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**Market interactions and competition between public and private
oyster production and supplies from other states**

Hsu, Ya-Ke, Ph.D.

The College of William and Mary, 1993

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Ann Arbor, MI 48106

MARKET INTERACTIONS AND COMPETITION BETWEEN PUBLIC AND
PRIVATE OYSTER PRODUCTION AND SUPPLIES FROM OTHER STATES

A Dissertation

Presented to

The Faculty of the School of Marine Science
The College of William and Mary in Virginia

In Partial Fulfillment

Of the Requirements for the Degree of
Doctor of Philosophy


by

YA-KE HSU

1993

This dissertation is submitted in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy

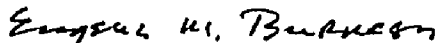


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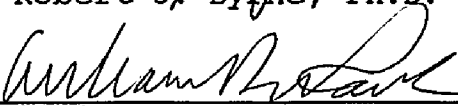
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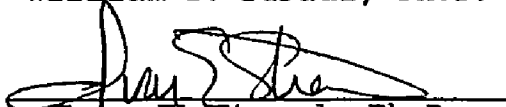
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ABSTRACT

Oyster production in Virginia has declined dramatically in the past ten years, causing Virginia oyster processors to rely increasingly on oyster supplies from other regions. In response to the industry problems, the Virginia Marine Resources Commission (VMRC) developed and began implementing an Oyster Fishery Management Plan (OFMP) in 1985. Primarily, the plan seeks to increase Virginia oyster production from both public and leased grounds. A large increase in production could significantly affect the oyster market.

There is thus a need to understand the Virginia oyster market, which derives raw material supplies primarily from public and leased-grounds production and from other states. Although the level of competition among the three sources is uncertain, it is thought to be substantial and quite important for the success of the OFMP. This study assesses the level of competition and associated sector interaction. A simultaneous equation system is specified and estimated by Full-Information-Maximum-Likelihood procedure. Estimates and a market simulation model are used to assess the impact of the OFMP on market behavior.

Analyses indicate that the market for the public ground fishery consists of an elastic demand and an inelastic supply, but the market for private oyster cultivation consists of an inelastic demand and an elastic supply. The market interaction between the eastern oyster and Pacific oyster is weak. Oysters from leased grounds compete with supplies from other regions and with Pacific oysters.

Market simulations indicate that the OFMP will increase total revenue for both public and private producers, suggesting that (1) the seasonal closure on commercial oyster fishery may be extended as stock size recovers, (2) increasing private production may reduce oyster supplies from other states, and (3) from the market interaction point of view, the Pacific oyster may be an alternative for private oyster planters.

**MARKET INTERACTIONS AND COMPETITION BETWEEN PUBLIC AND
PRIVATE OYSTER PRODUCTION AND SUPPLIES FROM OTHER STATES**

INTRODUCTION AND OBJECTIVES OF THE STUDY

Introduction

The oyster fishery was once one of the more important fisheries in Virginia. Annual production of the eastern oyster (*Crassostrea virginica*) was over five million bushels between 1890 and 1925 (Haven *et al.*, 1981), but due to overexploitation, oyster production fell to 2.5 million bushels from 1926 through the late 1950's (Insley, 1986). Oyster production further declined from the presence of MSX (*Haplosporidium nelsoni*) and "Dermo" (*Perkinsus marinus*), and in 1991, annual oyster production dropped to 0.2 million bushels (VMRC, 1992).

Prior research has suggested that the large decline in oyster production may result from several factors. The outbreak of MSX in 1959 reduced private oyster production initially, and its persistence, combined with "Dermo," has continued to discourage private oyster planting (Bosch and Shabman, 1989; Hargis and Haven, 1988a; Haven and Whitcomb, 1986). Overfishing is the most important factor affecting the production of public ground fisheries (Hargis and Haven,

1988a; Haven *et al.*, 1981). Other factors such as inadequate oyster management policy, degradation of environmental quality, reduction in spatfall, high costs of production, and market competition from Gulf and west coast states also resulted in production decline (CEC, 1989; Hargis and Haven, 1988b; Haven *et al.*, 1981; JLARC, 1984; Haven and Fritz, 1986; Haven and Whitcomb, 1986; Insley, 1986; Thunberg, 1986).

In response to industry and resource problems, the Virginia Marine Resources Commission (VMRC) developed and began implementing an Oyster Fishery Management Plan (OFMP) in 1985. Primarily, the plan seeks to increase Virginia oyster production from both public and private leased grounds and to maximize biological, sociological, and economic benefits with available resources (Bosch and Shabman, 1988; Insley, 1986).

Success of the oyster management strategy, however, requires an understanding not only of oyster production but also of the market's effect on the goals established to benefit the oyster industry. As total Virginia production declines, the demand for Virginia oysters is affected by insufficient supplies; thus, Virginia oyster processors have had to rely increasingly on oyster supplies from other regions. For instance, supplies from other states were

negligible before the outbreak of MSX in 1959, but over half of the oysters shucked in Virginia now come from Maryland and the Gulf states (VMRC, 1989). Unfortunately, little information is available on the current Virginia oyster market or on the market relationships between public ground fishery, private oyster cultivation, and oyster supplies from other regions.

Objectives

Since the success of management strategies requires an understanding of the market conflicts between the public ground fishery, private cultivation, and oyster supplies from other regions, several important questions must be addressed. What are the market relationships between public and private leased grounds and supplies from other states? If the goals of the oyster management plan are reached, what will be the impact of the plan on the Virginia oyster market? What is the effect of private oyster production on oyster supplies from other regions? What is the market relationship between the native Virginia oysters and Pacific oysters -- will Pacific oysters compete with native oysters in the Virginia shellstock market?

This study analyzes the interrelationships between

public ground fishery, private cultivation, and oyster supplies from other regions, using econometric models of production and market conditions. A simulation then evaluates the oyster fishery management plan's impact on the Virginia oyster market. Objectives of this study are as follows:

1. To construct an empirical framework of the interrelationships of public ground fishery, private cultivation, and supplies from other regions;
2. To develop modeling specifications for econometric analysis, including
 - (a) the demand for unshucked oysters from public grounds, private leased grounds, and supply from other regions,
 - (b) the supply of oysters from public and private leased grounds, and
 - (c) the identities for market equilibrium; and
3. To specify a simulation model for public ground fishery, private cultivation, and supplies from other regions based on the econometric model.

THE U.S. AND VIRGINIA OYSTER FISHERIES

Introduction

The oyster fishery has been traditionally one of the more important fisheries in the world (Borgese, 1980). Numerous oyster species are exploited worldwide: among them, the eastern oyster (*Crassostrea virginica*), European flat oyster (*Ostrea edulis*), and Pacific or Japanese oyster (*Crassostrea gigas*) comprise over 80 percent of total worldwide oyster production (Table 1). However, oyster production is concentrated primarily in a few countries -- South Korea, Japan, the United States, and France -- which account for approximately 80 percent of total worldwide production (Table 2).

The U.S. Oyster Fisheries

In the United States, two major oyster species have been exploited: the eastern oyster on the east coast and Gulf region and the Pacific oyster on the west coast. This geographic distinction does not imply that other species are not utilized on either coast; for instance, the eastern and

Table 1. Worldwide oyster harvests by species
(metric tons).

| | <i>O. edulis</i> | <i>C. gigas</i> | <i>C. virginica</i> | Other Species | Total |
|------|----------------------|---------------------|-------------------------|------------------|-----------|
| 1978 | 6426 | 435,059 | 325,399 | 133,993 | 900,877 |
| 1979 | 7661 | 422,674 | 303,750 | 139,005 | 873,090 |
| 1980 | 7114 | 498,716 | 329,971 | 135,883 | 971,684 |
| 1981 | 1,137 | 487,741 | 329,469 | 134,416 | 961,763 |
| 1982 | 1,354 | 488,472 | 324,768 | 150,235 | 973,829 |
| 1983 | 9368 | 556,709 | 321,504 | 153,962 | 1,041,543 |
| 1984 | 1,344 | 567,544 | 303,028 | 158,364 | 1,042,280 |
| 1985 | 1,810 | 614,938 | 272,604 | 187,947 | 1,088,299 |
| 1986 | 15,359 | 620,297 | 254,704 | 192,279 | 1,082,639 |
| 1987 | 13,267 | 690,561 | 229,608 | 178,684 | 1,112,120 |
| 1988 | 14,613 | 707,671 | 192,401 | 179,841 | 1,094,526 |
| 1989 | 17,700 | 649,327 | 183,142 | 192,347 | 1,042,516 |
| 1990 | 16,168 | 654,706 | 148,033 | 209,747 | 1,028,654 |

Sources: FAO Yearbook, Fishery Statistics:
Catches and Landings, 1981 - 1990

Table 2. Oyster production by major producing nations
(metric tons).

| | France | Japan | S. Korea | USA | Total |
|------|---------|---------|----------|---------|-----------|
| 1978 | 95,304 | 232,068 | 158,283 | 314,383 | 900,877 |
| 1979 | 105,919 | 205,509 | 171,118 | 290,083 | 873,090 |
| 1980 | 109,675 | 261,323 | 187,033 | 314,714 | 971,684 |
| 1981 | 92,984 | 235,241 | 206,361 | 313,637 | 961,763 |
| 1982 | 96,519 | 250,288 | 189,204 | 315,193 | 973,829 |
| 1983 | 109,191 | 253,247 | 218,463 | 307,033 | 1,041,543 |
| 1984 | 112,445 | 257,126 | 211,886 | 284,260 | 1,042,280 |
| 1985 | 139,786 | 251,247 | 254,515 | 260,449 | 1,088,299 |
| 1986 | 146,319 | 251,574 | 268,775 | 234,273 | 1,082,639 |
| 1987 | 138,424 | 258,776 | 303,223 | 217,632 | 1,112,120 |
| 1988 | 137,783 | 270,858 | 298,719 | 167,700 | 1,094,526 |
| 1989 | 146,766 | 256,313 | 256,262 | 158,425 | 1,042,516 |
| 1990 | 153,843 | 248,793 | 248900 | 148,497 | 1,028,654 |

Sources: FAO Yearbook, Fishery Statistics:
Catches and Landings, 1981 - 1990

European oysters are also raised on the west coast but on a smaller scale. The European flat oyster, introduced into the New England area from Holland in 1949 (Clime and Hamill, 1979), has been underutilized because of its slow rate of growth in cold water. Production of the European oyster is relatively small compared to the eastern and Pacific oysters.

The Pacific oyster was introduced on the west coast in the 1920s after the population of the native Olympia oyster (*O. lurida*) was damaged severely by overfishing (Wiegardt, 1988), but the water temperature of the west coast was often too cold for Pacific oysters to spawn naturally. Subsequently, a large number of Pacific seed oysters were imported from Japan, because of the undesirable fluctuation of natural production of Pacific seed oysters. Until the late 1970s, the west coast Pacific oyster production depended primarily upon the availability of Pacific seed oysters from Japan. As prices of Pacific seed oysters increased, the seed supplies from Japan became difficult to obtain, and in response, local oyster producers developed hatcheries (Chew, 1984).

These became very important to west coast oyster farmers. A new technique, called remote setting, was initiated in 1982 (Chew, 1984). Traditionally, spat and

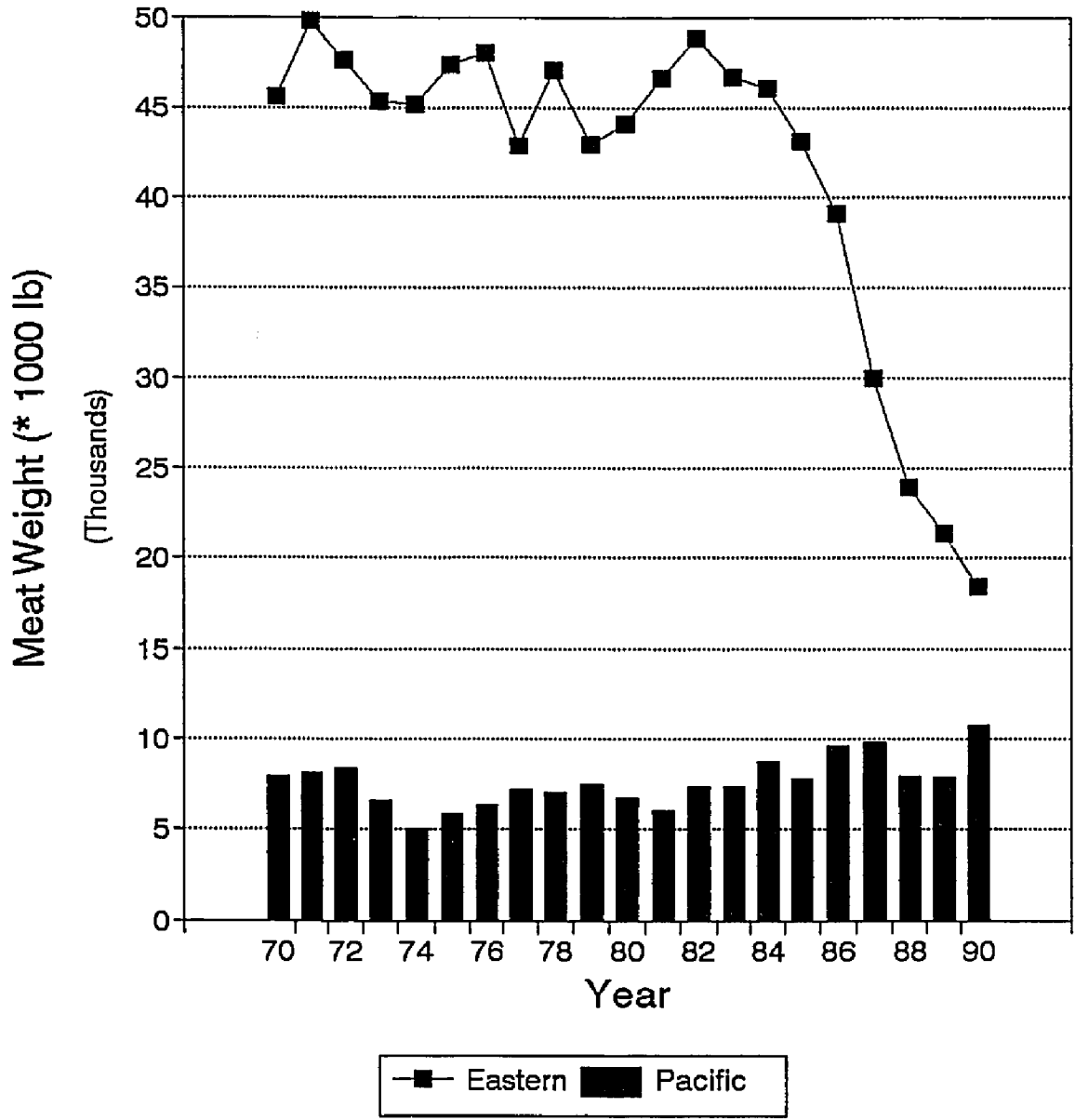
seed oysters were produced in local hatcheries, but the new technique, which allowed many eyed-larvae to be shipped to distant areas and had a fairly high success rate for spat collection in tanks, promised to produce a large quantity of seed oysters in any suitable location. The Pacific oyster, produced in hatcheries and then raised on private leased grounds now accounts for most west coast oyster production (NOAA, 1977; Burrell, 1983).

The eastern oyster is a native oyster found all along the coast of the Atlantic Ocean to the Gulf of Mexico (Galtsoff, 1964; NMFS, 1977), with the Gulf Coast and the Chesapeake Bay the major resource areas. Many states in these areas have extensive oyster repletion programs that attempt to enhance and maintain stock levels via planting oyster shells and seed oysters on state-owned grounds. The programs may provide sufficient stock levels for maintaining a fishery on public grounds and low cost seed oysters for private oyster growers.

Unfortunately, oyster production on the east coast has declined dramatically (Fig. 1). The sharp decline in eastern oyster production is believed to be associated primarily with MSX and "Dermo" diseases and overfishing. For example, the oyster fishery in Delaware has been closed

Figure 1

The U.S. oyster production, 1977-1990.
(Source: Fisheries of the United States)



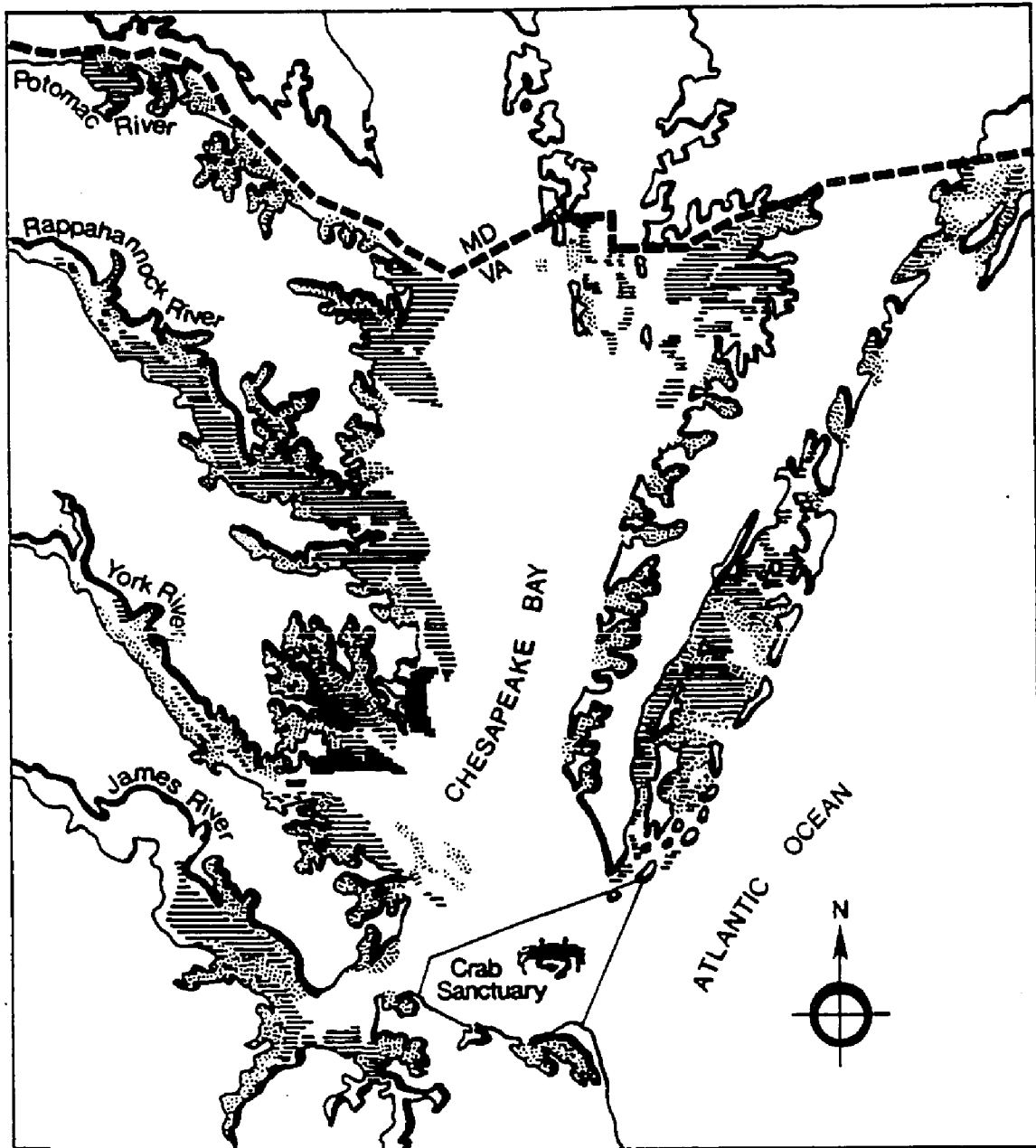
since 1985 as a result of MSX-related mortalities (Lewis, 1987), and oyster production in Maryland fell to about 0.3 million bushels in 1988. Similarly, in Virginia, most public grounds were no longer producing market oysters, except for the James River areas (CEC, 1989, Barber and Mann, 1991).




