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A bioeconomic model of the middle Atlantic surf clam (Spisula solidissima) fishery

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A BIOECONOMIC MODEL OF THE MIDDLE ATLANTIC SURF CLAM (*SPISULA SOLIDISSIMA*) FISHERY

A Dissertation

Presented to

The Faculty of the School of Marine Science

The College of William and Mary in Virginia

In Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

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by

Thomas Marshall Armitage

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APPROVAL SHEET

This dissertation is submitted in partial fulfillment of

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Doctor of Philosophy

Thomas M. Armitage

Approved, December 1985

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ABSTRACT

A bioeconomic simulation model of the middle Atlantic surf clam (Spisula solidissima) fishery has been developed from a survey of biological and econometric relationships. While identifying the biological input parameters available in the literature, the economic submodel of the fishery has been developed with price and landings time series data, and with data obtained through the use of survey questionnaires and interviews with surf clam fishermen and processors. Alternative management scenarios in the fishery have been evaluated from industry costs in both the harvesting and processing sectors and analysis of the demand for raw product confronting surf clam fishermen.

Multiple regression analysis of time series data indicates that surf clam ex-vessel prices may be negatively related to surf clam landings whereas hard clam prices are positively related to ex-vessel ocean quahog prices and ex-vessel oyster prices. The strength of this relationship confirms the status of ocean quahogs as very close substitutes for surf clams.

The results of case studies using the model suggest that the Mid-Atlantic Fishery Management Council has followed a prudent course of action in managing the surf clam fishery. The model also projects that, 1) larger yield quotas may be possible in the immediate future without jeopardizing surf clam population stability, 2) overcapitalization in the fishery appears to remain a problem, and 3) the economic outlook for the operators of small vessels remains relatively bleak.

A BIOECONOMIC MODEL OF THE MIDDLE ATLANTIC SURF CLAM (*SPISULA SOLIDISSIMA*) FISHERY

INTRODUCTION

The concept of sovereignty over territorial waters adjacent to coastal states has been a subject of international debate for more than 300 years. During the past century, the discovery of natural gas, oil, minerals, and abundant fishery resources on and above the continental shelf of the United States has provided motivation to extend jurisdiction over virtually the entire shelf region. In 1976, the Fishery Conservation and Management Act (FCMA) established a 197 mile wide Fishery Conservation Zone extending from the baseline of the United states territorial sea. In 1983, a 200 mile wide Exclusive Economic Zone was established by Presidential Proclamation, further asserting sovereign rights over ocean resources within 200 miles of the baseline from which the breadth of the territorial sea is measured (Federal Register, 1983). The FCMA directed that management plans be drafted for all non-migratory species harvested within the Fishery Conservation Zone. Certain highly migratory species, such as tuna, were excluded from management. Management plans were to be drafted upon the basis of maximum sustainable yield (MSY), modified by any relevant economic and social factors, to develop an optimum sustainable yield (OSY). The requisite data for optimum management of these species, however, were not immediately available to policy makers.

in many cases, policy is still formulated upon the basis of inadequate data. Early management plans were, of necessity, based upon educated guesses and limited, but best information available.

The objective of this study is to demonstrate how effective management of an offshore fishery can be achieved through the development of a bioeconomic simulation model, and the provision of improved economic data.

The first Atlantic coast fishery to be regulated under the FCMA was the offshore clam fishery comprised of surf clams (Spisula solidissima) and to a lesser extent, ocean quahogs (Arctica islandica). The surf clam fishery is the focus of this investigation. Management attention was initially focused upon the offshore clam fishery because overcapitalization threatened the resource with economic extinction. In 1977, regional management of the surf clam fishery was provided when federal regulations were promulgated under an approved management plan (Federal Register, 1977).

Prior to implementation of management efforts, it became evident that the surf clam industry was suffering from an economic ill typical of many industries exploiting common property resources. Individual firms were overharvesting in communal fishing areas. The open access market resulted in a level of fishing effort much greater than required for optimum economic and biological return.

Optimum output in an economic system occurs at the point where marginal costs are equal to marginal revenue, an increase in output above this point will result in a net economic loss to industry. The divergence between private marginal costs incurred by individual fishermen and social marginal costs incurred by society as a whole has been documented in a number of open access fisheries (Demsetz, 1967). Market failures have been studied by using fishery models (Gordon, 1954; Christy and Scott, 1965; Smith, 1969; Carlson, 1970; Copes, 1970). In the case of the surf clam fishing industry, the Mid-Atlantic Fishery Management Council believed that a restrictive management program would be the best course of action to follow in order to reverse the downward trends in economic and biological yield in the fishery.

Thus, management of the surf clam fishery represents a case study in regional or multi-state allocation of resources. A principal objective of the fishery management plan initially drafted by the Mid-Atlantic Fishery Management Council was to stabilize the abundance of declining middle Atlantic surf clam populations, and then to rebuild these populations to levels that would sustain total annual harvests of 50 million pounds of meats. To achieve this objective, the plan established a variety of regulations, including an annual total landings quota of 1.8 million bushels (30 million pounds of meats). As a result of these stringent management regulations, total middle Atlantic surf clam landings from the fishery conservation zone declined from 43 million pounds of meats in 1977 to 31.4 million pounds of meats in 1978 (Murawski and Surchuk, 1979). National Marine Fisheries Service biological assessments have indicated that surf clam biomass off New Jersey increased in 1982 due to strong 1976 and 1977 year classes (Mid-Atlantic Fishery Management Council, 1982). Data from the logbook records of surf clam fishermen further suggest that initial management efforts have succeeded in stabilizing the abundance of the resource. This is evidenced by the fact that quarterly mean catch per effort indices did not vary greatly during the period of 1978 through 1981.

Although the current fishery management regime for surf clams has addressed the important problem of stock replenishment upon the basis of maximum sustainable yield, controversy surrounds many of the management plan regulations. Economic dislocation of the labor force in the fishing sector of the industry, curtailed supplies of raw product for clam processors, and the expense, difficulty, and possible geographic disparity of enforcing and administering cumbersome regulations have all been cited by various sources, including industry representatives, as undesirable by-products of the current surf clam management plan.

The complexity of biological and economic interactions in many fisheries makes assessment of a large number of management options an extremely formidable task. One method by which alternative fishery management strategies may be evaluated is through the development of bioeconomic models (Anderson, 1977; Grant and Griffin, 1979). Model development is a logical and systematic method for representing the response of a natural resource to proposed alternative management plans. Model development, however, is extremely time-consuming and data-intensive for fishery management.

By definition, an econometric model attempts to quantify an observed relationship between two or more economic variables. For example, the price of a commodity in a market may be regarded as a function of the quantity of that commodity supplied, the prices of substitute commodities, disposable income, and other factors. Economic theory describes hypothetical and actual functional relationships comprising the whole of an economic system. Econometric researchers estimate these relationships, measure them, then statistically test them.

The purpose of this study is to survey and refine the biological input parameters and econometric relationships required for the development of a realistic bioeconomic simulation model of the middle Atlantic surf clam fishery. These relationships have been used to construct a simulation model of the fishery with data from this survey. The model can be used for assessing the impact of alternative management strategies upon clam industry profits and levels of clam population abundance. While identifying the biological input parameters available in the literature, this study has emphasized the development of an economic submodel of the fishery. Industry costs in both the harvesting and processing sectors have been identified and determined, analysis of the demand for raw product confronting surf clam fishermen has been undertaken, and the potential economic impact of the existing fishery management plan has been investigated and described.

Chapter II

The Surf Clam Fishery as a Bioeconomic System

Concept of a Fishery Simulation Model

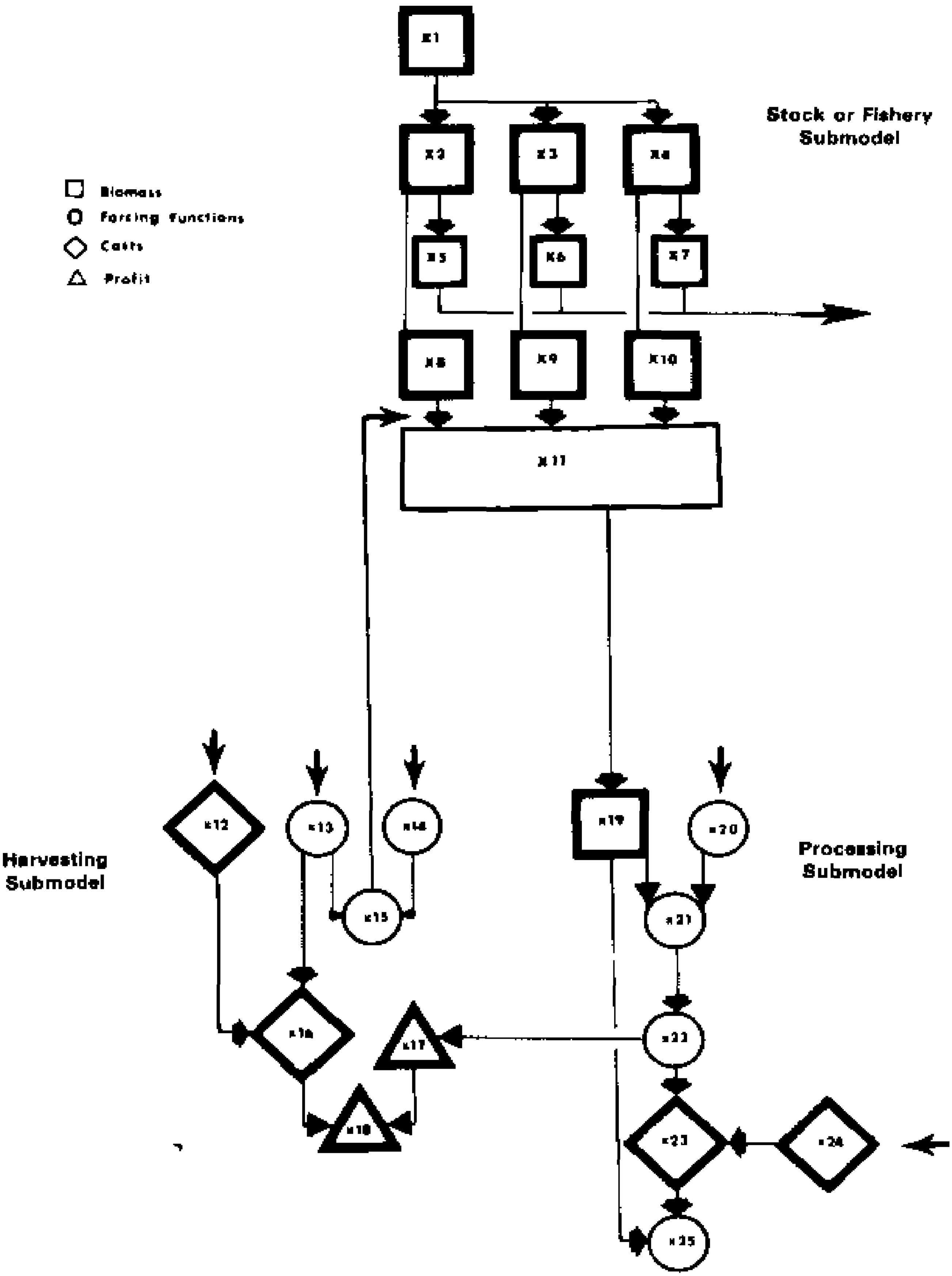
Simulation models have long been used to solve problems in the physical sciences, engineering, and business. However, only in recent years have they been used to analyze and understand the behavior of dynamic biological and socioeconomic systems. Fisheries, as dynamic systems, may realistically be described through the use of simulation models. Indeed, a number of generalized single species fishery simulators have been constructed (Walters, 1969; Devanney et al., 1977; Anderson et al., 1982). The most reliable models, however, use species specific characteristics of a stock and fishery. Walters (1969) has noted that the fishery simulation model is simply a bookkeeping procedure employed to solve commonly used equations for density, growth, and yield by age group, and to join age groups over time. Thus, simulation models can represent the structure of a fish population as a series of specific compartments representing an age or size portion of the total fish population. Changes in the structure and size of the population can be depicted by moving individuals from one compartment to another with a series of rate equations.

Sissenwine (1977) has identified the important activities that remove the fish from a given compartment and advance them to a new compartment. Fishing results in a continuous transfer of fish from an age or size compartment to a yield compartment. Natural mortality results in a continuous decay of each age-size compartment and a loss of fish from the system. Aging results in discrete advancement of fish to the next higher age group at the beginning of each year or designated time interval. Recruitment is represented as the discrete addition of individuals to the youngest age group of the model at the beginning of each year or other time interval. Growth results in continuous increase in size, and can therefore move individuals from one size compartment to another. If age, growth, mortality, and recruitment to a fishery can be described and incorporated within a set of input variables, a realistic model of the fishery may be developed. Once a biological simulator is constructed, estimated yields may be provided as input to an economic submodel which quantifies the relationship between harvest and annual economic rent in the fishery.

A conceptual model of the major biological and economic aspects of the middle Atlantic surf clam fishery is presented in Figure 1. The biological rates and variables influencing the movement of clams through the system, and the economic inputs and parameters required to

Figure 1

Conceptual Model of Mid-Atlantic Surf Clam Fishery



Stock or Fishery Submodel
Biomass
Forcing functions
Costs
Profit
X1
X2
X3
X4
X5
X6
X7
X8
X9
X10
X11
Harvesting Submodel
x12
x13
x14
x15
x16
x17
x18
Processing Submodel
x19
x20
x21
x22
x23
x24
x25

Key to Compartments in Figure 1

Compartment	Contents	Factors Influencing Flux Into and Out of Compartment
X_1	Biomass of newly recruited clams	Environmental factors, size of parent stock.
X_2, X_3, X_4	Biomass of clams available for harvest in each Mid-Atlantic sub-region.	Growth rates, processes of natural mortality.
X_5, X_6, X_7	Clams removed due to natural mortality within each sub-region (biomass, number).	Processes of natural mortality.
X_8, X_9, X_{10}	Biomass and number of clams harvested in each sub-region.	Processes of fishing mortality.
X_{11}	Entire mid-Atlantic harvest (biomass).	Processes of fishing mortality.
X_{12}	Unit costs of fishing.	Economic conditions.
X_{13}	Fishing effort by vessel class, sub-region, season.	Effort restrictions, yield quotas.
X_{14}	Number of vessels in each size class.	Effort restrictions, profitability.
X_{15}	Effective fishing effort.	Fishing power.
X_{16}	Variable and fixed fishing costs.	Economic conditions.
X_{17}	Revenue from fishing.	Function of surf clam price and supply.
X_{18}	Vessel Profits.	Total fixed and variable costs and harvessting revenues.

Compartment	Contents	Factors influencing flux into and out of compartment
X_{19}	Supply of surf clams.	Harvest, determined by profitability and management regulations.
X_{20}	Prices of shell-fish species used as substitutes for surf clams.	Economic conditions, supply of substitutes.
X_{21}	Processor demand.	Processor demand function, economic conditions
X_{22}	Ex-vessel surf clam price.	Function of supply and prices of substitute commodities.
X_{23}	Total processing costs.	Supply processed, economic conditions.
X_{24}	Unit costs of processing.	Economic conditions.
X_{25}	Wholesale prices associated with levels of return.	Total processing costs, supply of clams available for processing.

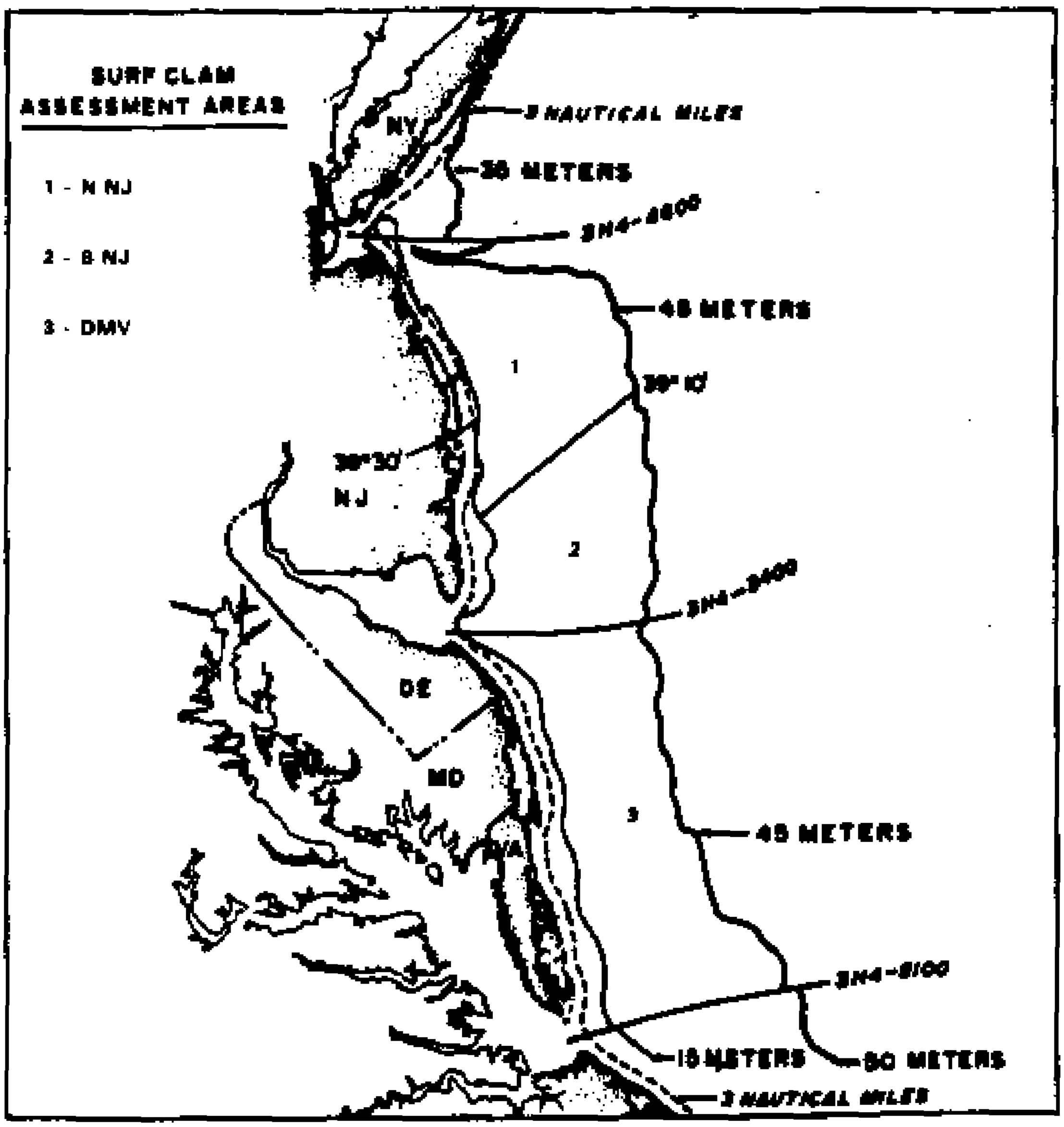
estimate economic health of the fishery are displayed in this figure. As Figure 1 illustrates, the surf clam fishery can be compartmentalized, and the factors controlling the flow of biomass and economic resources between compartments can be identified.

Flow through the system, depicted in Figure 1, begins in compartment X_1, which contains the biomass of clams newly recruited each year to the middle Atlantic stock. The middle Atlantic stock is defined to include those clams in the Fishery Conservation Zone (FCZ), an area reaching from three to 200 miles offshore from Cape Hatteras to Cape Cod - or the area offshore of eastern Long Island (Figure 2.) This is the region under management jurisdiction of the Mid-Atlantic Fishery Management Council. Although there is a small inshore fishery for surf clams, this analysis is confined to the offshore fishery of the FCZ. There are inadequate data available to include inshore clams under state jurisdiction in this analysis. Moreover, recent statistics indicate that surf clam harvesting activity is concentrated in the FCZ (during the past seven years only 7-13 percent of the reported surf clam harvest has been identified as having been taken from the territorial sea). Environmental factors, and the size of the parent stock in each subregion influence recruitment success and the movement of clams into subregional compartments X_2, X_3, and X_4 (Ropes et al., 1976; Murawski and Surchuk, 1981). As noted below, the relative

Figure 2

Area Designations Used for Surf Clam Assessments

Area Designations Used for Surf Clam Assessments



(From Brown et al., 1977)

importance of these factors in determining the recruitment success of clams is presently unknown. Compartments X_2, X_3, and X_4 contain the biomass of surf clams in three distinct subregions, northern New Jersey, southern New Jersey, and Delmarva. The three subregions are groupings of National Marine Fisheries Service surf clam survey strata identified to be homogenious in depth and sediment type (Brown et al., 1977).

Within the three subregional compartments, seasonal growth rates determine the availability of surf clam biomass to fishermen. Processes of natural mortality move clams from each of these compartments into compartments X_5, X_6, and X_7 where they are lost to the system. Fishing mortality, which is dependent upon fishing effort, moves clams from each of the subregional compartments into compartments X_8, X_9, and X_{10}. These compartments contain the biomass of the middle Atlantic surf clam harvest within each subregion. Compartment X_{11} contains the biomass of the entire mid-Atlantic harvest.

Conceptualization of Harvesting and Processing Sectors

The level of surf clam harvest is determined by input from a harvesting sector submodel depicted in Figure 1. Hours of fishing by each vessel class in each subregion are input to the system through compartment X_{13}, and are controlled by effort restrictions yield quotas, and weather. Compartment X_{15} contains effective fishing *effort described as effort days of fishing.* Effective fishing effort is determined by converting effort hours to effort days and multiplying by the number of vessels present in the fishery, and by a catchability coefficient derived separately for each vessel class (Anderson et al., 1982; Mid-Atlantic Fishery Management Council, 1981). One effort day may be taken to equal 12 hours of fishing activity. Vessel surveys and interview data described in Chapter IV have indicated that a fishing trip involves approximately 12 or more hours of steaming time to travel to and from the clam beds, and 12 hours of actual fishing activity. Elements within compartment X_{15} function as input to the biological submodel used to calculate clam harvests. Compartment X_{14} contains the number of vessels in each of three separate size categories within each subregion. This compartment determines the effective fishing effort contained in compartment X_{15}. The number of vessels within each fishery subregion is determined by vessel profits and returns to vessel owners and operators. It is reasonable to expect fishing activity to be concentrated in subregions where the highest return on investment could be achieved. In the absence of limited entry, it is also reasonable to expect the entry of new vessels into the fishery if returns exceed those available in other sectors of the economy. Similarly, vessels could be expected to exit the fishery in times of low available returns on investment. Vessel profits, contained in compartment X_{18}, are determined by total fixed and variable fishing costs contained in compartment X_{16}, and by harvesting revenues input from the processing sector submodel. Total costs are a function of fishing effort contained in compartment X_{13} and unit fishing costs contained in compartment X_{12}. Those costs were derived by vessel surveys and interviews described in Chapter IV. Revenue from fishing operations, contained in compartment X_{17}, is a function of surf clam price and supply. Both price and supply are inputs from the processing sector submodel.

The processing sector submodel of the fishery is also depicted in Figure 1. Within the processing sector of the surf clam fishery the ex-vessel price of surf clams is determined by input variables in a processor demand function contained in compartment X_{21}. This relationship describes surf clam ex-vessel price, compartment X_{22}, as a function of supply, compartment X_{19}, and the prices of species used as substitutes for surf clams, X_{25}. Wholesale prices that are associated with various levels of processor profits are contained in compartment X_{26}. These prices are a function of the unit costs of processing, X_{24}, total processing costs, X_{23}, and the supply of clams processed, X_{19}.

The remainder of this chapter is devoted to identification of the biological factors influencing movement of clam biomass through the system. The processor demand function is derived in Chapter III, and fishing and processing cost inputs are quantified in chapter IV.

Life History and Population Dynamics

Spawning of surf clams has been studied along the New Jersey coast (Ropes, 1968). Reproductive behavior of surf clams off New Jersey is not atypical of the spawning activity occurring throughout the middle Atlantic region. Ropes determined that major spawning occurs in mid-July to early August with a second minor spawning in mid-October to early November. Equal proportions of each sex occur, with hermaphroditism being observed as an anomaly (Ropes, 1980).

Studies of age at sexual maturity have indicated that sexual maturity is attained within two years after larval settlement (Ropes, 1978). Belding (1910) reported that surf clams in Massachusetts waters reach sexual maturity at a length of 45 mm (1.9 inches) a short time after reaching one year of age.

Although temperature has not clearly been observed to be a stimulus for spawning, it is believed that a minimum temperature threshold can elicit a spawning response, and is the driving mechanism dictating when spawning will occur (Ropes, 1968). In the laboratory, abrupt temperature change can induce spawning activity. However, it is believed that gradual gonadal development prior to spawning, accompanied by the production of neurosecretory products, leads to the induction of spawning activity

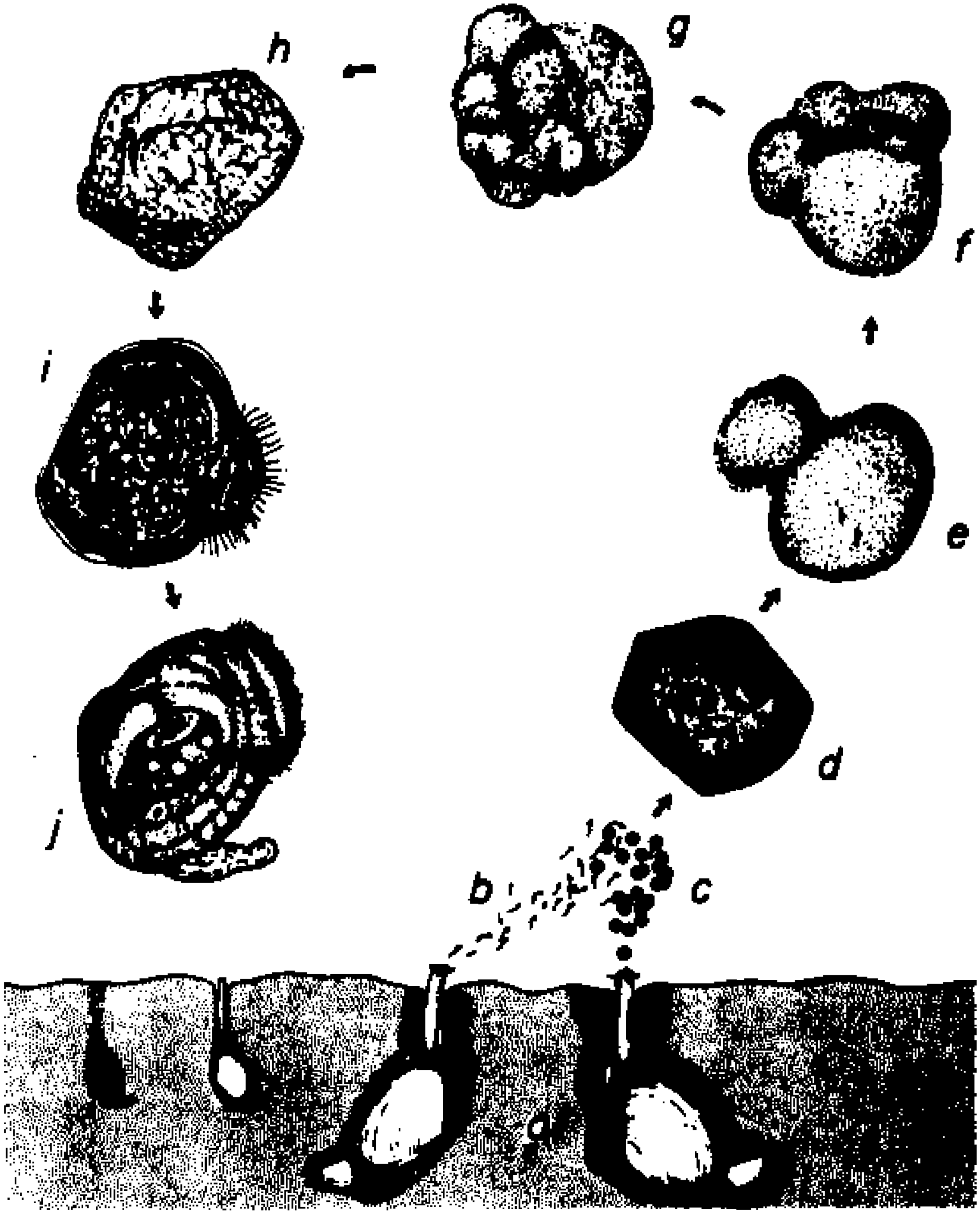
(Loosanoff and Davis, 1963). Although Ropes' 1968 publication cited above is the most authoritative study of surf clam spawning behavior, several earlier investigations have reported temperature-dependent spawning activity in this species. Westman and Bidwell (1946) indicated that populations of surf clams occurring in the ocean off Long Island, New York were observed to begin spawning when water temperatures reached 16 degrees C. Stickney (1965) reported that the optimum temperature range for spawning and development of larval surf clams is 14 to 20 degrees C. A review of the available scientific data appears to indicate that, in the middle Atlantic region, progressive development of the gonads to a turgid or ripe state during the period of warming temperatures to between 8 and 12 degrees C precedes the first annual spawning of surf clams. Ripeness and sensitivity to spawning stimuli preceed the natural spawning period of surf clams by many months. Thus, seasonal temperature change appears to be a significant environmental determinant of spawning patterns in surf clams.

Larval Development

After fertilization, larval surf clams pass through developmental stages typical of bivalves (trochophore, veliger, and pediveliger). Figure 3 depicts stages in the development of surf clam larvae. Loosanoff and Davis (1963) have studied surf clam larval development

Figure 3

Stages in the Development of Surf Clam Larvae



Stages in the development of surf clam larvae: (a) adult male and female clams spawning, (b) sperm, (c) eggs, (d) unfertilized egg, (e) two-cell stage of division after fertilization, (f) four-cell stage, (g) eight-cell stage, (h) trochophore larva, (i) veliger larva with velum extended, and (j) pediveliger larva with foot and velum extended.

(From Ropes, 1980)

extensively in the laboratory. Larvae have been raised to the pediveliger stage in 19 days at 22 degrees C. The early veliger stage can develop 28 hours after fertilization at 22 degrees C, but forms more slowly at lower temperatures. Stickney (1965) noted that larval growth appears to be optimum at 20 degrees C, but is inhibited at higher and lower temperatures. When held at 20 degrees C, larvae metamorphosed 18 to 30 days after fertilization. Recent research has indicated that Ekman transport and upwelling, can influence year class success in many species of marine organisms by transporting larvae to and from areas conducive to survival (Norcross and Shaw, 1983). Because of their relatively long period of larval development, 20 to 30 days, recruitment success of surf clams may be dependent upon factors such as: 1) occurrence of optimum environmental temperatures for larval development, 2) favorable wind driven circulatory patterns [live surf clams have never been recovered from depths greater than 128 m, and clams living in the beach zone are frequently washed onto land by severe storms (Ropes, 1980)], 3) abundance of larval food resources ranging from nanno-and ultraplankton to larger phytoplankters, and 4) abundance and distribution of predators. The importance of these factors in influencing year class success in many fisheries has been well documented (Applegate, 1983; Austin, 1972; Cushing, 1972).

Clam Development and Environmental Factors Affecting Growth

After reaching the pediveliger stage, juvenile clams skim the substrate searching for a suitable area within which to assume an infaunal existence. Factors influencing the location of settlement are presently unknown. At the time of settlement, the pediveligers are about 250 microns long. Ropes (1978) has suggested that the environmental factors most important to year class strength after metamorphosis are: 1) adequacy of food abundance (principally diatoms), 2) oxygenation of bottom water, and 3) abundance of predators. There are, however, few data to support these hypotheses.

Few diseases of economic significance have been identified in surf clams. A protozoan hyperparasite, the haplosporidean _Urosporidium spisuli_, has been observed to infect an anisakid nematode found in surf clams (Perkins et al., 1975). This infection, while apparently causing few problems for surf clams themselves, turns the meat of the adductor muscle and foot brown when the haplosporidean sporulates. This type of brown meat, while probably not harmful to consumers, has been withheld from the market. Although disease has not been documented in surf clams, there are undoubtedly some parasitic organisms that contribute to surf clam natural mortality.

The effect of abundance of food upon surf clam growth has been investigated. Ambrose et al. (1980), assuming that reduction in surf clam food abundance occurred with increased distance offshore, compared surf clam growth rates at near shore and offshore stations. Water temperature, depth, and population density were also correlated with growth rates to determine their relative importance. The results of this study indicated that more rapid rates of growth can be observed at offshore stations rather than inshore stations. Ambrose et al. thus hypothesized that variables such as temperature, water depth, and population density may be more limiting to growth and subsequent year class strength than food abundance, although food densities were not measured in this study. Correlation of these environmental parameters to growth rate was undertaken. Intercorrelations between the independent environmental variables, however, obscured the importance of each to the growth of clams. Ambrose et al. stated a belief that lower water temperature, greater water depth, and decreased population density offshore were responsible for faster growth rates. This was not, however, quantitatively demonstrated in their study.

Jones (1980) found an inverse correlation between the growth rate of surf clams and sea surface temperature. He noted that it is not clear why cool years are more conducive to growth and recruitment than warm years. Temperature may influence growth rate directly, or do so indirectly through other factors such as availability of food, nutrients, or oxygen.

On at least one occasion low oxygen levels in the

Middle Atlantic Bight have given rise to mass mortalities of surf clams (National Marine Fisheries Service, 1976). However, in the absence of anomalous climatological conditions and excessive nutrient loading, low oxygen levels do not generally present a problem for surf clams.

According to Ropes (1978), predation is probably greatest upon small juvenile surf clams because of their size and inability to burrow deeply into bottom substrata. Fish, crabs (Cancer irroratus and Cancer borealis), and moon snails (Lunatia heros and Polinices duplicata) have all been identified as predators of juvenile and adult surf clams. Studies in Chincoteague Inlet have documented that holes were bored in 50 percent of the shells of small surf clams (Ropes and Merrill, 1970). Franz (1977) reported that off Long Island, New York, moon snails preyed mostly upon clams less than five years old and 80 mm long.

It should be quite evident from the research results discussed above that surf clam recruitment success is dependent upon complex interaction among a number of environmental factors. As such, difficulties are encountered in attempting to develop a biological predictive model of recruitment for surf clams. Walters (1969) has indicated that recruitment into many fish populations, at the start of any year, may be some function of the spawning stock present and a set of age specific reproductive potentials. Spawner-recruit curves have been proposed to estimate the relationship between stock size and recruitment in fish stocks (Ricker, 1954; Beverton and Holt, 1957; Larkin et al., 1964). Surf clam recruitment, however, is highly variable. Hancock (1973) has noted that, "cockles and other burrowing bivalves seem to be able to make a spectacular recovery from low stock levels. With clams and scallops, extremely irregular recruitment seems to be a function of variable environmental factors, which mask any dependence on spawning stock. With clams, recruitment is so irregular that any relationship between parent stock and recruits is not apparent". Because there is no demonstrated or quantified relationship between parent stock and recruits in the surf clam fishery, year to year variability cannot be predicted beyond that period of time during which a specified population of pre-recruit cohorts gradually enters the fishery. If population surveys can provide reasonably accurate estimates of the initial surf clam population size and age structure, then individual year class population size and weight may be reliably predicted within a period of time termed the planning horizon.

Population Dynamics, Age and Growth

Once an incoming year class has been recruited to the middle Atlantic region, it becomes possible to derive difference equations describing the fluctuations in population size that occur with time.

Growth of clams within discrete time intervals can best be described through the development of species specific growth curves. *Surf clam growth* has been extensively studied by a number of investigators using several different methods (Jones et al., 1978). These studies indicate that growth may be very accurately described through the use of the von Bertalanffy growth equation (von Bertalanffy, 1938). Belding (1910) studied surf clam growth off Cape Cod, Massachusetts by keeping clams in sand filled raft boxes and periodically measuring their growth. Annular shell ring formation in surf clams has been verified and studied by: Westman and Bidwell (1946) off Long Island, New York, Kerswell (1944), off Prince Edward Island, Canada, Welch (1963) off Point Pleasant, New Jersey, Caddy and Billard (1976) off Buctouche, Canada, Loesch and Ropes (1977) off Virginia, Murawski and Serchuk (1979) off Virginia, Murawski (1977) off Maryland, and Murawski and Surchuk (1979) throughout the middle Atlantic region. Ropes et al. (1970) studied shell sizes of discrete settlements of surf clams at yearly intervals at Chincoteague Inlet, Virginia, and Yancy and Welch (1968) reported the growth of a discrete settlement of surf clams during the summer at Boothbay Harbor, Maine. Growth studies have recently been performed by cutting the shells of surf clams and measuring ring distances directly on the sectioned shell and upon an impression created in plastic (Jones et al., 1978). The von Bertalanffy growth equations derived from some of these studies are displayed in Table 1. Chang et al (1976) examined the relationship between shell length and clam weight to determine whether isometric growth is evident in surf clams. A statistical test of isometry was insignificant for shell length versus drained meat weight. Therefore, applying the von Bertalanffy growth equation based upon length and weight is valid. The maximum age attained by surf clams seldom exceeds 25 years offshore and 16 years inshore (Ambrose et al., 1980). Figure 4 displays a general growth curve for surf clams using the equation of Chang et al. (1976). It illustrates a pattern of growth during which 50 percent of maximum length is achieved by year three, 75 percent of maximum length is achieved by year six, and 95 percent of maximum length is achieved by year twelve. Mean length at sexual maturity is 70 mm (two years of age, and the age at which clams reach ninety percent of their maximum length (157.3 mm) is eight and one half years.

<u>Length-Weight Relationships</u>

The length-drained meat weight relationship in surf clams, where $wt=(a)(length)^{(b)}$, has been reported (Chang et al., 1976; Mid-Atlantic Fishery Management Council, 1979; Mid-Atlantic Fishery Management Council, 1981). These relationships are provided in Table 2. Using the relationships in Tables 1 and 2, growth and resultant meat weight of post larval clams can be simulated.

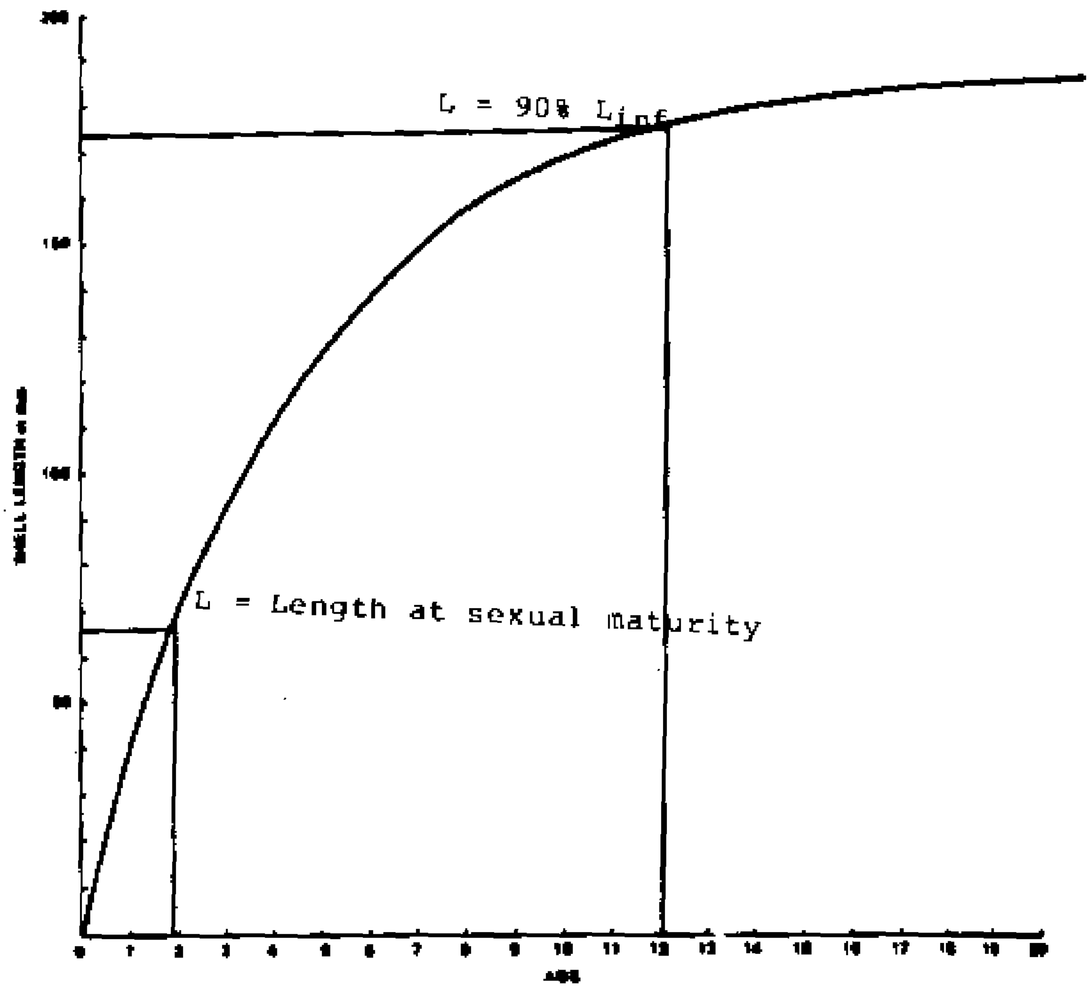
Table 1

von Bertalanffy Growth of Surf Clams

Authors	Year	Location	L_{inf} (mm)	K	t_0 (yrs)
Westman and Bidwell	1946	Long Island (inshore)	171.51	0.619	0.5607
Loesch and Ropes	1975	Virginia	147.3	0.3848	0.0062
Chang et al.	1976	Mid-Atlantic	174.8	0.19	0.18
Murawski	1977	Maryland (offshore)	167.20	0.3189	0.1874
Murawski and Surchuk	1981	New Jersey (offshore)	166.64	0.2731	0.0255
Murawski and surchuk	1981	Delmarva (offshore)	166.43	0.2984	0.0794

Figure 4

General Age and Growth Relationship for Surf Clams



General age and growth relationship for surf clams, *Spisula solidissima*.

