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#### AN ANALYSIS TO DETERMINE OPTIMUM SHRIMP FISHING

EFFORT BY AREA

by

Victor Arnold .

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(continued on inside back cover)

#### ABSTRACT

In this study vessels from 13 major shrimp ports were surveyed to determine the cost and earning structure for Gulf shrimp vessels. This information was combined with effort data for a sample of vessels spending 50 percent or more of their time on the Tortugas shrimp grounds.

Using both these series of data, broken down into vessel size categories and specifying the distribution of landings between three Florida ports, a linear programming model was developed for the express purpose of determining the optimal distribution of vessels between ports based upon the effort patterns, the distribution of species and the cost components of vessel operations.

Using constraints based on various assumptions results were derived which suggested considerable differences from current port use patterns. Social benefits derived from their application demonstrate the value of this technique.



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#### CHAPTER I

#### INTRODUCTION

Shrimp is the most valuable fishery resource in the United States. It has held this position since 1952 with the exception of 1961 (Table 1). Domestic landings in 1966 were valued at \$95.8 million and were \$28.7 million greater than the value of salmon, the nation's second most valuable fishery. Historically, approximately 80 percent of the domestic annual catch has been landed in the Gulf of Mexico. Landings in the Gulf have increased from 84.5 million pounds (heads off weight),<sup>1</sup> valued at \$2.76 million in 1936 to 139.6 million pounds (heads off weight) valued at \$70.8 million in 1965.<sup>2</sup> The disproportionate growth between pounds of shrimp landed and dollar value has resulted from rapidly expanding markets and increasing domestic demand for fresh and frozen shrimp. Domestic demand increasing at a more rapid rate than domestic supply has increased the

<sup>1</sup>Heads off weight is defined as the weight of shrimp after removal of the head (protocephalon) and the thorax (gnathothorax) or the weight of the abdominal section.

<sup>2</sup>The increase in value relative to quantity landed is further demonstrated by deflating the 1965 values to 1936 levels via the wholesale price index for all commodities. A value of \$30.53 million for 1965 is yielded by such deflation.

				Percent of total value of		
Year	<u>Relati</u> Shrimp	<u>ve value (</u> Salmon	<u>000)\$</u> Tuna	<u>landed</u> f	Salmon	<u>esources</u> Tuna
1966	95,800	67,100	44,608	21.1	14.8	9.8
1965	82,409	65,159	41,734	18.5	14.6	9.4
1964	70,376	55,995	39,398	18.1	14.4	10.1
1963	70,044	49,012	40,170	18.6	13.0	10.6
1962	73,236	56,353	45,112	18.5	14.2	11.4
1961	51,688	52,027	42,346	14.3	14.4	11.7
1960	66,932	44,730	37,571	18.9	12.7	10.6
1959	58,133	35,741	37,429	16.8	10.3	10.8
1958	72,930	45,904	43,184	19.7	12.4	11.6
1957	73,145	39,830	37,523	20.8	11.3	10.7
1956	70,894	46,220	43,574	20.2	12.5	11.8
1955	61,782	40,704	39,516	17.4	11.4	11.1
1954	60,831	43,948	53,375	17.1	12.4	15.0
1953	76,641	37,806	47,173	21.8	10.7	13.4
1952	55,103	45,241	49,456	15.3	13.0	13.7
1951	51,862	52,509	47,887	14.4	14.6	13.3
1950	43,452	37,450	61,419	12.6	10,9	17.9
		• •		•		

Table 1.--Ex-vessel value relationships of the three most valuable fishery resources.

ex-vessel price<sup>3</sup> for fresh shrimp and has made the United States market attractive for foreign shrimp and shrimp products. Similarly, rising ex-vessel prices have stimulated investment by entrepreneurs in shrimp fishing vessels.

Between World War II and 1950 the number of vessels engaged in shrimp fishing activity increased 260 percent to a fleet numbering 2,200 vessels. The established fishery during this period was concentrated in the northern Gulf of Mexico in sounds, bays, bayous, and adjacent coastal waters of the Gulf states out to a distance of approximately ten miles. The rapid growth in the number of vessels resulted in intense competition among hundreds of vessels for the stock of shrimp in the established fishery.

The discovery of offshore and distant water shrimp fishing grounds in 1950 altered the spatial distribution of vessels among ports and across the fishing grounds and somewhat eased the competition among individual producers exploiting the inshore waters, but set the stage for an increase in the overall intensity of competition for shrimp resources in the Gulf of Mexico. Today the Gulf fishery extends from the Florida Keys around the Gulf coast of the United States and Mexico to the eastern tip of the Yucatan Peninsula. Shrimp populations to a depth of 40 fathoms are being exploited (Figure 1).

The alteration of the spatial distribution of fishing activity

<sup>3</sup>Ex-vessel price is the dockside price paid the vessel owner for fresh shrimp. The only processing that has occurred is the heading process (removal of the head and thorax) and has been accomplished by the vessel's crew while at sea.



Figure 1. Gulf of Mexico shrimp fishing grounds.

has shifted the investment pattern from relatively small inshore vessels requiring investment of approximately \$30,000 to larger, more powerful vessels requiring investments ranging from \$50,000 to \$80,000. The shifting investment pattern is a result of the individual decision maker's attempt to enhance his competitive position by investing in vessels that are physically capable of fishing the new distant water fishing grounds for extended periods of time, which in turn would enable him to increase his landings.

Currently there exists a fishing fleet which includes 2,849 vessels ranging from 5 gross tons to those exceeding 150 tons (Table 2). Preliminary analysis has shown that today's fleet is characterized by vessels that are underutilized in terms of their potential productive fishing time.<sup>4</sup> Interviews by this author with vessel owners disclosed that the production planning by the individual firm within the shrimp fishing fleet is concentrated on increasing physical production. The current trend in the Gulf shrimp fishing industry is still toward larger vessels, but increased horsepower and increased size of nets are now being emphasized. Individual decision makers in the industry believe that such investment patterns will increase revenue because of increased production. Little concern is directed by individual members

<sup>4</sup>Roy L. Lassiter, Jr., <u>Utilization of U.S. Otter Trawl Shrimp</u> <u>Vessels in the Gulf Areas, 1959-1961</u> (Gainesville: Bureau of Economic and Business Research, University of Florida, 1964).

Carter C. Osterbind and Robert A. Pantier, <u>Economic Study of</u> the Shrimp Industry in the Gulf and South Atlantic States (Gainesville: Bureau of Economic and Business Research, University of Florida, 1965).

Gross Tonnage	<b>1</b> 964 (number)	1965 (number)
	<b>1</b> 04	124
10-19	483	512
20-29	340	321
30-39	387	379
40-49	399	385
50-59	265	260
60-69	535	534
70-79	211	220
80-89	41	50
90-99	9	53
100-109	4	8
110-119	1	<b>1</b> .
130-139	. 1	1
140-149	1	
160-169	1	1
Total vessels	2,782	2,849
Total gross tonnage	116,837	121,693
Average gross tonnage	41.99	42.71
Percent increase in a	average tonnage	1.7

Table 2.--Distribution of Gulf of Mexico shrimp vessels by gross tonnage.

of the industry toward production costs or returns to capital. Similarly, little effort has been devoted to the most effective way to utilize a given fleet of vessels to minimize the costs of producing given quantities of raw headless shrimp or to maximize returns to given levels of investment.

#### Scope of the Study

The purpose of this study is to analyze the existing shrimp fleet which is now exploiting a portion of the offshore fishing grounds in the Gulf of Mexico. Analysis will be directed toward determining the necessary conditions of fleet use which minimize the total production costs for a predetermined level of physical production from the fishing grounds. Emphasis will be on the optimal allocation of fishing effort in time and space to achieve this objective. Chapter II includes a review of the current literature in fishery economics and develops the individual fishing firm concept in the short and long run and its relationship to the industry. The equilibrium of a fishing industry characterized by unregulated entry is described, as are problems confronted by developers and exploiters of common property resources. Biological sustained yield concepts are treated as a static variable and as a stochastic variable, and are presented in the literature review section. Chapter III covers the biological and economic char-.acteristics of the shrimp fishing grounds that will be utilized in the empirical analysis followed by methodology, empirical analysis, interpretation of empirical analysis, and policy implications in subsequent chapters.

#### CHAPTER II

8

LITERATURE REVIEW AND ECONOMIC THEORY

## Externalities and Common Property Resources

Exploiters of marine fishery resources are confronted by external economies and diseconomies similar to those faced by users of any other natural resources which have no formal property structures. These resources have been aggregated and called common property resources.<sup>5</sup> Natural resources often classified under this general term are air; in some cases water, i.e. groundwater; public grazing land; petroleum deposits; and marine resources.

A common property resource is characterized by its ability to be utilized simultaneously by more than one individual or economic unit. No user has exclusive rights to the resource, nor can he prevent others from sharing in its exploitation. Common property resource externalities are primarily fostered by this characteristic. Externalities as defined by McKean<sup>6</sup> are the uncompensated effects on the costs or receipts of any industry caused by the actions of another

<sup>&</sup>lt;sup>5</sup>An exception to this case is the public park. It has a formal property structure but is still considered a common property resource.

<sup>&</sup>lt;sup>6</sup>Roland McKean, <u>Efficiency in Government Through Systems</u> <u>Analysis, With Emphasis on Water Resource Development</u> (New York: Wiley & Sons, 1958), p. 134.

industry or productive unit. Hartman and Seastone<sup>7</sup> define externalities as "a concept applied to those economic effects which lie outside the decision making scope of micro units. . . ."

The term externality is an ambiguous concept for it includes external costs, external benefits, and monetary as well as nonmonetary externalities. Inclusion of such diverse components make quantification of externalities an extremely difficult task. One should note, however, that some individual(s) or producing unit(s) always enjoy or suffer from the effects of externalities. Observing a harmful or beneficial effect, and noting that the costs of bringing the effect to bear on the decisions of one or more of the interacting persons are too high to make it worthwhile, will qualify an effect to be considered an externality. In the marine fisheries an individual vessel engaging in fishing a particular portion of a fishing ground immediately subsequent to another vessel having just fished the same portion of the fishing ground would be a case in which an externality is being absorbed by the second vessel. The second vessel would incur additional costs per unit of catch because of the decrease in the fishable biomass caused by the first vessel's effort.

External economies could be incurred if there are vessels engaged in fishing on a fishing ground with no adjacent port facilities. As the number of vessels fishing on the ground increased, adjacent port

7L. M. Hartman and D. A. Seastone, "Welfare Goals and Organization of Decision Making for the Allocation of Water Resources," <u>Committee on the Economics of Water Resources Development of the</u> <u>Western Agricultural Economists Research Council Report No. 12</u> (Salt Lake City, 1963), p. 15.

facilities may be constructed, thus offering the vessels economies in transporting fish from the fishing ground to port.

Basically there are four externality characteristics for marine common property resources:<sup>8</sup>

- 1. The private costs of appropriating and defending exclusive use rights may be higher than the added returns that such an appropriation and defense might bring. The reasoning behind this is that common property resources can extend indivisibly over larger geographic areas because of their mobility and fluidity.
- 2. Private ownership of the resources may have low extra anticipated returns. Appropriating and defending exclusive rights which insure restricting the freedom of use of a resource may be considered to be of little or no advantage to the users. Anticipation of low extra returns usually occurs when the resource appears to be of such magnitude that its use by one individual will not diminish the use of the resource by others. This basic philosophy was instrumental in establishing the "freedom of the seas" doctrine under which individual commercial fishermen argue: "fish as long and as hard as you wish because there will always be fish." There is biological evidence available that demonstrates the fallaciousness of such an argument.

<sup>8</sup>Francis T. Christy, Jr. and Anthony Scott, <u>The Common Wealth</u> <u>in Ocean Fisheries</u>, Resources for the Future (Baltimore: Johns Hopkins Press, 1965), pp. 6-7. The concept will be developed theoretically in the following section.

The production decision for members of the industry, in 3. terms of labor and capital that is applied in the exploitation of a common property resource, is not subject to the economic constraints that govern the rational exploitation of resources that have formal institutional property relationships. Within the framework of common property the individual user is in competition with all other users of the same resource base. Thus, the individual will attempt to exploit the largest share of the resource that is economically possible from his individual production decision. It would be unreasonable to assume that the individual would restrain his efforts and not exploit this share because any portion he does not exploit will be exploited by other users of the same resource. 4. There are social costs incurred through customs, laws, and other institutional arrangements that prevent acquisition of exclusive rights to the use of a common property resource. Acquisition of such rights could internalize many of the externalities. Marine fisheries have "grandfather clauses" in most fishing treaties and international agreements to insure the use of the resource by individuals, provinces, or countries who were exploiters of the resource during the initial use phase.

The marine fisheries serve as an excellent example to discuss the four preceeding externality characteristics in economic terms. Direct unrestrained competition for use of a common property resource requires the individual exploiter within the industry to consider the firm production decisions in terms of average productivity rather than marginal productivity. The individual firm engaged in commercial fishing in a short run marine fishery situation is forced, by the motive of self interest, to harvest the largest quantity of fish that is physically possible under his given short run labor-capital combination. To reduce uncertainty in his decision process the individual firm will consider the average productivities of each fishing ground. For example: assume two fishing grounds, A and B; A having the higher average productivity. Individual firms will allocate fishing effort to ground A until the average productivities of the two fishing grounds are equated. At this level a long run stable equilibrium between fishing grounds is achieved. Under these decision conditions, many firms will allocate effort to ground A and increase the probability of over-investment, i.e. over allocation of labor and capital to ground A and production in stage III on the fishing ground.

Frank Knight, discussing the allocation of resources to intermarginal and marginal farmland, concludes,<sup>9</sup> "It is the social function of ownership to prevent this excessive investment in superior situations." He further states,<sup>10</sup> "The owner of a

9F. H. Knight, "Some Fallacies in the Interpretation of Social Cost," <u>Quarterly Journal of Economics</u>, Vol. 38, 1924, p. 586.

<sup>10</sup>Ibid., p. 587.

superior opportunity for investment can set the charge for its use at any amount not greater than the excess of the product of the first unit of investment above what that unit could produce on the free opportunity."

Internalizing externalities frequently requires a shift in the institutional property arrangement to bring the external effects to bear on all interacting individuals. External effects may be ignored and a second best alternative selected, the classical tax-subsidy policy could be adopted, <sup>11</sup> or the affected parties might engage in bargaining and attempt to arrange a solution between themselves.

The difficulty of quantifying externalities has led this author to consider externalities only to the effect that they are expressed in the empirical cost data. It was felt, however, that the existence of externalities should be brought to the attention of the reader.

#### Biological and Economic Theory

A review of fishery economics literature reveals the occurrence of a metamorphic process. Early considerations were by fishery biologists who developed physical relationships between the fishable biomass and its environment. The natural resource exploiter, i.e. the commercial fisherman, was treated as an exogenous variable in the biological-economic analysis. As the developmental stages of economic analysis occur, the fisherman becomes an endogenous variable in much of the literature.

<sup>11</sup>Alfred Marshall, <u>Principles of Economics</u> (London: The Macmillan Company, 1961), pp. 467-476.

The present study begins a short review of the literature at the endogenous variable stage and traces the development of fishery economic analysis through the sustainable-yield concept, the effects of an unrestricted entry fishery, and a bionomic equilibrium model.

Biological Model

The biological concept of sustainable yield has been concisely summarized by Crutchfield.<sup>12</sup> He maintains:

The key variable determining production possibilities from a fish population can be grouped under four headings: rate of entry into the 'fishable' age (recruitment); growth rates of individual fish; natural mortality (from disease, old age, and nonhuman predators); and fishing mortality. In the absence of human intervention, any marine population tends toward a maximum aggregate weight, or biomass, at which net increments to stock from recruitment and growth are exactly offset by decrements from natural mortality. Thus, at zero and at maximum population the instantaneous rate of change in the weight of the fishery population is zero. At intermediate levels, the aggregate weight of the stock, in the absence of other disturbances, will tend to rise toward its maximum value, and the instantaneous rate of change in weight will be positive.<sup>13</sup>

Assuming for the moment that recruitment and growth rates are independent of population size, these relationships can be translated into a simple physical production function. As fishing effort (expressed in terms of standard units) is increased from zero level, sustainable yield--that is, the catch equal to the instantaneous rate of change in the biomass in the absence of fishing by man increases at a decreasing rate while the number and average size of fish will decline continuously. If the selectivity of the gear with respect to fish of different sizes is held constant, the sustainable yield will peak at some level of fishing effort. Further increases in fishing effort will produce an absolute decline in sustained physical yield. The common sense of this is apparent.

12James Crutchfield, "The Marine Fisheries: A Problem in International Cooperation," <u>American Economic Review</u>, Vol. 54, No. 3, May 1964, pp. 207-218.

13<sub>Ibid.</sub>, p. 209.

Assuming a recruitment rate independent of population and a sigmoid growth function, fishing by man would yield a larger net physical product as long as the marginal reduction in weight losses from natural mortality is greater than the marginal rate loss resulting from capture of individual fish before they achieve maximum weight.<sup>14</sup>

Effort expended at level  $X_1$  will yield a catch of OA (Figure 2) per unit of time. At this level of effort incremental increases of effort would increase the aggregate weight of the catch.

Most biologists subscribe to the expansion of effort to level  $X_2$ . This level of effort would result in a catch of OB per unit of time or a maximum sustainable yield. Incrementally increasing units of effort beyond level  $X_2$  would decrease the weight of the total catch. For example: effort expended to level  $X_3$  would result in marginal weight loss from capture and natural mortality exceeding the weight gains from growth and recruitment, thus affecting the population size. The extent of the effects are dependent on the level of effort expended beyond  $X_2$ . A level of effort could be expended that results in a fish population reaching the critical or nonrenewable zone<sup>15</sup> and the fishery "destroyed" by human action.

Crutchfield asserts:

The assumption that recruitment is independent of population obviously cannot be of completely general validity. For anadromous fish such as salmon the relationship is critical. Nature is so

14<sub>Crutchfield, op. cit., pp. 209-210.</sub>

<sup>15</sup>S. V. Ciracy-Wantrup, <u>Resource Conservation Economics and</u> <u>Policies</u> (Berkeley: University of California Press, 1963), p. 39. "Critical zone means a more or less clearly defined range of rates below which a decrease in flow cannot be reversed economically under presently foreseeable conditions."



Figure 2. Biological sustainable yield.

prolific in her production of fertilized eggs, however, that the case in which the number of fish surviving to catchable size is independent of the total biomass over relevent ranges is the rule rather than the exception. The other assumptions are less tenable. Growth rates are almost certain to be density dependent as are some types of natural mortality and the production possibilities implicit in the foregoing analysis are not necessarily reversible. As the size of the desired stock is reduced through commercial fishing, permanent shifts in predator prey relations and in relative numbers of competing food users may occur. Moreover, large and frequent shifts in parameters are inevitable in the ecological setting of the sea.<sup>16</sup>

Most fishery biologists associate the maximum sustained yield with optimum yield despite the insistence by a few that the optimum yield involves social considerations that are not explained by the physical relationships. Dr. Martin D. Burkenroad, an eminent fishery biologist, has written, "The management of fisheries is intended for the benefit of man, not fish; therefore, the effect of management upon fish stocks cannot be regarded as beneficial per se."<sup>17</sup>

#### Economic Model

H. Scott Gordon,<sup>18</sup> in his pioneering paper in the field of fishery economics, explains the social consideration by combining physical and economic relationships to consider the optimum degree of utilization of a fishing ground. Construction of his initial model views the optimum degree of utilization as the maximization of net

<sup>16</sup>Crutchfield, op. cit., p. 210.

<sup>17</sup>M. D. Burkenroad, "Some Principles of Marine Fishery Biology," <u>Publications of the Institute of Marine Fishery Biology</u>, Vol. 2, No. 1, University of Texas, September 1951.

<sup>18</sup>H. Scott Gordon, "The Economic Theory of a Common Property Resource: The Fishery," <u>Journal of Political Economics</u>, Vol. 62, 1954, pp. 124-142. economic yield (total revenue minus total costs) of the fishery. Total cost and total revenue are considered to be functions of the intensity of fishing effort.

Gordon, using a production-function approach (Figure 3), assumes a linear decreasing functional relationship between average productivity (productivity per unit of fishing effort)--as well as marginal productivity--and the quantity of fishing effort expended.

Marginal factor cost is equal to average factor cost under the assumption that costs (including opportunity costs) do not affect the quantity of effort expended. The optimum intensity of effort on the fishing ground and the resource is OX which provides a maximum net economic yield of apqc. Maximum physical sustained yield occurs when marginal productivity equals zero with a corresponding fishing effort of OZ.<sup>19</sup> Gordon concludes that the optimum fishing intensity, in economic terms and directed toward the fishing grounds, is less than the intensity which would maximize physical sustainable yield. Area apqc reflects the rent yielded by the fishery resource and the economic productivity of the fishing ground. This simplified analysis describes the intensive margin of utilization of the intramarginal fishing ground.

Gordon complicates his analysis by introducing the common property aspect of the fishery resource. Under this condition, entry to the fishing industry is unrestricted and fishermen are free to fish wherever they please. Rent yielded by the intramarginal fishing ground

<sup>19</sup>H. Scott Gordon, "Misinterpretation of the Law of Diminishing Returns," <u>Canadian Journal of Economics and Political Science</u>, February 1952.



cannot be appropriated by a single individual. The result is a pattern of spatial competition among fishermen that culminates in a dissipation of the rent yielded by the intramarginal grounds.