The Virginia Oyster Fisheries

Virginia oysters are harvested from state-managed public grounds and private-leased grounds. The Virginia legislature has defined that the right to use the natural oyster grounds belongs to all citizens of the state. However, in the past, the lack of a definite boundary for natural oyster beds resulted in a conflict between oystermen and private planters on the use of state-owned oyster grounds (Armstrong, 1879). In 1892, a survey by J.B. Baylor divided all the Virginia tidal water areas into two categories, within the Baylor survey and outside the Baylor survey. The Baylor survey, also called public grounds, contains the most naturally productive oyster beds (Fig. 2), while the area outside the survey does not produce oysters naturally and may be leased to whomever desires to use the grounds for oyster cultivation (Richmond News Leader, 1930).

Figure 2

Virginia shellfish grounds.
(Reprinted from JLARC, 1984)



- 
 Original Baylor Survey and Additional Public Oyster Grounds Set Aside by Legislation
- 
 Location of Private Leased Oyster Grounds
- 
 Public Clam Grounds

Hand tongs, patent tongs, and dredges are the common tools used to harvest oysters (Fig. 3). The number of oyster gear licenses varies and may be related to stock abundance (Table 3). Additionally, oysters are harvested frequently by hand on the seaside of the Eastern Shore (Insley, 1986; VMRC, 1989). Once harvested, market oysters are sold to shucking or packing houses for further processing; seed oysters (larger than one inch) are sold to a buy-boat or trucker for transplanting onto private leased grounds. The variation of seed production may depend on the needs of private planters. Prior to 1980, over 75 percent of seed oysters supplied to private planters were from the James River (Haven *et al.*, 1981).

The private leased grounds are not naturally productive and thus require considerable effort and expense to cultivate oysters. Because they do not produce enough seed oysters to satisfy the needs of private planters, seed oysters must be harvested from public grounds and transplanted onto the leased bottoms. The rate of planting seed oysters on the leased grounds is 500-1000 bushels per acre (Haven *et al.*, 1981).

Frequently, these bottoms are too soft to support

Figure 3

Types of oyster gears.
(Reprinted from JLARC, 1984)

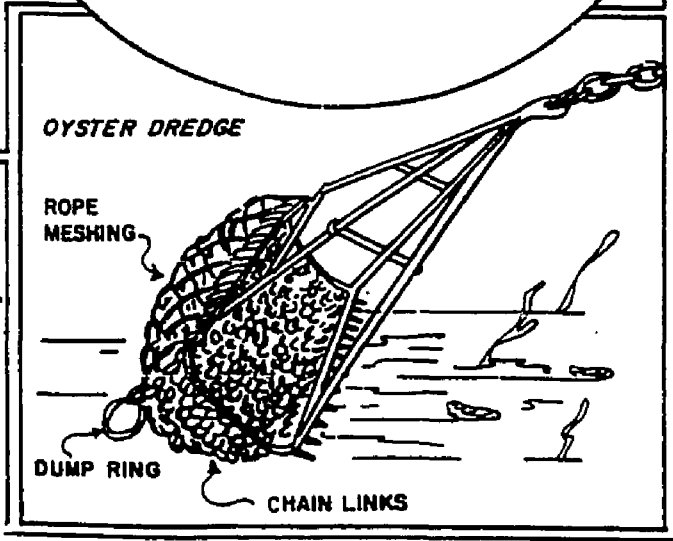
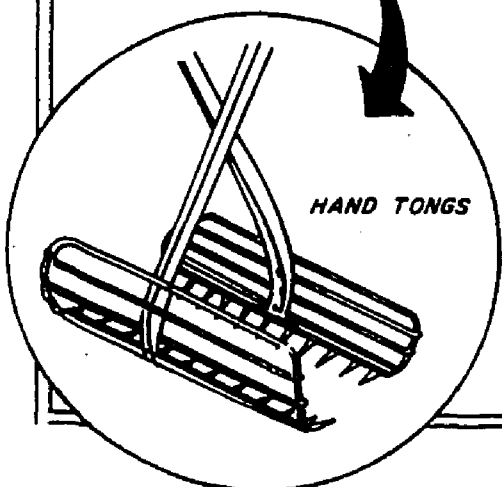
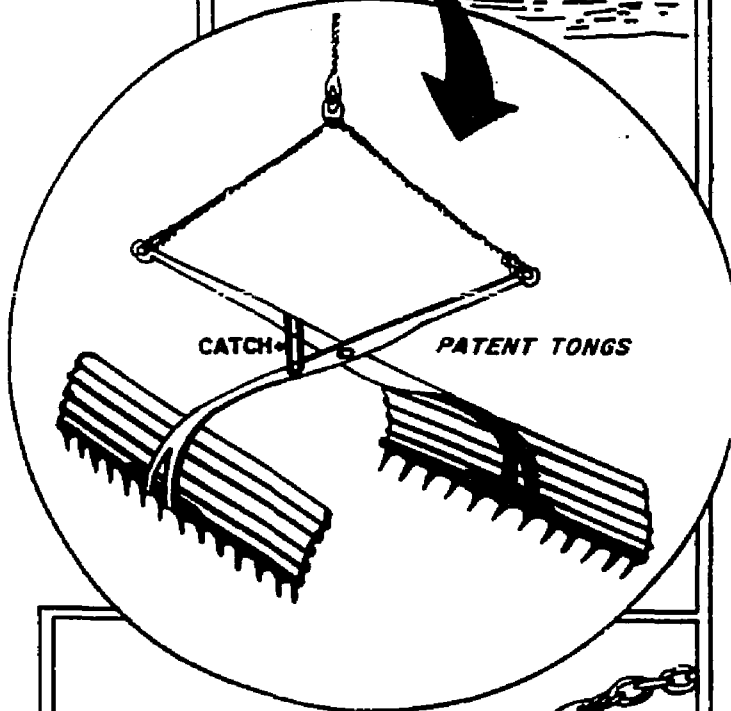
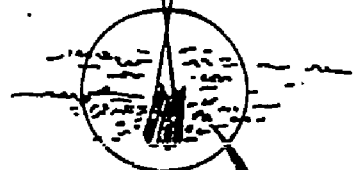
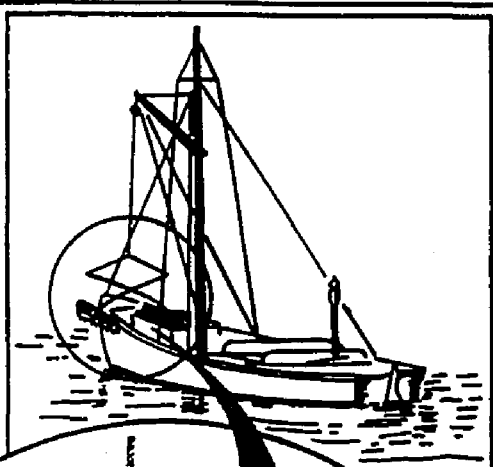


Table 3. Annual number of oyster gear licenses in Virginia.

| Year | Hand | Patent | Dredge |
|------|-------|--------|--------|
| 1955 | 3,234 | 345 | 43 |
| 1956 | 3,413 | 370 | 30 |
| 1957 | 4,431 | 388 | 8 |
| 1958 | 3,879 | 291 | 1 |
| 1959 | 4,096 | 275 | 50 |
| 1960 | 3,912 | 247 | 104 |
| 1961 | 3,214 | 120 | 28 |
| 1962 | 2,885 | 49 | 5 |
| 1963 | 3,217 | 48 | 0 |
| 1964 | 3,098 | 57 | 0 |
| 1965 | 3,129 | 28 | 0 |
| 1966 | 2,679 | 24 | 0 |
| 1967 | 2,309 | 41 | 0 |
| 1968 | 2,191 | 22 | 0 |
| 1969 | 1,865 | 20 | 0 |
| 1970 | 1,540 | 4 | 0 |
| 1971 | 1,485 | 8 | 0 |
| 1972 | 1,310 | 5 | 4 |
| 1973 | 1,376 | 24 | 5 |
| 1974 | 1,568 | 74 | 11 |
| 1975 | 1,758 | 95 | 28 |
| 1976 | 1,711 | 159 | 25 |
| 1977 | 1,867 | 215 | 41 |
| 1978 | 2,052 | 284 | 235 |
| 1979 | 2,189 | 286 | 144 |
| 1980 | 1,956 | 379 | 160 |
| 1981 | 1,968 | 436 | 138 |
| 1982 | 1,942 | 345 | 141 |
| 1983 | 1,717 | 278 | 94 |
| 1984 | 1,785 | 423 | 121 |
| 1985 | 1,403 | 440 | 121 |
| 1986 | 1,594 | 373 | 131 |
| 1987 | 1,755 | 225 | 44 |
| 1988 | 1,524 | 5 | 0 |
| 1989 | 1,257 | 41 | 0 |
| 1990 | 1,149 | 60 | 1 |

Data source: VMRC

oyster growth, so an initial shell planting should be carried out to firm the bottom before transplantation. To cover an acre of leased ground one inch deep with shells requires over 2000 bushels of oyster shells (Webster and Meritt, 1988). The amount of shells needed to stabilize the bottom depends upon the type of the ground and the rate of bottom sedimentation. In 1986, approximately 110,000 acres outside the Baylor survey were made into private leased grounds on a relatively small scale; over 80 percent of leases held were less than 20 acres (Haven *et al.*, 1981).

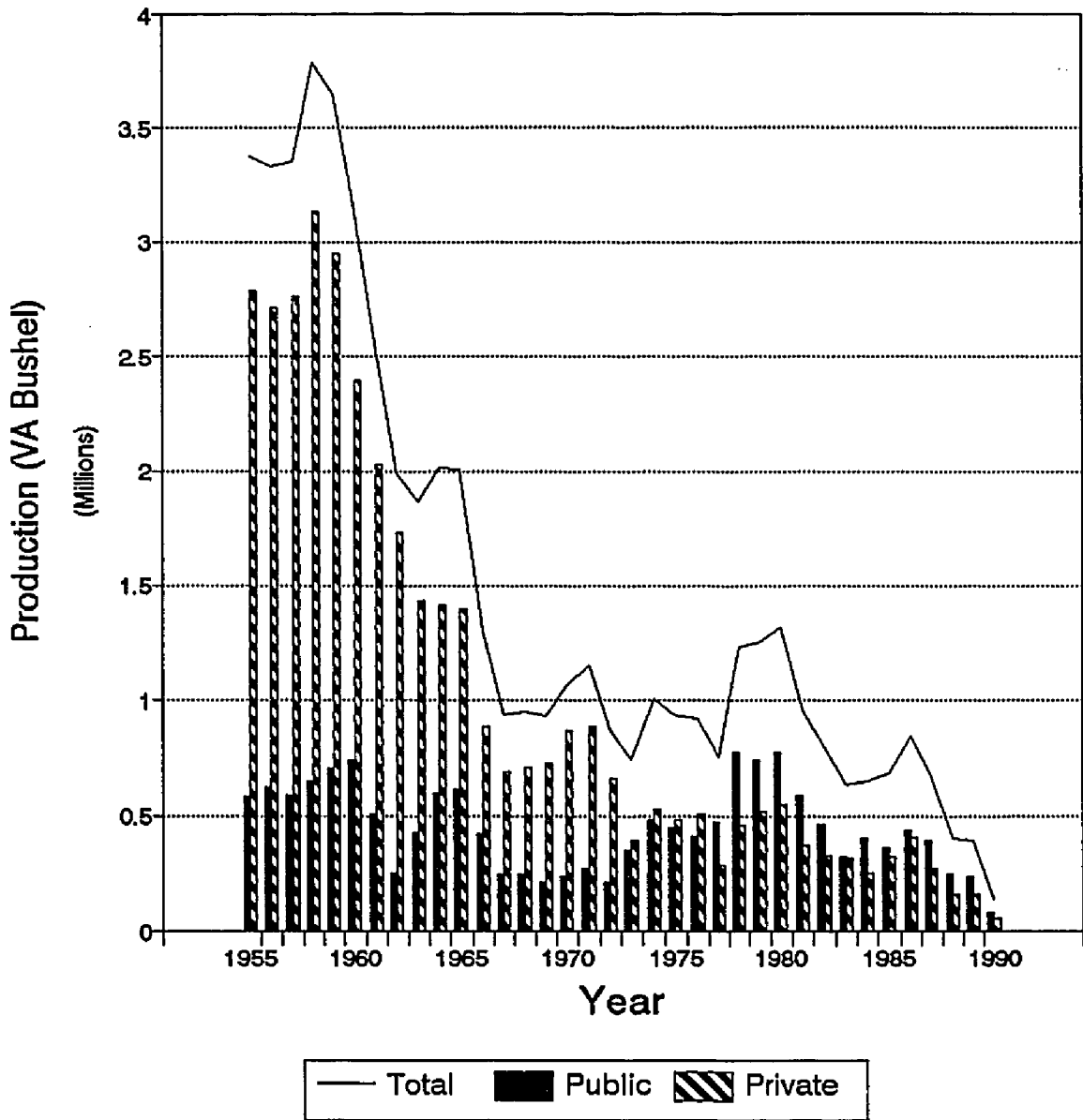
Oyster production from private leased grounds has declined drastically from the time prior to the occurrence of MSX in 1959, when production from private leased grounds comprised most of Virginia's production. By 1990, less than 40 percent of total production was from private leased grounds (Fig. 4). The continuous decline in production from private leased grounds resulted primarily from the persistence of MSX and "Dermo," as well as from high production costs (Bosch and Shabman, 1989; Haven and Whitcomb, 1986). It is believed that less than 10 percent of leased grounds are productive (VMRC, 1989).

Prior to the MSX epidemic, oyster supplies from outside Virginia were negligible (VMRC, 1989), but after total

Figure 4

Virginia oyster production.

(Source: Hargis and Haven, 1988; VMRC, 1991)



production of Virginia oysters declined sharply, Virginia oyster processors were forced to look elsewhere for supplies. Currently, over half of the oysters shucked in Virginia come from other states (Table 4), primarily from Maryland and the Gulf states.

Virginia Oyster Management and Problems

The Baylor grounds set aside for public use are managed by VMRC. Small portions of public grounds within the James River, Great Wicomico River, Piankatank River, and the seaside of the Eastern Shore are designated seed oyster areas, where the spat set is intensive but the growth of oysters slow. The purpose of the seed areas is to provide sufficient seed oysters to the Oyster Repletion Program (ORP) and to private oyster planters.

The minimum size for a market oyster is three inches, except for oysters taken from the James River seed areas, which may be 2.5 inches; however, there are no size limits on oysters taken from those seed areas and sold as seed oysters. If market oysters are being caught, culling consists of returning to the water all empty shells and undersized oysters. Market oysters are processed in

Table 4. Virginia oyster production and supplies from outside Virginia (VA Bushels).

| Year | Maryland ¹ | Gulf ² | Others | Total Outside Supplies | Virginia Production |
|------|-----------------------|-------------------|--------|------------------------|---------------------|
| 1981 | 1,340,266 | 6,987 | 75,940 | 1,423,193 | 959,032 |
| 1982 | 970,303 | 226,878 | 10,558 | 1,207,739 | 790,400 |
| 1983 | 536,432 | 352,813 | 5,965 | 895,210 | 631,769 |
| 1984 | 607,672 | 134,983 | 35,981 | 778,636 | 647,967 |
| 1985 | 678,510 | 139,503 | 3,066 | 821,079 | 678,117 |
| 1986 | 616,611 | 65,232 | 31,857 | 713,700 | 843,398 |
| 1987 | 271,378 | 140,595 | 69,420 | 481,393 | 667,446 |
| 1988 | 258,844 | 139,342 | 57,877 | 456,063 | 398,463 |
| 1989 | 333,637 | 110,087 | 35,001 | 478,725 | 391,504 |

Source: VMRC data.

1: Including oysters from Potomac River but landing in VA.

2: Including Alabama, Florida, Louisiana, Mississippi, and Texas.

shucking or packing houses.

Only one type of gear, either hand tong, patent tong, or dredge is allowed at one time, but two of the same type are permissible at once. Hand tongs are commonly used on the public ground fishery, although patent tongs and dredges are more efficient thanks to their mechanical assistance. However, patent tongs and dredges may damage oyster beds; therefore their usage is restricted on certain public grounds.

The daily catch limit of market-size oysters is 15 bushels per person by hand tong or 45 bushels per boat. The oyster fishing season is circumscribed by time, fishing gear, and area, but in general, oysters may be harvested from October 1 to June 1 by hand tongs and from November 1 to March 1 by patent tong and dredge. In addition, Virginia prohibits oystering from sunset to sunrise, and on Sunday.

The Virginia Marine Resources Commission also manages an Oyster Repletion Program (ORP). The goal of the ORP is to provide sufficient seed oysters for VMRC to maintain adequate oyster stocks on public grounds (Haven et al., 1981); it also provides sufficient quantities of seed oysters at a low price to private oyster growers. The ORP

has been used by VMRC since the 1920s to maintain the stocks on the public grounds. Primarily, the program spreads oyster shells as cultch material in known striking areas for spat settlement. Since the occurrence of MSX started in 1960, transplanting seed oysters to suitable growing areas on public grounds has expanded as a disaster-relief program to support public ground fishery (Baker *et al.*, 1977).

A program of bagless dredging, was started in 1986 to clean the previously planted shells in order to enhance an oyster strike (Insley, 1986). The shells are cleansed by dragging a bagless crab dredge over the oyster beds, dredge serving essentially as a rake with the teeth picking up shells on the bottom, while the sediment is carried away with the tide or current.

The area outside the Baylor survey may be leased from VMRC by private oyster growers for renewable ten-year periods. Each lessee may not have more than 3,000 acres outside of the Chesapeake Bay area or 500,000 acres within the Bay, but aside from that, there are few laws and regulations pertaining to harvesting oysters from private leased grounds. Limits such as those on market-size oysters and harvesting gears are not imposed on private leased grounds, and therefore, highly efficient dredges are

typically employed on private leased grounds. Unlike the public grounds fishery, there is no seasonal closure on private leased grounds.

In addition to disease and other environmental factors, the decline in Virginia oyster production is thought to have been caused by inadequate management (Hargis and Haven, 1988). Although limits on size, daily catch amounts, type of gear, and seasonal closures have been used to limit the harvesting of oysters from public grounds, these restrictions may have had little effect on controlling total mortality and thus conserving the oyster resource (CEC, 1989).

However, oystermen believe that the decline in oyster production from public grounds may not have been caused by overfishing, but rather by other factors such as disease and environmental degradation. In 1979, oyster production from public grounds was about 0.8 million bushels, a level higher than any year from 1952 to 1985 (Stagg, 1985). Haven *et al.* (1981) argues that there were three factors responsible for the increase in public production in the late 1970s: first, a low salinity had persisted since 1972, reducing the impact of disease; second, tropical storm Agnes caused a flood in 1972, wiping out oyster predators and increasing oyster

survival in later years; and finally, new fishing grounds around the Pocomoke-Tangier Sound areas were opened to dredges in 1978, increasing public production. In addition to Haven's suggestions, two other factors may have been responsible for high production in the late 1970s. Massive shelling occurred between 1973 and 1976 (Table 5), and large seed oyster transplanting took place between 1970 and 1974, excepting fiscal year 1972-73. An intensive spatfall in the lower James River during these periods might be related to the massive shelling (Haven and Fritz, 1986). Second, the number of licenses issued in the early 1970s was relatively low, thus reducing pressure on the stocks.

