MARKET ALTERNATIVES FOR CARP, ALEWIFE AND SUCKER FROM THE MICHIGAN GREAT LAKES

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ABSTRACT

"Market Alternatives for Carp, Alewife and Sucker from the Michigan Great Lakes" is a study of the potential economic value of three species of fish existing in large supply in the great lakes. The study focuses on the feasibility of potential uses of carp, sucker and alewife as a food source and as a protein source for industrial meal, oil and solubles.

The potential demand for these species as a marketable food fish was analyzed using the theory of consumer demand. Tuna, sardines, cod, perch and salmon products were selected to study the affect of changes in price and income on demand. Conclusions from this analysis were used to specify an ordinary least squares equation of demand for canned and processed tuna, sardines, cod, perch and salmon products at the retail level. The equations were then used to derive demand elasticities for those species and to measure the consumers sensitivity to changes in price. The conclusions were used to measure consumers willingness to accept substitute goods for premium ocean species.

The analyses showed consumers' willingness to accept substitute ingredients for processed cod and perch. Consumers were generally unprepared to accept canned tuna, salmon or sardine prototypes. While carp, sucker and alewife might be accepted as substitute ingredients for processed cod or perch sticks, cakes, or puffs, their use as substitutes for canned tuna, salmon or sardines appeared less assured. Under the conditions set forth, a manufacturer considering alternatives to higher priced species for processing could substitute the lower priced carp, sucker or alewife with confidence in the products performance.

An analysis of the market for carp, sucker and alewife as a protein source in the industrial meal, oil and solubles market was used to consider the feasibility as a profitable local processing facility. The price of the three forms was forecasted for 1977. Physical production processes of four alternative plants were compared. Changes in fixed and variable costs on the rate of return of the most feasible plant showed industrial meal porcessing of carp, alewife and sucker to be only marginally profitable within existing prices, costs, technology and liberal harvest limits.

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CHAPTER I

INTRODUCTION

This research paper explores two potential uses of carp, alewife, and sucker found in the Michigan waters of the Great Lakes. These three types of fish are underharvested relative to their large numbers and potential value. The following sections of Chapter I will give a short definition of the problem, the scope and purpose of the paper and summarize the critical historical events that underlie the need to utilize presently underutilized species.

Statement of the Problem

Only a fraction of the carp, sucker and alewife available for harvest were harvested from the Michigan waters of the Great Lakes in 1975. These species had an average value of only $.02 per pound. At the same time, harvests of tradionally popular and presently marketed species, such as whitefish, lake trout and chubs, were overharvested and in short supply. Harvest of these species has been strictly regulated by the Michigan Department of Natural Resources (DNR) through their restrictions of licenses and harvest methods of commercial fishermen. The DNR was given authority to regulate fishing subsequent to a series of events notably the introduction of sea lamprey, the introduction of alewives, the increase in pollution and development of the sport fishery. These events lowered the profitability of commercial fishing to the point where the potential for rebuilding the commercial fishing industry depended on a more diversified fishery with increased focus on the harvest of low value species such as carp, sucker and alewife. Up to 1975 there was little or no demand for these species or their products. Commercial fishermen have expressed interest in expanding their harvest of underutilized species if a more profitable market could be established. Further utilization of these species would make use of a resource that would otherwise be wasted. The success of the fishery, however, would require: developing information on abundance of the existing stock; re-evaluation of the existing legislation restricting efficient methods of harvesting; and the development of marketable products.

Purpose and Scope

The primary focus of the study is the development of a marketable product using carp, sucker and alewife, found in the Michigan waters of the Great Lakes (see Fig. 1). It is concerned with selected uses of industrial meal, oil and solubles. These alternatives are not exclusive, but are those that lend themselves to easy comparison and potential incorporation into the existing markets.

The paper is divided into six chapters. Chapter I gives an introduction and a historical perspective of the legislative events that have influenced the Michigan Great Lakes Fishery, resulting in the need to consider marketable products for presently underutilized resources such as carp, alewife and sucker. Chapter II suggests a means of determining the availability of renewable resources like carp, sucker and alewife in the absence of accurate data measuring existing supply. Chapter III analyzes the use of carp, sucker and alewife as food fish, canned in oil, processed, or minced. It extrapolates potential demand for these three species for substitutable species with more developed marketing channels. Chapter IV examines the use of carp, alewife and sucker as a protein source for industrial meal, oil and solubles and Chapter V analyzes the

GREAT LAKES FISHERY

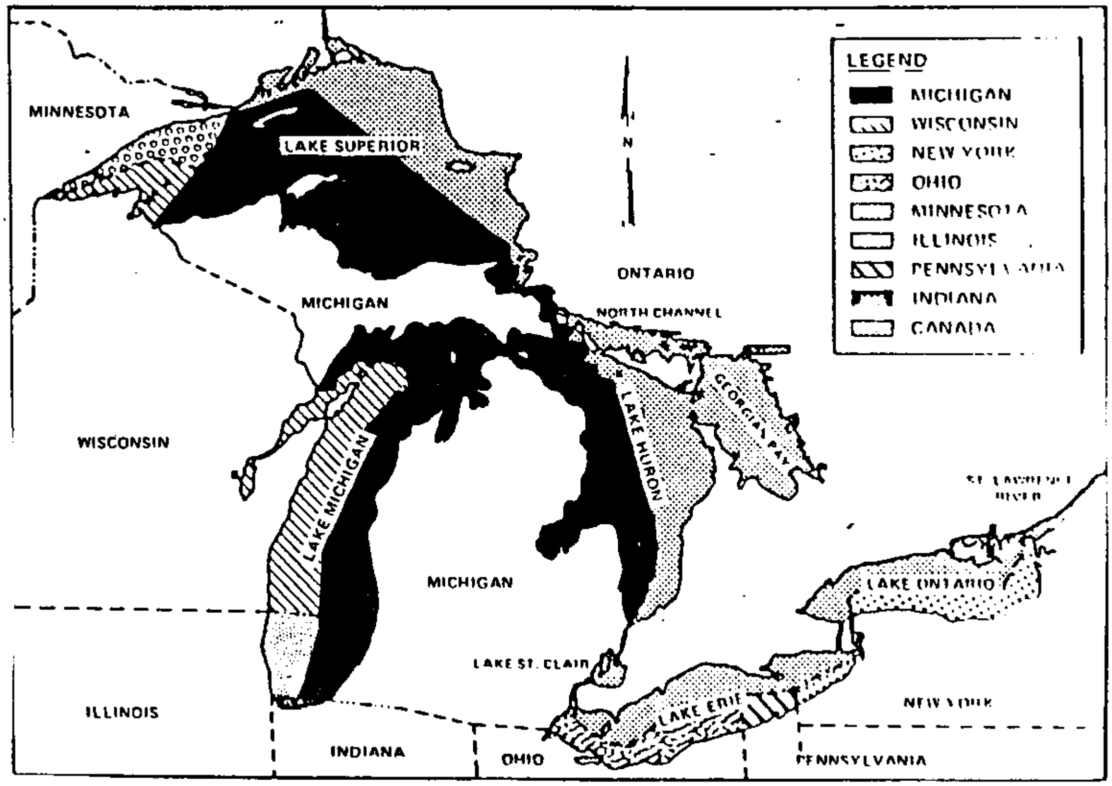

Fig. 1

SOURCE: Report to the congress by the Comptroller General of the United States, The U.S. Great Lakes Commercial Fishing Industry-Past, Present & Potential, CED - 77-96, Washington D.C. (September 30, 1976) feasibility of a Michigan manufacturing facility to process these species into meal, oil and solubles. Chapter VI then summarizes the potential of the two alternative markets and makes recommendations on the direction of future research.

Summary of Fishing History and Regulation

The Great Lakes waters have been the source of a valuable renewable resource- fish. Until the late 1800s, harvests were plentiful and the commercial fishing industry was flourishing. Stocks were considered limitless and harvesting was virtually uncontrolled. Since then there has been a substantial reduction in many of the popular species particularly lake trout and herring. The composition of fish stock has changed over time and is graphically illustrated by the substantial reduction of lake trout and herring and the emergence of salmon (see Fig. 2).[3] The introduction of exotic species with completion of the St. Lawrence seaway; the emergence of the lamprey and subsequent destruction of lake trout stocks; the loss of fish spawning areas with the development of the Michigan coastal areas and the establishment of a sports fishery have intensified the competition for popular species. Restrictive conservation legislation followed lower harvests and attempted to ease subsequent destructive competition for the surviving resources and stabilize the species balance in a desirable mixture. A lot of variation in the population cannot be explained.

The emergence of the sports fishery with the enfranchisement of the sports fishery has altered the traditional balance. Efforts to stabilize commercial fish have been complicated by the goals of equitable and economic treatment of different users of the fishery. This chapter outlines the historic attempts at balancing fishing with resource supply. The response of fishermen to legislative changes is used as justification

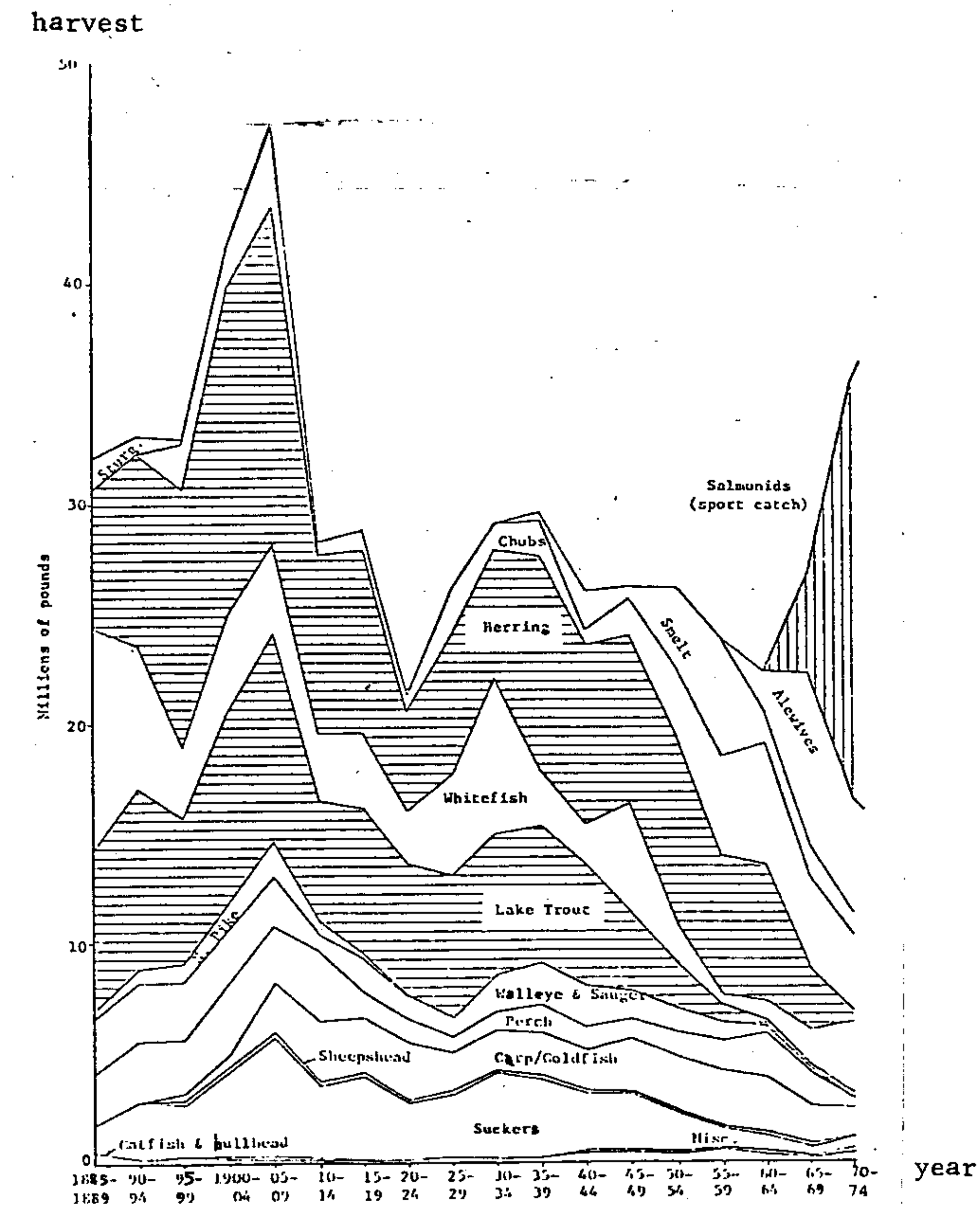

Fig. 2 Michigan Great Lakes Commercial Landings, 1885 - 1974. Data Based upon 5 - year averages.

SOURCE: D. Talhelm, "Limited Entry in Michigan Fisheries Draft", Michigan State University, East Lansing, Michigan (1977): Appendix for a more coherent systematic model of lake management in Chapter II. The framework discussed there is the same as used by present lake managers in their regulation efforts. Fishery legislation ultimately determines the feasibility of market alternatives for great lakes carp sucker and alewife by establishing a limit on fish harvests. The legislative history is discussed here as background for the topics of Chapters III-V.

As early as 1850, it became quite apparent that certain whitefish populations were declining. The legislature attempted to regulate the nets used and began to enforce mesh size restrictions. However, other more sophisticated gear was developed which allowed harvest in the deeper waters and resulted in further decline.[5]

Until the enactment of the Michigan Commercial Fishing Law of 1929, state managers of the public resources had only limited power to regulate harvesting gear and fishing seasons, and to restrict the harvest of species in low supply. However in 1929 the Commercial Fishing Law substantially restricted commercial fishing. Black bass, sunfish, and various species of trout became protected species. The legislature decreed..."it is unlawful for any person...to catch with any kind of net or other device used in commercial fishing in any waters mentioned in (The Commercial Fishing Law)."[7] "Closed Seasons" were defined for designated fish: trout, whitefish, northern pike, perch, white bass, sucker and black crappie.[8] Several areas were ruled off limits for the harvest of perch.[9] Several extremely restrictive gear regulations were promulgated prohibiting "gill nets, pound nets, trap nets and other devices, except the hook and line," in legislated areas.[10]

Fishermen were required to report their efforts. Every person taking fish to market was required to keep an accurate report of each day's catch "of the number of pounds of each kind of fish taken, of the locality fished, and of the kind and amount of fishing gear employed." Only those complying with the reporting regulations, demonstrating sufficient supportive marketing and transportation facilities, were entitled to commercial fishing licenses.[11]

Then in 1955, Public Act 218 reemphasized the extensive power granted the conservation commission to regulate commercial fishermen. The Act granted the commission a free reign to "suspend, abridge, extend or modify" the provision of any law, if "in the opinion of said commission, such action is necessary." When challenged in 1962, the Michigan Attorney General stated that this power included the closing of Lake Superior to commercial fishing.[12]

Pursuant to their broad grant of authority, in 1968 the Department of Natural Resources (superceding the conservation commission, P.A. 1955, No. 218 as amended in 1959) took the first step toward limiting entry into commercial fishing and tampering with traditional "freedom of the seas." Licenses were limited for the first time and no new licenses were issued. The number of licenses was reduced by eliminating the license for any vessel not earning $1000.00 or more in any one of the five years from 1963-1967.[13]

Continued spotty legislation tightened up restrictions and set up new barriers for the commercial fishermen. In 1974, the regulations were amended in favor of individual gear and location restrictions, and supplemented to ban most gill netting under a forced buyout plan. A "quota shares" system was initiated in 1975 to protect the chub fishery in Lake Superior. In 1976, a $1.5 million dollar plan to force a buyout of gill net operations was implemented.[14] In light of these restrictions, it is not surprising that employment in the Great Lakes commercial fishing industry has declined (see Table 1).

Presently, commercial fishing is being further threatened by the claims of the native Americans who claim control of all fisheries in about 2/3 of Michigan's Great Lakes Waters.[15] The law governing native American rights is yet to be settled. The Michigan Supreme Court in People v. Tondreau, 384 Mich. 539 (1971) set forth limitations on the State of Michigan's power to regulate native American fishing. The Supreme Court held that State regulation is valid only if: "(1) it is necessary for the preservation of the fish protected by the regulation; (2) the application of the regulation to the Indians' holding off-reservation rights is necessary for the preservation of the fish protected; and (3) the regulation does not discriminate against the treaty Indians."[16] The Michigan courts have interpreted this to mean that regulations currently in effect which reflect goals other than conservation such as designation of certain fish as sports fish (which promotes sport fishing); limits on the size of catch (which spreads the harvest among more people); general gill net restrictions (which preserves more than designated species) apply to non-Indians but not to Indians to the extent it is a basis for infringing on treaty rights.[17]

The revitalization of the commercial fishery depends on the initiation of specific statutory guidelines to quell the uncertain impact of native American unregulated fishing on future available supply for commercial use. A re-evaluation of the scope and breadth of existing legislation is a prerequisite to diversification of the fishery.

This study will examine the feasibility of extending the fishery by harvesting and utilizing presently low-value species - carp, sucker and alewife. Carp, sucker and alewife are not among the ranks of depleted species that the public resource managers are attempting to rebuild. Yet the gear restrictions, licensing regulations, quota systems and location

TABLE I

NUMBER OF COMMERCIAL FISHERMEN

Year	Full-time	Part-time	Total
1930	5,284	1,617	6,901
1940	3,647	1,372	5,019
1950	3,193	1,568	4,761
1960	1,914	1,911	3,825
1965	540	1,805	2,345
1970	177	1,293	1,470
1975	137	1,043	1,180

SOURCE: Report to the Congress by the Comptroller General of the United States, The U.S. Great Lakes Commercial Fishing Industry Past and Present & Potential, CED-77-96, Sept. 30, 1976, Washington, D.C., p. 12.

regulations on commercial and sports species also affects the potential productivity of carp, sucker and alewife harvest. The following suggestions for uses of carp, alewife and sucker, as a food source and use in meal, oil and solubles, assume that the present restrictions and limitations will be re-evaluated and amended to encourage rather than discourage the production of these species.

FOOTNOTES

CHAPTER I

[1] National Marine Fisheries Service, Great Lakes Fishery Annual Summary, CFS 7410, NMFS/OAA, Washington, D.C. 1975.

[2] Report to the Congress by the Comptroller General of the United States, The U.S. Great Lakes Commercial Fishing Industry - Past, Present and Potential, CED-77-96, Washington, D.C. (1976). Graph of decline in harvest, 1885 - 1976 shown in Appendix A.

[3] Talhelm, Michigan Fisheries,

[4] John A. Scott, A Historical Review of the Productivity and Regulation of Michigan's Commercial Fisheries, 1870-1970, Michigan Department of Natural Resources, 1974 Michigan Fisheries Centennial Report 1873-1973, Fish Management Report No. 6, (1974): 75-82.

[5] Talhelm, Michigan Fisheries.

[6] Michigan, Revised Statutes, Annotated (Aug. 29, 1929) Sec. 13.507

[7] Ibid. 13.1507.

[8] Ibid. 13.1497.

[9] Ibid. 13.1539; 13.1541.

[10] Specific delineation of the areas listed in Appendix A.

[11] MSA 13.1568 (2).