Table 2

Length-Drained Meat Weight Relationship in Surf Clams
Weight (g)=(a)(length mm)$^{(b)}$

Authors	Area Sampled	a	b
Mid-Atlantic Fishery Management council (1981)	New Jersey	.000100	2.8251
Mid-Atlantic Fishery Management council (1981)	Delmarva	.000111	2.7675
Mid-Atlantic Fishery management Council (1979)	Mid-Atlantic	.000258	2.6224
Chang et al. (1976)	Mid-Atlantic	.0001264	2.776

Meat Weight Loss Due to Processing

Barker and Merrill (1967) studied the seasonal variation in meat weight evident in surf clams taken off Cape may and Point Pleasant, New Jersey. They concluded that meat weight is generally constant throughout the year, with a slight decrease evident during or after the spawning period. This meat weight decrease during the spawning period is reflected in higher clam processing costs per pound of meat produced. They also evaluated the weight loss due to processing as drained clam meat weights were measured before and after processing. Percent weight loss due to removal of stomach and gonad tissues from the meats of surf clams was between 11 and 20 percent of total wet tissue weight. Meat weight loss resulting from processing activity can be simulated using this relationship.

Natural Mortality

Clams are removed from the system through processes of natural mortality and fishing mortality. Several authors (Ropes, 1980; Chang et al., 1976; Murawski and Serchuk, 1979) have reported a surf clam population instantaneous natural mortality rate of between 0.20 - 0.26 calculated as an annual unit for all age classes . No age specific estimates of natural mortality have been provided by any investigators. All of the estimates cited above were derived through the use of age composition and cohort analysis to determine survival rates and subsequent instantaneous natural mortality rates.

Population Structure

Population structure may be defined as the size, sex composition and numerical abundance of year classes or cohorts in a population. Development of an analytical biological planning model requires the acquisition of standing stock data. Specifying levels of population abundance, while requiring some approximation, is not as arbitrary as attempting to specify unknown stock-recruitment relationships. Estimates of surf clam population structure have been derived by Murawski and Surchuk (1981) and Anderson et al. (1982). Chang et al. (1976), used catch and effort data to estimate the size by weight of the middle Atlantic surf clam population for the years 1965 to 1975. These estimates, displayed in Table 3, provide an approximation of year class strength for three year old clams during a ten year period. Murawski and Serchuk (1980) have provided relative abundance indices for surf clam populations off the coasts of Delmarva, southern New Jersey, and northern New Jersey. Abundance estimates have been taken from sample tows of a standard size in each locale. Abundance indices have been provided for clams less than 5.5 inches and greater than 5.5 inches. Using these abundance indices, Anderson et al. (1982) estimated the population structure of pre-recruit cohorts one through five (clams less than 5.5 inches long) and six through

Table 3

Estimated Recruitment Size in Weight and Numbers of Middle Atlantic surf Clams (1965-1975)*

Year	Weight (tons)	Numbers (10*)
1965	51,982	1,321
1966	164,563	1,931
1967	99,427	1,036
1968	99,437	1,308
1969	99,296	1,499
1970	191,597	2,077
1971	228,384	2,291
1972	173,817	1,836
1973	71,758	905
1974	53,932	675
1975	53,615	600

* Chang et al. (1976)

twenty-five (clams greater than 5.5 inches long) in 1981.

Based upon the data provided by Murawski and Serchuk (1981), Anderson et al. (1982) estimate the numerical abundance of surf clams greater than 5.5 inches long to be approximately 2.2 X 10^{11} off Delmarva. This estimate was derived by dividing the number of clams taken per experimental tow by the number of square meters covered by a tow, and multiplying times the number of square meters covered by known Delmarva clam beds. Using this estimate and relative abundance indices, population estimates were derived for clams less than 5.5 inches long and greater than 5.5 inches long off northern New Jersey, southern New Jersey, and Delmarva. Using these data, Anderson et al. estimated the population structure displayed in Table 4. Although this population structure reflects the limited knowledge of the distribution and abundance of surf clams, it is in accord with reports in the literature that southern New Jersey does not have a strong year class which will recruit to the fishery over the next five years.

Reasonable abundance estimates are essential to the development of a realistic analytical fishery model. Limited information concerning abundance and distribution is perhaps the weakest link in the chain of information required for the development of a surf clam fishery model. While confidence can be placed in the orders of magnitude of these estimates, it is more difficult to assess their precision within one order of magnitude. Nevertheless,

Table 4

Population Structure of Mid-Atlantic Surf Clams

Cohort	Delmarva	Southern New Jersey	Northern New Jersey
6-25	2.2×10^{10}	2.797×10^{10}	6.983×10^{9}
5	1.2×10^{10}	2.365×10^{9}	1.92×10^{10}
4	1.6×10^{10}	2.365×10^{9}	8.348×10^{10}
3	6.7×10^{10}	2.365×10^{9}	1.92×10^{10}
2	1.6×10^{9}	2.365×10^{9}	1.467×10^{10}
1	1.2×10^{10}	2.365×10^{9}	2.365×10^{10}

*Anderson et al. (1982)

they represent an adequate data base for comparing the relative merits of alternative regulatory strategies.

Effort, Fishing Power, and Catchability Coefficients

After accounting for surf clam growth (X_2, X_3, and X_4) and natural mortality (X_5, X_6, and X_7), it is possible to calculate fishing mortality (X_8, X_9, and X_{10}) and subsequent level of harvest to be used as input into a processing sector sub-model. Fishing mortality will vary as a function of fishing effort (X_{13}) and vessel/gear fishing power (X_{15}). Most frequently, fishing mortality (F) is expressed as a function of fishing effort (f) and catchability coefficient (q), where F=(q)(f). In this equation, f represents effective fishing effort and q, termed the catchability coefficient, is an operator relating fishing effort to fishing mortality. Fishing mortality rates are most frequently expressed as instantaneous annual units (Rounsefell and Everhart, 1953; Ricker, 1968; Royce, 1972).

$$Z=-(\ln S)$$

$$Z=M+F$$

Z= Instantaneous total mortality rate.

M=Instantaneous natural mortality rate.

F=Instantaneous fishing mortality rate.

S=Survival rate.

Several investigators have estimated the relative fishing power of vessels in the surf clam fishery. Chang et al. (1976), using catch and effort data from the middle Atlantic region, estimated a catchability coefficient for the entire surf clam fishery. This estimate did not account for differences in gear efficiency and fishing power between fishing vessels. Effective effort was measured in hours, and an estimate of the catchability coefficient (q) was 6.0×10^{-6} effort hour $^{-1}$. This same study also determined fishing power coefficients using vessel horsepower as a criterion of evaluation. Fishing power coefficients determined using catch per unit effort data and vessel horsepower data are displayed in Table 5. Recently, estimates of catchability coefficients have been calculated separately for each of three vessel classes defined on the basis of gross registered tonnage (Anderson et al., 1982). Effort was measured on the basis of fishing trips. Using the equation, Catch/Vessel=(Catchability Coefficient)(Effort Trips)(Surf Clam Population Size), catchability coefficients for each size category of vessel were calculated. Data on catch per unit of effort and effort were available from National Marine Fisheries Service publications and the Mid-Atlantic Fishery Management Council. These catchability coefficients were calculated for clams of length greater than 5.5 inches. Depending upon gear efficiencies, catchability coefficients may be lower for clams of length less than 5.5 inches.

Table 5

Fishing Power Coefficients in the surf Clam Fishery

Vessel Horsepower	Fishing Power Coefficient
0-100	1.000
101-200	1.11268
201-300	1.46414
301-400	1.67947
401-600	1.21196
601-900	1.86349
901-	1.02339

*Chang et al. (1976)

Probably this is because small clams are not captured between the dredge slats. However, inadequate data exist to test this hypothesis. Estimates of catchability coefficients derived by Anderson et al. were:

Class I Vessels = 9.6054×10^{-7} effort $trips^{-1}$.
(0-50 Gross Registered Tons)

Class II Vessels = 1.1898×10^{-6} effort $trips^{-1}$.
(50-100 Gross Registered Tons)

Class III Vessels = 1.8884×10^{-4} effort $trips^{-1}$.
(>100 Gross Registered Tons)

Effort trips or effort days are a very convenient unit of effort to use in the surf clam fishery because fishing activities do not occur over a period of time longer than 12 to 24 hours. Vessels return to port with their catches after a single day-long fishing trip. The determination of catchability coefficient is important because it permits calculation of harvest levels from effort and population data.

After a thorough review of the literature, it becomes apparent that, while development of a complex biological simulator will require more information about the effects of environmental factors and stock size upon recruitment success, adequate data do exist to develop a model capable of accounting for age, growth, natural mortality, and fishing mortality. Certainly then, adequate data do exist to develop a biological simulator capable of providing yield data to an economic sub-model of the fishing industry. This type of model, while less useful as a predictor of long range absolute fluctuations in population levels, finds its greatest value as a management tool capable of assessing the merits of alternative management strategies in the short run.

CHAPTER III

DEMAND ANALYSIS

This chapter outlines the procedure followed to derive a short run price model for surf clams in the middle Atlantic landings market. The model is postulated to explain the demand for clams confronting middle Atlantic surf clam fishermen. This relationship will provide price levels to be used in the determination of total revenue accruing to surf clam vessel owners. Fishing revenue is a function of ex-vessel price and level of harvest. The primary function of this price relationship is, therefore, to predict certain ex-vessel price levels associated with various levels of harvest and prices of substitute commodities. Estimates of total vessel revenue can then be calculated and ranked according to management option, thereby providing resource managers with a tool for evaluating the merits of each proposed set of regulations.

Variables In the Price Equation

In an industry-wide survey conducted by the author (Appendix B), processing firms have identified factors that are influential in determining ex-vessel prices for surf clams. The size of clams offered for sale is a price determinant. According to current management regulations, surf clams harvested in the Fishery Conservation Zone must be of a length greater than or equal to five and one half inches in order to be harvested. Three of the ten major firms purchasing surf clams indicated that a price differential is paid for different size categories of surf clams. Small clams, usually taken inshore, are more costly to process than large clams taken offshore. Although size categories are not clearly defined by processors, a premium price may be paid for a shipment of clams if the processor determines that they are sufficiently large. Clam size may therefore be viewed as influential in determining price, with large clams commanding higher prices.

A review of the fishery price and demand literature indicates that several additional economic variables have also been considered in price models for clams. Visgilio (1973), in a review of fishery demand literature, specified several variables that may determine ex-vessel prices for surf clams. Visgilio's study indicated that quantity of fish product landed, inventory of fish product, fish size, consumer income, and the prices of substitute products, may all be important in specification of a price model for surf clams. Economists at the Virginia Polytechnic Institute and State University have developed a preliminary econometric model of Virginia's hard clam fishery. Preliminary studies have indicated that ex-vessel hard clam price may be determined by landings of hard clams, consumer demand for hard clams reflected in retail prices, and the prices of substitute products available (Kerns, 1981).

Such a price model may be applied to the surf clam fishery. Using only summary landings data from Fishery Statistics of the United States, the Mid-Atlantic Fishery Management Council has developed predictive annual and quarterly price equations for surf clams (Mid-Atlantic Fishery Management Council, 1981). The annual model described surf clam price as a function of United States per capita surf clam supply, United States per capita ocean quahog supply, and deflated United States per capita income. The quarterly model incorporated data for a five year period from 1976 through 1980. Surf clam price was determined to be a function of quarterly United States surf clam landings, quarterly United States ocean quahog prices, and quarterly United States per capita disposable income. Dummy variables were used to control for perceived structural differences in the fishery. Cessine and Strand (1978) postulated that surf clams may be viewed as an exhaustible resource. They hypothesized that the price of surf clams may be a function of time, surf clam supply, and the price of one substitute commodity, hard clams.

In summary, it would appear that middle Atlantic ex-vessel surf clam price can be realistically described as a function of the following variables: production, ex-vessel prices of substitute commodities, consumer demand reflected in retail clam product prices, size of clams, quality of clam meats, processor inventory of fresh and frozen product, consumer income, and time. Some of these variables are not included in the price model developed below because their distant relation and significance to surf clam price does not warrant a reduction in the model's degrees of freedom. Other variables are not included in the price model because adequate time series of data do not exist, and satisfactory proxy data are not available for these variables.

Variables Included in the Analysis

An examination of the variables expected to influence surf clam price indicates that there are a number of significant variables for which time series data are available. These variables have been included in the middle Atlantic price model.

Quantity of surf clams landed in the middle Atlantic region were expected to be negatively related to price. Time series data of monthly landings of surf clams are available and were included in the price equation.

The quantity demanded of a commodity has traditionally been expressed as a function of its price, the prices of all other commodities, and consumer income, $Q=f(p_1, p_2, p_3, \ldots p_n, y)$, where $p_2 \ldots p_n$ represent the prices of substitute commodities and y represents consumer income (Shumpeter, 1954). The results of a processor survey (Appendix B) and a review of the literature have identified substitute commodities for surf clams. Cessine and Strand (1978) have noted that large "chowder" hard clams (*Venus mercenaria*) taken inshore may serve as substitutes for surf clams. Surf clam processing industry executives note that, as a result of improved processing techniques, ocean quahogs have become completely substitutable for canned surf clam products. "In the canning industry it does not matter how small clams are, you can still grind them up. In the breaded clam strip business, a large foot is required. Companies that are not selling breaded product can use the smaller ocean quahog." (Personal Communication, Andrew Drewer, 1982). A survey of clam processors has indicated that consumers may view the following items as substitutes for surf clam products: all clam products, including whole and processed hard and soft clams (Venus mercenaria and Mya arenaria), oysters, seafood stew and chowder products, breaded shrimp, and breaded fish products. Visgilio (1973) indicates that soft clams and ocean quahogs may be viewed as close substitutes for surf clams. Miller and Nash (1970) have indicated that there may be a seasonal pattern of clam consumption that complements a seasonal change in oyster consumption.

Monthly ex-vessel landings and value data are available for ocean quahogs, hard clams, soft clams, and oysters from the middle Atlantic market area. The ex-vessel prices of these species were selected to be used as substitute commodity variables in the price model. Monthly landings data, in pounds of meats and dollar value of landings, were available for all of the middle Atlantic states except Delaware. Delaware state landings were not recorded, and were therefore excluded from the price model. As indicated below, the small portion of total landings contributed by this state justifies its exclusion. Monthly middle Atlantic landings were obtained by aggregating the landings of each individual state. Dollar values of landings in each month were similarly summed over all four states. Ex-vessel prices were calculated on the basis of meats landed, and then deflated by the producer price index to constant 1967 dollars. This year is used in U.S. Department of Commerce reports as a standard for calculation of a deflator index. When adequate data are available, other variables may be considered in the development of an ex-vessel price equation. However, adequate monthly time series data were not available to include the following relevant variables in the ex-vessel price equation: consumer demand reflected in retail surf clam product prices, clam size, quality of clam meats, and processor inventory of clams. Wholesale fish prices from Fulton Fish Market in New York, and National Marine Fisheries Service records of annual cold storage holdings might be used to measure the influence of consumer demand and processor inventory. These variables, however, were not included in this analysis.

Disposable income, often included in demand analysis, has not been included in the surf clam price equation because, as Visgilio (1973) notes, "Disposable income, is regarded as insignificant with respect to the demand for surf clams at the processor level. This judgement rests upon the fact that the percentage of disposable per capita income devoted to the purchase of all clams is approximately 0.0001 percent." Although some have advocated the use of per capita supply data to avoid confusing the time trend for population with one that might reflect other effects (Foote, 1957), per capita data are not used in this analysis because a monthly time series of this parameter was not available. Annual or quarterly data could not be expected to yield significantly improved results.

Ocean quahogs, because of their status as nearly perfect substitute commodities for surf clams, deserve special consideration. Historical ex-vessel prices for ocean quahogs should certainly be included in a surf clam price model. Middle Atlantic clam processors have shipped large numbers of ocean quahogs to their plants to be used in canned products. Since 1976, most of this product, 80 to 90 percent, has come from ports in New Jersey and Maryland. Prior to 1976, however, the center of the ocean quahog fishing industry was the state of Rhode Island. Prior to 1976, there were virtually no landings of ocean quahogs in any eastern seaboard state except Rhode Island. The primary landings market for this product, however, has always consisted of clam processors in the middle Atlantic states. Ocean quahogs were shipped to middle Atlantic plants in refrigerated trucks. Because of the importance of this clam as a substitute commodity for surf clams, and because a middle Atlantic fishery for this species has only developed in recent years, monthly Rhode Island landings and value data for ocean quahogs covering the entire history of the fishery have been included in the data set used to develop a middle Atlantic price model for surf clams.

An ex-vessel price model for surf clams in the middle Atlantic landings market is thus represented by the following equation:

$$P_s = f(Q_s, P_{oq}, P_{sc}, P_{hc}, P_{er}, S_{d1}, S_{d2}, S_{d3}, M_{dum})$$

Where,

P_s = Deflated ex-vessel surf clam price.

Q_s = Surf clam landings in pounds of meats.

P_{oq} = Deflated ex-vessel ocean quahog price.

P_{sc} = Deflated ex-vessel soft clam price.

P_{hc} = deflated ex-vessel hard clam price.

S_{d1}, S_{d2}, S_{d3} = A dummy variables used to explain seasonal price fluctuations.

M_{dum} = A dummy variable accounting for the effects of the surf clam management plan.

The results of the processing and harvesting sector surveys indicate that surf clam demand may slacken during the summer months creating a soft seasonal market. Processors attribute this slackening of demand to fluctuations in consumer preferences for soups and specialty products. The effect of this shift upon ex-vessel price is tested through the use of dummy variables.

Mdum is a dummy variable inserted to describe the effects of the surf clam management plan established in 1977. A number of structural changes in the fishery occurred with the implementation of fishery management regulations. In addition to supply constraints, minimum size limit restrictions resulted in the substitution of ocean quahogs for small surf clams, and the harvesting of larger surf clams. The net effect of these changes was to raise ex-vessel prices in the years after regulations were placed in force. The effect of structural change in the fishery is reflected in slightly higher ex-vessel prices.

Mechanism of Price Formation

A survey of surf clam processing firms and fishermen has indicated that, while it is generally accepted that industry-wide prices exist, short run ex-vessel prices do fluctuate significantly depending upon a number of determining factors. Results of the processor survey (Appendix B) indicate that there are in fact no formal contractual or written agreements between clam processors and boat owners to deliver quantities of clams at specific prices. Most processing firms have long standing agreements or relationships with surf clam fishermen. Most of these informal verbal agreements have existed for 12 to

15 years. To purchase clams, processors must contact fishermen, request a specific supply of clams, and quote the ex-vessel price that they would be willing to pay. Clam fishermen are thus given the option of agreeing to supply clams at a quoted price, or contacting different processors to seek higher prices. During periods when clams are abundant, fishermen often contact processing firms directly to offer clams for sale. Thus, for varying periods of time there is a relatively standard industry price which fluctuates depending upon, among other factors, the supply of clams offered for sale. The standard industry price fluctuates as processing firms raise or lower their prices. One industry executive (Andrew Drewer, Personal Communication, 1982) has provided the following account of ex-vessel surf clam pricing:

> If a company increases its price it tells the catchers that it needs additional supplies, other catchers then come in and sell at a higher price. Other processors must then raise their prices in order to obtain product. Processors will follow the price leader. Since there are generally less than ten companies that buy clams, individual companies can't afford to pay higher or lower prices for any length of time, they are more or less forced into line. When prices are rising, price information filters back to individual processors through the catchers. When prices are declining, processors see reflections of this in the marketplace.

Thus, quantity of clam meats harvested, tempered by less than perfect competition among processing firms, appears to be a significant short run determinant of ex-vessel clam price.

<u>Market Area</u>

the first task to be undertaken in an analysis of commodity price formation is determination of a relevant market area for price. This model confines itself to a consideration of surf clam price in the middle Atlantic region. The entire middle Atlantic region constitutes a relatively homogeneous ex-vessel market area for surf clams and related shellfish products. This argument is supported by information obtained from a survey of surf clam fishermen and processors, and also by the results of several recent analyses of clam price formation.

During the period of time spanning the years of 1950 through 1980, New England ports contributed only 0.5 percent of the surf clam meats landed in the United States. The remainder of the landings have came from the middle Atlantic states of New York, New Jersey, Delaware, Maryland, and Virginia. Surf clam landings in Delaware have historically contributed only 3.6 percent of the clam meats landed in the middle Atlantic region. Furthermore, landings in Delaware have been inconsistent. Few surf clams were landed at Delaware ports during the years of 1970 through 1975. These data would indicate that 96 percent of the ex-vessel landings market for surf clams exists at ports in the four middle Atlantic states of New York, New Jersey, Maryland, and Virginia. Landings from these states comprise virtually the entire surf clam catch taken in the United States. It was determined, therefore, that these four middle Atlantic states should comprise the market area to be used in the development of an ex-vessel price model.

The homogeneity of this market area may be inferred from the processor survey (Appendix B). Five of the ten middle Atlantic shucking plants surveyed do not operate landing facilities at their processing plants. Virtually all processing operations, even the dockside plants, purchase a large portion of their raw product directly from catchers landing clams at middle Atlantic ports. Clams are then shipped to plants in refrigerated trucks. Although processing plants prefer to obtain clams from the nearest available port, clams are routinely shipped from all of the middle Atlantic ports to processing plants throughout the middle Atlantic region. Homogeneity of the middle Atlantic shellfish market has been further substantiated by resource economists at the Virginia Polytechnic Institute and State University. An analysis of variance of hard clam prices in eastern seaboard states has indicated that prices in the middle Atlantic states are not significantly different. It was determined that the middle Atlantic region constitutes a large homogeneous market area for hard clams (Kerns, 1981). Interstate transport of shellfish has, in fact, created a large relatively homogeneous market in the middle Atlantic region. The mobility of the surf clam fleet, and the willingness of processing firms to purchase product wherever it is available, clearly indicates that the middle Atlantic states of Virginia, Maryland, New Jersey, and New York comprise a well defined and relatively self contained market area.

Statistical Estimation Procedure

Ordinary least squares regression was used to estimate the price model described above. Use of the single equation least squares approach appears to be justified in this case because, as indicated below, all of the independent variables in the price equation may be viewed as exogenous variables.

Arguments have been developed to support the use of both single equation and simultaneous equation methods in demand analysis. Fox (1953) has indicated that the decision regarding the use of single or multiple equation approaches is dependent upon the purpose of the investigation, and the possible joint dependence between dependent and independent variables. Fox notes:

> "If the purpose of the investigation is to estimate the expected price associated with given values for such variables as size of crop and consumer income, the best answer can be obtained by least squares regression with price dependent and other variables independent. If the purpose is to estimate the elasticity of demand and other structural coefficients, this equation may not give an unbiased estimate. It will do so if, and only if, current supply and other independent variables are not measurably affected by price during the marketing period. These conditions are approximately met for farm products. If they are not met, a system

> of simultaneous equations is needed if valid estimates of several coefficients of interest to economists and commodity analysts are to be obtained."

Support for the use of the single equation approach is evident in the work of Visgilio (1973) who identifies the proponents of this approach.

> "Foote (1957) supported the position that the single equation approach under certain conditions provides valid estimates of demand elasticity. He proclaimed, 'In some analyses we can assume that the quantity supplied is essentially unaffected by current price...Under these circumstances we may be able to obtain valid estimates of the elasticity of demand by use of a least squares regression analysis for which price is the dependent variable and supply and some demand shifters are used as independent variables.'"

Other resource economists have addressed the problem of determining whether to use single or simultaneous equation systems. Working (1927) has noted that:

> "Even though shifts of the supply and demand curves are correlated, a curve which is fitted to the points of intersection will be useful for purposes of price forecasting, provided no new factors are introduced which affect price during the period of study."

The purpose of this study is, in fact, evaluation of the efficacy of existing management efforts through forecasting. Hildreth (1968) and Klein (1960) both have argued that the use of single equation ordinary least squares analysis may be appropriate in situations where the investigator has adequate _a priori_ knowledge of the economic sector being studied. Hildreth has stated:

> "It is the responsibility of each empirical researcher to make the best choice based on available knowledge of statistical properties of different procedures under alternative circumstances, his a priori knowledge and beliefs about the workings of the economic sector being studied, and the particular purpose of the study."

Viegilio (1973) further notes:

> "The best prediction of economic variables is often provided by the single equation least squares approach; while the unbiased estimation of parameters such as demand elasticity may require a simultaneous equation approach."

The choice of the single equation method, therefore, appears to be justified if either of two conditions are satisfied. First, the primary objective of the study should be price prediction. Secondly, simultaneity should not exist between current price and current quantity during the market period.

Development of a price model is undertaken in this study in order to evaluate the economic impact of alternative surf clam management strategies. A primary objective of the study is the prediction of prices under different management regimes. This study therefore satisfies the first condition listed above. The second condition is also satisfied because, during the monthly market period surf clam supply is primarily determined by population stock size, level of fishing effort, weather conditions, and the operating schedules of surf clam processors. The importance of these factors in determining surf clam supply has been substantiated by the results of the survey of surf clam fishermen undertaken in this investigation. Under the assumption that monthly surf clam landings are an exogenous variable, single equation ordinary least squares regression provides the best linear unbiased estimator of price. This estimation technique can produce an accurate unconditional forecast of ex-vessel price. The most practical alternative to the use of ordinary least squares regression would be to run a two stage least squares procedure (Johnston, 1963). Given the complex nature of the supply function described above, the use of ordinary least squares regression is probably the most realistic, and certainly the most straightforward technique available to predict ex-vessel prices in a comparative management model.

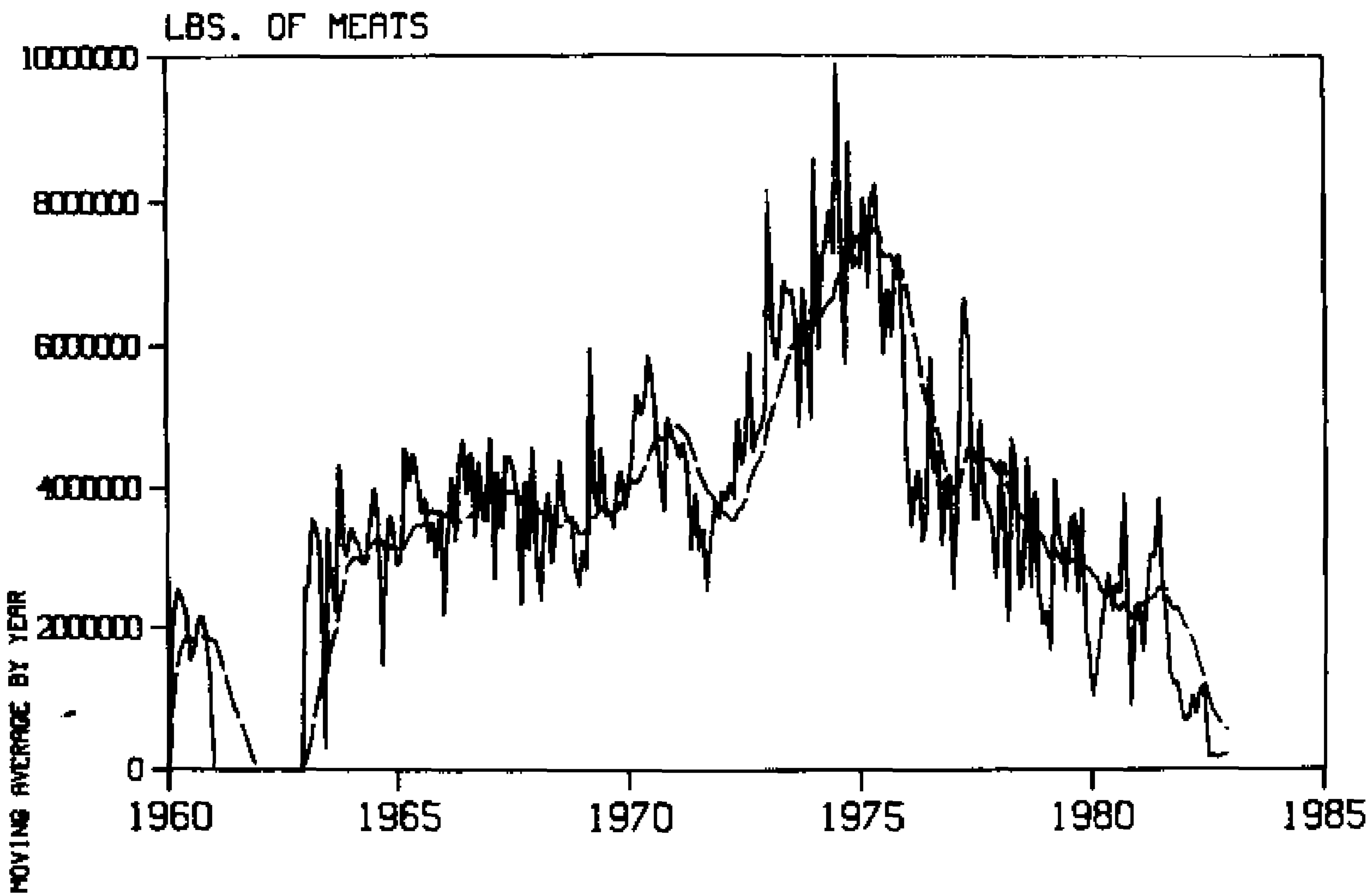
Results

The ex-vessel landings and value data used to derive the demand model were both located and identified by state and aggregated for the entire middle Atlantic region. Monthly deflated ex-vessel surf clam prices were calculated using the producer price index. The time series (Figure 5) illustrates a general increase in landings, peaking in 1975. This peak is followed by a substantial decline in landings during the years following 1975. Seasonal fluctuations in landings, while not clearly discernible,

Figure 5

Surf Clam Landings

SURF CLAM LANDINGS
1960 - 1982



may be indicated. Deflated ex-vessel surf clam prices exhibit relative stability until 1976, ranging from $0.13 per pound to $0.08 per pound. In 1976, there was a marked increase in deflated price to $0.26 per pound. This price increase is probably due to restricted surf clam supply resulting from resource depletion in 1976, and landings quotas established in 1977. Size limit restrictions may have also in part been responsible for ex-vessel price increases. Dummy variables have been introduced into the price model to measure the effects of seasonal demand shifts and externalities imposed by the establishment of a new management regime.

Bivariate linear regressions of deflated ex-vessel surf clam price on surf clam landings, on deflated ocean quahog price, on deflated hard clam price, on deflated soft clam price, and on deflated oyster price were derived. These variables were chosen upon the basis of their relationship as substitutes for surf clam meats. A demand equation was estimated using ordinary least squares multiple regression.

Various combinations and transformations of the data were applied, including log transformations and generalized first difference equations. In determining the type of transformation to be used, one seeks to decrease the heterogeneity of variance, bring the data closer to normality, and produce an additive model of the independent variables. As Snedecor and Cochran (1980) note, the transformation that restores additivity will unfortunately usually differ from the transformation that improves homogeneity of variance or induces near normality. Given this conflict, there is not likely to be an ideal transformation for a single body of data. It has been suggested that, in view of the simplicity and efficiency of an additive model, much can be said for giving primary attention to removal of non-additivity while remaining attentive to heterogeneity of variance (Snedecor and Cochran, 1980).

The criterion used to choose the appropriate relationship was the squared correlation for a significant regression coefficient, and a double logarithmic relationship was chosen as the appropriate transformation.

There were some missing values of ocean quahog prices in the time series of data. Ocean quahog prices were reported on a monthly basis only from 1969 through 1982. SPSS (Statistical Package for the Social Sciences, release 7-9, 1981) was used to analyze the data. This package provided several options for dealing with missing values. Each correlation coefficient is thus computed using records with complete data on the pair of variables correlated, regardless of whether the records have missing values on any other variable. Options included: 1) listwise deletion from the computation of all records with missing values, 2) pairwise deletion of records with missing values, 3) mean substitution (all missing values, y_{x}, are replaced with the mean of y_t). The analysis was performed using each option. It was determined upon the basis of squared correlation that the first option, listwise deletion of all records with missing values, produced the most statistically sound equation. Since all of the missing observations occurred in a block of data before 1969, the Durbin-Watson statistic was computed correctly. The number of workable observations was reduced from 276 to 145. However, this methodology ensured that partial correlations were all computed from the same populations. The results of the regression analysis are displayed in Table 6. As Table 6 indicates, the equation demonstrates reasonably solid statistical properties, and appears to perform well. The squared correlation, R^2, is high, explaining 94 percent of the variation in middle Atlantic ex-vessel price. All of the regression coefficients are significantly different from zero with at least 97 percent assuredness. An overall F test for goodness of fit of the regression equation indicates that the multiple correlation is significantly different from zero with greater than 99 percent assuredness. This result, however, should be interpreted with reservation due to the indication of autocorrelation described below. A sequential plot of the residuals was examined and provided no evidence of positive or negative heteroscedasticity. A frequency distribution of the standardized residuals superimposed upon a standard normal curve indicated that the residuals are approximately

Table 6

Regression Coefficients Describing the Ex-vessel Price Model for Middle Atlantic Surf Clams

SCP = -.0464 - .0596SCL + .6373OQP - .1960HCP + .1485OP + .8745DUM - .0728SD1

Std. Error	.0278	.0626	.0662	.0467	.0282	.0245
T Statistic	-2.14	10.18	-2.96	3.18	31.04	-2.98
Significance of T	.03	.00001	.003	.001	.00001	.003

F Ratio = 369.07 Significance of F = .00001
R Squared = .94
Durbin-Watson Coefficient = 1.12

Where:
SCP = Natural log of deflated ex-vessel surf clam price (in 1967 dollars/lb)
SCL = Natural log of middle Atlantic surf clam landings (in pounds of meats)
OQP = Natural log of deflated ex-vessel ocean quahog price (in 1967 dollars/lb)
HCP = Natural log of deflated ex-vessel hard clam price (in 1967 dollars/lb)
OP = Natural log of deflated ex-vessel oyster price (in 1967 dollars/lb)
DUM = A dummy variable controlling for the effect of the surf clam mamagement plan (= 0 prior to 1977, else = 1)
SD1 = A seasonal dummy variable controlling for seasonal fluctutations in price (= 1 for the months of December, January, and February, else = 1)

normally distributed. Examination of the correlation matrix indicated that, while there is some degree of multicollinearity, this is not a problem of importance. In fact, one could infer that the significance of the regression coefficients may be slightly underestimated as a result of variance inflation associated with multicollinearity.

Certainly, the most significant problem with this price equation is the evidence of some positive serial correlation. The D value of the Durbin-Watson statistic is rather low, indicating some positive autocorrelation of the error terms in the equation. This result is not unexpected since the data base used to develop the price equation is monthly time series data. Serial correlation has been noted in several seasonal and monthly seafood demand models developed from similar data (Waugh and Norton, 1969; Visgilio, 1973; Cessine and Strand, 1978; Kerns, 1981). Autocorrelation of the error component would violate the Gauss-Markov assumption that the covariance of the error terms must equal zero. The estimated regression coefficient is thus underestimated, resulting in inflated T ratios, and the appearance of greater levels of significance than in fact exist. Some econometricians have argued that, when serious autocorrelation is evident, the absolute value of the T ratios should be quite large to ensure a highly significant relationship between the dependent and independent variables (Granger and Newbold, 1974). *The T ratios of the regression coefficients in this* equation lie within an acceptable range (2.14-31.04). Correction for autocorrelation as described below was determined to be impractical and, despite some serial correlation indicated by the Durbin Watson Coefficient, the equation represents a useful tool for the projection of monthly ex-vessel surf clam prices.

Discussion

With the exception of the seasonal dummy variable, the signs of all regression coefficients in the demand equation are consistent with theoretical and a priori knowledge of the fishery. Surf clam ex-vessel prices were negatively related to surf clam landings, hard clam prices, and a winter fishing season during the months of December, January, and February. The price of a commodity is normally expected to be negatively related to the prices of substitute commodities. The regression coefficients of the equation are displayed in Table 6

The negative regression coefficient of the ex-vessel surf clam quantity variable conforms to economic theory. The price flexibility estimate for surf clams of -.0596 would indicate that surf clam price elasticity of demand is relatively elastic.

The negative regression coefficient associated with winter season is contrary to the expected relationship. Decreased winter landings due to bad weather and increased winter demand for soup and chowder products were expected to result in higher seasonal prices. Several dummy variables were initially introduced into the regression equation. Spring, summer, and fall dummy variables, and various combinations of these variables, were dropped from the equation because they were statistically insignificant. The negative regression coefficient on the dummy variable can be attributed to several factors. This equation did not account for processor or retailer inventories. The confounding effects of inventory shifts may actually produce a lower winter price despite higher consumer demand during these months. An additional explanation of this negative price-season relationship may be inherent variation in seasonal demand for several different surf clam products. Although soups and chowders may be in greater demand during the winter months, it is certainly possible that demand for other surf clam products, clam strips, minced clams, clam juice, and stuffed clams, may demonstrate peaks during the spring, summer, or fall seasons.

The negative regression coefficient of the ex-vessel hard clam (Venus mercenaria) price variable would appear to contradict economic theory. The complexity of the relationship between hard clams and surf clams, however, explains the observed result. Hard clams displace surf clams in the soup market. Rising ex-vessel prices of hard clams are often indicative of clam harvests containing a large percentage of chowder grade clams. This result occurs because, if taken in sufficient quantity, lower priced, less desirable, chowder grade hard clams are culled before a sale is made. The ex-vessel price of hard clams thus rises since the harvest is considered to be more desirable by processors and shuckers. If taken in less abundance, chowder grade hard clams are not culled before a sale is made and ex-vessel hard clam prices remain constant. Therefore, ex-vessel surf clam prices are negatively affected by rising hard clam prices, because rising hard clam prices are often associated with the availability of more chowder grade hard clams in the soup market. The increased availability of chowder grade clams functions to drive down the ex-vessel price of surf clams.

Surf clam ex-vessel prices were positively related to ex-vessel ocean quahog prices, ex-vessel oyster prices, and a dummy variable accounting for recent structural changes caused by new management regulations. Ex-vessel ocean quahog prices demonstrate a highly significant positive relationship with ex-vessel surf clam price. The strength of this relationship confirms the status of ocean quahogs as very close substitutes for surf clams. The positive relationship between ex-vessel surf clam and oyster prices indicates a degree of substitutability of oysters for surf clams. This result is in accord with the views expressed by many surf clam processors, who believed that oysters and surf clams are competitors in the soup and seafood specialty markets. The dummy variable, used to account for a structural change in the fishery induced by the surf clam management plan, indicates that management has functioned to increase the ex-vessel price of surf clams.

Ex-vessel soft clam prices were not significantly related to ex-vessel surf clam prices. This variable was dropped from the price equation. Such a result is not unexpected. Although small numbers of soft clams are processed to provide clam strips, soft clams are not used to produce soup, chowders, or other surf clam food products. Ocean quahogs, chowder grade hard clams and oysters were identified as the closest substitutes for surf clams. These species are all used in soups, chowders, stews, and specialty products. Thus, the price equation accurately reflects both theoretical economic precepts and *a priori* beliefs regarding the demand for surf clams in the middle Atlantic landings market.

Problems and Future Research Needs

Construction of an improved ex-vessel price model for surf clams would require the development of a realistic supply relationship, and experimentation with additional variables in the price equation. Development of a surf clam supply curve will be very difficult, if not impossible, because binding quotas are used to manage the fishery. Therefore, the equation developed above must suffice for this analysis. As indicated above, an attempt was made to correct this price equation for autocorrelation. Using the method of Theil and Nager (1971), the first order autocorrelation coefficient was calculated, and all variables were transformed into generalized first differences as indicated below.

$$z = n^2(1-1/2d) + k^2n^2 - k^2$$

where:

z = Estimated autocorrelation coefficient

d = Durbin - Watson coefficient

k = Number of variables in the equation

n = Number of observations in the time series

$$y^* = y_t - y_{t-1}$$

$$x^* = x_{jt} - x_{jt-1}$$

where:

y^* = Transformed dependent variable

y_t = Dependent variable in time period t

y_{t-1} = Dependent variable in period t-1

x^* = Transformed independent variable

x_{jt} = Independent variable in period t

x_{jt-1} = Independent variable in period t-1

The generalised first difference equation failed to produce an improved model. There are two probable reasons why this correction did not improve the model. The Durbin-Watson coefficient tests for any non-randomness in the error term. The problem might, in fact, be caused by omitted variables, not autocorrelation.

It is hard to form a judgement about the amount of bias that could be caused by omitted variables. A variable such as surf clam landings could be positively correlated with omitted variables such as surf clam quality or size. Omission of these variables could result in overestimation of the regression coefficient on surf clam landings. Similarly, high levels of processor inventories may be correlated with lower surf clam prices as well as lower ocean quahog prices. Omission of this variable would result in underestimation of the regression coefficient on ocean quahog price. Future research might attempt to include some of the variables identified above in a surf clam price model. Adequate time series data are not currently available to develop a more comprehensive price model. It is also possible that higher order autocorrelation is a cause of serial correlation. It has been demonstrated that, if higher order autocorrelation does present a problem, it is much better to apply ordinary least squares regression analysis than to correct for first order autocorrelation (personal communication, Moody, 1982). Future research might, therefore, focus upon identification of the higher order autocorrelation problem. Despite its limitations, the price model developed above appears to be quite satisfactory for evaluating the effects of alternative surf clam management strategies.

Chapter IV

Cost Analysis

In order to develop a realistic bioeconomic model of surf clam fishing and processing operations, it is imperative that information about the cost structure of the fishing and processing industry be gathered. These data are often very difficult to collect due to the reluctance of entrepreneurs and businessmen to disclose information perceived to be of value to competitors. Fortunately, some data describing the cost structure of the surf clam fishing industry have been gathered by the National Marine Fisheries Service. These data are reported in the Regulatory Impact Review of Amendment #3 to the Surf Clam and Ocean Quahog Fishery Management Plan (Mid-Atlantic Fishery Management Council, 1981). The cost inputs generated for use in this model have been derived from the Regulatory Impact Review, as well as from a survey of all surf clam fishing and processing firms in the United States. The surveys employed are displayed in Appendix B. The following chapter identifies the variable and fixed costs incurred during business operations in the surf clam industry, describes the capital and raw material inputs required by processors and fishermen, and characterizes the surf clam processing industry. The chapter also explains the procedure followed to gather these data.