However, production and number of licenses may not be satisfactory indicators of what proportion of a stock is harvested. An alternative indicator -- catch per unit effort (CPUE) -- is often used to indicate a relative change in stock size (Anthony, 1989). However, fishing effort is difficult to determine; thus, calculating CPUE usually involves obtaining a proxy measure for effort (Anderson, 1986), such as the number of licenses. Although, the number of oyster licenses does not exactly indicate fishing effort, it is the only complete data available from VMRC. Catch per unit effort (CPUE) of Virginia oysters is obtained by dividing public production by the number of hand tong

Table 5. The number of bushels of seed and shell planted on the public grounds by fiscal year (VMRC).

| Fiscal Year | Seed Transplanted | Shell ¹ Planted |
|-------------|-------------------|----------------------------|
| 1961-62 | 96450 | 421871 |
| 1962-63 | 23358 | 1054819 |
| 1963-64 | 82350 | 2318379 |
| 1964-65 | 9577 | 4148702 |
| 1965-66 | 95425 | 2978088 |
| 1966-67 | 37500 | 2241563 |
| 1967-68 | 53418 | 2884580 |
| 1968-69 | 57366 | 1032944 |
| 1969-70 | 114613 | 944897 |
| 1970-71 | 129122 | 1488494 |
| 1971-72 | 114866 | 946826 |
| 1972-73 | 0 | 1885718 |
| 1973-74 | 118901 | 2256007 |
| 1974-75 | 50379 | 3481727 |
| 1975-76 | 90273 | 3608737 |
| 1976-77 | 50702 | 1471791 |
| 1977-78 | 80837 | 762061 |
| 1978-79 | 33822 | 1153165 |
| 1979-80 | 65483 | 1193057 |
| 1980-81 | 61291 | 1474432 |
| 1981-82 | 12321 | 1443080 |
| 1982-83 | 33245 | 1437441 |
| 1983-84 | 11824 | 1297148 |
| 1984-85 | 26579 | 1956099 |
| 1985-86 | 42136 | 1860090 |
| 1986-87 | 111232 | 1551294 |
| 1987-88 | 155699 | 1805986 |
| 1988-89 | 204392 | 1801814 |
| 1989-90 | 186392 | 1107376 |

Note:

1 - including reef shell and house shell.

licenses (Fig. 5). The patent tongs and dredges are not considered in the CPUE, since these gears are used primarily on private leased grounds and certain limited public grounds.

Relatively high CPUEs, associated with a low number of licenses and high production, were found between 1978 and 1980. High production from public grounds was caused partly by an increase in dredged production as Haven *et al.* (1981) mentioned (Table 6). However, public production by hand tongs also increased in this time period, and thus, the level of stock may simply have been high during these periods.

Although oyster stocks in the late 1970s were likely to recover from the long-run depletion, most CPUEs remained low. In general, the phenomenon of overfishing is indicated when the level of CPUE is relatively low and interspersed with unusual peaks (Anthony, 1989). Generally, high peaks are related to good recruitment but not to the success of management. VMRC may have been confused by the unusual recruitment and ignored the signal of declining stocks.

The oyster CPUE declined quickly as the number of hand tongs remained at high levels in the early 1980s. The

Figure 5

The CPUE for Virginia oyster fishery.

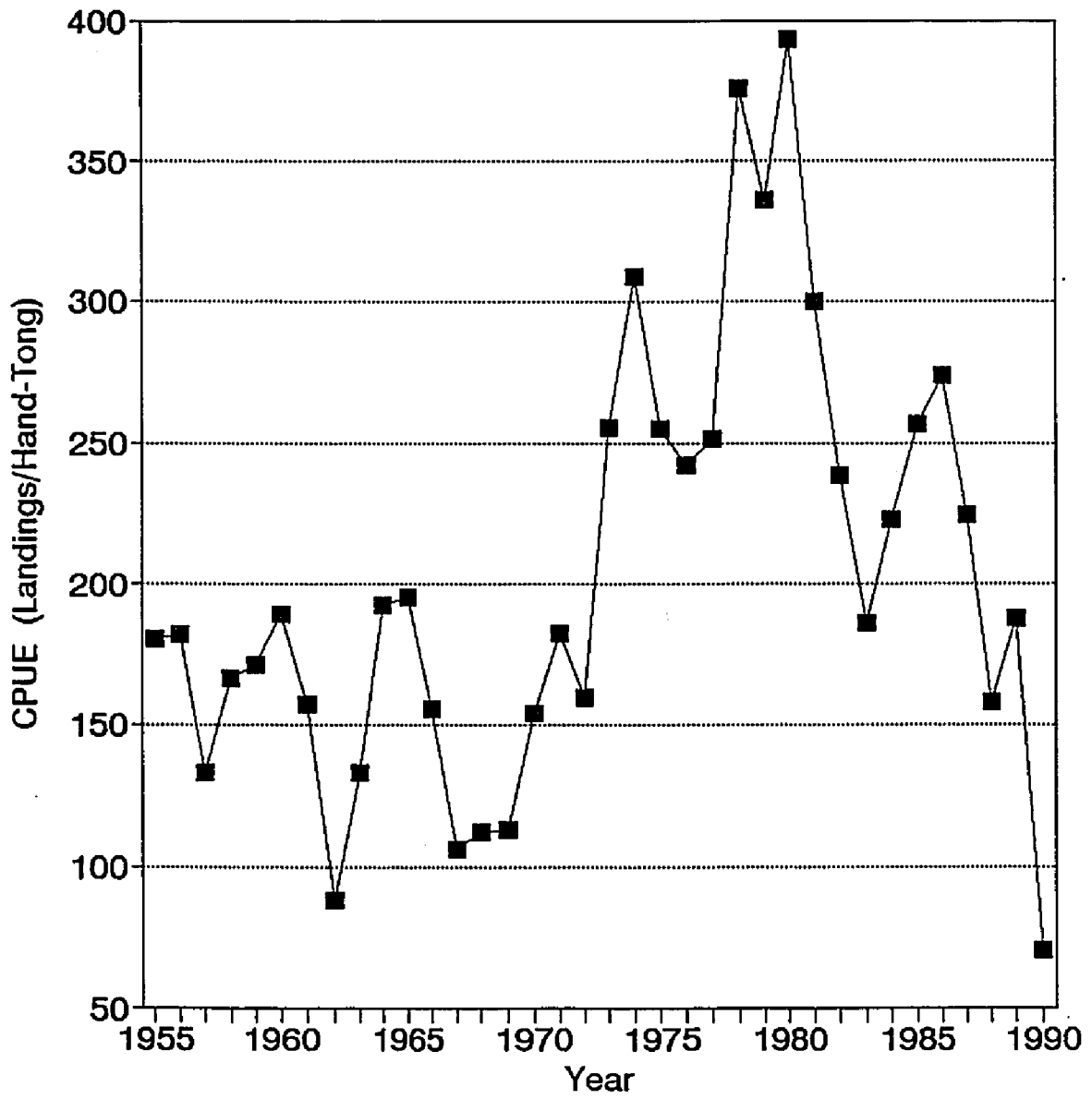


Table 6. Oyster landings from public grounds by gear type.

| Year | Dredges | Hand/Patent | Others | Total |
|------|---------|-------------|--------|--------|
| 1973 | 0 | 351669 | 0 | 351669 |
| 1974 | 6856 | 478245 | 0 | 485101 |
| 1975 | 6783 | 430179 | 0 | 436962 |
| 1976 | 19181 | 367469 | 12053 | 398703 |
| 1977 | 38151 | 422306 | 9791 | 470248 |
| 1978 | 165242 | 578841 | 27764 | 771847 |
| 1979 | 175622 | 533665 | 26309 | 735596 |
| 1980 | 167943 | 570179 | 31706 | 769828 |
| 1981 | 73814 | 499831 | 17101 | 590746 |
| 1982 | 76799 | 344316 | 42146 | 463261 |
| 1983 | 25991 | 255228 | 38101 | 319320 |
| 1984 | 48584 | 318557 | 31145 | 398286 |
| 1985 | 53544 | 294830 | 11813 | 360187 |
| 1986 | 24625 | 398352 | 11040 | 434017 |

Source: VMRC.

public ground fishery collapsed from the prevalence of disease between 1985 and 1988; public production fell from 800,000 bushels in 1979 to 60,000 bushels in 1991.

One impediment to production may be oyster bed depletion. An oyster bed consists of oysters, shells and other cultches. As oysters are taken from a bed, shells and cultches are brought up together, meaning the sizes of productive beds may be reduced -- a phenomenon identified as the 'ground externality' (Agnello and Donnelley, 1976). Eventually, if there is no reshellng of the beds, the naturally productive beds are reduced or destroyed by the public ground fishery. The importance of the ORP is to eliminate the ground externality of the fishery.

Haven and Whitcomb (1986) surveyed about 84 percent of the total public oyster grounds and found that average oyster production of public grounds was low. Only 22 percent of the total surveyed areas were considered as to have a moderate or high potential for oyster productivity in which the bottoms consisted of shells or cultches. Reduction of the productive beds occurs primarily because harvest levels exceed replenishment of public beds (Andrews, 1991), and because with limited resources, the ORP can only maintain up to 10 percent of total public grounds (Hargis and Haven, 1988). The decrease in the sizes of oyster beds

indicates that the current management regime of the ORP is maintaining the rebuilt beds insufficiently.

Existing oyster laws and regulations, which have developed over years and are concerned mainly with managing the traditional fisheries, may be inadequate for private oyster cultivation. Although there are few limitations on harvested oysters from private leased grounds, most regulations for private oyster cultivation are associated with owners' rights, which may involve the rights of navigation, riparian rights, and public right to fishing (Theberge and Neikirk, 1987). These laws limit private oyster growers from obtaining suitable sites or using other culture techniques. For instance, off-bottom cultivation cannot be employed in the Virginia waters because it hinders the rights of navigation.

JLARC (1984) suggested that Virginia oyster policy should be changed to improve oyster production. The Agreement Commitment Report from the Chesapeake Executive Council (CEC, 1989) concurred, stating that prior oyster management was ineffective and that new regulations were necessary. In response, VMRC has been developing the Oyster Fishery Management Plan (OFMP) to revive the industry (Table 7). The objectives of the OFMP are to improve long-range

Table 7. The goal and objectives of the Virginia oyster fishery management plan.

Goal: To "achieve and maintain a level of Virginia's public and private ground oyster stocks, to generate the greatest possible biological, sociological, and economic benefits from their harvest and utilization."

Objectives:

1. By 1993, to increase public ground production to at least 700,000 bushels (20 percent above the ten year average). To the greatest extent possible, reduce major inter-annual fluctuation in public production.
2. To assist private oyster producers in ensuring an increase in private oyster ground production, to 700,000 bushels (the approximate 20-year average) by 1995.
3. Ensure the collection of biological, sociological, and economic data, as well as fisheries statistics, in order to monitor and evaluate the effectiveness of management measures.
4. Allow the Marine Resources Commission's regulatory authority to impose effective and timely management measures.
5. Support water and habitat quality standards necessary for natural production. Where practical, encourage reclamation of condemned oyster grounds through VMRC cooperation with the State Water Control Board and other state agencies.

Source: VMRC.

production and to achieve optimum yield for public ground fishery and private production, based on its limited resources. However, production proposed under the OFMP is much higher than the current production. The OFMP is, thus, likely to affect the Virginia oyster market.

CONCEPTUAL FRAMEWORK, ECONOMIC MODEL, AND METHODOLOGY

Market

The concept of a market is often quite confusing. A market may vary in geographic scope and be as limited as a building or extended worldwide. A market, the place or context in which buyers and sellers buy, sell, or trade goods and services, consists of buyers, sellers, and often third parties such as brokers. The object of the market may be a good, a group of goods, or services. In general, the definition of a market depends upon its particular purpose (Mansfield, 1985); for instance, the meaning of the term 'oyster market' may represent the entire oyster species, with all types of oyster products being traded as a whole around the world.

Historically, Virginia has been the nation's largest producer of eastern oysters. Oysters harvested from public and private leased grounds were processed in Virginia shucking houses and shipped primarily to areas outside Virginia for further processing or consumption (Richmond News Leader, 1930; Wheatley, 1959). The processor's demand

for oyster shellstock is the derived demand for the Virginia oyster, and therefore, this study concerns itself primarily with the oyster shellstock in Virginia as the market's object.

Since a large quantity of oyster shellstock is from other regions, this study proposes that the Virginia oyster market consists of three sectors: oysters from public ground fishery and private leased grounds in Virginia, and oyster supplies from other states. These market sectors will be referred to hereafter as public, private, and outside supply respectively.

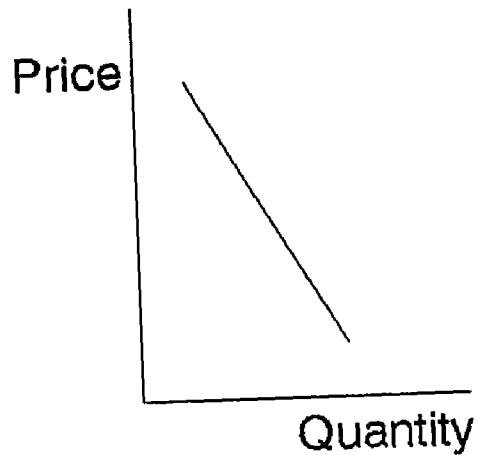
Market Demand and Supply

A market may be characterized by demand and supply curves, which indicate the amount of a commodity buyers are willing to purchase and sellers are willing to sell at various prices. The demand curve of a normal good slopes downward and to the right -- a negative slope. A normal good is a commodity with a demand related positively to income. The negative slope of the demand curve indicates that an increase in price will decrease the quantity demanded of a commodity (Fig. 6-a). The supply curve is

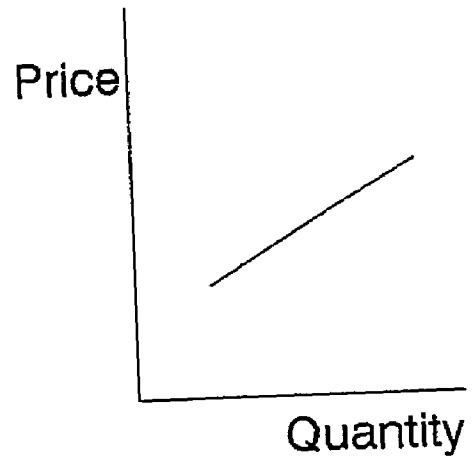
Figure 6

The demand and supply curves.

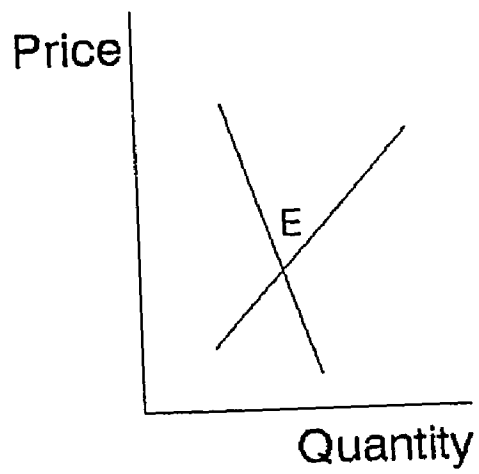
(a) Demand Curve



(b) Supply Curve



(c) Market Equilibrium



assumed to slope upward and to the right -- a positive slope. The positive slope of the supply curve suggests that an increase in price will increase the quantity supplied of the commodity (Fig. 6-b). The demand and supply curves represent the total demand and supply for the commodity at various prices and at a particular period of time.

Changes in the demand and supply and changes in the quantity demanded and supplied of a commodity must be distinguished from one another. A change in the demand or supply shifts the demand or supply curve because of a change in the relationship between price and quantity demanded or supplied, resulting from a change in factors such as the number of consumers and producers, consumer preference, income, population, prices of related goods, or production techniques. A change in the quantity demanded or supplied refers to the variations in quantity and price of a commodity, given all other factors are held constant. A change in the demand or supply will shift the entire curve, but a change in the quantity demanded or supplied results only in a movement along the curve.

Market Equilibrium and Disequilibrium

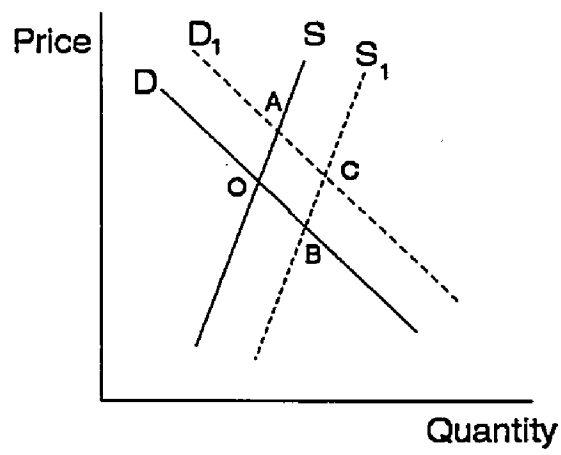
The quantities demanded and supplied of a commodity

interact as price and production change. The intersection of the demand and supply curves in E is called the market equilibrium (Fig. 6-c). Once at market equilibrium E, the quantity demanded equals the quantity supplied. In reality, the market may not be in equilibrium, because demand may not equal supply. However, if there are no outside influences preventing prices from being bid up or down, the actual price will move toward the equilibrium price, and the market will converge at an equilibrium price-quantity combination (Ferguson and Maurice, 1974).

Alternatively, the demand and supply curves may shift in response to changes in the number of consumers and producers, consumer preference, income, population, prices of related goods, or production techniques. As the demand or supply curve shifts, the market equilibrium changes. The new equilibrium will be established depending upon the new intersection of demand and supply curves. For example, a market equilibrium is assumed to be at O (Fig. 7). If an increase in the demand for a commodity occurs and the supply is held constant, the demand curve shifts from D to D_1 . The new market equilibrium is established at point A. If an increase in the supply of the commodity occurs and the demand is held constant, the supply curve shifts from S to S_1 , and the new equilibrium is B. If both demand and supply of the commodity increase simultaneously, the equilibrium

Figure 7

Shifts in market equilibrium.



may be established at point C.

The market equilibrium model has been criticized widely (Bennassy, 1982; Bockstael, 1982; Doorn, 1975; Lambert, 1988). If the supply cannot increase immediately, price adjustment or movement from one equilibrium to the other may take a certain period of time to reach the new equilibrium. Also, a commodity's quantity and price may be constrained institutionally in many ways. For instance, price ceilings and floors, fixed prices, tariffs, or quota restrictions may be imposed on a market by government, resulting in the market's inability to achieve a competitive market equilibrium.

A market disequilibrium occurs when quantity demanded does not equal quantity supplied. The assumption of market equilibrium may be inappropriate if the demand or supply of a commodity changes frequently, market adjustment is very slow or impossible, or the movement of the price or quantity is restricted. Therefore, a market analysis needs to distinguish the characteristics of market equilibrium from those of disequilibrium.

Fisher (1983) suggests that the view of equilibrium should rest logically on two underlying properties about the dynamics of equilibrium. First, the market system must be

convergent, or tending towards the equilibrium. Second, the movement or returning to the equilibrium state must take place quickly so that the transient process of shifting from one equilibrium to the other equilibrium may be ignored. The requirements of an equilibrium system are thus convergence and sufficient speed of the market adjustment (Fisher, 1983). Once the market reaches an equilibrium, the equilibrium will then persist (Froyen and Greer, 1989).

Equilibrium of Virginia Market

A disequilibrium market system or non-convergent market is often caused by constraints imposed by government or institutions. The constraints limit the movement of price and quantity to achieve the market equilibrium or to reduce the speed of the market adjustment (Maddala, 1986). There are several regulations and laws in the Virginia oyster industry which may affect the market equilibrium: restrictions imposed by VMRC on public ground fishery such as gear limitations, daily catch limits, and seasonal closures. Patent tongs and dredges are relatively efficient compared to hand tongs, but since these gears may damage oyster grounds, they have been restricted on certain public grounds. However, the number of patent tongs and dredges is small compared to hand tongs, and they are used primarily on

the private grounds because of their efficiency (Insley, 1986). The impact of gear limitations on production from public ground fishery may thus seem to be small.

A daily catch limit of 15 bushels per person or 45 bushels per boat has been imposed by VMRC. Insley (1986) estimated that a three-person boat may yield 10 to 30 bushels of market oysters per day in Virginia public grounds. A report from the CEC (1989) also suggested that the average catch per man-day was lower than the permitted daily limits, meaning the daily catch limit probably does not affect current production from public grounds.

Finally, the closure of the fishing season may affect the oyster production of the public grounds, but the seasonal closure limits the market itself rather than the market adjustment. As the market is subject to seasonal closure, the market for public oysters does not exist. The study therefore assumes that the limitations of these regulations and laws have little effect on the market equilibrium for public oysters.

Alternatively, there are few regulations on taking oysters from private leased grounds -- no catch, size, or gear limitations, or seasonal closures on private oyster production (JLARC, 1984). Oyster supplies from private

leased grounds may be year-round. Also, few laws and regulations exist for delivering oyster shellstock from other regions to Virginia, except for the purpose of tax collection, VMRC requires that oyster shippers provide a shipping document detailing the costs, volume and source areas. It is reasonable to assume that each market sector tends towards an equilibrium.