[12] Opinions, Attorney General, Michigan, Aug. 31, 1962, No. 4050.

[13] Talhelm, Michigan Fisheries, p. 12.

[14] Ibid. p. 14.

[15] Ibid. p. 18.

[16] People v. Tondreau, 384 Mich. 539 (1971).

[17] Kathleen Brandimore,"Indian Law - Treaty Fishing Rights - The Michigan Position, Wayne State University Law School, Law Review, Vol 24 (1978);1187.

CHAPTER II

AVAILABILITY OF CARP, SUCKER AND ALEWIFE

This study of potential uses for carp, sucker and alewife found in the Michigan waters of the Great Lakes assumes that there exists a substantial sustainable supply of these species. The following discussion will review landing data and set forth a method for measuring the availability of carp, sucker and alewife. The number of fish of a particular species is difficult to observe. Recorded landings and fishing regulations are often used to proxy landings. Where a market exists for a particular species and the quantity landed is close to the quantity available, recorded landings could be a reliable basis for estimating the economic supply of fish. However, in the case of carp, sucker and alewife, where no market presently exists, the quantity landed is not an accurate measure of potential availability of these species. For example, in 1975, 246,100 pounds of sucker, 1,068,400 pounds of carp and 3,678,200 pounds of alewife were landed in Michigan.[1] Yet in a 1975 Federal study of the Great Lakes sucker, sheepshead (carp) and smelt, it was estimated that the potential harvest of sucker could be 16 times the 1975 levels, and carp 8 times the 1975 yield.[2]

The dichotomy between the landing figures and potential supply is in part due to the absence of existing markets for these species. In 1975, sucker sold for $.038 per pound, carp $.068 per pounds and alewife

\$.014 per pound[3] in contrast to the popular common whitefish selling for .68 per pound, and lake trout for .55 per pound.[4] Even when the more popular species are not available, harvest of carp, sucker and alewife is avoided. Landings of the low-value species are often the unintentional by-product of other commercial fishing efforts and often go unreported.

An alternative to relying on the landing data for determining the availability of carp, sucker and alewife is a normative analysis based on the regenerative capacity of a renewable resource. In the absence of tangible data, the concept of maximum economic yield (the calculation of which is outside the scope of this paper) can be employed to determine availability by measuring the yield per unit of effort.

As development and processing advancements produce viable market alternatives for carp, sucker, and alewife, an accurate estimate of maximum economic yield of carp sucker and alewives must be made. For the purpose of this paper the maximum economic yield method of determining supply set forth in Anderson's model of renewable resource in his book Economics of Fisheries Management,[5] will be discussed in general and adapted where appropriate.

Anderson's model of renewable resources assumes that fish of a particular species within a population are homogeneous and uniformly distributed. The dockside market provides no premium for size, age, or any other individual characteristics. The catch of fish is determined by effort which is the product of fishermen and their capital. Effort is a proxy or common denominator describing the intensity of different fishing inputs. Effort encompasses number of days labor, capital, variable inputs in homogeneous proportions and technological change. The yield per unit of effort is a function of fish population, technology, and a vector of variable inputs. Fishing effort is presumed to have a constant cost. Effort is measured in effective rather than nominal terms. By the nature of fishing, effort must be represented by a consistent proxy which usually requires continuous modification.

Yield is measured by the total weight or amount of biomass harvested. As fish recruit into the biomass or individual fish grow to larger sizes, the yield from the lake would increase. Every point along the population equilibrium curve would balance the harvest and mortality of the species. The total weight of fish in Michigan waters is affected by weather, currents, number of fish, feeding habits, photosynthesis levels, and natural mortality and many other variables. Stock growth is determined by effort, population, and species. Under normal circumstances the smaller the population of fish in the lake, the greater the difference between recruitment/individual growth and all sources of mortality. Under more crowded circumstances, growth declines. At P*, in Figure 3, the

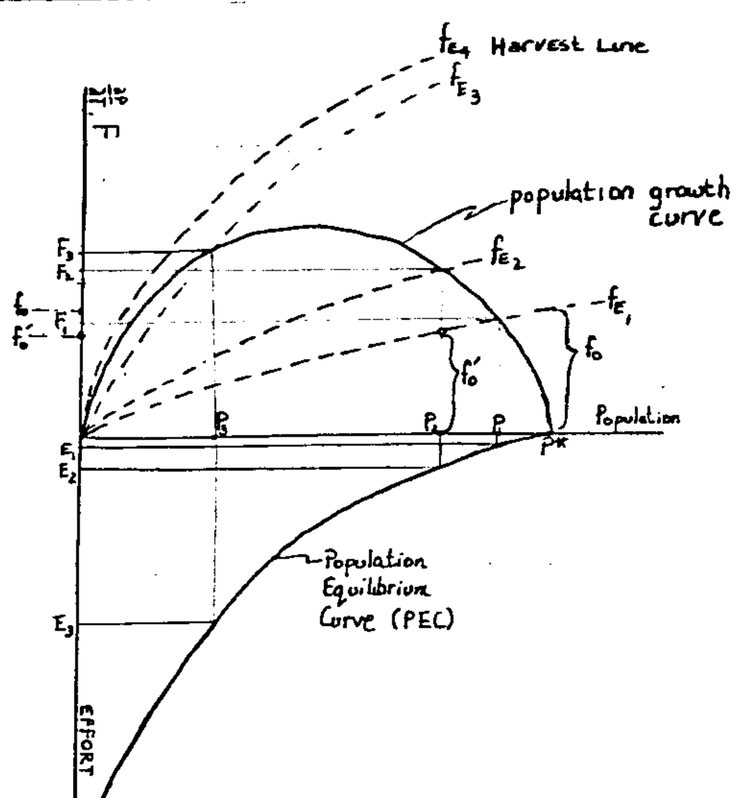

Fig. 3. Population Growth Curve

Note: fE_1 = catch weight with E_1 = effort and PEC = Population Equilibrium Curve.

forces causing growth and those causing attrition are in balance. The balanced population is unique to the particular level of effort. Increases in biomass were plotted as a function of population, or effort, while respectively holding effort and population constant. In the former case, each population is represented by a locus of harvest weight for a range of fish populations. Population (P_i) has a growth rate of (F_i). Catch (f_{E_i}) and the growth (F_i) are represented by the distance to the locus (f_{E_i}) and the growth curve respectively. Any point of intersection of the growth curve and the harvest line (f_{E_1}-f_{E_4}) depicts a stable situation. Harvest and mortality equal maturation. The locus of such points for a range of efforts is referred to as the population equilibrium curve (PEC).

Equilibrium stock size is determined by fishing effort. If the fishery is operating in its unexploited state, it is operating on the sustained yield curve, where population equals P* and effort equals zero. If E_1 units of effort are applied during an initial fishing season, the f_o units would be caught. Since growth is zero in the natural state population falls by the amount of the catch. If the new post harvest population dips as low as P_2, natural growth will amount to F_2 and harvest will amount to f_o. Since the catch is less than natural growth, population increases. For larger populations, catch exceeds growth causing population to decrease. Population growth exceeds catch in more depleted populations resulting in an increased fish stock. Population will fluctuate but eventually settle at P_1 when readjustments in the population are completed, as long as E_1 effort is held constant. For P_1, effort f_{E_1} produces catch f_o' (see Fig. 3).

Population (P_i) grows at a rate (F_i) regardless of harvest level. The level of effort which produces a balanced population (PEC) often needs to be phrased in terms of harvest weight. Sustainable yield describes the level of effort whose catch by weight equals gain from maturation and matriculation. Sustainable yield is important to the Great Lakes Fishery because it is a renewable resource providing a continuous supply of resources. For effort (E_1) in the population (P_1) the weight of the harvest (f_1) is approximately stable. The mass of fish mortality and harvest will equal the weight of those spawned or matriculated into the population (see Fig. 3). The sustainable yield relation between effort and population is shown in Figure 4. Effort (E_1) is applied to a given population (P_o), which provides a quantity of fish (F_r) and a stable population indefinitely. As effort for a particular population increases from zero sustainable catch first rises and eventually declines to zero. At every point on the curve below, catch equals growth. As effort is applied beyond E*, harvest yield and equilibrium population decline causing growth to decline.

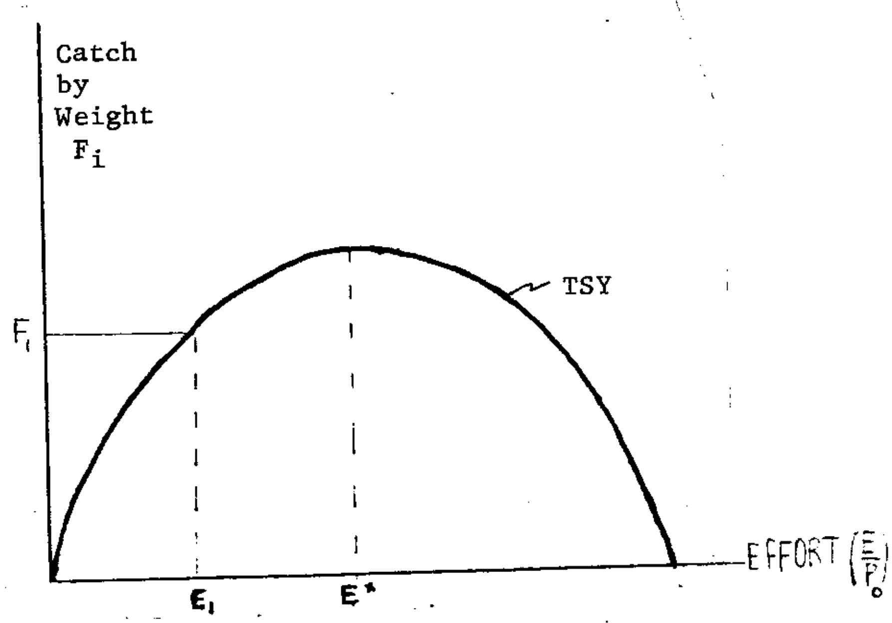

Fig. 4 Total Sustainable Yield Curve (TSY)

In some circumstances, a different production function is required to describe the short run adjustment for each population. Where catch equals natural growth of the fish stock, the short run unadjusted production function intersects the sustainable yield curve, and catch equals the growth rate. Each population level has an equilibrium population size or sustained yield. By assumption of the model, size of an individual in the population is not affected by fishing though in reality, size of the average individual is likely to decrease with the increased probability of harvest before individual maturation. The sustainable yield curve is considered the long run production function. As effort increases, equilibrium population falls continually from its natural level (P* in Fig. 3). Growth of the fish mass will successively increase, remain static, or decrease with the intensity of effort. As effort is increased from E_1 to E*, the equilibrium population size decreases while growth rate from recruitment and natural maturation increases. The net change in sustainable yield varies with the preexisting balance. When large amounts of effort are already being exerted, further increases reduce the stock. Natural growth, and consequently, sustainable yield both decrease.

The marginal sustainable yield curve, the change in sustainable yield relative to the change in effort, falls over the entire relevant range of the curve (see Fig. 5). If enough effort is applied to the fish population, the total catch, as a percent of total effort, will asymptotically approach zero. Average sustainable yield should asymptotically approach zero. Average sustainable yield per unit of effort $\left(\frac{F}{E}\right)$ in Figure 5 falls with each additional effort until total sustainable yield equals zero. The rate of change recorded by the marginal yield curve becomes negative where total sustainable yield begins to decline. Further effort beyond the maximum sustainable yield actually decreases catch. Growth rates can be expected to vary by species and environmental conditions.

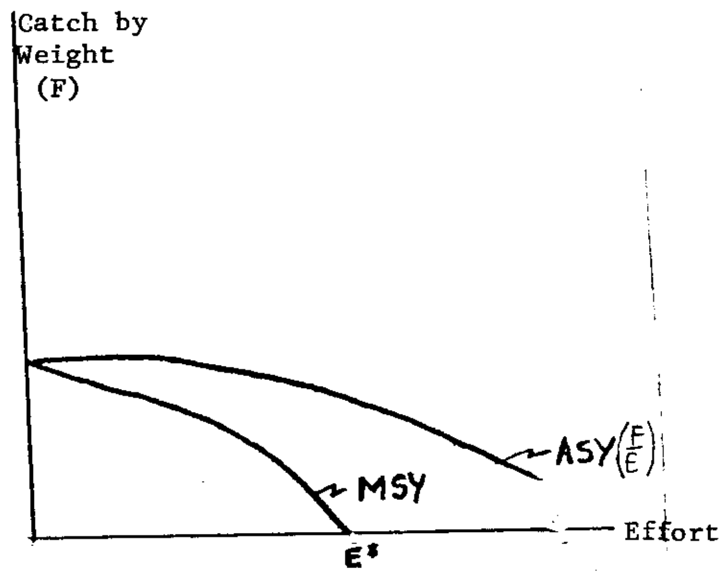

Fig. 5 Average Sustainable Yield (ASY)
Marginal Sustainable Yield (MSY)

NOTE: E* = Level of effort associated with Maximum Total Sustainable Yield.

Total revenue and total cost respectively are the product of price and cost per unit of effort when multiplied by yield. The difference between the two is profit π which appears graphically in Fig. 6. The profit maximizing level of effort (E_1) generates the most efficient allocation of resources. R_1 is the profit maximizing level of revenue for harvest E_1. E_1 can be applied annually without depleting the resource. However, the individual fisherman is concerned with average revenue rather than economic efficiency or maximizing social welfare. Fishermen would continue to harvest up to point E_3 where average revenue equals average cost. Despite the economic efficiceny of E_1, there is no incentive for a fisherman to cease effort before E_3 where total costs first exceed total revenue.

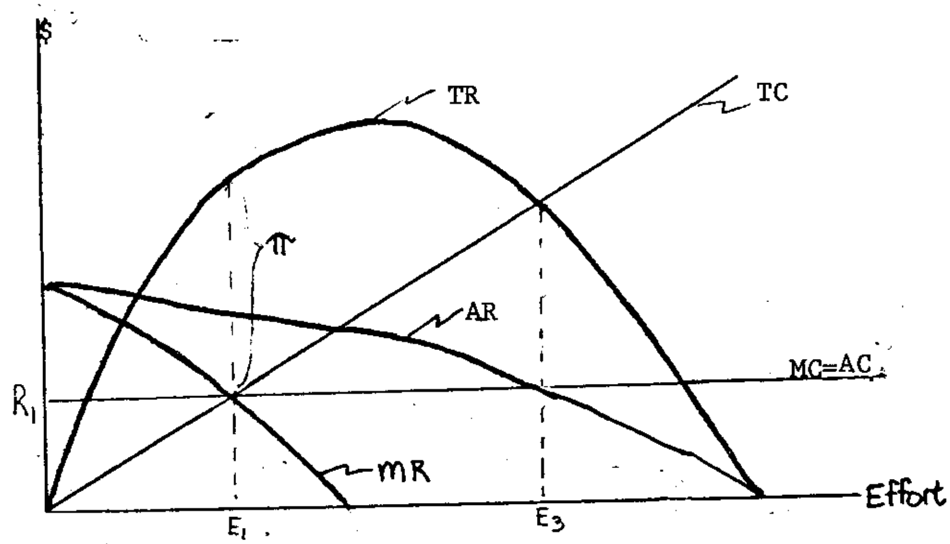

Fig. 6
Revenue and Cost Curves of a Renewable Resource
Inter-Relationship of Total Cost (TC), Total Revenue (TR), Marginal Cost (MC), Marginal Revenue (MR), Average Cost (AC) and Average Revenue (AR) Under A Fixed Set of Prices. Maximum Profit for the Fishery is Achieved When Each Fisherman Harvests (E_1) Earns Profit (π) and Produces Total Revenue (TR).

Adapting Anderson's model to the Michigan Great Lakes, Asa Wright of the Michigan Department of Natural Resources considered a number of additional factors that influence the lakes' yield of carp, sucker and alewife. The interactive dynamics among fish population (i.e. sports fish need alewife as forage) lowers the optimum yield for the Michigan Lakes below E_1. The migration of fish to other states' waters and the impact of the discount rate (allowing for growth in the resource) were considered. Wright estimated the Michigan waters of the Great Lakes could sustain harvest of two million pounds of carp, 1.5 million pounds of sucker and 5 million pounds of alewife per annum.[6]

Summary

Anderson's model and variations formulated therefrom are useful methods for determining the continuing availability of carp, alewife and sucker in the event marketable products such as those suggested in chapters III and IV are developed. However, other factors threatening continuous availability must be considered and closely monitored. Present and future legislation, environmental factors (water pollution, contamination, destruction of spawning areas), and competing users (recreational fishing and Indians fishing without restriction) must be evaluated to determine their impact on supply and continuous availability. The collection of this data and a consistent measure of effort will give substance to a maximum sustainable yield analysis and will enable a determination of the marginal operating characteristics and optimal harvest.

FOOTNOTES

CHAPTER TWO

[1] Report to the Congress by the Comptroller General of the United States, The U.S. Great Lakes Commercial Fishing Industry - Past, Present and Potential, CED-77-96, Washington, D.C. (1976): Appendix 5.

[2] Ibid. p. 39. These were estimates of potential harvest of sucker and carp for all of the Great Lakes. Michigan waters comprise 60% of the Great Lakes. See Fig. 1.

[3] National Marine Fishery Service, Great Lakes Fishery Annual Summary, CFS 7410, Washington D.C. (1975).

[4] National Marine Fisheries Service, Food Fish Market Review and Outlet 1960-1976, Economic and Marketing Research Division, NOAA/NMFS, Washington D.C. (1975).

[5] L. Anderson, Economics of Fisheries Management, Johns Hopkins Press, Baltimore, Maryland (1977) Chapters 2-5.

[6] Asa Wright, Michigan Department of Natural Resources, Fisheries Division, Lansing Michigan an authority on District Regulation and Conservation of Great Lakes species.

CHAPTER III

ANALYSIS OF THE DEMAND FOR CARP, SUCKER AND ALEWIFE AS FOOD FISH

The oceans, lakes, rivers, and streams provide the source of supply to meet the consumer demand for fish as food. Fish for consumption can be marketed (1) unprocessed: fresh, frozen, or canned or (2) processed: minced, pickled, salt-cured, or processed into convenience-type products such as cales, portions, puffs, logs, and sticks. The Michigan Great Lakes have been a productive source of unprocessed fresh and frozen fish (i.e., fillet of trout and whitefish). This chapter will analyze the possibility of extending the Great Lakes resources to the canned and processed fish markets, using carp, sucker, and alewife.

The canned fish and processed fish markets were chosen to take into account the unappealing characteristics of carp, sucker, and alewife, particularly oiliness, boniness, and strong seasonality. These characteristics discourage their use as fresh or frozen fillets. The mincing process has the potential to alter these undesirable characteristics by finely grinding the bones. Pickling and salting mask the otherwise muddy taste, and canning in oil is capable of dissolving the bones. Similarly, "convenience-type" products, such as fish cakes, allow carp, alewife, and sucker to be minced and processed with other fish, meat or soy additives and seasoned to enhance the appeal to the consumer.

