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NMFS-SEFC-101

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The Southeast Fisheries Center, National Marine Fisheries Service has, as one of its responsibilities the role of providing fisheries related data and the analysis of that data in support of fishery management. An important area within that role is data and analyses which provide information on economic aspects of fishery management. The south Atlantic and Gulf of Mexico Fishery Management Councils are in the process of submitting a joint plan (Fishery Management Plan, FMP) for the management of species identified as migratory coastal pelagics to the Secretary of Commerce for approval and subsequent implementation. Routinely an economic analysis of the regulations considered in an FMP is performed that estimates the potential effects of the alternative regulations. This, of course, was done prior to the Councils' submission of the FMP. However, since the Councils have considered these species sufficiently important to prepare an FMP, the Office of Fishery Management, Southeast Fisheries Center has prepared a report identifying the economic data associated with the species in this FMP (Ward and Poffenberger 1981). The purpose of the analysis herein is to combine the data described in Ward and Poffenberger (1981) in an economic analysis of the mackerel fisheries.

The term fishery economic analysis is employed in this report rather than the conventional bio-economic model for several reasons. First, the analysis in this report does not utilize any biological parameters, such as growth, natural mortality, etc., in its development. The fishery aspect of the analysis is the inclusion of landings and effort information in the estimation of a fishery economic production function. Second, cost functions which represent vessel operating expenditures are estimated as a means of incorporating various measures of economic efficiency related to separate components of the mackerel fisheries. Finally, the analysis attempts to synthesize the above two functions into an integrated representation of the fisheries within the migratory coastal pelagic management unit. Unfortunately, this hoped-for synthesis is greatly restrained by severe limitations of data as discussed in the subsequent sections. Therefore, the important result of this report is to clearly identify these limitations and to demonstrate the constrained and highly simplified types of analyses that can be performed with the existing data.

The previous paragraph presented the objectives of this report. The discussions of these objectives constitute the outline for this report. The first section uses existing data in the estimation of a fishery economic production function. This type of function estimates the relationship between the input factors necessary to catch fish and the output in terms of the amount of fish caught. As will be discussed in the third section, the estimation of a fishery economic production function(s) for the mackerel fisheries has to be reduced to a highly simplistic mathematical relationship. The reason for this simplistic approach is the lack of appropriate data. The second objective is the estimation of cost functions for vessels (or groups of vessels) fishing the mackerel resources. Since cost functions are related to the economic production functions, the estimates which are presented in section four are also highly simplistic and the usefulness of these functions is questionable. The fifth section presents the results of regression analyses of dockside price on landings data for the important commercial mackerel species. In the sixth section attempts are made to synthesize these three types of mathematical functions into an integrated fishery economic analysis. This section also presents the important data deficiencies identified in this analytical synthesis. The report is concluded with a section presenting the author's recommendations on future data collection emphasis.

## BACKGROUND

The FMP for migratory coastal pelagics identifies the following species for this management unit; king mackerel, Spanish mackerel, bluefish, cobia, dolphin and little tunny. The important commercial species for which management measures are considered in the FMP are king and Spanish mackerel. Bluefish are harvested commercially in some areas and cobia are often landed and sold commercially, but these species are usually caught incidentially in other commercial fisheries. The economic analyses I have done for this report, however, are constrained to the commercially important species of king and Spanish mackerel because of the limitations of existing data. The magnitude of the data limitations are discussed throughout the report, but these limitations and the scope of the analyses should not be misinterpreted to imply that the other species in this management unit and especially the recreational segments of these fisheries are unimportant. It is only the data that contains the analyses in my report and not the relative importance of the diverse segments of the fishery.

From a population dynamics perspective, these affected species should be managed throughout the range of their habitat which provides the rationale for the joint management plan prepared by the South Atlantic and Gulf of Mexico Councils. Unfortunately, the fishing operations of fishermen targeting these pelagic species may not coincide with the habitat range of the species. In other words, there may only be one population (or stock) of a species throughout the Gulf and south Atlantic areas, but there may be several identifiably separate commercial fisheries targeting various segments of a single population. Furthermore, commercial fisherman may not target only species within this management unit. Thus, analyzing the economic operations of commercial mackerel fishermen on a species-by-species or a single species basis is inappropriate. As a first step in the analysis of these fisheries, the commercial fisheries should be identified and as detailed a description of these fisheries as possible should be provided. The remainder of this section provides a description of the available data on the commercial fisheries for king and Spanish mackerel.

The FMP identifies four primary commercial users and one secondary user of the king and Spanish mackerel resources. They are:

Primary Users:

1. Florida king mackerel hook & line fishery
    - east coast around the Ft. Pierce area and
    - Florida keys;

2. Florida king mackerel large gillnet fishery

   - Florida keys and
   - west coast around Naples, Florida;

3. Small boat Spanish mackerel gillnet fishery

   - Florida east coast, Salerno to Sebastian;

4. Large Spanish mackerel gillnet fishery

   - west coast around Naples, Florida,
   - Florida keys and
   - east coast, West Palm Beach to Cape Canaveral, Florida; and

Secondary Users:

1. Southeast Florida small gillnet fisherery for king mackerel.

With this array of commercial users targeting these two species, the analytical questions become: are these distinct fisheries, and if so, to what extent do vessels participate in more than one of the fisheries?

The answer to this question is similar to the definition of a commercial versus a recreational fisherman - i.e., inexact. Certainly a fishery should not be described as an isolated, static group of fishing vessels. However, analytically it is necessary to "define" separate fisheries if there are reasons for such a delineation. In the present analysis, the rationale is the data. Since there are several data sources upon which the analysis is based, the fisheries must be defined in ways consistent with the data. Therefore, prior to estimating specific functional representations of these fisheries, a brief review of the existing data available for this analysis is essential.

The NMFS collects and reports several different types of data that are utilized in the analysis. The first and most basic are monthly landing (pounds and value) data by state, specifically the east and west coasts of Florida. These landings data, however, do not include information on who caught the fish, where they were caught or the amount of fishing effort expended in catching them. As a modification to the landings data, the NMFS also reports landing data by the type of gear used in catching the respective species. These data are reported for the east and west coasts of Florida and examples are presented in Ward and Poffenberger (1981) (Tables 2A and 2B). These catch-by-gear-type data are annual estimates based on individual fish dealer's estimates of the percent of the fish landed by the various types of gear. The third type of data that the NMFS compiles are annual files on the vessels registered with the U. S. Coast Guard and operating in one or several fisheries within a given geographical area. The vessel operating units file (VOUF) have data on various physical characteristics, such as vessel size, engine horsepower, crew size, type of gear, etc., for vessels greater than five gross tons. Consequently, no historical information on the small gillnet fishery operating on the east coast of Florida is available.

In addition to the NMFS data two sample surveys that have been done through the Florida Sea Grant Program provide data on these fisheries. These surveys provide the only information on the operating costs and revenues of vessels targeting king or Spanish mackerel. One study, Cato et al (1978), provides these economic data for a sample of the Spanish gillnet vessels operating off the east coast of Florida. The second study, Morris et al (1977), presents the results of a cost and revenue survey which sampled hook & line vessels also operating on the east coast of Florida. One of the important questions that is addressed in the subsequent section on fishery production functions is whether the two samples used in these surveys are representative of the vessel populations maintained in the NMFS' vessel operating units file.

Two additional reports that provide qualitative information on these fisheries are also used in this analysis. However, they provide only limited primary data on these fisheries. The first report, Austin et al (1978), is a report on a workshop that was held in 1977 to discuss various aspects of the king and Spanish mackerel fisheries. The second report was prepared by Centaur Associates (1981) and is a very thorough description of these fisheries which provides updated estimates of the survey data provided in Cato et al (1978) and Morris et al (1977).

Combining the primary data collected by the NMFS and the secondary information from the published surveys and reports leads to a division into four possible commercial fisheries. These divisions are equipment related and geographical. They are; large gillnet equipped vessels on the east and west coasts of Florida and hook & line vessels on the two Florida coasts. The rationale for this initial separation is straightforward. The main reason is that the NMFS data do not contain data on fishing effort; therefore, the two sample surveys must be relied upon to provide data on the relation between catch and effort. Consequently, tests regarding the statistical representativeness of the two sample surveys with respect to the historical data contained in the VOUF need to be performed in order to combine these data sets with some degree of confidence. More detailed discussions of these statistical tests are presented in the next section.

One final qualification is necessary prior to discussing the fishery production functions. The analyses contained in this report are limited to landings data on the mackerel fisheries in Florida. This limitation is due to the lack of data on "other" fisheries. For example, the FMP identifies North Carolina charter boats as a secondary user of king mackerel during the spring and fall. However, no quantitative data are available on the magnitude of this fishery or its operating costs and revenues. Secondly, the contributions of non-Florida fisheries are inconsequential relative to the annual landings of the vessels operating and landing their catch in Florida (Ward and Poffenberger 1981).

## Fishery Production Functions

This section combines the data from various sources and estimates fishery production functions for the king and Spanish mackerel fisheries. A production function is a mathematical representation of a firm or industry's (i.e., a group of firms producing a common or similar product) output in terms (as a function) of the materials they use in the process of producing the output. Thus, a production function can be used to estimate the amount of output resulting from different combinations of the factor inputs. This enables a firm to determine its most advantageous production process based on the anticipated returns to scale. For example, if the firm is in a position of increasing returns to scale, then an increase in the amount of factor inputs would yield a more than proportionate increase in output. Production functions can also represent situations in which firms or industries have constant or decreasing returns to scale.

In the context of this analysis, a fishery production function should estimate catch as a function of the input factors necessary to harvest the catch. The Schaefer-Gordon model is an example which uses a parabolic shaped function such that catch is a function of standarized fishing effort (Gordon, 1954). Initially catch increases as effort increases and then decreases as the amount of effort increases beyond the amount of effort required to harvest the maximum sustainable yield. This mathematical model provides reasonable intuitive interpretations and has become one of the most classical and integral parts of bio-economic models. However, for purposes of this analysis, a lack of appropriate time series or cross sectional data preclude the estimation of this type of mathematical model.

Being constrained by an almost total lack of data on fishing effort for the four mackeral fisheries, a more simplistic approach is necessary. The production function that is developed in the remainder of this section is based on the following simple linear relationship:

$$Y = f(E) \tag{1}$$

where Y is the firm's output in landings and E is a measure of fishing effort. The measurement of fishing effort used in this analysis is estimated from the amount of annual fishing time reported in Cato et al (1978) and Morris et al (1977) for gillnet equipped vessels and hook & line vessels respectively.

The use of fishing time as a measure of fishing effort forces the analysis to incorporate several important assumptions. First, the amount of fishing time is assumed to be related to the size of the vessel. The implication of this assumption means that the arithmetic relationship between catch and time fished is the average for all vessels in the respective size categories. Furthermore, the same relationship between hours fished and vessel size must be assumed for all years. That is, this arithmetic relation implies that the relationship between hours fished and vessel size has not, nor will it change over time. A third, but related, assumption is that all the vessels have historically used the same amount and size of fishing gear. Fourth, the production function in equation (1) does not include a parameter representative of year-to-year changes in the stocks of these species. Finally, this model assumes that environmental conditions either do not have any effects on these fisheries or have historically remained the same.

