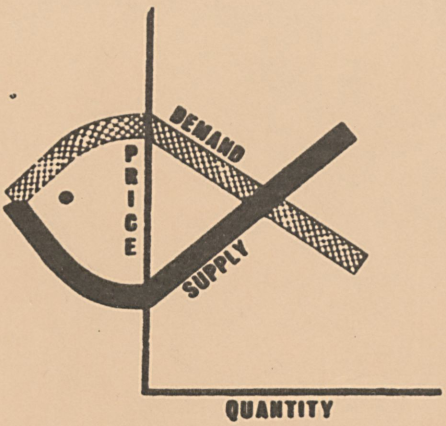

THE FUTURE OF THE WORLD'S FISHERY RESOURCES: FORECASTS OF DEMAND, SUPPLY AND PRICES TO THE YEAR 2000 WITH A DISCUSSION OF IMPLICATIONS FOR PUBLIC POLICY

by

Frederick W. Bell

Darrel A. Nash

Ernest W. Carlson

Frederick V. Waugh

Richard K. Kinoshita

Richard F. Fullenbaum

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By

Frederick W. Bell, Darrel A. Nash, Ernest W. Carlson, Frederick V. Waugh,
Richard K. Kinoshita, and Richard F. Fullenbaum, Economists

Economic Research Laboratory, National Marine Fisheries Service
College Park, Maryland 20740

ABSTRACT

In the past few years, the world community has become increasingly aware of the sea and its resources. The increasing pressure of world population expansion is expected to lead to more intensive exploitation of the fishery resources of the world's oceans. It is the purpose of this study to integrate all relevant biological and utilization factors into one complete model of the world demand and supply for seafood products. Forecasts of anticipated consumption and expected price over the next 30 years are derived within the framework of the model. The species which are studied include: (1) Tuna, (2) Salmon, (3) Groundfish, (4) Halibut, (5) Sardines, (6) Shrimp, (7) Crabs, (8) Lobsters, (9) Oysters, (10) Clams, (11) Scallops, and (12) other food fish. With the exception of sardines, oysters, clams, and scallops, it is estimated that all of the species will reach the point of maximum sustainable supply in the 1985-2000 period. Policy implications are discussed and possible program areas are outlined.

CHAPTER 1

Introduction and Summary

1.1 Introduction

In an industry based upon a relatively fixed (but renewable) resource, it is especially urgent that we be able to predict the economic impact of demand pressures on that resource. Many important public policy questions arise: Will there be enough of the resource to satisfy human needs? Will prices rise substantially? Are we about to overexploit our resources?

The world fishery resource is not only relatively fixed, but is common property in nature.[1] When no one owns scarce fishery resources, government regulations are often necessary to prevent wasteful exploitation or overfishing. This is an additional reason to project the future course of demand so that overfishing may be avoided. Finally, demand and supply projections serve as a useful input into a broad range of policy foundation regarding fishery resources.

One aspect of world fishery consumption since World War II has been its propensity to increase at a greater rate and, for some periods, at a considerably greater rate than the increase in world population (FAO, June 1969). Between 1958-65, world fishery consumption (or utilization) increased at an annual rate of 7.0% per year. Over this same period, the consumption of fish commodities increased at a rate greater than any other basic food commodity. The rate of increase in human population was of the order of 2.0% per annum.

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[1] We are referring here to fishery stocks in the wild state which are renewable but nevertheless fixed on a sustainable yield basis for a given level of fishing effort.

The world is presently consuming approximately 62% of maximum sustainable yield for finfish (Chapter 3). Shellfish are consumed at 23% of their potential yield. However, there are wide variations as to the extent of utilization of the stock within these categories. Many of the stocks are fully utilized and have already attracted surplus capital and labor.

The situation is likely to get worse if free access to the resource is permitted. The rising world demand will contribute to the problem. The principal factor influencing further exploitation of the fishery resources is market demand, the main determinants of which are the growth in population and income (assuming tastes and preference constant). This is true for both fish meal and fish used directly as human food. The demand for fish meal is derived indirectly through demand for poultry products, which depends in turn upon the growth of population and income.

For the above reasons, we must know more about the future course of world population, income and the available supplies of fish.

1.2 The Nature and Purpose of Projections

To make an economic projection of supply and demand for fish products we first set up an "economic model." This model is essentially a set of relationships describing the main biological and economic forces that determine the maximum sustainable supply of fish from the ocean, the amounts caught and consumed, the prices, the costs of production, and consumer income and population. Such a model, for example, must show how fish production and prices respond to changes in the human population and per capita income.

To make a projection we start with a commonly accepted projection of the future trends in the human population and in the per capita income. We inserted these data into our model and solved the equations in order to estimate future production and consumption of fish, and future prices and costs of production. Thus, the projection is a mechanical process that can be carried out by a computer.

The real world is much more complicated than any model we set up. Also the projections assume no change in the present programs or policies. It helps us see where present programs and policies might lead us in the future. The main purpose of the whole exercise is to help us see whether we need changes in these programs and policies.

These projections are not fatalistic prophecies like those of fortune tellers and soothsayers. They point out possible future trends. But the United States and other countries can do a great deal to modify future trends if they understand the forces that are shaping them. Economic projections give advance warning of problems that need attention.

1.3 Summary

After making the economic projections (Chapters 2-6), the following basic conclusions were reached:

A. The World

(1) The world demand for species fished by U.S. fishermen will, in many cases, outstrip the maximum world supply potential before 1985.

The projections indicate that, on a world basis, maximum sustainable supplies of the species shown in Table 1.1 will be reached in the years given in the table.[2]

Critical problems of resource supply are occurring or are about to occur for groundfish, salmon, halibut, lobsters, crabs, and fish meal. Unless proper management policies are adopted, overfishing for crabs, lobsters, groundfish, and fish meal on a world basis is possible within the next 15 years.

(2) Aggregate fish consumption (including fish meal) for the world will expand from approximately 57.1 million metric tons in the 1965-67 base period to 83.5 million metric tons (round weight) by the year 2000, an increase of 66.3%.

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[2] The authors recognize that the term "species" is not accurate in a biological sense. We really have broad categories such as crabs that contain many diverse species of crabs. However, these categories represent the limit disaggregation for purposes of this report. We hope that scientists will understand our use of the word "species" to designate a broad category.

Table 1.1.--Year world will reach maximum sustainable supply

Species[1]	Year[2]
Salmon[3]	1970
Halibut	1970
Groundfish[4]	1970
Crabs	1980-85
Fish meal (i.e., species for reduction)	1980
Lobsters	1985
Tuna[5]	2000
Shrimp	2000
Sardines	2000+
Scallops[6]	2000+
Clams	2000+

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[1] Aquaculture not assumed in these projections. See Chapter 6 for results for aquaculture.

[2] For halibut and salmon, projections cannot go below MSY because of existing regulations to protect the resource from overfishing. Oysters were excluded from the above list because of aquaculture augmenting natural stock supplies. See Chapter 6 for a fuller discussion.

[3] Does not include the possibility of expanded supply through hatchery operations and stream improvements. See Chapter 6 for a relaxation of this assumption.

[4] Excludes hake and hake-like fish. See Chapter 6.

[5] Excludes central Pacific skipjack. See Chapter 6 for justification.

[6] Includes recent discovery of calico scallops.

B. The United States

(1) Aggregate consumption of food fish for the United States will expand from approximately 2.2 billion pounds in the 1965-67 base period to almost 2.9 billion pounds (edible weight) in the year 2000, an increase of 33%.

(2) Because of resource supply problems and declining income elasticities for fish products, per capita consumption of all food fish in the United States is expected to decline from 11.02 pounds in the base period to 9.38 pounds by the year 2000, a decrease of 14.9%.

(3) Reaching of world potential for species fished by U.S. fishermen will put increasing pressure on our regional stocks which, in many cases, are almost fully utilized. Unless effective management is instituted, U.S. regional resources may be among the first world resources to be seriously damaged or completely destroyed.

(4) These results show that it is imperative that the United States enter into management schemes with other nations and that we institute our own management of domestic fishery resources. Of great importance is the fact that the United States will not enjoy the luxury of being able to import all the fishery products it desires because of world supply limitations relative to demand. In order to augment our supply of fishery products, we must carefully manage our resources to achieve their maximum potential consistent with economic efficiency.

(5) Because of the limited supplies of established species, we must make every attempt to exploit underutilized species, if economically feasible.

(6) Attempts should be made to stop the detrimental effects of pollution on the fishery reserves which will grow increasingly valuable over time, as sustainable supplies are utilized.

(7) To augment limited supplies of fishery products, research on fish farming should be given high priority.

(8) Because of rising real costs (and prices) of catching fish as demand expands, every attempt should be made to increase harvesting efficiency within a proper management program.

CHAPTER 2

TRENDS IN DEMAND AND SUPPLY OF FISH PRODUCTS FOR THE WORLD AND THE UNITED STATES, 1950-1967

2.1 Introduction

To formulate a set of economic projections and to interpret and understand the results, it is first necessary to become familiar with the past and current status of the fisheries. We found this a considerable learning process, particularly in regard to the fisheries of other countries. Surprisingly, this knowledge provided several insights into the U.S. fisheries as well. The purpose of this chapter is to provide the reader with the background of U.S. and world demand for and supply of fishery products during the post-World War II period.

2.2 World Supply and Demand

Depending upon the particular need for the information, there are several ways of measuring the catch of fish on a world basis. The most commonly used measure is physical weight (tonnage), probably because of the simplicity of calculation compared to other bases. However, this method is only useful for certain types of information, such as relating the catch of a species to its maximum sustainable yield. Using tonnage to make inter-species comparisons is quite questionable. It is also often used as a means of computing total world catch by adding across species and making inter-country comparisons of this total. For the latter purpose, physical weight is of limited value, because of vast price differences among the species of fish. Moreover, fish meal, the biggest volume item, is not used directly by humans. The best available method for inter-species and inter-country comparisons of total landings of fish therefore, is on a monetary basis. It expresses the value placed on the product according to the use for which the product is harvested and purchased (human nutrition, in connection with recreational activities, or animal production).

The more meaningful value measure is usually avoided, however, probably because it is extremely difficult to obtain comparable prices across the many countries and dozens of species. This measure has only recently been used for the major fishing nations. Table 2.1 ranks these nations by value of fish landed in 1967. Japan, U.S.S.R., and the United States are the leading fishing nations, measured by value of landings.

Table 2.2 shows the value of world landings for the major fisheries. The U.S. ex vessel prices are multiplied by world catch to obtain an estimate of world value of these species.[1] With this in mind, the value figures shown can be taken only as rough approximations to actual value. Nevertheless, groundfish is unquestionably the highest in total value of catch on a world basis. Shrimp is second, being only 57% as large in value as groundfish in 1967.

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[1] The designation of which species are included in the species groups utilized in this report are found in Appendix B2.

Table 2.1.--Value and volume of catch by countries landing over $100,000,000, 1967 1/

Country	Thousand U.S. dollars	Thousand metric tons
Japan	1,952,851	7,850.4
U.S.S.R.	1,037,046 2/	5,777.1
United States	439,144	2,430.5
Spain	325,524	1,435.7
Philippines	271,426	769.2
France	265,358	820.0
Italy	186,890	373.1
United Kingdom	174,659	1,026.1
Norway	166,227	3,268.7
Pakistan	153,473	417.0
Canada	149,460	1,302.6
Thailand	146,421	847.1
Peru	124,046	10,133.7
South Korea	112,454	749.2
Taiwan	103,390	458.2
Viet Nam (South)	3/	410.7

1/ Statistics from People's Republic of China not available.

2/ Figure is a weighted average price of all other countries in the table multiplied by U.S.S.R. landings. This is done for each species in the U.S.S.R. catch and summed to obtain the total.

3/ Value figure cannot be derived.

Source: Food and Agricultural Organization, United Nations, Yearbook of Fishery Statistics, 1967, Rome, Italy.

Derived by: Market Research and Services Division, National Marine Fisheries Service, NOAA, U.S. Department of Commerce

Tabel 2.2.--Value of major world fishery products of interest to the U.S., 1950, 1960, and 1967

(Quantities in round weight1/ except where otherwise noted)

Product	1950			1960			1967		
	Mil. lbs.	$/lb. 2/	Mil $	Mil. lbs.	$/lb. 2/	Mil. $	Mil. lbs.	$/lb. 2/	Mil. $
Groundfish	5,388.0	.070	370.2	11,089.1	.057	632.1	21,425.8	.070	1,499.8
Shrimp3/	332.9	.430	143.1	970.0	.414	401.6	1,521.1	.566	860.9
Tuna	1,115.0	.188	209.2	2,330.9	.124	289.0	2,931.6	.128	375.2
Lobster	149.9	.429	64.3	262.4	.443	116.2	308.6	.720	222.2
Salmon	580.5	.136	78.9	903.4	.184	166.2	1,031.7	.150	154.7
Fish meal4/	1,544.0	.010	15.4	4,586.0	.010	45.9	10,134.0	.012	121.6
Oyster5/	23.2	.462	10.7	48.4	.473	22.9	54.8	.471	25.8

1/ Equivalent to live weight

2/ U.S. ex vessel price ÷ Consumer Price Index (all commodities)

3/ Heads-off basis

4/ Actually no exchange takes place at the ex vessel level for menhaden, the principal U.S. species. This is an estimated price for comparative purposes. Fish meal can be made from many sources. In the U.S., manhaden and herring make up about 95% of production, the remainder coming from undersized food fish and from plant offal. It is likely that the 95% figure is low for most major producing countries.

5/ Meat weight basis

Sources: FAO Yearbook of Fishery Statistics (annual editions) and Fishery Statistics of the United States (annual editions)

After groundfish and shrimp, value falls off considerably to tuna, lobster, salmon and fish meal. Oysters, the next highest value item, are included mainly to indicate that other species are quite low in value compared to the top few.

Substantial changes have taken place in world fishing since the end of World War II. The growth rate of the catch in terms of tonnage has been little short of phenomenal--7.0% per year in the post-War period. By comparison total food output has increased about 2.8% per year for the same period (USDA, October 1964). The most widely noted increase is the rapid increase in fish meal production (Table 2.3). In 1955 world production was 2.2 billion pounds. However, by 1967 this had reached 10.1 billion. Peru has emerged from virtually no production in the mid-1950's to the unquestioned leader producing 4.0 billion pounds in 1967.

Most important from a value standpoint are the substantial catch increases of high-valued species. The U.S.S.R. tripled groundfish catch; Japan's was nearly doubled. Japan and the U.S. made substantial increases in tuna catch. Crab production by the U.S. increased 250%, while Japan and the U.S. also significantly increased the catch of clams.

Table 2.3.--Rank of three leading countries, by catch of specified species, 1955 and 1967

(Round weight)

	1955		1967	
Species	Country	Mil. lbs.	Country	Mil. lbs.
Groundfish	U.S.S.R.	1,884	U.S.S.R.	5,284
	United Kingdom	1,304	Japan	3,621
	Japan	871	United Kingdom	1,419
	Total world	10,560	Total world	21,426
Tuna	Japan	786[1]	Japan	1,278
	United States	355[1]	United States	426
	Peru	214[1]	Peru	109
	Total world	1,659[1]	Total world	2,932
Salmon	Japan	395	Japan	357
	U.S.S.R.	393	United States	217
	United States	282	U.S.S.R.	194
	Total world	1,270	Total world	1,032
Halibut	United States	49	Canada	42
	Canada	34	United States	39
	Norway	11	U.S.S.R.	20
	Total world	112	Total world	128
Sardines (canned herring)	United States	147	Portugal	187
	Portugal	109	Spain	96
	Norway	103	Norway	95[2]
	Total world	1,254	Total world	1,920
Shrimp	United States	244	United States	308
	India	235	India	202
	Japan	107	Mexico	154
	Total world	1,024	Total world	1,521
Lobsters	Canada	48	Chile	44
	South & Southwest Africa	47	Canada	35
	United States	32	Australia	32
	Total world	227	Total world	309
Crabs	Japan	152	United States	326
	United States	137	Japan	190
	U.S.S.R.	83	U.S.S.R.	93
	Total world	425	Total world	739

Table 2.3.--Rank of three leading countries, by catch of specified species, 1955 and 1967 (continued)

(Round weight)

	1955		1967	
Species	Country	Mil. lbs.	Country	Mil. lbs.
Clams	Japan	232	United States	390
	United States	207	Japan	384
	United Kingdom	17	Spain	91
	Total world	500	Total world	1,065
Scallops	United States	194	United States	111
	Japan	36	Canada	107
	Canada	14	Australia	30
	Total world	247	Total world	289
Oysters	United States	1,061	United States	903
	Japan	216	Japan	512
	Mexico	23	France	153
	Total world	1,376	Total world	1,828
Fish Meal 3/	United States	750	Peru	4,004
	Norway	438	Norway	1,084
	United Kingdom	199	United States	539
	Total world	2,276	Total world	10,132

1/ 1956
2/ 1966
3/ Product weight

Source: FAO Yearbook of Fishery Statistics (annual editions)

France has made notable increases in oyster production principally as the result of the application of culture techniques.

Because of our preoccupation with import and tonnage statistics, the fact that the United States is an important producer of a number of valuable fishery products has been underemphasized. This country ranks first in production of all species of shellfish except lobsters. It is also an important producer of tuna, salmon, and halibut. Surprisingly, the United States is not among the first three in groundfish production, primarily because this category has such a high volume on a worldwide basis. In sum, out of the twelve fishery products shown in Table 2.3 the United States ranked <u>first</u> in the production of five species and second in the production of three species for the year 1967.

Table 2.4 shows that, relative to other countries, the United States, even in 1955, was a major world fish consumer. By 1967, it was the leading user of 10 of the 12 categories shown on this table. The exceptions are sardines and groundfish in which case the United States ranks second and third, respectively, in consumption. Japan and the U.S.S.R. are the remaining major consumers of these products on a world basis. Japan is an important consumer of the world's supplies of oysters, clams, shrimp, groundfish, tuna, and salmon. The U.S.S.R. consumes significant quantities of groundfish and salmon.

Table 2.4.--Rank of three leading countries in consumption of selected fish products, 1955 and 1967

(Round weight)

	1955		1967	
Species	Country	Mil. lbs.	Country	Mil. lbs.
Groundfish	U.S.S.R.	1,884	U.S.S.R.	5,284
	United Kingdom	1,304	Japan	3,621
	United States	1,124	United States	1,608
	Total world	10,560	Total world	21,426
Tuna	United States	585 1/	United States	944
	Japan	455 1/	Japan	730
	Peru	73 1/	E.E.C.	367
	Total world	1,659 1/	Total world	2,932
Salmon	U.S.S.R.	382	United States	276
	Japan	352	Japan	263
	United States	308	U.S.S.R.	185
	Total world	1,270	Total world	1,032
Halibut	United States	84	United States	82
	Norway	10	Canada	7
	United Kingdom	7	Norway	7
	Total world	112	Total world	128
Sardines (canned herring)	United States	123	Portugal	187
	Portugal	109	United States	127
	United Kingdom	62	Spain	61
	Total world	1,254	Canada	61
			Total world	1,920
Shrimp	United States	319	United States	543
	India	235 2/	Thailand	134 2/
	Japan	97	Japan	109
	Total world	1,024	Total world	1,521
Lobsters	United States	121	United States	174
	France	14	United Kingdom	23
	Canada	10	France	21
	Total world	227	Total world	309
Crabs	United States	163	United States	272
	Japan	103	Japan	212
	France	15	United Kingdom	34
	Total world	425	Total world	739

Table 2.4.--Rank of three leading countries in consumption of selected fish products, 1955 and 1967 (continued)

(Round weight)

	1955		1967	
Species	Country	Mil lbs.	Country	Mil. lbs.
Clams	Japan	232	United States	390
	United States	207	Japan	345
	United Kingdom	17	Spain	91
	Total world	500	Total world	1,065
Scallops	United States	202	United States	231
	Japan	36	Australia	30
	France	8	Japan	15
	Total world	247	Total world	289
Oysters	United States	1,070	United States	1,144
	Japan	216	Japan	390
	Mexico	23	France	273
	Total world	1,376	Total world	1,828
Fish meal[3]	United States[4]	957	United States	1,943
	United Kingdom[4]	420	Federal Republic of Germany	1,301
	Federal Republic of Germany[4]	407	Japan	1,079
	Total world	2,276	Total world	10,132

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[1] 1956 data

[2] No export data available; data probably overstates consumption

[3] Product weight

[4] 1958

Source: FAO Yearbook of Fishery Statistics (annual editions)

Because a high proportion of the total fish supply is consumed by these three countries, they will largely determine when consumption of fishery products will reach the world's sustainable yield.

2.3 World Potential: Estimates of Maximum Sustainable Yield

Fish (which almost completely depends upon the forces of nature for growth and productivity) is one of the few remaining products of importance to man. Man's effort dictates how much is caught, but does not greatly influence how much is grown.[2] (Aquacultural practices which are in scattered use are exceptions.) The significance of this fact is that there is a finite limit to the quantity of fish available on a sustainable basis. This limit must be known in order to estimate future production and consumption. Chapter 3 develops these relationships more fully.

For some of our popularly consumed species, i.e., groundfish, salmon, and halibut, the catch is now near maximum sustainable yield (Table 2.5). In addition, tuna, crabs, lobsters, and shrimp are experiencing a rapid growth in catch, thus hastening the day when they will also be nearly fully utilized. Within these major groups, there are species which are being fished at or beyond MSY in certain fishing grounds. The ratio of present landings to potential yield, assuming a world MSY of 120 million metric tons, of all species is 47%. However, if we compute this ratio for the species of fish and shellfish which are commonly consumed at present, the ratio

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[2] Man, however, can destroy the natural productivity by such acts as overfishing and pollution.

Table 2.5.--Relation of world landings to world maximum sustainable yield (MSY) for fisheries included in the analysis

(Round weight)

Species	MSY	Landings 1/*	Landings as a percentage of MSY
	Thousand metric tons		
Selected finfish			
Groundfish	9,117.1	6,270.9	68.78
Tuna 2/	1,770.0	1,320.0	74.6
Salmon	--	476.3	--
Halibut	56.5	60.8	107.61
Sardines 3/	39,474.1	18,466.7	46.78
Total, selected finfish	50,417.7	26,118.4	51.8
Selected shellfish			
Shrimp	1,491.9	634.4	42.7
Lobsters	192.5	137.3	71.32
Crabs	671.5	328.0	48.84
Clams 4/	4,000.0	478.1	11.95
Scallops 5/	1,490.9	166.4	11.16
Oysters	--	777.0	--
Total, selected shellfish	6,355.9	1,744.2 6/	27.44
All other fish and shellfish	63,226.4	28,460.46 7/	45.01
World Total	120,000.0	56,323.06 6/	46.9

* Due to lack of complete information, sum of regional landings do not always add up to world landings.

1/ 1965 through 1967
2/ Does not include the potential maximum sustainable yield of Central Pacific skipjack estimated at 800,000 metric tons.
3/ Includes other herring-like species -- See Appendix B-2 for list of species.
4/ Assuming no aquaculture.
5/ Includes the recently discovered calico scallop resource.
6/ 1965-67 average -- excludes oyster landings in order to compute column 3.
7/ 1965-67 average.

Source: FAO Yearbook of Fishery Statistics (annual editions) and John A. Gulland, The Fish Resources of the Ocean, FAO, Technical Paper No. 97, 1970.

rises to 61%. Given that the growth in the demand for fish will be concentrated primarily in these species and that the under-utilized species may be unacceptable in terms of relative substitutability for the more commonly consumed fish, the ratio of 61% presents a much more realistic view of the impending resource problem. We shall also demonstrate in Chapter 3 that there is a difference between the world maximum sustainable yield and the world maximum sustainable supply. The latter is usually a smaller quantity. Hence, Table 2.5 represents the most optimistic total potential from the sea.

There are wide ranging estimates of the world maximum sustainable yield of fish and shellfish. Therefore, the use of the control total of 120 million metric tons was a selection by the authors based on our reading of published information on the subject. Our summary of these sources follows, together with the reasons why the particular selection was made.

Previous estimates of world maximum sustainable yield have varied from a low of 21.6 million metric tons to a high of 2,000 million metric tons (Schaefer and Alverson, 1968). The techniques involved in these estimates use either extrapolation methods--of catch or standing stock--or a food chain approach in which ecological efficiency factors are employed. Recent examples of the latter include the works of

Ryther (1969) and Moiseev (1969), whereas examples of the former include the findings of Graham and Edwards, Schaefer, Pike and Spilhaus. The range of variability of estimates is markedly reduced when one considers the following quote:

> "Several of the authors have, in fact, estimated the potential fisheries harvest of the system; that is, they are estimating total potential harvest as at some stated trophic level independent of physical and/or economic capability by man to intervene . . . . . When realistic limitations based on technological capabilities are imposed, the figures are much lower . . . . . The range of estimates from this group--80 to 200 million metric tons --is understandable, in view of limitations on basic scientific information now available . . . ." (Schaefer and Alverson, 1968)

Using 200 million metric tons as a conservative upper limit to the maximum harvest rate, we may divide this figure between traditional species and species not presently exploited on a commercial scale. There is a surprising consensus of opinion among biologists on the maximum sustainable yield of the traditional species, i.e. large pelagic fish, demersal, and medium pelagic fish. The FAO estimates approximately 120 million metric tons (inclusive of Cephalopods and Crustaceans) (FAO, June 1969) and Ryther recently gave a total of 100 million metric tons (Ryther, 1969). The major issue of contention, in fact, revolves around the economic feasibility of harvesting the species not presently exploited--Antarctic krill, lantern fish, etc. There are essentially two schools of thought on this subject. The first, taken from FAO, is very optimistic with respect to the potential development of these species:

> ". . .It seems probably, however, that as pressure on the more accessible stocks grows increasing attention will have to be paid to the possibilites of exploiting these unconventional species, and this will in turn bring with it the development of a technology adapted to their commercial exploitation. . . ."(FAO, June 1969)3/

On the other hand, Ryther believes that these species "are too small and too widely dispersed in the sea to be economically harvestable and useful to man, and that, in fact, they are a part of the food chains that support those larger species already being utilized."(Ryther, 1970)

We have used a control total of 120 million metric tons for world MSY for two reasons. First, there is no reason to believe that change in technology will suddenly become available to harvest these hitherto unexploited species. In other words, we make the same assumptions that economists have traditionally employed in forecasting structural changes for national economies; namely, that if a technological advance has

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3/ For more evidence with respect to traditional species, and the point of view expressed above, see Gulland (1970).

not occurred for the past 30 years, it will not occur in the next 20-30 years. Secondly, even if it became technically feasible to exploit these species -- and there is no convincing evidence on this point -- it still might not be <u>economically</u> feasible to undertake this type of activity. That is, there is no compelling evidence that consumers would be willing to pay a price sufficiently high so that fishermen engaged in the exploitation of these marine resources could recover at least a competitive rate of return on their investments.

2.4 United States Demand and Supply

Aggregated statistics on the utilization of fishery products in the United States suggest that very few changes in consumption patterns are taking place. Per capita consumption remains relatively constant while imports account for greater shares of the supply. By probing more deeply, however, a different picture emerges. Within the overall level of fish consumption, important changes are taking place in the products entering into use. Also, there is a lively market for fish meal, the use of which is continually increasing as the production of broilers and other animals fed on fish meal increases.

The changing pattern of fish consumption can be seen in the trends in per capita consumption over the time period considered (Table 2.6). Compared to the overall stability of fish consumption per capita, there are dramatic changes among species and products. The per capita consumption of each of certain important species such as salmon, halibut, sardines, and oysters, all of which are important species on the U.S. market, decreased during this time period. Consumption of tuna, shrimp, and crabs, however, increased by at least 3% per year. Species such as surf clams, spiny lobsters, and king and dungeness crabs, which were relatively unimportant in 1950, had by 1967 become important fish products for consumption. The increase in surf clams accounts for the increase in consumption of all clams. The same situation occurs for spiny lobsters and king and dungeness crab. Consumption of fish meal also increased significantly, showing an annual increase of 3.2%.

As will be discussed in later chapters, the principal factors affecting growth in demand are the continually rising income of consumers and population increases. Obviously there are other

Table 2.6.--U.S. per capita consumption of selected species, 1950, 1960, and 1967, ranked by annual percentage change in consumption during the period 1950-67

Species/product	Per capita consumption 1950	1960	1967	Average annual growth*
	Pounds			Percent
Crabs, total 1/	.72	1.08	1.49	4.7
Blue 2/	.13	.13	.11	1.2
King and dungeness 2/	.07	.11	.19	7.4
Tuna 2/	1.13	2.05	2.32	4.3
Fish meal 3/	4.00	4.69	8.71	3.2
Shrimp 1/	1.47	2.22	2.75	3.0
Clams, total 1/	1.86	1.84	2.31	2.4
Hard and soft 2/	.23	.13	.13	-2.6
Surf 2/	.06	.15	.23	8.9
Lobster, total 2/	.12	.16	.18	2.3
Northern 2/	.08	.07	.06	-1.4
Spiny 2/	.04	.09	.12	5.8
Groundfish 1/	6.12	6.84	8.13	2.0
Sea scallops 1/	.14	.20	.13	1.9
Halibut 2/	.21	.23	.17	-0.8
Oysters 1/	4.27	3.11	3.27	-2.8
Sardines 2/	1.56	.48	.41	-3.3
Salmon, total 2/	1.55	.81	.89	-3.5
Canned 2/	1.42	.72	.72	-4.1
Fresh and frozen 2/	.13	.09	.17	.02
All other food fish 2/	3.8	2.6	2.0	-4.2

* Computed from: $\log(p.c.c.) = a + bT$. Data are for 1950 to 1967 inclusive.

1/ Round weight
2/ Edible weight
3/ Per capita utilization, product weight

Source: Compiled in the Economic Research Laboratory.

socioeconomic determinants of demand, such as geographic region, and religion, however, these have little effect on growth. On the other hand, the per capita consumption decrease can be attributed, in large part, to upper limits on the biological production of certain fish species; oysters, salmon, and halibut being particularly affected.

Another factor which influences fish purchases is the method and degree of preservation. There is a definite trend toward frozen fish and away from canned, cured, and smoked fish. We must hasten to add that canned tuna, the largest single item in U.S. fish consumption, does not fit this picture. If canned tuna were omitted from the data, there would be a sharp decline in canned fish consumption. The volume and value of fishery products processed in the United States, by method of preservation, for selected years, are shown in Table 2.7. The information is a good indicator of fish consumption, but is not wholly complete because products imported for consumption without being further processed are not included. Likewise, small amounts of processed products are exported and should be deducted to obtain U.S. consumption.

In keeping with general food consumption trends, those fishery products which are highly processed and leave little final preparation to the household or institutional user have enjoyed rapid expansion, replacing those which require considerable preparation by the final user, (Table 2.8). Two products which have had the advantage of these changing tastes are frozen breaded shrimp and frozen breaded

Table 2.7.--U.S. production of fish and shellfish by method of preservation, selected years

Method of preservation	1950		1960		1966	
	Mil. lbs.	Mil. $1/	Mil. lbs.	Mil. $1/	Mil. lbs.	Mil. $1/
Canned	836	317	666	343	822	508
Cured	84	35	68	43	66	52
Fresh	74	26	53	18	78	35
Frozen	182	64	314	147	476	256
Fresh and frozen, unspecified	71	46	183	149	308	247

1/ F.o.b. plant

Source: Fishery Statistics of the United States (annual editions)

Table 2.8.--U.S. production of fresh and frozen fish and shellfish by method of processing, selected years

Type of processing[1]	1950		1960		1966	
	Mil. lbs.	Mil. $	Mil. lbs.	Mil. $	Mil lbs.	Mil. $
Filleted fish	184	50	144	44	156	63
Shelled[2]	151	92	287	204	422	347
Breaded products	7	4	201	105	371	213
Sticks and portions	0	0	115	46	235	91

1/ Some duplication exists between breaded and the other types of processing.

2/ Includes all types of processing of crustaceans and molluscs in which the meat is removed from the shell.

Source: Fishery Statistics of the United States (annual editions) sticks and portions produced from groundfish. Again, this table is not an exact measure of U.S. consumption by processing form, as imports, not further processed, and exported processed products are not included. Both quantities, however, represent very small portions of the figures in this table.

In the almost two decades covered by this study, the situation in the United States has changed from one in which one-quarter of all fish consumed was imported to one where more than two-thirds of the supply is being provided by other countries. There is little question that import changes are the most dynamic forces taking place in the industry.

There have been many opinions expressed and studies made concerning the rise of this phenomenon. On the domestic side, application of technological improvements in fishing have lagged behind, relative to many other fishing nations. Developments in the Unites States are in sharp contrast to those which occurred in other countries after World War II, when many nations looked to the sea as a new source of food supplies and economic development. Particularly notable is the development of distant water fisheries in which fleets of many countries, often with their government support, travel to the rich fishing grounds in proximity to the United States. The northwest Atlantic became a source of great fishing acitivity in the late 1950's and early 1960's. A major development has also taken place in the tuna fishery in that nations sent fleets to distant fishing grounds, rapidly increasing world production over the period. Also

Table 2.9.--Domestic production, imports, and imports as percent of supply, specified species, 1950, 1960, and 1967

	1950			1960			1967		
Species	Production	Imports	Imports as percent of supply	Production	Imports	Imports as percent of supply	Production	Imports	Imports as percent of supply
	--Million pounds--			--Million pounds--			--Million pounds--		
Groundfish 1/ 5/	208	70	25.1	167	176	51.3	146	319	68.6
Tuna 1/ 5/	403	80	16.6	317	357	53.0	426	452	51.5
Salmon 2/ 6/	323	54	14.3	235	45	16.1	217	11	4.8
Halibut 1/ 5/	39	17	30.3	38	24	38.7	30	24	44.4
Sardines 1/	318 7/	32 7/	9.1 7/	74 8/	27 8/	26.0 8/	29 8/	52 8/	63.4 8/
Shrimp 3/ 5/	114	40	26.0	149	119	44.4	190	202	51.5
Lobsters 2/ 5/	23	22	48.9	31	21	40.4	27	16	37.2
Crabs 2/ 5/	155	21	11.9	219	26	10.6	315	13	4.0
Clams 1/ 5/	41	6	12.8	50	2	3.8	71	2	2.7
Scallops 1/ 5/	20	1	4.8	27	7	20.6	10	13	56.5
Oysters 1/ 5/	76	0.4	0.5	60	7	10.4	60	18	23.1
Fish Meal 4/ 5/	480	128	21.0	580	264	31.3	422	1,302	75.5

Footnotes for Table 2.9

1/ Edible weight.

2/ Round weight.

3/ Heads-off weight.

4/ Meal weight.

5/ Bell, F. W. and R. Kinoshita, "Major Economic Trends in Selected U.S. Master Plan Fisheries: A Graphical Survey," (unpublished manuscript), Economic Research Laboratory, National Marine Fisheries Service, U.S. Department of Commerce, 1969.

6/ "Basic Economic Indicators-Salmon," Economic Research Laboratory, National Marine Fisheries Service, U.S. Department of Commerce, 1970.

7/ Fisheries of the United States 1960, U.S. Department of the Interior, April 1961.

8/ Fisheries of the United States 1969, C.F.S. No. 5300, U.S. Department of the Interior, March 1970.

important is the development of certain shellfish fisheries, particularly shrimp, along the coast of several countries. These nations have, in turn, looked to the United States as a market for their catch. Presently, over 70 countries export shrimp to the United States.

Another factor in the status of fisheries is that various states have instituted conservation laws which, while achieving the objective of maintaining the resource have in effect, legislated inefficiencies in fishing. One example is shortened seasons which tend to commit greater capital to the fishery, each firm hoping to get the maximum of the common property resource. Another inefficiency is prohibiting the use of the most efficient technology.

As in consumption, there are considerable differences in the relative importance of supplies which are domestically produced and imports, by species. From Table 2.9 it is obvious that the four major items showing rapid consumption increases--tuna, groundfish, shrimp, and fish meal--are also the same products which have had major increases in the quantities imported. Clams and crabs stand out as species where domestic production is increasing while imports are decreasing.

2.5 United States Potential: Maximum Sustainable Yield in Waters Adjacent to the U.S.

Marine areas adjacent to the United States are unmatched in biological productivity of fish species of commercial importance. Because of this, the United States fishing industry has concentrated on

Table 2.10--MSY in waters adjacent to the U.S. (ocean fisheries)

Species/Region[1]	MSY	Landings estimate	Percent of MSY
	Thousand metric tons		
Groundfish			
I. Northwest Atlantic	2,454.7	2,371.3	96.6
II. Northeast and Eastern Central Pacific	2,702.4	1,332.7	51.2
Tuna			
I. Pacific[2]	792.0	792.0	100.0
Salmon			
I. Northeast Pacific	406.7	406.7	100.0
Halibut			
I. Northeast Pacific	40.0	42.3	105.8
II. Atlantic	18.5	18.5	100.0
Sardines			
I. Northwest Atlantic	759.8	590.0	77.6
II. Western Central Atlantic	5,088.4	805.7	15.8
III. Northeast Pacific	944.3	931.4	23.5
IV. Eastern Central Pacific	3,020.0		
Shrimp			
I. Northwest Atlantic	27.0	8.6	31.8
II. Western Central Atlantic[3]	160.0	125.0	78.1
III. Northeast Pacific	130.0	41.1	31.6
Lobsters			
I. Northwest Atlantic	45.0	31.7	70.4
II. Western Central Atlantic Spiny Lobsters	21.0	13.3	63.3

Table 2.10--MSY in waters adjacent to the U.S. (ocean fisheries) (cont.)

Species/Region 1/	MSY	Landings estimate	Percent of MSY
	Thousand metric tons		
Crabs			
I. Northwest Atlantic	40.0	2.2	5.5
II. Western Central Atlantic	80.0	76.9	96.1
III. Northeast Pacific	190.0	177.0	93.2
IV. Eastern Central Pacific	32.5	1.5	4.6
Clams			
I. Northwest and Western Central Atlantic 4/	352.4	188.8	53.6
II. Northeast Pacific 4/	28.6	2.8	9.8
Scallops			
I. Northwest and Western Central Atlantic 5/	146.0	146.0	100.0
II. Northwest and Western Central Atlantic 6/	888.0	146.0	16.4

1/ See Appendix E for a definition of regions.
2/ Includes tropical Pacific yellowfin tuna fishery
3/ Includes fisheries off the coast of Mexico and Central America
4/ Excludes aquaculture
5/ Without calico scallops
6/ With calico scallops

Source: Derived from, John A. Gulland, The Fish Resources of the Ocean, FAO Technical Paper No. 97 and FAO Yearbook of Fishery Statistics, 1967.

these grounds. The far-ranging tuna and portions of the Gulf shrimp fleets are the exception.

These very productive areas have attracted fishing effort to the point that many of the traditionally-caught species are being fished at or beyond MSY. Much of the take is by other countries. Some species which can support considerable catch increases on a world basis are fished very heavily in waters near the U.S. coasts. Particularly critical limits occur for crabs, tuna, salmon, halibut, and Atlantic groundfish. Shrimp, lobster, and sardine catches are restricted in many areas. Shellfish species which will support considerable catch increases are tanner crab, northern shrimp (both off Alaska and New England), calico scallops, offshore lobsters, and offshore clams. A number of finfish species such as Atlantic pollock, Atlantic ocean perch, and Pacific groundfish could also support much higher catches. The lack of a developed market and sufficient consumer demand for these species, however, account for the low utilization.

2.6 Price and Consumption Trends in the U.S. for selected Fishery Products

We have traced the overall development of fisheries for the world and the United States since World War II. The following pages present details of U.S. per capita consumption and prices for these products. Prices are divided by the consumer price index (CPI) to adjust for general price inflation. The major trends are noted together with a brief statement on the causal factors which have determined the position of each fishery through the period.

Groundfish: Upward trends in consumption of groundfish have been maintained since the end of World War II, but dynamic changes have taken place within this industry. At the beginning of the period it was primarily a domestic fresh fish trade, while at the present it is dominated by foreign-supplied frozen products. If the consumption of fish sticks and portions are excluded, there would be a distinct downward trend in the remaining products.

Table 2.11.--U.S. per capita consumption and deflated ex vessel prices of groundfish, 1948-68

Year	Per capita consumption Pounds 2/	Ex vessel 1/ price ÷ CPI Cents/pound	Year	Per capita consumption Pounds 2/	Ex vessel 1/ price ÷ CPI Cents/pound
1948	6.33	6.89	1958	6.40	6.36
1949	6.36	6.05	1959	7.13	6.26
1950	6.12	7.04	1960	6.84	5.66
1951	6.82	6.73	1961	7.49	5.52
1952	6.46	6.51	1962	7.75	5.83
1953	5.87	6.14	1963	7.72	6.20
1954	6.49	5.75	1964	8.04	5.90
1955	6.81	5.38	1965	8.51	6.38
1956	6.48	5.58	1966	8.75	7.50
1957	7.03	5.63	1967	8.13	7.00
			1968	9.50	6.96

1/ Consumer price index (CPI) 1957-9 = 100   2/ Round weight

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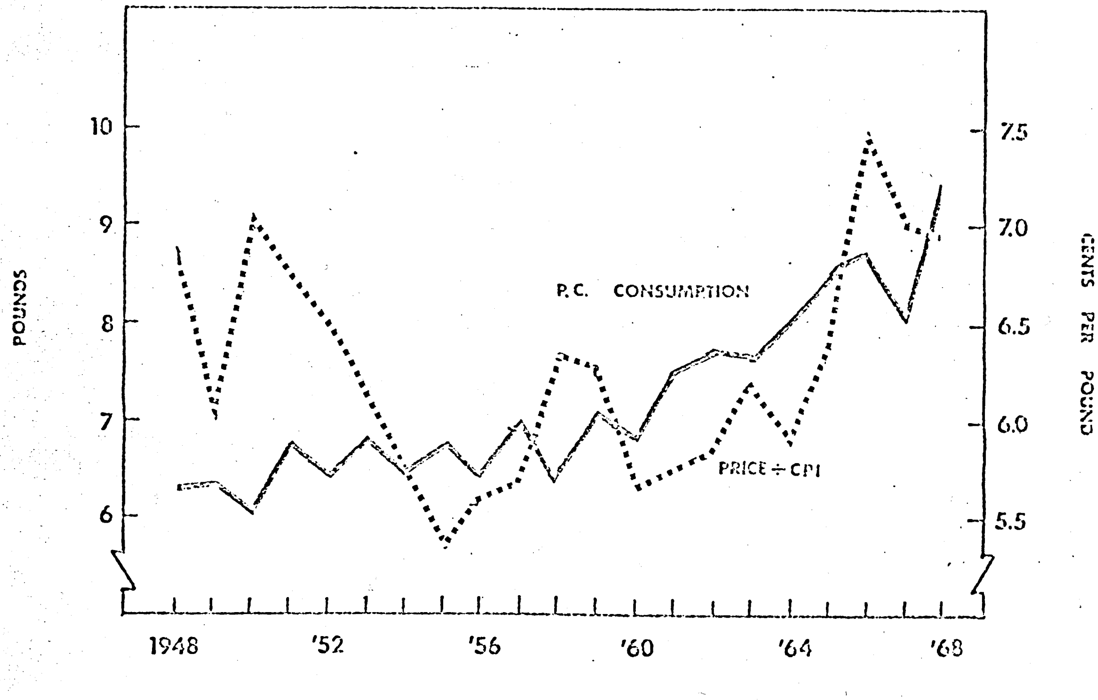
Figure 2.1--Groundfish, per capita consumption and price



Canned tuna: Virtually all the tuna consumed in the United States is canned. Since World War II, technological improvements in catching and continually rising imports have resulted in a downward real price trend. This, together with an adequate resource base, has resulted in a strong rise in consumption. At present nearly one-fourth of the U.S. consumption of fish consists of canned tuna.

Table 2.12.---U.S. per capita consumption and deflated ex vessl prices of tuna for canning, 1947-67

Year	Per capita consumption	Ex vessel 1/ price ÷ CPI	Year	Per capita consumption	Ex vessel 1/ price ÷ CPI
	Pounds 2/	Cents/pound		Pounds 2/	Cents/pound
1947	0.78	21.1	1958	1.77	13.5
1948	0.89	22.2	1959	1.88	12.8
1949	0.89	19.6	1960	2.05	12.0
1950	1.13	18.7	1961	2.08	12.4
1951	1.22	16.6	1962	1.97	13.8
1952	1.27	16.5	1963	1.98	11.8
1953	1.37	16.6	1964	2.01	11.8
1954	1.37	17.6	1965	2.32	11.8
1955	1.43	15.6	1966	2.20	14.7
1956	1.57	13.9	1967	2.32	11.0
1957	1.58	12.9			

1/ Consumer price index (CPI) 1957-9 = 100 2/ Edible weight

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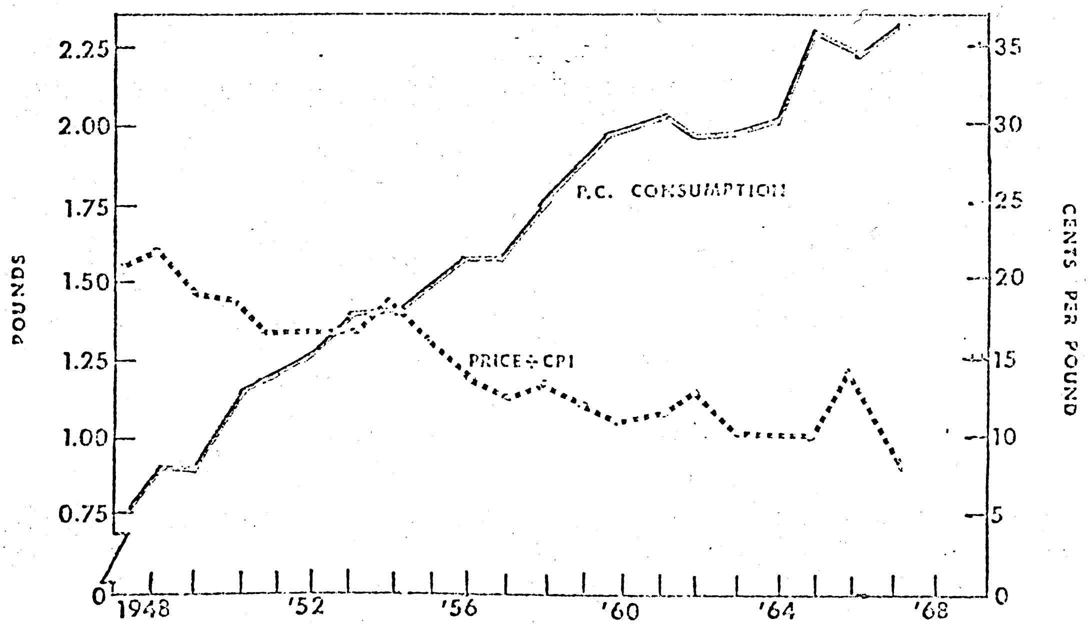

Figure 2.2.--Tuna, canned, per capita consumption and price

Canned salmon: The greatest portion of salmon consumption is in the canned form. A combination of changing consumer food preferences during this period and a restriction on supplies resulting from fewer spawning areas has discouraged growth of canned salmon consumption. Under current conditions, production cannot be significantly increased.

Table 2.13.---U.S. per capita consumption and deflated wholesale prices of canned salmon, 1948-67

Year	Per capita consumption Pounds 2/	Wholesale 1/ price ÷ CPI Cents/pound	Year	Per capita consumption Pounds 2/	Wholesale 1/ price ÷ CPI Cents/pound
1948	1.63	62.1	1958	1.08	51.4
1949	1.60	47.0	1959	0.94	59.8
1950	1.42	63.1	1960	0.72	62.9
1951	1.41	53.8	1961	0.79	63.3
1952	1.44	49.6	1962	0.84	55.5
1953	1.31	47.0	1963	0.94	52.1
1954	1.12	49.4	1964	0.58	49.1
1955	1.04	55.3	1965	0.93	64.1
1956	1.11	59.7	1966	0.79	57.1
1957	1.03	57.0	1967	0.72	63.3

1/ Consumer price index (CPI) 1957-9 = 100 2/ Edible weight

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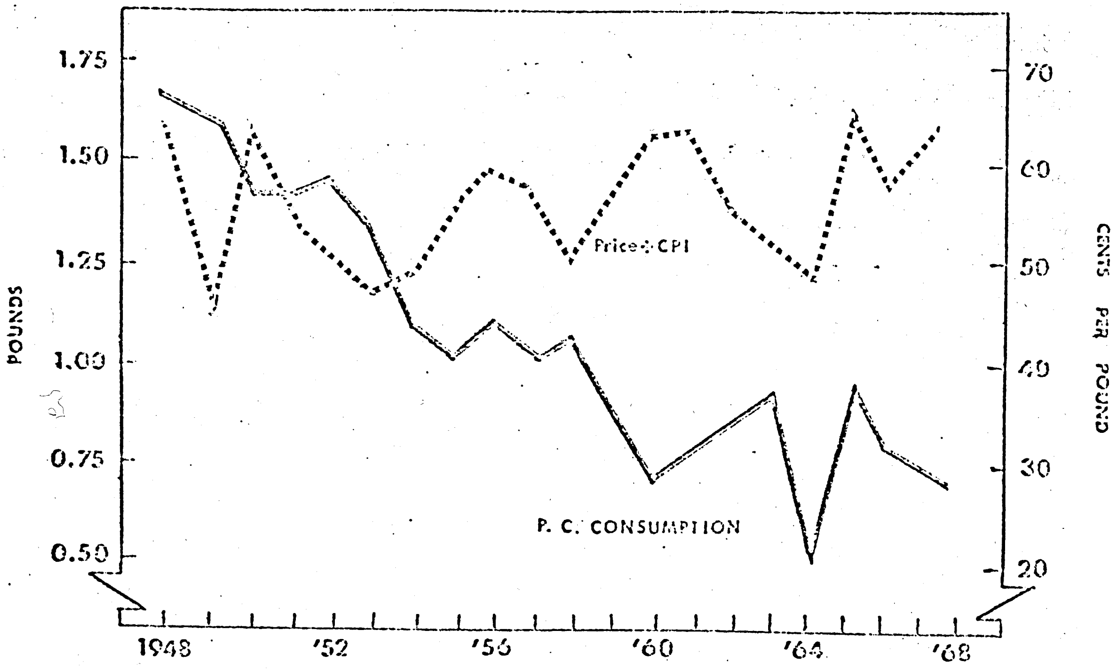
Figure 2.3--Salmon, canned, per capita consumption and price



Fresh and frozen salmon: A slowly increasing trend is now apparent in the consumption of fresh and frozen salmon, following a decline in consumption during the first half of the post-war period. Consumption of total salmon has been dropping continuously, so that fresh and frozen consumption is taking a greater share of the total. Until very recently production of fresh and frozen salmon was confined primarily to king salmon, but is now expanding into others including pink, the most important salmon species.

Table 2.14.--U.S. per capita consumption and deflated wholesale prices of fresh and frozen salmon, 1948-67

Year	Per capita consumption	Wholesale 1/ price ÷ CPI	Year	Per capita consumption	Wholesale 1/ price ÷ CPI
	Pounds 2/	Cents/pound		Pounds 2/	Cents/pound
1948	0.16		1958	0.17	72.8
1949	0.19		1959	0.10	76.2
1950	0.13	59.8	1960	0.09	82.3
1951	0.14	58.6	1961	0.13	83.4
1952	0.22	56.1	1962	0.14	90.7
1953	0.22	53.2	1963	0.19	85.8
1954	0.18	60.3	1964	0.18	81.6
1955	0.16	60.6	1965	0.19	78.8
1956	0.16	67.1	1966	0.17	80.2
1957	0.13	65.5	1967	0.17	80.7

1/ Consumer price index (CPI) 1957-9 = 100   2/ Edible weight

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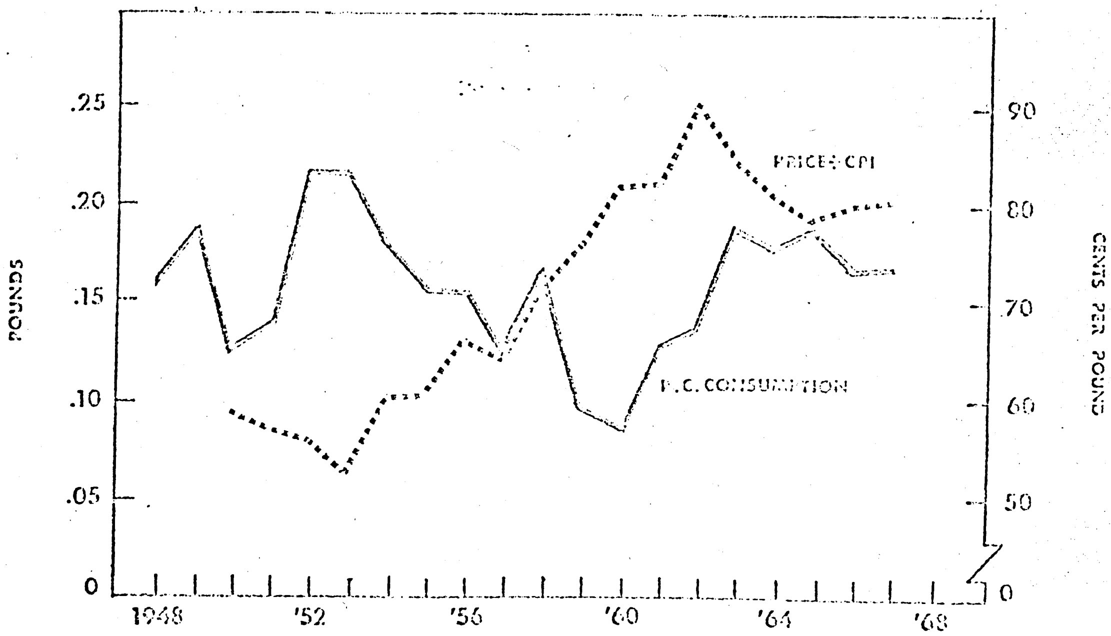
Figure 2.4--Salmon, fresh and frozen, per capita consumption and price



Halibut: International regulation of the fishery has enabled the comparatively low resource base to produce at about a constant total catch (United States and Canada combined). It has been fished at or beyond MSY for most of the post-war period. Without management, the resource would have been decimated a number of years ago.