The study of the potential demand for processed and canned carp, alewife, and sucker was analyzed using comparable ocean species presently being marketed in canned, frozen, or processed form. Fish prices and consumption trends for tuna, sardines, cod, perch and salmon were analyzed to determine the receptiveness of the existing canned and processed markets to new species. Income and substitution effect of the consumer demand theory were studied to assist in the specification of a regression equation and give meaning to the price analysis. Tuna and sardines were chosen because they are often canned in oil. Cod and perch were selected because a large portion of the catch is used for frozen fish cakes, portions, puffs, logs, and sticks. Salmon was considered not only for its use as a canned product but also its status as a luxury food. Existing technical and market conditions of the five popular species only approximate the strict assumptions of the theory of consumer demand[1]: (1) full knowledge; (2) utility is derived from services over time; (3) the consumer is able to rank commodity bundles; (4) indifference curves pass through every point in commodity space and do not intersect; and (5) utility curves are convex to the origin. Where the assumptions of the theory were satisfied, quantity of fish demanded was a function of income and price.

Figure 7 outlined the limits of purchasing power under a particular income and set of relative prices in a static world (budget line—AB, AC). The slope of the budget line was equal to the price ratio of two species. The point of tangency between the highest indifference curve and the budget line maximize consumer utility. The total portion of the household budget spent for fish in general, was determined by the cost of fish relative to all other items desired and income. Successive changes in price are shown graphically in (AB—AC) Fig. 7. Substitution and income effects associated with changes in income are shown in Fig. 7. (X_1 - X_2 and X_2 - X_3, respectively).

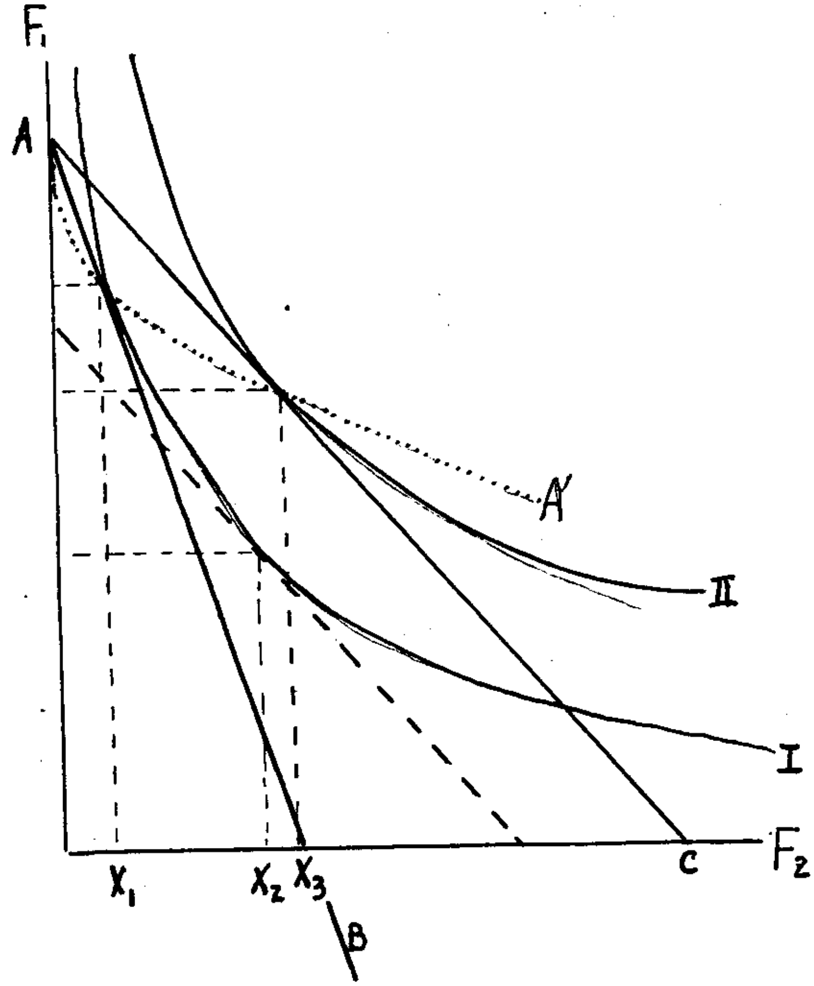

Fig. 7. Income and Substitution Effect of a Normal Good.

NOTE: Substitution effect (X_1 X_2) of a normal or luxury good F_1 (Tuna, Cod, Perch, Salmon, or Sardines) for a normal or luxury substitute F_2 (Carp, Sucker, or Alewife) and income effect (X_2 X_3) of a price decrease AB—AC.

According to the Engel Curve (Fig. 8) decreasing proportions of consumers income will be allocated toward goods with income elasticities less than one. An absolute increase in quantity of fish consumed accompanied each increase in income, giving quantity of fish consumed and income a convex relationship for luxury goods and a concave relation for necessities.

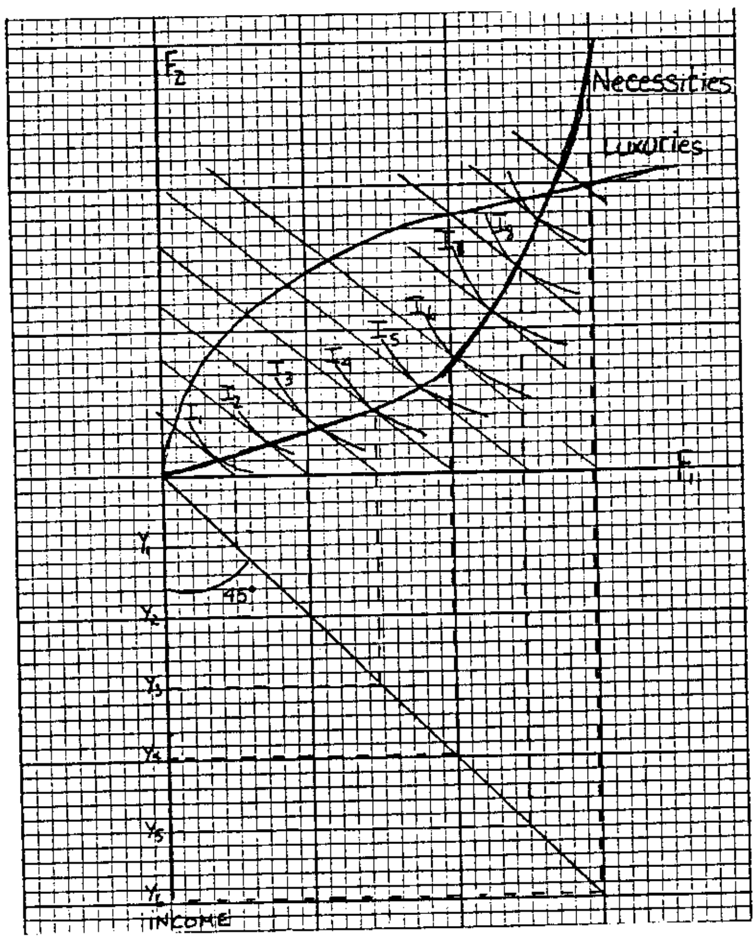

Fig. 8. Engel Curve Indicating Response of Popular Ocean Species (F_1) to Changes in Income (Y_i).

NOTE: F_2 = other goods in the economy or substitute goods.

Figure 9 showed the negative correlation between changes in relative price and quantity demanded. The demand for one of the premium species (F_1) such as tuna was measured against the demand for substitute goods (F_2), e.g. "Hicks-Marshall" money or substitute fish species. The cross elasticity of F_2 was expected to be greater than zero where substitutes were available. Normally a change in income would outweigh the substitution effect. Goods with such characteristics would be termed 'normal' or 'superior' and goods with income elasticity greater than 1 would be termed 'luxuries'. Change in the price of substitute fish products would produce diminishing price movements in the same direction. For necessities the cross elasticity of substitute goods (F_2) would increase with the household food budget. Where substitute goods (F_2) (e.g. carp, alewife and sucker) were perceived as necessities (goods with elasticity less than one) changes in income would move quantity demanded in the same direction at a decreasing rate. The quantity of luxuries demanded would increase with income at an increasing rate. Consumers with larger food budgets who would be less sensitive to price, would allocate smaller portions of their budget for these species with each increase in income. Successive changes in the relative price of fish were graphed by a series of shifts in Figure 9. For normal or elastic goods it was reasonable to expect the price consumption curve to slope downward as prices increased and show a negative relation between price and quantity.

Analysis of Cod, Perch, Sardines, Salmon and Tuna Markets

Fig. 10 and Table 2 (P. 29) described behavior under changes in income and price level. By use of regression analysis, it was possible to test the signs and size of each species' coefficients, analyze the influences on price and define the significance of changes in prices and income on the amount consumers were willing to pay for tuna, salmon, sardine, perch, and cod.

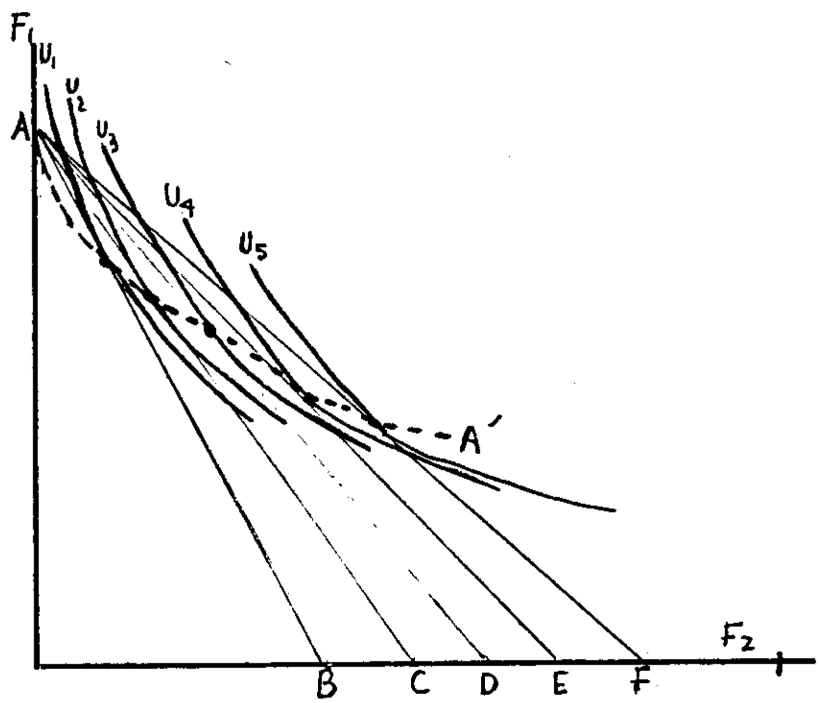

Fig. 9. Price Consumption Curve (AA) of F_1 (Tuna Salmon, Cod, Perch, and Sardines) for F_2 (Hicks-Marshall money, Fish, Meat, Poultry, or Carp, Sucker and Alewife). AA reflects the impact of decreases in price of substitute goods (F_2) from AB through AF on demand for goods (F_1).

$$P_{TUNA} = \underset{(.218)}{.566} + \underset{(.141)}{.516Q} + \underset{(.277)}{.34P_s} - \underset{(.052)}{.349Y} + e, \quad \bar{R}^2 = .486 \quad D.W. = 2.02 \quad n = 12$$

$$P_{PERCH} = \underset{(27.6)}{33.67} - \underset{(.110)}{.223Q} + \underset{(.225)}{.769P_s} + \underset{(.46)}{1.54Y} + e, \quad \bar{R}^2 = .78 \quad D.W. = 2.43 \quad n = 16$$

$$P_{COD} = \underset{(38.21}{174.3} - \underset{(.684)}{3.16Q} + \underset{(.507)}{.92P_s} + \underset{(5.76)}{9.07\ Y} + e, \quad \bar{R}^2 = .816 \quad D.W. = .6627 \quad n = 16$$

$$P_{SALMON} = \underset{(.229)}{55.4} - \underset{(.014)}{.228Q} + \underset{(.184)}{.772P_s} + \underset{(.0029)}{.000323Y} + e, \quad \bar{R}^2 = .887 \quad D.W. = 2.43 \quad n = 9$$

$$P_{SARDINE} = \underset{(.222}{-1.815} - \underset{(.582)}{1.355Q} + \underset{(.342)}{.684P_s} + \underset{(.033)}{.187Y} + e, \quad \bar{R}^2 = .857 \quad D.W. = 2.10 \quad n = 11$$

Fig. 10. Demand at Retail Level for Tuna, Perch, Cod, Salmon and Sardines.

SOURCES:

Prices (P): National Marine Fisheries Service, Food Fish Market Review and Outlet, 1960-1976, Economic and Market Research Division, NOAA/NMFS, Washington, D. C. (See Appendix B).

Changes in Income (Y) and Price Index of Fish Meat and Poultry: Bureau of Labor Statistics, Index of Annual Prices, 1960-1976, Washington D. C. (Appendix B).

NOTES:

(Y) Changes in income: estimates median income for the head of a family deflated by the consumer price index (1967=100).

(Q) Variation of quantity demanded is based on retail sales of each species.

(P_s) Changes in the price of substitute goods is measured by the change in the price index of fish, meat and poultry (1967=100).

The equations estimated and shown in Fig. 10 assumed that the regression satisfied the ideal conditions of the single equation ordinary least squares model. The regression coefficients were assumed linear in the parameters. The linear functional forms employed in Fig. 10 may have oversimplified the relationship between price and its explainors; however, alternative specifications of functional forms with more complex polynomials produced insignificant coefficients and coefficient signs inconsistent with the price analysis in the beginning of this chapter. The equations in Fig. 10 measured demand for processed and canned tuna, perch, cod, salmon, and sardines at the retail level. Based on the economic analysis at the beginning of this chapter and the equations estimated in Fig. 10, the demand flexibility of canned and frozen fish could be measured. (See Table 2)

Flexibilities were estimated in Table 2 by normalizing the change in the independent variable and measuring change in the dependent variables as a percent of change in the independent variable. Price flexibility measures the change in price as a percent of quantity of each species supplied. Income flexibility measures relative changes in price in response to changes in consumer's income. Substitute price flexibility measured the percentage change in price of each species in response to a one percent change in the price of a competing substitute product. For example, a one percent increase in consumer income resulted in a nine percent increase in price of cod (see Table 2).

This work is not the first to measure demand for fish, but, the equations in Fig. 10 and coefficients in Table 2 were unique in analyzing the flexibilities by type of product (e.g. canned, frozen). The regression estimates were consistent with estimates presented in other studies. George and King published widely recognized estimates in 1969, which still stand as reliable bases for estimating price response for fish in general.[1]

TABLE 2

ESTIMATES OF DEMAND ELASTICITY FOR FIVE SPECIES OF FOOD FISH BASED ON ORDINARY LEAST SQUARES ESTIMATES OF COEFFICIENTS OF A PRICE DEPENDENT EQUATION

	Processed Frozen Fish		Canned Fish Inferior Good	Canned Fish Normal Good	
	Cod	Ocean Perch	Sardines	Salmon	Tuna
flexibility of income	.97	.821	1.019	.51	.228
flexibility of quantity	1.9	1.345	.508	.17	.122
cross price flexibility	.97	.100	.66	2.12	.347

Elasticity estimates for fish and principal meat alternatives resulting from the George and King study were charted in Table 3.[2] Estimates by Waugh and Norton[3], Bell[4], and those derived in Chapter 3 indicated a wide range of opinion on the size of these relative measures. Table 3 would give some perspective to the estimates provided in Table 2 by comparing responsiveness of demand for meat (beef, veal, pork, lamb/mutton and chicken) fish in general, cod, perch, sardines, salmon and tuna as estimated in previous research.

In price dependent equations, relative changes in independent variables were expressed as flexibilities rather than elasticities. Inverting the income flexibility coefficient would not always produce elasticity estimates since quantity demanded would not always be determined by the same influences as price. Flexibilities and elasticities are included in Table 3. Flexibilities are indicated by parenthesis ( ). The implications of flexibilities were the same as those of elasticities except that the signs were reversed. Table 3 showed cod and perch were inflexible

TABLE 3

ESTIMATES OF ELASTICITY & (FLEXIBILITY) OF FISH AND FISH SUBSTITUTES

		FISH	COD	PERCH	SARDINES	SALMON	TUNA	BEEF	VEAL	PORK	LAMB/MUTTON	CHICKEN
INCOME ELASTICITY	MARASCO[1]	.23	.04				1.17	.29	.59	.13	.57	.17
	George & King[2]											
	Tomek & Cochrane[3]											
	Nilsson	.02	(.09)	(.821)	(1.019)	(.51)	(.228)					
	Waugh/Norton[4]	.02	.366		1.15							
	Bell[5]	3.15										
	NMFS[6]				.98	1.30	.7					
	Ag Canada[7]	.2173						.5057	.515	.1325	.676	.149
SUBSTITUTE PRICE ELASTICITY	George & King	.013						.29	.59			
	Nilsson	(1.9)	(1.345)	(.508)	(.17)	(.122)						
	Waugh/Norton	.47										
	Bell	5.48										
	NMFS					.29						
	Ag Canada	.289						-.629	.685	.176	.899	.198
PRICE ELASTICITY	George & King	-.23					-1.7	-.29	-.59			
	Raukinar & Purcella[8]	-.65						-.64		-.75		-.77
	Nilsson		-(.97)	-(.1)	-(.66)	-(2.12)	-(.347)					
	Waugh/Norton			-(.098)		-.5						
	Bell		-.1									
	NMFS			-.29	-1.62	-1.21						
	Brandow[10]	-.65					-.64		-.75		-.77	
	Ag Canada		-.7929				-.5057	-2.593	-.9547	-1.866	-.563	

SOURCES: *

1. Richard Marasco, "Food From The Sea: An Economic Perspective of the Seafood Market", American Journal of Agriculture Economics (Dec. 1974): 202.

2. P.S. George, G.A. King, "Consumer Demand for Food Commodities in the U.S. and Projections for 1980, Giannini Foundation, Monograph 26, Univ. of Calif., Div. of Ag. Sciences (1971): 21.

3. Tomek and Cochrane "Long Run Demand: A Concept, and Elasticity Estimates for Meats", Journal of Farm Economics, Vol 44 (1963): 56

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*Sources continued at end of Chapter.

with respect to income and price. Yet cod and perch prices were sensitive to changes in the price of near substitutes. Sardine prices were slightly sensitive to changes in income but were generally impervious to fluctuations in real income or the price of substitutes.

Tuna, sardines, and salmon were studied as being typical of canned fish products. Though neither species resembles the other in organaleptic characteristics, they shared low price flexibility and minimal response to the change in the price of near substitutes. The analyses showed further that salmon prices would not fluctuate significantly with changes in consumer income. The high income flexibility with regard to salmon was consistent with salmon's image as a luxury species. Moreover, salmon prices dropped commensurately more than prices of other species for the given change in quantity demanded. Tuna prices were shown to remain stable in the face of dramatic changes in quantity demanded, income, and the price of its closest substitutes. In the absence of significant changes elsewhere in the economy, the change in fish prices in response to changes in consumer income, quantity demanded and the price of near substitutes would agree with Table 2 elasticity estimates.