Notwithstanding these rather severe assumptions, the remainder of this section develops estimates of the fishery production function specified in equation (1) for both gillnet equipped vessels and hook & line vessels. The geographical separation between the east coast and west coast of Florida may be somewhat unrealistic for these two types of gear; however, the initial hypothesis for analytical purposes is that there are four fisheries. For discussion purposes, these analyses are presented in two sections - gillnet vessels and hook & line vessels.

## Gillnet Equipped Vessels

Two categories of vessels using gillnets are readily discernible. They are smaller boats usually about 20 to 25 feet in length that do not have power assisted hydraulic roller rigs (used in the retrieval of the net) and larger vessels that have power assisted roller rigs. Not only is this distinction a visual one, but this hydraulic equpment makes a considerable difference in the size of net that the boat can fish. A difference in net sizes makes a difference in where the vessels can fish (i.e., the depths at which they can fish) and quite possibly it makes a significant difference in their catch per unit of effort (i.e., their relative efficiency). Therefore, in an analysis that attempts to measure input factor relative to the vessels' catch these two fisheries should be treated separately. Unfortunately, virtually no data are available on the small boat fishery except for the limited interview results in Cato et al (1978).[1] The results of the Cato (1978) survey indicate that 14 percent of the total catch of Spanish mackerel reported by the 13 interviewed boat and vessel captains were landed by the smaller boats. Therefore, an adjustment of 14 percent of the total east coast landings is made when the production function analysis involves gillnet landings reported by the NMFS.

Since the analysis is limited to large, power equipped large vessels, an understanding of the species harvested by these fisheries and their geographical locations is important. As described in the Background section, large gillnet vessels fish for both king and Spanish mackerel as their primary target species. They also harvest other species within the migratory coastal pelagics management unit (mostly bluefish), as well as other biologically unrelated species. For example, there is considerable effort by these vessels for spiny lobsters because of the relative ease with which the vessels can be adapted to this supplemental fishery and the complimentary nature of the fishing seasons for these separate species. This analysis does not address the multi-purpose aspect of these fishing vessels and restricts the production function to the harvest of only king and Spanish mackerel. The FMP describes the primary fishing areas for this type of gear as the west coast around Naples, Florida and the Florida keys for both king and Spanish mackerel. The east coast fishing area is described as extending from West Palm Beach to Cape Canaveral, Florida and is mainly a Spanish mackerel fishery. This is supported by Cato et al (1978) which provides an estimate of 82 percent of total annual catch of large gillnet equipped vessels on the east coast as being Spanish mackerel.

An initial step in developing fishery production functions is to establish any similarities in the geographical distributions of these vessels based on the combination of data from the different data sources. The following is an itemized list of the information on the number and geographical location of the gillnet vessels for the 1976-77 fishing season (this is the only year for which data are available from all three of the separate data sources):

1. Austin et al (1978) in their mackerel workshop report provided the following number of gillnet vessels by target species and area (these data are summarized from Table 1, p. 18 and Table 1, p. 38):

| | East Coast | West Coast |
|---|---|---|
| Spanish mackerel | 18 | 49 |
| king mackerel | - | 26 |
| Total vessels | 18 | 75 |

   These estimates of the number of vessels were provided by local fish houses (or dealers) and the text of the report does not discuss the possibility of duplicate identifications.

2. NMFS' vessel operating units file for 1977 lists 34 vessels registered on the east coast and 108 on the west coast (the west coast includes the Florida keys). These data are exclusive of duplication based on a comparison of the individual vessel's U. S. Coast Guard documentation numbers.

3. The Centaur Associates (1981) report estimates that there were 33 large scale net boats in 1976, however, according to footnote 2, Exhibit 2.2, this estimate is from a field survey for the Austin et al (1978) mackerel workshop. In the same exhibit, 67 vessels were estimated as participating in this fishery for 1977.

Based on the dissimilarity in these estimates, questions exist regarding either the identification of a large gillnet vessel or the method used in determining the number of these vessels in the fishery. For example, NMFS port agents identify any vessel using gillnets (gear code 475) for any part of the year as a gillnet vessel. Thus, the possibility exists that some of the vessels listed on the VOUF were not considered active enough gillnet fishermen by the fish dealers to include them in the interviews for the Austin et al (1978) or the Centaur Associates (1981) studies. Other possible explanations may exist; however, the rationalization of these differences is not the objective of this section. Therefore, for purposes of this analysis, the VOUF is considered the most useful data source, primarily because of the availability and reasonably consistent historical data.[2]

Since the vessels listed in the NMFS vessel operating units file are considered to be a reasonable proxy of the large gillnet fleet (or fleets), a fairly complete description of the physical characteristics of these vessels is available. Several of the important vessel chracteristics and the average values of these characteristics are listed in Tables 1 and 2 for the east coast and west coast of Florida respectively. Since these values are recorded at the time of the vessel's registration with the Coast Guard and may not have been updated since that time, the values may not reflect current specifications. The best example of this is the horsepower of the engine. Modifications to the engine either to increase the horsepower or the engine's fuel economy could possibly have been made that would render the values in Tables 1 and 2 inaccurate.

The important analytical problem, however, is to determine whether or not the vessel characteristics available in the VOUF are represented by the sample survey done by Cato et al (1978). The comparable characteristics are presented in Table 3. The first column presents the average values resulting from the vessel sample reported in Cato et al (1978). The second column lists the average values calculated from the data in the VOUF for the same physical characteristics that are listed in column one. The third column lists only a few of the same characteristics available in the Centaur Associates (1981) report. Comparing the first two columns indicates that vessel length and crew size are relatively close for these separate data sources. However, the values associated with the other vessel characteristics are quite dissimilar. Thus, a question still remains regarding the representativeness of the Cato et al (1978) sample with respect to the VOUF data.

In order to answer this question, vessel length was chosen as the parameter to be used in statistically comparing these two data sets. This parameter was also chosen because the size of the vessel is believed to be related to the amount of fishing effort expended by the vessel. However, the amount of data are too limited to provide any statistical verification of this hypothesis. The distribution (frequency) of the number of vessels in the VOUF per 5 foot size categories are presented in Tables 4 and 5 for the east and west coasts respectively. The number of vessels in the Cato et al (1978) survey is too small to be presented in similar tabular form due to the confidential nature of the data.

The frequency distributions by vessel size for these two data sets were used in contingency table analyses to test the hypothesis that they are from the same data set (see Zar, 1974 Chapter 6). Initially, only data from the east coast VOUF were compared to the Cato et al (1978) survey data. Because of the sample from this survey, the analysis was done using four size categories. They were; less than or equal to 30 feet, 31-40 feet, 41-50 feet and greater than 50 feet. The results of this test indicated that the null hypothesis should be rejected at any reasonable level of confidence. However, several of the expected frequencies in this contingency table had values less than one that could create a bias in the calculated chi-square value and should not be compared to the critical values in a chi-square table (see Zar, 1974 p 65-67).

Therefore, in an attempt to overcome this possible bias, the size categories were aggregated into two categories - i.e., less than or equal to 40 feet

TABLE 1

Description of Gillnet Fleet - Florida East Coast*

(1965 - 1977)

| Year | Vessels | Average Length | Average Tonnage | No. Crew/ Vessel | Construction FG | ST | WD | Average HP | Fuel Type Gas | Die |
|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 17 | 32.4 | 10.9 | 3.4 | NR | NR | NR | 186.5 | 76 | 24 |
| 1966 | 21 | 33.0 | 11.7 | 3.1 | NR | NR | NR | 194.9 | 76 | 24 |
| 1967 | 24 | 32.8 | 11.6 | 3.1 | - | NR | - | 192.0 | 75 | 25 |
| 1968 | 17 | 33.0 | 12.4 | 3.2 | - | - | 100 | 214.7 | 71 | 29 |
| 1969 | 18 | 33.5 | 12.6 | 3.1 | - | - | 100 | 209.3 | 61 | 39 |
| 1970 | 5 | 35.0 | 14.0 | 3.2 | - | - | 100 | 196.8 | 60 | 40 |
| 1971 | 15 | 34.5 | 12.2 | 3.1 | - | - | 100 | 190.5 | 40 | 60 |
| 1972 | 9 | 34.6 | 14.2 | 2.8 | 11 | - | 89 | 226.1 | 44 | 56 |
| 1973 | 11 | 33.5 | 12.4 | 2.6 | 9 | - | 91 | 204.3 | 64 | 36 |
| 1974 | 11 | 31.0 | 9.9 | 2.5 | 9 | - | 91 | 183.8 | 64 | 36 |
| 1975 | 15 | 37.0 | 18.5 | 3.1 | 20 | - | 80 | 326.9 | 33 | 67 |
| 1976 | 22 | 38.4 | 20.7 | 3.6 | 23 | - | 77 | 298.9 | 27 | 73 |
| 1977 | 34 | 38.4 | 21.2 | 3.7 | 24 | 3 | 73 | 286.0 | 24 | 76 |

Source: Unpublished Data. National Marine Fisheries Service. Southeast Fisheries Center. Miami, Florida. 1965 - 1977

* The Average Length is hull length measured in feet. The Average Tonnage is the vessel's gross tonnage. The acronyms for the type of construction are: FG for fiberglass, ST for steel, and WD for wood. The acronyms for the type of fuel are; GAS for gasoline and Die for diesel.

TABLE 2

Description of Gillnet Vessels - Florida West Coast

(1965 - 1977)

| Year | Total Vessels | Average Length | Average Tonnage | No. Crew/ Vessel | Construction FG | ST | WD | Average HP | Fuel Type Gas | Die |
|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 69 | 34.3 | 12.1 | 3.3 | - | - | - | 153.2 | 42 | 58 |
| 1966 | 84 | 34.2 | 14.2 | 3.3 | - | - | - | 164.7 | 49 | 51 |
| 1967 | 73 | 36.4 | 14.9 | 3.7 | - | - | - | 181.2 | 48 | 52 |
| 1968 | 75 | 36.9 | 16.5 | 3.5 | - | 3 | 97 | 184.5 | 29 | 71 |
| 1969 | 60 | 37.6 | 17.0 | 3.3 | - | 3 | 97 | 203.3 | 28 | 72 |
| 1970 | 57 | 37.2 | 16.1 | 3.7 | - | 3 | 97 | 202.6 | 21 | 79 |
| 1971 | 59 | 37.0 | 16.9 | 3.6 | 2 | 3 | 95 | 210.8 | 19 | 81 |
| 1972 | 61 | 37.0 | 15.8 | 3.3 | 11 | - | 89 | 237.9 | 16 | 84 |
| 1973 | 66 | 37.3 | 17.3 | 2.8 | 18 | 2 | 80 | 260.7 | 9 | 91 |
| 1974 | 86 | 37.7 | 18.1 | 3.0 | 23 | 1 | 76 | 249.2 | 12 | 88 |
| 1975 | 97 | 37.6 | 17.5 | 2.9 | 36 | 1 | 63 | 267.4 | 7 | 93 |
| 1976 | 114 | 37.7 | 18.3 | 3.0 | 39 | 1 | 60 | 264.3 | 12 | 88 |
| 1977 | 108 | 36.7 | 17.0 | 2.9 | 50 | - | 50 | 286.6 | 13 | 87 |

Source: See Table 1.