Table 2.15--U.S. per capita consumption and deflated ex vessel prices of halibut, 1950-67

Year	Per capita consumption Pounds 2/	Ex vessel price ÷ CPI 1/ Cents/pound	Year	Per capita consumption Pounds 2/	Ex vessel price ÷ CPI 1/ Cents/pound
1950	0.207	19.49	1959	0.215	14.24
1951	0.220	15.75	1960	0.227	11.86
1952	0.199	16.22	1961	0.216	15.15
1953	0.205	12.94	1962	0.208	20.43
1954	0.214	14.13	1963	0.185	14.15
1955	0.214	11.32	1964	0.202	15.63
1956	0.197	17.25	1965	0.177	20.70
1957	0.213	13.41	1966	0.162	21.28
1958	0.200	16.02	1967	0.174	13.28

1/ Consumer price index (CPI) 1957-9 = 100   2/ Edible weight

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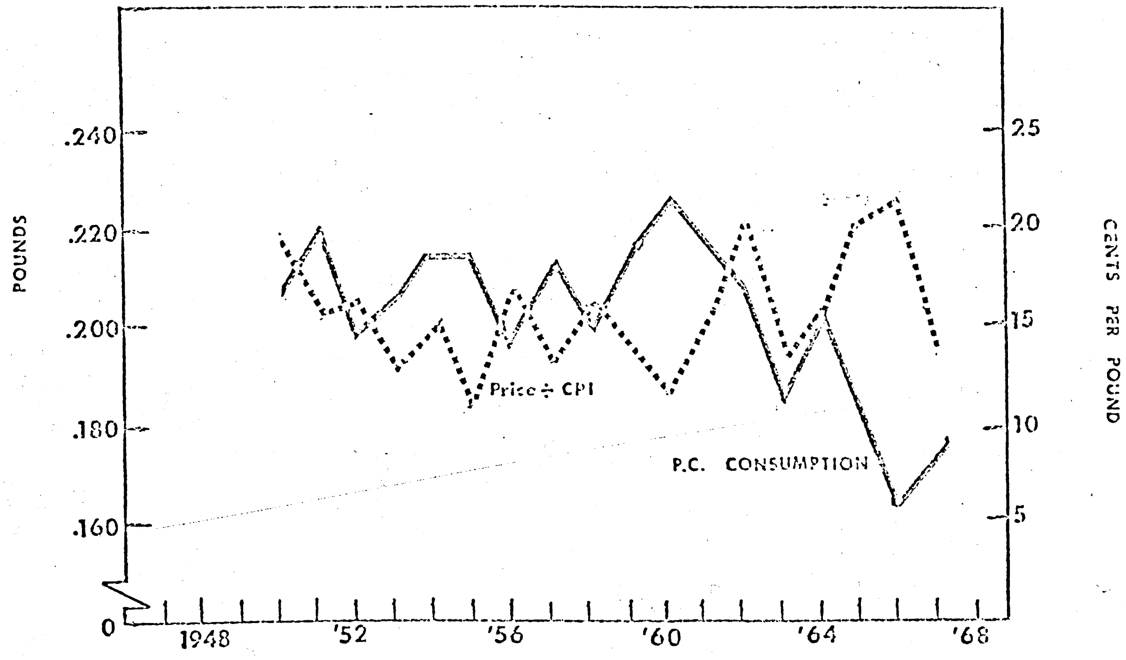
Figure 2.5--Halibut, per capita consumption and price



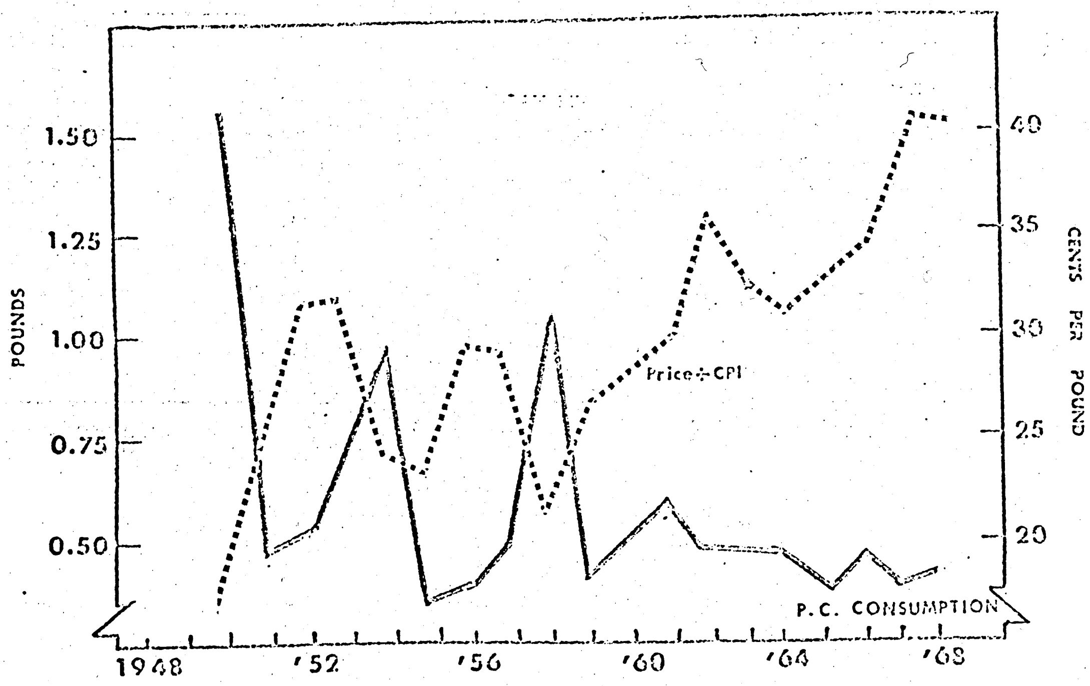
Canned sardines: The availability of alternative fish products, including frozen convenience products, has caused a downward shift in consumption of canned sardines compared to pre-World War II. Short-term consumption changes are quite responsive to price levels in that lower prices tend to encourage consumption. Foreign suppliers are taking an increasing share of the domestic market.

Table 2.16.--U.S. per capita consumption and deflated wholesale prices of canned sardines, 1950-68

Year	Per capita consumption	Wholesale 1/ price ÷ CPI	Year	Per capita consumption	Wholesale 1/ price ÷ CPI
	Pounds 2/	Cents/pound		Pounds 2/	Cents/pound
1950	1.56	18.53	1960	0.48	27.83
1951	0.46	23.05	1961	0.57	29.52
1952	0.50	31.70	1962	0.48	35.95
1953	0.73	31.83	1963	0.47	32.27
1954	0.97	24.95	1964	0.46	31.01
1955	0.37	23.19	1965	0.41	33.16
1956	0.40	29.87	1966	0.46	34.71
1957	0.51	29.45	1967	0.41	40.74
1958	1.00	21.55	1968	0.43	40.17
1959	0.40	26.68			

1/ Consumer price index (CPI) 1957-9 = 100 2/ Edible weight

Figure 2.6--Sardines, canned, per capita consumption and price



<u>Shrimp</u>: Shrimp, a relatively important fishery product even in 1948, has shown a steady gain in aggregate consumption, so that for several years the retail value has been the highest of all fish products. Some increase in domestic landings is evident; however, imports have surpassed domestic supplies since 1960. Many of the less developed countries now look to the United States as an outlet for their shrimp production.

Table 2.17.--U.S. per capita consumption and deflated ex vessel prices of shrimp, 1948-67

Year	Per capita consumption	Ex vessel 1/ price ÷ CPI	Year	Per capita consumption	Ex vessel 1/ price ÷ CPI
	Pounds 2/	Cents/pound 3/		Pounds 2/	Cents/pound 3/
1948	1.408	20.98	1958	1.775	33.86
1949	1.448	23.21	1959	2.142	23.83
1950	1.469	27.06	1960	2.224	26.02
1951	1.714	25.52	1961	2.142	28.38
1952	1.816	26.22	1962	2.123	36.34
1953	1.816	31.56	1963	2.366	27.29
1954	1.856	24.21	1964	2.407	30.75
1955	1.938	27.11	1965	2.591	30.78
1956	1.836	33.82	1966	2.550	35.57
1957	1.652	36.60	1967	2.754	32.56

1/ Consumer price index (CPI) 1957-9 = 100

2/ Round weight

3/ Based on heads-on weight

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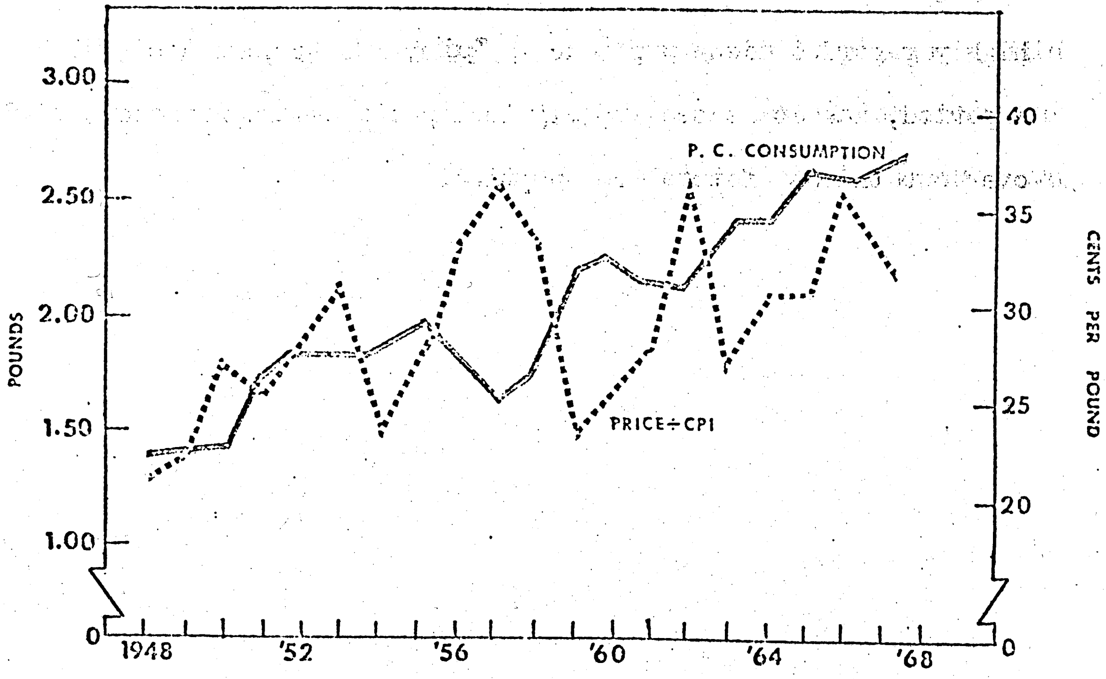
Figure 2.7--Shrimp, per capita consumption and price



Lobsters: Lobster consumption is increasing rapidly. An approximate doubling in per capita consumption has occurred since 1948. Rising consumer incomes have apparently increased demand for this highly regarded fishery product. Spiny lobster, most of which is imported, has increased rapidly in importance and now accounts for over two-thirds of total consumption.

Table 2:18.--U.S. per capita consumption and deflated ex vessel prices of lobster, 1948-67

Year	Per capita consumption	Ex vessel 1/ price ÷ CPI	Year	Per capita consumption	Ex vessel 1/ price ÷ CPI
	Pounds 2/	Cents/pound		Pounds 2/	Cents/pound
1948	0.096	49.6	1958	0.145	48.2
1949	0.109	43.5	1959	0.150	49.0
1950	0.117	42.9	1960	0.163	44.3
1951	0.130	39.9	1961	0.157	49.9
1952	0.127	45.6	1962	0.165	48.1
1953	0.142	41.5	1963	0.195	51.9
1954	0.138	40.8	1964	0.194	59.3
1955	0.147	41.8	1965	0.182	66.5
1956	0.140	47.4	1966	0.181	66.6
1957	0.160	39.0	1967	0.183	72.0

1/ Consumer price index (CPI) 1957-9 = 100 2/ Edible weight

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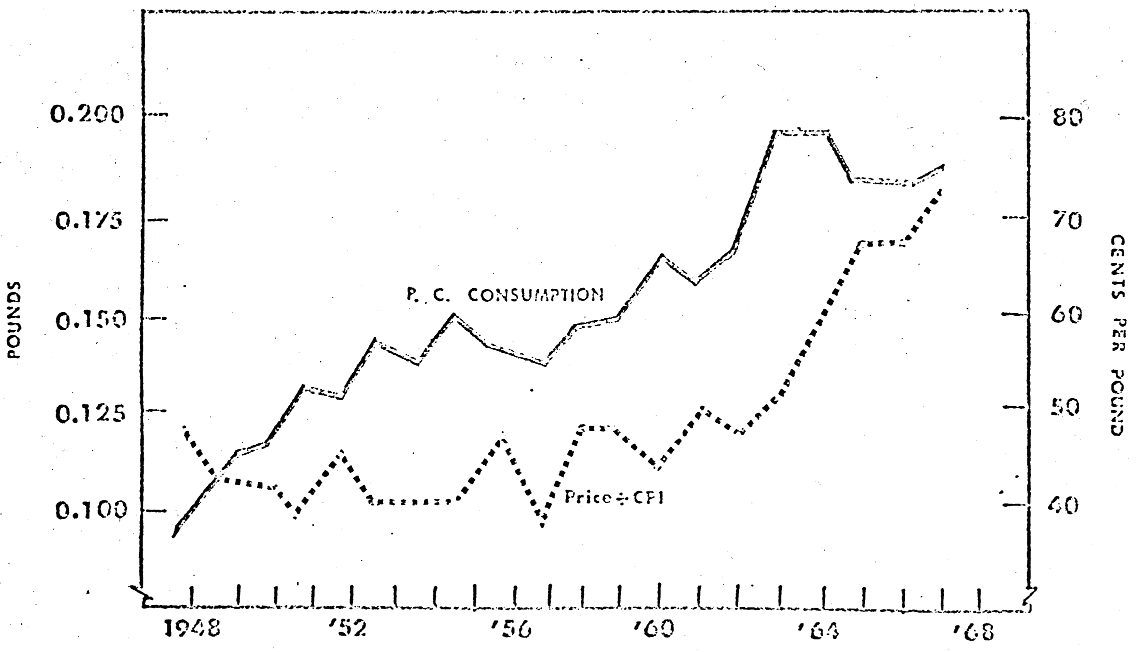
Figure 2.8--Lobsters, per capita consumption and price



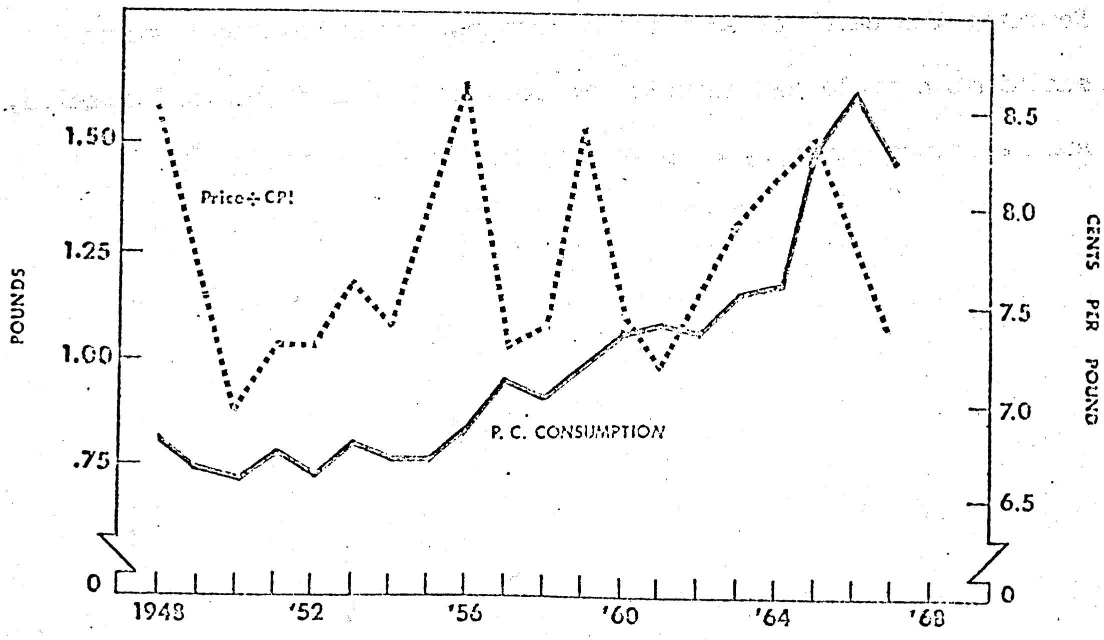
Crabs: Crab consumption, composed primarily of blue, king, and dungeness, remained stable until the mid-1950's and has increased rapidly since then. Increases since 1960 have been due totally to the rapid development of the Alaskan king crab fishery. More recently this resource has declined because of overfishing. Dungeness and tanner crab are now gaining in popularity.

Table 2.19.--U.S. per capita consumption and deflated ex vessel prices of crabs, 1948-67

Year	Per capita consumption	Ex vessel 1/ price ÷ CPI	Year	Per capita consumption	Ex vessel 1/ price ÷ CPI
	Pounds 2/	Cents/pound 3/		Pounds 2/	Cents/pound 3/
1948	0.814	8.49	1958	0.927	7.39
1949	0.742	7.74	1959	0.986	8.35
1950	0.720	6.92	1960	1.076	7.47
1951	0.792	7.29	1961	1.094	7.18
1952	0.729	7.28	1962	1.071	7.57
1953	0.806	7.59	1963	1.143	7.93
1954	0.765	7.38	1964	1.170	8.14
1955	0.770	7.97	1965	1.485	8.36
1956	0.824	8.63	1966	1.629	7.84
1957	0.963	7.29	1967	1.485	7.37

1/ Consumer price index (CPI) 1957-9 = 100
2/ Round weight
3/ Based on round weight

Figure 2.9--Crabs, per capita consumption and price



Clams: Hard, soft, and surf clams comprise the U.S. supply. Hard clams have been the traditionally important species, however, in 1960 half the catch consisted of surf clams and now this species accounts for about 65 percent of the total landings. The price per pound for surf clams is much lower than that for hard or soft clams. Recently the catch of surf clams has apparently reached maximum sustainable yield and industry is looking to other abundant species, such as ocean quahogs, as potential replacements for surfs.

Table 2.[illegible].--U.S. per capita consumption and deflated ex vessel prices of clams, 1948-67

Year	Per capita consumption	Ex vessel 1/ price ÷ CPI	Year	Per capita consumption	Ex vessel 1/ price ÷ CPI
	Pounds 2/	Cents/pound 3/		Pounds 2/	Cents/pound 3/
1948	1.833	5.02	1958	1.417	4.42
1949	1.755	4.59	1959	1.716	3.87
1950	1.859	4.80	1960	1.840	3.64
1951	1.911	4.51	1961	1.859	3.41
1952	1.748	4.88	1962	1.950	3.16
1953	1.658	5.03	1963	2.242	3.23
1954	1.358	5.02	1964	2.242	3.30
1955	1.410	4.77	1965	2.418	3.30
1956	1.534	4.56	1966	2.483	3.47
1957	1.573	4.43	1967	2.308	3.71

1/ Consumer price index (CPI) 1957-9 = 100 3/ Based on shell-on weight
2/ Round weight

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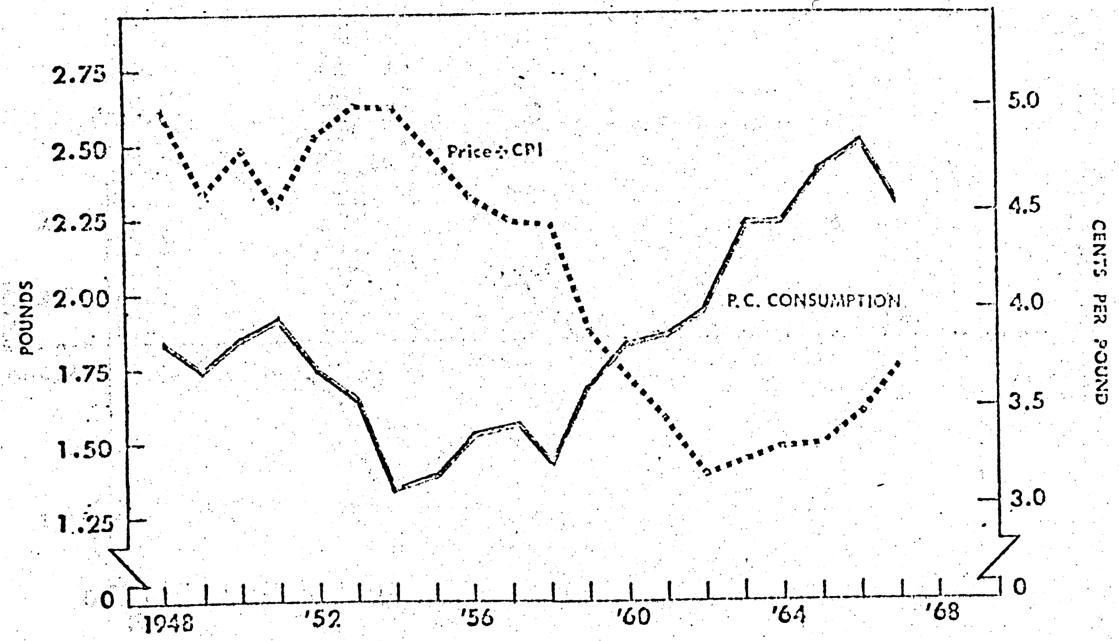
Figure 2.10--Clams, per capita consumption and price



Scallops: Per capita consumption of scallops has been steady throughout the period with the exception of about a 25 percent higher figure from 1960 through 1966. Unusually high prices prevailed from 1963 through 1966. Not incidentally, this was a time of heavy promotion by industry. Canadian imports increased rapidly from 1957 to 1964 and now supply about half of the U.S. market.

Table 2.21.--U.S. per capita consumption and deflated ex vessel prices of scallops, 1948-67

Year	Per capita consumption	Ex vessel 1/ price ÷ CPI	Year	Per capita consumption	Ex vessel 1/ price ÷ CPI
	Pounds 2/	Cents/pound 3/		Pounds 2/	Cents/pound 3/
1948	0.124	6.86	1958	0.153	5.66
1949	0.141	5.56	1959	0.166	5.61
1950	0.140	6.54	1960	0.200	3.99
1951	0.146	5.82	1961	0.207	4.29
1952	0.138	7.56	1962	0.190	4.54
1953	0.161	5.55	1963	0.182	5.04
1954	0.151	5.64	1964	0.184	5.94
1955	0.148	6.60	1965	0.173	7.22
1956	0.140	6.71	1966	0.188	5.12
1957	0.152	5.82	1967	0.127	7.81

1/ Consumer price index (CPI) 1957-9 = 100
2/ Edible weight
3/ Based on shell-on weight

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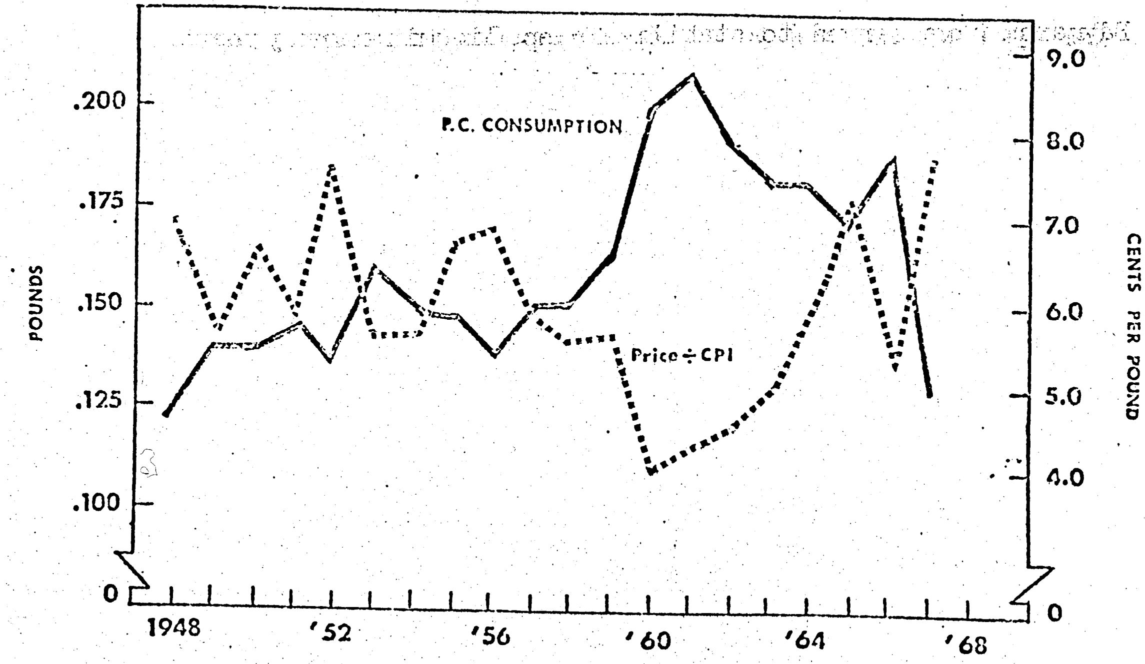
Figure 2.11--Scallops, per capita consumption and price



Oysters: Dwindling resource supplies, caused in some cases by pollution and in others by oyster diseases, have resulted in a sharp downward trend in consumption. Seeding programs in the Chesapeake Bay area have served to stabilize supplies in recent years.

Table 2.22.--U.S. per capita consumption and deflated ex vessel prices of oysters, 1948-67

Year	Per capita consumption	Ex vessel 1/ price ÷ CPI	Year	Per capita consumption	Ex vessel 1/ price ÷ CPI
	Pounds 2/	Cents/pound 3/		Pounds 2/	Cents/pound 3/
1948	4.590	5.13	1958	3.442	5.35
1949	4.463	5.40	1959	3.332	5.28
1950	4.267	5.44	1960	3.111	5.56
1951	4.038	5.19	1961	3.204	6.01
1952	4.437	5.00	1962	2.882	5.80
1953	4.242	4.60	1963	2.984	5.12
1954	4.318	5.04	1964	3.043	5.02
1955	4.020	4.95	1965	2.814	5.49
1956	3.842	5.11	1966	2.678	5.55
1957	3.630	4.93	1967	3.272	5.54

1/ Consumer price index (CPI) 1957-9 = 100
2/ Round weight
3/ Based on shell-on weight

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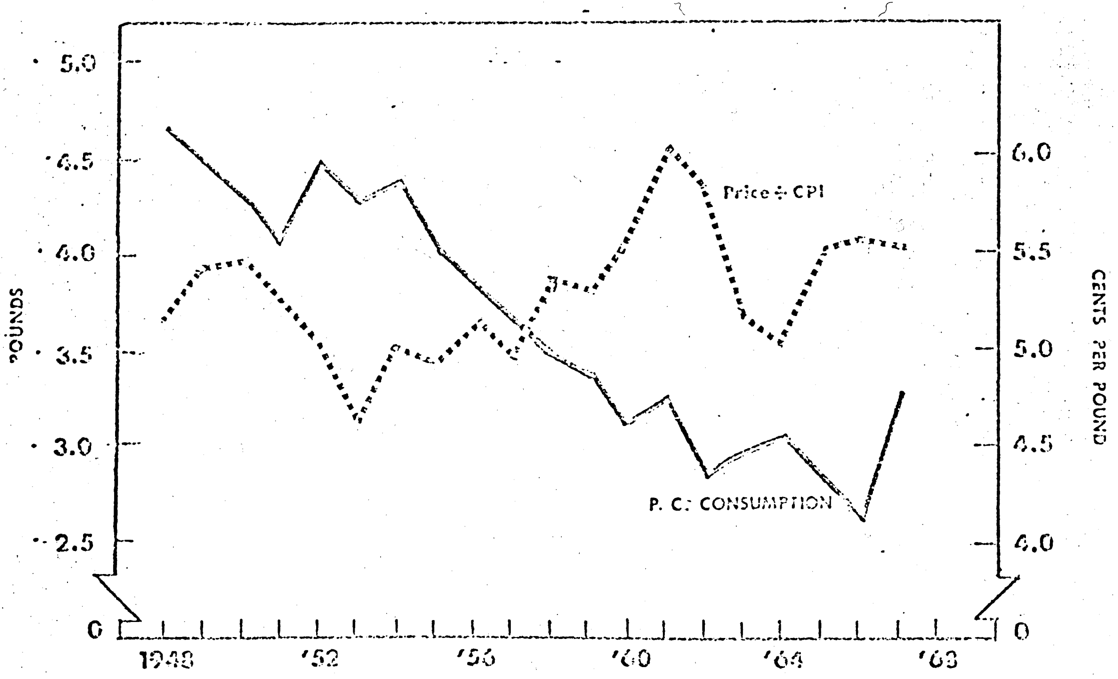
Figure 2.12--Oysters, per capita consumption and price



Other food fish: There are over a hundred additional species of fish used commercially in the United States but not included in the preceding data. These may be classed within one of the following categories, (1) those for which there is a low resource base, often quite important in local areas, (2) those that are low valued relative to harvesting cost, and (3) newly developed resources which may become important.

Table 2.23.--U.S. per capita consumption and deflated ex vessel prices of other food fish, 1950-67

Year	Per capita consumption	Ex vessel 1/ price ÷ CPI	Year	Per capita consumption	Ex vessel 1/ price ÷ CPI
	Pounds 2/	Cents/pound 3/		Pounds 2/	Cents/pound 3/
1950	3.8	13.0	1959	3.3	10.2
1951	3.8	11.2	1960	2.6	9.8
1952	3.7	11.0	1961	2.6	8.8
1953	3.8	10.4	1962	2.6	9.3
1954	3.4	10.3	1963	2.3	9.5
1955	3.5	9.4	1964	2.4	9.4
1956	3.2	8.4	1965	1.9	9.7
1957	2.9	10.5	1966	1.9	9.6
1958	2.6	10.6	1967	2.0	11.2

1/ Consumer price index (CPI) 1957-9 = 100
2/ Round weight
3/ Edible weight

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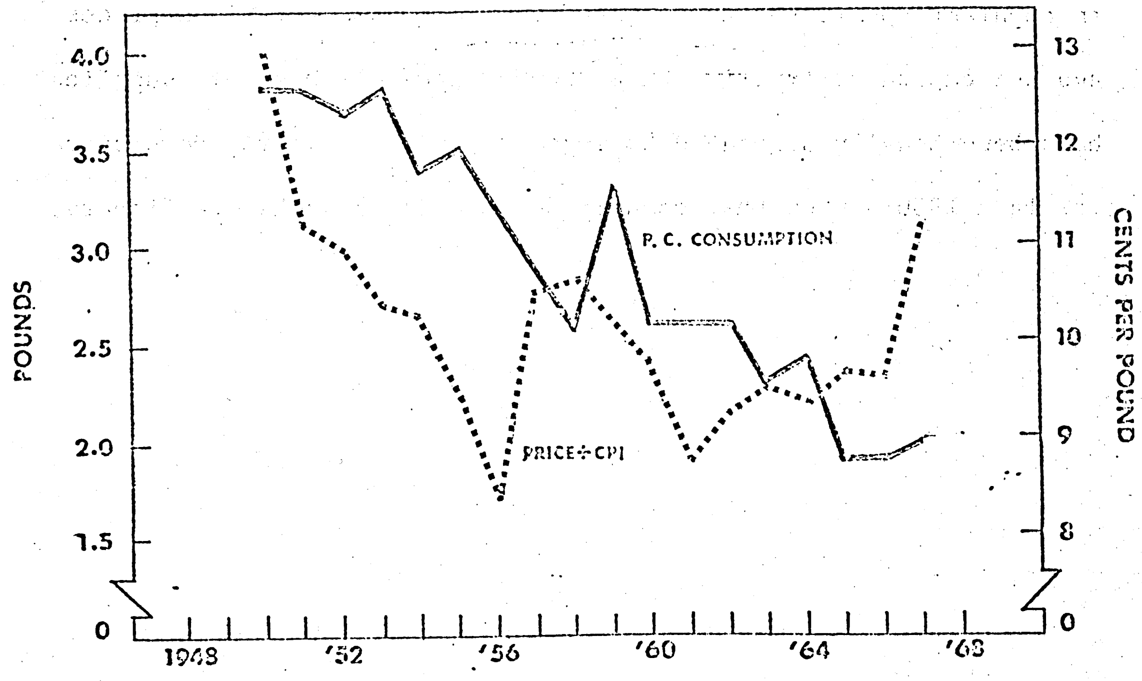
Figure 2.13--Other food fish, per capita consumption and price



Fish meal: Demand for fish meal parallels the demand for broiler chickens and other farm animals which utilize this product. Prices in turn, are heavily influenced by the availability of soybean and other protein meal products used in livestock rations. There is an apparent upward shift in demand beginning about 1960 as prices and per capita utilization have trended upward. Domestic supplies have been heavily augmented by imports principally from Peru since the late 1950's when that country developed the anchoveta fishery.

Table 2.24.--U.S. per capita utilization and wholesale price of fish meal, 1950-1967

Year	Per capita utilization	Wholesale price	Year	Per capita utilization	Wholesale price
	lbs. meal	$ per short ton		lbs. meal	$ per short ton
1950	4.08	124.30	1959	5.17	117.70
1951	4.49	120.30	1960	4.87	87.80
1952	5.58	123.70	1961	5.91	104.30
1953	4.78	124.40	1962	6.22	117.70
1954	5.11	129.90	1963	6.85	120.80
1955	4.51	133.50	1964	7.20	124.60
1956	4.71	130.40	1965	5.53	147.00
1957	4.14	126.40	1966	6.99	152.10
1958	4.10	130.70	1967	8.90	128.00

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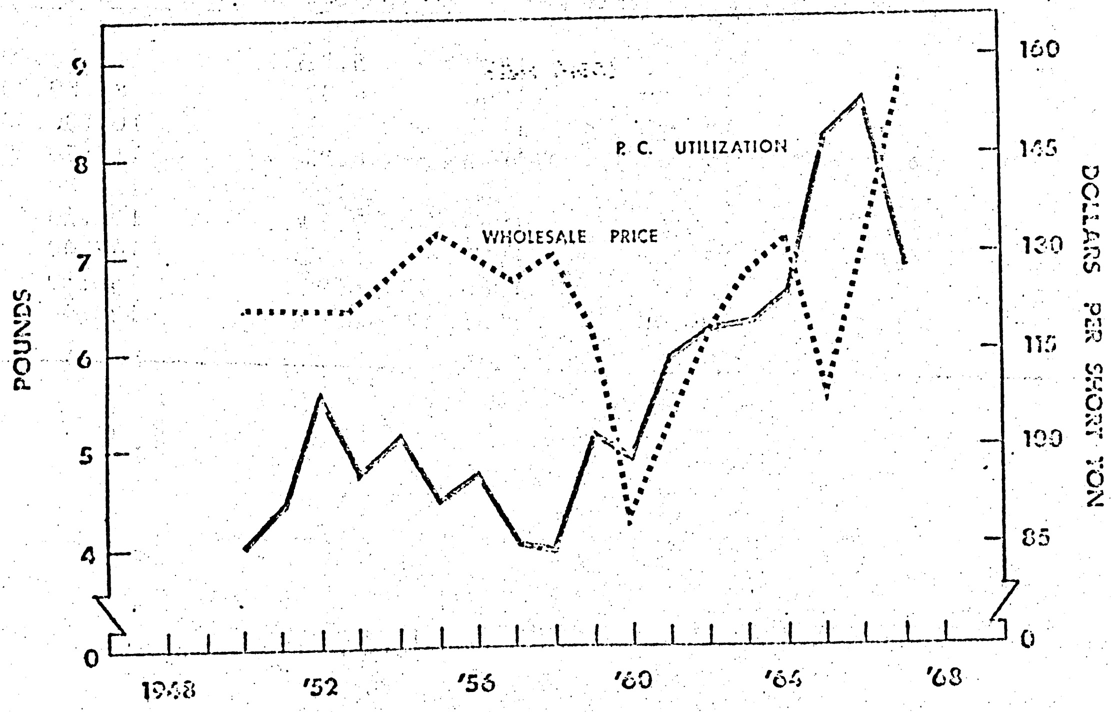
Figure 2.14--Fish meal, per capita consumption and price



Chapter 3

BIOLOGICAL GROWTH, YIELD, AND SUPPLY

3.1 Introduction

In this chapter, we shall discuss the basic determinants of the supply of fish. This will establish the theoretical foundation for the supply side of one projection model which is presented in Chapter 5. Two possible models of the yield from a fishery will be considered. The models are essentially variants of the model developed by Milner B. Schaefer (1954). The models assume logistic growth of the biomass of fish. One model assumes that the yield from fishing is linearly related to effort. We shall call this the logistic-constant returns (LCR) model. The other assumes decreasing returns from effort. This we call the logistic-decreasing returns (LDR) model.

3.2 The LCR Model

The LCR model indicates a linear relationship between "fishing effort" and "sustainable yield" per unit of effort. Ideally, fishing effort is an index of inputs, including ships, gear, labor, time, and others used to catch fish. In practice, we usually must be content with some proxy, such as the number of ship-days spent in fishing. Corresponding to any given effort, there is a sustainable yield--that is, an average yield that could be maintained indefinitely.

Let us consider in some detail the basis of the LCR model. First, consider biological growth. The LCR model assumes the simple logistic growth curve

$$m_t = \frac{M}{1 + ce^{-gt}} \qquad (3.1)$$

where m_t is the biomass of some species of fish at time t, M is the stable biomass that would be approached gradually from biological causes alone (recruitment, growth, & mortality), e is the base of natural logarithms ($e \sim 2.718$), and c and g are constants.[1]

This curve has been used by many biologists, population experts and economists. Davis (1941), Tintner (1952), and Pearl & Reed (1923) have discussed the properties of such curves in detail. There is one caveat of which the reader should be aware. These writers have used the logistic to describe the numbers in a population and not its weight. The extension to weight may be unwarranted.

---

[1] It should be mentioned that an alternative approach to the logistic model (or variations on the logistic) for exploring the effect of fishing on catch is the dynamic pool or yield per recruit model. This model uses the relationship among growth, natural mortality and fishing mortality to compute the yield in weight theoretically obtainable from a constant number of recruits entering the fishery. For a discussion of this approach, see R. J. H. Beverton, and S. J. Holt, "On the Dynamics of Exploited Fish Populations," Min. Agr., Fish and Food (U.K.), Fish. Investig., Ser. II, 19: 1-533, 1957 and E. W. Ricker, Handbook of Computations for Biological Statistics of Fish Populations. Bull. Fish. Res. Bd. Canada, 119: 1-300, 1958.

The logistic curve rises throughout, but the rate of increase first increases, then declines; and it approaches the upper limit, M. (Figure 3.1). The maximum size of the biomass is limited by food, space, and other environmental parameters.

More specifically the rate of increase (found by differentiating (3.1)) is

$$\frac{dm_t}{dt} = gm_t \left(1 - \frac{m_t}{M} \right) \tag{3.2}$$

Note that: (1) growth (i.e., increment to the biomass) approaches zero as m_t approaches M, and (2) the greatest growth is where the current biomass is one-half the maximum biomass.

Now consider the yield from fishing. The LCR model assumes that yield is proportional to effort:

$$y_t = kx_t m_t, \qquad 0 \leq kx_t \leq 1. \tag{3.3}$$

where y_t is the yield, k is a constant, x_t is fishing effort, and m_t is the biomass of the species we are studying (all at time t).

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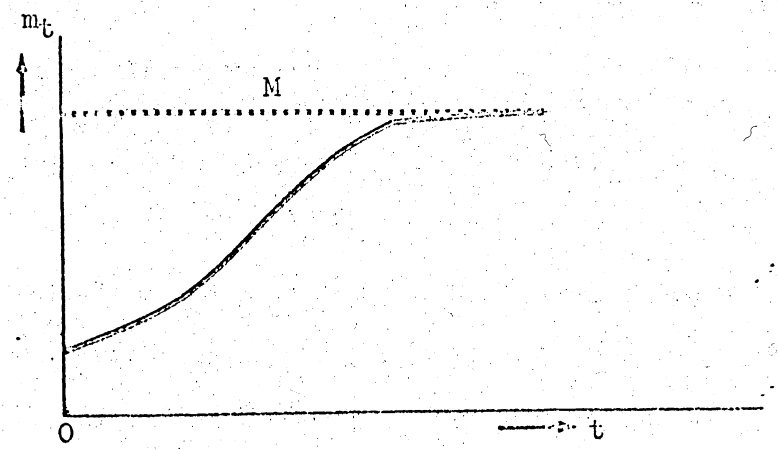
Figure 3.1--General shape of the logistic curve



Equations (3.2) and (3.3) together imply that the yield is a second-degree function of effort. Pella (1967) explained the detailed mathematics. Let us briefly go through the mathematics ourselves. When the biomass is stabilized with fishing (steady-state equilibrium), the increase due to biological causes is just matched by the yield from fishing (thus, making the net change in population zero). Thus, from (3.2) and (3.3),

$$y_t = gm_t\left(1 - \frac{m_t}{M}\right) = kx_t m_t. \tag{3.4}$$

solving for m_t,

$$m_t = M(1 - \frac{k}{g} x_t). \tag{3.5}$$

Inserting (3.5) into the last expression in (3.4), we get

$$y_t = M\left(kx_t - \frac{k^2 x_t^2}{g}\right) \tag{3.6}$$

Equation (3.6) is a second-degree polynomial. Simplifying, we have

$$y_t = ax_t - bx_t^2. \tag{3.7}$$

where $a = kM$ and $b = \frac{k^2}{g} M$.

To estimate the sustainable yield associated with any stated effort, we need only to estimate the two constants, a and b. We shall discuss this problem in Section 3.4.

3.3 The LDR Model

Equation (3.7) depends on the two assumptions: first, that the natural biological growth rate is a logistic curve; second, that (3.3) expresses the relation between effort and yield at time, t. Although (3.7) has been used extensively in the analysis of fishery behavior by fishery biologists, we have some doubts about the assumption expressed by equation (3.3). We doubt if doubling the effort would double the yield. The first unit of effort takes some proportion of the biomass, say pm_t, leaving $(1-p)m_t$. We shall now assume with Beverton and Holt (1957)[2] that a second unit of effort would take $p(1-p)m_t$, leaving $(1-p)^2 m_t$. Then x_t units of effort would leave $(1-p)^{x_t} m_t$, or say $z^{x_t} m_t$, (where $z = (1-p)$). And the yield would be

$$y_t = m_t (1 - z^{x_t}), \tag{3.8}$$

where y_t is yield, x_t is effort, and where $0 < z < 1$ is the proportion of the biomass that would be left after one unit of effort.

Following the same procedure as before, if (3.8) holds, at equilibrium

$$y_t = gm_t (1 - m_t/M) = (1 - z^{x_t})m_t . \tag{3.9}$$

---

[2] The rationale for this procedure is explained in Beverton and Holt (1957). However, because they could assume that p was small they replaced (1-p) with e^{-a}. (Continued)

2 (Continued)

Richard Hennemuth, NMFS, Woods Hole, Massachusetts, and Jerome Pella, NMFS, Auke Bay, Alaska, and others have expressed doubts as to whether this procedure was a proper interpretation of Beverton and Holt's work. Pella suggested that a better rationale for this equation could be either "that the fraction of the population removed by a unit of economic effort decreases with increasing economic effort even with the fish population biomass fixed," or it could be "based on fishing gear interference combined with a reduction in concentration with increasing economic effort."

Hennemuth questioned the LDR model as an approximation of the response of supply to increase in consumer demand beyond MSY (i.e., what the right side of the yield function looks like.). They indicated quite correctly that neither the LCR, or LDR models have been validated so that we can solve the question of the "other side of the yield function." It probably varies by species. We agreed and pointed out that both projections under the LCR and LDR models were included in the manuscript and that we were only interested in showing a decline in production after fishing effort expanded beyond E_{MAX}. They agreed that this was a desirable feature, although the exact path and rate of decline in production was debatable.

from which we find that

$$m_t = M\left(1 - \frac{1 - z^{x_t}}{g}\right) \quad , \tag{3.10}$$

and inserting (3.10) into the right-hand side of (3.9),

$$y_t = M\left[(1 - z^{x_t}) - \frac{(1 - z^{x_t})^2}{g}\right] \tag{3.11}$$

Since $0 < z < 1$, equation (3.11) shows that the annual yield would approach $M(1 - 1/g)$ if fishing effort were increased indefinitely. It also indicates that with no effort there would be no yield. As effort increased, yield would increase until it reached a maximum and then depending upon the value of g it might fall.

3.4 Statistical Estimation of Yield Functions

If there were series of observations on effort and corresponding yields in a number of periods of time, we could estimate the parameters in (3.7) and (3.11) by the classical method of least squares or by other techniques (Fox 1970) for fisheries on a world basis. We made estimates of the yield curves on a regional basis by utilizing the information we had at hand. The derivation of our yield function utilizes (3.7) and (3.11) together with landings and price in a base period, and biologists' estimates of MSY.[3] We

---

[3] Biologists have devised a number of ways to estimate MSY, some by intuitive judgment alone. We have merely taken their estimates as an input to our study and selected two theoretical yield-curves which will have a maximum coinciding with the empirical estimates of MSY.

used (3.7) or (3.11) to estimate the relative yield y_t/y_1 associated with the relative effort x_t/x_1. (Here y_1 and x_1 are yield and effort in some base period, such as the past 5 years.) The effort-yield function will then tell what proportional increase in yield would result from any stated proportional increase in effort.

The base-period yields (catches), for each principal species are readily available. Several biologists have estimated the maximum sustainable yield, y^*, for various species in particular regions, using a variety of technical methods together with individual judgment. Gulland (1970) surveyed these estimates and published a detailed summary.

More specifically, we employed the following procedure in estimating the catch-yield relation for any stock of fish. Our second-degree parabola can be written[4]

$$y_t/y_1 = ax_t/x_1 - b(x_t/x_1)^2 \qquad (3.12)$$

Where y_1 and x_1 are yield and effort in some base period, such as the past 5 years and y_t and x_t are projected yield and effort.

Our problem is to compute the constants, a and b, so that the curve goes through the points (0,0) and (1,1); and is tangent to y^*. Differentiating (3.12), we have

$$\frac{d(y_t/y_1)}{d(x_t/x_1)} = a - 2bx_t/x_1. \qquad (3.13)$$

---

[4] The constants (a and b) in 3.12 differ from those in 3.7, since the y's and x's in 3.12 are normalized.

When yield is a maximum y^*, and when x^* is the corresponding effort,

$$x^*/x_1 = a/2b. \tag{3.14}$$

Inserting (3.14) into (3.12),

$$y^*/y_1 = a^2/2b - a^2/4b = a^2/4b \tag{3.15}$$

In the base period, $y_t/y_1 = 1$ and $x_t/x_1 = 1$. So, from (3.12),

$$1 = a - b;\ b = a - 1. \tag{3.16}$$

Equations (3.15) and (3.16) together indicate that

$$y^*/y_1 = a^2/(4a - 4);$$

that is,

$$a^2 - 4ay^*/y_1 + 4y^*/y_1 = 0. \tag{3.17}$$

Solving (3.17) for a

$$a = 2y^*/y_1\ \left(1 \pm \sqrt{1 - y_1/y^*}\right). \tag{3.18}$$

If we know y^* and y_1, we can compute "a" from (3.18). Then, from (3.16), b = a - 1. So we have an estimate of both constants in (3.12). Of course, (3.18) gives us two values of a and two corresponding values of b. We will use the larger of the two values of a when there is current overfishing but otherwise we use the smaller value.

We derive the LDR yield function in the following way. If we have given only the yield (i.e., catch) in the base period, y_1, and the maximum sustainable yield, y^*, and if we assume some value of g in (3.1), we can estimate the relative yields, y_t/y_1, that would correspond to various degrees of relative effort, x_t/x_1. Thus, if we assume that the yield would approach zero if effort became very large, we are assuming that $g = 1$. In this study, we assumed that $g = 1$. In that case, equation (3.11) can be written

$$y_t/y_1 = Mz^{x_t/x_1} (1 - z^{x_t/x_1}). \tag{3.19}$$

Equation (3.19) is maximized when $z^{x_t/x_1} = 1/2$. So the maximum ratio y^*/y_1 is reached when $y^*/y_1 = 1/4\ M$, or $M = 4\ y^*/y_1$. Thus (3.19) is equivalent to

$$y_t/y_1 = 4\ y^*/y_1\ z^{x_t/x_1} (1 - z^{x_t/x_1}) . \tag{3.20}$$

Since y_1, x_1 and y^* are known, and since in the base period,

$$\frac{y_1}{y_1} = 1 = 4\,\frac{y^*}{\bar{y}_1}\,\bar{Z}\,(1-Z), \qquad (3.21)$$

we can compute $Z = \frac{1 \pm \sqrt{1-y_1/}}{2}$

3.5 A Numerical Example of the Two Catch-Effort Functions

The following Worksheet 3.1 shows how we computed yield functions for groundfish, Atlantic northeast. In this case, there appears to have been overfishing in the base year (1965), so the effort-yield curve was downward sloping. Figure 3.2 shows the results graphically. The two curves are somewhat similar until approaching the base period, when $x_t/x_1 = 1$ and $y_t/y_1 = 1$. The striking difference between the two curves can be seen when they are extrapolated to estimate the yields that would result from substantial increases in effort. The LCR curve drops sharply, and reaches zero with an increase of about one-quarter in effort. The LDR curve drops much less rapidly, and would never quite reach zero, even if effort were increased without limit.

Which of the two curves is better for purposes of projection, where we must extrapolate far beyond the range observed in the past? This is a matter of judgment. We are inclined to favor the LDR function, based upon (3.20).

