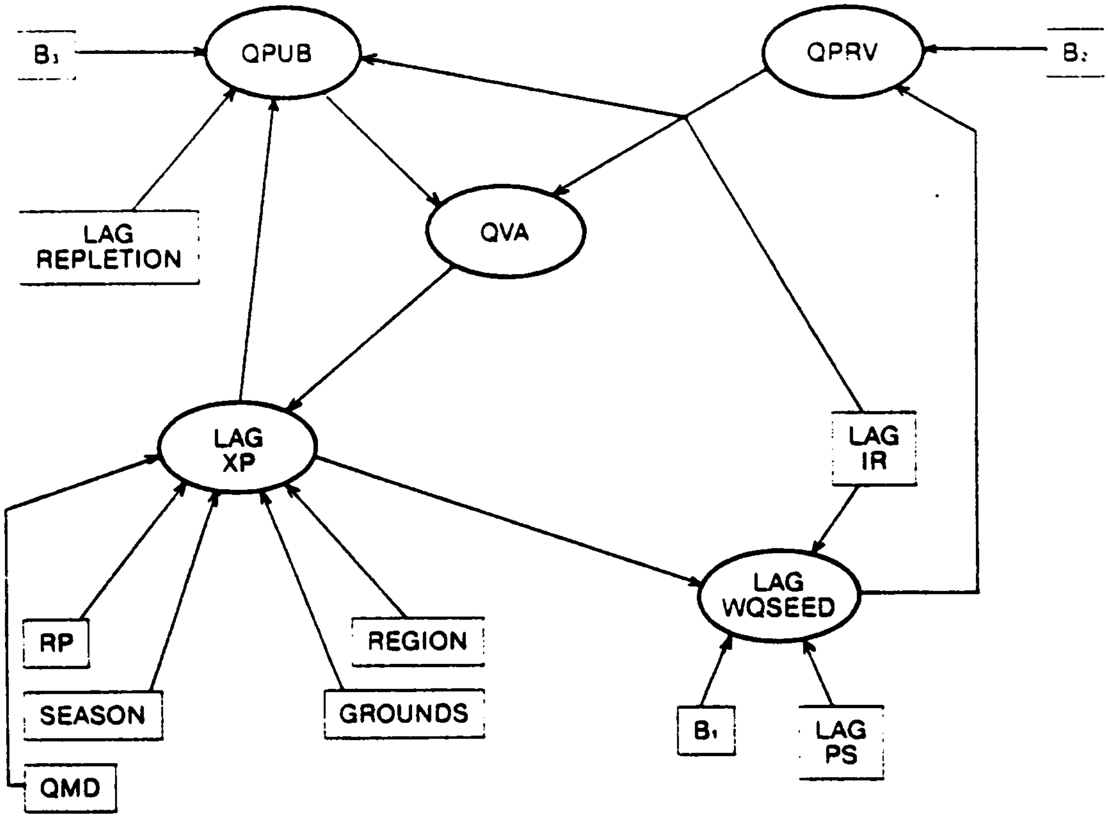

Figure IV-1 Structure of the Forecasting Model

(All variables are the same as those in Figure III-1 in Chapter 3.)

4.4 OVERVIEW OF THE OYSTER MODEL AS A SYSTEM

4.4.1 Background

The oyster model depicted in Figure IV-1 is the full model which is used for dynamic forecasts of the effects of policy alternatives. For purposes of conducting static backcasts, a smaller system consisting of Equations (4.2), (4.3) and (4.4) in Figure IV-1 was used. The basic differences between the system used for backcasting and the one used for forecasting is that, in the forecasting system, ex-vessel price is endogenous. Making the ex-vessel price endogenous and introducing a mutual interdependence between price and quantity allows the system to be run dynamically. To understand the difference between the static and dynamic systems it will be helpful to discuss each system separately.

4.4.2 The Static Backcast Model

In order to isolate the separate effects of the economic, biological and public policy effects on the harvest, from the public grounds and private grounds, only Equations (4.2), (4.3), (4.4) and (4.5) from Figure IV-1 will be used. Equation (4.3), the public grounds component, is independent of Equations (4.2) and (4.4), the seed component and the private grounds component, respectively. The interdependence between the seed sector and the private grounds sector in the backcasting model is assumed to be purely biological with no effect of private grounds harvest on price or seed planting.

4.4.3 The Forecasting Model

The forecasting model incorporates the price formation component, shown in Equation (4.6). The incorporation of the price formation component allows dynamic simulations of the impact of changes in exogenous, biological, public policy, or economic forces. In order to do this it is necessary to link the regionalized, seasonalized price formation component with the statewide annual model components for the public grounds, private grounds and seed sector.

In order to simulate prices for the public grounds and the private grounds in the future, it is necessary to construct a weighted average predicted price. Since the model assumes separate prices for the private grounds it is straight- forward to adjust the private grounds price by adding .116 (the coefficient on the grounds variable) to the base (public grounds price). Note that this constitutes a weighted average price with a weight of 1 on the grounds dummy coefficient (which acts as an intercept shifter) in the private grounds price and a weight of 0 on this coefficient in the public grounds price.

The concept of a weighted average price is also used to incorporate the regional and seasonal effects on price in the forecasting model.

Earlier arguments suggested that, public grounds oyster harvest is expected to occur earlier in the season than private grounds harvest. A model was run (Appendix B) which tested the hypothesis that the seasonal distribution of harvest was the same on public grounds and private grounds. This hypothesis was rejected. To incorporate the seasonal effect into the model the weighted average seasonal price is calculated by adding to the intercept term of the ex-vessel price equation, and amount equal to .0024 (the estimated spring price premium) times and estimated share of the harvest from each type of grounds in the spring (see Appendix B).

The same type of procedure is used to adjust for regional variations. The regional share of harvest for the period 1975-1976 to 1978-1979 was calculated and the coefficients on the regional dummies multiplied by the regional share to obtain a regional effect to be added to the intercept of the weighted average equation. Thus, for the simulations, the effects of the dummy variables in Equation (4.6) are incorporated into the intercept term. The model in essence initializes series of exogenous variables, sets up a lag structure which dynamically moves forward through time, computes values for endogenous variables for the initial time periods and then makes projections based on the estimated endogenous variables and the projections of the exogenous variables. For the base case scenarios all variables except quantity of seed oysters and prices and quantities of private ground oysters and public ground oysters are set equal to their 1980 levels. These can be combined into the constant term. The system then reduces to:

$$QSPRI_t = a_1 + b_1 \; WQSEED_t \qquad (4.15)$$

$$QSEED_t = a_2 + b_2 \; PPRI_t \qquad (4.16)$$

$$QSPUB_t = a_3 + b_3 \; WLPPUB_t \qquad (4.17)$$

$$PPUB_t = a_4 + b_4 \; (QSPRI_t + QSPUB_t) \qquad (4.18)$$

$$PPRI_t = a_5 + b_5 \; PPUB_t \qquad (4.19)$$

where:

QSPRI = harvest of private grounds oysters in time t.

$WQSEED_t$ = weighted seed plantings lagged 2, 3, and 4 years.

$QSEED_t$ = seed planting in time t.

$QSPUB_t$ = harvest of public grounds oysters in time t.

$WLPPUB_t$ = a weighted average of current and past public oyster prices (lagged 1, 2, 3 and 4 years).

$PPRI_t$ = Private grounds oyster price.

$PPUB_t$ = Public grounds oyster price.

Substituting terms it is possible to express.

$$QSPRI_t = f(QSPRI_{t-2,\ t-3,\ t-4}) \; QSPUB_{t-2,\ t-3,\ t-4}) \qquad (4.20)$$

$$QSPUB_t = g(QSPRI_{t,\ t-1,\ t-2,\ t-3,\ t-4}) \; (QSPUB_{t,\ t-1,\ t-2,\ t-3,\ t-4}) \qquad (4.21)$$

The private harvest component is purely recursive; once private harvest has been determined, public harvest and market oyster prices adjust simultaneously to equilibrate the system. This price feeds back into the seed planting equations and private harvest two years in the future is determined. Then the process starts again.

4.5 RESULTS OF THE BACKCAST MODEL OF HISTORICAL CONDITIONS ON PUBLIC GROUNDS

4.5.1 Background

The analysis of the historical performance of the Virginia oyster fishery is designed to identify the influence of public policy, economic and biological forces on the production levels obtained by the fishery. In order to evaluate these effects eight simulations are run representing combination of base year (1957-58) and actual biological and economic conditions and actual and doubled repletion levels. Since three choice variables are modeled, each at two levels, eight (2^3) simulations are necessary. The eight simulations run are:

1. Repletion doubled; base biological productivity (1958 level); base deflated prices (1958) level. This scenario is denoted S1.

2. Actual repletion levels; base biological productivity; base deflated prices. This scenario is denoted S2.

3. Repletion doubled; base biological condition; actual deflated prices. This scenario is denoted S3.

4. Repletion doubled; actual biological conditions; based deflated prices. This scenario is S4.

5. Actual repletion levels; actual biological productivity; base deflated prices. This scenario is denoted S5.

6. Actual repletion levels; actual biological productivity; actual deflated prices. This scenario is denoted S6. Note: S6 is the predicted value of QPUB, when Equation (4.3) is estimated.

7. Actual repletion levels; base biological productivity; actual deflated prices. This scenario is denoted S7.

8. Double repletion levels; actual biological productivity; actual deflated prices. This scenario is denoted S8.

The simulated values for public harvest under scenarios (1) through (8) are shown in Table IV-1 below. As expected, scenario (1) with doubled repletion and base biological and economic conditions yields the highest public grounds harvest. The isolated effects of repletion, biological conditions, which in this formulation are assumed to be mutually independent, are shown in Table IV-2 below.

TABLE IV-1

Estimated Public Grounds Oyster Harvest Under Alternative Scenarios

YEAR	QPUV	S1	S2	S3	S4	S5	S6	S7	S8
1951	2349300	4289415	4178119	3823496	4300284	4188988	3723069	3712200	3834365
1952	2586300	4358709	4212767	3404408	4369578	4223636	3269335	3258466	3415277
1953	2859800	4437313	4252068	3360454	4448182	4262937	3186079	3175210	3371323
1954	3102300	4326852	4196838	3423494	4337721	4207707	3304350	3293481	3438363
1955	3896200	4342467	4204645	3389892	4342467	4204645	3252071	3252071	3369892
1956	4336100	4423859	4245241	3879426	4423659	4245241	3701009	3701009	3879426
1957	3964300	4428387	4247606	3648584	4428387	4247606	3467802	3467802	3646584
1958	4495200	4524998	4295911	4076287	4524999	4295911	3847200	3847200	4076287
1959	3285700	4503033	4284928	3632853	4486730	4268625	3598445	3614748	3816549
1960	3996100	4501227	4284025	3692892	4484923	4267722	3459387	3475690	3676588
1961	3195400	4620536	4343580	3842303	4486730	4268625	3598445	3614748	3816549
1962	1431000	4539524	4303174	4108993	3197212	2960862	2530331	3872643	2766681
1963	1993500	4370546	4216685	4011235	3028234	2876373	2517061	3859374	2668923
1964	3331800	4217279	4142051	4647461	2874986	2799739	3129921	4472233	3205146
1965	4440000	4647092	4356958	6878096	3304779	3014645	4245650	5567962	4355784
1966	4802300	5488485	4777655	6642439	4146173	3435342	4589296	5931608	5300127
1967	4065600	6143055	5104939	7148367	4800742	3762627	4767939	6110252	5806054
1968	3965800	6563241	5315033	7501353	4345980	3097774	4035883	6253145	5284092
1969	4236300	6080559	5073692	7188060	3863298	2856434	3963931	6181193	4970799
1970	3110600	5585007	4825916	5767534	3367748	2808654	2791181	5008442	3550273
1971	2902900	5486309	4776566	5773279	3269048	2559305	2846275	5063537	3556018
1972	1897700	4941201	4504013	4654538	2723940	2286752	2000088	4217349	2437277
1973	2330800	4931739	4499262	3923519	4029619	3597161	2588940	3491061	3021398
1974	3250600	4933541	4500182	4243085	4031420	3598062	2907606	3809727	3340984
1975	2992100	4934558	4500691	4531558	4032437	3598570	3195570	4097690	3629437
1976	3181500	5761371	4914098	4907218	4859250	4011977	3157823	4059944	4005097

4.5.2 Repletion Effect

The increment in harvest attributable to the repletion program is shown in Table IV-2 below as REPLETE. The repletion effect is uniformly positive, since it is assumed that the doubled repletion has existed throughout the time period, so there is no period of reduced harvest before the benefits of the expanded repletion program are realized. REPLETE is derived from Table IV-1 by sub- tracting S6 from S8. Since repletion is modeled as entering the public grounds harvest equation in a linear form, the value of REPLETE also represents the amount by which harvest would fall if there were no repletion program. The level of harvest which would have obtained with no repletion program is shown in Table IV-3 below as NOREP.