Any expended effort of fishing grounds number 2 (Figure 4) will yield a lower average revenue product than on fishing grounds 1. Maximization of net economic yield on grounds 1 and 2 is accomplished when the marginal revenue products are equal on both grounds, i.e. when marginal cost equals C, OX and OY effort intensities will maximize net economic yield. Fishermen, however, are not interested in marginal revenue product, but in average revenue product and, being free to fish any fishing ground, will fish ground 1 because the average revenue product ac (ground 1) is greater than bc (ground 2). The allocation of effort on ground 1 would predominate until the average revenue product of ground 1 is equal to the average revenue product of ground 2. When the average revenue products are equal, a stable equilibrium for both fishing grounds will exist.

On the extensive margin, average cost equals average revenue product; average revenue product for all fishing grounds equated by the free competition of fishing. Since it is assumed that average cost is equal for all grounds, other intramarginal grounds will yield no rent because fishing effort has been misallocated. Through gross misallocation of fishing effort it is feasible for a fishing ground to exist that is being exploited in the range of negative marginal productivity. This situation clearly represents an over-expenditure of fishing effort.





Developing the long-run static equilibrium concept one step further, Gordon considers a bionomic equilibrium for a fishing industry. Under simplifying assumptions of constant product prices, fixed prices of factor inputs, and a nonlinear landings function, the relative quantities of expended effort, total cost involved in fishing activity, and the value of landings are described. Generation of a stable equilibrium results in the derivation of four basic equations:

P = P(L)				(1)
L = L(P,E)				(2)
C = C(E)		¢		(3)

$$C = L$$

P = population of fish or the fishable biomass.

L = landings in value terms.

E = intensity of fishing effort.

C = total cost of expenditure of fishing effort.

Point A (Figure 5) describes the stable equilibrium as the equalization of total costs for expended fishing effort and landings in value terms. Crutchfield and Zellner<sup>20</sup> explain this analysis and point out:

At this point, total receipts just cover total costs including a minimum necessary return to the vessel owner. At any lower level of fishing effort profits in excess of this minimum would be earned and vessels would enter the fishery. At higher levels returns would not cover total costs and fishing effort would be curtailed. Some vessels would be diverted to other operations and the usual reductions in number of vessels due to depreciation

<sup>20</sup>James Crutchfield and Arnold Zellner, "Economic Aspects of the Pacific Halibut Fishery," <u>Fishery Industrial Research</u>, Vol. I, No. 1, Fish and Wildlife Service, April 1962, pp. 14-15.

(4)



Figure 5.
and losses would not be fully replaced. Obviously any increase or decrease in prices received by fishermen whether caused by an increase in retail demand or a reduction in the cost of marketing services would increase or decrease the fishing effort. Similarily, increases or decreases in fishing costs would restrict or stimulate fishing activity.

It is interesting to not that, given the yield-revenue function, the point of stable equilibrium of total costs and landings in value terms is dependent upon the slope of the cost function. Figure 6 poses three possible general stable equilibriums for alternatively sloped cost functions. Effort, landings, and total costs in Figure 6a would be stable equilibrium at a point less than the maximum sustainable yield; in Figure 6b equilibrium is reached at the maximum sustainable yield level; and in Figure 6c equilibrium is reached at a level greater than maximum sustainable yield.

Scott, Crutchfield, Zellner, Turvey, and Christy do not differ in their interpretation of an unrestricted fishery.<sup>21</sup> All have considered a long-run equilibrium of a fishery in generally the same terms as Gordon in his analysis.

<sup>21</sup>Christy and Scott, <u>op. cit</u>.

James A. Crutchfield, "The Economic Objectives of Fishery Management," <u>The Fisheries: Problems in Resource Management</u> (Seattle: University of Washington Press, 1965).

Crutchfield and Zellner, op. cit.

Anthony Scott, "The Fishery: The Objectives of Sole Ownership," Journal of Political Economics, Vol. 66, 1955, pp. 116-124.

Ralph Turvey, "Optimization and Suboptimization in Fishery Regulation," <u>American Economic Review</u>, Vol 54, No. 4, March 1964, pp. 64-76.

Ralph Turvey and Jack Wiseman, Editors, <u>The Economics of</u> <u>Fisheries</u> (Rome: Food and Agriculture Organization of the United Nations, 1957).





These authors advocate a management practice that would maximize the social gain, and propose that a fishery be fished at a point where the net economic yield is maximized. Graphically, (Figure 7) this would be a point less than the maximum sustainable yield. Under these conditions the fishery would operate as a monopoly or as a single firm would operate. Gordon summarizes by saying, "In this case we are maximizing the yield of a natural resource, not a privileged position, as in standard monopoly theory. The rent here is a social surplus yielded by the resource, not in any part due to artificial scarcity, as in monopoly or rent."<sup>22</sup>

# The Static Sustainable Yield vs. <u>A Stochastic Sustained Yield</u>

The static industry approach considered by all fishery economists is a valuable contribution to the literature, but has shortcomings when applied to real life situations. Such is the case with the preceeding analysis. Consideration of the minimization of production costs for a particular fishing ground within an industry requires an understanding of the actions and reactions of the individual firm under the assumption of unrestricted entry. There is a definite gap in the literature that must be filled if continuity between the theory of the fishing firm and the theory of the fishing industry 'is to be achieved.

<sup>22</sup>H. Scott Gordon, "The Economic Theory of a Common Property Resource: The Fishery," <u>op. cit</u>., p. 141.





A second shortcoming of the current literature and its application to real life situations is the development of a theoretical body of knowledge that considers only the stable sustainable yield curve. As population dynamics theory increases in sophistication, the biologist is becoming increasingly aware of considerable short run variations around the sustained yield curve.<sup>23</sup> The variations are phenomena resulting from natural causes such as large and sudden changes in salinity, water temperature, availability of food supplies, etc. McHugh explains, ". . . rational development of a single species fishery usually cannot be accomplished under the single concept of a single maximum sustainable yield." <sup>24</sup>

The sustainable yield curve (Figure 8) is actually an expected or mean yield curve. The expenditure of effort  $(X_1, Figure 8)$  will yield an expected catch of OA. The actual catch varies within a range of about catch level OA (Figure 8) with effort expended at level  $X_1$ . The actual catch will be a stochastic variable following some distribution around the long run expected sustainable yield.<sup>25</sup>

The implications of the stochastic variation have the most impact on the individual firm. The uncertain variations in yield per

24<u>\_\_bid</u>.

<sup>25</sup>This stochastic variation concept was applied by Drs. Virgil Norton, Darrel Nash, and Harvey Hutchings, economists with the Bureau of Commercial Fisheries, Fish and Wildlife Service, Department of the Interior, to long run fishery industry analysis.

<sup>&</sup>lt;sup>23</sup>J. L. McHugh, "Conservation of Fishery Resources," <u>An</u> Appendix to Food from the Sea and World Protein Deficiency, unpublished.





unit of effort has made the short run production decision similar to one based on game theory. The "player" under conditions of game theory is completely ignorant of what act or strategy his so-called opponent will follow.<sup>26</sup> The individual fishing firm in a short run situation is uncertain of the combinations of variable factor inputs to utilize in order to maximize profit under stochastically variable yield conditions. The firm's logical alternative is to assume the expected yield function and constant prices and develop decision criteria under these conditions. Essentially, the rational firm will calculate expected marginal costs, average costs, and average variable costs and develop an expected output level (Figure 9). The absence of a stochastic variation in the yield per unit of effort would result in an output level of X, per unit of time and profit of APCE. The occurrence of a stochastic variation that increased the yield per unit of effort would result in a downward shift, to the right in the SAC and SMC curves relative to the increase in yield per unit of effort. A "windfall" gain in production  $X_2 - X_1$  would occur with a "windfall" gain in profit, area ADBFCE.

The occurrence of a stochastic variation that decreased the yield per unit of effort would increase and shift the SAC" and SMC" upward and to the left relative to the increase in yield per unit of

<sup>26</sup>Two introductory books are available to the reader who wishes to expand the concepts of game theory presented here: W. J. Baumol, <u>Economic Theory and Operations Analysis</u> (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1965.) C. West Churchman, Russel L. Ackoff and E. Leonard Arnoff, <u>Introduction to Operations Research</u> (New York: John Wiley and Sons, 1957).



effort. A decrease in profit, zero profit, or a short run loss could occur, depending upon the relative shift in the cost curves.

The short run equilibrium of the industry under conditions of stochastic variations is simplified considerably by the assumption: constant ex-vessel prices. In effect, this simplifying assumption assumes the short run equilibrium of the industry away.<sup>27</sup>

The long run situation and its relationship to the individual firm allows for greater variation in the level of output for any individual firm. The long run allows for changes in the utilization of the existing facilities and changes in the number and scale of the fishing vessels. Assumptions of freedom of entry and exit allow new firms to enter the industry as well as existing firms to leave. These assumptions will increase the elasticity of the individual firm's supply curve because fixed costs become fewer as the time period is extended.

The short run analysis of the firm implied the cost curves of the firm were dependent on the law of variable proportions and considered capital and management as fixed factor inputs. In the long run the rational individual firm will "consider" a finite series of short run average cost curves, and "fit" a long run cost curve that is tangent to some short run cost curve at each scale of plant and level of output.<sup>28</sup>

<sup>27</sup>The assumption is realistic for the Dry Tortugas shrimp analysis because the intrayear price variation is relatively stable between periods of high and low productivity (Appendix B).

<sup>28</sup>A finite series of short run average cost curves will be considered because of the indivisibilities associated with the scale of fishing vessels.

The freedom of entry assumption will allow for new firms to enter the industry if profits are present and may bid up the price of the factor inputs. The increased competition for the resource base will also give rise to externalities which will increase the long run average cost curve of the industry via the short run average cost curves. Theoretically, firms will be attracted to the industry as long as profit is present, and a long run equilibrium (Figure 10) will result in which long run average cost is tangent and equal to the marginal revenue and long run marginal cost.

The entry of new firms in the long run causes an increase in output, i.e. a shifting of the industry supply curve to the right; to maintain the constant price it is also assumed that the industry demand will shift upward and to the right relative to the increase in demand.

The long run analysis can be complicated, as was the short run analysis, by the short run stochastic variation in yield per unit of effort. The individual firm in the long run attempts to develop a scale of plant and, hence, a long run average cost curve that considers the expected mean yield per unit of effort. The individual firm also considers the distribution of the stochastic variation in yield per unit of effort. These two factors are prime input in the decision process for the optimum scale of the primary production unit. It should be clearly evident that any catch which results in total revenue exceeding total cost will be inducement for the new firms to enter the industry. The result is an industry that is perhaps overcapitalized and underutilized in relation to the expected sustainable



yield concept. This is to say that the total costs incurred by the industry exploiting a fishery, in the short run, may exceed the total revenue.

# Empirical Analysis in Fishery Economics

Fishery economics literature to date has been theoretical in context with very little emphasis placed on extensive empirical analysis. This should not be interpreted as a harsh criticism because there have been numerous impediments to detailed empirical analysis.

Fishery economics is a relatively new area of research endeavor for the economist. The first detailed economic literature contribution was made by H. Scott Gordon in 1954. His efforts were directed toward developing a theoretical framework for common property fishery resources for the serious fishery economics student.<sup>29</sup> Additional efforts have been undertaken by other economists to develop a sound theoretical economic framework.<sup>30</sup>

A second impediment is the lack of economic data. Any empirical analysis requires reliable data as the major input. The Bureau of Commercial Fisheries has been engaged in gathering biological and secondary economic statistics on a systematic basis for the last decade, but to date no provisions have been made to collect primary economic statistics. Canada has made demonstrable efforts to collect

<sup>29</sup>H. Scott Gordon, "The Economic Theory of a Common Property Resource: The Fishery," <u>op. cit</u>.

<sup>30</sup>See footnote 9, literature review and economic theory section, for a brief bibliography.

economic statistics as testified by their current publications.<sup>31</sup> Canadian economists are presently engaged in an empirical bio-economic study of a limited entry lobster fishery in southeastern Canada, and published results will be available in late 1967.

Pressing public policy issues have necessitated research emphasis to be directed toward management problems. Crutchfield and Zellner<sup>32</sup> and Turvey<sup>33</sup> have engaged in hypothesizing the effects of various management techniques on the allocation of labor and capital to a fishery resource.

Another major impediment to empirical analysis has been the lack of financial assistance to the development of mathematical models. The construction of general economic mathematical models requires the aid of skilled professional personnel to develop mathematical relationships, both biological and economic, and generate the necessary data to test these models.

The preceding impediments to empirical analysis are recognized by public policy makers, however, and serious efforts are being undertaken to rectify the situation. It is through this recognition that this study has been made physically and financially possible. The purpose of this study is to develop one general empirical approach to fishery economics and to extend the preceding theoretical and

<sup>31</sup>For example: John Proskie, "Costs and Earnings of Selected Fishing Enterprises Atlantic Provinces 1962," <u>Primary</u> <u>Industry Studies</u>, Vol. 12, No. 1 (Ottawa: Department of Fisheries of Canada, 1964).

<sup>32</sup>Crutchfield and Zellner, <u>op. cit</u>.
<sup>33</sup>Turvey, <u>op. cit</u>.

incomplete empirical analyses into a more sophisticated economic approach which will be useful to the public policy decision maker and to members of the fishing industry. By increasing the knowledge of how and why the fishing industry acts and reacts as it does, it is hoped that the economic efficiency of the industry can be increased.

#### CHAPTER III

# BIOLOGICAL AND ECONOMIC CHARACTERISTICS OF THE DRY TORTUGAS SHRIMP FISHERY

The fishing ground to be emphasized in the development of a general production cost minimization model is the Dry Tortugas fishing ground in the Gulf of Mexico. The Dry Tortugas is an offshore fishing ground north and south of the Florida Keys and west of Key West, Florida (Figure 11). It is bounded geographically by 81° and 84° longitude and 24° and 26° latitude. The fishery is distinguished by four characteristics which make it suitable for initial empirical analysis:

- The fishery has an indigenous species: Penaeus duorarum (commonly called pink shrimp). There is little or no interaction with populations found in other fisheries.
- The Tortugas fishery is a year-round fishery and the population exploited throughout the calendar year (Table 3).
- The fishery is exploited by numerous vessel sizes.
   These sizes range from 10 gross tons to over 80 gross tons (Table 4).
- 4. The fishery has received prime consideration in biological research. Biological research programs have been underway in this fishery since the mid-1950's. Shrimp life cycles, population movement, and population dynamics have all



Figure 11. Dry Tortugas fishing ground, Gulf of Mexico.

Month	1964 Trips	1965 Trips
. January	1,687	997
February	1,102	735
March	927	866
April	555	877
May	470	386
June	385	240
July	145	128
August	- 176	200
September	348	276
October	422	599
November	648	728
December	862	824

Table 3.--Total trips for all vessels, by month, in the Dry Tortugas fishery, 1964 and 1965.\*

\*Trips vary in length by area fished and size of vessel. The length of the trips range from 4 to 7 days.

Size class	Gross • tons	1964 (number)	1965 (number)	
1	5-9	0	0	
2	10–19	6	4	
3	20-29	23	19	•
4	30-39	123	103	
5	40-49	148	131	
6	50-59	59	50	
 7	60-69	127	152	
8	70-79	32	50	
9	80+	10	24	

Table 4.--Vessels fishing Dry Tortugas, by size class, 1964 and 1965.

been studies on the Dry Tortugas and numerous biological publications are available.<sup>34</sup>

34Kenneth N. Baxter, "Abundance of Postlarval Shrimp--One Index of Future Shrimping Success," <u>Gulf and Caribbean Fisheries</u> <u>Institute</u>, 15th Annual Session, November 1962, pp. 79-87.

Albert Walker Collier, <u>The Shrimp Fishery of the Gulf of</u> <u>Mexico, Bio notes and recommendations</u>, Gulf States Marine Fisheries Commission, 1959.

T. J. Costello and Donald M. Allen, "Migration and Geographic Distribution of Pink Shrimp, Penaeus duorarum, of the Tortugas and Sanibel Grounds, <u>Florida Fishery Bulletin</u>, Vol. 65, No. 2, pp. 449-459.

T. J. Costello and Donald M. Allen, <u>Migrations, Mortality</u>, and Growth of Pink Shrimp in Galveston Biological Laboratory, Fishery Research, U.S. Fish and Wildlife Service, Cir. 129, pp. 18-21.

T. J. Costello and Donald M. Allen, "Notes on the Migration and Growth of Pink Shrimp (Penaeus duorarum)," <u>Gulf and Caribbean</u> <u>Fisheries Institute</u>, 12th Annual Session, November 1959, pp. 5-9.

William C. Cummings, "Maturation and Spawning of Pink Shrimp, Penaeus duorarum, Burkenroad," <u>Transactions of the American Fisheries</u> <u>Society</u>, Vol. 19, No. 4, pp. 462-468.

Sheldon Dobkin, <u>Early Developmental Stages of Pink Shrimp</u>, <u>Penaeus duorarum, From Florida Waters</u>, Fishery Bulletin 190, U.S. Fish and Wildlife Service, Vol. 6, 1961, pp. 321-349.

Bonnie Eldred, Robert M. Ingle, Kenneth D. Woodburn, Robert Hutton, and Hazel Jones, <u>Biological Observations on the</u> <u>Commercial Shrimp, Penaeus duorarum Burkenroad, in Florida Waters</u>, Professional Papers Series, No. 3 (St. Petersburg, Florida: Florida State Board of Conservation, October 1961).

Clarence P. Idyll, <u>The Commercial Shrimp Industry of Florida</u>, Florida State Board of Conservation, Educational Service, No. 6, p. 6.

Edwin S. Iverson, Andrew E. Jones, and C. P. Idyll, <u>Size</u> <u>Distribution of Pink Shrimp, Penaeus duorarum, and Fleet Concentrations</u> <u>on the Tortugas Fishing Grounds</u>, Special Scientific Report--Fisheries No. 356, U.S. Fish and Wildlife Service, August 1960.

The fishery, established in 1950 during the rapid growth period of the Gulf of Mexico shrimp fishery, has produced approximately 11 million pounds of heads off shrimp annually (Table 5). The fishing grounds are comprised of approximately three thousand square nautical miles of sea, but fishing activity is concentrated in an area 60 miles long, east and west, and 25 miles wide, north and south; and is located west and northwest of Key West, Florida. The southeast corner of this actively fished area is approximately 50 miles west of Key West. The shrimp population occurs outside this area of concentrated activity; but the ccean bottom is covered by loggerhead sponges, coral, and rock outcroppings, making fishing difficult. For purposes of this study, however, the entire Dry Tortugas fishing ground will be considered to maintain continuity with the statistical area designations developed by the Bureau of Commercial Fisheries for their catch-landing statistics. The statistical areas designated for the Dry Tortugas are 0010, 0020, and 0030 (Figure 11).

The commercially exploited shrimp population on the Tortugas grounds is almost entirely pink shrimp, <u>Penaus duorarum</u>. The life cycle of the pink shrimp is approximately 13 months. The pink shrimp spawn at sea and the larvae migrate via tides and currents to the estuarine and bay area adjacent to the Florida Keys and the southwest

34(Continued) Edwin A. Joyce, Jr. and Bonnie Eldred, <u>The Florida Shrimping Industry</u>, Florida State Board of Conservation, Educational Series, No. 15, November 1966.

Joseph H. Kutkuhn, <u>Dynamics of a Penaeid Shrimp Population</u> and <u>Management Implications</u>, Fishery Bulletin, Vol. 65, No. 2, pp. 313-338.

Percent of Gulf Percent of of Mexico yearly ten-year Total Year production total 6.00 12,366,554 11.41 1956 9,664,755 8.92 5.00 1957 7.00 13,733,249 12.68 1958 7.07 3.00 7,658,696 1959 6.00 12.99 14,068,192 1960 10,113,859 9.33 7.00 1961 7.64 5.00 1962 8,281,319 4.00 8.88 9,620,137 1963 6.00 10,919,561 10.08 1964 6.00 10.96 1965 11,867,562 100.00 108,294,763 Ten-year total Ten-year average -- 10,829,476.3

(Pounds, heads off weight)

Table 5 .-- Yearly production of shrimp from the Dry Tortugas.

coast of Florida. Generally, the juvenile shrimp remain in these areas until they attain a body length of approximately 100 millimeters. Upon attaining this length, the shrimp begin migrating from the estuarines and bays in northwesterly, westerly, and southwesterly directions onto the fishing grounds. Biological research and observation have established that most of the migration occurs in a northwesterly direction.

Annual periods of peak spawning activity are typical of the Tortugas pink shrimp. These periods result in a population "wave" migrating onto the fishing grounds in September of each year. The population wave is reflected in the fishing effort and catch statistics from October through March of the following year (Table 6). The shrimp are rapidly increasing in size during the early phases of migration, but are subject to natural mortality estimated by Costello and Allen to be 19.7 percent per two-week period.<sup>35</sup> The migration from inshore waters to offshore waters is accompanied by a direct relationship between size of shrimp and ocean depth.<sup>36</sup> Dispersion of the shrimp population is also occurring as the migration of the population continues over time. It is estimated that the dispersion rate is of such magnitude that fishing becomes uneconomical after a depth of 40 fathoms.

36<sub>See</sub> Appendix C.

<sup>35&</sup>lt;sub>T.</sub> J. Costello and Donald M. Allen, "Mortality Rate in Pink Shrimp, <u>Penaeus duorarum</u>, Populations of the Sanibel and Tortugas Grounds, Florida," unpublished report of the U.S. Fish and Wildlife Service.