Application of Analysis to Carp, Sucker, and Alewife

The physical substitutability and resemblance of carp, sucker and alewife is a separate question from the consumers' interest in substitute products. If claims by food scientists about the processing flexibility of carp, sucker and alewife are valid, producers could synthesize sufficient physical resemblance to gain acceptance as a reasonable substitute for tuna, salmon, sardines, cod or perch. From the foregoing analysis, it is possible to conclude that a consumer would be prepared to accept a processed cod or perch prototype (e.g., sucker fish stick) but generally unwilling to accept a canned tuna, salmon or sardine prototype (i.e., carp canned in oil, when the consumer desired sardines). The price insensitive sardine, tuna, or salmon consumer displayed little willingness to be wooed by substitutes such as carp, sucker, and alewife even if they were less expensive. Their insensitivity to a change in price of close substitutes indicated that a consumer desiring to buy a can of tuna for a tuna salad sandwich on rye, would not substitute for sucker salad on pumpernickel.

In contrast, the analysis showed a consumers' willingness to accept processed carp, alewife, or sucker substitute for processed cod and perch, measured by the high cross price flexibility of cod or perch reported in Table 3. A one percent reduction in the price of a processed frozen fish prototype lowered the amount consumers were prepared to pay for processed cod and perch. If the price of processed cod or perch was perfectly elastic for the individual consumer, a reduced price of near substitutes would transfer demand to the cod or perch prototype. Thus, if manufacturers and processors were able to process a competitive sucker, alewife, or carp fish stick; minced, seasoned, flavored, shaped and packaged as the perch or cod equivalents, the demand would be comparable.

Recent studies have experimented with processing and marketing of new products with unused species. Experiments with sucker demonstrated the wide range of tastes and sensory characteristics the raw product could assume.[5] An independent study on alewife concluded that these species could be processed in a manner which would give them the taste, appearance, and smell of canned sardines.[6] Despite marketing problems likely to confront attempts to substitute another species for canned sardines, the sardine/alewife study indicated processing alewife could be profitable. In a recent study at Michigan State University, consumers' expectations were surveyed in regard to the characteristics recognized in hotdogs. Sucker was then minced, flavored, colored, seasoned, and shaped in a product that reflected these attributes. Many survey respondents were reported satisfied with these products.[7]

The development of marketable products is indeed in its infant stages. It is beyond the scope of this paper to analyze the economic feasibility of subsequent substitution, processing and marketing of new products. This analysis does, however, give the processors and developers an idea of where the demand will be and direct their efforts toward substitution in the frozen processed markets, rather than trying to displace the popular canned tuna, sardine, and salmon market.

Limitations on the Conclusions Derived from the Theory of Consumer Demand

The assumptions of perfect knowledge, the negatively sloped non-intersecting convex utility curves (Fig. 9, p. 26) were critical to the validity of the conclusions on the consumers' willingness to purchase goods with substituted species. It was assumed that the marginal rate of substitution of carp, sucker and alewife for popular species was greater than the average rate of substitution of commodities in the index of fish, meat and poultry for popular ocean species. The validity of such an assumption would depend largely on the calibre of the product developed from carp, sucker, and alewife. If this assumption held , it could be inferred that the marginal rate of substitution of carp, sucker and alewife for fish, meat and poultry was greater than 1. The analysis did not imply that consumers could not taste the difference between products. Rather it was asserted that at a given price consumers could be made equally well off by reducing the quantity of meat, poultry and high value species of fish and increasing the quantity of substitute goods consumed until their marginal rates of substitution were equated.

The analysis in Chapter III concluded that substitute goods produced from carp, sucker, and alewife could be used for processed and convenience type foods such as fish sticks and cakes, on the assumption that the alternative species were substitutable at a constant (though not necessarily equal to 1) marginal rate of substitution. The conclusion could falter on several levels. Processors willingness and capability to substitute is important to the successful employment of carp, sucker, and alewife. Prospective processors could be expected to closely scrutinize the supply, price, and location of the great lakes species in relation to comparative ocean species presently of little use. Ocean species such as pollock, whiting, and turbot, in abundant supply with relatively unrestricted harvests would be more logical substitutes. Pollock blocks, already widely accepted as a substitute for cod and ocean perch; would face fewer marketing difficulties and require far less processing before acceptance as fair substitutes.

The quantity of carp, alewife, and sucker has been severely limited by local restrictions on access and efficient harvesting techniques. The uncertainty of continued supply in light of the Native American's claims and the wide latitude of the Department of Natural Resources in limiting commercial fishing are particularly discouraging to prospective processors. The large cost of research and development of substitutable products for the comparatively few underused lake species and the cost of reviving Great Lakes fish production also mitigate against the development of carp, sucker, and alewife.

At the consumer level, it was necessary to assume that there will be no psychological resistance to the substitution of sucker, carp, and alewife for the more recognizable and appealing sounding names such as cod and perch. This assumption presumed no negative apriori consumer reactions to the thought of consuming sucker, alewife, and carp. The substitution of carp, sucker and alewife for popular species of fish or meat would also depend on the interpersonal demand which the above analysis did not provide. By separating universal and technical properties from personal preferences for each good, demand could be analyzed in terms of attributes of the product. By associating each good with a set of characteristics rather than a single characteristic, it would be possible to exploit physical resemblances or differences of new species. The degree of resemblance and whether the attribute would be material to consumers' preference for premium species determined demand for the species. Such an approach would be valuable in identifying those attributes or characteristics most commonly associated with improved quality and selecting new combinations of attributes appealing to producers and consumers. It would deemphasize previous overemphasis on the casual physical resemblance of sucker, carp, and alewife to other species. It would treat species and product substitution in a manner capable of recognizing diminishing utility of substitution by analyzing demand in terms of special preferences of individuals for different aspects of the product or species. Kelvin Lancaster of Columbia University developed a characteristic space approach that allowed separation of universal properties of demand for a good into product activity or species characteristics.[8] A detailed analysis of Lancaster was outside the scope of this paper, however, some aspects of his analysis could be applicable to this topic. Characteristic space analysis would give an indication of future direction of research and enrich the treatment of substitution between species in standard models of consumer demand. Analysis of substitution in terms of the characteristics substituted would allow more realistic representation of the manner in which consumers substitute one species for another and help identify those attributes which would have smaller price and income flexibilities and more clearly define those markets open to new products.

According to Lancaster's approach, fish attributes produced characteristics by variable transformation. The characteristics generated utility. By disaggregating species of fish into their respective characteristics, consumer purchases of the good could be separated into psychological and technical properties. Once product attributes were identified and disaggregated, analysis of characteristic space would allow a processor to analyze the demand and determine the price that consumers would be willing to pay for those characteristics. For example, if the chunkiness and flakiness of tuna were identified as desired characteristics, the characteristic space approach model could be used to assess the demand and price that consumers were willing to pay for "chunkiness" and "flakiness" as well as the profitability of certain combinations of these characteristics. Thus, if carp, alewife, or sucker were processed to imitate the optimal combination of chunk and flake, a new range of products could be introduced (e.g., chunk style fish gumbo).

A characteristic space approach was used in a recent study of the acceptability of a sucker hotdog.[9] There, it was shown that consumers were not as sensitive to substituted products (i.e., fish for beef in hotdogs) as to the inferior quality these products afforded in terms of preferential characteristics (plumpness and firm texture). Bold claims by food scientists suggest that these characteristics can be approximated when using carp, sucker, and alewife. Additional research examining the appealing characteristics of the presently unmarketed species would lend insight into future development of processed fish alternatives comprised of carp, sucker, and alewife.

Summary

Canned and frozen processed markets were the two alternatives considered for the future use of carp, alewife, and sucker. By use of the theory of consumer demand and a regression analysis, it was determined that a consumer would be more willing to accept a processed substitute in the form of a fish cake or fish stick than one canned in oil to approximate tuna, sardine, and salmon. Key limitations of the model were discussed, and the characteristic space approach was suggested as a follow-up model to be used to test substitutability of individual characteristics and minimize the limitations inherent in the theory of consumer demand.

FOOTNOTES

CHAPTER 3

[1]C.E. Ferguson and J.P. Goold, Microeconomic Theory, Rich D. Irwin Press, Homewood, Illinois (1975), p. 12-14.

[2]P.S. George and G.A. King, Consumer Demand for Food Commodities in the United States and Projections for the 1980 Giannini Foundation Monograph 26, University of California, Division of Ag. Sciences, (1975): 150.

[3]V. Norton and F. Waugh, Some Analysis of Fish Prices, U.S. Bureau of Commercial Fisheries, Division of Economic Research, Working Paper 10, (1969): 20, 21.

[4]Frederick W. Bell, "The Future of the World's Fishery Resources: Forecasts of Demand Supply and Price to the Year 2000 With A Discussion of Implications for Public Policy," U.S. National Marine Fisheries Service, Economic Research, File Manuscript 65 (Dec. 1970).

[5]A.E. Reynolds and L. Dawson, "Quarterly Progress Report to the Upper Great Lakes Regional Fisheries Commission," Unpublished material, East Lansing, Michigan (1976): p. 30-32.

[6]Swanson and Associates, "Investigation into the Feasibility of Producing Appetizers and Horsdoevres Using Carp and Alewife," Unpublished material, Swanson, Inc., Minneapolis, Minnesota (1975): 20.

[7]Herral, Bennenson, Anderson & Nilsson, "Multi-dimensional Scaling Applied to Developmental New Minced Products," Unpublished Monograph, Michigan State University, East Lansing Michigan, (July, 1976).

[8]Lancaster, Kelvin, Consumer Demand A New Approach, Columbia University Press, London (1971), Chapters 1-4.

[9]Herral, Benneson, Anderson & Nilsson, "Multi-dimensional Scaling", (July, 1976).

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*SOURCES continued from page 30:

4. F. Waugh and V. Norton "Some Analysis of Fish Prices", U.S. Bureau of Commercial Fisheries, Div. of Econ., Research Working Papers, No. 10 (July 1969).

5. Frederick W. Bell, "The Future of the World's Fishery Resources: Forecasts of Demand, Supply and Price", National Marine Fisheries Service, File Manuscript 65 (Dec. 1970).

6. National Marine Fisheries Service "Basic Economic Indicators", CFS, NO. 6130, 6129, 6271, Washington, D. C. (1974).

7. Agriculture Canada, "Consumer Demand for Major Food Products in Canada", Economics Branch, Publication No. 76/2 (April, 1972).

8. Purcell, J. C. and J. Raukinar, "Analysis of Demand for Fish and Shelfish" Research Bulletin, Georgia Agriculture Experiment Station, No. 51 (Dec. 1971).

9. G. E. Brandow "Interrelationships Among Demands for Farm Products and Implications for Control of Market Supply", Penn. Agriculture Experimnet Station Bulletin, No. 680 (August 1961).

CHAPTER IV

USE OF CARP, SUCKER AND ALEWIFE IN MEAL, OIL AND SOLUBLES

Introduction

This chapter will discuss the use of carp, sucker, and alewife harvested from Michigan Great Lakes as a protein source for industrial meal, oil and solubles. Ocean fish have been the basis of fish meal, oil, and soluble production. Fish from Michigan waters have not been included in the market because of the abundant supply in coastal regions where manufacturing operations presently process fish meal. This chapter will examine the feasibility of introducing Michigan Great Lakes fish into the national market for fish meal and forecast the price likely to prevail in mid-1977. The price forecast was used to determine the feasibility of a local processing plant in Chapter V.

Alewife, carp and sucker could be valuable sources of protein for use in meal, and solubles. Fish meal and solubles are principally used as poultry and other livestock feed. Solubles are often added to fish meal, and most often used in hog starter rations. Fish oil can be used as a cooking oil as well as in protective coatings, linoleum, oil cloth, leather treatment, core oils, lubricants and grease, ore flotation agents, insecticidal compounds and fire retardants.[1] The processing of these species for the production of these products is highly technical and expensive relative to the price of raw inputs. Meal, oil, and solubles are jointly produced by an intricate series of processes termed "wet processing" involving: drying, cooking, centrifuging, and dehydrating raw fish (Fig. 11). Wet processing, the least costly process for producing fish meal, is used by 80 percent of processors.[2] It involves extensive reduction in processing, large scale production, seasonal operation, and intense energy use.

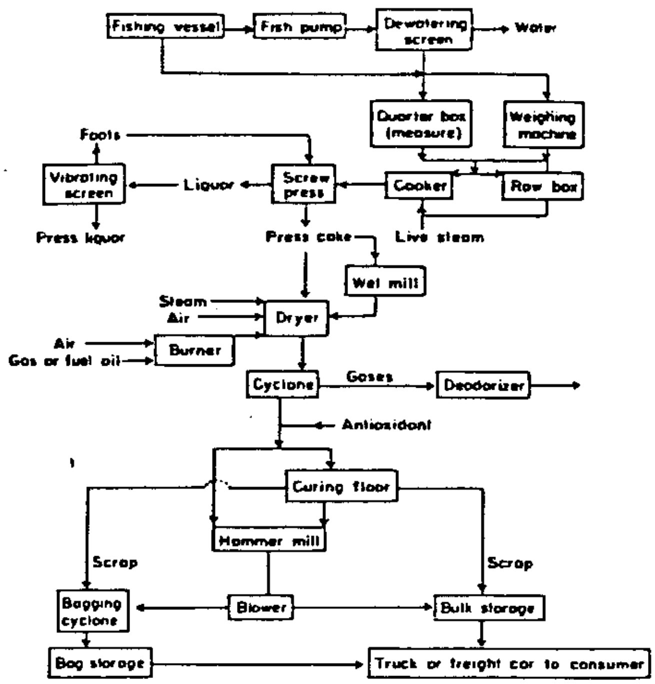

Fig. 11. Flow Diagram of Production of Fish Meal, Fish Scrap, and Press Liquor by the Wet-rendering Process.

SOURCE: Maurice Stansby, Industrial Fishing Technology (Krieger Publishing Co., Huntington N.Y., 1963): 235.

Profitable production by wet processing requires mass harvesting and bulk processing and handling techniques. Consequently the feasibility of a local manufacturing facility would depend on the availability of inexpensive raw inputs. More efficient harvesting techniques would be necessary before production of fish meal using carp, sucker and alewife could be profitable in Michigan.

Demand Analysis

Existing technology, quantity of livestock on feed and the price of alternative sources of protein (soybean meal, meat and bone meal) determined the price of protein for meal.[3] Table 4 shows the protein content of a variety of meal commodities.

TABLE 4

RELATIVE PROTEIN CONTENT OF DIFFERENT MEAL FORMS

	Crude Protein %	Crude Fat %	Phosphorus %	Ash %	Lysine %	Methoinine %
Soybean Meal	44	0.5	0.6	6.0	2.7	0.6
Meat and Bonemeal	50	8.5	4.7	33.0	2.2	0.5
Fish Meals						
Menhadden	62	10.2	3.0	20.0	4.7	1.3
Anchovy	65	10.0	2.8	15.0	4.9	1.9
Alewife	66	12.8	2.9	14.6	5.5	1.9
Fish Solubles (50% Solids)	31	4.0	0.5	10.0	1.5	0.5

SOURCE: Harcourt, Bruce, Javonovich, Feedstuffs, 1975 Year Book Issue, New York, (Sept. 19, 1975): 32.

Soybean is the primary source of protein used in meal and the chief substitute for fish. Fish and soy are used for feed according to their relative costs. In 1975, soy concentrates, which were 70 percent protein, ranged in price between \$.20-\$.26 per pound. Soy isolates (88 percent-90 percent protein) sold for \$.42-\$.50 per pound. This contrasted with the price of fish meal (65 percent protein) which ranged between \$203 and \$271 per short ton (10-14 cents per pound) in 1975 and 1976.[4] Fig. 12 showed the maximum amount users were willing to pay for three different forms of protein—50% soymeal, 44% soymeal and 60% fish meal. The fish meal analyzed was processed from menhadden. Menhadden, the primary specie harvested for industrial meal by coastal processors, was estimated to have approximately the same protein content as carp, sucker, and alewife.[5] Soybean prices increased according to protein concentration. Fish prices also increased relative to protein content, but at a faster rate (Fig. 12). Between 1950 and 1976 one ton of protein produced from 60% protein menhadden meal was more expensive than one ton of protein from 50% protein soymeal, (i.e., the price of 50% protein meal x 2 tons of meal per ton of protein was greater than the price of 60% protein x 1.538 tons of meal per ton of protein). Among high concentrate feeds, fish meal was less expensive than soybean meal, however soybean meal remained the primary source of protein for feed where less concentrated feed rations were tolerable.

Soybean meal (44% protein concentration) is the primary source of protein for livestock feed making it the chief substitute for fish meal.[6] The following regression used the price of 44% soymeal to estimate the future price of fish meal. The fish meal price (P) in June, 1977 was determined by the quantity of fish meal produced from menhadden (Q), the number of broiler placements during the period (C) and the relative monthly price of 44% protein soybean quoted between January 1974 and December 1976 (P_S).[7] The quantity of fish meal demanded in any month was assumed predetermined and equal to the quantity supplied.