4.5.3 Biological Effect

The biological effect is shown in Table IV-2 as BIO. BIO is calculated from Table IV-1 by subtracting S6 from S7. Since the biological variable in Equation (4.8) moves in discrete steps the biological effect, BIO, also moves in discrete steps, mirroring the changes in the biological variable B_3 in Equation (4.3).

Table IV-2 shows that the biological effect has been the most important effect on public grounds oyster harvest throughout the post-1962 period. However, Table IV-2 shows that the biological effect, presenting a decline in oyster densities, was most severe in the late 1960's and early 1970's. This may reflect the fact that MSX significantly reduced brood stocks, so that the full effects of MSX were felt only with a lag of several years. It may also reflect the decline in spatfall, which according to Haven, et al, (1978) was largely independent of MSX. The biological effect declined in the last few years of the study period suggesting that the public grounds may be regaining a portion of their former natural productivity.

4.5.4 Economic Effect

The economic effect, reflecting changes in the real price of oysters, is calculated by subtracting S6 from S5. The economic effect, ECON, takes on a negative sign during the post-1960 time period. The negative sign on the variable ECON for the years 1963-64 through 1970-71 indicates that during that time period economic conditions, as measured by the real price of oysters, were relatively more favorable (i.e, weighted lagged prices were higher) than during the 1957-58 base period.

Recent harvest cost increases combined with relatively stable nominal oyster prices have resulted in the economic effect acting to augment the harvest-depressing effect of biological conditions. In 1972-73 for the first time in the post-MSX period, the economic effect was greater than the biological effect.

TABLE IV-2

Estimated Magnitude of Repletion, Biological and Economic Effects on Public Grounds Oyster Harvests

YEAR	QPUV	S6	REPLETE	BIO	ECON
1951	2649300	3723069	111295	10869	-465919
1952	2586300	3269335	145943	10869	-954301
1953	2859800	3186079	185244	10869	-1076859
1954	3102300	3304350	130014	10869	-903357
1955	3896200	3252071	137821	0	-952574
1956	4336100	3701009	178417	0	-544232
1957	3964300	3467802	180782	0	-779804
1958	4495200	3847200	229087	0	-448712
1959	3285700	3598445	218104	-16303	-870180
1960	3996100	3459387	217201	-16303	-808355
1961	3195400	2223134	276856	-16303	-2104243
1962	1431000	2530331	236350	-1342313	-430531
1963	1993500	2517061	151861	-1342313	330182
1964	3331800	3129921	75227	-1342313	330182
1965	4440000	4245650	290134	-1342313	1231004
1966	4802300	4589296	710831	-1342313	1153594
1967	4065600	4167939	1038115	-1342313	1005312
1968	3965800	4035883	1248209	-2217261	938112
1969	4236300	3963931	1006888	-2217261	1107501
1970	3110600	2971181	759092	-2217261	182527
1971	2902900	2846275	709742	-2217261	286970
1972	1897700	2000088	437189	-2217261	286664
1973	2330800	2588940	432458	-902121	-1008221
1974	3220500	2907606	433358	-902121	-690456
1975	2992100	3195570	433867	-902121	-403001
1976	3181500	3157823	847274	-902121	-854153

TABLE IV-3

Estimated Public Ground Harvest in the Absence of Repletion

YEAR	QPUV	S6	NOREP
1951	2649300	3723069	3611774
1952	2586300	3269335	3123392
1953	2859800	3186079	3000834
1954	3102300	3304350	3174336
1955	3896200	3252071	3114250
1956	4336100	3701009	3525592
1957	3964300	3467802	3287020
1958	4495200	3847200	3618112
1959	3285700	3958445	3380341
1960	3996100	3459387	3242186
1961	3195400	2223134	1946278
1962	1431000	2530331	2293980
1963	1993500	2517061	2365200
1964	3331800	3129921	3054693
1965	4440000	4245650	3955518
1966	4802300	4589296	3878465
1967	4065600	4767939	3729824
1968	3965800	4035883	2787675
1969	4238300	3963931	2957064
1970	3110800	2791811	2032089
1971	2902900	2846275	2136533
1972	1897700	2000088	1562899
1973	2330800	2588940	2156842
1974	3250600	2907606	2474247
1975	2992100	3195570	2761702
1976	3181500	3157823	2310550

4.5.5 Summary

As of 1975-76, the last year covered by this part of the study, the biological and economic effects were roughly equal. The repletion effect, which, as described above, may be interpreted as the increment of harvest attributable to the repletion program, was also roughly equal to the biological and economic effects. If one views the repletion program as attempting to restore the biological productivity of the public oyster grounds to levels comparable with pre-1960 levels, then, based on this analysis the program was approaching this objective, at least in 1975-76.

4.6 HISTORIC SIMULATION OF ECONOMIC AND BIOLOGICAL EFFECTS ON THE PRIVATE OYSTER GROUNDS.

4.6.1 Background

The seed planting and seed oyster-market oyster transformation Equations (4.2) and (4.3) were used to simulate, over the range of the data included in the model, the separate effects of biological forces and economic forces. Public policy variables do not explicitly appear in the private ground models, so only four scenarios are presented rather than eight policies as were simulated for the public grounds models.

The models which are analyzed over the range of the historical data involved prediction of harvest under four alternative scenarios:

1. Actual economic and actual biological conditions. Evaluating this scenario involves the estimation of seed planting from the seed planting equation in Chapter IV, calculation of $WQSEED_t$ as a weighted average of lagged seed plantings as predicted by this equation and substitution of this value into the seed oyster-market oyster relationship given by Equation (4.4). This quantity is denoted QSHAT1.

2. Actual economic and baseline (1958) biological conditions. Evaluating this scenario involves predicting $WQSEED_t$ with B_1 constant at 19037 (its 1958 level) throughout, in the seed planting equation. This prediction of $WQSEED_t$ was substituted into the seed oyster-market oyster relationship setting B_2 equal to 0 throughout the period of analysis. This quantity is denoted QSHAT2.

3. Actual biological condition and baseline economic conditions. This scenario involved predicting $WQSEED_t$ with E_t held constant at its 1958 level (-.402) throughout. The predicted value for $WQSEED_t$ from this equation is substituted in the equation. This quantity is denoted OSHAT3.

4. Baseline (1958) biological and baseline (1958) economic conditions. This simulation involves holding B_1, B_2, and E_t constant at their 1958 levels. This results in a single value being predicted throughout the study period. This quantity is denoted QSHAT4.

4.6.2 Seed Sector

Results of these simulations for the seed planting equation are shown in Table IV-4 below. QSHAT1. represents the predicted seed harvest using actual economic and biological condition as input data. QSHAT2 represents the seed planting expected under actual economic and baseline (1958) biological conditions. QSHAT3 represents the seed planting predicated under actual biological conditions and baseline (1958) economic conditions. QSHAT4 represents seed planting predicted with baseline economic and baseline biological conditions. The difference between QSHAT1 and QSHAT2 in the pre-1960 period represents rounding error. In 1957-58 the predicted seed harvest from each scenario is identical, within the limits of rounding error.

Because of the assumed independence of the biological and economic effects, the following identity holds:

$$\text{QSHAT1} = \text{QSHAT2} + \text{QSHAT3} - \text{QSHAT4}.$$

This implies that Predicted Value (Base + Economic Effect + Biological Effect) = (Base + Economic Effect) + (Base + Biological Effect) - Base. The seed plantings in the base year, 1957-58, was fairly typical for the pre 1959-60 period; the model predicts base year harvest well, being off by only 1%. The model predicts a 73.3% decline in seed plantings between 1957-58 and 1976-76; in fact, a decline of 74% was observed.

One can partition this decline into a "biological" component and an "economic" component, much as was done for the public grounds model. The full discussion of the partitioning of effects is given below, in the presentation of the results of the scenario depicting private grounds market oyster harvest. If one were interested in partitioning the effects in the seed planting model, one would calculate:

Biological Effect =

QSHAT3	-	QSHAT4
(Base + Biological Effect)		(Base)

Economic Effect -

QSHAT2	-	QSHAT4
(Base + Economic Effect)		(Base)

TABLE IV-4

Estimated Seed Oyster Harvest Under Alternative Scenarios

YEAR	QSPVB	QSHAT1	QSHAT2	QSHAT3	QSHAT4
1946	1711964	N/A	N/A	1787590	1787590
1947	1516941	N/A	N/A	1787590	1787590
1948	1745809	N/A	N/A	1787590	1787590
1949	1721011	N/A	N/A	1787590	1787590
1950	1721011	1991145	1991148	1787590	1787590
1951	1908611	1907323	1907326	1787590	1787590
1952	1616814	1699420	1699423	1787590	1787590
1953	1616814	1809437	1809440	1787590	1787590
1954	2001050	1738157	1738159	1787590	1787590
1955	2280353	1784998	1785001	1787590	1787590
1956	1961048	1925718	1925721	1787590	1787590
1957	2146278	1844985	1844987	1787590	1787590
1958	1770104	1787590	1787593	1787590	1787590
1959	1368427	1860387	1860389	1787590	1787590
1960	1853344	830439	2069783	548249	1787590
1961	1060808	1007546	2246890	548249	1787590
1962	1185770	1079172	2318516	548249	1787590
1963	782075	910032	2149376	548249	1787590
1964	574614	634478	1874093	548249	1787590
1965	478093	608860	1848204	548249	1787590
1966	592989	938902	2178246	548249	1787590
1967	592989	355699	1595043	548249	1787590
1968	556026	709057	1948402	548249	1787590
1969	362764	633923	1873268	548249	1787590
1970	251294	636639	1875983	548249	1787590
1971	423915	474376	1713720	548249	1787590
1972	280079	320275	1559619	548249	1787590
1973	291437	280839	1520183	548249	1787590
1974	377595	254184	1493528	548249	1787590
1975	281033	347599	1586943	548249	1787590
1976	443742	477603	1716943	548249	1787590

For 1975-76, the biological effect is 548249 - 1787590 = -1239341 Virginia bushels; for the same year the economic effect is 1716947 - 1787590 = -70643. This implies that "biological" forces account for approximately 95% of the reduced seed plantings in 1975-76 compared to the based period. However, this 70643 Virginia bushel deficit attributable to economic conditions represents some 16% of 1975-76 Virginia seed oyster harvests.

4.6.3 Private Market Harvest Sector

Having estimated the impact of economic and biological effects on seed planting, the next stage in the analysis is to translate these changes in seed planting into changes in private market harvest, as shown in Table 4.5. This modeling exercise is simplified somewhat by the assumption, which is supported by the data, that economic forces do not influence the level of oyster harvests, holding lagged seed planting constant.

Substituting QSHAT1 into Equation (4.1) yields a value of WQSEED1 which is then substituted in Equation (4.4) to yield a predicted value for private grounds harvest, QPHAT1 representing the predicted private harvest with actual economic and actual biological conditions, as shown in Table IV-5. Calculating weighted lagged seed plantings using QSHAT2 and substituting this value into Equation (4.4) with B2 set to 0 throughout yields estimates of the harvest which would have been obtained from private grounds if market and seed prices had followed historic patterns and biological conditions had remained at 1958 levels, shown as QPHAT2. Calculating weighted lagged seed planting using QSHAT3 and substituting this value into Equation (4.4) with B2 taking on estimated values yields OPHAT3 which represents predicted private grounds harvests with actual biological conditions and baseline economic conditions.

QPHAT4 is calculated from QSHAT4 assuming that B2 in Equation (4.4) is set to 0 throughout. This scenario yields a constant as a predicted value, since it assumes no change in economic or biological conditions from the baseline 1958 levels.