Month	1964	1965
January	1,526,403	1,478,744
February	1,090,877	902,843
March	1,099,618	1,262,147
April	898,876	828,827
May	678,570	421,988
June	519,798	239,076
July	251,200	172,627
August	413,022	304,546
September	736,909	638,842
October	719,859	1,900,437
November	1,734,954	2,067,341
December	1,232,307	1,644,911
	•	

Table 6.--Shrimp landings by month, Dry Tortugas fishery, 1964 and 1965.

The Dry Tortugas fishing fleet, ranging at various points in time from 300 to 500 vessels, intercepts the population "wave" migration in 9 to 11 fathoms of water in the southeast corner of the actively fished portion of the Tortugas grounds. Weather permitting, the fleet follows the migration pattern of the population until the dispersion reaches a level where there is no established or identifiable migration direction.

The fishing fleet exploiting the Dry Tortugas is concentrated in four ports in southwest Florida -- Key West, Marathon, Fort Myers, and Tampa. The vessel size typically ranges from 10 gross tons to over 80 gross tons and the vessels are generally of wood construction.<sup>37</sup> The vessels generally return to their homeports upon completion of a trip. A typical trip of a vessel fishing the Dry Tortugas is 5 to 10 days in duration, of which 4 to 7 nights are engaged in the fishing process.<sup>38</sup> A vessel traveling from its homeport over the fishing ground tows a try net on the bottom until a concentration of shrimp is located. When a vessel comes in contact with a concentration, two large nets ranging in width from 40 to 65 feet are attached to cables which are in turn attached to booms extending over the gunnels of the vessel. The vessel then tows the nets along the substrata and picks up shrimp, fish, benthic organisms, and debris. During peak periods of dense shrimp population movement, the nets are towed along the bottom for approximately three hours. The nets are then raised

37 See Appendix D for vessel and crew characteristics.

38<sub>Pink</sub> shrimp are nocturnal in habit; consequently, fishing activity is conducted at night.

to the vessel and the contents of the nets are emptied on the stern deck. The boat crew--typically consisting of the vessel captain; the rig man whose duties include lowering the net, controlling the net on the bottom, and raising the net; and a header who is responsible for deheading the shrimp--begin sorting the shrimp from other organisms and debris.

Heading shrimp is a manual process and occurs after the shrimp have been separated from the extraneous materials and organisms. Headed shrimp are then placed in the hold of the vessel and are "iced down" in a one to one ratio by weight with shaved ice. Shrimp remain in this condition until the vessel reaches port. Upon returning to their homeports, the shrimp are unloaded at dockside intermediate processing facilities.<sup>39</sup> Remuneration per pound of shrimp varies with size, thus the intermediate processing facilities grade the shrimp by size and weigh each size count before the payment is made. A processing and handling fee is usually exacted and the burden of payment falls on the vessel owner.

Remuneration of the crew is on a share basis. A typical crew share agreement in southwestern Florida is two-thirds of the gross receipts for the boat owner and one-third for the crew. The boat crew agrees to purchase groceries utilized during the fishing trip and the boat owner usually agrees to cover all other expenses, both fixed and variable, associated with the fishing trip.

39Intermediate processing facilities are facilities where shrimp are landed, weighed, graded, sometimes headed, and repacked in ice for shipment by truck to fresh wholesale markets or secondary processing facilities. With the exception of Tampa, the major ports servicing the Tortugas fishery (Key West, Marathon, and Fort Myers) are unloading and intermediate processing ports. Tampa is the only Tortugas port with substantial secondary processing capacity.<sup>40</sup> Fresh, raw headless shrimp are transported from the other ports to Tampa for packaging and freezing, breading, and portion packing and wholesale distribution. Key West, Marathon, and Fort Myers merely offer dockage and vessel supply facilities adjacent to the fishing grounds. Most of the fresh raw shrimp landed in these three ports are transferred by truck to secondary processing facilities or to fresh wholesale markets.

 $40_{\rm A}$  secondary processing facility is a facility where shrimp are packaged whole or peeled and deveined and packaged, breaded, or portion packed for wholesale distribution.

# CHAPTER IV

#### METHOD

#### Alternative Spacial Models

The optimum allocation of fishing effort in time and space to minimize total production costs for a predetermined level of physical production can be attained via two alternative spatial models: (1) The standard equilibrium formulation utilizing demand and supply relations; or (2) activity analysis models involving physical production activities and demand relationships. "The two groups of models are not mutually exclusive--both may portray partial or complete equilibrium, their representation of shipping and consumption activities are similar, and the simplest model of each is the standard transportation model with preassigned regional quantities produced and consumed." <sup>41</sup>

The activity analysis transportation model is appropriate for this study because this type model usually specifies discrete regions, representative producing points, and representative consuming points. Regional consumption can be preassigned, perfectly elastic at a constant price, or a function of a price range. Supply functions are replaced by production costs for at least one level of the production process and are specified for each region.

41D. Lee Bawden, "An Evaluation of Alternative Spatial Models," <u>Journal of Farm Economics</u>, Vol. 46, No. 5, December 1964, p. 1372.

The regional resources may be assumed geographically fixed or mobile between regions. Likewise, the physical plant may be assumed to be fixed or variable. Transportation costs are specified between regions for all mobile resources, intermediate goods, and final products. A purely competitive market system is also assumed to be present.42

#### Linear Programming

Standard linear programming techniques for minimizing an objective function were found to be most applicable to this study; hence, they were utilized. The standard techniques have three basic components which reflect the data specifications:

- 1. A linear objective function stating the objectives of the model. The objective function can be either maximization of the objective or minimization of the objective. Formulated, a general linear objective is:
  - $\mathbf{F}(\mathbf{X}) = \sum_{j=1}^{n} \mathbf{C}_{j} \mathbf{X}_{j}$ (5) j=1 j = 1, 2, 3, . . . , n; i.e. activities C; = price or cost coefficient X; = structural variable; i.e. competing activities
- Linear structural constraints which embody the technical 2. specification and resource capacities:

42<u>Ibid</u>., pp. 1372-1373.

# $\sum_{j=1}^{n} \sum_{i=1}^{n} A_{ij} X_{j} \leq bi$ $i = 1, 2, 3, \dots, n$ $j = 1, 2, 3, \dots, n$ $A_{ij} = set of structural coefficients reflecting$ the technical specifications of the problembi = set of constants reflecting the maximum resource $capacities cr minimum resource requirements <math display="block">f(A) = \frac{1}{2} \sum_{j=1}^{n} A_{ij} X_{j} \leq bi$ (6)

- 3. Nonnegativity constraints for:
  - (a) structural variables

X; ≥ 0

(7)

(8)

 $j = 1, 2, 3, \ldots, n$ 

These constraints do not allow negative production or shipments.

(b) slack variables

s, ≥ 0

i = 1, 2, 3, ..., m

These variables prevent resource use in excess of the original supply.

- (c) artificial slack variables
  - $A_{i} \geq 0$  (9) i = 1, 2, 3, ..., m

The constraints denote the use of requirements of resources by the artifical variables.

The general concept of the transportation problem in linear programming restricts the values that can be assigned the structural coefficients  $(A_{ij})$  and limits the constraints to only one type of unit. One can conclude that the general linear programming concept can be reduced to the transportation problem if two conditions are met:

 The A<sub>ij</sub>'s are restricted to values of zero or a positive coefficient; i.e. the decision to be made is simply whether or not to transport goods from origin to destination.

2. There exists homogeneity of units among the constraints.

# Model I

Nine vessel size classes were chosen from the Gulf of Mexico shrimp fishing fleet. These classes are:

1. 5 to 9 gross tons

2. 10 to 19 gross tons

3. 20 to 29 gross tons

4. 30 to 39 gross tons

5. 40 to 49 gross tons

6. 50 to 59 gross tons

7. 60 to 69 gross tons

8. 70 to 79 gross tons

9. Over 80 gross tons

Also noted is the absence of vessel size class one (5-9 gross tons) utilization in the exploitation of the Dry Tortugas fishery.

Utilizing the standard Bureau of Commercial Fisheries regional biological catch data techniques, it was noted that the Dry Tortugas comprises 13 separate production regions (Table 7). Landings are recorded for three ports in the Dry Tortugas--Key West, Fort Myers, and Tampa. Landings in other ports are of such insignificant magnitude that they can easily be assumed zero and the capacity assigned to the nearest major port (Table 8).

Production region	Area	Depth (fathoms)	Pounds Production
1	1	6–10	116,550
2	1.	11–15	9,527
3	1	16-20	1,600
4	2.	6–10	<b>301,</b> 354
5	2	11-15	8,604,223
6	2	16-20	2,028,821
7	2	21-25	301,419
8	2_	26-30	19,149
9	2	31-35	5,153
10	3	11–15	140,071
11	3	16-20	331,296
12	3	21-25	6,584
13	3	26-30	1,815
			Total 11,867,562

Table 7.--Shrimp production by region, Dry Tortugas, 1965.

Table	8Landings	of Dry	Tortugas	shrimp t	by ports	, 1902.
					•	•**

Port	Pounds landed	Combined landings	Port number	Port name
Key West, Florida Marathon, Florida	8,986,729 97,696	9,084,425	Port 1	Key West, Florida
Fort Myers, Florida Punta Gorda, Florida	2,505,450 68,486	2,573,936	Port 2	Fort Myers, Florida
Tampa, Florida Alabama Bayou La Batre, <del>Inision</del> a	207,937 1,264 Total	209,201 = 11,867,562	Port 3	Tampa, Florida

Substituting the Dry Tortugas characteristics into standard linear programming jargon, the following objective function and constraints are obtained:

 $43_{\text{Capacity of port j}}$  is defined as the number of pounds landed in port j during the time period under consideration.



Sum of all production by vessel size class i in port j from regions 1 through 13 is equal to or less than the production capacity of vessel size class i in port j.

D\_j = Production capacity of vessel size class i in port j.

$$\sum_{b=1}^{13} B^{b} = \sum_{j=1}^{3} A_{j}$$
(14)

Production capacity of region 1 through 13 is equal to the capacities of ports 1 through 3.

The purpose of this simplifying assumption equating supply of raw headless shrimp from the Dry Tortugas with the demand, i.e. port capacity, for raw headless shrimp from the Dry Tortugas during the time period under consideration is to insure that no accumulation, inventory, or waste of fresh raw headless shrimp occurs.

This is a nonnegativity constraint to insure negative production or shipment of raw headless shrimp does not occur in the model.

#### Available Data Requirements

Data requirements for the model are production capacity in pounds of each of the 13 individual regions in the Dry Tortugas; port capacities for shrimp caught in the Dry Tortugas; capacity coefficients for each vessel size class within each of the three principal ports; and traveling, production, and transporting cost per pound coefficients for each individual size class within each of the three principal ports.

(13)

(15)

Constructing a general linear programming model and performing an empirical analysis of the minimization of total production costs for a predetermined level of physical production from a fishing ground requires the introduction of a time element. The decision was made to pattern the general model and analysis to 1965, the latest calendar year for which complete statistics were available for the Dry Tortugas.

Regional production capacity<sup>44</sup> for the Dry Tortugas for 1965 was obtained from the biological catch data. Bureau of Commercial Fisheries personnel stationed in each major shrimp landing port collect landings statistics by individual vessel for each trip. Also, recorded on a random interview basis, is the area, depth fished, size composition, and value of the landings. Table 7 reveals the quantity of shrimp caught in each region.

Recording the individual vessel's landings in each port automatically records the total pounds of shrimp landed in individual ports. Summing over individual vessels will yield this figure (Table 8).

#### Synthesized Data Requirements and Sampling Procedure

Capacity coefficients for all vessels within a size class for an individual port and travel, production, and transport cost-per-pound

<sup>44</sup>The simplifying assumption--physical production capacity for each region is equal to the total number of pounds of raw headless shrimp landed in each region--has been made in this analysis. Consideration was not given to the size composition of the shrimp landed. Such consideration would be essential if the objective function was to maximize total or net revenue because of the value differential between size counts. coefficients required data not available to this author. Consequently, a vessel technological characteristic and operating cost questionnaire (Appendix A) was developed and administered to shrimp vessel owners who exploited shrimp populations in the Gulf of Mexico. The questionnaire was administered in a manner that would generate data which would be readily accessible were the general model expanded to consider the entire Gulf of Mexico shrimp fishery.<sup>45</sup> The author administered the questionnaire to vessel owners on a personal interview basis. Vessel owners responding to the questionnaire had vessels actively participating in shrimp fishing during the calendar years 1964 and 1965, or 1965.<sup>46</sup> The population for the survey was obtained from the landings, value, and area fished data held in computer storage by the Bureau of Commercial Fisheries, Division of Economics, Branch of Statistics. Essentially, all vessels actively participating in the Gulf of Mexico shrimp fishery are recorded in this data.

To expedite the sampling procedure, 13 ports from which samples were taken were selected. These ports were selected on the basis of two criteria. First, when they are aggregated, the selected interview ports must adequately cover the geographical areas currently comprising the shrimp fishery (Figure 12 and Table 9.) Second, the ports must give adequate representation of the vessel size classes

<sup>45</sup>The sampling process relates to the entire Gulf of Mexico shrimp fishery, but the empirical analysis in this study is confined to the Dry Tortugas fishery. The entire Gulf was sampled to generate data concerning the aggregate Gulf of Mexico shrimp fishery. This data can be utilized to expand the current study.

<sup>46</sup>Two calendar years were used to reduce intra-year variations in characteristics and costs.


Figure 12. Gulf of Mexico shrimp fishing grid zones.

.

<u> </u>	Port											
Zone	1	2	3	6 4	5	6	7	8	9	10	11 12	13
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17		x x x x			x x x x x x	x x x x	x x x x x	X X X X X X	x	X X X	x	
18 19 20 21 22 23 24 25 26 27 28 29							•		<b>X</b>	x	x x x x x x x x x x x x x x x x x x x	
2) 30 31 32 33 34 35 36 37 38 39 40 41		x x x x x x x	- x x x x x x x x x x x x								χ.	x x x x x x x x x x x x x x x x x x x

Table 9.--Thirteen selected ports; geographical pattern of fishing.

61

being considered in the sample (Table 10).

The vessels and vessel owners were selected on the basis of a stratified random sample drawn from the major strata based on vessel size class. The vessel size class limits for each stratum were 5-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, and 80 and over gross tons. Stratum sample sizes were determined by consideration of two factors: (1) size of the stratum, and (2) expected variations within the stratum.

Sampling size was at least 10 percent of the population in the 5-9, 10-19, 20-29, 30-39, 70-79, and 80 and over gross ton classes; and at least 15 percent in the 40-49, 50-59, and 60-69 gross ton classes (Table 11). The reason for an increase sampling percentage in the 40-49, 50-59, and 60-69 gross ton classes is that these vessels are in a transition zone. These vessels are physically capable of fishing both inshore and offshore, whereas the vessel classes smaller than 40 gross tons generally are limited to inshore fishing and those vessels larger than 69 gross tons are primarily offshore fishing vessels. A set of alternatives for each stratum was chosen. If needed, alternatives were brought into the study in the order that they were drawn. If the vessel owner was at sea or was unavailable for interview, two additional contact attempts were made. If, after three attempts, the vessel owner was not contacted, an alternate was selected. Likewise, alternates were chosen for elements of the sample 'who had sold their vessel, moved, died, retired, quit fishing, or refused to cooperate. The questionnaire was pretested on ten vessel owners chosen at random from the population,

	Vessel size class													
Port	City and State	BCF code	1.	2	3	4	5	6	7	8	9		Total	
1	Key West, Florida	1		2	15	68	88	31	33	11	5		253	
2	Fort Myers, Florida	2	0	1	1	30	31	21	64	19	12		179	
3	Tampa, Florida	4	0	0	0	1	2	3	84	34	17		141	
4	Ala. Bayou La Batre, Ela.	21	19	43	28	22	14	10	11	5	1		153	
5	Lafitte, Louisiana	45	0	12	13	12	20	11	17	6	3		94	
6	Golden Mendow, La.	47	6	47	32	-35	28	13	9	7	8		185	
7	Houma, Louisiana	48	21	57	34	16	23	8	4	1	0		164	
8	Morgan City, La.	49	1	0	8	12	- 20	20	27	5	8	÷	101	
9	Galveston, Texas	72	3	40	12	16	9	6	5	1	3.		95	
10	Freeport, Texas	73	1	15	6	20	33	26	32	13	6		152	
11	Aransas Pass, Texas	78	2	14	21	18	25	11	51	27.	· 6		175	. ۵
12	Port Isabel, Texas	81	<b>)</b> 0	0	1	11	14	25	67	39	21		178	
13	Brownsville, Texas	82	0	1	0	6	16	24	80	34	18		179	
	Total Total fleet		53 124	232 512	171 321	267 379	<b>3</b> 23 385	209 260	484 534	202 220	108 114		2,049 2,849	
	Percent of f	leet	42.7	45.3	53.2	70.4	83.8	80.3	90.6	91.8	94.7		71.9	

Table 10.--Distribution of vessel size classes within sample ports, 1965.

.С

•	Vessel size class	Numbe in Por	r sampled ts 1, 2, 3
	1	•	0
	2		2
	3		6
	4		10
	5		15
	6	2 <u>-</u> 11-11-11-11-11-11-11-11-11-11-11-11-11	5
	7		36
	8		13
	9		3
		Total	90

# Table 11.--Dry Tortugas vessels random sample breakdown, 1964-1965.\*

\*During the analysis it was decided that 4 vessels in size class 6 were not conducive to the sample, hence were not included. The 15 percent quota in this size class was not met for the Dry Tortugas, but this investigator believes this will not affect the analysis. but were not included in the sample.

The number of Dry Tortugas sample vessels was 63 for 1964, and 88 for 1965. These sample vessels were then subjected to analysis in order to derive capacity coefficients for each vessel size class within each of the three principal Dry Tortugas ports, and traveling, production, and operating cost per pound coefficients for each individual size class within each of the three principal Dry Tortugas ports.

Capacity coefficients for each vessel size class within each of the three principal ports are determined via the equation:

> Port j capacity coefficient for vessel size class i = (Average catch per trip of vessels in class i) (Average number (16) of trips per year by vessels in class i) (Number of vessels of size class i in port j)

j = 1, 2, 3 i = 2, 3, 4, . . . , 9

Average catch per trip in the Dry Tortugas per vessel size class is determined by summing the 1964 and 1965 landings of sample vessels within size class i and the number of trips within size class i for 1964 and 1965 (Table 12).

> Average catch per trip = <u>Total catch 1964 and 1965 per size class i</u> (17) Total trips 1964 and 1965 per size class i

Average number of trips per year is derived from Bureau of Commercial Fisheries data. These data record all trips for all vessels fishing the Dry Tortugas fishery. A two-year average (1964-1965) was determined (Table 13).

					Trine		2-vr. average
Size class	1964	1965	Total	1964	1965	Total	catch*
2	81,605	47,680	129,285	35	23	58	2,229.052
3	172,891	160,831	333,722	116	95	211	1,581.621
4	297,791	286,023	583,814	221	206	427	1,367.246
5	649,806	553,195	1,203,001	361	301.8	662.8	1,815.029
6	82,311	136,460	218,771	39.5	59	98.5	2,221.025
7	355,385	542,659	898,044	141.3	230.4	371.7	2,416.045
8	25,255	102,109	127,364	12	42	54 .	2,358.593
9	15,356	55,351	70,707	6	25	31	2,280.871
		· · · · · · · · · · · · · · · · · · ·					

Table 12.--Tortugas sample vessels, 1964 and 1965; total catch and number of trips.

\*2-year average catch figure represents average catch per trip.

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	Vessel size class			Two-year average (number of tr	ips)	
	2			10		
	3			16		
•	4			17	•	
•	5	- 		17		
	6	, : 		13		<u>.</u>
	7		•	8		
	8			8		
•	9			5		

Table 13.--Average number of trips to Tortugas per vessel size class, 1964 and 1965.\*

\*Includes all vessels fishing the Tortugas in 1964 and 1965.

The number of vessels of size class i in port j is also taken from Bureau of Commercial Fisheries data (Table 14).

The computed capacity coefficient for each vessel size class within each port is reflected in Table 15.47

Throughout this portion of the data input computation it is assumed that the average catch per trip and the average number of trips per year per vessel size class is constant among ports 1, 2, and 3. Examination of the data offers no reason why such an assumption is invalid.

An interesting sidelight in the determination of port capacity coefficients within vessel size classes is the noticeable lack of individual vessel capacity utilization on a trip basis (Table 16). This study, in trying to maintain a realistic approach, will not alter this inadequate utilization in the first portion of the analysis.

The development of traveling, production, and transport cost coefficients for raw headless shrimp relies on the data generated in the questionnaire administered to the industry:

Traveling to the fishing ground and transporting raw headless shrimp from a region to port can be aggregated and referred to as transport rates. This reference is valid because a vessel, in order to transport raw headless shrimp from a fishing region to a port must

<sup>47</sup>A sample computation of capacity coefficient for vessel size class 2 in port 1 is shown below:

Size class 2--Average catch per trip: 2,229 pounds Size class 2--Average number of trips per year: 10 Size class 2--Vessels of size class 2 in port 1: 2 ubstituting into the general formula (equation 16): Port 1 capaci

Substituting into the general formula (equation 16): Port 1 capacity coefficient for vessel size class 2 = (2,229) (10) (2) = 44,580 pounds.

