Husin, Zulkifli

DEMAND, SUPPLY AND BIOECONOMIC ANALYSIS OF A REPLENISHABLE RESOURCE: A STUDY OF MICHIGAN'S GREAT LAKES COMMERCIAL FISHERY

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By

Zulkifli Husin

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Resource Development

1984

ABSTRACT

DEMAND, SUPPLY AND BIOECONOMIC ANALYSIS OF A REPLENISHABLE RESOURCE:
A STUDY OF MICHIGAN'S GREAT LAKES COMMERCIAL FISHERY

By

Zulkifli Husin

This study provides economic values for several Great Lakes commercial fish species (whitefish, chub, perch, catfish, and alewife) and evaluates their price and production relationships.

Bioeconomic modeling and linearized surplus production equations were used to estimate maximum sustainable yield (MSY) and maximum economic yield (MEY) for whitefish and MSY for perch, catfish, and alewife. The estimated MEY of whitefish using different time periods varied from about 2.7 million pounds to 8.4 million pounds. Producer surplus for whitefish varied from $1.6 million to $9.2 million. This study indicates that whitefish stocks may be over exploited, although this cannot be firmly concluded. The MSY of perch was estimated to be 1.22 million pounds, catfish was 1.0 million pounds and alewife was 5.87 million pounds.

The estimated elasticities for several fish species were:

1. Whitefish price elasticity of demand was between -2.4 and -2.89; income elasticity of demand between 0.89 and 1.4; cross price elasticity with beef about 0.32; and cross price elasticity with shrimp between 0.13 and 0.4.
   Price elasticity of supply was between 0.2 and 0.3; and cross

elasticity of supply with the price of trout was about -0.98. Price flexibility of supply was between 3.23 and 5.0.

2. Chub price elasticity of demand was between -0.51 and -0.9; cross price elasticity with beef was between 1.48 and 1.6; and cross elasticity with canned fish was between 1.34 and 2.42.
   Price elasticity of supply was between 0.23 and 0.85; and cross elasticity of supply with the price of perch was between -0.74 and -1.24. Price flexibility of supply was between 1.18 and 4.34.

3. Perch price elasticity of demand was between -0.80 and -2.51; and cross price elasticity of demand with shrimp was between 0.18 and 0.36.

4. Catfish price elasticity of demand was about -1.95; cross price elasticity with beef was between 0.21 and 0.29; and cross price elasticity with fish steaks was between 0.21 and 0.24.

5. Alewife price elasticity of demand was between -0.24 and -0.28; income elasticity of demand about 10.8; and cross price elasticity with beef between -2.0 and -2.7. Negative signs indicated that beef was a complementary good with alewife rather than a substitute good.

Price elasticity of demand was between 1.66 and 4.0, and the price flexibility of supply was between 0.25 and 0.60.

6. The estimated social surplus (net all-or-none value) was about $2.4 million for whitefish, $3.6 million for chubs, $0.8 million for perch, and $0.2 million for alewife.

These estimates ranged widely over the different time periods examined.

Among several econometric models used in estimating the demand and supply of selected commercial fishery species in Michigan, *only* the single equation and a system of two equations using 2SLS and 3SLS gave the best estimates. Other methods yielded unsatisfactory results.

This study was limited by the model's inability to incorporate much of the necessary information either because the data were unavailable or were available but inaccurate. Therefore, the model itself may not best represent the situation of the Michigan's commercial fishery. A more suitable model might be required and at the same time more complete and accurate data are also needed to improve the estimates for Michigan's Great Lakes commercial fishery.

Dedicated to my father and father-in-law who both passed away while I was pursuing my studies.

ACKNOWLEDGMENTS

Thanks to the Almighty God, "Allah," without whose blessing this study would not have been possible.

Then, I wish to express my appreciation to the Indonesian government for providing me with a scholarship through MUCIA-AID to support my graduate studies at Michigan State University.

My gratitude and thanks go to Dr. Daniel R. Talhelm (Resource Economist), chairman of my guidance committee and my thesis advisor, who has spent a great deal of his time guiding this study. He gave me insight to a new field, fishery economics.

I also wish to express my gratitude to Dr. Milton H. Steinmueller (Resource Economist) of my guidance committee and my advisor who never said "no" any time I wanted to discuss any academic problems I had during my graduate studies. His understanding of students' problems, and his continuous support for my progress can never be adequately thanked.

I also wish to thank the other members of my Thesis and Guidance Committee, Dr. Daniel E. Chappelle (Resource Economist) and Dr. Anthony C. Koo (Economist) for their guidance, constructive comments and suggestions which have substantially improved this study.

I also greatly benefited from discussions and information supplied by Dr. Douglas Jester, Fishery Division, Michigan Department of Natural Resources. To him, I express my sincere thanks.

My thanks also goes to Dr. Abdullah Ali, Rector of University of Syiah Kuala, Dr. Irahim Hasan, former Rector, University of Syiah Kuala, and Dr. Syamsuddin Mahmud, former Dean of Faculty of Economics, University of Syiah Kuala for giving me a leave of absence to pursue graduate studies at Michigan State University. In addition, I thank my colleagues at the Faculty of Economics for all their support and encouragement.

I acknowledge with many thanks The Ford Foundation in Jakarta for providing support for my family to join me in the United States; and to The Asian Foundation which gave me the opportunity to get additional training at the end of my study, and made me feel better prepared before going back to Indonesia.

I am indebted to Dr. Jean Taylor and Christine Lott (MUCIA-AID office in Madison), and Pamela and Jeff Peters, for all their support and encouragement throughout my studies; to Scott Jordan for assisting with the computer programming; to Heidi Grether for her help in editing the draft; and to Nora Beckett for painstakingly typing several drafts of the manuscript before typing this final copy.

I wish to thank my mother, who in spite of her sorrow of losing my father, always prayed for my success and patiently waited for my return home.

Without support of my family, who have shared the hardships of student life with me for many years, this work would probably never have been completed. For this, I thank my wife Ellyza, my daughters Indry, Fita, Yuli, and my young son Amer, who always failed to understand why I was never home.

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CHAPTER I

INTRODUCTION

In general, this chapter will discuss the problems and issues faced by fishery resources world wide, the world demand for and supply of fish commodities, and their prospects in the future. The situation of fishery resources in the Great Lakes and problems faced by the commercial fishery industry in Michigan will be reviewed briefly. Finally, the important, objectives and organization of this study will also be presented in this chapter.

Problems and Issues for Fishery Resource

Fisheries, as a replenishable resource, have not gotten much attention until the last two decades, especially regarding how this resource was exploited and allocated to satisfy human need. This was mainly due to the belief that a fishery is an inexhaustible resource, therefore, everybody can have access to the resource stock and exploit it as much as possible. However, as the world's population has grown rapidly, fish consumption has grown as well. In response to growing demand, fishermen improve fishing technology to enable them to more intensively and extensively harvest fish stocks. This in fact has put more pressure on fish populations and has forced the world production level to the point of diminishing returns. Consequently, the stocks might not be able to renew themselves to the former level of harvesting. This occurs because the numbers of fish caught at certain points in time may exceed the growth of the fish population. The fish stock will therefore decrease and the future harvest will probably drop as well. Without any effort to control and regulate the use of fishery resources, the continuation of overfishing could collapse overall production of certain fish species.

In recent years, more attention has been given to the problem of fishery resource utilization by international agencies and by coastal states. Many efforts have been made to prevent over exploitation by controlling the level of fish harvesting or by other regulations.

As a renewable but destructible resource, fisheries have a two fold conservation problem. Fish stocks may be viewed both as an inventory which should be utilized wisely and economically, and also as the capital equipment which provides for replenishment of the resource for future use (Crutchfield and Pontecorvo, 1968). This concept of fishery resources is similar to two types of characteristics mentioned by McInerney (1981): (a) utilization of a unit of the resource implies its destruction, a consequent depletion of the existing physical resource stock and the complete and irrevocable loss of those resource services; and (b) the stock of resource services can be augmented again to enable a continuing availability through time.

Due to its biological nature, fish exploitation can be increased in order to get higher yield without reducing the stock, as long as the rate of exploitation is not greater than the rate of biomass growth. However, with increased effort, yield can reach a maximum, after which further increases in effort will result in a lower yield. This condition is generally considered overexploitation. As efforts are increased further, the rate of biomass growth cannot keep pace with the rate of exploitation, therefore the stock will decrease further to a lower level, and may even be depleted. This scenario has been experienced in the past, and conceivably could be continued in the future in the absence of private ownership or regulation.

As a common property resource[1] everybody has access to exploit the fishery resource and usually has an objective to maximize current profit. However, with free competition under open access the level of exploitation could reach the range in which no more profit could be obtained from the fishing effort. This range, from an economic view, would be regarded as a misallocation of the factors of production. Under open access the production of fish would occur at the point where marginal cost of extra units of fishing would equal the average revenue from that unit (Butlin, 1973).

This exploitation behavior is not unusual for common property resources as described by Hardin (1968) in the "Tragedy of The Commons"

> "As a pasture open to all, it is expected that each herdsman will try to keep as many cattle as possible on the commons. ....As a rational being each herdsman seeks to maximize his gain. ......, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another, and another. But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein the tragedy. Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruins is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."

---

[1]Crutchfield and Pontecorvo (1968) do not use the term "common property resource" if the resource is not owned, or is not property as in the case of fisheries. They instead use the term "open access resource." However, in this study, I use both of these terms indifferently.

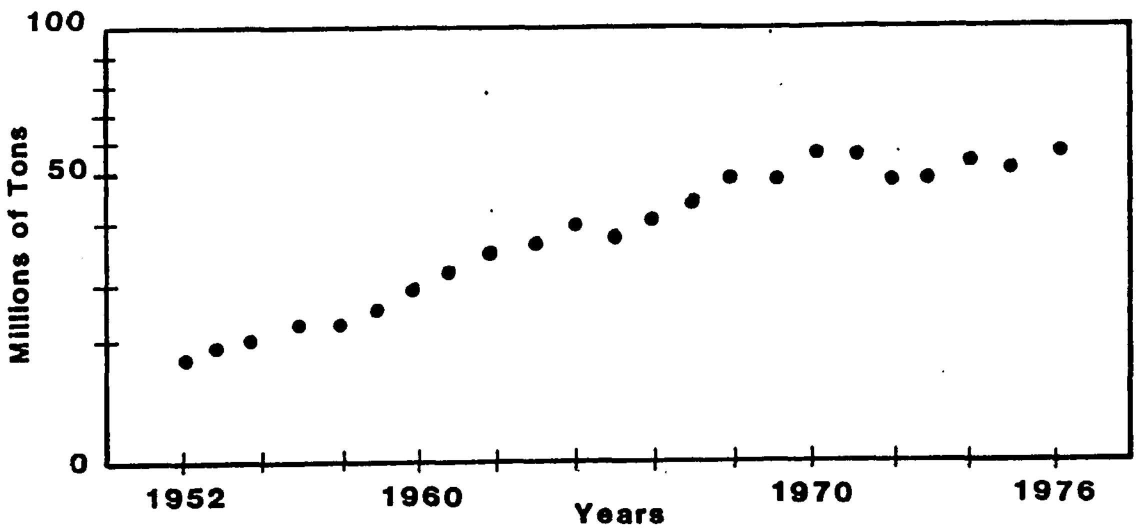
More fisherman will enter the fishery industry as long as the revenues exceed the costs. This process will continue until all their net profits have been completely drained away, and the fishery resource is apparently over exploited. This problem has been aggravated further by water pollution. Many coastal or inland water resources have been used as waste dumps. Contamination will reduce the water's carrying capacity as a living environment for fish species and/or produce contaminated fish. This contamination may, in effect, reduce the quantity as well as the quality of fish harvested, therefore, reducing the availability of fish for human use. Pollution then competes with natural mortality and fishing effort in reducing fishery resources.

World Demand for and Supply of Fishery Resource

As world population grew and nutrition became a central problem, many countries began to look to the ocean as one of the resources which could help to solve this problem.

Different models and techniques have been used by scholars to estimate the food potential from oceans. The estimates vary from under 100 million to 2 billion tons of annual production. A four-billion world population would require 60 million metric tons of fish to provide 30 percent of the 36 grams of protein needed daily per person. By the year 2000, 100 million tons of fish would be required just to maintain the same level of protein.

Over the last decade, however, the total fish harvest seems to be leveling off despite increased fishing effort (Figure I-1).



Source: Hennemuth, 1979.

Figure I-1. The World Catch of Marine Fishes from 1950-1976

The rate of growth of world fish production had declined sharply from about 6 percent in the 1960's to less than 1 percent in the 1970's (Table I-1).

Table I-1. World Production of Living Aquatic Organism

	Production (mill tons)			Increase (mill tons)		Rate of increase (%/year)	
	1960	1970	1977	1970/60	1977/70	1970/60	1977/70
Total World	40.2	70.7	73.5	30.5	2.8	5.8	0.5
Developing Countries	17.0	36.1	34.2	19.1	-1.9	7.8	-0.6
Developed Countries	23.2	34.6	39.3	11.4	4.7	4.1	1.8

Source: Robinson, 1980.

The basic cause of this decline appears to be the diminishing stocks of those conventional fish which offer the possibility of a sustained increase in catch. Some species' stocks have collapsed and now yield much lower catches. Unless careful management and regulation of fishing efforts for those species are imposed, catches may not increase to former levels (Robinson, 1980). Robinson also estimates that consumption of aquatic organisms will increase at about 3.3 percent per year by the end of this century while the production will increase about 1 percent per year (see Table I-2 and I-3). Therefore, the growth in production will be inadequate, on the average, to maintain current per capita consumption levels.

Data from Table I-3 also indicates that the rate of production growth is relatively more favorable in developing countries. They will contribute 75 percent of the total increase by the year 2000. This is due to the fact that less exploited resources in developing countries have left more fish than in the developed countries where technological innovation has led to the earlier exploitation of stocks. Improved technology in the fishery resources is mainly directed toward harvesting rather than producing. In effect this may over exploit fishery stocks further, as is happening in many areas. As a consequence, the stocks can be depleted and fish production reduced.

Along with the current stagnant total fish harvest, about 35 percent of the fishing catch or nearly 25 million tons of fish are lost annually during the processing procedure. This loss mainly occurs in the developing countries which lack the capital, skills and technology in handling, processing and marketing of fish (Pariser, 1979). Therefore, reducing post harvest losses is essential not only to reduce

Table I-2. Estimated Demand for Fish 1980, 1990, 2000
(in live weight equivalent)

	Total (million tons)				Feed (million tons)		Food (million tons)				Food (kg/per capita)			
	Consumption	Projected demand			Comsuption	Projected demand	Consumption	Projected demand			Consumption	Projected demand		
	1972-74	1980	1990[a]	2000[a]	1972-74	1980	1972-74	1980	1990	2000	1972-74	1980	1990	2000
World	67.2	83.4	78.8	97.1	17.8	23.0	49.9	60.4	78.8	97.1	13.1	13.9	14.9	15.5
Developing	25.5	33.1	42.6	56.7	2.6	3.8	22.8	29.3	42.6	56.7	8.4	9.3	10.6	11.5
Lating America	3.5	4.6	4.2	6.0	1.2	1.7	2.4	2.9	4.2	6.0	7.7	7.9	8.8	9.8
Africa	2.7	3.4	5.0	7.3	0.1	0.1	2.6	3.3	5.0	7.3	8.2	8.7	9.8	10.8
Near East	0.7	1.1	1.2	1.9	0.2	0.3	0.6	0.8	1.2	1.9	3.1	3.6	4.3	5.1
Far East	9.5	12.4	16.0	21.6	1.1	1.4	8.4	11.0	16.0	21.6	8.1	9.1	10.0	11.1
Asian Centrally planned countries	9.1	11.5	16.0	19.6	0.2	0.3	8.9	11.2	16.0	19.6	10.1	11.4	14.2	15.4
Other developing	0.1	0.1	0.2	0.3	0.0	0.0	0.1	0.1	0.2	0.3	23.0	24.7	28.1	31.2
Developed	42.2	50.3	36.3	40.4	15.2	19.2	27.0	31.1	36.3	40.4	24.5	26.6	28.5	29.6
North America	5.5	6.2	4.9	5.7	1.8	2.0	3.7	4.2	4.9	5.7	15.7	16.7	18.0	19.4
Western Europe	13.6	15.1	8.2	9.1	6.7	7.8	6.9	7.3	8.2	9.1	19.1	19.7	21.4	23.1
EEC	8.7	9.6	4.8	5.3	4.5	5.2	4.2	4.4	4.8	5.3	16.2	16.8	18.2	19.6
Other Western Europe	4.9	5.5	3.4	3.8	2.1	2.6	2.8	2.9	3.4	3.8	26.1	26.5	28.8	30.8
Erstern Europe & USSR	11.2	14.5	11.6	13.0	3.4	4.8	7.9	9.7	11.6	13.0	22.1	25.5	28.1	29.6
Eastern Europe	3.1	4.1	2.2	2.6	1.8	2.3	1.2	1.8	2.2	2.6	11.5	15.9	18.7	20.8
Oceania	0.3	0.4	0.3	0.4	0.1	0.1	0.2	0.3	0.3	0.4	14.4	14.4	15.2	16.2
Other developed	11.7	14.1	11.2	12.2	3.3	4.5	8.4	9.6	11.2	12.2	62.1	64.3	66.4	64.8

[a] Excluding demand for meal

Source: FAO Agricultural Commodity Projections (Quoted from Robinson, 1980)

Table I-3. Aquatic Organisms -- Actual and Estimated Production

	Production (million tons)					Rate of increase (%/year)				
	1963[a]	1975[b]	1980	1990	2000	1974-76 / 1961-65	1980 / 1974-76	1990 / 1980	2000 / 1990	2000 / 1974-76
World	47.7	72.5	84.7	84.7	92.5	3.6	0.7	1.2	0.9	1.0
Developing countries	22.8	34.1	37.3	45.6	51.9	3.4	1.8	2.0	1.3	1.7
Latin America	8.9	7.7	7.6	9.0	10.2	-1.2	-0.4	1.7	1.2	1.1
Africa	2.1	3.8	4.1	5.1	6.0	6.1	1.5	2.2	1.8	1.8
Near East	0.5	0.8	1.0	1.3	1.5	4.3	3.9	2.8	1.9	2.7
Far East	5.3	11.2	12.6	15.6	18.1	6.4	2.4	2.2	1.5	1.9
Asian centrally planned	5.9	10.3	11.5	13.8	15.3	4.8	2.1	1.9	1.0	1.6
Other developing	0.1	0.3	0.5	0.7	0.7	10.7	8.6	3.8	1.0	3.6
Developed countries	24.9	38.4	38.0	39.1	40.6	3.7	-0.2	0.3	0.4	0.2
North America	4.0	4.1	4.9	6.4	6.9	0.1	3.7	2.7	0.9	2.1
Western Europe	8.9	11.5	11.7	12.5	12.9	2.3	0.1	0.7	0.3	0.4
EEC	4.2	5.3	5.2	5.3	5.5	2.0	-0.4	0.1	0.4	0.1
Other Western Europe	4.7	6.2	6.5	7.2	7.4	2.3	1.0	1.1	0.3	0.7
Eastern Europe & USSR	4.6	11.3	10.6	9.7	10.0	7.7	-1.3	-0.8	0.3	-0.5
Oceania	0.1	0.2	0.3	0.4	0.6	3.8	8.7	4.8	4.1	5.3
Other developed	7.2	11.3	10.6	10.1	10.2	3.8	-1.3	-0.5	0.1	-0.4

[a] 1963 = average 1961-65
[b] 1975 = average 1974-76

Source: FAO Agricultural Commodity Projections (Quoted from Robinson, 1980) resource waste, but also to increase world fish production in order to meet the increasing consumption.

It is conceivable that an increase in unconventional species which are still unexploited could ease a bit of the pressure on the conventional stocks. Moreover, we can expect an increase in aquaculture production, which at present only represents about 6 percent of total world fin fish production, and we can expect future growth in the production of freshwater fisheries. The Great Lakes, as one of the largest fresh water resources in the world, plays an important role in producing freshwater fish. It might increase its share of the world production with proper management and the support of all other fishery concerns.

An Overview of the Fishery Situation in the Great Lakes[2]

The Great Lakes, composed of Lake Michigan, Lake Superior, Lake Erie, Lake Huron, Lake Ontario, and Lake St. Clair, have a surface area of approximately 94,710 square miles (statute) which contains about 1/5 of the surface freshwater in the world. About two thirds of the Great Lakes area is in the U.S. and one third is in Canada. About two thirds of the U.S. area is in Michigan with 38,575 square miles of surface area and over 3,100 miles of coastline.

The Great Lakes (G.L.) fishery has been a unique case of renewable resource (biological resource) use and regulation. The total catch by weight in Michigan waters has remained stable over the last one hundred

[2]This section is heavily drawn from: W.J. Christie (1974); Smith (1968), Talhelm (1978).

years with close to 30 million pounds per year. However, the species composition has experienced a continuous change. Overfishing is considered a significant factor in the succession of several species, but the process has been accelerated by invading species and degradation of the environment.

The abundance of many species has changed dramatically. This change, however, did not cause drastic decline in the total fish catch. Fishermen simply shifted to other species in the absence of premium species. Harvesting tended toward smaller fish such as yellow perch, smelt, and alewife which have lower market values than the premium species (such as lake trout), and in effect may have reduced the fishermen's gross revenue.

Overfishing

Lake sturgeon, lake herring, and lake whitefish were among the species apparently affected by overfishing. Lake sturgeon was overexploited not due to its high value but because fishermen wanted to remove them from the fishing grounds in order to be able to catch more valuable fish. On the other hand, the collapse of the lake herring stocks might have been caused by intense exploitation and possible interaction with environmental change. The collapse of the lake whitefish stocks were also apparently due to overfishing after the development of the deep trap net, in the early 1920's, which was very efficient for catching lake whitefish.

The recovery of premium stocks (larger species) does not always occur even though the fishing pressure eases. This is mainly due to the fact that after the premium stocks collapse, the fishery shifts to a smaller species in the same area. Fishermen use smaller gillnet mesh sizes, so that the younger of the larger species may be captured together with smaller species. This, in effect, may suppress the premium species permanently as in the case of deepwater ciscoes.

The Invasion of Sea Lamprey

The invasion and expansion of sea lamprey, which probably came by way of the shipping canal around Niagara Falls, had exterminated lake trout in Lake Huron and Lake Michigan in the late 1950's. Lake trout in Lake Superior, whitefish and other species in Lake Huron and Lake Michigan were also seriously affected. The mortality of trout caused by sea lamprey was estimated at about 70 percent annually in Lakes Michigan and Huron.

After the collapse of lake trout, lake whitefish became prey for the sea lamprey, which reduced the whitefish population stock. As the more favored prey, lake trout and whitefish, became scarce the sea lamprey attacked lake herring, white suckers and many other species.

The sea lamprey invasion, in addition to overfishing, contributed to the decline of whitefish production in the G.L. to a low of 0.1 million pounds in 1942 from over 4.1 million pounds in 1931.

As a result of the collapse of many fish species, the composition of fish stock and species in the G.L. changed. Lake trout, burbout, and deep water predators were depleted. As a result of the depletions, small species such as smelt, deep water cisco (chubs), and alewife stocks increased. Lake herring stocks also decreased in response to the smelt increase. Alewife increased rapidly and dominated the fish stocks in Lake Huron and Lake Michigan.

Degradation of Environment

The effect of environmental degradation may have magnified the problems faced by fish species on the G.L. The discharge and accumulation of milling wastes from the lumbering industries of Lakes Huron, Michigan and Superior, for instance, apparently had serious effects on reproduction of some species such as lake whitefish and lake herring.

The construction of dams blocked spawning migration and destroyed of spawning areas. Deforestation of the drainage basin caused reduced flows at critical times for the fish, and a large number of streams became uninhabitable because of increased temperatures and heavy silt burdens. Water eutrophication caused by plant nutrient waste has at times taken large expanses of water out of fish production through oxygen depletion.

Eutrophication also encourages species composition changes. It favors the species having the best tolerance for nutrient-enriched water such as smelt and yellow perch. The domination of Lake Erie by these species reflects the tolerances of these species.

After sea lamprey was brought under control by reducing its stock in the mid 1960's, lake trout and salmon were planted into G.L. to establish a new species balance of more preferable species. This stocking program has resulted in the establishment of a large sport fishery on the G.L. Whitefish and white sucker commercial catches have also improved significantly. However, in the late 1960's and 1970's, DDT (Dichlorodiphenyl-trichloro-ethane) used as pesticide in agriculture, PCB (polichlorinated biphenyl) similar to DDT, mercury and other poisons were found to contaminate many of the fish on the G.L., particularly salmonids.

As a result of this contamination, the commercial sale of coho salmon, chinook salmon and lake trout were banned by the governors of Michigan and Wisconsin. The level of contamination was so high, that Michigan residents were warned not to eat some Great Lakes fish for more than one meal a week. This caused a considerable economic loss for the commercial fisheries, which already were in a depressed situation.

Problems of Michigan's Great Lakes (G.L.) Commercial Fishery

The change in the fish composition on the G.L. away from the more valuable and preferable species to the less valuable (mainly due to overfishing, sea lamprey disruption, and environment degradation) has caused deterioration of Michigan's commercial fisheries. This situation has been hastened by the competition with sport fishing.

Estimates of the public recreational values of the fishery resource are more than ten times greater than commercial values (Talhelm, 1978), and public policy had changed more in favor of sport fishing. Therefore, the composition of fish catch is shifting more to sport rather than commercial although the total catch has not changed. In recent years sport fishing harvested about three times that of the commercial catch from the total G.L. catch of 60 million pounds. Many restrictions and regulations have been placed not only to prevent overfishing and to restore depleted population of sport and commercial fish, but also to give more leverage for sport fishing.

In 1968, the Michigan legislature granted the Michigan Department of Natural Resources (MDNR) authority to limit entry into the fishery. Since then the MDNR has imposed several restrictions such as:

- Restricted licenses to full-time fishermen
- A zone management program
- Stringent gear restrictions for individual fishermen
- Banned certain gear types in various zone and water depths.
- Allowed no commercial fishing in non-commercial zones
- Restricted the species which can be caught, etc.

The Michigan Department of Natural Resources also proposed to buy out all large mesh and most small mesh gillnet in 1974. Then gillnets were to be banned in order to eliminate the incidental catch of lake trout for the purpose of rehabilitating the lake trout population. Fishing licenses were reduced from 300 in 1969 to about 140 in 1970.

There is very little chance that Michigan's commercial fishery, as well as the U.S. Great Lakes commercial fishery, will expand in the future. Commercial fisheries depend heavily on the state's willingness to allocate fish to them and are strongly affected by contamination of certain fish species (Comptroller General of the U.S.,1977).

Canada, which shares all Great Lakes with the U.S. except Lake Michigan, is experiencing the problems faced by Michigan's Great Lakes fishery resources. However, in the commercial sector, the Canadian commercial fishing industry has not been affected by such intense competition from sport fishing or by restrictive government regulation as their U.S. counterpart. As a result, since 1975, Canada, which has only about 36 percent of Great Lakes waters, produces more commercial fish value than the U.S. as shown in Table I-4. These differences widened over the years, growing to more than two fold by 1982. Moreover, the gap does not occur only in value, but also in production. The United States landings have decreased about 23 percent while Canada's increased about 65 percent over the same period.

Table I-4. The Value of the U.S. and Canadian Commercial Fishing Catch from the Great Lakes 1975 - 1982 (in Million)

Year	U.S.		Canada	
	Quantity (lb)	Value ($)*	Quantity (lb)	Value ($)*
1975	61.7	9.0	45.4	11.1
1976	66.7	10.5	41.1	12.5
1977	72.8	10.1	51.9	14.6
1978	70.0	10.4	56.0	17.2
1979	55.5	12.6	55.4	26.1
1980	38.5	12.0	59.0	23.5
1981	48.3	15.4	61.9	31.8
1982	47.6	13.8	75.2	36.8

*The differences in value of U.S. and Canadian dollars are not adjusted.

What has been shown in Table I-4 may indicate the differences in public policy approaches to managing fishery resource between two countries which share the same resources. Canada, which opens more access to commercial fishery in its waters, harvests more fish and fish of much higher value. On the other hand, the U.S. which imposes more restrictions on commercial fishing, produces less commercial fish than Canada.

The Problem Statement

Michigan Great Lakes commercial fishery resources, as mentioned earlier, face many problems, whether it's change in the biological composition, environment, competition with sport fishing, public policy or by fishermen themselves who apparently tend to overfish. These problems would affect the nature of policy in managing fishery resources as well as prices.

Fishery prices are affected by a great number of forces. Volumes of fish landed, tastes and preferences of the consumers, quality of fish landed, consumer incomes, varieties of fish landed, level of contaminants in the fish, the availability of substitutes, and costs of fish harvesting all affect fish prices. Policies and regulation imposed by government agencies in managing the resource also affect prices through their influences on market demand and supply.

The future of the Michigan Great Lakes commercial fishery depends on the extent to which the state wants to develop and maintain a viable commercial fishery (Comptroller General, 1977). State agencies have a pivotal role in setting policies which affect the commercial fishery industry. Lack of information, understanding and specific knowledge about the socio-economic aspects of the commercial fishery required to improve upon the policy of fishery resource utilization may hamper their effort to attain efficiency. As mentioned by Haveman (1973), the nature of natural resource use which is associated with the commons, external diseconomics, and public goods is dominated by market failure. Leaving policy decisions to the private sector, without any government intervention to correct this failure, may result in inefficiency, economic waste, misallocation, and over production of the resource. However public policy alone without relying on economic values might not alleviate the problem. It might generate another inefficiency through the regulatory system in controlling resource use. Research that could provide more information about economic aspects as well as the biological nature of the fishery resource may help remedy the problem of lack of information, and enhance the public policy decision making process.

Little research has been conducted on the economic aspects of commercial fisheries on Michigan's Great Lakes (to the author's knowledge). Because of this, any research or study on the economic aspects of commercial fisheries will provide valuable information to individuals, organizations and public agencies. This information can aid in the understanding and planning better uses of the Great Lakes fish resources.

The Objectives of the Study

It is acknowledged that the Michigan Great Lakes commercial fishing industry in general is in a depressed situation. There are many factors that have contributed to the problems faced by the industry. Therefore, this study is designed to explore, to some extent, how fish production has been affected by those factors over time, and try to estimate the optimum sustainable yields. The study also will discuss the factors which affect Michigan fish prices and their relative importance.

By analyzing prices this research may provide valuable information for the fishermen, fish processors, wholesalers, public agencies and the public in general who are interested in economic aspects of the commercial fishery. By knowing what factors affect prices and quantities purchased or the trend of prices and quantities over time, they can to some extent, predict the future course of the market potential for the fish products. They also may determine revenue changes resulting from changes in the quantity of fishes sold. Moreover, this information may influence market expansion efforts. Although this study may not solve the problems faced by the commercial fishing industry, it may provide a better understanding of the situation in the industry.

The more specific objectives of this study are:

1. To estimate the bioeconomic values of the Michigan Great Lakes Commercial Fishery.
2. To estimate and analyze the demand and supply of several fish species.
3. To estimate the elasticities between resources and prices as well as income and price flexibility.
4. To estimate the potential consumer, producer and social surplus of commercial fishery.

Fish Species to be Studied

Five fish species will be analyzed in this study based on the highest catch and value during the period of 1960 - 1982. These species are:

1. Whitefish (Coregonus clupeaformis)

2. Chubs (Coregonus hoyi)

3. Yellow Perch (Perca flavescens)

4. Catfish (Ictalurus punctatus)

5. Alewife (Alosa pseudoharengus)

The area included in this study is the whole Great Lakes under Michigan State jurisdiction; including portions of Lakes Michigan, Superior, Huron, Erie, and St. Clair.

Organization of the Study

This study is divided into several chapters. Chapter I, the Introduction, briefly describes the situation of world fishery resource, and Michigan Great Lakes commercial fishery industry. It also lays out the study framework in which the problem statement and study objectives are presented.

Chapter II reviews the literature on the subject of bioeconomic approach, demand and supply, management of commercial fishery, as well as the previous studies which have been conducted in these fields.

Chapter III introduces the research methods and procedures used in this study.

Chapter IV provides the description and analysis the state of the Michigan Great Lakes commercial fishery from 1960-1982.

Chapter V presents the estimation of the bioeconomic model parameters of several commercial fish commodities in Michigan; and Chapter VI presents the estimation of demand and supply parameters for the same fish commodities.

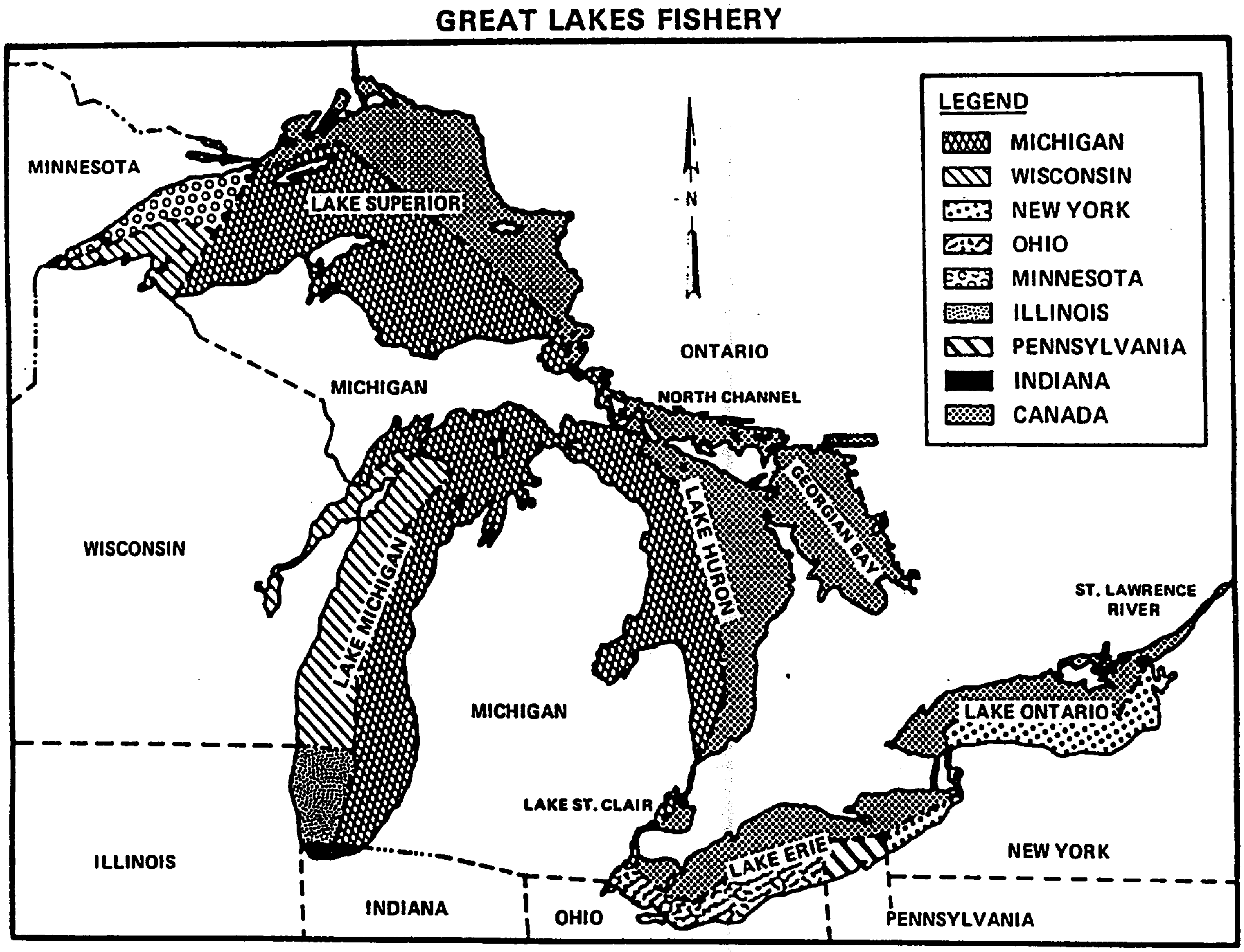


Figure I-2. Great Lakes Fishery

Chapter VII gives a summary of the study, presents the conclusion and recommendations.

CHAPTER II

REVIEW OF LITERATURE

This chapter will review and discuss the literature dealing with the development of biological and economic approaches to the management of fishery resources. It will also describe the role of economic theory which, when applied into the biological concept of fishery, resulted in a new approach called bioeconomic modeling. The applications of the bioeconomic model in empirical studies conducted previously as well as studies on the demand and supply of the commercial fishery commodity, will also be discussed in this chapter.