Worksheet 3.1

Computation of world supply functions for groundfish in the Atlantic northeast

y_1)	Landings (1965) Gulland	2,658 thousand metric tons
y^*)	MSY Gulland	3,960 thousand metric tons

A. Schaefer Yield Function

$$y_1/y^* = 0.67121 \qquad y^*/y_1 = 1.48984$$

$$a = 2y^*/y_1\ (1 \pm \sqrt{1 - y_1/y^*} = 2.97968\ (1 + \sqrt{0.32879})$$

$$= 2.97968\ (1.57340) = 4.68822$$

$$y_t/y_1 = 4.68822\ x_t/x_1 - 3.68822\ (x_t/x_1)^2$$

B. LDR Yield Function

$$z = \frac{1 \pm \sqrt{1 - y_1/y^*}}{2} = \frac{1 - \sqrt{0.32879}}{2} = \frac{0.42660}{2} = 0.21330$$

$$y_t/y_1 = 4y^*/y_1\ z^{x_t/x_1}(1 - z^{x_t/x_1}) = 5.95936\ z^{x_t/x_1}(1 - z^{x_t/x_1})$$

x_t/x_1	$(x_t/x_1)^2$	LCR Yield ratio y_t/y_1	$0.21330^{x_t/x_1}$	$z^{x_t/x_1}(1-z^{x_t/x_1})$	LDR yield Ratio y_t/y_1
1/4	1/16	0.94154	0.67959	0.21775	1.29765
1/2	1/4	1.42206	0.46184	0.24854	0.48114
1	1	1.00000	0.21330	0.16780	1.00000
3/2	9/4	-0.12662	0.09850	0.08880	0.52919
2	4	. . . .	0.04550	0.04343	0.25882
3	9	. . . .	0.00971	0.00962	0.05733
4	16	. . . .	0.00207	0.00207	0.01234

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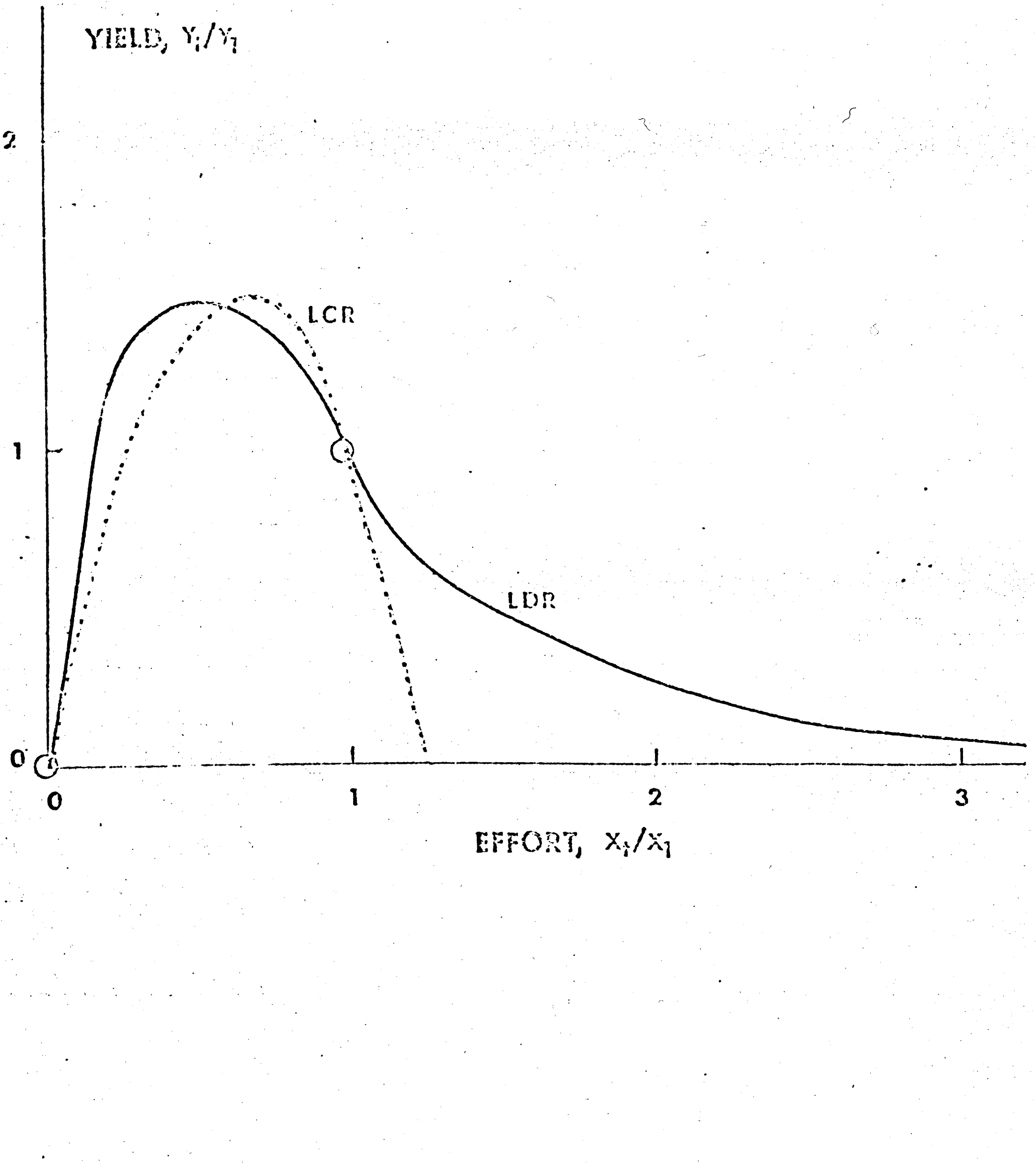
Figure 3.2--Groundfish, Atlantic northeast, response of yield to effort



3.6 Industry Cost Functions

To derive cost curves, we assume that total cost of harvesting, c_t, varies with effort, x_t (Gordon 1954) so that the relative cost in any region is proportional to relative effort (that is, if effort increases by x%, total cost goes up by x%);

$$c_t/c_1 = x_t/x_1. \qquad (3.22)$$

Then (3.12) can be written

$$y_t/y_1 = ac_t/c_1 - b(c_t/c_1)^2. \qquad (3.23)$$

Solving (3.23) for c_t/c_1,

$$\text{Total cost:} \quad c_t/c_1 = \frac{a \pm \sqrt{a^2 - 4by_t/y_1}}{2b} \qquad (3.24)$$

Where from (3.16), $1 = a-b$ and a is given in (3.18).
Equation (3.24) indicates the change in total cost required to attain any given increase in yield. Thus, to increase yield, 50% (so that $y/y_1 = 1.5$) the total cost would be $\frac{a \pm \sqrt{a^2 - 6b}}{2b}$ times the cost in the base period.

Dividing (3.24) by y/y_1,

$$\text{Average cost:} \quad \frac{c_t/c_1}{y_t/y_1} = \frac{a \pm \sqrt{a^2 - 4by_t/y_1}}{2by_t/y_1} \tag{3.25}$$

and differentiating (3.24)

$$\text{Marginal cost:} \quad \frac{d(c/c_1)}{d(y/y_1)} = \frac{F\ 1}{\sqrt{a^2 - 4by_t/y_1}} \; . \tag{3.26}$$

Equations (3.23) through (3.26) are based upon the logistic-constant returns model (LCR), as indicated by (3.12). The logistic-decreasing returns model (LDR), indicated by equation (3.19) can be rewritten

$$y_t/y_1 = M \left[z^{x_t/x_1} - z^{2x_t/x_1} \right] , \tag{3.27}$$

or

$$z^{2x_t/x_1} - z^{x_t/x_1} + \frac{1}{M} y_t/y_1 = 0$$

Thus

$$z^{x_t/x_o} = \frac{1 \pm \sqrt{1 - 4y/y\ M}}{2} \; . \tag{3.28}$$

Again, assuming that $c_t/c_1 = x_t/x_1$, we can solve (3.28) for c_t/c_1:

$$c_t/c_1 = \frac{\log \left[\dfrac{1 \pm \sqrt{1 - 4y_t/y_1\ M}}{2} \right]}{\log z} \; , \tag{3.29}$$

where Z is given in (3.21).

Equation (3.29) gives total cost. Average cost is, as before, $\dfrac{c_t/c_1}{y_t/y_1}$. That is

$$\frac{c_t/c_1}{y_t/y_1} = \frac{\log\left[\dfrac{1 \pm \sqrt{1 - 4y_t/y_1 \quad M}}{2}\right]}{\log z \cdot y_t/y_1} . \qquad (3.30)$$

Equations (3.25) and (3.30) indicate curves of average cost, as a function of landings, as shown in the diagram below. Both curves rise at an increasing rate as yield increases from zero to y*; then, as yield is pushed beyond the maximum sustainable yield, average costs continue to rise as yield drops on account of overfishing. In general, the LDR curve lies above the LCR curve except for yields below those in the base period. (See Figure 3.3).

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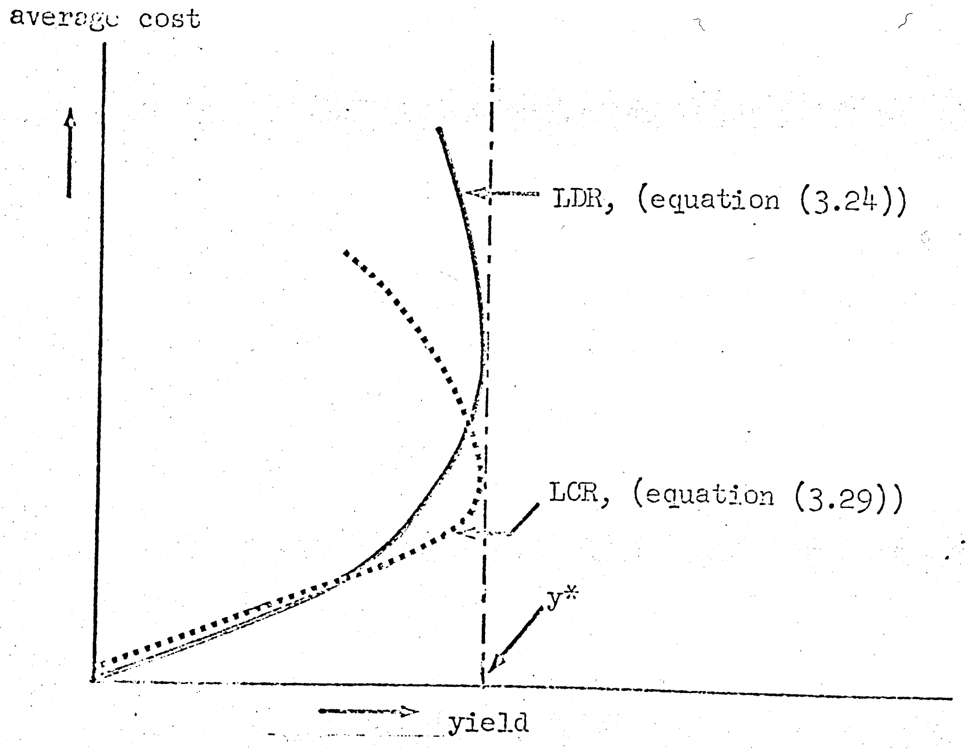
Figure 3.3--Average cost for LDR and LCR functions given the same basic data



3.7 Industry Supply Functions for a Region

Under conditions of perfect competition, increasing costs, and free access to the resource, production is increased up to the point where price, p_t, equals average cost.[5] This condition should apply, at least approximately, to fisheries. In any case, we will assume,

$$p_t/p_1 = c_t/c_1, \tag{3.31}$$

For example, if average costs should rise 50%, we would expect production to be adjusted so that the price of fish would rise 50%.

Thus, for the LCR model, we can substitute (3.31) into (3.25):

$$\frac{p_t/p_1}{y_t/y_1} = \frac{a \pm \sqrt{a^2 - 4by_t/y_1}}{2by_t/y_1} \tag{3.32}$$

As it stands, (3.32) indicates price as the dependent variable; yield, as independent. But we shall consider the curve to be reversible. We shall use (3.32) to estimate the landings (i.e., the yield) that would result from any given price. In other words, we shall use (3.32) as the supply curve for the LCR model.

---

[5] If each operator could ignore the actions of his competitors, he would increase production only to the point where price was equal to <u>marginal</u> cost. This would provide net profits to the operators. But, since there is free access to the common resource, these profits would attract additional operators So the position where price equals marginal cost would be unstable. The industry would expand until price equaled average cost. This position would be stable; there would be no incentive for further expansion.

Similarly, the supply curve for the LDR model is

$$\frac{p_t/p_1}{y_t/y_1} = \frac{\log \left[\frac{1}{2} (\pm \sqrt{1 - 4y_t/y_1 M}) \right]}{y_t/y_1 \cdot \log z} \qquad (3.33)$$

So far, we have discussed the supply curve in any region; that is, the amount that the region could be expected to supply at various assumed prices. Next we need to combine these regional supply functions into a world supply function.

3.8 Supply Function for the World: An Aggregation of Regional Supply Functions

To make projections of future supplies and prices, we need to equate world supply with world demand (assuming certain levels of world population and income).

World sustainable supply at any specified price is the total amount that would be supplied by all regions at that price. Figure 3.4 illustrates the procedure for the case of three regions.

We first estimate each of the three regional supply curves (the heavy lines in the diagram). In the case illustrated, region 1 may be a region near the big market center, where fish may be caught at little expense, but where the stock is soon reduced by overfishing. Regions 2 and 3 are further removed from market; the potential supplies from these regions are large, but can be obtained only at greater expense. We shall assume that all three regions sell at the "world price" minus transportation; thus, supplies in all three regions respond to the same world price.

The curve of world sustainable supply is obtained by summing the regional supplies at any given price. For example, the diagram illustrates the case where the world price is p. (The price in each region is assumed to be some known percentage of the world price.) When the world price is p, the regional amounts supplied are q_1, q_2, q_3. Their sum, ($Q = q_1 + q_2 + q_3$) is the world supply at price p. Similarly, the world sustainable supply at any other price can be found by adding the curves horizontally.

We note that the world maximum sustainable yield (MSY) is the sum of the MSY's for the individual regions. It is indicated by the vertical line to the right of Figure 3.4. But this maximum sustainable yield would not be attainable without maintaining each region at MSY. It is biologically possible, but economically unfeasible, under competitive conditions. For example, as the world price would rise, it would be necessary to prevent overfishing in region 1 (and perhaps in region 2), if the potential world MSY were to be attained.

The heavy curve indicates the response of world supply to changes in world price. It assumes no controls--only the normal competitive responses of the fishing industry to prices and costs. That is what we have assumed in most of the projections reported here.

Whenever the regional supply functions are markedly different from one another, we found it necessary to estimate them separately,

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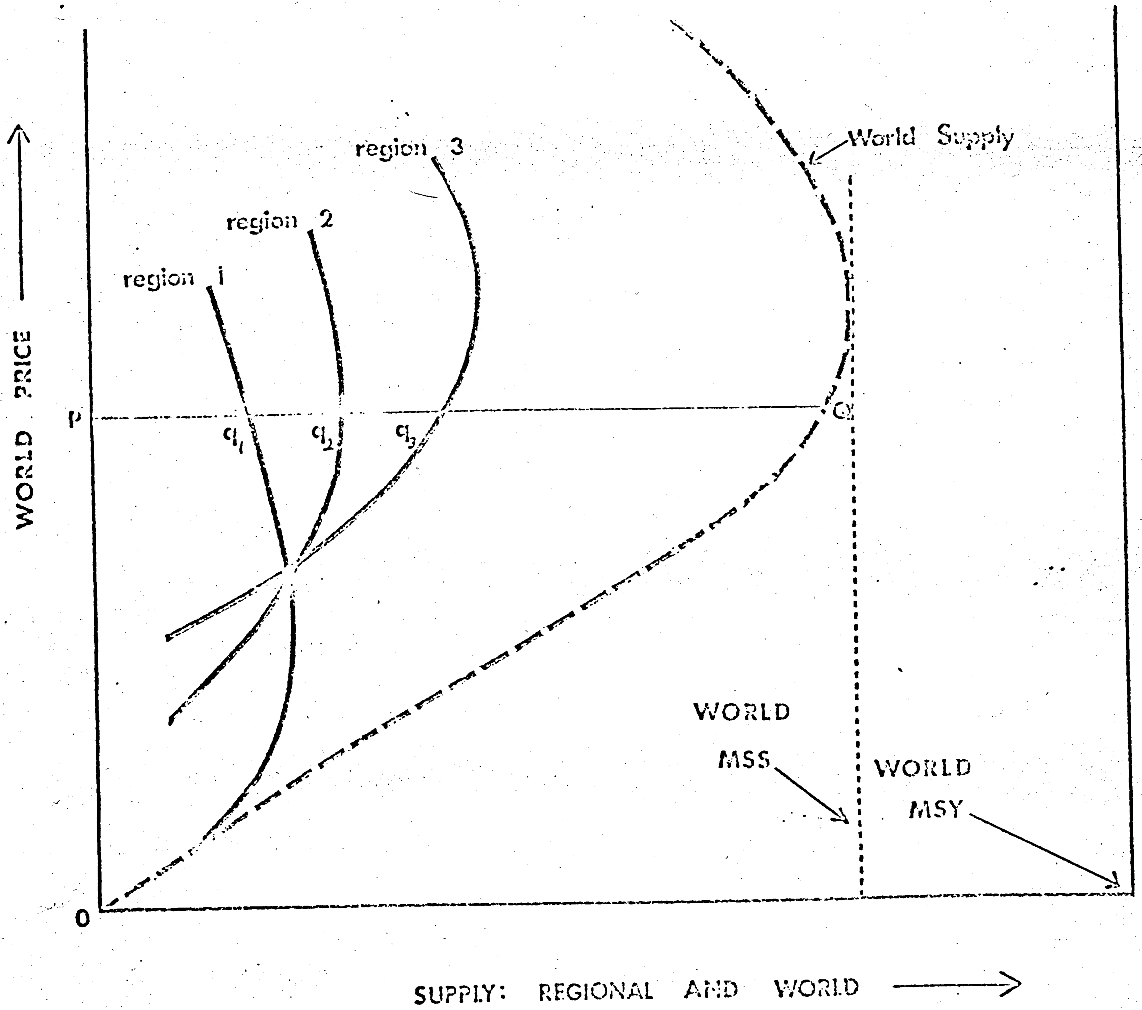
Figure 3.4--World supply and regional supply



and to derive the world supply function as indicated previously. But in some cases, we found it adequate to compute a world supply curve directly from world landings and world prices.

Therefore, we have two important concepts:

1) World maximum sustainable yield (MSY)

$$\sum_{i=1}^{n} MSY_i$$

2) World maximum sustainable supply (MSS)

$$\max \sum_{i=1}^{n} S_i$$

Only in the case where each region is controlled at MSY will the two concepts be equivalent.

3.9 Regional and World Supply Functions: A Mathematical Analysis

Regional variations in the degree of exploitation may have profound effects in terms of the aggregate world supply curve. Let us revert to the LCR model, and equation (3.23)

$$y_t/y_1 = ac_t/c_1 - b(c_t/c_1)^2 \quad . \qquad (3.34)$$

If we replace the expression c_t/c_1 by $p_t y_t/p_1 y_1$, and rearrange terms, we may solve for y_t in terms of p_t alone,

$$y_t = \frac{ap_1 y_1}{bp_t} - \frac{p_1^2 y_1}{bp_t^2} \quad , \qquad (3.35)$$

where p_1, y_1, are base period price and landings, respectively. Differentiating (3.35) with respect to price, and setting the resultant expression equal to zero, we may obtain the price, p^*, at which maximum sustainable yield is attained:

$$p^* = 2p_1/a \quad . \tag{3.36}$$

Since prices are assumed to be the same for all regions, the price at which MSY is reached in any given region is dependent upon the parameter "a" of the yield function, and this parameter is determined solely by the ratio y^*/y_1. Substituting (3.36) into (3.35), we get

$$y^* = \frac{a^2}{4b} y_1 \quad . \tag{3.37}$$

Let us now assume that there are n regions. The sum of the regional maximum yields is then given by:

$$\sum_{i=1}^{n} y_i^* = \sum_{i=1}^{n} \left(\frac{a_i 2}{4b_i} y_{1_i} \right) \tag{3.38}$$

where y_{1_i}, a_i and b_i are, respectively, the yield function parameters and the base period level of landings in the ith region. Equation (3.38) represents a global upper bound, a "maximum maximorum." On the other hand, let us define the world supply function as the sum of the regional supply schedules,

$$\sum_{i=1}^{n} y_{t_i} = \sum_{i=1}^{n} \left(\frac{a p_1 y_{1_i}}{b p_t} - \frac{p_1^{2} y_{1_i}}{b p_t^{2}} \right). \qquad (3.39)$$

Differentiating (3.39) with respect to price and then setting it equal to zero, we can solve for the price at which the world supply function reaches a maximum,

$$p_s^* = \frac{2 p_1 \sum_{i=1}^{n} \frac{y_{1_i}}{b_i}}{\left(\sum_{i=1}^{n} y_{1_i} \frac{a_i}{b_i} \right)} . \qquad (3.40)$$

When (3.40) is substituted into (3.39), the maximum point of the world supply function can be found,

$$\left(\sum_{i=1}^{n} y_{t_i} \right)^* = \frac{1}{4} \frac{\left[\sum_{i=1}^{n} \left(\frac{a_i}{b_i} y_{1_i} \right) \right]^2}{\sum_{i=1}^{n} \left(\frac{y_{1_i}}{b_i} \right)} . \qquad (3.41)$$

In general (3.41) will be less than (3.38),[6] but will approach (3.38) as differences in regional yield coefficients become smaller. When the regional coefficients are the same, the following holds:

$$\left(\sum_{i=1}^{n} y_{t_i} \right)^* = \frac{\frac{1}{4} \left[\sum_{i=1}^{n} \frac{a_i}{b_i} y_{1_i} \right]^2}{\sum_{i=1}^{n} \left(\frac{y_{1_i}}{b_i} \right)} = \frac{\frac{1}{4} \frac{a^2}{b^2} \left[\sum_{i=1}^{n} y_{1_i} \right]^2}{\frac{1}{b} \sum_{i=1}^{n} y_{1_i}} = \frac{1}{4} \frac{a^2}{b} \sum_{i=1}^{n} y_{1_i} . \qquad (3.42)$$

---

[6] A general statement about the relationship between (3.40) and (3.36) cannot be made. In other words, we cannot say a priori whether the price at which MSY is reached will be higher or lower than the price consistent with the maximum of the world supply function.

However, it is also true that

$$\frac{1}{4}\frac{a^2}{b}\sum_{i=1}^{n} y_{1_i} \equiv \sum_{i=1}^{n}\left(\frac{a_i^2}{4b_i}\, y_{1_i}\right) \equiv \sum_{i=1}^{n} y_i^* . \qquad (3.43)$$

Thus, world maximum sustainable yield can be attained in the market only if the regional yield parameters are the same.

Similar conclusions can be drawn from the LDR model. Given the relative yield equation from the decreasing returns model,

$$y_t/y_1 = Mz^{x_t/x_1}(1 - z^{x_t/x_1}) \qquad (3.44)$$

we may derive the price at which maximum sustainable yield will be forthcoming by first differentiating with respect to x_t/x_1, setting it equal to zero, and substituting the expression $p_t y^*/P_1 Y_1$ for x_t/x_1. Thus,

$$p^* = \frac{\log\left(\frac{1}{2}\right) p_1}{\log z}\,(y_1/y^*) . \qquad (3.45)$$

Since z depends upon the ratio y^*/y_1 (as does M in equation (3.44)), it follows that here too all regions must have the same degree of exploitation in order to harvest world maximum yield.

Thus, in summary, any one of three conditions would be sufficient to permit the maximum resource potential from the world's oceans to be harvested: first, if world yield and world landings are equally distributed between regions; secondly, if the <u>ratio</u> of landings to maximum sustainable yield is the same in all regions;[7/] and, finally, if each region's harvest rate is "frozen"--via regulations maintaining the level of the permissible harvest rate--at regional MSY. The ultimate effect of these regional variations is basically an empirical question. However, it is possible that for some species the impact of the spatial dimension could be significant, i.e., a considerable difference could arise between MSY and maximum supply.

[7/] It should be pointed out that given the specification in (3.34) that the slope of the absolute supply curve, i.e., $y_t = f(p_t)$, does depend upon the absolute level of base period landings, y_1; however, the elasticity of supply does not. Thus, the attainment of MSY merely depends upon the assumption that all regional supply curves have the same elasticity. The formula for the price elasticity of supply for the LCR model is given by:

$$E_s \equiv \frac{p_t}{y_t} \frac{dy_t}{dp_t} = \left[\frac{p_1}{ap_t - p_1} \right] - 1,$$

and thus is independent of base period landings.

The limit of E_s as $p_t \longrightarrow p^* = 0$, i.e., when $p_t = p^*$, the elasticity of supply is equal to zero.

CHAPTER 4

THE DETERMINANTS OF DEMAND FOR FISHERY PRODUCTS AND EMPIRICAL ESTIMATES OF THESE RELATIONSHIPS

4.1 Introduction

In Chapter 3, we showed how the supply of fishery products is derived. In this chapter, we shall discuss the basic determinants of the demand for fishery products. In addition, we shall quantify these relationships through the estimates of demand functions and present the functions to be used to make the projections.

4.2 Theory of Demand

First, let us set out the theoretical basis for demand estimation. Let Q/N be the per capita consumption of a good, (N symbolizing the size of the population): P_0/CPI be the deflated price of that good, P_1/CPI, ..., P_n/CPI the deflated prices of other goods, Y/N be the deflated per capita income of consumers, and Z_1, ..., Z_n are non-economic forces affecting fish purchases. This implies the following general demand function

$$Q/N=f\left(\frac{P_0}{CPI}, \frac{P_1}{CPI}, \ldots, \frac{P_n}{CPI}, \frac{Y}{N}, Z_1, \ldots, Z_n\right). \quad (4.1)$$

Hence per capita consumption of a given fishery product is determined by the price of the product, the prices of other products, the income of consumers, and other variables such as habit, product form, advertising, etc. The theory of demand used in this chapter is the most simplified with which one can work. The Economic Research Laboratory is presently working with more complicated dynamic demand functions which may reveal the influence of habit formation as well as income and price on per capita consumption of a commodity. See Houthakker and Taylor (1970). In practice, this complete functional relationship is rarely used to obtain empirical estimates and this study is no exception. One reason is that it is difficult to determine which variables should be included in the set P_1 through P_n and Z_1 through Z_n for any given product. Almost as common is the difficulty of obtaining data over a historical period especially for many non-economic variables.

Initial efforts were made to determine the effects of other prices on the consumption of the fish products. There was little statistical support for including these variables, as explained more fully in Chapter 5. We recognize that prices of other products may become important outside the range of the data, such as projections which are greater than current consumption. However, since no estimates are available these could not be taken into account.

This model has been criticized for not taking into account the possible simultaneous determination of supply and demand functions. This occurs when there are a number of jointly determined variables in a system. The most commonly investigated case occurs when price affects quantity, quantity affects price, and both are affected by outside forces (exogenous variables). This creates the so-called identification problem and necessitates a simultaneous estimation of demand and supply functions. Failure to consider this "identification problem" when it exists results in meaningless parameter estimates.

Year to year variations in fish catch are almost certainly highly dependent on natural phenomena, leaving economic forces, principally price, as a minor determinant. One study finds fish catch as a random variable (Doll, unpublished). In such cases the identification problem is not serious. The study by Doll, in which two-stage and three-stage least squares were used, shows that price and income elasticities were quite close to similar elasticities obtained from classical least squares. (See Section 4.3 of this chapter.)

For these reasons we have used the following version of the demand function in order to obtain empirical estimates to be used in projections.

$$Q/N=f\left(\frac{P_0}{CPI}, \frac{Y}{N}\right) \qquad (4.2)$$

Next, we chose the form of this function. Equations were run both in linear and logarithmic form. In the majority of cases, the log equations were superior from a statistical standpoint. Therefore, this form was used throughout in order to simplify summation across countries. The form shown in (4.3) was used except as noted later.

$$Q/N=A(P_0/CPI)^{\alpha} \quad (Y/N)^{\beta} \qquad (4.3)$$

In logarithms, (4.3) can be written

$$\log (Q/N) = \log A + \alpha \log P_0/CPI + \beta \log Y/N \, . \qquad (4.4)$$

α is the elasticity of consumption with respect to price, (sometimes called "price elasticity"). β is the elasticity of consumption with respect to income, (sometimes called "Engel's elasticity" in honor of Ernst Engel (1895)). The theory also specifies the sign of α and β. The price elasticity for normal goods is negative; that is, as price increases, consumption is discouraged, with the opposite effect if price goes down. In the case of an income increase, there tends to be an increase in consumption; while a decrease in income discourages consumption.

It should be recognized that this modified equation is likely to result in certain biases of the elasticity estimates. Omitting other prices is likely to affect both α and β. Also, the income coefficient is likely to be affected by other upward trends in the economy such as improved products which would be expected to bias the coefficient upward. We felt it was better to include these additional trend effects rather than use a "true" income elasticity and assume all trends will cease in the future.

During the past 50 years, economists and statisticians have developed practical methods of estimating the constants in (4.3) or (4.4). An enormous quantity of literature is available in this area. Among the pathbreaking studies, we mention Moore (1917), Working (1922), Ezekiel (1930), Schultz (1938), Stone (1954), and Wold and Jureen (1953).

In recent years, a number of economists have studied the demand for fish (Waugh and Norton, 1969; Lampe and Farrell 1965; Bell, 1968; Gillespie et. al., 196[illegible] Suttor and Aryan-Nejad, 1969; Doll, 1971; Purcell, 1968; Nash, 1967; and Cleary, 1969). These studies served as a basis for deriving the fishery demand equations used in the present study. To give a basis for worldwide projections, we found it necessary to make our own estimates of demand elasticities.

Fish meal presents a unique case among the products because it is an intermediate product--not used directly by humans, but used as a feed ingredient for poultry and meat animals. Thus, the demand for meal is termed a derived demand. In addition, the level of use of fish meal is highly sensitive to its price relative to that of other feed ingredients. These facts require a different specification of the demand function for fish meal. The broiler chicken industry is by far the largest user of fish meal. Soybean meal is the closest substitute for fish meal in rations fed to the chickens.

Therefore, the demand equation for fish meal in the United States was specified as follows:

$$Q_1 = a + b_1 \left(\frac{P}{CPI}\right) + b_2 \left(\frac{P_s}{CPI}\right) + b_3 C \quad \text{(United States)} , \qquad (4.5)$$

where Q and P are as above, and

C = the consumption of chickens in the United States,

P_s = the price of soybean meal.

Since it is difficult to reflect the numerous factors affecting fish meal use in other countries, a generalized equation was specified to reflect the various factors:

$$Q_2 = a + b_1 \left(\frac{P}{P_s}\right) + b_4 T \qquad \text{(Rest of World)} \quad , \qquad (4.6)$$

where T or time (one year) represents all other secular factors in other countries. World consumption, Q is then obtained by adding Q_1 and Q_2.

4.3 Empirical Estimation of Demand Parameters for Selected Fishery Projects, by Country

The primary interest in this study is to project fish consumption and prices by species for the United States. In order to accomplish this, however, we must take the rest of the world into account. Therefore, estimates of the demand relationship for each species by country were derived. Demand projections for each country were made based on these equations. We are quite confident that the U.S. demand projections are reliable for decision-making purposes. However, due to the possibility of inaccuracies in the projections for some countries, the projections for countries other than the United States are combined. However, each country's demand was first projected individually. While some individual foreign country estimates are questionable, we feel the total non-U.S. projections are reasonable.

The fishery products which are of major importance to the United States were selected for intensive analysis. They are discussed in chapter 2, but for reference are: (1) groundfish, (2) canned tuna, (3) canned salmon, (4) fresh and frozen salmon, (5) halibut, (6) canned sardines, (7) shrimp, (8) lobster, (9) crabs, (10) clams, (11) scallops, (12) oysters, (13) other food fish, and (14) fish meal.

Countries recording significant consumption were included in the demand analysis. Thus for those products such as halibut, where consumption is concentrated in a few countries, the coverage of the total project consumed is quite high (93 %). On the other hand, groundfish is consumed by many countries of the world, most of which are individually unimportant. In this case, the analysis covers only 57 % the total world consumption. Extrapolation to total world demand was done by assuming the same relationship holds for the excluded countries as well as for those in the analysis. (See Chapter 5.)

There are various techniques available to derive the coefficients to be used for projections. The general practice is to use an objective estimating procedure and accept the results of this without further consideration. The values of α, β, etc., are extremely critical in making the projections, particularly for those several years hence. Therefore, we felt it was desirable to interject judgment into selecting the elasticities to be used for making projections. For several reasons, outlined below, it was necessary to change some of the coefficients when they were at variance with a priori theory.

Annual time series observations were used as data to obtain the objective estimates. Statistics on landings, consumption, prices, and related information were obtained mainly from the Food and Agricultural Organization (FAO, Annual editions). Where possible, (i.e., Canada and the U.S.) data were obtained directly from the nations' statistical reports. Population and consumer income data were taken from sources in the U.S. Department of Agriculture (1968). We found many problems with the data; for example, the definitions for "tuna," "groundfish," and "flatfish," etc., were not uniform by country. Also, FAO must use considerable judgement in combining individual country reports which come to them in diverse forms and with different bases for reporting weight. More work is needed to improve these basic data, but for now, it is the only source available for many countries. The study would not have been possible without FAO data. Any improved data series will be used in these equations as soon as they are obtainable.

We used ordinary least squares procedures to estimate the demand function (4.3) for each country. While the results are far from perfect, they do provide useful approximations to the elasticities α and β, for the species in question in each country. These results are shown in Tables 4.1 through 4.14.

After completing the objective (statistical) analysis, the demand equations were analyzed to determine if they were acceptable for projection purposes. The two most common reasons for changing them were (1) the elasticities had the "wrong" sign from a theoretical standpoint, and (2) the elasticities were obviously incorrect in terms of magnitude. General solutions were to use the elasticity of a similar fishery products, or to use the elasticity of the same product from a country with similar consuming habits. The changes made from the statistically-derived demand functions and the explanation for these changes appear in Tables 4.15 through 4.26.

Statistical estimation of economic relationships, particularly with data which are not highly accurate, is subject to several pitfalls. It is often the case that the analyst accepts less than highly reliable results. Nevertheless, there are means of measuring the reliability of the results. They are both economic and statistical tests. The economic tests are those theoretical underpinnings described earlier.

Three statistical tests of reliability are used in judging our results. The t-value, which appears in the parentheses in Tables 4.1 to 4.14, tests whether the elasticity (the figure directly above the t-value) can be regarded as being different from zero.

(That is, it tests whether a variable has any effect on the results.) For the number of observations used here, a t-value of about 2.2 (in absolute terms) is needed to conclude the significance of the elasticity coefficient at the commonly accepted 95% confidence level. We compromised sometimes and accepted elasticities with lower t-values if the coefficient was acceptable from a theoretical point of view. A second test is R^2 which shows what percent of the variation in consumption is explained by price and income. Both mathematically and logically this figure must be between 0 and 1.0; therefore, the closer it is to 1.0, the more reliable is the consumption estimate. The Durbin-Watson statistic (D-W) is a test of the reliability of the t-values and of the proper specification of the equation. Two common types of specification errors are: including the wrong set of variables, and using an unacceptable form of the equation (for example, logarithmic versus linear). This is a fairly common problem when using time series data because many factors, which have no causal relationship to the one being estimated, change over time. For our sample size, D-W values between about 1.4 and 2.6 denote acceptable specification of the equations.

The equation used for making the demand projections are shown in Tables 4.15 to 4.26. Because some of the demand estimates were statistically weak or were not supported by economic logic, the authors changed certain parameter estimates designated by footnotes. Given the critical use of the parameters, we felt this was justified. We did not want to be confined to mechanically accepting the statistical results.

The projections in Chapter 6 are sufficiently plausible to justify the demand relationships presented in these tables.

Table 4.1.--Regression results of groundfish demand equations by selected countries

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	-2.0145 (-6.7514)	0.1014 (0.7541)	0.8518 (9.1877)	0.84	2.23	1948-68
Japan	-1.6923 (-3.4357)	0.2767 (0.7008)	1.0467 (6.5060)	0.83	1.05	1956-67
Canada	6.6006 (0.4757)	-3.6297 (-0.7904)	-1.2045 (-0.2481)	0.30	2.37	1953-66
Korea 1/	2.2774 (1.6845)	0.7873 (0.8476)	-1.0595 (-1.6433)	0.26	1.33	1956-67
Denmark 2/	-3.9025 (-4.1255)	-0.3016 (-0.4763)	1.9469 (5.8995)	0.83	0.93	1956-67
France 2/	-10.3194 (-1.5965)	-7.1220 (-1.8019)	6.5998 (2.7293)	0.46	2.76	1956-67
Netherlands	-6.9719 (-4.8273)	-0.0783 (-0.2316)	2.6716 (4.6651)	0.88	1.86	1956-67
United Kingdom	-4.1534 (-2.1125)	-1.3952 (-1.6296)	2.1924 (2.5550)	0.55	2.06	1955-66

1/ Japanese price data were used in the equation
2/ U. S. price data were used in the equation
Dependent variable is per capita consumption of groundfish in round weight.

Prices are ex vessel deflated by the individual country's CPI and converted into U.S. cents per pound by the exchange rates.
Income is deflated by the individual country's CPI and converted into U.S. dollars per capita by the exchange rates.
T values in parentheses.

Table 4.2--Regression results of tuna demand equations by selected countries

(In logarithms)

Country	Product form	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	can	-2.6099 (-2.3862)	-0.8632 (-4.9220)	1.1675 (4.1626)	0.94	1.44	1947-67
Canada	can	0.3115 (0.1151)	-0.1353 (-0.6090)	-0.0868 (-0.1068)	0.04	1.77	1956-67
United Kingdom	can	3.0045 (0.9403)	0.8675 (2.0944)	-1.4787 (-1.4950)	0.45	1.92	1956-67
EEC	can	-1.9451 (-1.1439)	-0.3524 (-0.9966)	0.8313 (1.6023)	0.32	1.14	1956-67
Spain	raw	-2.2564 (-1.0961)	-0.4058 (-0.5344)	1.0425 (1.6359)	0.29	2.33	1956-67
	can	-0.3610 (-0.3273)	0.5865 (1.4416)	-1.3867 (-0.0406)	0.20	1.85	1956-67
Turkey	raw	13.8698 (1.4047)	-0.2453 (-0.1720)	-5.7316 (-1.4898)	0.22	2.06	1956-67
Japan	raw	-0.4085 (0.4439)	-0.5095 (-0.6674)	0.3434 (1.2366)	0.15	1.59	1956-67
	can	2.4965 (2.4297)	0.9953 (1.1675)	-1.3954 (-4.5004)	0.70	1.65	1956-67

Table 4.2--Regression results of tuna demand equations by selected countries (continued)

(In logarithms)

Country	Product form	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
Taiwan	raw	-0.2467 (-0.2561)	-0.2190 (-0.9106)	0.4926 (1.2008)	0.23	2.89	1956-67
	can	-10.5766 (-5.2343)	-0.0583 (-0.1155)	5.5071 (4.7395)	0.78	1.87	1956-67
Peru	raw 1/	0.1854 (0.0274)	0.1392 (0.0485)	0.2715 (0.1299)	0.002	1.29	1956-67

1/ U.S. price data were used in the equation.

Dependent variable is per capita consumption of tuna in round weight, except for the U.S. which is in edible weight.

Prices are ex vessel deflated by the individual country's CPI and converted into U.S. cents per pound by the exchange rates.

Income is deflated by the individual country's CPI and converted into U.S. dollars per capita by the exchange rates.

T values in parentheses.

Table 4.3.--Regression results of salmon demand equations by selected countries
(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	4.3032 (4.8916)	-0.7066 (-2.1229)	-0.9743 (-2.9165)	0.73	1.62	1950-67
Canada	2.9662 (0.9647)	-0.9312 (1.5707)	-0.3584 (-0.3421)	0.23	1.79	1950-68
Denmark	-31.1268 (-4.9545)	3.9913 (2.6827)	7.6541 (5.5241)	0.67	1.72	1948-67
U.S.S.R.[1]	6.9748 (2.7694)	0.3080 (0.5266)	-2.5719 (-2.3031)	0.75	2.29	1955-67
Japan	0.9930 (1.2899)	0.0266 (0.0430)	-0.2235 (-0.4403)	0.06	2.74	1955-67

[1] Japan's price data used in the equation.

Dependent variable is per capita consumption of salmon in round weight.
Prices are ex vessel deflated by the individual country's CPI, converted into U.S. cents per pound by the exchange rates.
T values in parentheses.

Table 4.4--Regression results of halibut demand equations by selected countries

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	1.1649 (2.9158)	-0.1571 (-2.0486)	-0.5112 (-4.0781)	0.63	1.66	1950-67
Canada	-11.6941 (-2.1387)	0.1474 (0.1934)	3.3220 (1.8229)	0.28	1.71	1951-67
West Germany 1/	3.1432 (2.3293)	-1.0387 (-1.9436)	-0.9960 (-2.2109)	0.53	1.00	1958-67
Iceland 1/	-2.6609 (-0.8071)	-0.7300 (-0.9012)	1.5474 (1.2883)	0.14	0.66	1954-67
Norway	4.0482 (7.7186)	-0.8395 (-2.1017)	-0.7894 (-4.0483)	0.73	1.40	1948-67
United Kingdom	7.8900 (5.9746)	-1.8467 (-2.8282)	-1.8823 (-7.5762)	0.78	0.68	1948-67

1/ U.S. price data were used in the equation.

Dependent variable is per capita consumption of halibut in round weight, except for the U.S. which is in edible weight.

Prices are ex vessel deflated by the individual country's CPI and converted into U.S. cents per pound by the exchange rates.

Income is deflated by the individual country's CPI and converted into U.S. dollars per capita by the exchange rates.

T values in parentheses.

Table 4.5 .--Regression results of sardine demand equations by selected countries

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D.W.	Period
U.S.A.	2.1501 (0.8860)	-0.9837 (-1.7955)	-0.2984 (-0.3295)	0.38	2.24	1950-68
Canada	1.8602 (1.0848)	0.0947 (0.1881)	-0.7578 (-0.4307)	0.04	2.47	1950-68
United Kingdom 1/	-3.0007 (-1.4326)	-0.9947 (-1.8096)	1.4843 (1.8039)	0.21	2.08	1950-68
Portugal 1/	-1.0345 (-2.4028)	-0.6970 (-2.1418)	1.3641 (5.6397)	0.71	2.01	1950-68
Norway	4.8934 (0.4998)	-0.5126 (-0.1734)	-1.1061 (-0.6227)	0.09	1.74	1950-68
Spain	-4.2031 (-5.5411)	-1.0694 (-1.7391)	2.2947 (5.1536)	0.71	1.32	1950-68

1/ U.S. price data were used in the equation.

Dependent variable is per capita consumption of sardine in round weight, except for the U.S. which is in edible weight.

Prices are ex vessel deflated by the individual country's CPI, converted into U.S. cents per pound by the exchange rates.

Income is deflated by the individual country's CPI and converted into U.S. dollars per capita by the exchange rates.

T values in parentheses.

Table 4.6--Regression results of shrimp demand equations by selected countries

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	-4.8075 (-12.0400)	-0.3099 (-2.7001)	1.6999 (11.5558)	0.91	0.80	1948-67
Mexico	-11.5852 (-5.2599)	-1.6584 (-3.1705)	5.2396 (5.8561)	0.84	2.15	1958-67
India [1/]	-1.0936 (-0.7041)	0.4761 (1.7194)	-0.0133 (-0.0157)	0.31	1.72	1958-67
Japan	-0.0306 (-0.0589)	-0.1492 (-0.4616)	0.1350 (1.1603)	0.11	0.62	1953-67
Pakistan [1/]	-4.5177 (-5.2110)	0.1692 (0.5791)	2.0226 (4.5649)	0.65	1.61	1953-67
Thailand [1/]	-8.8344 (-14.4455)	0.6047 (2.3746)	3.9753 (14.4492)	0.97	1.50	1958-67

[1/] U.S. price data were used in the equation.

Dependent variable is per capita consumption of shrimp in round weight.

Prices are ex vessel deflated by the individual country's CPI and converted into U.S. cents per pound by the exchange rates.

Income is deflated by the individual country's CPI and converted into U.S. dollars per capita by the exchange rates.

T values in parentheses.

Table 4.7--Regression results of lobster demand equations by selected countries.

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	-6.5746 (-14.3989)	-0.5995 (-4.4039)	2.0688 (10.7665)	0.91	1.16	1949-67
Canada	4.6584 (1.0098)	0.2598 (0.2498)	-1.6457 (-0.8848)	0.13	1.74	1949-67
France 1/	-3.5692 (-11.6583)	-0.8607 (-4.4823)	1.5187 (9.7867)	0.87	1.83	1948-67
United Kingdom	-13.9238 (-7.4579)	-0.2824 (-1.4479)	4.3569 (8.3917)	0.94	0.62	1948-67
Australia 1/	-4.8080 (-2.2517)	-1.7219 (-3.0896)	2.5499 (2.6944)	0.43	1.35	1952-67

1/ U.S. price data were used in the equation.

Dependent variable is per capita consumption of lobster in round weight, except for the U.S. which is in edible weight.

Prices are ex vessel deflated by the individual country's CPI and converted into U.S. cents per pound by the exchange rates.

Income is deflated by the individual country's CPI and converted into U.S. dollars per capita by the exchange rates.

T values in parentheses.

Table 4.8--Regression results of crab demand equations by selected countries

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	-6.2101 (-10.8588)	0.0661 (0.1948)	1.8789 (11.2304)	0.89	1.09	1948-67
Canada	-3.3492 (-1.9950)	-0.6313 (-1.1843)	1.0154 (1.8161)	0.17	1.31	1948-67
U.S.S.R.	-1.4653 (-2.7352)	0.5674 (1.0842)	0.1956 (1.7555)	0.28	1.45	1953-67
Japan [1]	-3.0586 (-2.6417)	0.7755 (0.6023)	0.9467 (6.1192)	0.70	0.50	1948-67

[1] U.S. price data were used in the equation.

Dependent variable is per capita consumption of crab in round weight.

Prices are ex vessel deflated by the individual country's CPI and converted into U.S. cents per pound by the exchange rates.

Income is deflated by the individual country's CPI and converted into U.S. dollars per capita by the exchange rates.

T values in parentheses.

Table 4.9 --Regression results of clam demand equations by selected countries.

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	-0.2051 (-0.1460)	-0.6047 (-2.1199)	0.2564 (0.6641)	0.53	0.50	1948-67
Spain 1/	-1.3840 (-0.5341)	-1.5768 (-1.5974)	1.3854 (2.5951)	0.71	1.66	1948-67
United Kingdom 1/	-3.4578 (-1.1303)	0.5353 (0.8751)	0.7105 (0.9713)	0.05	0.96	1948-67
Japan 1/	0.3275 (0.2563)	-0.2391 (-0.4617)	0.2171 (0.9757)	0.46	1.16	1955-66
Korea 1/	-10.1612 (-2.6641)	-1.9574 (-1.9766)	6.2974 (4.8140)	0.91	1.97	1953-67

1/ U.S. price data were used in the equation.

Dependent variable is per capita consumption of clam in round weight.

Prices are ex vessel deflated by the individual country's CPI and converted into U.S. cents per pound by the exchange rates.

Income is deflated by the individual country's CPI and converted into U.S. dollars [illegible] capita by the exchange rates.

T values in parentheses.

Table 4.10-Regression results of scallop demand equations by selected countries

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	-1.1225 (-2.2794)	-0.6337 (-7.1560)	0.4285 (2.9821)	0.80	1.31	1950-67
Canada	-6.5116 (-1.3957)	-1.8038 (-3.1131)	2.5809 (1.9211)	0.54	1.90	1949-67
France 1/	-5.5043 (-5.2420)	-0.2800 (-0.9502)	1.7366 (6.3162)	0.75	2.47	1950-67
Japan 1/	2.8155 (3.9621)	-0.5765 (-1.8047)	-0.4194 (-6.0979)	0.75	0.79	1955-66
Australia 1/	-25.6822 (-6.2612)	0.1106 (0.1557)	8.0216 (6.3720)	0.76	0.77	1952-67

1/ U.S. price data were used in the equation.

Dependent variable is per capita consumption of scallop in round weight, except for the U.S. which is in edible weight.

Prices are ex vessel deflated by the individual country's CPI and converted into U.S. cents per pound by the exchange rates.

Income is deflated by the individual country's CPI and converted into U.S. dollars per capita by the exchange rates.

T values in parentheses.

Table 4.11--Regression results of oysters demand equations by selected countries

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D-W	Period
U.S.A.	4.6330 (10.2186)	-0.6729 (-2.2513)	-1.1002 (-7.4115)	0.83	1.14	1948-67
Canada	-4.2628 (-1.6879)	-0.7692 (-5.5048)	1.3493 (1.6694)	0.85	2.23	1949-66
Mexico 1/	-6.3484 (-6.4935)	0.7795 (1.4943)	1.9792 (6.0096)	0.84	1.79	1955-67
France 1/	-19.2491 (-3.8699)	5.6396 (1.6700)	3.2901 (2.5000)	0.62	1.90	1954-67
Japan 1/	1.2535 (0.6641)	-2.6102 (-2.1351)	1.3794 (9.3016)	0.84	0.64	1948-67
Korea 1/	-26.0971 (-8.8361)	5.0759 (2.6912)	8.7790 (8.8742)	0.92	1.86	1954-67
Taiwan	-2.9142 (-3.4078)	0.4263 (2.3435)	1.4209 (3.5638)	0.55	1.63	1953-67

1/ U.S. price data were used in the equation.

Dependent variable is per capita consumption of oysters in round weight.

Prices are ex vessel deflated by the individual country's CPI and converted into U.S. cents per pound by the exchange rates.

Income is deflated by the individual country's CPI and converted into U.S. dollars per capita by the exchange rates.

T values in parentheses.

Table 4.12--Regression results of all other food fish demand equations by U.S. and rest of world.

(In logarithms)

Country	Constant	Price elasticity	Income elasticity	R^2	D.W.	Period
U.S.A.	6.9033 (9.1192)	+.01[illegible] (.0555)	-1.9735 (10.0528)	0.89	2.55	1950-67
Rest of World 1/	-1.2320 (3.5000)	-.1528 (-1.2204)	.9560 (9.5158)	0.89	1.21	1950-67

1/ U.S. price data were used in the equation.

Dependent variable is per capita consumption of all food fish and shellfish not included in the individual species anlaysis, in edible weight. World in round weight.

Price is ex vessel deflated by CPI.

Income is deflated by CPI.

3

Table 4.13.--Regression results of fish meal demand equations by U.S. and rest of world[1]

(Linear equations)

Country	Constant	Price coefficient	Soybean price coefficient	Chicken consumption coefficient	Time coefficient	R^2	D-W	Period
U.S.A.	-460.68 (1.32)	-3.35 (1.54)	10.09 (3.62)	.22 (8.84)		0.88	1.73	1950-67
Rest of World[2/]	1,553.37 (1.50)	-1,150.81[3/] (1.93)			433.36 (15.99)	0.94	.73	1950-67

1/ These results were also used in making demand projections.

2/ U.S. price data was used in the equation.

3/ Price of fish meal ÷ price of soybean meal.

Dependant variable is fish meal in million pounds.
Price is price per short ton.
Soybean price is price per short ton.
Chicken consumption is million pounds ready-to-cook weight.

Table 4.14.--Groundfish equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	----------------	logarithms	----------------
United States	-1.0919 1/	-1.0 2/	0.8518 3/
Canada	-2.7681 1/	-1 4/	1.211 5/
Denmark	-2.3922 1/	-1.3952 6/	1.9469
France	-4.4452 1/	-1.3952 6/	2.1924 6/
Netherlands	-3.9736 1/	-1.3952 6/	2.1924 6/
United Kingdom	-4.1534	-1.3952	2.1924
Japan	-0.9106 1/	-1.0 2/	1.0467
Korea	-1.1102 1/	-1.0 2/	1.0467 7/

See footnotes following Table 4.25.

Table 4.15.--Tuna equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	-------------------	logarithms -------------------	
U.S.-canned	-2.3164 1/	-0.8632	1.1675
Canada-canned	-3.1757 1/	-0.8632 8/	1.1675 9/
U.K.-canned	-3.4410 1/	-0.8632 9/	1.1675 9/
EEC-canned	-2.3904 1/	-0.8632 9/	1.1675 9/
Spain-not canned	-2.2564	-0.4058	1.0425
Spain-canned	1.4874 1/10/	-1.0000	0 11/
Turkey-not canned	0.3720 1/	-0.2453	0 11/
Japan-not canned	0.4085	-0.5095	0.3434
Japan-canned	0.8389 1/10/	-1.0000 2/	0 11/
Taiwan-not canned	-0.2467	-0.2190	0.4926
Taiwan-canned	-3.4832 1/	-1.0000 12/	2.0000 13/
Peru-not canned	-1.2773 1/	-0.4058 14/	1.0425 15/

See footnotes following Table 4.25.

Table 4.16.--Salmon equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	----------	logarithms	----------
U.S.	1.0747 1/	-0.7066	0 11/
Canada	1.8370 1/	-0.9312	0 11/
Denmark	-10.8606 1/	-1.0 2/	4.0 13/
U.S.S.R.	1.2955 1/	-1.0 2/	0 11/
Japan	1.8742 1/	-1.0 2/	0 11/

See footnotes following Table 4.25.

Table 4.17.--Halibut equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	----------	logarithms	----------
United States	-1.9600 1/	-1.0 12/	.8518 5/
Canada	-1.8336 1/	-1.0 2/	.8518
West Germany	-5.1620 1/	-1.0387	1.5474 5/
Iceland	-2.6609	-0.7300	1.5474
Norway	-1.2406 1/	-0.8395	.8518 5/
United Kingdom	-0.8386 1/	-1.8470	.8518 5/

See footnotes following Table 4.25.

Table 4.18.--Canned sardines equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	---------------------	logarithms	---------------------
United States	1.39 1/	-0.9837	0 11/
Canada	1.8602	-0.9837 9/	0 11/
United Kingdom	-3.0007	-0.9947	1.4843
Portugal	-1.0345	-0.6970	1.3641
Norway	1.28 1/	-0.5126	0 11/
Spain	-0.85 1/	-1.0694	1 13/

See footnotes following Table 4.25.

Table 4.19.--Shrimp equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	logarithms		
United States	-4.8075	-0.3099	1.6999
Mexico	-8.2105 1/	-1.6584	4 13/
India	-3.0222 1/	-1 2/	2.0226 16/
Japan	-0.0306	-0.1492	0.135
Pakistan	-2.8301 1/	-1 2/	2.0226
Thailand	-2.3305 1/	-1 2/	2.0226 17/

See footnotes following Table 4.25.

Table 4.20.--Lobster equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	------------------	logarithm	------------------
United States	-5.9374 10/	-0.5995	2.0688
Canada	-6.227 1/10/	-0.5995 9/	2.0688 9/
France	-3.5922 10/	-0.8607	1.5187
United Kingdom	-6.1873 1/ 10/	-0.5995 8/	2.0688 13/
Australia	-4.6618 10/	-1.7219	2.5499

See footnotes following Table 4.25.

Table 4.21.--Crab equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	--------------------	logarithms	--------------------
United States	-5.9941 1/10/	-0.1487 18/	1.8789
Canada	-3.3619 10/	-0.6313	1.0154
U.S.S.R.	-0.268 1/10/	-0.6313 19/	0.1956
Japan	-2.1003 1/10/	-0.4 18/	0.9467

See footnotes following Table 4.25.

Table 4.22.--Clam equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	----------	logarithms	----------
United States	-0.1530 1/	-.6047	0.2564
Spain	-2.5300 1/	-1.5768	1.3854
United Kingdom	-1.9460 1/	-1.1761 18/	0.7105
Japan	0.0632 1/	-0.2391	0.2171
Korea	-7.4255 1/	-1.9574	4 13/

See footnotes following Table 4.25.