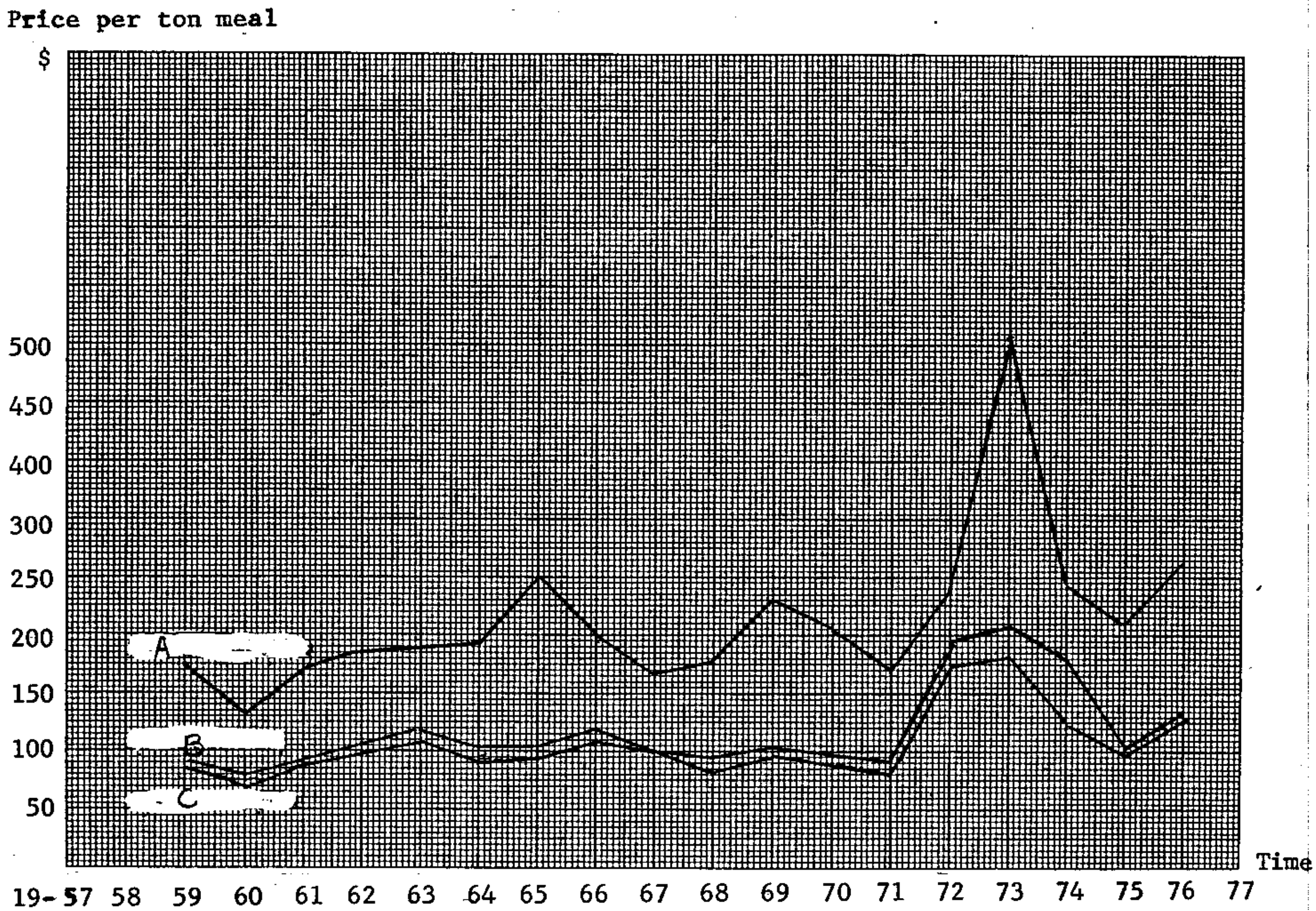

Fig. 12 Time Series Analysis of Fish and Soybean Meal Prices

SOURCE: U.S. Department of Agriculture, "Feed Grain Situation" Economic Research Service (1950 - 1975)

NOTES: Line A: Price of Menhaden Meal (60% Protein) P_{1972}=100

Line B: Price of Soybean Meal, F.O.B. Decatur Illinois, (50% Protein) P_{1972}=100

Line C: Price of Soybean Meal, F.O.B. Decatur, Illinois, (44% Protein) P_{1972}=100

The equation below explained 73% of the variation of price within the three year period between January, 1974 and December, 1976. It captured 24 of 36 turning points and provided the correct coefficient signs. Two of the three explainors (the price of soybean meal and the number of broiler placements) were statistically significant at the .10 level. More sophisticated model specifications (Polynomial Functional Forms and a Lag Models) were tested but resulted in inconsistent coefficients. A regression equation using annual data was also examined.[8] Annual estimates requiring the forecast of only one period beyond the time series did not require extrapolation of the data six period into the future as was required in the monthly regression forecast. However, the shifting supply occurring over the longer period made it unrealistic to assume that quantity was predetermined, as assumed by a price dependent equation.[9]

$$P_{Fishmeal} = \underset{(.519)}{.583} - \underset{(.103)}{1.80Q} = \underset{(90.5)}{260.1P_s} + \underset{(.2738)}{.7C} + e \qquad \bar{R}^2 = .73$$

Q = Quantity Fish Meal
C = Broiler Placements
P_s = Price of substitute meal (44% soybean meal)
P = Price of Fish meal substitute (1972=100), F.O.B. Coastal Port

NOTE: Feed for broilers is the primary market for fish meal.

To predict price of fish meal in 1977, quantity of broilers placed and quantity of meal demanded in June, 1976 were raised by five precent to account for meal industry growth.[10] These trend estimates and the relative price of soybeans were inserted into the regression equation. The price forecast for fish meal in mid-1977 was $205.85 per short ton.[11] The relative price ratio of fish oil to fish meal was static (1.74 = price of fish oil/price of fish meal). Assuming technology was constant and conditions of the forecast were accurate, the price of fish oil was estimated to average $360.00 per short ton in the same period.[12] Solubles produced in the manufacturing of fish meal faced a smaller market. Price quotations reflected a smaller precentage of the total solubles marketed. The price ratio of meal to solubles between January 1974 and December 1975 ranged between 2.71 and 3.86 and averaged 3.29. Under the assumption that the price ratio would remain constant, the price of solubles was estimated at $62.56 per short ton in 1977.[13] It should be noted that the price estimates from the regression were calculated from recorded prices "F.O.B. Coastal U.S. Ports". Prices paid by farmers and other users of fish meal, oil and soluble in Michigan would be considerably higher by an amount equal to shipping and handling costs. Estimates of the effect of transportation costs on local prices are discussed in Chapter 5.

Summary

The market for fish meal and oil was sufficiently large to accommodate any foreseeable increase in meal and oil from the great lakes. The price of meal produced from carp, sucker, or alewife would not differ significantly from that of other species. As long as the supply of meal was predetermined within any month, the price of carp, sucker, and alewife for the processor of meal in Michigan would depend on the relative price of soybeans and broiler placements. The ample production of beans in Michigan was sufficiently large in 1977 to accommodate the existing local poultry producers. Production of meal in Michigan would depend on specialized local needs for a high concentrate feed. The feasibility of producing meal for the local market from carp, sucker, and alewife in 1977 would obviously require production at a cost below the price forecast for June of 1977, plus some transportation charge. However, the exogenous factors of demand and the assumptions of constant technology, ready substitution of fish meal and growth in the broiler industry were equally critical to utilization of carp, sucker, and alewife in fish meal and oil.

FOOTNOTES

CHAPTER IV

[1]See Maurice Stansby, Industrial Fishery Technology (Krieger Publishing Co., Huntington, N.Y., 1963), pp. 1214 and United States Department of Agriculture, "Vegetable Oil Situation, 1976 Annual Summary", (Washington, D. C. 1976), pp. 10-15.

[2]Maurice Stansby, Industrial Fishery Technology, pp. 233-245.

[3]The demand for oil depends on the price and availability of substitutes. The Department of Agriculture in the publication "Vegetable Oil Situation" outline the principle substitutes: vegetable oils (olive, corn, safflower, soybean, peanut, and palm, dominating 63 percent of the market); lard and animal oils (butter, lard, and tallow shortening, dominating 30 percent of the market); cottonseed, and imported substitutes (such as: palm, coconut, and caster oils) representing 7 percent of the market.

[4]National Marine Fisheries Service "Industrial Fishery Products", Marketing Economic and Marketing Research Division, Current Economic Analysis NOAA/NMFS, Washington, D.C. (1975): 20.

[5]David Stuiber, "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes", unpublished, University of Wisconsin Sea Grant Program, (1975) pp. 30.

[6]National Marine Fisheries Service, "Industrial Fishery Products", Marketing Economic and Marketing Research Division, Current Economic Analysis, NOAA/WMFS, Washington, D. C. (1975): 4.

[7]See Appendix C.9 and C.10.

[8]See Appendix C.6, C.7 and C.8.

[9]Frederick Bell, "The Future of the World's Fishery Resources", pp. 56-57.

[10]See Appendix C.5.

[11]See Appendix C.5.

[12]See Appendix C.5.

CHAPTER V

ANALYSIS OF A LOCAL MANUFACTURING FACILITY FOR THE PRODUCTION OF FISH MEAL, OIL AND SOLUBLES

Introduction

The feasibility of a local manufacturing facility to process carp, sucker and alewife found in the Michigan Great Lakes into industrial meal, oil and solubles would be dependent on the price of these products, supply of these species and the production costs of the manufacturing facility. Chapter IV forecasted the price of fish meal to be $205.85 per short ton in mid 1977, the price of oil to average $360 per short ton, and the price of solubles to reach $62.56 per short ton. Profitable processing of carp, sucker and alewife into meal, oil and solubles, by "wet processing" methods discussed in Chapter IV, would depend on a continuous supply of these species. The following analysis assumed that more efficient harvesting techniques would be developed and incentives to catch previously unmarketed species would accompany a reevaluation of the restrictive regulations discussed in Chapter I. However, even with harvests equal to the optimum sustainable yield, discussed in Chapter II, the capacity of the plants considered in this chapter would necessitate harvests from other waters of the Great Lakes for profitable production. The optimum sustainable yield (OSY) of the Michigan waters of the three species was estimated by Wright in Chapter II to be 8.5 million pounds. Even the smallest profitable plant required harvests 65% greater than the optimum sustainable yield (OSY). The large capacity of the plants required for even marginally economic production could present the potential for recurrence of the over-harvest problems considered in Chapter I. Further study must be made to determine the quantity of various species available in the Great Lakes as a whole and a plan proposed for efficient but controlled harvest to avoid depletion.

Chapter V assesses the feasibility of a local manufacturing facility under the assumption that the price of meal and oil was $205.85 and $360.00 per ton as forecasted in Chapter IV. This analysis also assumes that the supply problems considered above and in Chapter II could be resolved. The following analysis focused on costs and the impact of changes in critical fixed and variable costs on the profitability of a facility located in a central port in Michigan.

Four different sized plants were examined in Appendix C. Profitability was measured in terms of plant output. The proposed plants would produce both fish meal and fish oil. Costs were measured in terms of tons of meal produced. Each ton of meal produced was jointly produced with .36 tons of fish oil. The joint product was termed meal/oil. The consistency of meal/oil was the same for all plants (i.e. Each ton of raw fish input produced .22 tons of meal and .08 tons of oil). Each ton of meal/oil produced required 4.5 tons of raw fish and was the equivalent of one ton of meal and .36 tons of oil.[1]

Cost estimates of producing meal/oil from fish meal and fish oil were obtained from a Wisconsin study and a Louisiana study which were pooled and updated to more accurately reflect the local conditions and industrial price index in Michigan in 1976. The estimated processing costs of inputs provided by these two studies and the output prices reported in the NMFS Outlook Summaries were the basis for the calculations determining the estimated fixed and variable costs and rate of return for the four alternative plant sizes.[2]

Processing costs and factor prices were assumed constant and linear homogeneous. Technology of industrial fish meal production and uses of industrial meal were assumed to remain constant. Meal processors were assumed to behave as profit maximizers. Because of the small anticipated contribution of the Michigan Lakes to the total fish meal supply, the industry supply curve was presumed to be predetermined at a fixed sustainable yield and market structure.

Presumably the institutional rigidities would not be severe and economic profits would encourage expanded production. The results would not generalize to the case where the proposed processing plant possessed a natural monopoly or where one fisherman leased the entire harvest from Michigan waters. Despite the large fixed cost requirements of production, processors were presumed willing to supply fish meal at the margin as long as their price exceeded the marginal cost of production.

According to the theory of the perfectly competitive firm, Figure 13 estimated the quantity of fish meal/oil output necessary to maximize profit in plants II,III, and IV (Plant I's inefficiency made further analysis unnecessary). **In that case, maximum profit for each firm** would be obtained by producing that amount of fish meal (Q_o) where marginal cost equaled marginal revenue. The hypothesized processor in this case would not have enough information to anticipate the profit maximizing level of output. The available data estimated processing efficiency when each plant operated at 75 percent of plant capacity under the premise that marginal

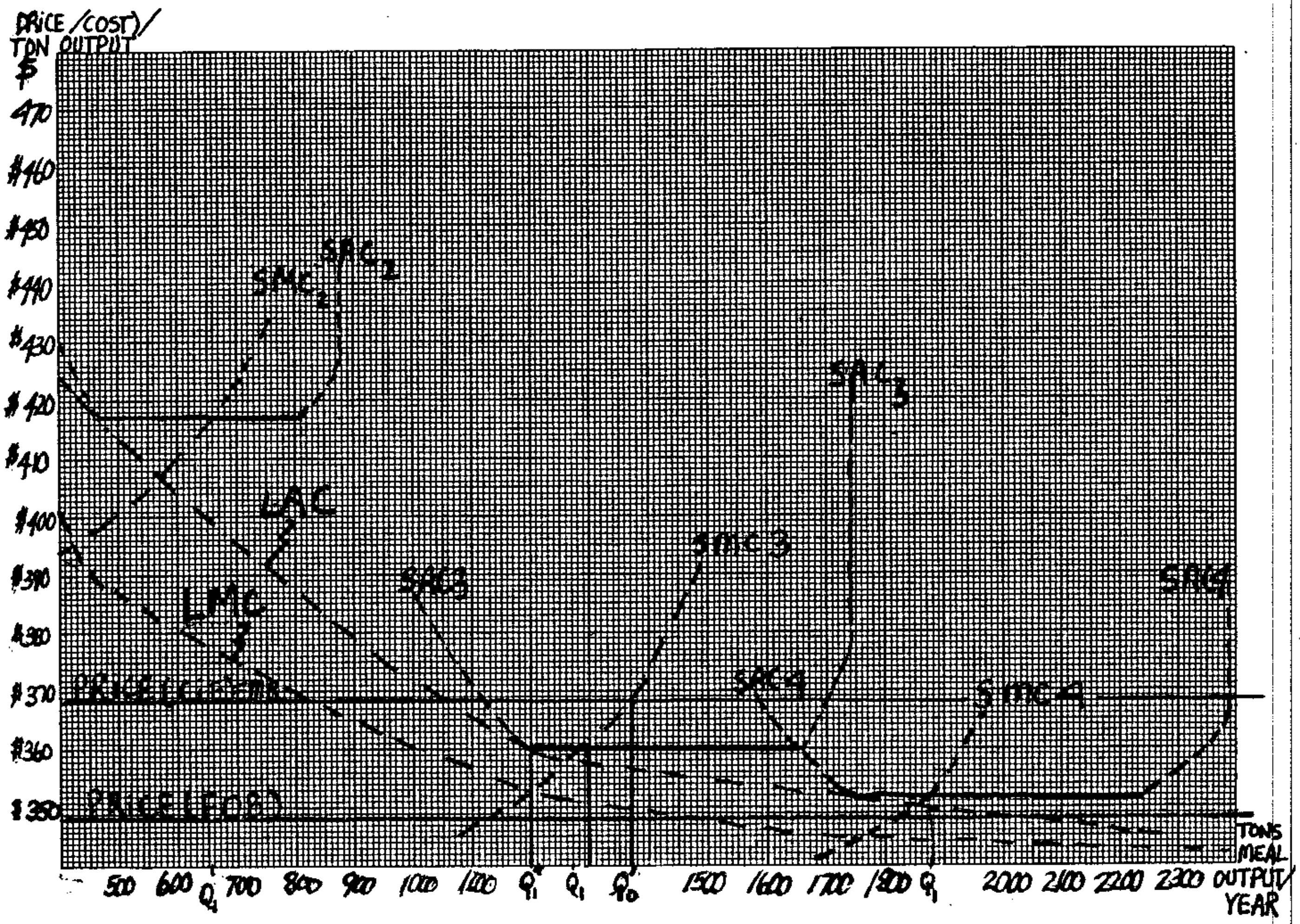

Fig. 13 Long Run Variable Cost Curve

Notes: SAC = the average cost of producing meal/oil; MR = marginal revenue per ton of meal/oil output (including .36 tons fish oil); long run average variable cost (LAC) = costs before plant construction, when all inputs are variable; SAC_2, SAC_3, SAC_4 = short run average variable costs for Plant II, Plant III, and Plant IV, respectively; SMC_1, SMC_2 and SMC_3 = short run marginal cost curve. The slope of the dotted cost curves (SAC) reflected the hypothesized diminishing productivity of different levels of output (less than 60% or greater than 90% of capacity). Q_1'' is the output level at which LMC = SMC and LAC is tangent to SAC_3; Q_1' is the output level at which SAC_3 equals SMC_3; Q_o' is the output level at which price (CIF) = SMC_3 = marginal revenue (MR). Price stated in 1972 dollars.

fluctuations from this level did not significantly alter costs. The processing estimates were consistent with the yield efficiency used to determine the revenue from a ton of processed output. As long as price exceeded average variable cost, the processor profited. From available data, the level of output at which marginal cost equaled marginal revenue and price was indeterminate. However, variable cost would equal marginal cost when average variable cost was at a minimum. At output (Q_1'), variable cost equals the cost of producing each subsequent unit of meal/oil and understates the optimal meal production. Figure 13 indicated the difference between price and cost when processors will produce (Q_1'). Profit maximization would involve producing (Q_o). Once the plant was in operation, the inferiority of (Q_1') would be obvious. Sub optimal production would unnecessarily dampen plant profits during the process of adjustment since the plants would not be operated at optimum levels. If price equaled marginal revenue and marginal cost, as it would at (Q_1'), the price mechanism would offer no economic incentive to change production levels. If profit from the last unit produced was calculated based on marginal cost, the profitability and output of each size plant could be increased by producing at (Q_o) rather than (Q_1').

Once the plant was constructed the manufacturers would choose that output level which equates the particular short run marginal cost (SMC) with price. Output (Q_1') would maximize the difference between price and variable cost. (Q_1') would also maximize profit under fixed productivity while (Q_o) would maximize profit under conditions of variable productivity. Given the existing information, a fish meal processor would automatically produce (Q_1'), but might not reach output(Q_o). Whether production would reach (Q_o) would depend on the processors' efficiency in operation and knowledge of costs. According to Fig. 13 and the calculations in Appendix C all of the plants considered were at best only marginally profitable. However, varying critical fixed and variable costs in a sensitivity analysis significantly changed the profitability of the plants considered.

Sensitivity Analysis

The impact of changes in technology and costs and price of critical outputs on the profitability of Plant III were studied in Appendix D by means of a sensitivity analysis. Plant III was selected as the optimal size for a local facility on the basis of processing capacity and profitability.[3] Plant III could process 6187.5 tons of input per year into 1314 tons of meal and 884 tons of oil while operating 150 days a year at 75 percent of its capacity. Plant III provided a profit of $3.49 per ton of meal output based on mid 1977 price estimates.[4] Plant IV, though more profitable, processing 8500 tons of raw fish input per year at a profit of $4.86 per ton of meal, required 126% more raw fish than the optimum sustainable yield.[5] Plant III's capacity required only 65% more raw fish than the optimum sustainable yield of the Michigan waters of the Great Lakes.[6] Plants I and II would process 1485 tons and 3094 tons respectively at a loss of $303.30 and $108.72 per ton of fish meal output.[7]

The profitability of one ton of meal output produced in Plant III was examined to determine the effect of varying variable costs (hourly wages, maintenance, raw input costs - $30 to $50 a ton, fish prices - $20 to $50 a ton, fuel prices and transportation costs) and fixed costs (plant life - 1 to 20 years, contruction - $300,000 to $500,000 and interest rate of - 8 percent to 16 percent).[8] Further analysis was done to study the impact of changes in meal and oil processing efficiency, and the effect of the emergence of a profitable soluble market on the rate of return.[9] When construction costs increased $100,000, the profit on total investment decreased from less than 1 percent to 1.6 percent.[10] Interest rates of 6 percent on a long term note for the facility instead of 8 percent, increased return an additional 3 percent.[11] The sensitivity analysis showed further that wages influenced variable cost of production. With three workers employed, a $1/hr. wage increase would only change the price of Plant III output by .7 percent.[12] If maintenance costs increased $5000 over the levels assumed in the initial cost estimates of Plant III, the profit on the sales price of one ton would decline 1 percent.[13] A $.20 per gallon increase in fuel oil prices would lower profit on processing cost per unit of sales by 1.8 percent.[14]

The savings in transportation costs afforded by a local facility also had a significant impact on the feasibility of a fish meal plant in Michigan. NMFS price quotes used in the previous analysis were reported F.O.B. The price premium of fish meal in Michigan was attributable to the transportation cost savings from a local source of supply over a coastal source of supply. Freight rates vary significantly by mode, route, cargo distance, and volume of traffic.[15] The total annual savings from locally manufacturing meal in Michigan would increase with alternative modes and different levels of traffic and vary by location. According to industry sources, approximately 33 percent of fish meal travelled by rail and 66 percent by truck in 1975.[16] The savings associated with avoiding shipping costs from the east coast by processing Michigan Great Lakes species in a centrally located manufacturing facility was $27,000 per year by rail (using fully allocated costs, 1,500 mile shipping distance, 1000 pound lots). The transportation savings or price discount associated with a local source of supply when meal was trucked was $89.91 per ton for 1500 mile shipments and $79.11 per ton for 1200 mile shipments.[17] The price of one ton of meal/oil in Michigan was $19.00 per short ton higher than the F.O.B. price at a coastal port. A $10 increase in shipping costs from the coast would increase profit per ton of output by 3.2 percent.[18]

To determine the effect of changes in meal and oil processing productivity on rate of return the analysis in Appendix D varied the percent of fish reduced to oil from 19 percent to 25 percent. This caused profit to range from -13 percent to +9.5 percent. Variation in the oil yield from 3 percent to 10 percent altered profit per unit of output from -25 percent to 12.6 percent.[19] Fish solubles would be produced in the processing of fish meal and oil. Emergence of a stable solubles market was shown to alter profitability of plant investment. An active soluble market in Michigan, in which soluble revenue exceeded processing costs by $20, would increase the rate of return to a favorable 6.4%.[20] The emergence of a profitable soluble market showed the most positive effect on the feasibility of a great lakes plant of all alternatives considered in the sensitivity analysis. However, since only isolated markets exist for solubles their reclamation cost or efficiency would have to be improved before investors could depend on profitable soluble production.