Vessel size class	Port 1	Port 2	Port 3	Total
2	2	1		3
3	15	1		16
4	68	30	1	99
5	88	31	2	121
6	31	18	3	52
7	33	64	84	181
8	11	19	34	64
9	5	12	17	34
Total	253	176 •	141	570

Table 14.--Distribution of shrimp fishing vessels, Ports 1, 2, and 3; 1965.\*

\*Port 1: Key West, Florida Port 2: Fort Myers, Florida Port 3: Tampa, Florida

Vessel size class	Port 1 (pounds)	Port 2 (pounds)	Port 3 (pounds)
2	44,580	22,290	
3	379,680	25,312	<b></b>
4	1,580,252	697,170	23,239
5	2,715,240	956,505	61,710
6	895,063	519,714	86,619
7	637,824	1,236,992	1,623,552
8	207,592	358,568	641,648
9	57,025	136,860	193,885
	• • •		

Table 15.--Capacity coefficient per vessel size class within Ports 1, 2, and 3.

Vessel size class	Average net tons*	Shrimp capacity in pounds**	Average catch per trip	Percent capacity utilization per trip
2	10.0	8,500	2,229	26.22
3	15.0	12,750	1,582	12.40
4	12.4	10,540	1,367	12.96
5	18.4	15,640	1,815	11.60
6	28.6	24,310	2,221	9.13
7	32.2	27,370	2,416	8.82
8	38.8	32,980	2,359	7.15
9	68.3	58,055	2,281	3.92

Table 16.--Average percent capacity utilized per average trip, Tortugas sample vessels.

\*One net ton equals 100 cu. ft. of cargo space.

\*\*8.5 pounds of shrimp mixed with an equal volume by weight of shaved ice occupies one cu. ft. of cargo space. incur a cost in traveling to the region to catch the shrimp it will transport. Development of the transport rate requires a round trip mileage coefficient from each port to the center of each fishing region in the Dry Tortugas. Average traveling speed, average fuel consumption, and average fuel price per gallon data were generated from the questionnaire for each vessel size class. The average transport rate per vessel size class per port was developed via the equations:

> Travel hours to and from fishing region b for vessel size class i = (18) <u>Miles round trip port i</u> Average mph vessel size class i

> Gallons of fuel consumption of vessel size class i on round trip to region b from port j = (equation 18) (gallons (19) of fuel consumption per hour by vessel size class i)

Average cost of round trip of vessel size class i to region b from port j = (equation 19) (fuel cost per gallon in port j<sup>48</sup>

Average transport rate per pound of raw headless shrimp for vessel size class i fishing in region b to port j = (21)<u>Equation 20</u> Average catch per trip for vessel size class i

A complete tabular description of the transport rates is presented in Appendix E.

Assuming constant production costs for a given vessel size class within ports and regions fished in the Dry Tortugas, fixed and variable cost coefficients can be developed for each vessel size class

48The determination of the transport rate is simplified by considering no fixed costs and only one variable cost: fuel.

(20)

from the questionnaire data.

Individual vessels within the sample that fished the Dry Tortugas have been stratified according to size class. Migration characteristics<sup>49</sup> were noted when the data were subjected to analysis (Table 17 and Appendix F).

It has become necessary to adjust every cost element for each sample vessel so that realistic costs would be allocated to the Dry Tortugas within vessel size classes. Adjustment is merely multiplying the cost elements of an individual vessel by the percentage of effort allocated by the owner-decision-maker to the Dry Tortugas for the calendar years 1964 and 1965.<sup>50</sup>

Vessels were then reaggregated according to size class and cost elements summed over vessels within the size class and a two-year average calculated for each cost element per vessel size class. Cost elements were then aggregated into one of the two groups: fixed cost

<sup>49</sup>It has been noted that vessels migrate freely throughout the Gulf of Mexico and fish alternative fishing grounds. Producers have concluded that they should fish grounds during their peak periods of production. This practice, however, is not necessarily the best allocation of fishing effort because little consideration has been given to transport differentials. Such a practice is visible evidence of the consideration of average productivity of a fishing ground discussed in Chapter 2.

> 50The general equation is: (Yearly cost element of individual vessel) (% of total effort by individual vessel in Dry Tortugas during calendar year under consideration)

Example:

Individual vessel's yearly cost of fuel = \$100 Individual vessel allocated 20% of fishing effort in Dry Tortugas during 1965.

(\$100) (.20) = \$20 = cost of fuel allocated to Dry Tortugas for individual vessel in 1965

Vessel size class	Total vessels fished in Tortugas	Number of migratory vessels	Percentage migratory
2	4	2	50.00
3	19	2	10:53
4	103	8	7.77
5	131	20	15.27
6	50	8	16.00
7	152	60	39.47
8	50	27	54.00
9	24	9	37.50
Total	533	136	25.52

Table 17.--Percentage of migratory vessels in Tortugas, 1965.

è

and variable cost (Table 18).

Average variable cost per vessel size class was computed:

Σ variable cost elements (2-year average) size class i

(Average number of trips per year in size class i) (Average number of pounds of raw headless shrimp landed per trip by vessel size class i)

Table 19 lists the average variable cost per pound of raw headless shrimp per vessel size class.

Average fixed cost per vessel size class was computed:

Σ fixed cost elements (2-year average) size class i (Average number of trips per year in size class i) (Average number of pounds of raw headless shrimp caught per trip by vessel size class i)

(24)

(25)

(23)

Table 19 lists the average fixed cost per pound of raw headless shrimp per vessel size class.

Production cost per pound of raw headless shrimp in each region per vessel size class i in port j is computed:

> Production cost per pound of shrimp in each region for vessel class i in port j = (Variable cost per pound of raw headless shrimp in size class i) + (Transport rate of vessel size class i to region b from port j)

Appendix G lists the total production cost incurred by each vessel size class fishing each region from each port.

Total cost incurred by the vessels, computed after the model is optimized:

 $\begin{array}{rl} 9\\ \text{Total cost} = \sum (\text{Total production cost per} \\ i=2 \\ \text{vessel size class i}) + (\text{Total fixed cost per} \\ \text{vessel size class i}) \end{array} \tag{26}$ 

Fixed	Variable
Hull Depreciation	Repairs
Engine Depreciation	Salaries
Electrical Gear Depreciation	Fuel
Other Depreciation	Galley
Taxes Business Property	Ice
Insurance	Packaging and Handling
Legal	Supplies
Interest	Nets
Association Dues	FICA
Bank Charges	
Office Supplies	
Travel	
Miscellaneous	
Licenses	
Taxes	
Telephone	
Radio	

Table 18.--Categories of vessel operating expenses included in the analysis.\*

\*The expenses (on a per pound basis) are presented in Tables 19 and 20.

Vessel size class	Average fixed cost	Average variable cost	
2	.022	.086	
3	.055	.361	
4	<b>.15</b> 5	.416	
5	.067	.283	
6	.082	.386	
7	-084	352	•
8	.173	.410	
9	.153	.541	
• •			
	· · · ·	•	•

## Table 19.--Average fixed and variable costs (1964 and 1965) per pound of raw headless shrimp per vessel size class.

Table 20.--Total costs (1964 and 1965) per pound of raw headless shrimp per vessel size class.

Vessel size class	Total cost	
2 3 4 5 6 7 8 9	.108 .416 .571 .350 .468 .436 .483 .694	

Total fixed cost =  $\sum_{i=2}^{7}$  (Pounds of raw i=2 headless shrimp caught per vessel size (27) class i) (Fixed cost per pound of raw headless shrimp per vessel size class i)

A social cost will be derived because the total vessel-port capacities exceed the total demand for raw headless Dry Tortugas

shrimp.

Social cost =  $\sum_{i=2}^{9} \sum_{j=1}^{3}$  (Pounds of excess i=2 j=1 (28) capacity per size class i) (Fixed cost per pound per size class i)

The derived social cost will reflect the magnitude of the cost to society for idle vessel capacity in the "optimal" solution.

#### Simplifying Assumptions

An analysis of so broad a topic requires certain basic assumptions and specifications, in addition to those already specified in this chapter, to narrow the problem to workable proportion. Although these assumptions and specifications (stated below) simplify the analysis considerably, they are not unrealistic since they retain basic regional relationships.

- 1. The abstract, perfectly competitive market in space, form, and time, is assumed throughout.
- 2. The individual firm and, therefore, the producing region has minimum total production costs as an objective; thus will produce and transport to the port from the region which yields the lowest total production cost per pound of raw headless shrimp.

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- 3. Supply and consumption areas are treated as points. Supply points are chosen as the center of presently important producing regions. Consumption points are chosen where raw headless shrimp from the Dry Tortugas are landed in large quantities.
- 4. Producers are considered to be indifferent as to the source of this production as long as it is at least cost. This assumes absence of size or other inherent characteristic differentials among shrimp or different regions or indifferences on the part of producers concerning existing differences.
- 5. Producers will return to the port from which they departed and, if a shortage of vessel capacity occurs in another port, the producers are mobile and will migrate to the port with the shortage of vessel capacity if there is existing over-capacity within vessel size classes after the homeport demand has been satisfied.
- 6. The estimated costs of producing and transporting on a pound basis are considered to be representative for vessels within the vessel size class landing shrimp at each port.
- 7. Shrimp are readily available on the Dry Tortugas fishing grounds throughout the calendar year. Peak production periods do not exist.
- 8. Vessels do not migrate out of the Dry Tortugas fishery until all Dry Tortugas port demands are satisfied.

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9. The individual firms within the industry exploiting the Dry Tortugas fishery are treated as members of one large firm in the effort allocation process. This will insure 'rational allocation of effort at minimum total production cost.

#### CHAPTER V

#### EMPIRICAL ANALYSIS

## Model I: Allocation of Fishing Vessels and Effort Under Existing Conditions

Considering the assumptions in the previous chapter, the next step was to utilize the generated data in the linear programming model. The objective function, to minimize  $\sum_{b=1}^{13} \sum_{i=2}^{9} \sum_{j=1}^{3} C^{b}_{ij} x^{b}_{ij}$ , for the calendar year 1965 under conditions in this model was equal to \$4,336,478. This figure represents the total variable cost plus transport rate incurred by the vessel owners in the production of 11,687,562 pounds of raw headless shrimp. The allocation of vessels from their respective ports is summarized in Table 21.

The fixed cost incurred per vessel size class is equal to the number of pounds landed in the optimum solution for each unique vessel size class multiplied by the fixed cost per pound coefficient for the respective vessel class (Table 22). Under Model I, the aggregate fixed cost incurred by vessel owners fishing the Dry Tortugas during calendar year 1965 is estimated to be \$1,121,889.

Model I total cost involved in the production of raw headless shrimp from the Dry Tortugas is estimated to be \$5,368,367.<sup>51</sup>

51<sub>Total</sub> cost equals total variable production cost plus total fixed cost.

B	Veccol	Number of		Pounds	Total r	production
	class	vessels	Area	landed	cost	VC + TR*
Port 1	01400			•		
Kev West	2	2.00	5	44,580	\$	4,101
ney nebe	3	15.00	5	379,680		140,102
· · · · · · · · · · · · · · · · · · ·	4	5.00	1	116,550		48,834
	4	.41	2	9,527		4,001
	4	.07	3	1,600		672
	4	62.52	5	1,452,575		618,797
	5	88.00	5	2,715,240		790,135
	6	31.00	5	895,063		350,865
	7	30.35	5	586,653		210,022
	7	2.65	6	57,171		10,422
	8	11.00	5	207,592		21 102
	9	5.00	4	57;025		51,195
Migration of vess	sels			• • • • • •	,	•
to assist in ful-	•			<b>N</b>		•
filling Port 1	÷	•				·
demand	1	6 17	5	186 877		73.256
From Port 2		3 00	5	86,619		33,955
2	0	12.6/	) I	244.329	-	87,225
2	1	63 73	4	1.231.732		440,960
ر د	¢ (	19 00	5 *	358,568		149,523
2	8	24.32	5	459.044		191,421
	U U	Port 1	ź =	9.084,425	<b>Z</b> = \$3	,280,050
Port 2	<b>,</b> .		•			
Fort Myers	2	1.00	6	22,290	\$	2,318
	3	1.00	7	25,312	•	9,694
	5	12.66	6	390,684	• •	119,549
•	5	2.85	7	87,870		26,976
•	5	4.54	10	140,071		41,401
•	5	10.74	11	331,296	÷.	78,373
	5	.21	12	6,584		121 166
	. 6	11.53	6	332,837	· ·	154,400
•	7	63.73	0	,201,007 5 152		1 907
	7	•21 Dent 0	9 _	2 572 036	$\Sigma = S$	891,277
-		Port 2		2,57,6,77,0		0)19~11
Port 3	<b>-</b>	1 22	7	10.717		12.916
Tampa	י סי בי	1.52	ġ	19,1/9		6.070
		.02	13	1.815		561
	. 7	7 63	7	147.491		55,604
•	1	Port 3	ź =	209.201	<b>Σ</b> = \$	75,151
	•		~		_	•
			ΣΣ=	= 11,867,562	≥ ΣΣ = \$	4,336,478
			4. s			

Table 21.--Optimal allocation of vessels from port to fishing ground in the Dry Tortugas, 1965.

\*TR = Total transport cost.

Vessel size class	Pounds landed	Fixed cost* Coefficient	Total fixed cost by vessel size class
2	66,870	.022	\$ 1,471
3	404,992	.055	22,275
4	1,580,252	.155	244,939
5	3,733,455	.067	250,142
6	1,501,396	.082	123,114
7	3,498,368	.084	293,863
8	1,025,204	.173	177,360
9	57,025	.153	8,725
		Fixed co	ost = \$1,121,889

Table 22.--Total fixed cost incurred in 1965 under Model I effort allocation conditions.

\* <u>∑</u> fixed cost element (2-year average) size class i (Average number of trips per year in size class i) (Number of pounds of raw headless shrimp caught per trip by vessel size class i) Estimated real total costs are approximately \$5,920,923.<sup>52</sup> Comparison of this figure with the Model I total cost (Table 23) reveals a possible total cost savings of \$552,556 available to the Dry Tortugas fishing industry through more efficient allocation of fishing effort. Equal distribution of the savings among the estimated 1,300 fishermen (Table 24) employed in the Model I allocation solution would result in an increase in real income of \$425 for each individual fisherman. An important implication when comparing this figure with the average income per fisherman derived from the Dry Tortugas is that there is a potential increase in yearly income from the Tortugas ranging from 16 percent to 53 percent (Table 25).

## Model II: Reallocation of Fishing Vessels and Effort Under Increased Vessel Capacity Utilization

It was noted in Chapter IV that, under existing conditions, the Dry Tortugas shrimp fleet did not utilize their carrying capacity effectively. Model II was developed to examine the effects of increased vessel capacity utilization on a trip basis. One method of increasing capacity utilization is to force the vessel to spend as many days at sea engaged in fishing as is physically possible. Economies could be gained by decreasing the transport cost. A constraining physical characteristic would be the fuel capacity. In this section of the empirical analysis fuel capacity is treated as the constraining element limiting the number of days a vessel can stay at sea.

 $52_{\text{Based}}$  on actual distribution of effort, actual total cost = ( $\Sigma$  actual pounds of shrimp landed per vessel class) (Average transport rate per vessel class + variable cost per vessel size class + fixed cost per vessel class).

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Vessel size class	Estimated total cost	
2	\$ 8,292	
3	205,027	
4	1,459,185	
5	1,475,342	
6	754,412	
7	1,345,676	
<b>8</b>	484,067	
9	188,922	

Table 23.--Estimated real total cost of production, Dry Tortugas, 1965.

Vessel size class	Average number in Crew	Number of vessels utilized in optimum	Estimated number of fishermen
2	2	3	6.
3	2'	16	32
4	2	68	136
5	2	121	242
6	3	52	156
.7	3	181	543
8	3	54	162
9	3	5	15
			Σ = 1,292

Table 24.--Estimated employment of fishermen in Model I allocation of vessels and fishing effort, 1965. Additional simplifying assumptions in this section of the analysis are:

- 1. The average number of days fished per year within each vessel class remains constant.
- 2. Landings per day is a linear function.
- 3. Transshipment of raw headless shrimp is allowed to occur but the average cost functions are not affected by such action.

The model II total catch per trip and the percentage of carrying capacity utilized for each unique vessel size class is reflected in Table 26.<sup>53</sup> The port capacity coefficients for each unique vessel class are listed in Table 27.<sup>54</sup>

The Model II objective function, minimize  $\sum_{b=1}^{13} \sum_{i=2}^{9} \sum_{j=1}^{3} c_{ij}^{b} x^{b}$ , for

the calendar year 1965 under Model II conditions equals \$4,162,665.

<sup>53</sup>Model II total catch per trip per size class i computed: Model II days fished per trip per size class i = <u>Average fuel capacity per size class i</u> Gallons of fuel consumption per 15-hour day per (29) size class i minus 2 days travel adjustment

Model II total catch per trip per size class i = (30) (Catch per day per vessel class i) (Equation 29)

<sup>54</sup>Model II port capacity coefficient per size class i: Model II trips per year per size class i = 4verage total days fished per year (21)

Model II days fished per trip per size class i (31)

Model II port capacity coefficient per size class i per port j = (Equation 30) (Equation 31) (32) (Number of vessels of size class i in port j)



Vessel size class	Catch/day fished/ vessel size	Adjusted days at sea/trip	Capacity per trip	Model II total catch/trip	Percent of capacity utilized/trip
2	557.25	8	8,500	4,458	52.4
3	395.50	14	12,750	5,537	43.4
4	273.40	14	10,540	3,828	36.3
5	302.50	18	15,640	5,445	34.8
6	317.29	23	24,310	7,298	30.0
7	345.14	33	27,370	11,390	41.6
8	393.17	41	32,980	16,120	48.9
9	325.86	43	58,055	14,012	24.1

Table 26.---Model II catch per trip and percent capacity utilization, Dry Tortugas, 1965.

Vessel size class	Port 1 (pounds)	Port 2 (pounds)	Port 3 (pounds)
2	44,580	22,290	
3	415,275	27,685	). <b></b>
4	1,561,825	689,040	22,968
5	2,874,960	1,012,770	65,340
6	904,952	525,456	87,576
7	1,503,480	2,915,840	3,827,040
8	177,320	306,280	548,080
9	<b>70,</b> 060	168,144	238,204
	$\Sigma = 7,552,451$	= 5,667,505	$\Sigma = 4,789,208$
	ΣΣ	= 18,009,164	

Table 27.--Model II port capacity coefficients, Ports 1, 2, and 3,\* by vessel size class, Dry Tortugas, 1965.

\*Port 1: Key West, Florida Port 2: Fort Myers, Florida

Port 3: Tampa, Florida

The allocation of vessels from their respective ports is summarized in Table 28.

The fixed cost incurred is computed as in the preceeding section, and is estimated to be \$1,043,179 (Table 29).

Model II total cost of production in 1965 is an estimated \$5,205,844. Comparison with the estimated real cost of \$5,920,923 reveals a savings of \$715,079 through reallocation of fishing effort. Equal distribution of this savings among the 867 estimated fishermen (Table 30) in the reallocation solution offers a potential increase in real income of approximately \$825 for each individual fisherman. The average increase in earnings ranges from 31 percent to 102 percent (Table 31).

### Social Cost

Social cost as defined in Cahpter IV reflects the magnitude of the cost to society for idle vessel capacity in the "optimal" solution.

Model I allocation of effort at least cost indicates the existence of 1,233,758 pounds excess vessel capacity or 70 vessel equivalents (Table 32). The presence of excess vessel capacity can be interpreted as overcapitalization in terms of labor and capital among the fishing firms exploiting the Dry Tortugas. Reflecting overcapitalization as a social cost reveals an estimated social cost of \$193,857 for calendar year 1965.

An additional social cost can be imputed for the excess undepreciated capital investment in the excess vessels. This social cost is estimated to be \$2,815,041 (Table 33).

	Vessel	Number of	·····	Pounds	Total p	roduction
	class	vessels	Area	landed	cost :	VC + TR*
Port 1						
Key West	2	2.00	5	44,580	\$	4,101
• 	3	15.00	5	415,275		153,236
	4	5.07	1	116,550		48,834
	4	.42	2	9,527		4,001
	4	.07	3	1,000		610 9/7
	4	62.44	5	1,424,147		836 613
	5	88.00	フ・ 5	00/ 052		354.741
	0	33.00	5	1 503 /80		538,246
	d 1	7 83	5	126,149		52,604
	o g	3 17	6.	51,171		21,441
	q	5.00	Ĩ.	70.060		38,323
Migration of ves	sels					
to assist in ful	-					
filling Port 1				· ·	. 2	
demand		•		•***		
From Port 2	7	5.08	4	231,294		82,572
2	7	25.15	5	1,145,670		410,150
3	7	3.40	5	155,010	5 - 40	55,474
	•	Port 1	_Σ=	9,084,425	رھ = ۲	,211,975
Port 2						
Fort Myers	0	1 00	6	22 200	\$	2.318
	2	12.00	6	1.21 637	¥	129.021
	2	2 /1	7	111,367		34.190
	5	1. 29	10	140.071		41,461
	5	10.14	11	331,296	1. A.	98,395
	5	.20	12	6,584		1,962
	5	.06	. 13	1,815		543
	. 7	33.66	6	1,533,723		565 <b>,</b> 944
•	7	.11	9	5,153		1,907
		Port 2	Σ =	2,573,936	Σ = \$	875,741
Port 3		· · ·			$\sim 4$ $\sim$	4. (10
Tampa	5	1.41	7	46,191		14,643
	5	• 59	8	19,149		6,070
	7	3.16	7	143,861	л Т — Ф	54,250
•		Port 3	Σ =	209,201	∠ =⊅	14,747
	•	•	F F _	11 867 567	55- ¢.	162 665
•	•	•	L L =	11,007,002	· LL- 92	رەن <sub>6</sub> مەر <sub>6</sub> +
		•				

Table 28.--Model II allocation of vessels from port to fishing ground in the Dry Tortugas, 1965.