Table 4.23.--Scallop equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	------------------logarithms------------------		
United States	-0.7736 10/	-0.6337	0.4285
Canada	-7.2177 10/	-1.8038	2.581
France	-5.7759 10/	-0.2799	1.7366
Japan	-1.9617 1/10/	-0.5765	0.4285 9/
Australia	-6.7802 10/	-1.8038 4/	2.581 4/

See footnotes following Table 4.25.

Table 4.24.--Oyster equations used for making projections

Country	Constant	Price elasticity	Income elasticity
	----------	logarithms	----------
United States	0.9639 10/	-0.6729	0 11/
Canada	-4.2628	-0.7692	1.3493
Mexico	-4.7072 1/	-1.0522 18/	1.9792
France	-3.1815 1/	-0.7692 18/	1.3493 18/
Japan	1.2535	-2.6102	1.3794
Korea	-1.5272 1/	-2.6102 7/	1.3794 7/
Taiwan	-3.4116 1/	-2.6102 7/	1.4209

See footnotes following Table 4.25.

Table 4.25.--All other food fish equations used for making projections

Country	Constant	Price elasticity	Income elasticity
		logarithms	
United States	1.8155 1/	-1 2/	0 11/
Rest of World	-.5187 1/	-1 2/	.9560

1/ Constant changes so that equation goes through the 1965-67 value of each variable after the elasticity coefficients are changed and where original equations did not approximate 1965-67 base.

2/ Price elasticity has "wrong" sign, assumed to be -1.

3/ Low relative to other countries. U.S. was unrealistically losing share of world consumption.

4/ Elasticity "too high," and low t value assumed to be -1.

5/ Income elasticity taken from U.S. groundfish.

6/ Magnitude of elasticities unacceptable; those for United Kingdom used (culturally similar country).

7/ Elasticities has "wrong" signs and low t values; those for Japan used (culturally similar country).

8/ Elasticity "too low;" and had low t value; U.S. coefficient used.

9/ Elasticity has "wrong" sign; U.S. coefficient used.

10/ Constant term changed to put equation in round weight.

11/ Income elasticity has "wrong" sign, assumed to be zero.

12/ Price elasticity "too low," and had low t value; assumed to be -1.

13/ Income elasticity too large, felt to result partially from other time-related changes.

14/ Elasticity has "wrong" sign and low t value; Spain coefficient used (culturally similar country).

15/ Elasticity "too low" and low t value; Spain coefficient used (culturally similar country).

[16] Elasticity had "wrong" sign and low t value; elasticity of Pakistan used (culturally similar country).

[17] Data unreliable; elasticity of Pakistan used (culturally similar country).

[18] Elasticity had "wrong" sign and low t value; taken from alternative form of the equation which was run.

[19] Price elasticity had "wrong" sign and low t value; that of Canada used instead.

Table 4.26.--Fish meal equations used for making projections

Country	Constant	Price coefficient	Soybean price coefficient	Chicken consumption coefficient	Time coefficient
United States	-1888.08	-17.2653	54.0072	0.9827	
Rest of World	7621.38	-5660.08			2165.95

Price is price per short ton.
Soybean price is price per short ton.
Chicken consumption is million pounds ready-to-cook weight.
Time; 1950=1.

Chapter 5

THE MECHANICS OF PROJECTION

5.1 Introduction

Using the theoretical and empirical relationships developed in Chapters 3 and 4, it is now possible to combine these tools into one overall model of the long-run economic development of a fishery. The final model will yield an economic structure which is capable of projecting future trends in fish supplies, consumption and prices.

5.2 The General Procedure for Food Fish

The following procedures were employed in making economic projections of the demand and supply for each fishery product considered:

(1) For the ith species, the demand functions (Chapter 4) for 1 . . . k countries were employed to project the level of per capita consumption $\left(\frac{Q}{N}^{\dagger}\right)$ in each of the countries based upon projected increases in per capita $\left(\frac{Y}{N}^{\dagger}\right)$ income (or product) at a given relative price level, $\left(\frac{\overline{P}}{CPI}\right)$ (sword $(\dagger)$ indicates projected figure). Projected per capita income for 1 . . . k countries was obtained from the U.S. Department of Agriculture (1968) (Appendix D).[1]

Put mathematically, we have,

---

[1] Assumptions behind these projections are discussed in the Appendix. The same applies to population projections.

$$\left(\frac{Q}{N}^{\dagger}\right)_1 = A_1 \left(\frac{P}{CPI}\right)_1^{-\alpha_1} \left(\frac{Y}{N}^{\dagger}\right)_1^{\beta_1} \tag{5.1}$$

$$\left(\frac{Q}{N}^{\dagger}\right)_2 = A_2 \left(\frac{P}{CPI}\right)_2^{-\alpha_2} \left(\frac{Y}{N}^{\dagger}\right)_2^{\beta_2}$$

$$\vdots \qquad\qquad \vdots \qquad\qquad \vdots$$

$$\left(\frac{Q}{N}^{\dagger}\right)_k = A_k \left(\frac{P}{CPI}\right)_k^{-\alpha_k} \left(\frac{Y}{N}^{\dagger}\right)_k^{\beta_k}$$

where $\left(\frac{Y}{N}^{\dagger}\right)_1, \ldots \left(\frac{Y}{N}^{\dagger}\right)_k$ are projected independently

while $\left(\frac{P_1}{CPI_1}\right) = \gamma_1$; $\left(\frac{P_2}{CPI}\right) = \gamma_2; \ldots \left(\frac{P_k}{CPI_k}\right) = \gamma_k$.

Of course, the price and income parameters may be fixed or variable over time. Later in this chapter, we shall argue that there are cogent reasons to believe that income elasticities for food items such as fish decline with rising per capita income. In this case, the income elasticities, β 's, will decline with increases in per capita income over time.

(2) Projected per capita consumption (demand) for the ith species in the 1 . . . k countries was then multiplied by projected population, $N^{\dagger}$, to obtain projected aggregate consumption at a given level of relative prices. Projected population was obtained from the U.S. Department of Agriculture (1968) (Appendix C). These projected consumption figures were then summed across countries or

$$\sum_{i=1}^{k} \left(\frac{Q}{N}\dagger\right)_i \quad (N\dagger)_i \quad = \left(Q_w^{\,nD}\right)\dagger \qquad (5.2)$$

where $\left(Q_w^{\,nD}\right)^{\dagger}$ is the net demand for the world as a whole. The concept of net demand is used since we did not estimate the demand for all countries but selected leading consuming countries (Chapter 4). In most cases, these leading countries consumed over three-quarters of the world consumption. Gross demand was estimated by multiplying 1/k by $\left(Q_w^{\,nD}\right)^{\dagger}$. "k" is the ratio of net to gross world demand which was assumed to be constant for the projection period.[2]

$$\left(\frac{1}{k}\right) Q_w^{\,nD} \quad = \quad Q_w^{\,gD} \qquad (5.3)$$

(3) The weighted world price $(P_1)_w$ was obtained by weighting the real price (absolute) existing in each country by its consumption in the base period (1965-1967). This was done since prices are held constant for the <u>initial</u> projections

$$\frac{\sum_{i=1}^{k} (p_1)_i \, (Q_1)_i}{\left(Q_w^{\,nD}\right)_1} \quad = \quad (p_1)_w \qquad (5.4)$$

where $(p_1)_i$ = base period price for ith country; $(Q_1)_i$ = base period

---

[2] k was obtained by dividing total consumption in the countries studied by total world production in the 1965-1967 base period.

consumption for ith country; $\left(Q_w^{nD}\right)_1$ = net world consumption in the base period.

(4) The regional supply functions for the ith species (Chapter 3) were then summed across j regions to obtain a world supply function. As discussed in Chapter 3, two supply functions were formulated.[3]

LCR

$$y_w = \sum_{i=1}^{j} y_i = \sum_{i=1}^{j} (y_1)_i \left\{ a \left[(P_0)_w/(P_1)_w\right] - b \left[(P_0)_w/(P_1)_w\right]^2 \right\}_i \tag{5.5}$$

LDR

$$y_w = \sum_{i=1}^{j} y_i = 4 \sum_{i=1}^{jj} y_1^* \, z_i^{\frac{(P_0)_w}{(P_1)_w}} \left[1 - z_i^{\frac{(P_0)_w}{(P_1)_w}} \right] \tag{5.6}$$

Since $(P_0)_w = (P_1)_w$ in the base period, (5.5) and (5.6) merely yield world landings (i.e., supply) for 1965-1967. y_w = world supply while y_i = supply in each region while z is defined in Chapter 3.

(5) The projected world demand, $(Q_w^{gD\dagger})$ was then compared to world supply, y_w, at the given weighted world price (base period price).

---

[3] Equations (5.5) and (5.6) are merely equations (3.12) and (3.20) solved for world landings as a function of world price. Time subscripts have been eliminated to simplify the above expressions.

$$\left(Q_w^{gD}\right)^{\dagger} \gtrless y_w \qquad (5.7)$$

Since $\left(Q_w^{gD}\right)^{\dagger} > y_w$, prices were automatically increased in each of the 1 . . . k countries by an arbitrary percent. A new weighted world price $(P_0)_w$ was obtained after the first iteration. Then a new supply response was obtained. This iterative procedure was carried out until projected demand and supply $(y_w^{\dagger})$ were equal at a projected equilibrium world price, $(P_0)_w^{\dagger}$.

$$\left(Q_w^{gD}\right)^{\dagger} = y_w^{\dagger} \qquad (5.8)$$

Through the use of these mechanics, the following projections can be obtained:

1) Projected World Demand, $\left(Q_w^{gD}\right)^{\dagger}$

2) Projected World Supply, $y_w^{\dagger}$

3) Projected Equilibrium World Weighted Price, $(P_0)_w^{\dagger}$

Finally, step (5) assures us that each country's consumption of the ith species will also be projected since total world consumption must be exhausted by the consuming countries. Hence, the additional output of the above procedure is the following:

4) Projected Consumption of Countries 1 . . . k at equilibrium world values.

Figure 5.1 shows the above model in graphical form.

5.3 Specific Procedures and Assumptions

The general procedure outlined in 5.2 may be used with fixed or varying parameters. Also, the form of the supply function may

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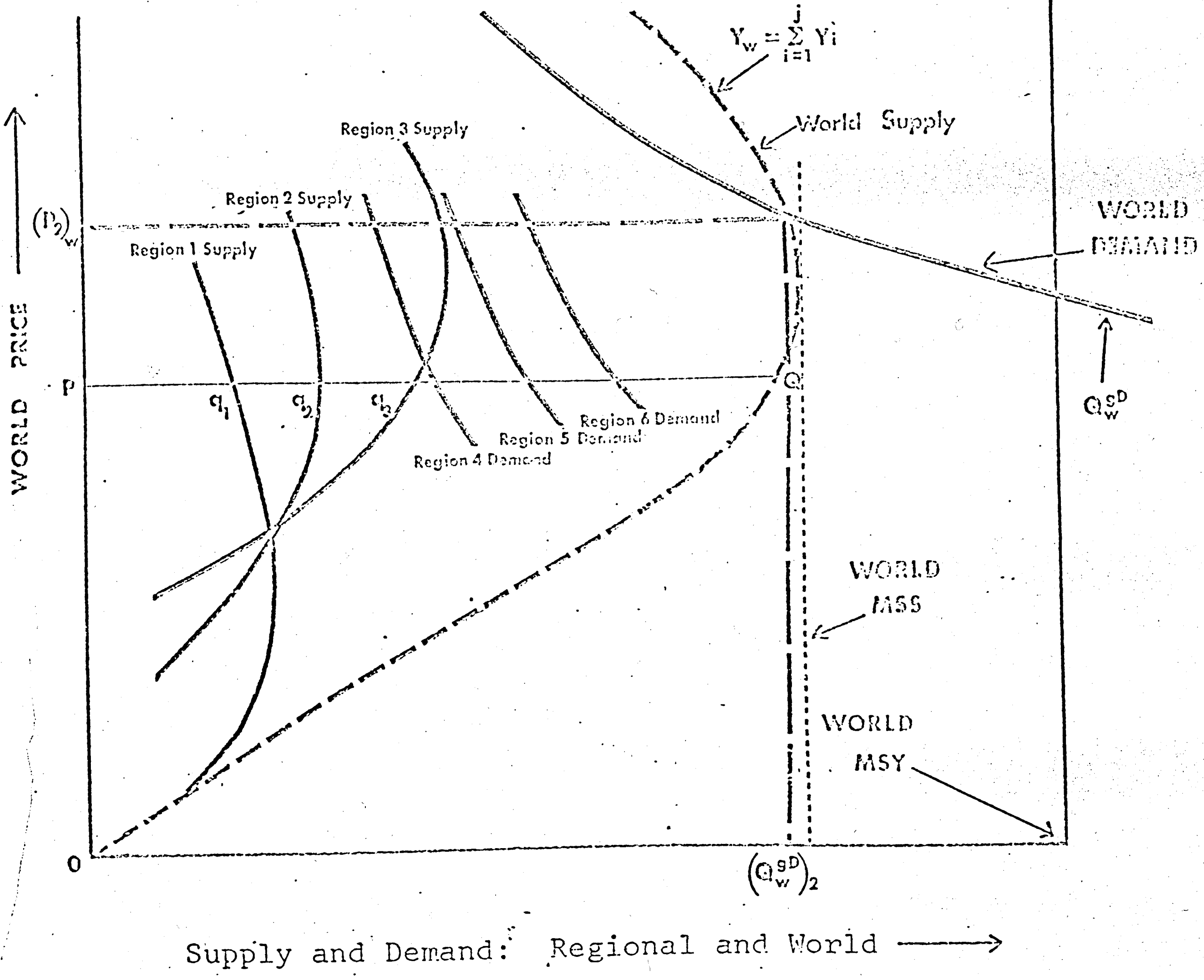
Figure 5.1--Equilibrium of world supply and demand for a fishery product



be changed. Two supply classifications will be used with demand variations coming under each class:

1. <u>LCR Supply Function</u>
    1.1 Constant Income Elasticities (LCR-CIE)
    1.2 Declining Income Elasticities (LCR-DIE)
    1.3 Zero Income Elasticities (LCR-ZIE)

2. <u>LDR Supply Function</u>
    2.1 Constant Income Elasticities (LDR-CIE)
    2.2 Declining Income Elasticities (LDR-DIE)
    2.3 Zero Income Elasticities (LDR-ZIE)

It is possible to make six sets of projections (Appendix A). For purposes of this report, we have decided to discuss the declining income elasticities (Chapter 6) since this set of projections represents a middle ground between constant and zero income elasticities. We believe it is plausible on theoretical grounds that income elasticities decline with increasing per capita income. The decline in the base period income elasticity (estimated in Chapter 4) was accomplished through the following formula:

<u>1st Period</u>; $t = 0$

$$\log\left(\frac{Q}{N}\right)_{i,1} = \log A_{i,1} + \alpha_{i,1} \log\left(\frac{P}{CPI}\right)_{i,1} + \left[\frac{\beta_{i,1}}{(1+.4)^{t-1}}\right] \log\left(\frac{Y}{N}\right)_{i,1}$$

where $\alpha_{i,1}$ and $\beta_{i,1} \equiv \alpha_i$ and β_i ; $(-\!-)_{i,1}$ is the value of a variable in the i^{th} country during the first period, and $t = 0$;

2nd Period; t = 1 (5 years)

$$\log\left(\frac{Q}{N}\right)_{i,t} = \log\left(\frac{Q}{N}\right)_{i,t-1} + \frac{\beta_i}{(1+.4)}t\left[\log\left(\frac{Y}{N}\right)_{i,t} - \log\left(\frac{Y}{N}\right)_{i,t-1}\right] \quad (5.10)$$

for t=1,..,n.

The expression above indicates an income elasticity that decreases over time, according to a "decay function." Eventually, it would approach zero as a limit. The elasticity, β , is the one found in the base period. We have observed a tendency for income elasticities for fish to decline with rising incomes; and such a decline seems theoretically appropriate. The decay rate of 1/1.4 each 5-year interval is a rough estimate based upon studies of tuna and other species.[4] We believe that the most likely projections are those based upon the assumption of declining income elasticities and upon the LDR supply function.

---

[4] This is probably one of the most serious criticisms of our study. In defense of this criticism we must make two very relevant points. First, most economists would agree that the assumption of constant income elasticity over the next 30 years is completely unrealistic. Consumers cannot continue to increase their per capita consumption of many species indefinitely. Therefore, it was necessary to build some dampening effect into the projections. Second, limited work on the decay in the income elasticity for tuna and groundfish--two principal fish species--indicated that the elasticity fell at the rate of $\beta_i/(1 + .4)^t$ on the average. Therefore, we built this decline into the demand functions for all species in order to obtain a more "conservative" estimate of the expansion in demand. Analysis of nationwide cross-sectional fish consumption data indicates a lower income elasticity for high income groups than at lower levels. The actual projections agree pretty much with expectations under these assumptions. The projections may easily be modified by the reader if he feels he has better information on the decay in the income elasticity over time. We are convinced that the "decay" assumption is valid. The rate is admittedly a debatable point. We did the best we could based on the information at hand. Projections using constant and zero income elasticities are given in Appendix A as alternates.

The projection model is based upon various assumptions in addition to those specified above. These assumptions are explicitly listed below.[5]

1. No change in the existing degree of fishery management. As indicated in Chapter 1, one of the prime purposes of making an economic projection is to ascertain just where we will be without taking certain actions. Therefore, the projections can serve as a guide to policy formulation. This is discussed in Chapter 7.

2. No change in the rate of technological advance relative to other sectors in the economy. One assumption behind the supply projections is that the rate of technological change is the same as in other sectors of the economy. This is perhaps a fairly restrictive assumption; however, it is much more realistic than the alternative of assuming a constant level of technology (i.e., zero technological change).

3. Input prices to the fishing industry increase at the same rate as input prices in other sectors of the economy. This proposition reduces to the assumption that the relative cost of labor, capital, and raw material inputs remain constant.

---

[5] Another assumption which is implicit in the projection model is the use of point estimates. That is, because forecasts of income and population may be presented for "ranges" or "intervals", it follows that our projections might likewise be mase as interval estimates. However, because this amounts to an unusually cumbersome framework, and because it tends to obscure qualitative trends, we have decided that point estimates in this context will serve as useful indicators as to direction of change.

4. No change in the level of pollution. This is an extremely critical assumption. Since pollution is probably related to an expansion in population and income, this assumption is clearly untenable unless steps are taken. Our projections assume no rise in the general pollution index. This will be discussed in Chapter 7.

5. No major disruptions in international trade or production, through insurrection, war or other abnormalities.

6. No significantly high cross-elasticities between fishery product groups selected for projection. In Chapter 4, we specified a simple demand function of each fishery product which did not explicitly include strong cross-elasticity effects between products. That is, an increase in the price of the fishery product, has *ceteria paribus*, resulted in a substitution of all other goods for fishery products. Some of the studies we conducted tend to confirm the hypothesis that strong cross-elasticities are not prevalent for the fishery product groups selected for projection (Cleary, 1969; Bell, 1969; Waugh and Norton, 1969).[6] To the extent that strong cross effects exist at higher prices, the projections will be biased.

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[6] Cleary's study showed low cross-elasticities for shrimp and other shellfish. Bell's study showed no statistically significant cross-elasticity between tuna and salmon.

7. No change in price differentials between countries. The observed price differential between countries was thought to reflect differences in transportation cost, given the extensive international trade in fishery products. To the degree that trade patterns change over the projection period, this relative configuration will change. No correction was made in the relative configuration in the base period since (1) trade patterns were not projected and (2) the trend in transporation cost was not available.

8. No change in share of fish consumption of residual countries. To simplify matters, we assumed that the residual countries--the countries not included in the demand analysis--would consume the same share of projected fish consumption as they did in the base period. Because of the uncertainity of the increase in consumption among the underdeveloped areas and the question of which countries will be included in the future, we did not try to speculate on the possible changes in this share.

5.4 The General Procedure for Fish Meal

Modifications were made in the procedures for projecting fish meal use. These changes are: the entry of soybean meal prices as a determinant; substituting chicken (i.e., broilers) consumption and time as variables in place of consumer income; and directly estimating a single function for all foreign countries (rather than estimating one equation for each major consuming country).

The projections of chicken consumption and soybean meal prices were obtained from discussions with the Division of Economic and Statistical Analysis and the Economic Research Service, U.S. Department of Agriculture, which is currently engaged in work in these areas.[7] A critical assumption is that the price of soybean meal will remain constant throughout the projection period. The officials in the above-mentioned agencies foresee only slight, if any, price rises---principally because production can be greatly expanded with presently available resources.

Given this assumption, the U.S. equation is:[8]

$$Q_1 = A + \alpha P + \gamma C + \lambda P_s \qquad (5.11)$$

$$= B + \alpha P + \gamma C$$

where $B = A + \lambda P_s$.

The rest-of-world equation is:

$$Q_2 = A + \alpha \frac{P}{P_s} + \eta T \qquad (5.12)$$

$$= A + \left(\alpha \frac{1}{P_s} \right) P + \eta T$$

where Q_1 = U.S. utilization of fish meal, million pounds

P = U.S. price of fish meal, dollars per short ton

---

[7] Responsibility for the conclusions derived by using these projections rests with the authors.

[8] The variables used in the fish meal model are defined in Chapter 4.

C = U.S. consumption of chicken, retail weight, million pounds

P_s = U.S. price of soybean meal, dollars per short ton

Q_2 = utilization of fish meal, all other countries, million pounds

T = time, 1950 = 1

Total world demand is then $Q_1 + Q_2 = Q_w$, derived by projected increases in C and T at a given price level of P. Projections of the equilibrium price and output for fish meal are the same as for the food fish with one change in the supply function.[9] Fish meal is produced almost totally from herring-like fish. These fish are also used for human consumption in making canned sardines, pickled herring, and a wide variety of other canned, cured, and smoked products. The fish used for human consumption command a higher price than products destined for fish meal. Therefore, the projected use of herring-like fish for human use is subtracted from the maximum sustainable supply. The remaining production is available for manufacturing fish meal. Therefore, as demand for herring for human use expands, the amount which is available for use as fish meal declines. The major pressure on the resource comes from utilization as fish meal, because consumption as human food is projected to require a very small proportion of the total resource supply.

9/ Although the <u>money</u> price of fish meal was used in the analysis, all projected money prices were deflated to put them in real terms and on a comparable basis with food fish projections.

CHAPTER 6

ECONOMIC PROJECTIONS OF DEMAND, SUPPLY AND PRICES FOR SELECTED FISHERY PRODUCTS TO THE YEAR 2000

6.1 Introduction

Economic projections of world supply, demand and price for selected fish products were made using the model outlined in Chapter 5. For each of the two yield functions (i.e., LCR, LDR) we have three levels of demand projections.[1] A constant positive income elasticity will yield large demand increases over the projection period (CIE). A declining positive income elasticity (i.e., declining, but asymptotic to zero) will yield smaller increases in demand (DIE). Finally, a zero income elasticity represents no income effect--just population--and is the most conservative estimate of likely increases in demand (ZIE). Each set of assumptions gives a different projection for world demand, supply and price. In this chapter we have decided to present the declining income elasticity demand model (DIE) and the LDR supply model which we believe represent the most reasonable assumptions regarding supply and demand.[2] These projections represent our best judgment as to the future

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[1] LCR = Logistic Constant Returns Yield Function
LDR = Logistic Decreasing Returns Yield Function
See Chapter 4 for a more complete description of these yield functions.

[2] In some cases, we made other assumptions regarding supply for particular species. For example, it was assumed for oysters and sardines, that supply was infinitely elastic within the relevant range. See the discussion below for further elaboration.

course of events. The other sets of projections may be found in Appendix A. We shall discuss the projections for each species individually.[3]

It must be pointed out that the projections presented in the chapter are not mathematical certainties, but our best judgment as to the most probable outcome with current information. The reader should be aware of this qualification.

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[3] Unfortunately, these projections do not include Mainland China. It is a leading producer and consumer of fishery products, however, no data have been supplied publicly since 1960. Even in prior years only aggregated data are available. In the mid-1950's approximately one-third of the then 2 to 3 million metric tons annual catch was freshwater fish, thus not competing for the marine resource. To the extent that China competes for the marine resources, both in landings and consumption, the current projections should be modified. (See FAO Yearbook of Fishery Statistics through 1960 for Mainland China fishery statistics.) The probable impact of including Communist China, if data were available, would be to slightly modify the other food fish category. A discussion of the principle points concerning the projections is given, together with (1) a table showing world and United States projections of quantity, price and related factors, (2) a chart showing world consumption both past and projected, (3) a similar chart for the U.S. and (4) a chart showing world supply, demand projections, price and MSY. To keep the chapter within a reasonable size, only the highlights of each species group are given.

6.2 Groundfish

World production of groundfish has increased steadily since the late 1940's. In the 1965-67 base period, the world utilized 70% of the maximum sustainable yield (MSY). However, the groundfish located in the northeast Atlantic are greatly overexploited where decreases in effort would materially raise physical production (i.e., rate of exploitation is well beyond that level of effort needed to harvest MSY for that region). Both the Gulf of Alaska and the northwest Atlantic are fully exploited at maximum sustainable yield. In contrast to salmon and halibut which are regulated at MSY (See Sections 6.3 and 6.4), we must include the possibility of overfishing the resource since widespread management regimes have not been instituted.

Because of the acute overfishing in the northeast Atlantic and resource restrictions in other areas, we project that world maximum sustainable supply (MSS) for groundfish will be reached in 1970 or 15,400 million pounds in contrast to MSY of 20,100 million pounds (see Chapter 3 for a more precise definition of MSS and MSY). If demand pressures persist, dwindling physical production of groundfish is projected for the 1970-2000 period. Real prices will more than quadruple from 6.2 cents a pound in the 1965-67 base period to 28.3 cents a pound in the year 2000.[4]

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[4] The reader should observe that our projections often show some difference in real price between the world and U.S. This is due to species mix problems, temporary disequilibrium, local demand, and data problems as well as transportation costs. See Section 8.7 for a discussion of some of these problems.

Without management, the world outlook for groundfish is extremely bleak. Table 6.1 indicates these trends.

The repercussions of the world resource problem will be felt in U.S. consumption of groundfish. U.S. aggregate and per capita consumption of groundfish is projected to drop over the 1965-67 - 2000 period. The U.S. share of world consumption is expected to decline from 11.8% in the 1965-67 base period to 7.9 % in the year 2000. This is in line with the historical period which saw the decline in U.S. share of groundfish from 19 % in 1951 to 11.8 % in the 1965-67 base period. Groundfish supplies could be augumented through the use of the hake resource. However we specifically assumed that much of the hake resource is not easily substitutable for the more established groundfish on the demand side. We have treated hake in the demand and supply categories of "all other fish." Thus, any increased demand pressure for that species will not affect the supply-demand situation for groundfish and, conversely, an increase in the demand for groundfish is assumed to be independent of the demand for hake.

Table 6.1--Groundfish projections* (LDR - DIE assumptions)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of world
1965-67 †	14,040	6.2	70	91	1,658	8.45	7.0	11.8
1970	15,400	8.9	77	100	1,370	6.65	10.0	8.9
1975	15,300	11.3	76	99	1,250	5.69	12.7	8.2
1980	14,900	14.6	74	97	1,115	4.74	16.4	7.5
1985	12,700	18.3	63	82	995	3.93	20.5	7.8
1990	11,600	22.5	58	75	890	3.28	25.2	7.7
2000	10,500	28.3	52	68	830	2.69	31.8	7.9

World maximum sustainable yield (MSY) - 20,100 million pounds
World maximum sustainable supply (MSS) - 15,400 million pounds

* Species included in Groundfish: FAO data include Atlantic cod, haddock, pollock, Pacific cod, poutassou, redfish, bastard halibut, brill, dab, European flounder, lemon sole, megrin, European plaice, common sole, and pleuronectiforms; and Canadian data include cod, haddock, redfish, flounder and soles.

† Average of actual data

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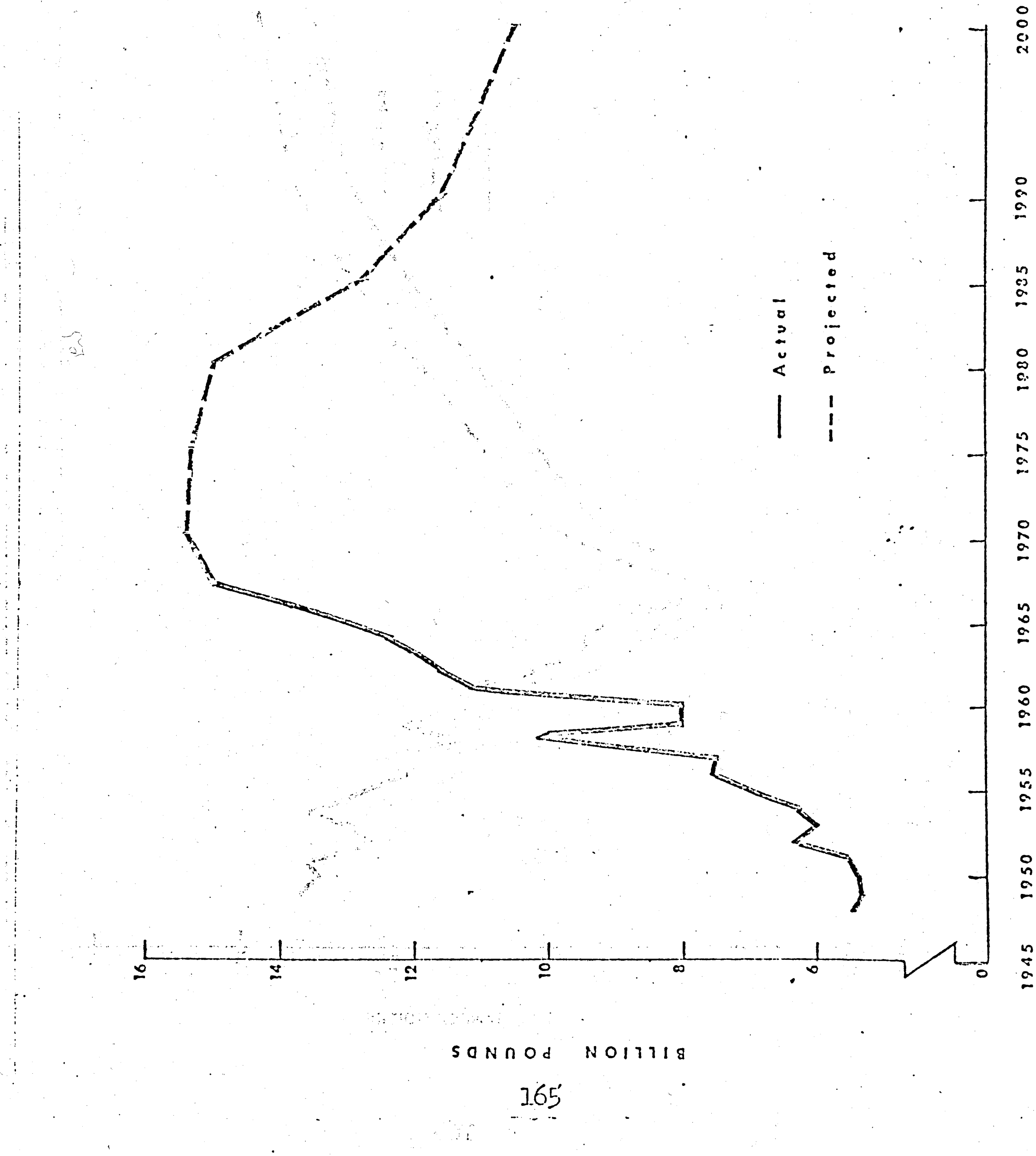
Figure 6.1--Historical and projected world consumption of groundfish *



*Assumption: LDR-DIE

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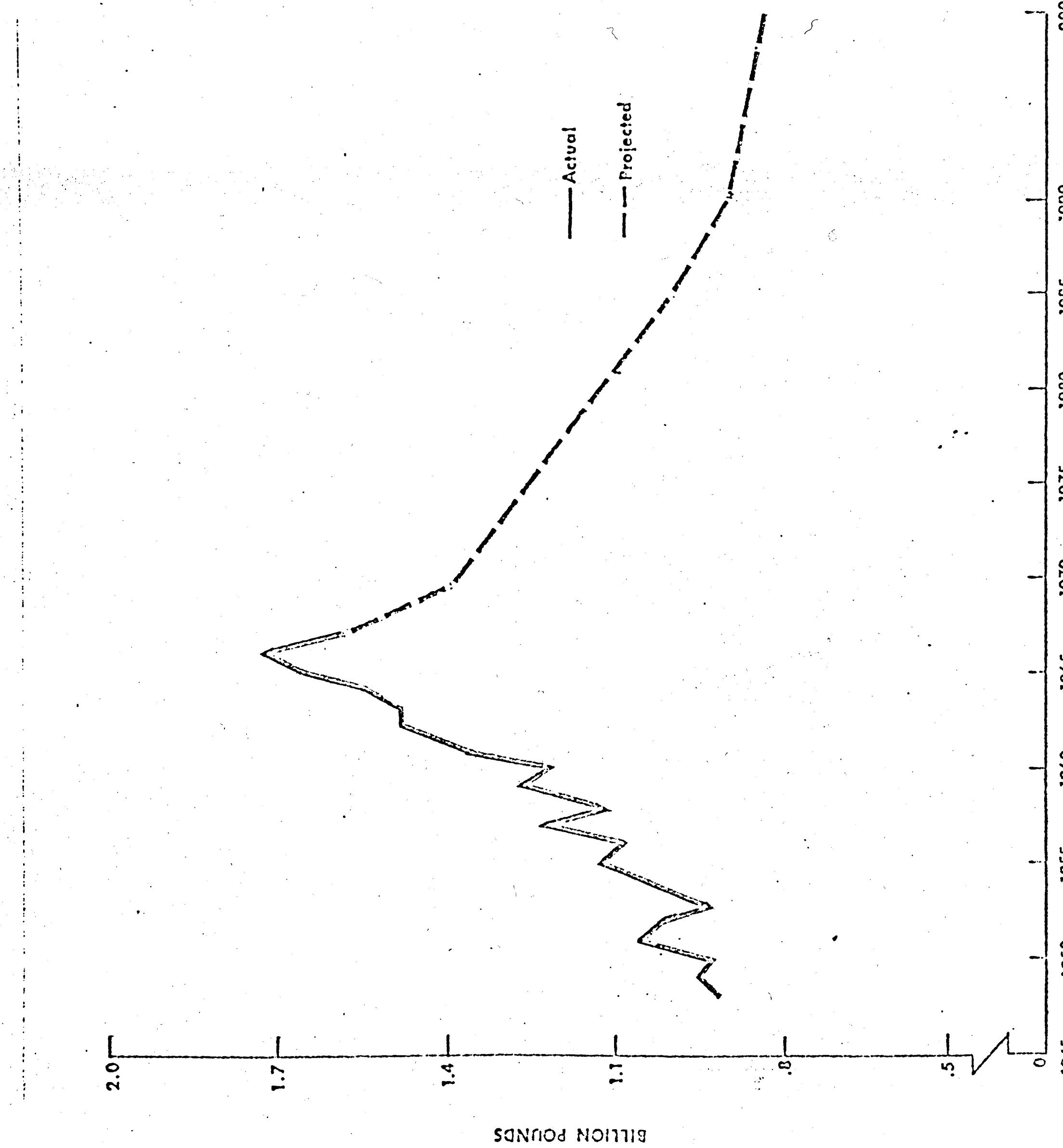
Figure 6.2--Historical and projected U.S. consumption of groundfish*



*Assumption: LDR-DIE

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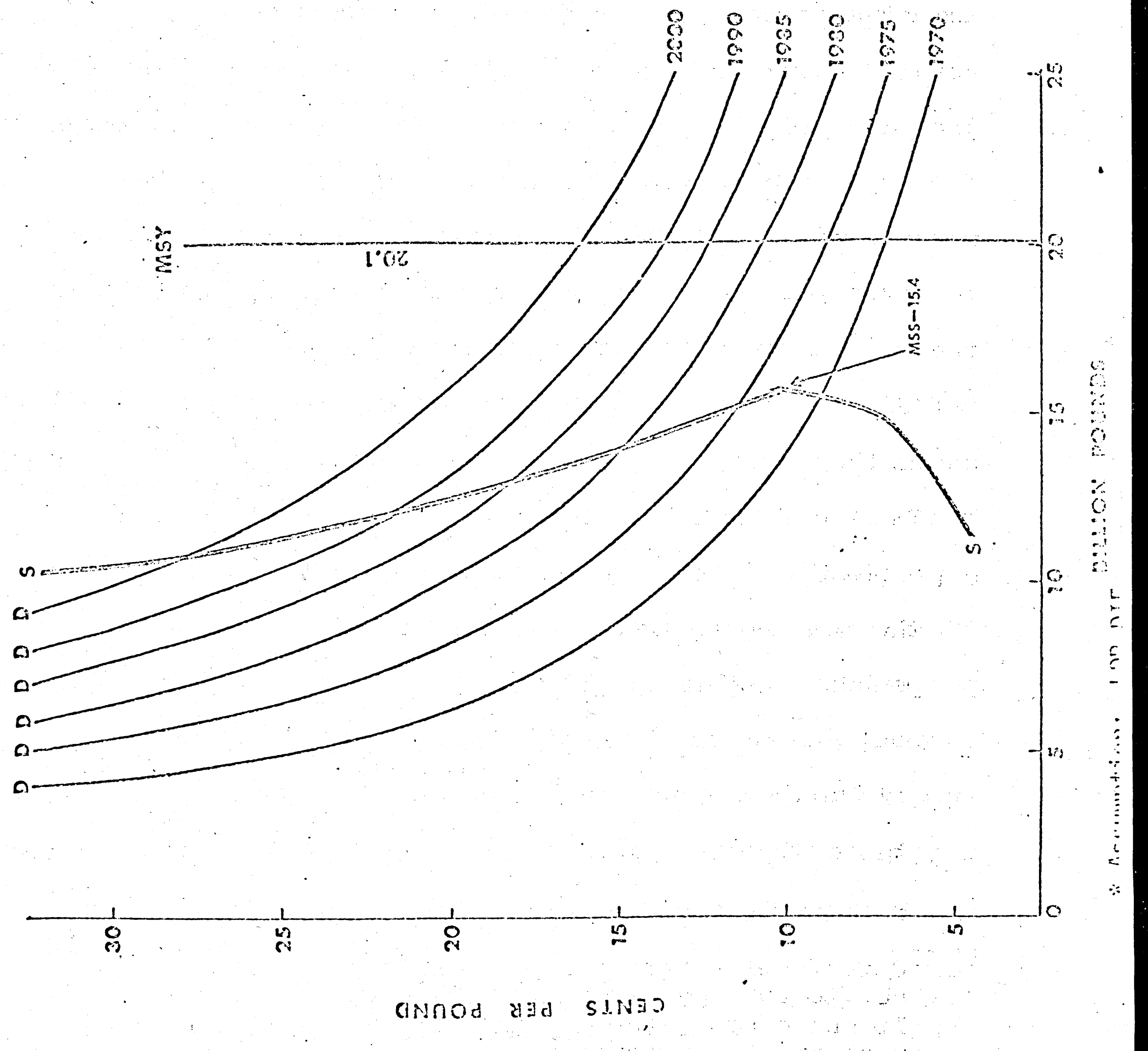
Figure 6.3--World demand and supply functions for groundfish, 1970-2000*



6.3 Tuna

Tuna production has increased considerably over the last 15 years. However, the future production potential of tuna is uncertain. The uncertainty stems from the fact that the potential of the central Pacific skipjack is relatively unknown. For tuna, we formulated a discontinuous supply function based upon the considerably lower catch rates envisioned in the central Pacific under known technology. For purposes of analysis we assumed that catch rates in the central Pacific for skipjack are probably not more than one-tenth of catch rates for exploited stocks. Therefore, unless real prices were to rise by 1000%, it would not be economical to attempt to harvest central Pacific skipjack. This is the reason for the discontinuous supply curve. In Figure 6.4 SS shows the world supply response without while SS' shows the supply response with the central Pacific resource. The critical factor is the increase in price produced by expansion in demand. Excluding the central Pacific resource, the maximum sustainable yield for tuna is 3,903 million pounds. According to our projections, the world maximum sustainable supply (excluding skipjack) will be reached around the year 2000. Real prices will almost double, but this probably will not be sufficient to bring into production the central Pacific resource under existing technology.[5]

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[5] Government programs are presently under way to discover a new technology for harvesting central Pacific skipjack. If successful, these programs will help moderate projected real price increases.

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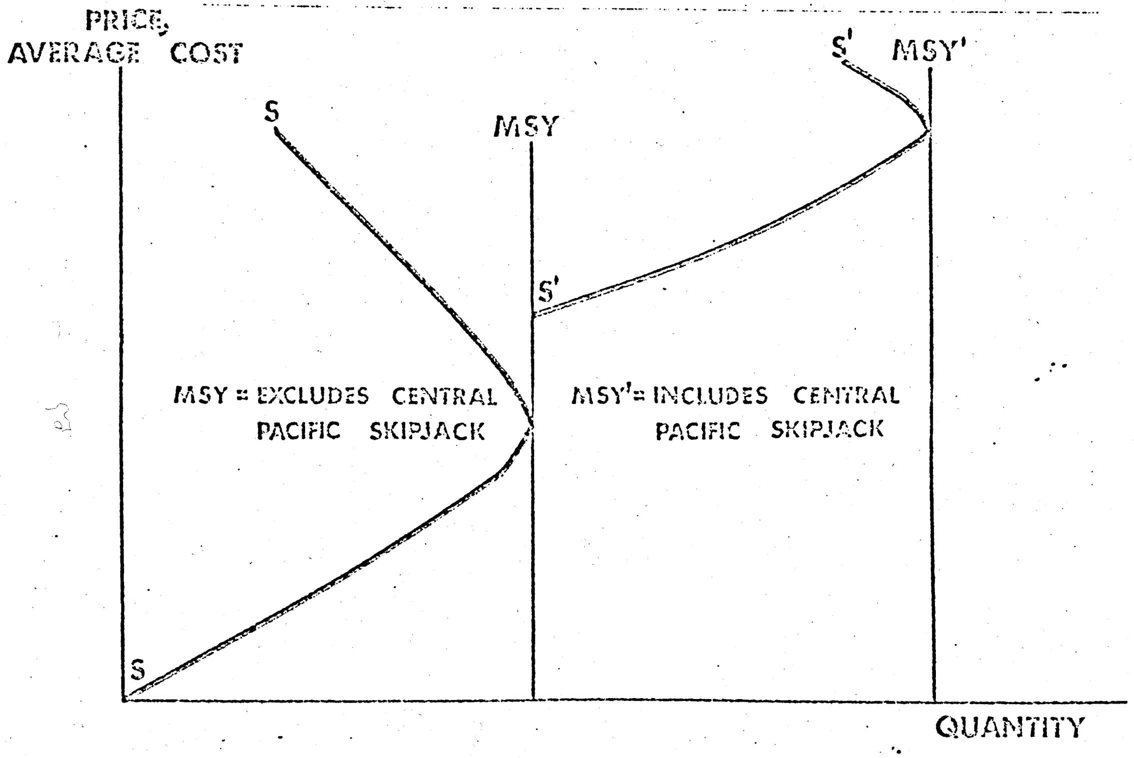
Figure 6.4--Supply functionsfor tuna



The U.S. is expected to increase its consumption of tuna from 898 million pounds in the 1965-67 base period to 1,395 million pounds by the year 2000, with a rise in the share of the world market.

Table 6.2--Tuna projections (LDR - DIE assumptions)*

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of the world
1965-67†	2,845	16	73	78	898	4.56	12	32
1970	2,900	16	74	79	1,105	5.36	13	38
1975	3,210	18	82	88	1,215	5.54	14	38
1980	3,430	20	88	94	1,285	5.46	16	37
1985	3,560	23	91	97	1,320	5.22	18	37
1990	3,630	25	93	99	1,370	5.06	19	38
2000	3,650	30	94	100	1,395	4.53	23	38

World maximum sustainable yield (MSY) = 3,903 million pounds
World maximum sustainable supply (MSS) = 3,659 million pounds

†Average of actual data

* See footnote 4 of Chapter 6 for a discussion of differences in real price between the U.S. and the world.

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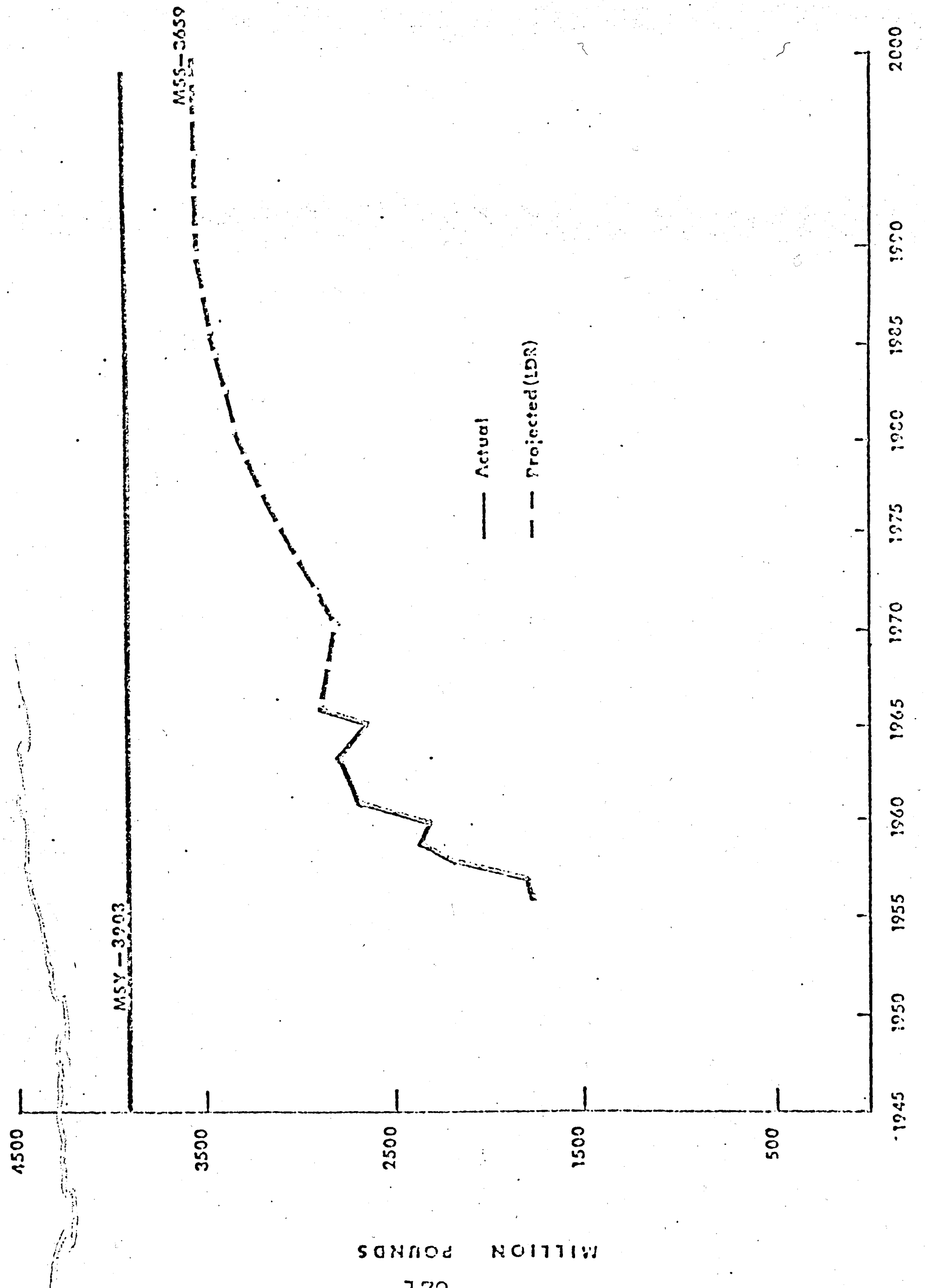
Figure 6.5--Historical and projected world consumption of tuna*



* Assumption: LDR - DIE

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Figure 6.6---U.S. consumption of tuna 1947-1966 and projected to year 2000*

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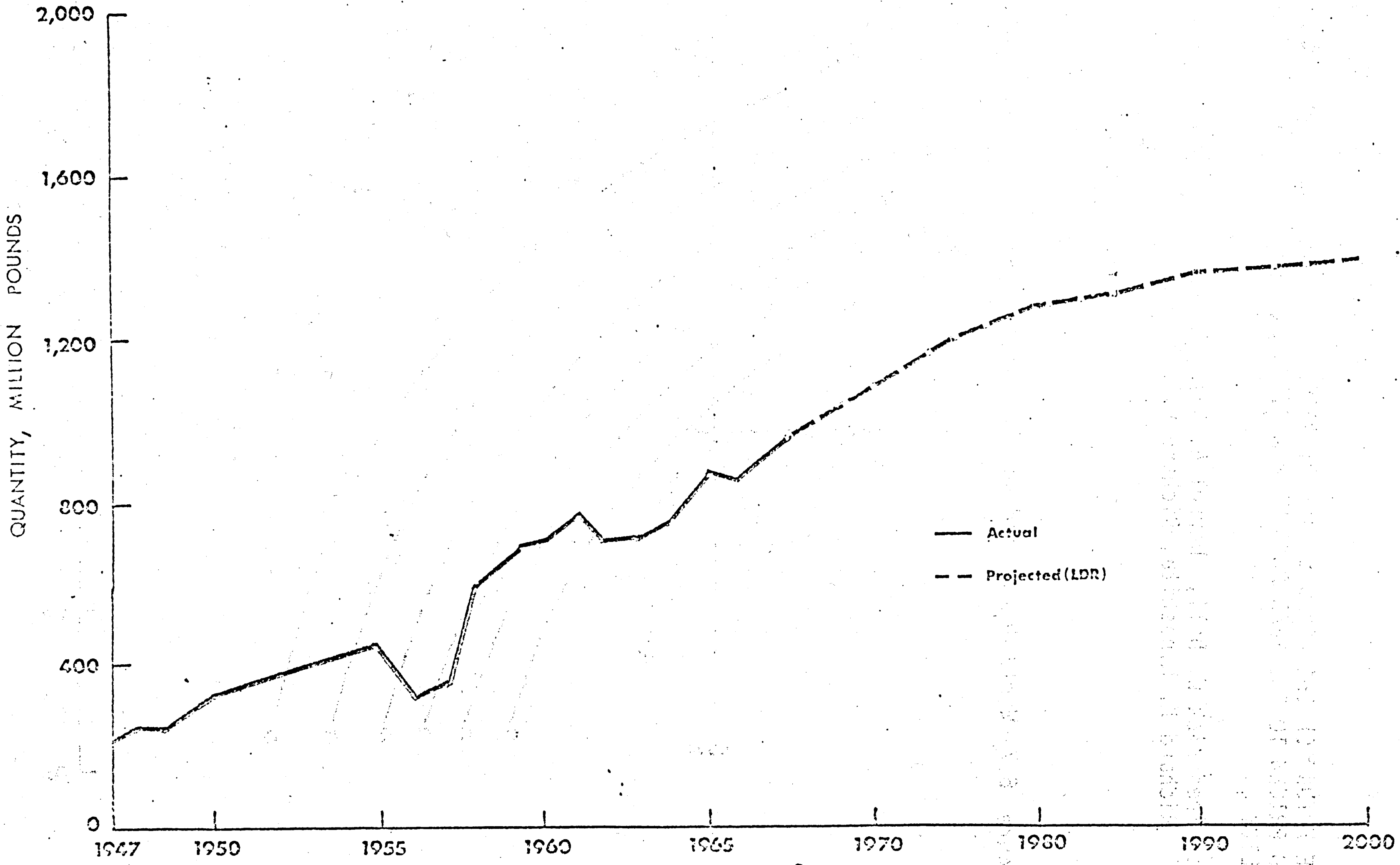

* Assumption: LDR - DIE

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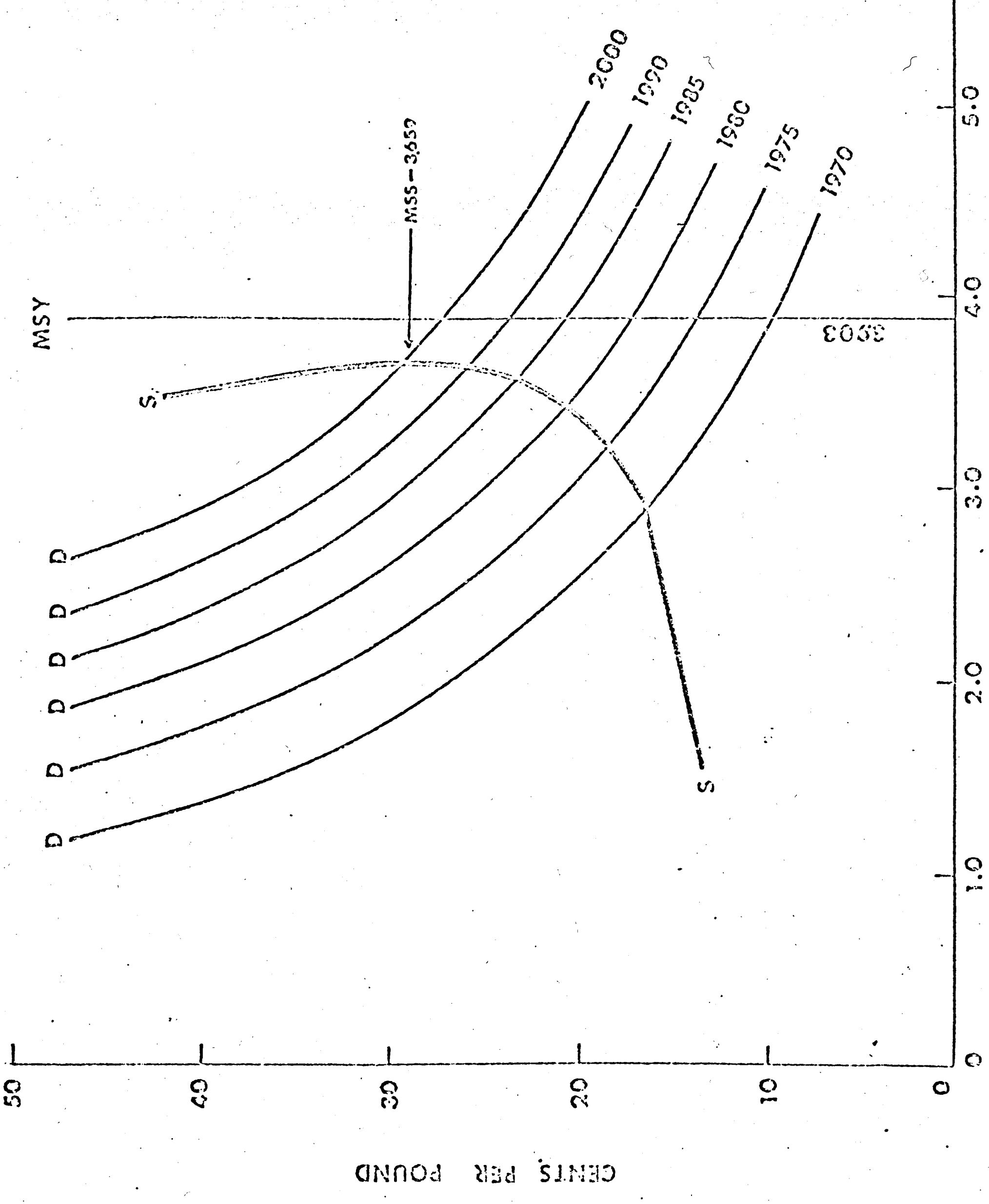
Figure 6.7--World demand and supply functions for tuna, 1970-2000*



* Assumption: LDR - DIE

6.4 Salmon

Salmon is a highly valued species of fish which enjoys a rapidly rising demand throughout the world. Since 1955, there has been no appreciable increase in the production of salmon on a world basis. According to our best estimates, we are presently taking the maximum sustainable salmon potential from the seas. To eliminate the possibility of destruction of the salmon resource, most of the major salmon streams are presently regulated. This regulation takes the form of limiting the number of hours that fishermen can fish and gear they can use in order to assure that adequate spawners reach the upper limits of the streams. Because of the existing management policy to protect the resource, we projected aggregate consumption at maximum sustainable yield. In constructing the world supply curve, we did not build it up from regional supply functions (see Chapter 3) because of the heavy concentration of the resource in the northwest Pacific region. It was also not necessary since each region is controlled through management at MSY.