The private grounds biological effect may be calculated by subtracting QPHAT4 (Base) from QPHAT3 (Base + Biological Effect). The slight difference between QPHAT4 and QPHAT3 in the pre-1960 period is attributable to rounding error, as is the slight difference between QPHAT1 and QPHAT2 in this period. Similarly the private grounds economic effect may be calculated by subtracting QPHAT4 (Base) from QPHAT2 (Base + Economic Effect). As with the public grounds model it is possible to establish the following identity: QPHAT1 (Base + Biological Effect + Economic Effect) = QPHAT2 (Base + Economic Effect) + QPHAT3 (Base + Biological Effect) - QPHAT4, (Base) within the limitation of rounding error.

TABLE IV-5

Estimated Private Grounds Harvest Under Alternative Scenarios

YEAR	QSPRI	QPHAT1	QPHAT2	QPHAT3	QPHAT4
1954	19128000	17018818	17018815	16261764	16261763
1955	17864000	16187625	16187624	16261764	16261763
1956	17317000	16061467	16061466	16261764	16261763
1957	16622000	16091962	16091961	16261764	16261763
1958	18096000	16439881	16439880	16261764	16261763
1959	19978000	16967869	16267869	16261764	16261763
1960	14266000	13156572	16801203	12741643	16261763
1961	13170000	12955231	16539444	12741643	16261763
1962	11207000	11410217	17174171	10708407	16261763
1963	9580000	8440784	18600404	6641937	16261763
1964	9751000	7449698	19955279	4608701	16261763
1965	9827000	7697784	20277811	4608701	16261763
1966	6825000	6808695	19121926	4608701	16261763
1967	4408000	6585490	17531664	4608701	16261763
1968	4285000	5590380	17538022	4608701	16261763
1969	3196000	5674038	17646783	4608701	16261763
1970	4493000	4881632	16616594	4608701	16261763
1971	5581000	4961003	16719782	4608701	16261763
1972	4369000	5298643	17158741	4608701	16261763
1973	2677000	4918087	16663968	4608701	16261763
1974	3103000	4137319	15648929	4608701	16261763
1975	3458000	3300787	14561372	4608701	16261763
1976	3079000	2874847	14007617	4608701	16261763

The magnitude of the private ground biological and economic effects is shown in Table IV-6 below. Table IV-6 shows that between 1958 and 1973 the economic conditions facing seed planters were generally more favorable than they were in the base period. Beginning in 1974 the economic effect became negative, aggravating the negative biological effects.

The major conclusions that can be drawn from Table IV-6 are:

1. The great majority of the decline in Virginia private market oyster harvest may be attributed to changed biological conditions or the changed planters perceptions of biological condition; and

2. A significant part of the decline, since 1974, may be attributed to worsened economic conditions facing seed planters (seed oyster-market oyster price relationships).

TABLE IV-6

Estimated Magnitude of Biological and Economic Effects on Private Ground Harvest

YEAR	PRIBIO	PRIECON
1954	1	756852
1955	1	-74139
1956	1	-200927
1957	1	-169802
1958	1	176117
1959	1	706106
1960	-3520120	549440
1961	-3520120	277681
1962	-5553536	912408
1963	-9619826	2338641
1964	-11653062	3695316
1965	-11653062	4016046
1966	-11653062	2860163
1967	-11653062	1269901
1968	-11653062	1276259
1969	-11653062	1385020
1970	-11653062	354831
1971	-11653062	458019
1972	-11653062	896978
1973	-11653062	402225
1974	-11653062	-612834
1975	-11653062	-1700391
1976	-11653062	-2254146

4.6.3 Summary

Table IV-2 and IV-6 above show that the decline in the Virginia oyster fishery has occurred both on private oyster grounds and on public oyster grounds. Both biological and economic conditions have contributed to this decline; from Table IV-6 it is evident that the biological effects on private grounds, representing the unwillingness of private seed planters to plant seed on MSX-affected grounds, was quantitatively the largest factor in the decline of the Virginia oyster fishery.

Having identified the major sources of decline in the Virginia oyster fishery, the next phase in the analysis is to evaluate what might be expected to happen if various policies were to be adopted attempt to reverse this decline. These policies will be examined in the following section.

4.7 EVALUATION OF POLICY ALTERNATIVES

4.7.1 Background

The model developed may also be used to evaluate potential effects of public policy changes on the Virginia oyster fishery. The historic simulations demonstrate the importance of biological forces in the changes which have affected the fishery. As a policy option it is impossible to recreate previous environmental conditions, although to the extent that these conditions are an outgrowth of human inventions in the fishery they may be, to some extent, reversible.

For purposes of this part of the study biological conditions are taken as given, as an outside constraint on attainable harvest. Six policy alternatives are evaluated.

1. Status quo
2. Increasing the amount which consumers are willing to pay for Virginia oysters; this could entail improved product quality through such means a stricter enforcement of sanitation standards, advertising, development of new product forms, etc.*
3. Increasing the amount of money spent on the public repletion program
4. Improving the efficiency with which seed is harvested to reduce the cost of seed
5. Intensively managing and cultivating unproductive areas of the public grounds and allowing dredging on these areas; and
6. Leasing portions of the public grounds to private parties for intensive management and cultivation.

*Note that this system is "open" at the retail end, in that retail price is exogenous. Additional research is needed to extend the model so that changes in such factors as consumer income, price of substitutes, advertising, product quality, etc. could be directly incorporated in the model and changes in the level of each factor affecting retail price could be evaluated.

The no change scenario used actual data through 1980 as input into the model. Because of the lags in the model observed data from 1976 to 1980 was used as input to derive base case projections.

The base case scenario involves allowing all exogenous variables (biological conditions, real seed costs, real oyster prices, real harvest costs, and repletion) to remain at the 1980 levels throughout the simulation.

Scenarios are simulated by either changing the values of one or more of the exogenous variables or by artificially changing the slope and/or intercept coefficients in one of the endogenous relationships in the model.

Two distinct types of changes were modeled. (1) a change which persists over time, in this case retail price increasing at a given rate (2%) per year throughout the period study; and (2) a permanent fixed change in the level of a variable.

The first type of change does not result in prices and quantities stabilizing at a unique level; so long as the exogenous shocks to the system continue, prices and quantities will not stabilize. The second type of change, because of the stability of the system, results in convergence to a determinate equilibrium price and quantity level. The overall effect of the on-time change can thus be determined by comparing the stable equilibrium price and output levels given the change in the exogenous variable to the base equilibrium price and output levels.

Because of the importance of biological factors, which are difficult to predict, on the observed harvest from the oyster fishery, results of the policy option scenarios are presented as changes from a 1990 base level. The differentials between the base harvest level and the predicted harvest level which obtains when a policy is adopted is largely unaffected by the biological productivity of the system; there is a slight variation in the magnitude of the differentials because of the interdependence of price and quantity.

The base case scenario, against which the results from the scenarios where policy parameters are varied are compared, uses historical input data from 1976 to 1980 to establish the lags which appear in the simulation model. The base case scenario assumes that 1979-80 values of the exogenous variables persist throughout the remainder of the time period simulated. Results from the simulation and actual 1980 values for the endogenous variables are presented in Table IV-7 below.

TABLE IV-7

Projections of Endogenous Variables Through 1990, Base Case

VARIABLE	EXPLANATION	VALUE IN 1990
QTOTHAT	Total quantity, pounds	8,271,322
QSPUB	Public grounds quantity, pounds	2,526,689
QSPR1	Private grounds quantity, pounds	5,744,533
NOMPPUB	Nominal public grounds price ($/lb)*	$1.333
PPRI	Nominal private grounds price ($/lb)*	$1.449
PUBTR	Public grounds total revenue ($)	3,368,751
PRITR	Private grounds total revenue ($)	8,324,116
AGTR	Aggregate Total revenue ($)	$11,692,867
WQSEED	Weighted average of seed plantings lagged 2, 3 and 4 years (Va. bushels)	721,590

*Although the prices are labelled as nominal, the implicit assumption which is made is that the cost of harvesting oysters, as measured by the interest rate index do not change from their 1980 levels.

4.7.2 Scenario 1 - Expanded Consumer Demand

The expanded consumer demand scenario is simulated by increasing retail price 2% a year beginning in 1982. Expanded consumer demand and increased willingness to pay for oysters could come about as a result of increase promotional activity, and increase in the real or perceived quality of improved water quality, improved varieties of oysters, or increase advertising, development of new oyster products etc. Because the increased retail price scenario involves continued shocks to the system each period, the system will not reach a stable equilibrium so long as the repeated shocks to the system persist. The changes from the 1990 base case scenario are shown in Table IV-8 below.

Table IV-8 below shows that the benefits of higher retail prices, reflected in higher ex-vessel prices, are shared by the public grounds sector and the private ground sector. The model shows that private grounds harvest increases proportionally more than public grounds harvest does in response to an increase in retail price. It should be noted that this model assumed a constant differential between nominal public grounds prices and nominal private grounds prices.

Because the model indicates a constant differential between private grounds price and public grounds price, and since private grounds price is higher than public grounds price, the percentage change (in absolute value) in the public grounds price will always be greater than the percentage change in the private grounds price.

TABLE IV-8

Changes from 1990 Base Levels for 2% Annual Increase in Retail Price

VARIABLE	CHANGE - 1990 SCENARIO LEVEL - 1990 BASE LEVEL	% CHANGE
QTOTHAT	+401379	+4.9%
QSPUB	+109487	+4.3%
QSPRI	+291892	+5.1%
NOMPPUB	+.245	+18.0%
PPRI	+.245	+16.9%
PUBTR	+791970	+23.5%
PRITR	+1902190	+22.9%
AGTR	+2694160	+23.0%
WQSEED	+85136	+11.8%

The quantities of seed required for this scenario are within the range of historic seed harvest. It should be noted, however, that this scenario assumes that there is no change in seed price as a result of the increased demand for seed. Thus, the entire increase in private grounds oyster prices appears in the market price-seed price differential.

4.7.3 Scenario 2 - Double Repletion Expenditures

In this scenario the repletion level is doubled from the base 1980 level. This scenario assumes that the mix of seed and shell in the repletion program does not change. Further, it assumes no growth in technical knowledge on the part of repletion officials about the optimal pattern of planting by geographical areas to maximize returns to the repletion program. Repletion is maintained at this higher level throughout the time period being simulated; since this is a one-time shock to the system, prices and quantities tend to converge to a new stable equilibrium with higher public ground harvest, higher total harvest, lower oyster prices, and slightly lower private grounds harvest. The changes associated with the doubled repletion scenario are shown in Table IV-9 below.

TABLE IV-9

Changes from 1990 Base Levels for Double Repletion Scenario

VARIABLE	CHANGE - 1990 SCENARIO LEVEL - 1990 BASE LEVEL	% CHANGE
QTOTHAT	+506200	+6.1%
QSPUB	+513733	+20.3%
QSPRI	-7533	-0.13%
NOMPPUB	-.0040	-0.30%
PPRI	-.0040	-0.28%
PUBTR	+672727	+20.0%
PRITR	-33966	+.041%
AGTR	+638761	+5.5%
WQSEED	-1159	-1.4%

*By 1990 the system has stabilized to the point that there is no change in the first four digits between years. This may exceed the number of significant figures in the original data from which the models were developed. Thus, these figures approximate estimated long-run equilibria for the relevant variables.

The change in WQSEED, annualized seed requirements, reflects only the change in seed needed to support the private grounds harvest. In addition 65,483 additional Virginia bushels of seed oysters would be needed to support the doubled repletion program. Consequently the total change in annualized seed requirements for this scenario is an increase of 64,324 Virginia bushels. However, this level of seed harvest is still well within the historic record for Virginia seed oyster production.

4.7.4 Scenario 3 - Lower Seed Cost

In this scenario, the price of seed was assumed to be $1.21 per bushel rather than the 1979-80 price of $2.35 or the 1980-81 price of $2.42. The $1.21 was chosen because it represents the Potomac River Fisheries Commission price (equivalent to $0.46 per bushed) plus $0.75 per bushel to cover transportation, planting and other miscellaneous expenses.