Sources of Fishing Sector Data

Survey questionnaires provided in Appendix B were mailed to the owners or operators of 320 fishing vessels licensed to harvest surf clams or ocean quahogs in the United States. Personal interviews based upon the results of questionnaire returns were conducted with ten vessel owners. Thus, virtually all vessels licensed to fish for surf clams or ocean quahogs in the United States were contacted. Responses were obtained from 35 active surf clam vessels, or approximately ten percent of all licensed surf clam fishing vessels. Although this represents a relatively small percentage return, it should be noted that many vessels licensed to harvest surf clams are not presently operating in the fishery. Current regulations require that, in the middle Atlantic region, vessels must harvest at least 8,000 bushels of clams from the Fishery Conservation Zone (surf clams or ocean quahogs) annually in order to receive a permit in a subsequent year. In New England, permits of vessels that do not meet this criterion can be renewed indefinitely without requiring that the permit holder actually harvest any surf clams or ocean quahogs. Thus, many New England owners retain surf clam and ocean quahog harvesting permits while fishing for groundfish or lobsters. A number of New England clam vessel owners responding to the questionnaire survey indicated that they plan to initiate fishing operations for ocean quahogs in the future. Bi-weekly and monthly logbook reports on Fishery Conservation Zone surf clam fishing activities were obtained from the National Marine Fisheries Service for the years 1978, 1979, 1980, and 1981 (National Marine Fisheries Service, 1981). These reports indicate that, as of July 1981, the last month examined, there were a total of 145 vessels licensed to harvest surf clams and ocean quahogs in New England, and only 63 vessels licensed to fish for ocean quahogs only. According to National Marine Fisheries Service logbook records examined, an average of only 70 vessels were actually engaged in clam harvesting activities during each monthly reporting period from 1978 through 1981. The total number of licensed vessels was 331 in 1982. The low percentage return of survey questionnaires can thus be attributed both to the reluctance of fishermen to disclose any financial information concerning their operations, and to the large number of license holders who do not operate their vessels in the fishery. According to National Marine Fisheries Service statistics, only 44 vessels harvest approximately 70 percent of Fishery Conservation Zone surf clams (National Marine Fisheries Service, 1981). It would appear, therefore, that even a small sample of fishing vessels would be quite representative of harvesting activities.

Identified Costs of Fishing

Survey returns and a review of the literature have indicated that the following cost categories define the surf clam fishing operation. Vessel costs have been segregated according to three vessel size classes. This division is in keeping with the convention employed by the Mid-Atlantic Fishery Management Council for various analyses of the surf clam fishery. The three vessel classes have been determined upon the basis of gross registered tonnage. Class I vessels are less than or equal to 50 gross registered tons, Class II vessels are between 51 and 100 gross registered tons inclusive, and Class III vessels are greater than 100 gross registered tons. Fixed costs of fishing include: 1) port fees (wharfage), 2) fixed boat and equipment repair and maintenance costs (this includes services for welding, electricians, mechanics, shipbuilders, and the marine railway), 3) vessel hull insurance, 4) personal liability and indemnity insurance, 5) loan interest payments, 6) license fees and taxes, 7) legal-accounting fees, and 8) depreciation on vessels and equipment. Variable fishing costs include: 1) labor, 2) fuel and oil, 3) food, 4) variable maintenance, and 5) variable supplies.

Quantification of Identified Fixed Costs

Because of the diversity of vessels engaged in the surf clam fishery, and the variety of operations management strategies in the fishery, it is difficult to identify average costs of fishing for surf clams. Costs within specific categories may be widely divergent from one fishing operation to another. Table 7 displays the mean values of vessel characteristics for vessels sampled in the fishing industry survey. This table reflects the great variation in physical characteristics of vessels comprising the surf clam fleet. Table 8 displays data obtained from surf clam fishing license applications by the Mid-Atlantic Fishery Management Council, and further demonstrates the diversity of surf clam fleet characteristics. These data describe the surf clam fleet in 1979. According to the Council, "Tonnage per vessel ranged from one to 306 tons, with an average of 110 tons. Vessel length ranged from 198 to 146 feet, with an average of 81 feet. Crew size ranged from two to seven men, with an average of three men. The size of the dredges used on surf clam vessels ranged from 22 to 240 inches in width with an average length of 88 inches" (Mid-Atlantic Fishery Management Council, 1981).

Development of a bioeconomic management model requires estimates of average operating expenses to be used as input parameters. Average costs are therefore described and defined below. Costs are defined in 1981 dollars because this was the last year for which complete data were available at the time of the vessel survey. Where deemed necessary, costs that have been obtained from the literature have been inflated or deflated to 1981 dollars using the consumer price index.

Port Fees

Table 7

Mean Characteristics of Vessels Sampled in the Surf Clam Fishing Industry Survey

Characteristic	Class I	Class II	Class III
Length	37 ft	74.9 ft	84.3 ft
Draft	4.25 ft	7.4 ft	11 ft
Fuel Capacity	530 gal	2,893.7 gal	10,000 gal
Cruising Range	100 mi	891.3 mi	5,000 mi
Age	21 yr	22.4 yr	10.3 yr
No of Dredges	1.0	1.1	1.0
Blade Width	46 in	83.5 in	96.6 in
Crew Size	1.6	2.0	2.3
Load Capacity	200 bu	800 bu	1,400 bu
Market Value	$53,333	$225,000	$530,000

Table 8

Mean Vessel Characteristics Obtained From Vessel Licenses

	Length	Gross Tonnage	Crew Size
Minimum	18 ft	1	2
Maximum	146 ft	306	7
Average	80 ft	108	3

Port fee expenses were not uniformly incurred by all vessels in the surf clam fishing fleet. Many vessel operators owned their docking facilities and therefore reported no port fees. Movement between ports, however, often necessitated payment of port fees. Average port fee costs, when incurred, were $200.00 per month or $2,400.00 per year.

Boat Repair, Hull Insurance, Depreciation, and Interest

The fixed costs of boat repair and maintenance, hull insurance, depreciation, and interest payments were determined to be very closely related and unique to each vessel. It is virtually impossible to separate these expenses into well defined average costs representative of each vessel class, although such a procedure was initially attempted. This finding is in agreement with the Regulatory Impact Review of Amendment #3 to the Surf Clam Fishery Management Plan, "Charges for hull insurance, maintenance, depreciation, and interest are probably unique to each vessel, and are determined by age, vessel construction, vessel activity, type of ownership, and length of current vessel ownership. These four cost items remain the same, given the size of the vessel. For example, a new steel hulled vessel would have low hull insurance and maintenance costs and very high depreciation and interest costs. An old wooden hulled vessel would have very high insurance and maintenance costs and very low depreciation and interest costs" (Mid-Atlantic Fishery Management Council, 1981). For some extremely old vessels, hull insurance was identified as an unacceptable operating expense. Table 9 provides the average annual costs for these items as identified by the survey of surf clam fishermen conducted for this study. Table 10 displays a list of the electronic equipment required to conduct surf clam fishing operations and associated average annual depreciation expenses. Table 11 displays average depreciation expenses associated with other durable equipment, average annual costs for hull insurance, fixed equipment repair and maintenance costs, and other fixed costs. Average annual values for interest costs and vessel depreciation expenses are not indicated because of the great variation in these expenses among vessels within the same size classes. These values provide interesting comparative statistics. As noted above, however, it is impossible to assign meaningful absolute values to each of these costs when they are considered independently. The individual magnitude of each of these expenses is determined by the operating strategy of each vessel owner. Distribution of expenses among the cost categories is dependent upon the operator's decision to use old or new equipment. A more realistic, albeit less precise, approach to defining these costs has been outlined in the Regulatory Impact Review of Amendment #3 to the Surf Clam Ocean Quahog Fishery Management Plan (Mid-Atlantic Fishery Management

Table 9

Summary of 1981 Average Reported Fixed Fishing Costs

Fixed Costs	Class I (N=14)	Class II (N=22)	Class III (N=9)
Port Fees	$2,400	$2,400	$2,400
Boat Repair, Hull Insurance, Vessel Depreciation, Interest Costs	$34,000	$49,000	$78,000
P&I Insurance	$5,000	$6,000	$10,000
License Fees, Taxes	$1,000	$2,000	$4,000
General Admin. Expenses	$900	$1,000	$1,000
Total Fixed Costs	$43,200	$60,400	$94,500

Table 10

Electronic Equipment Required For surf Clam Fishing Vessel Operation

Equipment	(% of vessels operating with equipment) Class I (N=14)	Class II (N=22)	Class III (N-9)	All Vessels
Radar	64%	100%	100%	92%
Fathometer	100%	100%	100%	100%
VHF Radio	100%	100%	100%	100%
CB Radio	35%	50%	35%	43%
Scanner	33%	25%	0%	21%
LORAN	100%	100%	100%	100%
Plotter	0%	75%	100%	79%
Autopilot	0%	50%	65%	43%
Knotmeter	35%	38%	0%	29%
Average Years of Equipment Life	5	5	5	5
Average Replacement Cost of Electronic Equipment	$15,333	$35,285	$42,500	$27,000
Average Annual Depreciation Expense	$3,066	$7,057	$8,500	$5,400

Table 11

Average Annual Fixed Costs of Vessel Operation

Costs	Class I (N=14)	Class II (N=22)	Class III (N=9)
Equipment Repair and Maintenance	$5,000	$20,000	$40,000
Insurance	$3,100	$10,000	$14,000
Vessel Depreciation	Highly Variable Depending Upon Size/Age		
Interest	Highly Variable Depending Upon Size/Age		
Main Engine Depreciation	$1,400	$2,283	$2,166
Pump Engine Depreciation	$1,400	$2,283	$2,166
Time Between Engine Overhauls	5 yr	5.4 yr	6 yr
Main Engine Life	27.5 yr	20.6 yr	N/A
Replacement Cost of Engine	$10,000	$25,166	$50,000
Cost per Overhaul of Main Engine	$7,000	$12,333	$13,000
Legal-Accounting Fees	$1,300	$1,397	$2,000
Hydraulic Dredge Depreciation Expense	$1,600	$1,572	$1,625
Replacement Cost of Dredge	$8,000	$8,333	$8,125
Dredge Life	5 yr	5.3 yr	5.25 yr
Depreciation on Other Gear	$5,000	$5,000	$5,000
Port Fees	$2,400	$2,400	$2,400
Gen Admin Costs	$900	$2,000	$4,000

Table 11 Continued

Costs	Class I	Class II	Class III
License Fees and Taxes	$1,000	$2,000	$4,000

Note: Engine depreciation has been calculated as overhaul cost/average time between overhauls.

Overhaul costs for main and pump engines are approximately equal. Pump engine life is estimated to be 20% longer than main engine.

Depreciation costs of other gear includes hoses, cables, etc.

Council, 1981). Under this approach, the fixed costs of boat repair and maintenance, hull insurance, depreciation, and interest payments are estimated to equal seven percent of the value of the vessel. This value estimate is dependent upon the tonnage of the vessel and the annual landings of the vessel. Using this approach, the average annual fixed costs of hull insurance, maintenance, interest, and depreciation for each vessel class were estimated to be:

Class I	Class II	Class III
$34,000	$49,000	$78,000

Personal Liability and Indemnity Insurance

Vessel insurance costs have escalated dramatically during the past decade. Because many vessel owners are covered under an "umbrella" insurance policy, the fishing industry survey conducted for this study has not permitted separation of personal liability and indemnity or "P&I" insurance from vessel hull insurance expenses. Average annual total insurance expenses for a Class I vessel were reported to be $3,100.00. Average insurance expenses for a Class II vessel were $6,000.00, and average insurance expenses for a Class III vessel were $10,000.00.

License Fees and Taxes

Although not taxed uniformly in every state, vessel owners indicated that personal property taxes are paid on surf clam fishing vessels. State licenses are required for surf clam fishing within the state territorial waters of Delaware, Maryland, New Jersey, and New York. All vessels must be licensed by the United States Coast Guard and obtain a federal fishing permit for surf clams and ocean quahogs, ocean quahogs only, or New England surf clams only. Average annual license fees and taxes were reported to be $1,000.00 for a Class I vessel, $2,000.00 for a Class II vessel, and $4,000.00 for a Class III vessel. In Virginia personal property tax liability is highly variable, depending upon home port. Cities and counties use different valuation formulas and tax rates. In the City of Hampton, vessels are valued at ten percent of purchase price, and are assessed at $4.75 for every ten dollars of valuation.

Legal-Accounting Fees

Most vessel owners surveyed retained an accountant to handle tax reporting and corporate record keeping. Legal assistance was also occasionally required. Average annual expense for these items were reported to be $1,300.00 for Class I vessels, $1,397.00 for Class II vessels, and $2,000.00 for Class III vessels.

General Administrative Expenses

An additional fixed cost of conducting fishing operations was identified categorically as general administrative expense. This cost category includes travel, office expenses, and land based equipment depreciation expenses. Most independent fishermen operated offices in their own homes with no additional employees required. Vertically integrated fishing operations minimized fixed costs of fishing by conducting operations from large consolidated central offices. Estimated additional fixed administrative costs were reported to equal $400.00 per year for Class I vessels, and $500.00 per year for Class II and III vessels.

Quantification of Identified Variable Costs of Fishing

Labor

Labor represents the largest variable expense incurred by surf clam vessel operators. Wages are paid to crew members and vessel captains as percent shares of gross stock. The average boat share for both Class I and Class II vessels was reported to be thirty percent of gross stock. In each case, twenty percent of the gross stock was reserved as compensation for the vessel captain. Class III vessels reported an average crew and captain boat share totaling thirty-five percent of gross stock. Twenty percent of this total was paid as crew compensation, and fifteen percent was paid as compensation to vessel captains. These wage estimates are in agreement with labor cost estimates of the Mid-Atlantic Fishery Management Council, which total one third of gross stock for the entire surf clam fishing fleet (Mid-Atlantic Fishery Management Council, 1981). Owners who are also captains of their vessels collect the captain's share plus any additional income accruing as vessel earnings.

It should be noted that some individual vessel owners may pay larger boat shares, taking their own compensation as a greater portion of crew share instead of higher income through vessel earnings. The Mid-Atlantic Fishery Management Council has noted that, "Some corporately owned vessels, which pay crew expenses such as personal gear, food, and taxes, may pay a considerably lower crew share." However, if total compensation and benefits paid by the owner to the crew are included, labor costs are generally quite uniform.

Fuel Expenses

The second largest variable cost incurred by vessel owners is the cost of fuel. Survey results indicate that fuel and oil costs for surf clam fishermen increased 100 percent between 1977 and 1981. Fuel prices have, however, remained stable during the past four years. The average price of a gallon of fuel available to surf clam vessel owners in 1981 was $1.10. In 1982, this price declined for the first time in a decade to $1.05 per gallon. Fuel costs are dependent upon vessel fuel efficiency, which is determined by vessel age, engine specifications and tune-up, and vessel design. Differences in required travel distances to the surf clam beds and weather conditions also determine fuel costs. Despite these differences, it is possible to identify variable fuel expenses associated with each vessel class. Vessel owners provided data describing fuel consumption during a fishing trip. Class I vessels required an average of 300 gallons of fuel per trip, Class II vessels required an average of 500 gallons of fuel per trip, and Class III vessels required an average of 600 gallons of fuel per trip. These values can be expressed as gallons of fuel consumed per bushel of clams harvested. National Marine Fisheries Service logbook data for 1978, 1979, 1980, and 1981 may be used to derive average catch per trip estimates for each vessel class. Calculations indicate that during these years, Class I vessels consumed an average of 1.75 gallons of fuel per bushel of surf clams harvested, Class II vessels consumed an average of 2.14 gallons of fuel per bushel of clams harvested, and Class III vessels consumed an average of 1.47 gallons of fuel per bushel of clams harvested. Class II vessels would thus appear to be less fuel efficient than Class I or Class III vessels with respect to harvesting capacity. If the population density of surf clams were to increase significantly, fuel costs per bushel harvested could be expected to decline. However, given the relative stability of National Marine Fisheries Service catch per unit of effort statistics, these fuel consumption statistics appear to accurately reflect present variable fuel costs in the fishery.

<u>Other Variable Costs</u>

The remaining variable costs of conducting fishing operations include the cost of food and miscellaneous supplies consumed during a day of fishing. Such supplies include replacement blades for dredges, rope, and gear replacement parts. Average food cost per trip was reported to be $60.00 for Class I vessels, and $80.00 for both Class II and Class III vessels. An average variable cost estimate for both food and miscellaneous supplies equaled $372.00 per trip for Class I vessels, $371.00 per trip for Class II vessels, and $577.00 per trip for Class III vessels. These values can be expressed as approximate costs per bushel of clams harvested by using National Marine Fisheries Service logbook statistics of bushels of clams harvested per trip in 1978, 1979, 1980, and 1981. Once this calculation is performed, it is evident that food and miscellaneous supply costs have amounted to $1.99 per bushel harvested for Class I vessels, $1.74 per bushel for Class II vessels, and $1.56 per bushel for Class III vessels. These cost estimates reflect the economies of scale associated with larger vessel size.

Table 11 summarizes the average annual reported fixed costs of surf clam fishing operations, and Table 12 summarizes the variable costs of conducting surf clam fishing operations. Variable costs are reported as both

Table 12

Summary of 1981 Average Variable Fishing Costs

Variable Costs	Class I	Class II	Class III
Crew Wages	20% Gross	20% Gross	20% Gross
Captain's Wages	10% Gross	10% Gross	15% Gross
Fuel	300 gal/day	500 gal/day	600 gal/day
Miscellaneous Supplies and Food	$372/day ($1.99/bu)	$371/day ($1.74/bu)	$577/day ($1.56/bu)
Costs of Switching to Ocean quahogs	$25,000	$25,000	$25,000
Costs of Switching to Red Crabs or Lobsters	$150,000	$150,000	$150,000

costs per one day fishing trip and as costs per bushel of surf clams harvested. Also reported in Table 12 are estimated costs of switching from the surf clam fishery to ocean quahog or lobster/red crab fishing operations. The results of the fishing industry survey conducted for this investigation indicate that, if vessel owners were no longer able to operate at a profit in the surf clam fishery, 85 percent of the vessels currently equipped to fish only for surf clams would attempt a permanent switch to a directed fishery for ocean quahogs. The average estimated switching cost to go from surf clam to ocean quahog fishing operations was estimated by fishermen to equal $17,500.00. As noted in previous chapters, ocean quahogs are generally smaller than surf clams. Thus, switching to a directed fishery for this species would require welding additional slats on the hydraulic dredges used for surf clam harvesting. Start up costs associated with the initiation of new and unfamiliar fishing operations also comprise an undefined portion of switching costs. Switching to lobster and red crab fishing operations was identified as the next most attractive option after ocean quahog fishing. The average costs associated with this switch were estimated to be $150,000.00. Vessel owners surveyed also indicated that they would switch their fishing operations to target upon bottomfish should surf clams become unavailable, but no switching costs were reported. Approximately five percent of the vessels surveyed reported that they would leave the commercial fishing industry if they were unable to harvest surf clams.

Inflationary Changes in Costs

In addition to requesting data defining the cost of fishing operations, the fishing industry survey conducted for this study solicited estimates of operating cost changes that have occurred during the past ten years. Responses to these questions indicated that: during the five year period between 1976 and 1981, boat repair and maintenance costs increased 75 percent, port fees remained relatively constant, interest rates on loan payments increased 100 percent from an annual percentage rate of eight percent to an annual rate of 16 percent, legal-accounting fees increased 50 percent, and during the three year period between 1977 and 1981, fuel expenses increased 100 percent. These cost increases have inflicted hardships upon clam harvesters because, during the period of general cost increases, the ex-vessel price of surf clams declined from more than $12.00 per bushel to less than $9.00 per bushel. Management quotas also reduced the allowable catch during this same period of time.

The results of the fishing industry survey and a review of the literature have provided realistic estimates of surf clam fishing costs to be used as input parameters for the economic submodel of the harvesting sector. All of the surf clam fishing vessel owners surveyed provided these data reluctantly, and some were unwilling to provide data at all. The large vertically integrated firms were the least cooperative providers of economic data. To develop model input parameters in even greater detail, collection of data will require the force of law.

Sources of Processing Sector Data

There are two market levels in the surf clam processing sector. Clam shucking operations purchasing raw product ex-vessel constitute the first market level. Canners and clam specialty product producers comprise the second market level. On the second level, processors purchase shucked clam meats that are produced by clam shuckers on the first level. Producers may also produce their own shucked output in a vertically integrated operation. Thus, it is not always possible to distinguish the lines of demarcation between these levels. "In the case where large processing companies are vertically integrated from the wholesaling of packed surf clam products to engaging in fishing operations, distinct lines of separation among market levels becomes extremely vague or non-existant" (Visgilio, 1973). The processing plants of interest in this study, however, are those that purchase or obtain their clams directly from fishing vessels. The processing sector in this model is therefore defined as that portion of the industry obtaining ex-vessel clams and processing those clams into raw or frozen meats to be further processed.

Survey questionnaires were mailed to all 30 plants processing surf clams and ocean quahogs in the United States, and personal interviews were conducted with eight of the nine owners or managers of surf clam and ocean quahog processing plants in Virginia. Data were obtained from 12 different processing plants representing 40 percent of the identified surf clam processing operations in the United States. Most of the clams harvested in the middle Atlantic region are purchased by ten companies. Five of these major purchasors participated in this study. Several large vertically integrated firms declined to participate in the study. Those firms indicated that they feared leakage of confidential information and economic data to competitors.

Identified Costs of Processing

Based upon the results of the processor survey, the following cost categories have been identified for clam shucking operations. Most of these costs are either variable or semi-variable: raw product costs, cost of transporting clams into plants, royalty cost paid for the use of eviscerating machinery, labor costs, cost of salt or other chemicals used in the washing stage of processing, cost of diesel fuel used to heat plant and water, cost of propane used in shucking machinery and forklifts, cost of packaging material, electricity costs, depreciation of machinery and equipment, repair and maintenance costs, overhead costs (includes office and administrative expenses), and insurance costs. Clam-shucking operations sell clams in the fresh state to companies that slice them, bread them, freeze them, can them, or incorporate them into other specialty products. As the price of clams rises or falls, the selling price of shucked meats rises or falls. Shucking operations thus define all of of their processing costs in terms of costs per unit of shucked output, and determine the cost of shucked meats by adding these costs plus a profit margin to the ex-vessel price of clams. In so doing, processors thus attempt to maintain a stable profit margin. In most plants, processing costs are evaluated semi-annually and adjusted for inflation if deemed necessary.

Quantification of Processing Costs

Table 13 displays the mean percentage of total processing costs that processors allocated to each cost category identified above. It is somewhat difficult to characterize an average clam shucking operation because economies of scale, geographic location, and management effectiveness all contribute to operating efficiency. However, as Baumol (1961) notes, "In competitive equilibrium, every firm in the industry must have the same costs, for the product price will be the same for all such

Table 13

Surf Clam Processing Costs 1981-1982

Cost Category	Mean Percentage of Processing Cost Per Pound of Meat
Raw Product	*
Transportation of Raw Product to Plant	6.7%
Payment for Use of Patented Machinery	2.3%
Labor Costs	15.0%
Fuel Oil	3.4%
Propane	4.3%
Electricity	7.7%
Equipment Depreciation	5.2%
Repair and Maintenance	9.8%
Overhead (Includes All Other Administrative and Miscellaneous Costs)	14.7%
Insurance	2.8%
Legal-Accounting	1.2%
Storage and Freezing	1.3%
Salt and Other Chemicals	1.8%

* As noted in Chapter 3, the cost of raw product fluctuates depending upon its availability and the prices of substitute commodities. It is therefore considered separately from other processing costs.

companies, and both marginal and average costs will equal price for all firms." Moreover, as illustrated below in the discussion of processing plant characteristics, many of the clam-shucking operations surveyed are similar in scale, annual volume processed, plant capacity, and other operating characteristics. Labor costs, averaging 15 percent of processing costs, constitute the largest single percentage of total processing costs exclusive of raw product costs. Many plant operators, however, are currently reducing labor costs through increased automation of shucking, separating, and washing activities. Overhead costs, equipment repair and maintenance costs, fuel costs, transportation costs, and packaging costs contribute decreasing percentages of total processing costs respectively.

The total cost of processing a pound of clam meats did not display great variation among processing operations surveyed. Processing costs do, however, demonstrate marked seasonal fluctuation. Processors have indicated that, during the spring and fall months prior to clam spawning, the yield of meats per bushel of clams is higher than during the summer and winter months after spawning has occurred. Thus, processing costs per pound of clam meats are reduced ten to fifteen percent during the higher yielding months. During the months of low yield, less meat is produced, although the same number of shells must be handled. During the summer and winter months of 1981-1982, the mean cost of processing clam meats was $0.34 per pound. During the spring and fall months the mean cost of processing clam meats was $0.31 per pound. These processing costs are slightly less than the identified costs of processing ocean quahogs because ocean quahogs are smaller and more shells must be handled. Mean cost of processing ocean quahog meats was reported to be $0.40 per pound during the summer and winter fishing seasons and $0.34 per pound during the spring and fall fishing seasons.

Industry Profit Margin

As noted above, the price at which shucked meats are sold is determined by adding raw product costs and processing costs to a profit margin. The profit margins (return on investment) of the processing firms participating in this study ranged from ten percent to 15 percent of processing costs. The mean profit margin identified for surf clam shucking operations was 11.7 percent of processing costs. Some limited data were obtained identifying profit margins associated with higher levels of the clam processing industry (i.e. secondary processing of raw product). These data indicated that profit margins were considerably lower, approximately five percent of operating costs, for secondary processing operations farther removed from shucking operations.

Processing Plant Characteristics

In addition to deriving surf clam processing costs, one objective of this research was to investigate the raw materials and capital inputs required for clam shucking operations, and to characterize elemental facets of processing operations. The remainder of this chapter describes plant operations identified by the processor survey.

Supply Sources, Products, and Facilities

While most of the businesses participating in the study survey processed primarily surf clams, some plants also processed other species of shellfish, including oysters, hard clams, and ocean quahogs. Some secondary processing operations also processed canned vegetables in addition to clam products. Many processing plants that initially began operations as suppliers of hard clams and oysters later began processing surf clams. More recently they have begun processing ocean quahogs because the supply of surf clams has been limited by yield quotas. The mean length of time that plants have been processing surf clams is 11.8 years. This is in contrast to an average length of time of 3.37 years for ocean quahogs. Surf clams comprised approximately 75.57 percent of the clams processed by the plants surveyed, while ocean quahogs constituted approximately 21 percent of the clams processed. The remaining 3.79 percent of processed product was identified as other shellfish. Thus, surf clams remain the most important product for most of the processing plants surveyed. A small number of plants have converted their operations to ocean quahog meat production. All of the plants surveyed, however, process some surf clams.

All of the plants surveyed have owned surf clam fishing boats in the past. In recent years, escalating fishing costs and restrictive regulations have caused many owners to sell vessels and buy at least part of their raw product from independent fishermen. Vessel ownership averaged 1.71 vessels per processing operation. In 1982, the processing plants surveyed obtained an average of 80 percent of their raw product from independent fishermen. The remainder was harvested with processor owned and operated vessels. This percentage has changed in recent years. Although inadequate data were obtained to determine the magnitude of this change, several processors indicated that prior to implementation of the surf clam management plan, the industry-wide percentage of raw product purchased from independent fishermen was 40 to 50 percent.

None of the plants surveyed had written contractual agreements with surf clam fishermen, but all processors entered into informal agreements with clam suppliers for exclusive rights to vessel harvests. The mean number of suppliers per processing plant surveyed was 5.4. The most important factors influencing a decision to request clams from a specific independent vessel operator were quality of product (i.e. if the boat provides a full 32 bushels per cage measure), reliability, and willingness to sell at the prevailing market price.

All of the plants surveyed indicated that they wished to take daily deliveries, but in most cases were only able to obtain clams three to four times per week. In order to obtain adequate deliveries of clams, processors were required to seek delivery from many different ports. This situation is a result of similarities in allocated fishing time at geographically proximate ports. For example, vessels operating out of the major clam producing ports of Virginia and Maryland, Chincoteague and Ocean City, are currently limited to the same two days of fishing every week. Processors in Virginia wishing to operate more than two days per week must ship clams to their plants from ports farther north.

Independent sources of surf clam supply have not changed significantly during the past ten years. The number of suppliers has decreased, primarily as a result of curtailed harvesting activities among processors.

Other Inputs and Waste By-Products of Processing

The labor requirements of processing plants surveyed varied depending upon the capacity of the plant. Total employment ranged from 68 to 150 workers. The mean number of employees per plant was 92.6. surveyed plants averaged 8.6 salaried workers, including managers and supervisors, and 78.8 hourly workers. Some of plants surveyed had not instituted automated shucking operations at the time of the survey. These plants employed a piecework labor force of 35.3 individuals per plant to shuck clams and remove bellies. Plants utilizing piecework employees used 50 percent fewer salaried workers than plants without pieceworkers. Average wage statistics were unavailable for salaried employees. Hourly and piecework wages fluctuated depending upon the geographic locations of the plants. Wages paid in rural areas were lower than wages paid in and near heavily populated areas. The average hourly wage paid to processing plant employees was $4.35 per hour, and the average piecework wage was $1.42 per five gallon pot of clam meats processed.

The volume of meats processed by the plants surveyed in 1981 ranged from 1,200,000 pounds per year to 12,775,000 pounds per year. Production was clustered about the mean of 4,250,000 pounds of meats. Pounds of meats processed is presently dependent upon regulated supply and availability of clams.

Waste products produced by processing plants include: shell, clam visceral mass, and wastewater. All of the plants surveyed treated and disposed of waste products similarly. Clam shell is either shipped directly to landfill disposal sites, provided free of charge to processors requiring landfill, stored and sold as oyster cultch or road fill, or stored and planted on oyster leases held by the processing firms. None of the firms surveyed indicated that they encountered or anticipated any difficulty disposing of shell. Although all of the firms indicated that there is presently a market for shell bringing $0.30 to $0.45 per bushel, selling this by-product requires a relatively large storage area. Lack of adequate storage space was cited as an impediment to selling shell. Clam belly material is pumped to holding tanks for later disposal in municipal sewage systems, trucked to landfill disposal sites, or provided free to persons using it as hog feed, fertilizer, and bait. No problems are encountered in disposing of this material. Processing firms indicated that wastewater disposal, although not problematical at this time, will become prohibitively expensive for many firms if effluent standards become more restrictive. Because most plants dispose of wastewater into natural embayments or rivers, wastewater must meet standards set by the Clean Water Act Amendments for pH, suspended solids, BOD, and oil and grease. Quarterly effluent reports are sent by firms to their respective state water control authorities, and effluent is tested annually to verify the accuracy of these reports. Eighty-five percent of the firms surveyed were capable of meeting effluent standards by simply screening their wastewater, a relatively inexpensive procedure. Most of the solids are thereby captured when the screen is emptied several times per day. The remaining firms were required to screen their wastewater and pass it through grit chambers, air floatation tanks, and settling tanks before discharging effluent. The additional estimated cost of treating the wastewater with these systems was between 40 and 50 thousand dollars per year.

Because fresh water is used in repeated washing steps, it is an important resource. Water use calculations across all shucking plants indicate that an average of 6.13 gallons of fresh water are required for every pound of clam meats processed. This figure ranged from 2.5 gallons of water per pound of meats processed to 9.0 gallons per pound of meats processed. Only one plant surveyed indicated that obtaining an adequate fresh water supply was a problem. Geographic location appears to determine whether fresh water supply limits production. In heavily populated areas, where water is obtained from municipal reservoirs, water may become a limiting resource for industrial growth. Where wells are used as sources of fresh water, state regulatory agencies apply annual supply ceilings. Individual processing plants on Virginia's Eastern Shore may presently pump up to 150 million gallons of water per year from their wells. This total is much higher than any single plant's annual water requirement. Several processors, however, expressed fears that as the demand for water rises with increased population density, industry will be allocated a smaller supply. Whether water will become a limiting resource remains to be demonstrated.

Production Inventory, Sales, and Distribution Network

During warm weather, rapid processing (within 24 hours of landing) of clams is required to avoid spoilage. Clams may be held as long as five days without spoilage loss at temperatures near or below freezing. All of the processing plants surveyed, however, processed clams the same day they were delivered, and therefore held little or no raw product inventory. One third of the plants surveyed held inventories of processed meats in either frozen or raw form. Inventories ranged from 25,000 to 300,000 pounds of meats.

None of the firms surveyed sold shucked product through their own retail outlets, although several vertically integrated firms engaged in secondary processing operations to produce products which were sold by the firm. This survey would indicate, however, that a majority of clam shucking operations sell product directly and through brokers to other firms for further processing into wholesale products. Advertising was not demonstrated to be important at the primary level of production. Only 16 percent of the firms surveyed engaged in any kind of advertising activity.

Industrial Production Capacity and Growth Potential

Fluctuations in the supply and prices of surf clams have affected the growth of the surf clam processing industry. Although several of the firms surveyed have been operating successfully since the early 1900's, many companies have recently been required to curtail harvesting activities, cut surf clam meat production, and shift processing operations to ocean quahogs. None of the firms surveyed have introduced new surf clam products into their markets, however some firms currently engaged in shucking activities only are planning to integrate breading and freezing operations into their businesses. Some firms have introduced new frozen oyster and hard clam products to replace lost volume of surf clams. Frozen oysters on the half shell were identified by shucking plant managers as one product with good future market potential.

None of the plants surveyed are currently producing at full plant capacity. Processors estimated that they could increase their production from 10 to 100 percent without any expansion or need for additional capital except increased personnel. The calculated mean possible production increase over all plants surveyed was 72.5 percent. Production capacity per eight hour shift was estimated by all plants surveyed, and demonstrated remarkably little variation among plants. Production capacity ranged from 10,000 pounds of meats per shift to 40,000 pounds of meats per shift. Mean production capacity per shift over all plants surveyed was 22,500 pounds of meats. Most plants surveyed indicated that only two production shifts could be utilized because of the necessity for a third six to eight hour cleaning shift.

There does, however, appear to be significant underutilization of processing capacity in the industry.

Factors impeding surf clam processing plants from operating at full capacity were investigated. The problem most frequently cited was the scarcity of fresh raw product. Shortages may exist because of management quotas (low resource abundance) and poor weather. Processors indicated that, with increased availability of raw product, it would be possible to boost production approximately ten percent per year within market constraints.

Scarcity of labor was not identified as a problem by any of the processors surveyed, although worker shortages were temporarily encountered. The labor force employed by processing plants was identified as unskilled or semi-skilled with most activities requiring no education or only one to two days of training. A large percentage of transient workers are employed by processing plants. Quality of available personnel and work force turnover were identified as problems by most processing firms surveyed. On the Eastern Shore of Maryland and Virginia, processing plants employ workers on an evening shift. Those workers also work a daytime shift at chicken or vegetable processing plants. Processors indicated that work force turnover averaged 20 percent annually.

Unionization is not popular among workers in surf clam plants. This may be attributable to the transient nature of employment in surf clam processing plants. None of the plants surveyed were unionized. In recent years, unions have tried to enter two plants, but were defeated in both cases.

Capital and equipment required to initiate processing operations were identified as land, buildings, trucks, forklifts, shucking machinery, conveyor systems, a reel washer, floatation tanks, extracting equipment, washing equipment, pumps, a fresh water well system, refrigeration and freezing equipment, and boats. The minimum estimate of venture capital required to establish such an operation was $500,000.00. No exclusive patents would prevent acquisition of the necessary equipment. Payment for the rights to use eviscerating machinery, however, would be required.

Although adequate sources of capital, labor, and market potential exist for business growth, entry of new firms into the processing industry appears to be unlikely while clam supply is restricted by short natural supplies requiring restrictive management regulations. Limited growth potential exists for processing firms presently in the industry. One third of the processing firms surveyed indicated that they will not expand business operations unless clam supply limitations are eliminated. Two thirds of the firms surveyed planned to expand, "within the limits of the management plan", investing in more sophisticated automation and expanding into new markets for breaded and sliced clams. A pervasive business strategy under the current regulatory regime appears to be: 1) gain access to more expensive limited supplies of clams by cutting costs through investment in new efficient equipment and curtailment of expensive fishing operations, 2) increase production at the expense of competitors, 3) vertically integrate and expand into new markets for breaded or sliced product, 4) expand production of chowder meats by processing more ocean quahogs and hard clams and using salvage more efficiently, and 5) where possible expand operations to process and sell oysters and hard clams.

Chapter V

Model Construction

Using the parameters derived in the foregoing chapters, a surf clam management model has been constructed to measure the response of middle Atlantic surf clam populations and the economic environment to fishing activities. As noted above, a number of generalized fishery models have been previously constructed. However, there have been no previous efforts to develop an analytical single species model for the middle Atlantic surf clam fishery. Anderson et al. (1982) developed a generalized multispecies, multicohort fishery model originally designed to investigate management options for the New England groundfish fishery. After its construction, the model was applied to investigate surf clam and ocean quahog harvesting activities. The Anderson model, while clearly influential in the direction taken by the present investigation, differs substantially from this work as illustrated in the following section of this report.

A Unique Modeling Approach

The foundation of the present analysis lies in the work of many investigators, but the management model described below is unique in the several respects. First, this research quantifies industry costs in both the processing and harvesting sectors through a survey of all surf clam fishermen and processors in the United States, and interviews with processors and fishermen in Virginia and Maryland. The Anderson model cited above, on the other hand, developed empirical estimates of harvesting costs using running time, fuel use, and other factors reported in the literature. Certainly, these estimates have been useful as a starting point for a more comprehensive investigation. Most of the cost equations employed by Anderson et al. were generalized for use in a "typical" multispecies fishery, and were initially derived from information on the New England groundfish fishery. The processing sector was not included in the Anderson model, and no survey work specific to the surf clam fishery was performed. Second, this research examines the relationship between ex-vessel price, quantity landed, and the prices of substitute species in the surf clam fishery. Ex-vessel clam prices can thus be expressed as a function of the quantities listed above. The Anderson approach was to use a constant price model, the great weakness of which is that it does not include demand elasticities. At high levels of clam harvest, this is a serious omission. Failure to account for cross elasticity of demand between substitute species and surf clams can also lead to the development of an unrealistic model. Third, in contrast to previous efforts, this research employs a biologically based method of calculating biomass in pre-recruit cohorts. The von

Bertalanffy growth equations and length-weight relationships are used in this model to calculate biomass. Fourth, while this research seeks to develop a species specific fishery model, it is flexible enough to incorporate new biological and economic information as it becomes available, and to evaluate the permutations of combined management strategies. The model is capable of incorporating cohort specific natural mortalities as well as total natural mortalities specific to any one of the three middle Atlantic subregions. The Brody growth coefficient can be altered by subregion or season to account for temporal or regional fluctuations in growth rate. In addition to evaluating the harvest of mature clams greater than 5.5 inches in length as permitted by current management regulations, the model can determine the economic and biological effects of harvesting clams of length smaller than 5.5 inches. Various fixed and variable costs of vessel operations can be changed according to vessel class or region to examine the impact of changing specific costs. Variable processing costs can be altered, the effects of an ex-vessel price floor or changing fixed processing costs can be examined, and vessels can be permitted to leave or enter the fishery depending upon profits available inside the fishery relative to those outside the fishery. Effort hours can be altered by subregion and vessel class, landings taxes can be imposed by subregion and by vessel class, quotas may be imposed by season, and the movement of vessels from areas of low productivity to areas of high productivity may be investigated. Few of these management options have been included in earlier fishery models.

While this research builds upon the work of earlier investigators, the model described below has not been drawn from any previous investigative work. This model is an improvement over earlier ones, and is useful in improving the management of the surf clam/ocean quahog resource.

Model Structure

The model has been written as a set of equations, and has been programmed in FORTRAN for use on a digital computer. All of this work has been performed using thePrime 850 computer at the Virginia Institute of Marine Science. The model has been constructed in the framework of 11 subroutines containing equations representing the flow of resources through the fishery. Each of these subroutines is called by a main program designed as a bookkeeping function to coordinate and track activities occurring in the fishery. These subroutines and their functions are displayed in table 14. The equations and input parameters used in each subroutine are detailed in model program included in Appendix A.

Main Program

At its outset, the main program calls subroutine INPUT to initialize all model variables, and then

Table 14

Program Subroutines and Functions

Subroutine	Function
Main Program	1) Drives the model. 2) Calls subroutines as required on a monthly or yearly basis. 3) Maintains and updates monthly and yearly statistics. 4) Increments model on a monthly and yearly basis. 5) Requests and implements user initiated changes in management variables.
INPUT	1) Initializes all input parameters and passes them to subroutines.
GROWTH	2) Calculates biomass change in each subregion by cohort based upon von Bertalanffy growth.
EFFORT	1) Calculates the number of effort days of fishing per month of three classes of vessels in three subregions. This is based upon allowable effort hours.
HARVST	1) Calculates, by three classes of vessels, harvest in three subregions in biomass.
CQUOTA	1) Checks to see whether quarterly harvest quotas have been exceeded. 2) If they have, it closes the fishery until the end of the current quarter.

Subroutine	Function
VESRET	1) Calculates average and total vessel revenues and profits by vessel class and subregion based upon defined fishing costs, ex-vessel prices, and harvest.
PRORET	1) Calculates processing costs and wholesale prices associated with various levels of profit.
MONDAT	1) If requested by user, writes monthly statistics to an output file and to the user's terminal.
SWITCH	1) Calculates profit potential in all subregions according to vessel class and moves vessels from subregions of low profit to subregions of high profit.
VENEX	1) If requested, calculates potential return on investment available outside the fishery and moves vessels either into or out of the fishery according to profit potential. Moratorium on vessel entry-exit may also be imposed.
YRPRNT	1) Writes annual statistics to an output file and to the user's terminal.

interactively requests input concerning the number of years to be analyzed. It also requests instructions regarding the generation of monthly or annual output. Initial management options are entered as variables in subroutine INPUT, and may be altered after the completion of each year of analysis or at the end of an entire simulation run. This option permits considerable analytical flexibility. The main program next enters a loop responsible for yearly increments. If ex-vessel prices are not fixed, the price model nested within subroutine VESRET is automatically invoked. The program next enters a loop accounting for monthly time step increments. Within this loop subroutines are called to define monthly growth and natural mortlity, fishing effort, and harvest according to vessel class, subregion, and cohort. A check is performed to determine whether quarterly harvest quotas have been exceeded. If they have, the fishery is closed until the beginning of the next quarter. All of the calculations performed in these subroutines are displayed in detail in Appendix A.