The analysis revealed that the demand (income and population effects) throughout the world will increase, which will put added pressure on the fixed resource base. The consequences will be rapidly rising prices and falling per capita consumption to the year 2000. In fact, real prices for the world are expected to increase from 24 cents in the 1965-67 base period to 38 cents per pound by the year 2000. These price projections do not include normal increases in inflation. The U.S. is expected to maintain its share of aggregate world salmon consumption, and experience a continuation of the historical fall in per capita consumption.

Many have argued that the salmon supply potential can be increased through hatchery operations and stream improvement. In this case, the maximum sustainable yield for salmon may be appreciably increased. This is shown in Table 6-4 where an infinitely elastic supply is assured.

Table 6.3--Salmon projections[1] (LDR - DIE assumptions)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of the world
1965-67†	1050	24.2	98	98	301	1.54	18.0	29.0
1970	1051	24.2	98	98	317	1.54	18.0	30.2
1975	1069	25.5	100	100	325	1.48	19.0	30.4
1980	1069	27.6	100	100	330	1.40	20.6	30.9
1985	1069	29.9	100	100	335	1.32	22.3	31.3
1990	1069	32.5	100	100	338	1.25	24.2	31.6
2000	1069	37.7	100	100	346	1.12	28.1	32.4

*World maximum sustainable yield (MSY) - 1,069 million pounds

1. Projections are identical to those obtained under LCR-DIE assumptions because projections are held at MSY. Fishery management is in force (see text for discussion).

†Average of actual data

Table 6.4--Salmon projections (IES - DIE assumptions)

(Round weight - U.S. dollars)

	World		United States			
Year	Quantity million pounds	Real price ¢/lb.	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of the world
1965-67†	1050	24.2	301	1.54	18.0	29.0
1970	1051	24.2	317	1.54	18.0	30.2
1975	1126	24.2	338	1.54	18.0	30.0
1980	1211	24.2	362	1.54	18.0	29.9
1985	1302	24.2	389	1.54	18.0	29.9
1990	1396	24.2	417	1.54	18.0	29.9
2000	1590	24.2	474	1.54	18.0	29.8

†Average of actual data

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Figure 6.8--Historical and projected world consumption of salmon*

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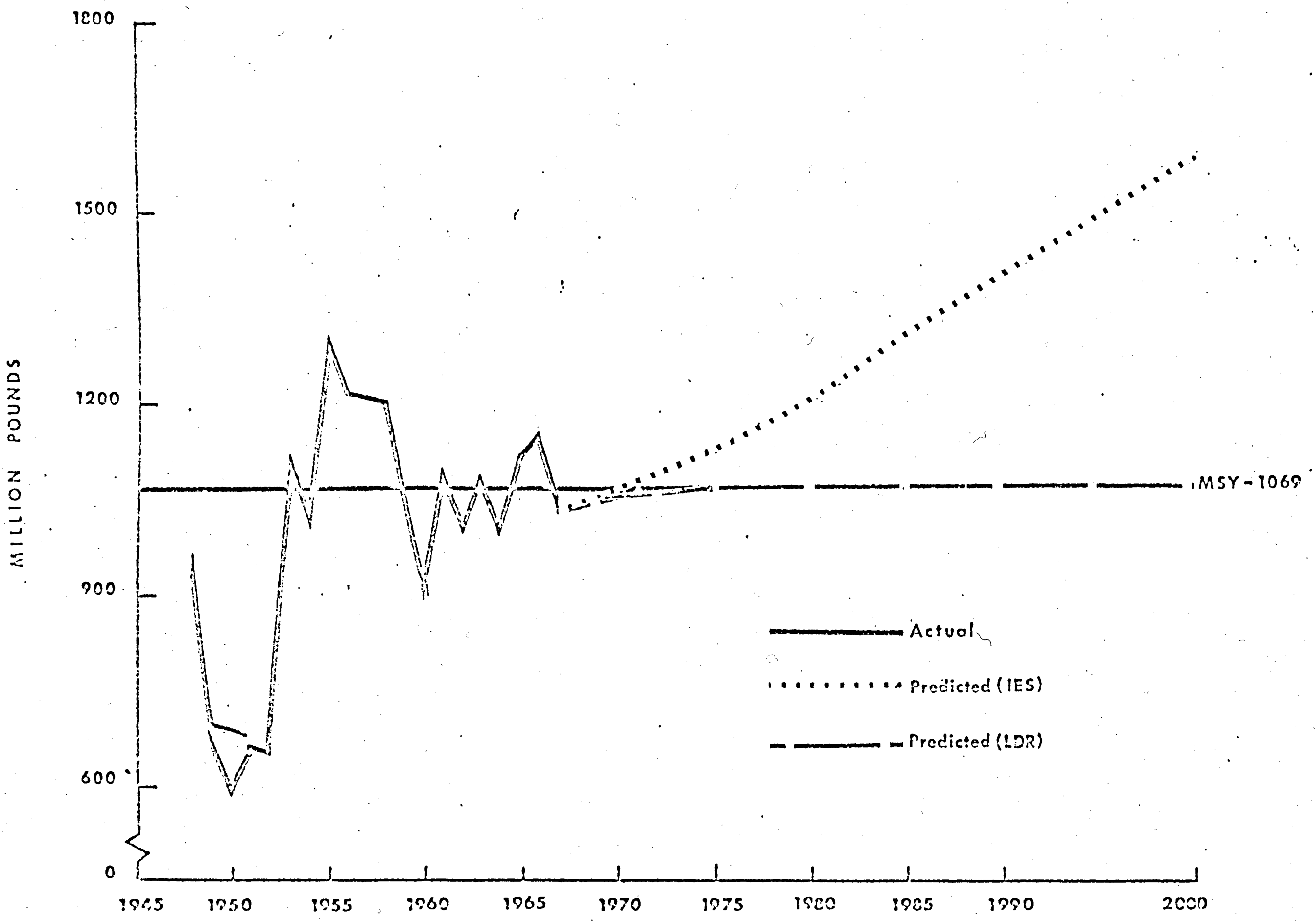

* Assumption: LDR - DIE and IES-DIE

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Figure 6.9--U.S. consumption of salmon 1948-1967 and projected to year 2000*

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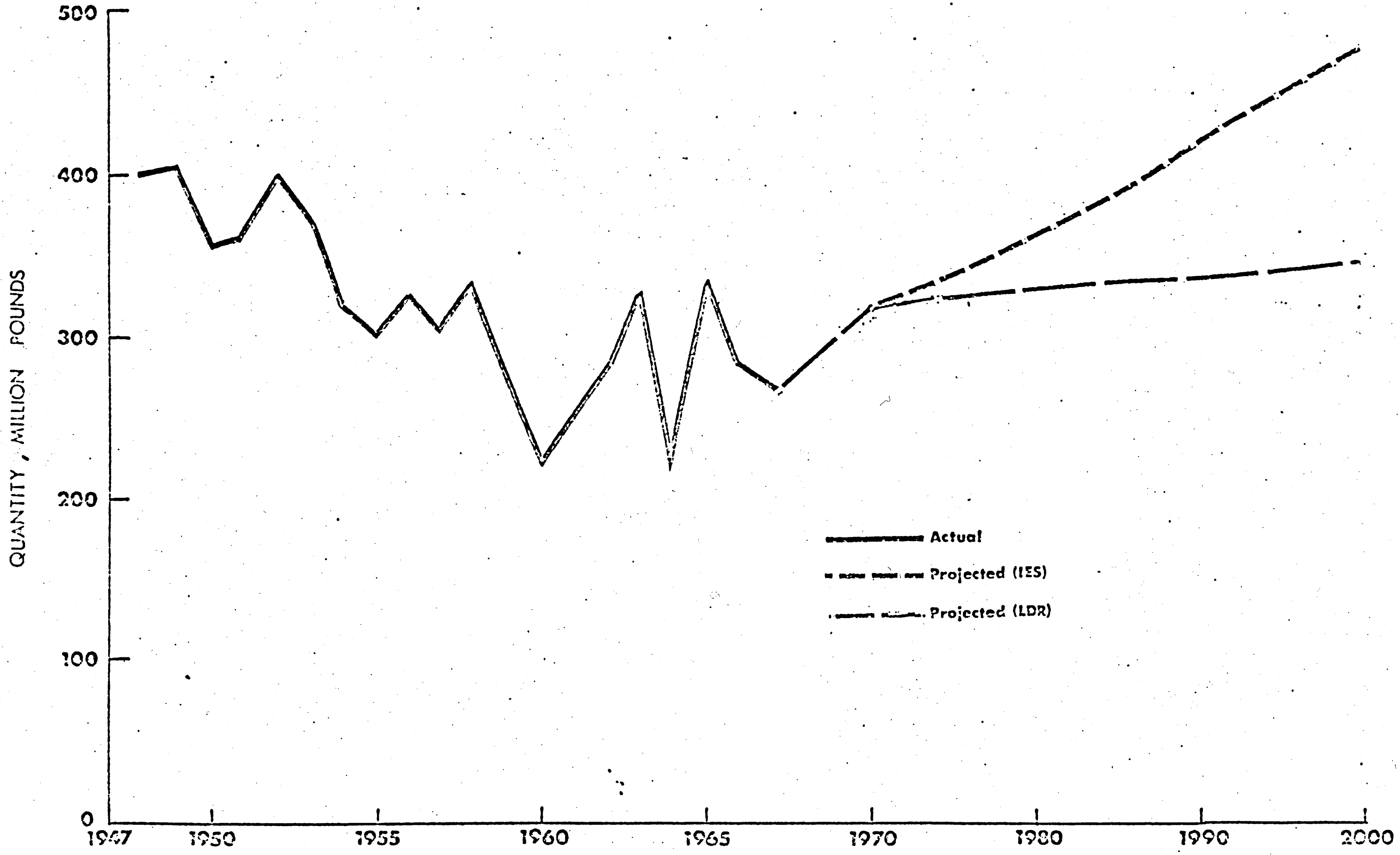

* Assumption: LDR - DIE and IES - DIE

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Figure 6.10--World demand and supply functions for salmon, 1970-2000*

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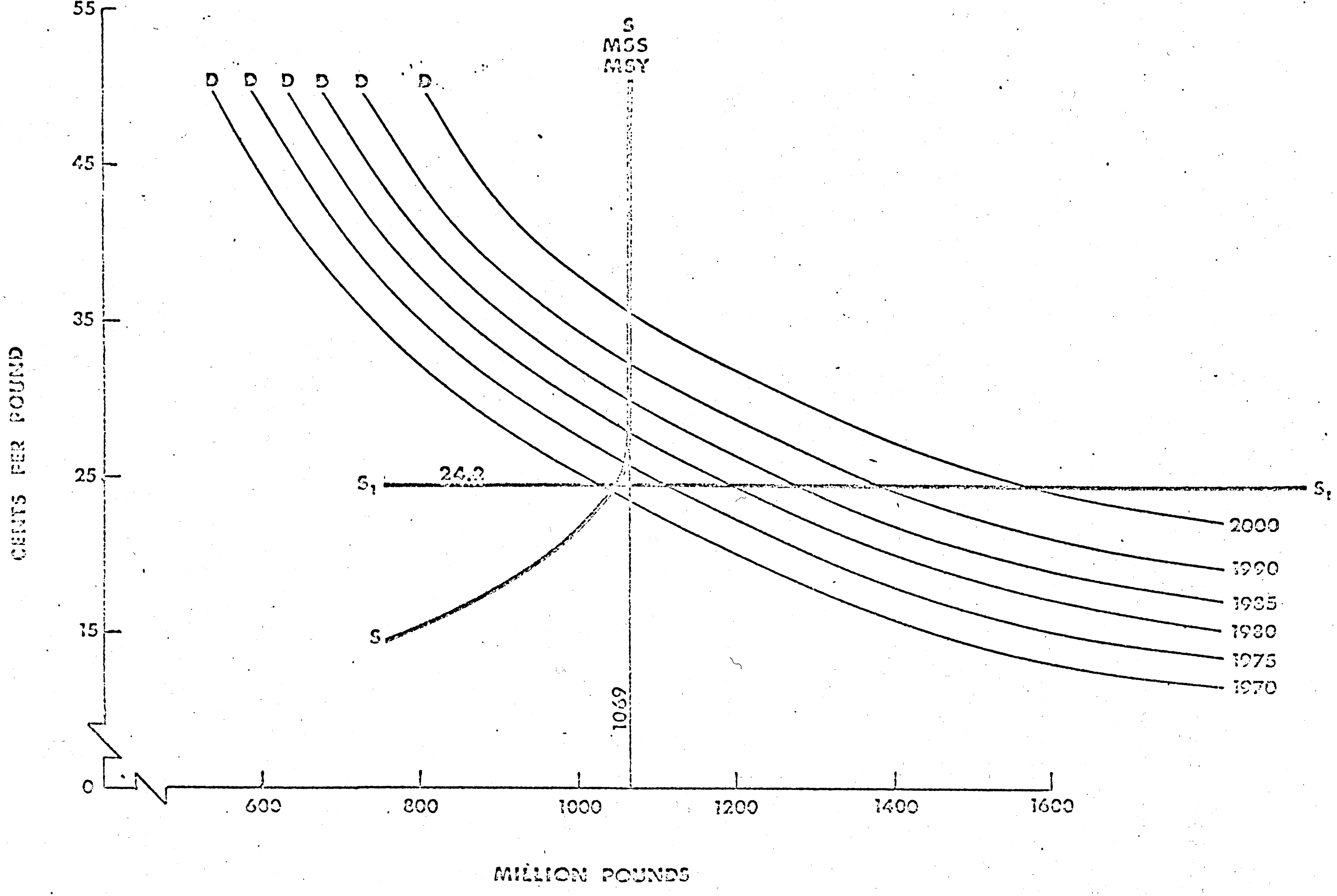

*Assumption: LDR-DIE and managed at MSY
S_1S_1 = IES-DIE

6.5 Halibut

Since 1933, the catch of most of the world's halibut has been regulated under a treaty between the United States and Canada. The International Pacific Halibut Commission has been the principal investigatory agency under the treaty. It has been the duty of the Commission to preserve the halibut resource. World halibut landings have not increased since 1955 since the resource is fished at maximum sustainable yield.

As in the case of salmon, halibut is expected to experience no increase in production with rapidly rising prices and falling per capita consumption. Real prices are expected to increase by over 100% by the year 2000 from 25 cents per pound in the 1965-67 base period to 52 cents a pound by the year 2000. The U.S. share increases gradually over the projection period.

Table 6.5--Halibut projections[1] (LDR - DIE assumptions)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real * price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of the world
1965-67†	128	25	99	99	80	.40	18	62
1970	129**	28	100	100	87	.42	20	68
1975	129	32	100	100	88	.40	23	68
1980	129	36	100	100	88	.37	26	68
1985	129	40	100	100	88	.35	30	68
1990	129	45	100	100	88	.32	33	68
2000	129	52	100	100	89	.29	38	69

†Average of actual data.

*For an explanation of differences in real price between the U.S. and the world see footnote 4 of Chapter 6.

**World maximum sustainable yield (MSY) = 129 million pounds

1. Projections are identical to those obtained under assumptions because projections are held at Fishery management is in force (see text for discussion).

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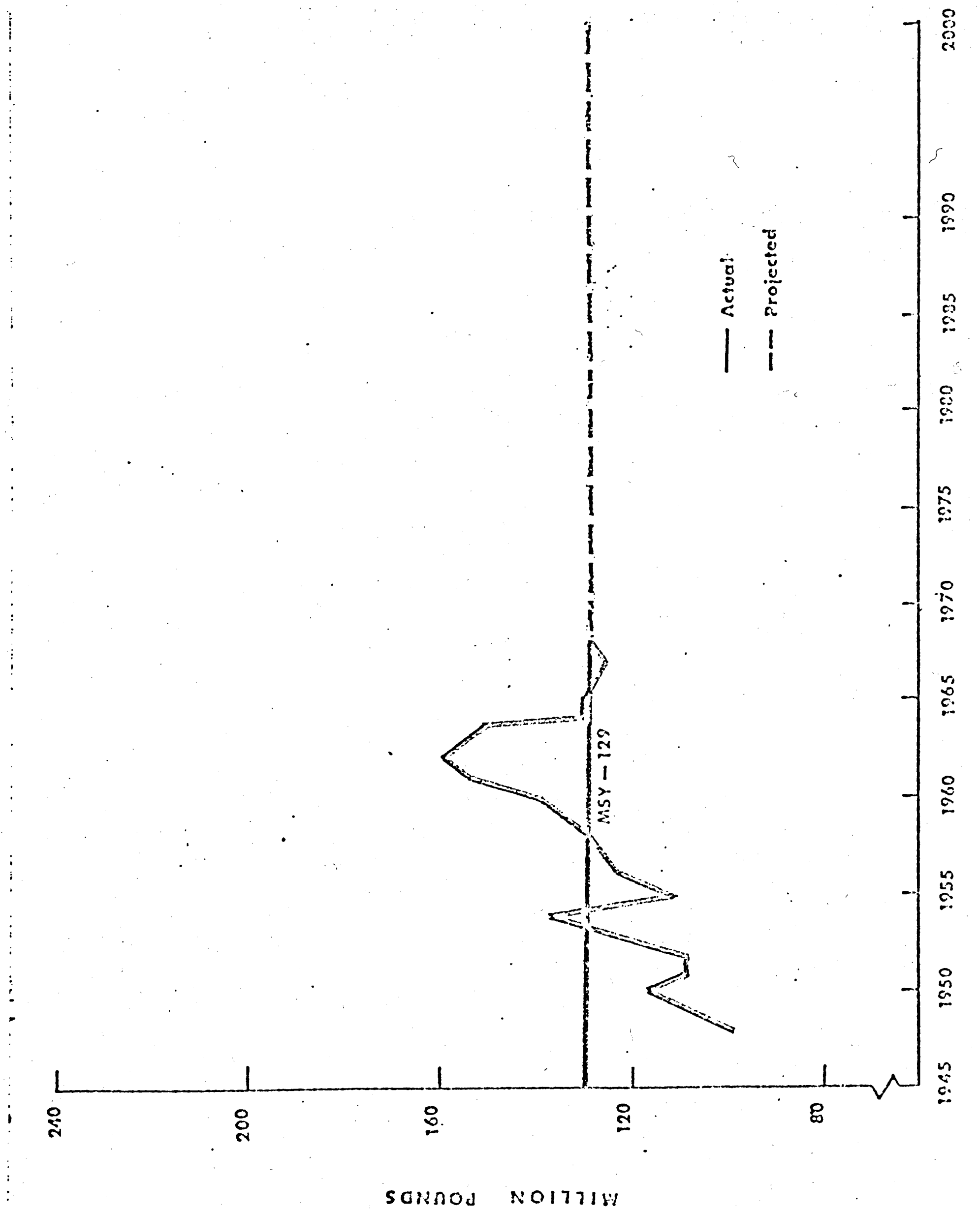
Figure 6.11--Historical and projected world consumption of halibut*



* Assumption: LDR - DIE

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Figure 6.12--U.S. consumption of halibut 1950-1967 and projected to year 2000*

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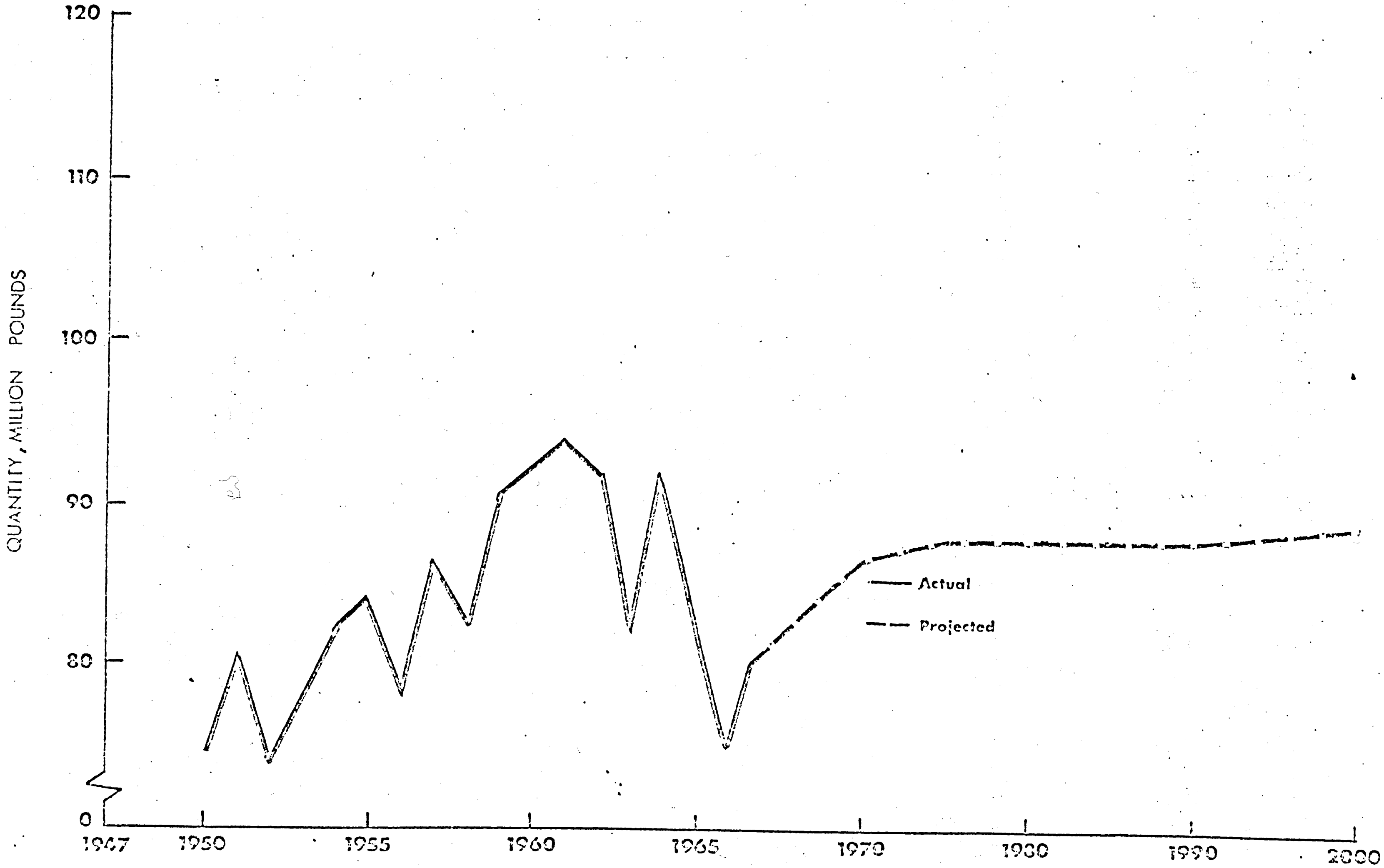

* Assumption: LDR = DIE.

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Figure 6.13--World demand and supply functions for halibut, 1970-2000*

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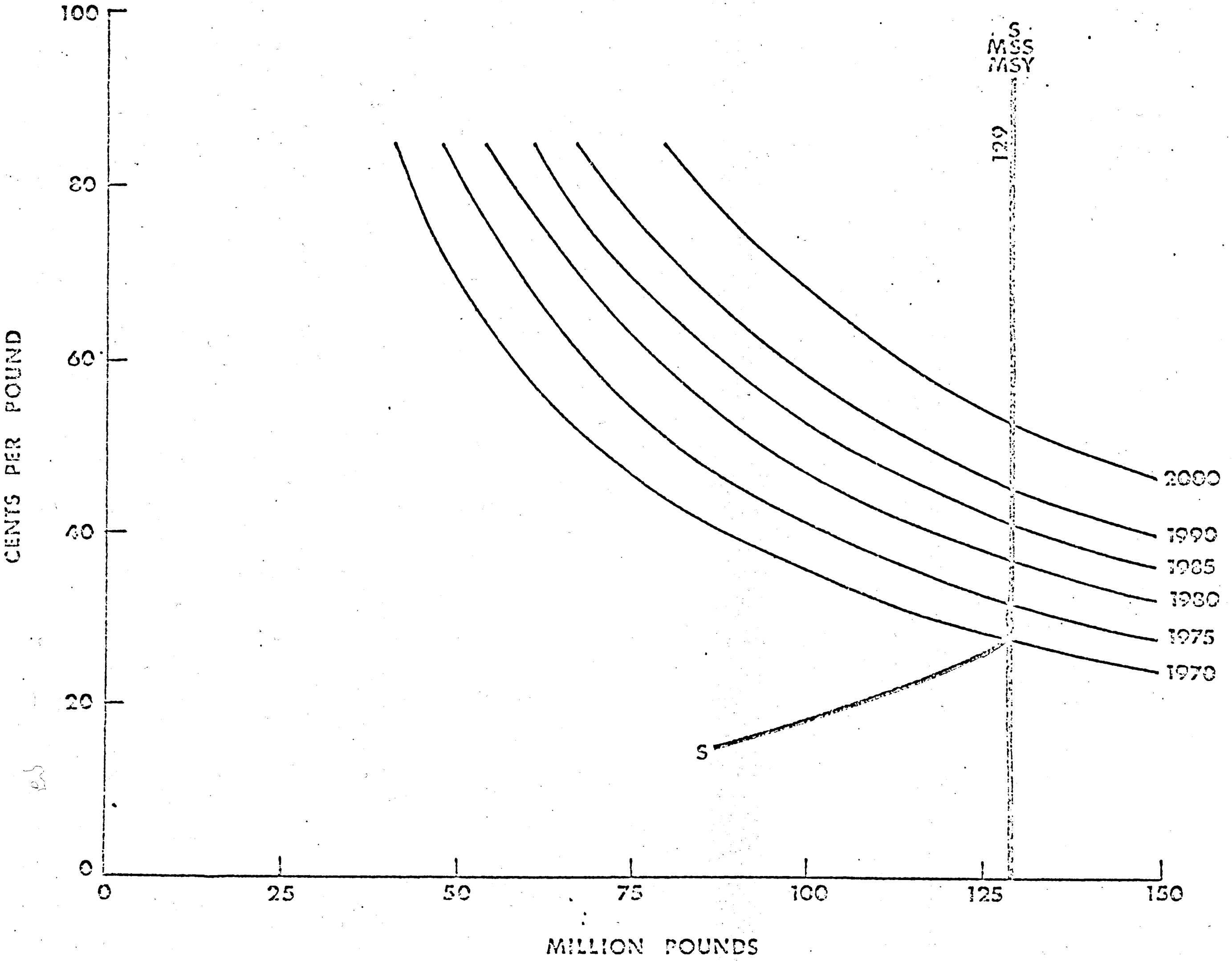

*Assumptions: LDR-DIE and managed at MSY

6.6 Sardines

Presently, the world has an ample supply of sardines and herring-like fish for food consumption.[6] Best available estimates indicate that the world utilizes about 3% of available supplies. Therefore, we decided to assume an infinitely elastic supply of sardines within the range of our projections. The world is expected to more than double its consumption of sardines by the year 2000. The U.S. per capita consumption is not predicted to change since our estimated income elasticity is zero; therefore, the U.S. share of world consumption is projected to decline from 7.0% in the 1965-67 base period to 4.0 % in 2000.

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[6] See Section 6.22 for a discussion of the use of the supply potential for herring-like fish.

Table 6.6--Sardine projections (IES - DIE assumptions)

(Round weight - U.S. dollars)

World*			United States			
Year	Quantity million pounds	Real price ¢/lb.	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of world
1965-67†	1,920	31	134	.68	36	7.0
1970	2,570	31	139	.67	36	5.4
1975	3,228	31	148	.67	36	4.6
1980	3,652	31	159	.68	36	4.4
1985	4,074	31	171	.68	36	4.2
1990	4,438	31	183	.68	36	4.1
2000	5,225	31	208	.68	36	4.0

*Assumes constant price within projection range

†Average of actual data

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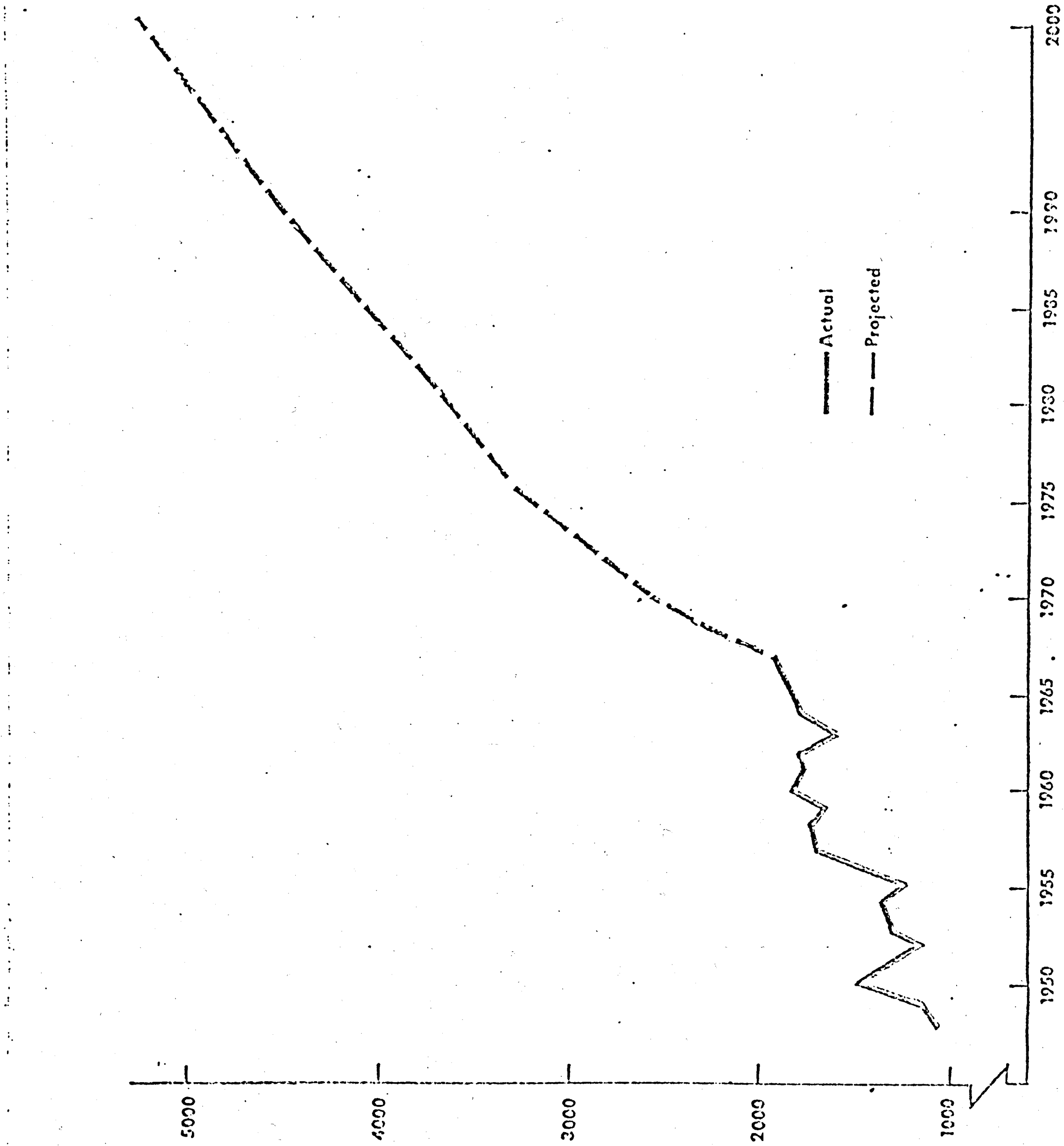
Figure 6.14--Historical and projected world consumption of sardines *



* Assumption: IES-DIE, [illegible]

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Figure 6.15--U.S. consumption of sardines 1950-1967 and projected to year 2000 *

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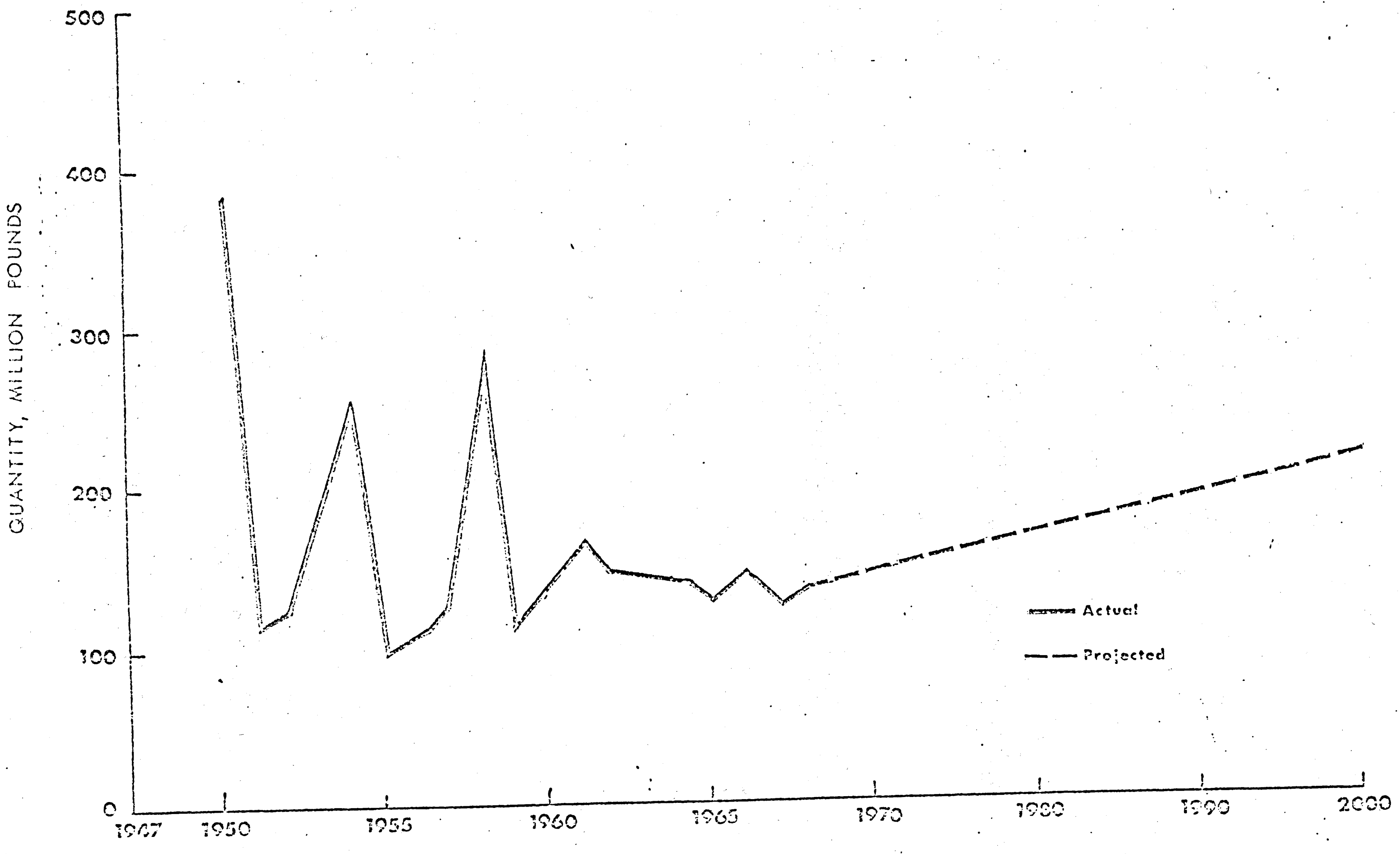

*Assumption IES-DIE

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Figure 6.16--World demand and supply functions for sardines, 1970-2000*

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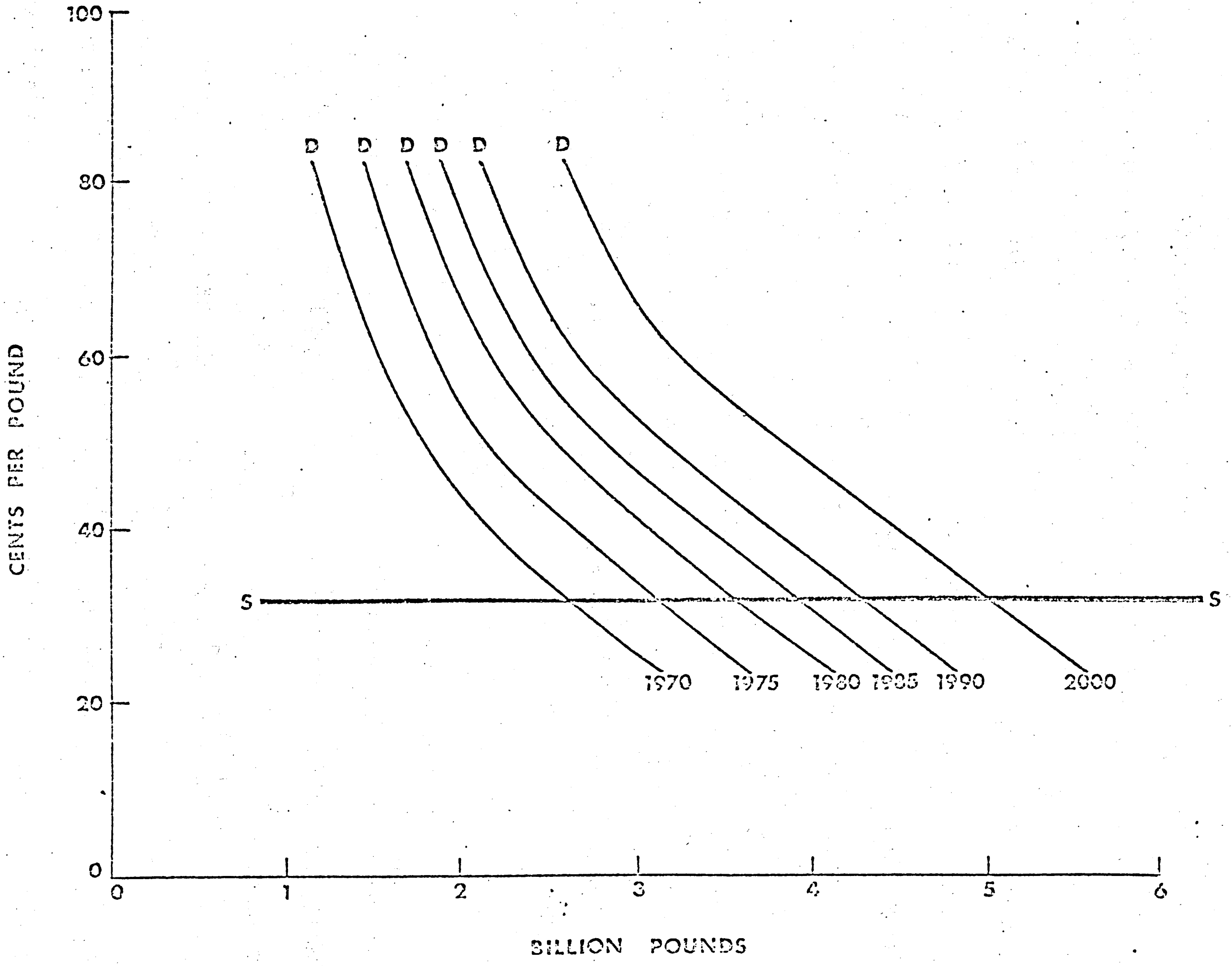

*Assumption IES-DIE and managed at MSY

6.7 Shrimp

World production of shrimp has increased steadily over the last 20 years. In the 1965-67 base period, we utilized about 43 % of the world shrimp potential (MSY). The life cycle of most shrimp virtually precludes overfishing. This is because the majority of shrimp have a short life cycle. Therefore, increases in demand will probably not reduce physical production. Because of this fact, shrimp production and consumption can only increase or remain constant at the maximum potential in the face of rising demand. However, there are some species of shrimp that have longer life cycles; therefore, backward bending supply curves were taken into consideration for these species in making the projections. The reader is referred to Appendix B for a division of shrimp based upon life cycle.

As we can see, world demand will not increase to utilize the full potential (MSS) for shrimp until about the year 2000. However, real prices will increase by over 154 % from the 1965-67 base period to the year 2000 because of the increasing difficulty of harvesting additional shrimp (i.e., declining yields). The United States is expected to increase its share of world consumption of shrimp because of its high income elasticity. U.S. per capita consumption of shrimp is expected to increase steadily over the 1970-2000 period.

Table 6.7--Shrimp projections (LDR - DIE assumptions)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of world
1965-67†	1,399	37	43	43	518	2.63	33	37
1970	1,970	42	60	60	690	3.35	37	35
1975	2,350	46	72	72	840	3.83	41	36
1980	2,740	52	84	84	990	4.21	46	36
1985	2,970	58	91	91	1,120	4.29	52	38
1990	3,170	67	97	97	1,210	4.47	60	38
2000	3,260	94	99	99	1,320	4.29	84	40

World maximum sustainable yield = 3,278 million pounds
World maximum sustainable supply = 3,278 million pounds

†Average of actual data

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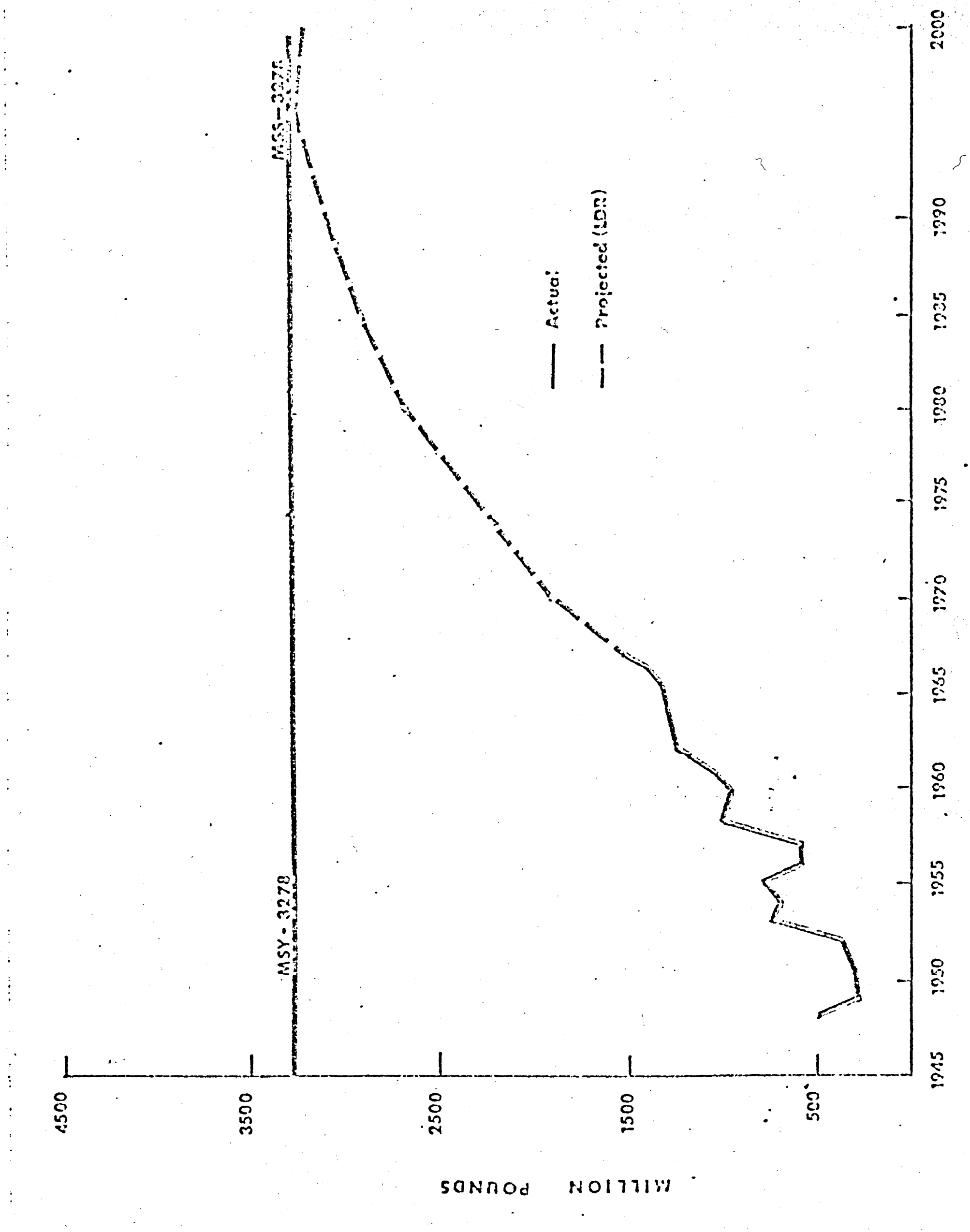
Figure 6.17--Historical and projected world consumption of shrimp*



* Assumption: LDR-DIE

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Figure 6.18--U.S. consumption of shrimp 1947-1967 and projected to year 2000*

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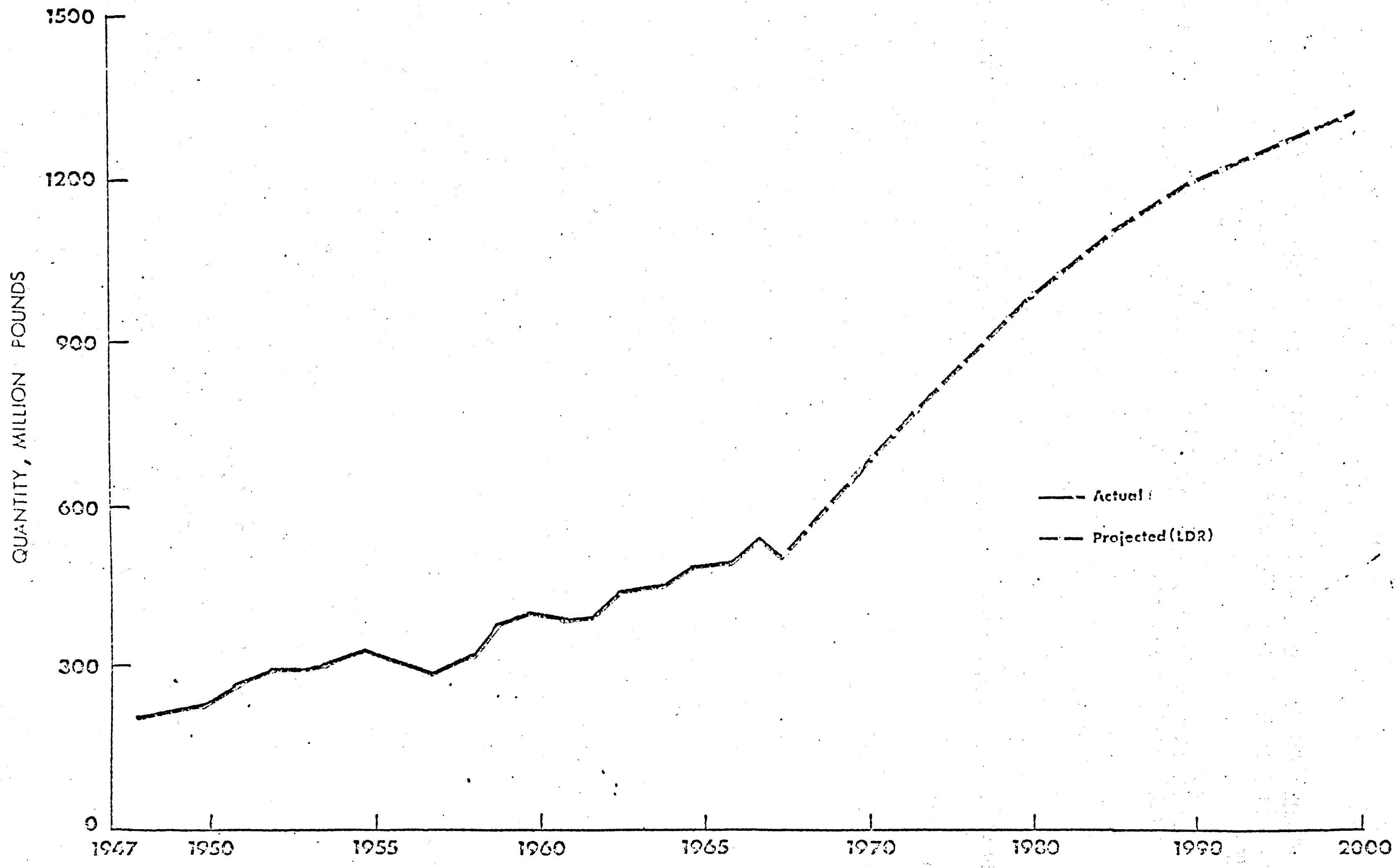

*'Assumption: LDR-DIE

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Figure 6.19--World demand and supply functions for shrimp, 1970-2000*

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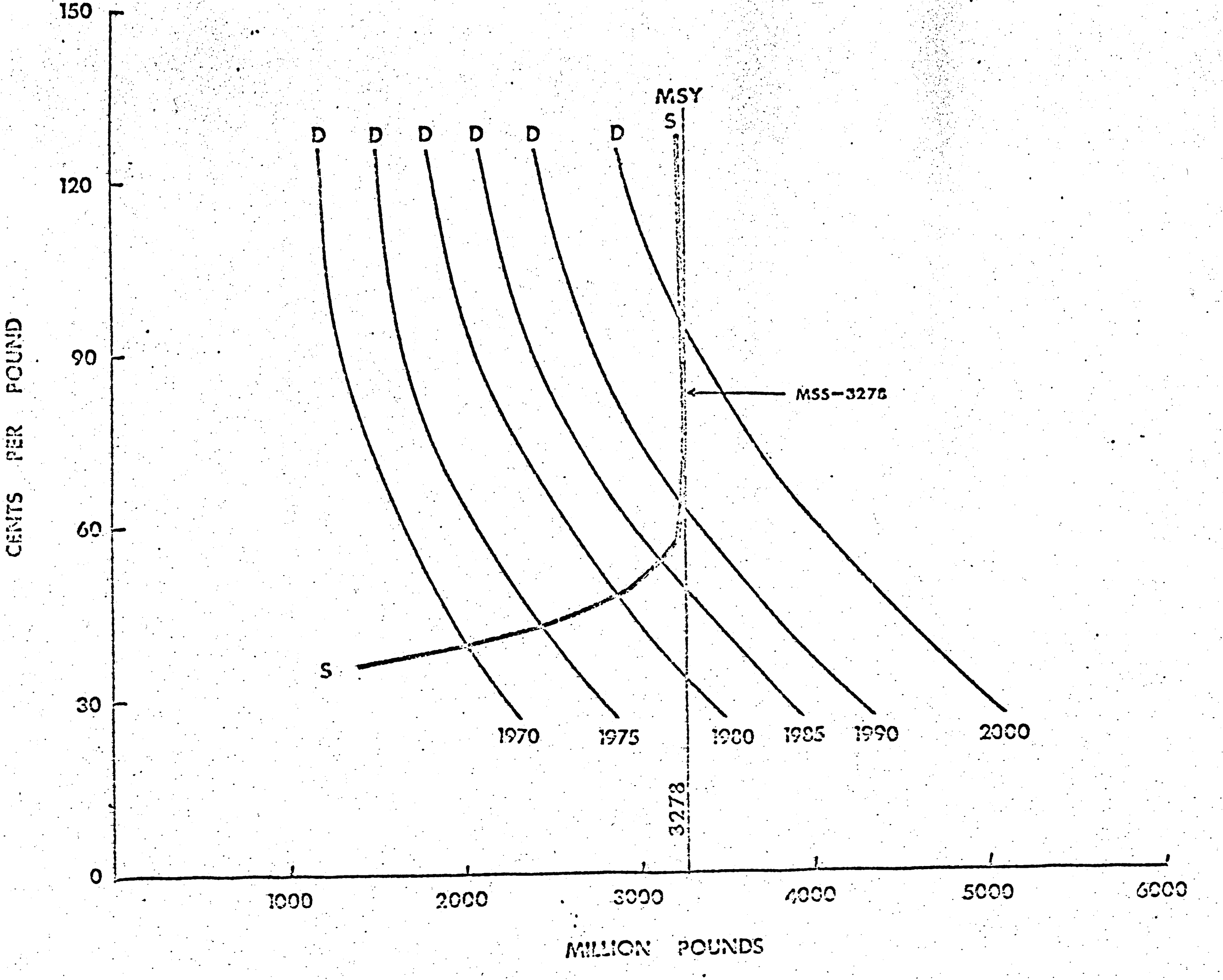

* Assumption: LDR-DIE

† Supply functions for world shrimp bends backward because some shrimp have a longer than annual life cycle. See Appendix B.