\*TR = Total transport cost.

Vessel size class	Pounds landed	Fixed cost coefficient	Total fixed cost by vessel size class
2	66,870	.022	\$ 1,471
3	415,275	.055	22,840
4	1,561,824	.155	242,083
5	3,953,070	.067	264,856
6	904,952	.082	74,206
7	4,718,191	.084	396,328
8	177,320	.173	30,676
9	70,060	.153	10,719
Σ	= 11,867,562		Σ = \$1,043,179

Table 29.--Total fixed cost incurred in 1965 under Model II effort allocation conditions.

Vessel size class	Average number in crew	Number of vessels utilized in optimized optimum solution	Estimated number of fishermen
2	2	. 3	6
3	2	15	30
4	2	68	136
5	2.	121	242
6	3	31	93
7	· · · · · · · · · · · · · · · · · · ·	104	312
8	3	11	33
9	3	5	15
		<b>Σ</b> = 358	<b>Σ</b> = 867

Table 30.--Estimated employment of fishermen in the Model II allocation of vessels and fishing effort, 1965.

Vessel size class	Avera fishe	Average individual fisherman's income wi		Average percent change in income th equal distribution		
2		1,242	66	•		
3		1,670	49			
4		2,032	41			
5		2,699	31			
6		1,797	- 46	• • • •		
7		1,167	71			
8		1,337	62			
9		806	102			

Table 31.--The effects of equal distribution of the savings in Model II on the individual fisherman's income, Dry Tortugas, 1965.
Vessel size class	Port	Pounds excess capacity	Number of vessel equivalents	Social cost (pounds x fixed cost/size class)
4	2 .	697,170	30	\$108,061
9	2	136,860	12	20,940
4	3	23,239	1	3,602
8	3	182,604	10	31,590
9	3	193,885	17	29,664
		<b>Σ</b> = 1,233,758	<b>Σ</b> = 70	Σ = \$193,857

Table 32.--Excess capacity reflected in pounds, vessels, and social cost, Model I solution, Dry Tortugas, 1965.

Vessel si class	ze	Number of vessels	Average cost per vessel	Total investment	
		31	21,063	\$ 652,953	
- 8		10	46,611	466,110	
9		29	58,482	1,695,978	
	•		Σ	<b>E</b> = \$2,815,041	

Table 33.--Model I excess undepreciated capital investment in Dry Tortugas, 1965.

Model II, the reallocation of effort under increased vessel capacity utilization per trip reflects excess vessel capacity amounting to 6,141,602 pounds or 212 vessel equivalents (Table 34). The overcapitalization interpreted as a social cost amounts to approximately \$668,492 (Table 34).

Additional social cost imputed for excess undepreciated capital investment in the excess vessels is estimated to be \$9,167,950 (Table 35).

Vessel size class	Port	Pounds excess capacity	Number of vessel equivalents	Social cost (pounds x fixed cost/size class)
3	2	27,685	1	\$ 1,523
4	2	689,040	30	106,801
6.	2	525,456	18	43,087
8	2	306,280	19	52,986
9	2	168,144	12 +	25,726
4	3	22,968	• 1	3,560
6	3	87,576	3	7,181
7	3	3,528,169	77	296,366
8	3	548 <b>,0</b> 80	34	94,817
9	3	238,204	17	36,445
	Σ	= 6,141,602	Σ = 212	Σ = \$668,492

Table 34.--Excess capacity reflected in pounds, vessels, and social costs, Model II solution, 1965.

Vessel size class	Number of vessels	Average cost per vessel	Total Investment	
3	1	\$ 9,800	\$ 9,800	•
4	31	21,063	652,953	
6	21	36,357	763,497	•
. 7	77	46,407	3,573,339	
8	53	46,611	2,470,383	
9	29 -	58,482	1,695,978	
	Σ = 212		Σ = \$9,167,950	

Table 35.--Model II excess undepreciated capital investment in Dry Tortugas, 1965.

### CHAPTER VI

#### SUMMARY AND CONCLUSIONS

The application of linear programming techniques to empirical problems in ocean fisheries has demonstrated its usefulness to public policy decision-makers and firm decision-makers by elucidating the possibilities of reducing the aggregate production cost for a specified quantity of raw headless shrimp.

Utilizing existing vessel capacity coefficients it has shown that a reallocation of fishing effort could reduce the total cost of production in 1965 by \$552,556. The solution of Model I revealed an excess vessel capacity of 1,233,758 pounds, or a social cost of \$193,857. In addition, this excess capacity reflected in vessels amounted to an estimated 70 excess vessel equivalents. These vessels represented approximately \$2.8 million in excess undepreciated capital investment. The total social cost of overcapitalization amounted to \$3,008,898 during calendar year 1965 for the Dry Tortugas.

Increasing the vessel capacity utilization of the existing fleet on a trip basis and constrained by fuel carrying capacity Model II revealed a reduction in total production costs of \$715,079 under efficient fishing effort allocation conditions. Based on this model, excess vessel capacity in 1965 is estimated to have been 6,141,602 pounds, or a social cost of approximately \$668,492. There are 212 excess vessel equivalents, or \$9,167,950 in excess undepreciated capital investment. The total social costs of overcapitalization amounted to \$9,836,442 during calendar year 1965 for the Dry Tortugas.

The implication of the entire empirical analysis is that the total production cost of harvesting and transporting raw headless shrimp to intermediate processing facilities can be reduced through more efficient spacial allocation of fishing effort. This implication, however, is perhaps not the most important contribution of the analysis. Overcapitalization occurs and is reflected as excess capacity. The social cost of such overcapitalization is a substantial sum in each phase of the empirical analysis. The presence of overcapitalization substantiates Knights' hypothesis which was elucidated in Chapter II. Common property ownership of natural resources will result in excessive allocation of labor and capital because average product is considered instead of marginal product.

The most efficient vessel size classes are implicit in the analysis, but tabulation of average fixed and variable costs in Table 36 describes the vessel size classes which are most efficient in terms of production cost. Vessel size classes 2 and 5 are clearly most efficient. The emphasis by vessel owners on maximum physical production with little concern for production costs results in investment in the most inefficient (in terms of production cost) vessel class. Vessel owners are apparently not extremely rational in investment decisions. This conclusion is further substantiated when comparison is made between average total cost per pound per vessel size class and 1965 average ex-vessel value of raw headless shrimp per vessel size class (Table 37). Vessels of size class 9

Vessel size class	Average fixed cost/lb.	Average variable cost/lb.	• Average total cost/lb.
2	.022	.086	.108
3	.055	.361	.416
- 4	•155	•416	•571
5	.067	.283	.350
6	.082	<b>.3</b> 86 -	.468
7	.084	•352	.436
8	.173	•410	•583
9	•153	•541	.694

Table 36.--Average fixed and variable costs per pound of raw headless shrimp per vessel size class, 1964-1965, Dry Tortugas.

Vessel size class	Average value per pound	Average total cost per pound	Average profit margin per pound
2	\$.370	\$.108	\$.262
3	.428	.416	.012
4	•533	.571	038
5	.577	.350	.207
6	•577	.468	.109
7	.570	.436	.134
8	.636	•583	.053
9	.633	•694	061

Table 37.--Average profit margin per pound of raw headless shrimp per size class, Dry Tortugas, 1965.

lost an average 6.1 cents per pound of shrimp while fishing in the Dry Tortugas, while vessels in size classes 2 and 5 received an average profit per pound of raw headless shrimp of 26.2 and 20.7 cents, respectively.

Dry Tortugas fishermen appear to be exploited in a social sense of the word. Emphasis on larger vessels has resulted in a lower average income for fishermen on the larger vessels than for any other vessel size class. It should not be inferred that the exploitation of the fisherman is intentional, but rather they are exploited because of lack of knowledge on the part of the individual investor.

The major conclusion of this analysis is that an economic and social problem does exist in the Dry Tortugas fishery. The magnitude of this problem can be expected to increase over time if emphasis is maintained on larger, more costly vessels in anticipation of increased physical production, and if the vessel capacity utilization does not change significantly.

## CHAPTER VII

### POLICY IMPLICATIONS

The results of the preceeding analysis clearly indicate that management policies for the Dry Tortugas should be re-evaluated. Currently the State of Florida has a closed area (Figure 13) that insures against over-exploitation of the Dry Tortugas shrimp fishery. The area was established under the assumption, "It is desirable to catch the greatest possible number of pounds of shrimp, this desirability being enhanced as the sizes of shrimp caught are increased."55 The law establishing a portion of the Dry Tortugas fishing grounds as a closed area was passed in the 1957 session of the Florida Legislature. It was incorporated into the Florida Statute as Chapter 370.151 (Ervin and Henderson, 1957). The controlled area is sampled periodically, and when the survey shows that the shrimp in the area are of a size less than 50 to the pound (heads off), the area is closed. If the survey finds the shrimp larger than 50 to the pound (heads off) the area is opened to commercial shrimp fishing. The law was to expire in 1962, but was reinstated for another five years. The 1967 Florida legislature is debating the benefits of a 70 count law for the Dry Tortugas. Such a law would make it illegal to catch shrimp smaller than 70 to the pound (heads off).

<sup>55</sup>Robert M. Ingle, "Synoptic Rationale of Existing Florida Shrimp Regulations," <u>Proceedings of the Gulf and Caribbean Fisheries</u> <u>Institute</u>, Thirteenth Annual Session, November 1960, p. 22.





Clearly evident is the lack of economic consideration in either regulatory measure. The emphasis is on maintaining a stock of shrimp. Such a goal is noble, but should be integrated with economic analysis.

### A Note on Regulatory Policy Measures

There are two immediate policy recommendations that can be made based on the preceeding analysis. The Florida legislature should begin consideration of management policy that treats economic and technological, as well as biological, implications. Such consideration would necessitate establishing precise resource management policy objectives which would be useful in comparing alternative regulatory measures.

The Bureau of Commercial Fisheries, which has initiated vessel loan and vessel subsidy programs for United States fisheries, should consider the effects that such programs have on overcapitalization in the Gulf of Mexico shrimp fishery. If the effects are determined to be positive, a recommendation would be to cease such programs in the Gulf for a period sufficient to retire a significant portion of the excess fleet. When the excess vessels have been retired from the fleet the programs could be reinitiated and act to direct the construction of vessels that are technologically and economically efficient. Such action would have a positive effect by improving the competitive position of the firms in the Gulf shrimp industry in the world market.

In the long run there are many alternative objectives for management policy:

1. Maximize the physical production of this fishery.

- 2. Maximize the aggregate revenue to the industry.
- 3. Maximize regional income.
- 4. Minimize total production costs of harvesting specified levels of output and transporting to onshore processing facilities.
- 5. Maximize the opportunity for employment of labor and capital in the fishery.
- 6. Facilitate the continued availability of fish and fishery products to meet projected demand in the United States.
- Maintain the status quo of the fishery and attempt to increase the physical production of individual vessels.
   Maximize the net yield from the resource.

The important point is that policy decision-makers should be completely aware of their objectives before management criteria are established. It is apparent that maximization of physical production may not be conducive with the overall objectives. State and federal agencies are becoming increasingly aware of the complexity of establishing objectives for management programs, and some are attempting to specify them as precisely as possible. The Bureau of Commercial Fisheries, for example, is currently engaged in evaluating the objectives of management programs. This is clearly a step in the correct direction in 'attempting to establish "optimal" resource management. Suppose the management objective is to minimize the total production cost of a specified level of raw headless shrimp from the Dry Tortugas in the short run, as it was in this analysis, the management policy decision-maker is confronted with the problems of excess capacity, i.e. overcapitalization in terms of labor and capital, and numerous alternative regulations that could be established:<sup>56</sup>

- 1. Restricting the size of fishing gear
- 2. Regulation by size and weight limit
- 3. Sex or condition limits
- 4. Closed fishing areas
- 5. Limitation of landings by gear efficiency 57
- 6. Limitation of landings by quota
- 7. Limited entry into the fishery

Limitation of the number of fishing units is probably the most unpopular method of regulation, but perhaps the most efficient in terms of economics. Opponents to this method see it as a step toward a managed economy. To the economist a concept of limited entry is most appealing; it seems to be the most efficient method of regulation. The most efficient means of fishing could be applied and the fishing effort could be reduced. Assuming correct decision processes, the actual yield would approach the point where maximum

<sup>56</sup>For a summary of methods of fishery regulations, see: Donald E. Bevan, "Methods of Fishery Regulation," <u>The Fisheries</u>, <u>Problems in Resource Management</u>, James A. Crutchfield, editor (Seattle: University of Washington Press, 1965), pp. 25-40.

57See Turvey, "Optimization and Suboptimization in Fishery Regulations," op. cit.

economic yield is obtained. As pointed out in Chapter II this point could be well below the maximum sustained yield. Is this an undesirable position?--no, because of the opportunity cost. Society is interested in conserving the natural resources, as well as the labor and capital that is necessary to utilize them. If the fishing effort is forced beyond the point of maximum economic yield, the value of other products sacrificed is greater than the value of the additional catch. In terms of regulation, the limited entry concept would be difficult to establish, but would render the greatest return to society. It is now proper to ask how such a regulation can be established. The state of the fishery today is not conducive to limited entry. Most of today's commercial fishing occurs in international waters, and much conflict over fishing rights in international waters is evident.

Establishment of an international fishery jurisdiction group is perhaps a long run method to initiate such a proposed regulation. This group must be allowed to settle all grievances and controversies of all fishing nations. To do so requires that each fishing nation be a member of the group. The group could also be endowed with the power to sell rights to the highest bidder for every major fishing ground in the world. A power such as this could insure that only the most efficient methods of fish capture would be employed. This proposal sounds radical in terms of freedom of the seas, but remembering opportunity costs, could be most efficient and beneficial to the world society. At present the data requirements and research endeavors that would need to be undertaken to make such a plan

feasible would be enormous. However, it must be remembered that, as population pressure increases, demand for protein will also increase. Perhaps we must change basic institutions in order to satisfy this increase in demand.

## CHAPTER VIII

## RECOMMENDATIONS FOR FUTURE RESEARCH

The current status of the economic theory of common property fishery resources leaves much to be desired and, therefore, many profitable avenues for basic research.

Immediate research should be directed to applying economic theory to common property resources. The theory in this area is still in its embryonic stages and has not been emphasized by economic theoreticians. Increasing demands by a growing population on common property resources require rational and efficient allocation of economic resources in the exploitation and management so that utility is maximized. Elucidation of relationships of common property resources and current economic theory of the markets would provide a useful first step in understanding the economics of this unique institutional concept.

Research should be directed toward continuation of the general model presented in this study. Minimizing the aggregate production cost of a specified quantity of raw headless shrimp with a given time period for the entire Gulf of Mexico would focus attention on the extensiveness of excess capacity and overcapitalization in the Gulf of Mexico shrimp industry.

Models should also be developed for testing various alternative objective functions, such as those discussed in

Chapter VI for the Gulf of Mexico shrimp industry. Comparisons between various objectives would be useful to the policy-maker in specifying objectives that would be most beneficial to society.

The average cost functions developed in this study should be extended by regression analysis to develop more realistic cost functions for the vessel size classes discussed. A step supply function for labor and capital might be developed to illustrate the most cost effective vessel classes for various levels of fishing effort.

Coordinated research efforts should be attempted by the economist, biologist, and technologist. The economist should develop demand and market studies; the biologist should develop more explicit population dynamics for shrimp population and the short and long run stochastic variations which occur; and the technologist should devote effort to the development of cost-reducing harvesting and processing facilities, together with more efficient vessel designs. These efforts could be major inputs in a simulation model testing various objective functions.

Finally, the research efforts described above should not be limited to the shrimp fishery, but should be attempted for various species of fish. The output of such research should prove beneficial in the development of overall policy and management techniques.

## APPENDIX A

Gulf of Mexico Shrimp Vessel Operating Cost and Physical Characteristic Questionnaire Budget Bureau No. 42-66020 Expires May 31, 1967 Bureau of the Budget Approved October 19, 1966 Questionnaire No.

1964 and 1965 Gulf of Mexico Shrimp Vessel Operating Costs and Physical Characteristics Questionnaire

> UNITED STATES Department of the Interior Bureau of Commercial Fisheries Division of Economics Confidential For Statistical Purposes Only

"The United States Bureau of Commercial Fisheries is updating a study of the production costs of shrimp by various vessel size classes conducted by the Federal Trade Commission during the calendar years 1952 through 1954.

By updating this study we can determine and classify economic problems confronting the shrimp fishing industry today and point out areas where economic problems may arise in the future. Analyses will then be conducted to recommend courses of action designed to alleviate existing economic difficulties and to avoid such problems in the future.

Would you be willing to provide us data on the expenses incurred in operating your shrimp fishing vessel during the calendar years 1964 and 1965?

This information will be used for scientific studies and only summary data will be published. Individual reports will be kept strictly confidential." I. Owner Information

A. Name of owner

B. Address

C. Indicate the number of shrimp vessels you own or in which you have controlling interest.

Own \_\_\_\_\_ Controlling interest \_\_\_\_\_

D. Indicate your method of marketing raw shrimp. Check the appropriate method(s).

your own processing facilities

dealer

\_\_\_\_ co-op

II. Individual Vessel Information

A. General

1.	Vessel's registered name	Lode
2.	Documentation number	
3.	Overall length	
4.	In what year did you purchase the vessel?	د
5.	Cost of the vessel when purchased	
6.	Horsepower rating of engine when the vessel was purchased	
7.	How many engines have been installed since you purchased this vessel? Please list horsepower rating of each engine ' <u>horsepower</u> year installed Present engine Previous engines	
· ·		· · · · · · · · · · · · · · · · · · ·

	Code
8.	Number of hours the engine was operated:
	previous engine present engine
	1964 hrs. 1965 hrs
	1964 nrs. 1965 nrs.
9	Under ideal conditions, the
	Under radar condrerency and
	a. cruising speed to the fishing grounds
	mph rpm
	b. travling speed
	mph rpm
	c. cruising speed to port
10	Fuel capacity gallons
10.	
11.	Estimated fuel consumption per hour of running
	time at speeds indicated in 9:
	the trip to the grounds gel/hr
	a. on the trip to the grounds gal/h
	c on the trip to port gal/hr
12.	Fresh water capacity gallons
13.	In how many states is this vessel licensed to
	fish and land shrimp
- 1/	Did you land any shrimp 1964 1965
14.	outside the U.S.? yes no yes no
	If yes, what percent of yearly catch? % 1964
	% 1965
15.	Have any of the following major vessel
	alterations been made since the vessel was
	the alteration was made and the cost of the
	alteration. year of
	yes no last major cost
	alteration
	a. engine change
	b. rebuild hull
	c. rebuild cabins
	d. rebuild wheelhouse
· .	e. rebuild galley
	a install freeze
	$\mathbf{B}_{\mathbf{i}}$ in $\mathbf{i}$
	h. change rigging
	or winches

				Code
	16	Uerro	any simificant changes been made in	ooue
	10.	the	net type or net size in the last five	
		vear	$\frac{1}{2}$	
	•	Jear Tf v	es specify type of change and date the	
		chan	de occurred	•
		Chan		
				•
	17	Does	the vessel have as standard equipment:	
	1.7 •	DOCD		
			on vessel installed	
			no when after date	
			purchased purchased	
	- · ·	8.	insulated hold	
			If ves. indicate	
			type and thickness	
			styrofoam	
			thickness	•
			mortar	
			thickness	
		·	other (specify type)	÷
			thickness	
		Ъ.	freezer	
	÷		If yes, specify	
			type	
			shelf or plate	
			capacity/hr	
			blast	
			capacity/hr	
			immersion	
			capacity/hr	
		c.	auto pilot	
		d.	ship to shore	•
	a a		radio	· . <del>.</del>
		e.	radar	·
		f.	loran	
с. <sup>1</sup>		g.	depthfinder	
			(fathometer)	
		h.	electronic	
			rishfinder	
		1.	ice machine	•
		].	spare try nets	• • • • • • • • • • • • • • • • • • • •
	• .	•	11 yes, indicate	
		1_	number	
		к.	spare trawi nets	•
			II yes, inuicate	
		- -	number	
		1.	share offer poards	

			Code
Β.	Capt	tain and crew information	
	1.	Captain's shrimp fishing experience as of December 31, 1965 years months	
	2.	Does the captain own any share of the vessel? yesno If yes, specify percent%	
	3.	Crew number during the peak season	
	4.	Crew number during the slack season	
	5.	Crew share (check correct crew share) 1964 a. 60% owner-40% crew b. 50% owner-50% crew c. 2/3 owner-1/3 crew d. other If other, specify Crew share) 1965 a. 60% owner-40% crew b. 50% owner-50% crew c. 2/3 owner-1/3 crew d. other If other, specify	
	6.	Crew expenses	•
		<ul> <li>a. groceries (check correct breakdown of expenses) 1964 1965 (1) crew buys all (2) crew buys 1/2 (3) crew buys none (4) other 1f other, specify 1f other, specify 1f other, specify 16. ice (check correct breakdown of expenses) 1964 1965 (1) crew buys all (2) crew buys all (3) crew buys none (4) other 16 other, specify 17 other, specify 1964 1965 (1) crew buys all (2) crew buys all (3) crew buys all (4) crew buys all (5) crew buys all (5) crew buys all (6) crew buys all (7) crew buys</li></ul>	
		(2) crew buys 1/2 (3) crew buys none (4) other If other, specify (2) crew buys 1/2 (3) crew buys none (4) other If other, specify (5) crew buys 1/2 (3) crew buys none (4) other If other, specify	y

# C. Operating cost breakdown for individual vessel

	<u>1964</u> Dollars	<u>1964</u> Code	<u>1965</u> Dollars	<u>1965</u> Code
Doprogration hull	• ·			. •
depreciation null		<b></b>	<del></del>	<u> </u>
Theiro	•			
dopposisted life		<del></del>	<del> </del>	<del></del>
Flootmonia doom	•			
depresieted life	<del>6</del>	<del></del>	<del></del>	<del></del>
depreciated life years				
	<b></b>	<del></del>	<b>Calculation of the second second</b>	
depreciated life years			· .	
Other (pumps, generating plant)	<b>)</b>			
water pressure system)			•	<b></b>
depreciated life years	1 South State 1			
Taxes on business property	e			
Repairs (vesser and engine,	•			
including parts)			· · · · · · · · · · · · · · · · · · ·	<del></del>
Salaries (including crew share)				
Insurance		•	•	•
personal and indemnity		······.		<u> </u>
		. <del></del>		
Legal and professional fees	<del></del>			
Interest on business	· · · · ·			
		•	, <b></b>	
Association dues	<del></del>			
Bank charges				<del></del>
			•	
cost per gallon	<del></del>	<b>e</b>		
Galley provisions	<b></b>			
Ice			e de la companya de l	
Cost per ton Regime and handling		<b></b>	<u></u>	
Fucking and handling		· · · ·	<u></u>	
Supplies (rope, baskets, etc.)	<u> </u>			
Con thus and there is a more a	÷	<b></b>		
Miggollanooug (butong gag etc.)		<b></b>		
Liconsos				<b></b>
Taxes (city county ot a)				
Telephone		<del></del>		
Netting and net repairs				<del></del>
Redio repairs (including		•	-	<del></del>
electronic gear)				
FTCA taxes				
Office and storage rental	••••••••••••••••••••••••••••••••••••••	<del></del>	<u></u>	
orrest and busings relivat				
		· .	•	
Gross revenue from shrimp			•	

sales

D.