After calculating monthly harvests, the main program must again recalculate cohort size accounting for fishing mortality. To accomplish this, harvests for each of the three vessel classes are added together and subtracted from cohort weight in each subregion. The total weight of each cohort group is calculated as the product of cohort size and the weight of clams in a cohort (derived form subroutine GROWTH). At this point, the main program separately calculates the size and weight of the surf clam population in each subregion and the aggregate middle Atlantic population.

The next task addressed by the main program is the calling of subroutines required to invoke an economic submodel of the harvesting and processing sectors. Subroutine VESRET is called to calculate harvesting costs, revenues, and returns. The ex-vessel price model located within subroutine VESRET is called to calculate harvesting costs, revenues, and returns. Subroutine PRORET is next called to calculate processing costs and to identify the wholesale prices that would be required to break even, and to achieve various levels of return against costs. All of these subroutines must communicate with each other, and with the main program, and must therefore pass input and output parameters through common variables. After calling subroutines comprising the economic submodel, the main program checks to see if the user requires monthly output and if subroutine MONDAT should be called. This subroutine creates monthly output files, writes data to those files, and writes monthly output data to the user's terminal screen.

The main program must also determine how potential profits will affect the movement of fishing vessels between subregions of the middle Atlantic. Historically, the middle Atlantic surf clam fishing fleet has moved en masse between subregions, exploiting the available resource in a subregion until new clam beds with higher profiot potential were located. Subroutine SWITCH surveys the profit potential of each middle Atlantic subregion on a monthly basis, moving the fleet to subregions where the highest profits may be realized. After accounting for monthly fleet movement, the main program next calls subroutine VENEX, which is responsible for moving vessels into and out of the fishery. This subroutine calculates vessel profits on an annual basis and compares them to return on investment capital available outside the fishery. If potential profits are greater within the fishery, new fishing vessels enter the fishery at the end of each year. If a vessel entry moratorium is indicated, vessels are prevented from entering the fishery. If potential profits are higher in another fishery, vessels leave the clam fishery.

After accounting for changes in fishing fleet distribution and size, monthly iterations are completed, and the main program leaves the monthly loop. At this time, the remaining subroutine, YRPRNT, is called to create an output file to receive annual data. YRPRNT writes annual data to this file and to the user's terminal screen.

Two procedures remain to be completed by the main program before moving to a new year within the annual loop. The user is given the opportunity to change management parameters at the end of each year. The main program requests information regarding the following variables: the prices of competing species can be changed, landings taxes can be implemented or changed, monthly effort hour limits can be changed in any subregion, quarterly quotas can be changed for any specific quarter, and natural mortality rates can be changed according to subregion and cohort. The last task to be completed by the main program is the advancement of clams in each cohort group, after having aged one year, to the next cohort group. This occurs at the end of each year.

At the conclusion of each year, monthly procedures are reinitiated to calculate activity within the fishery for a new year. Once the end of the yearly loop is reached, output files are closed, and the user is notified that the simulation run has ended. The calculations performed by each subroutine are displayed in detail in Appendix A.

The model construct described above has been designed specifically to evaluate alternative management strategies in the surf clam fishery. Gaps in our knowledge of density independent and dependent influences upon year class strength have precluded the development of a stock or environmental predictor of recruitment. As Ricker (1975) notes, the abundance of mature spawners in a fish population is often of sufficient importance to make it of real value for analysis and prediction. Beverton and Holt (1957), Ricker (1958), and Cushing (1972) have proposed stock-recruitment relationships. The Ricker model permits the partitioning of mortality during the prerecruit stage of the life cycle into density dependent and density independent mortality:

$$R=ASe^{-DS}$$

where A is the coefficient of density-independent mortality and D is the coefficient of density independent mortality. S (the size of the spawning stock) and R (recruited stock) are measured in eggs spawned and lifetime egg production of recruits suffering only natural mortality. In some cases, variability in recruitment unexplained by the stock-recruitment function can be explained by abiotic factors. Nelson, Ingham, and Schaaf (1977) correlated deviations in recruitment from a Ricker stock-recruitment function with anomalies in zonal Ekman transport. However, uncertainties regarding the stock-recruitment relationship in the surf clam fishery, and the response of the surf clam fleet to increasing or decreasing profits have necessitated the use of several assumptions described in Appendix A. Despite its lack of sophistication in these areas, the model remains an extremely flexible and useful tool with which to compare and contrast the possible advantages and disadvantages of management options, and to make decisions that optimize economic and biological yields. The following chapter describes the results of several different approaches to regulating harvests in the surf clam fishery, and demonstrates how this model may be used to evaluate these management strategies.

Chapter VI

Results of Simulation Studies

The data and relationships between economic and biological parameters described in previous chapters were fitted into the model framework outlined in chapter V, and an evaluation of alternative management strategies was conducted. Before describing the results of varying management variables, however, it is important that a brief discussion of the details associated with verification of this model be presented.

Caswell (1976) has defined two general purposes for which ecosystem models can be developed. This research project may be viewed in the context of these purposes. Models may be developed for: 1) prediction of the behavior of state variables in response to specific possible perturbations and 2) the organization of thought concerning the internal dynamics of an ecosystem. In the former case the model is used primarily as a tool for ecosystem management decisions. This research is concerned with evaluating fishery management alternatives and is therefore concerned with the first general purpose listed above. No model can, however, produce a faithful one-to-one reflection of reality. Data gaps and an incomplete understanding of various rate expressions transferring resources between model compartments have necessitated the use of simplifications described in previous chapters. Nevertheless, as Levins (1966) has noted, "all models leave out a lot and are in that sense false, incomplete and inadequate. The value of a model is not that it is true but that it generate good testable hypotheses relevant to important problems". In that regard, this model is quite useful. Development of this model has in fact been a process through which gaps in the continuum of knowledge have been identified, the impact of alternative management strategies has been evaluated, and future research needs have been identified.

Model verification tests the relationship between a model and the results of a simulation, answering the questions, how good is the program and, does the program perform to its design specifications. Developmental methods have been used to verify this model. Structured programming, including top down design, has verified that there is no circularity of flow and no backward branching in the model. Code walk throughs were performed during model development, and tables were written deriving values that all variables in the program must assume at each step. The source level debugger available on the PRIME system was invaluable in this regard. Documentation development also was used to verify the model. Running commentary was inserted into the program to facilitate analysis and verify results. Because of the relatively uncomplicated feedback structure of the model, post developmental statistical methods were not required to verify the model.

Case Studies

A bioeconomic evaluation of the middle Atlantic surf clam fishery was performed under conditions describing different management scenarios or cases. These scenarios include a range of management options, each case representing a different approach to managing the fishery. The flexibility built into this model's analytical framework would permit many more different cases or permutations of management options to be evaluated. The cases presented in this chapter, however, were selected because each uniquely represents a basic policy decision or perturbation having significant impact. More specific questions and problems could be addressed by industry planners and managers using this analytical tool as the need arises. In each case, all dollar values of costs and prices are based upon data obtained in late 1981 and 1982. These values may, therefore be considered as 1982 dollars.

Case number one is a baseline simulation of what could be expected during a six year planning horizon if the status quo is maintained in the fishery. Conditions extant at the end of 1982 were used to simulate the baseline situation. Annual landings quotas of 45 million pounds of meats, drained meat weight, were imposed by quarter, and vessels were limited to 24 hours of fishing time per week.

The fishing fleet of 103 vessels was distributed according to vessel class primarily in the southern New Jersey and Delmarva subregions, a reflection of the minimal fishing effort concentrated in northern New Jersey. A vessel moratorium was imposed, preventing entry of any new vessels into the fishery. Vessels did not leave the fishery. This is a reflection of the current situation. Vessel owners are extremely reluctant to leave the fishery, even when faced with losses, because they are threatened with the possibility of future vessel catch rights regulations based upon historical landings data. A minimum size limit of 5.5 inches was imposed upon all surf clams harvested in the middle Atlantic region, a constant rate of natural mortality was assumed, and no landings taxes were imposed.

Case number two maintains the same conditions in the fishery, but lifts the moratorium imposed upon both vessel entry into and exit from the fishery. This would reflect a management decision to abolish both the current moratorium and any future consideration of a catch rights system of fishery management.

Case number three simulates a management scenario in which fishery managers might choose to regulate the fishery through the imposition of a landings tax. Under the conditions of case number three, all effort restrictions, quotas, and the vessel entry-exit moratorium are removed. The 5.5 inch size limit is retained, however, an ex-vessel landings tax of $0.40 per pound of clam meats is imposed upon surf clam fishermen in all subregions. This tax may easily be converted to dollars per bushel by using a conversion factor of 17 pounds of clam meats per bushel.

Case number four examines the impact of eliminating the minimum size limit restriction. In this case, the 5.5 inch size limit restriction is dropped, permitting fishermen to harvest clams as small as four inches in length. Clams of length shorter than four inches are prerecruits, considered too small to be useful to processors. This case thus eliminates all size limit restrictions while keeping the vessel moratorium, quotas, and effort hour restrictions in force.

Cases number five, six, and seven demonstrate the effects of changing ex-vessel prices of the closest market competitor to the surf clam, the ocean quahog. In each of these cases, baseline fishery conditions are maintained. In case five, the ex-vessel price of ocean quahogs is increased by $0.10 per pound. In case six, the ex-vessel price of ocean quahogs is increased by $0.20 per pound, and in case number seven, the ex-vessel price of ocean quahogs is decreased by $0.20 per pound.

The situation of restrictive quotas is represented by case one. Case eight depicts a situation in which an annual yield quota of 50 million pounds of clam meats, the estimated maximum sustainable yield in the fishery, is imposed.

Cases number nine and ten demonstrate the effects of high and low effort hour restrictions while maintaining all other baseline fishery conditions. Case nine increases the permitted monthly fishing hours by 100 percent and case ten decreases the permitted monthly fishing hours by 50 percent.

The final case considered, case number eleven, examines the impact of elevated levels of natural mortality. This case assumes a natural mortality rate of 0.80 in the northern New Jersey subregion during the second year of model projections. Such a situation in fact occurred in the summer of 1976 during an anoxic event with associated massive fish kills. Case number eleven, therefore, projects what might be expected in the event of a similar occurrence.

Results of the Analyses

Of the many output variables generated by the model for each case, seven were selected on the basis of their biological and economic importance as indicators of reflecting the effects of fishery management. Changes in these parameters were graphically examined by generating annual plots of the data with a graphics subroutine. The plotted variables include: number of fishing vessels in each vessel class, fleet landings by vessel class, fleet profits by vessel class, average monthly profits per vessel by vessel class, average monthly profits per vessel per year by vessel class, surf clam stock size, and wholesale clam meat prices. The results of a selected series of plots are displayed and described below. These plots provide approximate values of each variable examined.

Case Number One

Under the baseline conditions imposed by case number one, the fleet size would remain constant because of the vessel entry moratorium and the assumption that vessels are very reluctant to leave the fishery.

As indicated in Figure 6, fleet landings in case one range from 27 million pounds of clam meats in year one to 47 million pounds of clam meats in year four. The trend in landings demonstrates a sharp increase between years two and three, a gradual increase to peak landings at the end of year four, and somewhat lower but constant level of landings between years five and six. These landings reflect the population age structure described in Chapter III. Landings by class III vessels constitute more than 75 percent of the total clam meats landed. Landings by class II and class I vessels show little fluctuation in level with class II vessels landing between six and eight million pounds of meats, and class I vessels landing one to two million pounds of meats annually.

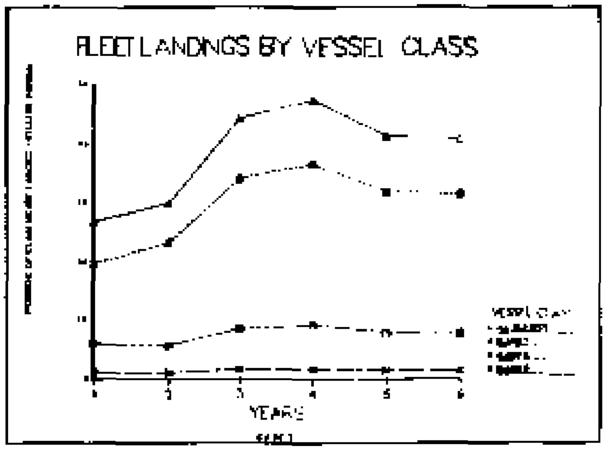
A plot of case one fleet profits indicates that, under the baseline conditions total fleet profits would range from minus two million dollars during periods of resource scarcity to 5.5 million dollars annually

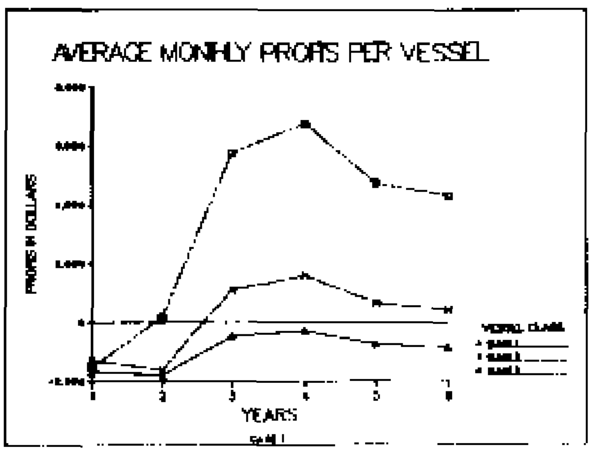
Figure 6). Projections indicate that surf clam fishing fleet profits would increase during the six year planning horizon from levels below the break even mark, to a peak of 5.5 million dollars at the end of year four, and then begin a decline, falling to the 3.75 million dollar level by the end of year six. Nearly all of this profit would be taken by the class III fishing vessel fleet. Under baseline conditions, the class I vessel fleet will not reach the break even level at all during the six year projection. The class II fleet is projected to reach peak profit levels of approximately 0.225 million dollars in year four and then decline to profit levels of approximately 0.12 million dollars by year six. In all three vessel classes, fleet profits exhibit a trend of decline after peaking in year four. This is a reflection of resource abundance.

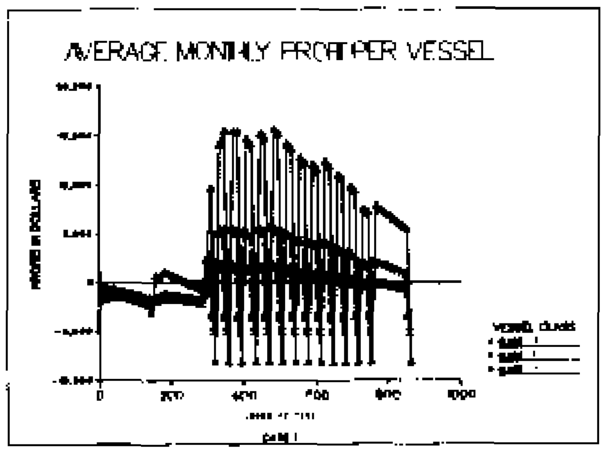
Average profits per vessel plotted by month are displayed in Figure 6. While providing a detailed picture of monthly and seasonal fluctuations in vessel profits, the detail of these plots makes them less useful than plots of average annual data for the identification of trends. Monthly plots of vessel profits indicate that as quarterly landings in year three begin to exceed quotas, the fishery will be closed under baseline restrictions and fixed costs will result in negative profits. Figure 6 shows that monthly profits per vessel will range between $16,000 and $8,000 for class III vessels, between $6,000 and $5,000 for class II vessels, and between $2,000 and $4,000 for class I

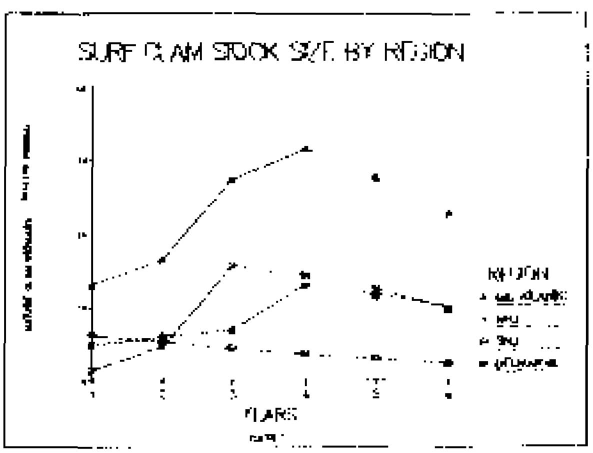
Figure 6

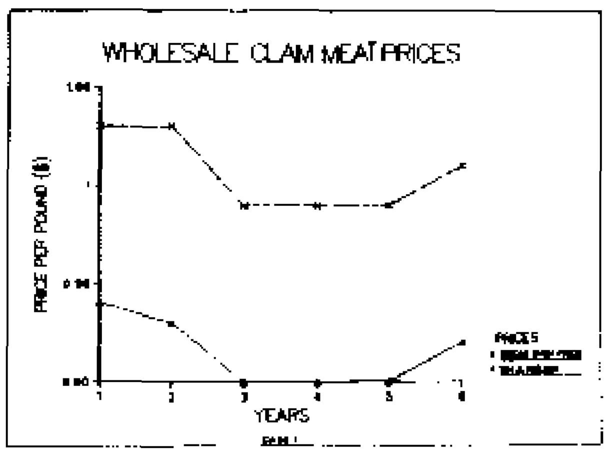
Case 1


FLEET LANDINGS BY VESSEL CLASS
VESSEL CLASS
YEARS


AVERAGE MONTHLY PROFITS PER VESSEL
PROFITS IN DOLLARS
VESSEL CLASS
YEARS


AVERAGE MONTHLY PROFIT PER VESSEL
VESSEL CLASS
0
200
400
600
800
1000


SURF CLAM STOCK SIZE BY REGION
REGION
YEARS


WHOLESALE CLAM MEAT PRICES
PRICE PER POUND ($)
PRICES
YEARS

vessels. This plot also shows a trend of profits per vessel peaking in year four and declining through year six, superimposed upon periodic monthly losses during closure of the fishery and regular declines in vessel profits during the winter season.

Figure 6 displays monthly profits per vessel calculated on an average annual basis. Monthly profits among class II vessels fluctuate from -$1,500 in year one to nearly $7,000 in year four, and decline to $5,000 in year six. Monthly class II vessel profits are considerably lower, dropping to -$1,800 in year one, increasing to $1,000 in year two, and falling once again to approximately $500 in year six. Monthly profits among class I vessels remain below the break even level, dropping to nearly -$2,000 in year two, and remaining at levels near -$500 during other projected years. It should be emphasized that these projections are for net profits after payment of vessel captain and crew wages. Vessel owners have stayed in the surf clam fishery for five years or longer below the break even level because limited entry has made a fishing permit a valuable if unmarketable commodity.

Figure 6 displays estimates of stock size, biomass of clams greater than 5.5 inches long in each subregion. Middle Atlantic stock size estimates in case one range from approximately 12 billion pounds of meats to nearly 30 billion pounds of meats, reflecting variable recruitment to the fishery and management quotas. Middle Atlantic stock biomass displays an increase to its maximum value in year four, and then undergoes a constant decline through year six. Biomass in southern New Jersey continues to decline at a constant rate from the year one level of approximately six billion pounds of meats to levels of between two and three billion pounds of meats by year six. Northern New Jersey biomass increases to a maximum size of approximately 14 billion pounds of meats in year three, and then exhibits a nearly constant rate of decline through year six. Stock in the Delmarva subregion shows a gradual increase to 6.5 billion pounds of meats through year three, increases to 10 billion pounds in year four, and shows a gradual decline through year six to levels equal to those seen in northern New Jersey.

Average wholesale clam meat prices in case one at the ten percent return level for shuckers show constancy at $1.03 per pound of meats for the first two projected years. Prices then drop to $0.99 per pound through year five, and finally increase to $1.02 during year six. At the break even level, wholesale prices are considerably lower, dropping from $0.94 per pound in year one to $0.90 per pound in years three, four, and five, and increasing to $0.92 per pound in year six.

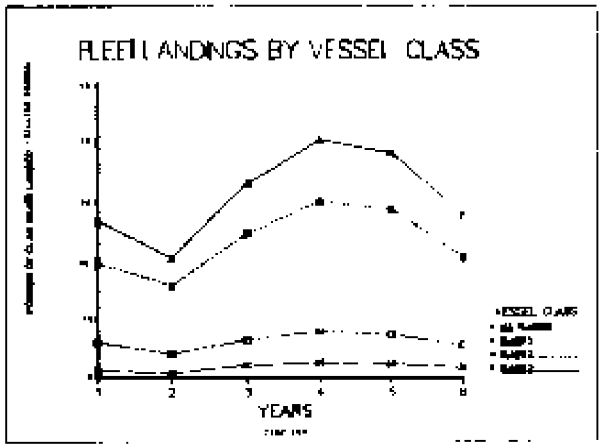
Case Two

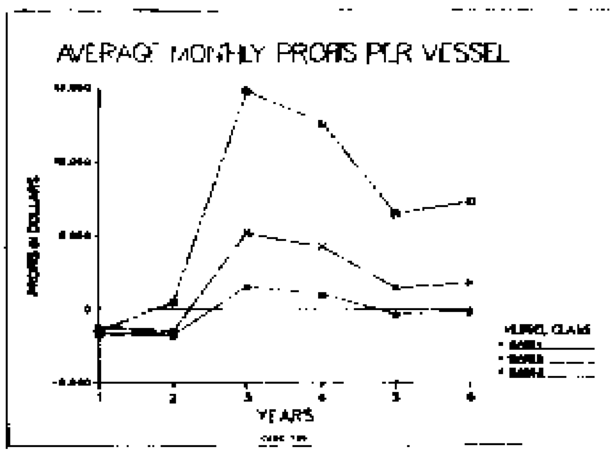
Case two, depicting the short run impact of removing the vessel moratorium with baseline quotas, shows interesting changes from the baseline study. It should be noted that this simulation does not reflect the long term impact of overcapitalization that could occur if the vessel moratorium were removed. Figure 7 indicates that without the vessel moratorium, the class III vessel fleet would demonstrate a short run decrease in size. The fleet would decrease in size from 60 vessels in year one to 30 vessels after two years, and recover to 50 vessels by the end of year four. This change in fleet size is a reflection of profits available under conditions of fluctuating resource abundance, management quotas, and the absence of limited entry assumed by case two. The class III fleet would fluctuate in size between 35 and 40 vessels during years five and six. The class II vessel fleet size demonstrates a decrease from its year one size of 33 vessels to approximately 20 vessels after two years, and increases nearly to year one levels by the end of year four. During years five and size, the size of the class II vessel fleet declines significantly to approximately one third of its size in year one. The class I vessel fleet shows a small decline in size after one year from 13 vessels to 9 vessels, it increases to its year one size by year four, and shows slight declines during years five and six.

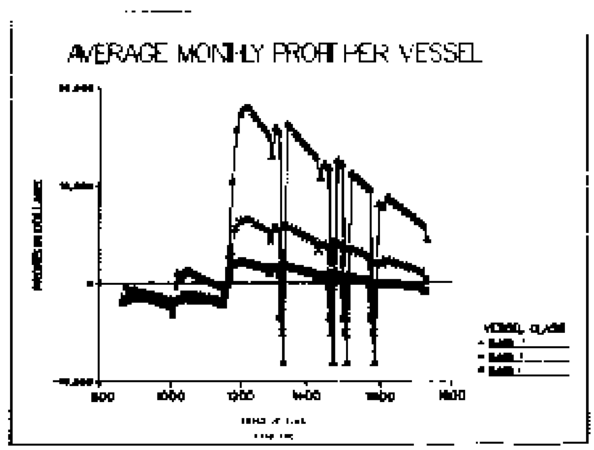
This case indicates that under baseline effort restrictions and quotas, removal of the moratorium and the possibility of future vessel quota assignments based upon historical catch would result in a decrease in fleet size

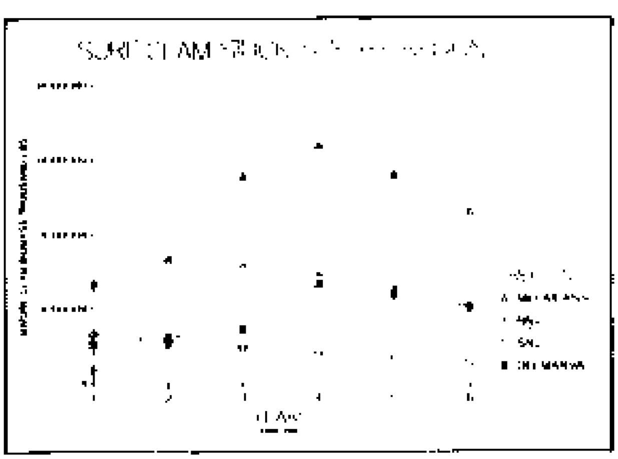
Figure 7

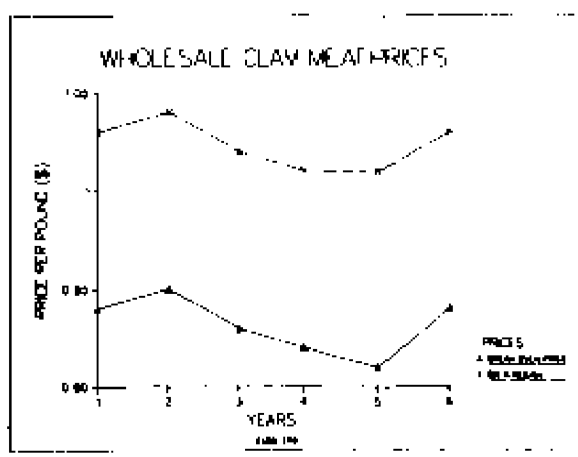
Case 2

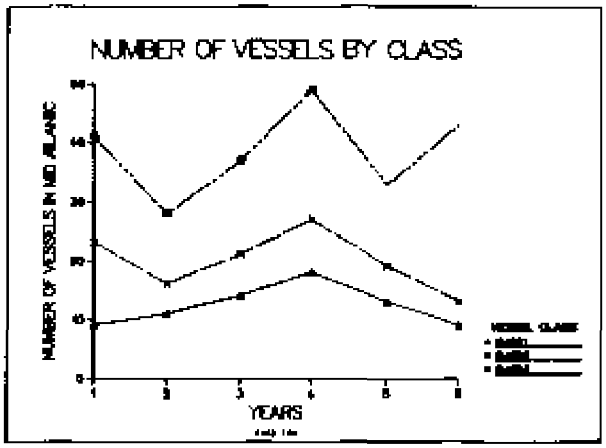

FLEET LANDINGS BY VESSEL CLASS
YEARS
VESSEL CLASS

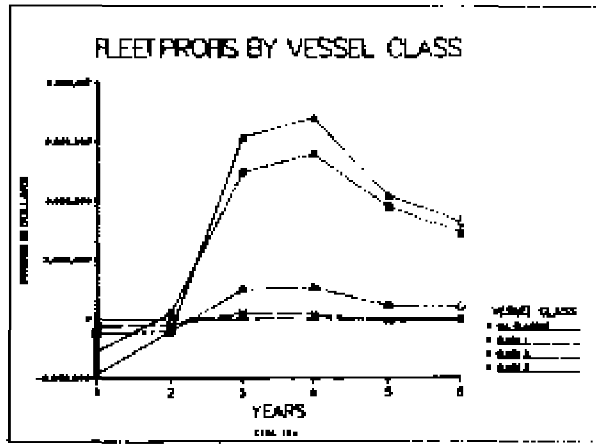

AVERAGE MONTHLY PROFITS PER VESSEL
PROFITS IN DOLLARS
YEARS
VESSEL CLASS


AVERAGE MONTHLY PROFIT PER VESSEL
PROFITS IN DOLLARS
VESSEL CLASS




WHOLESALE CLAM MEAT PRICES
PRICE PER POUND ($)
YEARS
PRICES


NUMBER OF VESSELS BY CLASS
NUMBER OF VESSELS IN MID ATLANTIC
YEARS
VESSEL CLASS


FLEET PROFITS BY VESSEL CLASS
YEARS
VESSEL CLASS

among all vessel classes after six years of fishing. This decrease in fleet size would be concentrated in the class III and class II fishing fleets.

Case two fleet landings are illustrated in figure 7. As this figure indicates, in the absence of a vessel moratorium, landings could be expected to decline to 21 million pounds of meats in year two, increase to 40 million pounds in year four, and again decline to 22 million pounds of meats by year six. Case two fleet profits are plotted by vessel class in Figure 7. As indicated, if the vessel moratorium were lifted under baseline conditions, changes in fleet profits would follow the same pattern exhibited in case one. Overall fleet profits would improve considerably, increasing by approximately two million dollars during year four due to the elimination of unprofitable class I and class II fishing operations. Class III fleet profits would peak in year four and show a steep decline during years five and six. Class II operations would climb to a peak of nearly one million dollars during year four and stabilize at .5 million dollars. The class I vessel fleet would become marginally profitable, with profits fluctuating above and below the break even level.

Case two monthly profits per vessel plotted on a monthly basis are displayed in figure 7. This figure shows that removal of the vessel moratorium under baseline restrictions would cause monthly vessel profits to peak at $15,000 among class III vessels, $5,000 among class II vessels, and $1,000 among class I vessels during year three, thereby increasing average profit per vessel by $3,000 to $5,000 through the elimination of unprofitable operations and the reduction of the number of necessary closures of the fishery. Declines in profits during years four, five, and six within the planning horizon follow these maxima. It should be noted that these declines in profits, may be attributable to fluctuations in recruitment to the fishery. Looking beyond the planning horizon, temporary stock recovery and increased fishing effort in the absence of an entry moratorium could exacerbate the problem of declining profits and overcapitalization. Within the planning horizon, seasonal dips in profits per vessel of 10-15 thousand dollars are evident during the winter months. Average monthly profits per vessel plotted on an annual basis in Figure 7 provide, with a smoothing effect, a further demonstration that profits per vessel could be expected to decline through year six after peaking in year three in case two.

Removal of the vessel moratorium would not appear to have a great impact upon stock size in the entire middle Atlantic region or any of its subregions if catch quotas and hourly effort restrictions are maintained (Figure 7).

With removal of the vessel moratorium and maintenance of all other baseline conditions, wholesale clam meat prices are slightly higher at both the break even and ten percent return levels (Figure 7). This result is probably a function of the decreased short run supply of raw product available to processors under this management option.

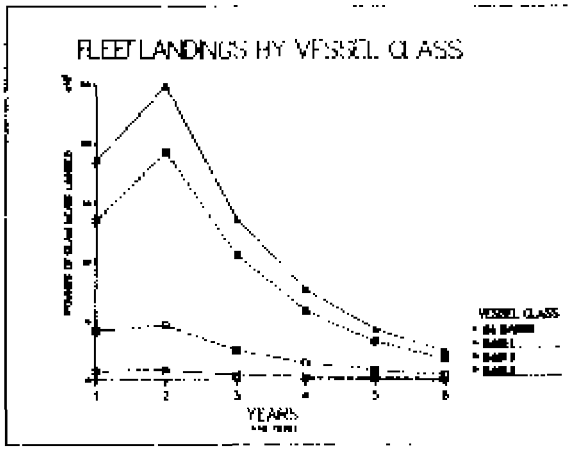
Case Three

Case three removes all effort restrictions, quotas, and the vessel moratorium, regulating the fishery with a landings tax imposed upon clam fishermen at the end of year one. With a landings tax sufficient to raise fishing costs $0.40 per pound of clams harvested, all three vessel class fleets demonstrate large decreases in size from year one levels to year six levels. Clearly, landings taxes sufficient to raise fishing costs $0.40 per pound of meats harvested cut fishing profits so severely that fleet size is dramatically reduced.

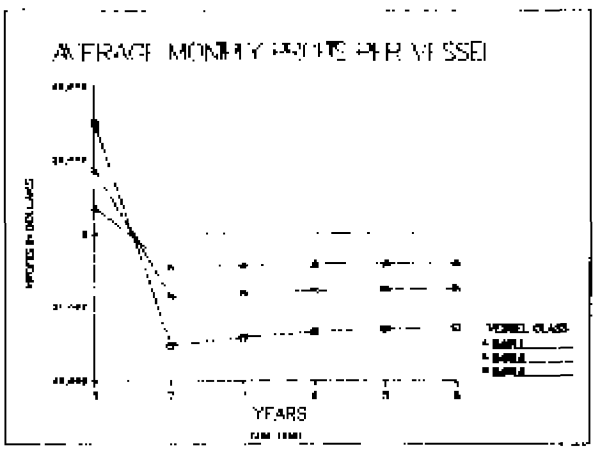
The effect of a landings tax increasing fishing costs by $0.40 per pound of harvest upon clam landings is illustrated in Figure 8. Landings peak in year two, after which reductions in fleet size would lead to concomitantly reduced landings through year six when less than 50 million pounds of meats are landed. Clearly, such a tax would reduce landings to less than the maximum sustainable yield by year six through rather drastic reductions in the size of the surf clam fleet. This management option, however, could be expected to produce long run stock reductions because of overharvesting during the years immediately

Figure 8

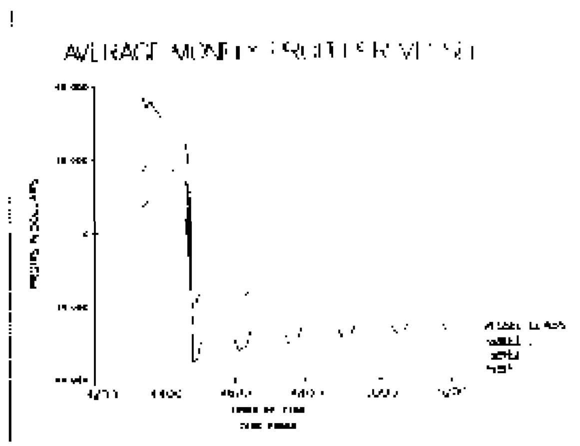
Case 3



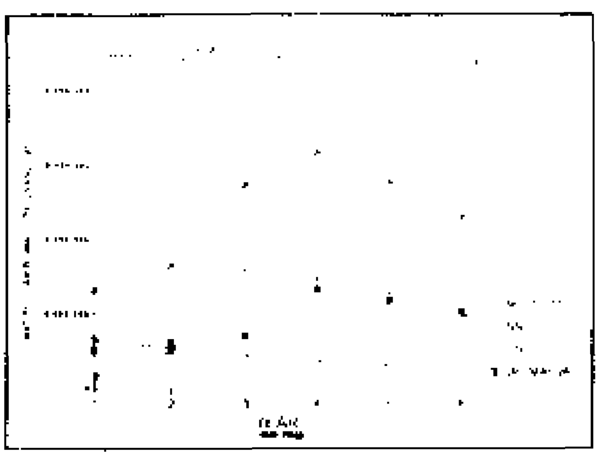
FLEET LANDINGS BY VESSEL CLASS
VESSEL CLASS
1
2
3
4
5
6
YEARS

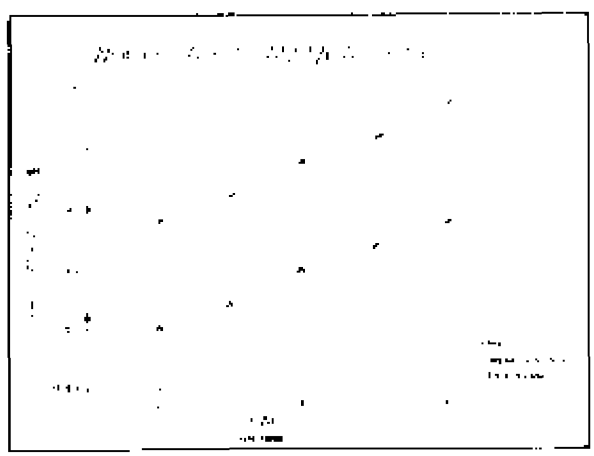


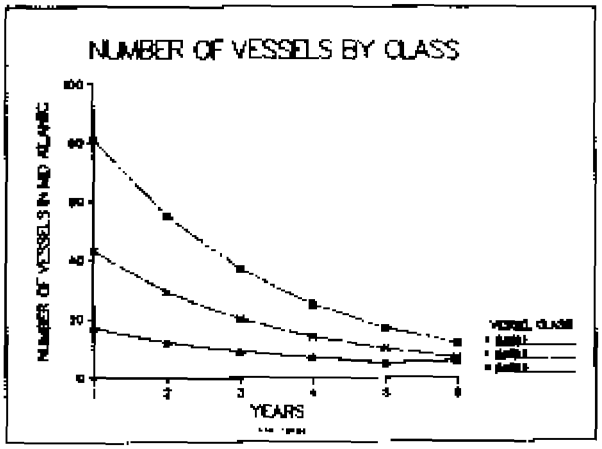
AVERAGE MONTHLY PROFITS PER VESSEL
PROFITS IN DOLLARS
VESSEL CLASS
1
5
6
YEARS

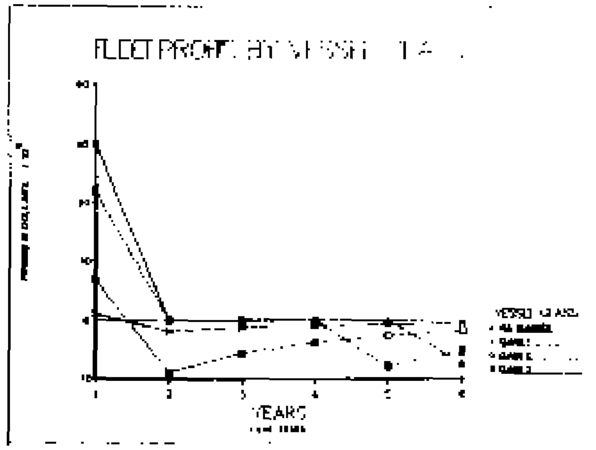


VESSEL CLASS






NUMBER OF VESSELS BY CLASS
NUMBER OF VESSELS IN MID ATLANTIC
YEARS
VESSEL CLASS


YEARS

following implementation of the tax.

The landings tax would produce hard economic times in the surf clam fishing industry. After imposition of the tax, profits for the entire fleet drop to or below the break even mark, with relatively large losses incurred by the class III fleet in years four, five, and six. A plot of average monthly profit per vessel with a landings tax sufficient to raise fishing costs by $0.40 per pound of meats harvested (Figure 8) reveals that the tax would depress profits among all three vessel classes. The tax would lead to monthly profit levels of -$10,000 to -$35,000 among all classes of vessels after year one, with class III vessels displaying the poorest performance. Once again, seasonal fluctuations in vessel profits are evident. Monthly profits per vessel plotted on an average annual basis with a landings tax raising fishing costs by $0.40 per pound of harvest reveals similar results without seasonal fluctuations. The tax leads to consistent losses among all classes of vessels, with class III vessel losses being the greatest.

The impact of a landings tax upon surf clam stock size is illustrated in Figure 6. The tax permits an overall reduction of middle Atlantic stock by 160 million pounds below baseline values at the end of the six year planning horizon. This reduction is primarily a result of increased fishing effort in the northern New Jersey subregion. Although the fleet size is reduced, the absence of fishing hour restrictions and quarterly catch quotas permits fishing effort to increase in this subregion. Both the Delmarva and southern New Jersey stocks remain relatively unchanged in size from baseline values. Middle Atlantic fishing effort is concentrated in northern New Jersey because resource abundance, a function of the population structure input variables, and profit potential are greatest there. Further reduction in stock size could be expected beyond the planning horizon due to poor recruitment resulting from recruitment overharvesting.

Wholesale clam meat price fluctuations under the landings tax are illustrated in Figure 8. These prices represent only increases in excess of that portion of the tax that would be passed through to processors. The management option of a landings tax initially depresses wholesale prices by approximately $0.10 per pound because, in the absence of quotas, the supply of meats landed initially increases. However, as profitability of fishing operations decreases, fishing effort and landings decline, and wholesale clam meat prices begin to climb.

Case Four

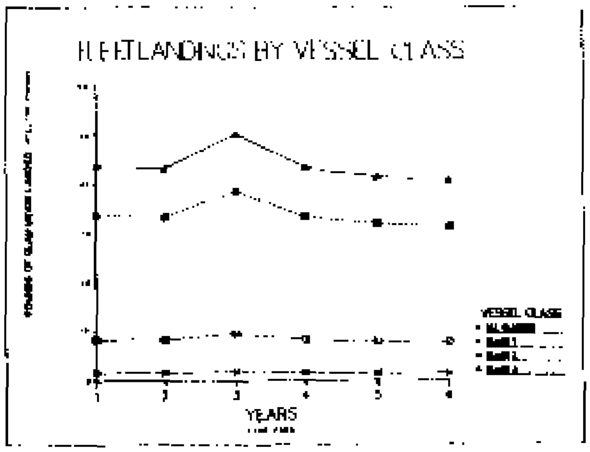
Case Four maintains all baseline management restrictions in the fishery, but describes the impact of harvesting clams smaller than 5.5 inches in length. Minimum size limits are set at 4.0 inches for this case.

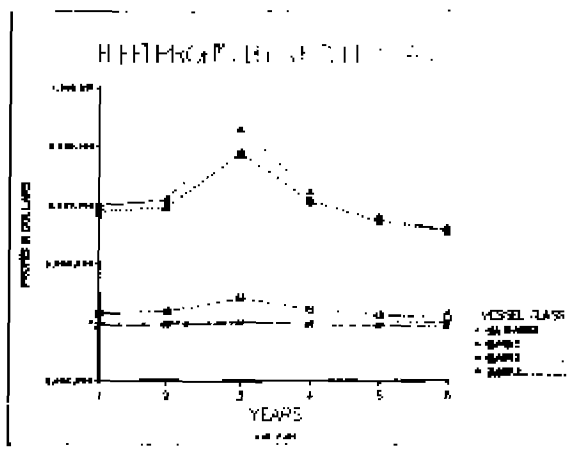
The number of vessels in the fishery in this case remains constant because the vessel entry moratorium is imposed. As Figure 9 illustrates, the harvest of smaller clams has a smoothing impact upon fluctuations in fleet landings during the six year planning horizon. Total middle Atlantic landings during years one and two increase by more than eight million pounds, peaking in year three, and leveling off in years four through six. The model suggests that early harvest of strong year classes could spread landings over a longer portion of the six year planning horizon. It should be recognized that harvesting smaller clams would decrease the mean age of clams recruiting to the fishery, and thus decrease the theoretical yield per recruit at equilibrium. Regulations permitting a minimum size limit below the maximum yield per recruit can quickly lead to overharvesting. Strict enforcement of quarterly harvest quotas can control this problem. However, changing the minimum size limit in a fishery should be approached with extreme caution.