6.8 Lobsters

Lobster production experienced rapid growth throughout the last 20 years. Presently, we are utilizing approximately 72 % of the world's maximum sustainable yield.

As indicated by our projections, the world is expected to utilize maximum sustainable yield by 1985. Of course, demand for this product will continue and thereby put tremendous pressure on the fixed resource and price. Unless fishery management is instituted, there may be an actual reduction in physical output (i.e., overfishing). This is indicated by a drop in world production to 411 million pounds in 1990 and to 320 million pounds in the year 2000. As a consequence of the expansion in demand and overfishing after 1985, it is expected that real prices will increase from 63 cents per pound in the 1965-67 base period to 311 cents per pound by the year 2000. The future demand needs relative to supply prospects for lobsters are hardly encouraging.

U.S. aggregate consumption of lobsters is expected to peak in 1985, the same year that world MSS is reached. Because of its higher income elasticity, the U.S. is expected to progressively increase its share of world consumption over the 1970-2000 projection period.

Table 6.8--Lobster projections (LDR - DIE assumptions)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb	U.S. consumption as percent of world
1965-67†	303	63	71.5	71.5	160	.82	68	52.8
1970	330	67	77.8	77.8	217	1.05	72	65.8
1975	383	81	90.3	90.3	258	1.18	87	67.4
1980	412	97	97.2	97.2	287	1.22	105	69.7
1985	424*	123	100.0	100.0	303	1.20	133	71.5
1990	411	147	96.9	96.9	299	1.10	159	72.7
2000	320	311	75.5	75.5	242	.79	336	75.6

*World maximum sustainable yield (MSY) = 424 million pounds
World maximum sustainable supply (MSS) = 424 million pounds

†Average of actual data

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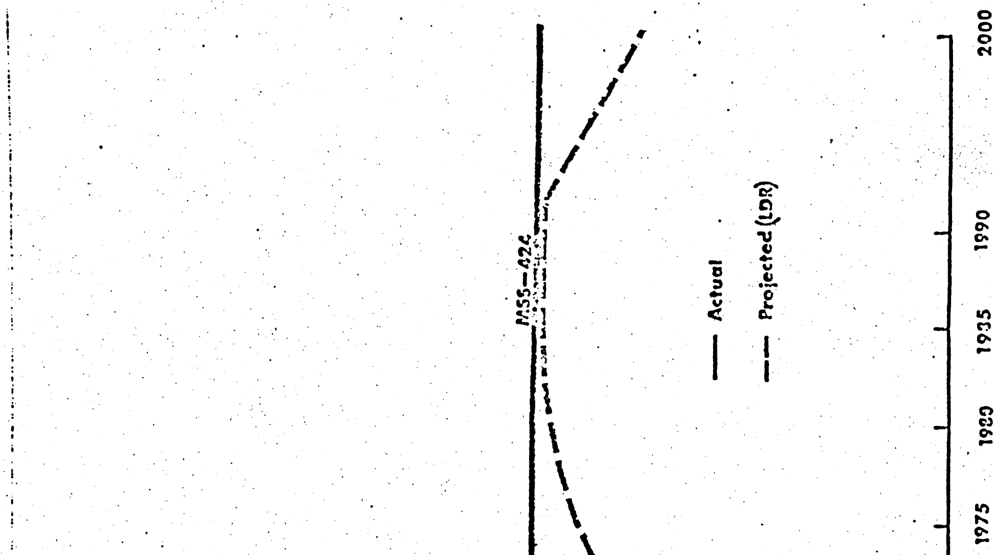
Figure 6.20--Historical and projected world consumption of lobsters*



* Assumption: LDR-DIE

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Figure 6.21--U.S. consumption of lobsters 1948-1967 and projected to year 2000

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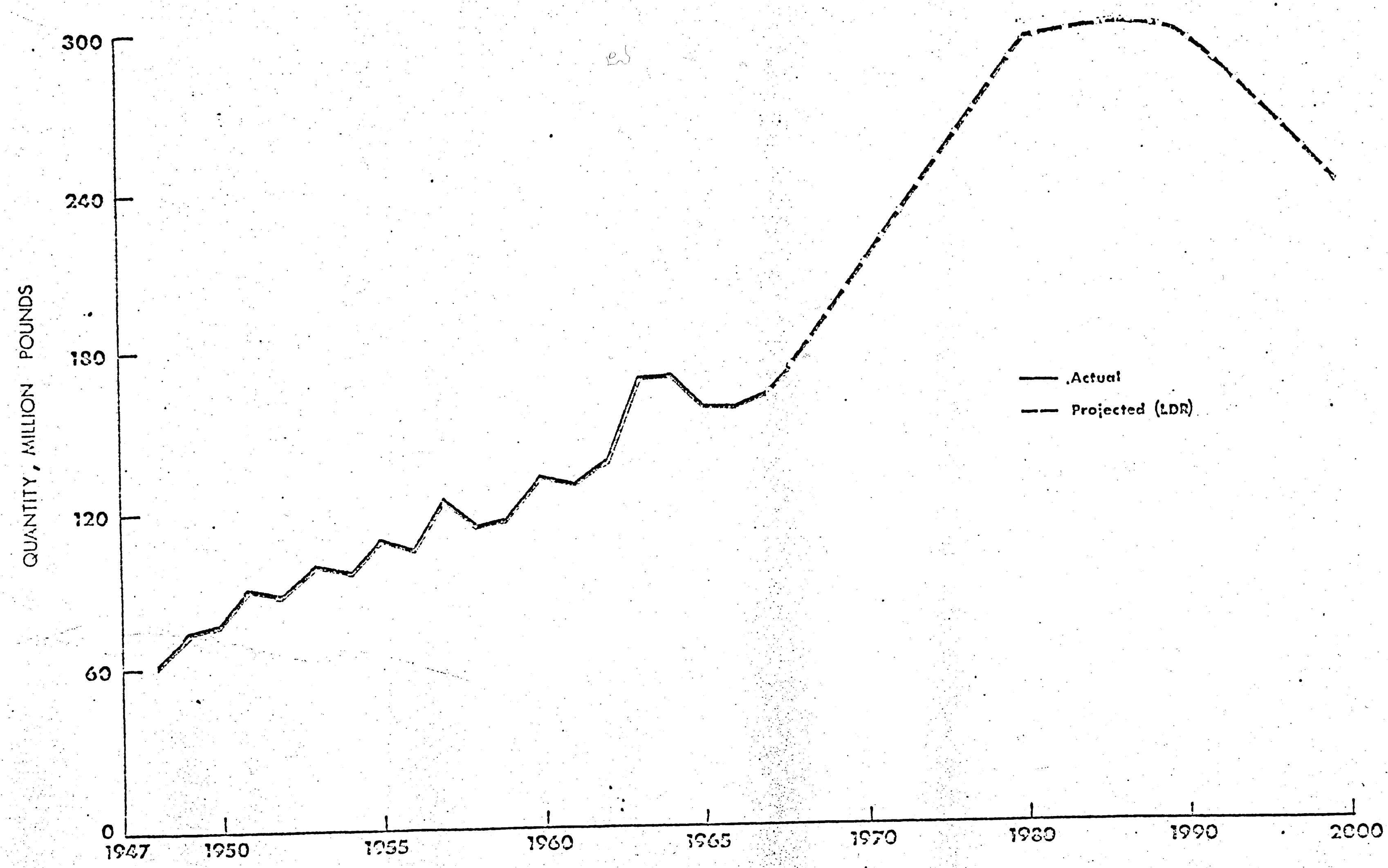
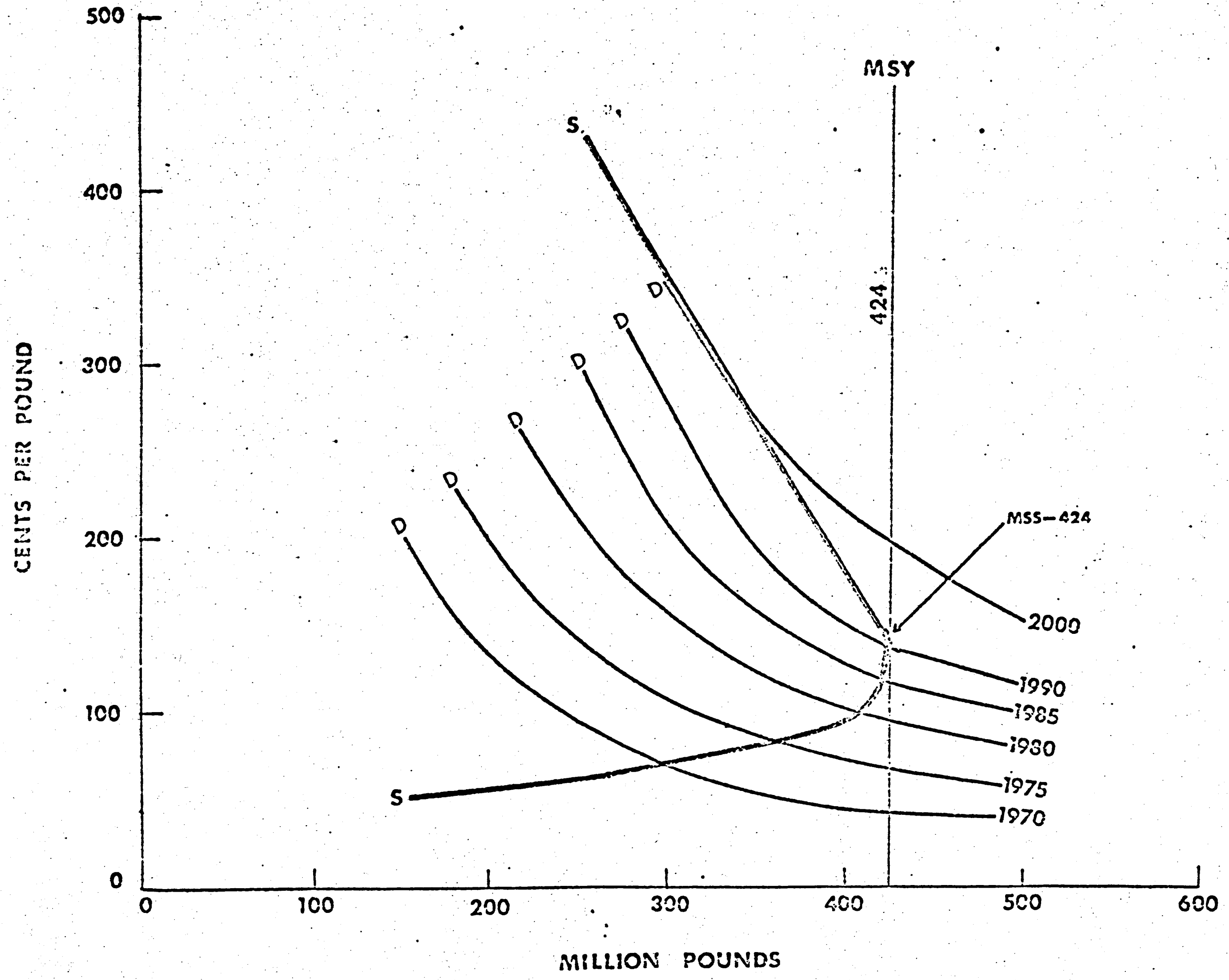


* Assumption: LDR-DIE



* Assumption: LDR-DIE

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Figure 6.22--World demand and supply functions for lobsters, 1970-2000*

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6.9 Crabs

The world crab situation is similar to that discussed for lobsters. Although world crab production has increased considerably, we are rapidly reaching the point where potential supply will be exhausted. Presently, the world is utilizing 58 % of maximum sustainable yield.

According to our world projections, the consumption of crabs will increase rapidly to 1980. As shown in Figure 6.25, the LDR supply function bends back abruptly after reaching maximum sustainable supply. This fact, coupled with the position of the world demand curve does not yield a determinant intersection of supply and demand after 1980. The model discussed above has worked amazingly well for all other species, but seems to have yielded poor results (indeterminant solutions) after 1980 for crabs. Fortunately, the model is indeterminant in the "overfishing" region. Theoretically, this would indicate rapid extinction of the resource. However, projections are sometimes made to be modified. Therefore it is sufficient to say that overfishing will occur after 1980 given the parameters and projections used in the model. Table 6.9 does show projections for crabs for the 1985-2000 period. These projections were obtained by assuming intersections of demand with the backward bending portion of the supply function. This was done by making demand for crabs more elastic over the 1985-2000 period. This is enough of an indication of a danger to the resource. Action should be taken (see Chapter 7).

Table 6.9--Crab projections* (LDR - DIE assumptions)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of world
1965-67†	732	12	58	58	302	1.53	7.9	41
1970	870	12	69	69	410	1.99	7.9	47
1975	1,060	15	84	85	520	2.37	9.8	49
1980	1,210	21	96	97	620	2.64	13.7	51
1985	1,140	58	90	91	570	2.25	58.0	50
1990	990	80	78	79	490	1.81	80.0	50
2000	850	114	67	68	425	1.38	114.0	50

World maximum sustainable yield (MSY) = 1,262 million pounds
World maximum sustainable supply (MSS) = 1,253 million pounds

*Not projected using entire model described in Chapter 5. See Section 6.8 of this chapter for a discussion of how these projections were derived.

†Average of actual data

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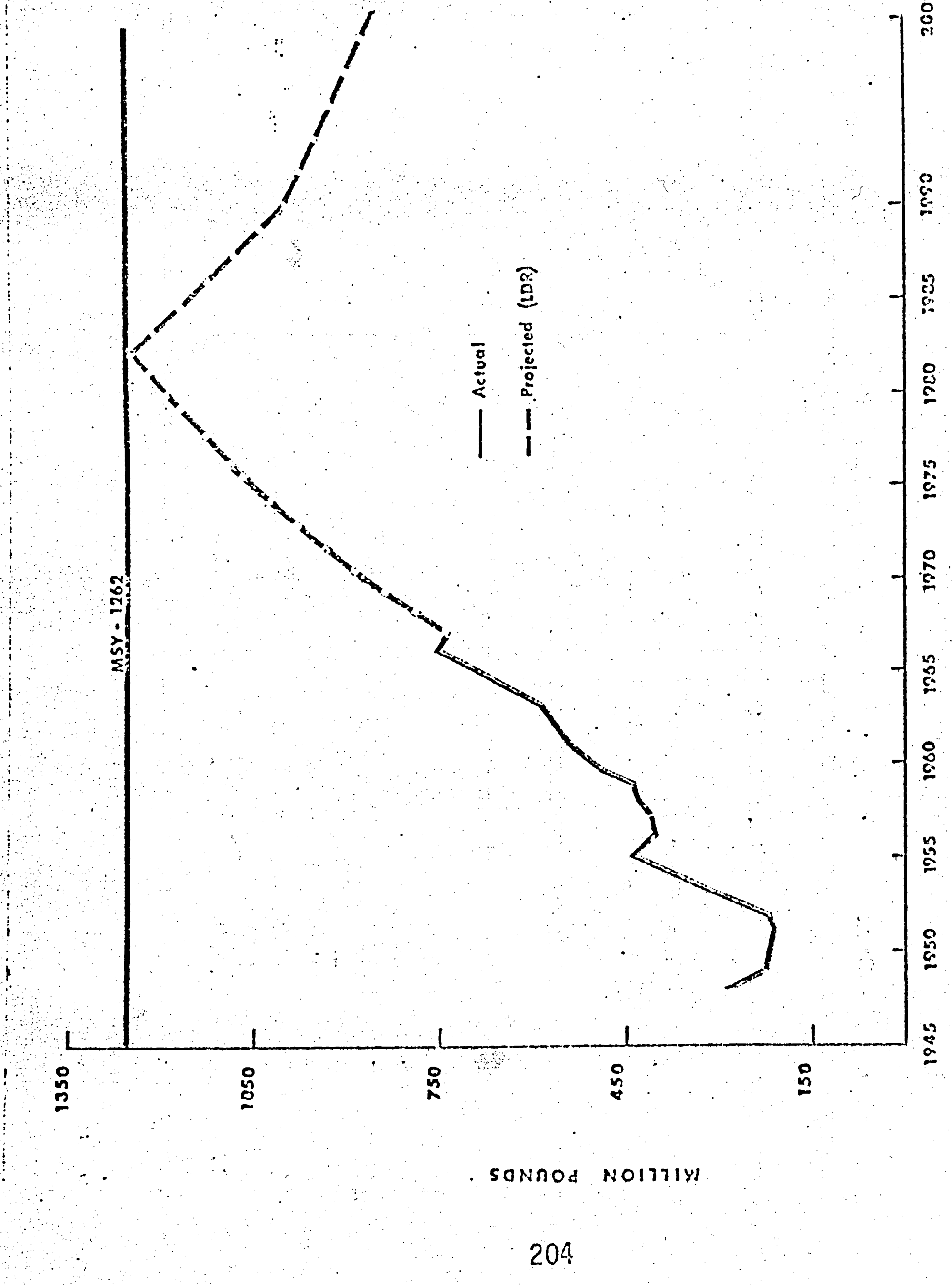
Figure 6.23--Historical and projected world consumption of crabs*



* Assumption: LDR-DIE

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Figure 2.4--U.S. consumption of crabs 1948-1967 and projected to year 2000*

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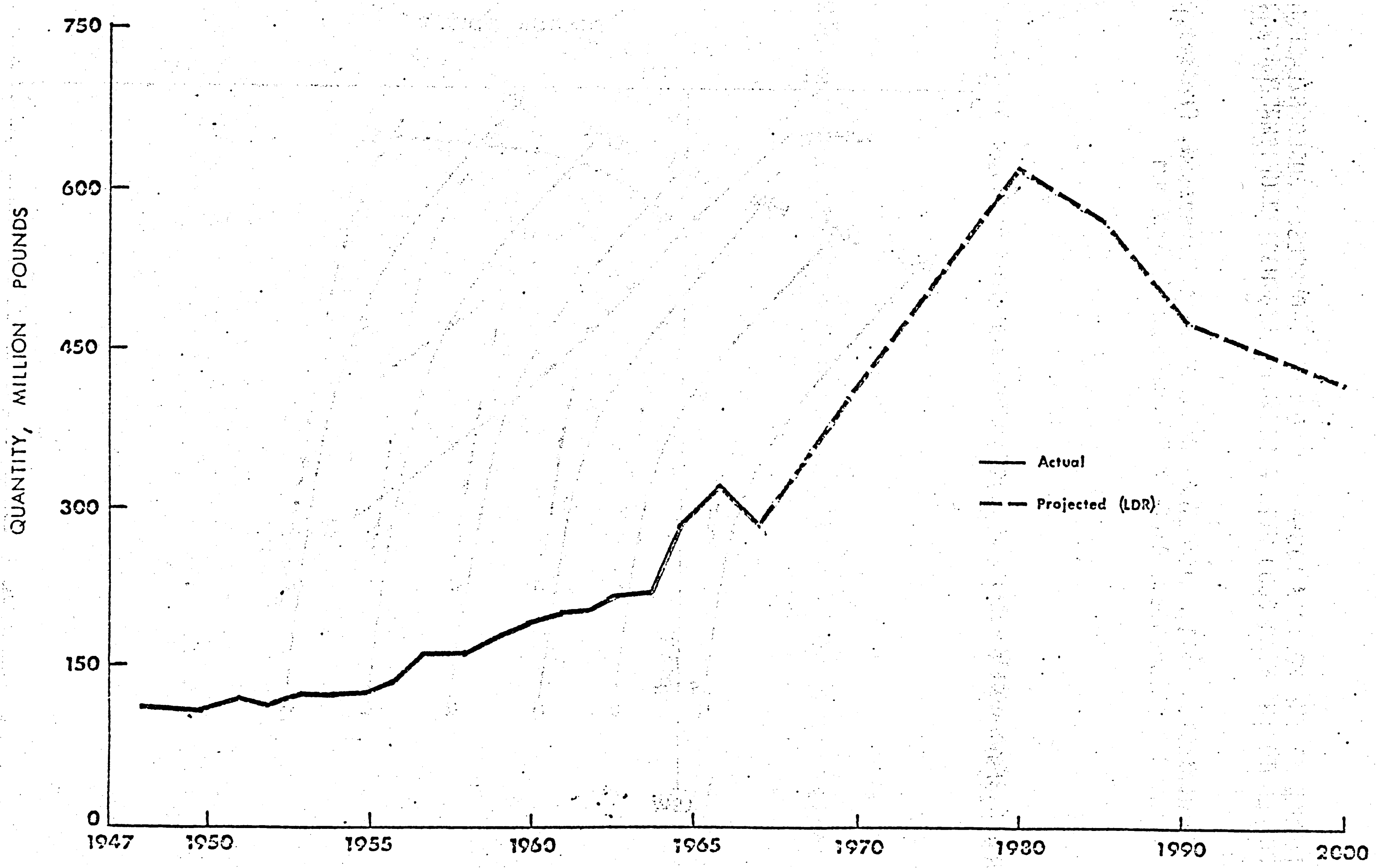

* Assumption: LDR-DIE

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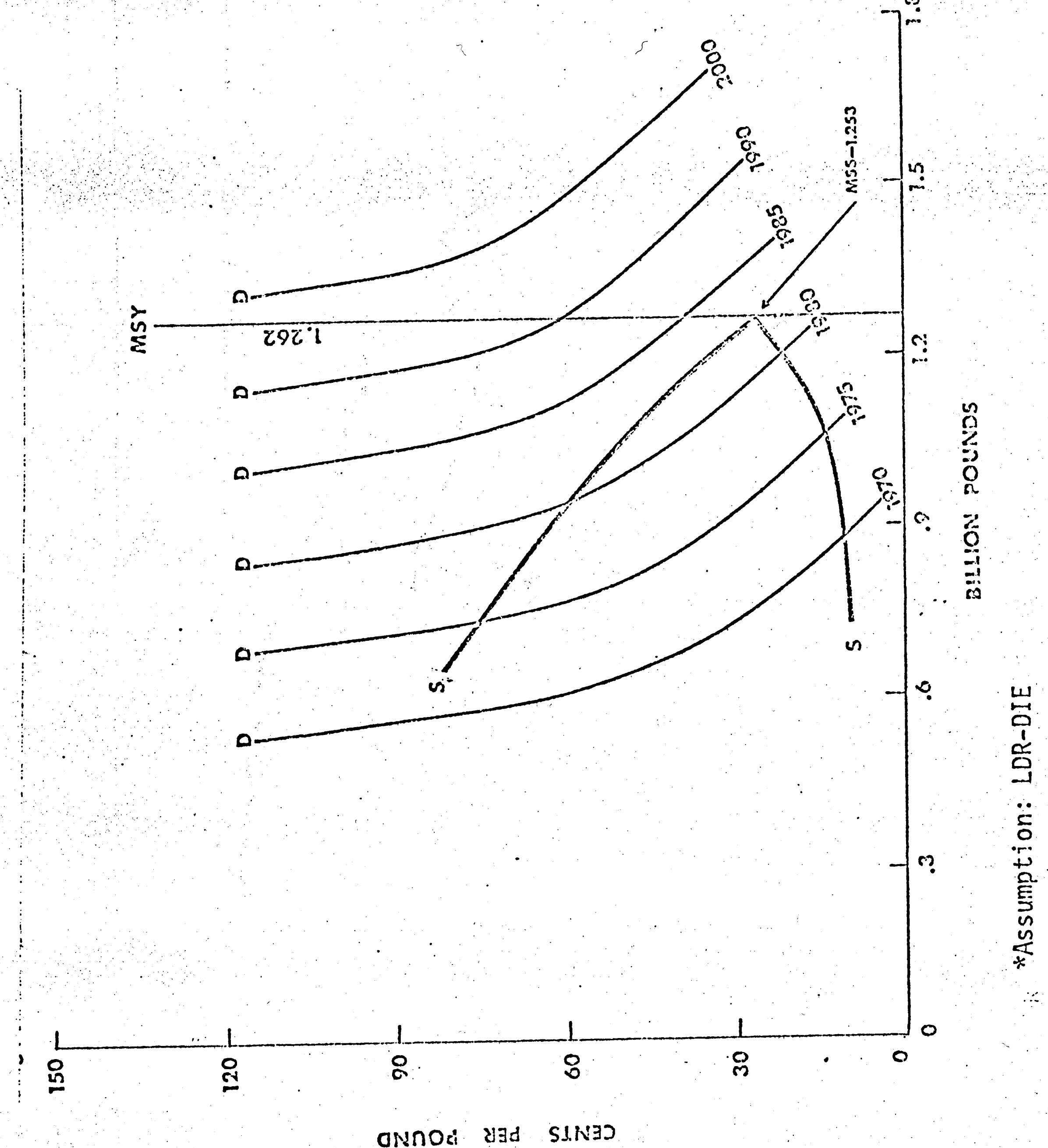
Figure 6.25--World demand and supply functions for crabs, 1970-2000*



*Assumption: LDR-DIE

6.10 Clams

Like scallops (Section 6.11), the present world consumption is considerably short of utilizing the full potential of supply. Presently, the world utilizes 12% of maximum sustainable yield.

Assuming that extensive aquaculture breakthroughs are not realized over the projection period, world demand is expected to increase by approximately 50% for clams over the 1965-67 - 2000 period. Real prices will increase from 3.5 cents for the 1965-67 base period to 4.8 cents in the year 2000.

U.S. per capita consumption will fall off slightly over the projection period because of its zero income elasticity and the negative effect of higher prices. However, the aggregate U.S. market for clams will increase from 474 million pounds to 690 million pounds over the 1965-67 - 2000 period.

Table 6.10 shows the world and U.S. projections assuming the existence of aquaculture which will make the real supply curve flat (See sardines and oysters). Relaxing the assumption of no extensive breakthroughs in aquaculture, the reader can readily compare the results.

Table 6.10--Clam projections (LDR - DIE assumptions - without aquaculture)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of world
1965-67†	1,054	3.5	60	60	474	2.40	3.5	45
1970	1,060	3.5	60	60	520	2.52	3.5	49
1975	1,180	3.6	67	67	560	2.55	3.6	47
1980	1,300	3.7	74	74	600	2.00	3.7	46
1985	1,380	3.9	78	78	635	2.51	3.9	46
1990	1,450	4.2	82	82	655	2.43	4.2	45
2000	1,530	4.8	87	87	690	2.24	4.8	45

World maximum sustainable yield = 1,762 million pounds
World maximum sustainable supply= 1,762 million pounds
†Average of actual data

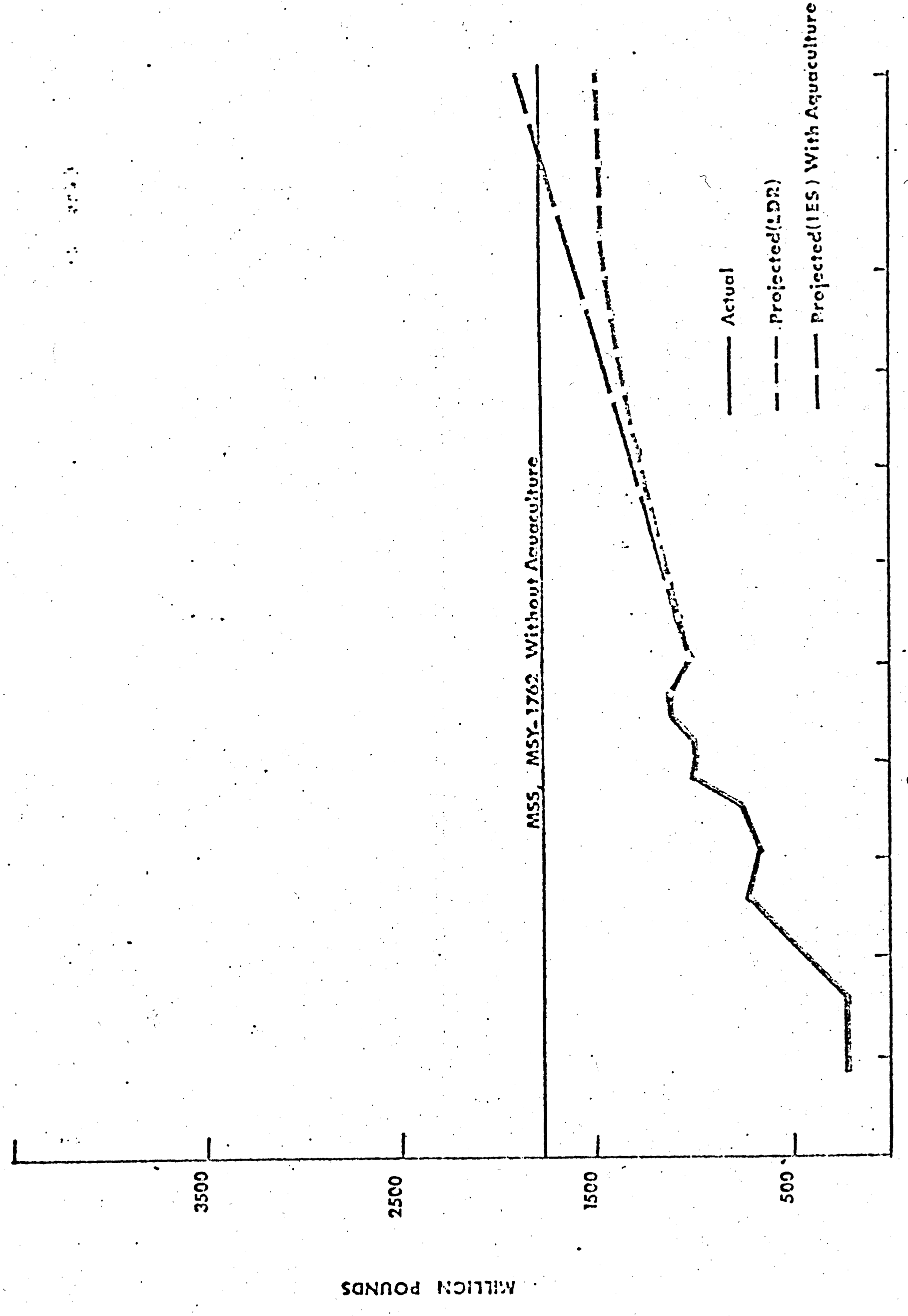
Table 6.11--Clam projections (IES - DIE assumptions - with aquaculture)

(Round weight - U.S. dollars)

	World		United States			
Year	Quantity million pounds	Real price ¢/lb.	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of world
1965-67†	1,054	3.5	474	2.40	3.5	45
1970	1,060	3.5	520	2.52	3.5	49
1975	1,210	3.5	570	2.60	3.5	47
1980	1,360	3.5	620	2.64	3.5	46
1985	1,520	3.5	680	2.69	3.5	45
1990	1,675	3.5	730	2.70	3.5	44
2000	1,970	3.5	840	2.73	3.5	43

† Average of actual data

Figure 6.26--Historical and projected world consumption of clams*



*Assumptions: LDR-DIE · IES-DIE with aquaculture

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Figure 6.27--U.S. consumption of clams 1948-1967 and projected to year 2000

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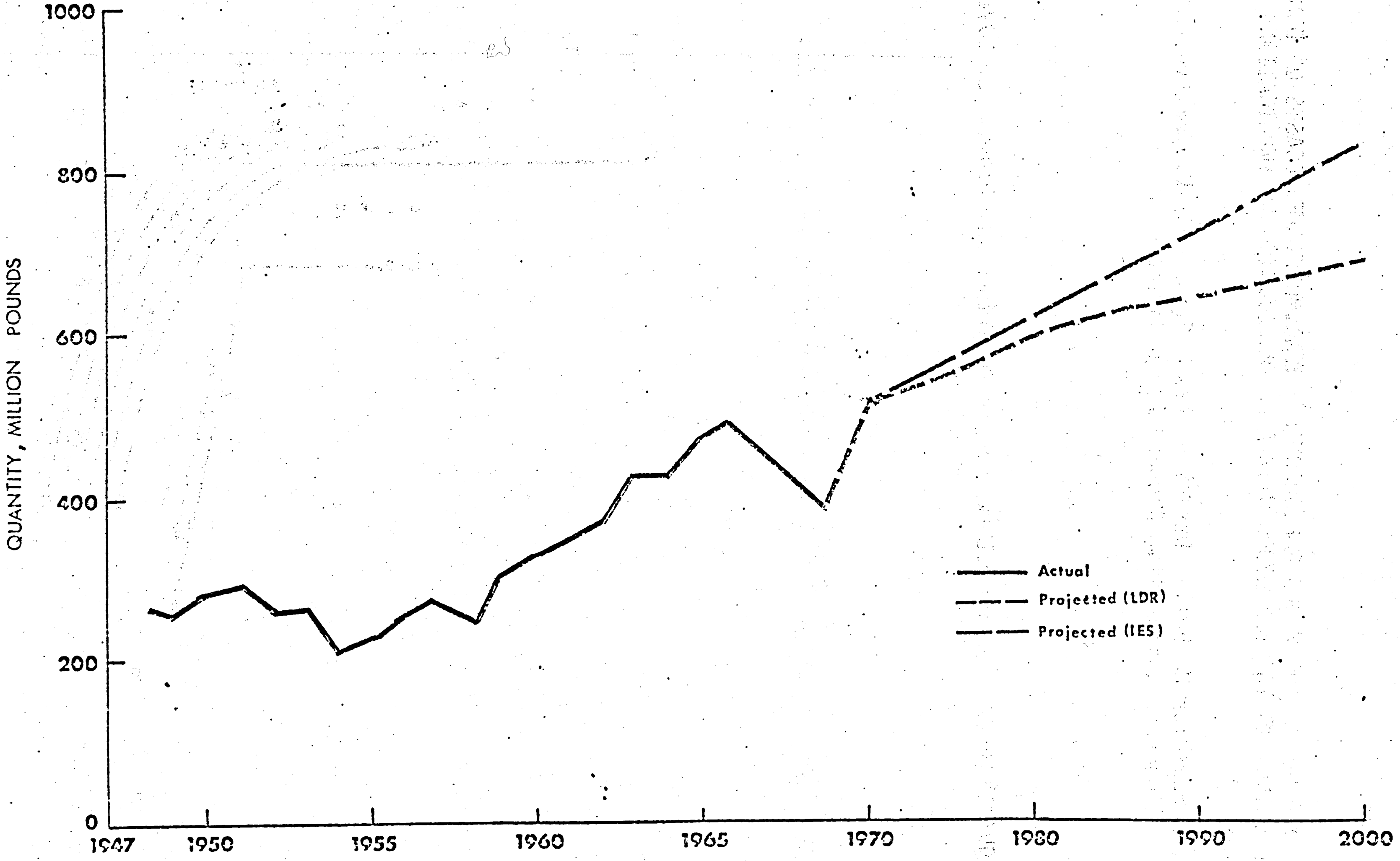

* Assumptions: LDR-DIE IES-DIE

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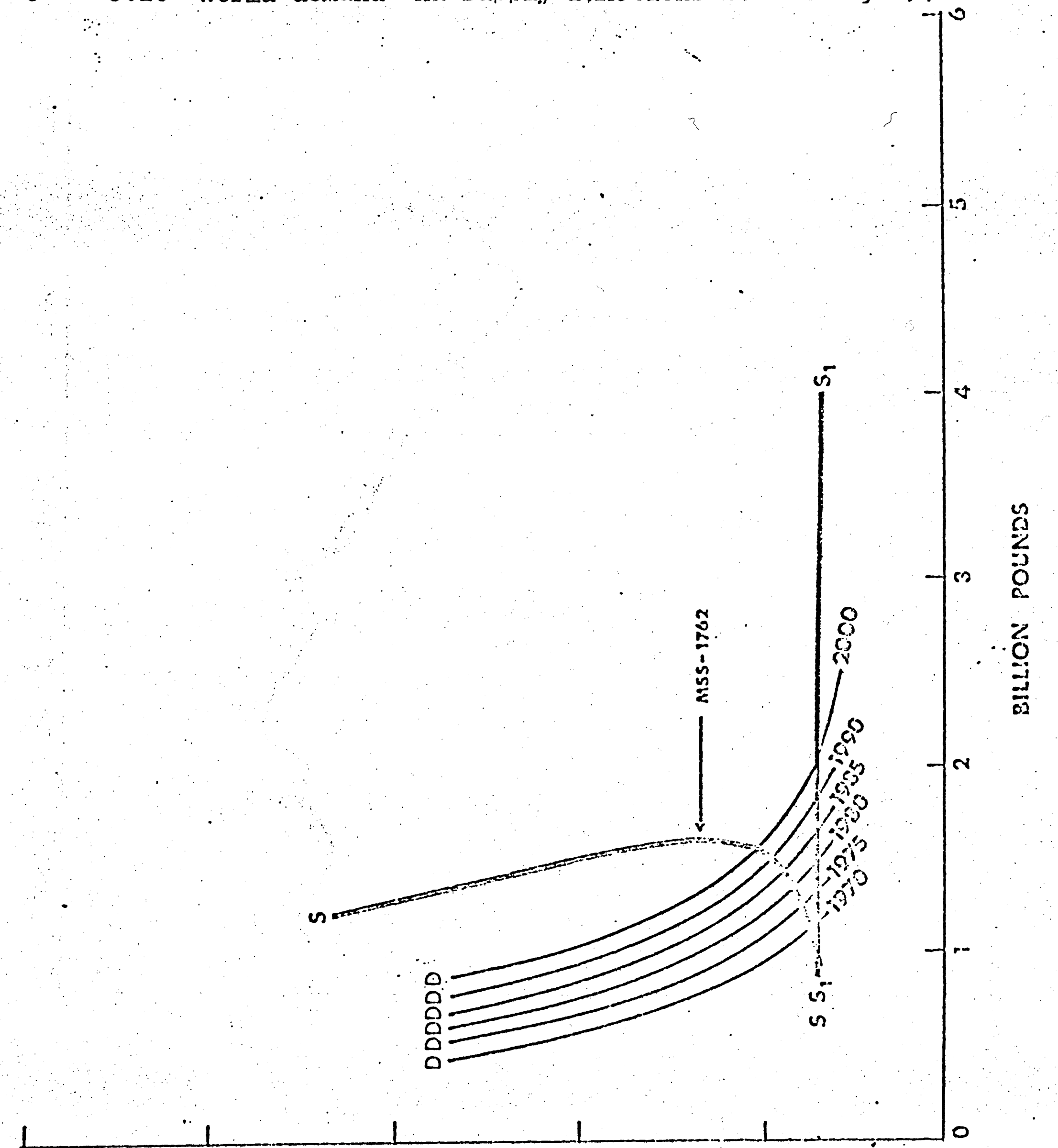
Figure 6.28--World demand and supply functions for clams, 1970-2000*



* Assumptions: SS = LDR-DIE
S_1S_1 = IES-DIE

6.11 Scallops

Because of the recent discovery of the calico resource, the world is a considerable time away from utilizing the maximum sustainable scallop production. Only 11% of maximum sustainable yield is presently consumed on a world basis. Because there is some debate concerning the immediate use of the calico scallop resource because of technological problems, we have decided to make two projections--one with the inclusion of the calico scallop resource and the other excluding this resource from consideration.

Assuming calico scallops as part of the world potential supply, it is projected that world scallop consumption will nearly double by the year 2000 with no appreciable increases in real prices. World MSY and MSS are for all general purposes practically identical in the case of scallops (See Chapter 3 for a discussion of these concepts).

U.S. per capita consumption is expected to increase from 1.37 pounds in the 1965-67 base period to 1.62 pounds in the year 2000. It is expected that the U.S. will maintain its share of world consumption over the 1965-67 - 2000 period.

Without the inclusion of the calico scallop resource, consumption will increase by approximately 78% (compared to 93% with the calico scallop resource) over the 1965-67 - 2000 period. Real prices will increase from 7.5 to 9.0 cents per pound. Little change in U.S. per capita consumption or share of the world market is projected under these assumptions.

Table 6.12--Scallop projections (LDR - DIE assumptions - with the calico scallop resource)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of world
1965-67 †	367	7.2	14	14	268	1.37	6.7	73
1970	460	7.2	18	18	300	1.46	6.7	65
1975	520	7.3	20	20	335	1.53	6.8	64
1980	570	7.4	22	22	370	1.57	6.8	65
1985	620	7.4	24	24	405	1.60	6.9	65
1990	650	7.5	26	26	435	1.61	7.0	67
2000	710	7.6	28	28	500	1.62	7.0	70

World maximum sustainable yield = 2,548 million pounds
World maximum sustainable supply = 2,548 million pounds
†Average of actual data.

Table 6.13--Scallop projections (LDR - DIE assumptions - without the calico scallops resource)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of world
1965-67 †	367	7.2	40	43	268	1.37	6.7	73
1970	440	7.5	48	52	295	1.43	7.0	67
1975	490	7.8	54	58	320	1.46	7.3	65
1980	540	8.2	59	64	345	1.47	7.6	64
1985	570	8.4	62	68	370	1.46	7.8	65
1990	610	8.7	67	72	400	1.48	8.1	66
2000	650	9.0	71	77	450	1.46	8.3	69

World maximum sustainable yield = 912 million pounds

World maximum sustainable supply = 844 million pounds

† Average of actual data

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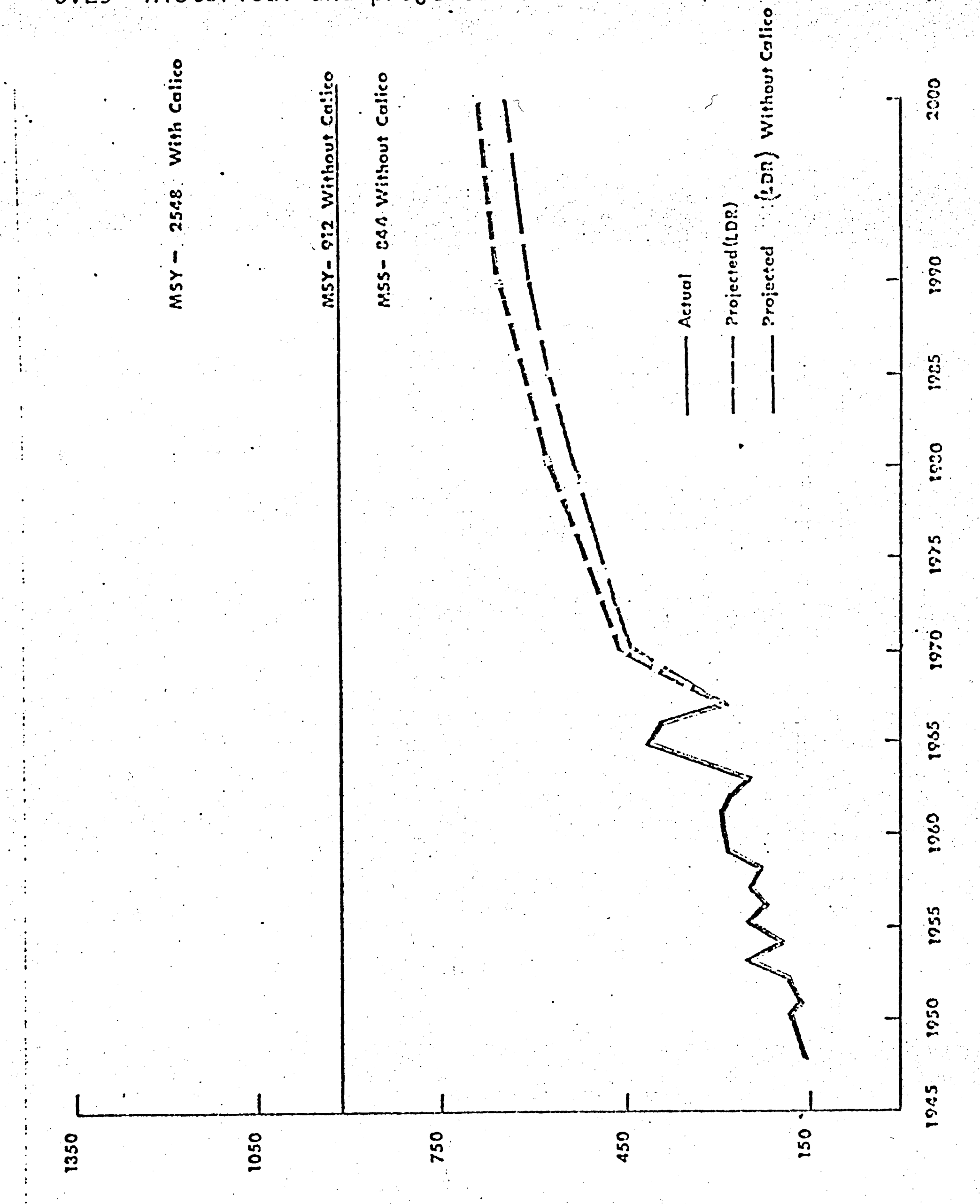
Figure 6.29--Historical and projected world consumption of scallops*



* Assumptions: LDR-DIE LDR-DIE without calico

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Figure 6.30--U.S. consumption of scallops 1948-1967 and projected to year 2000*

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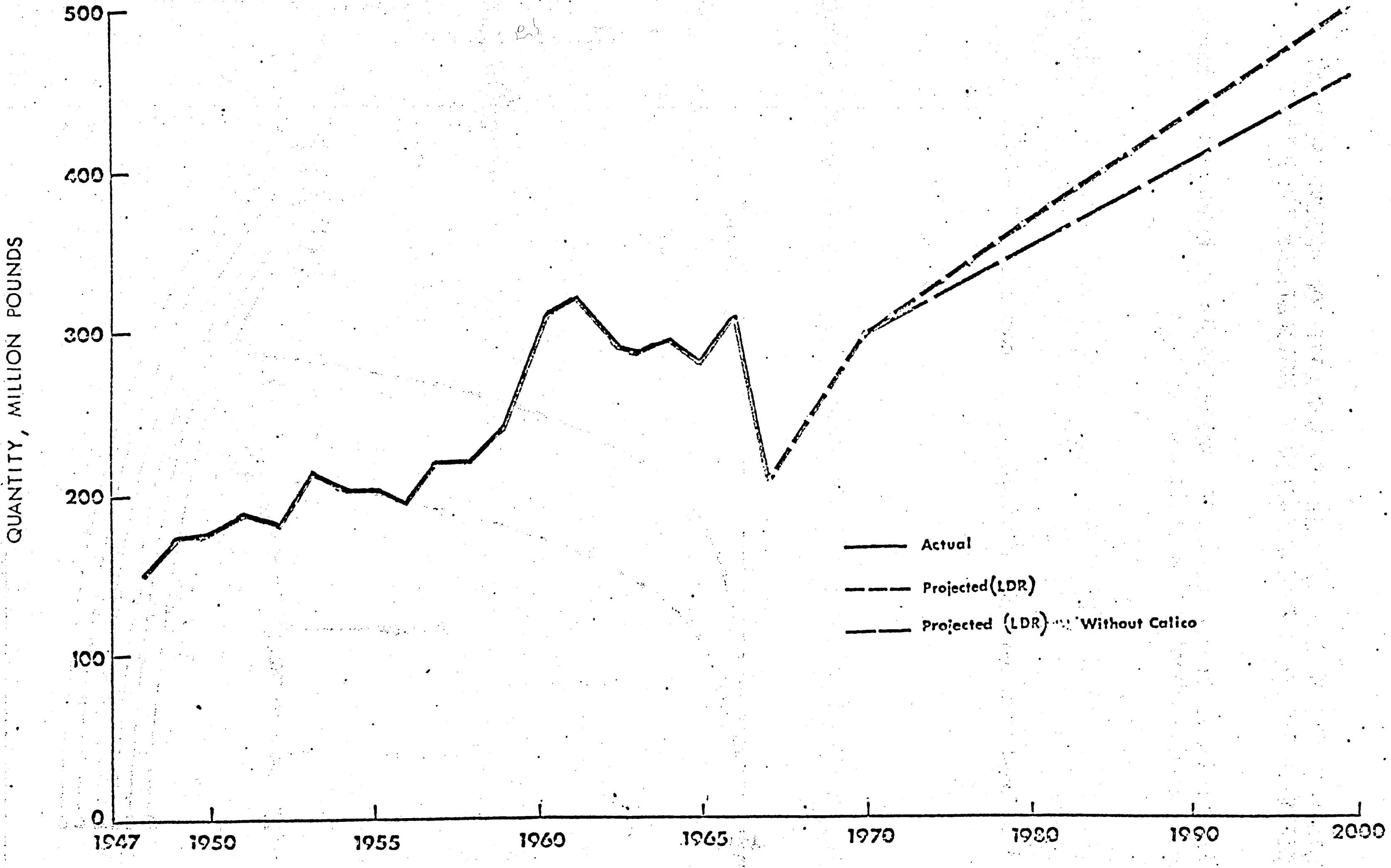

* Assumptions: LDR-DIE, LDR-DIE without calico

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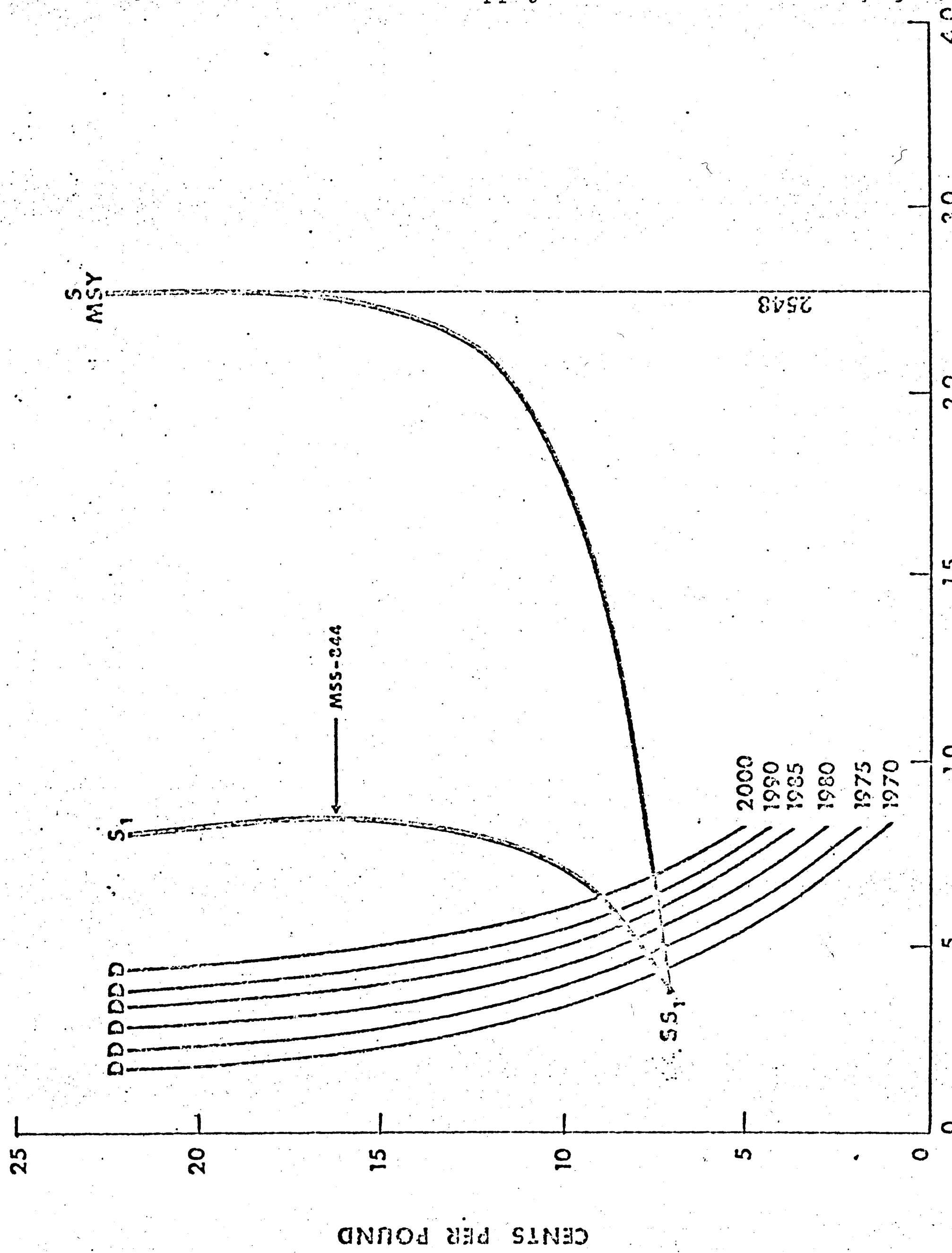
Figure 6.31--World demand and supply functions for scallops, 1970-2000*



* Assumptions: SS = LDR-DIE with calico
S_1S_1 = LDR-DIE without calico

6.12 Oysters

Oysters are one species which are not totally subject to a rising supply function. In many parts of the world, oysters are produced in beds which are cultured or farmed. Therefore, the supply of oysters on a world basis is assumed to be infinitely elastic (i.e., IES). This is shown in Figure 6.34. World oyster consumption is expected to increase from 1,713 million pounds in the 1965-67 base period to 5,409 million pounds by the year 2000.