III. What are your future investment plans as an individual enterprise for the next five years in the Gulf shrimp industry?

IV. What are your goals and objectives in the Gulf shrimp industry for the future?

To:						
	Name of Accountant or Bookkeeper					
	Street Address					
:						
•	City State					

• •

This is to certify that Victor Lewis Arnold, Economist, Department of Interior, Bureau of Commercial Fisheries, has my permission to examine the standard U.S. Treasury Department, Internal Revenue Service Schedule C (Form 1040) and other operating costs records for calendar years 1964 and 1965 for the \_\_\_\_\_\_.

Name of Vessel

Date:

Documentation Number

This data will be used in an economic study of the Gulf of Mexico shrimp fishery.

Signature of Owner

## APPENDIX B

1965 Pink Shrimp Price Variations Based on Key West, Florida, Ex-vessel Prices

					- Shrimp s	izes*				
Week end	ing	10–15	16-20	21-25	26-30	31-40	41–50	51-67	68+	
January	7	\$	\$.84	\$.77	\$.72	\$.65	\$.56	\$	\$ 20	
•	14		.84	.77	.72	.65	.56	44	20	
	21	· · · · ·	.84	.77	.72	.65	.56	- 44	20	
	28	2 2	.81	.77	.72	.64	.55	•44	.21	
February	4		.81	.76	.71	.63	. 54	./3	. 21	
	11	· · · ·	.81	.76	.71	.63	.54	.43	.21	
· . *	18		.81	.76	.71	.63	.54	.43	.21	
	25		.81	.76	.71	.63	•54	.43	.21	
March	4		.81	.76	.71	.63	.54	.43	.21	
	11		.81	.76	.71	.63	.54	.43	.21	•
	18	•	.81	.76	.71	.63	.54	.43	.21	
	25		.81	.76	.71	.63	•54	•43	.21	
April	1	•	.81	.76	.71	.63	•54	.43	.21	-
	8 .		.81	.76	.71	.63	.54	.43	.21	
	15		.81	.76	.71	.63	.54	.43	.21	
	22		.81	.76	.71	.63	.54	.43	.21	
	29		.81	.76	.71	.63	•54	.43	.21	
May	6		.81	.76	.71	.63	.54	•43	.21	
	13		.81	.76	.71	.63	.54	.43	.21	
•	20		.81	.76	.71	.63	.54	.43	.21	
	27	•	.81	.76	.71	.63	.54	.43	.21	

APPENDIX B Table 1.--Key West shrimp prices, 1965 (pink, heads off).

\*Size count refers to the number of raw headless shrimp per pound.

			التاريخية والتاريخية والتاريخية والتاريخية		· Shrimp s	sizes			
Week end	ling	10–15	16–20	21-25	26-30	31-40	41-50	51-67	68+
June	3	\$	\$.81	\$.76	\$.71	\$.63	\$.54	\$.43	\$.21
	10	. "	.81	.76	.71	.63	.54	.43	.21
	17		.81	.76	.71	.63	.54	.43	.21
	24		.81	.76	.71	.63	•54	.43	.21
July	1		- - 	.73	. 68	.60	•51	.43	.21
•	. 8			.66	.61	•54	.46	.43	.21
	15			.66	.61	•54	.46	.35	.21
•	22		· ·	.66	.61	.54	.46	.36	<b>.</b>
•	29		.76	.69	.63	•55	.46	.33	.17
August	5		•	.71	.65	•55	.47		.21
-	12		.76	-	.65	.56	.48	•35 ·	.21
	19		76		.66	.58	.49	.36	.21
	26		•	.71	.66	.58	•49	.36	.21
Septembe	er 2						•••	· · · · ·	
	9		.76	.71	.66	.58	•49	.33	.21
	16		.76		.66	•	•49	.36	.21
	23		.76	.71	.66	•58	•49	.36	.21
	30	.81	.76	.71	.66	.58	•49	.37	.21
October	7				•	.58	.47	.35	.20
	14		.76	.71	66	•54	.44	.34	.19
	21		.76	.71	.66	.54	44	.34	.19
	28		.78	.73	.67	.56	.48	.34	.21

APPENDIX B Table 1.--Continued.

	هم وي جن وي اين اين اين وي وي اين وي وي اين اين وي وي اين اين وي وي وي		Shrimp s	izes			
Week ending	10-15 16-20	21–25	26-30	31-40	41-50	51-67	68+
November 4	\$ \$	\$.73 .73	\$.67 .67	\$.56 .57	<b>\$.</b> 48 .47	\$.34 .36	\$.21 .21
18	.80	.74	.68	.58	.48	.37	.22
25		.75	.69	.59	.49	.38	.23
December 2	.81	.76	.70	.60	•50	•39	.23
9	.82	.77	.71	.61	•51	•40	.23
16	.84	.78	.72	.62	•52	•41	.25
23	.84	•79	.73	.63	•53	.42	.26
30		•79	.73	.63	•53	.42	.26

APPENDIX B Table 1.--Continued.

\$.83	21-25	26-30	31-40	41-50	51_67	10.
\$.83	•				J1-07	68+
	\$.77	\$.72	\$.65	\$.56	\$.44	\$.20
.81	.76	.71	.63	•54	.43	.21
.81	.76	.71	.63	•54	.43	.21
.81	.76	.71	.63	•54	.43	.21
.81	.76	.71	.63	•54	.43	.21
.81	.76	.71	.63	.54	.43	.21
.76	.68	.63	•55	.47	.38	.20
.76	.71	.66	.57	.48	.36	.21
.76	.71	.66	.58	.49	.36	.21
.77	.72	.67	.56	.46	.34	.20
.80	.74	.68	.58	.48	.36	.22
.83	.78	.72	.62	.52	.41	.25
	.80 .83	.80 .74 .83 .78	.80 .74 .68 .83 .78 .72	.80 .74 .68 .58 .83 .78 .72 .62	.80 .74 .68 .58 .48 .83 .78 .72 .62 .52	.80 .74 .68 .58 .48 .36 .83 .78 .72 .62 .52 .41

APPENDIX B Table 2 .-- Key West average monthly shrimp prices, 1965 (pink, heads off).

\*Size count refers to the number of raw headless shrimp per pound.

Month		16-20	21-25	26-30	31-40	41-50	51-67	68+ .
January		\$.0830	\$.1309	\$.1440	\$.0845	\$.0672	\$.0396	\$.0140
February		.1134	.0912	.0568	.0441	.0324	.0301	.0126
March		.1296	.1444	.0994	.0567	.0378	.0516	.0189
April		.1458	.1292	.0994	.0504	.0324	.0301	.0105
May		.0891	.0380	.0213	.0378	.0378	.0172	.0021
June		.0324	.0228	.0213	.0189	.0162	.0043	
July			.0068	.0252	.0165	.0094		
August			.0142	.0066	.0114	.0144	.0108	.0063
September		.0152	.0142	.0066	.0116	.0098	.0252	.0399
October	· · ·	.0154	.0144	.0536	.0784	.0598-	.0476	.0740
November		.0640	.0592	.0884	.0986	.1056	.0828	.0176
December	•	.1245	.0936	.0720	.0992	.0884	.0533	.0125
December Weighted average	e price	.1245 \$.81	.0936 \$.76	.0720 \$.69	.0992 \$.61	.0884 \$.51	.0533 \$.39	.0125 \$.21

APPENDIX B Table 3 .-- Key West weighted average shrimp prices, 1965 (pink, heads off).

\*Size count refers to the number of raw headless shrimp per pound.

## APPENDIX C

1965 Dry Tortugas Pink Shrimp Depth-Shrimp Size Relationships

-10	16-20	21-25	26-30	31–40	41-50	51-67	601	
-10			· · · · · · · · · · · · · · · · · · ·	S		2. 01	00+	Total
-10				p	ounds			
	' 88	221	2,936	8,801	6,209	42,903	55,392	116,550
-15	• •	33	1,350	2,192	4,594	877	481	9,527
-20					1,600			1,600
-10	330	3,412	9,708	55,542	87,916	92,165	52,281	301,354
-15	65,000	309,185	401,891	1,532,201	2,338,523	2,339,542	1,617,881	8,604,223
-20	78,741	406,800	404,066	561,092	446,736	108,902	22,484	2,028,821
-25	36,052	99,502	66,465	55,635	33,940	8,476	1,349	301,419
-30	•	3,044	3,548	7,089	4,912	556	-	19,149
-35			1,075	2,163		1,465		5,153
-15		7,507	15,712	57,472	40,704	13,928	4,578	140,071
-20	13,220	63,476	66,640	109,346	63,675	10,963	3,976	331,296
-25		2,403		1,170	3,011			6,584
-30		1,048		767				1,815
	-15 -20 -10 -15 -20 -25 -30 -35 -15 -20 -25 -30	-15 -20 -10 330 -15 65,000 -20 78,741 -25 36,052 -30 -35 -15 -20 13,220 -25 -30	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	-15 $33$ $1,350$ $2,192$ $4,594$ $877$ $-20$ $1,600$ $-10$ $330$ $3,412$ $9,708$ $55,542$ $87,916$ $92,165$ $-15$ $65,000$ $309,185$ $401,891$ $1,532,201$ $2,338,523$ $2,339,542$ $-20$ $78,741$ $406,800$ $404,066$ $561,092$ $446,736$ $108,902$ $-25$ $36,052$ $99,502$ $66,465$ $55,635$ $33,940$ $8,476$ $-30$ $3,044$ $3,548$ $7,089$ $4,912$ $556$ $-35$ $1,075$ $2,163$ $1,465$ $-15$ $7,507$ $15,712$ $57,472$ $40,704$ $13,928$ $-20$ $13,220$ $63,476$ $66,640$ $109,346$ $63,675$ $10,963$ $-25$ $2,403$ $1,170$ $3,011$ $-30$ $1,048$ $767$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

APPENDIX C Table 1.--1965 Dry Tortugas pink shrimp depth-shrimp size relationships.

\*Size count refers to the number of raw headless shrimp per pound.
APPENDIX D Dry Tortugas Sample Vessel Characteristics

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I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
 314	31	31	100.00	80,086	80,086	100.00
590	4	<b>4</b>	100.00	1,519	1,519	100.00

APPENDIX D Table 1.--Total landings and landings in the Dry Tortugas, vessel size class 2, 1964.

•	I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
<u></u>	856	28	28	100.00	56,604	56,604	100.00
	626	39	39	100.00	49,118	49,118	100.00
	205	20	9	45.00	10,420	2,675	25.67
	142	13	13	100.00	11,820	11,820	100.00
	382	28	27	96.42	53,415	52,674	98.61
							•

APPENDIX D Table 2.--Total landings and landings in the Dry Tortugas, vessel size class 3, 1964.

I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
713	38	38	100.00	51,265	51,265	100.00
714	40	40	100.00	49,743	49,743	100.00
737	42	42	100.00	59,585	59,585	100.00
488	42	32	76.19	54,464	44,944	82.52
366	7	3	42.85	9,269	2,354	25.39
843	38	32	84.21	52,129	42,567	81.65
650	26	2	7.69	47,996	2,613	5.44
488	33	9	27.27	50,631	17,820	35.19
888	. 17	6	35.29	19,710	6,901	35.01
059	35	17	48.57	51,968	19,999	38.48
	I.D. number 713 714 737 488 366 843 650 488 888 888 059	I.D. numberTotal trips7133871440737424884236678433865026488338881705935	I.D. numberTotal tripsTrips in Tortugas71338387144040737424248842323667384338326502624883398881760593517	I.D. numberTotal tripsTrips in TortugasPercent trips in Tortugas7133838100.007144040100.007374242100.00488423276.193667342.85843383284.216502627.6948833927.2788817635.29059351748.57	I.D. numberTotal tripsTrips in TortugasPercent trips in TortugasTotal pounds7133838100.00 $51,265$ 7144040100.00 $49,743$ 7374242100.00 $59,585$ 4884232 $76.19$ $54,464$ 36673 $42.85$ $9,269$ 8433832 $84.21$ $52,129$ 650262 $7.69$ $47,996$ 488339 $27.27$ $50,631$ 888176 $35.29$ $19,710$ 0593517 $48.57$ $51,968$	I.D. numberTotal tripsTrips in TortugasPercent trips in TortugasTotal poundsPounds in Tortugas7133838100.00 $51,265$ $51,265$ 7144040100.00 $49,743$ $49,743$ 7374242100.00 $59,585$ $59,585$ 488423276.19 $54,464$ $44,944$ 36673 $42.85$ $9,269$ $2,354$ 8433832 $84.21$ $52,129$ $42,567$ 650262 $7.69$ $47,996$ $2,613$ 488339 $27.27$ $50,631$ $17,820$ 888176 $35.29$ $19,710$ $6,901$ 0593517 $48.57$ $51,968$ $19,999$

APPENDIX D Table 3.--Total landings and landings in the Dry Tortugas, vessel size class 4, 1964.

I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
966	35	35	100.00 $100.00$ $55.55$ $79.48$ $100.00$ $54.54$ $100.00$ $53.48$ $77.50$ $86.84$ $27.02$ $60.00$ $87.17$ $76.66$ $15.38$	58,986	58,986	100.00
010	39	39		92,681	92,681	100.00
896	18	10		59,291	41,843	70.57
019	39	31		62,166	52,175	83.92
627	15	15		26,909	26,909	100.00
352	22	12		37,576	27,585	73.41
501	42	42		57,484	57,484	100.00
044	43	23		55,110	30,649	55.61
528	40	31		60,316	47,431	78.63
744	38	33		64,347	56,845	88.34
250	37	10		56,354	13,135	23.30
143	35	21		50,720	32,058	63.20
508	39	34		74,781	65,467	87.54
270	30	23		58,206	44,904	77.14
706	13	2		20,779	1,654	7.95

APPENDIX D Table 4.--Total landings and landings in the Dry Tortugas, vessel size class 5, 1964.

	I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
	963	29	7	24.13	48,347	11,273	- 23.31 .
. •	536	33	18	54.54	58,267	42,105	72.26
	693	29	3.	10.34	49,277	2,755	5.59
	521	19	2	10.52	52,255	4,348	8.32
•	364	28	10	35.70	57,948	21,830	• 37.67
-	т. С.						

APPENDIX D Table 5.--Total landings and landings in the Dry Tortugas, vessel size class 6, 1964.

	I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
• •	4 5 00		,	04.00	21 (05	10.056	21 81
	157	25	6	24.00	31,605	10,000	50.26
	177	22	8	36.36	43,012	27,071	J7.JU
	576	15	10	66.67	51,433	31,191	13.40
	831	32	. 4	12.50	37,321	4,121	11.04
	464	33	10	30.30	45,646	13,130	28.70
	857	14	1	7.14	59,656	2,015	3.37
	051	32	3	9.37	39,743	4,570	11.49
	722	16	3	18.75	53,130	5,984	11.26
	743	36	5	13.88	48,354	6,250	12.92
	878	. 20	6	30.00	43,531	12,839	29.49
	979	15	1	6.66	51,654	1,963	3.80
•	098	22	9	40.90	31,386	14,393	45.85
	318	35	7	20.00	.53,614	24,491	45.68
	530	27	4	14.81	57,061	9,113	15.97
	422	27	7	25.92	35,119	12,671.	36.08
	621	9	2	22.22	29,045	6,535	22.49
	112	33	25	75.75	1 75,262	63,275	84.07
	113	32	21	65.62	93,071	74,947	80.52
	781	19	5	26.31	54,618	12,865	23.55
	449	16	Ĺ	25.00	61,392	11,484	18.70
	982	17	1	5.88	55,198	995	1.80
-				•			

APPENDIX D Table 6.--Total landings and landings in the Dry Tortugas, vessel size class 7, 1964.

	I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
	510	20	1	5.00	73,682	4,300	5.83
	541	27	7	25.92	41,034	11,124	27.10
	415	10	3	30.00	20,687	6,407	30.97
	250	21	1	4.76	53,506	3,424	6.39
х. 	с , с,	· · · · · ·			-		

APPENDIX D Table 7.--Total landings and landings in the Dry Tortugas, vessel size class 8, 1964.

I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Founds in Tortugas	Percent pounds in Tortugas	
			· · · · · · · · · · · · · · · · · · ·	i		1.5	
316	37	6	16.21	81,770	15,356	12.17	,
						1	

APPENDIX D Table 8.--Total landings and landings in the Dry Tortugas, vessel size class 9, 1964.

I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas	
		<u>een erne hinnernaa</u>	e e e e e e e e e e e e e e e e e e e				
314	23	23	100.00	 47,680	47,680	100.00	
						•	

APPENDIX D Table 9.--Total landings and landings in the Dry Tortugas, vessel size class 2, 1965.

	I.D. number	Total trips	Trips in _ Tortugas	Percent trips in Tortugas	•	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
	856	30	30	100.00	!	65,979	65,979	100.00
•	626	33	33	100.00	1	50,626	50,626	100.00
	205	9	7	77.77	1	6,413	5,707	88.99
•	142	16	13	81.25		28,367	19,792	69.77
	382	11	8	72.72		20,078	17,188	85.60
	872	4	4	100.00		1,539	1,539	100.00
	•	• • • • • • •		· · · · · · · · · · · · · · · · · · ·	•			

APPENDIX D Table 10.--Total landings and landings in the Dry Tortugas, vessel size class 3, 1965.

	I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
•	713	35	35	100.00	46,272	46,272	100.00
11	714	44	44	100.00	52,226	52,226	100.00
	737	30	30	100.00	56,428	56,428	100.00
	488	28	25	89.28	26,676	24,478	91.76
	366	28	5	17.85	36,286	10,196	28.09
	843	36	36	100.00	52,608	52,608	100.00
	650	29	5	17.24	57,117	8,611	15.07
• 7	488	33	5	15.15	49,043	7,123	14.52
	888	2	2	100.00	950	950	100.00
	059	32	19	59.37	56,615	27,131	47.92

APPENDIX D Table 11.--Total landings and landings in the Dry Tortugas, vessel size class 4, 1965.

I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
966	34	25	73.52	.57,451	42,455	73.89
010	45	39	86.66	96,251	82,523	85.73
896	18	12	66.66	59,217	44,126	74.51
019	36	25	69.44	54,610	33,371	61.10
627	3.	3	100.00	5,922	5,922	100.00
352	25	14	56.00	45,404	29,962	65.98
501	28	28	100.00	35,332	35,332	100.00
0/%	38	20	52.63	66,188	30,981	46.80
528	32	20	62.50	47,875	. 25,490	53.24
71.1	36	36	100.00	70,450	70,450	100.00
250	31	8	25.80	41,764	7,987	19.12
1/3	33	20	60.60	72,893	41,075	56.34
508	33	32	96.96	66,290	66,067	. 99.66
270	. 33	19	57.57	69,622	37,454	53.79

APPENDIX D Table 12.--Total landings and landings in the Dry Tortugas, vessel size class 5, 1965.