Gordon's (1954) initial work to introduce the role of economic theory in the management of fishery resources which had been dominated by biological considerations (Mitchell 1979) can be considered a milestone. Gordon examined the role of economic theory in the utilization of fishery resources which is viewed as unusual resource due to its biological and common property nature. He mentions that most biologists ignored or did not give much attention to economic rationing in the management of fishery resources. Their sole consideration focused on maximizing the number of fish caught and neglecting the costs of factor inputs required for the catching effort. Therefore, the biologists tended to recommend exploiting the fish populations to the point of maximum sustainable yield (MSY) which is obtained when the marginal productivity of fishing effort is zero. On the other hand, from the economists point of view, the optimum fishing effort should be explored to the level which could provide maximum economic yield (MEY). Thus, fishing effort to produce MEY is less than the effort to produce MSY. The point of MEY will occur in the range of production in which the slope of marginal productivity is positive. In reality, however, open access fishery resource will apparently be exploited in the free competitive market to a level where AC (average cost) = AR (average revenue), which is most likely to be in the range of negative marginal productivity. Thus no economic rent is left to the fishermen.

The standard biological model of fisheries, which is used as a basic discussion in economic theory, is the logistic model of population growth developed by Schaefer in 1953. Schaefer's model (1957) shows that the underlying fish population grows when the natural rate of growth exceeds the reductions from the effects of both natural mortality and fishing effort. This can be shown by the following biological model:

$$\frac{dB}{dt} = f(B) \qquad (2.1)$$

$$Y = y(B, E) \qquad (2.2)$$

$$B = b(E) \qquad (2.3)$$

$$f(B) = t_1 B(K-B) \qquad (2.4)$$

$$Y = qEB \qquad (2.5)$$

where:

$\frac{dB}{dt}$ = growth of biomass

B = biomass

Y = the catch or yield

E = fishing effort

t_1 = constant

q = "catchability" of the fish which is also constant

K = maximum biomass (carrying capacity)

In equation (2.1) Schaefer indicates that the rate of natural increase of biomass is function of population size (biomass), whereas the catch (landings) is function of biomass and fishing effort as shown in equation (2.2). The biomass itself under equilibrium condition, according to Schaefer is a function of fishing effort (equation 2.3). In equation (2.4) and (2.5) Schaefer specifies the approximate form of biomass growth and fish landings. In equilibrium condition, catch (landings) equals the rate of natural increase in biomass as shown in equation (2.6).

$$qEB = t_1 B (K-B) \qquad (2.6)$$

this equation can be rearranged as:

$$B = K - (q/t_1) E \qquad (2.7)$$

Then "Schaefer's yield function" is derived by substituting equation (2.5) into (2.7), giving:

$$Y = qE (K- (q/t_1) E) \qquad (2.8)$$

From equation (2.6), if the natural rate of growth of biomass exceeds the mortality (natural and fishing effort), the right hand side of the equation is greater than the left hand side; then dB/dt is greater than zero; the biomass is growing. On the other hand, if biomass growth is less than the mortality, dB/dt is negative; the biomass is declining. Furthermore, the model shows that if fishing effort (which could be measured in terms of the number of boats, fishermen, or fishing days) is increased, it can increase yield to the level of MSY. Beyond this, any further increase in effort will result in a lower yield due to overfishing of the fishery resources[1] (Mitchell, 1979). At this stage the reproductive capability of the fish population cannot keep pace with the rate of mortality (natural and manmade), thus the population stock will decrease as will the yield from fishing effort (see Figure II-1). Population stock at P2 is smaller than at P1. Biologists tended to recommend exploitation at the MSY level which produced the largest amount of food. From the economic point of view, as expressed by Gordon, maximization will be reached when the marginal revenue of an extra unit of fish caught equals marginal cost. Gordon combined an economic model with a biological model to form a bionomic (bio-economic) model. He turned the physical fish production function (which shows the relationship between yield and effort) into the well behaved total revenue function. This was done by multiplying the points on the production curve times prices. By assuming a constant cost for each unit of effort, which implies that the cost will increase linearly with fishing effort, the total cost of fishing effort can be represented by a straight line. The intersection between the total revenue curve and the total cost curve indicates that at this point the average revenue of fishing effort is equal to the average cost, the point of long run and

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[1] According to Pauly (1980), overfishing may happen in terms of:
(a) "growth overfishing," occur when the young fish that become available to the fishery (the recruit) are caught before they can grow to a reasonable size.
(b) "Recruitment overfishing," occurs when the (parent) stock is reduced by fishing to the extent that not enough young fish are produced to ensure that the stock will maintain itself.
(c) "Ecosystem overfishing," occurs in mixed fisheries when the decline (through fishing) of the originally abundant stocks is not fully compensated for by the contemporary or subsequent increase of the biomass of other exploitable animals. Ecosystem overfishing would be the transformation of a relatively mature efficient system into an immature inefficient system (from stable to unstable low biomass).

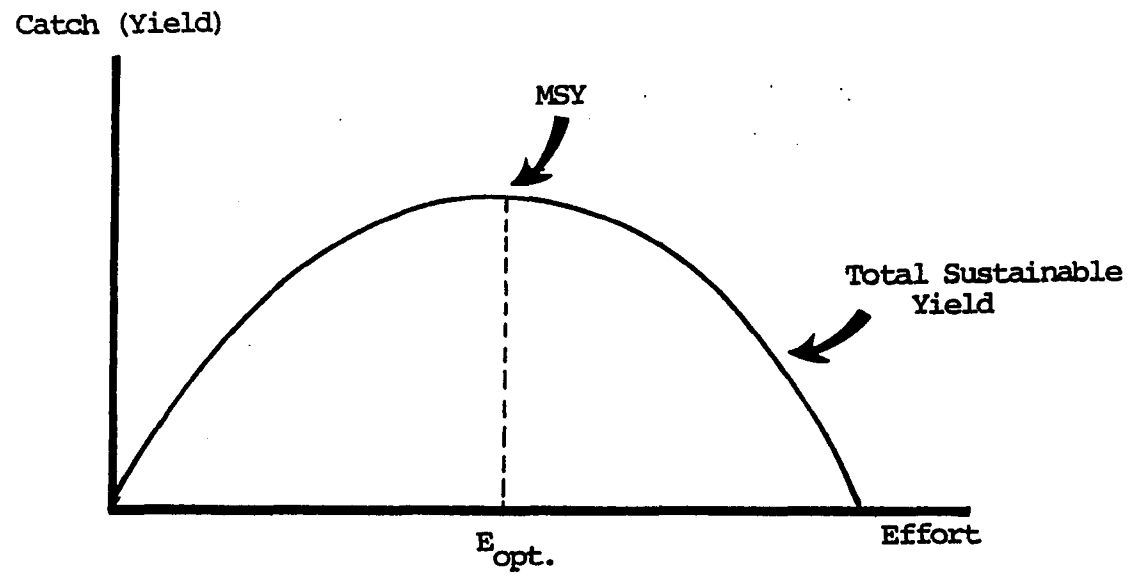


Figure II-1. Biological Model

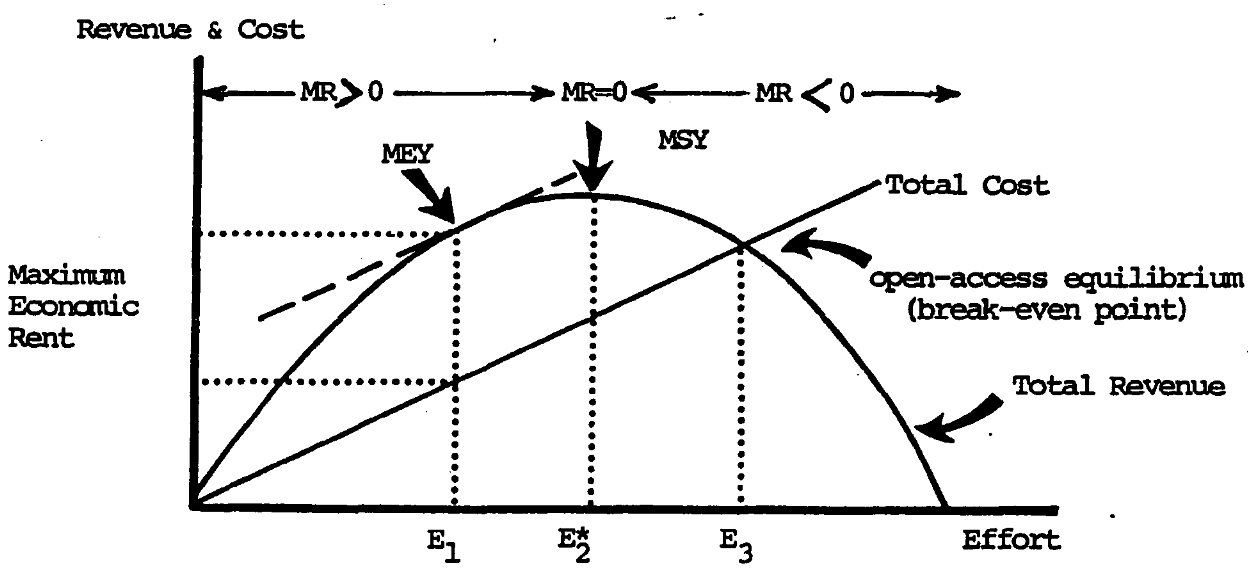


Figure II-2. Economic Model (Static)

open-access equilibrium for the fishery. Under uncontrolled exploitation of fishery resource (unregulated), the fishing industry will very likely end up operating at this level. Free entry (exit) into and out of the fish industry will apparently occur if industry operates to the left (right) of the break even point. Firms in the fishery industry will be forced to operate at the open access equilibrium; if they do not, any net surplus gained by firms operating to the left of this equilibrium will attract other firms to enter. At this point all the firms will end up at the open-access equilibrium; the equilibrium which leads to both biological and economic tragedy. The former will be characterized by overfishing, decline in population stock and lower sustainable yield, the latter by decreased returns despite the increasing factor (effort) used. The fishing industry is operating at the level of production in which marginal product (marginal revenue) turns out to be negative. This means that any additional fishing effort will not increase the total catch, but will decrease it instead. MEY can be obtained and will usually require less effort than open-access equilibrium (E_1 compared with E_3 in Figure II-2). However, there are forces which drive effort back to E_3 as long as there is no change in the nature of open-access resources.

The total revenue curve is a locus of any point which represents a biological equilibrium since at the existing level of effort, fish caught equals growth. Economic equilibrium will be obtained when the total cost curve intercepts the total revenue curve. At this point there would be no change in either the fish stock or the amount of effort. This situation is called a bionomic equilibrium (Anderson, 1977).

Gordon also utilizes a model which closely resembles one used in firm theory to determine the optimum use level of input, namely fishing effort. In making his point Gordon uses a production function approach in which he assumes linear functional relationships between average production (production-per-unit of fishing effort) and the quantity of fishing effort as can be seen in Figure II-3. The curves AP and MP represent, respectively, the average productivity and marginal productivity of the fishing effort. The costs of fishing supplies and other factors used in production are assumed to be unaffected by the amount of fishing effort. Thus, marginal cost and average cost of fishing effort are identical and constant, shown as the horizontal curve, MC and AC in Figure II-3. These costs are assumed to include an opportunity income for the fishermen. The optimum level of fishing effort will be Ox which provides a maximum economic yield (MEY) indicated by the area apqc. He further depicts that the maximum sustained yield (MSY), advocated by the biologist, will occur when marginal productivity of fishing effort equals zero with a corresponding fishing effort Oz. Obviously, the optimum economic fishing effort is less than that which would produce the maximum sustained yield.

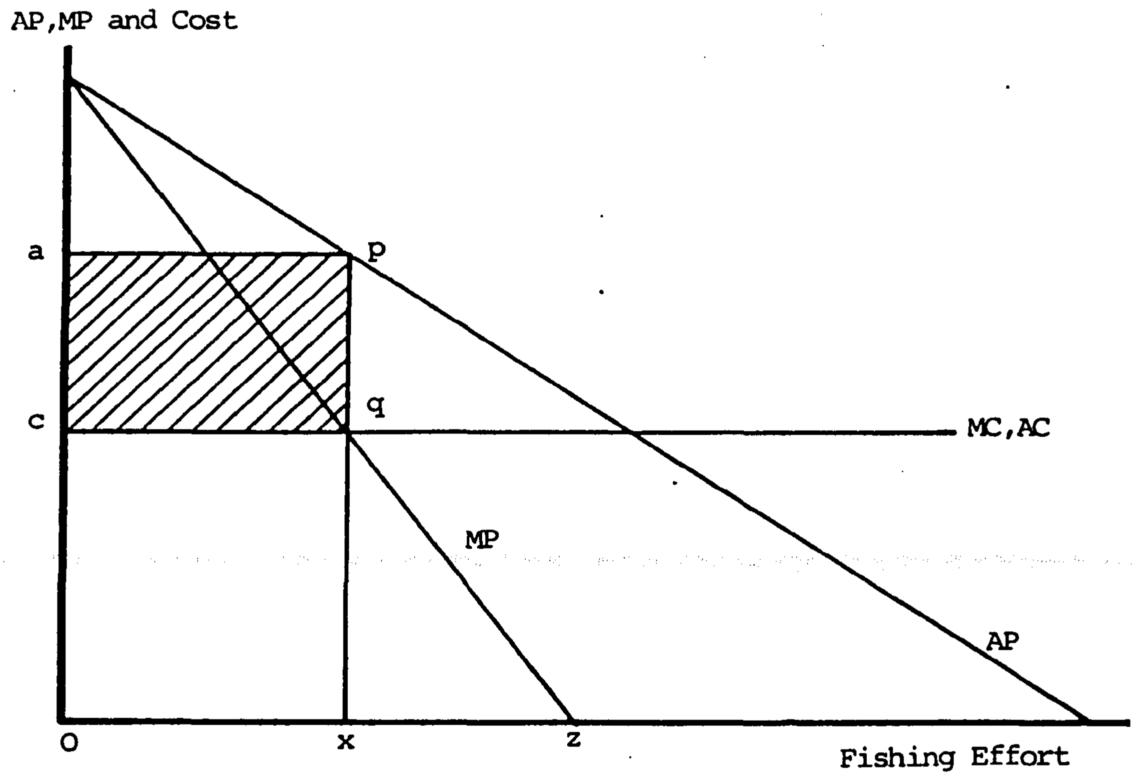


Figure II-3. Gordon's Optimum Level of Utilization of Fishing Resource

Schaefer's model, which is also called surplus-production (yield) model or logistic-type model, has been used widely as one approach to fishery resource management, especially in estimating the level of optimal effort and maximum sustained yield. This model is basically drawn from the biological nature of fish populations under different harvesting efforts and times in which the biomass changes in response to the harvest as illustrated in Figure II-4.

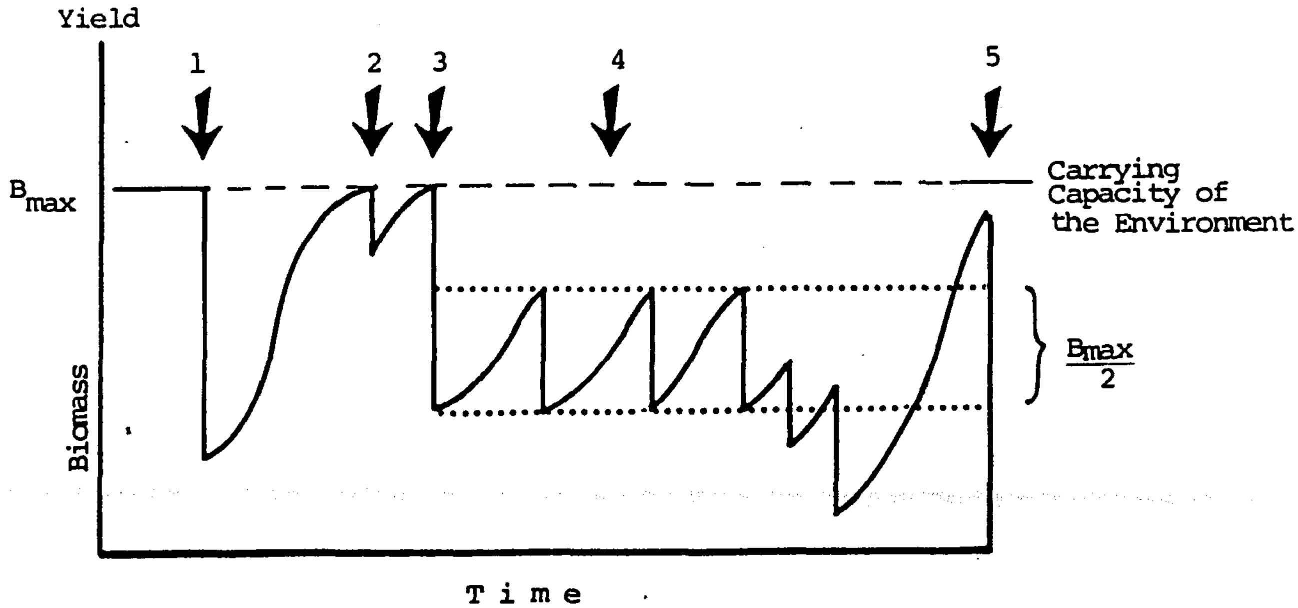


Figure II-4. The Biological of Fish Population and Response to the Harvest Over Time Based on Logistic Model

B_{max} represents the maximum biomass which is the carrying capacity of the environment (upper limit).

After the fish are harvested at time 1, the biomass will grow back to an equilibrium level along an S shape curve which indicates that at low stock levels the rate of biomass growth increases with stock size, the rate will then decrease as stock approaches maximum biomass, B_{max}. On the other hand, at higher stock level when the harvest is small, such as at time 2, the rate of biomass growth is also smaller. Between times 3 and 4, the fish are exploited at the level which gives the maximum rate of biomass regeneration, that is at $B_{max/2}$, where maximum harvest is reached. This level of exploitation is comparable to the level of maximum sustained yield on the production function as shown in Figures II-1 and II-2. After time 4, the fish have been over exploited, and biomass regeneration cannot keep pace anymore with the rate of predation, which could lead to the stock depletion (Pitcher and Hart, 1982). By using the illustration in Figure II-5 below we see how the surplus yield model developed.

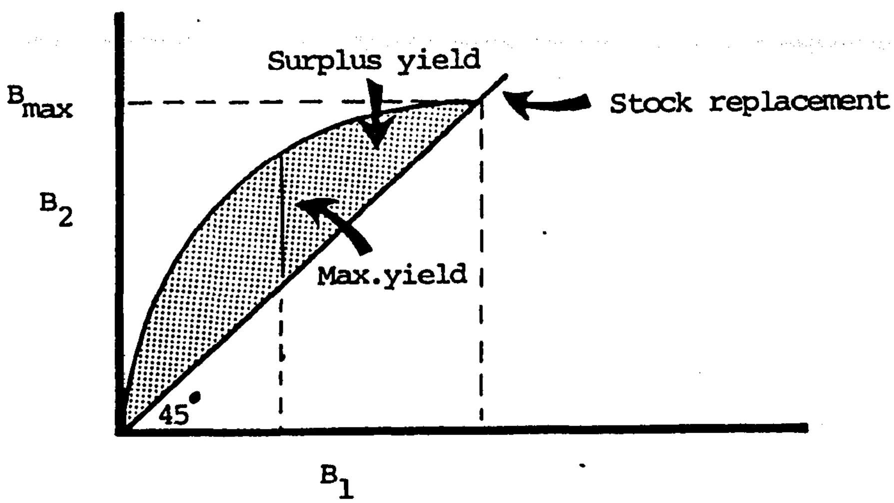


Figure II-5. Surplus Yield Model

B_1 and B_2 are the biomass of fish populations from two successive time periods, 1 and 2, before and after regeneration has taken place. A forty-five degree line shows the replacement of the biomass between periods. Along this line there will be no change in population stock. Any biomass produced above that required for exact replacement is considered a surplus, and therefore can be exploited. The fishery will be in equilibrium when the quantity of fish harvested is exactly equal to the surplus produced at period 2 over period 1. Consequently, there will be no change in fish biomass. From this basic concept, then a mathematical function of surplus yield is derived which expresses the relationship among the variables in fishing activities such as: the rate of change of biomass, fishing effort, fishing rate, catchability and yield in order to determine the level of maximum effort and MSY (see equation 3.5).

Pauly (1979) mentions that Schaefer's model can be used to make yield assessment when a minimum of data is available (catch and effort data only). This model has been applied to a number of fisheries throughout the world with varying success. Pauly follows through by presenting assumptions made for deriving Schaefer's model such as:

1. Fish population in a finite ecosystem grows in weight (w) until it reaches the maximum carrying capacity; the increase in total weight ceases when population stocks reach maximum biomass (B_{max}).
2. B_{max} corresponds to the virgin biomass of the stock.
3. The growth of the fish biomass toward B_{max} over time could be described by a logistic curve where first derivative, dw/dt , has a maximum at $B_{max/2}$ and zero values at B_{max} and B = 0.
4. The population stock at $B_{max/2}$ (population stock of half its original size) will give the highest net growth of the stock, and produce a maximum surplus yield to be harvested.

5. If the biomass of the exploited stock is maintained at $B_{max/2}$, then the maximum surplus yield can be sustained indefinitely. This is called maximum sustained yield (MSY). See Figure II-6.

Many studies have been conducted in several regions using the Schaefer model, as shown in Table II-1 below:

Table II-1. The Application of Schaefer Model

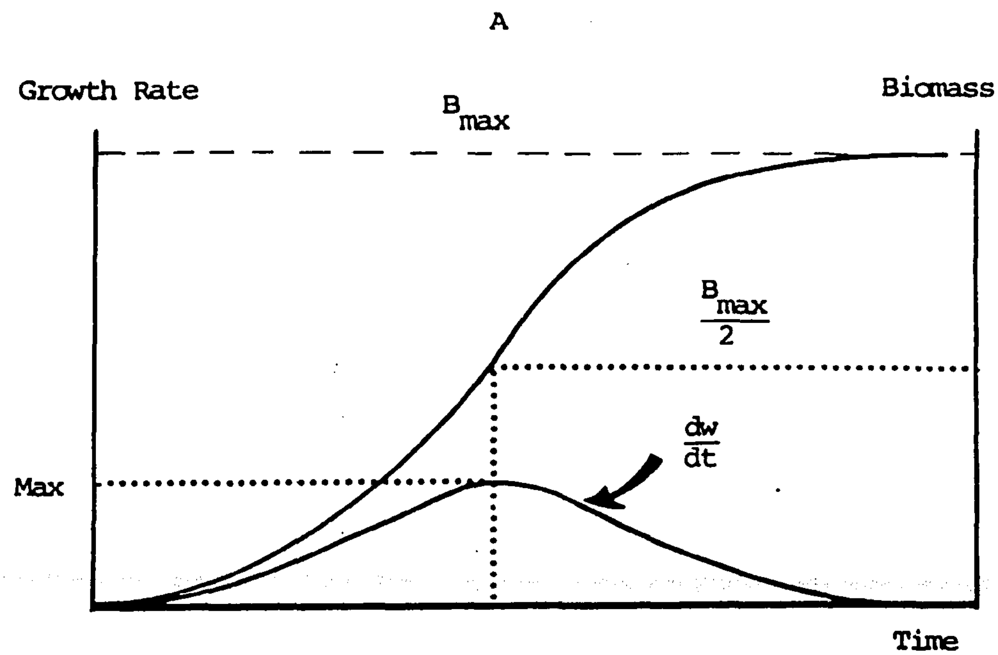
Area	Authors	
Georges Bank (USA)	Brown et al.	(1976)
Gulf of Thailand	Marr et al.	(1976)
	FAO	(1978)
Malacca Straits		
Indonesian	Sujastani et al.	(1976)
Malaysian Waters	Lam Ah Wang & Pathansali	(1977)
Thai Waters	SCSP	(1976)
Philippines		
Visaya and Samar Seas	SCSP	(1976)
Suke, Bohol Seas, Moro Gulf	SCSP	(1977)

Source: Pauly, 1979.

Many studies which modified Schaefer's model have been used and applied by many scholars such as Fullenbaum and Bell (1974), Walters (1978), and Hilborn (1979).[2]

There are, however, some criticisms of Schaefer's surplus yield model. Ricker states that in the Schaefer model, maximum yield or Y_{max} always occurs at $B_{max/2}$, the middle of the parabola. A consequence of this is that it is possible, by rearranging and solving a couple of

[2]For more detail and rigorous discussion and comparison of different bionomic models from Gordon, Schaefer, Turvey, Fullenbaum, etc. see in Ghanbari (1977).



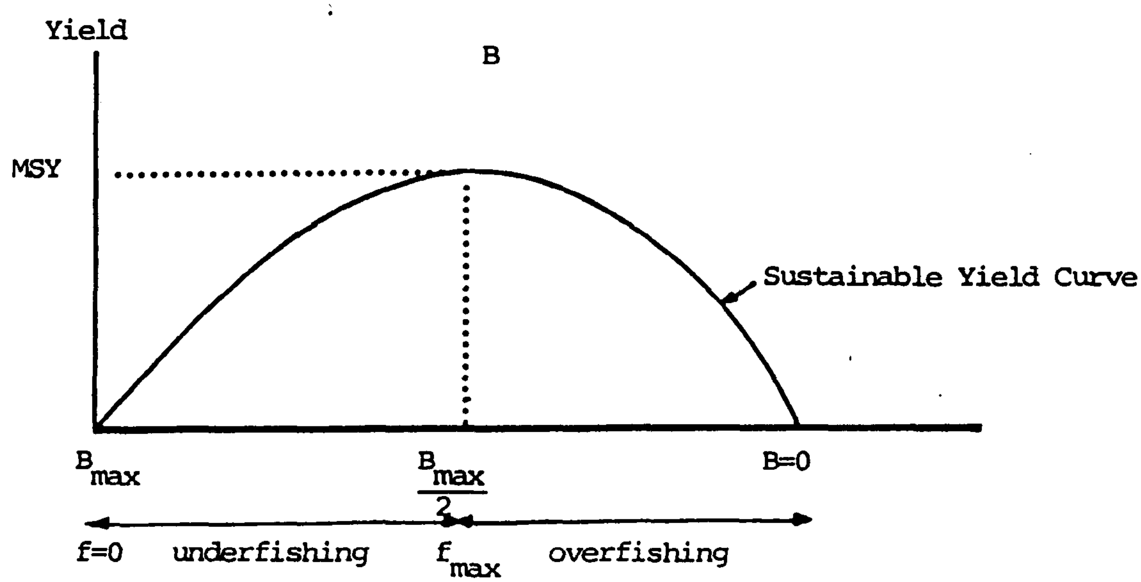


Figure II-6. The Simple Schaefer's Model

A. The Logistic Curve of Population Growth

B. The Yield-Biomass and Yield-Effort Relationship simultaneous equations, to estimate MSY and maximum effort (f_{max}) from two or more equilibrium yield taken in past years, without knowing q (catchability rate) or the stock size (Pitcher and Hart, 1982).

Pitcher and Hart also mention the advantages and disadvantages of surplus yield model. The advantages are that data is required only on catch and effort, which is easier to get, MSY will be easy to calculate, and it provides practical advantage.

The disadvantages are that:

- the model ignores the real biological process which actually generates the biomass, where biomass itself is an interacting process of growth, recruitment and mortality.
- the model also ignores the age structure of the fish population where differences in age structure can alter the growth process drastically.

Even though the Schaefer model is a rather simple way to represent the complex dynamics of the fishery, the extent of its use in fishery management in the past and in the future is evidence that the model is often regarded as an approximation of those complex dynamics. Therefore, the surplus yield model should be employed with great caution in fishery management. The model, however, only requires catch and effort data which is largely available (Uhler, 1980).

Another approach (model) used to estimate MSY is what is called a "dynamic pool" or Beverton and Holt model. This model is more complicated and needs a great deal more information than catch and effort for the surplus yield model. In dynamic pool models, one should deal with population processes such as tissue growth, mortality, and increases in the number of fish through reproduction (Pitcher and Hart

1982). Jensen (1973) describes the dynamic pool model as the estimation of biomass by specifying functions with respect to age, for size of cohort, individual weight, and application of the coefficient of fishery mortality. In the surplus yield model the terms for recruitment, growth, and natural and fishing mortality are all combined in the expression for annual biomass accumulation.

The nature of the supply of fishery resources is somewhat different than the supply of other products which generally have positive slopes. Evidence from a few previous studies reveals that fishery supply curves may have a backward slope (Copes 1970; Crutchfield and Pontecorvo, 1969; Clark, 1976). This indicates that after certain range fish supply has a negative slope (see Figure II-7). The backward bending supply curve occurs after the fishing effort exceeds the level of effort (E_{msy}) to maximize a sustained yield. After the MSY point, any increase in demand will raise prices and attract more entry into the industry which will cause overfishing, and therefore, limit output (yield). The reduced yield will be shared among an increased number of firms which operate in the negatively sloped portion of the supply function.

An increase in demand from D_1 to D_2 will increase the effort to catch the same or smaller number of fish. In the beginning, the fish production might increase, temporarily, with increasing demand. However, after passing MSY, any expansion in effort, to increase the supply in order to meet the demand, will lead to decreasing the amount of yield to Y_2. The fishery industry then is operating at the backward sloping supply curve range. Economic rent will dissipate and excessive fishing efforts (inputs) will probably occur which will in effect, reduce efficiency and lead to economic waste. Clark (1976) argues furthermore, that an increase in demand under this condition also will decrease the amount of consumer surplus. This indicates that in the fishery industry, where resources are limited by biological nature, an increase in demand might not necessarily benefit the fishermen due to increases in fish prices. This situation can be unfortunate for both consumers and producers in terms of higher prices, lower yields, and all profits lost.

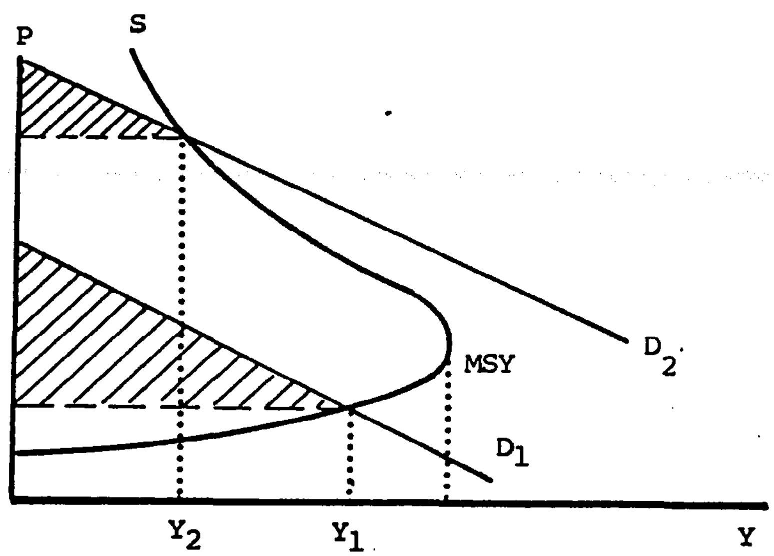


Figure II-7. Long-run Fishery Supply and Demand Curves

When more people and firms compete for a stable or shrinking supply of the fishery, it obviously creates more tension and makes regulation more difficult to enforce. This generates constant pressure for the government to intervene and regulate the utilization of the fishery resource. Moreover, the existing problems have been intensified by the instability of the fishery production and high seasonal variations which cause instability in the supply of fish, thus fluctuating the market prices.

Ghanbari (1977) conducted a study on demand and supply, as well as bioeconomic analysis of U.S. Great Lakes whitefish. He used models extensively to estimate demand and supply functions. Among the models used are simple ordinary least squares (OLS) equations, OLS equations with distributed lags, reduced form equations, and two and four simultaneous equations using two and three stage least squares. Results from his study gives a good explanation of the demand function. Ghanbari obtained statistically significant estimates by using either OLS, reduced form or two stage least square (2SLS) techniques. Supply estimates did not meet his expectation but rather, gave mostly negatively sloped supply curves. Only the estimates using a system of four equations gave a positively sloping supply equation, although most of the variables were not significant at the 10 percent level.

From his study, Ghanbari has been able to estimate the magnitude of whitefish elasticities in which price elasticity of demand ranged between -2 and -4; income elasticity of demand was about 2.2; cross-price elasticity of demand with beef price was about 2.3; cross elasticity with lake trout was about 2.0. Price elasticity of supply was .25. Cross elasticity of supply with lake trout price was about .18. Ghanbari did not expect to have a negative supply curve. His findings however, were not unexpected based on previous studies by Copes (1970) and Clark (1976). This might indicate that the fishing industry on the Great Lakes has operated under a backward sloping supply curve as a result of overfishing, which provides less fish for catching. There is another possibility which might explain this situation; U.S. Great

Lakes fishery regulation has restricted the number of fish to be caught and competition with sport fishing has left commercial fishermen with less fish to be caught despite the increasing prices.

Copes (1970) considered that the backward-bending supply curve was often representative of the fishing industry, a finding that was similar to Ghanbari's results.

Dow et al. (1975) conducted a study on Maine lobster fisheries which indicated that the expansion of demand for lobster was a driving force in the expansion of the fishing effort, in terms of the number of traps used. From 1940 to 1971 the number of traps increased about 5.6 percent annually, an increase from 220,000 to 1.2 million traps. Dow et al. concluded that Maine lobster fishery was over capitalized. Any increases in the demand for lobsters would result in decreasing the quantity supplied since the estimates indicated that maximum sustained yield could be caught with approximately half of the existing traps in 1971. Dow et al. also tried to measure the impact of various management strategies (using a simulation model) which could be imposed on the Maine lobster fishery through regulations such as:

1. Freezing existing (1969) fishing effort by placing a license fee on traps.
2. Reducing the existing level of fishing effort to the point of MSY by placing a license fee on traps.
3. Reducing the existing level of fishing effort to the level of marginal cost of landing equal to ex-vessel price (MC=MR), to get maximum economic benefit.

4. Issuing a stock certificate to each vessel owner based on average catch over the last 5 years while freezing the existing level (1969) of fishing effort. This certificate could be used either to catch fish or to sell for cash.

5. Doing nothing.

From these 5 management policy strategies Dow projected the impact on various aspects of the lobster fishery such as: catch, value of catch, number of vessels, traps, prices, license fees collected by state, license fee per vessel and fishermen. One thing that Dow did not estimate was costs incurred to impose those various regulations, especially for the state.

Marasco (1970) discussed the models used by Bell in 1969 to estimate the world demand and supply of tuna over the 1970-90 period. Bell introduced four relationships in the demand and supply of tuna.

-the producers' supply relation (raw tuna)

-the processors' demand relation (raw tuna)

-the processors' supply relation (canned tuna)

-the consumers' demand relation (canned tuna)

Bell only estimated the consumers' demand parameters and omitted the remainder of the demand and supply relationships. Marasco, using a model employed by Bell, estimated the demand and supply of raw tuna. Linear and logarithmic forms were used in the process and were estimated by using OLS methods. According to Marasco simultaneous estimation procedures were not required due to the fact that prices paid to fishermen are known prior to departure for the fishing ground. Evidently, the coefficients of supply equations from these estimates lack significance at 80 and 90 percent probability levels. Moreover, the supply equation has a negative price coefficient.

A study conducted by Nash in 1969 on demand analysis of the San Pedro wetfish, which was carried out on several fish species, revealed that prices did not change very much in response to changes in landings. Demand was price inelastic. The quantity of fish landings did not have any strong relationship with consumer income except for tuna and sardines. This implies that a rise in income is not necessarily an increase in the market size of these fish species.

Cleary (1969) in his study to project the U.S. shrimp consumption into the year 2000, estimated and measured the forces determining the level of consumption and the price level of shrimp in the United States. In his estimate, Cleary used logarithmic and arithmetic functions to estimate shrimp consumption. This resulted in a statistically significant estimation and a high R^2, regardless of whether he regressed total shrimp consumption or per capita shrimp consumption. He found that while the demand for shrimp is price inelastic with the magnitude of about -.60 to -.65, income elasticity for shrimp was about 1.70. Deflated income per capita for instance was able to account for 94 percent of the variation in total consumption, and 87 percent of the variability in per capita consumption.

Cato's study (1976) of the demand for Florida mullet indicated that the annual dockside price was influenced by the quantity of mullet and personal incomes, where the quantity of all other finfish landed did not seem important in influencing mullet prices. However, there was some indication of serial correlation in his estimates. Cato also estimated monthly demand functions using a first degree polynomial distributed lag model with 3 months lag. He found that the monthly price of mullet was not only influenced by the current month landings but also by landings in the preceding month. However, the quantity of mullet landed in previous months became less important in influencing the price than the current landing. He also estimated price flexibilities based on monthly, bimonthly, quarterly and annual data with magnitudes of .123; .129; .184; and 1.251, respectively. The coefficient of price flexibility for annual data is greater than for quarterly, quarterly greater than bimonthly and so forth. These figures indicate that prices become more flexible as the time period for price adjustment becomes longer. According to Cato, this is mainly due to the consumers' responsiveness to change in quantity of mullet landings at a longer period since storage for mullet beyond three months is less likely.