TABLE 3

Comparison of Vessel Characteristics

| | Cato et al[1] | NMFS[2] | Centaur[3] |
|---|---|---|---|
| Vessel Length | 42.3 | 38.4 | 46.6 |
| Hull Const. | | | |
| % Wood | 33.3 | 77.00 | - |
| % Fiberglass | 66.7 | 23.0 | - |
| Net Tonnage | 14.6 | 15.9 | 20.0 |
| Horsepower | 555 | 299 | 620 |
| Fuel Type | | | |
| % Gas | 50 | 27 | - |
| % Diesel | 50 | 73 | - |
| Crew | 3 | 2.6 | 3.5 |

1. Cato et al. 1978. Table 4,p.9. This survey included interviews from six captains of Spanish mackerel gillnet vessels on the Florida Atlantic coast. The survey was conducted in 1977, but collected data from operations during 1976. The range in vessel length is 30 to 55 feet.

2. These data are from the vessel operating units files, SEFC, NMFS. During 1976, there were 22 documented (with the U.S. Coast Guard) vessels reported as gillnet vessels (gear code 475) by SEFC Statistical Division Port Agents. The range in vessel hull length is 26 to 68 feet, see Table 1.

3. Centaur Associates (1981). These data are based on a survey of vessel captains during 1979.

TABLE 4

Distribution of Vessels by Length
For
Gillnet Vessels - Florida East Coast

| Year | 26 - 30 # | % | 31 - 35 # | % | 36 - 40 # | % | 41 - 45 # | % | 46 - 50 # | % | 51 - 55 # | % | › 56 # | % | Total Vessel |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 8 | 50 | 5 | 31 | 1 | 6 | 2 | 13 | - | - | - | - | - | - | 16 |
| 1966 | 8 | 38 | 9 | 43 | 1 | 5 | 3 | 14 | - | - | - | - | - | - | 21 |
| 1967 | 8 | 33 | 12 | 50 | 1 | 4 | 3 | 13 | - | - | - | - | - | - | 24 |
| 1968 | 8 | 47 | 5 | 29 | 1 | 6 | 3 | 18 | - | - | - | - | - | - | 17 |
| 1969 | 5 | 28 | 9 | 50 | 1 | 6 | 3 | 17 | - | - | - | - | - | - | 18 |
| 1970 | 1 | 20 | 2 | 40 | 1 | 20 | 1 | 20 | - | - | - | - | - | - | 5 |
| 1971 | 2 | 13 | 9 | 60 | 1 | 7 | 2 | 13 | 1 | 7 | - | - | - | - | 15 |
| 1972 | 4 | 45 | 2 | 22 | - | - | 3 | 33 | - | - | - | - | - | - | 9 |
| 1973 | 5 | 45 | 3 | 27 | 1 | 9 | 2 | 18 | - | - | - | - | - | - | 11 |
| 1974 | 6 | 55 | 4 | 36 | 1 | 9 | - | - | - | - | - | - | - | - | 11 |
| 1975 | 2 | 13 | 6 | 40 | 2 | 13 | 3 | 20 | 2 | 13 | - | - | - | - | 15 |
| 1976 | 3 | 14 | 8 | 36 | 4 | 18 | 3 | 14 | 3 | 14 | - | - | 1 | 5 | 22 |
| 1977 | 8 | 24 | 10 | 29 | 4 | 12 | 5 | 15 | 4 | 12 | 1 | 3 | 2 | 6 | 34 |

Source: Unpublished Data. National Marine Fisheries Service. Southeast Fisheries Center. Miami, Florida. 1965-1977

TABLE 5

Distribution of Vessels by Length
For
Gillnet Vessels, Florida West Coast

| Year | 26 - 30 # | % | 31 - 35 # | % | 36 - 40 # | % | 41 - 45 # | % | 46 - 50 # | % | 51 - 55 # | % | > 56 # | % | Total Vessel |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 15 | 21 | 31 | 43 | 18 | 25 | 7 | 10 | 1 | 1 | - | - | - | - | 72 |
| 1966 | 18 | 21 | 35 | 42 | 15 | 18 | 9 | 11 | 3 | 4 | 2 | 2 | 2 | 2 | 84 |
| 1967 | 13 | 17 | 32 | 41 | 18 | 23 | 10 | 13 | 2 | 3 | 2 | 3 | 1 | 1 | 78 |
| 1968 | 13 | 17 | 24 | 32 | 20 | 27 | 10 | 13 | 3 | 4 | 2 | 3 | 3 | 4 | 75 |
| 1969 | 11 | 18 | 18 | 29 | 17 | 27 | 8 | 13 | 4 | 6 | 1 | 2 | 3 | 5 | 62 |
| 1970 | 9 | 16 | 16 | 29 | 18 | 32 | 6 | 11 | 4 | 7 | - | - | 3 | 5 | 56 |
| 1971 | 11 | 19 | 19 | 33 | 13 | 22 | 9 | 16 | 4 | 7 | - | - | 2 | 3 | 58 |
| 1972 | 11 | 17 | 19 | 30 | 16 | 25 | 12 | 19 | 5 | 8 | - | - | - | - | 63 |
| 1973 | 7 | 10 | 19 | 28 | 19 | 28 | 14 | 21 | 8 | 12 | - | - | 1 | 1 | 68 |
| 1974 | 12 | 14 | 26 | 30 | 21 | 24 | 18 | 20 | 9 | 10 | 1 | - | 1 | 1 | 88 |
| 1975 | 15 | 15 | 25 | 26 | 27 | 28 | 20 | 21 | 9 | 9 | 1 | 1 | - | - | 97 |
| 1976 | 20 | 17 | 25 | 22 | 33 | 29 | 22 | 19 | 9 | 8 | 1 | 1 | 5 | 4 | 115 |
| 1977 | 24 | 22 | 26 | 24 | 27 | 25 | 21 | 19 | 8 | 7 | 1 | 1 | 1 | 1 | 108 |

Source: See Table 4

and greater than 40 feet. The chi-square value calculated using this distribution is 7.73 which is greater than the critical chi-square value for $\alpha = 0.01$. Thus, the null hypothesis is not rejected at this level and the data sets are not necessarily different. Similar contingency table chi-square tests were performed to evaluate the Cato et al (1978) sample as being representative of the west coast vessels (as reported by the VOUF) and the east coast-west coast vessels combined. In both situations, the null hypothesis was rejected for any reasonable confidence level. These statistical analyses provide sufficient rationale to consider the Cato et al (1978) survey as representative of only the vessels listed on the east coast VOUF.

The next step is to combine the information from these two sources into an estimated production function. The simple form for these functions was discussed previously and presented in equation (1). Based on the data from the VOUF and Cato et al (1978), this functional relationship could be estimated in two ways. For both calculations, the effort data (i.e., hours fishing) are aggregated by vessel size into two categories consistent with those specified in the above contingency table analysis.

The first method of estimating the production function is to assume that total hours fished by the entire east coast (VOUF) fleet is directly proportional to landings. That is:

$$Y = \rho \, (E_s + E_l) \qquad (2)$$

where $E_s$ is the total fishing hours for the vessels $<$40 feet and $E_l$ is the total hours fished for the vessels larger than 40 feet. $\rho$ is the calculated constant of proportionality and for this model is assumed to remain the same over time. $E_s$ and $E_l$ are calculated as follows:

$$E_s = \frac{(\text{hours fished})}{(\text{survey vessel})} \times (\#\text{ of vessels}) = (1580)(15)$$

$$E_l = \frac{(\text{hours fished})}{(\text{survey vessel})} \times (\#\text{ of vessels}) = (1957.3)(7)$$

Summing these two values and dividing it into the reported landings of king and Spanish mackerel by gillnet vessels on the east coast yields a value for the constant of proportionality ($\rho$) of 255.9 pounds per hour.

The second method does not estimate a proportionality constant per se. This method incorporates additional information from the Cato el al (1978) survey by calculating the average catch per hour and multiplying that by the hours fished per vessel. That is:

$$Y = C_s + C_l \qquad (3)$$

where $C_s$ and $C_l$ are defined as follows for vessels less than or equal to 40 feet (i.e., small vessels) and greater than 40 feet (i.e., large vessels) respectively:

$$C_s = \frac{(\text{catch})}{(\text{hour})}\left(\frac{\text{hours}}{(\text{survey vessel})}\right)(\#\text{ of small vessels})$$

$$= (200.4)(1580)(15)$$

$$C_l = \frac{(\text{catch})}{(\text{hour})}\left(\frac{\text{hours}}{(\text{survey vessel})}\right)(\#\text{ of large vessels})$$

$$= (276.8)(1957.3)(7)$$

$$\therefore Y = 8{,}542.8 \text{ thousand pounds}$$

The second method estimates landings directly as opposed to the first model which calculates the constant of proportionality from the reported landings for that year. Therefore, the Y value for the first model must be equal to the reported landings in the base year (1976) whereas the second model calculates a value for the pounds landed in the base year. It should also be pointed out that the only value that changes from year to year for either of these models is the number of vessels in the respective two size categories. The distinction between the models is that the first model assumes that the catch per hour fished is the same for large (>40 feet) and small ($\leq$40 feet) vessels (i.e., estimated by $\rho$) and the second model includes the average catch per hour value from the survey data for each of the two size categories of vessels.

Since the output of commercial fisheries is landings, it would be logical to compare the estimated landings calculated via the above production functions to the reported historical landings. The estimated landings are calculated based on the vessel distribution by size categories from the VOUF. These estimates from 1965 through 1977 are listed in the first and second columns of Table 6 for the two production function models respectively. The reported landings of king and Spanish mackerel[3/] are listed in the third column of this table and the respective differences between the estimated and actual landings are provided in the remaining two columns. From 1965 through 1971, neither model performs acceptably; however, from 1972 through 1975, the performance is considerably better. A possible explanation of the model's performance in latter years is the increased use of power equipment which permitted the use of larger nets, thus increasing the vessel's available fishing area and efficiency. Furthermore, since the Cato et al (1978) survey included vessels using this equipment, it would be logical to anticipate that the estimated production functions would overestimate landings during a time when power equipment was not being used. Thus, it is not surprising that the model performed better when the power equipment was being used relative to the earlier years when the fishermen pulled the nets by hand.

The data are too limited to utilize any statistical tests to determine whether one model is superior to the other. However, the magnitudes of the differences in the later years in Table 6 indicate that the second model may be slightly better than the first.