Changes in the price of raw fish significantly altered profits per ton. If raw fish were purchased for $20 per ton, profit would increase 27 percent per ton. If processors could not buy fish for less than $50 per ton, they would lose 11.6 percent on each ton sold.[21] The impact of less expensive harvests on the plants break-even level of output and long run equilibrium was shown in Fig. 14.

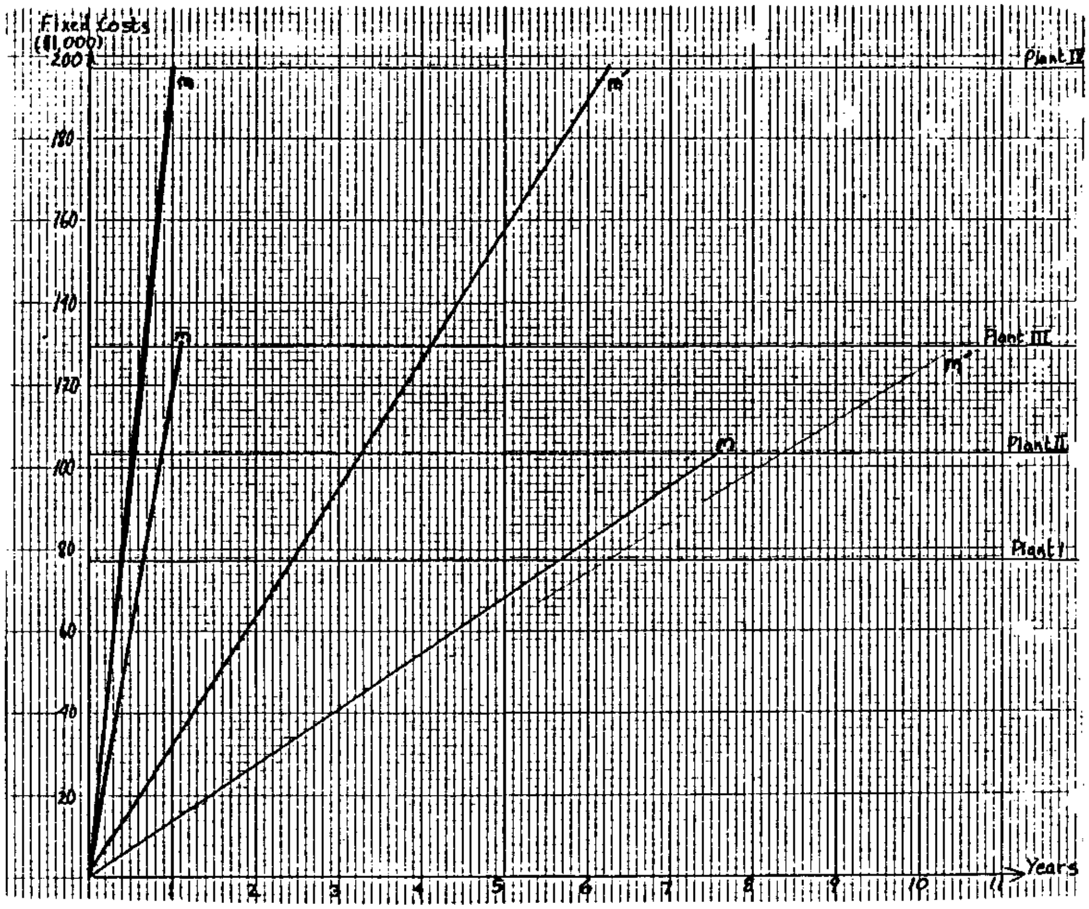

Fig 14 Estimated Breakeven Output for Plants I, II, III & IV

Note: Price-variable cost = margin (M and M^1); fixed cost/margin = output level and output level/output per year = number of years of operation necessary for plants to breakeven. Margin (M) based on $\hat{P}_{(CIF,\ 1977)}$ = \$448.60 with solubles market. Margin (M^1) based on $\hat{P}_{(CIF,\ 1977)}$ = \$368.95 with no solubles market. Plants with negative margins not shown.

Under present harvest regulations the estimated minimum harvest price for carp, sucker, and alewife ranged between \$.08 and \$.12 per pound.[22] This estimate would vary greatly with gear adaptations and fishermen's experience in harvesting the species. In any event profitable industrial meal production in Michigan would require a more competitive price. It was presumed that increased incentives to catch these previously unmarketed species would accompany a re-evaluation of restrictive regulations and the development of specialized gear adapted for the efficient harvest of carp, sucker, and alewife in Michigan.

The impact of changes in the price of substitutes was the last factor studied in the sensitivity analysis. Small changes in the price of substitute meals, especially soybean meal, significantly improved profit prospects of Plant III. According to the monthly price equation in Chapter IV, the mean cross price flexibility of soybean meal was 1.156. Thus a 1 percent increase in the price of 1976 December soybean meal would increase fish meal prices (1.156 * 169.2 = \$1.95/ton or 1.15%).

$\left(\frac{\overline{P}_s}{\overline{P}} \times \frac{\Delta P}{\Delta P_s} = \frac{139.2}{312.87} \times \frac{2.60}{.01}\right)$ A 10 percent increase in soybean meal prices would increase meal prices \$19.50 and increase the profit on a ton of meal/oil to \$28.87, 7.66 percent over f.o.b. cost of production in Plant III. To increase profits to 10 percent of processing costs, the price of fish meal/oil would have to reach \$415.91/ton in Michigan. A meal/oil price of \$415.91 implies a fish meal price of \$244.139. Fish prices reached this level in February of 1974 when fish meal prices were \$452.20/ton (\$160.00/ton in 1972 dollars). According to the monthly price equation in Chapter IV on page 45 soy price would have to increase 38.2 percent (up to \$233.22/ton) from their November 1977 level (\$169.62/ton), held constant, to raise fish meal/oil prices to \$415.92 per ton.

Summary

According to the price forecast for 1977, profit per ton of meal/oil produced in Plant III would equal to $4.86. At this price, production in Plants I and II would fail while Plants III and IV would be marginal. Plant III was the most promising of the four plants considered. While Plant III profitability varied significantly with the price of fish harvested and the percentage of meal obtained per ton of fish, exogenous factors were more critical and more likely to affect profitability. The existence of a solubles market, changes in soybean prices and the price of meal/oil were particularly critical. If compensation for risk required a return of 10 percent on the total investment per year, conditions in substitute markets would have to be more favorable. For Plant III to increase revenue 10 percent over costs, soybean meal prices would have to reach $239.12. While the price of soy meal remains too low to attract capital under present processing technology, profitable meal production from Great Lakes fish could be achieved by stabilizing the local fish solubles market or striving to process meal at more efficient levels.

FOOTNOTES

CHAPTER V

[1]Appendix C, Table C.2

[2]David Stuiber, "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes," unpublished report, University of Wisconsin Sea Grant Program (1975):41-43 and J. Lea and E. Roy, "Economic Feasibility of Processing Groundfish from the Gulf of Mexico" DAE Research Report, No. 502, Louisiana State University, (May 1976):10-12

[3]Appendix D

[4]Appendix C, Table C.5

[5]Appendix C, Table C.4

[6]Appendix C, Table C.4

[7]Appendix C, Table C.4

[8]Appendix D, Table D.2

[9]Appendix C, Tables D.3 and D.4

[10]Appendix D, Table D.2

[11]Appendix D, Table D.2

[12]Appendix D, Table D.1

[13]Appendix D, Table D.1

[14]Appendix D, Table D.1

[15]Interstate Commerce Commission, "Railroad Car Cost Sales 1975," Bureau of Accounts Statement ICI-75, Washington D.C. (1975):14-16

[16]Tannenbaum, Shillings and Scrimshaw, The Economics of Fish Protein Concentrates, (MIT Press, Cambridge, Massachusetts, 1974): 222-225

[17]Appendix D, Table D.1

[18]Interstate Commerce Commission, "Cost of Transporting Freight by Class I and Class II Motor Common Carriers of General Commodities, Statement No. ZCI-75, Washington, D.C. (December 1976)

[19]Appendix D, Table D.4

[20]Appendix D, Table D.4

[21]Appendix D, Table D.1

[22]David Stuiber, Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes: (unpublished) University of Wisconsin Sea Grant Program, Chapter 2

CHAPTER VI

The critical historical events summarized in Chapter I shaped the problem and accentuated the urgency for research on the utilization of unused species of fish in the Michigan Great Lakes. The history of over-harvest, decline of quantity of high value species, restrictive legislation limiting entry of new fishermen, controlled access to designated waters and species and gear restrictions have led to a substantial decline of great lakes commercial fishing. Many fishermen have been forced out of the industry and remaining fishermen are hampered by lost access to traditional species and low productivity of authorized harvest methods. Survival, revitalization and growth of the great lakes fishery is dependent on a re-evaluation of the scope and breadth of existing legislation and the exploration of ways to diversify the fishery. The history of the Michigan Great Lakes described in Chapter I suggested the complexity of lake resource management. The construction of the seaway, the dumping of industrial wastes and land run off, the treatment of native American fishing rights and the establishment of the sports fishery exemplify the frailty of resource planning tools and testify to the sensitivity of different interests to conflicting uses.

The history of the lakes was developed as background for the introduction of the economic model in Chapter II. The bioeconomic model of a renewable resource introduced a systematic approach for establishing limits on fishing. The simplicity of the model was justified by the narrow scope of its use: the study of the inter-relation of the cost of harvest effort and its impact on the continuous supply of fish. The model served as the intuitive basis for Wrights, estimates of sustainable yield of Michigan Great Lakes carp sucker and alewife (8,500 tons/year). Provided that this estimate approximates maximum economic yield it would be possible to weigh claims of sporting commercial and native American fishermen for the lakes resources. This maximum economic yield estimate was also used in Chapter V to estimate the continuously available supply of carp sucker and alewife available for product development.

Alternative markets for carp sucker and alewife were examined. The acceptance of carp, sucker and alewife as food fish in canned, processed or minced for was examined. The wide variety of factors affecting demand for food fish made it difficult to determine the feasibility of a specific new food fish product. Even if Wright's estimate of the continuously available supply and the elasticities are accurate, the complexities of marketing would require a separate study, provided with survey as well as historic time series data.

The potential demand for these species as food fish was developed with the theory of consumer behavior. Demand for the hypothesized carp sucker and/or alewife product was studied by analyzing demand response of ocean species (cod, perch, tuna, salmon and sardines-species whose attributes might be duplicated in a new product) to changes in price quantity; income and the price of substitute goods. A new frozen convenience product appeared most likely to succeed within conventional channels of fish products. The likelihood of success of a food fish product appeared less dependent on cost but particularly sensitive to consistent dependable quality. While the frozen, processed convenience-type foods displayed the most promise for species substitution it cannot be presumed infinite for species not previously tested. Consumers have been generally disinterested in substituting a different species of canned fish for the sake of small savings from purchasing a substitute species.

The inherent limitations in the model and consequent qualifications on its conclusions were discussed in the latter portion of Chapter III. The "characteristic space" approach was suggested as a useful model for more in-depth study of demand for the particular characteristics of substitute species. Future research into demand for new fish products would require measurement of preferences for product characteristics, by species, to effectively position fish with the appropriate market segment.

The feasibility of carp sucker and alewife in industrial meal and oil production was discussed in Chapter IV. By using sucker carp and alewife as livestock feed it would be possible to exploit their high protein content. These species have not been commercially processed as fish meal oil or solubles at the present price due to the cost of processing the unreliable source of supply and the less developed technology of smaller scale processing.

A soybean meal is the principal substitute for fish meal in livestock feeds. Its flexibility in a variety of uses and its lower price in less intensive protein concentrations make it preferable to fish meal for most uses. Chapter IV forecasted the market outlook for demand for fish meal by projecting time and present price relationships of fish relative to soybeans into the future. The resulting CIF price forecast for 1978 ($368.95/ton of fish/meal) was used to assess the profitability of fish meal plant in Chapter V.

Chapter V calculated the impact of changes in variable cost on the feasibility of meal production from great lakes species. It was determined that a local facility could be marginally profitable if the CIF price of fish meal reached $368.95 per short ton in 1978 as forecast by the demand equation of Chapter IV. A study of the influences of cost in the hypothesized plant showed profits extremely sensitive to changes in harvesting and processing efficiency (eg % of oil and meal obtained per raw ton of input).

The narrow feasibility of the fishmeal plant discussed in Chapter V ($9.37 per short ton of fish meal/oil output) would depend on the validity of the estimates of costs for the four plants considered. Furthermore the price of other protein feeds could also impose non-marginal price changes on the expected price of fish meal. In this case, soybean meal price offered a particularly interesting point of reference because of its reliability as a reference point and recent soybean price fluctuations. The steady growth in the number of broilers on feed also assure the fish meal industry of further increases in demand.

The relationship of changes in fish meal prices could be related in more detailed analysis to the price of soybeans. The narrow scope of this paper made it necessary to compare fish meal demand with soybean meal demand due to the more direct comparison and the active trading of soybean meal in commodity markets.

When soybean meal cross price elasticity was plugged in the profit-loss statement of the meal plant of Chapter V a 1% increase in the price of soybean meal was shown to improve the feasibility of the meal plant by raising fish meal prices by 1.15%. If soybean meal prices maintained a constant relationship to fish meal price a non-marginal increase in the price of soybean meal would raise fish meal prices 11.5% or $19.50 and materially improve the prospects for a Michigan fish meal plant. If soybean meal prices reached $233.22/ton in June 1977 while other factors in the demand for fish meal remained constant (i.e. broiler placements, soy:fish price ratio and quantity supplied) the equation predicted fish meal/oil prices would reach \$415.92 in June 1977 and produce a 10% profit margin. Whether this rate of return is sufficient to entice capital to rebuild the fishery depends on opportunity cost elsewhere in the economy.

The possibility of prices reaching 415.92 per ton in the near future makes local meal production worthy of further consideration. If soybean meal price increases in 1977 were accompanied by a 5% increase in broiler placements in 1977 the price of fish meal would increase an additional 4.09%. $\left(\frac{\$256.07}{\$312.87} * \frac{.7}{.05} = \frac{\overline{C}}{P_F} * \frac{\Delta P_F}{\Delta C} \right)$ In that case soybean meal prices would only have to reach \$223.45 per short ton in (1972 dollars) to produce a 10% profit over variable processing costs. If 10% return were sufficient to lure investment to meal prices, while the returns appeared fairly stable and variable costs were no higher than outlined in Appendix C, then fish meal and oil could be profitably produced from carp, sucker and alewife.

A re-evaluation of the existing restrictive regulations and limitation on productivity must accompany this effort. Efficient methods for harvesting must be developed and encouraged. It is imperative that the uncertainty connected with the regulations, limitations, and restrictions be addressed and remedied.

Fishermen in the Michigan Great Lakes who previously specialized in providing foodfish to consumers will have to diversify their fishing to survive. Carp, sucker and alewife exist in large numbers in the lake. By marketing these species as food fish, employing new food processing technology such as mincing or mixing fish with meat, fishermen can increase their chance for survival. In these forms carp, sucker and alewife are more qualified to compete with popular species processed in a similar manner. By developing a frozen food product made from carp, sucker and alewife, fishermen could reduce their dependence on eroding species.

Furthermore, harvest of food fish could be augmented by harvest of fish for meal production. There is a good possibility that the price of soybean meal will reach $223.45/short ton (1972 dollars) in the near future. This would open the Michigan Lake fishery to increased commercial fishing since it would raise the price of fish meal to a level which could justify plant construction.

If a plant were constructed the cost estimates of Appendix C could serve as rough estimates for production costs of fish meal and oil. Since the costs and technology were presumed linear in those cost estimates there is a good possibility that fishermen and processors could earn profits in excess of 10% on their investment. It is not unlikely that the efficiency of fish:oil conversion and harvest costs could also be improved with good management or that the relative price of more concentrated protein forms could increase significantly.

It is conceivable that industrial meal production, supplemental limited commercial fishing for traditional species, could further revive commercial fishing in the lake and provide employment for fishermen. If a fish meal plant were constructed it could furnish less expensive protein to local farmers and provide a ready source of oils to manufacturing. These benefits are mutually exclusive with goals of balancing the lake's species. More specific information on carp, sucker and alewife population and sound fishery management could allow both and prevent over fishing.

APPENDICES

APPENDIX A

Restricted Areas

MSA 13.1531 regulated the harvest of perch in the Northport Harbor. MSA 131541, subsequently repealed the restrictions on perch in Sutton Bay. The Attorney General interpreted the "Special Provision Regulating Fishing in Bay Areas" (MSA 13. 1531) as prohibiting nets of any kind to be set within 200 feet of the docks within the waters of the North Port Harbor (known as the North Port Bay) Op. Att. Gen. No. 0-4518, Sept. 25, 1946.