Kuaternik et al. (1983) using monthly landings of hard clams from Virginia, New York, New Jersey, Rhode Island, Maryland and North Carolina over the period 1960-1983, estimated the price flexibility by the least squares method. It turned out that price flexibility coefficients were very small and only about forty two percent of the ex-vessel price changes were explained by the supply response model used.

Johnson (1981), in his study on Lake Michigan chubs estimated the dockside demand for number one grade chubs. He found the expected sign (negative) for price and consumption relationships except for the per capita personal income which also had a negative sign. The price flexibility of the estimated demand equation was also very small.

Sudarsono (1979), who conducted a study on elasticities of demand and supply of Indonesian fisheries, estimated the demand and supply functions of Indonesia fresh fish (composed of marine fresh fish, cultivated inland water fish, and general inland water fish) using a linear logarithmic equation. The quantity of fresh fish demanded was regressed on prices of marine fresh fish, cultivated inland water fish, inland water fish, salted fish, meat and on gross national product per capita. This study revealed that per capita income has a greater impact on the quantity of fish demanded, than the impact of the marine fish price which is the largest portion of fish product in Indonesia. His estimates of supply functions for marine fish, cultivated inland water and inland water fish resulted in positive signs for all regression coefficients, namely own prices and technologies (in terms of labor or fishermen boat ratio). Moreover, for marine and inland water fishes, the responsiveness of quantity supplied toward technology is higher than toward price.

CHAPTER III

METHODS OF THE STUDY

In order to achieve the objectives of this study several models will be introduced. This chapter will discuss in detail the methods and models used to estimate bioeconomic factors and productivity; demand and supply; price and income elasticities; price flexibility; and consumer, producer and social surplus of Michigan Great Lakes commercial fisheries.

The Bioeconomic Model

This model will explain the behavioral factors and interrelationships of fishery resources such as fishing effort, catch, population biomass, earning and cost from fishing.

In the model, a series of mathematical relationships which approximate the structural behavior of the fishery resource from the real world are introduced. The bioeconomic model in this study attempts to estimate the level of commercial fishery utilization at the equilibrium level. The estimates will include:

- the level of maximum sustained yield (MSY) from several fish species.
- the level of harvesting which produces maximum economic yield (MEY).

- the level of effort associated with MSY and MEY.
- the population growth rate coefficient, catchability coefficients, and environmental carrying capacity for each fish species.

The logistic surplus yield technique which was developed from the logistic growth model is used.

$$\frac{dB}{dt} = k\ (B)\ \ B \qquad (3.1)$$

and

$$k\ (B) = k\ (1 - B/K) \qquad (3.2)$$

where:

B = population size (biomass)

k = intrinsic growth rate (population growth rate)

K = environmental carrying capacity

t = time

$\frac{dB}{dt}$ = growth in biomass in the absence of fishing

Equation (3.1) shows that the rate of population growth, which grows exponentially, cannot proceed indefinitely. Environmental limitations in terms of carrying capacity will force the growth rate to decline.

Substitution of (3.2) to (3.1) will give:

$$\frac{dB}{dt} = kB\ (1 - B/K) \qquad (3.3)$$

Equation (3.3) is called a logistic equation.

The harvest equation is shown in equation (3.4).

$$Y = qEB \qquad (3.4)$$

where:

Y = fish yield

q = catchability rate (coefficient)

E = fishing effort

By introducing a harvest equation into the model, the logistic surplus yield model could be written as:

$$\frac{dB}{dt} = kB\ (1-B/K) - qEB \qquad (3.5)$$

or

$$\frac{dB}{dt} = kB - (k/K)\ B^2 - qEB$$

Equation (3.5) shows that the change in fish population (biomass) is equal to the difference between the annual rate of increase of population size and the harvest.

Surplus production is the amount of biomass produced that can be taken out (harvested) without changing the stock size. In other words, at the equilibrium state, the annual growth of fish biomass is equal to the amount of fish harvested. Therefore, at the equilibrium yield in the steady state, $dB/dt = 0$; thus, equation (3.5) will give:

$$kB\ (1 - B/K) = qEB = Y \qquad (3.6)$$

or

$$Y = kB - \frac{k}{K} B^2 \qquad (3.7)$$

Equation (3.7) gives the equilibrium yield that will occur at each biomass level.

Factoring out B from equation (3.5), and then substituting it into equation (3.7), results in equation (3.8).

$$Y = qKE - \frac{K}{k} q^2 E^2 \qquad (3.8)$$

By differentiating equation (3.7), with respect to B, and equating it to zero, the population size at which the MSY occurs will be obtained:

$$\frac{dY}{dB} = k - \frac{2k}{K} B = 0 \qquad (3.9)$$

Rearranged eq. (3.9), gives us:

$$B^* = \frac{kK}{2k} = \frac{K}{2} \qquad (3.10)$$

where:

B^* = biomass at maximum sustained yield.

Equation (3.10) shows that the biomass (population size) at MSY is equal to half of the maximum biomass stock.

Substituting (3.10) into (3.7):

$$Y^* = k \; \frac{K}{2} - \frac{k}{K} \; \frac{K}{2}^{2}$$

$$= \frac{kK}{2} - \frac{kK^2}{4K}$$

$$Y^* = \frac{kK}{4} \qquad (3.11)$$

where:

Y^* = fish harvested at maximum sustained yield.

Equation (3.11) is a MSY equation.

Maximum fishing effort (E^*) at MSY is:

$$Y^* = qEB$$

$$E = \frac{Y^*}{qB}$$

$$= \frac{\frac{kK}{4}}{\frac{qK}{2}} = \frac{2kK}{4qK}$$

$$E^* = \frac{k}{2q} \qquad (3.12)$$

The surplus production model can also be applied for estimating the biomass of the stock which was derived from equation (3.4):

$$B = Y/qE \qquad (3.13)$$

Equation (3.13) shows that the biomass in a certain year (time) is equal to yield at certain time divided by the product of catchability rate and fishing effort.

The economic model (variables) should be introduced into the biological model to determine the maximum economic yield (MEY). This results in a level of fish harvest that will yield maximum economic rent (profit). In this case cost is assumed to be in proportion to effort, then:

$$TC = C_f E \qquad (3.14)$$

where:

TC = total cost (variable + fixed cost)

C_f = cost per unit of effort

E = effort

Total revenue (TR) or total value product (TVP) earnings from fishing is equal to the number of fish sold at a certain price (P). The revenue equation is:

$$TR = TVP = PY = P\,qEB \qquad (3.15)$$

where Y is the yield, which is equal to qEB (See eq. 3.4), profit (L) which is also called producers' surplus, can be derived from the differences between total revenue and total cost.

$$L = TR - TC \qquad (3.16)$$

Profit maximization is the objective of the bioeconomic model, subject to the biological constraints from equation (3.5).

The Lagrangian multiplier technique is employed to maximize profit (L),

$$L = PqEB - C_f E + \lambda \ (kB - k\, B^2/K - qEB) \qquad (3.17)$$

where λ is the shadow price of the constraint, that is the change in profit when the constraint changes by one unit.

By differentiating equation (3.17) with respect to B, E and L; setting all these equations equal to zero, and the values of B, E and L can be solved.

$$\frac{dL}{dB} = PqE + \lambda \ (k - \frac{2kB}{K} - qE) = 0 \qquad (3.18)$$

$$\frac{dL}{dE} = PqB - c_f - \lambda\, qB = 0 \qquad (3.19)$$

$$\frac{dL}{d\lambda} = kB - \frac{kB^2}{K} - qEB = 0 \qquad (3.20)$$

By solving equations (3.18); (3.19); and (3.20) simultaneously, we get:

$$B^e = \frac{K}{2} + \frac{C_f}{2qP} \qquad (3.21)$$

$$E^e = \frac{k}{2q} \ (1 - \frac{C_f}{qPK}) \qquad (3.22)$$

$$= P - \frac{C_f}{qB^e} \qquad (3.23)$$

where B^e is the biomass at MEY, and E^e is effort at MEY.

By substituting B^e and E^e into equation (3.4), the MEY level will be obtained.

$$MEY = qE^eB^e = kB^e - \frac{k}{K} (B^e)^2 \qquad (3.24)$$

By comparing equation (3.21) with (3.10), and equation (3.22) with (3.12), it can be concluded that:

- the biomass at MEY is greater than at MSY, or $B^e > B^*$
- effort at MEY is smaller than at MSY, or $E^e < E^*$
- yield at MEY is smaller than at MSY

Linearized Surplus Production Method

As mentioned by Jensen (1976) the estimates of k, K and q are difficult when only catch and effort data are used, therefore, linearization of the surplus production model should be explored.

Modifying equation (3.4)

$$Y = qEB$$

to be

$$B_t = \frac{1}{q}(Y_t/E_t) = (1/q)\ (U_t) \tag{3.25}$$

where:

U_t = yield per unit of effort in year t;

Y_t = annual yield in year t;

q = the catchability coefficient.

The derivative of equation (3.5) can be approximated with a two point formula. This will give

$$\left(\frac{dB}{dt}\right)_t = \frac{B_{t+1} - B_{t-1}}{2} \tag{3.26}$$

Substitution (3.26) into (3.25) will result:

$$\left(\frac{dB}{dt}\right)_t = \frac{1}{q}(\Delta U_t) \tag{3.27}$$

where:

$$\Delta U_t = \frac{U_{t+1} - U_{t-1}}{2}$$

Then, substituting equation (3.25) and (3.27) into equation (3.5) gives:

$$\left(\frac{dB}{dt}\right)_t = \frac{1}{q}(\Delta U_t)$$

$$\left(\frac{dB}{dt}\right)_t = k\ (1/q)\ (U_t) - \frac{kU_t^2}{q^2K} - q\ (Y_t/q) \qquad (3.28)$$

$$\Delta U_t = kU_t - k\ \frac{(U_t)^2}{qK} - qY_t \qquad (3.29)$$

Equation (3.29) can then be written in terms of a linear regression equation:

$$Z_t = a_1X_1 + a_2\ X_2 + a_3\ Y_3 \qquad (3.30)$$

where

$Z_t = U_t$

$X_1 = U_t$

$X_2 = U_t^2$

$X_3 = Y_t$

$a_1 = k$

$a_2 = -\dfrac{k}{qK}$

$a_3 = -q$

The constants a_1, a_2 and a_3 can be estimated by least squares, so the parameters of M, K, and q can also be solved.

Demand and Supply Model

To analyze the demand (D) and supply (S) of several fish species (whitefish, chub, yellow perch, catfish, and allewife), several regression models will be used.

Single-Equation Method

D and S will be estimated by using the single equation model where prices and quantities are assumed to be determined in sequence. This model is empirically relevant when time lags between variable changes are long or when the time over which variables are observed is short (Tomek & Robinson, 1977).

The general forms of D and S equations are:

$$\text{Demand: } Q = a - bP_Q + cP_S + dY \qquad (3.31)$$

$$\text{Supply: } Q = a + bP_Q - cP_S - dP_X \qquad (3.32)$$

where:

Q = quantity

P_Q = price of output

P_S = price of substitute

Y = income

X = price of input

a, b, c and d are parameters which indicate how the variables are related.

Through a single equation model, supply functions can be estimated based on the assumption that when the demand curve shifts over time and the supply curve remains stable, the supply curve can be identified. If the supply curve shifts over time, and the demand curve remains stable, the demand curve is identified as long as the shift in the two functions are not highly correlated (Tomek and Robinson, 1981). In this situation, either price can determine quantity or quantity can determine price.

There is also a possibility that the current production of fish is a function of the previous year's price. This assumes that the quantity of fish marketed in the current year is largely predetermined by the previous year's price.

$$Q_t = f\,(P_{t-1}) \qquad (3.33)$$

where:

Q_t = output at year t

P_{t-1} = price at year t-1 (previous year)

Therefore, it is justifible to use a distributed lag model in the analysis. Simple ordinary least squares (OLS) technique, and OLS with distributed lag will be used in analyzing D and S for the single equation model.

Simultaneous - Equation Method

In a situation where price does not determine quantity nor does quantity determine price, but rather price and quantity are simultaneously determined (jointly determined) within the same time period, then a simultaneous equation model should be used.

Identification of the Equation

In simultaneous-equation models the identification problem is very important and will be thoroughly considered (Tomek and Robinson, 1981). This model is concerned with whether or not estimates of structural parameters can be obtained, and then which technique is more appropriate to use in the estimation.

There are three categories of identification:

1. under identified, a situation in which the equation is unidentified, and any estimate of structural parameter coefficients is unavailable.
2. just identified, a situation in which unique estimates are obtained for each structural coefficient.
3. over identified, a situation with multiple estimates of coefficients (not unique).

To determine in which categories the equation under consideration will be included, the following formulas can be used (Foote, 1958).

Just identified equations will be obtained if:

$$S - N = E - 1$$

Under identified equations if:

$$S - N < E - 1$$

Over identified equations if:

$$S - N > E - 1$$

where:

S = number of variables in the system

N = number of variables in each equation

E = number of endogenous variables in the system

This formula can be applied to each equation in the system for checking whether the equations are just identified, over identified or under identified. The variables in the system equation are composed both of exogenous (predetermined) variables, whose values are not determined in the system, and endogenous variables whose values are determined in the system. If the equation is just identified, then reduced-form or indirect least squares (ILS) methods might be used in estimating the structural parameter coefficients of demand and supply equations.

<u>Reduced Form</u>

For jointly determined variables in simultaneous equations, it is conceivable that there is a correlation between explanatory variables and the error term. Consequently, the OLS will not be appropriate to estimate the model. By transforming the structural equations (3.34) and (3.35) into reduced form, each equation will contain only one endogenous variable (P and Q are endogenous variables), eliminating this problem.

$$D: \quad Q = a_1 + b_1P + c_1Y + e_1 \qquad (3.34)$$

$$S: \quad P = a_2 + b_2Q + c_2X + e_2 \qquad (3.35)$$

Substituting P from eq. (3.35) into Q in eq. (3.34) and substituting Q into P, then reduced form equations will be obtained:

$$Q = \frac{a_1 + b_1a_2}{1 - b_1b_2} + \frac{b_1c_2}{1 - b_1b_2}X + \frac{c_1}{1 - b_1b_2}Y + \frac{e_1 + b_1e_2}{1 - b_1b_2} \qquad (3.36)$$

$$P = \frac{a_2 + b_2a_1}{1 - b_1b_2} + \frac{c_2}{1 - b_1b_2}X + \frac{b_2c_1}{1 - b_1b_2}Y + \frac{e_2 + b_2e_1}{1 - b_1b_2} \qquad (3.37)$$

Equations (3.36) and (3.37) can be estimated by using OLS, and the result will be:

$$Q = \emptyset_1 - \hat{\pi}_{11} X + \hat{\pi}_{12} Y + W_1 \qquad (3.38)$$

$$P = \emptyset_2 + \hat{\pi}_{21} X + \hat{\pi}_{22} Y + W_2 \qquad (3.39)$$

Then, the original coefficients of structural equations (3.34) and (3.35) can be solved by the following steps:

$$b1 = \frac{\hat{\pi}_{11}}{\hat{\pi}_{12}}$$

$$b2 = \frac{\hat{\pi}_{22}}{\hat{\pi}_{12}}$$

$$c1 = \hat{\pi}_{12} \quad (1 - b_1 b_2)$$

$$c2 = \hat{\pi}_{12} \quad (1 - b_1 b_2)$$

$$a_1 = \emptyset_1 - b_1 \emptyset_2$$

$$a_2 = \emptyset_2 - b_2 \emptyset_1$$

In the new equations (reduced form equations (3.36) and (3.37)), there will be no correlation between new explanatory variables with error terms.

The reduced-form equations will be estimated by OLS, and then the estimates of the structural parameters calculated by using the estimates from reduced-form parameters.

Indirect Least Square (ILS)

In this method, the OLS estimates of the reduced form parameters are plugged in to estimate the variable from a structural equation.

$$Q = \emptyset_1 + \hat{\pi}_{11} X + \hat{\pi}_{12} Y \qquad (3.40)$$

$$P = O_2 + \hat{\pi}_{21} X + \hat{\pi}_{22} Y \qquad (3.41)$$

The estimated values of Q and P are then substituted into the structural equation, as independent variables, to produce the estimates of the structural parameter coefficients. The structural parameter coefficients can then be estimated as shown in the equations below:

$$\text{Demand:} \quad Q = A_1 + b_1 \hat{P} + C_1 Y \qquad (3.42)$$

$$\text{Supply:} \quad P = A_2 + b_2 \hat{Q} + C_2 X \qquad (3.43)$$

Two-Stage Least Square (2SLS) and Three-Stage Least Square (3SLS) with Two and Four Equations

When we put more variables (information) into the system, the equations may be over identified. Estimation through ILS will give multiple solutions (non-unique solutions). Therefore, the 2SLS or 3SLS technique will be appropriate for estimating the parameters with two and four simultaneous equation systems. The 2SLS is one way of weighing the multiple solution.

For 2SLS, first, reduced form equations are estimated by regressing endogenous variables on all predetermined (exogenous) variables in the system by OLS as shown in equations (3.38) and (3.39). These instrumental variables, created through reduced form, will not have any correlation with the error term, even though in the original structural equation there might be a correlation between some explanatory variables and the error term.

In the second stage, the estimated value from the reduced form at stage one, equations (3.38) and (3.39), can be used to estimate the parameters of the structural equations, again by using OLS technique. So equations (3.34) and (3.35) will be estimated as follows:

$$Q = a_1 + b_1\hat{P} + c_1 Y + e_1 \qquad (3.45)$$

$$P = a_2 + b_2\hat{Q} + c_2 X + e_2 \qquad (3.46)$$

Since:

$$Q = \hat{Q} + \hat{W}_1 \quad \text{or} \quad \hat{Q} = Q - \hat{W}_1$$

$$P = \hat{P} + \hat{W}_2 \qquad \hat{P} = P - \hat{W}_2$$

Then, substituting into equations (3.45) and (3.46) gives:

$$Q = a_1 - b_1P + c_1Y + (e_1 + b_1\hat{W}_2) \qquad (3.47)$$

$$P = a_2 + b_2Q + c_2X + (e_2 - b_2\hat{W}_1) \qquad (3.48)$$

where $\hat{W}1$ and $\hat{W}2$ are the estimated residual from the reduced form.

Three-Stage Least Squares involves the application of generalized least square estimates to the system of equations which has first been estimated by 2SLS. From the 2SLS parameters, which have been calculated, the residuals of each equation are used to estimate the cross equation variances and covariances.

Data and Information Used in this Study

The price per pound for each fish species in this study is arrived at by dividing the total number of landing pounds by the total nominal value in dollars. The price per pound of fish reflects the true ex-vessel value (dockside value) since the data supplied by MDNR (Michigan Department of Natural Resources) are based on the total landings and landing values reported by the fishermen. Similarly, data for effort from different types of gear used and the number of fish caught by each type of gear is based on the information provided by the fishermen. One type of gear is selected as a standard gear and used in this study to measure catch-per-unit of effort (CPE). This will be accomplished by dividing the number of fish caught (with standard gear) by the amount of effort (measured in terms of a 1000 linear foot net for one unit of effort).

Therefore:

$$\text{CPE} = \frac{\text{Catch by standard gear } (= Ys)}{\text{Amount of effort with standard gear } (= Es)}$$

Then, converting the total catch and effort to a standard gear results in:

$$\text{Total Effort} = Y_t/\text{CPE} = (Y_t)\,(Es)/Ys$$

where: Y_t = total yield

This study will use a constant or real price in dollars for the analysis. The reason for this is to reflect only the real element of price or income by removing the effect of generally increasing prices. This is also commonly called deflation in which price or income are measured as if there was no inflation occurring. This process is accomplished by dividing current dollars by the price series, called the consumer price index (CPI). The CPI measures the average change in prices over time in a fixed market basket of goods and services.

Method of Calculating CPI

In order to facilitate the visual comprehension of prices from a base period that is more up to date, a conversion of CPI from 1967 = 100 to 1982 = 100 as a standard reference base, is used. The data will be converted by dividing each value in the 1967 base series by its 1982 annual average, and then rounding that product to one decimal. In this study, for practical purposes, the CPI is presented in terms of three decimals without multiplying by 100. The conversion process from 1967 base to 1982 base is shown below:

Year	Base 1967	Base 1982
1967	100	$\frac{100}{289.1} \times 100 = 34.6$ (=0.346)
1982	289.1	$\frac{289.1}{289.1} \times 100 = 100$ (=1.000)

Now, the 1967 index on 1982 base will be 0.346 where 1982 itself has index of 1.000.

Most of the data and information used in this study are supplied by government agencies and institutions such as:

- Fishery Division, Michigan Department of Natural Resources, Lansing.
- Great Lakes Fishery Laboratory, U.S. Fish and Wildlife Service, Ann Arbor.
- Ministry of Natural Resources, Province of Ontario, Canada.
- U.S. government publications and statistical reports, which are cited in the footnotes and bibliography of this study.

The period of this study is 23 years, from 1960 to 1982.

In this study, two statistical computer programs, SPSS (Statistical Package for the Social Sciences) and TSP (Time Series Processor) packages were used. These packages are available at the Michigan State University computer center.

CHAPTER IV

DESCRIPTION AND ANALYSIS OF MICHIGAN'S GREAT LAKES COMMERCIAL FISHERY

The State of Michigan's commercial fishery for whitefish, chubs, perch, catfish, and alewife species from 1960-1982 will be discussed in this chapter. The discussion will include production and price relationships for each species, the growth of price and production during a 23 year period, the methods and types of gear used, as well as fish harvesting effort.

Whitefish (Coregonus clupeaformis)

Michigan whitefish landings have increased tremendously during the period 1960-1982, from a low of 550 thousand pounds in 1960 to a high of 7,148 thousand pounds in 1982, a twelve fold increase. (Table IV-1). The highest annual increase of production was about 70 percent in 1961. In 1980 there was an increase of 51 percent, which was the highest absolute increase during the 23 year period, an increase of 1,729 thousand pounds. During the years 1980, 1981 and 1982, the increases in whitefish production were partly contributed by the Indian (native American) catches of 1,214 thousand; 2,041 thousand; and 2,430 thousand pounds in each year, respectively. Their catch was not included in the annual Michigan fishery production report since it was not categorized under State license fishing. Michigan Department of Natural Resources

Table IV-1. Whitefish Production from Michigan Great Lakes and Its Relationship to U.S. and the Whole Great Lakes Production 1960-1982

Year	Michigan Produc- tion (in 1000 lbs.)	U.S. Produc- tion (in 1000 lbs.)	Whole G.L. (in 1000 lbs.) a)	Michigan Production as a % of US Produc- tion (in %)	Michigan Production as a % of the Whole G.L. Produc- tion (in %)
1960	551	830	4,419	66	12
1961	939	1,299	5,207	72	18
1962	809	1,027	4,667	79	17
1963	712	900	4,257	79	17
1964	1,098	1,423	4,653	77	24
1965	1,393	1,648	4,885	85	29
1966	1,744	1,972	4,784	88	36
1967	1,399	1,634	4,259	85	33
1968	1,548	1,770	4,675	87	33
1969	2,020	2,361	5,317	86	38
1970	1,905	2,375	5,244	80	36
1971	2,985	4,081	6,393	73	47
1972	3,949	4,792	6,992	73	50
1973	3,451	4,828	6,812	71	51
1974	2,961	4,699	7,058	63	42
1975	2,954	4,918	7,367	60	40
1976	3,451	5,828	8,380	59	41
1977	2,916	5,235	8,446	56	34
1978	3,239	5,248	9,010	62	36
1979	3,412	5,116	8,138	67	42
1980	5,141*	7,768*	11,514*	66	45
1981	6,797*	10,468*	14,310*	65	47
1982	7,148*	10,678*	14,600*	67	49

a) U.S. production plus Ontario (Canada) production.

* Includes Indian catches from Michigan jurisdictions for 1980, 1981 and 1982 in the amount: 1214; 2041 and 2430 thousand pounds, respectively.

Sources: Fishery Division, Michigan Dept. of Natural Resources.
National Oceanic and Atmospheric Administration.
Great Lakes Fishery Laboratory, Ann Arbor.
Ministry of Natural Resources, Ontario Province, Canada.
Calculated from data supplied by sources above for Michigan's share of production from US and GL.

issues a separate report for this catch. However, in this study both catches are used for the analysis.

During this period, Michigan's share of U.S. whitefish production varied from a low of 42 percent in 1961 to a high of 88 percent in 1966; with 67 percent in 1982. The share from the whole Great Lakes production also fluctuated from a low of 11 percent in 1961 to a high of 51 percent in 1973, with 49 percent in 1982. On the average, Michigan contributed about 72 percent of U.S. whitefish production and 35 percent of total Great Lakes production. (Table IV-2).

Table IV-2. Average Percentage of Michigan Production Over U.S. and the Whole Great Lakes Production for Several Fish Species 1960-1982.

Species	Percentage of U.S. Production	Percentage of Great Lakes Production
Whitefish	72	35
Chubs	41	32
Yellow Perch	16	4
Catfish	39	31
Alewife	16	16

Data in Table IV-1 shows that Michigan has had a steady increase in whitefish production, especially after 1963. This might have been caused by the decline in sea lamprey, with the whitefish population building up to a stable level after recovering from the biological disruption caused by sea lamprey predation in the 1950's. (Ghanbari, 1977).

Annual current prices of whitefish over the period were stable and not so responsive to the quantity of whitefish landed. Prices per pound varied from a low of 48 cents in 1971 to a high of 86 cents in 1979 and 1980. The price in 1982 was only 8 cents higher than the price in 1960. However, real prices (after deflating by CPI), have been more responsive to the quantity of whitefish landed. That is, the prices have declined about 65 percent, from $1.86 per pound in 1960 to $.65 in 1982. (See Table IV-3). This means that the larger the quantity of whitefish produced, the lower the real price paid by the consumer (in this case by the wholesaler) and the less revenue per pound received by the fisherman (producer). This might be caused by the nature of commercial fishing operations which require a large investment in equipment. Once the investment has been made it is difficult for the fishermen to shift the investment to other sectors or resources. They must, therefore, increase their catch, by increasing fishing effort, to maintain their investment (Everhart and Young, 1981). This is done to offset the decreases in prices.

The trends of annual whitefish landings from the Michigan Great Lakes waters, annual current and real landing prices during 1960-1982 are shown in the Figure IV-1. Annual whitefish landings fluctuated continuously with the sharpest increases from 1979 and 1980 to 1981. Annual real prices did not move in the same direction with production; but moved in an opposite direction and with a downward trend. Annual current prices seemed to be moving almost horizontally. The relationship between real prices and total quantity of whitefish landed can be seen more explicity in Figure IV-2, which shows that when the total quantity of whitefish increases over time, the real prices are declining.

Table IV-3. Annual Current and Real Landing Prices of Lake Whitefish, Chub, Lake Trout, Yellow Perch, Catfish and Alewife per pound in Michigan 1960-1982 (1982 is base year)

Year	Whitefish		Chub		Trout		Yellow Perch		Catfish		Alewive		Consumer Price Index (CPI) (1982=Base Yr.)
	Current	Real	Current	Real	Current	Real	Current	Real	Current	Real	Current	Real	
1960	.57	1.86	.19	.62	.53	1.73	.14	.46	.22	.72	.02	.07	.307
1961	.52	1.67	.17	.55	.58	1.87	.15	.48	.25	.81	.01	.03	.310
1962	.54	1.72	.16	.51	.62	1.98	.11	.35	.26	.83	.01	.03	.313
1963	.52	1.64	.18	.57	.63	1.99	.11	.35	.27	.85	.02	.06	.317
1964	.61	1.90	.17	.56	.67	2.09	.19	.59	.27	.84	.02	.06	.321
1965	.51	1.56	.18	.55	.69	2.11	.19	.58	.29	.89	.02	.06	.327
1966	.50	1.49	.18	.54	.69	2.05	.12	.36	.31	.92	.02	.06	.336
1967	.57	1.65	.17	.49	.61	1.76	.13	.38	.30	.87	.01	.03	.346
1968	.62	1.72	.16	.44	.60	1.67	.14	.39	.27	.85	.01	.03	.360
1969	.60	1.58	.14	.37	.58	1.52	.17	.45	.30	.79	.01	.03	.380
1970	.55	1.37	.17	.42	.53	1.32	.22	.55	.32	.80	.01	.02	.402
1971	.48	1.14	.17	.40	.62	1.48	.28	.67	.31	.74	.01	.02	.420
1972	.51	1.18	.26	.60	.63	1.45	.33	.76	.31	.72	.01	.02	.433
1973	.59	1.28	.43	.93	.66	1.43	.37	.80	.37	.80	.01	.02	.460
1974	.70	1.37	.50	.98	.72	1.41	.39	.76	.36	.70	.02	.04	.511
1975	.68	1.22	.65	1.16	.69	1.24	.44	.79	.41	.73	.01	.02	.558
1976	.71	1.20	.68	1.15	.73	1.24	.53	.90	.41	.69	.01	.02	.590
1977	.73	1.16	.50	.80	.76	1.21	.52	.83	.42	.67	.01	.02	.628
1978	.76	1.13	.57	.85	.76	1.13	.51	.76	.41	.61	.02	.03	.672
1979	.86	1.14	.70	.93	.84	1.12	.70	.93	.40	.53	.02	.03	.752
1980	.86	1.00	.66	.77	.80	.94	.61	.71	.42	.49	.02	.02	.854
1981	.75	.80	.61	.65	.89	.94	.81	.86	.44	.47	.02	.02	.942
1982	.65	.65	.86	.86	1.12	1.12	1.02	1.02	.43	.43	.02	.02	1.000

Sources: Fishery Division, Michigan Dept of Natural Resources, Lansing.
National Oceanic and Atmospheric Administration.
Great Lakes Fishery Laboratory, Ann Arbor.
Ministry of Natural Resources, Ontario Province, Canada.
Real prices are calculated from data supplied by the above sources.

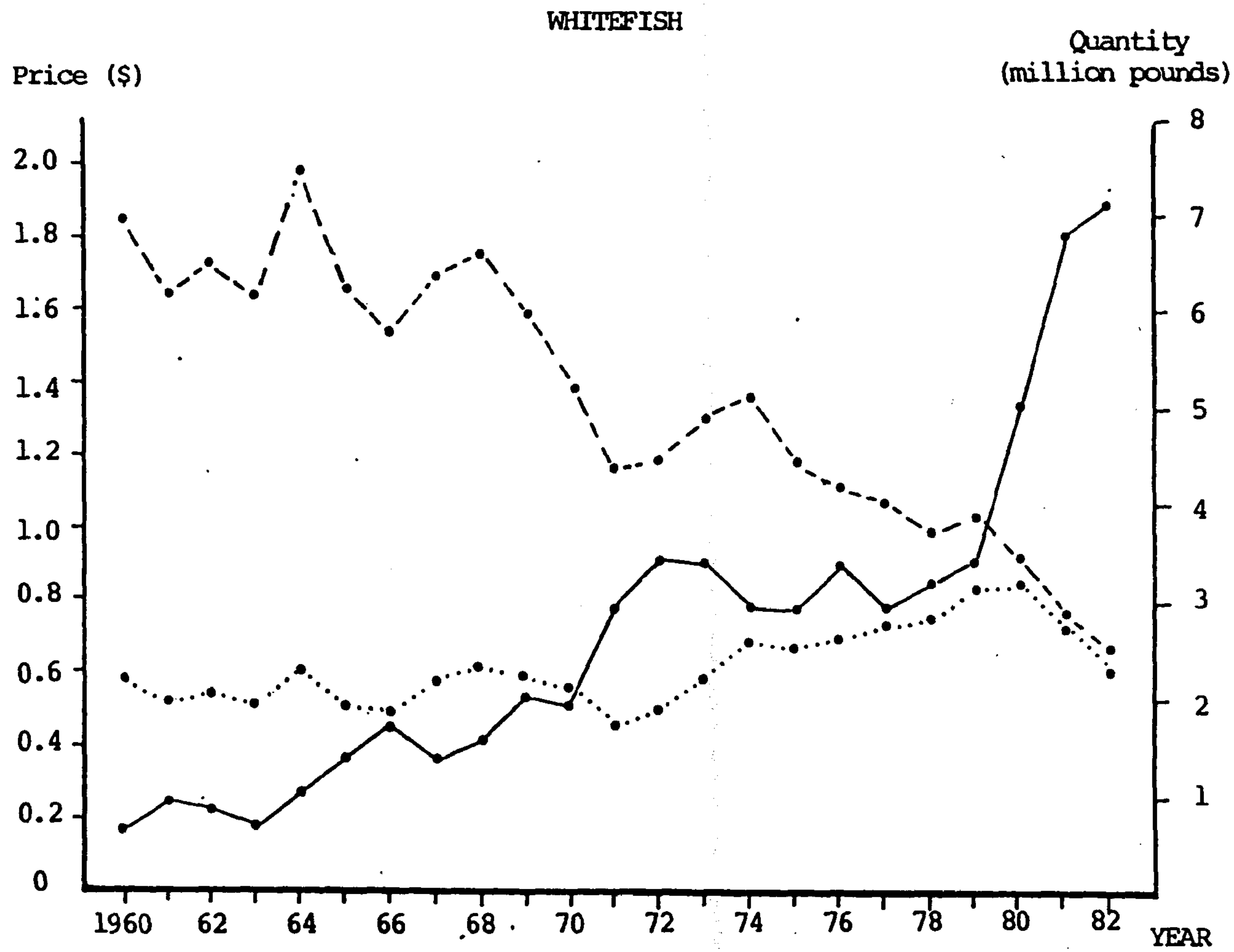


Figure IV-1. Annual Michigan Lake Whitefish Landings, Annual Current Price, and Annual Real Price 1960 - 1982

———— production   .... current price

-------- real price

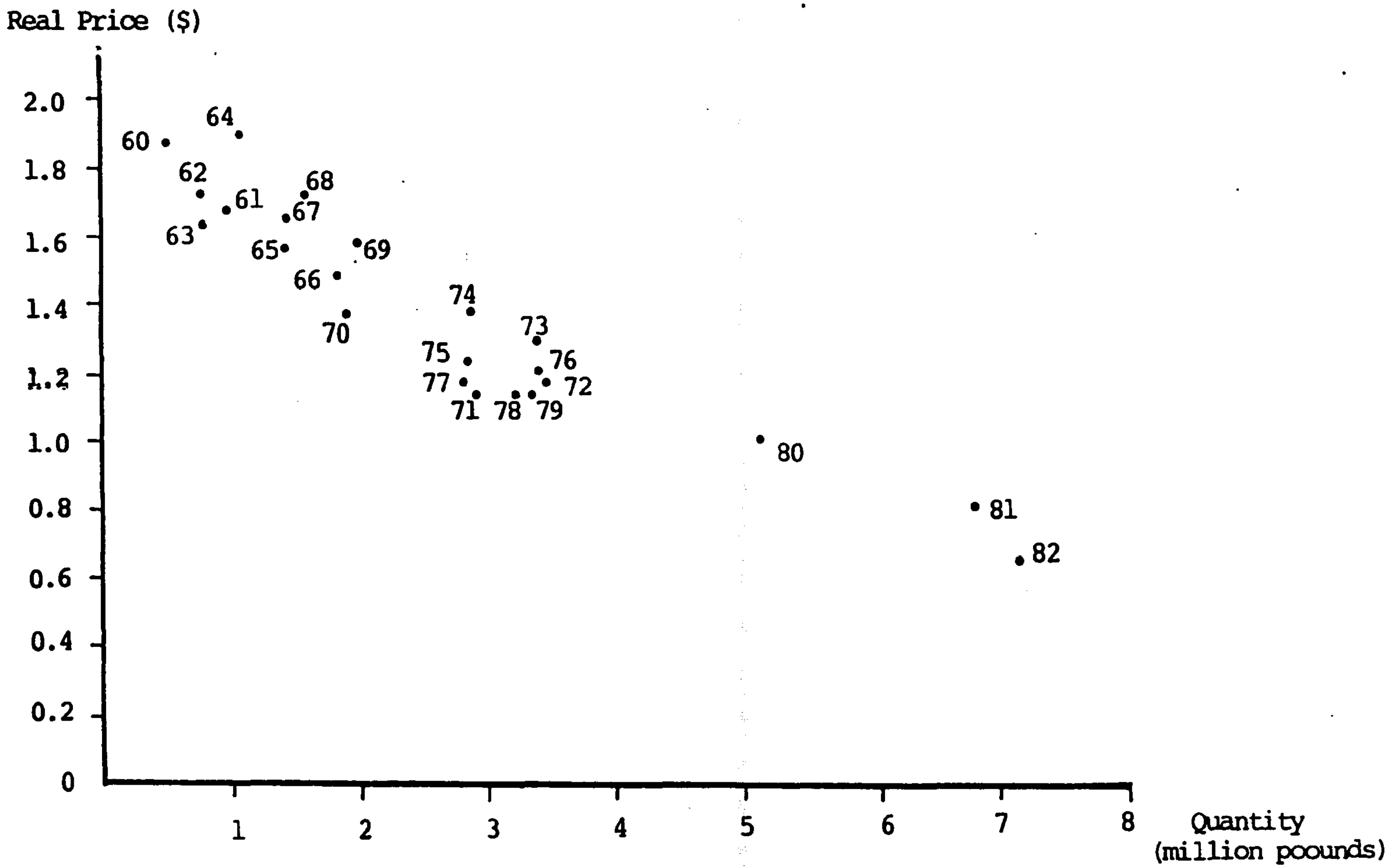


Figure IV-2. Real Price and Quantity of Whitefish Landings in Michigan 1960 - 1982

While the annual growth of whitefish landings during 1960-1982 was 12.4 percent, the real prices have decreased 4.7 percent annually. Although there are no data available, it is recognized that the types of gear used to catch whitefish influences the prices fishermen will receive. Whitefish caught using gill nets for instance have lower values than fish caught using trap nets.[1] This is due to the fact that gill nets tend to injure and kill the fish which results in a lower quality as compared with fish caught by trap nets. This is one of the reasons MDNR banned the use of gill nets and promoted trap nets in commercial fishing on Michigan Great Lakes waters. The main reason for the ban is the accidental or unintentional catch of other fish species, especially lake trout.