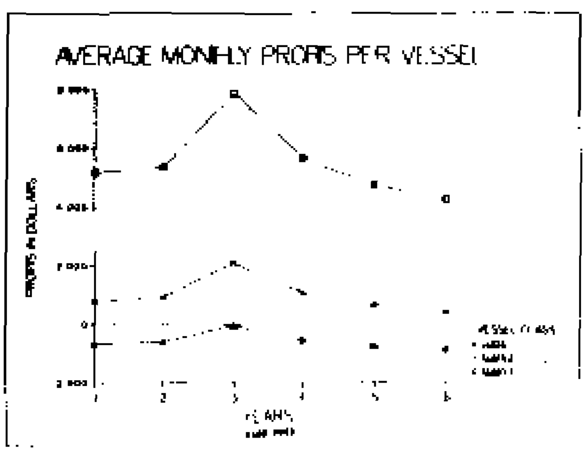
The model suggests that available fleet profits could also be spread over a greater portion of the planning period if size limits were lowered (Figure 9). Slightly larger catches bring substantial maximum monthly profits for class II and III vessels, on the order of $5,000 per month for class III vessels and $3,000 per month for class II vessels. However, the necessity for a greater number of fishery closures in the absence of higher quarterly quotas would keep average monthly profits during the planning

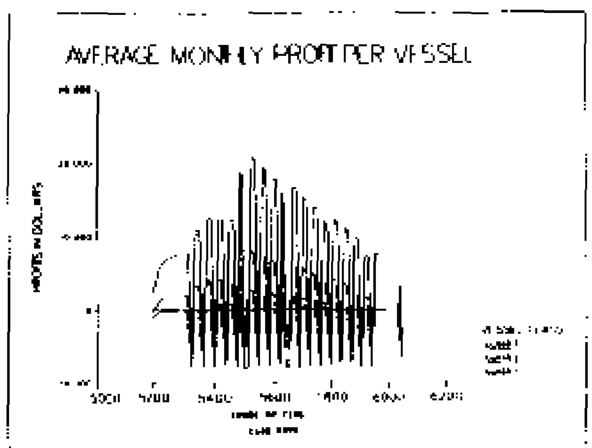
Figure 9

Case 4


FLEET LANDINGS BY VESSEL CLASS
YEARS
VESSEL CLASS


PROFITS IN DOLLARS
YEARS
VESSEL CLASS


AVERAGE MONTHLY PROFITS PER VESSEL
PROFITS IN DOLLARS
YEARS


AVERAGE MONTHLY PROFIT PER VESSEL
PROFITS IN DOLLARS

horizon at the same levels obtained under baseline conditions.

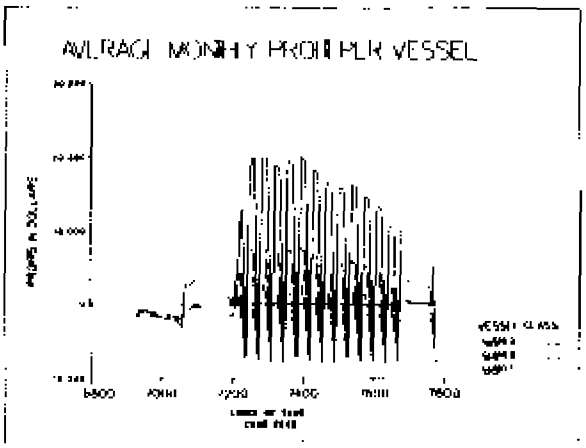
By permitting more intensive harvesting activity of small clams in northern New Jersey and Delmarva, lowering the size limit to 4.0" would be reduce stock size 400 million pounds by year six. This would not eliminate the stock, but it undoubtedly represents a severe reduction. Given the uncertainty of absolute biomass estimates, case four results would indicate that size limit reductions should be approached with extreme caution. If smaller clams could be harvested, wholesale clam meat prices would be lowered $0.03 to $0.04 per pound during years one and two, but would then recover to levels observed under the current management regime for years three through six.

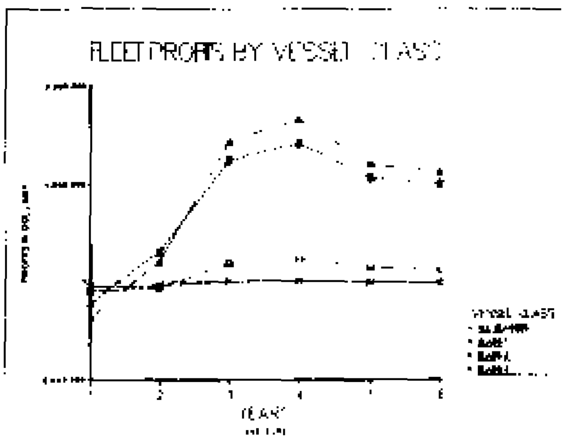
Cases Five, Six, and Seven

The effects of increasing ocean quahog ex-vessel price by $0.10 and $0.20 per pound are examined in cases five and six respectively, and the effect of a $0.10 per pound decrease in ocean quahog ex-vessel price is examined in case seven. These cases project the economic impact of a decline in the abundance of a substitute commodity for surf clams. This analysis is restricted to examining the impact of these price changes upon fleet profits and wholesale surf clam prices. Although ocean quahog price changes might be expected to affect surf clam fleet size, landings, and stock size, these cases were simulated under the assumption that the vessel moratorium, and the reluctance of surf clam fishermen to leave the fishery, would cause only minimal changes in fleet size and surf clam landings. Further investigation of fleet size changes and landings fluctuations would be possible if the assumption of a vessel moratorium were lifted. As Figure 10 indicates, a $0.10 per pound increase in ocean quahog price would lead to higher ex-vessel surf clam prices during the peak harvest period of years three and four, and increase total fleet profits more than one million dollars above profit projections under the current management regime. Class I vessel fleet profits would be lifted to the break even level through year six. A plot of case six fleet profits (Figure 11) shows that an increase of $0.20 per pound in ocean quahog ex-vessel price would raise class III vessel profits even more, while having only a relatively small impact upon class I and class II vessel fleet profits. A plot of case seven fleet profits (Figure 12) demonstrates the impact of a $0.10 per pound decrease in ex-vessel ocean quahog price. Total fleet profits are 50 percent lower than those observed in case one baseline conditions. Levels of profit in both the class I and class II vessel fleets remain below the break even level through year six. With an ex-vessel ocean quahog price decline of $0.10 per pound, class I and class II vessels are able to return a profit to their owners during months when the

Figure 10

Case 5


AVERAGE MONTHLY PROFIT PER VESSEL
6800
7000
7200
7400
7600
7800
VESSEL CLASS


FLEET PROFITS BY VESSEL CLASS
VESSEL CLASS
YEARS

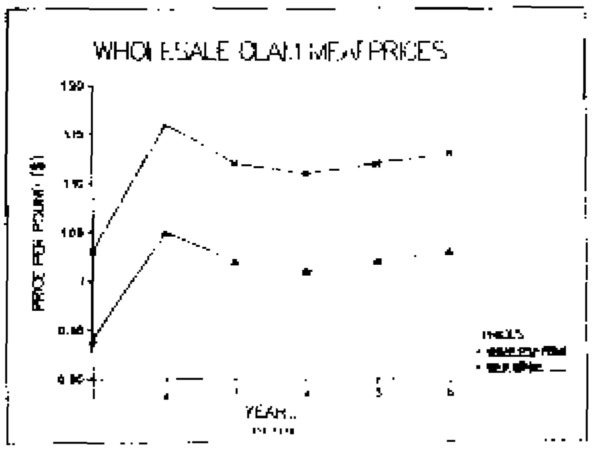
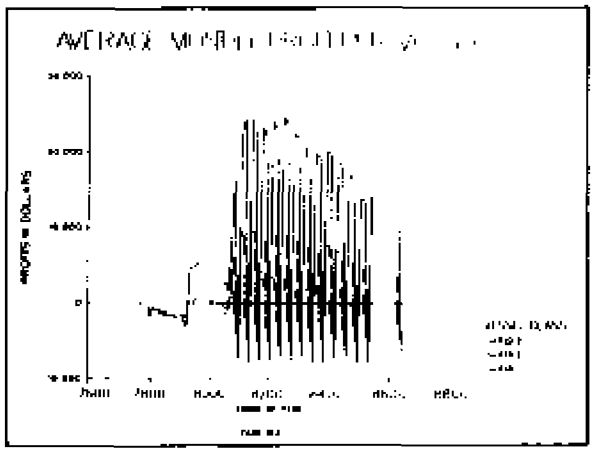
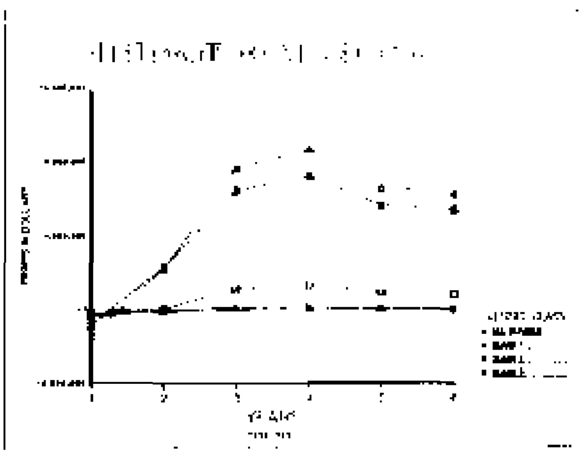
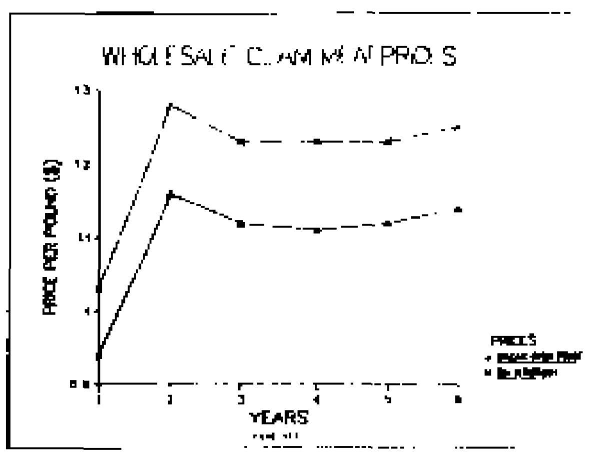

WHOLESALE CLAM MEAT PRICES
PRICE PER POUND ($)
YEAR
PRICES

Figure 11

Case 6




YEARS


PRICE PER POUND ($)
YEARS
PRICES

fishery is open. However, closures necessitated by the quarterly quota system push these vessels below the break even level when monthly profits per vessel are plotted on an average annual basis.

Wholesale surf clam meat prices could be expected to increase between $0.11 and $0.15 per pound during years two through six with ocean quahog ex-vessel price increases of $0.10 per pound (Figure 10). A surf clam price increase of $0.25 to $0.30 per pound could be expected with a $0.20 per pound ex-vessel ocean quahog price increase (Figure 11). A $0.10 per pound drop in ex-vessel ocean quahog prices would produce wholesale surf clam meat prices only $0.20 to $0.03 lower during years two through six (Figure 12)

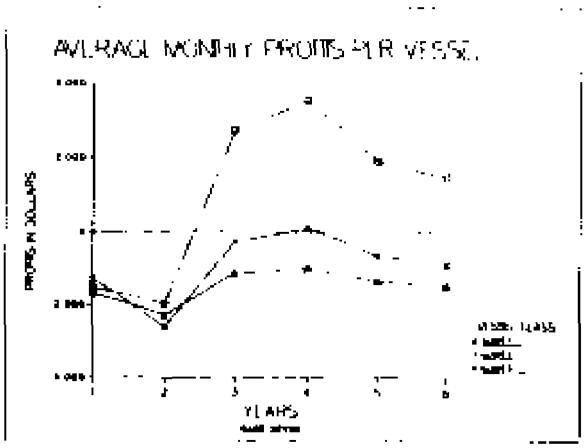
Cases Eight, Nine, and Ten

The effect of a quota imposed by the management plan has been examined in case one. Case eight examines the impact of an intermediate yield quota of 50 million pounds of meats per year. This is the current estimate of maximum sustainable yield. Case nine examines the effect of increasing the effort hour restriction ceiling by 100 percent above the baseline simulation, and case ten examines the effect of imposing an effort hour restriction ceiling 50 percent lower than the baseline simulation.

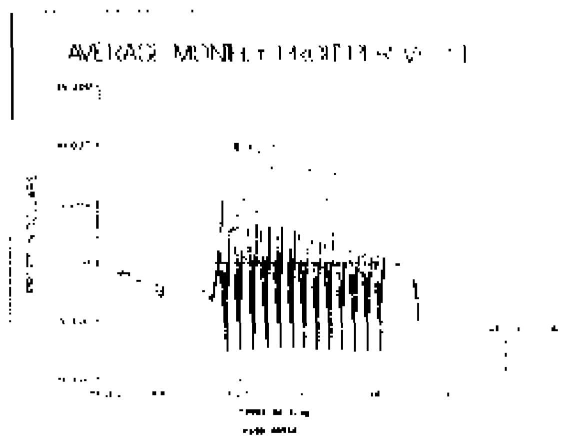
Because conditions of the vessel moratorium remain in force under all of these cases, no change in fleet size will occur. As illustrated in Figure 13, an annual yield

Figure 12

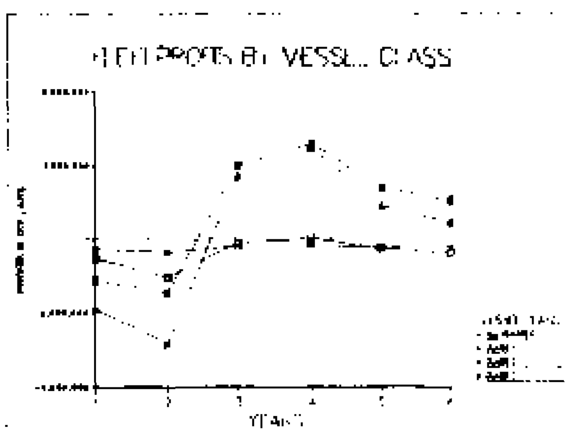
Case 7



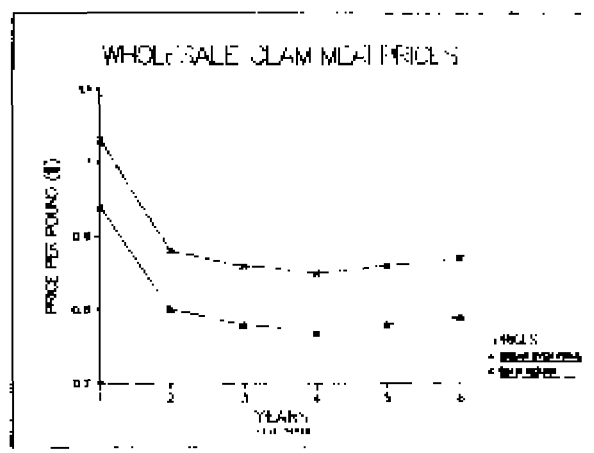
AVERAGE MONTHLY PROFITS PER VESSEL
PROFITS IN DOLLARS
YEARS
1
2
3
4
5
6
VESSEL CLASS



AVERAGE MONTHLY PROFIT PER VESSEL



FLEET PROFITS BY VESSEL CLASS
YEARS



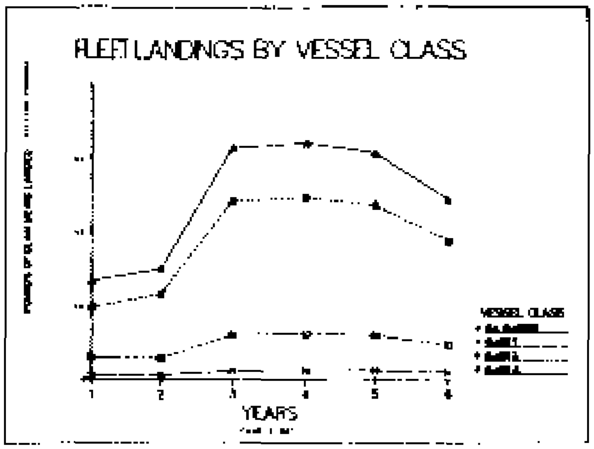
WHOLESALE CLAM MEAT PRICES
PRICE PER POUND ($)
YEARS
1
2
3
4
5
6
PRICES

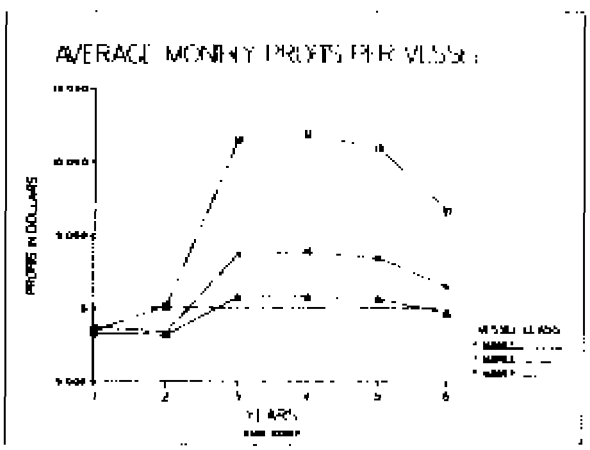
quota of 50 million pounds of meats would permit fleet landings to increase by approximately ten million pounds per year during years three, four, and five. Landings would begin to show a decline during year six due to fluctuations in year class strength. A plot of the effects of increasing allowable fishing effort hours by 100 percent above the baseline (Figure 14) shows that the effect upon landings would be minimal. However, a 50 percent cut in allowable fishing effort hours would decrease landings by almost 30 million pounds during years three, four, and five (Figure 15).

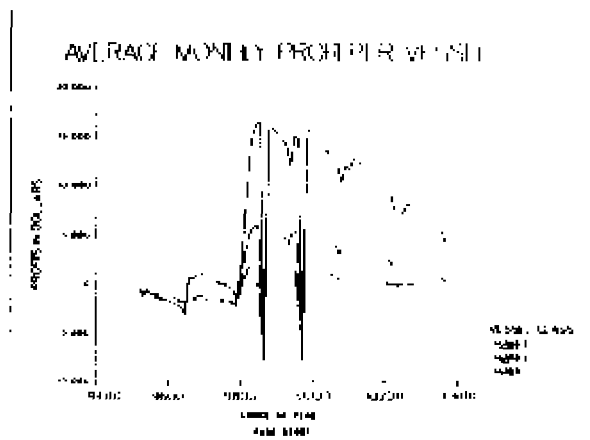
Fleet profits would be affected by all of these management options. Increasing the annual yield quota to 50 million pounds of meats would increase fleet profits by more than five million dollars per year during years three, four, and five. Fleet profits among class II vessels would be modestly affected, and profits among class II vessels would show little or no change (Figure 13). Increasing the monthly fishing effort hour ceiling by 100 percent would cause widely fluctuating fleet profits during years three, four, and five due to fishery closures (Figure 14). This is because profits plummet during periods when the fishery is closed. Decreasing effort hours by 50 percent , however, would have devastating effects upon fleet profits (Figure 15). An overall fleet operating loss of four million dollars would be incurred during year two, peak profits during years three, four, and five would be cut an

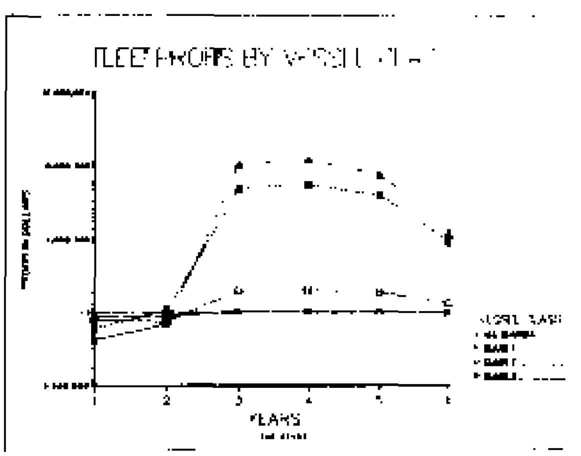
Figure 13

Case 8


FLEET LANDINGS BY VESSEL CLASS
VESSEL CLASS
1
2
3
4
5
6
YEARS


PROFITS IN DOLLARS
1
2
3
4
5
6
YEARS




YEARS

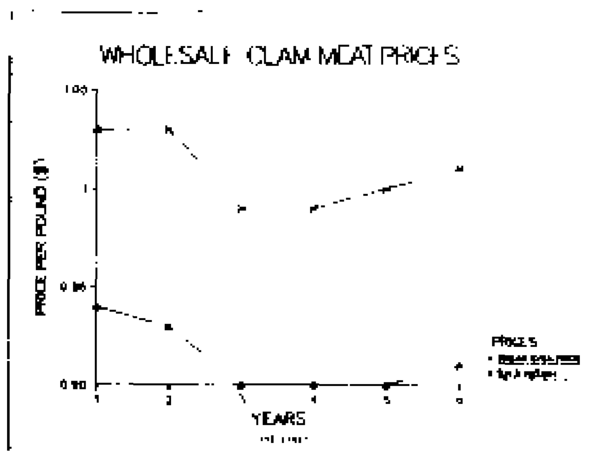
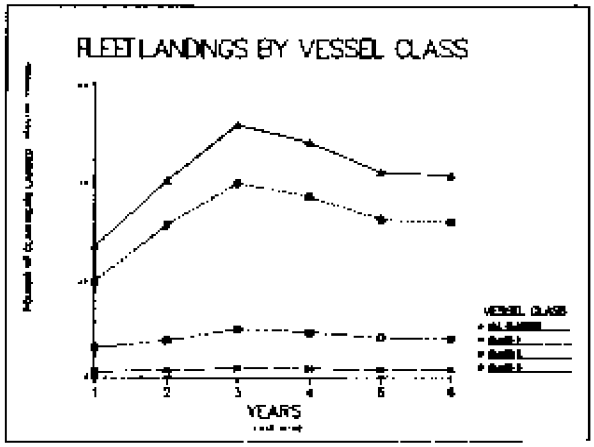
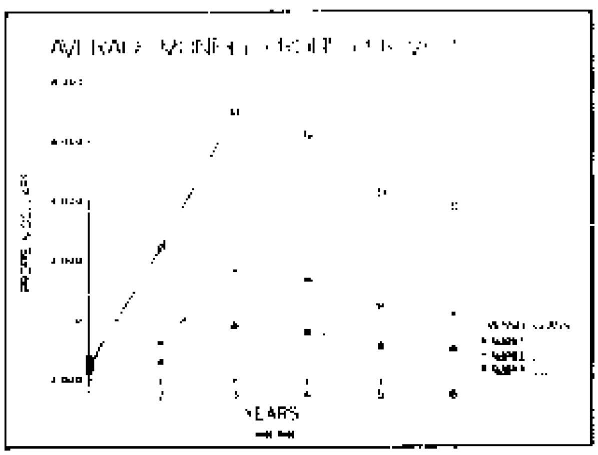
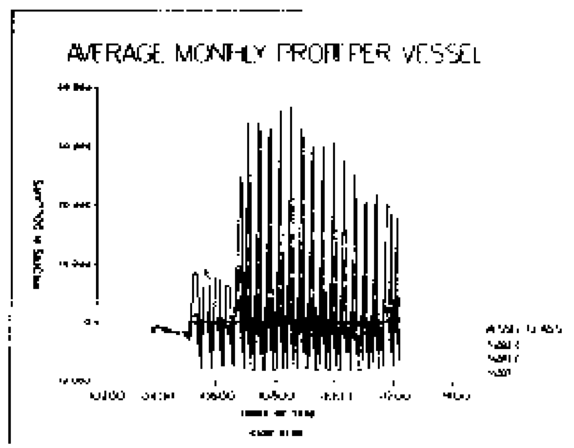

WHOLESALE CLAM MEAT PRICES
PRICE PER POUND ($)
PRICES
YEARS

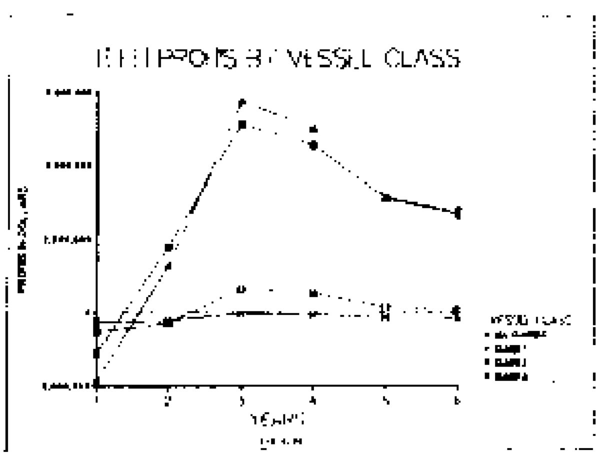
Figure 14

Case 9


FLEET LANDINGS BY VESSEL CLASS
VESSEL CLASS
YEARS


YEARS


AVERAGE MONTHLY PROFIT PER VESSEL


VESSEL CLASS

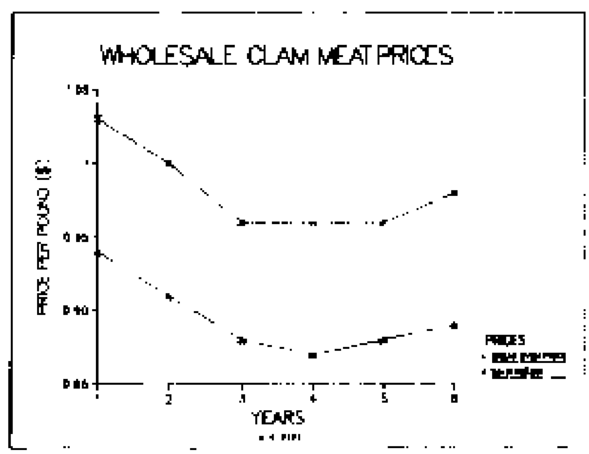
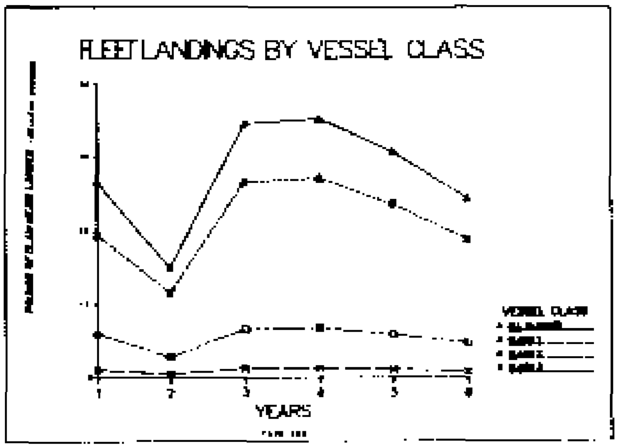
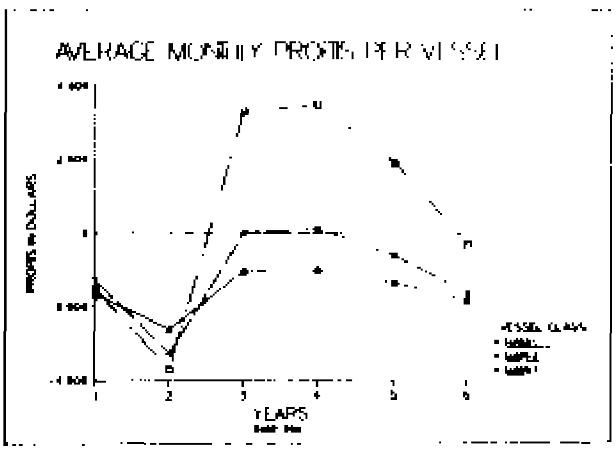
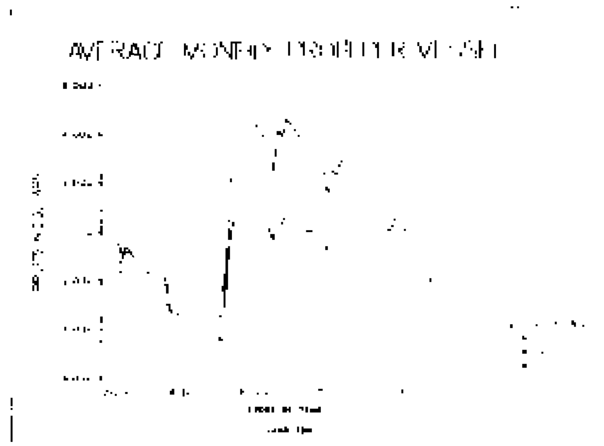

WHOLESALE CLAM MEAT PRICES
PRICE PER POUND ($)
PRICES
YEARS

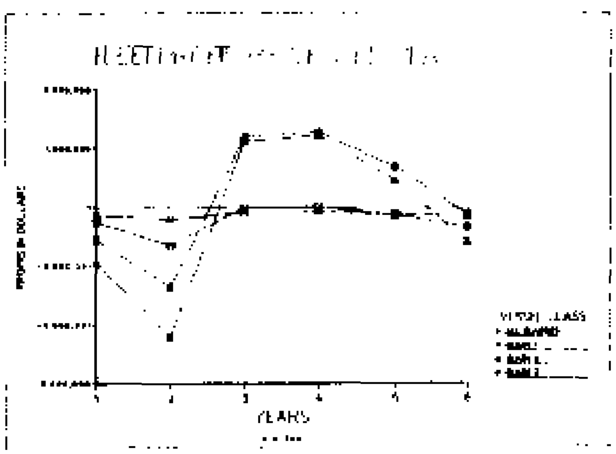
Figure 15

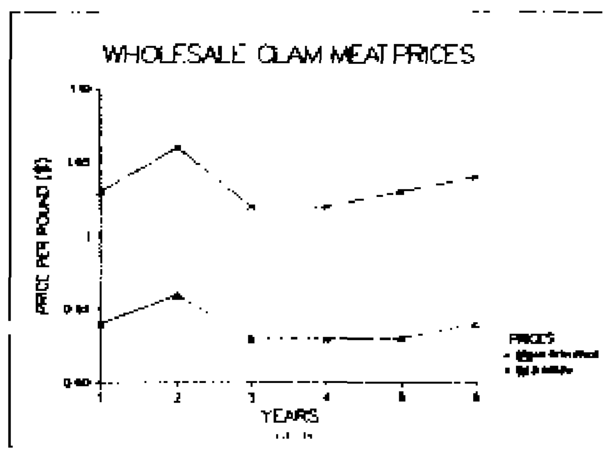
Case 10


FLEET LANDINGS BY VESSEL CLASS
YEARS
VESSEL CLASS


AVERAGE MONTHLY PROFITS PER VESSEL
PROFITS in DOLLARS
YEARS
VESSEL CLASS




PROFITS in DOLLARS
YEARS


WHOLESALE CLAM MEAT PRICES
PRICE PER POUND ($)
YEARS
PRICES

average of three million dollars, and the earnings of all three vessel class fleets would drop below the break even level by year six (Figure 15). Plots of monthly profits per vessel provide even greater insight into the mechanism behind these trends. With an increased annual yield quota of 50 million pounds of meats, the fishery is closed only during two quarters within the six year planning horizon (Figure 13). Average profits per vessel, however, drop below the break even mark for class I vessels by the end of year six. Cutting allowable effort hours by 50 percent (Figure 15) would eliminate the necessity for quarterly closures of the fishery because reduced harvest would not exceed quarterly quotas. However, resultant levels of harvest would be too low to prevent any class of vessel from staying above the break even mark by year six. Plots of surf clam stock size by region indicate that none of these management options would seriously affect stock sizes in any subregion within the six year planning horizon.

Wholesale clam meat prices could be expected to increase $0.01 to $0.02 per pound during years four, five, and six if annual yield quotas were raised to 50 million pounds of meats (Figure 13). Wholesale clam meat prices are $0.05 to $0.10 per pound lower when allowable fishing effort hours are increased by 100 percent. This decrease in price is due to the somewhat larger supply of clams harvested under this management option (Figure 14).

Wholesale clam meat price increases of $0.02 to $0.03 are demonstrated in case ten (Figure 15). Under this management option, restrictions in fishing effort hours and a subsequent drop in surf clams available to processors result in higher wholesale surf clam meat prices.

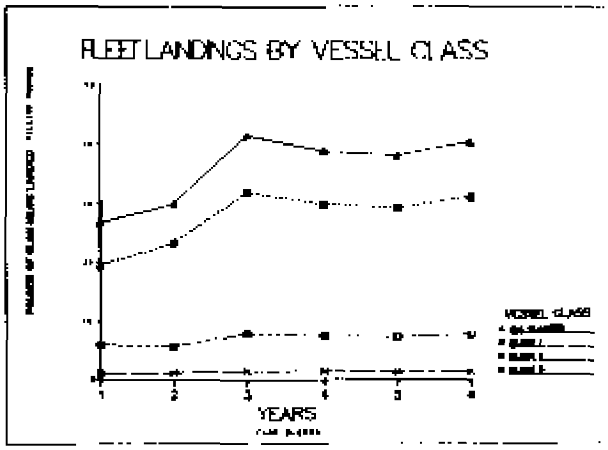
Case Eleven

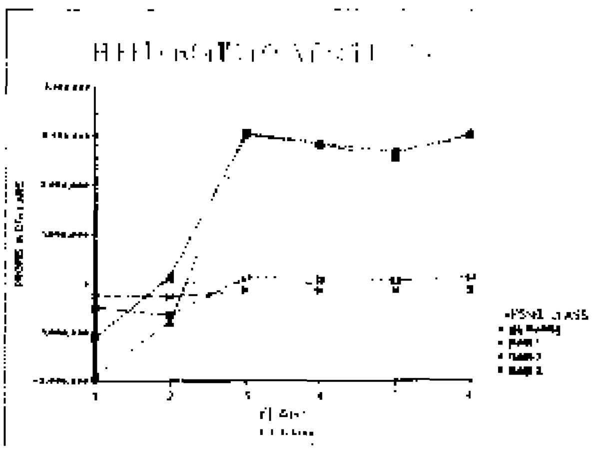
The last case considered in this analysis examines the impact of an anoxic event and associated mass mortalities similar to those observed in the northern New Jersey subregion during the summer of 1976. To simulate such an occurrence, natural mortality estimates in northern New Jersey were elevated to 0.80 during the entire second year of the simulation.

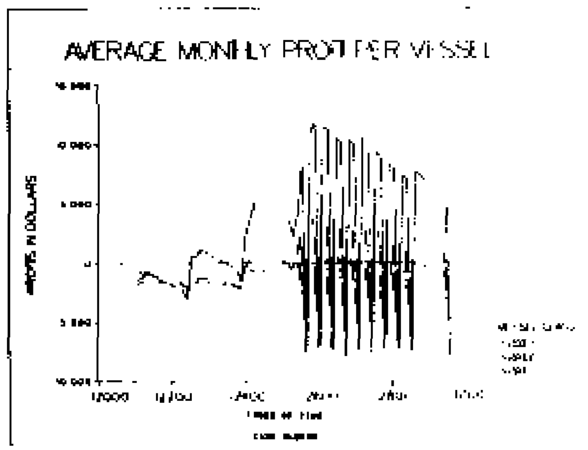
Once again, due to the restrictive vessel moratorium and the reluctance of fishermen to leave the fishery, fleet size would not change in any vessel class. The impact of such an occurrence upon year classes recruiting into the northern New Jersey fishery during years three, four, and five is evident in Figure 16. During these years, landings declined by five to six million pounds of meats. In case eleven, fleet profits are one to two million dollars lower during years three to six, and the class I fleet is unable to even approach the break even level. The distribution of fishing effort and biomass among the three subregions of the middle Atlantic region would be altered dramatically by

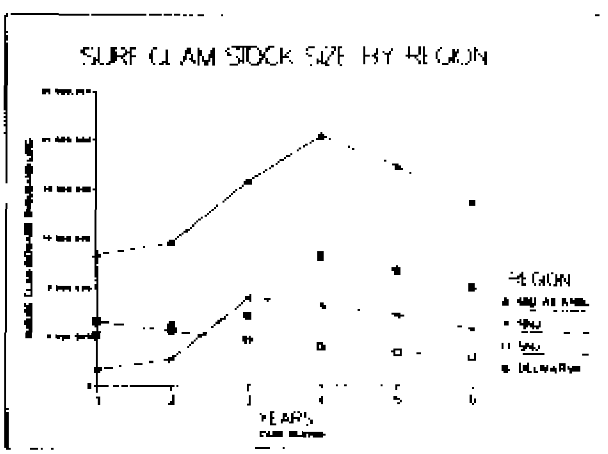
Figure 16

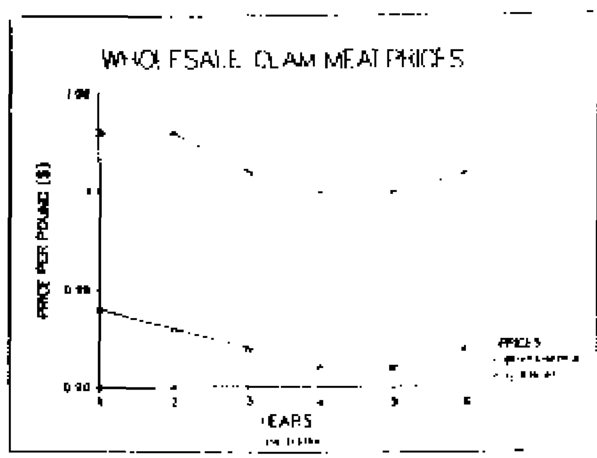
Case 11


FLEET LANDINGS BY VESSEL CLASS
VESSEL CLASS
YEARS




AVERAGE MONTHLY PROFIT PER VESSEL
PROFITS IN DOLLARS


SURF CLAM STOCK SIZE BY REGION
REGION
YEARS


WHOLESALE CLAM MEAT PRICES
PRICE PER POUND ($)

an anoxic event similar to that described in case eleven. A plot of middle Atlantic clam biomass expected during the six year planning horizon of case eleven illustrates that by year six, overall biomass is more than five billion pounds lower than under fishery conditions in case one. While southern New Jersey stock size would not be greatly affected, during years four, five, and six, fishing effort would shift from northern New Jersey to Delmarva. Delmarva stocks would be reduced by one to two billion pounds more than under case one baseline conditions. The northern New Jersey subregion shows stock sizes between three and four billion pounds lower than baseline estimates during years three, four, five, and six. Decreased clam landings following the anoxic event result in an increase in wholesale surf clam prices of $0.01 to $0.02 per pound (Figure 16).

Chapter VII

Abilities or Potential of This Approach

This model has been developed to provide a method by which fishery managers could consider alternatives for the complex issues confronting them in the development of public policy. A review of surf clam literature has been conducted, and the structure of the surf clam fishing and processing industries have been researched.

Model predictions are based upon population estimates from the National Marine Fisheries Service. The model provides a short term (6 year) outlook for managers evaluating alternative decision choices. This constraint is necessary because of uncertainties regarding the stock-recruitment relationship and the unknown effect of environmental variables on year class recruitment success.

This research does, however, provide a technique by which quantitative analysis of decision alternatives may be accomplished. The impact of management alternatives on stock size may be assessed, and the impact of management decisions on the consumer through wholesale price fluctuations evaluated. Perhaps most significantly, this model provides estimates of future profits or cash flows in the fishery generated by each alternative policy. With these data in hand, managers can proceed to apply evaluative capital budgeting techniques. Three of the most broadly accepted techniques, calculation of internal rates of return, calculation of net present values, and the use of profitability indices are readily adaptable to the output of this model, and could be employed to rank decision alternatives.

<u>Discussion of Case Studies</u>

The results of model analyses similar to those presented in the foregoing chapters could be used to make recommendations for management in the middle Atlantic surf clam fishery. The main objectives of surf clam management as identified by fishery managers are to protect surf clam stocks to permit eventual sustained harvests approaching 50 million pounds of meats (Maximum Sustainable Yield), to minimize economic dislocations while encouraging efficiency in the fishery, and to provide the greatest degrees of freedom and flexibility to all harvesters of this stock consistent with attainment of other management objectives.

As the results presented above suggest, regulations simulated in case one (an approach similar to the current management framework) can effectively prevent overharvesting. This type of management framework can, however, give rise to economic inefficiencies, unnecessarily depressing industry profits and inflating the wholesale price of surf clam meats. Some have noted that this regulatory approach is also expensive to enforce.

Model simulations suggest that we have currently entered a period within which greater yield quotas may be permissible. If this is in fact true, economic yield in the fishery could be improved without jeopardizing or sacrificing future surf clam population stability. Model simulations project that, if yield quotas are not raised in the near future, even a 50 percent decrease in allowable fishing effort hours will not be enough to avoid fishery closures. The model indicates that yield quotas somewhat closer to the current estimate of maximum sustainable yield, 50 million pounds of meats, would probably not have detrimental effects upon clam stock size within a six year planning horizon. Such an increase would improve the profitability of the class II and class III vessel fishing fleets significantly, and minimize economic dislocations in the fishery by assuring processors of an adequate and constant supply of raw product. The need for fishery closures would also be virtually eliminated. In conjunction with increased yield quotas, model case studies indicate that total allowable fishing effort hours could also be increased without causing disruptive closures in the fishery. The choice of such a management option might also result in a small reduction in the wholesale price of clam meats.

Overcapitalization in the fishery appears to remain a problem. Uncertainty regarding the future direction of surf clam management has aggravated the problem of overcapitalization by keeping many marginal operators in the fishery. As the results of case two assumptions indicate, removal of a vessel moratorium coupled with restrictive yield quotas could result in an overall decrease in the surf clam fishing fleet. This change is based upon potential economic return in the fishery. This result would be dependent upon the elimination of uncertainty regarding future management regulations. The elimination of unprofitable fishing operations would appear to boost average fleet profits and bring even class I operations to marginal productivity.