TABLE 6

Comparison of Estimated Landings for East Coast

Gillnet Fishery Production Functions

(Thousand Pounds)

| | Model 1 | Model 2 | Reported Annual Landings | Est - Actual Model 1 | Est - Actual Model 2 |
|---|---|---|---|---|---|
| 1965 | 6,662.3 | 5,516.4 | 3,298.6 | 3,363.8 | 2,217.9 |
| 1966 | 8,780.4 | 7,324.7 | 2,508.2 | 6,272.2 | 4,816.5 |
| 1967 | 9,993.4 | 8,274.6 | 3,353.5 | 6,639.9 | 4,921.1 |
| 1968 | 7,163.1 | 6,058.2 | 5,111.4 | 2,051.7 | 946.8 |
| 1969 | 7,567.4 | 6,374.8 | 3,682.3 | 3,885.1 | 2,692.5 |
| 1970 | 2,118.6 | 1,808.3 | 5,327.3 | -3,208.7 | -3,519.0 |
| 1971 | 6,354.5 | 5,424.9 | 3,708.0 | 2,646.5 | 1,716.9 |
| 1972 | 3,928.6 | 3,525.1 | 4,060.7 | -132.1 | -535.6 |
| 1973 | 4,640.6 | 3,933.2 | 3,773.1 | 867.5 | 160.1 |
| 1974 | 4,447.5 | 3,483.0 | 3,454.6 | 992.9 | 28.4 |
| 1975 | 6,547.6 | 5,875.2 | 5,285.9 | 1,261.7 | 589.3 |
| 1976 | 9,577.1 | 8,542.8 | 9,577.1 | - | -1,034.3 |
| 1977 | 14,905.6 | 13,467.3 | N/A | - | - |

These two methodologies were used to calculate production functions for the VOUF west coast vessels and rather unsatisfactory estimates were calculated. In fact, the second model yielded landing estimates that were several magnitudes removed from the reported landings and they are not reported in Table 7. The estimated landings for the proportionality model are provided in Table 7 and these results are also poor representations of the reported landing data. A qualification regarding these simple production function models and the resulting estimates should be discussed prior to the hook & line analysis. The distribution between king and Spanish mackerel landings appears to be somewhat different for the Cato et al (1978) survey relative to the NMFS landing data by gear type. The Cato et al (1978) survey found that only one percent of the catch by weight was king mackerel and the NMFS data estimated that 19.2 percent of gillnet landings were king mackerel in 1976. However, when the landings reported in the Cato et al (1978) survey for both species are combined and expanded to the 22 vessel population reported in the VOUF, a reasonably close estimate of the NMFS reported landings results. That is, 9,569,100 pounds of king and Spanish mackerel were reported (this includes the 14 percent adjustment for small gillnet boats) and the expanded estimate is 9,443,500 pounds. This large dissimilarity in the relative proportions of king and Spanish landings could significantly affect the estimation of vessel (or industry) revenue because king mackerel have a higher dockside value than Spanish mackerel.

## Hook & Line Equipped Vessels

Similar to the preceding section on gillnet equipped vessels, this section attempts to combine the survey data from Morris et al (1977) with the data available on the NMFS vessel operating units files. The general outline for the analysis of hook & line vessels follows the development of the fishery production function for gillnet vessels. The initial step is to provide a description of the hook & line fisheries on the east and west coasts of Florida. Similar to the gillnet fisheries, there is a vessel identification difficulty for hook & line vessels. NMFS identifies vessels by two gear codes that are quite similar. Vessels coded 660 are hook & line vessels or trolling vessels (as they are referred to in the Fishery Statistics of the U.S.) and vessels coded as 610 are referred to as handline vessels. The distinction between vessels using these two different types of gear is that vessels that are trolling are moving and those using handlines are not moving (at least not under their own power). Needless to say, this could create fairly significant problems in reporting since the reporting is done on shore and the vessel is rarely observed while fishing.

Another distinction, and the most important one for purposes of this analysis, is that different species are caught by the different gear types. The troll (hook & line) fisheries target pelagic species, such as mackerels, bluefish, dolphin, etc., and handline gear is used for demersal species, such as snapper, grouper, etc. This distinction is the rationale for including only vessels identified as 660 coded vessels in this analysis; however, this rationale does not really overcome a potential difficulty with misidentification. Furthermore, a handline vessel could predominately fish for

TABLE 7

Comparison of Estimated Landing for West Coast

Gillnet Fishery Production Functions

(Thousand Pounds)

| | Model 1 | Reported Annual Landings | Est - Actual Model 1 |
|---|---|---|---|
| 1965 | 5,360.1 | 5,596.7 | -236.6 |
| 1966 | 6,368.9 | 8,183.5 | -1,814.6 |
| 1967 | 5,916.5 | 7,003.4 | -1,086.9 |
| 1968 | 5,750.9 | 8,527.8 | -2,776.9 |
| 1969 | 4,773.5 | 9,292.9 | -4,519.4 |
| 1970 | 4,286.4 | 8,272.5 | -3,986.1 |
| 1971 | 4,466.0 | 7,945.2 | -3,479.2 |
| 1972 | 4,863.3 | 5,502. 6 | -639.3 |
| 1973 | 5,329.8 | 7,117.4 | -1,787.6 |
| 1974 | 6,884.2 | 12,081.1 | -5,196.9 |
| 1975 | 7,554.2 | 6,423.3 | 1,130.9 |
| 1976 | 8,974.7 | 8,974.7 | - |
| 1977 | 8,369.2 | NA | - |

demersal species and only fish for pelagics part-time because the vessel adaptations necessary for this gear transfer are easy which also adds to the problem of accurate vessel identification. The FMP describes the east coast hook & line fishery as primarily targeting king mackerel; whereas, the fishery has a more diversified catch in the Florida keys. The survey by Morris et al (1977) reports that 71 percent of the catch by weight for the interviewed vessels along the east coast were king mackerel in 1976. The NMFS landing data by gear type for 1976 indicates that 78 percent of the reported east coast catch by hook & line vessels were king mackerel.

The geographical distribution of vessels using hook & line gear as described in the FMP is in two main fishing areas. They are: (1) the east coast of Florida from Port Salerno to Cape Canaveral (including the Fort Pierce area) and (2) the Florida keys. The Centaur Associates (1981) report provides an estimate of 83 percent of the fleet around the West Palm Beach area with some vessels in the Florida keys and the panhandle area of northern Florida. The mackerel workshop report edited by Austin et al (1978) provides the following estimates on the number of hook & line vessels in the respective areas, for the 1976-77 season, (summarized from Table 1, p.18 and Table 1, p.38):

| | East Coast | West Coast |
|---|---|---|
| king mackerel | 267 | 48 |
| Spanish mackerel | - | - |
| Total | 267 | 48 |

The vessel operating units files (NMFS) lists 30 vessels identified as hook & line vessels on the east coast and 70 vessels on the west coast for 1977 (exclusive of duplication). A viable rationalization of such usage differences is difficult to make; however, the VOUF data are used in the subsequent analysis (per reasons discussed in the gillnet analysis).

As with gillnet vessels, the operating units files provide historical data on the physical characteristics of the hook & line vessels comprising these fisheries. The average values for several of the important characteristics for 1965 through 1977 are presented in Tables 8 and 9 for vessels on the east coast and west coast of Florida, respectively. A comparison of certain vessel characteristics between the survey results from Morris et al (1977), NMFS operating units files, and the Centaur Associates (1981) report are presented in the three columns respectively of Table 10. The average length of the vessels for the Morris et al (1977) report and the NMFS data are reasonably close. As with the gillnet vessel analysis, this parameter is used to test the representativeness of the Morris et al (1977) sample survey with respect to the VOUF data. The distributions of the number of hook & line vessels by five foot size categories are presented in Tables 11 and 12 for the east coast and west coast data respectively.

TABLE 8

Description of Hook & Line Vessels (660)

Florida East Coast

(1965 - 1977)

| Year | Total Vessels | Average Length | Average Tonnage | No.Crew/ Vessel | Construction FG | ST | WD | Average HP | Fuel Type Gas | Die |
|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 19 | 34.4 | 13.6 | 2.2 | - | - | - | 184.8 | 47 | 53 |
| 1966 | 26 | 34.5 | 13.0 | 2.1 | - | - | - | 154.2 | 42 | 58 |
| 1967 | 20 | 33.9 | 12.9 | 2.1 | - | - | - | 165.9 | 45 | 55 |
| 1968 | 19 | 32.0 | 12.0 | 2.2 | 5 | - | 95 | 193.8 | 32 | 68 |
| 1969 | 12 | 31.3 | 9.3 | 2.3 | 8 | - | 92 | 180.5 | 25 | 75 |
| 1970 | 10 | 33.1 | 10.8 | 2.1 | 10 | - | 90 | 169.6 | 30 | 70 |
| 1971 | 12 | 32.6 | 11.3 | 2.0 | 42 | - | 58 | 202.8 | 25 | 75 |
| 1972 | 25 | 32.6 | 13.3 | 1.6 | 56 | - | 44 | 222.7 | 25 | 75 |
| 1973 | 29 | 34.8 | 16.1 | 1.6 | 55 | - | 45 | 212.5 | 10 | 90 |
| 1974 | 31 | 34.6 | 15.8 | 1.5 | 52 | - | 48 | 213.6 | 13 | 87 |
| 1975 | 25 | 33.6 | 14.1 | 1.3 | 48 | - | 52 | 219.7 | 4 | 96 |
| 1976 | 28 | 33.9 | 13.8 | 1.4 | 61 | 4 | 35 | 239.6 | 7 | 93 |
| 1977 | 30 | 34.9 | 16.4 | 1.6 | 67 | - | 33 | 247.1 | 3 | 97 |

Source: Unpublished Data. National Marine Fisheries Service. Southeast Fisheries Center. Miami, Florida. 1965-1977

TABLE 9

Description of Hook & Line Vessels (660)

Florida West Coast

(1965 - 1977)

| Year | Total Vessels | Average Length | Average Tonnage | No. Crew/ Vessel | Construction FG | ST | WD | Average HP | Fuel Type Gas | Die |
|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 36 | 36.8 | 12.5 | 2.1 | - | - | - | 154.8 | 33 | 67 |
| 1966 | 41 | 34.3 | 14.2 | 2.0 | - | - | - | 176.1 | 15 | 85 |
| 1967 | 39 | 36.8 | 15.7 | 2.0 | - | - | - | 182.4 | 15 | 85 |
| 1968 | 33 | 35.8 | 17.1 | 2.1 | - | - | 100 | 188.6 | 3 | 97 |
| 1969 | 19 | 38.8 | 23.1 | 2.3 | - | - | 100 | 259.6 | 11 | 89 |
| 1970 | 32 | 46.1 | 33.4 | 2.7 | - | - | 100 | 441.3 | 3 | 97 |
| 1971 | 44 | 42.9 | 27.4 | 2.6 | 11 | - | 89 | 374.6 | 9 | 90 |
| 1972 | 44 | 43.0 | 26.7 | 2.4 | 16 | - | 84 | 392.9 | 14 | 86 |
| 1973 | 41 | 40.1 | 26.9 | 2.4 | 17 | - | 83 | 399.9 | 15 | 86 |
| 1974 | 49 | 38.4 | 25.6 | 2.3 | 14 | - | 86 | 356.4 | 20 | 80 |
| 1975 | 46 | 41.9 | 26.8 | 2.4 | 15 | - | 85 | 374.1 | 20 | 80 |
| 1976 | 64 | 41.3 | 25.6 | 2.1 | 27 | - | 73 | 389.4 | 17 | 83 |
| 1977 | 70 | 38.9 | 22.5 | 2.2 | 31 | - | 69 | 360.3 | 14 | 86 |

Source: See Table 8.