The Potomac River Fisheries Commission is a bi-state Commission composed of representatives from Virginia and Maryland which was established in 1958 under an interstate compact between Virginia and Maryland (see Va. Code Ann., Sec. 28, 1-203, 1979). The Commission is "charged with the establishment and maintenance of a program to conserve and improve" the fishery resources of the tidewater portion of the Potomac River within the two states (Va. Code Ann., Sec. 28, 1-203). As part of the program to conserve and improve the oyster resources the Commission is authorized to expend funds for the repletion of oysters (Potomac River Compact, Article III, Sec. 5). In general, the repletion program of the Commission is designed as a public utility, although the Commission is not mandated to operate so as to cover costs. The repletion program of the Commission is designed to recover most of its costs. Alford (1973) provides and overview of the oyster repletion program operated by the Commission and indicates that between 1967 and the early 1970's the repletion program was self-sufficient. Between 1970 and 1976 Potomac River oyster production by Virginians declined by 91 percent from 220,000 U.S. bushels to 19,800 bushels, so it is unclear whether the Potomac repletion program is still self-sufficient, although Potomac River harvest by Virginians recovered to 185,000 bushels in 1978 (VMRC, 1982). Because of the cost recovery aspect of the Potomac River repletion program, this cost was used as a measure of the costs of dredged seed.

It is believed that this is a reasonable proxy seed costs that would be attainable if dredging for seed oysters on public grounds, under regulation by the Commonwealth, were permitted. It is assumed that all of the dredged seed would be planted by private planters, although a portion of any seed dredged off public grounds could, in theory, be used to expand the repletion program. The results from the lowered seed cost scenario are shown in Table IV-10 below.

TABLE IV-10

Changes from 1990 Base Levels for Reduced Seed Cost Scenario

VARIABLE	CHANGE - 1990 SCENARIO LEVEL - 1990 BASE LEVEL	% CHANGE
QTOTHAT	+1697243	+20.5%
QSPUB	-19638	-0.8%
QSPRI	+1716881	+29.9%
NOMPPUB	-.0135	-0.1%
PPRI	-.0135	-0.9%
PUBTR	-59957	-1.8%
PRITR	+2387327	+28.7%
AGTR	+2327370	+19.9%
WQSEED	+261870	+36.3%

Total revenues to the seed sector fall by some $505,000, in spite of the fact that total harvest is greater. The dredging of seed may result in loss of employment and income to those currently engaged in hand tonging for seed. In 1976 some 445 people were employed in tonging for seed oysters. However, this includes both those whose primary source of income is from tonging for seed and those who derive a smaller portion of their income from seed tonging. Marine scientists at the Virginia Institute of Marine Science estimate that there are about thirty-five individuals whose income is dependent upon tonging for seed off public grounds (Haven, personal communication, December 1982).

The more intensive cultivation of public seed beds may require expanded repletion and/or management of these beds. Similar types of cost saving may also be attainable by the leasing of seed beds and by allowing private parties to use dredges or other efficient harvest technology under public regulation.

4.7.5 Scenario 4 - More Intensive Management of Currently Unproductive Public Grounds

This analysis applies to both the option of intensive management of unproductive public grounds by public officials with the use of efficient harvest technologies allowed and to the leasing of unproductive public grounds to private parties with the use of efficient harvest technologies permitted. Both options involved: (1) reduced costs through the use of more efficient harvest technologies; and (2) improved incentives for the harvest of oysters; and (3) access to grounds with a higher natural productivity than grounds currently available for lease. The public resource managers could through the use of varying incentive systems shift varying amounts of the risk (with respect to harvests, prices and/or costs) associated with the production of oysters. The optimal mix of private property rights and public control and management then can be seen to rest on the costs of processing information bearing upon the optimal level of harvest and on the costs of enforcing private property rights. When one starts dealing with changes in the institutional arrangements and modifications of the contents of the property right to harvest oysters then the concepts of private grounds harvest and public grounds harvest become unclear and a third type of harvest, quasi-public (or quasi-private) becomes applicable. (It should be recognized that as the various dimensions of the property right are varied, the number of possible "types" of property systems becomes almost infinite.) Thus, for the purpose of the discussion here the concepts of "public" grounds and "private" grounds will be retained, even through the content of the property right to harvest off the public grounds or private grounds has changed.

The scenario which is presented here involves the intensive cultivation and management (by either public or private parties) of 400 and 1000 acres of currently unproductive public grounds. It is assumed that these leased grounds are high productivity grounds, so that the marginal product of seed planted on these newly cultivated grounds would be comparable to the productivity of seed on privately leased grounds in the pre-MSX period.

Two assumptions about price will be considered. In the first case, it will be assumed that the prices received for the new production is equivalent to the private oyster grounds price. This could apply to the case where the unproductive public grounds are leased to private parties or to the case where the public management authority actively regulates the timing of harvest and product quality, so that public grounds oysters from the newly managed grounds receive the same price as private grounds oysters. In the second case, it will be assumed that the newly managed grounds produce oysters which are not distinguished from other public grounds oysters, so that the lower price is received.

For the first scenario to be examined assume that 400 acres of idle public grounds are leased (or managed). It will be assumed that 500 bushels of seed per acre are planted. If we assume that the oysters bring the same price as private ground oysters the results in Table IV-11 below obtain.

If one assumes that 1000 acres are cultivated intensively or leased the changes shown in Table IV-12 below obtain:

TABLE IV-11

Changes from Base Case with Leasing (or Intensive Management of 400 Acres of Unproductive Public Grounds (1990))

VARIABLE	CHANGE - 1990 SCENARIO LEVEL - 1990 BASE LEVEL	% CHANGE
QTOTHAT	+1656085	+20.0%
QSPUB	-19218	-0.8%
QSPRI	+1675303*	+29.2%
NOMPPUB	-0.013	-1.0%
PPRI	-0.013	-0.9%
PUBTR	+2330889**	+28.0%
PRITR	+57421	-1.7%
AGTR	+2273468***	+19.4%
WQSEED	-195593	+27.1%

* The change is QSPRI may be broken down into an increase of 1,700.00 pounds of the newly productive grounds and a decrease of 24,697 pounds off of formerly leased private grounds. Note that this decrease is a pure response to price changes and does not reflect a shift from formerly leased private grounds to newly leased grounds.

** This change in total revenue assumes that the new oyster brings the same price as other private grounds oysters. If they bring the same price as old public grounds oysters then the change in private ground total revenue (old and new) would be $2,134,063.

*** $2,076,642 if the oysters from newly productive grounds bring only the same price as public ground oysters.

TABLE IV-12

Changes from Base Case with Leasing (or Intensive Management of 1000 Acres of Unproductive Public Grounds (1990))

VARIABLE	CHANGE - 1990 SCENARIO LEVEL - 1990 BASE LEVEL	% CHANGE
QTOTHAT	+4,140,213	+50.1%
QSPUB	-48,045	-1.9%
QSPRI	+4,188,257	+72.9%
NOMPPUB	-.0329	-2.5%
PPRI	-.0329	-2.3%
PUBTR	+5,742,574	+69.0%
	(+5,362,300)	(+64.4%)
PRITR	-145,512	-4.3%
AGTR	+5,597,062	+47.8%
	(+5,216,788)	(+44.6%)
WQSEED	+488,742	+67.7%

* Figures in parentheses obtain if new production brings public grounds price, rather than private grounds price.

These scenarios shows that even with large increases in total oyster harvests, prices are depressed by only a relatively small amount. A sizeable leasing program substantially increases private grounds harvests and revenues, while having only a small effect on public grounds total revenue. A portion of the revenues lost to the public grounds sector may be made up by displaced public grounds tongers shifting over to the harvest of seed oysters.

4.7.6 Scenario 5 - Combination of Policies

The final scenario to be examined involves a combination of leasing, reducing seed cost to planters, increasing consumer demand and increasing repletion. The scenario presented here assumes that:

1. 400 acres of unproductive Baylor grounds are leased and planted at a rate of 500 bushels per acre
2. Seed price is reduced to a level of $1.21 per Virginia bushel
3. Repletion expenditures are doubled; and
4. Retail prices are allowed to increase 2% per year throughout the period to be modeled.

Like the other model where retail price was shocked upward at a 2% annual rate, the system never converges to a stable equilibrium. The change from the 1990 scenario is shown in Table IV-13 below.

TABLE IV-13

Changes from 1990 Base Level for Combination of Policies Entailing Lowered Seed Price, Increased Repletion, Leasing* of Unproductive Baylor Grounds and Expanded Consumer Demand

VARIABLE	CHANGE - 1990 SCENARIO LEVEL - 1990 BASE LEVEL	% CHANGE
QTOTHAT	+4,260,969	+51.5%
QSPUB	+584,436	+23.1%
QSPRI	+3,676,533**	+64.0%
NOMPPUB	+.214	+16.1%
PPRI	+.214	+14.8%
PUBTR	+1,446,279	+42.9%
PRITR	+7,347,491	+88.3%
AGTR	+8,793,720	+75.2%
WQSEED	+500,562***	+69.4%

* Or intense public management (see discussion above).

** This includes 1,700,00 pounds from the managed areas and 1,976,533 pounds from the previously leased grounds.

*** In addition to the change in WQSEED shown here an additional 65,483 bushels of seed would be needed to meet the needs of the expanded repletion program.

The results presented above indicate that with a combination of vigorously applied public policies it may be possible to substantially increase oyster harvests and revenues both to the private and public grounds sectors. In order to ensure that revenue gains to the private sector do not adversely affect the public grounds sector or (vice versa) it will be necessary to (a) increase the amount which consumers are willing to pay for oysters and oysters products at retail; (b) improve marketing efficiency so that the oyster harvester receives a larger share of the consumer dollar; and/or (c) implement programs designed to assist the private grounds sector in conjunction with programs designed to assist the public grounds sector.

4.8 SUMMARY

The above analysis has demonstrated that the bulk of the decline in oyster harvest between 1959 and 1976 was associated with the collapse of private seed planting sector following the appearance of MSX in the Chesapeake Bay. In the wake of biological forces altering the production relationships in the fishery there has been a fundamental restructuring in the pattern of resources used in the fishery and in the management structure. There has been a persistent downward trend in the share of the Virginia harvest off leased oyster grounds since 1963.

The analysis presented here indicates that the decline in Virginia oyster harvests off private grounds is associated both with reduced willingness to plant seed oysters and on a reduced yield of market oysters from seed oysters actually planted. The willingness to plant seed has declined both because of low expected yields of market oysters from planted seed oysters and because of the unfavorable price-cost relationship facing prospective planters.

The price-cost relationship between seed oysters and market oysters in turn depends upon costs of harvesting seed and the expected yield and price of seed. Over time these factors have tended to make seed planting and by extension private grounds harvest less attractive.

After a period of sustained low harvest, the public grounds oyster sector rebounded sharply from 1978 and 1980. This development was not predicted by the model. An important change in policy toward the public grounds oyster fishery was initiated in 1978 when the Virginia General Assembly established management areas in Pocomoke and Rangier Sounds within which the Virginia Marine Resources Commission was granted flexibility in the management of the oyster fishery and other fisheries. (Va. Code Ann., Sec. 28.1-128.1, 1982, Supp.) In 1982 the General Assembly expanded the grounds included in this management area to include those portions of the Chesapeake Bay mainstem immediately west of Tangier Island. (Va. Code Ann, Sec. 28.1-128.7, 1982, Supp.) The 1982 legislation also created a second management area within which the commission has flexible authority over the oyster and clam fisheries. This second management area is in the Chesapeake Bay mainstem between

Smith Point and Windmill Point. (Va. Code Ann., 28.1-128.3, 1982, Supp.) In these management areas, in contrast to most other public oyster grounds, the use of dredges to harvest oysters is permitted.

It is impossible to determine, at the present time, the extent to which the designation of management areas has been responsible for recent increases in public grounds oyster harvest. It is also difficult to predict whether these increased levels of production are sustainable or whether they represent a depletion of stock resource to the extent that future yields will be impaired. This stock resource consists both of natural cultch and the accumulation of oyster population on that cultch.

A number of policy alternatives exist which have the potential to significantly expand oyster output and income to the harvest sector. The policies which have been examined in this chapter all fall within the range of incremental changes. Within this range policies have been examined which have the potential for increasing Virginia oyster harvest by some 50% over baseline projections.

Although Table IV-12 and IV-13 indicate that the greatest potential for increased production comes from leased grounds, innovative public management may be able to yield similar increased in output from the public grounds. The nature of the policies which are adopted determines the distribution of the benefits from those policies. Because of the inter-relationships between the seed sector, the private ground fishery, and the public grounds fishery, a mix of policies may be required to benefit all segments of the oyster industry.