Model case studies suggest that regulation of the surf clam fishery through implementation of a landings tax would impose undue economic hardship upon the surf clam fishing industry, and could jeopardize long run stock size by permitting overharvesting. An adequate level of capitalization with only modest short run declines in stock size could be maintained with a landings tax sufficient to increase fishing costs by $0.40 per pound of meats harvested, but long run reductions in stock size would be likely to occur. Moreover, vessel profits would be reduced below levels achieved under current management regulations.

The results of this analysis indicate that size limit restrictions in the surf clam fishery may deserve further study. A lower size limit restriction could result in slightly greater vessel earnings among class II and III vessels while producing minimal stock size reductions during the six year planning horizon. However, uncertainties regarding the stock-recruitment relationship in the surf clam fishery indicate that reduction in size limits should be approached with extreme caution.

This analysis examines major management directions that might be followed to improve economic efficiency and protect stock size in the surf clam fishery during a six year planning horizon. It suggests that the Mid-Atlantic Fishery Management Council has been following a prudent course of action. Results of this analysis suggest that the council should continue to manage the fishery using quarterly yield quotas and effort hour restrictions. However, consideration should be given to lowering the minimum size limit on surf clams. Lowering the size limit to 4.0", essentially an unregulated harvest, would appear to threaten stock integrity. Consideration should also be given to raising the yield quota to a level closer to theoretical MSY. In the absence of higher yield quotas, the fishery will experience a large number of closures in the short run. Model results also suggest that consideration should be given to elimination of the vessel entry moratorium. Additional data describing propensity of surf clam vessel operators to enter and leave the fishery are required to determine whether lifting the moratorium is a feasible option.

Using this model fishery managers and planners may test and refine the results of even more specific ideas that could eventually lead to optimum management strategies. This model accomplishes its main objectives. It permits the identification of segments of the surf clam fishery that deserve further study, and elucidates general trends in fishery behavior in response to changes that might be imposed upon the system by management decisions. Continued research into the biology and population dynamics of the surf clam is vital to the construction of models with a greater degree of realism. This research has used what is known of surf clam biology and investigated recent changes that have occurred in the economy of the fishery to further our knowledge of the interaction between the biology and economics of the fishery.

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Glossary

Age Composition Analysis - A general method of estimating survival by comparing the number of animals alive at successive ages.

Autocorrelation - Measurement of the degree of correlation among elements of a given time series through the use of lagged coefficients.

Brody Growth Coefficient - A growth rate coefficient expressing the difference between the asymptotic size and the actual size of a fish. A measure of growth rate.

Catchability Coeffecient - The fraction of a fish stock which is caught by a defined unit of fishing effort.

Cohort Analysis - Computation of the fishing mortality rate experienced by a year class a successive ages using its catch at each age as obtained from catch statistics and yearly age composition data.

Durbin-Watson Statistic - A statistic used to test for serial correlation among the error terms in regression analysis.

Econometrics - The application of mathematical form and statistical techniques to the testing of economic theories.

Economic Dislocation - Disruption of established economic order because of failure in normal market mechanisms.

Economic Rent - Income or gain that is a differential return or surplus above costs.

Effective Fishing Effort - Rate of fishing effort which accounts for effort and gear restrictions.

Exogenous Variable - Originating or determined entirely by factors external to the equation system. Not influenced by other variables in the equation.

Gross Stock - Total revenue taken in by the fishing vessel.

Heteroscedasticity - A situation which occurs when the variance of a series of observations around a regression line is not constant. In a time series, the variance could become larger or smaller with the passage of time. This is an example of heteroscedasticity, and the Gauss-Markov assumption of constant variance is violated.

Marginal Costs - Incremental costs, or differential costs.

Marginal Revenue - Differential revenue.

Multicollinearity - Several independent variables having the same line or plane in common. This would be indicative of intercorrelation

Overcapitalization - An aggregate level of investment in a fishery which prevents individual firms from obtaining the optimum economic return.

Private Costs - Economic costs incurred by individual firms.

Social Costs - Macroeconomic costs incurred by the industry as a whole or society as a whole.

Appendix A

The calculations performed by each model subroutine are described in detail below. Each subroutine is presented below in the order in which it appears after the main program. This order is determined primarily by the frequency with which each subroutine must be used by the model. The program code follows the description of each subroutine.

Subroutine GROWTH

Subroutine GROWTH calculates the change in size of each cohort resulting from natural mortality, and the weight of each cohort resulting from von Bertalanffy growth. The following equations are used to calculate cohort size and weight:

$$(1)\quad COH_{x,y} = COH_{x,y} - Z_{x,y} * COH_{x,y}$$

where:

$COH_{x,y}$ = Population of clams in subregion x and cohort y.

$Z_{x,y}$ = Natural mortality rate of population in subregion x and cohort y.

$$(2)\quad Ln_{x,y} = L_{(\infty)} * (1-e^{(-K * ((IMO + 12) - t_0))})$$

where:

$Ln_{x,y}$ = Shell length of clams (mm) in subregion x and cohort y.

$L_{(\infty)}$ = Asymptotic shell length of surf clams (mm).

B = Brody growth coefficient for clams in region x (mm).

IMO = Month.

T_0 = Hypothetical time at which shell length is equal to zero (yrs).

$$(3)\quad Wt_{x,y} = (A * (ln_{x,y}^{3})) * (B)$$

where:

$Wt_{x,y}$ = Drained meat weight of clams in subregion x and cohort y (lbs).

A = Experimentally derived constant, .000111 for Delmarva, .000100 for New Jersey (see chapter II).

B = Conversion factor expressing grams as pounds (.002046).

This subroutine returns the following values to the main program: shell length of clams in each region and cohort weight of clams in each cohort and subregion. A weighted average of clam meat weight is used in cohorts 6-25 to calculate the weight of clams greater than 5.5 inches long.

<u>Subroutine PRORET</u>

Subroutine PRORET determines total and categorical costs of processing clam meats harvested in the fishery. As indicated in Chapter IV, total processing costs may fluctuate depending upon the season of the year. During the months of January, February, March, July, August, and September, total processing costs are equal to the winter-summer rate described in Chapter IV. During the months of April, May, June, October, November, and December the total processing costs are set equal to the spring-fall rate described in chapter IV. Variations in processing costs arise from differences in meat weight resulting from weight changes before and after spawning.

The subroutine calculates the number of bushels of clams available to processors and the pounds of meats from this harvest that are actually used by processing plants. Two conversion factors are used to derive these values. One bushel of middle Atlantic surf clams is considered to yield an average of 17 pounds of meats (Mid-Atlantic Fishery Management Council, 1982) and, as indicated in Chapter II, one bushel of clams yields an average of 11 pounds of clam meats after removal of the visceral material and cleaning. Individual processing costs are derived using the following relationships.

$$(4)\ CST_x = (PRCST) * (PCST_x)$$

where:

CST_x = Cost contributed by category x toward processing a pound of clam meats ($).

PRCST = Total cost to produce a pound of meats ($).

PCT = Percentage of total processing cost contributed by cost category x ($).

$$(5)\quad TCST_x = (CST_x) * (PLBS)$$

where:

$TCST_x$ = Total monthly processing costs contributed by Cost category x.

PLBS = Pounds of clam meats produced during the month (lbs).

Total monthly processing costs are determined by summing the costs derived for each processing cost category identified in Chapter IV. Because processing costs are primarily semi-variable, a lower limit on costs is identified in subroutine PRORET. Processing costs that fall below the identified floor are discarded. Wholesale prices are calculated in this subroutine using the following relationships.

$$(6)\quad TREV_x = (TPROC) * (TPROF_x)$$

where:

$TREV_x$ = Total industry revenue required to obtain profits x in excess of costs ($).

TPROC = Total processing costs ($).

$TPROF_x$ = Rate of profit x in excess of costs.

$$(7)\ WPR_x = (TREV_x)/(PLBS)$$

where:

WPR_x = Wholesale price of clam meats associated with profit x in excess of costs ($).

PLBS = Number of pounds of clam meats produced (lbs).

<u>Subroutine</u> <u>CQUOTA</u>

The function of subroutine CQUOTA is to determine whether quarterly harvest quotas have been exceeded, and to make it possible to stop all fishing activities if quotas have been exceeded. To accomplish this task, the subroutine identifies each quarter of the year by keying upon the month, keeps a running quarterly total of clam harvest levels during each quarter, and compares this running total with quarterly quotas applied to the fishery. If quarterly quotas are in excess of seasonal harvest totals, the fishery remains open. If, however, quarterly harvest totals ever exceed quarterly quotas, control is transferred to a step at the end of the subroutine that sets effort hours equal to zero until the end of the quarter. At the end of each quarter, control is once again transferred to the beginning of the subroutine where effort hours are reinstated and running quarterly harvest totals are once again set equal to zero.

Subroutine MODAT

Subroutine MODAT is responsible for writing monthly output to a user's terminal and to an output file. This subroutine opens an output file called MODAT into which the following data are entered at the termination of each month: current year and month of the simulation, quarterly harvest quota, and harvest during the current month. The following data are entered separately for northern New Jersey, Delmarva, and the entire middle Atlantic Region. These data are segregated according to vessel class, number of vessels actively fishing, number of effort days utilized, average profit realized per vessel, total fleet profits for each region, customary captain's share paid per vessel, and average vessel profits less customary captain's share. The following data are entered separately for each subregion and for the entire middle Atlantic: number of remaining clams in the natural population greater than or equal to 5.5 inches in length. This entry is made in numbers, pounds of meat weight, and in bushels of clams. A small amount of information about the processing sector is also entered each month. The following data are entered: bushels of surf clams processed, pounds of meats produced, total middle Atlantic processing costs, and the wholesale prices of surf clam meats that would be associated with breaking even, earning a 5% return over costs, earning a 10% return over costs, earning a 15% return over costs, and earning a 20% return over costs. Output is visible on a terminal screen during a simulation run, or may be printed from the output file.

<u>Subroutine HARVST</u>

Subroutine HARVST is responsible for calculating clam harvests in all regions. Harvest in each region is calculated by region and cohort using the following relationships:

$$(8)\quad HARV_{x,y,z} = V_{x,z} * ED_{x,z} * CA_{y,z} * COH_{x,y}$$

where:

$HARV_{x,y,z}$ = Harvest in subregion of x of cohort y by vessel class z.

$V_{x,z}$ = Number of vessels in subregion x of class z.

$ED_{x,z}$ = Number of fishing effort days worked by vessels in subregion x and class z.

$CA_{y,z}$ = Catchability coefficient for cohort y by vessel class z.

$COH_{x,y}$ = Population size of clams in subregion x of cohort y.

$THARV_{x,z}$ = Sum of harvests in subregion x by vessels of class z.

$$(10)\quad LBT_{x,z} = HARV_{x,y,z} * WT_{y}$$

where:

$LBT_{x,z}$ = Total weight of clams harvested in subregion x
by vessels of class z.

WT_y = Representative meat weight of a clam in cohort y.

After the total weight of the harvest has been determined for each vessel class and subregion, these values are summed to calculate total harvest for the entire middle Atlantic region and for each vessel class.

<u>Subroutine VENEX</u>

Subroutine VENEX calculates the number of vessels to enter or leave the fishery at the end of each year, depending upon potential profits available. At the beginning of this subroutine, nine profit arrays are established, one for each vessel class and subregion. Each month, fleet profits are entered into a unique location of the profit array created for each specific vessel class and subregion. At the end of the year, all of the monthly array locations are summed to derive annual fleet profits for each vessel class and subregion. Vessel profits are compared to profits that could be obtained by investing a sum equal to the market value of the fishing vessel at a prevailing market interest rate. If the rate of return available for a class of vessel fishing within any subregion is greater than the rate of return outside of the fishery, then the fleet size is automatically increased by a user defined percentage termed $VINC_z$, where z represents vessel class. If the rate of return available within the fishery is lower than that available outside the fishery, fleet size is decreased by a user defined percentage termed $VDEC_z$, where z represents vessel class. To simulate the effects of a moratorium on vessel entry and exit from the fishery, both $VINC_z$ and $VDEC_z$ may be set equal to zero. As noted in Chapter IV, it is very difficult to derive an average market value for vessels in any particular size category; however, the procedure that was used to produce estimates of vessel market value according to size classification was described there. Survey data were inadequate to measure the percentage of vessels that would leave or enter the fishery in search of greater profits during any single year. There is no single absolute expression that may be used to describe vessel movement into and out of the fishery. In order to simulate the effects of removing the vessel moratorium, VINC and VDEC were both initially set equal to 0.33. It is not unrealistic to assume that if greater profits were available in another fishery or occupation, and no disincentives to leave the fishery existed (i.e the threat of future vessel quota plans based upon levels of past harvest), one third of the fleet would exit the fishery. The difficulty associated with predicting such behavior is evident in the statistics describing vessel distribution in the middle Atlantic surf clam fishery. During the years between 1976 and 1982 inclusive, a period of time generally associated with depressed and declining profits for class I vessels in the fishery, the following percent changes in fleet size occurred annually: -6 percent, -33 percent, -5 percent, +33 percent, -50 percent, +14 percent, -6 percent (Mid-Atlantic Fishery Management Council, 1982). Of course, during this same period of time, fishermen did not leave the fishery in great numbers because they were not certain whether they would be able to reenter the fishery at a later date. Thus, the relationship describing vessel entry and exit from the fishery reflects a limited knowledge of behavior among surf clam vessel owners.

Subroutine INPUT

Subroutine INPUT defines all variables initially required for model calculations. In tabular form, this subroutine defines the variables listed below.

$V_{i,j}$ = Number of vessels fishing in subregion i and vessel class j.

$CA_{i,j}$ = Catchability coefficient for cohort i in subregion j (equal to zero when fishery closes).

$XNCO_i$ = Size of cohort i in northern New Jersey.

SCO_i = Size of cohort i in southern New Jersey.

DCO_i = Size of cohort i in Delmarva.

$Z_{i,j}$ = Natural mortality (instantaneous as monthly units) for cohort i in subregion j.

ZOQP = Ocean quahog ex-vessel price.

ZHCP = Hard clam (*Mercenaria mercenaria*) ex-vessel price.

Fishing costs:

ZOYP = Oyster ex-vessel price.

$CST_{i,j}$ = Fixed cost of fishing where i is a cost category (1 = port fees, 2 = interest payments, 3 = personal liability and indemnity insurance, 4 = license fees and taxes, 5 = legal accounting fees, 6 = general administrative expense) and j is a vessel class.

FU1, FU2, FU3 = Fuel consumption of class I, II, and III vessels respectively.

FUPR = Fuel price.

$ZMIS_z$ = Miscellaneous variable fishing costs identified in Chapter IV where z represents vessel class.

CRS_z = Percent of gross vessel stock paid as crew wages.

CPS_z = Percent of gross vessel stock paid as captain's wages.

Processing costs:

WCST = Total winter - summer processing cost.

SFCST = Total spring - fall processing cost.

TRNS = Transportation cost.

PAT = Payment of patent fees.

XLAB = Labor cost.

ELEC = Electricity cost.

FULO = Fuel oil cost.

DEPR = Depreciation cost.

REPR = Repair cost.

ZOVH = Overhead cost.

ZINS = Insurance cost.

ZLEGL = Legal - accounting fees.

STRG = Storage cost.

CHEM = Cost of chemicals.

PFLR = A cost floor defined for processing operations.

Other variables:

$ARATE_x$ = A discount rate representing the prevailing rate of interest in each subregion x.

$XMVAL_z$ = Vessel market value estimates for three classes of fishing vessel z.

Management variables:

$BHRS_x$ = Permitted monthly fishing effort hours in subregion x

$TXL_{x,z}$ = Landings taxes in subregion x applicable to vessel class z.

$QUOTA_i$ = Quarterly landings permitted in quarter i.

$WUTIL_i$ = Winter utilization rate of permitted fishing hours among vessels in class i.

$SUTIL_i$ = Summer utilization rate of permitted fishing hours among vessels in class i.

$SWTCH_z$ = Fishing costs incurred by vessels in class z when moving fishing operations from one subregion to another.

$RCVTM_z$ = Time required to recover costs of moving between subregions for vessels of class z.

BNJ = Brody growth coefficient for clams in waters off

New Jersey.

BDEL = Brody growth coefficient for clams in waters off Delmarva.

$AVWT_{i,x}$ = Weighted average of clam meat weight in cohorts 6 through 25, where i = cohort and x = subregion.

EXFLR = Ex-vessel price floor for surf clams.

Subroutine SWITCH

This subroutine calculates the number of vessels in each class moving from one subregion to another as a function of catch potential. Potential profits in each subregion are initially calculated using the following equations.

$$(11)\quad PH_{x,y,z} = 1.0 * ED_{x,z} * CA_{y,z} * CO_{x,y}$$

where:

$PH_{x,y,z}$ = Potential harvest in subregion x of cohort y by vessels in class z.

$ED_{x,z}$ = Fishing effort days expended by vessels of class z.

$CA_{y,z}$ = Catchability coefficient for cohort y by vessels of class z.

$CO_{x,y}$ = Size of cohort y in subregion x.

$$(12)\quad PVR_{x,z} = LBT_{x,z} * (SCP - TXL_{x,z})$$

$PVR_{x,z}$ = Potential revenue of fleet in subregion x and vessel class z.

$LBT_{x,z}$ = Pounds of clam meats harvested by vessels in subregion x and vessels class z.

SCP = Ex-vessel surf clam price.

$TXL_{x,z}$ = Landings tax per pound of clam meats harvested in subregion x by vessels of class z.

$$(13)\ POP_{x,z} = FCST_z + ((FU_z * FUPR + ZMIS_z) * ED_{x,z} + (CRS_z * PVR_{x,z}) + (CPS_z * PVR_{x,z}))$$

where:

$POP_{x,z}$ = Potential operating cost of vessels in subregion x and in class z.

$FCST_z$ = Monthly fixed costs of fishing by vessels in class z.

FU_z = Fuel consumption per trip of vessels in class z.

FUPR = Fuel price per gallon.

$ZMIS_z$ = Miscellaneous variable costs of fishing by vessels in class z.

$ED_{x,z}$ = Effort days of fishing expended by vessels of class z in subregion x.

CRS_z = Crew share of gross vessel stock.

$PVR_{x,z}$ = Potential gross stock (total revenue) for a vessel of class z fishing in subregion x.

CPS_z = Captain's share of gross stock for a vessel of class z.

$$(14)\quad PR_{x,z} = PVR_{x,z} - POP_{x,z}$$

where:

$PR_{x,z}$ = Potential earnings of vessels in class z fishing in subregion x. The other variables are as defined above.

$$(15)\quad XPOT_{x,z} = PR_{x,z} - (SWTCH_z / RCVTM_z)$$

where:

$XPOT_{x,z}$ = Profit potential of vessels in class z fishing in subregion x.

$PR_{x,z}$ = Vessel earnings as defined above.

$SWTCH_z$ = Costs required for vessels of class z to move between subregions.

$RCVTM_z$ = Period of time within which a class z vessel would expect to recover his costs to move to a new subregion.

Little is known of the willingness of surf clam vessel owners to move their fishing operations along the mid-Atlantic coast line. Clearly, a willingness-to-pay study would be useful in determining this type of behavior. Such a study, however, is beyond the scope of this work.

Data obtained from surveys and personal interviews shed little light upon the movement pattern of the fishing fleet between subregions in search of higher profits. Historically, however, the surf clam fleet has demonstrated great mobility and a readiness to exploit newly discovered clam beds. It is, therefore, not unreasonable to assume that one half of the vessels fishing in any particular subregion would move to a new subregion if profits were potentially greater there. Subroutine SWITCH incorporates this behavior pattern. If, in fact, a greater percentage of the fleet shifts operations to newly discovered clam beds in any subregion, subroutine SWITCH could underestimate the rate of exploitation in that subregion for a period of several months. Estimates of annual harvest would, however, probably not be affected to any significant extent. If historical surf clam fleet movement is any indicator of future behavior, it appears unlikely that more than half of the fleet would be willing to move within a month to clam beds in other subregions for the sake of greater catches.

Subroutine EFFORT

Subroutine EFFORT calculates the number of allowable fishing effort days utilized by vessels of each class within each subregion. The subroutine first converts effort hours into effort days. Subroutine EFFORT assumes that one effort day is equal to 12 hours of fishing activity. Vessel surveys and interviews have indicated that a fishing trip involves approximately 12 or more hours of steaming time to travel to and from the clam beds, and 12 or more hours of actual fishing activity. Under restrictions of 24 hours of allowable fishing activity per week, most surf clam vessels can make a maximum of only two trips per week. Subroutine EFFORT also accounts for a percentage of allowable fishing hours that are not used by the clam fishing fleet. Full fleet utilization of allowable fishing hours is often prevented by bad weather conditions. Moreover, a significant number of surf clam fishing vessels operate marginally, harvesting only a sufficient quantity of clams to keep their harvesting permits. These vessel owners are staying in the fishery because they expect that changes in management, increased surf clam population size, and improved market conditions will bring them greater future profit potential. The Mid-Atlantic Fishery Management Council has identified the average percent utiltization of allowable fishing time according to vessel class in the surf clam fishery (Mid-Atlantic Fishery Management Council, 1981). These estimates provide statistics to be used in subroutine EFFORT.

Subroutine VESRET

Subroutine VESRET calculates economic returns to vessel owners and operators. The first step undertaken by this subroutine is the implementation of the ex-vessel price model. Seasonal dummy variables are initialized depending upon the value of IMO, and the ex-vessel price equation described in Chapter III is applied. If ex-vessel prices are to be fixed, output from the price model is ignored and surf clam prices are set each year according to instructions from the user.

After defining the variable SCP, ex-vessel surf clam price, subroutine VESRET proceeds to calculate vessel revenues and costs according to vessel class and subregion using the following equations:

$$(16)\quad VR_{x,z} = XLBT_{x,z} * (SCP - TXL_{x,z})$$

where:

$VR_{x,z}$ = Revenues in subregion x taken by vessels of class z.

$XLBT_{x,z}$ = Pounds of clam meats harvested by vessels of class z in subregion x.

SCP = Ex-vessel surf clam price.

$TXL_{x,z}$ = Landings tax imposed upon meats landed by vessels of class z in subregion x.

$$(17)\quad VRA_{x,z} = VR_{x,z}/V_{x,z}$$

where:

$VRA_{x,z}$ = Average vessel revenue in subregion x by vessels of class z. $VR_{x,z}$ = As defined above.

$V_{x,z}$ = Number of vessels of class z in subregion x.

Total mid-Atlantic vessel revenue is calculated according to vessel class by summing the revenues from each subregion. Vessel costs are calculated in a fashion similar to the algorithm described above in subroutine SWITCH. The following equations are employed.

$$(18)\ FCST_z = (1/12) * (CST1_z + CST2_z + CST3_z + CST4_z + CST5_z + CST6_z)$$

where:

$FCST_z$ = Total monthly fixed costs of fishing for a vessel of class z.

$CST1_z$ = Annual cost of port fees for a vessel of class z.

$CST2_z$ = Aggregate annual cost of boat repair, hull insurance, and interest for a vessel of class z.

$CST3_z$ = Annual cost of personal liability and indemnity insurance for a vessel of class z.

$CST4_z$ = Annual cost of license fees and taxes for a vessel of class z.

$CST5_z$ = Annual cost of legal-accounting fees for a vessel of class z.

$CST6_z$ = Annual cost of general administrative expenses for a vessel of class z.

$$(19)\ XOP_{x,z} = FCST_z + ((FU_z * FUPR + ZMIS_z) * ED_{x,z} + (CRS_z * VRA_{x,z}))$$

where:

$XOP_{x,z}$ = Total monthly operating costs (fixed and variable) for a vessel of class z operating in subregion x.

$FCST_z$ = Monthly fixed costs as described above incurred by a vessel of class z.

FU_z = Monthly fuel use for vessels of class z.

FUPR = Fuel price per gallon.

$ZMIS_z$ = Monthly miscellaneous variable costs of fishing for vessels of class z.

$ED_{x,z}$ = Monthly effort days for vessels of class z in subregion x.

$VRA_{x,z}$ = Average vessel revenue for vessels of class z fishing in subregion x.

$$(20)\ TCST_{x,z} = XOP_{x,z} * V_{x,z}$$

where:

$TCST_{x,z}$ = Total fleet costs of class z vessels operating in subregion x.

$XOP_{x,z}$ = Number of vessels of class z fishing in subregion x.

$$(21)\ AERN_{x,z} = VRA_{x,z} - XOP_{x,z}$$

where:

$AERN_{x,z}$ = Average monthly earnings of a vessel of class z fishing in subregion x.

$VRA_{x,z}$ = Average vessel revenue as defined above.

XOP = Operating costs as defined above.

Total fleet earnings for the entire middle Atlantic region and average vessel earnings for the entire middle Atlantic region are computed separately for each vessel class by summing subregional totals.