Because of the zero income elasticity for the United States, oyster consumption will not increase as rapidly in this country, rising from 570 million pounds in the 1965-67 base period to 896 million pounds in the year 2000. Therefore, the U.S. will have a declining share of the world consumption of oysters, falling from 33.3 % to 16.6% over the 1965-67 - 2000 period.

Table 6.14--Oyster projections (IES - DIE assumptions)

(Round weight - U.S. dollars)

	World		United States			
Year	Quantity million pounds	Real price ¢/lb.	Quantity million pounds	Per capita consumption in lbs.	Real price ¢/lb.	U.S. consumption as percent of world
1965-67†	1,713	5.3	570	2.91	5.5	33.3
1970	2,127	5.3	600	2.91	5.5	28.2
1975	2,686	5.3	639	2.91	5.5	23.8
1980	3,278	5.3	685	2.91	5.5	20.9
1985	3,869	5.3	736	2.91	5.5	19.0
1990	4,443	5.3	788	2.91	5.5	17.7
2000	5,409	5.3	896	2.91	5.5	16.6

†Average of actual data

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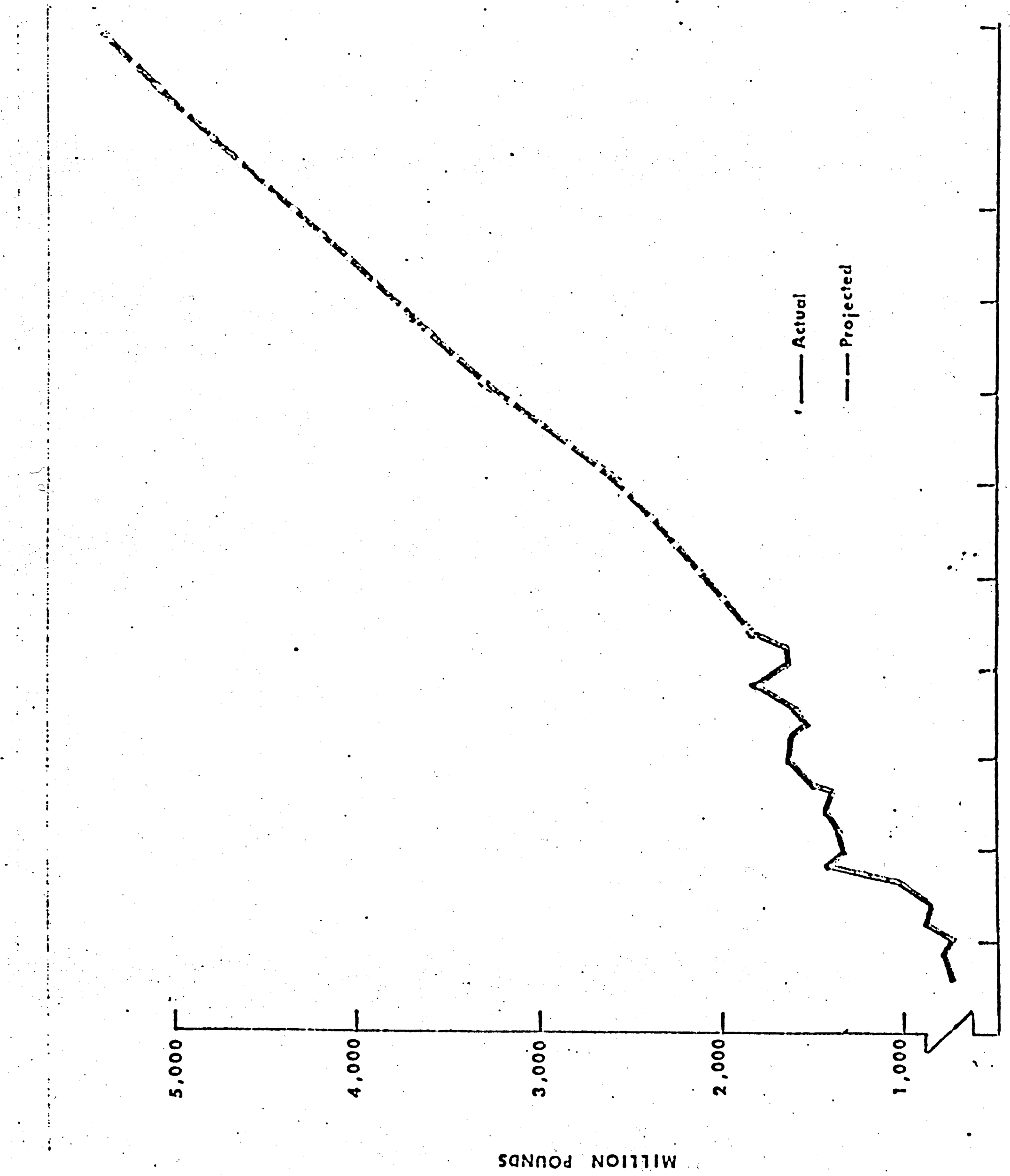
Figure 6.32--Historical and projected world consumption of oysters*



* Assumption: IES-DIE

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Figure 6.33--U.S. consumption of oysters 1948-1967 and projected to year 2000*

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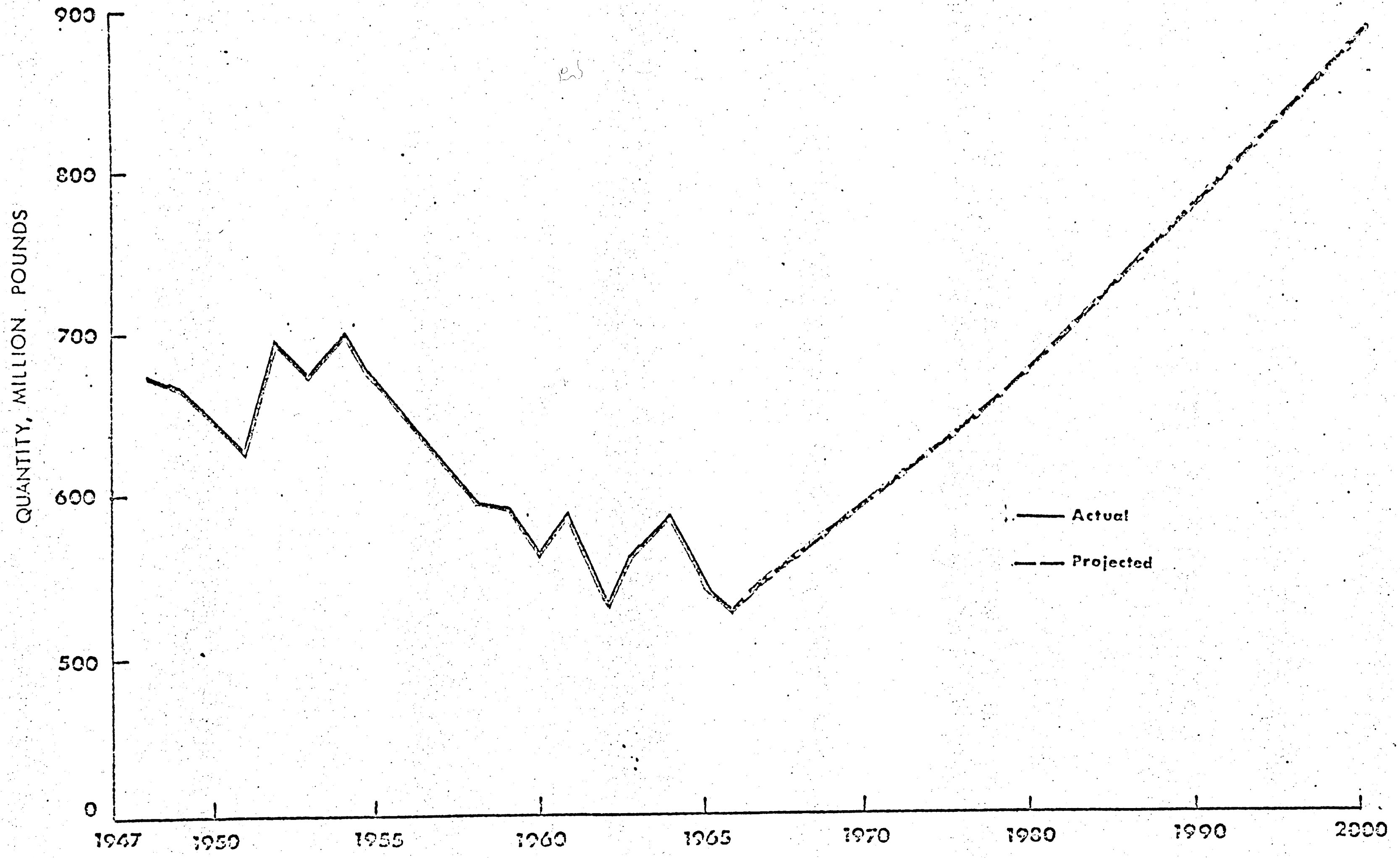

* Assumption: IES-DIE

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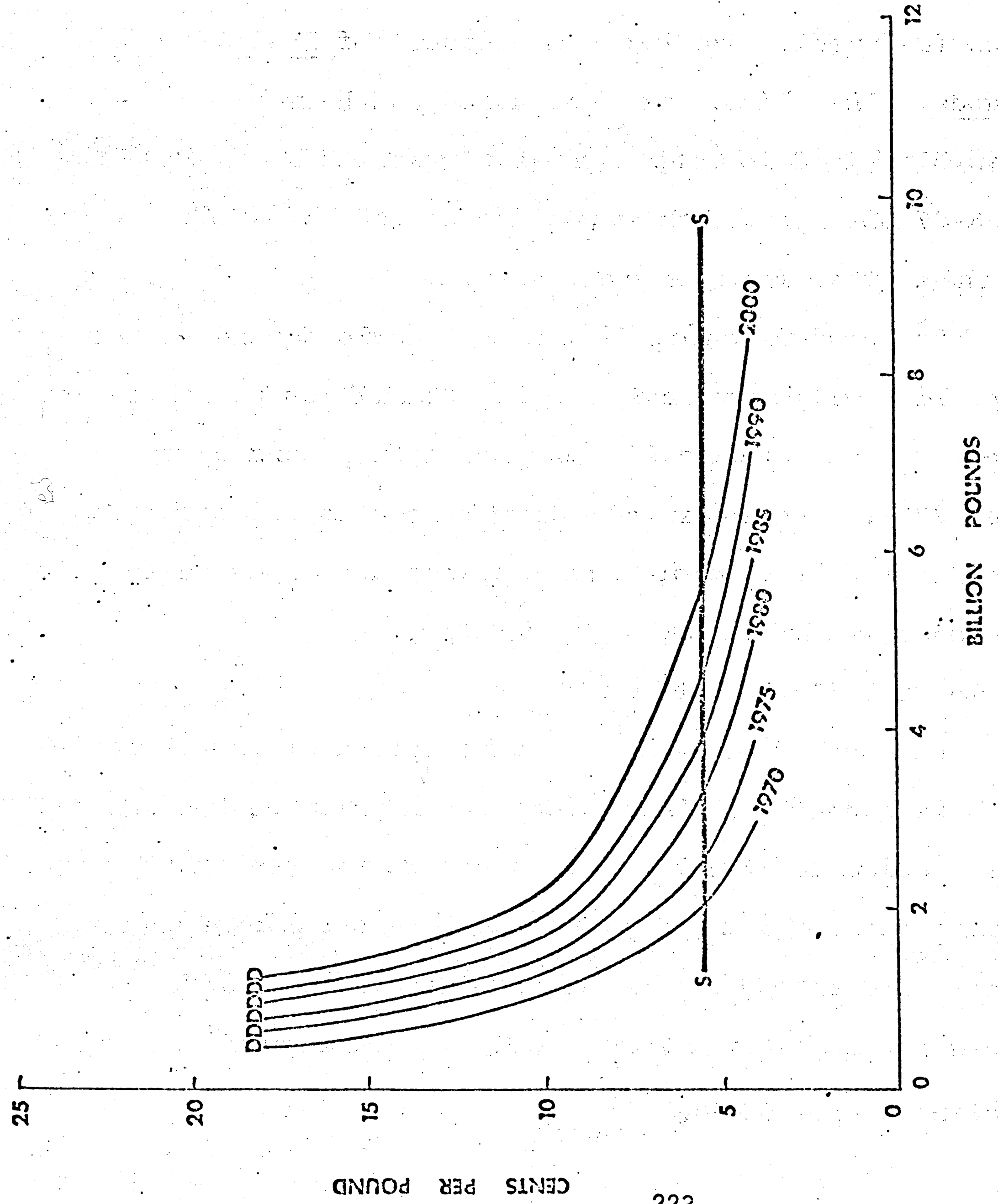
Figure 6.34--World demand and supply functions for oysters, 1970-2000*



*Assumption : IES-DIE

6.13 Other Food Fish

The other food fish category is extremely diverse and contains numerous species where supply potential is uncertain. However, we believe we should remain consistent in our procedures. As discussed in Chapter 2, the world maximum sustainable yield for all fish is 264,600 million pounds. We subtracted from this the world maximum sustainable yield for all species discussed above, plus fish meal. This left a residual of 153,881 million pounds. This figure was then used as the maximum sustainable yield for the other food fish category. In the 1965-67 base period, the world consumed 36% of MSY for the other food fish category.

Our projections indicate that world demand for other food fish will increase from 55,304 million pounds in the 1965-67 base period to 118,000 million pounds by the year 2000. Because of the low utilization of other food fish in the base period, real prices are expected to increase 24% by the year 2000, when 77% of world MSY will be utilized.

Although U.S. aggregate consumption of the other fish is expected to rise from 1266 million pounds in the base period to 1623 million pounds in the year 2000, per capita consumption will fall due to a zero income elasticity and rising real prices. The U.S. share of the world consumption of other food fish is expected to decline by nearly 50%.

Table 6.15 --Other food fish projections (LDR - DIE assumptions)

(Round weight - U.S. dollars)

	World				United States			
Year	Quantity million pounds	Real price ¢/lb.	% of MSY	% of MSS	Quantity Million pounds	Per capita consumption in lbs.	Real Price ¢/lb.	U.S. consumption as percent of world
1965-67	55,304	10.2	36	36	1266	6.43	10.2	2.3
1970	62,000	10.2	40	40	1321	6.41	10.2	2.1
1975	72,000	10.4	47	47	1380	6.29	10.4	1.9
1980	82,000	10.9	53	53	1412	6.00	10.9	1.7
1985	91,500	11.2	59	59	1477	5.84	11.2	1.6
1990	101,500	11.5	66	66	1540	5.69	11.5	1.5
2000	118,000	12.4	77	77	1623	5.27	12.4	1.4

World maximum sustainable yield - 153,881 million pounds
and maximum sustainable supply - 153,881 million pounds

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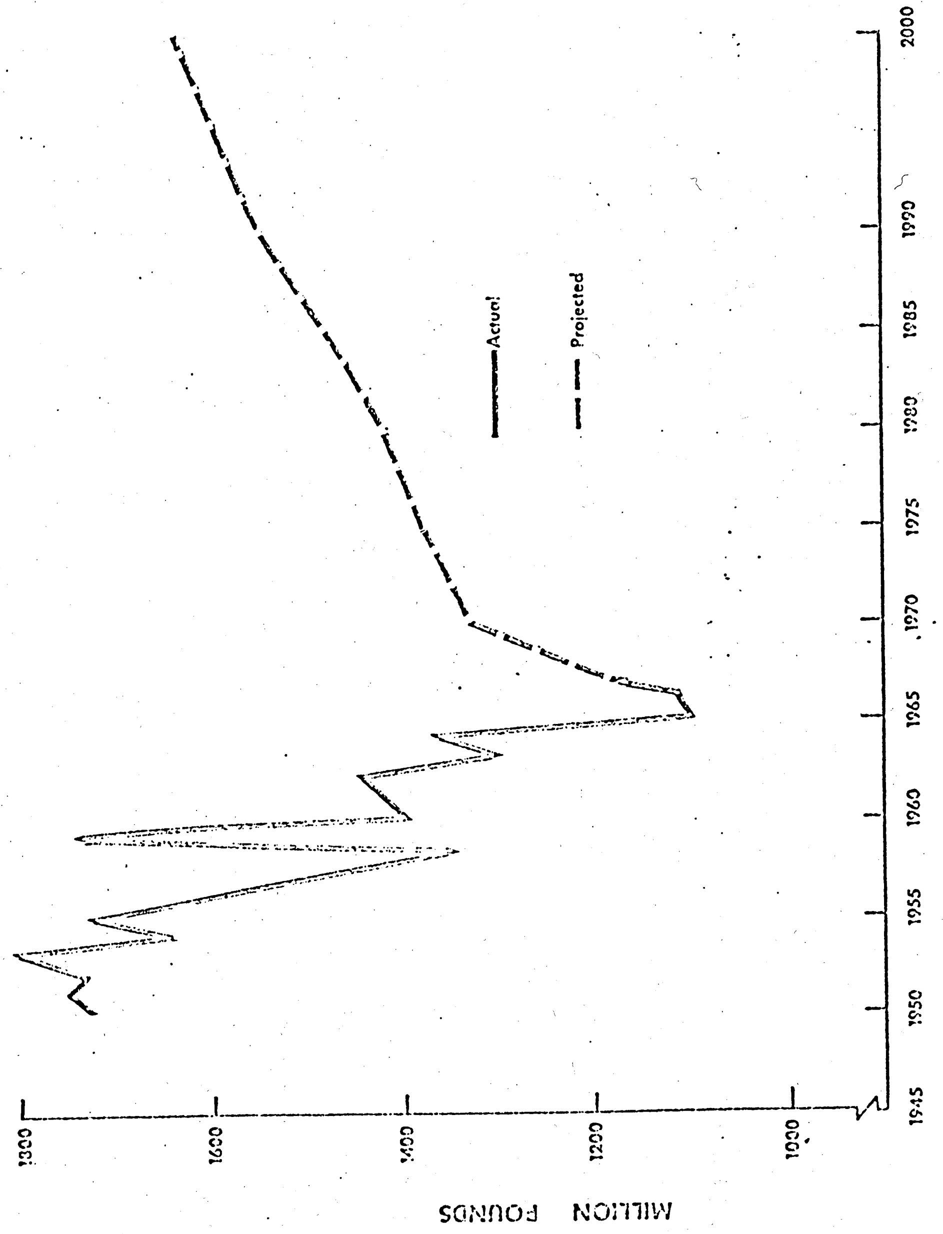
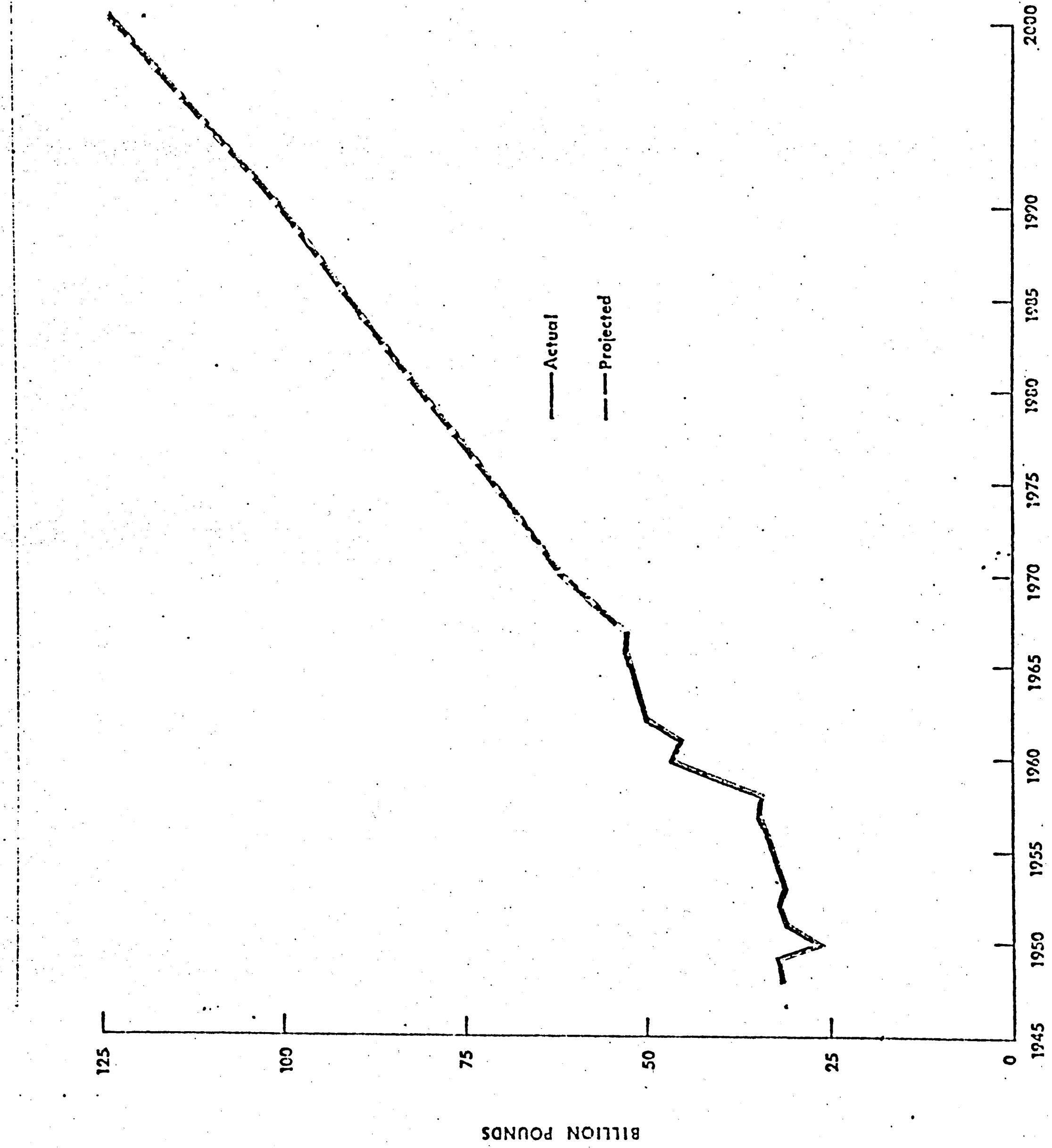
Figure 6.35--Historical and projected U.S. consumption of other food fish*



*Assumption: LDR - DIE

Figure 6.36--Historical and projected world consumption of other food fish*



*Assumption: LDR - DIE

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Figure 6.37--World demand and supply functions for other food fish 1970-2000*

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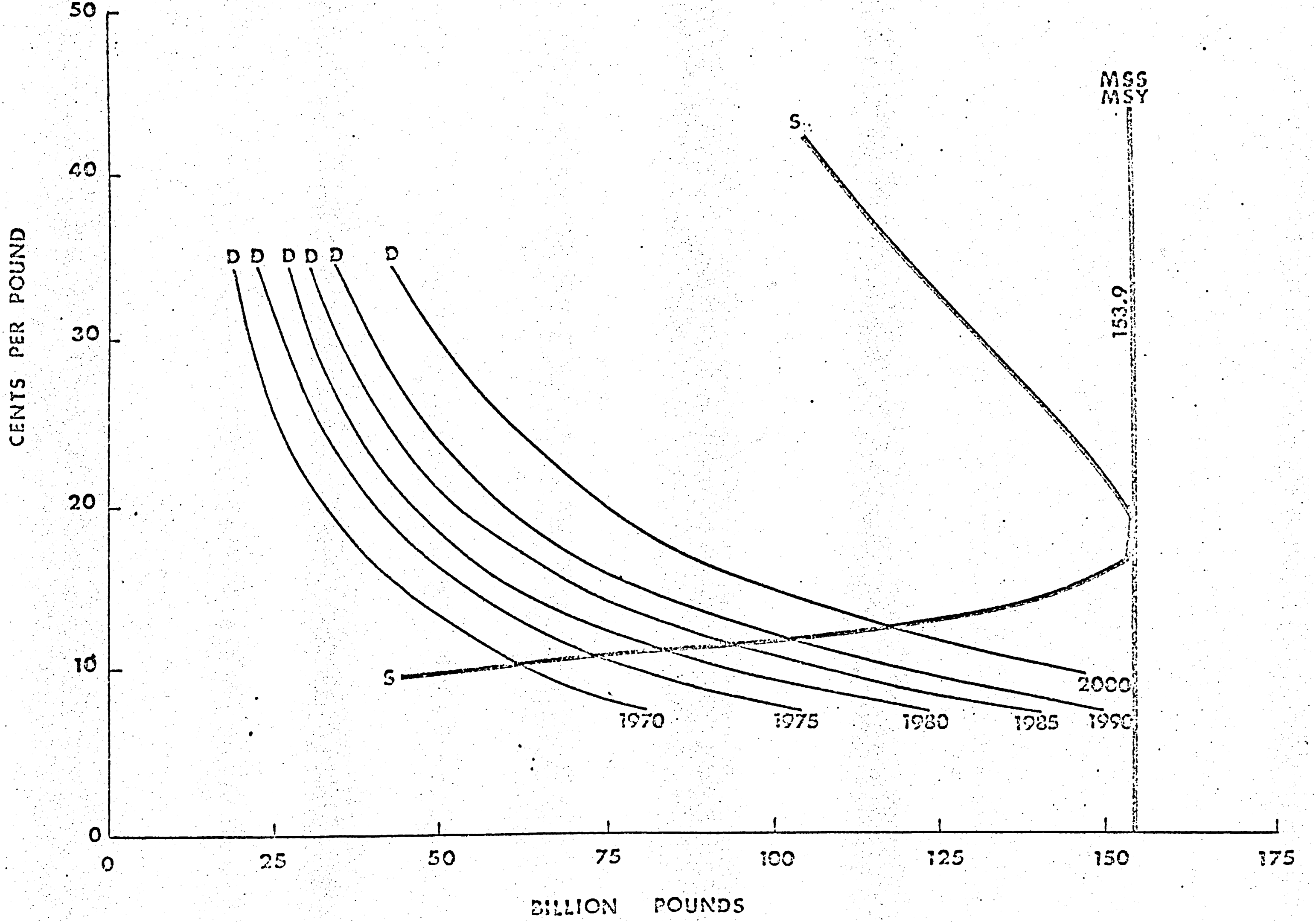


*Assumption: LDR

6.14 Fish Meal

Fish meal is the last claimant on use of fish resources, as the product commands a lower price than fish for human food. Fish meal can be made from a wide variety of fish products, although on a world basis, nearly all is manufactured from species of herring-like fish. U.S. production is now essentially based on menhaden which is caught from New Jersey to North Carolina and in the Gulf of Mexico. This resource is now being fished at or beyond maximum sustainable yield. By far the major world supplier of fish meal is Peru, which catches anchoveta off its coast and ships locally manufactured fish meal to North American and European markets.

World fish meal production increased 6.5 times from 1950 to 1967. This rate of increase cannot continue due to the limitation on the resource. In the 1965-67 period, about 60% of world maximum sustainable yield was harvested. Therefore, catch increases will be considerably curtailed.

In the past, there has been a fairly static ratio of fish meal to soybean meal prices (about 1.7:1). Since both had a high supply elasticity, the supplies of each could be adjusted to maintain the price ratio.

With the approaching limitations on expansion of fish meal, this ratio is not expected to hold since fish meal is becoming more expensive relative to soybean meal.

Within the category of herring-like fish certain species are used for direct human consumption, while the remainder goes into fish meal. Many species are on the borderline since their utilization shifts with changes in market opportunities. In estimating supply available for fish meal, we first substracted projected consumption of canned sardines. Resources available for fish meal production decline as sardine production increases. This occurs because fish for human purposes will command a higher price than fish meal, thus bidding it away from fish meal.

In spite of the large resource base of herring-like fish maximum sustainable supply will be reached by 1980. (See Table 6.16). By 1980, world equilibrium production will reach 62,500 million pounds. This will also be the peak consumption year for the U.S., reaching a total of 9,300 million pounds or 14.9% of the total world market. Drastic declines in utilization will occur between 1980 and 2000, the latter figure being nearly halved compared to 1980. Real prices are shown to increase 7.0 times between 1970 and 2000, rising from 1.1 cents per pound in the base period to 7.8 cents a pound by the year 2000. The U.S. share is projected to remain fairly constant over the period, ranging between 14.4 and 17.0. In sum, it looks like the outlook for fish meal is not very optimistic.

Table 6.16--Fish meal projections (LDR assumptions)

(Round weight - U.S. dollars)

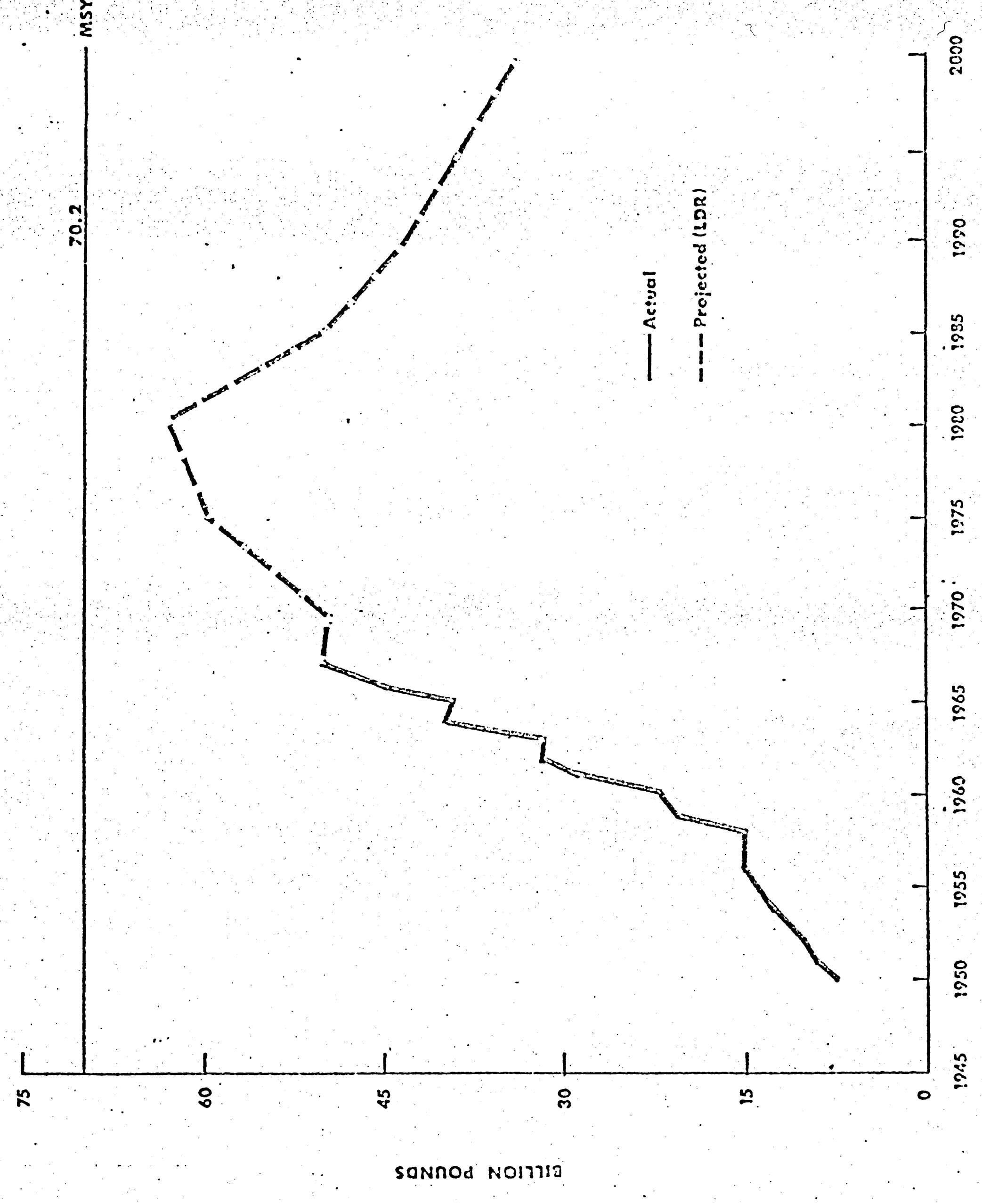
	World					United States		
Year	Quantity million pounds	Real price ¢/lb.	World consumption of sardines million pounds 1/	% of MSY 2/	% of MSS 2/	Quantity million pounds	Real price ¢/lb.	U.S. utilization as percent of world
1965-67+	45,070	1.0	1,920	67	71	6,860	1.0	15.2
1970	50,000	1.1	2,570	75	79	8,100	1.1	16.2
1975	59,900	1.3	3,228	90	95	9,250	1.3	15.4
1980	62,500	2.1	3,652	94	100	9,300	2.1	14.9
1985	49,900	4.2	4,074	77	81	7,000	4.2	14.0
1990	43,000	5.7	4,438	68	71	6,200	5.7	14.4
2000	33,500	7.8	5,225	55	58	5,700	7.8	17.0

World maximum sustainable yield (MSY) - 70,240 million pounds
World maximum sustainable supply (MSS) - 66,400 million pounds

\+ Average of actual data

1/ Included here to show total utilization of the herring-like resource.
2/ Including utilization of the resource for sardines.

Figure 6.38--Historical and projected world utilization of fish meal*



* Assumption: LDR

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Figure 6.39--Historical and projected U.S. utilization of fish meal*

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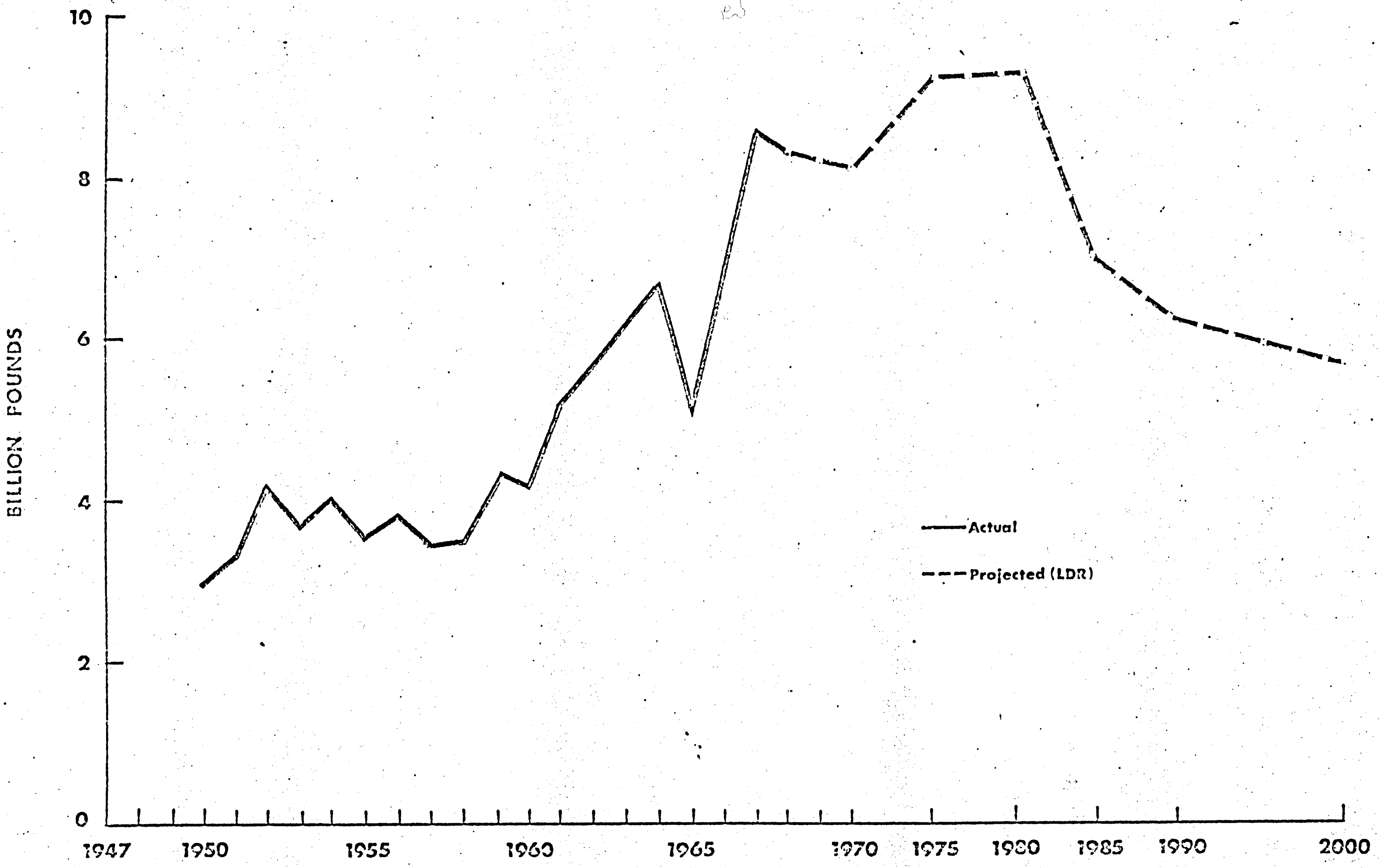

*Assumption: LDR

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Figure 6.40--World demand and supply functions for fish meal 1970-2000*

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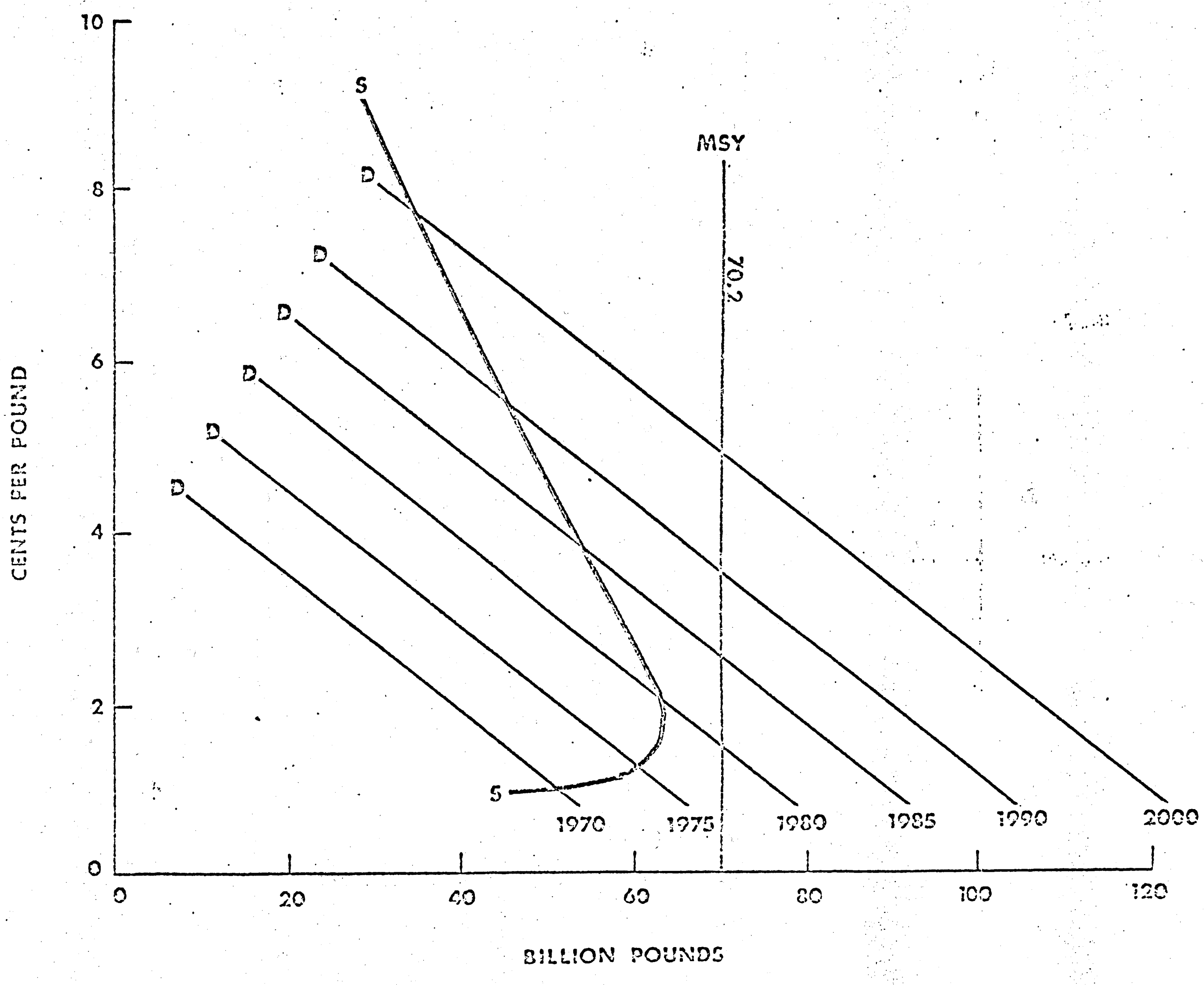

*Assumption: LDR-DIE

6.15 Overall U.S. Consumption of Food Fish

U.S. per capita consumption of all food fish has not changed appreciably over the last 50 years, averaging between 10 to 11 pounds. According to our projections, overall per capita consumption of food fish will decline from 11.02 pounds in the base period to 9.38 pounds by the year 2000, a decrease of 14.9 %. Of all the species considered, only shrimp and scallops are expected to experience an increase in per capita consumption from 1965-67 - 2000 period. The biggest decline is expected in groundfish. The decline in per capita consumption results from acute supply problems and consequent increases in real prices. For the presently utilized species, it is fair to say that no appreciable increase in per capita consumption is possible given the supply problems discussed in Chapters 3 and 6.

Of course, aggregate U.S. consumption of food fish will continue to increase. By the year 2000, Americans will be consuming almost 2.9 billion pounds (edible weight) in the 1965-67 base period, an increase of 33.2 %. Hence, there will be ample opportunity to supply an ever increasing market for fishery products in the United States. Except for groundfish, all species will experience an increase in sales by the year 2000, the largest percentage increase occuring in shrimp.

Table 6.17 -- U.S. per capita consumption of fishery products, actual and projected to year 2000 1/

	1965-67 Average	1970	1975	1980	1985	1990	2000	Changes 200 from 1965-6
	Pounds, edible weight							Percent
Groundfish	2.54	2.00	1.71	1.42	1.18	.98	.81	-68.1
Tuna	2.28	2.68	2.77	2.73	2.61	2.53	2.26	- 0.9
Salmon	.99	.99	.95	.90	.85	.80	.72	- 27.3
Halibut	.17	.18	.17	.16	.15	.13	.12	-29.4
Sardines	.43	.42	.42	.43	.43	.43	.43	0
Shrimp	1.29	1.64	1.88	2.06	2.10	2.19	2.10	62.8
Lobsters	.18	.23	.26	.27	.27	.24	.18	0
Crabs 2/	.34	.44	.53	.59	.50	.40	.31	- 8.8
Clams 3/	.37	.39	.39	.39	.39	.37	.34	- 8.1
Scallops 4/	.16	.17	.18	.18	.19	.19	.19	18.8
Oysters	.34	.34	.34	.34	.34	.34	.34	0
Miscellaneous	1.93	1.92	1.89	1.80	1.75	1.71	1.58	-18.1
Total	11.02	11.40	11.49	11.27	10.76	10.31	9.38	-14.9

1/ Under LDR-DIE assumptions

2/ Estimated for 1985, 1990, and 2000 based upon a more gradual decline in the resource base than shown in Chapter 6.

3/ Projections made without additional aquaculture of clams

4/ Includes calico scallops

Table 6.18 -- U.S. aggregate consumption of fishery products, projected to year 2000 1/

	1965-67 Average	1970	1975	1980	1985	1990	2000	Changes 2000 from 1965-67
	Million Pounds, edible weight							Percent
Groundfish	497.8	412.0	375.2	333.9	298.4	265.4	249.3	-49.9
Tuna	449.1	552.0	607.7	642.1	660.1	685.1	695.6	54.9
Salmon	195.0	203.8	208.9	212.1	215.3	217.3	222.4	14.0
Halibut	33.5	36.6	37.0	37.0	37.0	37.0	37.4	11.6
Sardines	84.7	86.5	92.2	101.1	108.8	116.4	132.4	56.3
Shrimp	254.1	337.8	412.5	484.5	531.1	593.1	646.4	154.4
Lobsters	35.5	47.4	57.0	63.5	68.3	65.0	55.4	56.0
Crabs 2/	67.0	90.6	116.3	138.8	126.5	108.3	95.4	42.4
Clams 3/	72.9	80.3	85.6	91.7	98.6	100.2	104.8	43.8
Scallops 4/	31.5	35.1	39.5	42.3	48.1	51.5	58.5	85.7
Oysters	67.0	70.1	74.6	80.0	86.0	92.1	104.7	56.3
Miscellaneous	380.2	396.3	414.0	423.6	443.1	462.0	486.9	28.1
Total	2,169.3	2,348.5	2,520.5	2,650.6	2,721.3	2,793.4	2,889.2	33.2

1/ Under LDR-DIE assumptions

2/ Estimated for 1985, 1990 and 2000 based upon a more gradual decline in the resource base than shown in Chapter 6 .

3/ Projections made without additional aquaculture of clams.

4/ Includes calico scallops

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Figure 6.41--Historical and projected U.S. per capita consumption of fish and shellfish

*Assumption: LDR-DIE
**Edible weight

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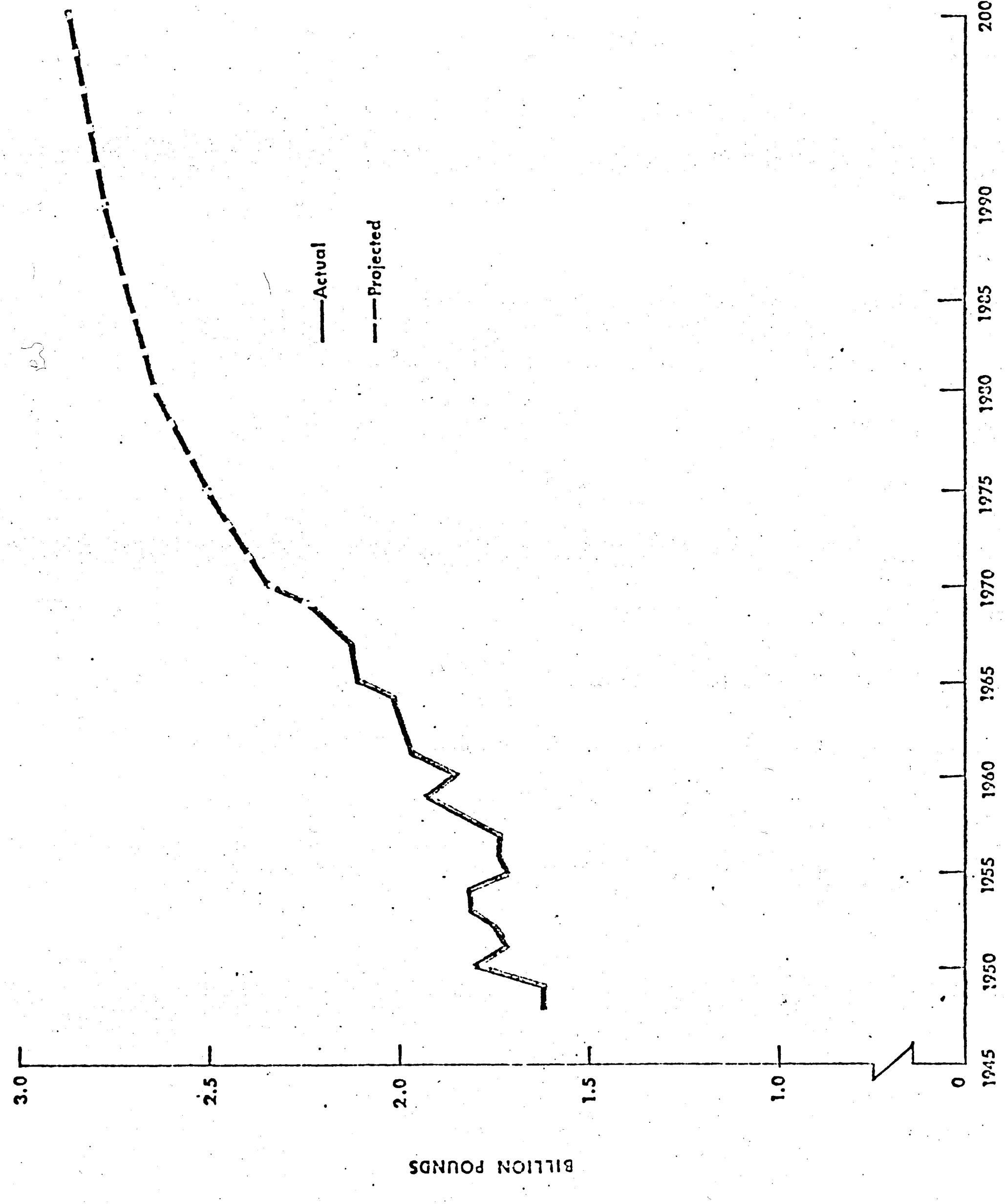
Figure 6.42--Historical and projected U.S. aggregate consumption of fish



*Assumption: LDR-DIE

**Edible weight

6.16 Overall World Consumption of Food Fish and Fish Meal

FAO Demand and Supply Forecasts: As indicated in Chapter 2, the maximum potential for fish from the world's oceans is probably no greater than 120 million metric tons (Ryther, 1969). This is admittedly a debatable figure but is consistent with the total world fish potential employed by FAO in their "The Prospects for World Fishery Development in 1975 and 1985." This is shown in Table 6.19. However, FAO does exclude molluscs (i.e., oysters, clams, scallops, etc.) which are included in our estimates although we used 120 million metric tons as a control figure.