Harvesting oysters in public grounds and private leased grounds may be daily activities. The harvested market oysters are transferred on the same day of their harvest to the shucking houses (Insley, 1986). The speed of the market adjustment from outside supplies to Virginia shucking houses is unclear. However, the shellstock cannot be stored for weeks without processing; the use of monthly data in the study, therefore, should be sufficient to respond to the market adjustment. It is assumed that the market adjustment of each sector in response to the change in the price is reflected adequately in the monthly data, and that each market sector is in equilibrium status.

Elasticity

Elasticity measures percentage changes in quantity or price of goods in response to changes in factors affecting

demand or supply. The value of elasticity does not depend on the units in which quantity, price, and other factors are measured; rather, it is a dimensionless measure and expressed as a relative percentage change. The sensitivities of goods to the buyers or sellers and the market relationships between goods can be compared through the use of elasticities.

Own-price Elasticity

Changes in quantity demanded and supplied depend upon changes in the prices of the commodity. The measurement of the changes in the relationship between price and production of a commodity is called the own-price elasticity of demand or supply. The own-price elasticity of demand or supply is expressed as:

$$\epsilon = (\Delta Q / \Delta P) (P / Q) \quad \dots\dots\dots (3.1)$$

where

- ϵ is the price elasticity of demand or supply,
- Q is the quantity demanded or supplied of a commodity,
- P is the price of a commodity, and
- Δ is the symbol meaning "a change in".

Given a mathematical relationship between quantity and price, $\Delta Q/\Delta P$ is equal to the partial derivative $(\partial Q/\partial P)$ of a demand or supply function. The own-price elasticity may thus be obtained as follows:

$$\epsilon = (\partial Q/\partial P) (P/Q) \quad \dots\dots\dots (3.2)$$

The own-price elasticity of demand is always negative for a normal commodity because of the demand curve's downward slope. Conversely, the own-price elasticity of supply is positive because of the upward slope of the supply curve. The magnitude of the own-price elasticity determines the sensitivity of the commodity to the buyers or sellers.

The own-price elasticity of demand also indicates the effect of a price change in the total amount spent on a commodity. However, the amount of money spent by buyers equals the sellers' revenue: the magnitude of the own-price elasticity of demand thus has an important relationship to the level of revenue (Table 8). If the quantity demanded is sensitive to the price change, or the own-price elasticity of demand is greater than one, a small increase in price will reduce the total revenue. This is because the percentage gain from the price increase is less than the percentage lost to the quantity sold. If the quantity

Table 8. The relationship between own-price elasticity and total revenue.

| Own-price Elasticity of Demand | Effect on Total Revenue of: | |
|--------------------------------------|-----------------------------|----------------|
| | Price Increase | Price Decrease |
| Price elastic ($ \epsilon > 1$) | Decrease | Increase |
| Unitary ($ \epsilon = 1$) | No change | No change |
| Price inelastic ($ \epsilon < 1$) | Increase | Decrease |

Note:

$|\epsilon|$ is the absolute value of own-price elasticity

demand is not sensitive to the price change, or own-price elasticity of demand is less than one, an increase in price will increase the total revenue. If the own-price elasticity equals one, a change in price will not affect total revenue.

Cross-price Elasticity

A shift in the demand curve may be caused by a change in other factors. For instance, the demand for a commodity may be affected by the prices of other related commodities. If two commodities are closely related, it is possible that one may substitute for the other. If two commodities serve the same purpose and are used together, changes in the demand for one good will affect the demand for the other good in the same direction. It is also possible that two commodities are unrelated to each other, and a change in the demand for one good will not affect the demand for the other. The measurement of the market relationship of two commodities is called the cross-price elasticity of demand, defined as a rate of change in the quantity demanded of a given commodity associated with a change in the price of another commodity. It may be expressed as

$$\epsilon_{xy} = (\Delta Q_x / \Delta P_y) (P_y / Q_x) \dots\dots\dots (3.3)$$

where

ϵ_{xy} is the coefficient of cross-price elasticity of commodity X with respect to a change in the price of commodity Y,

Q_x is the quantity demanded of X, and

P_y is the price of Y.

The coefficient of cross-price elasticity, ϵ_{xy} , can be negative or positive. If the cross-price elasticity is positive, two commodities are substitutes. An increase in the price of Y will result in an increase in the demand for commodity X. If the cross-price elasticity of demand is negative, two commodities are complements. An increase in the price of Y will result in a decrease in the demand for X. If the cross-price elasticity is close to zero, either positive or negative, two commodities may be unrelated to each other, and they are independent.

Economic Model for Virginia Oyster Market

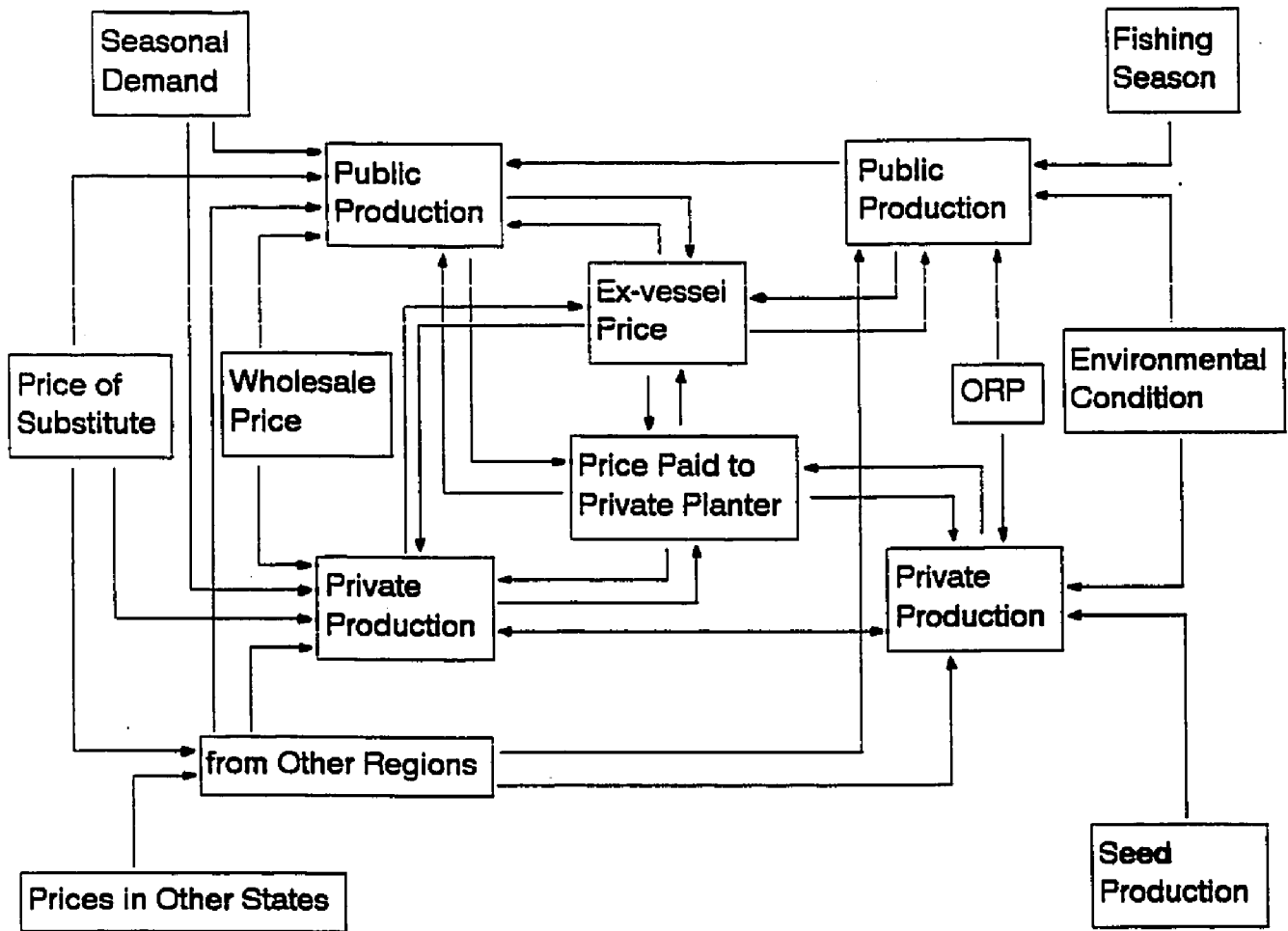
Many factors affect the Virginia oyster market: its complexity may be illustrated by a simplified economic flow chart with price at the center of the market (Fig. 8). For instance, the demand for public and private oysters may be

Figure 8

Virginia oyster market flows

Demand Side :

Supply Side :



affected by factors such as own price, prices of other oysters, wholesale price, seasonal demand, and/or the supplies from other regions. Production from public ground fishery may be affected by the ex-vessel price, fishing season, the success of the ORP, and/or environmental conditions such as water temperature and salinity. The production from private leased grounds is affected by its own price, the quantity of previously planted seed oysters, and environmental conditions. The arrows on both ends of the line represent market equilibrium.

This study proposes a complete Virginia oyster market consisting of eight market relationships, with three demand equations for the Virginia oyster market, including public and private oysters and oyster supplies from other regions. There are two supply equations, including public and private oyster production, and finally, there are three identifications for each market sector to complete the system. All relationships are assumed to be linear.

Demand for Oysters

Since the demand function for the Virginia oyster market has not been identified, this study proposes demand functions for each market sector as

$$\text{Public: } Q_{df} = F(P_f, P_p, Q_{so}, P_{wh}, P_{wa}, D_1) \quad \dots\dots (3.4)$$

$$\text{Private: } Q_{dp} = F(P_f, P_p, Q_{so}, P_{wh}, P_{wa}, D_1) \quad \dots\dots (3.5)$$

$$\text{Outside: } Q_{do} = F(Q_{sf}, Q_{sp}, P_o, P_{wa}) \quad \dots\dots (3.6)$$

where

- Q_{df} is the demand for oysters from public grounds,
 P_f is the oyster ex-vessel price or dockside price,
 P_p is the price paid to private planters,
 Q_{so} is the quantity of supply from other regions,
 P_{wh} is the wholesale price index in the Fulton market,
 P_{wa} is the oyster ex-vessel price in the state of Washington,
 D_1 is the seasonal demand dummy variable,
 Q_{dp} is the demand for oysters from private leased grounds,
 Q_{do} is the demand for oyster supplies from other regions,
 Q_{sf} is the oyster supply from public grounds,
 Q_{sp} is the oyster supply from private leased grounds,
 and
 P_o is the composite price index for other states.

The Virginia oyster processors' demand for oysters from public ground fishery and private leased grounds is assumed

to be affected by the oyster ex-vessel price, price paid to private planters, outside supplies, wholesale price index, the oyster ex-vessel price in the state of Washington, and a seasonal dummy variable.

Prior to 1986, records of monthly prices of oysters transported from other states to the Virginia market were not available from VMRC, but VMRC did maintain data on monthly quantity supplied from other states. The use of a quantity variable in the demand function for the Virginia oysters to measure a change in demand for oysters is arguable. However, over half of the unshucked oysters are supplied from other regions, so it is impossible to ignore this factor in modelling the Virginia oyster market. March (1985) has suggested that a quantity variable may be used in the demand function; thus, the quantity supplied from other states used in the estimation results from the lack of the prices of oysters supplied by other states.

A consistent series of monthly wholesale prices for Virginia oysters is also unavailable after 1984; instead, an oyster wholesale price in Fulton, New York, is used as an instrumental variable. The shucked oysters are sold in the Fulton market as half-pint, selects (210-300/gallon), extra selects (160-210/gallon), and 100 count. The wholesale price index is a weighted price obtained by averaging the

prices of selects and extra selects.

Pacific oysters differ both in taste and appearance from the eastern oysters. In the U.S., they are raised primarily on the west coast. Since Pacific oysters are also brought into the Virginia market, this study considers that the Pacific oyster may substitute for the eastern oyster. Oyster ex-vessel price in the state of Washington is used as the price of a substitute for the eastern oyster, because the state of Washington is the largest producer of the Pacific oyster in the nation.

Demand for oysters sharply increases during the Thanksgiving and Christmas seasons because oysters are a traditional food for these holidays (Haven *et al.*, 1981; Dressel *et al.*, 1983). A dummy variable is used to represent the seasonal shifts in the demand for oysters; its value will be given as one during these seasons, otherwise as zero.

The demand function for outside supplies is assumed to be affected by public and private production, the oyster ex-vessel price in the state of Washington, and a composite ex-vessel price index of other states. Before 1960, the level of oyster shellstock from other states to Virginia was negligible, because Virginia oyster production was able to

supply processors' demand (Insley, 1986). The increase in demand for oyster supplies from other states was caused by a decrease in Virginia oyster production (Haven et al., 1981; Insley, 1986; VIMS, 1989). In addition, Haven et al. (1981) state that Virginia oyster processors pay higher prices for Maryland oysters than for Virginia oysters. Based on previous research, the demand for outside supply is unlikely to be determined by Virginia oyster prices. This study considers that production from public and private leased grounds will be independent variables in the demand function for outside supplies.

Since large quantities of oyster shellstock are brought from many states into Virginia oyster market, changes in the ex-vessel prices or deck prices of oysters from these states may affect the desires of Virginia oyster processors for purchasing shellstock from these states. There are 14 states trading in the Virginia market during the observed periods: Alabama, Connecticut, Florida, Georgia, Louisiana, Maine, Maryland (including the Potomac River), Missouri, Mississippi, New Jersey, New York, North Carolina, South Carolina, and Texas.

If all prices are included in the demand function, the degrees of freedom will be reduced, and there is likely to be severe multicollinearity among the price variables

(Schrank et al., 1988). Since these prices may vary in the same direction, a high correlation among the prices is likely to occur; alternatively, focusing on only one state introduces possible bias. Econometric concept suggests an aggregate price best reflects demand: the model thus considers a composite index of the ex-vessel prices of other states. The composite ex-vessel price is formed by an approximation to the Divisia aggregate:

$$P_o = e^{\sum_{i=1}^s \left(\frac{P_i \cdot Q_i}{\sum_{i=1}^s P_i \cdot Q_i} \right) \cdot \ln P_i} \dots\dots (3.7)$$

where s represents the number of states that sell their oysters to Virginia. Although oyster supplies from Missouri are present in the records, they are unlikely to occur. The number of states used to construct the composite price index is 13. The state of Washington is not considered as one of the outside oyster supplier because of lack of records.

It is hypothesized that the oyster prices have negative effects on the quantity demand for public and private oysters (Table 9), while the wholesale price index and seasonal dummy variable may have positive effects on the demand for public and private oysters. Since the Pacific

Table 9. The hypothesized signs of the coefficients for the demand function.

| Independent Variable | Dependent Variable | | |
|----------------------|--------------------|----------|-----------------|
| | Q_{df} | Q_{dp} | Q_{do} |
| P_f | ? ^a | Negative | -- ^b |
| P_p | Negative | ? | -- |
| Q_{so} | Negative | Negative | -- |
| P_{wh} | Positive | Positive | ? |
| P_{wa} | Positive | Positive | Positive |
| D_1 | Positive | Positive | -- |
| Q_{sf} | -- | -- | Negative |
| Q_{sp} | -- | -- | Negative |
| P_o | -- | -- | Negative |

Note:

^a : the sign of coefficient is undetermined.

^b : the variable is not included.

oysters are assumed to be substitutes for the eastern oysters, the oyster ex-vessel price in the state of Washington may have a positive effect on the demand for public and private oysters. Oysters from other states are also assumed to be substitutes for oysters from public and private leased grounds. Therefore, oyster supply from other regions may have a negative effect on the demand for public ground fishery and private cultivated oysters, and production from public and private leased grounds may have a negative effect on the demand for outside oysters. Finally, the market relationship between public and private oysters is undetermined.

Supplies of Oysters

Fishery supply is often assumed to be exogenous because it is affected predominantly by environmental and biological factors (Lin, 1984; Wang, 1984), implying that fish production will not be affected by its own-price. However, the assumption must assume simultaneously that the price level is acceptable, given the quantity supplied of a fishery product. Otherwise, commercial fishery may not exist without an acceptable price. The latter assumption implies that the price of the product is also exogenous. Therefore, both the own-price and supply of a fishery

product are exogenous.

The goal of a commercial fisherman is to make a profit, a goal which relates to price and production. The market is thus determined simultaneously by production and price. The assumption of exogenous fish production resulting in an price unrelated to production violates a fundamental economic principle. This study proposes oyster supply functions for public and private oysters, even though data on environmental and biological variables are limited.

In contrast, the outside supply is assumed to be exogenous. This assumption implies that outside production is not influenced by the Virginia oyster market; therefore a supply function for outside supply is not proposed in this study. The supply functions for public and private oysters are specified as follows:

$$\text{Public: } Q_{sf} = F(P_f, \text{MSX}, D_2) \quad \dots\dots\dots (3.8)$$

$$\text{Private: } Q_{sp} = F(P_p, \text{Seed}_{t-16}, \text{MSX}) \quad \dots\dots\dots (3.9)$$

where

D_2 is the dummy variable of the oyster fishing season,

MSX is the MSX and "Dermo" diseases index, and

$Seed_{t-16}$ is the production of seed oysters two years prior to the present.

The supply function for public oysters, Equation 3.8, assumes that oyster production from public grounds is determined by its own price, a disease index, and a dummy variable for fishing season. Public production presents a seasonal pattern: production is high at the beginning of the fishing season and low at the end of the season. The eight months of oyster season are arbitrarily divided into two categories, the early and the late oyster seasons. The values of the seasonal dummy variable will be given as one for the first half of the oyster season and zero for the later half.

MSX and "Dermo" still threaten the Virginia oyster industry. To monitor disease activity, the oyster monitoring program at the Virginia Institute of Marine Science has used water temperature and salinity as disease indicators. In general, a temperature and salinity higher than the monthly average may indicate the threat of disease (Burreson, 1987).

Monthly water temperature and stream flow data are used to construct a disease indicator, MSX. Data are standardized initially by the monthly mean and deviation to

form an observed standard normal distribution with mean zero and variance unity. A negative value of flow represents a smaller flow than the monthly average of stream flow in terms of drought, while a positive value of water temperature represents a higher temperature than the monthly mean temperature. Finally, the standardized temperature data are subtracted from the stream flow data to form the disease index. A high water temperature and low flow will produce a high value of MSX, indicating a higher risk of the disease.

The supply function for private production assumes that oyster production from private leased grounds is determined by its price, seed oyster production of the previous two years, and the disease index. The production of seed oysters has been used as an index of expected production from leased bottoms two years later (Haven et al., 1981). A two-year lag of seed oyster production is represented by 16 months, because there are four months of oyster season closure for each year.

It is hypothesized that oyster prices have positive effects on production in public ground fishery and private leased grounds (Table 10) and that the disease indicator may have a negative effect on both supply functions. Finally,

Table 10. The hypothesized signs of the coefficients for the supply function.

| Independent Variable | Dependent Variable | |
|----------------------|--------------------|----------|
| | Q_{st} | Q_{sp} |
| P_t | Positive | -- |
| MSX | Negative | Negative |
| D_2 | Positive | -- |
| P_p | -- ^a | Positive |
| $Seed_{t,16}$ | -- | Positive |

Note:

^a : the variable is not included.

seed production may have a positive effect on private production two years later.

Identity Equations

The study assumes that each market sector is in equilibrium and that three identity equations for the market equilibrium are necessary:

$$Q_f = Q_{df} = Q_{sf} \quad \dots\dots\dots (3.10)$$

$$Q_p = Q_{dp} = Q_{sp} \quad \dots\dots\dots (3.11)$$

$$Q_o = Q_{do} = Q_{so} \quad \dots\dots\dots (3.12)$$

where

- Q_f is the production from public grounds,
- Q_p is the production from private leased grounds, and
- Q_o is the quantity of oyster supply from other states.

The identity equations state that the quantity demanded is equal to the quantity supplied for each market sector, based on the fact that the equilibrium of the Virginia oyster market will be achieved via quick adjustment and convergence. These identity equations complete the Virginia

oyster market system proposed in this study.

Simulation

A simulation is an experiment conducted with a specially designed model of the system. Simulation has been widely used in many sciences to project the behavior of a system given past and current information; it has also been applied to an economic system when the analytical techniques cannot perform controlled experiments. The economic simulation can be used for various purposes such as model testing, forecasting, and policy analysis (Theil 1966; Naylor, 1971).