<u>Subroutine</u> <u>YRPRNT</u>

The last subroutine to be called in the bioeconomic model is subroutine YRPRNT. The function of this subroutine is to write yearly output to the user's terminal, and to an annual output file, YRPRNT, opened by the main program. The first task performed by YRPRNT is to produce a fishing sector summary or "snapshot" describing conditions in the industry at the end of each year. The following information is provided and segregated according to vessel class, subregion, and region: number of vessels fishing, number of fishing effort days, total harvest in pounds, total harvest in bushels, and total fleet profits. After providing a fishing sector summary, YRPRNT next produces a biological summary. The biomass of clams and an estimate of the number of individual clams in each cohort and subregion and region are displayed. Finally, subroutine YRPRNT produces an end of the year processing sector summary. Total annual processing industry costs are displayed and identified according to the following cost categories: raw product costs, transportation costs, cost of patents, cost of labor, cost of energy (electricity, fuel oil, propane), packaging costs, depreciation costs, overhead costs, insurance costs, legal-accounting costs, storage costs, and the cost of chemicals used in processing. Also displayed are the number of bushels of clams produced during the preceding year, the number of pounds of clam meats produced by the processing industry, and the wholesale prices that clam shucking plant owners would be required to command for breaking even, and receiving 5, 10, 15, and 20 percent returns over costs.

```
C
C
C
C     SURF CLAM FISHERY MANAGEMENT MODEL
C
C
C
C     INITIAL PROGRAMMING 4-30-83
C
C
C       COMMON BLOCKS
C
        COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
       CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
       CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
       CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
       CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
       CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
       CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
       CCA13,CA23,CA33,CA43,CA53,CA63,XNCD1,XNCD2,XNCD3,XNCD4,XNCD5,
       CXNCD6,SCD1,SCD2,SCD3,SCD4,SCD5,SCD6,DCD1,DCD2,DCD3,DCD4,DCD5,
       CDCD6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
       CDTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
        COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
       CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,

 CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
       CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,

 CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,

 CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
       CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
       CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63

 COMMON/VRET/ZLSCP,ZCOP,ZHCP,ZOTP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,

 CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,

 CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,

 CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,

 CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
       CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
       CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,

 CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
       CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
       CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3

 COMMON/PRET/WSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
       CFULD,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,
```

```
CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TIOVH,TIINS,TILEGL,TSTRG,TCHEM,
      CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
      CWPR5,TREPR
       COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
      CVINC2,VINC3,VDEC1,VDEC2,VDEC3

COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
      CSUTIL3

COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
      CSEHRT3,SEHRT4,QUOTA4,QUOTA
       COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3

COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
      CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
      CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
      CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
      CAXNCD6,AXSCD6,AXDCD6,ABUN,ABUS,ABUD,APLBS,APROC,
      CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,AOVH,AINS,
      CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C      OPEN OUTPUT FILES FOR MONTHLY AND YEARLY DATA
C
C
       OPEN(6,FILE= 'MONDAT')
       OPEN(7,FILE= 'YRDAT')
C
C    COMMON BLOCK IDENTIFICATION
C    HARV - CONTAINS HARVEST PARAMETERS
C    GRW  - CONTAINS GROWTH AND POPULATION DYNAMICS PARAMETERS
C    VRET - CONTAINS VESSEL RETURN PARAMETERS
C    PRET - CONTAINS PROCESSOR RETURN PARAMETERS
C    ENEX - CONTAINS VESSEL ENTRY-EXIT PARAMETERS(ENTER OR LEAVE
FISHERY)
C    EFRT - CONTAINS EFFORT CALCULATION PARAMETERS
C    SWTCH- CONTAINS VESSEL SWITCHING PARAMETERS(MOVE BETWEEN REGIONS)
C    YRLY - CONTAINS ANNUAL TOTALS OF OUTPUT VARIABLES
C
C    CALL ALL OF THE INITIALIZED PARAMETERS
C
       CALL INPUT
       WRITE(1,*)'YOU HAVE ACCESSED THE SURF CLAM BIOECONOMIC
EVALUATION'
       WRITE(1,*)  'MODEL. INITIAL PARAMETERS MAY BE CHANGED BY
EDITING'
       WRITE(1,*)  'THOMAS>MODEL>INPUT.F77.'
        WRITE(1,*)'***********************************************'
       WRITE(1,*)  '                                    '
        WRITE(1,*) 'HOW MANY YEARS OF FISHING DO YOU WISH TO SIMULATE'
       READ(1,*) IYRSS
        WRITE(1,*)  'DO YOU REQUIRE A PRINTOUT OF MONTHLY DATA'
       READ(1,4) ANS6
4       FORMAT(A1)
```

```
C
C
C     INVOKE ANNUAL LOOP FOR YEARLY INCREMENTS
C
         DO 10 I=1,IYRSS
C
          WRITE(1,*) 'IF YOU WISH TO FIX SURF CLAM EX-VESSEL PRICE'
          WRITE(1,*) 'THIS YEAR, ENTER THE PRICE.  IF NOT, ENTER'
          WRITE(1,*) 'ZERO ,0, TO INVOKE THE EX-VESSEL PRICE MODEL'
          READ(1,*) EXPLR
C
          IYRS=I
C     INITIALIZE ANNUAL DATA AT ZERO
C
         SEHRT1=0
         SEHRT2=0
         SEHRT3=0
         SEHRT4=0
C
C
         AED11=0
         AED12=0
         AED13=0
         AED21=0
         AED22=0
         AED23=0
         AED31=0
         AED32=0
         AED33=0
         AEDMA1=0
         AEDMA2=0
         AEDMA3=0
         ANLBT1=0
         ANLBT2=0
         ANLBT3=0
         ASLBT1=0
         ASLBT2=0
         ASLBT3=0
         ADLBT1=0
         ADLBT2=0
         ADLBT3=0
         AMALB1=0
         AMALB2=0
         AMALB3=0
         YERNN1=0
         YERNN2=0
         YERNN3=0
         YERNS1=0
         YERNS2=0
         YERNS3=0
         YERND1=0
         YERND2=0
          YERND3=0
         ATHTN6=0
```

```
      ATWTS6=0
      ATWTD6=0
      AXNCO6=0
      AXSCO6=0
      AXDCO6=0
      ABUN=0
      ABUS=0
      ABUD=0
      APLBS=0
      APROC=0
      ASHCST=0
      ATRNS=0
      APAT=0
      AXLAB=0
      AELEC=0
      AFULC=0
      APROP=0
      APKG=0
      ADEPR=0
      ADVH=0
      AINS=0
      ALEGL=0
      ASTRG=0
      ACHEM=0
C
C    INVOKE MONTHLY LOOP FOR ALL MONTHLY INCREMENTS AND CALCULATIONS
C
      DO 20 J=1,12
       IMO=J
C
C    CALL MONTHLY SUBROUTINES INVOKING GROWTH, NATURAL MORTALITY, AND
C    FISHING EFFORT
C
       IF(IMO.EQ.1.OR.IMO.EQ.4.OR.IMO.EQ.7.OR.IMO.EQ.10)THEN
       EHRS1=RHRS1
       EHRS2=RHRS2
       EHRS3=RHRS3
       ENDIF
      CALL GROWTH
      CALL EFFORT
      CALL HARVST
      CALL CQUOTA
C
C    RECALCULATE COHORT SIZE ACCOUNTING FOR FISHING MORTALITY
C
      XNCO1=XNCO1-(HN11+HN12+HN13)
      XNCO2=XNCO2-(HN21+HN22+HN23)
      XNCO3=XNCO3-(HN31+HN32+HN33)
      XNCO4=XNCO4-(HN41+HN42+HN43)
      XNCO5=XNCO5-(HN51+HN52+HN53)
      XNCO6=XNCO6-(HN61+HN62+HN63)
      SCO1=SCO1-(HS11+HS12+HS13)
      SCO2=SCO2-(HS21+HS22+HS23)
      SCO3=SCO3-(HS31+HS32+HS33)
```

```
      SCO4=SCC4-(HS41+HS42+HS43)
      SCO5=SCO5-(HS51+HS52+HS53)
      SCO6=SCO6-(HS61+HS62+HS63)
      DCO1=DCC1-(HD11+HD12+HD13)
      DCO2=DCO2-(HD21+HD22+HD23)
      DCO3=DCO3-(HD31+HD32+HD33)
      DCO4=DCC4-(HD41+HD42+HD43)
      DCO5=DCO5-(HD51+HD52+HD53)
      DCO6=DCC6-(HD61+HD62+HD63)
C
C    CALCULATE TOTAL WEIGHT OF EACH NORTHERN NEW JERSEY
C    COHORT GROUP
C
      TWTN1=XWTN1*XNCO1
      TWTN2=XWTN2*XNCO2
      TWTN3=XWTN3*XNCO3
      TWTN4=XWTN4*XNCO4
      TWTN5=XWTN5*XNCO5
      TWTN6=XWTN6*XNCO6
C
C     CALCULATE TOTAL NORTHERN NEW JERSEY POPULATION SIZE AND WEIGHT
C
      TNPOP=XNCO1+XNCO2+XNCO3+XNCO4+XNCO5+XNCO6
      TNWT=TWTN1+TWTN2+TWTN3+TWTN4+TWTN5+TWTN6
C
C    CALCULATE TOTAL WEIGHT OF EACH SOUTHERN NEW JERSEY COHORT GROUP
C
      TWTS1=XWTS1*SCO1
      TWTS2=XWTS2*SCO2
      TWTS3=XWTS3*SCO3
      TWTS4=XWTS4*SCO4
      TWTS5=XWTS5*SCO5
      TWTS6=XWTS6*SCO6
C
C    CALCULATE TOTAL SOUTHERN NEW JERSEY POPULATION SIZE AND WEIGHT
C
      TSPOP=SCO1+SCO2+SCO3+SCO4+SCO5+SCO6
      TSWT=TWTS1+TWTS2+TWTS3+TWTS4+TWTS5+TWTS6
C
C    CALCULATE TOTAL WEIGHT OF EACH DELMARVA COHORT GROUP
C
      TWTD1=XWTD1*DCO1
      TWTD2=XWTD2*DCO2
      TWTD3=XWTD3*DCO3
      TWTD4=XWTD4*DCO4
      TWTD5=XWTD5*DCO5
      TWTD6=XWTD6*DCO6
C
C    CALCULATE TOTAL DELMARVA POPULATION SIZE AND WEIGHT
C
      TDPOP=DCO1+DCO2+DCO3+DCO4+DCO5+DCO6
      TDWT=TWTD1+TWTD2+TWTD3+TWTD4+TWTD5+TWTD6
C
C    CALCULATE TOTAL MID-ATLANTIC POPULATION SIZE AND WEIGHT
```

```
C
       TMPOP=TNPOP+TSPOP+TOPOP
       TMWT=TNWT+TSWT+TOWT
C
C    CALL ECONOMIC SUBROUTINES (VESSEL RETURNS, PROCESSOR RETURNS) AND
C    CALL PRINTOUT OF MONTHLY DATA IF REQUIRED
C
       CALL VESRET
        WRITE(1,*) SCP
       CALL PRORET
       IF(ANS6.EQ.'Y')CALL MODAT
C
C    UPDATE ANNUAL TOTALS OF ALL VARIABLES INCORPORATING MONTHLY
CHANGES
C
C    ANNUAL EFFORT DAYS
C
       AED11=AED11+ED11
       AED12=AED12+ED12
       AED13=AED13+ED13
       AED21=AED21+ED21
       AED22=AED22+ED22
       AED23=AED23+ED23
       AED31=AED31+ED31
       AED32=AED32+ED32
       AED33=AED33+ED33
       AEDMA1=AED11+AED21+AED31
       AEDMA2=AED12+AED22+AED32
       AEDMA3=AED13+AED23+AED33
C
C    ANNUAL HARVEST
C
       ANLBT1=ANLBT1+XNLBT1
       ANLBT2=ANLBT2+XNLBT2
       ANLBT3=ANLBT3+XNLBT3
       ASLBT1=ASLBT1+SLBT1
       ASLBT2=ASLBT2+SLBT2
       ASLBT3=ASLBT3+SLBT3
       ADLBT1=ADLBT1+DLBT1
       ADLBT2=ADLBT2+DLBT2
       ADLBT3=ADLBT3+DLBT3
         AMALB1=AMALB1+XLBTOT
         AMALB2=AMALB2+SLBTOT
         AMALB3=AMALB3+DLBTOT
C
C    VESSEL EARNINGS
C
       YERNN1=YERNN1+ERNN1
       YERNN2=YERNN2+ERNN2
       YERNN3=YERNN3+ERNN3
       YERNS1=YERNS1+ERNS1
       YERNS2=YERNS2+ERNS2
       YERNS3=YERNS3+ERNS3
       YERND1=YERND1+ERND1
```

```
      YERNO2=YERNO2+ERNO2
      YERNO3=YERNO3+ERNO3
C
C   SIZE OF POPULATION GREATER THAN 5 1/2 INCHES IN LENGTH
C
      ATWTN6=TWTN6+ATWTN6
      ATWTS6=TWTS6+ATWTS6
      ATWTD6=TWTD6+ATWTD6
      AXNCO6=XNCO6+AXNCO6
      AXSCO6=SCO6+AXSCO6
        AXDCO6=DCO6+AXDCO6
      ABUN=ATWTN6/17.0
      ABUS=ATWTS6/17.0
      ABUD=ATWTD6/17.0
C
C   ANNUAL PROCESSING SECTOR SUMMARY
C
      APLBS=APLBS+PLBS
      APROC=APROC+TPROC
      ASHCST=ASHCST+SHCST
      ATRNS=ATRNS+TTRNS
      APAT=APAT+TPAT
      AXLAB=AXLAB+TXLAB
      AELEC=AELEC+TELEC
      AFULD=AFULD+TFULD
      APROP=APROP+TPROP
      APKG=APKG+TPKG
      ADEPR=ADEPR+TDEPR
      AOVH=AOVH+TZOVH
      AINS=AINS+TZINS
      ALEGL=ALEGL+TZLEGL
      ASTRG=ASTRG+TSTRG
      ACHEM=ACHEM+TCHEM
C
C   CALL SUBROUTINE MOVING VESSELS FROM ONE REGION TO ANOTHER
C
      CALL SWITCH
C
C     CHANGE NUMBER OF VESSELS IN FISHERY IF END OF YEAR HAS OCCURRED
C
       CALL VENEX
C   END OF MONTHLY LOOP INCREMENTS
C
20    CONTINUE
C
C   CALCULATE AVERAGE ANNUAL WHOLESALE PRICES REQUIRED FOR
C   PROCESSOR RETURN OF 5%, 10%, 15%, 20%, AND BREAK EVEN
C
      AREV1=APROC
      AWPR1=AREV1/APLBS
      AREV2=APROC*1.05
      AWPR2=AREV2/APLBS
      AREV3=APROC*1.10
      AWPR3=AREV3/APLBS
```

```
        AREV4=APROC*1.15
        AWPR4=AREV4/APLBS
        AREV5=APROC*1.20
        AWPR5=AREV5/APLBS
C
C    CALL SUBROUTINE TO PRINT ANNUAL DATA TO OUTPUT FILE AND ECHO TO
C    SCREEN
C
        CALL YRPRNT
C
C
         IF(IYRS.EQ.IYRSS)GO TO 30
        WRITE(1,*)  'END OF YEAR ',IYRS
        WRITE(1,*)  'DO YOU WISH TO CHANGE PRICES OF COMPETING SPECIES'
        READ(1,4) ANS1
        IF(ANS1.EQ.'Y')THEN
        WRITE(1,*) 'ENTER NEW OCEAN QUAHOG PRICE'
        READ(1,*) ZOQP
        WRITE(1,*)  'ENTER NEW HARD CLAM PRICE'
        READ(1,*) ZHCP
        WRITE(1,*)  'ENTER NEW OYSTER PRICE'
        READ(1,*) ZOYP
        END IF
        WRITE(1,*)  'DO YOU WISH TO CHANGE THE LANDINGS TAX'
        READ(1,4) ANS2
        IF(ANS2.EQ.'Y')THEN
        WRITE(1,*)'ENTER NEW LANDINGS TAX IN DOLLARS PER POUND FOR
NORTHER
      CN'
        WRITE(1,*)  'NEW JERSEY'
        READ(1,*) TXL11
        TXL12=TXL11
        TXL13=TXL11
        WRITE(1,*)  'ENTER NEW LANDINGS TAX FOR SOUTHERN NEW JERSEY'
        READ(1,*) TXL21
        TXL22=TXL21
        TXL23=TXL21
        WRITE(1,*)  'ENTER NEW LANDINGS TAX FOR DELMARVA'
        READ(1,*) TXL31
        TXL32=TXL31
        TXL33=TXL31
        END IF
        WRITE(1,*)  'DO YOU WISH TO CHANGE EFFORT HOUR LIMITS PER
MONTH'
        READ(1,4) ANS3
        IF(ANS3.EQ.'Y')THEN
        WRITE(1,*)  'ENTER EFFORT HOURS FOR NORTHERN NEW JERSEY'
        READ(1,*) EHRS1
        RHRS1=EHRS1
        WRITE(1,*)  'ENTER EFFORT HOURS FOR SOUTHERN NEW JERSEY'
        READ(1,*) EHRS2
        RHRS2=EHRS2
        WRITE(1,*) 'ENTER EFFORT HOURS FOR DELMARVA'
        READ(1,*) EHRS3
```

```
        RHRS3=EHRS3
        END IF
        WRITE(1,*)  'DO YOU WISH TO CHANGE QUARTERLY QUOTAS'
        READ(1,4) ANS4
        IF(ANS4.EQ.'Y')THEN
        WRITE(1,*)  'ENTER QUOTA FOR FIRST QUARTER'
        READ(1,*) QUOTA1
        WRITE(1,*)  'ENTER QUOTA FOR SECOND QUARTER'
        READ(1,*) QUOTA2
        WRITE(1,*)  'ENTER QUOTA FOR THIRD QUARTER'
        READ(1,*) QUOTA3
        WRITE(1,*)  'ENTER QUOTA FOR FOURTH QUARTER'
        READ(1,*) QUOTA4
        END IF
        WRITE(1,*) 'DO YOU WISH TO CHANGE THE NATURAL MORTALITY RATE IN
 AN
      CY'
        WRITE(1,*)  'REGION'
        READ(1,4) ANS5
        IF(ANS5.EQ.'Y')THEN
        WRITE(1,*)  'DO YOU WISH TO CHANGE RATES IN NORTHERN NEW
 JERSEY'
        READ(1,4) ANS7
        IF(ANS7.EQ.'Y')THEN
          WRITE(1,*)  'ENTER NORTHERN JERSEY NATURAL MORTALITY RATES IN
 COHO
      CRTS ONE THROUGH SIX, SEPARATED BY COMMAS'
        READ(1,*) Z11,Z12,Z13,Z14,Z15,Z16
          END IF
        WRITE(1,*)  'DO YOU WISH TO CHANGE RATES IN SOUTHERN NEW
 JERSEY'
        READ(1,4) ANS8
        IF(ANS8.EQ.'Y')THEN
          WRITE(1,*)  'ENTER SOUTHERN JERSEY MORTALITY RATES BY COHORT'
          READ(1,*) Z21,Z22,Z23,Z24,Z25,Z26
          END IF
        WRITE(1,*)  'DO YOU WISH TO CHANGE RATES IN DELMARVA'
        READ(1,4) ANS9
        IF(ANS9.EQ.'Y')THEN
          WRITE(1,*)  'ENTER DELMARVA RATES BY COHORT'
          READ(1,*) Z31,Z32,Z33,Z34,Z35,Z36
        END IF
        END IF
C
C
C    ADVANCE CLAMS IN EACH COHORT TO THE NEXT COHORT SINCE THEY
C    HAVE AGED ONE YEAR.
C
C    NORTHERN NEW JERSEY
C
        XNCO6=XNCO6+XNCO5
        XNCO5=(XNCO5-XNCO5)+XNCO4
        XNCO4=(XNCO4-XNCO4)+XNCO3
        XNCO3=(XNCO3-XNCO3)+XNCO2
```

```
      XNCO2=(XNCO2-XNCO2)+XNCO1
      XNCO1=XNCO1-XNCO1
C
C   SOUTHERN NEW JERSEY
C
      SCO6=SCO6+SCO5
      SCO5=(SCO5-SCO5)+SCO4
      SCO4=(SCO4-SCO4)+SCO3
      SCO3=(SCO3-SCO3)+SCO2
      SCO2=(SCO2-SCO2)+SCO1
      SCO1=SCO1-SCO1
C
C   DELMARVA
C
      DCO6=DCO6+DCO5
      DCO5=(DCO5-DCO5)+DCO4
      DCO4=(DCO4-DCO4)+DCO3
      DCO3=(DCO3-DCO3)+DCO2
      DCO2=(DCO2-DCO2)+DCO1
      DCO1=DCO1-DCO1
C
C   END YEARLY LOOP AND INCREMENT TO NEXT YEAR
C
10    CONTINUE
C
30    WRITE(1,*)  'END OF SIMULATION'
      CLOSE(6)
      CLOSE(7)
      STOP
      END
C
      SUBROUTINE GROWTH
C
C   THIS SUBROUTINE CALCULATES THE CHANGE IN SIZE OF EACH COHORT
C   RESULTING FROM NATURAL MORTALITY AND THE WEIGHT OF EACH COHORT
C   RESULTING FROM VON BERTALLANFFY GROWTH.  THE WEIGHT OF COHORT
NUMBER 6
C   IS BASED UPON A WEIGHTED AVERAGE OF YEAR CLASSES 6 THROUGH 20.
C
       COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
      CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
      CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
      CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
      CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
      CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
      CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
      CCA13,CA23,CA33,CA43,CA53,CA63,XNCO1,XNCO2,XNCO3,XNCO4,XNCO5,
      CXNCO6,SCO1,SCO2,SCO3,SCO4,SCO5,SCO6,DCO1,DCO2,DCO3,DCO4,DCO5,
      CDCO6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
      CDTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
       COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
      CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,

CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
```

```
      CIMG,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,
     CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,
     CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
      CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
      CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63
     COMMON/VRET/ZLSCP,ZOCP,ZHCP,ZOYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,
     CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,
     CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,
     CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,
     CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
      CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
      CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,
     CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
      CTKAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
      CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3
     COMMON/PRET/WSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
      CFULD,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,
     CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
      CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
      CWPR5,TREPR
       COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
      CVINC2,VINC3,VDEC1,VDEC2,VDEC3
     COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
      CSUTIL3
     COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
      CSEHRT3,SEHRT4,QUOTA4,QUOTA
       COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3
     COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
      CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
      CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
      CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
      CAXNCD6,AXSCD6,AXDCD6,ABUN,ABUS,ABUD,APLBS,APROC,
      CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,AOVH,AINS,
      CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
C     CALCULATE THE SIZE AND WEIGHT OF NORTHERN NEW JERSEY COHORTS
C
C     CALCULATE THE LOSS TO EACH NORTHERN NEW JERSEY COHORT DUE TO AGE
C     SPECIFIC NATURAL MORTALITY
C
```

```
      XNCO1=XNCO1-Z11*XNCO1
      XNCO2=XNCO2-Z12*XNCO2
      XNCO3=XNCO3-Z13*XNCO3
      XNCO4=XNCO4-Z14*XNCO4
      XNCO5=XNCO5-Z15*XNCO5
      XNCO6=XNCO6-Z16*XNCO6
C
C   CALCULATE LENGTH OF INDIVIDUALS IN EACH NORTHERN JERSEY COHORT
GROUP
C
      E=2.7182818
      XLNN1=166.64*(1-(E**(-BNJ*(IMO/12.0-.0255))))
      XLNN2=166.64*(1-(E**(-BNJ*((IMO+12)/12.0-.0255))))
      XLNN3=166.64*(1-(E**(-BNJ*((IMO+24)/12.0-.0255))))
      XLNN4=166.64*(1-(E**(-BNJ*((IMO+36)/12.0-.0255))))
      XLNN5=166.64*(1-(E**(-BNJ*((IMO+48)/12.0-.0255))))
      XLNN6=166.64*(1-(E**(-BNJ*((IMO+60)/12.0-.0255))))
C
C   CALCULATE THE AVERAGE WEIGHT OF INDIVIDUALS IN EACH NORTHERN
JERSEY
C   COHORT GROUP
C
      XWTN1=(.000100*(XLNN1**2.8251))*.002046
      XWTN2=(.000100*(XLNN2**2.8251))*.002046
      XWTN3=(.000100*(XLNN3**2.8251))*.002046
      XWTN4=(.000100*(XLNN4**2.8251))*.002046
      XWTN5=(.000100*(XLNN5**2.8251))*.002046
      XWTN6=AVWT61
C
C   CALCULATE THE SIZE AND WEIGHT OF SOUTHERN NEW JERSEY COHORTS
C
C   CALCULATE LOSS DUE TO NATURAL MORTALITY .
C
      SCO1=SCO1-Z21*SCO1
      SCO2=SCO2-Z22*SCO2
      SCO3=SCO3-Z23*SCO3
      SCO4=SCO4-Z24*SCO4
      SCO5=SCO5-Z25*SCO5
      SCO6=SCO6-Z26*SCO6
C
C   CALCULATE THE LENGTH OF INDIVIDUALS IN EACH SOUTHERN JERSEY
COHORT
C
      XLNS1=166.64*(1-(E**(-BNJ*(IMO/12.0-.0255))))
      XLNS2=166.64*(1-(E**(-BNJ*((IMO+12)/12.0-.0255))))
      XLNS3=166.64*(1-(E**(-BNJ*((IMO+24)/12.0-.0255))))
      XLNS4=166.64*(1-(E**(-BNJ*((IMO+36)/12.0-.0255))))
      XLNS5=166.64*(1-(E**(-BNJ*((IMO+48)/12.0-.0255))))
      XLNS6=166.64*(1-(E**(-BNJ*((IMO+60)/12.0-.0255))))
C
C   CALCULATE THE WEIGHT OF INDIVIDUALS IN EACH SOUTHERN JERSEY
COHORT
C
      XWTS1=(.000100*(XLNS1**2.8251))*.002046
```

```
      XWTS2=(.000100*(XLNS2**2.8251))*.002046
      XWTS3=(.000100*(XLNS3**2.8251))*.002046
      XWTS4=(.0001000*(XLNS4**2.8251))*.002046
      XWTS5=(.000100*(XLNS5**2.8251))*.002046
      XWTS6=AVWT62
C
C    CALCULATE THE SIZE AND WEIGHT OF DELMARVA COHORTS
C
C    CALCULATE THE LOSS DUE TO NATURAL MORTALITY
C
      DCO1=DCO1-Z31*DCO1
      DCO2=DCO2-Z32*DCO2
      DCO3=DCO3-Z33*DCO3
      DCO4=DCO4-Z34*DCO4
      DCO5=DCO5-Z35*DCO5
      DCO6=DCO6-Z36*DCO6
C
C    CALCULATE THE LENGTH OF INDIVIDUALS IN EACH DELMARVA COHORT
C
      XLND1=166.43*(1-(E**(-BDEL*(IMO/12.0-.0794))))
      XLND2=166.43*(1-(E**(-BDEL*((IMO+12)/12.0-.0794))))
      XLND3=166.43*(1-(E**(-BDEL*((IMO+24)/12.0-.0794))))
      XLND4=166.43*(1-(E**(-BDEL*((IMO+36)/12.0-.0794))))
      XLND5=166.43*(1-(E**(-BDEL*((IMO+48)/12.0-.0794))))
      XLND6=166.43*(1-(E**(-BDEL*((IMO+60)/12.0-.0794))))
C
C    CALCULATE THE WEIGHT OF INDIVIDUALS IN EACH DELMARVA COHORT GROUP
C
      XWTD1=(.000111*(XLND1**2.7675))*.002046
      XWTD2=(.000111*(XLND2**2.7675))*.002046
      XWTD3=(.000111*(XLND3**2.7675))*.002046
      XWTD4=(.000111*(XLND4**2.7675))*.002046
      XWTD5=(.000111*(XLND5**2.7675))*.002046
      XWTD6=AVWT63
C
      RETURN
      END
C
      SUBROUTINE PRORET
C
C    THIS SUBROUTINE DETERMINES THE PROCESSING COST FOR A POUND OF
MEAT
C
      COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
     CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
     CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
     CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
     CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
     CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
     CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
     CCA13,CA23,CA33,CA43,CA53,CA63,XNCO1,XNCO2,XNCO3,XNCO4,XNCO5,
     CXNCO6,SCO1,SCO2,SCO3,SCO4,SCO5,SCO6,DCO1,DCO2,DCO3,DCO4,DCO5,
     CDCO6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
     CDTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
```

```
      COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
     CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,
     CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
     CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,
     CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,
     CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
     CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
     CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63
      COMMON/VRET/ZLSCP,ZGGP,ZHCP,ZDYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,
     CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,
     CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,
     CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,
     CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
     CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
     CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,
     CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
     CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
     CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3
      COMMON/PRET/HSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
     CFULD,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,
     CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
     CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
     CWPR5,TREPR
      COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
     CVINC2,VINC3,VDEC1,VDEC2,VDEC3
      COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
     CSUTIL3
      COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
     CSEHRT3,SEHRT4,QUOTA4,QUOTA
      COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3
      COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
     CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
     CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
     CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
     CAXNCD6,AXSCD6,AXDCD6,ABUN,ABUS,ABUD,APLBS,APROC,
     CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,AOVH,AINS,
     CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
C     SET SEASONAL PROCESSING COSTS
```

```
C
        IF(IMO.EQ.3.OR.IMO.EQ.1.OR.IMO.EQ.2)THEN
        PRCST=WSCST
       ELSE IF(IMO.EQ.4.OR.IMO.EQ.5.OR.IMO.EQ.6)THEN
       PRCST=SFCST
        ELSE IF(IMO.EQ.9.OR.IMO.EQ.7.OR.IMO.EQ.8)THEN
       PRCST=WSCST
        ELSE
        PRCST=SFCST
        END IF
C
C    CALCULATE THE NUMBER OF BUSHELS OF CLAMS AVAILABLE TO PROCESSORS
C    BASED UPON THE MEAT WEIGHT HARVESTED
C
        BUP=XMALBS/17.0
C
C    CALCULATE POUNDS OF MEATS FROM HARVEST ACTUALLY USED BY
PROCESSING
C    PLANTS (i.e. 11 POUNDS OF USABLE MEATS PER BUSHEL OF CLAMS)
C
       PLBS=BUP*11.0
C
C    CALCULATE TOTAL COSTS OF PURCHASING AND PROCESSING THIS SHELL-
STOCK
C
       SHCST=SCP*XMALBS
       CTRNS=PRCST*TRNS
       CPAT=PRCST*PAT
       CXLAB=PRCST*XLAB
       CELEC=PRCST*ELEC
       CFULO=PRCST*FULO
       CPROP=PRCST*PROP
       CPKG=PRCST*PKG
       CDEPR=PRCST*DEPR
       CREPR=PRCST*REPR
       CZOVH=PRCST*ZOVH
       CZINS=PRCST*ZINS
       CZLEGL=PRCST*ZLEGL
       CSTRG=PRCST*STRG
       CCHEM=PRCST*CHEM
C
C    CALCULATE TOTAL PROCESSING COST FOR EACH CATEGORY
C    BASED UPON POUNDS OF MEAT PROCESSED
C
       TTRNS=CTRNS*PLBS
       TPAT=CPAT*PLBS
       TXLAB=CXLAB*PLBS
       TELEC=CELEC*PLBS
       TFULO=CFULO*PLBS
       TPROP=CPROP*PLBS
       TPKG=CPKG*PLBS
       TDEPR=CDEPR*PLBS
       TREPR=CREPR*PLBS
       TZOVH=CZOVH*PLBS
```

```
      TZINS=CZINS*PLBS
      TZLEGL=CZLEGL*PLBS
      TSTRG=CSTRG*PLBS
      TCHEM=CCHEM*PLBS
C
C     CALCULATE TOTAL MID-ATLANTIC PROCESSING COSTS FOR MONTHLY PERIOD
C
      TPROC=TTRNS+TPAT+TXLAB+TELEC+TFULD+TPROP+TPKG+TDEPR+TREPR+
     CTZOVH+TZINS+TZLEGL+TSTRG+TCHEM+SHCST
C
C     SET PROCESSING COST FLOOR EQUAL TO SEMI-VARIABLE COST MINIMUM FOR
C     PERIOD AND CHECK TO SEE IF THIS FLOOR SHOULD BE INVOKED
C
      IF(TPROC.LT.PFLR)TPROC=PFLR
C
C     CALCULATE WHOLESALE PRICE OF SHUCKED OUTPUT ASSOCIATED WITH
C     0%, 5%, 10%, 15%, AND 20% RETURN TO PROCESSOR BEFORE TAX PAYMENTS
C
       IF(PLBS.NE.0)THEN
      TREV1=TPROC
      WPR1=TREV1/PLBS
      TREV2=TPROC*1.05
      WPR2=TREV2/PLBS
      TREV3=TPROC*1.10
      WPR3=TREV3/PLBS
      TREV4=TPROC*1.15
      WPR4=TREV4/PLBS
      TREV5=TPROC*1.20
      WPR5=TREV5/PLBS
C
       ELSE
       TREV1=0
       TREV2=0
       TREV3=0
       TREV4=0
       TREV5=0
       WPR1=0
       WPR2=0
       WPR3=0
       WPR4=0
       WPR5=0
       END IF
C
      RETURN
      END
C
      SUBROUTINE CQUOTA
C
C     THIS SUBROUTINE CHECKS TO SEE WHETHER QUARTERLY QUOTAS HAVE BEEN
C     EXCEEDED AND SETS EFFORT HOURS TO ZERO IF THEY HAVE
C
      COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
     CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
     CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
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     CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
     CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
     CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
     CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
     CCA13,CA23,CA33,CA43,CA53,CA63,XNCD1,XNCD2,XNCD3,XNCD4,XNCD5,
     CXNCD6,SCD1,SCD2,SCD3,SCD4,SCD5,SCD6,DCD1,DCD2,DCD3,DCD4,DCD5,
     CDCD6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
     CDTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
      COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
     CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,

CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
     CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,

CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,

CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
     CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
     CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63

COMMON/VRET/ZLSCP,ZDQP,ZMCP,ZDYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,

CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,

CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,

CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,

CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
     CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
     CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,

CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
     CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
     CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3

COMMON/PRET/WSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
     CFULD,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,

CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
     CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
     CWPR5,TREPR
      COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
     CVINC2,VINC3,VDEC1,VDEC2,VDEC3

COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
     CSUTIL3

COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
     CSEHRT3,SEHRT4,QUOTA4,QUOTA
      COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3

COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
     CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
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     CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
     CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
     CAXNCD6,AXSCD6,AXDCD6,ABUN,ABUS,ABUD,APLBS,APROC,
     CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,ADVH,AINS,
     CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
       SEAS=(IMO+3.0)/3.0
       IF(SEAS.LE.2)THEN
       EHRS1=RHRS1
       EHRS2=RHRS2
       EHRS3=RHRS3
       QUOTA=QUOTA1
       SEHRT1=SEHRT1+XMALBS
       IF(SEHRT1.GE.QUOTA)GO TO 20
       ELSE IF(SEAS.GT.2.AND.SEAS.LE.3)THEN
       EHRS1=RHRS1
       EHRS2=RHRS2
       EHRS3=RHRS3
       QUOTA=QUOTA2
       SEHRT2=SEHRT2+XMALBS
       IF(SEHRT2.GE.QUOTA)GO TO 20
       ELSE IF(SEAS.GT.3.AND.SEAS.LE.4)THEN
       EHRS1=RHRS1
       EHRS2=RHRS2
       EHRS3=RHRS3
       QUOTA=QUOTA3
       SEHRT3=SEHRT3+XMALBS
       IF(SEHRT3.GE.QUOTA)GO TO 20
       ELSE
       EHRS1=RHRS1
       EHRS2=RHRS2
       EHRS3=RHRS3
       QUOTA=QUOTA4
       SEHRT4=SEHRT4+XMALBS
       IF(SEHRT4.GE.QUOTA)GO TO 20
       END IF
       GO TO 30
20     EHRS1=0
       EHRS2=0
       EHRS3=0
30     RETURN
       END
       SUBROUTINE MODAT
C
C    THIS SUBROUTINE WRITES MONTHLY OUTPUT TO THE USER'S TERMINAL
C    AND TO A FILE CALLED MONDAT
C
       COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
     CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
     CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
     CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
     CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
     CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
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      CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
      CCA13,CA23,CA33,CA43,CA53,CA63,XNCO1,XNCO2,XNCO3,XNCO4,XNCO5,
      CXNCO6,SCO1,SCO2,SCO3,SCO4,SCO5,SCO6,DCO1,DCO2,DCO3,DCO4,DCO5,
      CDCO6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
      CDTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
       COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
      CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,
     CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
      CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,
     CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,
     CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
      CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
      CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63
     COMMON/VRET/ZLSCP,ZDDP,ZHCP,ZDYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,
     CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,
     CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,
     CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,
     CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
      CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
      CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,
     CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
      CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
      CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3
     COMMON/PRET/WSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
      CFULD,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,
     CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
      CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
      CWPR5,TREPR
       COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
      CVINC2,VINC3,VDEC1,VDEC2,VDEC3
     COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
      CSUTIL3
     COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
      CSEHRT3,SEHRT4,QUOTA4,QUOTA
       COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3
     COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
      CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
      CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
      CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
      CAXNCO6,AXSCO6,AXDCO6,ABUN,ABUS,ABUD,APLBS,APROC,
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     CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,ACVM,AINS,
     CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
       CNCPS1=CPS1*VRAN1
       CNCPS2=CPS2*VRAN2
       CNCPS3=CPS3*VRAN3
       CSCPS1=CPS1*VRAS1
       CSCPS2=CPS2*VRAS2
       CSCPS3=CPS3*VRAS3
       CDCPS1=CPS1*VRAD1
       CDCPS2=CPS2*VRAD2
       CDCPS3=CPS3*VRAD3
      WRITE(6,10) IYRS,IMO
      WRITE(1,10) IYRS,IMO
10    FORMAT('1','MONTHLY STATISTICS FOR YEAR ',I1,1X,'MONTH ',I2)
      WRITE(6,11) QUOTA
      WRITE(1,11) QUOTA
11    FORMAT(1X,'QUARTERLY QUOTA= ',G14.7,1X,'LBS')
       WRITE(6,9) XMALBS
       WRITE(1,9) XMALBS
9      FORMAT(1X,'MONTHLY HARVEST= ',T19,G14.7,1X,'LBS')
      WRITE(6,12)
      WRITE(1,12)
12    FORMAT('0','FISHING SECTOR SUMMARY')
      WRITE(6,13)
      WRITE(1,13)
13    FORMAT(1X,'REGION',23X,'NNJ',12X,'SNJ',7X,'DELMARVA',3X,'MID
ATLAN
     CTIC')
      T1=V11+V21+V31
      WRITE(6,14)V11,V21,V31,T1
      WRITE(1,14)V11,V21,V31,T1
14    FORMAT(1X,'CLASS I VESSELS',13X,F4.0,11X,F4.0,11X,F4.0,9X,F4.0)
      WRITE(6,15) ED11,ED21,ED31
      WRITE(1,15) ED11,ED21,ED31
15    FORMAT(1X,2X,'EFFORT DAYS',13X,F6.2,9X,F6.2,9X,F6.2)
      T3=XNLBT1+SLBT1+DLBT1
      WRITE(6,16) XNLBT1,SLBT1,DLBT1,T3
      WRITE(1,16) XNLBT1,SLBT1,DLBT1,T3
16    FORMAT(1X,2X,'HARVEST',1X,'(LBS)',7X,G14.7,T39,G14.7,T54,
     CG14.7,T67,G14.7)
      WRITE(6,17)
      WRITE(1,17)
17    FORMAT(1X,2X,'AVERAGE PROFIT')
       T4=(ERNN1+ERNS1+ERND1)/(V11+V21+V31)
      WRITE(6,18) AERNN1,AERNS1,AERND1,T4
      WRITE(1,18) AERNN1,AERNS1,AERND1,T4
18    FORMAT(1X,2X,'PER VESSEL ($)',6X,G14.7,T39,G14.7,T54,G14.7,
     CT67,G14.7)
      WRITE(6,19)
      WRITE(1,19)
19    FORMAT(1X,2X,'TOTAL FLEET')
      T5=ERNN1+ERNS1+ERND1
```

```
      WRITE(6,20) ERNN1,ERNS1,ERND1,T5
      WRITE(1,20) ERNN1,ERNS1,ERND1,T5
20    FORMAT(1X,2X,'PROFITS ($)',9X,G14.7,T39,G14.7,T54,G14.7,
     CT67,G14.7)
      T6=V12+V22+V32
      WRITE(6,49)
      WRITE(1,49)
      T21=CNCPS1+CSCPS1+CDCPS1
      WRITE(6,50) CNCPS1,CSCPS1,CDCPS1,T21
      WRITE(1,50) CNCPS1,CSCPS1,CDCPS1,T21
49    FORMAT(1X,2X,'CUSTOMARY CAPTAINS')
50    FORMAT(1X,2X,'SHARE ($)',11X,G14.7,T39,G14.7,T54,G14.7,
     CT67,G14.7)
      T22=AERNN1-CNCPS1
      T23=AERNS1-CSCPS1
      T24=AERND1-CDCPS1
      T25=T4-T21
      WRITE(6,51) T22,T23,T24,T25
      WRITE(1,51) T22,T23,T24,T25
51    FORMAT(1X,2X,'AVERAGE PROFIT LESS'/,3X,'CAPTAINS SHARE ($)',
     C2X,G14.7,T39,G14.7,T54,G14.7,T67,G14.7)
      WRITE(6,21) V12,V22,V32,T6
      WRITE(1,21) V12,V22,V32,T6
21    FORMAT(1X,'CLASS II
VESSELS',12X,F4.0,11X,F4.0,11X,F4.0,9X,F4.0)
      WRITE(6,22)ED12,ED22,ED32
      WRITE(1,22)ED12,ED22,ED32
22    FORMAT(1X,2X,'EFFORT DAYS',13X,F6.2,9X,F6.2,9X,F6.2)
      T8=XNLBT2+SLBT2+DLBT2
      WRITE(6,23) XNLBT2,SLBT2,DLBT2,T8
      WRITE(1,23) XNLBT2,SLBT2,DLBT2,T8
23    FORMAT(1X,2X,'HARVEST',1X,'(LBS)',7X,G14.7,T39,G14.7,T54,
     CG14.7,T67,G14.7)
      WRITE(6,24)
      WRITE(1,24)
24    FORMAT(1X,2X,'AVERAGE PROFIT')
      T9=(ERNN2+ERNS2+ERND2)/(V12+V22+V32)
      WRITE(6,25) AERNN2,AERNS2,AERND2,T9
      WRITE(1,25) AERNN2,AERNS2,AERND2,T9
25    FORMAT(1X,2X,'PER VESSEL ($)',6X,G14.7,T39,G14.7,T54,
     CG14.7,T67,G14.7)
      WRITE(6,26)
      WRITE(1,26)
26    FORMAT(1X,2X,'TOTAL FLEET')
      T10=ERNN2+ERNS2+ERND2
      WRITE(6,27) ERNN2,ERNS2,ERND2,T10
      WRITE(1,27) ERNN2,ERNS2,ERND2,T10
27    FORMAT(1X,2X,'PROFITS ($)',9X,G14.7,T39,G14.7,T54,
     CG14.7,T67,G14.7)
      T26=CNCPS2+CSCPS2+CDCPS2
      WRITE(6,49)
      WRITE(1,49)
      WRITE(1,50) CNCPS2,CSCPS2,CDCPS2,T26
      WRITE(6,50) CNCPS2,CSCPS2,CDCPS2,T26
```

```
        T27=AERNN2-CNCPS2
        T28=AERNS2-CSCPS2
        T29=AERND2-CDCPS2
        T30=T9-T26
        WRITE(6,51) T27,T28,T29,T30
        WRITE(1,51) T27,T28,T29,T30
       T11=V13+V23+V33
       WRITE(6,28) V13,V23,V33,T11
       WRITE(1,28) V13,V23,V33,T11
28     FORMAT(1X,'CLASS III
VESSELS',11X,F4.0,11X,F4.0,11X,F4.0,9X,F4.0)
       WRITE(6,29)ED13,ED23,ED33
       WRITE(1,29)ED13,ED23,ED33
29     FORMAT(1X,2X,'EFFORT DAYS',13X,F6.2,9X,F6.2,9X,F6.2)
       T13=XNLBT3+SLBT3+DLBT3
       WRITE(6,30) XNLBT3,SLBT3,DLBT3,T13
        WRITE(1,30) XNLBT3,SLBT3,DLBT3,T13
30     FORMAT(1X,2X,'HARVEST',1X,'(LBS)',7X,G14.7,T39,G14.7,T54,
      CG14.7,T67,G14.7)
       WRITE(6,31)
       WRITE(1,31)
31     FORMAT(1X,2X,'AVERAGE PROFIT')
        T14=(ERNN3+ERNS3+ERND3)/(V13+V23+V33)
       WRITE(6,32) AERNN3,AERNS3,AERND3,T14
       WRITE(1,32) AERNN3,AERNS3,AERND3,T14
32     FORMAT(1X,2X,'PER VESSEL ($)',6X,G14.7,T39,G14.7,T54,
      CG14.7,T67,G14.7)
       WRITE(6,33)
       WRITE(1,33)
33     FORMAT(1X,2X,'TOTAL FLEET')
       T15=ERNN3+ERNS3+ERND3
       WRITE(6,34) ERNN3,ERNS3,ERND3,T15
       WRITE(1,34) ERNN3,ERNS3,ERND3,T15
34     FORMAT(1X,2X,'PROFITS ($)',9X,G14.7,T39,G14.7,T54,
      CG14.7,T67,G14.7)
        T31=CNCPS3+CSCPS3+CDCPS3
        WRITE(6,49)
        WRITE(1,49)
        WRITE(1,50) CNCPS3,CSCPS3,CDCPS3,T31
        WRITE(6,50) CNCPS3,CSCPS3,CDCPS3,T31
        T32=AERNN3-CNCPS3
        T33=AERNS3-CSCPS3
        T34=AERND3-CDCPS3
        T35=T14-T31
        WRITE(6,51) T32,T33,T34,T35
        WRITE(1,51) T32,T33,T34,T35
       WRITE(6,35)
       WRITE(1,35)
35     FORMAT('0','STOCK SIZE OF'/' CLAMS GE 5 1/2'/' INCHES LONG')
       WRITE(6,36)
       WRITE(1,36)
36     FORMAT(1X,'REGION',23X,'NNJ',12X,'SNJ',7X,'DELMARVA',2X,'MID
ATLAN
      CTIC')
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      T16=XNCD6+SCD6+DCD6
      WRITE(6,37) XNCD6,SCD6,DCD6,T16
      WRITE(1,37) XNCD6,SCD6,DCD6,T16
 37   FORMAT(1X,'INDIVIDUALS',7X,G14.7,1X,G14.7,1X,G14.7,1X,G14.7)
      T17=TWTN6+TWTS6+TWTD6
      WRITE(1,38) TWTN6,TWTS6,TWTD6,T17
      WRITE(6,38) TWTN6,TWTS6,TWTD6,T17
 38   FORMAT(1X,'MEAT WEIGHT',7X,G14.7,1X,G14.7,1X,G14.7,1X,G14.7)
      T18=TWTN6/17.0
      T19=TWTS6/17.0
      T20=TWTD6/17.0
       T21=T18+T19+T20
      WRITE(6,39) T18,T19,T20,T21
      WRITE(1,39) T18,T19,T20,T21
 39   FORMAT(1X,'BUSHELS',11X,G14.7,1X,G14.7,1X,G14.7,1X,G14.7)
      WRITE(6,40)
      WRITE(1,40)
 40   FORMAT('0','PROCESSING SECTOR SUMMARY')
      WRITE(6,41) TPROC
      WRITE(1,41) TPROC
 41   FORMAT(1X,2X,'TOTAL PROCESSING COSTS FOR MID ATLANTIC ($)',2X,
     CG14.7)
      WRITE(6,42) PLBS
      WRITE(1,42) PLBS
 42   FORMAT(1X,2X,'POUNDS OF MEAT PRODUCED',22X,G14.7)
      WRITE(6,43) BUP
      WRITE(1,43) BUP
 43   FORMAT(1X,2X,'BUSHELS PROCESSED',28X,G14.7)
      WRITE(6,47) WPR1
      WRITE(1,47) WPR1
 47   FORMAT(1X,2X,'BREAK EVEN WHOLESALE PRICE PER POUND
($)',8X,F7.3)
      WRITE(6,44) WPR2
      WRITE(1,44) WPR2
 44   FORMAT(1X,2X,'WHOLESALE PRICE AT 5% RETURN ($)',16X,F7.3)
      WRITE(6,45) WPR3
      WRITE(1,45) WPR3
 45   FORMAT(1X,2X,'WHOLESALE PRICE AT 10% RETURN ($)',15X,F7.3)
      WRITE(6,46) WPR4
      WRITE(1,46) WPR4
 46   FORMAT(1X,2X,'WHOLESALE PRICE AT 15% RETURN ($)', 15X,F7.3)
      WRITE(6,48) WPR5
      WRITE(1,48) WPR5
 48   FORMAT(1X,2X,'WHOLESALE PRICE AT 20% RETURN ($)',15X,F7.3)
C
      RETURN
      END
C
      SUBROUTINE HARVST
C
C    THIS SUBROUTINE CALCULATES CLAM HARVESTS IN ALL REGIONS
C
C    IDENTIFY COMMON VARIABLES
C
```

```
 COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
CCA13,CA23,CA33,CA43,CA53,CA63,XNCD1,XNCD2,XNCD3,XNCD4,XNCD5,
CXNCD6,SCD1,SCD2,SCD3,SCD4,SCD5,SCD6,DCD1,DCD2,DCD3,DCD4,DCD5,
CDCD6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
CDTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
 COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,

CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,

CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,

CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63

COMMON/VRET/ZLSCP,ZDQP,ZHCP,ZDYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,

CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,

CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,

CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,

CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,

CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3

COMMON/PRET/WSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
CFULO,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,

CTXLAB,TELEC,TFULO,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
CWPR5,TREPR
 COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