	I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas		Total pounds	Pounds in Tortugas	Percent pounds in Tortugas	
•	963	26	9	34.61	I.	68,550	25,097	36.61	
•	536	26	16	61.53		71,872	45,326	63.06	•.
	693	29	9	31.03	•	55,161	13,826	. 25.06	
	521	28	14	50.00		67,063	30,218	45.05	
	364	29	11	37.93		69,457	21,993	31.66	
•					n an an the Ann		•••••	2	

APPENDIX D Table 13.--Total landings and landings in the Dry Tortugas, vessel size class 6, 1965.

157 177 576 659 831 464 857 051 689 722 878 979	28 23 16 26 30 29 19 27 24 32	12 11 26 5 11 5 5 3	42.85 47.82 68.75 100.00 16.66 37.93 26.31 18.50	50,091 41,227 53,440 45,510 55,527 38,302 60,143 49 369	18,558 23,808 39,529 45,510 12,163 12,331 12,492	37.04 57.74 73.96 100.00 21.90 32.19 20.77	
177 576 659 831 464 857 051 689 722 878 979	23 16 26 30 29 19 27 24 32	11 11 26 5 11 5 5 3	47.82 68.75 100.00 16.66 37.93 26.31 18.50	41,227 53,440 45,510 55,527 38,302 60,143 49 369	23,808 39,529 45,510 12,163 12,331 12,492	57.74 73.96 100.00 21.90 32.19 20.77	
576 659 831 464 857 051 689 722 878 979	16 26 30 29 19 27 24 32	11 26 5 11 5 5 3	68.75 100.00 16.66 37.93 26.31 18.50	53,440 45,510 55,527 38,302 60,143 49,369	39,529 45,510 12,163 12,331 12,492	73.96 100.00 21.90 32.19 20.77	
659 831 464 857 051 689 722 878 979	26 30 29 19 27 24 32	26 5 11 5 5 3	100.00 16.66 37.93 26.31 18.50	45,510 55,527 38,302 60,143 49,369	45,510 12,163 12,331 12,492	100.00 21.90 32.19 20.77	••••••••••••••••••••••••••••••••••••••
831 464 857 051 689 722 878 979	30 29 19 27 24 32	5 11 5 5 3	16.66 37.93 26.31 18.50	55,527 38,302 60,143 49,369	12,163 12,331 12,492	21.90 32.19 20.77	
464 857 051 689 722 878 979	29 19 27 24 32	11 5 5 3	37.93 26.31 18.50	38,302 60,143 79,369	12,331 12,492	32.19 20.77	
857 051 689 722 878 979	19 27 24 32	5 5 3	26.31 18.50	60,143	12,492	20.77	
051 689 722 878 979	27 24 32	5	18.50	19 369			· ·
689 722 878 979	24 32	3		4/9/0/	5,879	11.90	
722 878 979	32	-	12.50	47,094	7,846	16.66	
878 979	214	6	18.75	48,415	9,757	20.15	
979	24	9	37.50	33,380	12,622	37.81	
	27	10	37.03	56,517	18,369	32.50	
098	9	4	44.44	11,077	6,103	55.09	1 1
318	31	12	.38.70	85,039	41,481	48.77	
530	22	4	18.18	54,482	7,012	12.87	
465	27	6	22.22	51,639	13,648	26.42	
673	8	2	25.00	43,720	4,882	11.16	
422	23	10	43.47	52,634	24,246	46.06	- * ·
602	14	2	14.28	54,356	6,346	11.67	
802	20	5	25.00	54,540	13,364	24.50	
319	16	4	25.00	47,197	9,540	20.21	ананан айтар Алтариян айтар
112	. 37	18	.48.64	95,804	55,496	57.92	
113	30	17	53,12	98,806	56.766	57.45	

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APPENDIX D	Table	14Total	landings	and	landings	in	the Di	ry Tortuga	as, vessel	L size	class	7,	196	<i>5</i> .
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I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
909	16	3	18.75	52,928	8,640	16.32
910	19	4	21.05	58,384	9,938	17.02
910	19	1	5.26	63,521	2,778	4.37
911	13	3	23.07	54,714	4,742	8.66
348	17	3	17.64	57,189	6,200	10.85
981	16.	1	.6.25	78,098	1,235	1.58
982	26	2	7.69	79,336	2,415	3.04
570	13	2	15.38	67,956	3,272	4.81
040	. 18	3	16.66	76,116	3.484	4.57
341	17	1.	5.88	54,175	2,280	4.20
846	5	4	80.00	21,722	19,767	90.99
847	· · 5	· . 3	60.00	14,731	12,036	81.70

APPENDIX D Table 14.--Continued.

	I.D. number	Total trips	Trips in Tortugas	Percent trips in Tortugas	:	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas	-
	891	23	3	13.04	:	67.493	9,7/3	14.43	
	541	30	12	40.00	•	53,408	21,912	41.02	
	240	27	7	25.92	w.e	66,586	16,796	25.22	
· .	· 290	16	4	25,00		38,095	8,019	21.05	
	805	6	1	16.66		44,112	3,100	7.02	
	449	16	1 <b>1</b>	6.25	•	91,377	2,873	3.14	
	666	17	.1	5.88	•	62,642	3,047	4.86	
	724	17	4	<b>23.</b> 52 <sup>·</sup>	:	81,933	7,131	8.70	
	642	18	2	11.11		78,760	13,190	16.74	
	126	14	. 1	7.14	. 1	71,661	2,007	2.80	
	127	18	<u> </u>	5.55	·	88,278	3,793	4.29	
	704	23	3	13.04		72,308	6,817	9.42	
	705	15	2	13.33		67,978	3,681	5.41	

APPENDIX D Table 15.--Total landings and landings in the Dry Tortugas, vessel size class 8, 1965.

	I.D. number	Total trips	Trips in Tortugas	Percent trips.in Tortugas	Total pounds	Pounds in Tortugas	Percent pounds in Tortugas
•	316	38	17	44.73	108,016	. 31,115	28.80
	594	6	1	16.66	37,417	5,839	15.60
•	477	8	7	87.50	19,338	18,397	95.13

APPENDIX D Table 16.--Total landings and landings in the Dry Tortugas, vessel size class 9, 1965.

Vessel size class	Average number of calendar days fished per trip	Average landings per trip	Average catch per day per size class (pounds)
2	4	2,229	557.25
3	4	1,582	395.50
4	5	1,367	273.40
5	6	1,815	302.50
6	7	2,221	317.29
7	7	2,416	345.14
8	6	2,359	393.17
9	7	2,281	325.86

APPENDIX D Table 17.--Two-year average of days fished and catch per day per size class for Dry Tortugas vessels, 1964 and 1965.

•	Vessel size class	1964	1965
<b></b>	2	\$.3123	\$.3701
	3	.3661	.4281
	4	•5141	•5333
	5	•4992	.5567
	6	<b>.53</b> 40	.5772
	7	•5023	.5703
	8	.6454	.6358
	9	.6482	.6333

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APPENDIX D Table 18.--Dry Tortugas fishery: average value of shrimp per pound by vessel size class.

	Vessel size class	•		Average age (years)		
 	2	· · · · · · · · · · · · · · · · · · ·		25.0	•	
	3			15.9		
	4		·.	10.8		)
	5			7.6		
	6			8.9	· · ·	
	7		ж. 1	8.7	•	
	8			5.0		
	9			5.2		

APPENDIX D Table 19.--Dry Tortugas fishery: average age of sample vessels per vessel size class, 1964-65.

	Vessel size. class	Average net tonnage	
<b>.</b>	2	10.00	
1	3	15.00	
	1	12.40	
	5	18.43	
	6	28.60	
•	7	32.19	
	8	38.77	
	9	68.33	

APPENDIX D Table 20.--Dry Tortugas fishery: average net tonnage of sample vessels per vessel size class, 1964-65.

								•	
Vessel size class	Days at sea/trip	Average number of trips	Average number wk. hours at sea/year*	Average number wk. hours at sea/trip	Average crew share per trip**	Average individual crew share/trip***	Average hourly wage/crew member	Average yearly income for Tortugas	Percent time fishing Tortugas
2	5	10	600	60	\$247.95	\$123.98	\$2.07	\$1,242.00	100.00
3	5	16	960	60	208.78	104.39	1.74	1,670.40	88.47
4	6	17	1,224	72	238.61	119.31	1.66	2,031.84	66.05
5	7	17	1,428	84	318.07	159.04	1.89	2,698.92	71.88
6	8	13	1,248	96	415.33	138.44	1.44	1,797.12	34.86
7	8	8.	768	96	437.66	145.89	1.52	1,167.36	29.54
8	7	8	672	84	501.38	167.13	1.99	1,337.28	16.01
9	8	5	480	96	483.98	161.33	1.68	806.40	49.63
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APPENDIX D Table 21.--Dry Tortugas fishery: Days at sea per trip, average number of trips, average number of hours fished per year, and average hourly wage per crew member, 1964-1965.

"The days at sea assume a 12-hour work day.

\*\*Crew share equals 1/3 of the average value of the shrimp per trip.

\*\*\*Assumes two crew members on vessel size classes 2, 3, 4, and 5, and three crew members on vessel size classes 6, 7, 8, and 9, and equal distribution of the gross crew income.

	trip by sam	ple vessels,	1965.		
Vessel size class	Average net tonnage	Cubic feet of hold capacity*	Pound capacity**	Average catch/trip	Percent capacity utilization
2	10.0	1000	8,500	2229	26.22
3	15.0	1500	12,750	1582	12.40
4	12.4	1240	10,540	1367	12.96
5	18.4	1840	15,640	1815	11.60
6	28.6	2860	24,310	2221	9.13
7	32.2	3220	27,370	2416	8.82
8	38.8	3880	32,980	2359	7.15
9	68.3	6830	58,055	2281	3.92

APPENDIX D Table 22.--Dry Tortugas fishery: Average percent capacity utilized per average trip by sample vessels, 1965.

\*Hold capacity = (100 cubic feet) (Net tonnage).

\*\*8.5 pounds of heads off shrimp per cubic foot mixed in a 1:1 ratio with ice.

APPENDIX D Table 23.--Derivation of net ton capacity coefficient for empirical analysis.

Bureau of Commercial Fisheries indicates that:

1 pound of shrimp and crushed ice at a 1:1 ratio occupies 101.87 cubic inches.

1728 cubic inches = 1 cubic foot

 $\frac{1728}{101.87}$  = 16.96 = 17 (half of which is shrimp)

1 cubic foot contains 8.5 pounds of shrimp

1 net ton = 100 cubic feet = 850 pounds of shrimp









## APPENDIX E

## Transport Rate Matrix of the Dry Tortugas Fishing Vessels by Port and Vessel Size Class

Vessel size class	Average speed (mph)	Average gallons of fuel consumed per hour	Average fuel price per gallon		
2	7.57	8.20	\$.14		
3	8.35	8.45	•14		
4	9.00	9.22	.14		
5	8.73	<b>J.</b> 49	.14		
6	8.83	9.52	.14		
7	9.27	9.79	.14		
8	9.83	11.70	.14		
9	10.23	13.31	.14		

APPENDIX E Table 1.--Dry Tortugas sample vessels: average speed (mph), gallons of fuel consumed per hour, and price per gallon of fuel.

	Miles					1. 1.			
Area	round trip	2	3	4	-Vessel siz 5	ze class 6	7	8	9
A1 6-10	30	•4.00	3.60	3.33	3.44	3.40	3.24	3.05	2.93
A1 11-15	36	4.75	4.31	4.00	4.12	4.08	3.88	3.56	3.52
A1_16-20	36	4.75	4.31	4.00	4.12	4.08	3.88	3.56	3.52
A2 6-10	75	10.00	8.98	8.33	8.59	8.49	8.09	7.63	7.33
A2 11-15	94	12.42	11.25	10.44	10.77	10.65	10.14	9.56	9.19
A2 16-20	124	16.38	14.85	13.78	14.20	14.04	13.38	12.61	12.12
A2 21-25	154	20.34	18.44	17.11	17.64	17.44	16.61	15.67	15.05
A2 26 <b>-</b> 30	170	22.45	20.36	18.88	19.47	19.25	18.34	17.29	16.62
A2 31-35	190	25.09	22.75	21.11	21.76	21.52	20.50	19.33	18.57
A3 11-15	140	18.49	16.76	15.55	16.03	15.86	15.10	14.24	13.69
A3 16-20	160	21.14	19.16	17.77	18.33	18.12	17.26	16.28	15.64
A3 21-25	180	23.77	21.56	20.00	20.62	20.39	19.42	18.31	17.59
A3 26-30	200	26.42	23.95	22.22	22.91	22.65	21.57	20.35	19.55

APPENDIX E Table 2.--Port 1: travel hours to and from fishing grounds.

	Miles				TT _ 7 _ 9				
Area	round trip	2	3	4	-vessel si: 5	6	7	8	9
A1 6-10	250	33.03	29.94	27.78	28.64	28.31	26.97	25.43	24.44
A1 11-15	285	37.65	34.13	31.67	32.65	32.27	30.74	28.99	27.86
A1 16-20	285	37.65	34.13	31.67	32.65	32.27	30.74	28.99	27.86
A2 6-10	270	35.67	32.34	30.00	30.93	. 30.58	29.13	27.47	26.39
A2 11-15	260	34.35	31.14	28.89	29.78	29.45	28.05	26.45	25.42
A2 16-20	270	35.67	32.34	30.00	30.93	30.58	29.13	27.47	26.39
A2 21-25	290	38.31	34.73	32.22	33.22	32.84	31.28	29.50	28.35
A2 26-30	295	38.97	35.33	32.78	33.79	33.41	31.82	30.01	28.84
A2 31-35	300	39.63	35.93	33.33	34.36	33.98	32.36	30.52	29.33
A3 11-15	150	19.82	17.96	16.67	17.18	16.99	16.18	15.26	14.66
A3 16-20	165	21.80	19.76	18.33	18.90	18.69	17.80	16.79	16.13
A3 21-25	180	23.78	21.56	20.00	20.62	20.38	19.42	18.31	17.60
A3 26-30	195	25.76	23.33	21.67	22.34	22.08	21.04	19.84	19.06
	· · · · ·			an Taolain Taolain					•

APPENDIX E Table 3 .-- Port 2: travel hours to and from fishing grounds.

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	Miles				Waaa7	]			
Area	Area trip	2	3	4	-vesser sr 5	ciass 6	7	8	. 9
-A1 6-10	430	56.80	51.50	47.78	49.26	48.70	46.39	43.74	42.03
A1 11-15	470	62.09	56.29	52.22	53.84	53.23	50.70	47.81	45.94
A1 16-20	470	62.09	56.29	52.22	53.84	53.23	50.70	47.81	45.94
A2 6-10	430	56.80	51.50	47.78	49.26	48.70	46.39	43.74	42.03
A2 11-15	416	54.95	49.82	46.22	47.65	47.11	44.88	42.32	40.66
A2 16-20	. 410	54.16	49.10	45.56	46.96	46.43	44.23	41.71	40.08
A2 21-25	410	54.16	49.10	45.56	46.96	46.43	44.23	41.71	40.08
A2 26-30	410	54.16	49.10	45.56	46.96	46.43	44.23	41.71	40.08
A2 31-35	418	55.22	50.06	46.44	47.88	47.34	45.09	42.52	40.86
A3 11-15	315	41.61	37.72	35.00	36.08	35.67	33.98	32.04	30.79
A3 16-20	310	40.95	37.13	34.44	35.51	35.11	33.44	31.54	30.30
A3 21-25	310	40.95	37.13	34.44	35.51	35.11	33.44	31.54	30.30
A3 26-30	310	40.95	37.13	34.44	35.51	35.11	33.44	31.54	30.30

APPENDIX E Table 4.--Port 3: travel hours to and from fishing grounds.

			4	Veccel si	70 0]955			
Area	2	3	4	5	6	7	8	. 9
A1 6-10	32.80	30.42	30.70	32.65	32.37	31.72	35.69	39.00
A1 11-15	38.95	36.42	36.88	39.10	38.84	37.99	41.65	46.85
A1 16-20	38.95	36.42	36.88	39.10	38.84	37.99	41.65	46.85
A2 6-10	82.00	75.88	76.80	81.52	80.82	79,20	89.27	97.56
A2 11-15	101.84	95.06	96.26	102.21	101.39	99.27	111.85	122.32
A2 16-20	134.32 ·	125.48	127.05	134.76	133.66	130.99	147.54	161.32
A2 21-25	166.79	155.82	-157.75	167.40	166.03	162.61	183.34	200.32
A2 26-30	184.09	172.04	174.07	184.77	183.26	179.55	202.29	221.21
A2 31-35	205.74	192.24	194.63	206.50	204.87	200.70	226.16	247.17
A3 11-15	151.62	141.62	143.37	152.12	150.99	147.83	166.61	182.21
A3 16-20	173.35	161.90	163.84	173.95	172.50	168.98	190.48	208.17
A3 21-25	194.91	182.18	184.40	195.68	194.11	190.12	214.23	234.12
A3 26-30	216.64	202.38	204.87	217.42	215.63	211.17	238.10	260.21

APPENDIX E Table 5.--Port 1: (Hours travel time to and from fishing grounds) (Gallons fuel consumption per hour).

				-Vessel si	ze class			
Area	2	3		5	6 <b>6</b>		8	9
A1 6-10	270.85	252.99	256.13	271.79	269.51	264.04	297.53	325.30
A1 11-15	308.73	288.40	292.00	309.85	307.21	300.94	339.18	370.82
A1 16-20	308.73	288.40	292.00	309.85	307.21	300.94	339.18	370.82
A2 6-10	292.49	273.27	276.60	292.53	291.12	285.18	321.40	351.25
A2 11-15	281.67	263.13	266.37	282.61	280.36	274.61	309.47	338.34
A2 16-20	292.49	273.27	276.60	293.53	291.12	285.18	321.40	351.25
A2 21-25	314.14	293.47	297.07	315.26	312.64	306.23	345.15	377.34
A2 26-30	319.55	298.54	302.23	320.67	318.06	311.52	351.12	383.86
A2 31-35	324.97	303.61	307.30	326.08	323.49	316.80	357.08	390.38
A3 11-15	162.52	151.76	153.70	163.04	161.74 -	158.40	178.54	195.12
A3 16-20	178.76	166.97	169.00	179.36	177.93	174.26	196.44	214.69
A3 21-25	195.00	182.18	184.40	195.68	194.02	190.12	214.23	234.26
A3 26-30	211.23	197.14	199.80	212.01	210.20	205.98	232.13	253.69

APPENDIX E	Table 6Port 2:	(Hours travel	time to	and from	n fishing	grounds)		
	(Gallons	fuel consumpt:	ion per	hour)				
		· · · ·		Noggol gigo	a] 9 5 5			2
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Area	2	3	4	vesser size 5	6	7	8	9
A1 6-10	465.76 '	435.18	440.53	467.48	463.62	454.16	511.76	559.42
A1 11-15	509.14	475.65	481.47	510.94	506.75	496.35	559.38	611.46
A1 16-20	509.14	475.65	481.47	510.94	506.75	496.35	559.38	611.46
A2 6-10	465.76	435.18	440.53	467.48	463.62	454.16	511.76	559.42
A2 11-15	450.59	420.98	426.15	452.20	448.49	439.38	495.14	541.18
A2 16-20	444.11	414.90	420.06	445.65	442.01	433.01	488.01	533.46
A2 21-25.	444.11	414.90	420.06	445.65	442.01	433.01	488.01	533.46
A2 26-30	444.11	414.90	420.06	445.65	442.01	433.01	488.01	533.46
A2 31-35	452.80	423.01	428.18	454.38	450.68	441.43	497.48	543.85
A3 11-15	341.20	318.73	322.70	342.40	339.58	332.66	374.87	409.81
A3 16-20	335.79	313.75	317.54	336.99	334.25	327.38	369.02	403.29
A3 21-25	335.79	313.75	317.54	336.99	334.25	327.38	369.02	403.29
A3 26 <b>-</b> 30	335.79	313.75	317.54	336.99	334.25	327.38	369.02	403.29

APPENDIX E Table 7.--Port 3: (Hours travel time to and from fishing grounds) (Gallons fuel consumption per hour)

	•			Vessel size class			4	
Area	2	3	4	5	6	7	8	9
A1 6-10	\$ 4.59	\$ 4.26	\$ 4.30	\$ 4.57	\$ 4.53	\$ 4.44	\$ 5.00	\$ 5.46
A1 11-15	5.45	5.10	5.16	5.47	5.44	5.32	5.83	6.56
A1 16-20	5.45	5.10	5.16	5.47	5.44	5.32	5.83	6.56
A2 6-10	11.48	10.62	10.75	11.41	11.31	11.09	12.50	13.66
A2 11-15	14.26	13.31	- 13.48	14.31	14.19	13.90_	15.66	17.12
A2 16-20	18,80	17.57	17.79	18.87	18.71	18.34	20.66	. 22.58
A2 21-25	23.35	21.81	22.09	23.44	23.24	22.77	25.67	. 28.04 -
A2 26-30	25.76	24.09	24.37	25.87	25.66	25.14	28.32	30.97
A2 31-35	28.80	26.91	27.25	28.91	28.68	28.10	31.66	34.60
A3 11-15	21.23	19.83	20.07	21.30	21.14	20.70	23.33	25.51
A3 16-20	24.27	22.67	22.94	24.35	24.15	23.66	26.67	29.14
A3 21-25	27.29	25.51	25.82	27.40	27.18	26.62	29.99	32.78
A3 26-30	30.33	28.33	28.68	30.44	30.19	29.56	33.33	36.43

APPENDIX E Table 8. -- Port 1: (Gallons fuel consumption) (Fuel price).