The purpose of simulation in this study is to assess the market behavior in response to the proposed objectives of the OFMP, which are to initiate an improved oyster fishery management and to achieve an optimum yield on a long-term basis. The primary objectives of the OFMP are to increase both public ground fishery production to at least 700,000 bushels (20 percent above the ten-year average) by 1993 and privately cultivated oysters to 700,000 bushels (the approximate twenty-year average) by 1995. The annual average of production is 380,000 bushels for public oysters and 285,000 bushels for private oysters, meaning that the

proposed public production by the OFMP is 1.8 times larger than the observed annual public production, and the proposed private production is 2.5 times larger than the observed annual private production.

The market factors of the ex-vessel price, price paid to oyster planters, and outside supply are simulated given the estimated model and production proposed by the OFMP. The proposed public and private production is assigned proportionally to each month, based on the monthly mean of production during the observed periods (1981-1989). Monthly mean of all exogenous variables will be used as input data. The October values are used as the initial points.

Data

Data used in estimating market demand and supply were obtained from a variety of sources. All information related to Virginia oyster production was from VMRC, and most non-Virginia oyster-related information originated from the Statistics Division of the National Marine Fisheries Service (NMFS). Other data were obtained from various sources, such as the Maryland Department of Natural Resources, the Department of Fisheries of the state of Washington, and Virginia Institute of Marine Science's published and

unpublished papers. Monthly data from 1981 to 1989 were used, except that for seed oysters, which were from 1979 to 1987.

Data Limitation

In Virginia, oyster price paid to oystermen may vary based on the geographic location (Haven *et al.*, 1981). Prices are highest for oysters from the Rappahannock River, less for the York River, and lowest for the Eastern Shore oysters (JLARC, 1984). However, there is no evidence that the geographic variation of oyster prices is related to the quality of oysters (Haven *et al.*, 1981). This study assumes that the variation, if any, caused by the product differentiation may be considered a minor effect. The use of aggregate production ignores the effect of product differentiation on the geographic variation.

It is believed that the ORP has a positive effect on the Virginia oyster industry (Haven, *et al.*, 1981; Insley, 1986); however, Abbe (1988) suggests that the program may have positive effects on sustaining good harvests only in good spat set years (Abbe, 1988). Unfortunately, the effects of the ORP on Virginia oyster production have never been confirmed by quantitative analysis because of data

deficiency (JLARC, 1984; Thunberg and Santopietro, 1985; Shabman and Thunberg, 1988). Since the ORP data are formed annually, the ORP will not be considered in the economic model.

The state of Virginia prohibits harvesting oysters from public grounds between June and September in order to protect spawning stocks. Since there is no public ground fishery during these months, the data for public oyster production and ex-vessel prices are zeroes. The interruption of public ground fishery by Virginia laws and regulations creates two difficulties for the econometric estimation: the zero observations in the data cannot be considered as random samples, and the closure of the fishing season results in a discontinuous data series.

Tobin (1958) analyzed household expenditure on durable goods using a linear regression model. He found that there were no expenditures on certain durable goods when the incomes were lower than a certain level. This dependent variable with a limited range of data is called a limited dependent variable. A limited dependent variable is part qualitative (buy or not buy) and part quantitative (amount bought) in terms of discrete and continuous data (Pindyck and Rubinfeld, 1981), consequently an analysis of a limited dependent variable combines analyses of qualitative and

quantitative measures.

Both limited dependent variable and production from public ground fishery consist of zeroes and non-zero data. The fundamental difference between the zeroes in the limited dependent variable and the production from public ground fishery is the definition of the dependent variable. The zeroes in the limited dependent variable are caused by the system itself because the decision to spend on the durable goods is determined within the system, by consumers. These zeroes are regarded as random samples.

Conversely, a ban on public ground fishery from June to September is imposed from outside the market system. These zeroes in public production cannot be interpreted as zero landings because they imply that oystermen can harvest oysters from public grounds. These zeroes actually state that oystermen cannot take oysters from public grounds at all: the zero public production results from the regulations rather than from the public ground fishery itself. Therefore, the zero public production from public ground fishery may not co-exist with other non-zero data.

A dummy variable is commonly used as a qualitative factor, but adding a dummy variable as an independent variable to indicate the closure of the fishing season is

unlikely to solve the problem. First, the dependent variable still cannot satisfy the assumption of random sampling if zeroes are included in the dependent variable. Also, the dummy variable is likely to create a difficulty in interpreting the closed season -- the result may have a certain amount of estimated public oyster production between June and September that should not be allowed.

As mentioned previously, the limited dependent variable and the dummy variable addition methods violate relevant assumptions. Since there are no adequate methods to solve the problem caused by oyster fishery regulations, a redefined universe of data domain is considered. As the zero values of public production resulting from the seasonal closure do not satisfy the econometric assumption, all data from June to September are omitted. This study considers the Virginia oyster market in which only public ground fishery exists. There is no oyster supply from public ground fishery, and therefore no market for public oysters can exist. The redefined data domain has no effect on the public market sector.

The oyster supplies from other states are low during the closed fishing season, ranging from 5 to 10 percent of its annual supply (Table 11). This study thus assumes that

Table 11. Percentage of total supplies of private and outside Virginia in the closed fishing season (June-September).

| Year | Private Supplies | | | Outside Supplies | | |
|------|------------------|--------|------|------------------|---------|------|
| | Jun-Sep | Total | % | Jun-Sep | Total | % |
| 1981 | 131308 | 368286 | 0.36 | 98675 | 1423193 | 0.07 |
| 1982 | 94958 | 327139 | 0.29 | 65175 | 1207739 | 0.05 |
| 1983 | 92527 | 312406 | 0.30 | 46381 | 895210 | 0.05 |
| 1984 | 62448 | 249681 | 0.25 | 66917 | 778636 | 0.09 |
| 1985 | 112537 | 317930 | 0.35 | 78750 | 821079 | 0.10 |
| 1986 | 186511 | 406535 | 0.46 | 55584 | 713700 | 0.08 |
| 1987 | 110140 | 273245 | 0.40 | 24644 | 481393 | 0.05 |
| 1988 | 62369 | 158205 | 0.39 | 26291 | 456063 | 0.06 |
| 1989 | 61352 | 155571 | 0.39 | 24307 | 478725 | 0.05 |

Data Source: VMRC.

the seasonal closure has little impact on the outside market sector and that the redefined data domain may have little effect on it as well.

On the other hand, production from private leased grounds during the seasonal closure is between 25 and 46 percent of its annual production. The seasonal closure may have a definite impact on private oyster production: the redefined data domain will affect the private market sector, and the analysis of private market sector is not completed. Therefore, a supplemental model, incorporating all data, for the private market sector is provided.

Methodology for the Analysis

This study has proposed that the Virginia oyster shellstock market is comprised of the public ground fishery, private oyster cultivation, and outside supplies. Each market sector is assumed to be in equilibrium. Since the market equilibrium is determined by the intersection of the demand and supply curves, and each market sector is interrelated to other sectors, a simultaneous multiple-equations system is proposed.

In the linear regression model, the causal relationship between the dependent variable (Y) and the independent variables (Xs) is that Y is affected by X but not vice versa. However, the feedback from the dependent variable Y to the independent variables Xs is likely to occur in the market process; for instance, the quantity demanded or supplied is simultaneously interdependent on the price. A system describing the joint dependence of variables is called a system of simultaneous equations (Koutsoyiannis, 1973).

The simultaneous multiple-equations system is common in market analysis because the market equilibrium is determined simultaneously both by demand and supply functions. Two methods commonly used to estimate a simultaneous multiple-equations system are Three-Stage Least Squares (3SLS) and Full Information Maximum Likelihood (FIML). These methods are concerned not only with the correlation between the error term and some variables of the equation, but also with the correlation of error terms across the equations. The techniques and their differences can be found in Formby *et al.* (1988), Cramer (1986), Amemiya (1985), Intriligator (1978), and Koutsoyiannis (1973). The estimation method used in this study is FIML.

Estimation

Several statistical tests may be invalid for testing the simultaneous multiple-equations system, such as the F statistic and determination of coefficient or R^2 . R^2 , a measure of the goodness of fit, is not bounded between zero and one, but is bounded between negative infinity and one in the simultaneous multiple-equations system. A small value of R^2 consequently may not be an indication of a poor fit (Goldstein and Khan, 1978).

There are other criteria that measure the goodness of fit. The most popular alternatives are the Akaike information, Amemiya's prediction, and the Schwarz criteria (Kennedy, 1992). After comparing several criteria, Amemiya (1980) stated that "All of the criteria are based on somewhat arbitrary assumptions which cannot be fully justified...one can indefinitely go on inventing new criteria," and as a result, this study will not provide these criteria.

The statistic used to evaluate the fit of the model in the FIML technique is the value of the log of likelihood function, which measures the deviation of the observed data and the fitted data in a log form. A small number represents a small deviation between samples and fitted data

and hence indicates a better fit.

Alternatively, the F and R² also cannot be used to examine the performance of the simulation, and the Root-Mean-Square percentage error (RMS %) will be used as a criterion of the simulation analysis instead. The RMS % measures the sum of square of the percentage difference between the observations and the simulated data in squared root (Pindyck and Rubinfeld. 1981). A large value of the RMS % represents a great deviation between the observations and simulated data. The RMS % is defined as

$$RMS \% = \sqrt{\frac{1}{T} \sum_{t=1}^T \left(\frac{Y_t^p - Y_t^o}{Y_t^o} \right)^2} \quad \dots (3.18)$$

where

Y^p is the simulated or predicted endogenous variable,

Y^o is the observed endogenous variable, and

T is the number of data or periods in the simulation.

All estimation and tests will be performed using Soritec PC version 6.5. The convergence criterion of 0.001 will be used. Each estimated parameter will be examined by a t-statistic at the five percent level of significance.

EMPIRICAL RESULTS AND DISCUSSION

Estimation and Empirical Results

Estimation is complicated by the presence of multicollinearity and by serial correlation among some variables. Multicollinearity results in the problem that the estimates of the ordinary least squares (OLS) method may be inefficient, and statistical tests of the significance of the estimates tend not to reject the null hypothesis (Intriligator, 1978; Koutsoyiannis, 1973).

There are many options for dealing with multicollinearity: adding more non-correlated data, dropping one of the collinear variables, aggregating the collinear variables, or using the principal component and ridge techniques (Kennedy, 1992). The occurrence of multicollinearity depends upon the data set at hand (Kmenta, 1971). Since multicollinearity is not caused by model misspecification, a change in the model structure or techniques may be inappropriate in many situations (Blanchard, 1987; Conlisk, 1971; Maddala, 1988). Alternatively, Blanchard (1987) suggests that the problem of

multicollinearity may not be severe and may in fact be ignored if the t-statistics of the correlated variables are all greater than two.

The Virginia oyster ex-vessel price and the price paid to private planters were highly correlated; the correlation coefficient was 0.8. Since both prices were included in the demand functions for Virginia oysters, multicollinearity would pose a problem for estimation. However, a t-value for the difference between ex-vessel price and price paid to private oyster planters was 11.2, which indicated that both prices might have a different population distribution. Also, the estimated coefficients for both prices were significantly different than zero, suggesting that the problems of multicollinearity in the model could be tolerated.

Serial correlation occurs when the error term for one observation is related to the error term for another (Kennedy, 1992). Since the error terms are not temporally independent, the estimates of the OLS are also inefficient: if positive serial correlation occurs, the problem for the estimated model is that variance of the estimated parameters may be underestimated.

The Durbin-Watson (DW) test has been widely used for

testing first order serial correlation. The value of the DW statistic, ranging from 0 to 4, falls into one of three classifications: serial correlation, no serial correlation, and inconclusive. If the DW is close to 2, there is no serial correlation within the observed data; if the DW is close to zero or 4, the samples are likely to have a strong positive or negative serial correlation. Also, there is an indeterminate or inclusive region between the no serial correlation and the strong serial correlation regions. For the simultaneous multiple-equations system with the problem of serial correlation, Goldfeld and Quandt (1972) suggest that the estimates from the nonlinear FIML method are more efficient than estimates from other methods.

The DW statistic indicated that first order serial correlation existed in all equations, except the demand function for private production. The original model was therefore transformed in order to incorporate the coefficient of serial correlation into the model (Table 12). A non-linear FIML method was then applied to the transformed model and estimated.

Convergence of the FIML procedure did not occur in the early analysis. This might be attributable to the nature of the samples -- in the collected data, the production

Table 12. The transformed econometric model.

$$Q_{f,t} = a(1-\rho_1) + a_1(P_{f,t} - \rho_1 * P_{f,t-1}) + a_2(P_{p,t} - \rho_1 * P_{p,t-1}) + a_3(Q_{o,t} - \rho_1 * Q_{o,t-1}) + a_4(P_{wh,t} - \rho_1 * P_{wh,t-1}) + a_5(P_{wa,t} - \rho_1 * P_{wa,t-1}) + a_6(D1_t - \rho_1 * D1_{t-1}) - \rho_1 * Q_{f,t-1}$$

$$Q_p = b + b_1 * P_f + b_2 * P_p + b_3 * Q_o + b_4 * P_{wh} + b_5 * P_{wa} + b_6 * D1$$

$$Q_{o,t} = c(1-\rho_3) + c_1(Q_{f,t} - \rho_3 * Q_{f,t-1}) + c_2(Q_{p,t} - \rho_3 * Q_{p,t-1}) + c_3(P_{os,t} - \rho_3 * P_{os,t-1}) + c_4(P_{wa,t} - \rho_3 * P_{wa,t-1}) - \rho_3 * Q_{o,t-1}$$

$$Q_{f,t} = d(1-\rho_4) + d_1(P_{f,t} - \rho_4 * P_{f,t-1}) + d_2(MSX_t - \rho_4 * MSX_{t-1}) + d_3(D2_t - \rho_4 * D2_{t-1}) - \rho_4 * Q_{f,t-1}$$

$$Q_{p,t} = e(1-\rho_5) + e_1(P_{p,t} - \rho_5 * P_{p,t-1}) + e_2(SEED_{t-16} - \rho_5 * SEED_{t-17}) + E_3(MSX_t - \rho_5 * MSX_{t-1}) - \rho_5 * Q_{p,t-1}$$

where

Q_f is oyster production from public grounds,
 P_f is the oyster ex-vessel price or dockside price,
 Q_p is oyster production from private leased grounds,
 P_p is the price paid to private planters,
 Q_o is the supplies from other regions,
 P_{wh} is the wholesale price index in Fulton market,
 P_{wa} is the oyster ex-vessel price in the state of Washington,
 $D1$ is the seasonal demand dummy variable,
 P_{os} is the composite price index for other states.
 MSX is the MSX and "Dermo" diseases index,
 $D2$ is the dummy variable of oyster fishing season,
 $SEED_{t-16}$ is production of seed oysters two years prior to the present,
 ρ is the serial correlation coefficients,
 $a - e$ are the parameters to be estimated, and
 $t-1$ is the variable lagged one period.

variables consisted of large values, and the price and index variables of small values. The econometric package PC version by Soritec, Inc. may not deal well with this situation. Since the criterion had been set at 0.001, increasing the number of iteration was necessary to achieve convergence. Convergence finally occurred after 299 iterations, and the value of the log of likelihood function was -2218. In contrast, the supplemental model for private market converged quickly after 15 iterations, and the value of the log of likelihood function was -1114.

Demand for Oysters

All estimated coefficients of the demand function for public oysters were significantly different from zero at the 5 percent level of significance (Table 13). Thus, a change in any of the factors would have a significant influence on the demand for public oysters. The DW statistic was 1.55, indicating that serial correlation was uncertain.

A negative coefficient for ex-vessel price suggested that price had a negative effect on the quantity demanded. A dollar increase in ex-vessel price would decrease the quantity demanded for public oysters by 23 thousand bushels.

Table 13. Parameter estimates for the demand function for public oysters.

| Variable | Coefficient | Standard Dev. | Elasticity |
|-----------------|-------------------------|---------------|------------|
| Constant | 4847.14 ** ^a | 58.05 | |
| P _f | -23154.30 ** | 5129.21 | -6.48 |
| P _p | -8711.41 ** | 1917.10 | -4.21 |
| Q _{so} | 3.12 ** | 0.44 | |
| P _{wh} | 7163.34 ** | 2016.41 | |
| P _{wa} | -795.58 ** | 162.99 | -0.02 |
| D1 | 4554.41 * ^b | 1800.29 | |
| ρ_1 | 0.41 ** | 0.03 | |
| DW ^c | 1.55 | | |

Note:

- ^a - Significantly different from zero at the one percent level.
- ^b - Significantly different from zero at the five percent level.
- ^c - Durbin-Watson statistic.

The own-price elasticity, evaluated at mean values, -6.48 , indicated also that demand for public oysters was highly elastic. A change in ex-vessel price would have a large effect on the demand for public production.

The price paid to private planters was found to have a negative effect on the demand for public oysters. A dollar increase in the price paid to private planters would decrease demand for public oysters by about eight thousand bushels. The negative coefficient implied that oysters from private leased grounds were complementary to oysters from public grounds. Demand for oysters from public grounds was highly responsive to changes in the price paid to private planters, indicated by a cross-price elasticity of -4.21 .

The coefficient for outside supply was positive, which contradicted the prior hypothesis that outside supplies were substitutes for oysters from public grounds and had a negative effect on the demand for public oysters. The interpretation that an increase in one bushel of oysters supplied from outside would increase the demand for public production by three bushels was paradoxical.

A positive sign for the wholesale price index suggested that the wholesale price in the Fulton market had a positive effect on Virginia oyster processors' demand for public

production. An increase in the wholesale price would encourage oyster processors to buy more public oysters. The seasonal dummy variable also had a positive coefficient: during the Thanksgiving and Christmas seasons, the demand for public oysters increased 4.6 thousand bushels more than during the rest of the seasons.

The coefficient for the oyster ex-vessel price in the state of Washington was negative, contradicting prior substitution expectation. A negative coefficient suggested that oysters from the state of Washington were complementary to oysters from public grounds. A dollar increase in the oyster ex-vessel price of Washington may decrease the demand for public oysters by 800 bushels. The cross-price elasticity, however, was relatively small (0.02). However, a one-hundred percent increase in the oyster ex-vessel price of Washington would reduce demand for public oysters by only two percent.

All estimated coefficients of the demand function for private oysters were significantly different than zero (Table 14-a), and all signs of coefficients in the demand function for private oysters were the same as the demand function for public, except the oyster ex-vessel price in the state of Washington. A positive coefficient for outside

Table 14-a. Parameters estimate for the demand function for private oysters.

| Variable | Coefficient | Standard Dev. | Elasticity |
|-----------------|--------------------------|---------------|------------|
| Constant | 12833.80 ** ^a | 930.03 | |
| P _f | -1785.55 * ^b | 771.22 | -0.5 |
| P _p | -1570.74 ** | 434.98 | -0.76 |
| Q _{so} | 0.10 ** | 0.03 | |
| P _{wh} | 1090.79 ** | 248.40 | |
| P _{wa} | 4545.00 ** | 936.57 | 0.19 |
| D1 | 1791.59 ** | 669.79 | |
| DW ^c | 1.55 | | |

Note:

- ^a - Significantly different from zero at the one percent level.
- ^b - Significantly different from zero at the five percent level.
- ^c - Durbin-Watson statistic.

Table 14-b. Parameters estimate for the demand function for private oysters^a.

| Variable | Coefficient | Standard Dev. | Elasticity |
|-----------------|--------------------------|---------------|------------|
| Constant | 10191.10 ** ^b | 1.635 | |
| P _f | -1401.33 ** | 13.739 | |
| P _p | -1650.52 ** | 14.011 | -0.74 |
| Q _{so} | 0.06 | 0.021 | |
| P _{wh} | 1158.58 ** | 46.985 | |
| P _{wa} | 94.82 ** | 1.696 | |
| D1 | 985.24 ** | 1.004 | |
| DW ^c | 0.84 | | |

Note:

- ^a - The estimation includes June - September data.
- ^b - Significantly different from zero at the one percent level.
- ^c - Durbin-Watson statistic.

supply which contradicted the expectation was also found for the demand function for private oysters. The DW statistic of 1.55 indicated that serial correlation was indeterminate.