CHAPTER V

CONCLUSIONS

5.1 BACKGROUND

The discussions presented in the previous chapters indicated that the decline in Virginia oyster harvests and revenues has been the result of a complex mix of biological, economic and institutional factors. In this chapter the historical record of the Virginia oyster fishery will be highlighted and the sources of change identified. Impacts of possible public policy alternatives will be reviewed, and areas in need of future research will be suggested. Among these research areas are the impacts of basic changes in the institutional structure of the oyster fishery, which could not appropriately be modeled using the techniques employed in this study.

5.2 A REVIEW OF THE DECLINE OF THE VIRGINIA OYSTER FISHERY

This study focuses on the factors associated with the decline in harvest from the approximately 20,000,000 pounds harvested in the 1950's to about 5,000,000 pounds in the early 1970's and the subsequent recovery to around 8.5 million pounds in the 1980's. The data clearly indicate that the major portion of the decline has been on the private grounds.

Of the total decline in harvest between 1958 and 1980, 4,089,000 Virginia bushels or 98.2% of the decline was accounted for by change in private grounds harvest. Although this trend seems to run contrary to much of the literature (Agnello and Donnelley, 1975a, 1975b, 1975c, 1976, Christy, 1964, Alford, 1975) which points out the problems associated with management of a common property natural resource, the issue cannot be adequately addressed without considering the seed sector which is managed as a common property natural resource and where seed set has declined and high cost harvest methods are required.

Through the seed-sector the private grounds fishery is dependent on the public grounds common-property oyster resource to a degree comparable to the public grounds fishery. To develop an analysis of the relative efficiency of private property as a management system for the oyster fishery as opposed to common property without looking at the links between the private grounds and the public ground seed sector is misleading.

The economic model developed here suggests that historically biological forces have been most prominent in the decline in both private and public grounds harvest. On the public grounds the economic effect (which represents the change in deflated ex-vessel prices) is positive between 1964 and 1972; since 1972 the economic effect has been negative. On the private grounds the economic effect (which represents the relationship between market oyster prices and seed prices) was positive between 1958 and 1973. Thus, the unfavorable economic conditions in the oyster fishery are a fairly recent phenomenon.

In particular, biological conditions in the private sector, reflecting unwillingness of growers to plant seed oysters and the diminished productivity of seed actually planted, has been the major cause of the decline in the Virginia oyster fishery. The unwillingness to plant, in turn is related to unfavorable seed oyster-market oyster price relationships. Thus, in order to expand private grounds harvest, it will be necessary to maintain and enhance the productivity of the seed beds. The revitalization of the seed sector, either for planting on private grounds or for replenishing the public grounds, is essential to the future of the Virginia oyster industry. This revitalization may be done by an expanded public management program to enhance seed oysters populations coupled with measures to encourage the efficient harvesting of seed. This issue will be discussed in greater detail in a later section.

The situation on the public grounds is considerably different due to the fact that harvest off the public grounds involves the exploitation of a wild stock. As such public harvest of oysters, including both market and seed oysters, is more dependent upon environmental conditions than is the planting and harvest of market oysters on private grounds. The investment required to harvest oysters off the public grounds is usually less than for harvest off private grounds, both because it is necessary to plant seed on the private grounds and because, in general, more capital intensive technology is used on the private grounds. On the public grounds, by 1980, harvest approached pre-MSX levels. In contrast 1980-81 seed harvest was near an all-time low, so the need to increase seed harvest if the private market sector is to recover is obvious.

Therefore, a critical point to note is that both the public grounds fishery and the private grounds fishery are, at the present time, dependent upon the productivity of the natural beds. The long-term future of the oyster fishery will depend upon maintenance of natural sources of seed until the feasibility of use of hatchery-reared seed or other alternative seed sources can be demonstrated.

5.3 EVALUATION OF POLICY ALTERNATIVES

The above discussion has indicated that the decline in the Virginia oyster fishery is the result of a complex mix of biological, economic, and institutional factors. The discussion of policy options for the Virginia oyster fishery has suggested that a number of relatively minor changes in public policy are available to expand the output of the oyster fishery. More intensive cultivation of a relatively small area (1000 acres) of idle public grounds, whether by lessees or by individuals licensed to utilize efficient harvesting technology on the public grounds (Scenario 4) could, it is projected, increase harvest by some 4,000,000 pounds, an increase of about 50% over actual 1980 landings or projected 1990 landings with no policy change. When these output expansions are coupled with programs to promote the consumption of oyster products through advertising, quality control, development of new product forms, etc., it is projected that total revenues will increase by some $8.8 million, an increase of 75% over projected 1990 total revenues with no policy change and an increase of 10.0% over 1980 actual conditions. Other policy scenarios offer possibilities for small harvest increase. In particular doubling repletion expenditures results in only a 6% increase in total harvest, although the increase in public harvest (20%) is substantial.

These projections are predicated upon the existence of an adequate supply of seed. The price of seed oysters is exogenous to the current model; seed planters are viewed as being confronted with a perfectly elastic supply of seed to which they respond based on prevailing economic and biological conditions. The model has depicted the seed planting decision but has deliberately excluded the seed price formation process. This involves an implicit assumption that seed prices are perfectly inflexible within the range of the data. While this may be valid over relatively small changes in seed requirements, scenarios involving major increases in seed requirements such as Scenarios 4 and 5, may result in forces which raise the price of seed. (See Harris, Baker and Moody, 1977.) However, a number of policies may exist which can reduce, if not eliminate, these upward forces on seed prices. Some of these untapped potential sources of seed are discussed below.

5.4 POTENTIAL SOURCES OF SEED OYSTERS

Haven, et al, (1978) have noted: "A major problem which will accompany any attempt to grow more market oysters (to increase production) will be a shortage of high quality, low-cost seed. A significant increase in demand for seed caused by a change in management policy or economic conditions will certainly lead to a seed shortage (p. 599)." As with policy options for the market oyster fishery, policies to enhance the seed oyster sector may be aimed at either the private grounds sector or the public grounds sector. Virtually all Virginia seed oysters currently come from the public grounds. Prior to 1960 there was some private seed harvest in the lower James River; since 1960 the great bulk of seed oyster harvest has come from the public grounds. In 1975 about 0.6% of total Virginia seed harvest came from the private grounds. A major increase of the private seed share occurred in 1976 when 18.6% of Virginia seed oysters were produced off private grounds. In all areas of the U.S. other than Virginia, the seed oyster fishery is entirely a public grounds fishery. It should be expected that in Virginia the primary seed producing areas will remain the public bottoms.

A number of management-intensive methods for increasing the harvestable populations of seed oysters exist. Off-bottom culture in suspended traps or on suspended shellstrings are techniques which do not utilize natural bottoms as the setting medium. As a result, they are less sensitive to degradation of the bottom. Also, major research efforts on the development of oyster hatcheries are under way at the Virginia Institute of Marine Science, the Horn Point Environmental Laboratory of the University of Maryland, and the Ira C. Darling Center at the University of Maine. During the 1970's there was a major expansion in oyster harvest in the Middle Atlantic and North Atlantic oyster fisheries, primarily on private grounds using hatchery reared seed to augment public seed and private ground seed. Between 1966 and 1970 oyster harvest in the Long Island Sound off Connecticut increased some ten-fold as a result of expanded oyster culture. MacKenzie (1970b) reports that yields of oysters in the Long Island Sound of Connecticut increased from one bushel of market oysters per bushel of seed planted to ten bushels market per bushel of seed. A detailed description of one oyster farming operation in Long Island Sound is presented in Korringa, (1976), pp. 32-61. Hatchery-reared seed is generally more expensive than seed from either natural public ground seed beds or leased private seed beds. However, in an analysis of the relative advantages of alternative methods of increasing seed availability in Maryland, Krantz found that "...only hatchery procedure, which has only slightly higher production costs, produces predictable yields of seed oysters. (Krantz, 1981, p. 23.)"

Lipshultz and Krantz (1978) have developed linear programming models for optimal operation of oyster hatcheries. Results indicated that there are significant economics to scale in the operation of hatcheries. Further research is needed to determine the magnitude of cost savings attainable with these technologies.

Reducing the costs of harvesting and planting seed from existing sources would also result in greater seed production. Like the harvest of market oysters, the harvest of seed oysters off public grounds is subject to a number of restrictions on permissible harvest technologies. One way to reduce harvest cost, which is not permitted by current law, is the dredging of seed oysters from public seed-beds. More needs to be known about the potential long-term effects on the substrate and on the brood stock of dredging for seed. Haven (1981) reports that a highly efficient suction-type dredge is used in Long Island for the harvest of seed. In addition to mechanizing the harvest of seed, seed costs may be reduced by mechanizing the planting of seed; such mechanical planters are currently in use by several private grounds oyster growers. (Haven, 1981.) A summary of these and other technological changes which could reduce the cost of seed oysters is provided in Haven, et al, (1978, pp. 863-868). Detailed engineering studies of the costs of each of these alternatives are needed before a definitive statement as to the economic benefits of each technological change can be made.

Another alternative for increasing seed production would be to lease a portion of the seed beds to private interests. If the lessees of the seed beds also held oyster-planting ground, it would be possible to vertically integrate these operations so that seed harvest could be coordinated with planting needs. The assignment of seed areas for private use would facilitate the introduction of more efficient harvesting techniques for seed oysters. This policy option significantly expands the role of the private sector of the Virginia oyster fishery.

Nonetheless, the leasing of the public seed beds, like most proposals to expand the role of the private sector in the oyster fishery at the expense (real or perceived) of the traditional public grounds fishery, raises a host of political problems. One way possible to circumvent these problems is to operate the seed oyster fishery as a regulated public utility. There are major differences between this proposal and the current public grounds management system. In particular, the State would play a more active role in managing the level of effort exerted on the public seed beds. The state through an integrated policy of repletion and effort limitation would attempt to match the supply of seed harvested to the demand for seed at a specified price, including both the expected demands of private planters at a specified price and the needs of the public repletion program.

Although the operation of the seed sector as a public utility may have some beneficial effects by possible reducing the price of seed and uncertainty of seed supply, (as would vertical integration of the seed oyster-market oyster sector), if current harvest and seed growing technologies continue to be employed there is little reason to expect the cost of seed oysters to come down without an increase in public subsidies. Since there is and will likely continue to be a subsidy component of the repletion program, the distributional consequences of policies designed to enhance the oyster fishery need to be considered. A policy constrained by a need to maintain all or most of the traditional seed tongers may be unable to attain the monetary cost savings and output expansions projected with technically efficient harvest technology for seed oysters. Both leasing of public seed beds and operation of the seed beds as a public utility can be represented by Scenario 3 above.

5.5 MODERNIZING THE HARVEST AND PROCESSING SECTORS

Increasing the availability of seed oysters to the fishery is only one part of a plan to expand oyster production. The oyster fishery in Long Island Sound has been a leader in the development of more intensive oyster culture techniques, in addition to development of new sources of seed oysters. MacKenzie (1981) summarized the experience of the Long Island Sound oyster fishery with the advent of intensive private culture activities:

> An irruption of oyster abundance after years of low-yield in Long Island Sound proved that removal of limit ing factors in beds by application of specific methods and technologies is highly successful. Adequate knowledge obtained from field and laboratory studies about thesefactors made the application possible. Throughout the world, molluscan production for human consumption is largely derived from uncultured beds. Knowledge of the factors that limit molluscan abundance in these beds has heretofore been too scanty to permit culture, but it could be obtained with modern research methods. This would then open up the possibility of culture of the beds and multifold increases in molluscan abundance and production (p. 265).

More recently researchers at the University of Delaware and elsewhere have developed a closed-cycle mariculture system for the production of oysters (see Epifanio, Srna and Pruden, (1975), Thielkers (1981), and Epifanio, Pruden, Hartman and Srna (1973).

The development of intensive aquaculture can be facilitated or hampered by the legal and institutional structure within which such development takes place. In 1980 the National Aquaculture Act was passed with the stated purpose of promoting aquaculture by coordinating domestic programs and increasing the availability of fisheries resources. Further, the legislation has as its purposes: (1) declaring a national aquacultural policy; (2) establishing and implementing a national aquacultural development plan; and (3) encouraging aquaculture activities and programs in both the public and private sectors of the economy. (16 U.S.C. Sec. 2801, 1983, Supp.)