The combination of Public Acts of 1933,1935, No. 203; 1939, No.231; 1949 NO. 235; 1951, No. 194 designated specific prohibited areas, for example: MSA 13.1519 prohibted said gear in "the waters of Lake Superior within a radius of ½ mile from the Two Hearted River... Similar restrictions were placed on designated portions of Grand Traverse Bay (MSA 13.1542); Charlevoix Bay (MSA13.1542 (1); Saginaw and Tawas Bays (MSA 13.1544, repealed by P.A. 1945 No. 243); Marquette Bay (MSA 13.1546); Grand Marais Harbor (MSA 1546); False Presque Isle Bay and designated portions of Lake Huron (MSA 13.1547(1); Thunder Bay (MSA 13.1548); Whitney Bay (MSA 13.1549); Pike Bay and Island Harbor (MSA 13.1549(1); Straits of Mackinac (MSA 13.1550);Potagoniss Bay (upper lake huron) (MSA 13.1551(1); Little Traverse Bay (MSA 13.1552); Little Bay de Noquette (MSA 13.1553);Garden Bay(MSA 13.1553(1); Further restrictions on Little Bay de Noquette, Big Bay de Noquette and part of Green Bay (MSA 1553(2);L'Anse Bay (MSA 13.1554); Houghton Bounty, Portage Lake Ship Canal (MSA 13.1555; Duncan Bay(MSA 13.1558) and Munising and Murray Bays (MSA 13.1559)

This summary of restrictive legistation promulgated to regulate the catch of designated fish in designated areas is included to illustrate the expansiveness of the regulated areas over the last 20 years.

APPENDIX B

SUMMARY OF FOOD FISH PRICE DATA

CONTENTS

APPENDIX B

TABLE B.1

INCOME AND PRICE INDEXES, 1960-1971.

Year	Disposable Income In Constant 1972 Dollars	Consumer Price Index (1967=100)
1960	$35.01	$86.6
1961	36.29	89.6
1962	38.39	90.6
1963	40.28	91.7
1964	43.70	92.9
1965	47.22	94.5
1966	51.04	97.2
1967	54.45	100.0
1968	58.81	104.2
1969	63.04	109.8
1970	68.59	116.3
1971	74.28	121.3
1972	80.13	125.3
1973	90.17	133.1
1974	98.29	147.7
1975	108.09	161.2
1976	118.18	170.6

SOURCE: Department of Labor Statistics Basic Economic Indicators (BEI) CFS No. 6130, 6129, 6271 (1964, 1970, 1976) Washington, D.C.

TABLE B.2

SALMON FISHERY WHOLESALE AND RETAIL SALES DATA

Year	P_{pink}[1]	P_{red}[2]	Per Capita Consumption[3]	P_{retail}[4]	Q_{pink}[5]	Q_{red}[6]
1961	35.48	27.97	.9		1354	1442
1962	35.05	27.38	.7		1935	837
1963	36.05	24.04	.9		1956	606
1964	38.90	22.03	.7		1940	777
1965	38.65	23.40	.9		949	2041
1966	36.20	28.33	.8	.3126	2068	1385
1967	37.60	28.92	.7	.367	616	863
1968	31.99	40.31	.7	.342	1841	714
1969	31.28	42.64	.7	.352	1261	881
1970	32.65	43.19	.7	.361	1275	1831
1971	34.86	42.85	.7	.390	1251	1387
1972	40.01	51.08	.7	.450	609	660
1973	54.25	42.57	.4	.74	495	425
1974	70.97	55.42	.3	.786	464	419
1975	69.65	43.48	.4		543	501
1976	68.53	54.63	.4		1210	930

SOURCE: National Marine Fisheries Service "Food Fish Market Review and Outlook - Basic Economic Indicators" (1960, 1976) CFS No. 6130, 6129, 6271, NMFS/NOAA Washington, D.C.

[1]Wholesale Salmon Price per 48-1 lb. can deflated in 1972 dollars.

[2]Wholesale Salmon Price per 48-1 lb. can deflated in 1972 dollars.

[3]Per Capita Consumption—Pounds.

[4]Retail Price per $6\frac{1}{2}$ oz. can.

[5]Disappearance (100,000 cases) of Pink Salmon = production + exports - imports (pink salmon).

[6]Disappearance (100,000 cases) of Red Salmon = production + exports - imports (red salmon).

TABLE B.3

OCEAN PERCH, RETAIL SALES DATA

Year	P_r[1]	Q[2]
1961	$47.5	1.269
1962	50.0	1.385
1963	52.6	1.538
1964	52.8	1.740
1965	52.7	2.003
1966	54.1	2.147
1967	54.1	1.986
1968	53.9	2.526
1969	55.0	2.700
1970	63.2	2.985
1971	72.4	2.856
1972	76.8	3.435
1973	98.8	3.600
1974	108.1	2.734
1975	112.6	3.121
1976	140.9	3.993

SOURCE: National Marine Fisheries Service "Food Fish Market Review and Outlook - Basic Economic Indicators,"(1960, 1976) CFS No. 6130, 6129, 6271, NMFS/NOAA, Washington D.C.

NOTES: [1]Average Retail Price per pound of ocean perch 1960–1976.

[2]Total disappearance of frozen fish blocks stated in hundred million pounds.

TABLE B.4

COD RETAIL SALES DATA

Year	P_{cod}[1]	Q_{import}[2]	P_{cod}[3]	Q_{cod}[4]
1961	66.8	.5	38.2	1.269
1962	65.4	.3	46.3	1.385
1963	69.3	.4	46.0	1.538
1964	68.5	.2	42.1	1.740
1965	74.4	.3	46.8	2.003
1966	77.3	.4	48.0	2.147
1967	75.3	.4	49.9	1.986
1968	82.7	.9	57.7	2.526
1969	88.3	1.6	68.8	2.700
1970	101.2	1.2	74.3	2.985
1971	126.0	1.2	83.6	2.856
1972	134.3	1.9	106.0	3.435
1973	180.6	1.8	120.0	3.600
1974	195.7	1.5	127.8	2.734
1975	219.1	.4	146.7	3.121
1976	242.2	.6	151.3	3.993

SOURCE: National Marine Fisheries Service "Food Fish Market Review and Outlook - Basic Economic Indicators," 1960, 1976, CFS No. 6130, 6129, 6271, NMFS/NOAA Washington D.C.

NOTES: [1]Deflated price of fresh cod per pound in 1972 dollars, National Marine Fisheries Service, Food Fish Market Review and Outlook, 1960-1976, Economics and Marketing Division NOAA/NMFS, Washington D.C.

[2]Imports of cod (hundred million pounds).

[3]Retail price of frozen cod fillets per pound in 1972 dollars.

[4]Frozen block disappearance (hundred million pounds).

TABLE B.5

TUNA RETAIL SALES DATA

Year	Retail Tuna Price 1967 = 100 [1] P_{Tuna}	Wholesale Price of Private Labeled White Solid Tuna Canned [2]	Wholesale Price of Canned Advertised Light Chunk Tuna [3]	Total Supply Canned Tuna in Hundreds of Millions of Pounds [4] Q_{Tuna}
1960	$89.1	-----	-----	-----
1961	88.9	-----	-----	-----
1962	94.3	-----	-----	-----
1963	91.6	-----	-----	-----
1964	91.6	$13.00	$13.46	-----
1965	91.8	12.61	13.50	-----
1966	100.7	14.12	14.55	-----
1967	100.1	13.39	13.71	4.541
1968	99.1	14.05	14.24	4.631
1969	103.1	14.90	15.19	4.715
1970	115.4	18.20	17.01	5.099
1971	128.4	20.25	18.61	4.985
1972	133.0	21.59	19.42	6.763
1973	143.5	24.68	20.74	6.745
1974	168.1	28.45	24.25	7.131
1975	175.3	26.31	24.85	5.810
1976	-----	32.32	27.62	6.571

SOURCE: National Marine Fisheries Service "Food Fish Market Review and Outlook-Basic Economic Indicators,"(1960, 1976.) CFS No. 6130, 6129, 6271, NMFS/NOAA Washington D.C.

NOTES: [1]Retail Price of Tuna per pound.

[2]Wholesale price of private labeled tuna($ per case of 24 6½ oz. can).

[3]Wholesale price canned light chunk tuna($ per case of 24 6½ oz. can).

[4]Total quantity of tuna sold

TABLE B.6

SARDINE RETAIL SALES DATA

Year	Wholesale Price of Sardines ($/case)[1]	Retail Price of Sardines (cents per 3-3/4 oz.can)[2] P	Per Capita Consumption (in cans)[3] Q	Sardine Price Index 1967 = 100[4] $P_{sardine}$	Relative Price of Substitute Fish/Meat/Poultry 1967 = 100[5] P_s
1960	-----	----	.870	-----	$ 89.1
1961	-----	----	1.041	-----	89.3
1962	-----	----	.894	-----	91.5
1963	-----	----	.878	-----	90.1
1964	-----	----	.889	$86.5	88.7
1965	-----	----	.794	91.2	94.5
1966	$10.50	$14.2	.801	93.8	102.6
1967	11.56	15.1	.817	100.0	100.0
1968	12.25	16.1	.994	106.6	102.2
1969	12.31	16.5	.698	108.8	110.8
1970	14.07	17.4	.658	116.6	116.5
1971	15.96	20.4	.723	134.7	116.9
1972	16.84	22.1	1.067	147.3	128.0
1973	16.53	23.5	.907	162.4	160.4
1974	20.21	39.5	.943	197.5	169.2
1975	22.53	49.8	.571	235.3	178.1
1976	22.26	52.9	.788	-----	175.0

SOURCE: National Marine Fisheries Service , "Food Fish Market Review and Outlook-Basic Economic Indicators," 1960, 1976 CFS No. 6130, 6129, 6271, NMFS/NOAA Washington D.C.

NOTES: [1]Wholesale price of sardines($ per case of 24,3-3/4 oz. can).

[2]Retail price of sardines(cents per 3-3/4 oz. can).

[3]Per capita consumption number of cans sold per population.

[4]Deflated price of sardines 1967 = 100.

[5]Relative price of substitute foods, Index of fish meat and poultry prices 1967 = 100.

APPENDIX C

COST DATA AND PROCESSING COEFFICIENTS FOR FOUR FISH MEAL PLANTS

CONTENTS

APPENDIX C

TABLE C.1

CALCULATION OF ANNUAL DEPRECIATION CHARGES ON ALTERNATIVE PLANTS IN A 150 DAY YEAR

PLANT I. Maximum Capacity--420 Tons Meal Per Year, 310 Lbs. Oil Per Year, 381 Tons Solubles Per Year

Plant Investment	$345,000.00
Building	22,977.00
Storage	10,290.00
Total Investment	378,267.00
Annual Depreciation	37,826.00

PLANT II. Maximum Capacity--875.5 Tons Meal Per Year, 589.2 Lbs. Oil Per Year, 795.8 Tons Solubles Per Year

Plant Investment	$414,000.00
Building	43,125.00
Storage	21,117.00
Total Investment	478,242.00
Annual Depreciation	47,824.00

PLANT III. Maximum Capacity--1751 Tons Meal Per Year, 1178 Lbs. Oil Per Year, 1591 Tons Solubles Per Year

Plant Investment	$483,000.00
Building	74,750.00
Storage	41,838.15
Total Investment	599,588.15
Annual Depreciation	59,958.00

PLANT IV. Maximum Capacity--2492 Tons Meal Per Year, 1679 Lbs. Oil Per Year, 2266 Tons Solubles Per Year

Plant Investment	$747,500.00
Building	106,372.00
Storage	59,537.00
Total Investment	913,409.00
Annual Depreciation	91,340.00

SOURCE: [1]John Lea and Ewell Roy "Economic Feasibility of Processing Groundfish from the Gulf of Mexico", p.35-40, DAE Research Report No. 502 May 1976, Louisiana State University. [2]David Stuiber, "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes" unpublished report of the University of Wisconsin Sea Grant Program, 1975, Madison, Wisconsin.

NOTE: Estimated for plants I, II and III were adapted from studies performed by Roy.[1] Plant IV estimates based on work by Stuiber.[2] Both sets of estimates were deflated by 1972 price index.

TABLE C.2

ESTIMATED FIXED COST PER YEAR

	Plant I	Plant II	Plant III	Plant IV
Depreciation	$32,826	$47,824	$59,958	$ 91,340
Interest	30,261	38,259	47,967	73,072
Insurance	4,933	6,237	7,745	11,914
Tax	8,200	10,375	12,900	19,850
Other fixed cost	1,000	1,000	1,000	1,000
Total fixed cost/year	77,220	103,695	129,570	197,176
Total fixed cost/processed ton	245.14	154.76	98.60	105.44

SOURCE: [1]John Lea and Ewell Roy "Economic Feasibility of Processing Groundfish from the Gulf of Mexico", p. 35-40, DAE Research Report No. 502 May 1976, Louisiana State University.

[2]David Stuiber "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes" unpublished report of the University of Wisconsin Sea Grant Program, 1975, Madison, Wisconsin.

NOTE: Cost estimates for four alternative plant sizes operating 150 days per year at 75% of capacity based on 1976 estimates deflated in terms of 1972 dollars collected from two independent studies.

TABLE C.3

ESTIMATED VARIABLE COST PER TON OF OUTPUT

Output	Plant I	Plant II	Plant III	Plant IV
Electricity[1]	$ 3.02	$ 3.85	$3.85	$3.85
Fuel Oil[2]	36.00	36.00	36.00	36.00
Water and Sewer[3]	4.54	4.54	4.54	4.54
Operator [4]	45.70	32.23	16.43	15.40
Cost of Handling[5]	5.44	5.44	5.44	5.44
Transportation to and from Storage	2.30	2.30	2.30	2.30
Maintenance and Repair	72.05	42.82	27.37	29.30
Supplies and Miscellaneous[6]	53.96	25.37	12.93	9.09
Management[7]	63.49	29.85	15.22	10.69
Total Variable Cost	286.50	182.40	124.08	116.61

SOURCE: [1]John Lea and Ewell Roy "Economic Feasibility of Processing Groundfish from the Gulf of Mexico", p. 35-40, DAE Research Report No. 502, May 1976, Louisiana State University

[2]David Stuiber, "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes" unpublished report of the University of Wisconsin Sea Grant Program, 1975, Madison Wisconsin.

NOTES: Variable cost computed for four sizes of fish plants operating operating 150 days per year at 75% of capacity based on 1976 prices, deflated in terms of 1972 dollars.

[1]Plants I-IV use 60.5,77,77,77kwh per ton of output at .05/kwh.

[2]Each plant uses 72 gals. of fuel oil to produce 1 ton of meal; oil price is predicted at $.50 per gal.

[3]Water and sewerage cost amount to $1.00 per ton of input.

[4]Plants I-IV use 2, 3, 3 and 4 men for 150 days paid at $6.00 per hour.

[5]Assumed fixed and equal for all plant sizes.

[6]Assumed fixed for all plants, inflated from 1973 estimates provided by producers.

[7]$20,000 per year.

TABLE C.4

PROFIT LOSS STATEMENT

	Plant I[2]	Plant II[3]	Plant III[4]	Plant IV[5]
C.5 Total Revenue (349.85)[6]	$110,202.00	$234,999.50	$459,702.90	$654,219.50
C.5 Total Revenue (429.50)[7]	135,292.50	282,411.45	564,822.90	803,819.50
Total Fixed[8]	77,220.00	103,695.00	129,570.00	197,176.00
Total Margin	32,982.00	131,304.50	330,132.90	457,043.50
Margin per ton	104.70	195.98	251.24	244.40
Variable Cost of Fish Landed per ton	286.50	182.40	124.08	116.61
Variable Cost per ton Output[9]	427.80	323.70	265.38	259.91
Variable Cost per ton Output[10]	474.90	370.80	312.48	305.01
Variable Cost per ton Output[11]	522.00	417.90	359.58	352.11

SOURCE: [1]John Lea and Ewell Roy "Economic Feasibility of Processing Groundfish from the Gulf of Mexico," p. 35-40, DAE Research Report No. 502, Louisiana State University (May, 1976)

David Stuiber, "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes" unpublished report of the University of Wisconsin Sea Grant Program, 1975, Madison Wisconsin.

NOTE: Interest costs equal .08×investment and interest costs are based on $25.00 per $1,000.00 of land and buildings. Plant III assumed to operate 150 days per year. Prices are based on 1977 estimates of $360/ton of fish oil and $205.85/ton of fish meal, in 1972 dollars.

[2]Plant I processes 1485 tons of raw fish per year producing 315 tons of meal/oil - 315 tons of meal, 233 tons of oil and 315 tons of solubles (Appendix C.1).

TABLE C.4. Continued

[3] Plant II processes 657 tons of meal/oil - 657 tons of meal, 442 tons of oil and 657 tons of soluble (Appendix C.1).

[4] Plant III processes 6187.5 tons of raw fish per year into 1314 tons of meal/oil - 1314 tons of meal, 884 tons of oil and 1314 tons of solubles (Appendix C.1).

[5] Plant IV processes 8500 tons of raw fish input per year into 1870 tons of meal/oil - 1870 tons of meal, 1260 tons of oil and 1870 tons of solubles (Appendix C.1).

[6] Price based on Appendix Table c.5, 1977 forecast \$360.00/ton of oil, \$205.85 C.I.F. price of meal and \$349.85/short ton of meal/oil.

[7] Price based on Appendix Table C.4, 1977 including solubles production, C.I.F. price estimate \$448.60/ton.

[8] Costs based on Louisiana and Wisconsin studies Appendix Table C.1 to C.4 adjusted to 1972 dollars by the formula (Cost = Cost $\hat{C}$, where $\frac{CPI_{1974}}{CPI_{1972}} = 1.15 = \hat{C}$)

[9] \$30 per ton raw.

[10] \$40 per ton raw.

[11] \$50 per ton raw.

TABLE C.5

REGRESSION FORECASTS FOR 1977

	Price Forecast '77	Revenue Per Ton Fish Inputs	Revenue Per Ton Meal	Revenue Per Ton Meal
Fish Solubles	$80.00	$16.00	$80.00	
Fish Oil	360.00	28.80	144.00	$144.00
Fish Meal	205.85	41.17	205.85	205.85

NOTE: Price forecast based on linear extrapolation of trend holding fish price and meal conversion ratio constant relative to soybean prices; assuming meal, oil and solubles maintain same relative prices in 1977.

TABLE C.6

DECEMBER MEAL PRODUCTION AND BROILER PLACEMENTS AND RELATIVE MOVEMENTS OF SOY MEAL PRICE 1960-1976.

Year	Total Meal Produced Q'	Menhadden Price[1] $P_{fishmeal}$	Chicken Placements[2] C	Total Meal Production & Imports[3] Q	Soybean Meal Price / Fish Meal Price[4] P_s	Soybean Meal Price[5]
1960	281.4	$131.1	1.3470	323.6	1.64	$74.6
1961	300.5	172.9	1.5230	411.7	1.89	89.9
1962	301.0	185.0	1.5338	458.2	1.72	99.9
1963	248.0	187.0	1.5735	497.0	1.59	107.4
1964	225.1	193.6	1.6540	354.1	1.86	93.2
1965	242.5	250.3	1.8044	457.3	2.38	96.1
1966	212.1	199.4	1.9857	516.4	1.65	110.2
1967	201.5	166.5	2.0033	633.8	1.66	100.0
1968	227.0	175.7	2.0067	818.1	1.83	86.7
1969	244.2	229.7	2.1518	524.0	2.20	95.6
1970	257.1	205.2	2.3140	430.1	2.12	89.8

Table C.6. Continued.

TABLE C.6. Continued.