The coefficient for the ex-vessel price was negative, suggesting that oysters from public grounds were also complementary to oysters from private leased grounds. Since oysters from both public and private leased grounds are complements, an increase in the price of one would decrease the demand for the other. However, a small cross-price elasticity indicated that the demand for private was not very sensitive to the ex-vessel price. A one percent increase in ex-vessel price would decrease the demand for private oysters by 0.5 percent.

The coefficient for the price paid to private oyster planters was negative, which confirmed the assumption that price had a negative impact on quantity demanded. A dollar increase in price paid to private planters would decrease the demand for private oysters by 1.5 thousand bushels; however, the own-price elasticity suggested that the demand for private oysters was not sensitive to its own-price. If the price paid to private planters was increased by one percent, the demand for private oysters would decrease by 0.76 percent.

Estimated coefficients for the wholesale price index and the dummy variable were positive: an increase in oyster wholesale price in Fulton market would increase the Virginia processors' demand for private oysters. Demand for private oysters would also increase during the Thanksgiving and Christmas seasons. However, the amount of increase in the demand for private oysters was not as large as that for public oysters.

The coefficient for the oyster ex-vessel price in the state of Washington oysters was positive, suggesting that the Pacific oyster was a substitute for the Virginia oyster from private leased grounds. The small cross-price elasticity, 0.19, suggested that demand for private oysters was not very sensitive to the oyster ex-vessel price of the Washington oysters -- a ten-percent increase in the oyster ex-vessel price in Washington would increase the demand for private oysters by only two percent.

All signs of coefficients in the supplemental demand function for private oysters, including information between June and September, were the same as in the original model (Table 14-b). The demand for private oysters was also inelastic at 0.74. However, the coefficient for outside supplies was no longer statistically significant, since the DW statistic was 0.84, indicating the occurrence of serial

correlation of the model.

All estimated coefficients of the demand function for outside supplies were significantly different than zero (Table 15), meaning that a change in any of the factors would have a significant influence on the demand for outside supply. These estimated parameters might be biased since the demand function was missing a relevant variable, the price for outside supply. The DW statistic was 1.58, which indicated that serial correlation was uncertain.

The coefficient for private production was negative, which indicated that oysters from private leased grounds were substitutes for outside supplies. An increase in private production would decrease the demand for outside supply. Alternatively, the coefficient for public production was positive. The negative coefficient contradicted the prior hypothesis that public production had a negative effect on the demand for outside supplies.

A positive coefficient for the composite ex-vessel price index was also contrary to prior expectations, suggesting that an increase in the ex-vessel price in other states would increase processors' demand for outside supplies. A negative coefficient of the oyster ex-vessel

Table 15. Parameter estimates for the demand function for outside supplies.

| Variable | Coefficient | Standard Dev. | Elasticity |
|-----------------|-------------------------|---------------|------------|
| Constant | 16455.5 ** ^a | 1014.20 | |
| Q _f | 0.4 ** | 0.07 | |
| Q _p | -0.5 ** | 0.14 | |
| P _o | 12260.7 ** | 2539.04 | |
| P _{wa} | -10927.7 ** | 2095.20 | -0.11 |
| ρ_2 | -0.37** | 0.04 | |
| DW ^b | 1.58 | | |

Note:

^a - Significantly different from zero at the one percent level.

^b - Durbin-Watson statistic.

price in the state of Washington was found in the demand function for outside supply, making Pacific oysters complementary to oysters from other regions. The demand for outside supplies was still not very sensitive to the oyster ex-vessel price in the state of Washington because of the small cross-price elasticity: a ten percent increase in the oyster ex-vessel price in the state of Washington would only increase the demand for outside supply by 1.1 percent.

Supplies of Oysters

The study assumed that the ex-vessel price, disease index, and seasonal changes were the most important factors for the public supply function, but the statistical results indicated that only the seasonal variable was important to oyster production from public grounds (Table 16). The DW statistic was 1.9 for the public supply function, which indicated no serial correlation in the transformed supply function.

A positive coefficient for the ex-vessel price confirmed the hypothesis that price had a positive effect on the quantity supplied. However, the coefficient of ex-vessel price was not significantly different than zero at

Table 16. Parameter estimates for the supply function for public oysters.

| Variable | Coefficient | Standard Dev. | Elasticity |
|-----------------|-------------------------|---------------|------------|
| constant | 6143.99 ** ^a | 409.48 | |
| P _f | 87.06 | 225.24 | 0.02 |
| MSX | 2234.28 | 1320.27 | |
| D2 | 21065.00 ** | 731.01 | |
| ρ_3 | -0.43 ** | 0.60 | |
| DW ^b | 1.90 | | |

Note:

^a - Significantly different from zero at the one percent level.

^b - Durbin-Watson statistic.

the 5 percent level of significance, and the own-price elastic of supply was relatively small as well (0.02). These suggested that the ex-vessel price within the observed ranges was not an important determinant for public production.

The coefficient for the disease index was positive but not significantly different from zero, meaning the factor of diseases was not important to public production during the observed periods. This contradicted the previous assumption that disease was one of the most important factors causing a decrease in Virginia oyster production. Conversely, the coefficient for the seasonal variable was positive and statistically significant. Oysters production from public grounds was determined primarily by the season: supply from public grounds was 21,000 bushels higher in the early fishing season than in the late.

The supply function for private oysters was assumed to be determined by the price paid to private planters, seed oyster production, and the disease index. Production of seed oysters was assumed to have positive effect on private production two years later. The DW statistic was 1.91, showing no serial correlation in the transformed supply function (Table 17-a).

Table 17-a. Parameter estimates for the supply function for private oysters.

| Variable | Coefficient | Standard Dev. | Elasticity |
|-----------------|-------------------------|---------------|------------|
| Constant | 9285.23 ** ^a | 141.99 | |
| P_p | 25523.90 ** | 5509.53 | 12.35 |
| See_{t-16} | -0.01 | 0.09 | |
| MSX | 3202.82 ** | 688.50 | |
| ρ_4 | 0.87 ** | 0.04 | |
| DW ^b | 1.91 | | |

Note:

^a - Significantly different from zero at the one percent level.

^b - Durbin-Watson statistic.

Table 17-b. Parameter estimates for the supply function for private oysters^a.

| Variable | Coefficient | Standard Dev. | Elasticity |
|---------------------|-------------------------|---------------|------------|
| Constant | 8639.06 ** ^b | 1.00001 | |
| P _p | 21258.20 ** | 1.02972 | 9.53 |
| See ¹⁻¹⁶ | -0.24 | 0.15488 | |
| MSX | -2525.19 ** | 1.00180 | |
| ρ_4 | 0.83 ** | 0.02 | |
| DW ^c | 1.7 | | |

Note:

- ^a - The estimation includes June - September data.
- ^b - Significantly different from zero at the one percent level.
- ^c - Durbin-Watson statistic.

The price paid to private planters had a positive coefficient. Oyster production from private leased grounds was sensitive to its price because of the high own-price elasticity of supply. A one percent increase in the price paid to private planters would increase oyster production from private leased grounds by 12.35 percent.

The negative coefficient for seed oyster production confounded prior expectations, but the coefficient was not significantly different from zero -- production of seed oysters was not important to private production. The negative coefficient for seed oyster production may be caused by large mortality because of disease in the private sector during the observed periods. The disease index had a positive coefficient, also contrary to the hypothesis that disease negatively affects private production.

All signs of coefficients in the supplemental supply function for private oysters, including information between June and September, were the same as in the original supply model, except for the coefficient for MSX index (Table 17-b). A significantly negative sign of coefficient for disease index suggested that disease had negative impact on private production. The supply of private oysters was also elastic.

Discussion

Empirical results suggested several conclusions contrary to prior expectations. First, the estimated supply functions for public and private oysters had positive signs for the disease index. A higher value of the index indicated a higher risk of the disease. However, the occurrence of diseases was triggered by many thresholds: water temperature, salinity, and time of incubation. For instance, the mortality of "Dermo" was largely found in oysters from two to four years old, and disease was eliminated during the winter season. Also, the water temperature and salinity were related to the growth of oysters: a high temperature or high salinity would have a positive effect on oyster growth.

The coefficient for the disease index was negative and significantly different from zero in the supplemental model. The significantly negative coefficient suggested that disease was an important factor for private production. The different results of the supplemental and original private supply functions were caused by the included or excluded information in the closed fishing season. High disease mortality occurred during the closed fishing season because of high water temperature; excluding information between

June and September thus underestimated the prevalence of diseases. Therefore, the positive coefficient for the disease index in public and private supply functions might indicate growth of oysters and not disease occurrence.

A positive coefficient for the composite ex-vessel price index variable in the estimated demand function for outside supply indicated that an increase in the price of oysters from other states would increase Virginia processors' demand for outside supplies. The positive coefficient occurred if an increase in the oyster ex-vessel price in other states was caused by the increase in the total demand for eastern oysters. It was also possible that estimates of demand function for outside supply were biased as a result of the excluded price paid to outside supply. Lacking adequate information, the cause of the positive coefficient for the composite ex-vessel price could not be concluded.

Market Equilibrium for Public Oysters

The estimated demand and supply functions for public oysters indicated that the market equilibrium for public ground fishery consisted of an elastic demand and a very inelastic supply. If public production increased, the

supply curve shifted to the right; if the demand for public oysters was held constant, the equilibrium would shift down and to the right. The shift in supply curve resulted in a decrease in the ex-vessel price and an increase in the quantity demanded for public oysters. Since the demand for public oysters was elastic, an increase in public production would be likely to increase the total revenue for public ground fishery.

The supply curve shifted instead to the left if oyster production from public grounds was decreased further. The equilibrium would shift up and to the left if the demand for public oysters was held constant. The shift in the supply curve caused an increase in the ex-vessel price and a decrease in the quantity demanded. Therefore, a continuous decline in public production would decrease the total revenue for public ground fishery.

The estimated demand and supply functions for public also indicated that the market for public oysters was seasonal, with a relatively high demand for public oysters occurring during the Thanksgiving and Christmas seasons along with a relatively high supply from public grounds, causing both demand and supply curves to shift seasonally. Since the market for public oysters consisted of an elastic demand and a very inelastic supply, the seasonal shifts in

the public oyster market would yield higher total revenue in the early season than in the late.

Market Equilibrium for Private Oysters

There was little difference in two private market sectors: included and excluded June-September data. Both models indicated that the market equilibrium for private oysters was determined by an inelastic demand and a highly elastic supply. If private production increased, the supply curve would shift to the right, causing a decrease in the price paid to private planters if the demand for private oysters was held constant. Since the demand for private oysters was inelastic, an increase in private production would decrease the total revenue for private planters. Alternatively, a decrease in private production was likely to increase the total revenue for the private oyster industry.

Alternatively, if the demand for private oysters increased, the demand curve shifted to the right. The shift in demand oysters would increase not only the price but also production if the supply curve was held constant, indicating that increase in the demand for private production would increase the total revenue for private oyster planters.

The structure of market equilibrium for private oysters, consisting of inelastic demand and elastic supply, was opposite to the public market. In the public market sector, production from public ground fishery increased as demand for oysters was high, and production decreased as demand was low (Fig. 9). In contrast, production from private leased grounds decreased as the price rose and production increased as price dropped (Fig. 10).

The difference of market structure between public and private oysters was based on a lower price for private oysters than the ex-vessel price during the observed periods. This phenomenon suggested that private oyster growers had less costs than oystermen, but this was questionable. Some private oyster planters also owned oyster processing houses, which possibly resulted in a low price paid to private oyster planters. Therefore, the quantity demanded and supplied of oysters from private leased grounds might represent processors' needs and not be the real market demand.

Market Relationships among Oysters

A shift in market equilibrium was caused not only by

Figure 9

Monthly production and price of public ground fishery.

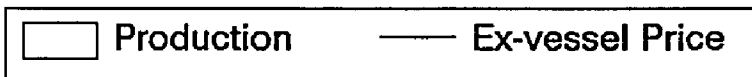
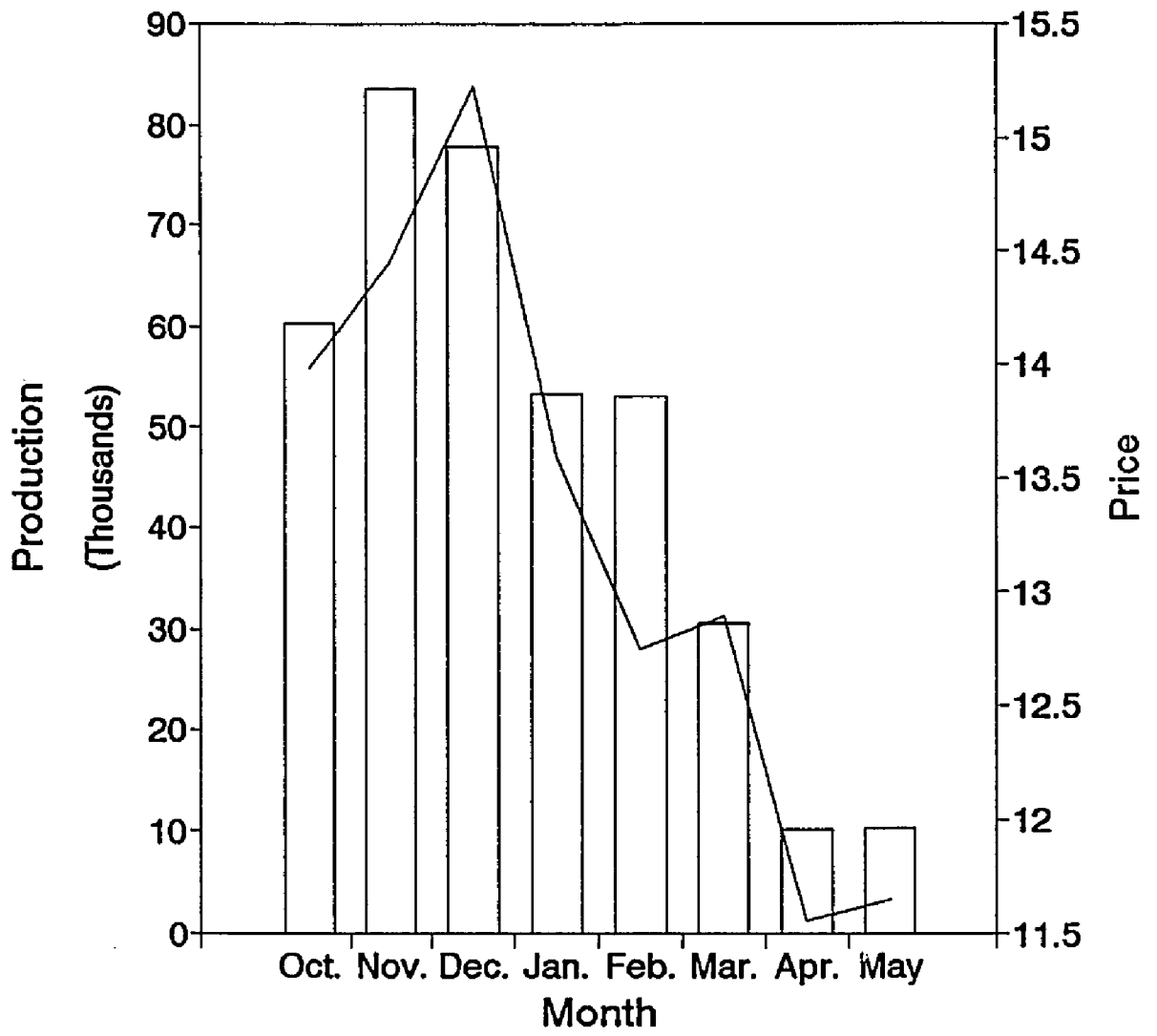
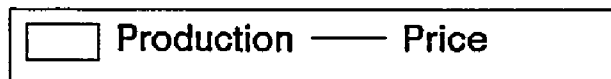
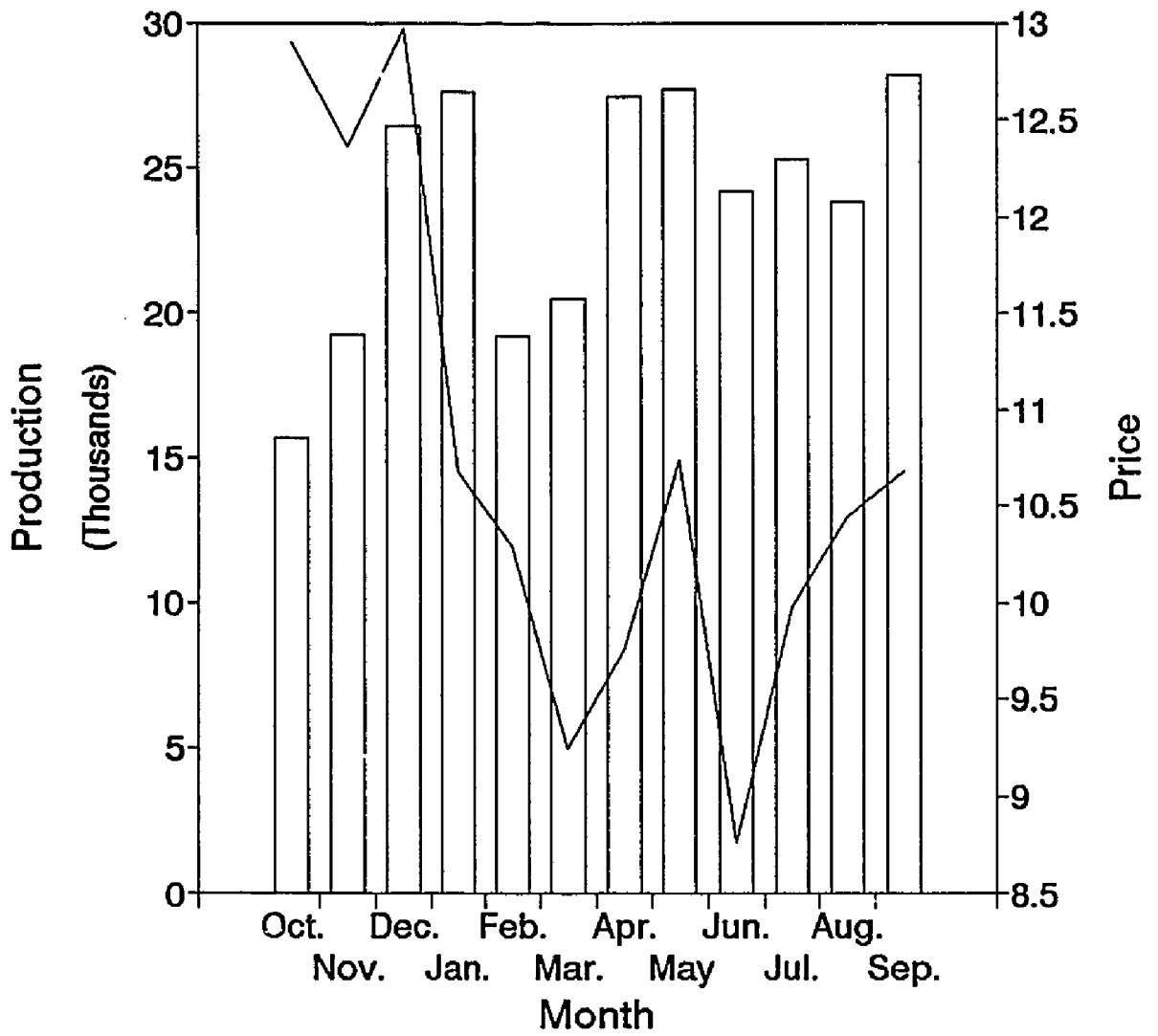


Figure 10

Monthly production and price for private oysters.



changes in price and production of a commodity but also by changes in price and production of related commodities. Consequently, each market sector was affected by the other sectors: the market relationships among various oysters from different sources were determined by the cross-price elasticity.

Oysters from public ground fishery and private leased grounds were complements: an increase in the price of one would decrease the quantity demanded for both oysters. Oysters from public ground fishery and outside supplies were also complements. However, oysters from private leased grounds and outside supplies were substitutes. An increase in the price paid to private oyster planters would increase the demand for outside supplies.

In general, the market relationship between Pacific and eastern oysters was weak because of the small values of cross-price elasticities. Pacific oysters were substitutes for oysters from private leased grounds, complements for outside supply, and independent goods for oysters from public grounds -- oysters from private leased grounds and the Pacific oysters would compete with each other in the Virginia oyster market. An increase in the oyster ex-vessel price of Washington would likely increase the demand for private oysters.