Assuming no rise in real prices, FAO projects a world demand for food and fish meal of 106.5 million metric tons by the year 1985 (i.e., this is as far as they made their projections). The FAO projected total and *per caput* demand for fish (i.e., demand for human consumption) in 1975 and 1985 are given in Table 6.20. As stated above this demand has been forecast on the basis of the assumptions of population and income increase. An important methodological assumption underlying these projections is that of constant prices. Although this is an unrealistic assumption, FAO states that it is extremely difficult to relax

Table 6.19-- Catch of marine fish, crustaceans and molluscs (1965) and estimated world potential by marine area and species 1/

'000 tons

	Large Pelagic		Demersal		Shoaling Pelagic		Cephalopods		Crustaceans		Total	
	1965 catch	Potent -ial	1965 catch	Potent -ial	1965 catch	Potent -ial	1965 catch	Potent -ial	1965 catch	Potent -ial	1965 catch	Potent -ial 2/
Atlantic Ocean												
Northeast	85	700	3,750	6,900	5,152	7,500	33	1,000	109	170	9,129	53,700
Northwest	9		2,741	3,300	302	2,300	9	500	43	70	3,104	
Western Central	42		234	3,000	668	3,000	1	1,000	215	260	1,160	
Eastern Central	137		616	930	382	2,200	123	700	7	80	1,265	
South Western	23		254	5,000	146	5,000	2	1,000	56	110	481	
South Eastern	43		446	1,080	1,631	7,450	4	500	13	20	2,137	
Total Atlantic	339	700	8,041	20,210	8,281	27,450	172	4,700	443	710	17,276	53,700
Pacific Ocean												
Northwest	290	2,000	3,107	3,800	1,609	2,100	559	1,000	218	270	8,211	55,500
Northeast	334		1,468	3,800	626	3,000	–	1,000				
Western Central	207		4,055	11,000	1,222	5,000	46	200	342	680	5,872	
Eastern Central	339		91	750	120	650	9	300	67	110	626	
Southwest	47		65	600	15	1,200	0	500	21	40	148	
Southeast	88		158	2,000	7,783	15,000	0	500	26	80	8,055	
Total Pacific	1,305	2,000	8,944	21,950	11,375	26,950	614	3,500	674	1,180	22,912	55,500
Indian Ocean												
Eastern	60	100	575	1,000	102	700	0	500	68	110	805	7,300
Western	92	110	504	1,700	451	3,000	0		22	140	1,069	
Total Indian	152	210	1,079	2,700	553	3,700	0	500	90	250	1,874	7,300
Mediterranean Sea	35	45	318	400	506	700	40	500	27	50	926	1,700
World Total	1,831	2,955	18,382	45,260	20,715	58,800	826	9,200	1,234	2,190	42,988	118,200
Indicated Expansion Factor	x 1.6		x 2.5		x 2.8		x 11.1		x 1.8		x 2.7	

1/ Cephalopods only
2/ Figures for potential do not add horizontally due to rounding

Table 6.20 -- Consumption and projected demand for fish meal

(product weight)

	Consumption		1975		1985	
	1962* '000 tons	1965* '000 tons	Projected Rate of Increase on 1962*, percent per year	Projected Demand '000 tons	Projected Rate of Increase on 1962*, percent per year	Projected Demand '000 tons
Developed Countries	2,408	3,042	4.5	4,250	3.6	5,390
North America	668	688	2.8	960	2.4	1,140
Europe						
EEC	734	926	4.4	1,280	3.5	1,620
Northwest Europe	517	713	4.1	870	3.1	1,040
South Europe	104	181	8.5	300	6.7	460
Other developed countries						
Japan	340	457	5.8	710	4.6	960
Others	45	77	8.5	130	5.9	170
Centrally Planned Countries	231	494	11.2	920	8.6	1,550
USSR	119	218	11.0	460	9.2	900
Other European	112	276	11.5	460	7.9	650
China	...	...	...	...	...	...
Other Asian	...	...	...	...	...	...
Developing Countries	221	326	8.3	620	8.9	1,560
Latin America	...	...	...	310	...	710
Africa, South of Sahara	...	...	...	30	...	130
Near East	...	...	...	60	...	130
Asia	...	...	...	220	...	590
World Total	2,860	3,862	5.6	5,790	4.9	8,500

World Total	2,860	3,862	5.6	5,790	4.9	8,500
Less meal from offal	230	242	6.2	500	6.6	1,000
Demand for meal from fish	2,630	3,620	5.5	5,290	4.7	7,500

(live weight)

Demand for fish for meal 1/	13,150	18,100	5.5	26,450	4.7	37,500

1/ To convert the demand for meal from fish to the demand for fish a conversion factor of five is used, i.e. it is assumed that 5 tons of fish make 1 ton of meal in any systematic manner, since changes in the price of one commodity will have an effect on the demand for all other commodities, the effect being greatest where one commodity is easily substituted for the other. The FAO data in Table 6.20 relate to the demand for fish meal for use as animal feed which currently accounts for one third of the total world fish catch. Although there is a small but growing demand for fish meal for use as supplemental feed in fish culture, its principal use is in the preparation of balanced feeds for pigs and poultry. It follows, therefore, that the demand for fish meal will be influenced, to a marked extent, by changes in the demand for these products. Another important factor influencing the fish meal market is the extent to which pig and poultry producers switch from extensive to intensive methods of farming and the corresponding attention given to the use of balanced feeds. The extent to which this takes place is, of course, dependent on the spread of knowledge of animal nutrition and feeding techniques--a factor which is of considerable relevance when considering the developing countries. No econometric methodology for estimating the future demand for fish meal has yet been established, therefore, a somewhat pragmatic approach has been adopted in arriving at the projected demands. The main factors influencing the choice of growth rates are set out below.

(a) For North America relatively low rates of increase in the demand for fish meal have been assumed in view of the comparatively low rate of population increase expected and the extremely low income elasticities prevailing for pork and poultry products. Somewhat higher rates of increase were used for the European Economic Community (EEC) countries because of the Community's policy of expanding pig and poultry production. Allowance was also made for the presently lower degree of intensified poultry production in certain countries of the Community (e.g. Italy), and the generally higher income elasticities for pork and poultry products than are found in North America. These same considerations apply to northwest Europe, although the increase in demand assumed for this region is marginally lower than that for the EEC. This is due to the dominant position of the United Kingdom where balanced feeding is already in widespread use by pig and poultry farmers and, therefore, more modest increases in the demand for fish meal are visualized.

(b) In south Europe and the centrally planned eastern European countries, higher growth rates in the demand for fish meal have been assumed on the basis of fairly high income elasticities of demand for pork and poultry products - poultry meat in many countries having a unit elasticity. Those high growth rates are justified also on the basis of the anticipated increase in <u>per caput</u> GDP and the anticipated improvements in animal husbandry in a number of countries where pig and poultry production is still rather unscientific.

(c) The most rapid growth in demand is projected for developing countries, where the implementation of the IWP proposals for livestock production will not be realized without the adoption of modern scientific methods of production. In many of these countries there is not only a general lack of knowledge of the value of balanced concentrate feeds, but there is also a very high income elasticity for pork and poultry products. It is also believed that only through a rapid increase in the production of pigs and poultry will many of these countries be able to meet their nutritional requirements by 1985.

(d) The assumed production of offal was estimated by extrapolating the demand for frozen and canned fish and making certain assumptions with regard to the offal available. An increasing trend in offal availability has been assumed not only because an increasing quantity of fish is expected to be frozen and canned, but also because a greater amount of the offal actually available is expected to be used.

The major unknown in these projections is the extent to which fish meal is likely to be replaced by other sources of protein in animal feed. In this respect the demand for fish for meal is subject to even greater uncertainty than the demand for food fish. The use of fish meal by animal feed compounders is very closely controlled on a strict comparison of the price of protein and amino acids derived from different sources and most of the ingredients used in animal feeds are capable of being synthesized or are obtainable from alternative sources, such as soybean meal or petroleum.

Bell, et al., Demand and Supply Forecasts. Table 6.21 shows our projections to the year 2000 for food fish and fish meal. By 1985, we project demand (in equilibrium) to increase to approximately 78.6 million metric tons. The following is a brief comparison of our projections and those made by FAO:

	Bell, et al	FAO
Food fish	56.0	69.0
Fish meal	22.6	37.5
Meal and food fish	78.6	106.5

The reasons for the different projections may be broken down according to the two categories:

(a) Food Fish

The difference between the Bell et al., projections of food fish consumption for 1985 of 56 million metric tons and the significantly higher FAO projections of 69 million metric tons can be accounted for by four basic factors.

(1) The Bell et al., forecasts utilize a decaying income elasticity, while the FAO group used a constant income elasticity (= to .68).

By the year 1985, the world income elasticity (Bell, et al.,) is decayed to .22, while the FAO world elasticity remains at .68.

(2) The second important factor is the incorporation by the Bell group of supply constraints, which allow for a rising price and thus a dampening in the rate of increase of consumption. The FAO forecasts assume a perfectly elastic supply of fish with no upward pressure upon prices.

(3) (4) The last two factors relate to the estimates of annual world growth in population and per capita world income. FAO's estimates of 2.1 % and 3.2 % for world population and income respectively are higher than the Bell et al., estimates of 1.7 % and 3.0 %.

(b) Industrial Fish

Here again, the FAO projections show a significantly higher level of expected consumption in 1985. Bell et al., forecasts 22.6 million metric tons, whereas FAO forecasts a level of 37.5 million metric tons--65.9% higher. While FAO based its projections of fishmeal upon the growth in demand for oil cake and did not rely explicitly upon any econometric techniques for estimating expected consumption, it is nonetheless evident that the lack of consideration of supply constraints was a particularly important factor in the inflated forecast given by FAO.

We project that world demand (and supply) for fish meal and food fish will increase by 46.3 % over the 1965-67 - 2000 period. By the year 2000 the world is projected to consume approximately 84 million metric tons of all fish (meal and food) which is approximately three-quarters of the potential from the world's oceans. Because of the rise in real prices, as supply constraints become more acute, we expect demand to increase at a slower pace after the year 2000.

Over the projection period, oysters, shrimp, and sardines are expected to have the greatest increase in production on a world basis. Groundfish, salmon, halibut, lobsters, crabs and fish meal are expected to have either declines or small increases in production over the projection period on a world basis. The future for the presently highly valued species is especially bleak.

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Figure 6.43--Comparison of Bell *et al*. and FAO world projections for food fish

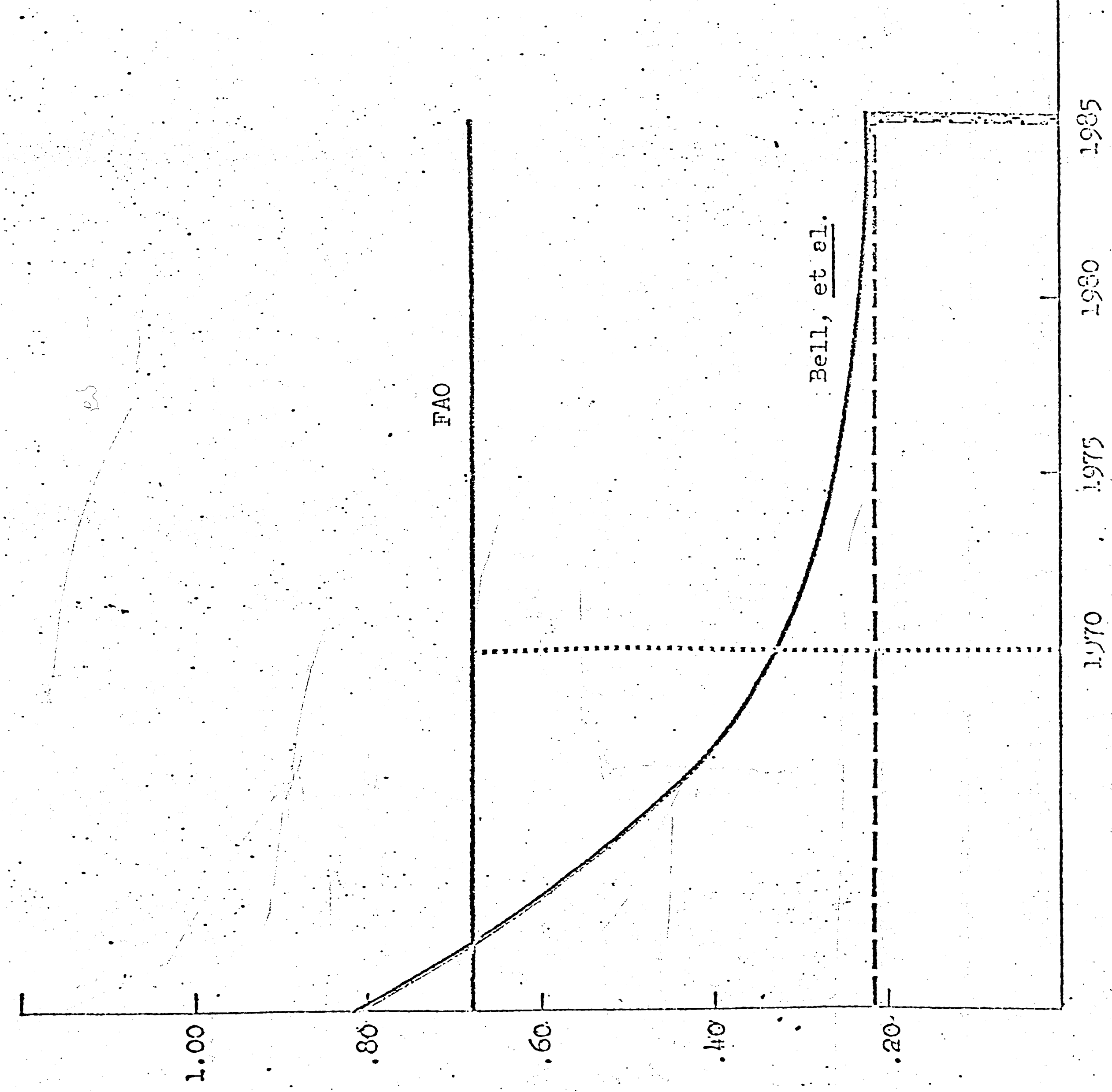

Table 6.21 --World aggregate consumption of fishery products, projected to year 2000[1]

	1965-67[2]	1970	1975	1980	1985	1990	2000	Changes 1965-67 to 2000
	Thousand metric tons, round weight							Percent
Food fish								
Groundfish	6,368	6,985	6,940	6,759	5,761	5,262	4,763	-25.2
Tuna	1,291	1,315	1,456	1,556	1,615	1,647	1,657	28.4
Salmon	476	476	481	485	485	485	485	1.9
Halibut	58	58	58	58	58	58	58	0
Sardines	871	1,166	1,464	1,657	1,848	2,013	2,370	172.1
Shrimp	634	894	1,066	1,243	1,347	1,438	1,479	133.3
Lobsters	137	150	174	187	192	186	145	5.8
Crabs[3]	328	395	481	549	517	449	386	17.7
Clams[4]	478	481	535	590	626	658	694	45.2
Scallops[5]	166	209	236	259	281	295	322	94.0
Oysters	777	965	1,218	1,487	1,755	2,015	2,453	215.7
Other fish	25,086	28,123	32,659	37,195	41,504	46,040	53,524	113.4
Total food fish	36,670	41,217	46,768	52,025	55,989	60,546	68,336	86.4
Fish meal	20,440	22,680	27,170	28,350	22,634	19,505	15,196	-25.7
Total (food and meal)	57,110	63,897	73,938	80,375	78,623	80,051	83,532	46.3

1/ Under LDR-DIE Assumptions

2/ Average of actual

3/ Estimated for 1985, 1990 and 2000 based on a gradual decline in the resource base.

4/ Without additional aquaculture

5/ Includes calico scallops

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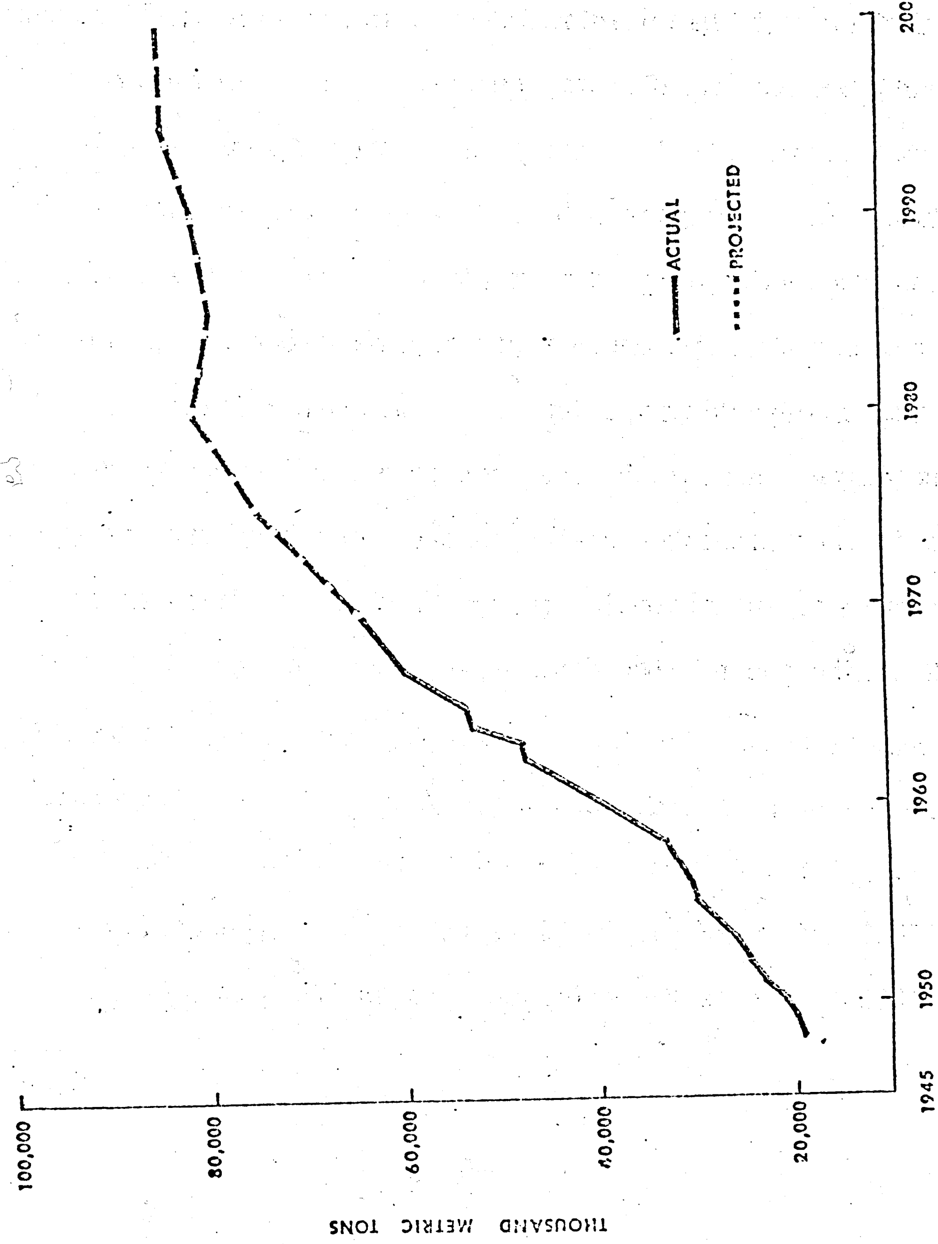
Figure 6.44--Historical and projected world aggregate consumption of fishery products*



*Assumption: LDR - DIE

CHAPTER 7

IMPLICATIONS OF THE DEMAND AND SUPPLY PROJECTIONS FOR PUBLIC POLICY

7.1 Introduction

The major purpose of the preceding analysis has been to integrate all relevant bio-technological factors into one economic model of the world's fisheries and to derive from that model the projected quantitative changes in resource utilization, prices, and consumption to the year 2000. The major emphasis in this chapter will be to focus attention upon areas of policy application. Our projections have been predicated upon the assumption that policy initiatives would not be forthcoming. In this context then, we can discuss areas where new policies or more extensive policy applications could be utilized. The most fundamental conclusions that can be drawn from the preceding analyses is that without a change in present policy many of the traditionally consumed species of fish will be utilized at or near MSS within the not too distant future. In fact, our projections indicate that in the next 30 years fishing effort for many species will increase to the point where world physical output, i.e., MSS, will be reduced for groundfish (1970), crabs (1980), fishmeal (1980), lobsters (1985) and tuna before the year 2000. The ranking of fisheries on the basis of projected utilization is shown in Table 7.1. It is additionally important to note that the ultimate potential of alternative supplies of living marine resources is questionable. Ryther has argued that, "...the open sea - 90% of the ocean and three-fourths of the earth's surface - is essentially a biological desert. It produces a negligible fraction of the world's fish catch at present, and has little or no potential for yielding more in the future." (Ryther, 1969)[1]

Even graver doubts exist with respect to the possible substitutability of species not now exploited for those traditionally consumed, especially those consumed in the U.S. Thus the concept of "spaceship earth" would appear to be relevant regarding the world's oceans.

It is not our purpose to suggest in the context of public choice that a decision must be made by society to preserve the world's resources at a level consistent with MSS. There may be other considerations for individual nations or individual groups of nations which may preclude following a policy of fishery management designed to limit entry. It is also not our purpose to present relative policy evaluations or, for that

---

[1] There is some debate about the ultimate potential of the sea as a source of food. For a critique of Ryther's article, see Alverson, Longhurst, and Gulland (1970).

Table 7.1.--Ranking of fisheries on the basis of projected utilization

Species	Year fully utilized at MSS	Region problems
Halibut	Presently	At MSY and inefficiently utilized 1/
Salmon	Presently	At MSY and inefficiently utilized 1/
Groundfish	1970	Overfishing in northwest, and northeast Atlantic
Crabs	1980	Overfishing in North Pacific; near MSY in west central Atlantic
Lobsters	1985	Nearly at MSY in southwest Atlantic and southwest Pacific
Shrimp	Before 2000	
Tuna	Before 2000	Eastern tropical Yellowfin nearly at MSY
Scallops	2/	At MSY in northeast Atlantic
Clams	3/ 4/	
Sardines	5/	
Oysters	4/	
Fish meal	1980	northwest Atlantic at MSY

1/ Gear limitations introduce technological inefficiencies. Also salmon may only be at MSY if expanded hatchery operations and stream improvements are ignored.

2/ By 2000 only 28% of MSY is expected to be utilized when calico scallops are included.

3/ By 2000 only 87% of MSY is expected to be utilized without additional aquaculture.

4/ Infinitely elastic supply, within relevant range with additional aquaculture.

5/ Infinitely elastic supply, within relevant range as food fish.

Source: See Chapter 6.

matter, to give precise policy prescriptions for particular regional fisheries. It is our purpose, however, to present various options in the event that society decides that a policy of conservation of living marine resources is the proper decision to be followed. A discussion of the major areas of public policy would have to include:

1. A Fishery Management Policy
2. A Fish Farming Policy
3. An Underutilized Species Policy
4. A Harvesting Efficiency Policy
5. An Anti-Pollution Policy
6. A Policy to Avoid.

We do not mean to suggest that many of these policies are not already in application. We merely intend to give a comprehensive review of both ongoing and new policies within the context of the projections.

7.2 A Fishery Management Policy to Prevent Overfishing

The free market has not operated to create the most efficient allocation of capital and labor in exploiting the fishery resources throughout the world. As demand for the fishery products expands, more and more firms are attracted to harvesting the resource. However, the physical yield of a given fisheries stock, like any other factor of production, is subject to diminishing and, ultimately, to negative returns (as shown in Chapter 3). That is, as the inputs of labor and capital (which we will here combine under one heading as "fishing effort") are increased, each successive increment increases the total catch by a smaller and smaller amount, until at some level the maximum annually sustainable catch is reached. Beyond that level, further increases in fishing effort will diminish the actual catch and may deplete or destroy the resource.

What makes the ocean fisheries differ so fundamentally from most other resource-oriented industries is that the resource stock is unappropriated; that is, unowned. The fish stocks are open to exploitation by anyone who is willing to expend the effort to harvest the resource. Such a private market mechanism coupled with a common property resource will eventually lead to overfishing, reduction in physical output, and higher prices. Failures in the private market (under the present management schemes) emphasize the urgency for solving questions relating to management jurisdiction over fisheries.

A further problem is often connected with government attempts to conserve the common property resource itself. If the fishery in question is completely under the jurisdiction of a single political entity, i.e., a state, the chronic crisis of the industry and inevitable declining yields will produce a demand for "conservation." The usual goal pursued by regulatory agencies is a reduction of effort to the maximum sustainable catch level. In any case, the conservation measures usually chosen--the shortening of seasons and restrictions on the effectiveness of gear--tend to be self-defeating from the point of view of the welfare of the fishing industry and of the general public.

Then the dynamics of a regulated fishery usually turn out to be a tug-of-war between the fishermen, who attempt to improve their position by improving the efficiency of their gear and their techniques, and the regulating agency which tries to "conserve" the resource by reducing the efficiency of each unit of fishing effort. Given sufficient rise in demand, the free market approach results in too many fishermen and too many boats when everyone fishes to whatever extent they wish.

Our projections indicate that the process discussed above will continue and worsen for many species in the next 30 years. Without fishery management, fishing effort will increase to the point where world physical output (maximum sustainable supply) will be reduced for groundfish (1970); crabs (1980); fishmeal (1980); lobster (1985) and tuna before the year 2000. These species need immediate attention. Other species need attention in some areas of the world.

Potential benefits from fishery management are substantial. Generally, fishing beyond maximum sustainable yield is an economic crime of the first magnitude.[2] The extra effort beyond that point is not only unproductive--it is counter productive. The resources spent in this way are worse than wasted. Society could afford to pay to keep the extra resources idle. Of course, idle resources are not an ideal answer. Obviously, we should try to

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[2] This statement should be qualified by two possibilities. First, nations with high social discount rates (i.e., prefer present to future consumption) may rationally overfish a resource. Second, overfishing may be necessary to expand employment in areas of low opportunity cost. The latter policy is dangerous because of the possibility of total collapse of the resource thereby rendering all fishermen unemployed.

divert some of these resources to other uses that are really productive.

Fishery management will require international cooperation. We already have international commissions to limit the catch of some yellowfin tuna and of halibut. We will soon need them for other species of fish. Setting up international commissions, however, is not enough. To be effective, commissions must set up controls that are workable and that are economically sound. And they must police the controls to see that they are effective.

The controls should not only prevent fishing beyond maximum sustainable yields, they should discourage other forms of overcapacity in fishing. Instead of ships and crews being idle in many cases after the appropriate catch as been reached, we should have only enough ships and crews to catch the proper amount of fish.

However, retiring excess capacity is difficult in any kind of business. Even if a cheese plant or a steel mill is antiquated, inefficient, and poorly located, it may stay in business for decades if the owners can cover variable costs. Fishing fleets face the same predicament. Even though the ocean is a free resource, the fishing industry has a great deal of capital tied up in ships and gear. Fishermen find it difficult to shift from fishing to other occupations. One of our most difficult problems in the remainder of the 20th century will be to eliminate overcapacity. We should try to do this without impeding progress. We will need to build new and more efficient ships and equipment, but this will increase the difficulty of solving the problems of retiring inefficient ships and equipment.

Another significant argument is that in rural areas where labor is especially immobile, limiting entry may not be socially desirable. The trade-off between efficiency and maximum employment should be considered as part of the policy prescription.

Of course, we should look after our own interests, and the costs and benefits should be fairly shared. Our statesmen should be able to work this out with statesmen of other countries and set up additional international fisheries commissions to manage the world's fish supplies to benefit mankind.[3] Already there is much talk of the establishment of country quotas. The costs of such commissions might be met by the major fish-producing nations, each bearing the costs proportionate to the total value of the fish catch. This would not be a "give-away" deal as all nations including the United States would benefit by getting more fish at lower prices.

Table 7.2 shows some of the losses from either improper fishery management or open access to the resource for selected

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[3] In 1973, a Law of the Sea meeting will be held under the sponsorship of the United Nations to work toward such agreements. Some consider this meeting a last attempt at "saving" the world's oceans from overexploitation. There may also be other ways of resolving the overfishing problem by establishing 200 mile limits for coastal nations or other devices. The implications of this policy recommendation is beyond the scope of this report.

Table 7.2--Estimated economic losses resulting from common property nature of the resource for selected fisheries, 1966

Fishery	No. of Vessels & Boats	No. of fishermen	Landings (thou.lbs)	Value (thou.dol.)	Excess cost (thou.dol.)	Inefficiently utilized[1] Vessel & boats	Fishermen	Value vessels inefficiently utilized (thou.dol.)
New Eng. groundfish	624	3,065	480,709	40,764	12,200[2]	187	920	1,900
Atlantic menhaden	65	1,066	515,025	7,843	3,100[3]	26	426	1,300
Gulf shrimp	7,739	13,756	179,230	82,973	41,500[4]	3,870	6,878	38,700
Pacific groundfish	243	873	119,363	7,936	0[5]	--	--	--
Northern lobster	7,001	7,974	29,541	22,266	0[5]	--	--	--
Chesapeake oysters	6,007	8,997	21,232	14,453	10,100[6]	4,205	6,298	5,900
Tropical tuna	154	1,720	285,200	49,000	7,400[7]	23	258	1,200
Pacific salmon	17,076	27,814	387,512	73,465	51,400[8]	11,953	19,470	59,800
King crab	382	1,065	159,202	15,671	7,800[9]	191	533	4,800
Halibut	326	1,213	40,326	9,708	3,900[10]	130	485	1,300
Total above	39,617	67,543	2,217,340	324,079	137,400	20,585	35,268	114,900
Total U.S.	82,122	135,636	4,365,900	472,354				325,000

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[1] The number of inefficiently utilized vessel and fishermen was obtained by multiplying percentage excess cost (i.e., excess cost divided by value of catch) by existing fleet and fishermen.

[2] 30% of value of catch. Estimated by Working Group, International Commission for the Northwest Atlantic Fisheries (1968)

[3] 40% of value of catch

Table 7.2--Estimated economic losses resulting from common property nature of the resource for selected fisheries, 1966 (Continued)

4/ 50% of value of catch. Estimated by Economic Research Division. Calculated on the basis that the net tonnage of the fleet has doubled since 1950 with little increase in output.
5/ Below MSY with respect to effort
6/ 70% of value of catch. Estimated by NMFS Oxford Laboratory
7/ 15% of value of catch. Calculated on basis of the number of days vessels are needlessly idle during year
8/ 70% of value of catch. Estimated by Crutchfield and Pontecorvo
9/ 50% of value of catch. Estimated by Economic Research Division
10/ 40% of value of catch. Estimated by Crutchfield at Law of the Sea Conference (1968)

U.S. fisheries in 1966. These losses will continue to grow as our projections indicate unless proper fishery management is instituted. (See Section 7.7 for a discussion of policies to be avoided.)

7.3 An Anti-Pollution Policy

Our projections indicate that future world sustainable supplies of fish will be utilized rapidly and that fish prices will rise appreciably. Some readers may think that such a gloomy outlook is overly pessimistic, but actually the squeeze on future fish supplies may turn out to be tighter than our projections indicate.

Our projections are based upon current estimates of the maximum sustainable yields of various species. These maximum sustainable yields are not fixed permanently. They change as the biological environment (ecology) changes. Water pollution has become a serious problem. It has already spoiled fishing in many of our streams, rivers, and lakes--and has reduced the yield of fish in many coastal areas of the world. Further uncontrolled pollution could lower the maximum sustainable yields of some of the principal species of commercial fish. Table 7.3 indicates some recent losses due to pollution. Such losses are likely to continue, and even to increase, unless anti-pollution policies are successful. Table 7.4 shows a more detailed breakdown of shellfish areas closed by sewage pollution.

Table 7.3.--Estimated losses in revenue to fishermen due to pollution for selected cases and time periods.*

1. <u>Sewage pollution of shellfish areas</u>	
Areas closed because of pollution: 1,751,800 Acres Estimated potential loss in revenue	$12,126,400 1/
2. <u>DDT pollution of mackerel</u>	
Landings of mackerel curtailed for 2 months (1969) Estimated potential loss in revenue	320,000 2/
3. <u>Heavy metal (mercury) pollution</u>	
(a) Closure of inland fishing areas estimated annual loss in revenue to fishermen	3,200,000
(b) Closure of Brunswick estuary estimated annual loss in revenue to fishermen	300,000

*All revenue figures are based on ex vessel prices and do not reflect retail value which could be on the average three times greater.

1. Based on average yield of shellfish and the weighted average price.

2. If vessels were tied up in port, they would have lost 20% of annual revenue.

Source: Economic Research Laboratory and Office of Resource Utilization, NMFS; U.S. Department of Health, Education, and Welfare, Public Health Service, <u>National Register of Shellfish Production Areas</u>, 1966.

Table 7.4.--Shellfish production areas closed due to pollution or toxicity, 1966

Region/State	Interstate areas closed		Intrastate areas closed		Total areas closed		
	Active	Inactive	Active	Inactive	Active	Inactive	Total
	Acres						
Region I. Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut	29,800	800	72,800	-	102,600	800	103,400
Region II. New York, New Jersey, Delaware	53,600	17,500	152,200	10,200	205,800	27,700	233,500
Region III. Maryland, Virginia, North Carolina	66,500	-	112,100	-	178,600	-	178,600
Region IV. South Carolina, Georgia, Florida, Alabama, Mississippi	367,000	15,800	712,500	140,000	1,079,500	155,800	1,235,300
Region VII. Louisiana, Texas	-	5,000	182,000	50,100	182,000	55,100	237,100
Region IX. California, Oregon, Washington	-	900	3,300	9,400	3,300	10,300	13,600
U.S. Total	516,900	40,000	1,234,900	209,700	1,751,800	249,700	2,001,500

Source: National Register of Shellfish Production Areas, U.S. Department of Health, Education, and Welfare; Public Health Service, 1966.

The prophet of this danger was Rachel Carson (1962). She presented a wealth of evidence that the uncontrolled use of "hard" insecticides, such as DDT, are upsetting the balance of nature, destroying wildlife, poisoning fish, and even causing serious problems of human health.

For several years, some of the practical agriculturalists poked fun at Miss Carson. They called her a sentimental do-gooder and an alarmist. They continued to promote DDT and related pesticides and herbicides. Meanwhile, many factories dumped their wastes into streams and rivers. And for a few years, the testing of atomic and hydrogen bombs resulted in an indiscriminate shower of strontium 90. Since World War II, the pollution of our air and water has increased so enormously that almost everyone is now aware of its dangers. At long last, the political system has begun to react and is searching for ways to stop or at least to reduce pollution.

Aside from prohibitory legislation, much could be done by the judicious use of economic incentives and penalties, aimed at making pollution unprofitable. This would cost a great deal of money, but perhaps it would be even more costly to continue to ignore pollution.

Most pollution results because under present laws it is cheaper to the individual firm to discharge untreated waste into the ecosystem than to treat it before discharge. In small amounts the ecosystem can do quite a commendable job cleaning itself up. Unfortunately, its capacity, though large, is limited. As our society grew wealthier, it produced more waste but its attitude on waste disposal, formed in the years when the system was adequately regenerative, did not change. At the present time, society is becoming aware of the extent of pollution, and of the fact that something can be done about it through the political process. An economist's view of the pollution problem is that those who pollute and, by extension, those who buy products that pollute, should pay the full cost for what they do or buy; and this full cost includes all the damages done to the public and/or means to avoid this pollution.

The effect of pollution on fisheries is as varied as the kinds of pollution. Many shellfish areas have been closed because raw sewage has made the fish unsafe to eat (Table 7.3). Other effects of pollution have been the deterioration of the nursery grounds of some species such as menhaden. The U.S. Food and Drug Administration (FDA) has prohibited the sale of salmon from the Great Lakes and mackerel from the Pacific Ocean because of high DDT concentrations found in them. Some species of birds have been made sterile by DDT. The same thing could happen to fish. The adverse effects of pollution can reduce the effective and actual maximum sustainable yields of many species.

It is beyond the ability of the market to handle externalities[4] such as, for example, water pollution. Water pollution has

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[4] By externalities we mean a situation where the action of using common property resources, such as water, affects other consumers.

prevented millions of recreationists from utilizing rivers, lakes and ocean fronts. Commercial fishermen suffer financially because they are prevented from making a living in these lakes and ocean fronts. From the standpoint of developing overnment programs, water pollution is defined as the effects of any agent or combination of agents which degrade the aquatic environment to the extent that yield of a major fishery resource is reduced, or the commercial utilization of fish or shellfish is impaired by contamination.

Pollution of aquatic environment is brought about in various ways. Some examples are: massive pollution at irregular time intervals by accidental release of industrial chemicals during their manufacture or transport, or during their mining as raw materials (as in the Santa Barbara oil seepage, or the most recent one in the Gulf of Mexico); massive and long-term release of industrial wastes of varying levels of toxicity; insidious long-term release of industrial and domestic wastes at low instantaneous rates but having serious ecological consequences; the release of agricultural dusts and industrial and domestic gaseous exhausts into the atmosphere, and eventually into the aquatic environment, again having serious ecological consequences; and massive quantities of domestic or industrial solid or semi-solid waste materials, dumped over extended periods in rather restricted locations.

Much concern has been shown over the degradation of fish, wildlife, and recreation values associated with our estuaries.

It is often alleged that the problem is that the estuarine resources are being destroyed by pollution and land fill operations. The real problem, however, seems to be of an economic nature.5/ Destruction of estuarine resources involves an economic cost to society. If we expect prices to adequately serve as the basis for social choice, then the opportunities foregone in the use of estuarine resources for any given purpose must be reflected in the price figures. In other words, to alter the use of estuaries, the social costs of destruction should be reflected in the private costs to those who would destroy the resources by development or pollution. Unfortunately, the costs facing land developers and potential polluters do not reflect the losses to others. (In other words, they do not include the externalities.) Thus the problem is that individuals are making decisions concerning estuarine resources without being made adequately responsible and accountable for their actions with respect to the use of these resources.

There is considerable evidence that pollution is affecting our fish resources (Tables 7.3 and 7.4). Some species, such as the salmonoid, whitefishes, and perches of the Great Lakes, are failing to reproduce and are disappearing sequentially due to long-term pollution of the lakes. Other species, such as surf-perches in California, exhibit a high percentage of individuals with deformities and neoplasma, especially near sewer outfalls. Almost all species are, to some degree, contaminated within their body tissues by residues of pesticides or heavy metals -- in some

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5/ It should be pointed out that many conservationists also place a high value on survival of the species. This kind of social choice should also be recognized.

cases to the extent which exceeds FDA's tolerance for contamination.

Government programs with respect to pollution problems are restricted to research which is directly related to endangered commercial fish species. These programs include: collection of data on the nature, quantities, and sources of pollutants; toxicological and ecological studies on commercially important species and their food chains; monitoring the status of pollutants in the aquatic environment and the safety and wholesomeness of fishery products; studies on cleaning up the environment; and studies on decontamination of fishery products.

7.4 A Fish Farming Policy

Effective control over water pollution could probably prevent future drops in the maximum sustainable yields of many species of fish, but this is not enough. Rapidly rising populations and real incomes will mean a big increase in the demand for fish, as we have shown in Chapter 6. Table 7.5 shows the rise in real prices (assuming the supplies that can be anticipated from present methods). To moderate these projected price increases and satisfy an increasing world demand, we need to explore every feasible way of increasing supply from new sources.

To some degree, at least, the world's fish production can be increased by "fish farming."[6] Most commercial fishing is done by

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[6] Some prefer the term "aquaculture," but aquaculture includes the culture of anything in water (for example, tomatoes).

Table 7.5.--Projected real world price increases for selected fishery products without augmentation in supply through aquaculture, specified years

Species	1965-7	1970	1980	1990	2000	Increase (1965-7-2000)
	Cents per pound					Percent
Groundfish	6	8.9	15	23	28	366.7
Tuna	16	16	20	25	30	87.5
Salmon	24	24	28	32	38	58.3
Halibut	25	28	36	45	52	108.0
Shrimp	37	42	52	67	94	154.0
Lobster	63	67	97	147	311	393.6
Crabs	12	12	21	80	114	850.0
Clams 1/	3.5	3.5	3.7	4.2	4.8	37.1
Scallops 2/	7.2	7.2	7.4	7.5	7.6	5.6
Fish meal	1.0	1.1	2.1	5.7	7.8	680.0

1/ Without additional aquaculture.

2/ With newly discovered calico scallop resource.

Source: Chapter 6.

Why / [illegible]

[illegible]

hunting. Man once got his supplies of meat mainly by hunting. Later he found he could do better by enclosing and improving pastures, scientific breeding and feeding of animals, and similar farming techniques.

To some extent, such farming techniques have been used for fish production for centuries in many countries. Iverson states that "Oysters were raised by the Japanese as early as 2000 B.C., and by the Romans about 100 B.C." (Iverson, 1968) Recently, some kinds of fish farming have been growing in the United States. An estimated 10 million pounds of catfish were harvested from fish farms in the United States in 1967 -- compared to 33 million pounds caught in public waters (U.S. Department of Interior, 1970). Kussman estimated in 1967 "that the production of farm-raised catfish will double during the next year or two." (Kussman, 1967).

Of course, catfish represents only a small percentage of our total national fish consumption (although it is important in the South and Midwest). However fish farming is not limited to catfish.

Fish farming includes the care, cultivation, and harvesting of any species of fish under private ownership. The care and cultivation may be very intensive, as in the case of pond-raised catfish. Or it may involve only a few operations, such as stocking with fingerlings.

A recent study by Bardach refers to the farming of plaice, sole, shrimp, crab, abalone, sea bream, puffer fish, carp, and mullet in various parts of the world. (Bardach, 1968) They concluded that, "The practice of aquaculture may not only be greatly expanded, particularly in those parts of the world most in need of its products, but also that its yields may be very appreciably increased through the use of modern science and technology."

The Japanese have led the way in fish farming. Not only have they developed commercial oyster farming but they are now producing a substantial percentage of their fresh-water fish from farming. Brown states that in Japan in 1965, "The following percentages of fish produced were cultured: 100% of the trout, 88% of the eel, 72% of the carp, 14% of the Crucian carp, and 10% of the ager." (Brown, 1969)

In general, it is doubtful whether many of the presently exploited commercial species would be successful candidates for fish culture. Prerequisites for success should be rapid growth and high conversion of feed to meat. These are attributes of, for example, catfish or oysters which may reach marketable size in 1 or 2 years. Therefore, work might be done in developing new varieties of fish that might have the same taste and texture of the present commercial species but which have the attributes necessary for commercial culture.

The opportunities for profitable fish farming are probably greatest in ponds and rivers, somewhat less in brackish waters near the ocean shore, and much less in the open ocean. The United States and other countries would be wise to encourage and promote fish farming wherever it has a good chance of competing successfully with the capture of wild fish. The main effort at present should be that of research and education. Potential fish farmers should be given detailed and up-to-date facts about methods, costs, prices, and likely profits. We need to intensify research not only on fish culture, but also on the processing and marketing of cultured fish.

7.5 An Underutilized Species Policy

Our projections indicate that supplies of some of the principal market species of fish will soon be fully utilized and that their prices will rise (table 7.6). But if consumers prove willing to buy some of the presently less preferred species, total per capita supplies of fish need not decline much, at least for many decades. Also, such a switch in buying would tend to dampen down the increases in prices of the more preferred species.

Thirty years ago, Rachel Carson wrote, "If . . . fisheries are to yield their full quota of food, now and in the future years, the burden of overexploitation must be lifted from the few species that now make up more than four-fifths of the catch; the slack of wasted pounds must be taken up from the fishes that are now underutilized. Still little utilized are fishes like cusk, dogfish, skates, anglers, and dozens of others. From the standpoint of human welfare, thousands upon thousands of pounds of these less known fishes go to waste in the sea each year." (Carson, 1941)

Because many consumers are not aware of underutilized species, our fishermen avoid them--often throwing them back if they are caught. Table 7.6 shows some presently underutilized species and their potential economic value, assuming they could be substituted for presently utilized species. How can markets be opened up to some of the species that are now underexploited?

The most basic (and most difficult) way is to change consumer preferences. This will require more reports like that of Rachel Carson. It will take much research and education on the nutritional values of fish. And it may need intensive promotion and advertising of the right kind. For example, the Plentiful Foods

Table 7.6--Selected underutilized species and their additional potential economic value

Species	Current world landings	Maximum sustainable yield	Retail price*	Total value of additional catch to MSY	Regions for further major exploitation
	(thousand metric tons)		(dollars/lbs)	(thousand dollars) 2/	
Calico scallops	0	740.9	1.74 1/	334,140	East coast of Florida 4/
Tanner crab	20.0	50.0	1.43 1/	210,022	North Pacific (off of Alaska) 5/
Clams	478.1	799.8	1.28	139,589	Northwest & west central Atlantic, Northeast Pacific, northeast Atlantic 6/
Pacific groundfish	1,332.7	2,602.4	.52	1,455,574	North Pacific 7/
Sardines and fish meal	17,820	30,111.9	.079 3/	601,149	West central Atlantic, southeast Atlantic southwest Pacific, northeast and east central Pacific 8/

* Latest U.S. price. Assumes U.S. price and world price identical.

1/ Assumes species could be readily substitutable for current utilized species at existing utilized species prices.

2/ Assumes no decrease in price as result of increased landings. This assumption is acceptable over a period of time where income and population will increase. Also, we did not consider rising real prices which will alter revenue estimates. These will depend on price elasticities which are not available.

3/ Weighted average of sardines and fish meal.

4/ Derived from John A. Gulland, The Fish Resources of the Ocean, FAO Fisheries Technical Paper No. 97, 1970.

5/ Ibid.

6/ Ibid.

7/ Ibid.

8/ Ibid.

Program of the U.S. Department of Agriculture should emphasize the species that <u>really are</u> plentiful and inexpensive. But a realistic marketing specialist will realize that changing consumer preferences is likely to be slow and hard. The Romans used to say "de gustibus non disputandum," meaning that there is no use arguing about taste. A free market accepts the consumer as king and caters to his tastes--even if some experts call these tastes "irrational." As incomes rise, the consumer can indulge his tastes even more. This is not an argument against research, education, or promotion aimed at inducing consumers to accept some of the currently less-preferred species of fish. On the contrary, it is an argument that we will need stronger efforts along this line in the future.

One current trend may be that of breaking down old preferences. This is the trend toward highly processed fish, such as sticks and portions. Usually the consumer of these processed items does not know what species of fish he is getting, and doesn't seem to care much. He simply wants some fish that is easy to prepare and that does not taste bad.

The role of the Government in the promotion of underutilized species is debatable. It can legitimately do two things to help broaden the tastes of the consumer: (1) It can assess the stocks of various species available as to their magnitude, catchability and palatability, and (2) it can help make industry aware of them.[7] Industry is quite capable of promoting underutilized species if it believes the market can be developed.

Industry does not have the proper incentive to assess stocks of fish. Industry has, of course, over the years, discovered and promoted many species successfully but industries' efforts are halting because of the uncertainties involved. It might take many years for a full scale fishery to develop in some instances.

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[7] There are many philosophies regarding government assistance to industry. Any activity involving the development of products from unfamiliar species on one hand, to outright promotion of products through advertising (for example) on the other, are forms of subsidy to the industry. This is not to say that consumer benefits are not also involved. The two, in fact, through a considerable range, can be complimentary in nature. One can approach the whole subject from the standpoint of modern communication theory in marketing and relate the purpose of promotional activities throughout the product development process to adoption theory. For example, it might be more legitimate to engage in promotional activities at the "awareness," "information," and "trial" stages of product adoption than to engage in physical product development itself. The organization of the fisheries may make it more difficult for a single firm to justify expenditures for creating product awareness than for physical product development. Some see no distinction with regard to the government's appropriate role among stages of product development. That is, product development begins with the physical aspects and ends with the communication aspects. If the government is to engage in any of these activities one could build a stronger argument for some of the communication requirements, the difficulties of the industry providing for itself, than for some of the physical product modifications required. The fundamental debate arises when a group of physical scientists make a judgement based upon their appreciation and feeling of legitimacy surrounding activities that modify products in a physical way and their lack of appreciation for the need for services such as marketing that do not contribute to the physical improvement of the product.

A recent example of government industry partnership is the calico scallop. The calico scallop beds were mapped by BCF on exploratory cruises. Although a ready market exists for the finished product, several problems in vessel design and shucking had to be solved before these beds were ready for full scale exploitation. Many of these problems were solved by industry with minor aid from BCF. Because of the work of BCF, these scallops are several years closer to the table than they would have been without this catalyst. The benefit-cost analysis for this program is shown in Table 7.7.

Sokoloski and Carlson (1969) recently proposed a "price-incentive plan" under which the government would pay fishermen to land certain underexploited species. This plan was intended only to help alleviate unforeseeable resource problems. For example, haddock has been the preferred fresh fish in the Boston market, but supplies of haddock have dropped drastically in recent years. Sokoloski and Carlson proposed payments to stimulate increased marketings of pollock, which is plentiful.

Table 7.7.--Benefit-cost analysis of the calico scallop program

Year	Economic benefits[1]	Present value economic benefits	Program cost[2]	Present value of costs
	Thousand dollars			
1971	2,910	2,910	2,250	2,250
1972	4,889	4,074	2,048	1,707
1973	7,096	4,928	1,723	780
1974	8,898	5,149	848	491
1975	17,097	8,246	641	309
	40,891	25,307	6,910	5,537

B/C = 4.57

[1] Savings to consumers in cost per unit of scallops as a result of greater quantities available which lower the price (consumers' surplus).

[2] Includes all Federal, non-Federal costs.

Source: Economic Research Laboratory, National Marine Fisheries Service

Incentive payments of this kind could be socially beneficial, especially if they help consumers to discover desirable species. This could modify some tastes that have been based partly upon habit. If so, the incentive payments could be temporary. They could be dropped as soon as a market was developed for the underexploited species. In addition to incentive payments to stimulate the buying of underexploited species, we may need taxes to discourage the consumption of overexploited species. For example, we may need to tax haddock, as well as to subsidize pollock. Such a program of taxes and subsidies could be self-supporting. And it could help protect our future supplies of fish. It should be pointed out that the incentive payments plan is meant to be illustrative and not a firm proposal. Obviously, more research is needed before such a plan could be adopted.

7.6 A Harvesting Efficiency Policy

As demand expands, there will be an upward pressure on prices, since fishing is a rising cost industry (Chapter 3). Price rises may be abated if investments are made in the research and development of cost-reducing fishing techniques.

Many marketable species are not harvested at present because the individual members of the stock are not sufficiently aggregated to allow harvesting at present prices. Research could be done on the techniques of aggregation. The Japanese use such a technique in their saury fishery where they employ bright lights to attract saury so that they can be harvested economically. Experiments could be conducted using this and other techniques to attract fish. Essentially such techniques would be instrumental in shifting the production function for a fishery.

Other work could be done in gear research either to improve existing gear or develop new gear. One recent example of the potential for gear improvement occurred in the U.S. tuna fleet. In the late fifties the fleet was contracting as a result of high costs and a price ceiling for its product imposed by Japanese imports. Experiments by a few innovative fishermen and gear designer Mario Puretic drastically cut costs. Their experiments caused a change in the technology used by the fleet, transforming it from a pole and line fishery to a seine fishery. The new technology was adopted rapidly by the fleet and now the U.S. fleet is rapidly expanding while the Japanese fleet is contracting. Who knows what technological innovations could be made in other fisheries that could dramatically reduce costs in those fleets?

If a fishery is producing at MSY, improvements in technology cannot lower prices to the consumer. However, under proper management, resources could be transferred to other species. The increased output could lower the prices of fishery products indirectly through the production of substitutes.

Another field where much cost-reducing work can be done is that of short-term forecasting. Short-term forecasting helps the fisherman by giving him information as to the location, spatially and temporally, of the fish. This allows the fisherman to reduce his search time thereby increasing his catch. A notable and successful example of such aid is the NMFS albacore forecasting program. NOAA collects oceanographic and atmospheric data and processes the information into a form so that the fleet can interpret it and then locate the best probable fishing areas.

7.7 A Policy to Avoid

Over the years, regulatory mechanisms have been developed which have imposed an increasing burden of legislative inefficiency. This regulatory tangle now includes jurisdictional, scientific, and quasi-economic dimensions. Most of the fisheries are in state waters, and thus the states have been forced to adjudicate the growing conflict between fishing and other uses of the coastal zone. These regulations spread beyond territorial waters as fisheries originally limited to these zones have extended. The pressures of increasing demand have added new regulation upon old to attempt further conservation and management. These piecemeal accumulations have grown so as to virtually dominate the character of the industry in terms of the capital-labor ratio and technological change. This accumulated maze of regulations has now grown to be as significant a problem as the original motivation for their enactment -- the common property nature of the resource.

This sequence of regulations has led to several outstanding facts: (1) the resulting number of regulations is staggering and, in most instances, efficient harvesting techniques have been precluded; (2) the goal of limiting fishing effort has not been reached; (3) there are few examples of effective state or regional-Federal coordination to manage common fisheries; and (4) individual states vary considerably in the success of their biological, technological, and management activities and capabilities.

International fisheries suffer from a similar inability to develop coordinated management. With growing pressure on the resource, many of these fisheries are characterized by overfishing, inefficient regulations, and questionable extensions of national jurisdiction.

3 As many of these international fisheries involve U.S. territorial waters and the contiguous zone, some management must be initiated in international waters before U.S. waters can be managed effectively.

It is becoming increasingly evident that new steps in fishery management and development cannot be channeled through existing State organizations without some alteration in the Federal-State-local interrelationship. This is especially true as we move forward with legislation to provide a mechanism for managing the contiguous zone and as our fisheries increasingly expand their scope of operation so that many are both domestic and international in dimension. The policies mentioned above are definitely to be avoided.

7.8 Policy Implications for Meeting Projected Demand: The World Indicative Plan

We have tried to point out some of the policy implications of our demand and supply projections. For purposes of comparison, let us look at some of the policy implications explored by FAO in their Prospects for World Fishery Development in 1975 and 1985. Although the FAO demand projections differed from those developed in this report, the general conclusion of increasing demand pressures on relatively fixed fishery resources is common to both studies.

1. In many countries there is a great need for fish protein for food purposes as well as for export to other countries. In order to increase their catching potential, these countries should replace traditionally low productivity fishing craft by powered vessels designed to meet the specific needs of the local fishery.
2. To develop the fisheries, there is a great need for port and harbour facilities. The lack of these facilities has become one of the major factors inhibiting the expansion of offshore fishing operations.
3. If vessel mechanization is to become widespread, there is also a need for official credit schemes.
4. With increased mechanization, there is a clear need for fishermen training.
5. The complexities of successful fish culture indicates a need for improved and expanded extension services, if high yields are to be obtained.

6. In the case of fully exploited stocks, management is required if technological developments are to lead to cost reductions and not to a smaller catch at a higher cost per ton. The objective of management should, therefore, be to maintain fishing effort at the level giving the greatest net returns since beyond this point the cost of any extra effort will be greater than the value of the resulting yield. The IWP, therefore, emphasizes the importance of management measures aimed at a more rational utilization of fish stocks and supports the efforts being made to this end.

7.9 Need for Adequate Information

Finally, to implement many of the policies discussed above, it will be necessary to improve the nature of both biological and economic information on fisheries. Therefore, it will be necessary to collect reliable data on which to base more precise policy judgments. Although stated last, we believe that rapid answers about the status of fisheries is certainly a priority item.

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