Many types of gear are used to catch whitefish. However, in Table IV-4 only the pound net; 2" gill net; 4-6" gill net; small mesh trap; and large mesh trap net are presented as the most common gears used. The number of fish caught by pound nets has been quite stable over the period 1960-1980 except during the late 1960's and early 1970's when the number of whitefish caught increased slightly. The record annual harvest was 415 thousand pounds in 1973. Two inch gill nets were not used as much as the 4-6" gill nets which were dominant in the 1960's and early 1970's.

After the MDNR banned the use of gill nets in 1974, the amount of fish caught by 4-6" gill nets decreased drastically, from the high of 2,000 thousand pounds in 1973 to only about 21 thousand pounds in 1982.

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[1]Personal communication with Fishery Division, Michigan Department of Natural Resources.

These data did not, however, include any fishing effort conducted by Indian fishermen.

With the absence of gill nets, most fishermen shifted to large mesh trap nets. This resulted in a significant increase in the amount of fish caught. In 1960 about 269 thousand pounds were caught and that number increased to over 4,500 thousand pounds in 1982. Small mesh trap nets on the other hand did not increase in use, and the amount of fish caught decreased to about 28 thousand pounds of fish caught in 1982.

During 1970, large mesh trap nets were not used, as shown in Table IV-4. This is because in 1970 there were changes in the definition of the types of gear used; deep trap nets were changed to large mesh trap nets, and shallow trap nets were changed to small mesh trap nets. At the same time, the fishermen were not allowed to fish deeper than 90 feet, therefore all fishing efforts using deep trap nets were categorized under shallow trap nets. When these definition changes took place, unfortunately, there was no catch using deep trap nets listed under large mesh trap nets; all catches were listed under small mesh trap nets. Therefore, the effort from small mesh trap net in 1970 was used to compute CPE (Catch Per-unit Effort) for the large mesh trap net.

Chubs (Coregonus hoyi)

Michigan chub landings, unlike whitefish, decreased drastically during the period 1960 to 1982, from a high of 6,812 thousand pounds in 1960 to a low of 811 thousand pounds in 1982, a decline of more than 85 percent. Michigan chub landings were only about 196 thousand pounds in

Table IV-4. Catch and Effort for Different Types of Gear, and Catch per Unit of Effort (CPE) for Standard Gear for Lake Whitefish in Michigan Great Lakes Water 1960-1982

	Pound Net		2" Gill Net		4-6" Gill Net		Small Mesh Trap		Large Mesh Trap		CPE for Large
Year	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Mesh Trap
1960	38,584	1,109	2582	0	163,031	15,982	61,308	1,766	269,389	2030	132.70
1961	69,193	1,422	1868	0	370,046	30,978	125,358	2,142	371,190	2909	127.60
1962	84,860	1,363	714	3	278,850	21,373	167,855	2,469	239,686	2110	113.60
1963	142,502	1,537	180	0	299,536	18,319	159,831	2,618	72,094	1314	54.87
1964	175,011	1,939	274	4	540,565	36,707	214,708	2,652	104,805	1050	99.81
1965	244,997	1,773	619	47	708,510	45,941	314,888	2,922	121,616	1555	78.21
1966	308,548	2,267	2924	52	1,012,321	50,688	114,607	1,748	304,460	1913	159.15
1967	117,319	1,390	666	93	812,294	43,141	104,475	1,320	353,091	2342	150.76
1968	114,765	1,821	425	52	943,092	50,341	107,064	1,637	381,912	2856	133.72
1969	186,291	1,727	2985	234	1,197,560	51,964	545,599	4,131	83,841	542	154.69
1970	226,944	1,964	1152	133	935,178	40,209	739,043	4,673	0	0	158.15
1971	296,339	1,754	121	10	1,668,946	46,708	612,795	2,932	403,197	1954	206.34
1972	408,969	1,489	64	15.6	1,799,482	44,716	18,469	99	1,265,491	4716	268.34
1973	415,272	1,902	2877	112.8	2,065,227	47,241	46,900	277	919,268	4387	209.54
1974	414,538	1,425	8596	256.3	1,307,388	38,440	2,547	99	1,226,197	5632	217.72
1975	272,962	1,333	8060	126.4	976,477	28,910	10,734	314	1,680,545	6961	241.42
1976	212,063	872	70	98.7	887,101	26,102	27,155	248	2,315,862	9014	256.92
1977	60,140	354	5725	230.1	568,663	14,835	17,786	471	2,290,777	9816	223.18
1978	86,553	505	159	56.6	522,264	15,025	13,748	586	2,474,553	10317	239.85
1979	55,264	397	16	2.6	515,719	15,251	16,741	554	2,686,741	11537	232.88
1980	18,439	197	397	49	468,031	11,064	33,442	693	3,258,785	13299	245.04
1981	23,671	196	1411	80	118,811	2,106	29,066	879	4,423,154	14814	298.58
1982	28,993	115	10	2.4	21,099	252	28,013	743	4,511,606	15562	289.91

Sources: Calculated from raw data supplied by Fishery Division, Michigan Dept. of Natural Resources for 1960-1970.
Fishery Division, Michigan Dept. of Natural Resources for 1971-1982 data.

1982, excluding the Indian catch (as much as 614.8 thousand pounds) for this year.

The downturn of chub production might have been caused by the combination of overfishing and competition with a new species, alewife. Overfishing of chubs was due to the fishermen shifting their effort from the declining lake trout and whitefish, which had been aflicted by the sea lamprey, to the deep water ciscoes. Additionally, the use of the otter trawl which captured large numbers of young chubs in the late 1950's and early 1960's further aggravated the decrease in the chub population stocks (Johnson, 1981). As a result of this decrease in 1976 all of the Lake Michigan chub fisheries were closed except for small assessment fisheries in the respective states. This policy was imposed to enable the chub population stock to renew and grow to its former level.

While Michigan chub production declined from the 1960's, its production still made up a large portion of U.S. as well as Great Lakes production, which indicated that this decline was not confined only to the Michigan production, as can be seen in Table IV-5. In spite of this decrease in production, Michigan's share of the chub production was the highest during the period 1975 to 1978 with an average share of about 54 percent of the U.S. chub production over this time. Michigan's share of production dropped to its lowest level, 19 percent in 1982. This decline was caused by the MDNR's slower reopening of the chub fishery for commercial fishing than Wisconsin's, partly because of pesticide contaminations found in Michigan chubs. Michigan's share of the whole Great Lakes production also varied from a high of 42 percent in 1970 to a low of 17 percent in 1982. Over the period of 1960-1982, Michigan

Table IV-5. Chub Production from Michigan Great Lakes and Its Relationship to U.S. and the Whole Great Lakes Production 1960-1982

Year	Michigan Produc-tion (in 1000 lbs.)	U.S. Produc-tion (in 1000 lbs.)	Whole G.L. (in 1000 lbs.) a)	Michigan Production as a % of US Produc-tion (in %)	Michigan Production as a % of the Whole G.L. Produc-tion (in %)
1960	6,812	16,854	18,876	40	36
1961	6,494	16,516	19,508	39	33
1962	6,331	14,428	17,253	44	37
1963	4,891	11,023	13,352	44	37
1964	3,010	7,218	9,253	42	33
1965	5,296	10,920	12,812	49	41
1966	3,903	9,992	11,257	39	35
1967	4,793	11,313	12,478	42	38
1968	3,719	11,126	11,807	33	31
1969	3,439	10,157	10,617	34	32
1970	4,674	10,977	11,259	43	42
1971	3,200	8,879	9,681	36	33
1972	3,501	7,848	8,567	45	41
1973	3,088	6,963	7,907	44	39
1974	2,428	5,685	6,734	43	36
1975	1,539	2,824	4,140	54	37
1976	1,071	1,939	3,551	55	30
1977	844	1,582	2,920	53	29
1978	814	1,474	2,714	55	30
1979	805	2,378	3,488	34	23
1980	773*	2,634*	3,516*	29	22
1981	797*	3,603*	4,469*	22	18
1982	811*	4,153*	4,838*	19	17

a) US production plus Ontario (Canada) production.

* Includes Indian catches from Michigan jurisdictions for 1980, 1981 and 1982 in the amount: 110.1; 504.1 and 614.8 thousand pounds, respectively.

Sources: Fishery Division, Michigan Dept. of Natural Resources.
National Oceanic and Atmospheric Administration.
Great Lakes Fishery Laboratory, Ann Arbor.
Ministry of Natural Resources, Ontario Province, Canada.
Calculated from data supplied by sources above for Michigan's share of production from US and GL.

harvested an average of 41 percent of the U.S. chub production and 32 percent of total Great Lakes production, as shown in Table IV-2.

The current annual price of chubs were considerably responsive to the quantity of chubs landed. The price per pound has increased from 19 cents in 1960 to 86 cents in 1982, an increase about 350 percent. This indicates that the current price of chubs rises when the quantity produced has declined over a period. However, during the period 1960 to 1971, the current price declined slightly from 19 cents in 1960 to 17 cents in 1971. After 1971, the current prices began to increase sharply, until 1982. In terms of real prices, chubs were less responsive to the quantity landed especially during the period 1960 to 1971 where real prices decreased from 62 cents in 1960 to 40 cents in 1971. In 1972, the price increased to 60 cents and continued to increase to the high of $1.16 in 1975. During the 1972-1982 period, real prices were obviously more responsive to the quantity of chubs produced. The chub production over the twenty year period has decreased by 9.2 percent annually while the current and real prices have increased by 7.1 and 1.5 percent, respectively. The trend of the annual Michigan chub landings, annual current, and real prices are presented in Figure IV-3. The annual chub production seems to fluctuate with a downward trend and levels off after 1976. The annual real prices also moved downward before turning upward after 1971. Annual current prices also moved upward after 1971. The relationship between annual real prices and total production of chubs is presented in Figure IV-4.

There are several types of gear used to harvest chubs in Michigan's Great Lakes waters such as seine net, otter trawl, 2" gill net, 3" gill net, 4-6" gill net, and large mesh trap net. In this study, only two

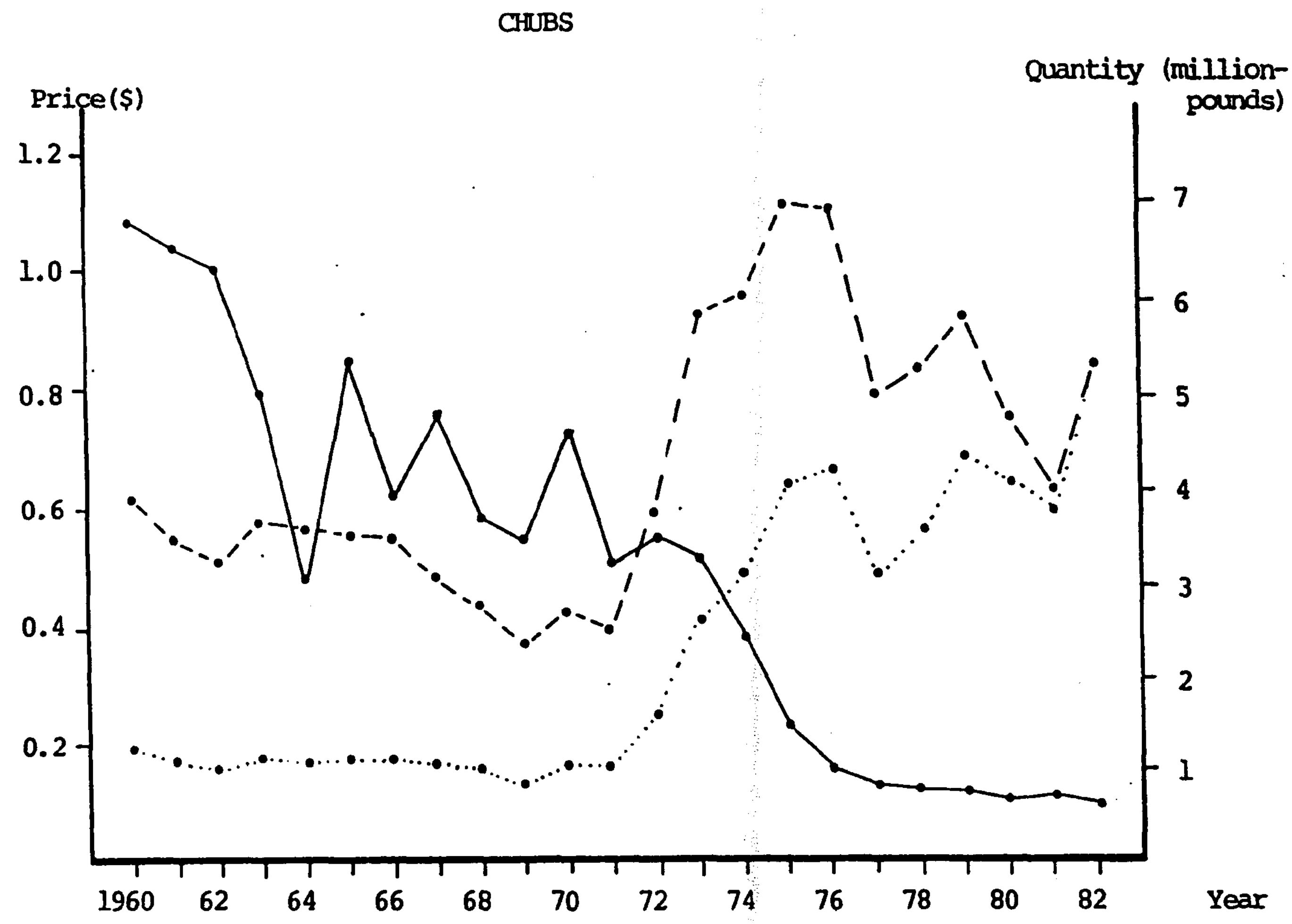

Figure IV-3. Annual Michigan Chub Landings, Annual Current Prices , and Annual Real Prices 1960 - 1982 (in 1982 dollars)

——— production
– – – – real price
.... current price

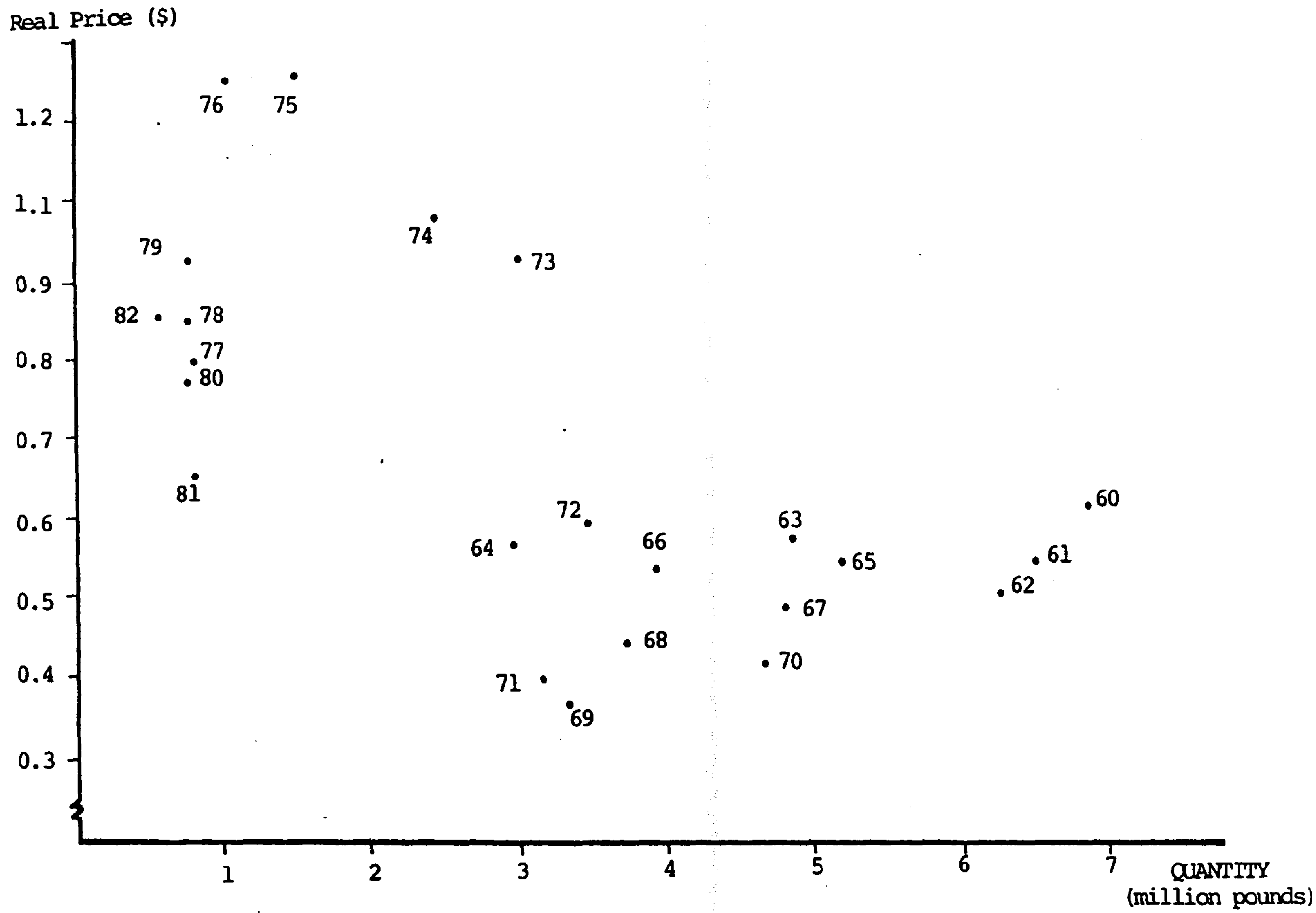

Figure IV-4. Real Price and Quantity of Chub Landings in Michigan 1960-1982 main types of gear are presented, the 2" gill net and 4-6" gill net, as shown in Table IV-6.

Chubs were caught from Lake Michigan, Lake Huron, and Lake Superior. Lake Michigan chubs are considered superior in quality to those from other lakes and therefore receive a premium price (Johnson, 1981).

Chubs used for human consumption are usually smoked and sold in two grades: Grade one smoked chubs have a count of 300 or less chubs per 100 pounds; grade two smoked chubs which are smaller fish have a count of more than 300 per 100 pounds.

Yellow Perch (*Perca flavescens*)

The yellow perch harvest from Michigan's Great Lakes waters is facing similar problem. Production has decreased drastically from about 2,000 thousand pounds in 1960 to a low of 197 thousand pounds in 1982, a decrease of about 90 percent, as shown in Table IV-7. This downturn is not confined to Michigan catch, but also relates to overall U.S. production which decreased from a high of 12,000 thousand pounds in 1962 to a low of 2,300 thousand pounds in 1982, a decrease of about 78 percent from the 1960 harvest. Average annual production in Michigan during the 1960's was about 1,800 thousand pounds. Production decreased rapidly in the 1970's to an average of about 300 thousand pounds annually. This decrease was detected in the late 1960's as perch stocks showed signs of stress and deterioration (Hartman, et al., 1980). More immature perch were caught in the mid-1970's than in the 1960's, and the average total length of perch in the catches also decreased from over 8

Table IV-6. Catch and Effort for Different Types of Gear, and Catch per Unit of Effort (CPE) for Standard Gear for Chubs in Michigan Great Lakes Water 1960-1982

Year	2" Gill Net		4-6" Gill Net		CPE for 2" Gill Net
	Catch	Effort	Catch	Effort	
1960	5,423,554	136,800	1,600	-	39.65
1961	5,664,277	123,751	703	-	45.77
1962	5,309,753	123,889	123	-	42.86
1963	4,361,492	110,991	-	9	39.30
1964	2,626,400	55,843	42	-	47.03
1965	5,045,943	92,703	208	16	54.43
1966	3,711,613	64,134	3,149	85	57.87
1967	4,671,077	66,460	722	278	70.28
1968	3,702,977	42,705	496	166	86.71
1969	3,388,815	26,647	1,435	294	127.17
1970	4,601,509	35,900	2,156	193	128.20
1971	3,173,457	31,843	25,796	451	99.66
1972	3,499,076	42,591	568	12	82.16
1973	3,059,825	45,228	5,954	183	67.65
1974	2,410,354	38,097	5,202	536	63.27
1975	1,530,117	25,304	9,238	63	60.47
1976	1,071,459	17,749	0	0	60.37
1977	843,738	12,155	0	0	69.41
1978	813,849	12,554	1	3	64.83
1979	804,862	11,939	0	0	67.41
1980	663,092	9,961	0	0	66.57
1981	293,128	5,028	0	0	58.30
1982	196,178	3,027	2	3	64.81

Sources: Calculated from raw data supplied by Fishery Division, Michigan Dept. of Natural Resources for 1960-1970
Fishery Division, MDNR for 1971-1982

Table IV-7. Yellow Perch Production from Michigan Great Lakes and Its Relationship to U.S. and the Whole Great Lakes Production 1960-1982

Year	Michigan Produc- tion (in 1000 lbs.)	U.S. Produc- tion (in 1000 lbs.)	Whole G.L. (in 1000 lbs.) a)	Michigan Production as a % of US Produc- tion (in %)	Michigan Production as a % of the Whole G.L. Produc- tion (in %)
1960	1,922	10,238	22,539	19	8
1961	2,234	9,351	27,959	24	8
1962	1,505	12,024	33,663	13	4
1963	1,672	11,275	29,946	15	6
1964	3,256	8,303	17,666	39	18
1965	1,820	5,499	24,964	33	7
1966	1,850	6,164	27,316	30	7
1967	1,703	5,805	28,536	29	6
1968	1,238	5,303	30,271	23	4
1969	1,164	4,926	35,433	24	3
1970	588	4,283	25,603	14	2
1971	594	3,995	19,272	15	3
1972	346	3,338	20,174	10	2
1973	320	3,002	22,077	11	1
1974	232	3,957	17,369	6	1
1975	271	3,040	12,489	9	2
1976	323	3,125	9,244	10	3
1977	260	4,151	13,856	6	2
1978	169	3,470	13,482	5	1
1979	168	4,460	17,628	4	1
1980	249*	4,252*	17,918*	6	1
1981	247*	3,680*	14,008*	7	2
1982	197*	2,251*	13,123*	9	2

a) US production plus Ontario (Canada) production.

* Includes Indian catches from Michigan jurisdictions for 1980, 1981 and 1982 in the amount: 54.1; 61.6 and 41.6 thousand pounds, respectively.

Sources: Fishery Division, Michigan Dept. of Natural Resources.
National Oceanic and Atmospheric Administration.
Great Lakes Fishery Laboratory, Ann Arbor.
Ministry of Natural Resources, Ontario Province, Canada.
Calculated from data supplied by sources above for Michigan's share of production from US and GL.

inches in the 1960's to less than 8 inches in the 1970's. Michigan's share of U.S. perch production also declined from about 25 percent annually in the 1960's to about 9 percent in the 1970's. Concern over the deterioration of yellow perch stock prompted state agencies sharing the management of yellow perch on Lake Erie to establish a Yellow Perch Technical Committee in 1975 under the auspices of the Great Lakes Fishery Commission. The committee, which was directed to develop an interim management strategy to protect perch in western Lake Erie, recommended increasing the minimum size limit (MSL) from 8.0 inches to 8.5 inches. This change was expected to protect and restore the yellow perch population to former levels of abundance with greater stability. Even though this recommendation was accepted, it was not imposed by most of the states, and the condition of the yellow perch has not improved. On the other hand, in Michigan waters such as Lake Erie, Lake Huron, and Lake Michigan; perch fishing was restricted to favor sport fishing rather than to protect and restore perch stocks as recommended by the committee.

Both the annual current and the real prices of yellow perch over the period were apparently responsive to the quantity of perch landed, although during the 1960's the prices were relatively stable, as shown in Table IV-3. Annual current prices have increased from 14 cents per pound in 1960 to $1.02 in 1982, an increase of more than 600 percent. Annual real prices also have increased about 120 percent, from 46 cents in 1960 to $1.02 in 1982, which indicates that the decline in quantity of yellow perch available has contributed to an increase in price.

Annual yellow perch harvest fluctuated considerably between 1960 and 1966 when the level of harvest reached its peak in 1964, and after

1966 began to decline sharply until 1970, as shown in Figure IV-5. From 1972 to 1982 perch production seemed to be leveling off below a half million pounds annually. Both annual current and real prices moved upward, almost parallel with each other. Over the period 1960 to 1982, the level of perch production decreased about 9.8 percent annually. At the same time the current and real prices of perch had an annual growth of 9.5 and 3.7 percent, respectively. The relationship between real price and quantity of yellow perch is presented in Figure IV-6.

Most of Michigan's yellow perch were caught from Lakes Michigan, Huron, Superior, and Erie. The main gear used to harvest yellow perch from Michigan Great Lakes waters is presented in Table IV-8. There are several other types of gear such as pound net, set hooks, and 4-6" gill net which were also used in the fishing effort. Among the three types of gear shown in Table IV-8, the small mesh trap net is the most dominant gear in use. Two inch gill net had been used heavily during the 1960's which accounted for about 50 percent of the total catch during that time. After 1972, however, almost all catches were made using small mesh trap nets.

Catfish (Ictalurus punctatus)

The production of catfish in Michigan waters over the 23 year period has increased from 370 thousand pounds in 1960 to 692 thousand pounds in 1982, an increase of about 87 percent. Despite a considerable fluctuations in annual catfish landings, especially during the 1960's where production was declining, production began to increase steadily in the mid 1970's until 1982.

YELLOW PERCH

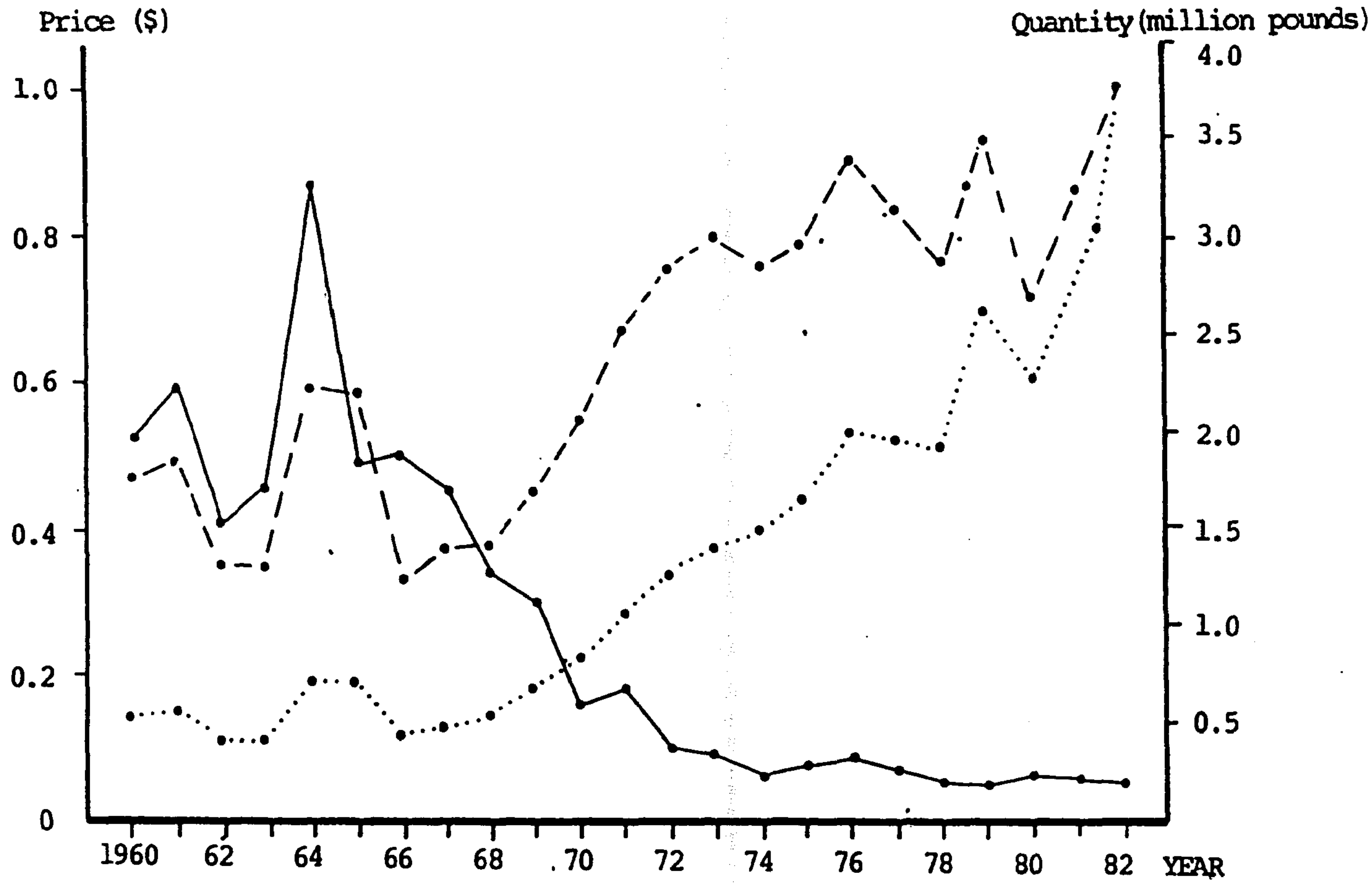

Figure IV-5. Annual Michigan Perch Landings, Annual Current Price, and Annual Real Price 1960 - 1982

——— production .... current price

------- real price

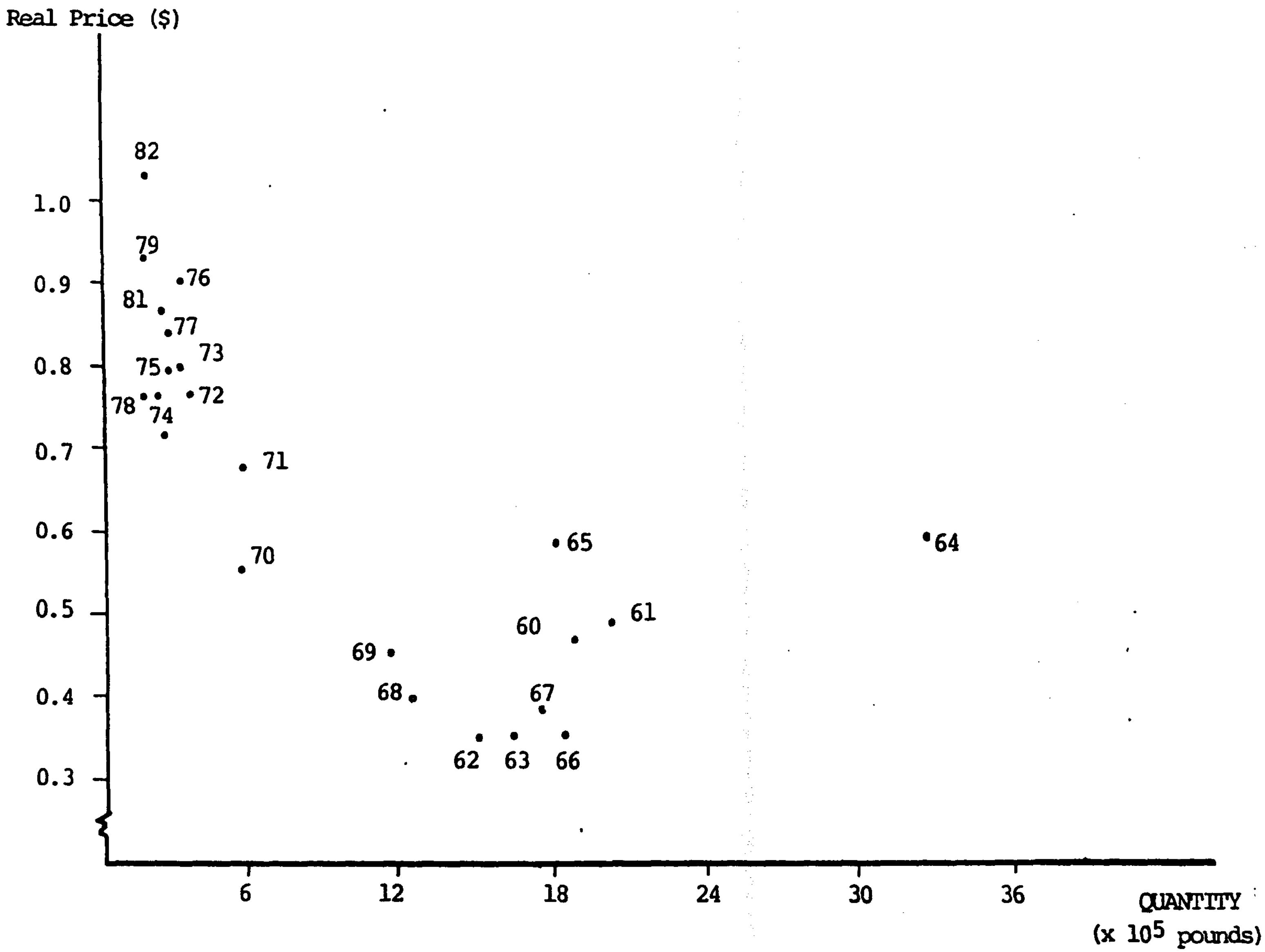

Figure IV-6. Real Price and Quantity of Yellow Perch Landings in Michigan 1960 - 1982

Table IV-8. Catch and Effort for Different Types of Gear, and Catch per Unit of Effort (CPE) for Standard Gear for Yellow Perch in Michigan Great Lakes Water 1960-1982

	2" Gill Net		Sm. Mesh Trap		Lg. Mesh Trap		CPE for
Year	Catch	Effort	Catch	Effort	Catch	Effort	Sm. Mesh Trap
1960	1325177	25436	377411	17165	80	25	21.99
1961	1446112	35434	369428	6889	300	35	53.63
1962	879678	17780	274467	13545	91	45	20.26
1963	1090759	19566	298574	12655	0	0	23.59
1964	1281326	33076	291086	12305	143	4	23.66
1965	753030	18362	419427	11311	10322	288	37.08
1966	632674	9068	883119	10834	0	0	81.51
1967	590682	8614	732485	8909	0	0	82.22
1968	481841	7127	603102	7621	5	12	79.14
1969	459942	7391	477845	7583	1802	62	63.02
1970	261839	2559	318338	5427	0	0	58.66
1971	404228	3596	184978	5760	40	24	32.11
1972	20406	259	321456	6460	148	90	49.76
1973	1	11	313499	7343	141	45	42.69
1974	0	0	229607	6502	3	4	35.31
1975	0	0	268911	7638	2	4	35.21
1976	15	0	321925	7201	0	0	44.71
1977	0	0	259112	6546	50	1	39.58
1978	0	0	168609	5731	71	3	29.42
1979	0	0	167673	5144	90	20	32.60
1980	0	0	193840	4895	0	0	39.60
1981	0	0	182337	5428	75	4	33.59
1982	0	0	150877	5669	0	0	26.61

Sources: Calculated from raw data supplied by Fishery Division Michigan Dept. of Natural Resources for 1960-1970.
Fishery Division, Michigan Department of Natural Resources for 1970-1982.