On the other hand, an increase in the oyster ex-vessel price in the state of Washington would decrease the demand for outside supplies. The demand for public oysters was unlikely to be affected by the changes in the oyster ex-vessel prices of Washington.

The results of the model indicated that most market relationships among oysters were complementary (Table 18). Since the demand for oysters was related to the seasons, the study suggested that the complementary relationships among oysters were caused by the seasonal demand.

The Ex-vessel Price

Production from public grounds was not affected by the ex-vessel price, as indicated by the statistically insignificant coefficient. From an economic point of view, an irrelevant price indicates that the supply curve is vertical to the X axis and has a zero elasticity of supply, or a perfectly inelastic supply. The perfect inelasticity of supply usually occurs in a very short market period (Bronfenbrenner et al., 1986). In the very short market period, the supply of a commodity in the market is fixed because the time period is too short to produce or transport

Table 18. The relationships among oysters from different sources.

| Market Demand for | Oysters from | | | |
|----------------------|------------------|---------|---------|----------------|
| | Public | Private | Outside | Washington |
| Public Oysters | --- ^a | C | C | r ^b |
| Private Oysters | C ^c | --- | C | S ^d |
| Outside supply | C | S | --- | C |

Note:

- ^a - no estimation.
- ^b - Independent.
- ^c - Complements.
- ^d - Substitutes.

any amount of the commodity into the market; thus the supply of a commodity cannot be affected by changes in its own price.

However, the market period used in the study was assumed to be sufficient for the market adjustment. Harvested oysters would reach the market in a short period, so the unrelated ex-vessel price to public production was not caused by the market period. The insignificant coefficient for the ex-vessel price implied that stock levels were limited (Smith and Peterson, 1979; Kirkley, 1986). As the ex-vessel price increased, it was impossible to increase oyster production given the current oyster stock and fishing effort. Since Virginia laws and regulations were inadequate to manage oyster stocks, the study suggested that the ex-vessel price unrelated to public production occurred because of limited stocks on public grounds.

PRICE, REVENUE, AND OYSTER MANAGEMENT

Simulation

As suggested previously, as the demand or supply of Virginia oysters was changed the market equilibrium of Virginia oysters would shift. Since the demand for Virginia oysters was related to that for other oysters, changes in the demand or supply of other oysters would also affect the Virginia oyster market. The purpose of the simulation was to analyze such impacts.

The simulation was based on the market equilibrium given an estimated economic system, but the process also involved shifts in the market equilibrium; for instance, the ex-vessel price was simulated through the entire oyster season. The simulation process thus included changes not only in oyster production and prices but also in the seasonal demand.

The observed mean of the ex-vessel price and price paid to private planters was considered as only one base. The simulation of the experiments was classed into two groups:

the first based on the observed production level, the other on the OFMP proposed level (Table 19).

In Group One, there were five experiments: (1) the success of the OFMP, (2) the failure of the OFMP, (3) a continuous decline in current production, (4) a decrease in the ex-vessel price of Washington oysters, and (5) an increase in the demand for outside supplies. A 50 percent increase in the observed mean of public and private production was assumed given that the OFMP improved Virginia oyster production but did not achieve its goal. Alternatively, a decline in oyster production would continue if VMRC could not reverse the current downward trend. A 50 percent decrease in the observed public and private production was proposed.

Oyster production in the state of Washington increased over the periods. A decrease in the ex-vessel price of Washington oysters would occur if the demand for Pacific oysters was held constant; therefore, a 20 percent decrease in the oyster ex-vessel price of Washington was assumed. On the other hand, the demand for outside supplies would increase if the ex-vessel price in other states was decreased due to the increase in production; a 20 percent increase in the demand for outside supplies was assumed.

Table 19. The experiments of simulation .

| Group | Experiment |
|--------|--|
| One | 1. An increase in the observed production to the OFMP proposed level |
| | 2. An increase in the observed production by 50 percent |
| | 3. An decrease in the observed production by 50 percent |
| | 4. A decrease in the ex-vessel price of Washington oysters by 20 percent |
| | 5. An increase in the demand for outside supply by 20 percent |
| Two | 1. An increase in the observed production to the OFMP proposed level |
| | 2. A decrease in the oyster ex-vessel price of Washington by 20 percent |
| | 3. An increase in outside supply by 20 percent |
| Others | 1. An increase in the observed private production by 50 percent |

In addition to the success of the OFMP, there were two experiments in Group Two: a decrease in the ex-vessel price of Washington oysters and an increase in the demand for outside supplies while Virginia production increased simultaneously to the OFMP proposed level. Group Two's simulation was based on the success of the OFMP, and its experiments would analyze the impacts of the OFMP on the demand or supply of oysters from other areas.

In addition, there was an experiment increasing only private production. Because the market relationship between private oysters and outside supplies was not clear in the previous analysis, the experiment was necessary to determine the effect of private oysters on outside supplies.

All given values of percentage in the experiments were arbitrary. All experiments in Group One were compared to the base; in Group Two, all experiments were compared to the simulated OFMP.

Simulation on Group One

Price and Revenue for Public Oysters

The results of simulation on the ex-vessel price were

mixed compared to the base one (Fig. 11-a). If Virginia oyster production was increased as the first and second scenarios assumed, the ex-vessel price would increase and then decrease. If oyster production decreased as assumed experiment 3, the ex-vessel price decreased in the late season.

The ex-vessel price fell sharply during the late season, particularly in the experiment on the success of the OFMP. The reduction of ex-vessel price was caused primarily by a large increase in total production: proposed public production was 1.85 times larger than observed public production, and proposed private production was 2.45 times larger than observed private production. As previously indicated, the demand for public oysters was low during the later season, so it was possible that a large scale of increase in oyster production might result in a very low ex-vessel.

Conversely, an increase in the ex-vessel price in November and December should not be interpreted as a positive slope of the demand curve for public oysters during these months. The model simulation was based on the market equilibrium. An increase in the supply implied that the demand for oysters also increased; the market equilibrium

Figure 11

Price and revenue simulations for public oysters.

for the scenarios one and two would have a higher demand for public oysters than the base. For such high demand in the early season, the proposed production could not satisfy the demand; for instance, a 50 percent increase in Virginia oyster production could not reduce the ex-vessel price of November and December, which was reduced as production increased to the OFMP proposed level.

In general, an increase in the demand for outside supply decreased the ex-vessel price, indicating that oysters from other regions were complementary to public oysters, but a decrease in the ex-vessel price of Washington oysters did not have a consistent effect on the ex-vessel price. This suggested that Pacific oysters and oysters from public ground fishery were independent goods.

As Virginia oyster production increased, the total revenue for public ground fishery also increased, except during April and May (Fig. 11-b). A large increase in the total revenue in the early season resulted from an increase in the demand and supply of public oysters, and a negative revenue in the late season resulted from a large decrease in the ex-vessel price. The results of simulation indicated that the total revenue would decrease if Virginia oyster production continuously declined.

As the ex-vessel price of Washington oysters was decreased by 20 percent, or the demand for outside supply increased by 20 percent, changes in the total revenue for public ground fishery were negligible. These indicated that the market relationships among public oysters, oysters from other regions, and Pacific oysters were weak. Thus, changes in the demand or supply for outside supplies and Pacific oysters would have little effect on the total revenue for public ground fishery.

Price and Revenue for Private Oysters

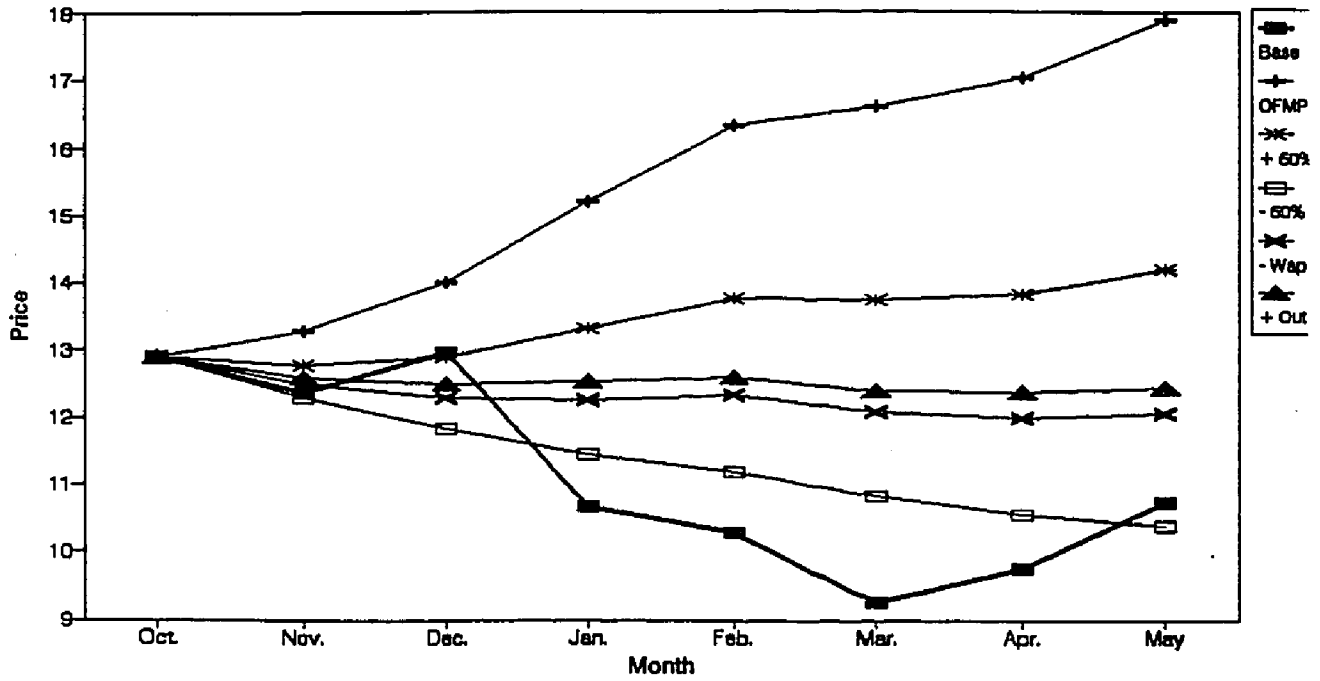
In most experiments, the prices paid to private planters were higher than the base (Fig. 12-a). A lower observed price was expected because many oyster processors were also oyster growers. As total production increased, the price paid to private planters increased, higher in the late season than the early season. This study suggested that the price paid to private planters might not be the market price. Also, the increase in oyster production might result from the increased demand. Therefore, an increase in production would elevate the price.

The total revenue for the private oyster industry

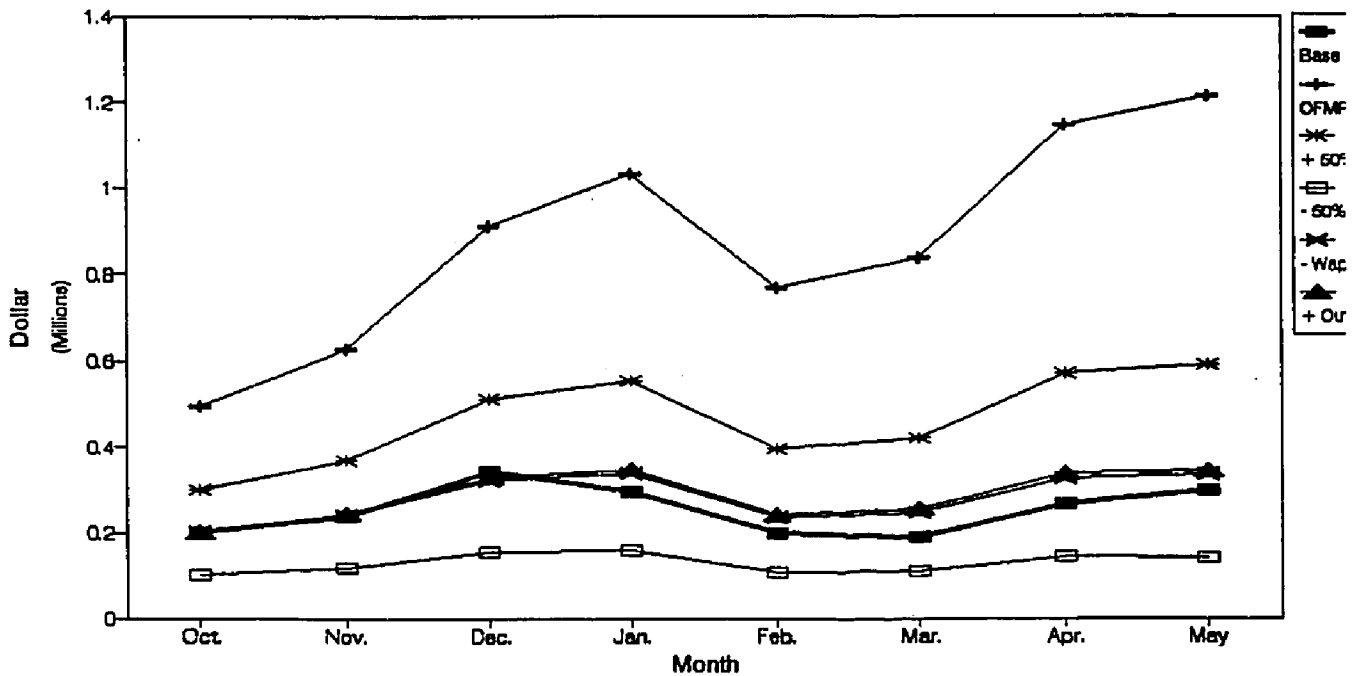
Figure 12

Price and revenue simulations for private oysters.

(a) Simulated price paid to private planters



(b) Total revenue for private oyster cultivation



increased as Virginia oyster production increased (Fig. 12-b). The increase in the total revenue resulted from the increases in price and production, but the total revenue would decrease if production fell. Changes in demand or supply of Washington oysters and outside supplies would slightly affect the total revenue for private oyster industry in later season.

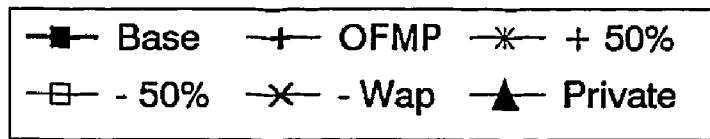
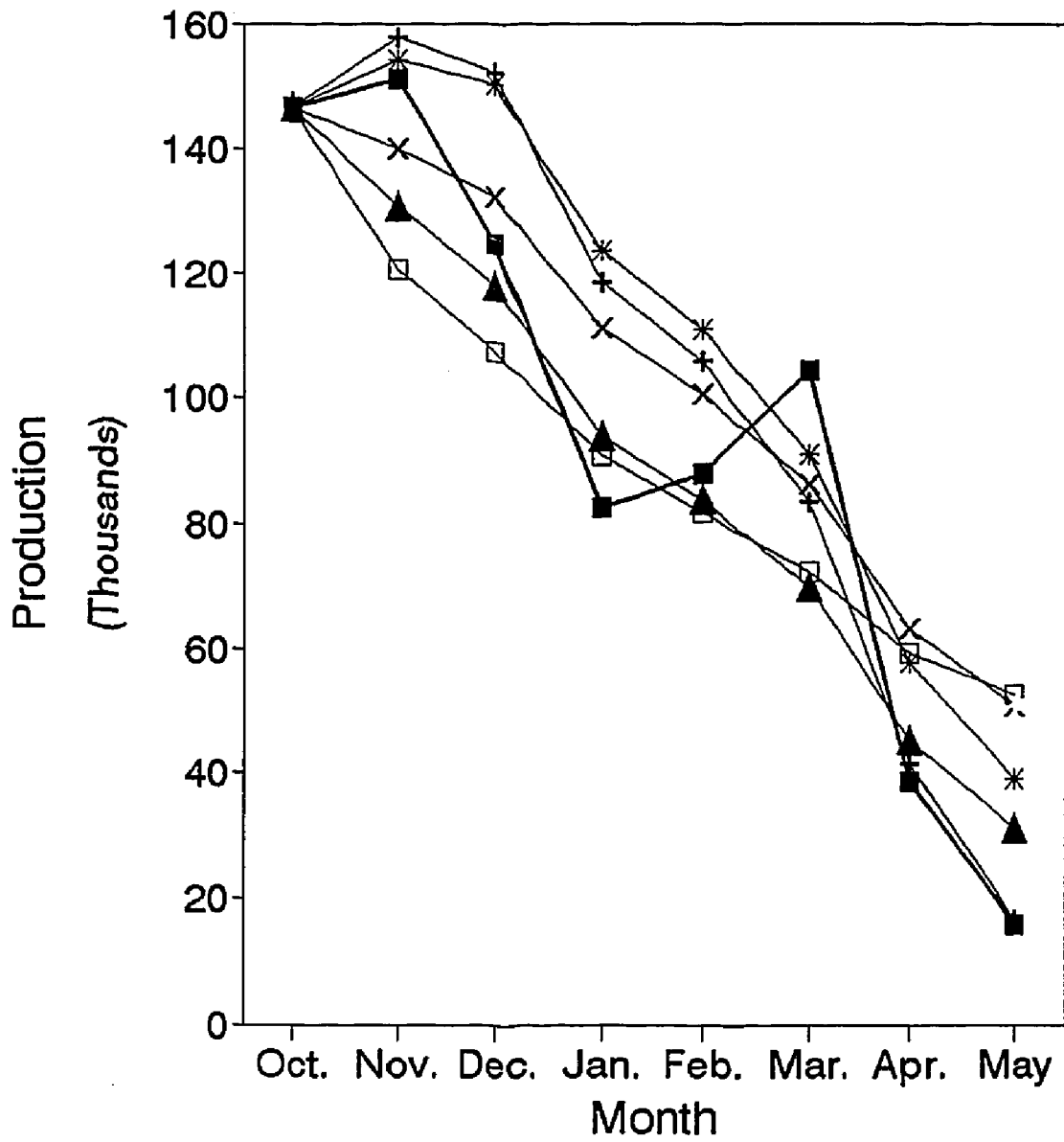
Oyster Supplies from Other Regions

The results of simulation indicated that demand for outside supplies would increase if Virginia oyster production increased (Fig. 13). The increase in outside supply resulted from the increase in public production, because oysters from public grounds were complementary to oysters from other regions.

A decrease in the ex-vessel price of Washington oysters did not have consistent impact on the outside supplies, suggesting that Pacific oysters were independent of outside supplies. Finally, an increase in private production only decreased the demand for outside supplies in the early season. Oysters from private leased grounds would thus be substitutes for outside supplies when the demand for outside supplies was high.

Figure 13

Simulation on oyster from other regions.



Simulation on Group Two

The results of the model indicated that changes in the demand for outside supplies or supply of Washington oysters or public oysters had little effect on both public ground fishery and private production (Fig. 14 and 15). This suggested that the market relationships between Virginia oysters and outside supply and Pacific oyster were weak. As Virginia oyster production increased to the OFMP proposed levels, a 20 percent decrease in the ex-vessel price of Washington oysters or 20 percent increase in the outside supplies would have little impact on the total revenue of Virginia oyster industry.