TABLE 10

Comparison of Vessel Characteristics

| | Morris et al[1] | NMFS[2] | Centaur[3] |
|---|---|---|---|
| Vessel Length | 29.9 | 33.9 | 28 |
| Hull Const. | | | |
| % Wood | 20 | 35 | - |
| % Fiberglass | 80 | 61 | - |
| % Steel | - | 4 | - |
| Net Tonnage | 2 | 10.0 | 1 - 2 |
| Horsepower | 264 | 240 | 239 |
| Fuel Type | | | |
| % Gas | 50 | 7 | - |
| % Diesel | 50 | 93 | - |
| No. Crew | .6 | .4 | .3 |

1. Based on a survey of 10 king mackerel hook & line vessel captains on the east coast of Florida. Data are for operations during 1976. The range in vessel length is 24 to 36 feet.

2. Data are from the vessel operating units files, SEFC, NMFS. During 1976 there were 28 documented (with the U.S. Coast Guard) vessels reported as trolling vessels (gear code 660). The range in vessel hull length is 26 to 46 feet.

3. Centaur Associates (1981). These data are for 1979 and are based on a survey of vessel captains.

TABLE 11

Distribution of Vessels by Length

For

Hook & Line Vessels - Florida East Coast

| Year | 26 - 30 # | % | 31 - 35 # | % | 36 - 40 # | % | 41 - 45 # | % | 46 - 50 # | % | 51 - 55 # | % | > 56 # | % | Total Vessel |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 6 | 32 | 5 | 26 | 6 | 32 | 1 | 5 | - | - | 1 | 5 | - | - | 19 |
| 1966 | 9 | 36 | 6 | 24 | 7 | 28 | 3 | 12 | - | - | 1 | 4 | - | - | 25 |
| 1967 | 9 | 45 | 4 | 20 | 4 | 20 | 2 | 10 | - | - | 1 | 5 | - | - | 20 |
| 1968 | 9 | 47 | 4 | 21 | 3 | 16 | 2 | 11 | - | - | 1 | 5 | - | - | 19 |
| 1969 | 8 | 67 | 3 | 25 | 1 | 8 | - | - | - | - | - | - | - | - | 12 |
| 1970 | 4 | 40 | 3 | 30 | 3 | 30 | - | - | - | - | - | - | - | - | 10 |
| 1971 | 4 | 33 | 5 | 42 | 3 | 25 | - | - | - | - | - | - | - | - | 12 |
| 1972 | 9 | 36 | 11 | 44 | 3 | 12 | 1 | 4 | 1 | 4 | - | - | - | - | 25 |
| 1973 | 10 | 34 | 13 | 45 | 2 | 7 | 1 | 3 | 1 | 3 | - | - | 2 | 7 | 29 |
| 1974 | 11 | 35 | 14 | 45 | 2 | 6 | 1 | 3 | 1 | 3 | - | - | 2 | 6 | 31 |
| 1975 | 10 | 36 | 12 | 43 | 2 | 7 | 3 | 11 | 1 | 4 | - | - | - | - | 28 |
| 1976 | 10 | 36 | 8 | 29 | 6 | 21 | 3 | 11 | 1 | 4 | - | - | - | - | 28 |
| 1977 | 12 | 40 | 7 | 23 | 4 | 13 | 3 | 10 | 2 | 7 | 2 | 7 | - | - | 30 |

Source: Unpublished Data. National Marine Fisheries Service. Southeast Fisheries Center. Miami, Florida. 1965-1977

TABLE 12

Distribution of Vessels by Length

For

Hook & Line Vessels - Florida West Coast

| Year | 26 - 30 # | % | 31 - 35 # | % | 36 - 40 # | % | 41 - 45 # | % | 46 - 50 # | % | 51 - 55 # | % | > 56 # | % | Total Vessel |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 4 | 8 | 14 | 28 | 25 | 50 | 2 | 4 | 3 | 6 | - | - | 2 | 4 | 50 |
| 1966 | 6 | 15 | 19 | 46 | 10 | 24 | 2 | 5 | 3 | 7 | - | - | 1 | 2 | 41 |
| 1967 | 5 | 13 | 17 | 44 | 8 | 21 | 3 | 8 | 3 | 8 | - | - | 3 | 8 | 39 |
| 1968 | 4 | 12 | 13 | 39 | 9 | 27 | 3 | 9 | 2 | 6 | - | - | 2 | 6 | 33 |
| 1969 | 1 | 5 | 8 | 42 | 6 | 32 | 1 | 5 | - | - | - | - | 3 | 16 | 19 |
| 1970 | 1 | 3 | 8 | 25 | 7 | 22 | 3 | 9 | 2 | 6 | 1 | 3 | 10 | 31 | 32 |
| 1971 | 6 | 14 | 5 | 11 | 15 | 34 | 6 | 14 | 2 | 5 | 1 | 2 | 9 | 20 | 44 |
| 1972 | 5 | 11 | 8 | 18 | 14 | 32 | 7 | 16 | 2 | 5 | 1 | 2 | 7 | 16 | 44 |
| 1973 | 4 | 8 | 8 | 16 | 21 | 43 | 6 | 12 | 3 | 6 | 1 | 2 | 6 | 12 | 49 |
| 1974 | 6 | 13 | 13 | 27 | 13 | 27 | 4 | 8 | 3 | 6 | 1 | 2 | 8 | 17 | 48 |
| 1975 | 6 | 13 | 12 | 26 | 12 | 26 | 4 | 9 | 3 | 7 | 1 | 2 | 8 | 17 | 46 |
| 1976 | 13 | 20 | 12 | 19 | 15 | 23 | 8 | 13 | 2 | 3 | 4 | 6 | 10 | 16 | 64 |
| 1977 | 16 | 23 | 18 | 26 | 17 | 24 | 6 | 9 | 3 | 4 | 3 | 4 | 7 | 10 | 70 |

Source: See Table 11

Contingency table chi-square analyses were performed to test the hypothesis that the Morris et al (1977) sample and the NMFS east coast vessel registration data for 1976 are from the same data set. The distribution by vessel size of the Morris et al (1977) survey data indicates that a disaggregation into two size categories is appropriate. The size categories are less than or equal to 30 feet and greater than 30 feet. The chi-square value from this 2x2 contingency table was 1.783 which is greater than the critical chi-square value for $\alpha = 0.25$ but less than the value for $\alpha = 0.10$. Combining the data for the east and west coasts and testing the same null hypothesis, the chi-square value for this contingency table analysis was 5.43. This value is greater than the critical chi-square value for $\alpha = 0.025$ and it is therefore considered reasonable not to reject the null hypothesis for the east and west coasts combined.

The fishery production function for the hook & line fisheries is estimated using the same methodology that was used to estimate the gillnet vessels' production functions. The above contingency table analysis indicated that a two size category aggregation is appropriate. Furthermore, the contingency table analyses indicate that some questions regarding the separation of the east and west coast vessels into distinct fisheries may exist. Production function models for vessels on the east coast of Florida did not yield results that were considered reasonable. These models consistently underestimated landings relative to those reported by the NMFS. The two models were estimated using the combined east and west coast vessel populations with slightly more encouraging results.

In the first model, the catch per hours fished is assumed to remain the same for the two size categories and the constant of proportionality ($\rho$) was calculated to be 24.34 pounds per hour (equation 2). Using this constant value and the distribution of vessels by size for both Florida coasts, the estimated landings for 1965 through 1977 were calculated and are presented in column one of Table 13. The estimated landings calculated by the second model (equation 3) in which the average catch per hour for the two vessel size categories has been included are listed in column two. In the third column, the NMFS reported landings for the east and west coasts of Florida for hook & line gear are listed and the respective differences between the estimated and the actual landings are provided in the fourth and fifth columns. As with the estimated landings by the gillnet production functions, rigorous statistical tests were not performed to evaluate the superiority of one model versus the other. However, causal observations indicate that the second model may be slightly better than the first one.

In summary, this section has developed economic production functions which relate an input factor, fishing effort, to the vessels' output, landings. The lack of historical data on fishing effort and associated catch have restricted the analysis to the calculation of a simple arithmetic relationship between effort, measured in hours fished per vessel, and landings for 1976. This arithmetic relationship was combined with the distribution by vessel size provided by NMFS historical data and landings were estimated from 1965 through 1977 (Tables 6, 7 and 13 present these estimates). In the development of these fishery production functions, the statistical representativeness of two sample surveys conducted on the east coast gillnet and hook & line fisheries were analyzed with

TABLE 13

Comparison of Estimated Landing for East and West Coast

Hook & Line Fishery Production Functions

(Thousand Pounds)

| | Model 1 | Model 2 | Reported Annual Landings | Est - Actual Model 1 | Est - Actual Model 2 |
|---|---|---|---|---|---|
| 1965 | 3,797.6 | 3,260.5 | 2,443.4 | 1,354.2 | 817.1 |
| 1966 | 3,613.0 | 3,042.0 | 1,864.0 | 1,749.0 | 1,178.0 |
| 1967 | 3,170.5 | 2,660.2 | 1,778.1 | 1,392.4 | 882.1 |
| 1968 | 2,785.0 | 2,329.1 | 1,772.6 | 1,012.4 | 556.5 |
| 1969 | 1,642.7 | 1,359.2 | 2,110.3 | -467.6 | -751.1 |
| 1970 | 2,326.9 | 2,060.8 | 2,649.4 | -322.5 | -588.6 |
| 1971 | 3,112.6 | 2,602.1 | 1,978.7 | 1,133.9 | 623.4 |
| 1972 | 3,741.3 | 3,166.8 | 3,000.2 | 741.1 | 166.6 |
| 1973 | 4,255.0 | 3,622.6 | 3,176.4 | 1,078.6 | 466.2 |
| 1974 | 4,269.8 | 3,602.9 | 4,517.4 | -247.6 | -914.5 |
| 1975 | 3,998.5 | 3,373.1 | 4,353.8 | -355.3 | -980.7 |
| 1976 | 4,927.5 | 4,120.8 | 4,927.5 | - | -806.7 |
| 1977 | 5,313.6 | 4,408.7 | N/A | - | - |

respect to existing NMFS data. The indications of these statistical analyses based on vessel size as the analyzed parameter are that the Cato et al (1978) sample of Spanish mackerel large gillnet vessels is adequately representative of NMFS vessel registration data and the Morris et al (1977) sample of hook & line vessels is less adequate. However, when the sample from Morris et al (1977) was compared to the entire distribution of hook & line vessels on both the east and west coasts, the statistical results were much more acceptable. These statistical analyses will be the basis for the next section that attempts to use the existing data to develop cost functions for these fisheries.

## Industry (Fishery) Cost Functions

The development of fishery production functions in the preceding section was not very successful largely due to the lack of historical data on fishing effort. Unfortunately the estimation of a total cost curve (or function) will suffer from lack of the same data. It will be recalled that the classical Schaefer-Gordon model plots dollars on the Y-axis and effort (standardized) on the X-axis. Thus, a fishing industry's costs must be described as a function of the amount of fishing effort expended in catching the fish and therefore, producing revenue. This section reviews the existing data and attempts to develop cost functions for the gillnet and hook & line vessels fishing on the east and west coasts of Florida.