Area	2	3	4	Vessel siz 5	e class 6	7	. 8	9
A1 6-10	\$37.92	\$35.42	\$35.86	\$38.05	\$37.73	\$36.97	\$41.65	\$45.54
A1 11-15	43.22	40.38	40.88	43.38	43.01	42.13	47.49	51.94
A1 16-20	43.22	40.38	40.88	43.38	43.01	42.13	47.49	51.94
A2 6-10	40.95	38.26	38.72	40.95	40.76	39.93	45.00	49.18
A2 11-15	39.43	36.24	37.29	39.57	39.25	38.45	43.33	47.37
A2 16-20	40.95	38.26	38.72	41.09	40.76	39.93	45.00	49.18
A2 21-25	43.98	41.09	41.59	44.14	43.77	42.87	48.32	52.83
A2 26-30	44.74	41.80	42.31	44.89	44.53	43.61	49.16	53.74
A2 31-35	45.50	42.51	43.02	45.65	45.29	44.35	49.99	54.65
A3 11-15	22.75	21.25	21.52	22.83	22.64	22.18	25.00	27.32
A3 16-20	25.03	23.38	23.66	25.11	24.91	24.40	27.50	30.06
A3 21-25	27.30	25.51	25.82	27.40	27.16	26.62	29.99	32.80
A3 26-30	29.57	27.60	27.97	29.68	29.43	28.84	32.50	35.52

APPENDIX E Table 9. -- Port 2: (Gallons fuel consumption) (Fuel price).

Area	2	3	4	Vessel siz 5	ze class 6	7	8	9
A1 6-10	\$65.21	\$60.93	\$61.67	\$65.45	\$64.91	\$63.58	\$71.65	\$78.32
A1 11-15	71.28	66.59	67.41	71.53	70.95	69.49	77.14	85.60
A1 16-20	71.28	66.59	67.41	71.53	70.95	69.49	77.14	85.60
A2 6-10	65.21	60.93	61.67	65.45	64.91	63.58	71.65	78.32
A2 11-15	63.08	58.94	59.66	63.31	62.79	61.51	69.32	75.77
A2 16-20	62.18	58.09	58.81	62.39	61.88	60.62	68.32	74.68
A2 21-25	62.18	58.09	58.81	62.39	61.88	60.62	68.32	74.68
A2 26-30	62.18	58.09	58.81	62.39	61.88	60.62	68.32	74.68
A2 31-35	63.39	59.22	59.95	63.61	63.10	61.80	69.65	76.14
A3 11-15	47.76	44.62	45.18	47.94	47.54	46.57	52.48	57.37
A3 16-20	47.01	43.93	44.46	47.18	46.80	45.83	51.66	56.46
A3 21-25	47.01	43.93	44.46	47.18	46.80	45.83	51.66	56.46
A3 26-30	47.01	43.93	44.46	47.18	46.80	45.83	51.66	56.46

APPENDIX E Table 10.--Port 3: (Gallons fuel consumption) (Fuel price).

			Average c	atch per tri	p per size	class i	•	
Area	2	3	4	Vessel si 5	ze class 6	7	8	9
A1 6-10	\$.002	\$.003	\$.003	\$.003	\$.002	\$,002	\$.002	\$.002
A1 11-15	.002	.003	.004	.003	.002	.002	.002	.003
A1 16-20	.002	.003	.004	.003	.002	.002	.002	.003
A2 6-10	.005	.007	.008	.006	.005	.005	.005	.006
A2 11-15	.006	.008	.010	.008	.006	.006	.007	.008
A2 16-20	.008	.011	.013	.010	.008	.008	.009	.010
A2 21-25	.010	.014	.016	.013	.010	.009	.011	.012
A2 26 <b>-</b> 30	.012	.015	.018	.014	.012	.010	.012	.014
A2 31-35	.013	.017	.020	.016	.013	.012	.013	.015
A3 11-15	.010	.013	.015	.012	.010	.009	.010	.011
A3 16-20	.011	.014	.017	.013	.011	.010	.011	.013
A3 21-25	.012	.016	.019	.015	.012	.011	.013	.014
A3 26-30	.014	.018	.021	.017	.014	.012	.014	.016
							-	

APPENDIX E	Table 11Port	1:	Cost of fuel
			Average catch per trip per size c]

Area	2	3		Vessel si 5	.ze class 6		8	
·····								•
.1 6–10	\$.017	\$.022	\$.026	\$.021	\$.017	\$.015	\$.018	\$.020
1 11-15	.019	.026	.030	.024	.019	.017	.020	.023
1 16-20	.019	.026	.030	.024	.019	.017	.020	.023
2 6-10	.018	.024	.028	.023	.018	.017	.019	.022
2 11-15	.018	.023	.027	.022	.018	.016	.018	.021
2 16-20	.018	.024	.028	.023	.018	.017	.019	.022
2 21-25	.020	.026	.030	.024	.020	.018	.020	.023
2 26-30	.020	.026	.031	.025	.020	.018	.021	.024
2 31-35	.020	.027	:031	.025	.020	.018	.021	.024
3 11-15	.010	.013	.016	.013	.010	.009	.011	.012
3 16-20	.011	.015	.017	.014	.011	.010	.012	.013
3 21-25	.012	.016	.019	.015	.012	.011	.013	.014
3 26-30	.013	.017	.020	.016	.013	.012	.014	.016

Cost of fuel Average catch per trip per size class i APPENDIX E Table, 12.--Port 2:

•			الله المراجع وي وي وي وي وي وي من ا	-Vessel si	ze class			
Area	2	3	4	5	6	7	8	9
A1 6-10			\$.045	\$.036	\$.029	\$.026	\$.030	\$.034
A1 11-15		-	.049	.039	.032	.029	.033	.038
A1 16-20			.049	.039	.032	.029	.033	.038
A2 6-10			.045	.036	.029	.026	.030	.034
A2 11-15			.044	.035	.028	.025	.029	.033
A2 16-20			.043	.034	.028	.025	.029	.033
A2 21-25			.043	.034	.028	.025	.029	.033
A2 26-30			.043	.034	,028	.025	.029	.033
A2 31-35			.044	.035	.028	.026	.030	.033
A3 11-15	••••••		.033	.026	.021	.019	.022	.025
A3 16-20			.033	.026	.021	.019	.022	.025
A3 21-25		and and 1971	.033	.026	.021	.019	.022	.025
A3 26-30			.033	.026	.021	.019	.022	.025

INDIVITY T	m-1-1 - 12	Domt 2.	Cost of fuel	
APPENDIX E	TADLE 13	POPU J:	UUSU UI IUUI	-
			the sector sector that non	

#### APPENDIX F

Migration Characteristics of the Shrimp Fishing Vessels in the Dry Tortugas Fishery

Vessel size class	Total vessels fishing in Tortugas	Number of migratory vessels	Percent migratory
1	2	) 1	50.00
2	6	2	33.33
3	23	1	4.35
4	123	13	10.57
5	148	19	12.84
6	59	10	16.95
7	127	44	34.65
	32	11	34.38
9	10	4	40.00
Total	530	105	19.81

APPENDIX F Table 1.--Migratory vessels in Dry Tortugas, 1964.

	Vessel size class	Average calendar	number of days fished
	2		4
	3		4
	4		5
	5_		6
	6		7
	7		7
	8		6
•	9		7

APPENDIX F Table 2.--Average number of days fished per trip on Dry Tortugas by sample vessels, 1964-1965.

•	Vessel size class		Average calendar	number of days fished	
	2	•		0	
· · · · · · · · · · · · · · · · · · ·	3			1	
	4			5	
	5			5	
	6		· c	7	
	7			7	•
	8 :			8	
	9			6	

APPENDIX F Table 3.--Average number of days fished per trip on grounds other than Dry Tortugas by sample vessels, 1964-1965.\*

\*Vessels included in this sample fished a portion of the calendar years 1964 and 1965 on the Tortugas.

•			· . 		•			• •			
Port					Ve	ssel si	ze clas	s			
Code		1	2	3	4	5	6	7	8	9	Total
• 1	•	1	4	21	76	103	33 -	30	9	. 3	280
2		0	0	0	1	0	0	0	0	0	1
3	(	0	0	1	33	26	16	53	12	3	144
4	, . <b>(</b>	C	0	0	1	2	. 2	19	5	3	32
6		1	Q	0	2	1	. 1	3	2	0	10
21	. (	<b>)</b>	1	0	0	0	0	0	0	0	1
45	(	2	0	0	1	0	Ō	1	0	0	2
48	C	C	1	, <b>O</b>	0	0	0	0	0	0	1
49	( )	<b>כ</b>	0	0	0	0	0	1	0	0	1
52	(	<b>)</b>	0	0	0	· <b>1</b>	0	0	0	0	1
72	· · · (	0	0	0	1	0	0	0	0	0	1
73		D	0		5	10	5	13	1	0	34
78	C	5	0	0	3	8 3	1	5	2	1	15
80	Ċ	)	0	0	0	1	0	0	0	0	1
81`	. (	)	0	1	0	0	0	1	0	0	2
82	Ċ	)	0	0	0	1	1	1	1	0	4
Total	2	5	6	23	123	148	59	127	32	10	530

APPENDIX F Table 4.--Port distribution of vessels fishing Dry Tortugas; 1964.

1	2	3	4	5	6	7	8	9	Total
0	2		· · · · ·						
		13	63 ,	84	29	33	10	5	239
0	0	1	1	1	0 /	1	0	0	4
Ò	0	3	31	26	13	58	13	10	154
0	0	0	2	4	2	40	21	8	77
0	1	0	0	2	0	0	1	0	. 4
0	0	0	1	0	Ó	0	0	0	1
0	1	0	0	0	0	0	· <sup></sup> 0	0	1
0	. 0	0.	3	11	5	· 11 <sup>·</sup>	. 1	0	31
0	0	0	2	3	1.	7	4	• 1	18
0	0	2	0	0	0	2	0	0	4
0	4	19	103	131	50	152	50	24	533
	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 0	0       0       1         0       0       3         0       0       0         0       1       0         0       0       0         0       1       0         0       0       0         0       1       0         0       0       0         0       0       0         0       0       2         0       4       19	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

APPENDIX F Table 5.--Port distribution of vessels fishing Dry Tortugas, 1965.

## APPENDIX G

Variable Production Cost Coefficients by Port, Vessel Size Class and Region of the Dry Tortugas Fished; 1964, 1965

Linear programming activity	Transport rate per pound	Variable cost per pound	Total variable production cost per pound
c121	\$.002	. \$.086	\$.088
c131	.003	.361	.364
c141	.003	.461	.419
c151	.003	.283	.286
c161	.002	.386	.388
c171	.002	.352	.354
c181	.002	.410	.412
c191	.002	•541	•543
c122	.017	•086	.103
c132	.022	.361	.383
c142	.026	.416	.442
c152	.021	.283	.304
c162	.017	.386	.403
c172	.015	•352	.367
c182	.018	.410	•428
c192	.020	•541	.501
c143	.045	.416	.401
c153	.036	.283	.319
c163	.029	.380	•412
c173	.026	•352	• 310
c183	.030	.410	• 440 E775
c193	.034	•541	•272
c221	.002	.086	.088
c231	.003	.361	•364
c241	.004	.416	.420
c251	.003	.283	.286
c261	.002	.386	.388
c271	.002	.352	•354
c281	.002	.410	•412
c291	.003	•541	•544
c222	.019	.086	.205
c232	.026	.361	• 381
c242	.030	.410	•440
c252	.024	.283	• 307
c262	.019	.380	•4U5 940
c2/2	.017	• 552	• 207
C282	.020	.410	•42U #41

APPENDIX G Table 1.--Variable production cost coefficients by port, vessel size class, and region of the Dry Tortugas fished, 1964-1965.\*

\*Variable cost + transport rate = c<sup>b</sup><sub>ij</sub>.

			J.
Linear Programming activity	Transport rate per pound	Variable cost per pound	Total variable production cost per pound
c243 c253 c263 c273 c283 c293	\$.049 .039 .032 .029 .033 .038	\$.416 .283 .386 .352 .410 .541	\$.465 .322 .418 .381 .443 .579
c321 c331 c341 c351 c361 c371 c381 c391 c322 c322 c322 c342 c342 c352 c362 c372 c382 c392 c343 c353 c363 c373 c383 c393	.002 .003 .004 .003 .002 .002 .002 .003 .019 .026 .030 .024 .019 .026 .030 .024 .019 .020 .023 .049 .039 .032 .029 .038	.086 .361 .416 .283 .386 .352 .410 .541 .086 .361 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .551 .541 .551 .541 .551	.088 .364 .420 .286 .388 .354 .412 .544 .105 .387 .446 .307 .405 .369 .430 .564 .465 .322 .418 .381 .443 .579
c421 c431 c441 c451 c461 c471 c481 c491 c422 c432 c432 c442 c452 c462	.005 .007 .008 .006 .005 .005 .005 .006 .018 .024 .028 .023 .018	.086 .361 .416 .283 .386 .352 .410 .541 .086 .361 .416 .283 .386	.091 .368 .424 .289 .391 .357 .415 .547 .104 .385 .444 .306 .404

Linear	Transport	Variable	Total variable
programming	rate per	cost per	production cost
activity	pound	pound	per pound
c472	\$.017	\$.352	\$.369
c482	.019	.410	.429
c492	.022	.541	.563
c443	.045	.416	.461
c453	.036	.283	.319
c463	.029	.386	.415
c473	.026	.352	.3'78
c483	.030	.410	.440
c493	.034	.541	.575
c521 c531 c541 c551 c551 c571 c581 c591 c522 c532 c542 c542 c552 c562 c572 c582 c592 c543 c553 c553 c553 c553 c553 c553 c553	.006 .008 .010 .008 .006 .007 .008 .018 .023 .027 .022 .018 .016 .018 .021 .044 .035 .028 .025 .029 .033	.086 .361 .416 .283 .386 .352 .410 .541 .086 .361 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .552 .541 .5541 .552 .55	.092 .369 .426 .291 .392 .358 .417 .549 .104 .384 .443 .305 .404 .368 .428 .562 .400 .318 .414 .377 .439 .574
c621	.008	.086	.094
c631	.011	.361	.372
c641	.013	.416	.429
c651	.010	.283	.293
c661	.008	.386	.394
c671	.008	.352	.360
c681	.009	.410	.419
c691	.010	.541	.551
c622	.018	.086	.104
c632	.024	.361	.385

Linear programming activity	Transport rate per pound	Variable cost per pound	Total variable production cost per pound
c642 c652 c662 c672 c682 c692 c643 c653 c653 c663 c673 c683 c693	\$.028 .023 .018 .017 .019 .022 .043 .024 .028 .025 .029 .033	<ul> <li>\$.416</li> <li>.283</li> <li>.386</li> <li>.352</li> <li>.410</li> <li>.541</li> <li>.416</li> <li>.283</li> <li>.386</li> <li>.352</li> <li>.410</li> <li>.541</li> </ul>	\$.444 .306 .404 .369 .429 .563 .459 .317 .414 .377 .439 .574
c721 c731 c741 c751 c761 c771 c781 c791 c722 c732 c742 c752 c752 c752 c762 c752 c762 c772 c782 c792 c743 c753 c763 c773 c783 c793	.010 .014 .016 .013 .009 .011 .012 .020 .026 .030 .024 .020 .024 .020 .018 .020 .023 .043 .034 .028 .025 .029 .032	.086 .361 .416 .283 .386 .352 .410 .541 .086 .361 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .352 .410 .541	.096 .375 .432 .296 .396 .361 .421 .553 .106 .387 .446 .307 .406 .370 .430 .564 .459 .317 .414 .377 .439 .573
c821 c831 c841 c851 c861 c861 c871 c881 c891	.012 .015 .018 .014 .012 .010 .012 .014	.086 .361 .416 .283 .386 .352 .410 .541	.098 .376 .434 .297 .398 .362 122 .555

Linear	Transport	Variable	Total variable
programming	rate per	cost per	production cost
activity	pound	pound	per pound
c822 c832 c842 c852 c862 c872 c862 c872 c882 c892 c843 c853 c853 c863 c873 c883 c893	\$.020 .026 .031 .025 .020 .018 .021 .024 .043 .034 .028 .025 .029 .033	\$.086 .361 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541	\$.106 .387 .447 .308 .406 .370 .431 .565 .459 .317 .414 .377 .439 .574
c921 c931 c941 c951 c961 c971 c981 c992 c932 c932 c942 c952 c942 c952 c962 c972 c982 c992 c943 c992 c943 c953 c963 c973 c983 c993	.013 .017 .020 .016 .013 .012 .013 .015 .020 .027 .031 .025 .020 .018 .021 .024 .024 .024 .024 .024 .024 .024 .024 .025 .020 .021 .024 .024 .025 .020 .021 .024 .025 .020 .021 .024 .025 .020 .035 .023	.086 .361 .416 .283 .386 .352 .410 .541 .086 .361 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .552	.099 .378 .436 .299 .399 .364 .423 .556 .106 .388 .447 .308 .447 .308 .406 .370 .431 .565 .460 .318 .414 .378 .440 .574
c1021	.010	.086	.096
c1031	.013	.361	.374
c1041	.015	.416	.431
c1051	.012	.283	.295
c1061	.010	.386	.396

APPENDIX G Table 1.--Continued.

Linear	Transport	Variable	Total variable
programming	rate per	cost per	production cost
activity	pound	pound	per pound
c1071	\$.009	\$.352	\$.361
c1081	.010	.410	.420
c1091	.011	.541	.552
c1022	.010	.086	.096
c1032	.013	.361	.374
c1042	.016	.416	.432
c1052	.013	.283	.296
c1062	.010	.386	.396
c1072	.009	.352	.361
c1082	.011	.410	.421
c1092	.012	.541	.553
c1043	.033	.416	.449
c1053	.026	.283	.309
c1063	.021	.386	.407
c1073	.019	.352	.371
c1083	.022	.410	.432
c1093	.025	.541	.566
c1121 c1131 c1141 c1151 c1161 c1171 c1181 c1191 c1122 c1132 c1142 c1152 c1162 c1172 c1182 c1192 c1143 c1153 c1163 c1173 c1183 c1193	.011 $.014$ $.017$ $.013$ $.011$ $.010$ $.011$ $.013$ $.011$ $.015$ $.017$ $.014$ $.011$ $.010$ $.012$ $.013$ $.026$ $.021$ $.019$ $.022$ $.025$	.086 .361 .416 .283 .386 .352 .410 .541 .086 .361 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552 .552	.097 .375 .433 .296 .397 .362 .421 .554 .097 .376 .433 .297 .399 .362 .422 .554 .449 .309 .309 .407 .371 .432 .566

Linear programming activity	Transport rate per pound	Variable cost per pound	Total variable production cost per pound
c1221 c1231 c1241 c1251 c1251 c1261 c1271 c1281 c1291 c1222 c1232 c1242 c1252 c1262 c1272 c1282 c1292 c1243 c1292 c1243 c1253 c1263 c1273 c1283 c1293	\$.012 .016 .019 .015 .012 .011 .013 .014 .012 .016 .019 .015 .012 .011 .013 .014 .033 .026 .021 .019 .022 .025	\$.086 .361 .416 .283 .386 .352 .410 .541 .086 .361 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .410 .541	\$.098 .377 .435 .298 .398 .363 .423 .555 .098 .377 .435 .298 .398 .363 .423 .555 .449 .309 .407 .371 .432 .566
c1321 c1331 c1341 c1351 c1361 c1361 c1371 c1381 c1391 c1322 c1322 c1342 c1352 c1342 c1352 c1362 c1372 c1382 c1392 c1343 c1353 c1363 c1373	.014 .018 .021 .017 .014 .012 .014 .016 .013 .017 .020 .016 .013 .012 .014 .016 .033 .026 .021 .019	.086 .361 .416 .283 .386 .352 .410 .541 .086 .361 .416 .283 .386 .352 .410 .541 .416 .283 .386 .352 .386 .352	.100 .379 .437 .300 .400 .364 .424 .557 .099 .378 .436 .299 .399 .364 .424 .557 .449 .309 .407 .371

APPENDIX G Table 1.--Continued.

Linear	Transport	Variable	Total variable
programming	rate per	cost per	production cost
activity	pound	pound	per pound
c1383	\$.022	<b>\$.</b> 410	\$.432
c1393	.025	•541	.566
•			

¢

APPENDIX H

Model II Coefficients

S

Vessel clas	size ss	Average fuel capacity (00's gallons)	Ga lons fuel consumption per hour	Unadjusted days at sea per trip	Adjusted days at sea per trip*
2		12.5	8.20	10.2	8
3		20.8	8.45	16.4	14
4		22.7	9.22	16.4	14
5		28.4	9.49	19.95	18
6	-	36.3	9.52	25.4	23
7		52.0	9.79	35.4	33
8	•	76.1	11.70	43.4	41
9		90.7	13.31	<b>45.4</b>	43

APPENDIX H Table 1.--Model II adjusted days at sea per trip.

\*A two-day allowance was made for travel time.

Vessel size class	Trips 2-year average	Average number of days fished	Total number of days fished per year	Model II number of trips per year*
2	10	4	40	5
3	16	4	64	5
4	17	5	85	6
5	17	6	102	6
6	13	7	91	4
7	18	7	126	4
8	8	• 6	48	<b>1</b>
9	5	7	35	<ul> <li>▲ <b>1</b></li> </ul>

APPENDIX H Table 2 .-- Model II number of trips per year.

\*Model II number of trips per year = <u>Total number of days fished per year</u> Adjusted days at sea per trip

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