Virginia Oyster Market and Management

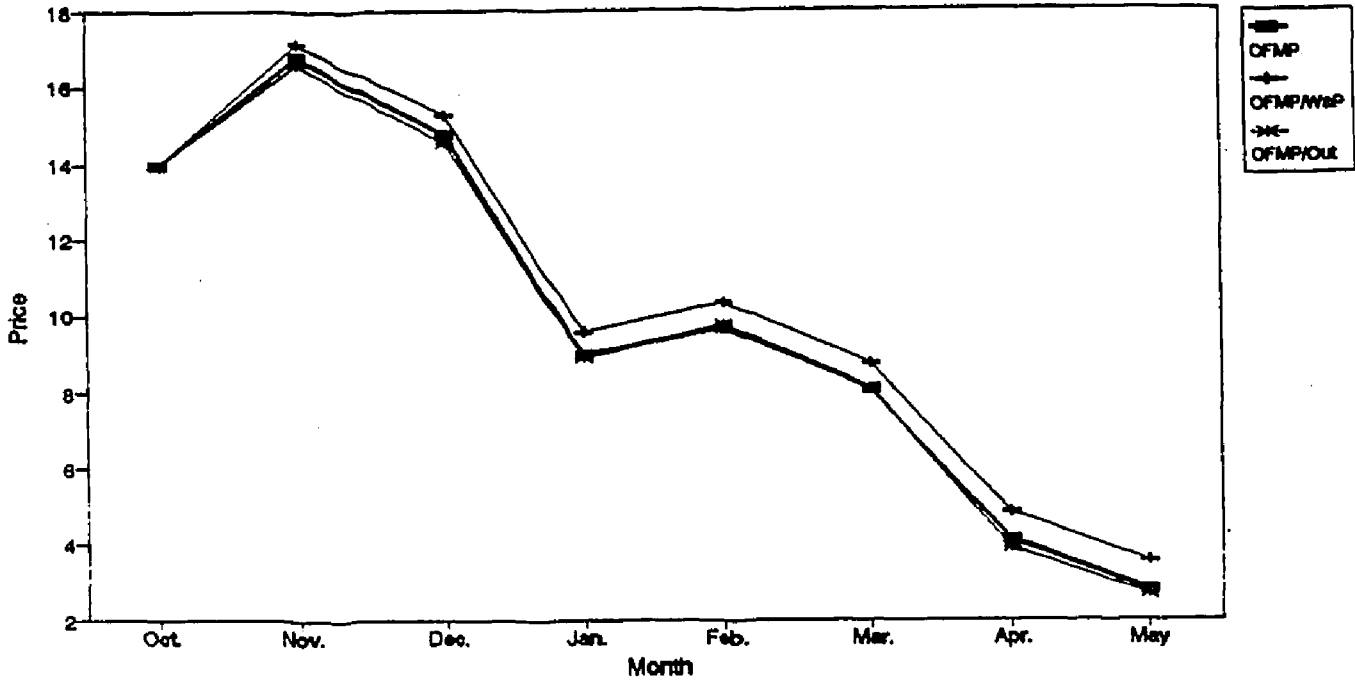
Virginia Public Ground Fishery

As demonstrated previously, the ex-vessel price was unrelated to public production and the low oyster CPUE suggests that current oyster stocks in the public grounds are limited. The results of the model suggest that regulations to limit fishing effort are necessary to maintain and increase stock levels. Also, the results of simulation indicate that most total revenue for public

Figure 14

Price and revenue simulations for public oysters.

(a) Simulated ex-vessel price



(b) Total revenue for public ground fishery

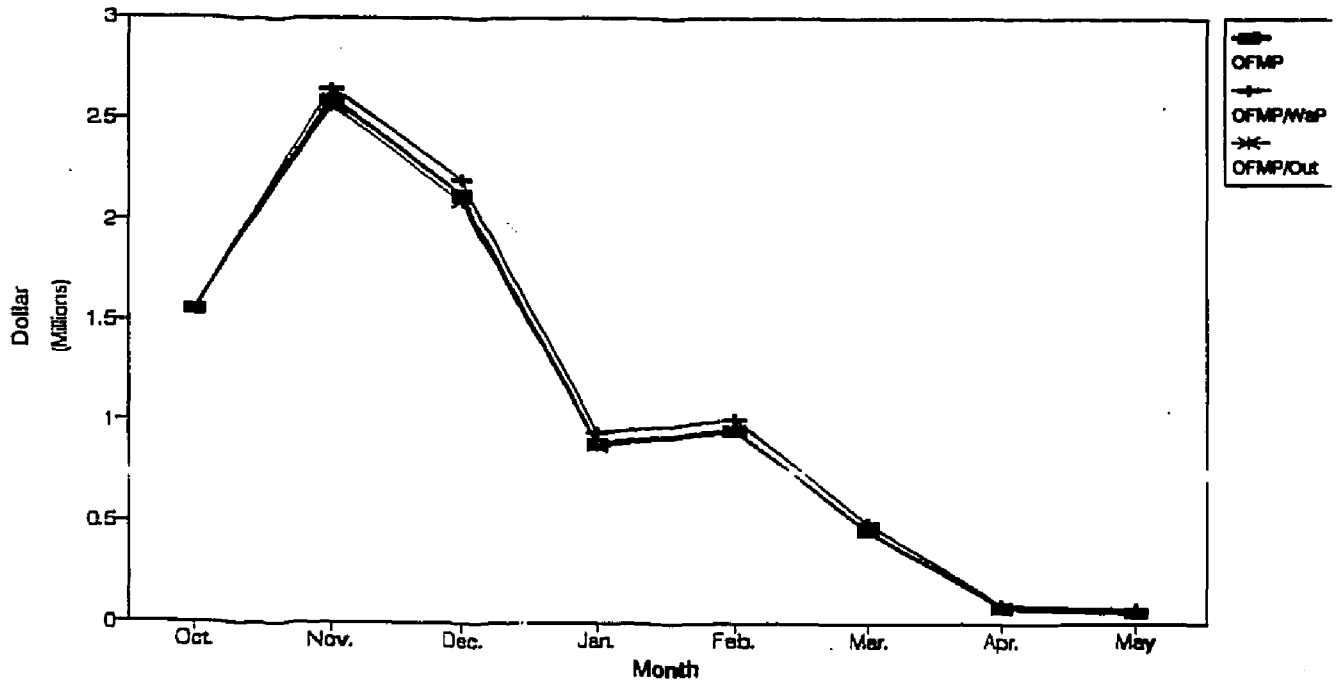
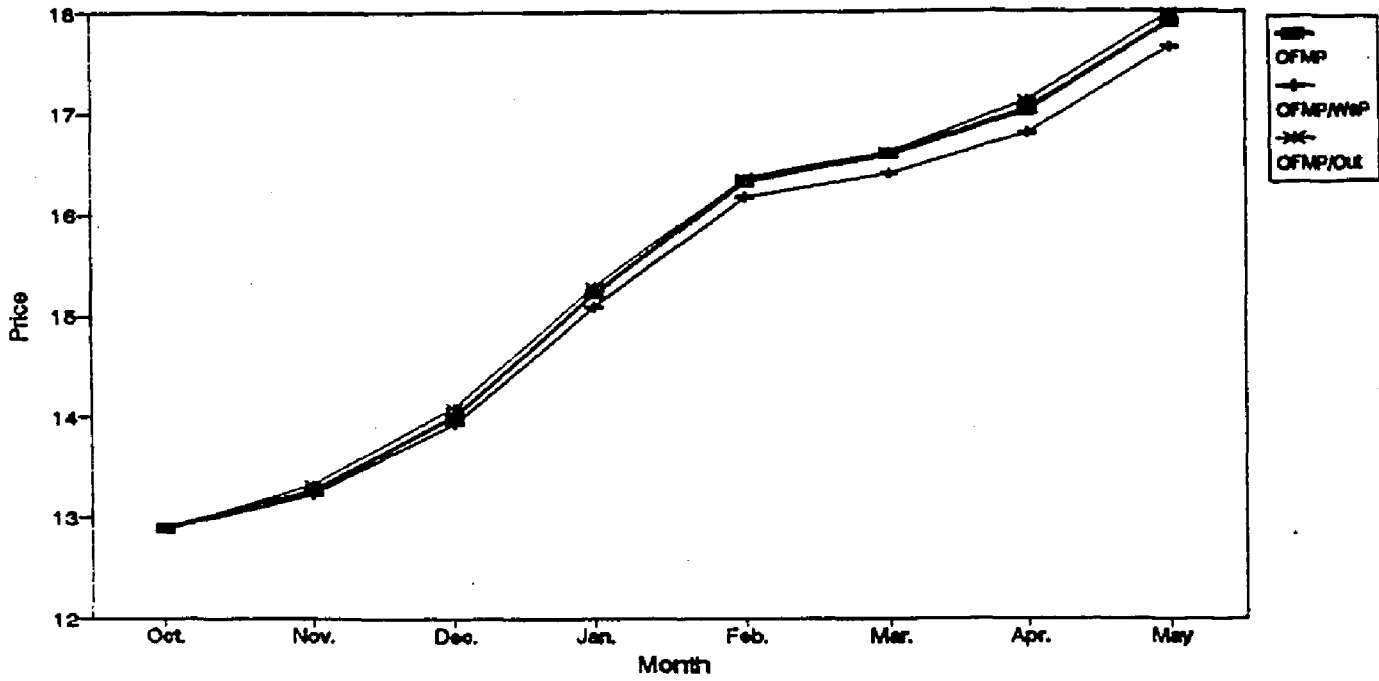


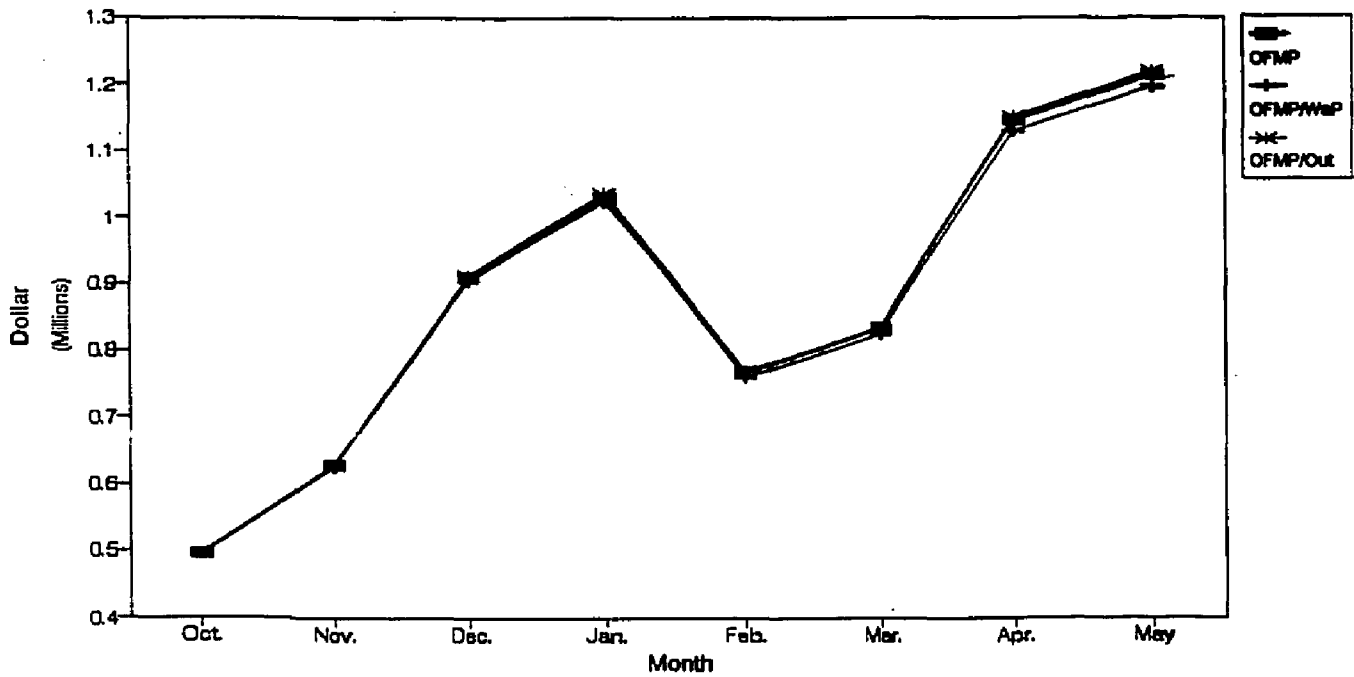
Figure 15

Price and revenue simulations for private oysters.

(a) Simulated price paid to private planters



(b) Total revenue for private oyster cultivation



ground fishery will increase if Virginia oyster production increases. Any improvement of production from public grounds will benefit the public oyster industry.

However, model simulation indicates that the effects of production proposed by the OFMP on the Virginia oyster market are affected by the seasonal demand. Also, the rate of net percentage increase in the total revenue is relatively small in the late season (Table 20). These may provide two implications for oyster management strategies; first, oyster season may be shortened, ending in April instead of the current June. The extension of seasonal closure would have little effect on public ground fishery because demand is low and the total revenue negative during these two months. This conclusion is valid only when the stock levels recover.

Second, the objective of an increase in public oysters to 700,000 bushels or an 85 percent increase in the observed mean may be set too high. The simulation results indicate that total revenue for public ground fishery falls quickly. This study suggests that to maintain a high level of public production set by the OFMP may not be necessary if a large investment is required to achieve it.

Table 20. The net percentage increase in the total revenue for public oysters.

| Month | Group One Experiment | | | | |
|-------|----------------------|--------|--------|--------|--------|
| | OFMP | 2 | 3 | 4 | 5 |
| Oct. | 0.846 | 0.5 | -0.5 | 0 | 0 |
| Nov. | 1.143 | 0.786 | -0.478 | 0.142 | 0.105 |
| Dec. | 0.789 | 0.607 | -0.511 | 0.058 | 0.002 |
| Jan. | 0.220 | 0.313 | -0.536 | -0.054 | -0.119 |
| Feb. | 0.404 | 0.486 | -0.473 | 0.073 | 0.015 |
| Mar. | 0.156 | 0.322 | -0.481 | 0.012 | -0.049 |
| Apr. | -0.343 | 0.088 | -0.467 | -0.042 | -0.132 |
| May | -0.555 | -0.015 | -0.472 | -0.079 | -0.152 |

Private Oyster Cultivation

The results of simulation indicate that the total revenue for private planters will increase as Virginia oyster production increases. The rate of net revenue is relatively high (Table 21), suggesting that a high level of private production will yield large revenue to private oyster industry. Thus, regulations to provide incentives to private oyster cultivation are necessary.

The results of the model indicate that production of seed oysters is unimportant for providing private production within observed periods. The seed production unrelated to private production may result from the high disease mortality -- the ORP's goal of providing sufficient seed oysters to private planters may be irrelevant. This study suggests that the ORP may provide low costs of seed oysters to private planters.

Historically, private production was dominant in Virginia oyster production. Oyster production from private leased grounds was more efficient in producing oysters than public grounds (Haven et al., 1981). Also, the results of simulation indicate that an increase in Virginia oyster production will largely benefit the private oyster industry.

Table 21. The net percentage increase in the total revenue for private oysters.

| Month | Group One Experiment | | | | |
|-------|----------------------|-------|--------|--------|--------|
| | OFMP | 2 | 3 | 4 | 5 |
| Oct. | 1.452 | 0.5 | -0.5 | 0 | 0 |
| Nov. | 1.635 | 0.549 | -0.503 | 0.010 | 0.017 |
| Dec. | 1.650 | 0.492 | -0.544 | -0.053 | -0.037 |
| Jan. | 2.494 | 0.871 | -0.464 | 0.148 | 0.173 |
| Feb. | 2.892 | 1.007 | -0.456 | 0.197 | 0.224 |
| Mar. | 3.400 | 1.226 | -0.416 | 0.306 | 0.339 |
| Apr. | 3.283 | 1.129 | -0.459 | 0.228 | 0.268 |
| May | 3.089 | 0.987 | -0.516 | 0.123 | 0.159 |

Hargis and Haven (1988b) suggest that to revive the Virginia oyster industry, the OFMP should rely on increasing private production.

Introduction of the Pacific Oysters

The introduction of the Pacific oysters into the West Coast has revived the oyster industry there. Thus, the suggestion of introducing Pacific oysters into Virginia has emerged. The Pacific oyster, unlike the eastern oyster, is less susceptible to diseases (Leffler, 1988), and it is believed that the Pacific oyster may have a higher survival rate than the eastern oyster in unfavorable conditions (VIMS, 1991). However, there is also a fear that the exotic Pacific oyster may expel the native oyster (Leffler, 1988). Since this study is not concerned with the biological characteristics of oysters, all suggestions will be based on the market interactions among oysters from various areas.

The results of the model suggest that oysters from public grounds are independent or weakly complementary to the Pacific oysters, meaning that the oysters will not compete with each other in the Virginia market, and introducing Pacific oysters to Virginia waters may have little effect on public production. Alternatively, the

Pacific oysters are substitutes for oysters from private leased grounds. Since both oysters are substitutable in the Virginia oyster market, raising Pacific oysters in private leased grounds may be an alternative to private planters.

SUMMARY AND CONCLUSION

An Overview

Virginia oyster production has declined because of many factors, and to revive the industry, VMRC has developed the OFMP to improve oyster production. The purposes of the study were to examine the market interrelationships among oysters from different sources and to evaluate the effect of the OFMP on the Virginia oyster market.

The Analytical Framework

This study developed the conceptual framework of the Virginia oyster market. The framework assumed that the Virginia oyster market was in equilibrium; although various laws and regulations have been posed on public ground fishery, the assumption of market equilibrium was maintained.

Since Virginia processors obtained various oysters from different sources, this study proposed that the Virginia

oyster market was made up of three sectors: public ground fishery, private oyster cultivation, and oyster supply from other regions. A complete market system consisted of eight market functions. These market relationships were estimated through the use of econometric analysis by the FIML technique.

The OFMP would greatly increase oyster production from public ground fishery and private leased grounds, and its success therefore would have a large effect on the current Virginia oyster market. A simulation model was used to project the impact of the OFMP on market behavior.

Virginia Oyster Market

The empirical results of the econometric analysis suggested that the market equilibrium for the public sector consisted of an elastic demand curve and a very inelastic supply curve, but the private market sector consisted of an inelastic demand curve and an elastic supply curve. The difference between the public and private oyster market resulted from a lower price in the private market sector.

The market relationships among oysters from different

sources were identified. Oysters from public grounds were complementary to oysters from private leased grounds and outside supplies. An increase in the ex-vessel price would thus decrease the demand for private oysters and outside supplies.

Alternatively, oysters from private leased grounds substituted for oysters from other regions, suggesting that oysters from private leased grounds would compete with outside supplies. An increase in the price paid to the former would increase the demand for the latter.

Pacific oysters were independent of public oysters and substitutes for private oysters. Changes in production and ex-vessel price of Washington oysters would not affect the demand for public oysters, but the demand for private oysters would be reduced if the ex-vessel price of Washington oysters decreased .

Simulation and Oyster Management

The results of simulation indicated that the OFMP would decrease the ex-vessel price but increase the total revenue for public ground fishery industry, excepting April and May.

Since the demand for public oysters was relatively low in the late oyster season, this study suggested the possibility of extending the closure of oyster seasons from April to September. The extended closure of oyster seasons between April and May would have little effect on public ground fishery. The suggestion was valid only if the objectives of the OFMP was achieved.

The simulation results also indicated that the OFMP would greatly increase the total revenue for the private oyster industry, a move caused by an increase in the demand for private oysters and the supply of public oysters. The study suggested that the OFMP might provide incentive programs to private oyster cultivation. On the other hand, if oyster production declined continuously, the total revenue for both private oyster cultivation and public ground fishery would be reduced.

Pacific oysters were independent of oysters from public grounds and were substitutes for oysters from private leased grounds. Thus, the study suggested that introducing Pacific oysters into Virginia waters would have little effect on public oysters but would provide an alternative for private planters, a suggestion based on market interaction.

Conclusions and Future Research

The purposes of this study were to outline the Virginia shellstock market for oysters from public and private leased grounds and to identify the interrelationships among various oyster sources. The study also projected the impacts of the OFMP on the Virginia oyster market. Several limitations restricted the completeness of the empirical results.

A major limitation was that the model was restricted to a market in which only public ground fishery existed. Closure of the fishing season created a fundamental problem for the analysis. All data between June and September were omitted so that the estimation could be carried out. Fortunately, the results of an additional private model suggested that the effect of the seasonal closure on the private market sector was small.

A related problem was the inadequate disease indicator for representing the threat of diseases. The additional private model indicated that the problem of the disease index was caused by excluding the June-September season from the model, thus underestimating the effect of diseases on oyster production.

Another limitation was associated with the limited

data. Prior to 1986, the monthly price paid for oysters from other states was unavailable. Lacking this price variable, the outside sector market cannot be completely estimated. Furthermore, the estimation might be biased, as the variable was excluded. The limitation suggested that additional information would be gained by including the variable in future research.

The approach was based on market behavior, which allowed responses to changes in economic conditions to be analyzed. Despite many limitations of the study, the approach and related analyses improved the understanding of the Virginia oyster market. The approach also provided valuable implications for oyster management strategies. Finally, and most importantly, the approach provided a richness of economic information on the Virginia oyster market.

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