Total costs of a fishing industry, as with any industry, are comprised of fixed costs and variable costs. Fixed costs are defined as those costs that do not change in the short run with a change in input factors. Variable costs logically are the costs which do change as factor inputs are changed; thus, for fishing industries variable costs are a function of the amounts of fishing effort and the total cost function can be written as:

$$TC = FC + VC = FC + f(E) \qquad (4)$$

where FC and VC are fixed and variable costs respectively and E is fishing effort. For the gillnet and hook & line fisheries, effort has been defined as hours fished per vessel. Furthermore, since the survey cost data (Cato et al, 1978 and Morris et al, 1977) have to be expanded to represent the entire gillnet and hook & line vessels, the costs need to be expressed on a per vessel basis. Therefore, equation (4) could be written as:

$$\frac{TC}{\text{vessel}} = \frac{FC}{\text{vessel}} + \left(\frac{VC}{\text{hours fished}}\right)\left(\frac{\text{hours fished}}{\text{vessel}}\right) \qquad (5)$$

Data on fishing time per vessle are unavailable historically and the simplifying assumption has to be made that this relationship remains the same both historically and in the future.[4/] With this assumption, the hours fished can be cancelled in the denominator and numerator and the cost function reduces to:

$$\frac{TC}{\text{Vessel}} = \frac{FC}{\text{Vessel}} + \frac{VC}{\text{Vessel}} \qquad (6)$$

This implies that the total cost curve is only dependent upon changes in the size composition of the vessels comprising these two fisheries. Using this highly simplified functionsl relationship, the cost functions for the gillnet and hook & line fisheries respectively are:

$$TC = (50{,}795)(\#\ \text{vessels} \leq 40) + (102{,}832)(\#\ \text{vessels} > 40)$$

and

$$TC = (9485.6)\ (\#\ \text{vessels} \leq 30) + (11997)(\#\ \text{vessels} > 30).$$

These results are disappointing from an analytical perspective because they do not include parameters that could measure changes in vessel efficiencies over time. Furthermore, this specification (equation 6) does not provide the analyst with a method for evaluating the effects that proposed managment regulations would have on the costs of operating gillnet or hook & line vessels. Thus, the usefulness of this model, that is due to a complete lack of data on fishing effort, is highly questionable from a fishery management perspective.

## Price Analysis

The analysis of dockside prices is an important aspect in understanding the economics associated with fishing industries. This section uses historical price and landings data to estimate the statistical relationship between these two parameters. From a management perspective, an estimate of this relationship is important because most regulations affect the amount of landings and therefore, with an estimate of the price-quantity relationship, estimates of the indirect effect on prices can be made. The numerical estimate of the percentage change in prices given a one percent change in landings is called the price flexibility. Estimating the price flexibilities for king and Spanish mackerel is one of the main purposes of this section which is accomplished using linear regression techniques.

There are two references, Prochaska, 1978 and Poffenberger, 1979, that have analyzed the dockside prices of these two species. Prochaska (1978) focused entirely on king mackerel landed on the east coast of Florida. Poffenberger (1979) extended this analysis in the following ways; by including more recent data (1976 and 1977) for the king mackerel analysis, by analyzing Spanish mackerel prices and landings on both the east and west coast, and by analyzing king mackerel prices and landings on the west coast. The regression analyses presented in this report (provided in the Appendix) extend the price analysis done in Poffenberger (1979) in two ways. First, the data for this analysis include monthly dockside prices and landings for 1978. Second, this report includes regression analyses of annual prices and quantities landed for king and Spanish mackerel on the east and west coasts. Since essentially separate analyses were performed for each of the four species and area combinations, the results of these analyses are discussed separately.

Spanish mackerel - west coast

The relationship between price and quantity landed for Spanish mackerel reported on the west coast was statistically significant only if the quantity variable was lagged one month and monthly data for the fishing season were used (Poffenberger, 1979). Furthermore, the price flexibility estimate was low so that a one percent change in landings would cause only a .02 percent change in the dockside price. Including monthly data from 1978 produced results which were very similar. Equation (6-7) includes a dummy variable to simulate the on and off seasons with almost identical results to those reported in Poffenberger (1979) except that the calculated t-value of the lagged landings variable decreased.[5] This indicates that less confidence exists for the statistical relationship between Spanish mackerel prices and landings on the west coast. These regression results do indicate the Spanish mackerel prices on the east coast and west coast king mackerel prices lagged a month are the influential factors in determining the west coast Spanish mackerel prices.[6]

The results of the regression analysis using annual data also indicate that no definite statistical relationships exist between price and landings for Spanish mackerel. However, in equation (2-5), the quantity landed variable (QSW) does have a reasonably high t-value and the sign of the coefficient is correct. The magnitude of the estimated price flexibility is low (.06) and the influence of east coast Spanish mackerel prices and per capita personal income appear to be more influential. Furthermore, per capita personal income is included in the regression equation as a demand shifter that attempts to account for the shifting out of the demand curve over time. The statistical significance of this variable makes a clear interpretation regarding the "direct" influence which changes in per capita personal income would have on dockside Spanish mackerel prices difficult.

King mackerel - west coast

A reasonable statistical relationship appears to exist between price and quantity of landings lagged one month for king mackerel landed on the west coast of Florida. The results in equation (5-5) also show that dockside prices are influenced by the previous monthly price and king mackerel prices from the previous year. The estimated value for the price flexibility is .02 which indicates that prices are fairly insensitive to changes in king mackerel landings. An additional result of these regression analyses is that king mackerel prices on the west coast are not influenced by either dockside prices on the east coast or wholesale prices as reported by the Fulton Fish Market in New York.

The regression results using annual data (equation 1-4) indicate that there are reasonably significant relationships between prices and quantity landed if per capita personal income is not included. The estimated coefficient of the quantity variable (i.e., the price flexibility estimate) is -.10 and it also has the correct sign. This relationship is somewhat suspect as being representative of the actual market relationship between price and quantity because of the influence of the personal income variable or deflating the variables with the consumer price index. Comparing equations (1-3), (1-4) and (1-5) indicates that the reduction in the t-value of the quantity variable when either of these adjustment variables are included. The reaction of the quantity landed variable when these trend variables are included, indicates that the statistical relationship demonstrated in equation (1-4) is due mostly to the trends of these two data series (price and quantity landed) over time and not to actual market relationships.

Spanish mackerel - east coast

As with the analysis of the west coast landings, Spanish mackerel prices on the east coast show a weak but acceptable statistical relationship with monthly landings. Equation (8-3) also indicates that east coast prices are correlated with west coast Spanish mackerel prices, as well as east coast prices lagged one month. These results are complementary to those for the west coast model that also indicate the interactions of these species in a common market.

Using annual data, the regression analysis also shows a weak statistical relation between price and landings. This relationship is reduced if prices are deflated by the consumer price index that implies the statistical relation in eqution (4-1) was to some extent caused by similar trends in the annual data rather than a market relationship.

King mackerel - east coast

King mackerel prices and landings demonstrate the strongest statistical relationship of any of these fisheries. Equation (7-3) is essentially the same model estimated in Poffenberger (1979) and similar analytical results are estimated when 1978 monthly data are included. This equation also shows the strong influence of prices at the Fulton Fish Market in New York, as well as the influence of king mackerel prices lagged a year.

The regression equations estimated using annual data provide somewhat confusing results. Several of the equations demonstrate a strong relationship between the east coast and west coast prices. This relationship did not occur in the king mackerel west coast analysis which could indicate that the west coast prices influence east coast prices, but not vice-a-versa. This is counterintuitive because the landings of king mackerel are greater on the east and the dockside prices are also higher. Thus, it would be more realistic for the east coast fishery to be the cause and not the effect in these markets. Another problem in these estimated results is the sign of the quantity landed variable. In every equation that includes this variable, the sign is incorrect.

The results of analyzing the dockside price and landings relationships for these two species of mackerel and the two geographical locations can be summarized as follows:

- except for king mackerel landed on the east coast, landings must be lagged one month before a statistical relationship exists;

- the estimated magnitude of this price - landings (lagged one month) relationship is low - about .02 to .06 - which implies that prices are very inelastic with respect to changes in landings;

- the relationship between price and landings for king mackerel landed on the east coast of Florida is statistically acceptable and the estimated price flexibility is -.10. Dockside prices are also highly influenced by prices at the New York wholesale fish markets; and

- annual prices are more highly influenced by other mackerel prices and a trend variable or demand shifter, such as per capita personal income, than landings.

These results, although useful in themselves, can be combined in a more general systems approach that incorporates the interaction between these species at various market levels. The potential for combining these various analyses is discussed in the next section.

## Synthesis of Analyses

The purpose of this section is to synthesize the analyses that were presented and discussed in the previous sections. Conceptually, the best way to consider this synthesis is in the framework of the Schaefer-Gordon Model (Gordon (1954)). This model displays the industry's total revenue function as a dome-shaped curve that results from multiplying a constant price per pound times the yield curve of the Shaefer model. The total cost curve is plotted on the same graph and can be compared directly to the total revenue curve. The difference between these curves is the net economic yield. The most advantageous location on the effort axis (the x-axis) is the point where this difference is maximized (or the maximum economic yield) and occurs where the slopes of the curves are equal. The reason this is referred to as economic yield is that the cost curve is assumed to include estimates of the opportunity costs of fishing. Thus, this cost curve is somewhat different than the accounting definition that measures actual tangible costs. For purpose of this discussion, it is assumed that economic costs and accounting costs are the same which implies that maximizing economic yield is the same as maximizing net revenue.

With these preliminary qualifications, the following is the accounting identify for net revenue:

$$NR = GR - TC \qquad (7)$$

where GR is gross revenue and TC is total cost. Gross revenue is the price of the product times the total amount of output sold. That is:

$$GR = P \cdot Y \qquad (8)$$

Therefore, all the equations in this simplified model have been specified. They are; price (P) is a function of landings (or yield) and other prices, yield (Y) is a function of the amount of fishing effort or the fishery production function and total cost is the sum of fixed and variable costs per equation (4). The problem now becomes one of "fitting" the equations together.

Beginning with the fishery production functions, two functional relationships have been formulated. They are one for the east coast large gillnet vessels and the second for the east and west coast hook & line vessels. The contingency table chi-square analysis indicated that the two data sets should not be used in formulating production functions for either the west coast gillnet equipped vessels or the hook & line vessels registered on the east or west coasts separately. Since the same two data sets were used to formulate the cost functions, the same limitations apply to those functions as do the production functions. Consequently, an industry production function (i.e., the hook & line and gillnet fisheries combined to provide total yield) cannot be formulated because both production functions for the two fisheries cannot be established for the same geographical area (or areas).

A possible alternative would be to specify the two fisheries separately and essentially have two separate systems of equations. The difficulty with this possibility is that the price equations are estimated using total king or Spanish mackerel landings for the two geographical areas and not landings and prices by the specific type of gear. Thus, even with this simplifying assumption a reasonable synthesis cannot be achieved.

A final possibility is to assume that the respective prices for the two species in both geographical locations are completely insensitive to changes in landings (i.e., the fishermen and the industry are price takers). This is the same assumption that is made in the Schaefer-Gordon model regarding constant prices. In this situation, net revenue can be estimated as the difference between the gross revenue equation and the total cost specification. However, this simply reduces to the net revenue per vessel for the large and small size categories for gillnet and hook & line vessels respectively.