Year	Total Meal Produced Q	Menhadden Price[1] $P_{fishmeal}$	Chicken Placements[2] C	Total Meal Production & Imports[3] Q	Soybean Meal Price / Fish Meal Price[4] P_s	Soybean Meal Price[5]
1971	282.9	$ 169.6	2.2747	464.0	1.84	$ 83.9
1972	274.1	237.5	2.3833	568.6	1.22	174.0
1973	279.1	508.0	2.3038	291.0	2.41	181.5
1974	291.6	241.4	2.2816	291.5	1.80	123.2
1975	279.3	209.2	2.2717	310.7	2.01	98.3
1976	320.1	204.8	2.5238	358.3	1.88	127

SOURCE: National Marine Fisheries Service "Industrial Fishery Products", Current Economics Analysis, Economics and Marketing Division 1960-1976, NMFS/NOAA, IEC-28, Washington, D.C.

NOTES: [1]December wholesale price, stated in 1972 dollars/ton.

[2]Chick Placements (billions of birds).

[3]Total Meal Production and Imports (1000 short tons).

[4]Ratio of Menhadden Meal Price to Soy Meal Price, Deflated by (P_{1972} = 100) price deflator.

[5]Bulk price at Decatur, Ill. deflated by (P_{1972} = 100) price deflator.

TABLE C.7

OIL AND SOLUBLE PRODUCTION, BROILER PLACEMENTS AND RELATIVE MOVEMENTS OF SOYBEAN OIL PRICES 1960-1976

Year	Solubles Production & Imports[1]	Solubles Price ($/short ton)[2]	Total Fish Oil Production (millions of pounds)[3]	Menhadden Crude Oil Price ($/lb.)[4]	Soybean Oil Price / Menhadden Oil Price = Oil Price Ratio[5]
1960	79.3	37.5	163.0	6.2	1.48
1961	86.8	49.7	218.0	5.4	1.94
1962	99.9	55.3	205.3	4.1	1.97
1963	87.6	64.1	154.6	7.3	1.16
1964	85.5	61.2	157.4	9.1	1.06
1965	84.6	61.2	172.9	9.5	1.2
1966	73.9	72.5	132.0	9.4	1.30
1967	64.3	61.2	91.4	5.8	1.60
1968	60.6	51.8	132.1	4.4	1.70
1969	67.4	48.7	141.0	6.1	1.59
1970	78.8	48.7	175.5	9.7	1.24
1971	95.1	45.0	238.4	9.2	1.39
1972	108.9	42.8	167.8	7.8	1.25
1973	111.8	28.5	200.9	11.5	2.113
1974	115.2	80.5	220.9	25.0	1.62
1975	104.3	66.0	215.1	15.0	1.62
1976	116.3	27.5	205.1	18.0	1.244

SOURCE: National Marine Fisberies Service "Industrial Fishery Products", Market Review and Outlook, Economic and Marketing Research Division, (1960-1976) NOAA/NMFS, Washington D.C.

NOTES: [1]Domestic meal production plus imports (1000 tons).

[2]Price of solubles, $ per short ton.

[3]Total fish oil production in millions of pounds.

[4]Menhadden crude oil price per pound.

[5]Oil price ratio soybean oil price to menhadden oil price.

TABLE C.8

DEMAND EQUATION USING ANNUAL DATA

$$Q = \underset{(1.80)}{11.0477} - \underset{(.82)}{1.4247}\,P + \underset{(.438)}{.44}\,C + e$$

Q = quantity of fish meal
P = price of fish meal
C = broiler placements

SOURCE: National Marine Fisheries Service, "Industrial Fishery Products, Market Review and Outlook, Economics and Marketing Research Division," Current Economic Analysis, NOAA/NMFS, Washington, D.C. 1960-1976.

TABLE C.9

MONTHLY PRICE INDEX OF FISHMEAL
JANUARY 1974 - SEPTEMBER 1976

Year/Month		Menhadden Meal Production / month[1] ($/Q 1000 short tons) Q	Price of Menhad den Meal/Month ($/short ton) $P_{fishmeal}$	Chick Placements C	44% Protein Soybean Meal $/Short Ton $P_{1972=100}$ [3] Ps	50% Protein Soybean Meal $/Short Ton P1972=100[4] Ps'	Price Ration of Menhad den Meal: Soybean Meal[5]
1974	Jan.	5.9	532.00	238.5	172.00	192.40	.73
	Feb.	5.9	452.20	240.7	160.00	175.25	.58
	Mar.	6.5	403.75	316.6	147.10	160.40	.77
	Apr.	13.3	342.00	252.0	117.20	130.40	.91
	May	31.8	273.10	314.3	109.25	120.00	NA
	June	52.9	263.00	244.3	100.00	110.50	.71
	July	61.4	243.50	215.4	138.10	147.10	.63
	Aug.	49.8	314.35	262.3	155.90	165.90	.60
	Sept.	25.4	275.50	197.5	138.10	147.25	.62
	Oct.	13.7	301.25	188.8	168.20	179.80	.58
	Nov.	14.2	297.50	248.1	141.00	154.00	.64
	Dec.	10.7	281.00	217.8	143.40	155.80	.66
1975	Jan.	6.5	263.12	219.4	129.20	137.90	.74
	Feb.	5.1	231.12	223.1	117.25	126.90	.68
	Mar.	5.3	220.50	295.0	117.75	126.56	NA
	Apr.	3.2	238.75	240.6	122.00	131.80	NA
	May	27.5	226.87	300.3	118.50	129.00	.57
	June	37.0	218.75	242.0	120.90	130.75	.56
	July	47.3	234.50	231.2	124.00	134.20	.49
	Aug.	29.9	246.25	286.9	134.40	144.20	.51
	Sept.	25.5	259.00	222.5	133.70	144.30	.62
	Oct.	12.7	266.25	264.7	125.90	135.90	.71
	Nov.	5.5	269.38	227.5	119.90	126.80	.80
	Dec.	7.8	266.25	233.6	125.10	132.30	.92
1976	Jan.	.3	268.75	299.8	128.75	136.25	NA
	Feb.	NA	270.00	246.4	132.60	139.25	NA
	Mar.	NA	273.75	264.1	127.90	135.60	.92
	Apr.	8.8	253.12	272.1	127.10	136.40	.93

(Continued)

TABLE C.9

MONTHLY PRICE INDEX OF FISHMEAL
JANUARY 1974 - SEPTEMBER 1976

Year/Month		Menhaden Meal Production / month[1] ($/Q 1000 short tons) Q	Price of Menhaden Meal/Month ($/short ton) $P_{fishmeal}$	Chick Placements C	44% Protein Soybean Meal $/Short Ton $P_{1972=100}$ [3] Ps	50% Protein Soybean Meal $/Short Ton $P_{1972=100}$ [4] Ps'	Price Ration of Menhaden Meal: Soybean Meal[5]
1974	Jan.	5.9	532.00	238.5	172.00	192.40	.73
	Feb.	5.9	452.20	240.7	160.00	175.25	.58
	Mar.	6.5	403.75	316.6	147.10	160.40	.77
	Apr.	13.3	342.00	252.0	117.20	130.40	.91
	May	31.8	273.10	314.3	109.25	120.00	NA
	June	52.9	263.00	244.3	100.00	110.50	.71
	July	61.4	243.50	215.4	138.10	147.10	.63
	Aug.	49.8	314.35	262.3	155.90	165.90	.60
	Sept.	25.4	275.50	197.5	138.10	147.25	.62
	Oct.	13.7	301.25	188.8	168.20	179.80	.58
	Nov.	14.2	297.50	248.1	141.00	154.00	.64
	Dec.	10.7	281.00	217.8	143.40	155.80	.66
1975	Jan.	6.5	263.12	219.4	129.20	137.90	.74
	Feb.	5.1	231.12	223.1	117.25	126.90	.68
	Mar.	5.3	220.50	295.0	117.75	126.56	NA
	Apr.	3.2	238.75	240.6	122.00	131.80	NA
	May	27.5	226.87	300.3	118.50	129.00	.57
	June	37.0	218.75	242.0	120.90	130.75	.56
	July	47.3	234.50	231.2	124.00	134.20	.49
	Aug.	29.9	246.25	286.9	134.40	144.20	.51
	Sept.	25.5	259.00	222.5	133.70	144.30	.62
	Oct.	12.7	266.25	264.7	125.90	135.90	.71
	Nov.	5.5	269.38	227.5	119.90	126.80	.80
	Dec.	7.8	266.25	233.6	125.10	132.30	.92
1976	Jan.	.3	268.75	299.8	128.75	136.25	NA
	Feb.	NA	270.00	246.4	132.60	139.25	NA
	Mar.	NA	273.75	264.1	127.90	135.60	.92
	Apr.	8.8	253.12	272.1	127.10	136.40	.93

(Continued)

Table C.9: Continued

Year/Month		Menhad den Meal Production/month[1] ($/Q 1000 short tons)[1]	Price of Menhad den Meal/Month ($/short ton)[2]	Chick Placements	44% Protein Soybean Meal $/Short Ton $P_{1972=100}$[3]	50% Protein Soybean Meal $/Short Ton $P_{1972=100}$[4]	Price Ration of Menhadden Meal: Soybean Meal[5]
		Q	$P_{fishmeal}$	C	Ps	Ps'	
1976	May	17.5	283.00	339.6	152.25	161.75	.97
	June	36.9	353.00	273.4	187.90	200.30	.89
	July	48.6	385.00	327.4	193.90	207.88	.86
	Aug.	46.5	324.00	253.8	170.62	187.10	.81
	Sept.	37.8	361.00	247.2	179.38	192.50	.80
	Oct.		361.25	284.5	169.62	182.00	.90
	Nov.		361.88				
	Dec.						

SOURCE: National Marine Fisheries Service, "Industrial Fishery Products, Market Review and Outlook", Economics and Marketing Research Division, Current Economic Analysis, NOAA/NMFS, Washington D.C. 1974-1976.

NOTES: All prices stated in deflated 1972 dollars, NA means not available.

[1]Production of Menhaden (short tons) National Marine Fisheries Service, "Industrial Fishery Products, Market Review and Outlook," Economics and Marketing Research Division NOAA/NMFS, Washington, D.C.

[2]Price of Menhaden meal ($/short ton) 65% protein f.o.b. cash cost.

[3]Broiler placements (in millions of birds).

[4]Price 50% protein soybean meal f.o.b. Decatur, Illinois, Bulk.

[5]Price rates of Menhaden Meal to soy price.

TABLE C.10

Monthly Price Index of Fish Oil and Solubles
January 1974-September 1976

Year and Month		Fish soluble production (1,000 short ton)[1]	Fish soluble price[2]	Oil production (1,000 pounds)[3]	Oil price $/pound[4]	P Soy/fish[5]
1974	Jan.	1.9	159.00	.9	21.0	.73
	Feb.	1.4	165.00	.7	21.2	.58
	Mar.	3.3	132.50	.9	23.2	.77
	Apr.	6.3	129.16	7.0	25.7	.91
	May	13.1	103.75	30.1	NA	NA
	June	25.0	94.75	46.9	25.0	.71
	July	27.9	83.00	55.4	25.4	.63
	Aug.	24.4	86.25	54.1	26.0	.60
	Sept.	12.0	80.50	25.0	25.0	.62
	Oct.	7.5	85.00	7.3	24.9	.58
	Nov.	9.2	85.00	6.7	26.0	.64
	Dec.	5.4	84.00	3.2	25.0	.66
1975	Jan.	2.7	86.25	2.1	25.0	.79
	Feb.	1.3	77.50	.9	20.0	.68
	Mar.	2.4	75.00	.9	NA	NA
	Apr.	4.5	73.75	4.2	13.5	NA
	May.	14.7	71.25	36.6	13.0	.57
	June	17.0	64.06	38.0	13.5	.56
	July	23.1	63.50	54.9	14.0	.49
	Aug.	15.3	61.88	35.7	14.6	.51
	Sept.	15.3	66.00	36.8	15.0	.62
	Oct.	14.8	71.88	15.1	15.2	.71
	Nov.	4.0	73.12	2.1	15.2	.80
	Dec.	4.7	74.69	.5	15.5	.92
1976	Jan.	3.2	75.00	.1	NA	NA
	Feb.	1.3	75.00	NA	NA	NA
	Mar.	4.2	80.62	NA	15.2	.92
	Apr.	8.2	79.38	8.8	15.2	.93
	May	10.3	93.75	16.5	15.4	.87
	June	19.7	118.50	32.9	15.4	.89
	July	23.3	138.75	46.9	18.0	.86
	Aug.	24.1	128.00	44.5	16.6	.81
	Sept.	21.4	127.50	38.2	18.0	.80
	Oct.	NA	127.50	NA	18.7	.90
	Nov.	NA	NA	NA	NA	NA
	Dec.	NA	NA	NA	NA	NA

SOURCE: National Marine Fisheries Service, "Industrial Fishery Products, Market Review and Outlook" Economics and Marketing Research Division, Current Economic Analysis, NOAA/NMFS, Washington D.C. 1974-1976.

NOTES: [1]U.S. production of Fish solubles in tank curbs by month, Jan. 1975-Dec. 1976 (1,000 short tons).

[2]Average monthly price of menhadden solubles f.o.b. East Coast plants, 1975-1976 ($/short ton).

[3]Oil production(millions of pounds).

[4]Average monthly price of menhadden oil f.o.b. East Coast plants.

[5]Ratio of menhadden oil price to soybean oil price by month.

APPENDIX D

SENSITIVITY ANALYSIS OF COST AND PROCESSING VARIATIONS AND THEIR EFFECT ON RATE OF RETURN

CONTENTS

APPENDIX D

TABLE D.1

VARIATIONS IN INVESTMENT RETURN WITH ALTERNATIVE SPECIFICATIONS OF VARIABLE COST LEVELS IN PLANT III

HOURLY WAGE	AFFECT ON PROFIT/TON[1]	RATE OF RETURN[2]
$4/ hr.	10.33	.029
$5/hr.	7.60	.022
$6/hr.	4.86	.013
$7/hr.	2.12	.006
MAINTENANCE COST/YR.	MARGIN/TON	RATE OF RETURN/TON
$20,000	17.00	.048
$25,000	13.20	.038
$30,000	5.19	.015
$35,964	4.86	.013
$40,000	1.79	.005
$45,000	-2.01	.005
$50,000	-7.61	.021
PRICE OF RAW FISH ($/TON FISH HARVESTED)	CHANGE IN MARGIN/TON MEAL PRODUCED	RATE OF RETURN/TON
$20	95.45	.27
$25	72.72	.21
$30	50.31	.144
$35	27.58	.08
$40	4.86	.013
$45	-17.86	-.051
$50	-40.59	-.116
PRICE OF FUEL OIL	MARGIN/TON	PROFIT OF PER UNIT SALES
$.30	19.26	5.5%
$.35	15.66	4.4%
.40	12.06	3.4%
.50	4.86	1.3%
.60	-7.20	2.1%
.70	-10.80	3.1%
TRANSPORTATION COSTS/TON	MARGIN/TON	PROFIT % PER UNIT PRODUCT
$15	.86	0%
$19	$4.86	1.3%
$20	5.86	1.6%
$30	15.86	4.5%
$40	35.86	10.2%

SOURCE: [1]John Lea and Ewell Roy, "Economic Feasibility of Processing Groundfish from the Gulf of Mexico," p.35-40, DAE Research Report No. 502, May 1976, Louisiana State University.

[2]David Stuiber "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes" unpublished report of the University of Wisconsin Sea Grant Program, 1975, Madison Wisconsin.

NOTES: [1]Ton refers to each ton of meal produced. Includes from .4 tons of fish oil. [2]Profit/ton of output based on price per ton of meal=$205.85/ton and price per ton of oil=$360.00/ton. Total price per ton of meal output= $349.85.

TABLE D.2

VARIATIONS IN INVESTMENT RETURN WITH
ALTERNATIVE SPECIFICATIONS OF COSTS

PLANT LIFE	MARGIN/TON	RETURN ON INVESTMENT
1 yr.	- 410.67	-89%
5 yrs.	- 45.63	-35%
10 yrs.	4.86	.1%
15 yrs.	20.07	4%
20 yrs.	27.67	16%
INCREASED COST OF BUILDING PLANT III	**MARGIN/TON**	**RETURN ON INVESTMENT**
$500,000	7.57	1.5%
599,588	4.86	1%
600,000	.03	0%
700,000	7.64	1.6%
800,000	15.24	3.3%
900,000	22.86	5.0%
1,000,000	30.47	6.67
AFFECT OF DIFFERENT INTEREST RATES ON INVESTMENT	**MARGIN/TON**	**RETURN ON INVESTMENT**
.06	13.98	3%
.07	9.42	2%
.08	4.86	1%
.09	.30	.000%
.10	-4.26	-.9%
.12	13.38	.3
.14	22.50	5%
.16	31.68	6%

SOURCE: [1]John Lea and Ewell Roy "Economic Feasibility of Processing Groundfish from the Gulf of Mexico," p. 35-40, DAE Research Report No. 502, May 1976, Louisiana State University.

[2]David Stuiber, "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes" unpublished report of the University of Wisconsin Sea Grant Program, 1975, Madison Wisconsin.

NOTE: Based on return to total fixed expenditure in Plant III calculated in the work by Roy[1] and Stuiber.[2] Variable costs were held constant while processing output was fixed at 1,314 tons per year.

TABLE D.3

EFFECT OF CHANGES IN MEAL AND OIL PRODUCTIVITY ON INVESTMENT RETURNS

MEAL YIELD	MARGIN	%/RETURN
.19	44.72	- 13%
.20	30.64	-8.8%
.21	12.64	-3.6%
.22	4.86	1.3%
.23	13.09	03.7
.24	23.57	6.8%
.25	32.85	9.5%
.30	79.77	23.7%

OIL YIELD	MARGIN
3%	-25%
5%	-15%
7%	- 5%
8%	1.3%
9%	5%
10%	12.6%

SOURCE: [1]John Lea and Ewell Roy, "Economic Feasibility of Processing Groundfish from the Gulf of Mexico," p. 35-40, DAE Research Report No. 502, May 1976, Louisiana State University.

[2]David Stuiber, "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes" unpublished report of the University of Wisconsin Sea Grant Program, 1975, Madison, Wisconsin.

NOTE: Assumes price of meal in 1977 = $205.85/ton. The price of oil in 1977 = $360.00/ton. Price; CIF, Meal/Oil in 1977 = $349.85 (See Table C.5) Rate of return is calculated as a percent of purchaser price.

TABLE D.4

THE EFFECT OF THE EXISTENCE OF A LOCAL SOLUBLES MARKET WHERE SOLUBLES ARE COLLECTED BASED ON MARGIN INDICATED WHERE SOLUBLES ARE PRODUCED IN EQUAL PROPORTIONS WITH MEAL.

SOLUBLES MARGIN	RATE OF RETURN
$20.	7.7%
$30.	9.9
$40.	12.8
50.	15.7%
60.	18.5%
70.	21.4%

SOURCE: [1]John Lea and Ewell Roy "Economic Feasibility of Processing Groundfish from the Gulf of Mexico," p. 35-40, May 1976, Louisiana State University.

[2]David Stuiber, "Wisconsin Study of the Feasibility of Meal Processing in the Great Lakes" unpublished report of the University of Wisconsin Sea Grant Program, 1975, Madison Wisconsin.