Because Virginia policy has promoted the simultaneous development of private and public oyster fisheries there may be fewer problems in adopting a system of intensive aquaculture than in another state (such as Maryland) where the public grounds have traditionally been dominant. Bockrath and Wheeler (1975) note that "the Virginia Code exhibits a progressive attitude toward privately owned fisheries, citing as an example possession and sale of artificially propagated trout." (Va. Code Ann., Sec. 29.014, 1979.) Although the provision dealing with trout is necessitated by specific laws governing the possession of fish taken from inland waters a similar provision would clarify the status of oysters grown in closed mariculture systems.

Three types of property systems under which mariculture may occur are identified by Bowden (1981): (1) private property, (2) public property; and (3) common property. Although there are difficulties with all of the above approaches, the notion of common property may have the fewest flaws. He defines a common property natural resource as one which is "held by a class of users whose rights are co-equal (p. 177)." Common property allows for public regulation in the public interest while at the same time allowing room for private investment and initiative. However, evidence suggests that in oyster aquaculture as in other types of oyster harvest throughout history, public management has imposed inefficiency on the fishery. (See Power, 1970.)

The 1980 National Aquaculture Act directs the Secretaries of Agriculture, Commerce and Interior to establish a National Aquaculture Development Plan which includes programs "to analyze, and formulate proposed resolutions of, the legal or regulatory constraints that may affect aquaculture. (14, U.S.C. Sec. 2803 (b) (5), 1981, Supp.)" Policies to encourage the development of commercial aquaculture will necessitate a re-examination of a number of regulations which tend to impose inefficiency on the oyster fishery. One major class of restrictions is the limitation of gears which may be used on the public oyster grounds.

5.5.1 Gear Restrictions

There are a number of types of dredges and harvesters available which are able to harvest oysters more efficiently than conventional tow dredges and patent or hand tongs. (See Haven (1980) and Kennedy and Breisch (1981).) The adoption of one or more of these types of harvester for use on the private grounds or on the public grounds (with adequate administrative oversight) could significantly reduce harvest costs.

There is evidence that a positive externality resulting from the proper use of such dredges is the exposure of fresh shell surfaces which provide better surfaces to obtain higher natural sets of oysters. Evidence suggests that the use of harrows or bagless oyster dredges can result in a two-fold to five-fold increase in natural set over what can be obtained on untreated bottoms. (Haven, et al, (1978), pp. 849-855, Haven (1980), Sayce and Larson (1966).) The above evidence suggests that it may be possible to utilize dredges, subject to proper regulatory control, on public grounds to increase harvest efficiently and potentially increase the set of oysters on exposed shell surfaces. In addition to changes in harvest technology, another source of potential cost saving to the Virginia oyster industry may lie in the processing sector.

5.5.2 Modernizing the Processing Sector

Like other parts of the oyster industry the processing sector uses technology which, on the whole is little changed from techniques used hundreds of years ago. The National Marine Fisheries Service has developed programs to fund research and development "projects to improve storage techniques, improve processing or prevention methods to determine other methods which would increase the ability of the industry to utilize available fish resources and provide an increased variety of safe, wholesome and nutritious fish and fish products to consumers. (44 Federal Register No. 222, November 15, 1979, P. 65807.)" The development of an improved oyster shucker would serve to promote the economic well-being of many sectors of the Virginia oyster industry. Having looked at some of the technological developments occurring in the oyster industry, it will be helpful now to look at the public management issues associated with the changing character of the Virginia oyster fishery.

5.6 A PROPOSED MANAGEMENT FRAMEWORK FOR THE VIRGINIA OYSTER INDUSTRY

The dual public-private oyster fishery has a long history in Virginia. Given that many of the same problems beset the oyster fishery today as beset it in the late 1800's, when the current structure was established, there is reason to carefully consider the consequences of altering the management of the fishery so that it becomes totally dependent upon either the public grounds or the private grounds (or aquaculture or some other similar new system or institution). The cultivation and harvest of oysters is beset by a multitude of uncertainties and factors largely outside human control. Since private grounds harvest and public grounds harvest represent different systems of production, which exhibit differential vulnerability to different environmental stresses, there is some advantage to maintaining the dual system as a means of risk reduction from the perspective of maintaining the industry output as a whole. Further, a program which maintains the health of the public grounds sector, the private grounds sector, and the seed sector, even if in a changed form from what exists today, is apt to be more politically acceptable than a system which eliminates one or more of these sectors.

The first necessary step in countering the decline in oyster setting, in order to increase the density of oysters on the public grounds, is to assess the severity of the decline in different areas and to assess the cause or causes in each area. Much of the basic work in this area has been done and is reported in Haven, Hargis and Kendall (1978) and in Haven, Whitcomb and Kendall (1981). Once the condition of specific oyster bars is known, public repletion expenditures can be directed at those bars where the expected return over costs is greatest. Further, the public oyster resources must be incorporated into a planning program which recognized the multiple uses of the Chesapeake Bay and its tributaries, as well as seaside oyster grounds. The utilization of more capital intensive harvest technologies may create external effects not only on other oyster harvesters, but also on a variety of users of the coastal zone. (See Evans, 1980.) The identification of the areas particularly well suited for oyster harvest will need to take into account other competing uses for the waters and bottoms in the affected area. Public managers will have to play a leading role in identifying areas with high potential productivity either for exploitation as seed areas, for harvest of wild oyster stocks, or for intensive management and cultivation.

After the productive capacity of different locations has been determined the next part of the management program is for resource managers to assess the amount of fishing pressure which each area can optimally absorb. This will require continued oversight of the fishery to ensure that: (1) effective use is being made of the oyster resource; and (2) the resource base (oyster cultch) is maintained at some acceptable level, which may change over time.

The management of effort on the public grounds can take a number of forms. Stokes (1979) argues that programs to limit effort in a fishery can be judged on the basis of three criteria: (1) conservation; (2) economic efficiency; and (3) equity. Crutchfield (1961, p. 139) argues that "the ideal form of management would achieve the necessary restriction of fishing mortality while permitting use of the most efficient techniques known and encourage further cost-reducing research and innovation. Curtailment of fishing mortality would be accomplished by limiting the number of these optimal units to a level where their full-time use would produce only the permitted catch." Crutchfield's "ideal form of management" ignores the equity issue; the neglect of the equity issue will likely be politically and socially unacceptable so long as common property resources are involved and so long as the industry is receiving or is perceived as receiving a "subsidy" from general revenues. The ideal form of management will have to make allowance for these equity concerns.

Increased management, even if designed to enhance the survival of traditional oyster harvest techniques, is likely to meet with resistance from hand tongers on public grounds. McCay (1981) in a study of the New Jersey fishery has explained the opposition of traditional harvesters to technological innovation. She states, "Fishing (including lobstering and clamming) is one way that people in an industrialized society can maintain relative independence and gain personal satisfaction from their work. The penetration of capital and organizational forms of capitalism into fishing has been halting and incomplete because of the great risks involved in what is essentially a foraging or hunting activity (McCay, 1981, p. 376)."

Increased management, whether public or private, can reduce risk and this in turn, may attract new capital to the fishery. The choice of a management structure, then, depends upon how much and what types of technical in- efficiencies one is willing to permit to maintain a style of life for a relatively small number of tongers. It is proposed here that one more captial-intensive technology be phased in over a period of time to allow existing tongers a period to adjust and to be retrained for employment either in other parts of the seafood industry or in non-fishery related activity.

5.7 BAYWIDE MANAGEMENT OF THE OYSTER FISHERY

Since 1967 the processing and handling sector of the Virginia oyster in- dustry has handled more oysters imported from out-of-state than oysters harvested in Virginia (VMRC, 1982). Most of these imports come from Maryland where the public expenditures on oyster replenishment have exceeded revenues from oyster taxes by more than one million dollars per year. At present tax rates, Virginia derives in excess of $35,000 per year in tax revenues from imported oysters. The employment and income generated by the oyster packing and processing activity associated with imported oysters also contributes to the Virginia economy. The present research indicates that oyster prices are relatively inflexible so that high levels of Maryland imports do not appear to exert a major downward pressure on Virginia prices.

This interdependence suggests that there may be significant potential gains from interstate cooperation between Maryland and Virginia in management of the Chesapeake Bay oyster fishery. A further impetus for interstate cooperation is the changing judicial climate with respect to residency requirements for ex- ploiting fish and wildlife including, perhaps, oysters. In 1977 the U.S. Supreme Court in Douglas v Seacoast Products (431 U.S. 265, 1977) ruled that Virginia's refusal to issue a license to an out-of-state corporation which had been licensed under federal enrollment and licensing laws constituted a violation of the supremacy clause of the Constitution. The licensing provisions in question in the Douglas case have since been repealed and replaced by a procedure for issuing certificates of documentation and coastwise licenses and fishing licenses which authorize employment in the fisheries explicitly including the harvest of shellfish (46 U.S.C. 65-65w 1982, Supp.). Thus, the principle that Federally licensed nonresidents cannot lawfully be excluded from the fishery appears to be still applicable to the oyster fishery. (This view is supported by

Lewis and Strand, 1978 and Lewis and Power, 1979. For an alternative interpretation see Note; Rutgers Camden Law Journal, 1977).

Regardless of the legal question of whether or not nonresidents can lawfully be excluded from the oyster fishery of a state there is significant potential for intergovernmental cooperation between Virginia and Maryland to improve the utilization of the oyster resources of the two states. Some cooperation between Virginia and Maryland is already occurring under the Potomac River Fisheries Compact. Under this Compact the Potomac River Fisheries Commission, a citizen commission composed of three members from Maryland and three members from Virginia, has the authority to "by regulation prescribe the type, size and description" of oysters and other shellfish and finfish which may be taken or caught, the places where they may be caught, and the manner of taking or catching (Potomac River Compact Va. Code Ann. Sec. 28.1-203, Article III, Sec. 2, (1979).

The authority of the Potomac River Fisheries Commission is in many ways parallel to the authority granted to the VMRC to regulate the fisheries in the Tangier/Pocomoke Sound and Smith Point/Windmill Point Management Areas, although in the latter area this authority is restricted to regulation of the oyster and clam fisheries.

In addition, the Potomac River Fisheries Commission has the authority to reseed and replant the oyster bars within the jurisdiction of the Commission. In 1982 the Commission's authority to permit dredging was expanded and the Commission was given the authority to levy repletion fee on dredge operators within its jurisdiction (Va. Code Ann. Sec. 28.1-229, 1982, Supp.).

Research should be undertaken to study the feasibility of applying a management framework similar to that used by the Potomac River Fisheries Commission to the Chesapeake Bay oyster fishery.

5.8 CONCLUSIONS

1. The oyster resource of Virginia has the potential to yield a bountiful harvest. Constraints on realized output include:

   a. high costs of cultivating oysters

   b. limited management capabilities of those (both public and private) involved in cultivating and harvesting oysters

   c. a regulatory structure which offers strong disincentives to the introduction of new cost saving technology; and

   d. an industry structure which has been slow to respond to changing biological and economic conditions.

2. Changing environmental conditions have significantly reduced the profitability of planting seed oysters. This reduced profitability is attributable both to higher seed costs relative to

generally stable market oyster prices, and to diminished productivity of grounds on which seed is planted.

3. The decline in the private grounds fishery has resulted in an increased relative importance of the public fishery. There is a willingness on the part of public management officials to allow more efficient (and potentially more damaging to the resource base) harvest technologies, at least in limited areas. While these policies have resulted in an increase in harvests in the short-run the long-term effects of the increased fishing pressure on oyster stocks is unclear and the condition of oyster populations in public grounds will require continued scrutiny.

4. Utilizing the oyster resource for increased productivity can be accomplished either by increased private management or by increased public management or both. The management structure should encourage flexible response to changing conditions and foster innovation, while exhibiting an awareness of and concern for the importance of traditional ways of life in the oyster fishery.

5. Tax revenues from the incremental harvest attributable to the public repletion program do not cover the costs of the program. However, public officials (VMRC, 1982) indicate a desire to maintain both a private grounds fishery and a public grounds fishery. It is doubtful that such a fishery can exist without

public involvement in a repletion program. There is strong evidence (VMRC, 1982) that repletion planting of seed and shell are not made in an economically or biologically optimal way. With the costs of the repletion program increasing, there is a need to ensure that repletion planting are made on the basis of adequate biological and economic knowledge.