## Conclusions and Recommendations

The previous section summarized this report and attempted to synthesize the analyses into a useful tool that could assist in the determination of appropriate management regulations. The conclusion one has to draw based on the foregone discussions is that the available data cannot provide an adequate foundation on which economic analyses of the mackerel fisheries can be performed. This conclusion may appear quite obvious to anyone fimiliar with the migratory coastal pelagics FMP because of the relative lack of biological data. In an attempt to provide the needed biological data, the Councils have identified reporting requirements that are to be implemented by the NMFS as part of the FMP. Unfortunately, these requirements do not include any data that would assist in the economic analysis of these fisheries. Therefore, the remainder of this section provides recommendations on the type of data that are essential to adequate economic analyses of this management unit.

Three broad categories of data need to be acquired in order to adequately analyze these commercial fisheries. First, data providing a good inventory of the number and size of vessels and the type of gear they use should be collected. As discussed in the section on production functions, considerable dissimilarities on the number of vessels identified as gillnet or hook & line vessels exist between the three data sources used in that section. As a first step, a data collection effort must require more well-defined descriptions of the vessels. For example, gillnet vessels with power assisted equipment should be identified. Also, information on the smaller gillnet boats (less than five net tons) should be collected. For hook & line vessels, a clearer distinction between 610 and 660 coded vessels should be made. These data should be provided so that comparisons can be made between the type of gear and the amounts (or size) of gear. This is important in determining the relative efficiencies between vessels or groups of vessels.

Second, data on "some" measure of fishing effort must be collected. This is the primary reason that such disappointing analyses resulted from the foregone data synthesis. Certainly the more detailed and specific the effort data are, the more revealing the analyses will be. However, as a minimum, routine data should be collected on the amount of fishing time and amount of gear used during that fishing time. From an economic perspective, it would be helpful if estimates of the time travelling to and from fishing areas were available. That is, a description of the fishing patterns and the mobility of the vessels in following these migratory species is important.

These two categories of data should be collected for a management related reason as well. The FMP prescribes a quota on both king and Spanish mackerel as the regulatory means of conserving the stocks of these species. The prognosis of this management technique is gloomy based on fishery economic theory and past experience (see Crutchfield and Zellner, 1962). Theory suggests that a restriction on the amount of catch available to commercial fisheries could lead to a problem of economic overfishing. The rationale for this theoretical projection is fairly straightforward. In an open access fishery with no restrictions on fishing effort there will likely be an expansion of effort by investment in larger, faster vessels so that the participants can catch as much of the quota as quickly as possible. This, of course, implies that the same amount of fish will be caught, but it will cost the fishermen on the average more money to catch them. For this reason, the type of data described in the previous two paragraphs should be collected so that adequate monitoring for the potential situation of economic overfishing could be provided.

The third category of data is information on the amount and kinds of species which these vessels catch and land. As mentioned previously, these vessels target multiple species which include species in other important management units (most notably spiny lobster and swordfish).7/ This multi-purpose characteristic makes an economic analysis of these vessels both more intricate and data demanding.

In conclusion, this report clearly demonstrates the extremely limited economic analyses that can be performed with the data that are currently available or routinely collected. The lack of data for estimating biological parameters has been identified by the Councils in sections of the FMP. It is essential that concomitant economic data also be collected so that management strategies can be employed which are effective economically as well as biologically.

## Footnotes

1/ Since the NMFS does not collect data on the type of power equipment on a vessel, all vessels in the VOUF are assumed to have power roller rigs. This assumption is based mainly on the size of the vessels reported in the VOUF.

2/ This does not imply that the VOUF data are totally accurate and represent a census of these vessels. These dissimilarities do raise some questions and warrant further investigation.

3/ Spanish mackerel landings are reduced by 14 percent per the previous discussion regarding the estimated catch by small gillnet boats.

4/ This was the same assumption required to estimate the fishery production functions.

5/ The equation numbers in this section refer to the regression equations provided in the Appendix.

6/ The regression models presented in this report include only simple lagged specification. More complex lagged models, such as the Almon distributed lag, could not be used because of software limitations.

7/ See Centaur Associates (1981) Section 5.0 for a current description of these vessels' operating characteristics.

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APPENDIX

This appendix provides the regression results which statistically compared the price of king or Spanish mackerel to various independent variables, such as quantity landed, other mackerel prices and per capita personal income. These results are presented in the following way. All results of the regressions using annual data are presented first. The respective results for each species by geographical loction (east or west coast) are then presented separately. The outline is:

Annual model:

king mackerel - west coast

Spanish mackerel - west coast

king mackerel - east coast

Spanish mackerel - east coast

The second section presents the regression results using monthly data in the same general outline.

Two specifications were used for the estimated regression equations. A linear model which specified prices as a strictly linear function of the independent variables is one specification. The second is a log-linear form which is written as follows:

$$P = AX^{\alpha}Y^{\beta}$$

where P is price, X and Y are the independent variables, $\alpha$ and $\beta$ are the estimated coefficients (i.e., the estimates of the price flexibility for the quantity landed variable) and A is the intercept. The actual form of the equation for estimation purposes is:

$$\ln(P) = \ln(A) + \alpha\ln(x) + \beta\ln(Y)$$

where ln(P) is the natural logarithm of prices, etc. The results presented in the remainder of this appendix are reported in a linear equation; however, those results labelled log-linear have the above specification.

The price and landings data for these regressions are published data either in the Fishery Statistics of the U. S. or the landings statistics by state for annual and monthly data respectively. The per capita personal income and the consumer price index are from Working Data provided by the U. S. Department of Agriculture.

The following is a list of the labels and a description of the variables included in these regression equations:

PKW = price of king mackerel landed on the west coast;

QKW = quantity of king mackerel landed on the west coast;

PSW = price of Spanish mackerel landed on west coast;

QSW = quantity of Spanish mackerel landed on west coast;

PKE = price of king mackerel landed on east coast;

QKE = quantity of king mackerel landed on east coast;

PSE = price of Spanish mackerel landed on east coast;

QSE = quantity of Spanish mackerel landed on east coast;

QKW(-1) = quantity of king mackerel landed on west coast lagged one month;

PKW(-1) = price of king mackerel landed on west coast lagged one month;

PKW(-12) = king mackerel west coast prices lagged one year;

QSW(-1) = quantity of Spanish mackerel landed on west coast lagged one month;

PSW(-1) = price of Spanish mackerel landed on west coast lagged one month;

PKE(-12) = price of king mackerel landed on east coast lagged twelve months;

PSE(-1) = price of Spanish mackerel landed on east coast lagged one month;

PNK = price of king mackerel received at Fulton Fish Market in New York; and

PI = per capita personal income for the United States (48 states).

The following is a list describing the acronyms for the summary statistics reported with each regression equation. The t-ratio (or value) for each estimated regression coefficient is presented in parenthesis under the respective coefficient. The summary statistics' acronyms are:

$R^2$ = the coefficient of determination (R-squared);

MSE = mean square error;

DW = Durbin-Watson statistic which indicates the potential of serial correlation;

DF = degrees of freedom; and

F - ratio = the F-statistic indicating the statistical significance of the regression equation.

It should be noted that in any model specification in which the dependent variable is lagged and used as an explanatory variable, the Durbin-Watson statistic is <u>not</u> a valid measure of autocorrelation within the residuals.

Regression results for annual model:

king mackerel - west coast

- linear model - current dollars;

(1-1) $$PKW = .036 + \underset{(1.36)}{5.12\times10^{-6}\ QKW} + \underset{(6.09)}{.80\ PKE} + \underset{(0.53)}{17\ PSW} - \underset{(3.13)}{3.14\times10^{-5}\ PI}$$

| | | |
|---|---|---|
| $R^2$ = .953 | MSE= .00033 | DW = 1.45 |
| DF = 25 | F-ratio = 126.6 | |

(1-2) $$PKW = -.044 + \underset{(1.50)}{5.46\times10^{-6}\ QKW} + \underset{(9.06)}{.85\ PKE} - \underset{(3.40)}{3.26\times10^{-5}\ PI}$$

| | | |
|---|---|---|
| $R^2$ = .952 | MSF = .0032 | DW = 1.43 |
| DF = 26 | F-ratio = 173.6 | |

- log-linear model - current dollars;

(1-3) $$PKW = 4.01 + \underset{(.31)}{.016\ QKW} + \underset{(6.85)}{.97\ PKE} + \underset{(1.89)}{.39\ PSW} - \underset{(3.78)}{.46\ PI}$$

| | | |
|---|---|---|
| $R^2$ = .951 | MSE = .0098 | DW = 2.11 |
| DF = 25 | F-ratio = 121.1 | |

(1-4) $$PKW = .19 - \underset{(2.06)}{.10\ QKW} + \underset{(1.47)}{.82\ PKE}$$

| | | |
|---|---|---|
| $R^2$ = .907 | MSE = .017 | DW = 1.68 |
| DF = 27 | F-ratio = 131.9 | |

- linear model - constant dollars (prices deflated by CPI);

(1-5) $$PKW = -.017 - \underset{(.13)}{7.35\times10^{-7}\ QKW} + \underset{(4.40)}{1.61\ PSW} + \underset{(2.40)}{3.77\times10^{5}\ PI}$$

| | | |
|---|---|---|
| $R^2$ = .431 | MSE = .00082 | DW = 0.78 |
| DF = 26 | F-ratio = 6.6 | |

Spanish mackerel - west coast:

- linear model - current dollars;

(2-1) $PSW = .040 - 7.84x10^{-7}\ QSW + .48\ PSE + .07\ PKW + 5.31x10^{-6}\ PI$
(.75) (3.58) (.91) (1.80)

$R^2 = .920$ MSE= .00009 DW = 1.77

DF = 25 F-ratio = 71.7

(2-2) $PSW = -.058 - 1.25x10^{-6}\ QSW + .57\ PSE + 6.96x10^{-6}\ PI$
(1.38) (6.16) (2.92)

$R^2 = .917$ MSE = .00009 DW = 1.84

DF = 26 F-ratio = 96.0

(2-3) $PSW = -.003 + .57\ PSE + 6.36x10^{-6}\ PI$
(6.11) (2.77)

$R^2 = .911$ MSE = .00010 DW = 1.63

DF = 27 F-ratio = 138.5

- log-linear model - current dollars

(2-4) PSW = 1.59 - .04 QSW + .40 PSE + .17 PKE + .12 PI
(1.22) (3.59) (1.96) (2.47)

$R^2 = .920$ MSE = .0054 DW = 1.51

DF = 25 F-ratio = 71.8

(2-5) PSW = -.105 - .06 QSW + .57 PSE + .16 PI
(1.85) (7.67) (3.27)

$R^2 = .908$ MSE = .0060 DW = 1.58

DF = 26 F-ratio = 85.2

. linear model - constant dollars (CPI deflated):

$$(2\text{-}6)\quad PSW = .055 - \underset{(.90)}{8.6\times10^{-7}}\, QSW + \underset{(6.65)}{.58}\, PSE - \underset{(2.34)}{9.3\times10^{-6}}\, PI$$

$R^2 = .747$ MSE = .00008 D-W = 1.32

DF = 26 F-ratio = 25.6

**king mackerel - east coast**

- linear model - current dollars;