On the average, Michigan catfish production has made up about 39 percent of U.S. production during the period 1960 to 1982, which varied from a low of 14 percent in 1968 to a high of 75 percent in 1982 (shown in Tables IV-2 and IV-9). It also constituted an average of about 31 percent of the whole Great Lakes production, varying from a low of 11 percent in 1968, to a high of 61 percent in 1982. From these data, it seems that catfish production in Michigan has increased its share with respect to U.S. as well as Great Lakes catfish production, especially from 1973 to 1982 where Michigan catfish production dominated both U.S. and Great Lakes catfish production.

The annual current price of Michigan catfish has increased steadily from 22 cents per pound in 1960 to 43 cents in 1982, an increase of about 95 percent over the period (as presented in Table IV-3). This indicates that as the quantity of catfish landings increased, the current prices of catfish also increased. This suggests that annual current prices did not respond to the quantity of catfish harvested. However, real prices seem responsive to the quantity of catfish landed. Annual real prices decreased from 72 cents per pound in 1960 to 43 cents in 1982, a decrease of about 40 percent. The highest real price of 92 cents occurred in 1966. The annual growth rate of catfish production during 1960-1982 was about 2.9 percent while the current prices increased by 3.1 percent per year. On the other hand, the real prices decreased by 2.3 percent annually. The trend of annual current and real prices, as well as production are presented in Figure IV-7. The figure shows that even though annual production fluctuates considerably, the annual current prices seem more stable and increase modestly. Annual real prices fluctuate slightly and move in response to the level of

Table IV-9. Catfish Production from Michigan Great Lakes and Its Relationship to U.S. and the Whole Great Lakes Production 1960-1982

Year	Michigan Production (in 1000 lbs.)	U.S. Production (in 1000 lbs.)	Whole G.L. (in 1000 lbs.) a)	Michigan Production as a % of US Production (in %)	Michigan Production as a % of the Whole G.L. Production (in %)
1960	370	1,901	2,224	19	17
1961	325	1,869	2,113	17	15
1962	228	1,305	1,619	18	14
1963	213	1,266	1,566	17	14
1964	201	1,318	1,605	18	13
1965	196	1,137	1,380	17	14
1966	198	910	1,183	22	17
1967	161	788	1,038	20	15
1968	123	873	1,129	14	11
1969	143	860	1,080	17	13
1970	227	756	860	30	26
1971	339	973	1,129	35	30
1972	265	940	1,096	28	24
1973	336	583	763	58	44
1974	281	587	774	49	36
1975	297	560	825	53	36
1976	416	644	780	65	53
1977	456	715	859	64	53
1978	458	665	857	69	53
1979	484	729	943	66	50
1980	515	772	961	67	54
1981	561	939	1,196	60	47
1982	692	920	1,132	75	61

a) US production plus Ontario (Canada) production.

Sources: Fishery Division, Michigan Dept. of Natural Resources.
National Oceanic and Atmospheric Administration.
Great Lakes Fishery Laboratory, Ann Arbor.
Ministry of Natural Resources, Ontario Province, Canada.
Calculated from data supplied by sources above for Michigan's share of production from US and GL.

CATFISH

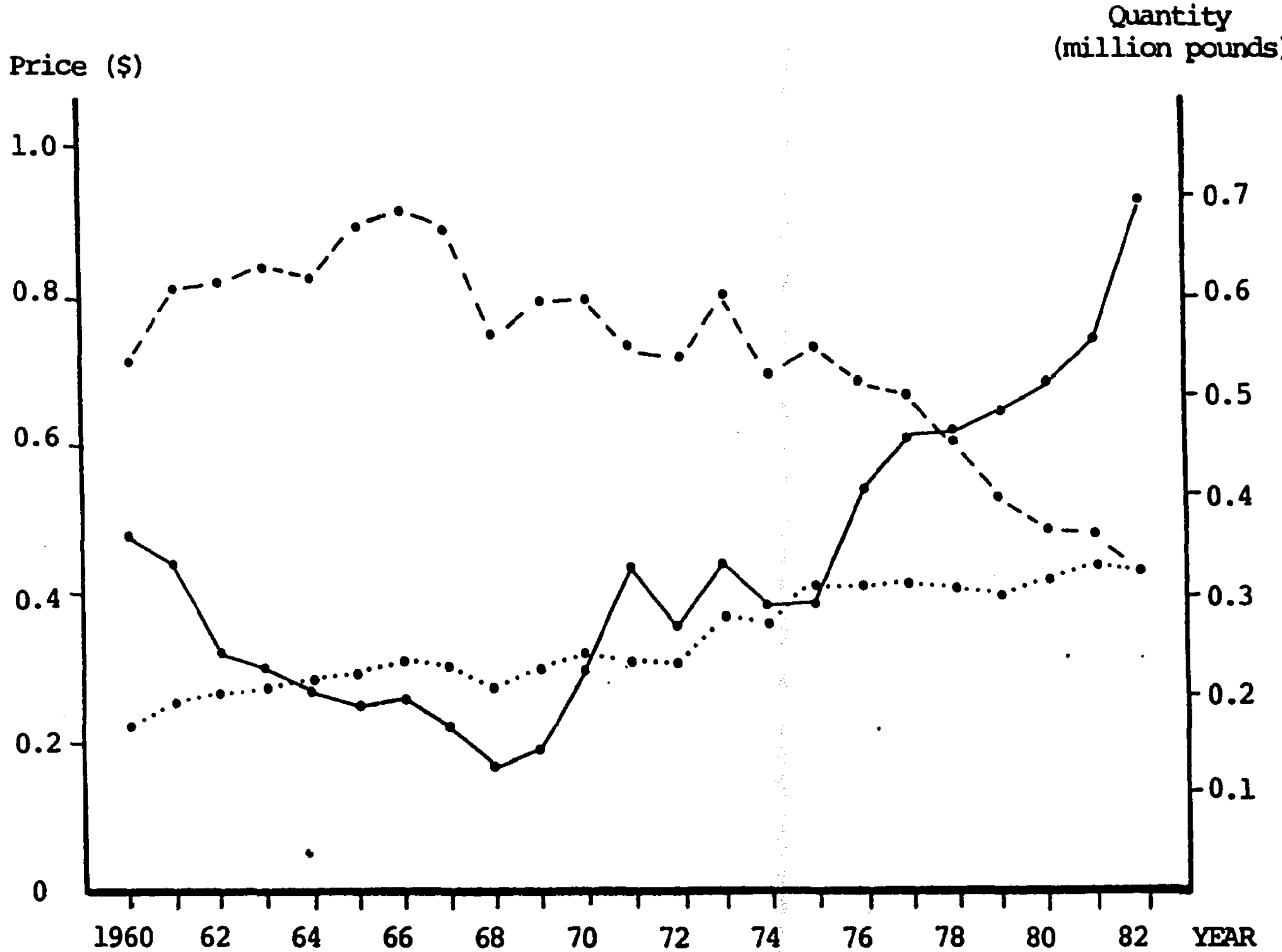

Figure IV-7. Annual Michigan Catfish Landings, Annual Current Price, and Annual Real Price 1960 - 1982 catfish production. Figure IV-8 is also presented to show the relationship between real prices and the quantity of catfish landings in Michigan.

Pound net, fyke, hoop net, seine, set hooks, 2" gill net, 7-9" gill net, small mesh trap, and large mesh trap are among the gear used to harvest catfish from Michigan waters. However, only the main gear such as set hooks, seine, small mesh trap, and large mesh trap are presented in Table IV-10. The quantity of catfish harvested using set hooks has been quite stable over the period, and varied from 172 thousand pounds in 1960 to 184 thousand pounds in 1982. During the mid-1960's however, the quantity of catfish caught using this gear began to decline to a low of 63 thousand pounds in 1970. After this decline the amount of catfish harvested started to increase gradually. The quantity of catfish harvested using seine net fluctuated somewhat, from about 82 thousand pounds in 1960 to 60 thousand pounds in 1982. Among the types of gear shown in Table IV-10, the small mesh trap net is the most dominant gear used in harvesting catfish. The quantity of catfish caught with this gear has increased significantly from about 103 thousand pounds in 1960 to 429 thousand pounds in 1982, an increase of more than three fold over the period. The share of catfish harvested with a small mesh trap net has increased from 28 percent of the total harvest in 1960 to 62 percent in 1982.

<u>Alewives (Alosa pseudoharengus)</u>

The quantity of alewife landings from Michigan's Great Lakes waters has fluctuated considerably from 1960 to 1982. The production has

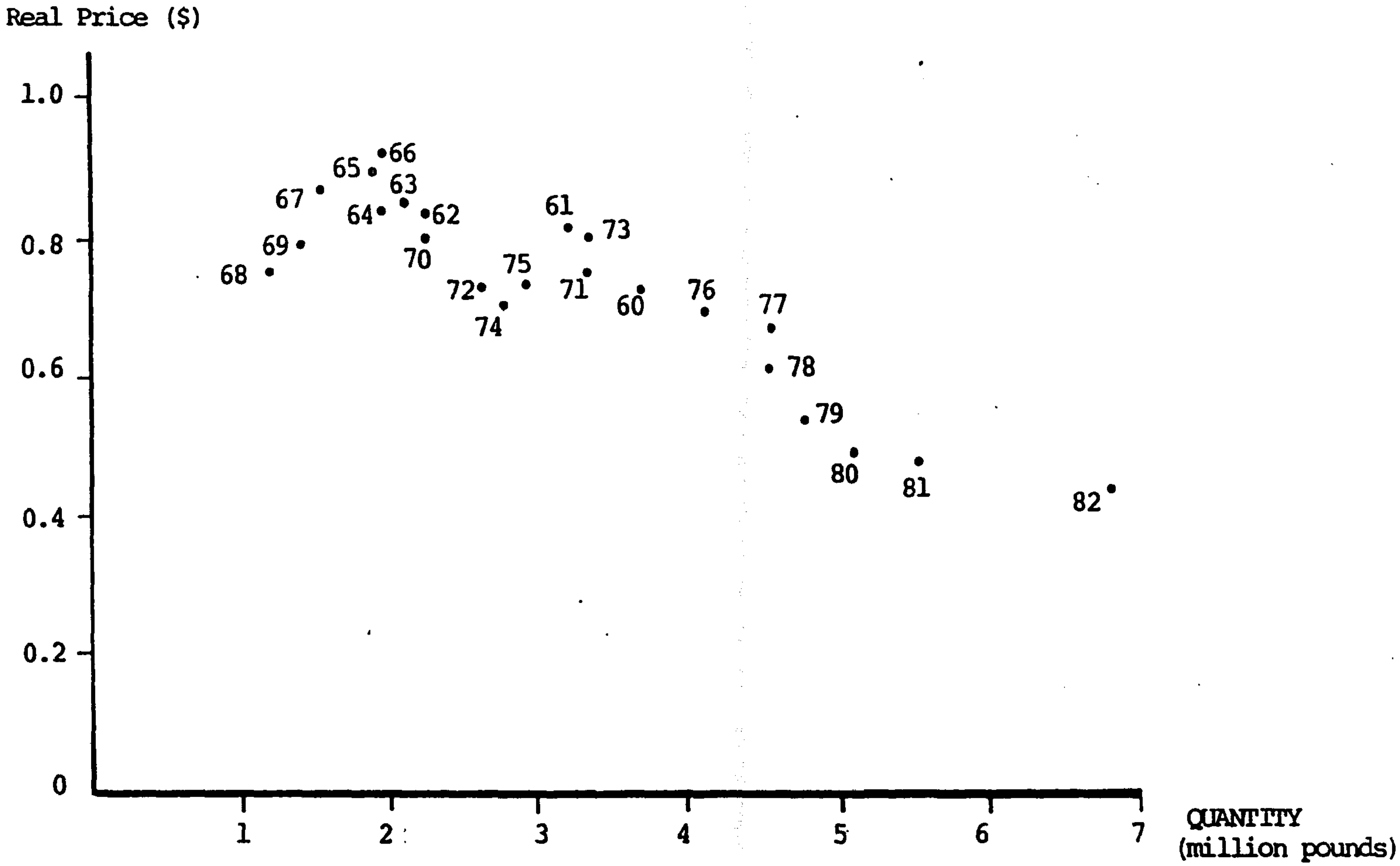

Figure IV-8. Real Price and Quantity of Catfish Landings in Michigan 1960 - 1982

Table IV-10. Catch and Effort for Different Types of Gear, and Catch per Unit of Effort (CPE) for Standard Gear for Catfish on Michigan Great Lakes Water 1960-1982

Year	Set Hooks Catch	Set Hooks Effort	Seine Catch	Seine Effort	Sm. Mesh Trap Catch	Sm. Mesh Trap Effort	Lg. Mesh Trap Catch	Lg. Mesh Trap Effort	CPE for Sm. Mesh Trap
1960	172,182	2,154	81,707	719	103,524	8,692	2	7	11.91
1961	172,243	2,374	78,531	620	66,925	9,298	41	10	7.20
1962	104,732	2,073	54,247	572	65,351	7,717	63	6	8.47
1963	104,397	1,776	35,269	367	69,410	7,636	0	0	9.09
1964	80,189	1,429	26,287	213	89,123	7,044	0	0	12.65
1965	63,537	1,233	34,194	285	93,630	7,787	0	0	12.02
1966	63,276	1,069	26,533	193	104,299	6,769	0	0	15.41
1967	61,577	887	17,084	198	75,297	5,497	0	0	13.70
1968	47,982	674	12,698	176	62,073	4,517	0	0	13.74
1969	60,589	927	9,704	107	65,173	4,162	61	12	15.66
1970	63,861	879	7,565	100	152,952	3,478	0	0	43.98
1971	77,539	808	56,451	407	202,780	4,299	265	32	47.17
1972	71,209	570	67,115	471	112,435	4,166	18	18	26.99
1973	90,013	780	80,250	480	164,562	5,334	339	50	30.85
1974	96,219	634	45,173	281	137,780	4,958	81	8	27.79
1975	94,569	564	71,106	307	130,899	5,395	39	12	24.26
1976	112,643	677	105,178	360	197,757	5,328	7	6	37.12
1977	157,002	887	119,455	407	178,338	5,265	2	11	33.87
1978	149,454	776	101,010	354	205,552	4,905	1204	98	41.91
1979	133,106	723	89,984	337	260,061	4,409	713	100	58.98
1980	150,412	955	80,515	320	278,194	3,764	988	108	73.91
1981	139,952	794	95,023	307	310,998	4,806	2313	231	64.71
1982	183,995	916	59,651	293	429,395	5,059	2847	474	84.88

Source: Calculated from raw data supplied by Fishery Division, Michigan Dept. of Natural Resources for 1960-1970
Fishery Division, Michigan Department of Natural Resources for 1971-1982

increased from about 1,690 thousand pounds in 1960 to a peak level of 13,370 thousand pounds in 1967, an increase approximately seven times that of 1960's production. After 1967, the production began to drop continuously to its lowest level of 605 thousand pounds in 1980, a decrease of 95 percent from 1967 landings. Production was at 1,694 thousand pounds in 1982 as can be seen in Table IV-11. Michigan's share of U.S. alewife landings also decreased significantly, from a high of 71 percent in 1960 to a low of 4 percent in 1980, with 8 percent in 1982. The averaged share over the 23 year period was about 16 percent (Table IV-2). The decline of Michigan alewives harvested after 1967 might have been contributed to by the massive die off of alewives in Lake Michigan in 1967 which probably was caused by saprolegnia infection and hemorrhaging (Brown, 1968). Due to contamination, most of the alewives harvested which were primarily for animal consumption, were unmarketable. This, in effect, has further aggravated the decline of Michigan alewife landings.[1]

Since alewives are not harvested in Canadian Great Lakes waters, all alewife landings from the Great Lakes are coming from U.S. jurisdictions.

Annual current prices of alewives were relatively stable, fluctuating between one cent and two cents over a 23 year period. It seems that annual current prices are not very responsive to the quantity of alewife landings. Annual real prices fluctuated and varied from a high of 7 cents per pound in 1960 to a low of 2 cents during 1970-1973; 1975-1977, and 1980-1982, a decrease of about 71 percent over the

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[1]Personal communication with Fishery Division, Michigan Department of Natural Resources.

Table IV-11. Alewife Production from Michigan Great Lakes and Its Share of U.S. Production 1960-1982

Year	Michigan Production (in 000 lbs.)	U.S. Production (in 000 lbs.)	Michigan Share of U.S. Production (in percent)
1960	1,690	2,381	71
1961	1,094	3,211	34
1962	1,399	4,746	29
1963	1,580	5,398	29
1964	3,331	11,745	28
1965	3,140	14,007	22
1966	6,443	29,008	22
1967	13,370	41,895	32
1968	9,038	27,194	33
1969	7,490	29,248	26
1970	5,981	33,461	18
1071	4,368	30,418	14
1972	5,196	31,033	17
1973	5,254	36,706	14
1974	5,770	45,095	13
1975	3,678	35,216	10
1976	4,621	39,212	12
1977	4,476	48,406	9
1978	3,455	43,879	8
1979	2,599	27,503	9
1980	605	13,512	4
1981	1,082	19,324	6
1982	1,694	22,159	8

Note: There is no alewife produced from Canadian Great Lakes waters. The whole production comes from the U.S. area.

Sources: Fishery division, Michigan Department of Natural Resources.
National Oceanic and Atmospheric Administration.
Great Lakes Fishery Laboratory, Ann Arbor.
Calculated from data supplied by sources above for Michigan's share of production from U.S. and GL.

period. (See Table IV-3). The quantity of alewives production in 1982 was only four thousand pounds higher than the level of production in 1960. On the average, during this period, there was almost no increase in annual alewives production, and the annual current price also did not change over the period. Although very small, in terms of absolute value, the annual real prices have decreased by an average of 5.5 percent over the period. Production trend, annual current and real prices of alewives over 1960-1982 period are presented in Figure IV-9, while the relationship between annual real prices and the quantity of alewives landings is presented in Figure IV-10.

There are many types of gear used to harvest alewives; however, only four types of gear considered as the main gear, used to catch a large portion of this species, are presented in Table IV-12. The pound net is the most dominant gear used from 1960 to the present. The use of the otter trawl has decreased drastically, especially after 1974. Two inch and 4-6" gill nets did not have a significant catch over the period.

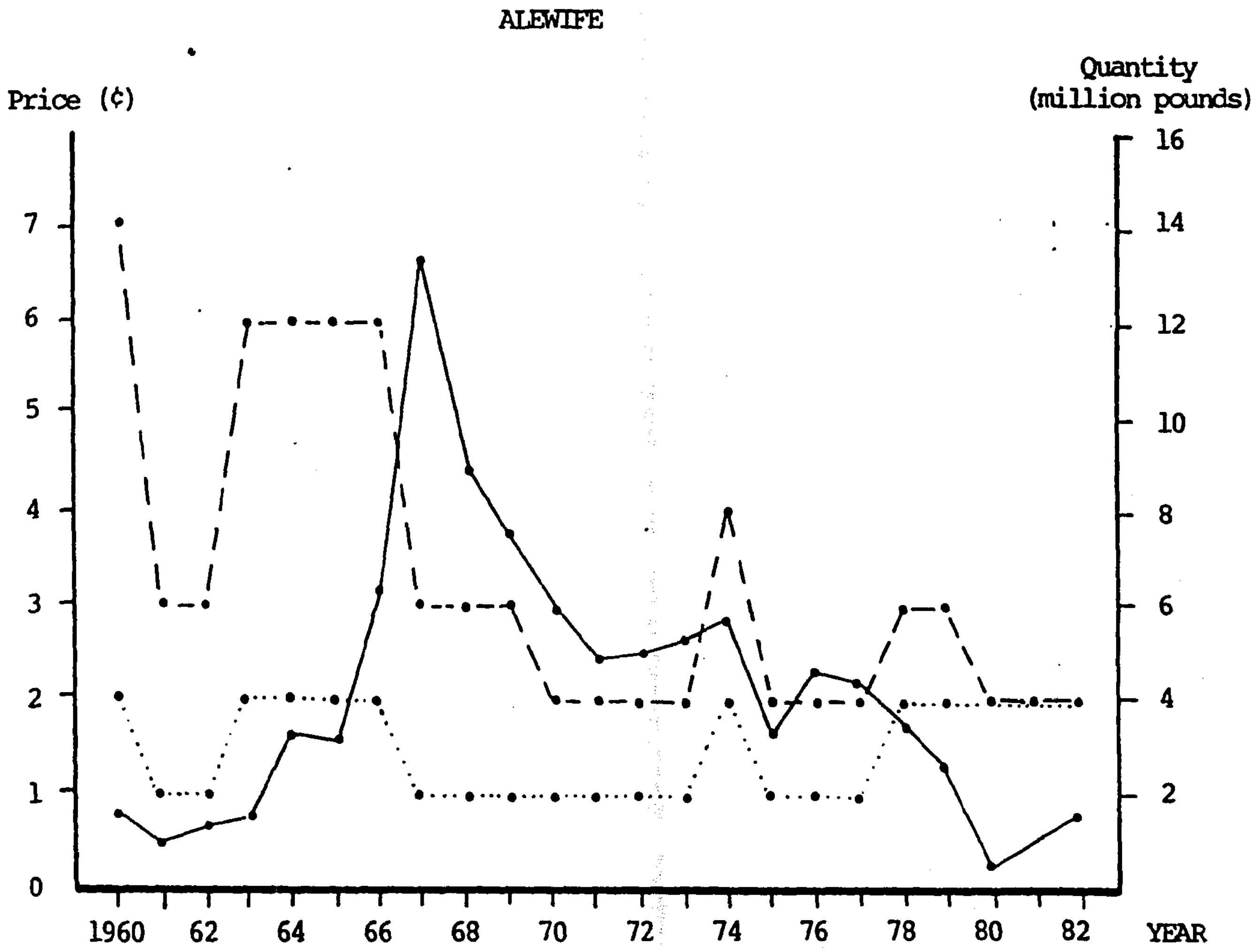

Figure IV-9. Annual Michigan Alewife Landings, Annual Current Price, and Annual Real Price 1960 - 1982

——— production .... current price

------ real price

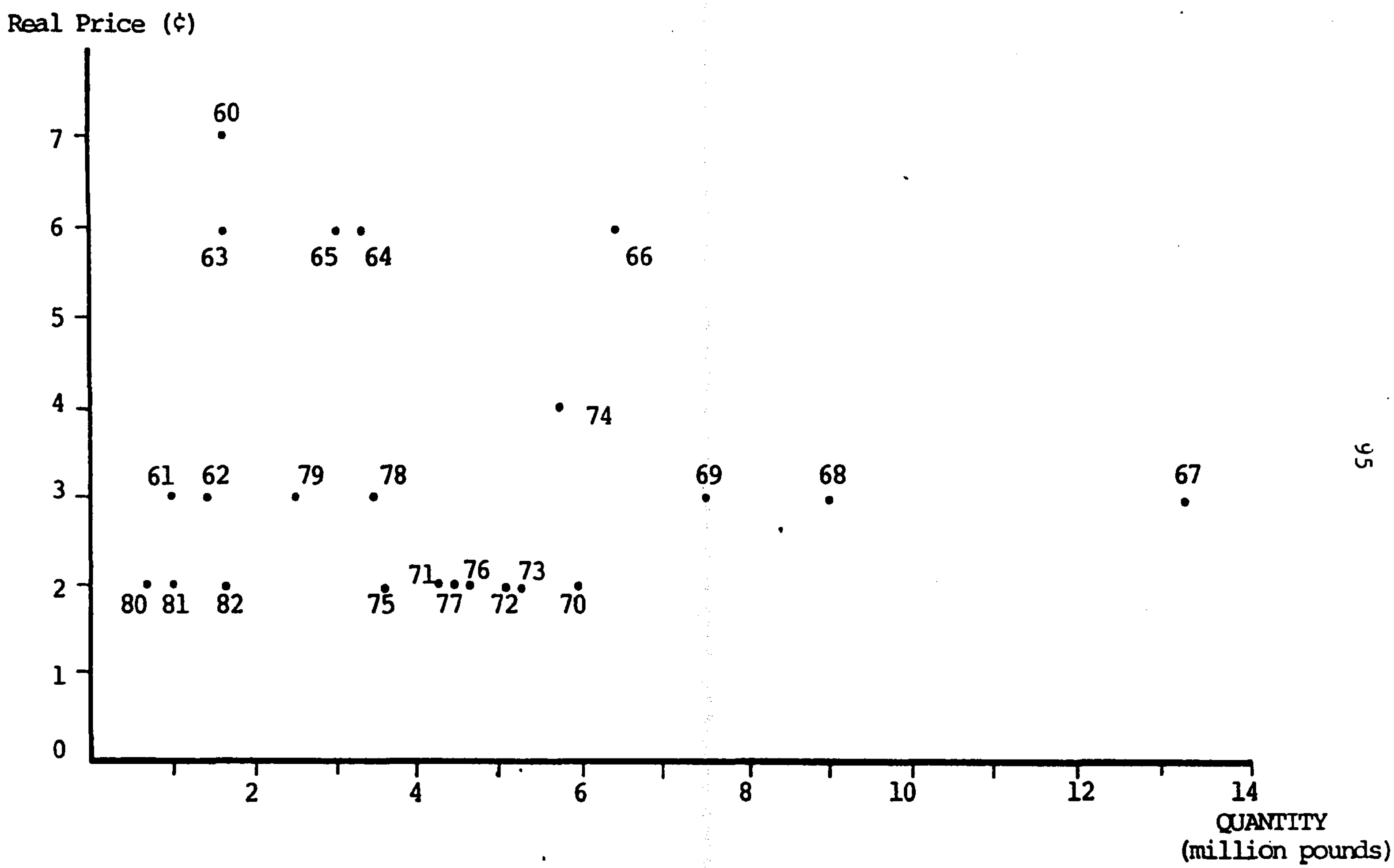

Figure IV-10. Real Price and Quantity of Alewife Landings in Michigan 1960 - 1982

Table IV-12. Catch and Effort for Different Types of Gear, and Catch per Unit of Effort (CPE) for Standard Gear for Alewives in Michigan Great Lakes Water 1960-1982

Year	2" Gill Net Catch	2" Gill Net Effort	Pound Net Catch	Pound Net Effort	4-6" Gill Net Catch	4-6" Gill Net Effort	Otter Trawl Catch	Otter Trawl Effort	CPE for Pound Net
1960	15,057	0	1,585,146	0	85	0	44,800	0	0
1961	2,230	324	723,940	0	30	0	3,54,510	815	0
1962	5,047	0	1,069,632	0	1	0	319,945	1,365	0
1963	1,240	121	1,030,965	249	68	6	402,986	7,806	4,140.4
1964	2,924	215	1,048,705	232	37	2	2,278,415	1,470	4,520.3
1965	616	63	700,800	96	80	12	2,438,690	12,203	7,300.0
1966	5,154	122	3,046,620	557	41	50	3,390,722	14,578	5,469.7
1967	81	46	9,856,421	2416	15	11	3,513,175	1,355	4,079.6
1968	201	132	4,914,255	848	1	6	3,845,333	1,370	5,795.1
1969	2,129	319	5,740,132	1066	1647	880	1,738,600	510	5,384.7
1970	1,150	863	4,085,280	944	1458	1630	1,893,510	392	4,327.6
1971	5,505	895	3,744,700	611	720	976	617,325	61	6,128.8
1972	599	412	5,133,660	547	2544	4102	59,227	53	9,385.1
1973	6,019	623	4,755,450	460	4725	4732	240,955	99	10,337.9
1974	4,365	604	5,024,800	663	861	1475	739,460	134	7,578.9
1975	3,349	888	3,652,380	441	5474	3222	17,040	75	8,282.0
1976	4,752	1157	4,589,870	745	4624	2722	21,540	35	6,160.9
1977	3	26	4,472,865	912	2585	990	275	5	4,904.5
1978	600	150	3,450,313	687	3935	1561	0	0	5,022.3
1979	41	187	2,586,800	531	11960	1771	0	0	4,871.6
1980	16	35	604,500	122	350	396	0	0	4,954.9
1981	10	80	1,082,230	164	0	0	0	0	6,599.0
1982	733	502	1,687,506	445	0	0	4,600	7	3,792.1

Sources: Calculated from raw data supplied by Fishery Division, Michigan Dept. of Natural Resources for 1960-1970.
Fishery Division, Michigan Department of Natural Resources, for 1971-1982.

The annual growth rate of production, current prices, and real prices of whitefish, chubs, yellow perch, catfish, and alewives are summarized in Table IV-13.

Table IV-13. Annual Growth Rate of Production, Current Prices, and Real Prices of Several Michigan Commercial Fish Species 1960-1982*

Species	Production	Current Prices (in Percent)	Real Prices
Whitefish	12.4	.6	-4.7
Chubs	- 9.2	7.1	1.5
Yellow Perch	- 9.8	9.5	3.7
Catfish	2.9	3.1	-2.3
Alewives	0.0	0.0	-5.5

*Negative signs indicate that production/prices decreased.

In Table IV-14, annual U.S. current and real prices of fish species included in this study are presented.

Table IV-14. Annual US Current and Real (per pound) Prices of Several Commercial Fish Species from US Great Lakes Waters (1960-1982)

	Whitefish		Chubs		Perch		Catfish		Alewives	
Year	Current	Real	Current	Real	Current	Real	Current	Real	Current	Real
1960	.57	1.86	.15	.43	.11	.36	.21	.68	.02	.07
1961	.52	1.68	.13	.42	.13	.42	.23	.74	.01	.03
1962	.53	1.69	.12	.38	.09	.29	.22	.73	.01	.03
1963	.51	1.61	.14	.44	.09	.28	.25	.79	.02	.06
1964	.59	1.84	.16	.50	.17	.53	.27	.84	.02	.06
1965	.50	1.53	.17	.52	.18	.55	.29	.89	.02	.06
1966	.50	1.49	.19	.57	.12	.36	.26	.77	.02	.06
1967	.57	1.65	.15	.43	.12	.35	.30	.87	.01	.03
1968	.60	1.67	.15	.42	.12	.33	.28	.78	.01	.03
1969	.60	1.58	.15	.39	.14	.37	.34	.89	.01	.03
1970	.56	1.39	.18	.45	.18	.45	.41	.98	.01	.02
1971	.44	1.05	.17	.40	.13	.31	.38	.88	.01	.02
1972	.50	1.15	.24	.55	.34	.79	.33	.76	.01	.02
1973	.55	1.20	.38	.83	.38	.83	.38	.83	.01	.02
1974	.67	1.31	.50	.98	.38	.74	.40	.78	.01	.02
1975	.67	1.20	.57	1.02	.53	.95	.46	.82	.01	.02
1976	.71	1.20	.61	1.03	.79	1.34	.45	.76	.01	.02
1977	.74	1.18	.52	.83	.61	.97	.45	.72	.02	.03
1978	.77	1.15	.58	.86	.68	1.01	.45	.67	.02	.03
1979	.85	1.13	.73	.97	.88	1.17	.43	.57	.02	.03
1980	.82	.96	.76	.89	.52	.61	.45	.53	.02	.02
1981	.74	.79	.73	.77	1.02	1.08	.45	.48	.02	.02
1982	.67	.67	.65	.65	1.26	1.26	.43	.43	.02	.02

Sources: Great Lakes Fishery Laboratory, Ann Arbor.
National Oceanic and Atmospheric Administration.
National Marine Fisheries.
Real Prices are calculated from data supplied by the same sources above.

CHAPTER V

ESTIMATION OF BIOECONOMIC MODEL PARAMETERS

The estimate of bioeconomic parameters using the linearized surplus production model, which is derived from the model developed by Schaefer, is one technique that is employed utilize information from yield and effort data.

In this study annual data for catch per unit of effort (CPE) and total effort (E) are based on standard gear used for each fish species from 1960-1982, which are given in Tables V-1; V-2; V-3; V-4; and V-5. The formula which has been used to convert catch and effort to a standard gear has been discussed in Chapter III.

The CPE for whitefish using either a large mesh trap net or a gillnet has increased considerably from 1960-1982. The catch per unit of effort for large mesh trap nets has increased from about 133 pounds in 1960 to 290 pounds in 1982, an increase of more than one fold. A similar trend also occurred with gillnets, where CPE increased from about 10 pounds in 1960 to 84 pounds in 1982, an increase of about seven fold. This increase might be caused by biological and technological effects as mentioned by Ghanbari (1977). The biological aspect is that the CPE fluctuates as fish stock fluctuates. When the fish stocks increase then the CPE will increase, and vise versa. Technological effects include improved gear efficiency and improved weather information. For instance, the introduction of monofilament net in the late 1950's and early 1960's, increased efficiency over the use of nylon nets. This net also allows for fishing in deeper water. The increase

Table V-1. Total Catch, Catch per Unit of Effort, and Total Effort of Whitefish from Michigan's Great Lakes Waters 1960-1982 (Using Large Mesh Trap Nets and Gillnets as Standard Gear)

Year	Total Catch (in lb.)	Large Mesh Trap Catch/Effort (CPE)	Total Effort	4-6" Gill Net Catch/Effort (CPE)	Total Effort
1960	550,700	132.70	4,149.96	10.20	53,990.2
1961	938,900	127.60	7,358.15	11.95	78,569.0
1962	809,300	113.60	7,124.12	13.05	62,015.3
1963	712,100	54.87	14,749.41	16.35	43,553.5
1964	1,097,800	99.81	10,998.90	14.73	74,528.2
1965	1,393,100	78.21	17,812.30	15.42	90,343.7
1966	1,744,200	159.15	10,959.47	19.97	87,341.0
1967	1,398,600	150.76	9,277.00	18.83	74,275.1
1968	1,548,200	133.72	11,577.92	18.73	82,658.8
1969	2,020,300	154.69	13,060.31	23.05	87,648.6
1970	1,904,726	158.15	12,043.79	23.26	81,888.5
1971	2,985,141	206.34	14,467.10	35.73	83,547.2
1972	3,493,971	268.34	13,020.69	40.24	86,828.3
1973	3,450,515	209.54	16,467.09	43.72	78,923.0
1974	2,960,558	217.72	13,598.01	34.01	87,049.6
1975	2,954,029	241.42	12,236.06	33.78	87,449.1
1976	3,451,308	256.92	13,433.40	33.99	101,538.9
1977	2,915,765	223.18	13,064.63	38.33	76,070.0
1978	3,239,175	239.85	13,505.00	34.76	93,186.9
1979	3,412,442	232.88	14,653.22	33.82	100,900.1
1980	5,140,726	245.04	20,979.13	42.30	121,530.2
1981	6,797,166	298.58	22,764.97	56.42	120,474.4
1982	7,148,236	289.91	24,656.74	83.73	85,372.5

Table V-2. Total Catch, Catch per Unit of Effort, and Total Effort of Chubs from Michigan's Great Lakes Waters 1960-1982 (Using 2 Inch Gillnets as Standard Gear)

Year	Total Catch (in lb.)	Catch/Effort (CPE)	Total Effort
1960	6,812,300	39.65	171,810.8
1961	6,493,700	45.77	141,876.8
1962	6,331,000	42.86	147,713.5
1963	4,890,600	39.30	124,442.7
1964	3,010,100	47.03	64,003.8
1965	5,296,300	54.43	97,304.8
1966	3,902,500	57.87	67,436.6
1967	4,792,900	70.28	68,197.2
1968	3,718,500	86.71	42,884.3
1969	3,439,000	127.17	27,042.5
1970	4,673,968	128.20	36,458.4
1971	3,199,583	99.66	32,105.0
1972	3,500,899	82.16	42,610.7
1973	3,087,949	67.65	45,646.0
1974	2,428,255	63.27	38,379.2
1975	1,539,355	60.47	25,456.5
1976	1,071,459	60.37	17,748.2
1977	843,741	69.41	12,155.9
1978	813,859	64.83	12,553.7
1979	805,447	67.41	11,948.5
1980	773,192	66.57	11,614.7
1981	797,228	58.30	13,674.6
1982	810,980	64.81	12,513.2

Table V-3. Total Catch, Catch per Unit of Effort, and Total Effort of Yellow Perch from Michigan's Great Lakes Waters 1960-1982 (Using Small Mesh Trap Nets as Standard Gear)

Year	Total Catch (in lb.)	Catch/Effort (CPE)	Total Effort
1960	1,921,900	21.99	87,398.8
1961	2,233,900	53.63	41,653.9
1962	1,504,800	20.26	74,274.4
1963	1,672,400	23.59	70,894.4
1964	3,256,200	23.66	137,624.7
1965	1,819,500	37.08	49,069.6
1966	1,849,500	81.51	22,690.5
1967	1,703,200	82.22	20,715.2
1968	1,238,400	79.14	15,648.2
1969	1,164,300	63.02	18,475.1
1970	588,269	58.66	10,028.5
1971	593,960	32.11	18,497.7
1972	345,855	49.76	6,950.5
1973	320,358	42.69	7,504.3
1974	231,797	35.31	6,564.6
1975	270,799	35.21	7,691.0
1976	323,071	44.71	7,225.9
1977	260,184	39.58	6,573.6
1978	168,879	29.42	5,740.3
1979	167,763	32.60	5,146.1
1980	249,175	39.60	6,292.3
1981	246,777	33.59	7,346.7
1982	196,844	26.61	7,397.4

Table V-4. Total Catch, Catch per Unit of Effort, and Total Effort of Catfish from Michigan's Great Lakes Waters 1960-1982 (Using Small Mesh Trap Nets as Standard Gear)

Year	Total Catch (in lb.)	Catch/Effort (CPE)	Total Effort
1960	370,100	11.91	31,074.7
1961	325,400	7.20	45,194.4
1962	228,300	8.47	26,954.0
1963	212,500	9.09	23,377.3
1964	200,800	12.65	15,873.5
1965	195,500	12.02	16,264.6
1966	197,500	15.41	12,816.4
1967	160,500	13.70	11,715.3
1968	123,400	13.74	8,981.1
1969	143,200	15.66	9,144.3
1970	227,279	43.98	5,167.8
1971	339,402	47.17	7,195.3
1972	265,136	26.99	9,823.5
1973	336,478	30.85	10,906.9
1974	281,482	27.79	10,128.9
1975	296,804	24.26	12,234.3
1976	415,606	37.12	11,196.3
1977	455,689	33.87	13,454.1
1978	458,027	41.91	10,928.8
1979	483,864	58.98	8,230.9
1980	514,527	73.91	6,961.5
1981	560,953	64.71	8,668.7
1982	692,373	84.88	8,157.1

Table V-5. Total Catch, Catch per Unit of Effort, and Total Effort of Alewives from Michigan's Great Lakes Waters 1960-1982 (Using Pound Nets as Standard Gear)

Year	Total Catch (in lb.)	Catch/Effort (CPE)	Total Effort
1960	1,690,200	0	0
1961	1,094,200	0	0
1962	1,398,600	0	0
1963	1,580,100	4,140.4	381.6
1964	3,331,200	4,520.3	736.9
1965	3,140,300	7,300.0	430.2
1966	6,442,700	5,469.7	1,177.9
1967	13,369,900	4,076.6	3,279.7
1968	9,037,700	5,795.1	1,559.5
1969	7,489,700	5,384.7	1,390.9
1970	5,981,418	4,327.6	1,382.2
1971	4,368,456	6,128.8	712.8
1972	5,196,160	9,385.1	553.7
1973	5,254,169	10,337.9	508.2
1974	5,769,676	7,578.9	761.3
1975	3,678,263	8,282.0	444.1
1976	4,620,786	6,160.9	750.0
1977	4,475,974	4,904.5	912.6
1978	3,454,898	5,022.3	687.9
1979	2,598,801	4,871.6	533.5
1980	604,866	4,954.9	122.1
1981	1,082,390	6,599.0	164.0
1982	1,694,318	3,792.1	446.8

in CPE of whitefish is accompanied by an increase in the total catch over the period.