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COURT CASES

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Appendix A

DEVELOPMENT OF AN INDEX OF BIOLOGICAL PRODUCTIVITY OF THE PUBLIC OYSTER BEDS OF VIRGINIA

Background and Data

As part of the larger effort to understand changes in oyster harvest in Virginia, it is desirable to obtain some measure of the biological productivity of the public oyster beds of Virginia. Data on the productivity of these beds, as measured by number of large oysters per bushel of bottom sample, number of small oysters and yearlings per bushel, and number of spat per bushel, is available for twenty-three of bars within five river systems (James, York, Rappahannock, Piankatank and Corrotoman) for a number of years between 1946-47 and 1975-76. The purpose of this section is to develop a statistical model to explain variation in the density of large oysters across bars, river systems and time, where time is a proxy for a number of unmeasured factors affecting the productivity of the grounds differentially.

Model Development

The basic model was formulated as:

$$LARGE_{ijk} = a + b_1Y_i + b_2X_{j(i)} + b_3T_k + E_{ijk}$$

where:

$LARGE_{ijk}$ = the reported density of large oysters (number/bushel of unculled bottom) from bar j located in river system i during time period (season) k.

Y_i = a series of 0-1 dummy variables with values as shown below:

Y_1 = 1 if from James River; 0 otherwise,
Y_2 = 1 if from York River; 0 otherwise,
Y_3 = 1 if from Piankatank River; 0 otherwise,
Y_4 = 1 if from Rappahannock River; 0 otherwise,
$Y_1 = 0$; $Y_2 = 0$; $Y_3 = 0$; and $Y_4 = 0$ if from Corrotoman River.

X_j = a series of 0-1 bar dummies; as shown below:
X_5 = 1 if from Brown Shoal; 0 otherwise,
X_6 = 1 if from Wreck Shoal; 0 otherwise,
X_7 = 1 if from Point of Shoals; 0 otherwise,
X_8 = 1 if from Horse Head Shoals; 0 otherwise,
$X_6 = 0$; $X_7 = 0$; $X_8 = 0$; and $X_9 = 0$ if from Deep Water Shoal.

X_{11} = 1 if from Green Rock; 0 otherwise,

X_{12} = 1 if from Page Rock; 0 otherwise,

X_{13} = 1 if from Aberdeen Rock; 0 otherwise,

X_{11} = 0; X_{12} = 0; X_{13} = 0 if from Bell Rock.

X_{15} = 1 if from Burton Point; 0 otherwise,

X_{16} = 1 if from Middle Ground; 0 otherwise,

X_{17} = 1 if from Palace Bar; 0 otherwise,

X_{15} = 0; X_{16} = 0; and X_{17} = 0 if from Ginny Point.

X_{19} = 1 if from Drumming Grounds; 0 otherwise,

X_{20} = 1 if from Hogg House; 0 otherwise,

X_{21} = 1 if from Smokey Point; 0 otherwise,

X_{22} = 1 if from Morratico Bar; 0 otherwise,

X_{19} = 0; X_{20} = 0; X_{21} = 0, and X_{22} = 0 if from Bowler Rock.

X_{24} = 1 if from Corrotoman Point; 0 otherwise,

X_{25} = 1 if from Middle Grounds; 0 otherwise,

X_{26} = 1 if from Island Bar; 0 otherwise,

X_{27} = 1 if from Black Stump; 0 otherwise,

X_{24} = 0; X_{25} = 0; X_{26} = 0; and X_{27} = 0 if from Shelton Point.

T_k = a series of 0-1 time period dummies as shown below:

T_1 = 1 if year is before 55-56 season; 0 otherwise,

T_2 = 1 if year is between 60-61 season and 66-67 season inclusive; 0 otherwise,

T_3 = 1 if year is between 1967-68 season and the 1971-72 season inclusive.

T_4 = 1 if year is after the 1971-72 season.

T_9 = 1 if year is between 1967-68 season and the 1972-73 season, inclusive.

T_{10} = 1 if year is after the 1972-73 season.

In the initial model the base period (where T_k = 0, for all k) was the period between the 1956-57 season and the 1959-60 season inclusive.

Note: A possible shortcoming of the present model is that it doesn't consider the interaction between biological factors and geographical areas, which would provide some measure of the different impact of these factors by area.

Results, Interpretation, and Refinements

The initial model was run including all the river dummies, all the bar dummies and time dummies T_1, T_2, T_3 and T_4. The results of this regression are presented in Table A-1 below.

The time periods were chosen to capture the effects of important natural events, such as the appearance of MSX in 1959-60, spillover effects from the decline in seed planting on leased grounds around 1960 which shows up as a decline in brood stock several years later, impacting on public ground oyster densities, Hurricane Agnes in 1972, etc.

The time period variable reflects the major biological forces affecting the fishery. An alternative approach would be to allow the index to take on a unique value each year. This approach was rejected because the oysters of a number of different ages (multiple cohorts) are in the harvestable population and because of the importance of one-time events, either negative (such as disease) or positive (such as exceptionally high spatfall). The effects of such one-time events is likely to be felt over a period of several years. The time variable thus is a measure of harvestable oyster populations.

Since all the variables in the model are dummy variables, the expected large oyster density on any bar in any river system in any time period may be calculated by taking the intercept value 47.78 which

TABLE A-1

Parameter Estimates for Full Oyster Density Model

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB !T!
Intercept	1	47.781628	7.208019	6.6290	0.0001
Y1	1	-16.216981	9.190607	-1.7645	0.0784
Y2	1	18.953184	9.107218	2.0811	0.0380
Y3	1	-6.997655	10.202093	-0.6859	0.4932
Y4	1	-1.287228	10.003697	-0.1287	0.8977
X6	1	38.144387	8.890294	4.2906	0.0001
X7	1	13.364281	8.725071	1.5317	0.1264
X8	1	21.574164	10.577211	2.0397	0.0420
X9	1	0.963246	9.085125	0.1060	0.9156
X11	1	-45.678397	9.638090	-4.7394	0.0001
X12	1	-23.041014	8.785219	-2.6227	0.0090
X13	1	-18.869565	8.876891	-2.1257	0.0341
X15	1	-3.858396	11.670827	-0.3306	0.7411
X16	1	1.003339	12.708151	0.0790	0.9371
X17	1	12.371992	12.695401	0.9745	0.3304
X19	1	15.007752	9.821340	1.5281	0.1273
X20	1	15.719291	9.915372	1.5853	0.1136
X21	1	21.681665	9.651362	2.2465	0.0252
X22	1	3.521665	9.651362	0.3649	0.7154
X24	1	21.909014	9.187197	2.3847	0.0175
X25	1	-0.371357	10.030446	-0.0370	0.9705
X26	1	0.293501	9.697332	0.0303	0.9759
X27	1	-7.370739	10.018767	-0.7357	0.4623
T1	1	-0.750483	4.851214	-0.1547	0.8771
T2	1	-12.135320	4.169590	-2.9104	0.0038
T3	1	-17.652664	4.816594	-3.6850	0.0003
T4	1	-14.297285	4.880015	-2.9298	0.0036

represents the expected large oyster density on the base bar (Shelton Point) in the base river (the Corrotoman) in the base time period (1956-57 through 1959-60 inclusive) and adjusting for the bar effect (given by the coefficient on the corresponding bar dummy variable x), the river effect (given by the coefficient on the corresponding river dummy Y_i), and the time effect (given by the coefficient on the corresponding time dummy T_k). For example, to compute the predicted large oyster density on Green Rock (X_{11}), which is located in the York River (Y_2) in time period T_2 (1960-61 through 1966-67) calculate:

$$\underset{\text{(base)}}{47.78} + \underset{\text{(river effect)}}{18.95} + \underset{\text{(bar effect)}}{0.96} - \underset{\text{(time effect)}}{12.14} = 55.55 = \text{LARGE}_{Y_2 X_{11} T_2}$$

In attempting to refine this model, several changes were made:

1. Dummy variables with statistically insignificant coefficients for rivers and bar were pooled into the intercept (for rivers) or into the river effect (for bars).

2. Since the coefficient on T_1 was insignificant, T_1 was pooled into the base time period.

3. Since the size of coefficients on T_2, T_3 and T_4 was similar, alternative times periods were examined in an effort to better describe the temporal effects (believed to represent unmeasured biological factors) acting upon oyster populations.

The best results, as determined by R^2, F-ratio and t-statistics were obtained using time dummies T_2 (1960-61 season to 1966-67 season inclusive), T_9 (1967-68 season to 1971-72 season inclusive), and T_{10} (1972-73 season and after). The results obtained using these time periods only those river dummies and bar dummies which are significantly different from the base areas are reported in Table A-2.

The model shown in Table A-2 is used to derive expected values for the large oyster density on each bar within each river for each time period using the decomposition:

> Predicted value = Base value + Bare effect + River effect + Time effect. Results are shown in Table A-3.

The figures in Table A-3 give a measure of the biological productivity of the different bars and river systems in different time periods. In order to incorporate these data into a time-series productivity model, a system of weights must be developed to account for the relative importance of each bar to the oyster fishery in each river

TABLE A-2

Parameter Estimates for Final Oyster Density Model

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB !T!
Intercept	1	45.734879	3.011780	15.1853	0.0001
Y1	1	-13.436671	5.064140	-2.6533	0.0083
Y2	1	21.135866	6.625011	3.1899	0.0015
X6	1	37.436185	7.524467	4.9753	0.0001
X7	1	12.664374	7.334200	1.7268	0.0849
X8	1	20.494101	9.385740	2.1835	0.0295
X11	1	-45.899853	9.486501	-4.8384	0.0001
X12	1	-23.077948	8.650919	-2.6677	0.0079
X13	1	-18.869565	8.742038	-2.1585	0.0314
X19	1	15.813908	6.621884	2.3881	0.0174
X20	1	16.727949	6.750617	2.4780	0.0136
X21	1	22.506206	6.387906	3.5233	0.0005
X24	1	23.599064	6.752215	3.4950	0.0005
T2	1	-12.401716	3.470040	-3.5739	0.0004
T9	1	-20.560129	3.851469	-5.3383	0.0001
T10	1	-8.284785	4.760252	-1.7404	0.0825

system and for the relative importance of each river system in the context of the Virginia public oyster rocks.

Data on oyster harvest, even when it is available by river system, does not directly reflect information on the biological conditions of the fishery. Catch is affected not only by the biological stock being exploited but also by the amount of nominal effort (for example boat-days) applied to the fishery and by the fishing power of each nominal efforts unit. Thus, it is believed that data such as that presented in Table A-3 can serve as useful inputs into a productivity model of the Virginia oyster fishery when appropriately weighted. One possible weighting scheme is to weight each bar within a river system equally. In this case the predicted value of large oysters per bushel of bottom for each river system takes the values shown in Table A-4.

The next step involved in computing an index of biological productivity for the Virginia public oyster fishery for inclusion in a time-series model is to aggregate the data in Table A-4 into a single measure for each time period. For completeness it will be necessary to include areas of the public rocks outside of the five river systems listed in Table A-4 in the computation of this index. The acreage of public oyster grounds by region for the year 1970 is presented in Table A-5.