(3-1) $PKE = -.076 + 5.42\text{x}10^{-6}\ QKE + .35\ PSE + .84\ PKW + 4.0\text{x}10^{-5}\ PI$
(0.81) (1.29) (5.56) (5.72)

$R^2$ = .983 MSE= .0038 DW = 2.56

DF = 25 F-ratio = 362.5

(3-2) $PKE = -.002 + .95\ PKW + 4.56\text{x}10^{-5}\ PI$
(9.03) (8.38)

$R^2$ = .981 MSE = .0004 DW = 2.06

DF = 27 F-ratio = 689.9

- log-linear model - current dollars;

(3-3) $PKE = .21 + .083\ QKE + .76\ PKW + .42\ PI$
(1.32) (13.26) (6.03)

$R^2$ = .978 MSE = .0067 DW = 2.55

DF = 26 F-ratio = 377.8

(3-4) $PKE = -2.20 + .35\ QKE + .98\ PKW$
(5.19) (14.67)

$R^2$ = .946 MSE = .015 DW = 2.31

DF = 27 F-ratio = 237.4

- linear model - constant dollars (deflated by CPI);

(3-5) $PKE = .065 + 7.99\text{x}10^{-6}\ QKE + 1.01\ PKW + 5.79\text{x}10\text{-}5\ PI$
(1.60) (13.09) (5.94)

$R^2$ = .937 MSE = .00021 DW = 2.66

DF = 26 F-ratio = 129.2

. log-linear model - current dollars;

$$\text{(3-6)} \quad PKE = -2.55 + \underset{(6.67)}{.35\ QKE} + \underset{(9.25)}{.81\ PKW}$$

$R^2$ = .843 MSE= .013 DW = 2.40

DF = 27 F-ratio = 67.9

$$\text{(3-7)} \quad PKE = .80 + \underset{(1.34)}{.082\ QKE} + \underset{(13.2)}{.81\ PKW} + \underset{(5.39)}{.66\ PI}$$

$R^2$ = .921 MSE = .0065 DW = 2.76

DF = 26 F-ratio = 102.0

. linear model including New York wholesale prices - current dollars;

$$\text{(3-8)} \quad PKE = .030 + \underset{(.65)}{1.28\text{x}10^{-5}\ QKE} + \underset{(8.58)}{.50\ PNY}$$

$R^2$ = .951 MSE = .00075 DW = 2.94

DF = 5 F-ratio = 48.0

$$\text{(3-9)} \quad PKE = 0.26 + \underset{(.55)}{1.59\text{x}10^{-5}\ QKE} - \underset{(.17)}{.16\ PSE} + \underset{(4.48)}{.51\ PNY}$$

$R^2$ = .951 MSE = .00093 DW = 2.96

DF = 4 F-ratio = 25.8

Spanish mackerel - east coast

. linear model - current dollars;

(4-1) $$PSE = .016 - \underset{(1.86)}{2.63\times10^{-7}\ QSE} + \underset{(1.87)}{.18\ PKE} + \underset{(2.81)}{.68\ PSW} - \underset{(1.18)}{6.79\times10^{-6}\ PI}$$

$R^2 = .905$ MSE= .00016 DW = 2.03

DF = 25 F-ratio = 60.0

(4-2) $$PSE = .007 + \underset{(.009)}{1.28\times10^{-8}\ QSE} + \underset{(1.52)}{.09\ PKE} + \underset{(3.13)}{.75\ PSW}$$

$R^2 = .900$ MSE = .00016 DW = 1.70

DF = 26 F-ratio = 78.4

(4-3) $$PSE = -.035 + \underset{(1.87)}{.091\ PKE} + \underset{(3.49)}{.75\ PSW}$$

$R^2 = .900$ MSE = .00015 DW = 2.00

DF = 27 F-ratio = 122.1

. log linear model - current dollars;

(4-4) $$PSE = -1.93 + \underset{(1.38)}{.14\ PKE} + \underset{(3.93)}{.87\ PSW}$$

$R^2 = .876$ MSE = .012 DW = 1.48

DF = 27 F-ratio = 95.1

. linear model - constant dollars

(4-5) $$PSE = -.095 + \underset{(1.03)}{1.16\times10^{-6}\ QSE} + \underset{(7.21)}{1.02\ PSW}$$

$R^2 = .662$ MSE = .00016 DW = 1.35

DF = 27 F-ratio = 26.5

Regression results for monthly model: king

mackerel - west coast

- linear model - current dollars;

(5-1) PKW -.018 - 1.46x10$^{-8}$ QKW(-1) + .32 PSW + .61 PKW(-1) + .35 PKW(-12)
(1.78) (1.58) (8.00) (4.17)

-.011 PNY
(.33)

R2 = .839 MSE = .0016 DW = 1.95

DF =89 F-ratio = 92.9

(5-2) PKW = -.019 - 1.36x10$^{-8}$ QKW(-1) + .30 PSW + .61 PKW(-1) + .35 PKW(-12)
(1.78) (1.59) (8.25) (4.18)

R2 = .839 MSE = .0016 DW = 1.88

DF = 90 F-ratio = 117.3

(5-3) PKW = .056 - 1.47x10$^{-8}$ QKW(-1) + .66 PKW(-1) + .40 PKW(-12)
(1.91) (10.02) (5.06)

R2 = .835 MSE = .0017 DW = 1.99

DF = 91 F-ratio = 153.0

- log linear - current dollars;

(5-4) PKW = .40 - .019 QKW(-1) + .16 PSW + .52 PKW(-1) + .36 PKW(-12)
(1.93) (1.57) (7.02) (4.68)

R2 = .834 MSE = .022 DW = 1.86

DF = 90 F-ratio = 112.8

(5-5) PKW = .45 - .021 QKW(-1) + .57 PKW(-1) + .40 PKW(-12)
(2.15) (8.10) (5.56)

R2 = .829 MSE = .023 DW = 1.92

DF = 91 F-ratio = 147.3

Spanish mackerel - west coast:

- linear model - current dollars;

(6-1) $PSW = .0188 - \underset{(0.51)}{1.73 \times 10^{-9}} QSW(-1) + \underset{(3.32)}{.20} PSE + \underset{(9.43)}{.681} PSW(-1)$

$R^2 = .759$ MSE= .00036 DW = 2.60

DF = 103 F-ratio = 108.0

(6-2) $PSW = -4.63 + \underset{(4.05)}{.310} PSE + \underset{(7.19)}{.578} PSW(-1)$

$R^2 = .716$ MSE = .017 DW = 2.47

DF = 104 F-ratio = 130.8

- log-linear model - constant dollars;

(6-3) $PSW = -.207 - \underset{(0.19)}{1.79 \times 10^{-3}} QSW(-1) + \underset{(3.92)}{.307} PSE + \underset{(7.11)}{.576} PSW(-1)$

$R^2 = .716$ MSE = .017 DW = 2.48

DF = 103 F-ratio = 86.4

(6-4) $PSW = -4.63 + \underset{(4.05)}{.310} PSE + \underset{(7.19)}{.578} PSW(-1)$

$R^2 = .716$ MSE = .017 DW = 2.48

DF = 104 F-ratio = 130.8

- linear model - constant dollars;

(6-5) $PSW = .050 - \underset{(0.52)}{9.94 \times 10^{-10}} QSW(-1) + \underset{(2.35)}{.121} PSE + \underset{(4.47)}{.406} PSW(-1)$

$R^2 = .288$ MSE = .00012 DW = 2.20

DF = 103 F-ratio = 13.9

Spanish mackerel - west coast (con't)

- linear model with dummy variable - current dollars;

$$\text{(6-6)} \quad PSW = .017 - \underset{(0.245)}{7.60\text{x}10^{-10}\ QSW(-1)} + \underset{(3.34)}{.20\ PSE} + \underset{(9.48)}{.68\ PSW(-1)}$$

$R^2 = .758$ MSE = .00036 DW = 2.60

DF = 103 F-ratio = 107.7

- log-linear model with dummy variable - current dollars

$$\text{(6-7)} \quad PSW = -.211 + \underset{(1.00)}{.0021\ QSW(-1)} + \underset{(4.15)}{.337\ PSE} + \underset{(6.92)}{.564\ PSW(-1)}$$

$R^2 = .718$ MSE = .017 DW = 2.47

DF = 103 F-ratio = 87.6

king mackerel - east coast

. linear model - current dollars;

(7-1) $$PKE = -.016 - \underset{(3.63)}{1.13\text{x}10^{-7}}\ QKE + \underset{(1.82)}{0.13}\ PKE(-12) + \underset{(3.46)}{.37}\ PKW + \underset{(7.13)}{.43}\ PNY$$

$R^2$ = .842 MSE = .0043 DW = 1.23

DF = 91 F-ratio = 121.9

. log-linear - current dollars;

(7-2) $$PKE = .44 - \underset{(2.70)}{.060}\ QKE + \underset{(2.31)}{.16}\ PKE(-12) + \underset{(1.65)}{.11}\ PKW + \underset{(7.32)}{.80}\ PNY$$

$R^2$ = .839 MSE = .020 DW = 1.17

DF = 91 F-ratio = 118.3

(7-3) $$PKE = 1.12 - \underset{(2.13)}{.039}\ QKE + \underset{(2.52)}{.18}\ PKE(-12) + \underset{(10.10)}{.90}\ PNY$$

$R^2$ = .834 MSE = .002 DW = 1.17

DF = 92 F-ratio = 154.0

. linear model - constant dollars;

(7-4) $$PKE = -.054 - \underset{(1.18)}{2.13\text{x}10^{-8}}\ QKE + \underset{(3.26)}{.24}\ PKE(-12) + \underset{(2.03)}{.24}\ PKW + \underset{(8.06)}{.50}\ PNY$$

$R^2$ = .659 MSE = 00195 DW = 1.14
DF = 90 F-ratio = 43.5

Spanish mackerel - east coast

- linear model - current dollars;

(8-1) $$PSE = .023 - \underset{(1.13)}{4.06 \times 10^{-9}} QSE + \underset{(4.64)}{.50} PSW + \underset{(4.67)}{.412} PSE(-1)$$

$R^2 = .622$ MSE = .00079 DW = 1.90

DF = 103 F-ratio = 56.5

(8-2) $$PSE = 2.1 \times 10^{-5} + \underset{(4.51)}{.48} PSW + \underset{(4.96)}{.44} PSE(-1)$$

$R^2 = .618$ MSE = .00079 DW = 1.89

DF = 104 F-ratio = 83.9

- log-linear model - current dollars

(8-3) $$PSE = .040 - \underset{(2.93)}{.022} QSE + \underset{(4.99)}{.418} PSW + \underset{(5.37)}{.441} PSE(-1)$$

$R^2 = .715$ MSE = .0186 DW = 1.98

DF = 103 F-ratio = 86.3

- linear model - constant dollars;

(8-4) $$PSE = .023 - \underset{(1.44)}{3.55 \times 10^{-9}} QSE + \underset{(3.27)}{.51} PSW + \underset{(3.91)}{.35} PSE(-1)$$

$R^2 = .330$ MSE = .00036 DW = 1.89

DF = 103 F-ratio = 16.9