Despite annual fluctuations in CPE of chubs, there was a sixty percent increase in CPE from 1960-1982. However, the increase in CPE of chubs is not associated with an increase in total catch, instead the total catch decreased. The causes of this decrease in total catch were discussed in Chapter IV.

Catch per unit of effort of yellow perch during the 1960-1982 period has fluctuated considerably, with the peak level reached in 1967. In 1982, however, CPE of yellow perch increased only about twenty percent above 1960 level. Catch per unit of effort of catfish has also increased from 12 pounds in 1960 to 85 pounds in 1982, a six fold increase over the 23 year period. The increase in CPE of catfish is also associated with an increase in total catch. Catch per unit of effort of alewives also fluctuated considerably from 4140 pounds in 1963 to a peak level of 10338 pounds in 1973, and then dropping to 3792 pounds in 1982. Total catch, CPE, and total effort, which are presented in Tables V-1 to V-5, are used to estimate the parameters of the bioeconomic model. The estimates of these parameters for each fish species: whitefish, chubs, yellow perch, catfish, and alewives from Michigan's Great Lakes waters, are presented in Table V-6.

Table V-6. Estimates of the Parameters, k, K, and q for the Logistic Surplus Production Model

Species	k	K	q
	With Large Mesh Traps		
Whitefish	0.14	62,300,000	0.51×10^{-5}
	With Gillnets		
	0.48	70,700,000	0.67×10^{-5}
	With Gillnets (1971-1982 data)		
	0.75	17,250,000	0.57×10^{-5}
	With Gillnets (1971-1982 data)		
Chubs	0.046	18,623,000,000	-0.33×10^{-5}
	With Small Mesh Traps		
Perch	0.14	34,800,000	-0.33×10^{-5}
	With Small Mesh Traps		
Catfish	0.30	13,400,000	-0.10×10^{-5}
	With Pound Nets		
Alewife	0.005	22,800,000	0.53×10^{-4}
	With Pound Nets (1971-1982 data)		
	0.05	469,854,000	0.74×10^{-4}

Note: Unless specified, all estimates are using 1960-1982 data.

k = population growth rate
K = environmental carrying capacity
q = catchability coefficient

The estimates of k for whitefish vary from 0.14 with the large mesh trap nets to 0.48 with gillnets and 0.75 with gillnets using 1971-1982 data. The estimates of carrying capacity, K, obtained by using gillnets is larger than those of using large mesh traps, however, 1971-1982 gillnet data gives the smallest carrying capacity. The catchability coefficients also vary from 0.51 x 10^{-5} with large mesh traps, 0.67 x 10^{-5} and 0.57 x $10^{-5}$with gillnets. The estimates of k and q parameters for chubs seem rather close to the estimation coefficients of other species, however, the estimates of chubs carrying capacity is quite large even after adjustment of the 1960-1982 data to 1971-1982 data. The estimate of k for yellow perch is 0.14 and the catchability rate, q, is 0.33 x 10^{-5}. With the same standard gear, small mesh trap nets, the catchability coefficient for catfish is 0.10 x 10^{-4} and k is 0.30. For alewives with pound nets as the standard gear, the catchability coefficient is 0.53 x 10^{-4}; and 0.74 x 10^{-4} using 1960-1982 and 1971-1982 data, respectively. The k parameters vary from 0.005 to 0.05 by using different time periods. The estimate of carrying capacity seems to be quite different between these two estimates, varying from about 23 million pounds to more than 400 million pounds.

The estimated parameters for each fish species in Table V-6 are substituted into equation (3.8) to obtain production functions for each species as shown below. These production functions represent the relationships between estimated equilibrium yield and effort.

<u>Whitefish</u>

Large Mesh Traps	$Y = 318E - 0.012E^2$	(5.1)
Gillnets	$Y = 474E - 0.006E^2$	(5.2)
Gillnets (1971-1982)	$Y = 98.5E - 0.00074E^2$	(5.3)

<u>Perch</u>

Small Mesh Traps	$Y = 115E - 0.0026E^2$	(5.4)

Catfish

Small Mesh Traps $Y = 134E - 0.0045E^2$ (5.5)

Alewife

Pound Nets $Y = 1208E - 12.8E^2$ (5.6)

Pound Nets (1971-1982) $Y = 34800E - 51.5E^2$ (5.7)

These production functions can be plotted into parabolas as shown in Figures V-1; V-2; V-3; V-4 and V-5. (From equation 5.2; 5.3; 5.4; 5.5; and 5.7).

By comparing Figure V-1 with V-2 which has different estimate periods, for whitefish two important features are evident. First, using 1960-1982 data results in an estimate which shows that less effort is needed to catch whitefish. In other words, CPE is high. Catch per unit of effort is relatively low in the second estimate. Except for observations in 1980, 1981 and 1982; all points of observation from 1960 to 1979 fall under or very near the yield curve (Figure V-2). In Figure V-1, however, most observations are outside the estimated equilibrium yield curve.

For yellow perch, high levels of effort and yield occurred during 1960s. Most post-1970 observations were very near the origin, which indicates that the amount of yellow perch caught declined to its lowest level (Figure V-3).

Catfish have two distinct observation patterns, one occurring during the 1960's and the other in the 1970's. During the 1960's, there was a high level of effort with lower yield and during the 1970's there

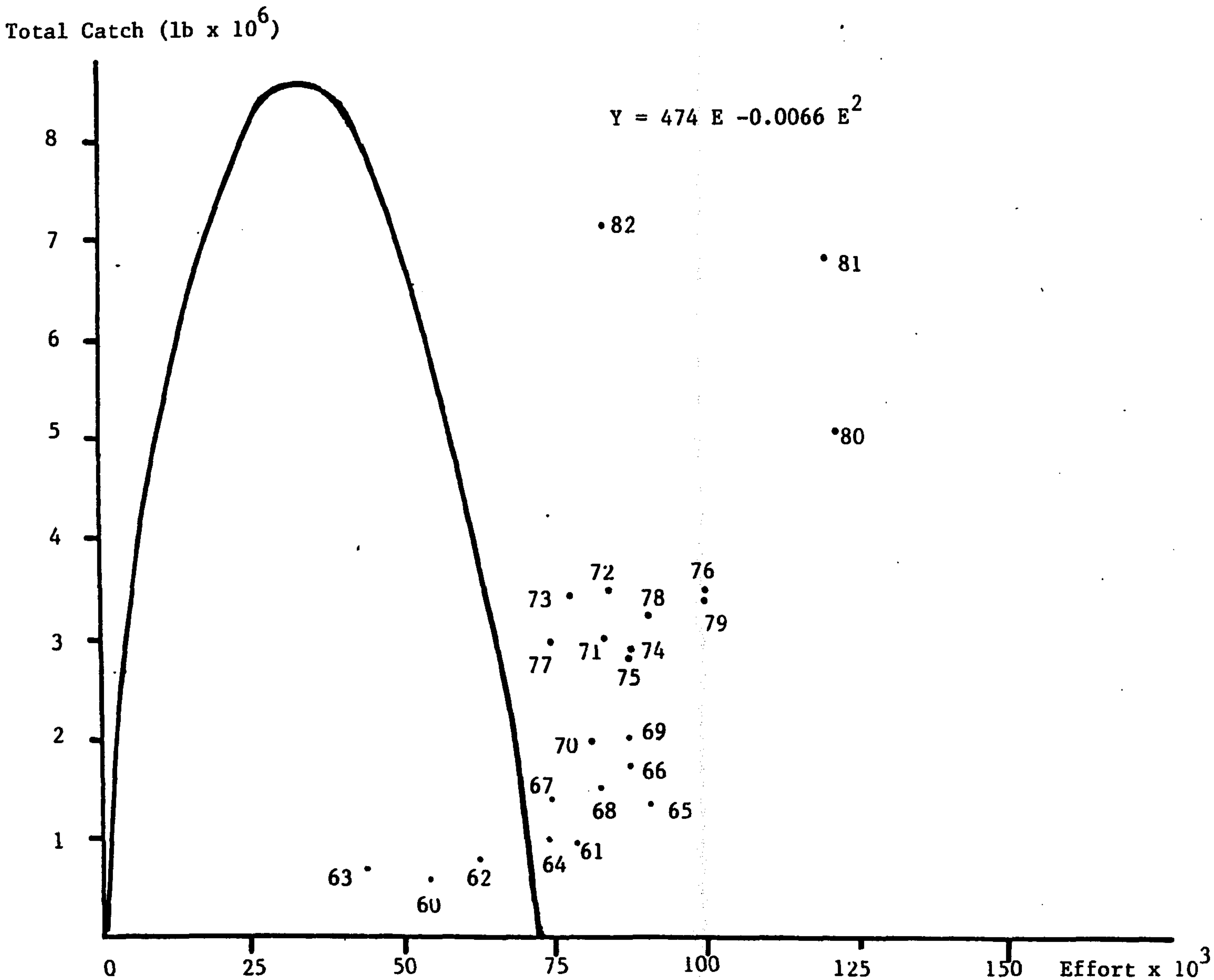

Figure V-1. Estimated Equilibrium Catch (yield) and Effort Relation of Whitefish Using Linearized Surplus Production Technique (1960-1982)

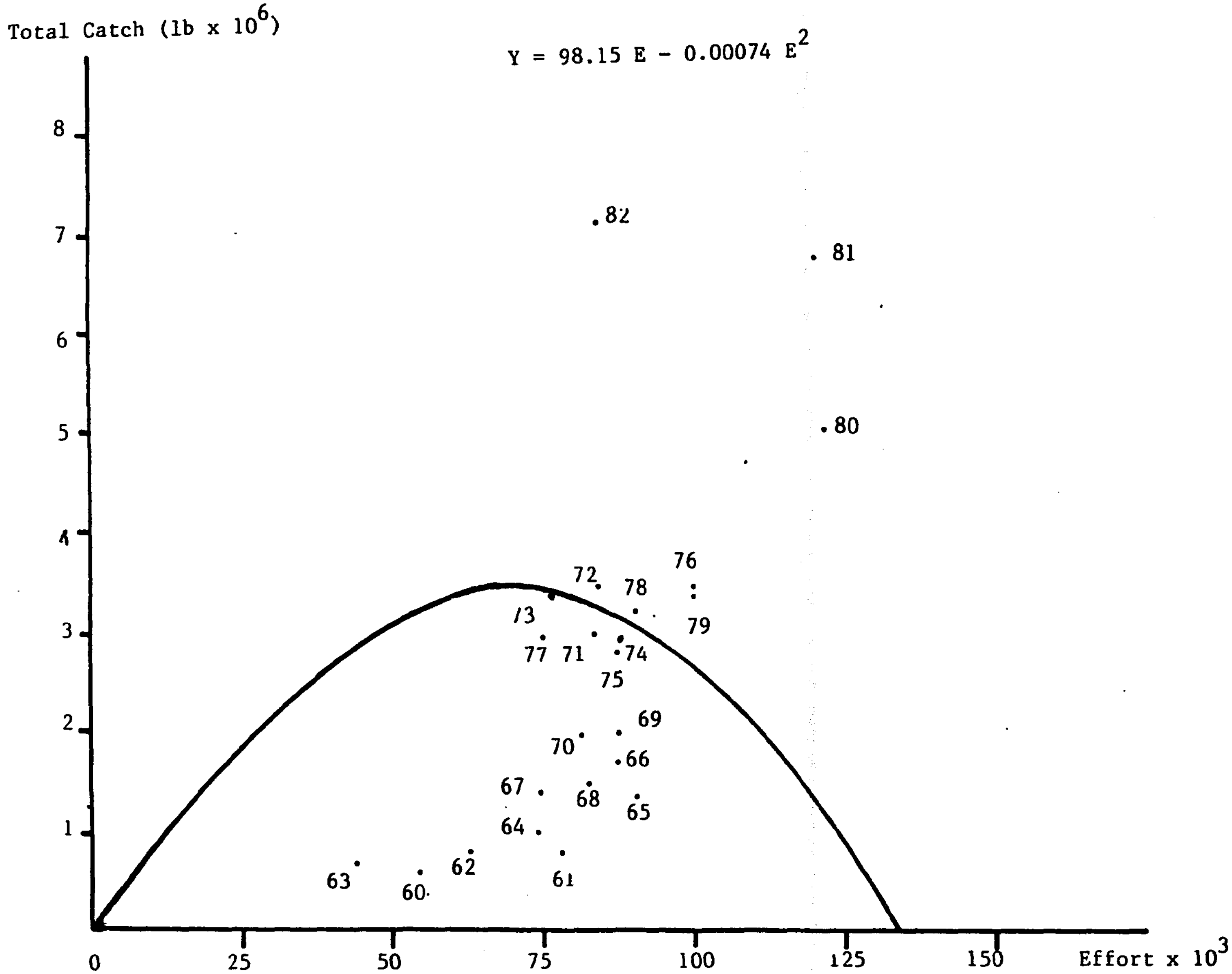

Figure V-2. Estimated Equilibrium Catch (Yield) and Effort Relation of Whitefish Using Linearized Surplus Production Technique (1971-1982)

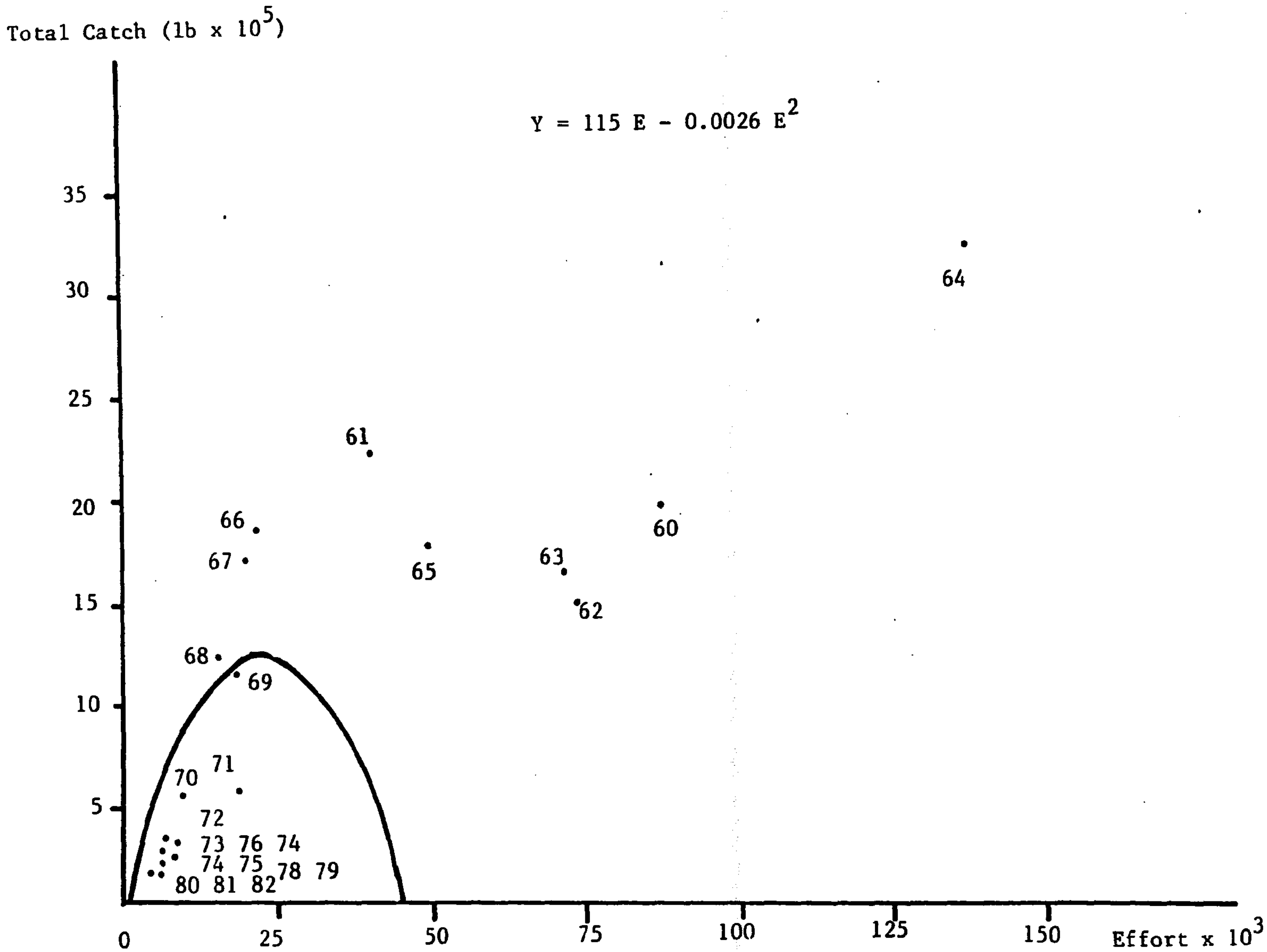

Figure V-3. Estimated Equilibrium Catch (Yield) and Effort Relation of Perch Using Linearized Surplus Production Technique (1960-1982)

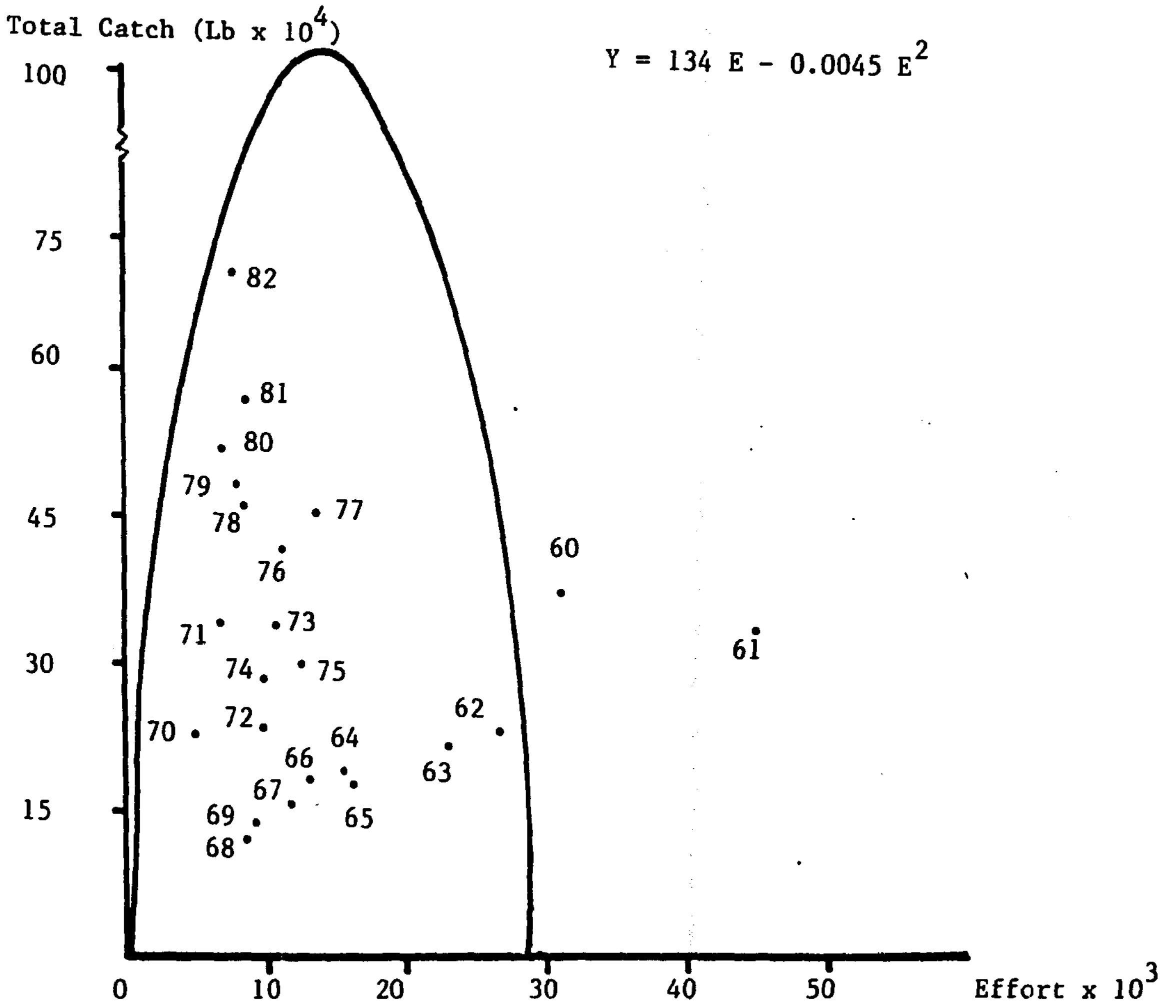

Figure V-4. Estimated Equilibrium Catch (yield) and Effort Relation of Catfish Using Linearized Surplus Production Technique (1960-1982)

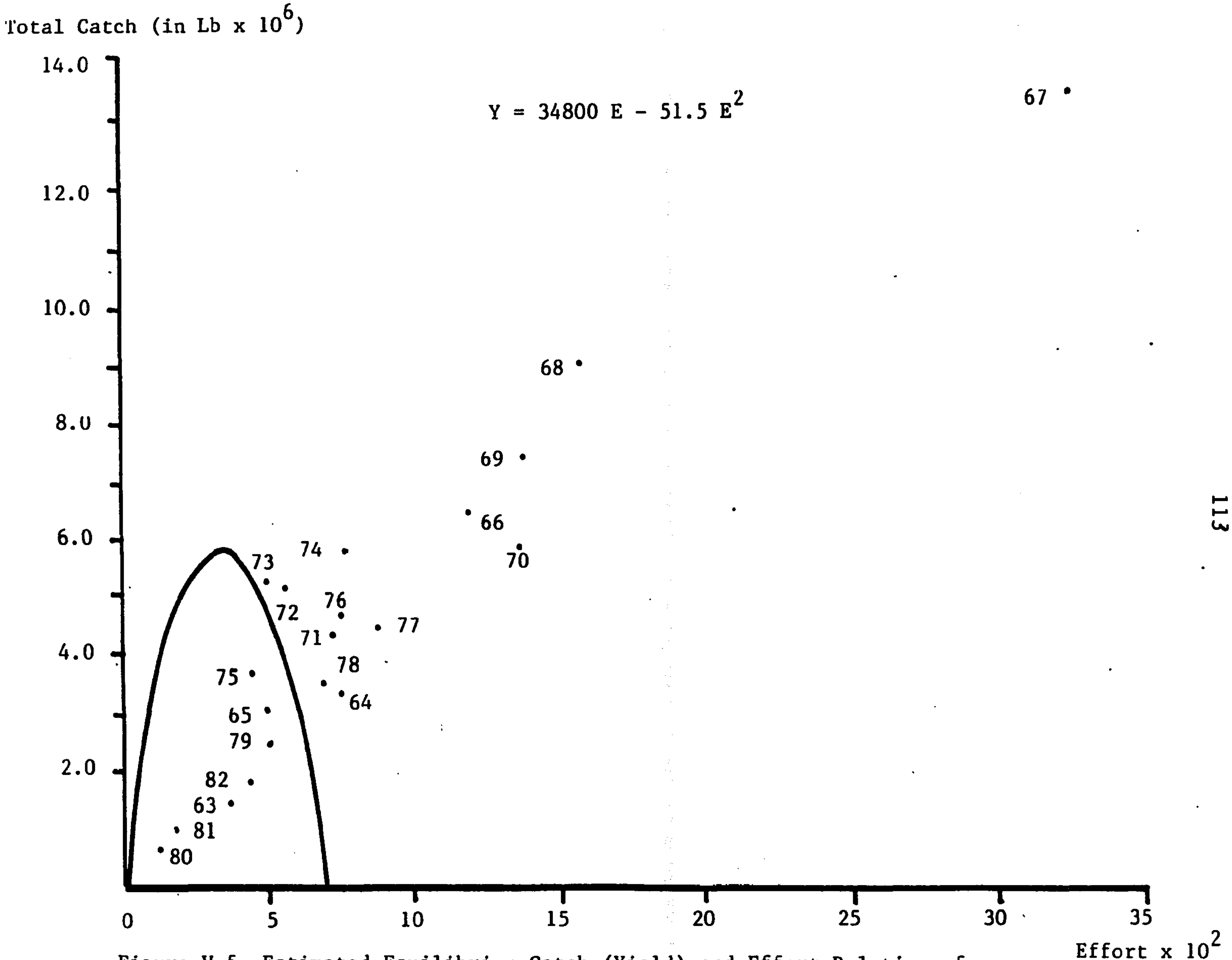

Figure V-5. Estimated Equilibrium Catch (Yield) and Effort Relation of Alewife using Linearized Surplus Production Technique (1971-1982) was a lower level of effort with a higher yield. It seems likely that current catfish production was below the point of maximum sustained yield (Figure V-4).

Alewife production, on the other hand, showed a great deal of fluctuation during the 1960-1982 observation period. Many observations fall out of the production curve as well as under the curve.

Estimate of Bioeconomic Analysis Using Linearization Surplus Production Technique

Substituting the parameters k, q, and K which have been estimated (Table V-6) for whitefish, using 1960-1982 and 1971-1982 data, into the bioeconomic model gives the result presented in Tables V-7 and V-8. From these estimates it can be seen that optimum effort (effort at MEY) is smaller than effort at MSY. Similarly, the amount of fish caught (yield) at MEY is lower than MSY. In spite of lower catch rates, MEY obviously provides higher producers' surplus (economic rent) than MSY.

Comparing the different estimates of bioeconomic values from Table V-7 and Table V-8 shows that there are considerable differences between these two estimates. These differences might be due to different catch per unit of effort trends for the two sets of observation periods examined. The use of 1960-1982 data results in a smaller estimate of the amount of effort with much a higher yield, which provides a large producer's surplus. On the other hand, using 1971-1982 data gives a larger estimate of the amount of effort with a smaller yield, which eventually gives a smaller producer's surplus.

Table V-7. Estimation of Bioeconomic Values for Whitefish (Using 1960-1982 data)

Parameters	Magnitude	Units
Optimum Effort (E^e)	33,100	1000 feet of 4 1/2 inches gillnet
Maximum Economic Yield (MEY)	8,420,000	pounds
Total Value Product at MEY	10,777,600	dollars
Total Long Run Cost at MEY	1,565,600	dollars
Producers' Surplus at MEY	9,212,000	dollars
MSY Effort (E^*)	35,900	1000 feet of 4 1/2 inches gillnet
Maximum Sustainable Yield (MSY)	8,500,000	pounds
Total Value Product at MSY	10,880,000	dollars
Total Long Run Cost at MSY	1,698,000	dollars
Producer's Surplus at MSY	9,182,000	dollars

Table V-8. Estimation of the Bioeconomic Values for Whitefish (Using 1971-1982 data)

Parameters	Magnitude	Units
Optimum Effort (E^e)	41,000	1000 feet of 4 1/2 inches gillnet
Maximum Economic Yield (MEY)	2,770,000	pounds
Total Value Product at MEY	3,545,600	dollars
Total Long Run Cost at MEY	1,939,300	dollars
Producers' Surplus at MEY	1,606,300	dollars
MSY Effort (E^*)	66,000	1000 feet of 4 1/2 inches gillnet
Maximum Sustainable Yield (MSY)	3,234,000	pounds
Total Value Product at MSY	4,140,000	dollars
Total Long Run Cost at MSY	3,122,000	dollars
Producer's Surplus at MSY	1,018,000	dollars

A comparison of the estimate of bioeconomic values from Tables V-7 and V-8 with the estimated bioeconomic value in Table V-9, reveals that the reported existing effort is much higher than the estimated effort using the bioeconomic model either at MEY or at MSY. The amount of effort estimated in 1973 was almost twice that of the optimum effort from the 1971-1982 data (Table V-8), and more than twice the optimum effort from the 1960-1982 data (Table V-7). The total yield in 1973 was higher than MEY or MSY from the 1971-1982 period (Table V-8), but smaller than MEY or MSY from the 1960-1982 period (Table V-7). However, the 1973 producer's surplus was less than the estimated producer surpluses from both the 1960-1982 and 1971-1983 periods (Table V-7 and V-8).

Table V-9. Estimation of the Bioeconomic Values for Whitefish Based on 1973 Data*

Parameters	Magnitude	Units
Total Effort (TE)	78,900	1000 feet of 4 1/2 inches gillnet
Total Yield (Y)	3,451,000	pounds
Total Value Product (TVP)	4,417,280	dollars
Total Long Run Cost (TLC)	3,731,970	dollars
Producers' Surplus	685,310	dollars

* The data about costs and returns were obtained from the Michigan Sea Grant study in 1976 conducted by F. Pattiason and D.R. Talhelm (1977).

From this comparison it cannot be firmly concluded whether or not whitefish stocks in Michigan's Great Lakes waters are over exploited. By comparing the results found in Table V-7 with those in Table V-9, might be said that whitefish stocks have been over exploited because the estimate from the 1960-1982 period shows that less effort can produce a higher yield than the 1973 effort. But this is not true using data from

Table V-8 with Table V-9. Even though 1973's effort is higher than the optimal effort, the amount of fish caught is also higher than the predicted yield either at MEY or MSY. However, the surplus gained by the fishermen in 1973 were smaller than the surplus gained either at MSY or MEY in spite of higher catches and efforts. Maximum sustainable yield (MSY) of whitefish was estimated at 8.5 million pounds with the maximum effort of 35,900 units. The producer surplus was about $9.2 million. Maximum economic yield (MEY) was reached at 8.4 million pounds with the maximum effort of 33,100 units, and producer surplus of $9.2 million. All of these estimated values were obtained using the 1960-1982 data as shown in Table V-7. However, using the 1971-1982 data (Table V-8) resulted in MSY of 3.23 million pounds with maximum effort of 66,000 units and producer surplus of $1.08 million. Maximum economic yield was reached at 2.77 million pounds with maximum effort of 41,000 units, and $1.61 million of producer surplus.

Cost data were not available for the other fish species, therefore only MSY and its effort were estimated for these species. Maximum sustainable yield of perch was reached at 1.22 million pounds as the maximum effort of 21,500 units. For catfish, maximum sustainable yield was $1.0 million pounds with the maximum effort of 14,700 units. Maximum sustainable yield of alewife was obtained at 5.87 million pounds with the maximum effort of 14,700 units.

The findings for whitefish indicated that the whitefish was over exploited, since most of the production occurred in the area well beyond MSY as shown in both Figures V-1 and V-2. Estimation using 1960-1982 data show that the fishermen produced outside sustainable yield curve, where using 1971-1982 data the production mostly falls under the yield curve, but both are operated byond MSY. However, it is believed that current whitefish production is very near the range of maximum sustained yield. Close observation should be undertaken to monitor the performance of whitefish production regularly, including measurements of the size and weight of whitefish caught, to help reduce the risk of sudden collapse of the stocks. It is admitted that the stochastic nature of fishery biomass causes difficulties in forecasting the amount of fish that will be caught. The abundance of fish stocks can vary in many unpredictable ways (Everhart and Youngs, 1981). Variation can be caused by migration, variability in the spawn survival, changes in the environment, productivity, weather, salinity, and characteristics of the locality fished.

In addition, catchability or catch per unit of effort also intensifies the stochastic dilemma of the fishery resource. The measurement of catch per unit effort (CPE) is imprecise. This caused problems in the analysis of CPE data. Measurements of CPE are oversimplified and usually under estimated (Hile, 1962).[1] Hile gave an example regarding the total lift of gillnets which were set by the fishermen on yellow perch. The nets were set in deep water for chubs and lake herring, but also included yellow perch. Since nets used for chubs and herring rarely catch any perch, the inclusion of those nets in the computation of CPE for perch yielded a very low CPE for perch. In this computation, one thousand feet of small mesh gillnets, for instance, was estimated to catch less than 5 pounds of perch when in reality if directed only toward perch, the catches were higher than

[1]Personal communication with Fishery Division, MDNR also reveals the same problem in the measurement of CPE.

twenty pounds. This problem is intensified further by the fishermen's attempts to take several species simultaneously when setting the nets. Therefore, any efforts to obtain an unbiased measurement of CPE is difficult. Without correcting this problem, any analysis using CPE data will give inaccurate results. For simple bioeconomic models, this situation became more critical as only catch and effort data were used in the analyses.

CHAPTER VI

ESTIMATION OF DEMAND AND SUPPLY PARAMETERS

Introduction

The main purpose of this chapter is to present an economic analysis of the demand and supply of several commercial fish species. The estimates of demand and supply parameters have been obtained by several techniques and methods.

By undertaking demand and supply analysis in this study, several goals are expected to be accomplished:

- to determine economic forces and factors that influence prices and quantities of fish purchased (sold), as well as what causes prices and quantities to be at existing levels.
- to quantify and isolate variables affecting the price and quantity of fish commodities.
- to determine the responsiveness of prices or quantities to changes in the variables or factors.

In analyzing demand and supply, a model is specified based upon selected economic principles. One principle states that the quantity of fish demanded is determined by its own price, price of substitute products, consumer income, taste, population, and other factors. In addition, another principle states that the quantity of fish supplied (produced) is determined by its own price, the price of other products which are substitute in production, cost of production, and technology.

Based on economic principles, the expected effects caused by all these factors will be as follows:

Demand function.

1. When the prices of fish increase, the quantity of fish demanded/purchased is expected to decrease, on the other hand, when the quantity fish sold increases, price is expected to decrease (all prices used here are dockside prices).
2. Increases in income are expected to raise the quantity of fish purchased. This might not be true in the case of inferior or Giffen goods, in which the goods demanded will decrease in spite of increases in income.
3. Prices of substitute products in consumption are expected to move in the same direction with respect to the quantity of fish under consideration. When the price of substitute goods decrease, it is likely that the quantity of substitute goods demanded will increase, therefore, the quantity of the respective goods (fish) demanded/sold will decrease. The closer the substitute, the more the effect will be felt.