TABLE A-3

Predicted Large Oyster Density by Bar and Time Period (Number/Bushel Bottom Sample)

BAR	1949-50 to 1959-60	1960-61 to 1966-67	1967-68 to 1971-72	1972-73 to 1975-76
+ Brown Shoal	69.73	57.33	49.17	61.45
+ Wreck Shoal	44.96	32.56	24.40	36.68
+ Point of Shoal	52.79	40.39	32.23	44.51
+ Horse Head Shoal	32.24	19.89	11.73	24.01
+ Deep Water Shoal	32.24	19.89	11.73	24.01
++ Green Rock	20.97	8.57	0.41	12.69
++ Page Rock	43.79	31.39	23.23	35.51
++ Aberdeen Rock	48.00	35.60	27.44	39.72
++ Bell Rock	66.88	54.48	46.32	58.60
+++ Burton Point	45.73	33.33	25.17	37.45
+++ Middle Ground	45.73	33.33	25.17	37.45
+++ Palace Bar	45.73	33.33	25.17	37.45
+++ Ginny Point	45.73	33.33	25.17	37.45
++++ Drumming Ground	61.54	49.14	40.98	53.26
++++ Hogg House	62.46	50.06	41.90	54.18
++++ Smokey Point	68.24	55.84	47.68	59.96
++++ Morratico Bar	45.73	33.33	25.17	37.45
++++ Bowler Rock	45.73	33.33	25.17	37.45
+++++ Corrotoman Point	69.33	56.93	48.77	61.05
+++++ Middle Ground	45.73	33.33	25.17	37.45
+++++ Island Bar	45.73	33.33	25.17	37.45
+++++ Black Stump	45.73	33.33	25.17	37.45
+++++ Shelton Point	45.73	33.33	25.17	37.45

TABLE A-4

Predicted Oyster Density (Large Oysters/Bushel Bottom) by River System Weighting Each Bar Equally

RIVER	1949-50 to 1959-60	1960-61 to 1966-67	1967-68 to 1971-72	1972-73 to 1975-76
James	46.41	34.01	25.85	38.13
York	44.92	32.51	24.35	36.63
Piankatank	45.73	33.33	25.17	37.45
Rappahannock	56.74	44.34	36.18	48.46
Corrotoman	50.45	38.05	29.89	42.17

No data comparable to the grab sample data for the James, York, Rappahannock, Piankatank and Corrotoman river systems exist for the Bayside and the Seaside of the Eastern Shore. Recent surveys of the condition are the Baylor bottoms in these areas have indicated that the bulk of the acreage of the Baylor grounds on the Bayside and Seaside of the Eastern Shore had low productivity potential based on the prevalence of sandy or muddy bottom conditions. (Haven, Whitcomb and Kendall, 1981, Vol. 2, pp. 67 and 122.) The productivity potential of the Baylor grounds for the Bayside and Oceanside of the Eastern Shore as evaluated by Haven, Whitcomb and Kendall is shown in Table A-6.

Oysters from the seaside of the Eastern shore generally suffer lesser mortality from MSX than do oysters from the seaside of the Eastern Shore suffer mortality from Seaside Organism (*Minchinia costalis*) which does affect oysters in the Chesapeake Bay and its tributaries. In addition oysters from the Seaside more susceptible to predation from oyster drills than are oysters from the Bay.

Between 1952 and 1955 only 3.4% of the oysters landed from public grounds came from the ocean, and between 1972 and 1976 only 25% of the oysters landed from the public grounds came from the ocean. Lack of quantitative data on the productivity of these grounds makes it infeasible to include these areas, which make up some 81,000 acres or roughly 1/3 of the total public grounds in Virginia, in the construction of the productivity index. This, in constructing the weighting system

TABLE A-5

Acreage of Public Oyster Grounds by Region - 1970

POOLED INTO	REGION	ACREAGE OF PUBLIC GROUND (1970)
Rappahannock	Potomac	2,988
Corrotoman	Little and Great Wicomico and Indian Creek	24,438
Rappahannock	Rappahannock	55,185
Piankatank	Piankatank	15,297
York	York	3,850
York	Mobjack Bay and Horn Harbor	24,634
York	Poquoson	3,447
James	James River System	27,841
	Eastern Shore Bayside	36,623
	Eastern Shore Seaside	44,591
	Total	238,894

TABLE A-6

Productivity Potential of the Bayside and Oceanside of the Eastern Shore

POTENTIAL	BAYSIDE PERCENT	SEASIDE PERCENT
High	4.9%	1.2%
Moderate	14.0%	16.5%
Low	81.1%	82.3%

(Computed from data in Haven, Whitcomb and Kendall, 1981, Vol. 2, pp. 67-122.)

the 81,214 acres on the Eastern Shore were omitted. In 1970, therefore, the base acreage divided into five areas was 162,057 acres. Those western shore areas not lying in one of the five river systems for which productivity indices were constructed were assigned to the geographic area to which they were closest.

Another problem to be faced in developing a weighting system is that there have been additions to the public grounds during the time period under study. This implies that if the river systems are to be weighted on the basis of acreage, then each time an area is added to the public grounds then the weight system in which the added acreage is located must increase relative to the weights on other river system.

The acreages in the pooled river systems and their relative weights for 1960 (such that the weights sum to 1) are shown in Table A-7.

Since there were additions to the public grounds during the time period of this study, it will be necessary to alter the weights for each addition to the public grounds if the logic of weighting river systems by acreages is to be maintained. Additions to the public grounds since 1950 are shown in Table A-8.

Adjusting the 1970 acreages for these changes it is possible to construct a system of weights for each year in the 1950-76 study period as shown in Table A-9.

TABLE A-7

Acreages of Public Grounds and 1970 Weights for Five River Systems for which Predicted Oyster Densities are Calculated

RIVER SYSTEM	ACRES (A_i)	WEIGHTS $\frac{A_i}{\Sigma A_i}$
* James	27,841	.18
** York	31,931	.20
*** Rappahannock	58,173	.37
**** Piankatank	15,297	.10
***** Corrotoman	24,438	.15
ΣA_i	157,680	

* Includes those areas in the James River System

** Includes those areas in the York River, Poquoson River, Mobjack Bay and Horn Harbor

*** Includes those areas in the Rappahannock and Potomac Rivers

**** Includes those areas in the Piankatank River

***** Includes those areas in the Corrotoman River, Little and Great Wicomico Rivers, and Indian Creek

TABLE A-8

Additions to the Public Oyster Grounds Since 1950

YEAR	LOCATION AND RIVER SYSTEM	ACREAGE
1954	Piankatank River and Milford Haven	1130
1956	Piankatank River	490
1956	Pocomoke Sound*	485
1958	Mobjack Bay (York River System)	600
1958	Poquoson River (York River System)	6170
1958	Piankatank River	340
1958	Chesapeake Bay*	685
1958	Potomac River** (Rappahannock River System)	2988
1981	Piankatank River***	

* Since grab sample data for Eastern Shore Area are unavailable, this area was not included in the analysis.

** The Potomac River Compact of 1958 guaranteed Virginia residents the right to take oysters from the Potomac River. Management of the Potomac oyster resources is of a qualitatively different nature than management of the oyster resource in the rest of the Commonwealth.

*** The 1981 amendment to 62.8-154 added an undetermined acreage to the public grounds in the Hole in the Wall - Milford Haven area of the Piankatank River system.

TABLE A-9

Development of a Weighting System for River Systems for the 1950-1976 Time Period

	RIVER SYSTEM									
	JAMES		YORK		RAPPAHANNOCK		PIANKATANK		CORROTOMAN	
YEAR	ACRES	Wt.	ACRES	Wt.	ACRES	Wt.	ACRES	Wt.	ACRES	Wt.
1950	27841	.19	25161	.17	55185	.38	13677	.09	24438	.17
1951	27841	.19	25161	.17	55185	.38	13677	.09	24438	.17
1952	27841	.19	25161	.17	55185	.38	13677	.09	24438	.17
1953	27841	.19	25161	.17	55185	.38	13677	.09	24438	.17
1954	27841	.19	25161	.17	55185	.38	13677	.09	24438	.17
1955	27841	.19	25161	.17	55185	.37	14807	.10	24438	.17
1956	27841	.19	25161	.17	55185	.37	14807	.10	24438	.17
1957	27841	.19	25161	.17	55185	.37	15297	.10	24438	.17
1958	27841	.19	25161	.17	55185	.37	15297	.10	24438	.17
1959	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1960	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1961	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1962	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1963	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1964	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1965	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1966	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1967	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1968	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1969	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1970	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1971	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1972	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1973	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1974	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1975	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17
1976	27841	.18	31931	.20	58173	.37	15297	.10	24438	.17

The final step involved in constructing a single biological productivity index for the Virginia oyster fishery is to multiply the predicted large oyster densities in Table A-4 by the appropriate river system weights in Table A-4 by the appropriate river system weights in Table A-9 and to convert these products into an index using 1950-54 as a base. (Note that in 1955 the weights on the Rappahannock and Piankatank river systems (from Table A-9) change slightly.) The values of this index for the years 1950-76 are shown in Table A-10.

After the model was developed additional data (Haven, personal communications) on oyster densities for the period 1977-1982 was obtained. An analysis of this data indicated that there was no statistically significant difference between expected densities in this period and expected densities in the 1973-76 period. Consequently the 1976 value of the index was used as the basis for simulating policy alternatives.

TABLE A-10

Index of Productivity for the Virginia Public Oyster Grounds 1950-1976

YEAR	PRODUCT OF VALUE IN TABLE A-4 x WEIGHT IN TABLE A-9	INDEX
1950	50.71	1.000
1951*	50.71	1.000
1952	50.71	1.000
1953	50.71	1.000
1954	50.71	1.000
1955	50.60	0.998
1956	50.60	0.998
1957	50.60	0.998
1958	50.60	0.998
1959	50.47	0.995
1960	50.47	0.995
1961	38.07	0.751
1962	38.07	0.751
1963	38.07	0.751
1964	38.07	0.751
1965	38.07	0.751
1966	38.07	0.751
1967	38.07	0.751
1968	29.91	0.590
1969	29.91	0.590
1970	29.91	0.590
1971	29.91	0.590
1972	29.91	0.590
1973	42.19	0.832
1974	42.19	0.832
1975	42.19	0.832
1976	42.19	0.832

* 1951 represents the 1950-51 season; each is reported by the latter year.

Appendix B

AN ANALYSIS OF SEASONALITY IN THE VIRGINIA OYSTER FISHERY

Oyster harvests in Virginia have been reported on a seasonal basis for many years. The inter-seasonal differentials in oyster harvests may have important implications for the performance of the fishery. An economically efficient oyster industry would be one where the marginal factor cost of each effort unit was equal to the marginal revenue product of that effort unit.

The seasonal pattern of prices has been examined elsewhere in this study. Data on the seasonal pattern of effort or on the average product of effort is unavailable. If one assumes that the average product of effort is a proxy for population, ceteris paribus, and that effort is equally distributed between the spring and the fall, then fall and spring harvests should serve as proxies for fall and spring populations.

It will be argued that, with these extreme simplicity assumptions there should be a clear difference in the harvesting patterns under sole ownership and under common property.

Under sole ownership, the sole owner would be expected to exert effort in a pattern which mirrored expected harvest. Ceteris paribus, one would expect an equal level of effort to be exerted to each time period provided that the area under control of the sole owner is large enough to be harvested more or less continuously with no significant resource depletion. Under common property there is no way for the individual fisherman to control the total effort applied to the fishery, nor the extent to which the harvestable stock is depleted. In this condition there is an incentive for each harvester to exert effort as early in the season as possible, when populations are expected to be at their peaks.

It is expected that oyster harvests on the public grounds will be more concentrated in the early part of the oyster season than is oyster harvest on the private grounds. The oyster season in general in Virginia runs from September through April. The fall harvest of oysters contains those harvested between August and December; the springs harvest contains those harvested from January to July.

In order to test the hypothesis that the public harvest occurs earlier than the private harvest the hypothesis that the spring share of public harvest equals the springs share of private harvest is tested. If the common property seasonal effect occurs it is expected that the spring share of private oyster harvest will be greater than the spring share of public harvest.

The following equation was estimated

$SSHARE_{ti}$ = f($GROUND_i$)

where:

$SSHARE_{ti}$ = the share of oyster harvest from ground i in year t, which is harvested in the spring.

$GROUND_i$ = a grounds dummy, equal to 0 for public grounds and 1 for private grounds.

The estimated equation is shown in equation (B-1) below:

$$SSHARE = .38664 + .14097\ GROUND_i \quad \text{(B-1)}$$

t	(28.60)	(7.42)
Pr	(.0001)	(.0001)

R^2 = .4706

F = 55.12

Pr > F = .001

Equation (B-1) shows that 38.7% of oyster harvest is expected to occur in the spring off public grounds, which 52.8% of oyster harvest is expected to occur in the spring off private grounds. In the absence of data on the seasonal pattern of effort on the public and private grounds it is impossible to separate out the independent effects of effort differences and population (catch per unit of effort) differences by season. In addition, it is impossible to determine the degree to which the season pattern is attributable to legal closure of the public grounds from June through September.

The share of harvest occurring in the spring is close to 50% on the private grounds while it is considerable less than 50% on the public grounds. The more strongly seasonal pattern of harvest of public grounds suggests that harvesters off these grounds may be more dependent upon outside earning opportunities than are private grounds harvesters.

The seasonal pattern of harvest in the public grounds fishery is apparently distorted by the common property externality so that the optimal inter-temporal harvest pattern is not achieved.

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