Supply Function

1. As the price of fish increases, more fish will be harvested/produced by the fishermen. Fishermen will be motivated to increase their production.
2. Prices of substitute goods in production will move in an opposite direction to the quantity of fish under consideration. If the price of substitute goods increases,

the production of fish might decrease, as most fishermen (producers) will now produce more substitute goods rather than the respective fish production.

3. Factor costs or costs of production and the quantity of fish produced tend to move in opposite directions. Commonly, whenever costs increase, the fishermen might pass them along in the form of higher fish prices. This will drive up price, and consequently will drive down the quantity demanded. In order to clear the market, less of the fish commodity must be offered otherwise the fishermen's profit at current prices will go down. As a result, some fishermen might be driven out of business and all producers will end up with a smaller amount of fish produced.

Some variables (factors), although considered dominant in affecting demand such as consumer tastes, are not available. In this case, income, other than its effect on demand, is considered a good proxy for the taste variable. In addition, the cost of factors which have an effect on the supply function are not available, and therefore effort or catch per unit of effort is used as its proxy. The model used in this study will be based on the ceteris paribus (other things being equal) assumption, that is, other variables which cannot be measured are held constant.

Based on information provided by the Fisheries Division of the MDNR about possible substitutes in the consumption (demand) and production (supply) of each fish species examined the model was specified. The prices of substitutable commodities were incorporated into the model to estimate demand and supply functions. The substitute goods for the demand functions of each species are:

Whitefish = beef, seafood, shrimp, cod, fillet, poultry, and flounder are considered substitutes for whitefish.

Chubs = smoked fish, ocean herring, and canned fish are considered substitutes for chubs.

Perch = ocean perch, shrimp and scallops are substitutes for perch.

Catfish = whitefish, trout, fillet and other ocean food are considered substitutes for catfish.

Alewife = for alewife, there was no substitute used in the model, beef was used as a complementary good rather than a substitute.

The substitute goods for supply are:

Whitefish = trout was considered as the closest substitute.

Chubs= the substitute goods for chubs were whitefih, trout, and perch.

Perch = Chubs and catfish were the substitutes for perch.

Catfish = perch was the only good substitute for catfish.

Alewife = no substitute.

Since the demands estimated in the model were demands at the dockside level (not at consumer level), there were no direct substitutes between fish species. The direct substitute of goods is expected to occur at the consumer level (retail market). However, those substitute goods were still functioning as indirect substitutes (derived) in terms of influencing the processors' or wholesalers' decisions on how much and at what price they would buy the fish from Michigan's Great Lakes (at dockside level).

All the principles discussed above, along with statistical tests, will be used to determine the best results from the estimates of demand and supply.

Estimation Procedure

To estimate demand and supply functions, two steps were used to run the regression.

1. A series of equations were run treating the quantity of fish landed (catch) as a dependent variable which was affected by all other independent variables.
2. Then, a series of equations were run treating price as a dependent variable which was affected by other independent variables.

In selecting which variables to include a series of equations, multicollinearity among the independent variables was taken into consideration. This was done by using a correlation coefficient matrix, that is, by avoiding the variables which have high multicollinearity in the same equation. As mentioned by Kmenta (1971), multicollinearity is a question of degree and not of kind. The distinction is not between the presence or absence of multicollinearity, but between its various degrees, or the degree to which two or more independent variables are correlated to each other or a linear combination of other independent variables.

A high degree multicollinearity is harmful in the sense that the estimates of the regression coefficients are not precise. The imprecision arises because of the large variances of the least square estimators. These high variances occur because multicollinearity will prevent the OLS procedure from being given enough independent variation to calculate the effect it has on the dependent variable (Kennedy, 1983). Therefore, in developing regression models, the multicollinearity problem will be reduced by including variables in the model which have correlation coefficients $r \leq 0.80$. Consequently, some variables will be excluded, or included in separate equations. In this study, the correlation coefficient matrix among the variables, as shown in Tables VI-1, VI-2, VI-3, and VI-4, will be used as a guide in estimating demand and supply for each fish commodity. However, this rule might be violated if, in the author's judgment, there are variables too important to be excluded despite high multicollinearity. In this case, the rule of thumb as suggested by Kennedy (1983) will be used. That is, multicollinearity is ignored if the R^2 from the regression exceeds the R^2 of any independent variable regressed on the other independent variables or if the "t" statistics are all greater than two.

Another factor which will be considered is the existence of a serial correlation, a situation in which the disturbance occurring at one point of observation is correlated with any other disturbance. In another words, it might be said that the effect of a disturbance occurring in one period may carry over to another period. The presence of a serial correlation will cause the least square estimators to become

Table VI-1. Correlation Coefficients Among the Variables Used in the Estimation of Demand and Supply Functions of Whitefish

	T	QW	PWD	QT	PTD	PBD	PCFD	DICD	PSD	PFLD	PCD	PFID	PSTD	WTE	WCPE	QWH	QWG	PGD	PWD1
T	1.000																		
QW	.091	1.000																	
PWD	-.916	-.923	1.000																
QT	.191	.481	-.263	1.000															
PTD	-.919	-.842	.858	-.361	1.000														
PBD	-.446	-.358	.403	-.104	.340	1.000													
PCFD	.818	.640	-.680	.009	.763	-.419	1.000												
DICD	.962	.802	-.848	.020	-.859	-.420	.747	1.000											
PSD	.687	.608	-.612	.031	-.561	-.084	.611	.623	1.000										
PFLD	.851	.660	-.771	-.103	-.802	-.391	.889	.844	.678	1.000									
PCD	.836	.705	-.793	-.158	-.784	-.209	.778	.840	.610	.884	1.000								
PFID	.879	.825	-.785	-.191	-.793	-.314	.802	.870	.634	.926	.960	1.000							
PSTD	.860	.717	-.777	-.010	-.806	-.507	.890	.825	.592	.934	.870	.896	1.000						
WTE	.707	.793	-.737	.346	-.534	-.362	.416	.633	.445	.379	.428	.455	.454	1.000					
WCPE	.883	.883	-.882	.245	-.881	-.323	.704	.837	.590	.802	.851	.833	.821	.468	1.000				
QWH	.913	.927	-.897	.329	-.863	-.449	.841	.803	.619	.817	.806	.789	.876	.682	.879	1.000			
QWG	.763	.769	-.750	.306	-.640	-.511	.708	.633	.598	.623	.509	.554	.708	.710	.603	.833	1.000		
PGD	.497	.628	-.463	.677	-.512	-.172	.555	.284	.489	.304	.216	.158	.363	.516	.403	.632	.633	1.000	
PWD1	-.280	-.327	.270	.267	.457	-.130	-.326	-.224	-.209	-.404	-.424	.308	-.320	.058	-.471	-.363	-.123	-0.282	1.000

Table VI-2. Correlation Coefficient Among the Variables Used in the Estimation of Demand and Supply Functions of Chubs

	QCH	PCHD	PCHD1	PHD	PBD	PCFD	DICD	PFLD	PSTD	PFID	PGD	CHTE	CHCPE	QCHM	QCHG	PWD	PPD	PTD
QCH	1.000																	
PCHD	-.618	1.000																
PCHD1	-.767	.742	1.000															
PHD	-.649	.531	.496	1.000														
PBD	.514	-.056	-.506	.031	1.000													
PCFD	-.830	.784	.852	.689	-.419	1.000												
DICD	-.906	.586	.659	.636	-.430	.747	1.000											
PFLD	-.828	.765	.746	.703	-.391	.889	.844	1.000										
PSTD	-.838	.758	.818	.546	-.507	.890	.825	.934	1.000									
PFID	-.844	.799	.718	.618	-.314	.802	.918	.926	.896	1.000								
PGD	-.437	.259	.412	.552	-.172	.555	.284	.304	.363	.158	1.000							
CHTE	.898	-.384	-.596	-.476	.565	-.613	-.928	-.674	-.698	-.777	-.223	1.000						
CHCPE	-.144	-.338	-.168	-.099	-.249	-.135	.358	-.005	.013	.146	-.264	-.524	1.000					
QCHM	.663	-.718	-.443	-.556	.215	-.740	-.587	-.761	-.719	-.693	-.342	.431	.188	1.000				
QCHG	.644	-.623	-.328	-.519	.213	-.668	-.620	-.715	-.667	-.674	-.310	.485	.020	.976	1.000			
PWD	.788	-.471	-.571	-.566	.403	-.680	-.848	-.771	-.777	-.785	-.463	.751	-.220	.509	.520	1.000		
PPD	-.802	.741	.655	.653	-.284	.760	-.810	.837	.813	.888	.317	-.686	.031	-.715	-.680	-.795	1.000	
PTD	.791	-.529	-.537	-.641	.340	-.763	-.859	-.802	-.806	-.793	-.512	.755	-.326	.631	.672	.858	-.755	1.000

Table VI-3. Correlation Coefficients Among the Variables Used in the Estimation of Demand and Supply Functions of Yellow Perch

	QP	PPD	PPD1	POPD	PSD	PSCD	PCHD	PCATD	DICD	PGD	PTE	PCPE	QPH	QPG
QP	1.000													
PPD	-.726	1.000												
PPD1	-.746	.768	1.000											
POPD	-.680	.790	.718	1.000										
PSD	-.512	.633	.634	.811	1.000									
PSCD	-.827	.739	.677	.661	.587	1.000								
PCHD	-.552	.741	.660	.617	.519	.386	1.000							
PCATD	.676	-.705	-.547	-.867	-.657	-.728	-.441	1.000						
DICD	-.865	.810	.825	.726	.623	.869	.586	-.666	1.000					
PGD	-.263	.317	.344	.616	.489	.323	.259	-.741	.284	1.000				
PTE	.852	-.500	-.668	-.463	.391	-.714	-.354	.450	-.785	-.169	1.000			
PCPE	.085	-.358	-.111	-.345	-.174	-.012	-.329	.328	.031	-.201	-.398	1.000		
QPH	.352	-.470	-.126	-.195	-.063	-.430	-.289	.327	-.465	-.040	.361	-.141	1.000	
QPG	.329	-.602	-.186	-.463	-.216	-.190	-.584	.500	-.284	-.274	-.034	.486	.635	1.000

Table VI-4. Correlation Coefficients Among the Variables Used in the Estimation of Demand and Supply Functions of Catfish

	QCAT	PCATD	PCAD1	PWD	PTD	PFID	PSTD	PPD	PBD	PGD	CATE	CACPE	QCAM	QCAG	DICD
QCAT	1.000														
PCATD	-.864	1.000													
PCAD1	.586	.530	1.000												
PWD	.747	.745	.136	1.000											
PTD	-.760	.875	.357	.858	1.000										
PFID	.598	-.596	-.061	-.785	-.793	1.000									
PSTD	.708	-.678	-.163	-.777	-.806	-.896	1.000								
PPD	.746	-.705	-.233	-.795	-.775	.888	.813	1.000							
PBD	-.214	.228	-.222	.403	.340	-.314	-.507	-.284	1.000						
PGD	.654	-.741	-.431	-.463	-.512	.158	.363	.317	-.172	1.000					
CATE	-.010	.338	-.242	.574	.543	-.567	-.420	.594	.407	-.085	1.000				
CACPE	.785	-.850	-.282	-.868	-.865	.615	.622	-.725	-.307	.625	-.592	1.000			
QCAM	-.570	.601	.538	.564	.733	-.707	-.652	.705	.151	-.280	.533	-.584	1.000		
QCAG	.564	.579	.584	.531	.715	-.670	-.619	.682	.141	-.232	.488	-.564	.991	1.000	
DICD	.567	-.666	.011	-.848	-.859	.918	.825	-.865	-.420	.284	-.769	.768	-.699	-.652	1.000

Variables name:

T = time 1 year
QW = quantity of whitefish
PWD = price of whitefish deflated
QT = quantity of lake trout
PTD = price of lake trout deflated
PBD = price of beef deflated
PCFD = price of canned fish deflated
DICD = disposable income per capita deflated
PSD = price of shrimp deflated
PFLD = price of flounder deflated
PCD = price of cod deflated
PFID = price of fillets deflated
PSTD = price of steaks deflated
WTE = whitefish total effort
WCPE = whitefish catch per unit of effort
QWM = quantity of whitefish from Michigan Great Lakes subtracted from US Great Lakes
QWG = quantity of whitefish Michigan Great Lakes subtracted from the whole Great Lakes
PGD = price of gasoline deflated
PWD1 = lag one year of price of whitefish deflated
QCH = quantity of chubs
PCHD = price of chubs deflated
PCHD1 = lag one year of price of chubs deflated
PHD = price of ocean herring deflated
CHTE = chubs total effort
CHCPE = chubs catch per unit of effort
QCHM = quantity of chubs from Michigan Great Lakes subtracted from US Great Lakes
QCHG = quantity of chubs from Michigan Great Lakes subtracted from the whole Great Lakes
PPD = price of perch deflated
QP = quantity of perch
PPD1 = lag one year of price of perch deflated
POPD = price of ocean perch deflated
PSCD = price of scallops deflated
PTE = perch total effort
PCPE = perch catch per unit of effort
QDM = quantity of perch from Michigan Great Lakes subtracted from US Great Lakes
QPG = quantity of perch from Michigan Great Lakes subtracted from the whole Great Lakes
PCATD = price of catfish deflated
QCAT = quantity of catfish
PCAD1 = lag one year of price of catfish deflated
CATE = catfish total effort

CACPE = catfish catch per unit of effort
QCAM = quantity of catfish from Michigan Great Lakes subtracted from US Great Lakes
QCAG = quantity of catfish from Michigan Great Lakes subtracted from the whole Great Lakes
QAL = quantity of alewife
PALD = price of alewife deflated
PALD1 = lag one year of price of alewife deflated
ALTE = alewife total effort
ALCPE = alewife catch per unit of effort
QALM = quantity of alewife from Michigan Great Lakes subtracted from US Great Lakes
WTEG = whitefish total effort with gillnet
WCEG = whitefish catch per unit of effort with gillnet

inefficient estimators. This is due to the fact that the dependence among the disturbances reduces the effective number of independent pieces of information in the sample (Kmenta, 1971). Therefore, to check serial correlation in the model, a Durbin-Watson test is employed. To apply this test, the value the value of statistic "d" is calculated by:

$$d = \frac{\sum_{t=2}^{T} (e_t - e_{t-1})^2}{\sum_{t=1}^{T} e_t^2}$$

where e is the ordinary least squares residual. Then the calculated "d" value is compared with the table value. The decision rules are:

if $d > d_u$; the hypothesis of no serial correlation is accepted.

if $d < d_L$; the hypothesis of no serial correlation is rejected.

if $d_L \leq d \leq d_u$; the test is inconclusive (the hypothesis is neither accepted nor rejected).

d_u = value of d for upper limit

d_L = value of d for lower limit

Estimates Using the Single Equation Method

In estimating demand and supply functions for each species with different models and techniques, many combinations of variables were tried. For each final equation presented the number of runs attempted for each equation varied from 10 to 60 runs each. The equation yielding the most satisfactory result was then selected as the best estimate.

Demand Estimations

Whitefish

A number of combinations of variables were used to estimate the demand function of whitefish. Equation (6.1) in Table VI-5 was selected as the best estimate from among the other equations. The quantity of whitefish, as well as the price, were placed as dependent variables. Most of the signs of the coefficient parameters in equation (6.1) are as expected except for the deflated price of fillet (PFID), used as a substitute for whitefish consumption. The sign of the fillet price parameter is expected to be positive. The sign of coefficients of the deflated price of shrimp (PSD) and disposable income per capita (DICD) are positive, as expected. The negative relationship between the quantity of fish demanded and the deflated price of whitefish indicates that any increase in price will decrease the quantity of whitefish demanded. The coefficient for the price of whitefish from the estimator is significant at the .01 level. The direction of quantity changes is also consistent with the change in income, where increases in income are associated with positive changes in quantity. This is also shown in terms of price elasticity. Equation (6.1) yields a fairly high price elasticity of -2.38 at the mean value. Use of 1973-1982 average values lead to a price elasticity estimate of -1.24. The fact that both of these estimates result in absolute values greater than one indicates that the fishermen would be able to land more whitefish and would be willing to receive lower prices which would result in higher total revenues. Price income elasticity is also high, 1.4 at the mean values. However, it drops to only 0.6 if 1973-1982 average values are used.

Table VI-5. The Estimated Demand Functions for Several Fish Species on Michigan Great Lakes Commercial Fishery with Ordinary Least Squares

Whitefish

$$QW = 7111963 - 4699468\ PWD + 894549\ PSD - 1993891\ PFID + 452.6\ DICD \qquad (6.1)$$

(2.4) (6.2) (1.3) (1.9) (1.3)

$R^2 = 0.907$ D-W Statistics = 1.57 F Statistics = 44.2

Chubs

$$QCH = 8525001 - 2372964\ PCHD + 3958459\ PBD + 2171910\ PCFD - 1512\ DICD \qquad (6.2)$$

(3.2) (2.8) (2.7) (2.7) (7.2)

$R^2 = 0.91$ D-W = 1.99 F = 42.9

Perch

$$QP = 3044476 - 1202093\ PPD + 151642\ PSD - 526050\ PSCD \qquad (6.3)$$

(6.2) (1.4) (0.3) (3.6)

$R^2 = 0.73$ D-W = 1.76 F = 15.9

Catfish

$$QCAT = 807043 - 867364\ PCATD + 32818\ PSTD + 58923\ PBD \qquad (6.4)$$

(2.9) (5.9) (1.0) (0.4)

$R^2 = 0.81$ D-W = 1.47 F = 26.0

Alewife

$$QAL = 2031991300 - 36043716\ PALD - 9670131\ PBD + 5461\ DICD - 1045593\ Year \qquad (6.5)$$

(4.1) (0.8) (1.9) (3.6) (4.1)

$R^2 = 0.57$ D-W = 1.25 F = 4.7

Note: Numbers in parenthesis are "t" values.

Cross price elasticity of demand with shrimp was 0.4 indicating that as the price of shrimp increases by one percent, the quantity of whitefish demanded at the dockside increases by 0.4 percent.

Chubs

The demand function for chubs was estimated using equation (6.2). The coefficient for chub price is significant at the .01 level. The quantity of chubs has a negative relationship with price and a positive relationship with the price of substitute goods, namely beef and canned fish, as expected. However, the negative sign of income per capita was unexpected. Various combinations of variables were examined, but none yielded a positive sign with respect to income. Price elasticity of demand for chubs is -0.51. Using 1973-1982 averages, price elasticity increased to -1.66. Cross price elasticity of demand with beef was rather high at 1.48. Similarly, the cross price elasticity with canned fish was 1.34 at the mean value.

Perch

The demand function as shown in equation (6.3) is the best estimate from the various estimates examined on perch, where the coefficient for the price of perch is significant at the .10 level. The sign of the coefficients, except for scallop price (PSCD), were as expected. Other combinations, which include the income per capita as the independent variable were examined, but all resulted in unexpected negative relationships between income and the quantity of perch demanded. Only 73 percent of the variation in the quantity of perch demanded is explained by the variable in the equation, however, there is no serial correlation occurring in the estimate. The estimate of price elasticity of demand was -0.8 at the mean value. Using 1973-1982 averages, the price elasticity increased drastically to -4.125. This increase was probably caused by the substantial decrease in perch landings due to restrictions imposed by MDNR in the 1970's to prevent further deterioration of the yellow perch stocks. It seems, therefore, that the small increases in the price of perch generates a huge decrease in the quantity of perch demanded.

Catfish

The estimate of the demand function for catfish is shown in equation (6.4). The level of significance for the price of catfish is .01. All the signs shown in this equation were expected. Other combinations of variables which included income per capita were also examined, but those equations did not give better estimates. The price elasticity of demand for catfish was -1.93 at the mean value. Cross price elasticity with fish steaks was 0.24; and cross price elasticity with beef was 0.21. These results which gave positive cross elasticity for the substitute products were expected. If the 1973-1982 average value was used, then the price elasticity of catfish demand decreased slightly to -1.18, still in the elastic range.

Alewife

The demand function for alewife was estimated by equation (6.5). All signs from the coefficient parameters in this equation were satisfactory. Quantity of alewife demanded has a negative relationship with its own price. Beef (PBD) has a complementary relationship with alewife rather than substitute. This is due to the fact that humans consume alewife indirectly through beef or poultry stocks which use alewife as their food. Alewife has a negative relationship with the price of beef in this case. Price elasticity of demand was a -0.28. Cross price elasticity with beef was -2.7. Income elasticity was fairly high at 10.8. Again, this might be caused by an increase in income which increases the demand for alewife as food for livestock, poultry, as well as other animals and pets. In spite of low R^2 and D-W tests which yield inconclusive results on whether or not to accept the hypothesis of no serial correlation in the estimation, all the signs of this estimate were expected. The coefficient for alewife price is not significant at the .10 level.

Supply Estimations

Whitefish

As in the case of demand estimation, various combinations of variables were also examined in estimating the supply functions of whitefish. Equation (6.6) in Table VI-6 was selected as the best estimate. The quantity of whitefish supplied has a positive relationship with the deflated price of whitefish, as expected. It was expected that the price of gasoline (PGD) would have a negative coefficient, however, it turned out to be positive. Even though the price of lake trout (PTD) was expected to have a negative sign as a substitute for whitefish the sign was positive. This result can be explained. The fishermen catch lake trout together with whitefish using the same nets. This was generally considered an incidental catch when

Table VI-6. The Estimated Supply Functions for Several Fish Species on Michigan Great Lakes Commercial Fishery with Ordinary Least Squares

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<u>Whitefish</u>

QW = -5282190 + 398017 FWD + 1751820 PGD + 206017 PTD + 165.6 WTE + 16433 WCPE (6.6)
(3.7) (0.7) (4.1) (0.7) (7.4) (7.7)

R^2 = 0.98 D-W = 1.44 F = 192.5

<u>Chubs</u>

QCH = 5100214 + 1081973 PCHD - 3259661 $PCHD_{t-1}$ + 1765519 FWD - 3685902 PPD - 607797 PGD (6.7)
(1.3) (0.62) (2.7) (1.3) (1.45) (0.35)

R^2 = 0.81 D-W = 1.81 F = 14.4

<u>Perch</u>

QP = 3106155 + 671583 PPD + 23.2 PTE + 21273 PCPE + 1844737 PCATD + 981975 PGD - 397518 PCHD + 0.035 QPM - 0.006 QPG (6.8)
(1.7) (0.74) (7.3) (3.7) (1.7) (1.6) (0.9) (0.6) (0.3)

R^2 = 0.95 D-W = 2.47 F = 13.2

<u>Catfish</u>

PCATD = 1.14 - 0.38 x 10^{-6} QCAT - 0.001 CACPE - 0.294 PGD + 0.32 x 10^{-7} QP + 0.43 x 10^{-6} CATE (6.9)
(12.2) (2.7) (1.0) (2.5) (1.77)

R^2 = 0.90 D-W = 1.85 F = 31.7

<u>Alewife</u>

PALD = 0.066 + 0.469 x 10^{-8} QAL - 0.0036 PGD - 0.63 x 10^{-9} QALM - 0.368 x 10^{-5} ALCPE - 0.186 x 10^{-4} ALTE (6.10)
(2.2) (1.35) (0.13) (1.6) (2.6) (1.5)

R^2 = 0.60 D-W = 1.4 F = 3.8

Note: Numbers in parenthesis are "t" values.

government regulation began to restrict lake trout catches for commercial fishing. The positive sign then, is not really unexpected, since lake trout could also be considered as a complement to whitefish. The positive signs of the total effort (WTE) and catch per unit of effort (WCPE) parameters were expected. This indicates that when WCPE and WTE increased, the number of whitefish caught also increases. Price elasticity of supply of whitefish was 0.2. The total effort elasticity of supply was 0.83. Indicating that each percent increase in fishing effort will increase the fish caught by 0.83 percent.

Chubs

The chub supply function was estimated by equation (6.7). The quantity of fish supplied has a positive relationship with its own price (PCHD). The negative relationship with the price of gasoline (PGD) and price of the perch (PPD) were expected, but not so with the negative sign of a one year lag in the price of chubs and a positive sign of price of whitefish (PWD). Price elasticity of chubs was 0.23 using the mean value but increased to 0.76 if the 1973-1982 average value was used. Cross elasticity of supply with perch was -0.74. This magnitude increased substantially to -2.38 (in absolute value) if the 1973-1982 average value was used.

Perch

Equation (6.8) was the estimate of supply function for perch. Most of the signs for parameter coefficients in this estimate were expected except for the price of gasoline (PGD) and the price of catfish deflated

(PCATD). The price elasticity of supply was 0.44. Cross price elasticity with chubs was -0.28. Total effort elasticity was 0.67.

Catfish

The supply function estimate for catfish did not satisfy any expectation. Various combinations of variables were examined, unfortunately none yielded a positively sloped supply curve. One of the example equations used to estimate catfish supply is presented in equation (6.9).

Alewife

The best estimation for the supply function of alewife is shown in equation (6.10), although only about sixty percent of the variation in the quantity of alewife supplied was explained by the independent variables (the regressors). Price flexibility of supply was 0.6 which can be used to approximate the elasticity of supply by taking the inverse of this flexibility coefficient which results in a magnitude of 1.67. Except alewife, all coefficients for prices of whitefish, chubs, and perch are not significant at the .10 level.

Estimates Using Simultaneous Equations Method

Several techniques from simultaneous equation methods were used to estimate demand and supply of commercial fisheries in Michigan.

Reduced Form

In situations where the system of demand and supply equations for each fish species was just identified, the reduced form technique was used to estimate the structural parameters of demand and supply. This means that every endogenous variable (dependent variable) is expressed as a function of all exogenous variables in the system. Thus, no endogenous variables appear as the independent variables. Each reduced form equation was estimated by ordinary least squares (OLS). The estimates of the reduced form parameters were then calculated to obtain the estimates of the structural parameters (original demand and supply functions). The estimated original demand and supply for whitefish, perch and catfish as well as reduced form equations, are presented in Table VI-7. The estimates for whitefish demand and supply functions in equations (6.13) and (6.14) were derived from equations (6.11) and 6.12). The estimated demand (6.13) gives all the expected signs with regard to price and income. However, the supply equation (6.14) yields a negatively sloped curve with respect to its own quantity. Other combinations of variables were also examined, but most yielded similar results.

The estimate for chubs using the reduced form technique did not give satisfactory results. Using total effort and deflated income per capita as predetermined variables gave a positive slope of demand and negative slope of supply in the original structural equation, the opposite of what was expected. The estimate for perch, seen in equations (6.15); (6.16); (6.17); and (6.18), did not give a

Table VI-7. The Estimated Demand and Supply Functions for Several Fish Species Using the Reduced Form Method

Whitefish

Reduced Form

$QW = -528197 - 1010032.7\ PWD_{t-1} + 1114.26\ DICD$ (6.11)

$PWD = 3.12 + 0.1235\ PWD_{t-1} - 0.000229\ DICD$ (6.12)

Structural Equation

Demand $QW = 30801811 - 8178402\ PWD + 3028\ DICD$ (6.13)

Supply $PWD = -2.01 - 2.1 \times 10^{-7}\ QW + 0.336\ PWD_{t-1}$ (6.14)

Perch

Reduced Form

$QP = 6262198 - 413143\ PPD_{t-1} - 602.2\ DICD$ (6.15)

$PPD = -0.341 + 0.327\ PPD_{t-1} + 0.938 \times 10^{-4}\ DICD$ (6.16)

Structural Equation

Demand $QP = 5831367 - 1263434\ PPD - 483.6\ DICD$ (6.17)

Supply $PPD = -0.636 - 0.156 \times 10^{-6}\ QP + 0.263\ PPD_{t-1}$ (6.18)

Catfish

Reduced Form

$QCAT = -497264 + 3.672\ CATE + 90.82\ DICD$ (6.19)

$PCATD = 1.573 - 0.324 \times 10^{-5}\ CATE - 0.949 \times 10^{-4}\ DICD$ (6.20)

Structural Equation

Demand $QCAT = 1285469 - 1133333\ PCATD - 16.71\ DICD$ (6.21)

Supply $PCATD = 1.053 - 0.1045 \times 10^{-5}\ QCAT + 0.596 \times 10^{-6}\ CATE$ (6.22) satisfactory result except for the quantity price relationship in the demand equation of the structural form (6.17). The estimate for catfish yields unsatisfactory results also. None of the estimates gave the expected signs as shown in equations (6.21) and (6.22). Although demand estimates gave a negative slope of the demand curve, a negative sign on income parameters was not expected. Other combinations of variables were also examined, but none of the estimates gave a better result. Due to the limitations of the data and information on alewife species, there was no simultaneous equation method examined for alewife.

Indirect Least Squares

The estimate of demand and supply functions using indirect least squares (ILS) technique was obtained by inserting the estimates of the parameters from the reduced form into structural equations. The endogeneous (dependent) variable coefficients estimated in the reduced form were substituted into the structural equations; then the parameter coefficients from the structural equations could be estimated.

Under just-identified conditions as used in the estimation of demand and supply, ILS technique gave a result equivalent to the estimates using the Two Stage Least Squares (2SLS) method. The differences in the parameter coefficients between the estimates using these two methods was caused by a rounding error such as shown between equations (6.23) and (6.24), which represents the demand and supply estimates for perch, with equations (6.31) and (6.32), to be presented below.

$$QP = 5831873 - 1263433\ PPD - 483.7\ DICD \qquad (6.23)$$

$$PPD = 0.635 - 0.156 \times 10^{-6}\ QP + 0.263\ PPD_{t-1} \qquad (6.24)$$

Therefore, this study presents only the estimates using 2SLS method with the just-identified case.

Two and Three Stage Least Squares (2SLS and 3SLS)

Under the just-identified condition, estimation using two and three stage least squares techniques gave identical results. Equations (6.25) and (6.26) in Table VI-8 are the demand and supply equations for whitefish estimated by 2SLS and 3SLS. Another combination, such as equations (6.27) and (6.28), used income per capita and total effort as the exogeneous variables. Both of these estimates gave negatively sloped supply curves. The demand function, as estimated by equation (6.25), gave satisfactory results where the deflated price of whitefish coefficient had a negative sign and the deflated price of lake trout, as substitute for whitefish, had a positive sign. However, demand estimated by equation (6.27) did not give the expected sign for the income parameter. The estimate of chub demand and supply, as shown in equations (6.29) and (6.30), gave the expected result for demand, but not for supply. The supply function has a negative slope. The same results were obtained in the estimation of the demand and supply of perch and catfish as shown in equations (6.31), (6.32), (6.33), and (6.34). The supply functions for both species have negative slopes. Income parameters in both demand equations gave unexpected negative signs.

Table VI-8. The Estimated Demand and Supply Functions for Several Fish Species Using Two and Three Stage Least Squares (2SLS and 3SLS) Method (With Just-Identified Case)

Whitefish

Demand $QW = 12139038 - 14712698\ PWD + 7048540\ PTD$ (6.25)

Supply $PWD = 1.85 - 0.221 \times 10^{-6}\ QW + 0.654 \times 10^{-6}\ QT$ (6.26)

Demand $QW = 16572644 - 7096133\ PWD - 498.6\ DICD$ (6.27)

Supply $PWD = 1.7 - 0.258 \times 10^{-6}\ QW + 0.266 \times 10^{-4}\ WTE$ (6.28)

Chubs

Demand $PCHD = 0.734 - 0.474 \times 10^{-7}\ QCH + 1.06\ PHD$ (6.29)

Supply $QCH = 4187284 - 6585434\ PCHD + 2549048\ PWD$ (6.30)

Perch

Demand $QP = 5831797 - 1263567\ PPD - 483.6\ DICD$ (6.31)

Supply $PPD = 0.635 - 0.156 \times 10^{-6}\ QP + 0.263\ PPD_{t-1}$ (6.32)

Catfish

Demand $QCAT = 1344684 - 1175357\ PCATD - 20.1\ DICD$ (6.33)

Supply $PCATD = 1.15 - 0.109 \times 10^{-5}\ QCAT - 0.107\ PCATD_{t-1}$ (6.34)

Adding more variables into the just-identified equation system will create an over-identification case which can be estimated by 2SLS and 3SLS techniques. Similar results in parameter coefficient estimates were obtained from the 2SLS and 3SLS techniques, except for the magnitudes of the parameter coefficients. There were no differences in the signs of coefficients between these two estimates. However, since three stage least squares estimators are more efficient than 2SLS, only 3SLS will be presented in this study. From the estimates, except for perch and catfish, all species have postively sloped supply functions as can be seen in the results of equations (6.36), (6.38), and (6.44) (Table VI-9). Moreover, the coefficients for price of whitefish and quantity of alewife in the supply functions are significant at the .05 level. The coefficient of chub price, however, is not significant at the .10 level, although it was more significant than that estimated by the single equation method. The estimates using the four equation system for whitefish and catfish as shown in equations (6.45) through (6.52) in Table VI-10 did not give expected results. Positive relationships between the price and quantity in the supply functions were not obtained from these estimates. The estimates using 2SLS and 3SLS did not show R^2 because R^2 is not meaningful in this method, and SPSS does not estimate R^2 values for 2SLS and 3SLS.

Only the single equation and 3SLS methods gave positively sloping supply functions for whitefish, chubs, and alewife species. The reasons that the other methods did not give the expected results are not clear, despite the fact that the variables have been specified according to the best available information. The results can be caused by factors other than costs and prices that affected the availability of fish, but were

Table VI-9. The Estimated Demand and Supply Functions for Several Fish Species Using Two and Three Stage Least Squares (2SLS and 3SLS) Method (With Over-Identified Case)

Whitefish

Demand $QW = 9528834 - 5708355\ PWD + 297356\ PSD - 1859269\ PFID + 730443\ PBD + 286\ DICD$ (6.35)

(2.1) (4.47) (3.4) (1.56) (4.97)

Supply $QW = 117745 + 615967\ PWD - 1739062\ PTD + 777583\ PGD + 5633\ WCPE + 185\ WTE$

(3.86) (2.19) (1.19) (6.09) (1.94) (1.93) (6.36)

Chubs

Demand $QCH = 6481854 - 4186541\ PCHD + 4328013\ PBD + 3934575\ PCFD - 1594\ DICD$

(2.19) (3.47) (2.74) (2.77) (5.75) (6.37)

Supply $QCH = 5835477 + 3960452\ PCHD - 4484195\ PCHD_{t-1} + 1080317\ PWD - 6167263\ PPD$

(1.71) (1.25) (2.59) (6.67) (1.78) (6.38)

Perch

Demand $QP = 3314867 - 3798355\ PPD + 298287\ PSD - 93473\ PSCD$

(6.58) (1.77) (3.41) (4.68) (6.39)

Supply $QP = 2835116 - 375580\ PPD + 384429\ PCATD + 2608343\ PGD$

(3.95) (1.44) (8.11) (1.19) (6.40)

Catfish

Demand $QCAT = 795647 - 879162\ PCATD + 28702\ PSTD + 80076\ PBD$

(2.5) (4.42) (8.28) (7.83) (6.41)

Supply $QCAT = 2010226 - 1653290\ PCATD - 189960\ PPD - 365003\ PGD$

(1.5) (1.8) (7.19) (7.23) (6.42)

Alewife

Demand $QAL = 2204931100 - 30611176\ PALD - 7315562\ PBD + 5516\ DICD - 1135008\ YEAR$ (6.43)

(3.7) (4.4) (9.6) (2.6) (3.65)

Supply $PALD = 0.06 + 0.198 \times 10^{-8}\ QAL - 0.008\ PGD - 0.32 \times 10\text{-}5\ ALCPE - 0.51 \times 10^{-9}\ QALM$ (6.44)

(1.27) (2.1) (3.3) (1.95) (1.51)

Note: Numbers in parenthesis are "t" values.

Table VI-10. The Estimated Demand and Supply Functions for Several Fish Species Using Two and Three Stage Least Squares (2SLS and 3SLS) Method (With Four-Equation Systems).

<u>Whitefish</u>

<u>Three Stage Least Squares</u>

Demand QW = 13476628 - 11531148 PWD + 4629504 PTD + 1209067 PFID - 447.2 DICD (6.45)

Supply PWD = 1.89 - 0.216 x 10^{-6} QW + 0.378 x 10^{-6} QT + 0.263 x 10^{-3} WCPE + 0.149 PGD (6.46)

Demand QT = 2202089 + 482383 PTD - 1260059 PWD - 126.9 DICD + 42020 PCATD (6.47)

Supply PTD = 1.82 + 1135584 QT = 25462299 QW + 0.137 PGD + 0.129 x 10^{-7}QCH (6.48)

<u>Catfish</u>

<u>Three Stage Least Squares</u>

Demand QCAT = 1398813 - 1163748 PCATD - 174434 PWD - 68.8 DICD + 167339 PTD + 232326 PFID (6.49)

Supply PCATD = 1.07 - 0.414 x 10^{-6} QCAT + 0.521 x 10^{-7} QP - 0.17 PGD - 0.0017 CACPE - 0.62 x 10^{-5} QCAH (6.50)

Demand QW = 11302719 - 5695366 PWD + 269 DICD - 135781 PTD - 2886799 PFID + 4307978 PCD (6.51)

Supply PPD = 1.06 - 0.397 x 10^{-7} QP + 0.113 x 10^{-5} QCAT - 0.368 x 10^{-7} QCH - 0.377 PCPE - 0.61 PGD (6.52) not incorporated into the model. There are many structural changes in the Michigan Great Lakes commercial fisheries system which could not be accomodated into the model. Environmental changes such as water pollution by DDT, PCB, mercury and other pollutants could not be specified explicitly in the model. Therefore, it is not possible to osberve what effects these changes would have on the supply and demand of commercial fisheries. Public policy and regulations also could not be incorporated into the model, although these factors are believe to have a strong influence on the commercial fish supply and demand. The model in this study analyzed the overall (aggregate) effects of all these factors on demand and supply without disaggregating the individual effect of each factor.

There is also a possibility that the supply curves of these commercial fisheries might actually slope backwards, as discussed by Crutchfield and Pontecorvo, 1969; Copes, 1970; and Clark, 1976. In this case, the estimated supply can be positive in the lower portion of the supply curve, and negative in the higher portion of the supply curve.

Elasticities and Flexibilities

Price elasticity of demand can be defined as the percentage change in quantity resulting from a given percentage change in price. Price-quantity flexibility, on the other hand, shows the percentage change in price resulting from a given percent change in the quantity (given that the effects of other variables on price remain constant). Price flexibility is often treated as the inverse of elasticity. Cato (1976) and Ghanbari (1977) in their studies used the inverse of price elasticity (price flexibility) to approximate price flexibility (price elasticity). There is an advantage to examining the price quantity relationship from different aspects, such as by approximation of price-elasticities from the price-quantity flexibilities. This will allow measurements and comparisons of the effect on total revenues from production increases and decreases to be made.

On the other hand, to know the price flexibility coefficient will also be important for certain products that by their biological nature are fixed in supply, such as certain agricultural and fish products. For these products the important information is the effects on price of given production levels. Hence, in this study, the inverses of the relationships (elasticities and flexibilities) are also employed. In Table VI-11, all elasticities and flexibilities which have been estimated from the single equation model are summarized. It should also be noted that very little significance can be found in the estimation of supply elasticities. Most of these estimates are derived from the parameter coefficients which have very low t values as shown in Table VI-6. Demand elasticities on the other hand, except for alewife, were derived from the coefficients which had high t values, with the significance levels were between .01 and .10.

The various estimations of demand elasticity coefficients on whitefish and catfish show that using different average values resulted in different elasticity coefficients. Using longer periods of average value gave larger elasticities. Conversely, for chubs and perch, the longer the period of average value used, the smaller the elasticity coefficients. This might occur because both commodity groups had different trends in production and price. Whitefish and catfish had increasing trends in production and decreasing trends in price, while

Table VI-11. Demand and Supply Elasticities for Several Fish Species from Michiga'sn Great Lakes

Method	Whitefish		Chubs		Perch		Catfish		Alewife	
	Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply
<u>Single Equation Method</u>										
Price Elasticity	-2.38	0.2	-0.51	0.23	-0.80	0.44	-1.93	----	-0.28	1.66*
1973-1982 Average Value	-1.24	0.11	-1.66	0.76	-4.125	2.30	-1.18	----		
1982 Value	-0.43	----								
Income Elasticity	1.4								10.8	
1973-1982 Average Value	0.6									
Beef Cross Price Elasticity			1.48				0.21		-2.7	
Canned Fish Cross Price Elasticity			1.34							
Perch Cross Price Elasticity				-0.74						
Shrimp Cross Price Elasticity	0.4				0.18					
Chubs Cross Price Elasticity						-0.28				
Steaks Cross Price Elasticity							0.24			
Price Flexibility		5.0*		4.34*		2.27*				0.60
Total Effort Elasticity	----	0.83			----	0.67				

Note: *Elasticities/Flexibilities which are approximated by the inverse of price flexibilities/price elasticities.
Unless specified, all values are calculated at mean values.

chubs and perch had increasing trends in price and decreasing trends in production. This situation might have shifted the equilibrium point of whitefish and catfish to the less elastic part of the demand curve (Figures IV-2 and IV-8), while chubs and perch shifted to the more elastic part of the demand curve (Figures IV-4 and IV-6). The magnitudes of the demand and supply elasticities which were estimated by the 3SLS method are shown in Table VI-12. The demand price elasticities estimated through 3SLS yielded larger coefficients than those estimated using the single equation method, except for alewife. Similarly, the supply price elaticity coefficients estimated by 3SLS also yielded higher supply elasticities.

Most of the supply price elasticities were low or inelastic. This might indicate that the fishermen (fishery industry) are not very responsive to market price changes. This implies that the commercial fishermen have been responding to the availability of fish, not to price. Therefore, fishermen have functioned as price takers. Ghanbari (1977) also indicated this supposition in his study on whitefish in the Great Lakes, as did Cato (1976) in his study of mullet fishermen in Florida.

Social Surplus (Net all-or-none Value) of Several Fish Species from Michigan Commercial Fisheries

"Social surplus" (net all-or-none value) is divided into two parts: consumer surplus and producer surplus. The "consumer surplus" is the net advantage of consumers able to buy a certain unit of a commodity at the equilibrium price P*, when they are willing to pay higher prices

Table VI-12. Demand and Supply Elasticities for Several Fish Species from Michigan's Great Lakes (Estimated by 2SLS and 3SLS Methods)

	Elasticities/Flexibilities									
	Whitefish		Chubs		Perch		Catfish		Alewife	
Method	Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply
<u>Simultaneous Equation Method</u>										
Price Elasticity	-2.89	0.31	-0.90	0.85	-2.51		-1.96		-0.24	4.0*
Income Elasticity	0.89								10.9	
Beef Cross Price Elasticity	0.32		1.6				0.29		-2.0	
Canned Fish Cross Price Elasticity			2.42							
Perch Cross Price Elasticity				-1.24						
Shrimp Cross Price Elasticity	0.13				0.36					
Chubs Cross Price Elasticity										
Trout Cross Price Elasticity		-0.98								
Steaks Cross Price Elasticity							0.21			
Total Effort Elasticity		0.93								
Price Flexibility		3.23*		1.18*						0.25

Note: *Elasticities or Flexibilities which are approximated by the inverse of price flexibilities or price elasticity.

(Hirshleifer, 1976). The consumer surplus is an area lying beneath the demand curve D but above the horizontal line through equilibrium price P*. The "producer surplus", on the other hand, is the net gain to producers able to sell at prices as high as P* when they would have been willing to sell a smaller number of commodities at lower prices. The producer surplus is the area lying above supply curve S but below P*B (see Figure VI-1). The area ABCO is the social surplus: the sum of consumer surplus (area ABP*) and producer surplus (area P*BCO). The value of social surplus can be estimated either by a geometric or calculus approach.

Whitefish

Since the estimates of the demand and supply were linear, a geometric approach will be used to measure the values of social surplus in this study. However, to measure these values, the demand and supply equations must be solved first, by taking them simultaneously. Solving equations (6.1) and (6.6) by substituting the mean values for the independent variables, the following equations are obtained:

$$\text{Demand: } QW = 9103384 - 4699468\ PWD \qquad (6.53)$$

$$\text{Supply: } QW = 1979994 + 398017\ PWD \qquad (6.54)$$

By solving equations (6.53) and (6.54) simultaneously, two equations with two unknowns, the equilibrium quantity and price can be estimated as 2,500,000 pounds of whitefish at a price of $1.40 per pound. By plotting equations (6.51) and 6.52) into the graph in Figure VI-1, the social surplus can then be measured.

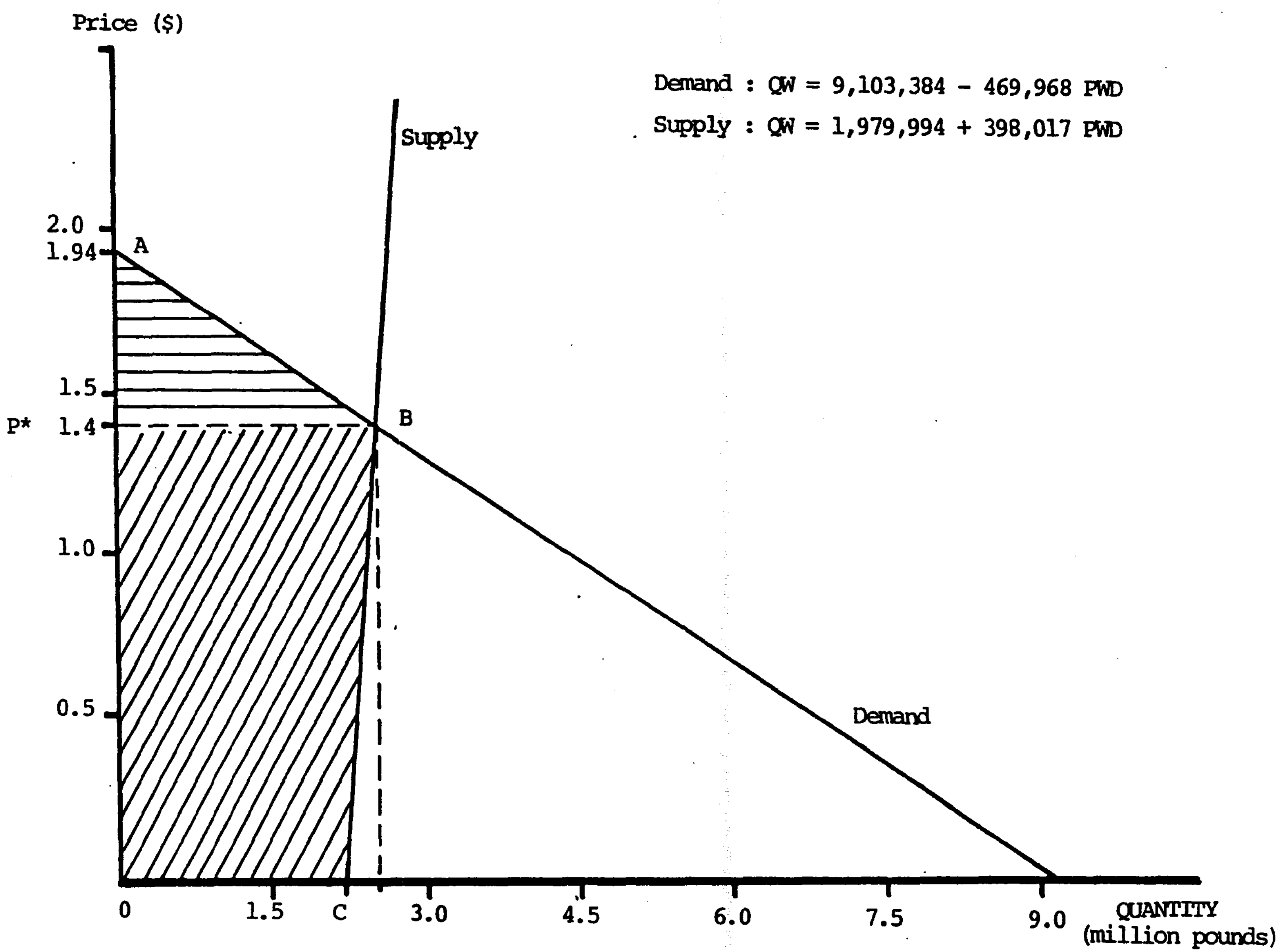

Figure VI-1. Estimated Demand and Supply Curves, Social Surplus of Whitefish from Michigan Great Lakes Waters

Consumer Surplus (area ABP*) = $ 675,000

Producer Surplus (area OP*BC) = $3,150,000

Social Surplus (Net all-or-none value) = $3,825,000

The social surplus obtained from this estimate was the surplus gained on the average, annually, during the 1960-1982 period based on the 1982 price of whitefish.

Chubs

Following the same procedure, the social surplus from chubs can be estimated. Substituting the mean values into equations (6.2) and (6.7) results in equations:

$$\text{Demand: } QCH = 4795063 - 2372964\ PCHD \quad (6.55)$$

$$\text{Supply: } QCH = 3049211 + 1081973\ PCHD \quad (6.56)$$

Solving these equations simultaneously will give 3,600,000 pounds of chubs at a price of $0.50 per pound at the equilibrium. Plotting the results of equations (6.55) and (6.56) gives Figure VI-2. Estimates:

Consumer surplus = $ 2,700,000

Producer surplus = $ 1,662,500

Social Surplus (Net all-or-none value) = $ 4,362,500

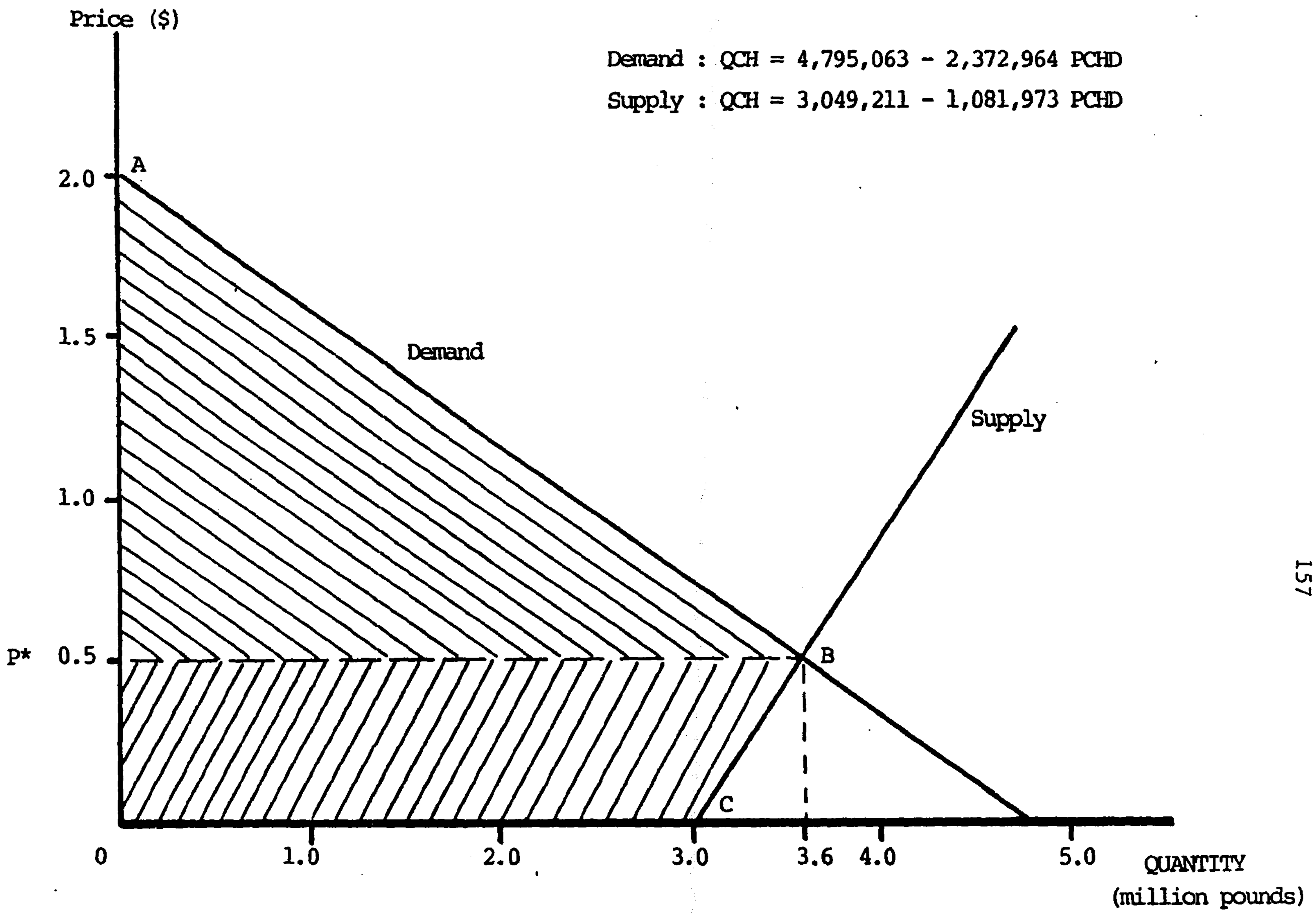

Figure VI-2. Estimated Demand and Suppy Curves, Social Surplus of Chubs from Michigan Great Lakes Waters

The average annual social surplus gained from chubs during the period 1960-1982 was $4,362,500.

Perch

Substituting the mean values from the independent variables in equations (6.3) and (6.8) would give the equations:

Demand: QP = 1740636 - 1202093 PPD (6.57)

Supply: QP = 795065 + 671583 PPD (6.58)

By solving equations (6.57) and (6.58) simultaneously the equilibrium quantity of 1,130,000 pounds at a price of $0.50 would be obtained. Then plotting equations (6.57) and (6.58) would result in Figure VI-3. The estimate of social surplus from perch was:

Consumer surplus	= $ 536,750
Producer surplus	= $ 482,500
Social surplus (Net all-or-none value)	= $1,019,250

This social surplus was also gained annually from perch during the 1960-1982 period.

Alewife

Substituting equations (6.5) and (6.10) with the mean values of the independent variables, results in:

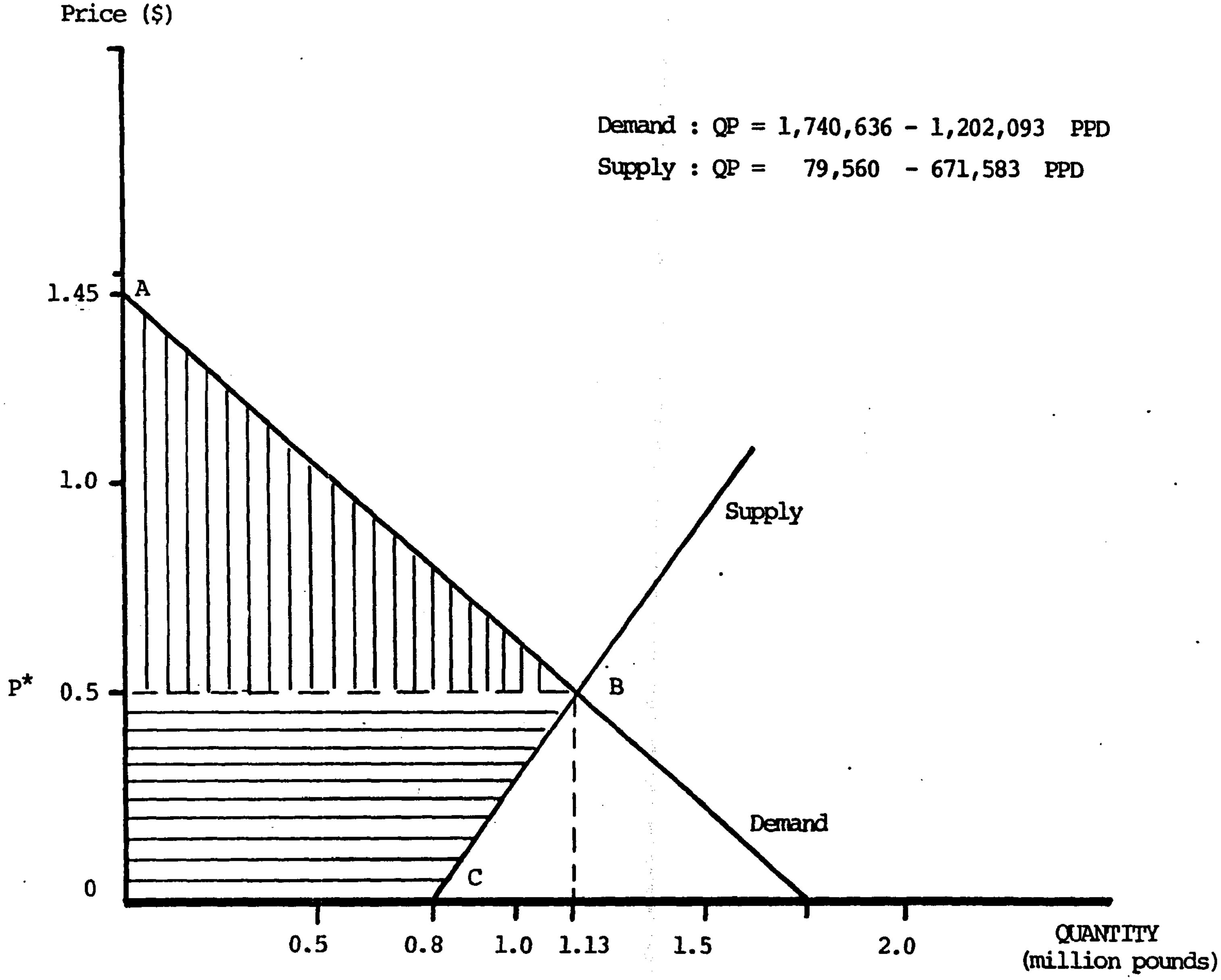

Figure VI-3. Estimated Demand and Supply Curves, Social Surplus of Perch from Michigan Great Lakes Waters

Demand: QAL = 5420650 - 36043716 PALD (6.59)

Supply: PALD = 0.02907 + 0.469 x 10^{-8} QAL (6.60)

Solving equations (6.59) and (6.60) simultaneously would provide an equilibrium price of $0.046 at a quantity of 3,740,684 pounds. These equations are plotted in Figure VI-4.

The social surplus gained from alewife was:

Consumer surplus	= $ 192,400
Producer surplus	= $ 31,450
Social surplus (Net all-or-none value)	= $ 223,850

Alewife contributed about $223,850 annually in terms of social surplus.

The social surplus from catfish was not estimated in this study since a satisfactory supply function could not be obtained. The estimate using equation (6.9) was examined (although it has a negative slope), but no equilibrium was obtained. The supply curve from equation (6.9) never intercepted the demand curve of equation (6.4).

Since the estimated supply curves of whitefish, chubs, and perch intersected the horizontal axis at positive quantity, the estimated producer surplus might have been high. Adjustments were made by assuming supply curves began at the point of origin. Therefore, more realistic producer surplus estimates were obtained. The adjusted producer surplus estimates were $1,750, $950 and $280 thousands for whitefish, chubs and perch, respectively.

The demand and supply of commercial fisheries might change over time. Any shifting in the demand and supply functions will affect the

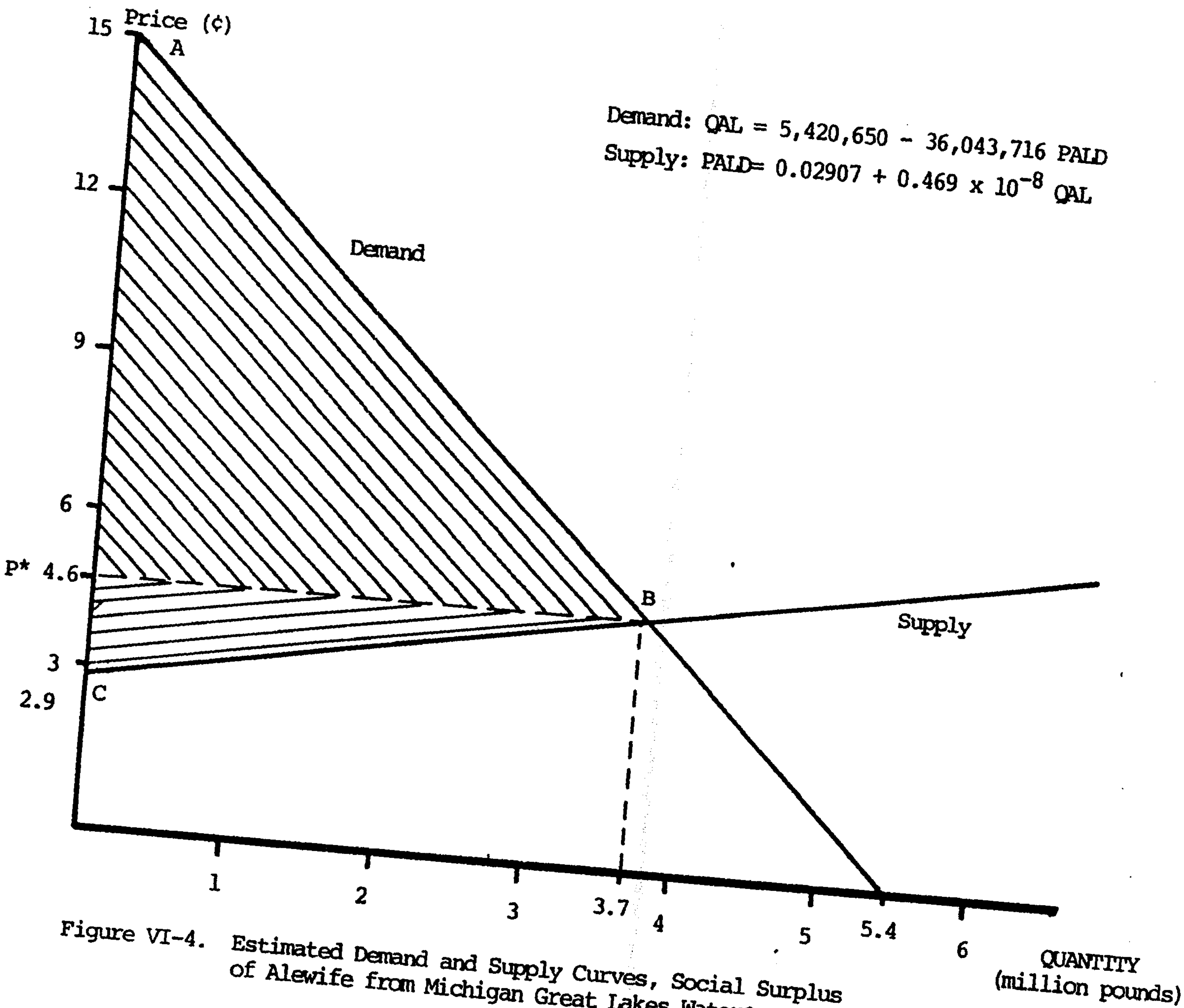

Figure VI-4. Estimated Demand and Supply Curves, Social Surplus of Alewife from Michigan Great Lakes Waters magnitude of social surpluses. If the changes caused an expansion in the social surplus, the welfare of society will increase. On the other hand, any contraction in the social surplus will reduce the welfare of society as the whole.

CHAPTER VII

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

As the world population has grown, world demand for fish as a nutrition source has also increased substantially. This, in effect, has put more pressure on marine fish stocks. World fish production over the last decade has leveled off while fishing effort increased. In the 1970's, world fish production increased by less than one percent, a decline from 6 percent in the 1960's. The basic cause of this decline appears to be the decrease of conventional fish species whose stocks might have collapsed, providing much lower yields. Aside from that, about 35 percent of the fish caught, which is equivalent to 25 million tons, are lost annually during processing in developing countries. An attempt to increase fish production in the future, other than reducing post-harvest losses, will depend upon efforts to exploit unconventional fish species. The role of aquaculture, as well as fresh water fish production, can be expected to grow in the future, which might ease the pressure on marine fish stocks.

The Great Lakes are one of the largest fresh water resources in the world. Almost 40 percent half of their area is located within Michigan's jurisdiction. Michigan's Great Lakes could become an important resource in producing freshwater fish if there is a willingness to assume this role together with proper management and the support from state and other fishery concerns. Over the last hundred years, Michigan's waters have been very stable in producing freshwater fish. Annual total catch from Michigan waters was close to 30 million pounds over this period. However, the unique case in Michigan's Great Lakes is that while providing a stable yield, fish species composition has changed continuously. The abundance of many species has changed drastically. Some species which were abundant in the past collapsed, and new, less popular or smaller fish species have increased their level of abundance. Overfishing was considered among the most significant factors affecting the succession of several species in the Great Lakes. The invasion of sea lamprey into the Great Lakes caused more deterioration of the Great Lakes fishing situation. Most of the premium species populations, such as lake trout and whitefish, collapsed or were reduced by the sea lamprey. As a result, in 1942 the whitefish production in the Great Lakes dropped to 0.1 million pounds from over 4.1 million pounds in 1931. The lake trout mortality rate was estimated at about 70 percent annually. Commercial fishing then shifted to smaller species after the collapse of the premium species. The environmental degradation of the Great Lakes has further aggravated the problems of Great Lakes fisheries. The discharge of milling wastes from lumbering industries into the lakes, the construction of dams, deforestation of drainage basins, plant nutrient wastes, and the contamination by DDT, PCB, mercury and other poisons into the lake waters indicated the seriousness of the problems faced by Great Lakes fisheries. This situation did not only affect fish reproduction, but also caused fish contamination. The levels of contamination were found so high, especially in the late 1960's and 1970's, that consumption of the fish posed a danger for human health. Michigan residents were warned not to eat Great Lakes fish more than once a week.

The competition with sport fishing has further aggravated the deterioration of Michigan's commercial fisheries, since current public policy in Michigan tends to favor sport fishing. Many restrictions and regulations have been imposed on commercial fishing by the state. This was done not only to restore fish populations or to prevent overfishing, but also to give a more dominant role to sport fishing interests. This shift in emphasis is reflected in the amount of fish harvested by commercial fishermen. Commercial fish catches amount to only one-third of the sport fish catches of some sixty million pounds annually. License and gear restrictions, banning of gillnets, and zone restrictions for commercial fishing are among many of the regulations imposed by the Michigan Department of Natural Resources on commercial fisheries. Policy decisions regarding the management of commercial fishery resources would require the consideration of economic values in addition to biological aspects. The exclusion of economic values in the formulation of public policy may hamper efforts to attain efficiency in the utilization of fishery resources.

The main objective of this study was to provide information on the economic aspects of commercial fisheries. The effect of various factors on fish production over time were explored and documented, and the level of fish harvested at maximum sustainable yield (MSY) was estimated. Maximum effort devoted to fish harvests at MSY was also estimated. For whitefish, where cost data was available, maximum economic yield (MEY) and effort at MEY were also examined. To analyze which factors affected

Michigan fish prices, demand and supply equations were estimated for several Michigan fish commodities. These models were then applied to analyze the responses of buyers and sellers to price changes, as well as the potential social surplus gained from commercial fisheries.

To attain this objective, the study was divided into two sections. First, a bioeconomic model was developed for the biological side of the analysis. Linearization techniques were introduced to estimate bioeconomic parameters. The results were:

Whitefish. For the period 1960-1982, maximum sustainable yield was reached at 8.5 million pounds, and maximum economic yield was at 8.4 million pounds. Effort at MSY was 35,900 and 33,100 at MEY. Producer surplus at MSY was $9.18 million, and $9.2 million at MEY. The 1971-1982 data yielded different estimates. Maximum sustainable yield was 3.23 million pounds, and 2.77 million pounds at MEY. Effort at MSY was 66,000 units, and effort at MEY was 41,000 units. Producer surplus at MSY was $1.08 million, and $1.61 million at MEY.

Perch. Maximum sustainable yield was reached at 1.22 million pounds with 21,500 units of effort.

Catfish. About one million pounds of catfish might be harvested at MSY with 14,700 units of effort.

__Alewife__. Maximum sustainable yield occurred at 5.87 million pounds with 338 units of effort.

Second, the demand for and supply of several fish species were estimated using several regression techniques. Both single-equation and simultaneous equation methods were used. The single equation and 3SLS methods provided the most satisfactory results for demand and supply estimations. From those results price elasticity and flexibility of demand and supply were then derived and summarized, as shown in Tables VI-11 and VI-12.

The estimated demand and supply equations were also used to estimate social surplus (net all-or-none value) for several Michigan fish species. The results are summarized in Table VII-1.

Table VII-1. The Estimates of Social Surplus (net all-or-none value) for Several Commercial Fish Species in Michigan (in thousand dollars)

Species	Consumer Surplus (1)	Producer Surplus (2)	Producer Surplus (adjusted) (3)	Social Surplus (4)=(1)+(2)	Social Surplus (adjusted) (5)=(1)+(3)
Whitefish	675	3,150	1,750	3,825	2,425
Chubs	2,700	1,662	950	4,363	3,650
Perch	536	482	280	1,019	817
Alewife	192	31	--	224	--

The social surplus of $4,362,500 yielded by chubs was the highest, followed by whitefish with $3,825,000. Then followed by perch and alewife.

Conclusions and Recommendations

Based on the findings of this study, current whitefish production seems very close to the maximum sustainable yield and maximum economic yield (using 1960-1982 data). However, the 1971-1982 data show that whitefish production was beyond the maximum sustainable yield, and whitefish stocks were overfished. The continuation of fishing at current levels will reduce the stocks, so the future catch will be smaller. Effort at present is larger than the estimated effort at both MSY and MEY. These two estimates might indicate that the current level of whitefish production is in the range of maximum sustainable yield. Precautionary steps might be undertaken to prevent substantial increases in the harvest of whitefish for two or three years. This would ensure that whitefish stocks are not in the stage of collapse. An event experienced in the depletion of Peruvian anchovy stocks in the early 1970's (Pitcher and Hart, 1982) reminded managers to be more cautious in the management of fishery resource. Two or three years will give time to observe the condition of whitefish stocks and almost enough time for whitefish maturation. In addition, regularly conducted measurements of size and weight of whitefish harvested at random and will function as an early warning to the condition of whitefish stocks. The surplus yield model, in combination with monitoring of harvest size and weight, can provide useful guidelines to fishery managers. While there are limitations in the surplus production model, as discussed in Chapter II, it can provide a "second best" guide for public policy decisions in managing fishery resources. Improving the estimates might be accomplished by using a more complete and sophisticated model such as a dynamic pool model. Presently, however, emphasis should be given to improving catch and effort data. This could advance the use of the surplus yield model.

The sport fishery was not incorporated in this study. If sport fishing was taken into consideration, the point of maximum and optimum level of resource exploitation might have been different than what was found in this study.

Generally, the estimated demand and supply for several Michigan commercial fish species yielded a relatively high price elasticity of demand for whitefish, chubs, perch and catfish. The supply elasticities were relatively low. This situation might indicate that the consumers (buyers), rather than the producers (fishermen), were more responsive to price changes. Since this study examined the price analysis at the dockside level, the buyers and price makers are the wholesalers or distributors. The fishermen, on the other hand, function as price takers.

By knowing the magnitude of elasticities (from demand and supply) public policy makers might be able to foresee what will be the price and revenue impacts of any policy change which affects the fish availability from Michigan's Great Lakes. Whitefish for instance, has a high elasticity (between 2.38 and 2.89). This indicates that any one percent increase in price will decrease the quantity of whitefish demanded by more than two percent. The total revenue received by the fishermen in this case will decrease as well. A similar situation occurs with catfish demand, where any one percent increase in price will decrease the quantity demanded by about 1.9 percent. On the supply side, with less elastic coefficients, except for alewife, an increase in price of one percent would increase the quantity supplied by less than one percent.

The estimates of social surplus for whitefish and chubs appears quite high. The supply curves intercepted the horizontal axis at a positive quantity, implying that at zero prices there were still some quantities of fish offered.

The supply curve estimates did not seem very consistant. Some had negative slopes, and all intersected the horizontal axis at large positive quantities. As a result, the producer surplus estimates seemed high. Theory suggests that these supply curves may actually be curvalinear. A simple adjustment significantly reduced the producer surplus estimates. These models were modified by assuming that the supply curve was a straight line from the origin to the equilibrium point. With this adjustment, the producer surplus of whitefish, chubs, and perch (also adjusted) would drop to $1.75 million; $0.9 million; and $0.28 million, respectively. Total revenue from whitefish, chubs, and perch (all at mean values) were $3.7; $2.2; and $0.6 million, respectively. On average, the ratios of producer surplus (after adjustment) to total revenue were 47% for whitefish, 42% for chubs and 45% for perch. The social surpluses of these fish commodities, except whitefish, were higher than total revenue.

Suggestions for Further Research

Few economic studies have examined Michigan's commercial fisheries. Lack of information and knowledge of socio-economic values could hamper efforts to manage fishery resources efficiently. Any research which would add information and accumulate more economic values would be very helpful to the public policy decision making process. Continuation of this study is one of many avenues for future research. Expanding the study of demand and supply, such as using a non-linear approach and other models which might be more suitable for Michigan fisheries commodities, is a possibility. A study on the possibility of backward slope of supply curves for Michigan commercial fishery is an area which could be explored. If not limited by the availability of data, research on demand and supply at the retailer level would be an interesting topic to be studied. A study of catch and effort relationships at the dockside level might improve the system of catch and effort data collection. Currently, reports made by fishermen sole method for obtaining this information. Improvements in the quality of catch and effort data may be a great help for the future fisheries economics researcher.

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