CVINC2,VINC3,VDEC1,VDEC2,VDEC3

COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
CSUTIL3

COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
CSEHRT3,SEHRT4,QUOTA4,QUOTA
 COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3
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      COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
     CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
     CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
     CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
     CAXNCD6,AXSCD6,AXDCD6,ABUN,ABUS,ABUD,APLBS,APROC,
     CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,AOVH,AINS,
     CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
C     CALCULATE THE NORTHERN NEW JERSEY HARVEST BY CLASS I VESSELS
C
      HN11=V11*ED11*CA11*XNCD1
      HN21=V11*ED11*CA21*XNCD2
      HN31=V11*ED11*CA31*XNCD3
      HN41=V11*ED11*CA41*XNCD4
      HN51=V11*ED11*CA51*XNCD5
      HN61=V11*ED11*CA61*XNCD6
C
C     CALCULATE TOTAL NORTHERN JERSEY HARVEST BY CLASS I VESSELS IN
C     BOTH WEIGHT AND NUMBER OF INDIVIDUALS
C
      HNT1=HN11+HN21+HN31+HN41+HN51+HN61
      XNLBT1=HN11*XWTN1+HN21*XWTN2+HN31*XWTN3+HN41*XWTN4+HN51*XWTN5+
     CHN61*XWTN6
C
C     CALCULATE THE NORTHERN NEW JERSEY HARVEST BY CLASS II VESELS
C
      HN12=V12*ED12*CA12*XNCD1
      HN22=V12*ED12*CA22*XNCD2
      HN32=V12*ED12*CA32*XNCD3
      HN42=V12*ED12*CA42*XNCD4
      HN52=V12*ED12*CA52*XNCD5
      HN62=V12*ED12*CA62*XNCD6
C
C     CALCULATE TOTAL NORTHERN JERSEY HARVEST BY CLASS II VESSELS
C     BOTH INDIVIDUALS AND WEIGHT
C
      HNT2=HN12+HN22+HN32+HN42+HN52+HN62
      XNLBT2=HN12*XWTN1+HN22*XWTN2+HN32*XWTN3+HN42*XWTN4+HN52*XWTN5+
     CHN62*XWTN6
C
C     CALCULATE THE NORTHERN NEW JERSEY HARVEST BY CLASS III VESSELS
C
      HN13=V13*ED13*CA13*XNCD1
      HN23=V13*ED13*CA23*XNCD2
      HN33=V13*ED13*CA33*XNCD3
      HN43=V13*ED13*CA43*XNCD4
      HN53=V13*ED13*CA53*XNCD5
      HN63=V13*ED13*CA63*XNCD6
C
C     CALCULATE THE TOTAL NORTHERN JERSEY HARVEST BY CLASS III VESSELS
C     BOTH INDIVIDUALS AND WIEGHT
C
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```
      HNT3=HN13+HN23+HN33+HN43+HN53+HN63
      XNLBT3=HN13*XWTN1+HN23*XWTN2+HN33*XWTN3+HN43*XWTN4+HN53*XWTN5+
     CHN63*XWTN6
C
C     CALCULATE TOTAL NORTHERN NEW JERSEY HARVEST
C
      XNNTOT=HNT1+HNT2+HNT3
      XLBTOT=XNLBT1+XNLBT2+XNLBT3
C
C     CALCULATE THE SOUTHERN NEW JERSEY HARVEST BY CLASS I VESSELS
C
      HS11=V21*ED21*CA11*SCD1
      HS21=V21*ED21*CA21*SCD2
      HS31=V21*ED21*CA31*SCD3
      HS41=V21*ED21*CA41*SCD4
      HS51=V21*ED21*CA51*SCD5
      HS61=V21*ED21*CA61*SCD6
C
C     CALCULATE TOTAL SOUTHERN JERSEY HARVEST BY CLASS I VESSELS
C     BOTH INDIVIDUALS AND WEIGHT
C
      HST1=HS11+HS21+HS31+HS41+HS51+HS61
      SLBT1=HS11*XWTS1+HS21*XWTS2+HS31*XWTS3+HS41*XWTS4+HS51*XWTS5
     C+HS61*XWTS6
C
C     CALCULATE THE SOUTHERN NEW JERSEY HARVEST BY CLASS II VESSELS
C
      HS12=V22*ED22*CA12*SCD1
      HS22=V22*ED22*CA22*SCD2
      HS32=V22*ED22*CA32*SCD3
      HS42=V22*ED22*CA42*SCD4
      HS52=V22*ED22*CA52*SCD5
      HS62=V22*ED22*CA62*SCD6
C
C      CALCULATE THE TOTAL SOUTHERN NEW JERSEY HARVEST BY CLASS II
VESSELS
C
       HST2=HS12+HS22+HS32+HSS42+HS52+HS62

SLBT2=HS12*XWTS1+HS22*XWTS2+HS32*XWTS3+HS42*XWTS4+HS52*XWTS5+HS62*
     CXWTS6
C
C     CALCULATE THE SOUTHERN JERSEY HARVEST BY CLASS III VESSELS
C     BOTH INDIVIDUALS AND WEIGHT
C
      HS13=V23*ED23*CA13*SCD1
      HS23=V23*ED23*CA23*SCD2
      HS33=V23*ED23*CA33*SCD3
      HS43=V23*ED23*CA43*SCD4
      HS53=V23*ED23*CA53*SCD5
      HS63=V23*ED23*CA63*SCD6
C
C     CALCULATE THE TOTAL SOUTHERN NEW JERSEY HARVEST BY CLASS III
VESSELS
```

```
C     BOTH INDIVIDUALS AND WEIGHT
C
        HST3=HS13+HS23+HS33+HS43+HS53+HS63
        SLBT3=HS13*XWTS1+HS23*XWTS2+HS33*XWTS3+HS43*XWTS4+HS53*XWTS5+
       CHS63*XWTS6
C
C     CALCULATE THE DELMARVA HARVEST BY CLASS I VESSELS
C
        HD11=V31*ED31*CA11*DC01
        HD21=V31*ED31*CA21*DC02
        HD31=V31*ED31*CA31*DC03
        HD41=V31*ED31*CA41*DC04
        HD51=V31*ED31*CA51*DC05
        HD61=V31*ED31*CA61*DC06
C
C     CALCULATE THE TOTAL DELMARVA HARVEST BY CLASS I VESSELS
C     BOTH INDIVIDUALS AND WEIGHT
C
        HDT1=HD11+HD21+HD31+HD41+HD51+HD61
        DLBT1=HD11*XWTD1+HD21*XWTD2+HD31*XWTD3+HD41*XWTD4+HD51*XWTD5+
       CHD61*XWTD6
C
C     CALCULATE THE DELMARVA HARVEST BY CLASS II VESSELS
C
        HD12=V32*ED32*CA12*DC01
        HD22=V32*ED32*CA22*DC02
        HD32=V32*ED32*CA32*DC03
        HD42=V32*ED32*CA42*DC04
        HD52=V32*ED32*CA52*DC05
        HD62=V32*ED32*CA62*DC06
C
C     CALCULATE THE TOTAL DELMARVA HARVEST BY CLASS II VESSELS
C     BOTH INDIVIDUALS AND WEIGHT
C
        HDT2=HD12+HD22+HD32+HD42+HD52+HD62
        DLBT2=HD12*XWTD1+HD22*XWTD2+HD32*XWTD3+HD42*XWTD4+HD52*XWTD5+
       CHD62*XWTD6
C
C     CALCULATE THE DELMARVA HARVEST BY CLASS III VESSELS
C
        HD13=V33*ED33*CA13*DC01
        HD23=V33*ED33*CA23*DC02
        HD33=V33*ED33*CA33*DC03
        HD43=V33*ED33*CA43*DC04
        HD53=V33*ED33*CA53*DC05
        HD63=V33*ED33*CA63*DC06
C
C     CALCULATE THE TOTAL DELMARVA HARVEST BY CLASS III VESSELS
C
        HDT3=HD13+HD23+HD33+HD43+HD53+HD63
        DLBT3=HD13*XWTD1+HD23*XWTD2+HD33*XWTD3+HD43*XWTD4+HD53*XWTD5
       C+HD63*XWTD6
C
C     CALCULATE THE TOTAL SOUTHERN NEW JERSEY HARVEST BY ALL VESSEL
```

```
C     CLASSES
C
         SNTOT=HST1+HST2+HST3
         SLBTOT=SLBT1+SLBT2+SLBT3
C
C     CALCULATE THE TOTAL DELMARVA HARVEST BY ALL VESSEL CLASSES
C
         DTOT=HDT1+HDT2+HDT3
         DLBTOT=DLBT1+DLBT2+DLBT3
C
C     CALCULATE THE TOTAL MID-ATLANTIC HARVEST
C
         XMATOT=XNTOT+SNTOT+DTOT
         XMALBS=XLBTOT+SLBTOT+DLBTOT
C
         RETURN
         END
C
         SUBROUTINE VENEX
C
C     THIS SUBROUTINE CALCULATES THE NUMBER OF NEW VESSELS TO ENTER OR
C     LEAVE THE FISHERY, BASED UPON POTENTIAL PROFITS
C
         COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
        CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
        CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
        CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
        CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
        CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
        CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
        CCA13,CA23,CA33,CA43,CA53,CA63,XNCO1,XNCO2,XNCO3,XNCO4,XNCO5,
        CXNCO6,SCO1,SCO2,SCO3,SCO4,SCO5,SCO6,DCO1,DCO2,DCO3,DCO4,DCO5,
        CDCO6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
        CDTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
         COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
        CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,

CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
        CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,

CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,

CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
        CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
        CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63

COMMON/VRET/ZLSCP,ZOQP,ZMCP,ZOYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,

CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,

CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,

CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,
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     CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
     CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
     CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,
     CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
     CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
     CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3
     COMMON/PRET/WSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
     CFULO,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,
     CTXLAB,TELEC,TFULO,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
     CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
     CWPR5,TREPR
      COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
     CVINC2,VINC3,VDEC1,VDEC2,VDEC3
     COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
     CSUTIL3
     COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
     CSEHRT3,SEHRT4,QUOTA4,QUOTA
      COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3
     COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
     CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
     CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
     CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
     CAXNCD6,AXSCD6,AXDCD6,ABUN,ABUS,ABUD,APLBS,APROC,
     CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULO,APROP,APKG,ADEPR,AOVH,AINS,
     CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
C    CALCULATE ANNUAL PROFIT AND NUMBER OF VESSELS
C    EITHER ENTERING OR LEAVING THE FISHERY
C
      DIMENSION XNPROF1(12), XNPROF2(12), XNPROF3(12)
      DIMENSION SPROF1(12), SPROF2(12), SPROF3(12)
      DIMENSION DPROF1(12), DPROF2(12), DPROF3(12)
C
        DO 5 I=1,12
        XNPROF1(I)=0
        XNPROF2(I)=0
        XNPROF3(I)=0
        SPROF1(I)=0
        SPROF2(I)=0
        SPROF3(I)=0
        DPROF1(I)=0
        DPROF2(I)=0
        DPROF3(I)=0
5       CONTINUE
C
C    NORTHERN JERSEY CLASS I
```

```
C
      K=IMO
      XNPROF1(K)=ERNN1
      IF(K.EQ.12)THEN
      XNAPRO1=0
        DO 10 I=1,12
        XNAPRO1=XNAPRO1+XNPROF1(I)
        XNPROF1(I)=0
10      CONTINUE
      ALRET1=ARATE1*XMVAL1
      XNDIF1=XNAPRO1-ALRET1
      IF(XNDIF1.GT.0)THEN
        DVE11=VINC1*V11
        V11=IFIX(DVE11)+V11
      ELSE IF(XNDIF1.LT.0)THEN
        DVE11=VDEC1*V11
        V11=V11-IFIX(DVE11)
      END IF
      END IF
C
C    NORTHERN NEW JERSEY CLASS II
C
      XNPROF2(K)=ERNN2
      IF(K.EQ.12)THEN
      XNAPRO2=0
        DO 20 I=1,12
        XNAPRO2=XNAPRO2+XNPROF2(I)
        XNPROF2(I)=0
20    CONTINUE
      ALRET2=ARATE2*XMVAL2
      XNDIF2=XNAPRO2-ALRET2
      IF(XNDIF2.GT.0)THEN
        DVE12=VINC2*V12
        V12=IFIX(DVE12)+V12
      ELSE IF(XNDIF2.LT.0)THEN
        DVE12=VDEC2*V12
        V12=V12-IFIX(DVE12)
      END IF
      ENDIF
C
C    NORTHERN JERSEY CLASS III
C
      XNPROF3(K)=ERNN3
      IF(K.EQ.12)THEN
      XNAPRO3=0
        DO 30 I=1,12
        XNAPRO3=XNAPRO3+XNPROF3(I)
      XNPROF3(I)=0
30      CONTINUE
      ALRET3=ARATE3*XMVAL3
      XNDIF3=XNAPRO3-ALRET
      IF(XNDIF3.GT.0)THEN
        DVE13=VINC3*V13
        V13=IFIX(DVE13)+V13
```

```
      ELSE IF(XNDIF3.LT.0)THEN
        DVE13=VDEC3*V13
        V13=V13-IFIX(DVE13)
      END IF
      END IF
C
C    SOUTHERN JERSEY CLASS I
C
      SPROF1(K)=ERNS1
      IF(K.EQ.12)THEN
        SAPRO1=0
          DO 40 I=1,12
          SAPRO1=SAPRO1+SPROF1(I)
          SPROF1(I)=0
40    CONTINUE
      SDIF1=SAPRO1-ALRET1
      IF(SDIF1.GT.0)THEN
        DVE21=VINC1*V21
        V21=IFIX(DVE21)+V21
      ELSE IF(SDIF1.LT.0)THEN
        DVE21=VDEC1*V21
        V21=V21-IFIX(DVE21)
      END IF
      END IF
C
C    SOUTHERN NEW JERSEY CLASS II VESSELS
C
      SPROF2(K)=ERNS2
      IF(K.EQ.12)THEN
      SAPRO2=0
        DO 50 I=1,12
        SAPRO2=SAPRO2+SPROF2(I)
        SPROF2(I)=0
50    CONTINUE
      SDIF2=SAPRO2-ALRET2
      IF(SDIF2.GT.0)THEN
      VDE22=VINC2*V22
      V22=IFIX(VDE22)+V22
      ELSE IF(SDIF2.LT.0)THEN
        DVE22=VDEC2*V22
        V22=V22-IFIX(DVE22)
      END IF
      END IF
C
C    SOUTHERN NEW JERSEY CLASS III VESSELS
C
      SPROF3(K)=ERNS3
      IF(K.EQ.12)THEN
        SAPRO3=0
        DO 60 I=1,12
        SAPRO3=SAPRO3+SPROF3(I)
      SPROF3(I)=0
60      CONTINUE
      SDIF3=SAPRO3-ALRET3
```

```
      IF(SDIF3.GT.0)THEN
        DVE23=VINC3*V23
        V23=IFIX(DVE23)+V23
      ELSE IF(SDIF3.LT.0)THEN
        DVE23=VDEC3*V23
        V23=V23-IFIX(DVE23)
      END IF
      ENDIF
C
C    DELMARVA CLASS I VESSELS
C
      DPROF1(K)=ERND1
      IF(K.EQ.12)THEN
      DAPRO1=0
        DO 70 I=1,12
        DAPRO1=DAPRO1+DPROF1(I)
        DPROF1(I)=0
70    CONTINUE
      DDIF1=DAPRO1-ALRET1
      IF(DDIF.GT.0)THEN
        DVE31=VINC1*V31
        V31=IFIX(DVE31)+V31
      ELSE IF(DDIF1.LT.0)THEN
        DVE31=VDEC1*V31
        V31=V31-IFIX(DVE31)
      END IF
      END IF
C
C    DELMARVA CLASS II VESSELS
C
      DPROF2(K)=ERND2
      IF(K.EQ.12)THEN
        DAPRO2=0
          DO 80 I=1,12
          DAPRO2=DAPRO2+DPROF2(I)
          DPROF2(I)=0
80    CONTINUE
      DDIF2=DAPRO2-ALRET2
      IF(DDIF2.GT.0)THEN
        DVE32=VINC2*V32
        V32=IFIX(DVE32)+V32
      ELSE IF(DDIF2.LT.0)THEN
        DVE32=VDEC2*V32
        V32=V32-IFIX(DVE32)
      END IF
      END IF
C
C    DELMARVA CLASS III VESSELS
C
      DPROF3(K)=ERND3
      IF(K.EQ.12)THEN
       DAPRO3=0
          DO 90 I=1,12
          DAPRO3=DAPRO3+DPROF3(I)
```

```
      DPROF3(I)=0
90    CONTINUE
      DDIF3=DAPRO3-ALRET3
      IF(DDIF3.GT.0)THEN
        DVE33=VINC3*V33
        V33=IFIX(DVE33)+V33
      ELSE IF(DDIF3.LT.0)THEN
        DVE33=VDEC3*V33
        V33=V33-IFIX(DVE33)
      END IF
      END IF
C
      RETURN
      END
C
      SUBROUTINE INPUT
C
C   THIS SUBROUTINE INITIALIZES ALL INPUT PARAMETERS FOR THE MODEL
AND
C   PASSES THEM TO THE MAIN PROGRAM AND SUBROUTINES WHERE THEY ARE
C   REQUIRED FOR CALCULATIONS
C
       COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
     CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
     CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
     CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
     CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
     CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
     CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
     CCA13,CA23,CA33,CA43,CA53,CA63,XNCO1,XNCO2,XNCO3,XNCO4,XNCO5,
     CXNCO6,SCO1,SCO2,SCO3,SCO4,SCO5,SCO6,DCO1,DCO2,DCO3,DCO4,DCO5,
     CDCO6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
     COTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
       COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
     CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,

CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
      CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,

CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,

CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
      CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
      CTHPOP,THWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63

COMMON/VRET/ZLSCP,ZDQP,ZHCP,ZDYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,

CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,

CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,

CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,

CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
```

```
      CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
      CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,

 CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
      CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
      CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3

 COMMON/PRET/WSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
      CFULD,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,

 CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
      CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
      CWPR5,TREPR
       COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
      CVINC2,VINC3,VDEC1,VDEC2,VDEC3

 COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
      CSUTIL3

 COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
      CSEHRT3,SEHRT4,QUOTA4,QUOTA
       COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3

 COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
      CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
      CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
      CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
      CAXNC06,AXSC06,AXDC06,ABUN,ABUS,ABUD,APLBS,APROC,
      CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,AOVH,AINS,
      CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
C    INITIALIZE NUMBER OF VESSELS IN EACH REGION
C
       V11=0
       V12=0
       V13=0
       V21=4.0
       V22=20.0
       V23=20.0
       V31=9.0
       V32=13.0
       V33=41.0
C
C    INITIALIZE CATCHABILITY COEFFICIENTS FOR EACH COHORT IN THREE
REGIONS
C
       CA11=0
       CA21=0
       CA31=0
         CA41=0
         CA51=0
       CA61=.00000096054
       CA12=0
```

```
      CA22=0
      CA32=0
        CA42=0
        CA52=0
      CA62=.0000011898
      CA13=0
      CA23=0
      CA33=0
        CA43=0
        CA53=0
      CA63=.0000018884
C
C   INITIALIZE POPULATION STRUCTURE (i.e. NUMBER OF INDIVIDUALS IN
EACH
C    COHORT IN EACH REGION)
C
        XNC01=2365000000.00
        XNC02=14670000000.00
        XNC03=19200000000.00
       XNC04=8348000000.00
       XNC05=19200000000.00
       XNC06=6980000000.00
        SC01=2365000000.00
        SC02=2365000000.00
        SC03=2365000000.00
       SC04=2365000000.00
        SC05=2365000000.00
        SC06=27970000000.00
        DC01=11850000000.00
        DC02=15500000000.00
        DC03=67400000000.00
        DC04=15500000000.00
        DC05=11850000000.00
        DC06=22000000000.00
C
C   INITIALIZE AGE SPECIFIC NATURAL MORTALITY FOR EACH REGION
C
      Z11=.02
      Z12=.02
      Z13=.02
      Z14=.02
      Z15=.02
      Z16=.02
      Z21=.02
      Z22=.02
      Z23=.02
      Z24=.02
      Z25=.02
      Z26=.02
      Z31=.02
      Z32=.02
      Z33=.02
      Z34=.02
      Z35=.02
```

```
      Z36=.02
C
C   INITIALIZE LENGTH OF EACH COHORT GROUP IN EACH OF THREE REGIONS
C
      XLNN1=38.94
      XLNN2=69.46
      XLNN3=92.68
      XLNN4=110.35
      XLNN5=123.80
      XLNN6=134.40
      XLNS1=38.94
      XLNS2=69.46
      XLNS3=92.68
      XLNS4=110.35
      XLNS5=123.80
      XLNS6=134.40
      XLND1=39.97
      XLND2=72.60
      XLND3=96.80
      XLND4=114.77
      XLND5=128.09
      XLND6=137.98
C
C   INITIALIZE PRICES OF COMPETING SPECIES
C
      ZOQP=.3518
      ZHCP=3.0000
      ZDYP=2.5000
C
C   INITIALIZE FIXED COSTS OF VESSEL OPERATIONS
C
      CST11=2400.00
      CST21=34000.00
      CST31=3100.00
      CST41=1000.00
      CST51=1300.00
       CST61=400.00
      CST12=2400.00
      CST22=49000.00
      CST32=6000.00
      CST42=2000.00
       CST52=1397.00
       CST62=500.00
      CST13=2400.00
      CST23=78000.00
      CST33=10000.00
      CST43=4000.00
      CST53=2000.00
      CST63=500.00
C
C     INITIALIZE FUEL CONSUMPTION DURING VESSEL OPERATIONS
C     (GALLONS USED PER TRIP)
C
       FU1=300.00
```

```
       FU2=500.00
       FU3=600.00
C
C      INITIALIZE FUEL PRICE
C
        FUPR=1.10
C     INITIALIZE VARIABLE MISCELLANEOUS COSTS OF VESSEL OPERATIONS FOR
C     THREE CLASSES
C
       ZMIS1=372.00
       ZMIS2=371.00
       ZMIS3=577.00
C
C     INITIALIZE CREW SHARE AND CAPTAIN'S SHARE FOR THREE VESSEL
CLASSES
C
       CRS1=.20
       CRS2=.20
       CRS3=.20
       CPS1=.10
       CPS2=.10
       CPS3=.15
C
C     INITIALIZE WINTER - SUMMER AND SPRING - FALL PROCESSING COSTS
C
       WSCST=.34
       SFCST=.31
C
C     INITIALIZE VARIABLE PROCESSING COSTS
C
       TRNS=.067
       PAT=.023
       XLAB=.15
       ELEC=.077
       FULO=.034
       PROP=.043
       PKG=.001
       DEPR=.052
       REPR=.099
       ZOVH=.147
       ZINS=.028
       ZLEGL=.012
       STRG=.013
       CHEM=.018
C
C     INITIALIZE COST FLOOR FOR PROCESSING
C
       PFLR=0
C
C     INITIALIZE RATE OF RETURN AVAILABLE OUTSIDE THE FISHERY FOR EACH
C     REGION
C
       ARATE1=.10
       ARATE2=.10
```

```
      ARATE3=.10
C
C   INITIALIZE MARKET VALUE OF THREE VESSEL CLASSES
C
      XMVAL1=53333.00
      XMVAL2=225000.00
      XMVAL3=530000.00
C
C   INITIALIZE NUMBER OF EFFORT HOURS PERMITTED PER MONTH
C
      EHRS1=96.00
      EHRS2=96.00
      EHRS3=96.00
      RHRS1=96.00
      RHRS2=96.00
      RHRS3=96.00
C
C   INITIALIZE LANDINGS TAXES
C
      TXL11=0
      TXL12=0
      TXL13=0
      TXL21=0
       TXL22=0
       TXL23=0
      TXL31=0
      TXL32=0
      TXL33=0
C
C   INITIALIZE QUARTERLY QUOTAS
C
        QUOTA1=6800000
        QUOTA2=8500000
        QUOTA3=8500000
        QUOTA4=6800000
C
C   INITIALIZE WINTER UTILIZATION RATE OF PERMITTED HOURS
C
      WUTIL1=.13
      WUTIL2=.22
      WUTIL3=.30
C
C   INITIALIZE SUMMER UTILIZATION RATE OF PERMITTED HOURS
C
      SUTIL1=.13
      SUTIL2=.22
      SUTIL3=.30
C
C   INITIALIZE SWITCHING COSTS TO MOVE TO ANOTHER REGION
C
      SWTCH1=0
      SWTCH2=0
      SWTCH3=0
C
```

```
C   INITIALIZE EXPECTED TIME REQUIRED TO RECOVER SWITCHING COSTS
C
      RCVTM1=1.0
      RCVTM2=1.0
      RCVTM3=1.0
C
C     INITIALIZE BRODY GROWTH COEFFICIENT FOR EACH REGION
       BNJ=.2721
       BDEL=.2984
C
C     INITIALIZE % INCREASE AND DECREASE OF VESSELS IN FISHERY
C     AS A FUNCTION OF PROFIT AND LOSS
C
       VINC1=0
       VINC2=0
       VINC3=0
       VDEC1=0
       VDEC2=0
       VDEC3=0
C
C
C     INITIALIZE AVERAGE WEIGHT FOR COHORT 6 (MATURE CLAMS)
       AVWT61=.3
       AVWT62=.3
       AVWT63=.3
C
C
C     INITIALIZE EX-VESSEL PRICE FLOOR FOR SURF CLAMS
C
       EXFLR=0.20
       MGMT=1
C
      RETURN
      END
C
      SUBROUTINE SWITCH
C
C   THIS SUBROUTINE CALCULATES THE NUMBER OF VESSELS MOVING FROM ONE
C   REGION TO ANOTHER
C
      COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
     CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
     CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
     CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
     CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
     CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
     CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
     CCA13,CA23,CA33,CA43,CA53,CA63,XNCO1,XNCO2,XNCO3,XNCO4,XNCO5,
     CXNCO6,SCO1,SCO2,SCO3,SCO4,SCO5,SCO6,DCO1,DCO2,DCO3,DCO4,DCO5,
     CDCO6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
     COTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
      COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
     CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,
```

```
CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
      CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,
CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,
CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
      CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
      CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63
COMMON/VRET/ZLSCP,ZDQP,ZHCP,ZOYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,
CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,
CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,
CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,
CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
      CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
      CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,
CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
      CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
      CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3
COMMON/PRET/WSCST,SFCST,PRCST,SUP,PLSS,SHCST,TRNS,PAT,XLAB,ELEC,
      CFULD,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,
CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
      CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
      CWPR5,TREPR
       COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
      CVINC2,VINC3,VDEC1,VDEC2,VDEC3
COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
      CSUTIL3
COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
      CSEHRT3,SEHRT4,QUOTA4,QUOTA
       COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3
COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
      CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
      CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
      CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
      CAXNCD6,AXSCD6,AXDCD6,ABUN,ABUS,ABUD,APLBS,APROC,
      CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,ADVH,AINS,
      CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
C    CALCULATE POTENTIAL PROFITS FROM EACH REGION - CLASS I
C
C       NORTHERN NEW JERSEY
```

```
C
        PHN11=1.0*ED11*CA11*XNCO1
      PHN21=1.0*ED11*CA21*XNCO2
      PHN31=1.0*ED11*CA31*XNCO3
      PHN41=1.0*ED11*CA41*XNCO4
      PHN51=1.0*ED11*CA51*XNCO5
      PHN61=1.0*ED11*CA61*XNCO6
      PNLBT1=PHN11*XWTN1+PHN21*XWTN2+PHN31*XWTN3+PHN41*XWTN4+PHN51*
     CXWTN5+PHN61*XWTN6
      PVRN1=PNLBT1*(SCP-TXL11)
      POPN1=FCST1+((FU1*FUPR+ZMIS1)*ED11+(CRS1*PVRN1)+(CPS1*PVRN1))
      PRNN1=PVRN1-POPN1
C
C     SOUTHERN NEW JERSEY
C
       PHS11=1.0*ED21*CA11*SCO1
       PHS21=1.0*ED21*CA21*SCO2
       PHS31=1.0*ED21*CA31*SCO3
       PHS41=1.0*ED21*CA41*SCO4
       PHS51=1.0*ED21*CA51*SCO5
       PHS61=1.0*ED21*CA61*SCO6
       PSLBT1=PHS11*XWTS1+PHS21*XWTS2+PHS31*XWTS3+PHS41*XWTS4+PHS51*
     CXWTS5+PHS61*XWTS6
        PVRS1=PSLBT1*(SCP-TXL21)
        POPS1=FCST1+((FU1*FUPR+ZMIS1)*ED21+(CRS1*PVRS1)+(CPS1*PVRS1))
        PRNS1=PVRS1-POPS1
C
C     DELMARVA
C
        PHD11=1.0*ED31*CA11*DCO1
        PHD21=1.0*ED31*CA21*DCO2
        PHD31=1.0*ED31*CA31*DCO3
        PHD41=1.0*ED31*CA41*DCO4
        PHD51=1.0*ED31*CA51*DCO5
        PHD61=1.0*ED31*CA61*DCO6
       PDLBT1=PHD11*XWTD1+PHD21*XWTD2+PHD31*XWTD3+PHD41*XWTD4
     C+PHD51*XWTD5+PHD61*XWTD6
        PVRD1=PDLBT1*(SCP-TXL31)
        POPD1=FCST1+((FU1*FUPR+ZMIS1)*ED31+(CRS1*PVRD1)+(CPS1*PVRD1))
        PRND1=PVRD1-POPD1
      XNPOT1=PRNN1-(SWTCH1/RCVTM1)
      SPOT1=PRNS1-(SWTCH1/RCVTM1)
      DPOT1=PRND1-(SWTCH1/RCVTM1)
C
C   CALCULATE SWITCHING BEHAVIOR FOR CLASS I VESSELS
C
      IF(XNPOT1.LT.SPOT1)THEN
      IF(DPOT1.LT.SPOT1)THEN
      IF(-FCST1.LT.SPOT1)THEN
         V21=(V11-IFIX(V11/2))+(V31-IFIX(V31/2))+V21
      V11=IFIX(V11/2)
      V31=IFIX(V31/2)
      ENDIF
      ELSE
```

```
      IF(-FCST1.LT.DPOT1)THEN
      IF(SPOT1.EQ.DPOT1)THEN
        V21=(V11-IFIX(V11/2))+V21
                 V11=IFIX(V11/2)
      ELSE
        V31=(V11-IFIX(V11/2))+(V21-IFIX(V21/2))+V31
      V11=IFIX(V11/2)
      V21=IFIX(V21/2)
      ENDIF
      ENDIF
      ENDIF
      ELSE
      IF(DPOT1.LT.XNPOT1)THEN
      IF(-FCST1.LT.XNPOT1)THEN
      IF(SPOT1.EQ.XNPOT1)THEN
        V21=(V21-IFIX(V31/2))+V21
      V31=IFIX(V31/2)
      ELSE
        V11=(V21-IFIX(V21/2))+(V31-IFIX(V31/2))+V11
      V21=IFIX(V21/2)
      V31=IFIX(V31/2)
      ENDIF
      ENDIF
      ELSE
      IF(-FCST1.LT.DPOT1)THEN
      IF(XNPOT1.EQ.DPOT1)THEN
         V31=(V31-IFIX(V21/2))+V31
      V21=IFIX(V21/2)
      ELSE
        V31=(V21-IFIX(V21/2))+(V11-IFIX(V11/2))+V31
      V21=IFIX(V21/2)
      V11=IFIX(V11/2)
      ENDIF
      ENDIF
      ENDIF
      ENDIF
C   CALCULATE POTENTIAL PROFITS FROM EACH REGION - CLASS II
C
C    NORTHERN NEW JERSEY
C
      PHN12=1.0*ED12*CA12*XNCD1
      PHN22=1.0*ED12*CA12*XNCD2
      PHN32=1.0*ED12*CA32*XNCD3
      PHN42=1.0*ED12*CA42*XNCD4
      PHN52=1.0*ED12*CA52*XNCD5
      PHN62=1.0*ED12*CA62*XNCD6

PNLBT2=PHN12*XWTN1+PHN22*XWTN2+PHN32*XWTN3+PHN42*XWTN4+PHN52*XWTN5
     C+PHN62*XWTN6
      PVRN2=PNLBT2*(SCP-TXL12)
      POPN2=FCST2+((FU2*FUPR+ZMIS2)*ED12+(CRS2*PVRN2)+(CPS2*PVRN2))
      PRNN2=PVRN2-POPN2
C
C   SOUTHERN NEW JERSEY
```

```
C
      PHS12=1.0*ED22*CA12*SCO1
      PHS22=1.0*ED22*CA22*SCO2
      PHS32=1.0*ED22*CA32*SCO3
      PHS42=1.0*ED22*CA42*SCO4
      PHS52=1.0*ED22*CA52*SCO5
      PHS62=1.0*ED22*CA62*SCO6
      PSLBT2=PHS12*XWTS1+PHS22*XWTS2+PHS32*XWTS3+PHS42*XWTS4+PHS52*
     CXWTS5+PHS62*XWTS6
      PVRS2=PSLBT2*(SCP-TXL22)
      POPS2=FCST2+((FU2*FUPR+ZMIS2)*ED22+(CRS2*PVRS2)+(CPS2*PVRS2))
      PRNS2=PVRS2-POPS2
C
C     DELMARVA
C
      PHD12=1.0*ED32*CA12*DCO1
      PHD22=1.0*ED32*CA22*DCO2
      PHD32=1.0*ED32*CA32*DCO3
      PHD42=1.0*ED32*CA42*DCO4
      PHD52=1.0*ED32*CA52*DCO5
      PHD62=1.0*ED32*CA62*DCO6
      PDLBT2=PHD12*XWTD1+PHD22*XWTD2+PHD32*XWTD3+PHD42*XWTD4+
     CPHD52*XWTD5+PHD62*XWTD6
      PVRD2=PDLBT2*(SCP-TXL32)
      POPD2=FCST2+((FU2*FUPR+ZMIS2)*ED32+(CRS2*PVRD2)+(CPS2*PVRD2))
      PRND2=PVRD2-POPD2
      XNPOT2=PRNN2-(SWTCH2/RCVTM2)
      SPOT2=PRNS2-(SWTCH2/RCVTM2)
      DPOT2=PRND2-(SWTCH2/RCVTM2)
C
C    CALCULATE SWITCHING BEHAVIOR FOR CLASS II VESSELS
C
      IF(XNPOT2.LT.SPOT2)THEN
           IF(DPOT2.LT.SPOT2)THEN
      IF(-FCST2.LT.SPOT2)THEN
        V22=(V12-IFIX(V12/2))+(V32-IFIX(V32/2))+V22
      V12=IFIX(V12/2)
      V32=IFIX(V32/2)
      ENDIF
      ELSE
      IF(-FCST2.LT.DPOT2)THEN
      IF(SPOT2.EQ.DPOT2)THEN
         V22=(V12-IFIX(V12/2))+V22
      V12=IFIX(V12/2)
      ELSE
         V32=(V12-IFIX(V12/2))+(V22-IFIX(V22/2))+V32
      V12=IFIX(V12/2)
      V22=IFIX(V22/2)
      ENDIF
      ENDIF
      ENDIF
      ELSE
      IF(DPOT2.LT.XNPOT2)THEN
      IF(-FCST2.LT.XNPOT2)THEN
```

```
      IF(SPOT2.EQ.XNPOT2)THEN
        V22=(V32-IFIX(V32/2))+V22
      V32=IFIX(V32/2)
      ELSE
         V12=(V22-IFIX(V22/2))+(V32-IFIX(V32/2))+V12
      V22=IFIX(V22/2)
      V32=IFIX(V32/2)
      ENDIF
      ENDIF
      ELSE
      IF(-FCST2.LT.DPOT2)THEN
      IF(XNPOT2.EQ.DPOT2)THEN
        V32=(V22-IFIX(V22/2))+V32
      V22=IFIX(V22/2)
      ELSE
         V32=(V22-IFIX(V22/2))+(V12-IFIX(V12/2))+V32
      V22=IFIX(V22/2)
      V12=IFIX(V12/2)
      ENDIF
      ENDIF
      ENDIF
      ENDIF
C
C     CALCULATE POTENTIAL PROFITS FROM EACH REGION - CLASS III
C
C       NORTHERN NEW JERSEY
C
      PHN13=1.0*ED13*CA13*XNC01
      PHN23=1.0*ED13*CA23*XNC02
      PHN33=1.0*ED13*CA33*XNC03
      PHN43=1.0*ED13*CA43*XNC04
      PHN53=1.0*ED13*CA53*XNC05
      PHN63=1.0*ED13*CA63*XNC06
      PNLBT3=PHN13*XWTN1+PHN23*XWTN2+PHN33*XWTN3+PHN43*XWTN4
     C+PHN53*XWTN5+PHN63*XWTN6
      PVRN3=PNLBT3*(SCP-TXL13)
      POPN3=FCST3+((FU3*FUPR+ZMIS3)*ED13+(CRS3*PVRN3)+(CPS3*PVRN3))
      PRNN3=PVRN3-POPN3
C
C     SOUTHERN NEW JERSEY
C
      PHS13=1.0*ED23*CA13*SC01
      PHS23=1.0*ED23*CA23*SC02
      PHS33=1.0*ED23*CA33*SC03
      PHS43=1.0*ED23*CA43*SC04
      PHS53=1.0*ED23*CA53*SC05
      PHS63=1.0*ED23*CA63*SC06
      PSLBT3=PHS13*XWTS1+PHS23*XWTS2+PHS33*XWTS3+PHS43*XWTS4
     C+PHS53*XWTS5+PHS63*XWTS6
      PVRS3=PSLBT3*(SCP-TXL23)
      POPS3=FCST3+((FU3*FUPR+ZMIS3)*ED23+(CRS3*PVRS3)+(CPS*PVRS3))
      PRNS3=PVRS3-POPS3
C
C     DELMARVA
```

```
C
      PHD13=1.0*ED33*CA13*DCC1
      PHD23=1.0*ED33*CA23*DCC2
      PHD33=1.0*ED33*CA33*DCC3
      PHD43=1.0*ED33*CA43*DCC4
      PHD53=1.0*ED33*CA53*DCC5
      PHD63=1.0*ED33*CA63*DCC6
      PDLBT3=PHD13*XWTD1+PHD23*XWTD2+PHD33*XWTD3+PHD43*XWTD4
     C+PHD53*XWTD5+PHD63*XWTD6
      PVRD3=PDLBT3*(SCP-TXL33)
      PCPD3=FCST3+((FU3*FUPR+IMIS3)*ED33+(CRS3*PVRD3)+(CPS3*PVRD3))
      PRND3=PVRD3-PCPD3
      XNPCT3=PRNN3-(SWTCH3/RCVTM3)
      SPOT3=PRNS3-(SWTCH3/RCVTM3)
      DPOT3=PRND3-(SWTCH3/RCVTM3)
C
C    CALCULATE SWITCHING BEHAVIOR FOR CLASS III VESSELS
C
      IF(XNPOT3.LT.SPOT3)THEN
      IF(DPOT3.LT.SPOT3)THEN
      IF(-FCST3.LT.SPOT3)THEN
         V23=(V13-IFIX(V13/2))+(V33-IFIX(V33/2))+V23
      V13=IFIX(V13/2)
      V33=IFIX(V33/2)
      ENDIF
      ELSE
      IF(-FCST3.LT.DPOT3)THEN
      IF(SPOT3.EQ.DPOT3)THEN
        V23=(V13-IFIX(V13/2))+V23
      V13=IFIX(V13/2)
      ELSE
         V33=(V13-IFIX(V13/2))+(V23-IFIX(V23/2))+V33
      V13=IFIX(V13/2)
      V23=IFIX(V23/2)
      ENDIF
      ENDIF
      ENDIF
      ELSE
      IF(DPOT3.LT.XNPOT3)THEN
      IF(-FCST3.LT.XNPOT3)THEN
      IF(SPOT3.EQ.XNPOT3)THEN
        V23=(V33-IFIX(V33/2))+V23
      V33=IFIX(V33/2)
      ELSE
        V13=(V23-IFIX(V23/2))+(V33-IFIX(V33/2))+V13
      V23=IFIX(V23/2)
      V33=IFIX(V33/2)
      ENDIF
      ENDIF
      ELSE
      IF(-FCST3.LT.DPOT3)THEN
      IF(XNPOT3.EQ.DPOT3)THEN
         V33=(V23-IFIX(V23/2))+V33
      V23=IFIX(V23/2)
```

```
      ELSE
         V33=(V23-IFIX(V23/2))+(V13-IFIX(V13/2))+V33
      V23=IFIX(V23/2)
      V13=IFIX(V13/2)
      ENDIF
      ENDIF
      ENDIF
      ENDIF
C
      RETURN
      END
C
      SUBROUTINE EFFORT
C
C    THIS SUBROUTINE CALCULATES THE NUMBER OF EFFORT DAYS
C    PER MONTH FOR EACH VESSEL CLASS
C
       COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
     CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
     CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
     CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
     CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
     CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
     CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
     CCA13,CA23,CA33,CA43,CA53,CA63,XNCO1,XNCO2,XNCO3,XNCO4,XNCO5,
     CXNCO6,SCO1,SCO2,SCO3,SCO4,SCO5,SCO6,DCO1,DCO2,DCO3,DCO4,DCO5,
     CDCO6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
     CDTOT,HATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
       COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
     CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,

CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
     CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,

CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,

CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
     CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
     CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63

COMMON/VRET/ZLSCP,ZOCP,ZHCP,ZOYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,

CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,

CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,

CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,

CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
     CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
     CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,

CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
     CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
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     CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3
      COMMON/PRET/WSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
     CFULD,PROP,PKG,DEPR,REPR,ZOVM,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,
     CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TZOVM,TZINS,TZLEGL,TSTRG,TCHEM,
     CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
     CWPR5,TREPR
      COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
     CVINC2,VINC3,VDEC1,VDEC2,VDEC3
      COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
     CSUTIL3
      COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
     CSEHRT3,SEHRT4,QUOTA4,QUOTA
      COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3
      COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
     CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
     CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
     CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
     CAXNCD6,AXSCD6,AXDCD6,ABUN,ABUS,ABUD,APLBS,APROC,
     CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,AOVM,AINS,
     CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
C    CALCULATE EFFORT DAYS PER MONTH FOR EACH VESSEL CLASS.  EFFORT
C    DAYS = 12 HOURS PER EFFORT DAY X AVERAGE PERCENT UTILIZATION OF
C    ALLOWABLE FISHING HOURS BY A VESSEL OF THAT CLASS.
C
      ED1=(EHRS1/12)
      ED2=(EHRS2/12)
      ED3=(EHRS3/12)
C
C    SET PUTIL ACCORDING TO SEASON
C
      IF(IMO.GE.10.OR.IMO.LE.3)THEN
      PUTIL1=WUTIL1
      PUTIL2=WUTIL2
      PUTIL3=WUTIL3
      ELSE
      PUTIL1=SUTIL1
      PUTIL2=SUTIL2
      PUTIL3=SUTIL3
      END IF
C
C    CALCULATE EFFORT DAYS
C
      ED11=ED1*PUTIL1
      ED12=ED1*PUTIL2
      ED13=ED1*PUTIL3
      ED21=ED2*PUTIL1
      ED22=ED2*PUTIL2
```

```
      ED23=ED2*PUTIL3
      ED31=ED3*PUTIL1
      ED32=ED3*PUTIL2
      ED33=ED3*PUTIL3
C
      RETURN
      END
C
      SUBROUTINE VESRET
C
C     THIS SUBROUTINE CALCULATE VESSEL RETURNS
C
      COMMON/MARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
     CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
     CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
     CHS53,HS63,HD11,HD21,HD31,HD41,HD51,HD61,HD12,HD22,HD32,HD42,
     CHD52,HD62,HD13,HD23,HD33,HD43,HD53,HD63,V11,V12,V13,V21,V22,
     CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
     CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
     CCA13,CA23,CA33,CA43,CA53,CA63,XNCO1,XNCO2,XNCO3,XNCO4,XNCO5,
     CXNCO6,SCO1,SCO2,SCO3,SCO4,SCO5,SCO6,DCO1,DCO2,DCO3,DCO4,DCO5,
     CDCO6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
     CDTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
      COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
     CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,

CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
     CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,

CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,

CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
     CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
     CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63

COMMON/VRET/ZLSCP,ZDOP,ZHCP,ZDYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,

CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,

CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,

CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,

CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
     CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
     CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,

CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
     CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
     CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3

COMMON/PRET/HSCST,SFCST,PRCST,BUP,PLBS,SMCST,TRNS,PAT,XLAB,ELEC,
     CFULO,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,
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```
CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
      CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
      CWPR5,TREPR
       COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
      CVINC2,VINC3,VDEC1,VDEC2,VDEC3

COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
      CSUTIL3

COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
      CSEHRT3,SEHRT4,QUOTA4,QUOTA
       COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3

COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
      CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
      CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
      CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
      CAXNCO6,AXSCO6,AXDCO6,ABUN,ABUS,ABUD,APLBS,APROC,
      CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULD,APROP,APKG,ADEPR,AOVH,AINS,
      CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
C    SET VALUES FOR DUMMY VARIABLES DEPENDING UPON SEASON AND YEAR
C
C
        IF(IMO.LT.3.OR.IMO.GT.11)THEN
          SD1=1.0
        ELSE
        SD1=0
        END IF
        IF(MGMT.NE.0)THEN
        ZMDUM=1.0
        ELSE
        ZMDUM=0
        END IF
C
C    CALCULATE THE EX-VESSEL SURF CLAM PRICE PER POUND BASED UPON
C    PRICES OF COMPETING SPECIES AND SURF CLAM LANDINGS
C
         WRITE(1,*)  XMALBS
         IF(XMALBS.LE.0)THEN
         SCP=0.0
         GO TO 10
         ELSE
        ZLSCP=-.0464-.0596*ALOG(XMALBS)+.6373*ALOG(ZDQP)-
.1960*ALOG(ZMCP)+
      C.1485*ALOG(ZDYP)+.8745*ZMDUM-.0728*SD1
         END IF
C
C    CONVERT NATURAL LOG OF SURF CLAM PRICE TO SURF CLAM EX-VESSEL
PRICE
C
        SCP=EXP(ZLSCP)
```

```
        IF(EXFLR.NE.0) SCP=EXFLR
C
C    CALCULATE VESSEL REVENUES FOR ALL CLASS I VESSELS FISHING IN
C    NORTHERN NEW JERSEY
C
10      VRN1=XNLBT1*(SCP-TXL11)
C
C    CALCULATE AVERAGE RETURN PER NORTHERN NEW JERSEY CLASS I VESSELS
C
        IF(V11.NE.0) THEN
       VRAN1=VRN1/V11
        ELSE
        VRAN1=0.0
        ENDIF
C
C    CALCULATE VESSEL REVENUES FOR CLASS II VESSELS FISHING IN
NORTHERN
C    NEW JERSEY
C
       VRN2=XNLBT2*(SCP-TXL12)
C
C
C    CALCULATE AVERAGE REVENUE PER NORTHERN NEW JERSEY CLASS II VESSEL
C
        IF(V12.NE.0) THEN
       VRAN2=VRN2/V12
        ELSE
        VRAN2=0.0
        END IF
C
C    CALCULATE VESSEL REVENUE FOR CLASS III VESSELS FISHING IN
NORTHERN
C    NEW JERSEY
C
       VRN3=XNLBT3*(SCP-TXL13)
C
C    CALCULATE AVERAGE REVENUE FOR A CLASS III VESSEL FISHING IN
NORTHERN
C    NEW JERSEY
C
        IF(V13.NE.0) THEN
       VRAN3=VRN3/V13
        ELSE
        VRAN3=0.0
        END IF
C
C      CALCULATE TOTAL NORTHERN NEW JERSEY VESSEL REVENUES
C
       VRTN=VRN1+VRN2+VRN3
C
C    CALCULATE VESSEL REVENUE FOR CLASS I VESSELS FISHING IN SOUTHERN
C    NEW JERSEY
C
       VRS1=SLBT1*(SCP-TXL21)
```

```
C
C   CALCULATE AVERAGE REVENUE FOR A CLASS I VESSEL FISHING IN
SOUTHERN
C   NEW JERSEY
C
       IF(V21.NE.0)THEN
      VRAS1=VRS1/V21
       ELSE
       VRAS1=0.0
       END IF
C
C   CALCULATE VESSEL REVENUE FOR CLASS II VESSELS FISHING IN SOUTHERN
C   NEW JERSEY
C
      VRS2=SLBT2*(SCP-TXL22)
C
C   CALCULATE AVERAGE REVENUE FOR CLASS II  VESSELS FISHING IN
SOUTHERN
C   NEW JERSEY
       IF(V22.NE.0) THEN
      VRAS2=VRS2/V22
       ELSE
       VRAS2=0.0
       END IF
C
C   CALCULATE VESSEL REVENUE FOR CLASS III VESSELS FISHING IN
SOUTHERN
C   NEW JERSEY
C
      VRS3=SLBT3*(SCP-TXL32)
C
C   CALCULATE AVERAGE VESSEL REVENUE FOR A CLASS III VESSEL FISHING
IN
C   SOUTHERN NEW JERSEY
C
       IF(V23.NE.0)THEN
      VRAS3=VRS3/V23
       ELSE
       VRAS3=0.0
       END IF
C
C   CALCULATE TOTAL SOUTHERN NEW JERSEY VESSEL REVENUE
C
      VRTS=VRS1+VRS2+VRS3
C
C   CALCULATE VESSEL REVENUE FOR CLASS I VESSELS FISHING IN DELMARVA
C
      VRD1=DLBT1*(SCP-TXL31)
C
C   CALCULATE AVERAGE VESSEL REVENUE FOR A CLASS I VESSEL IN DELMARVA
C
       IF(V31.NE.0) THEN
      VRAD1=VRD1/V31
       ELSE
```

```
          VRAD1=0.0
          END IF
C
C
C    CALCULATE VESSEL REVENUE FOR CLASS II VESSELS FISHING IN DELMARVA
C
        VRD2=DLBT2*(SCP-TXL32)
C
C    CALCULATE AVERAGE VESSEL REVENUE FOR A CLASS II VESSEL FISHING IN
C    DELMARVA
C
          IF(V32.NE.0) THEN
        VRAD2=VRD2/V32
          ELSE
          VRAD2=0.0
          END IF
C
C    CALCULATE VESSEL REVENUE FOR CLASS III VESSELS FISHING IN
DELMARVA
C
        VRD3=DLBT3*(SCP-TXL33)
C
C    CALCULATE AVERAGE VESSEL REVENUE FOR A CLASS III VESSEL FISHING
OFF
C    DELMARVA
C
          IF(V33.NE.0)THEN
        VRAD3=VRD3/V33
          ELSE
          VRAD3=0
          END IF
C
C    CALCULATE TOTAL DELMARVA VESSEL REVENUES
C
        VRDT=VRD1+VRD2+VRD3
C
C    CALCULATE MID-ATLANTIC VESSEL REVENUE
C
        VRMA=VRTN+VRTS+VRTD
C
C    CALCULATE VESSEL COSTS
C
C    FIXED COSTS
C
        FCST1=(1/12.0)*(CST11+CST21+CST31+CST41+CST51+CST61)
        FCST2=(1/12.0)*(CST12+CST22+CST32+CST42+CST52+CST62)
        FCST3=(1/12.0)*(CST13+CST23+CST33+CST43+CST53+CST63)
C
C    CALCULATE TOTAL COSTS FIXED AND VARIABLE, AND EARNINGS OF
C    VESSELS HARVESTING CLAMS IN DIFFERENT REGIONS
C
C    CALCULATE OPERATING COSTS OF THREE CLASSES OF VESSELS IN
C    NORTHERN NEW JERSEY
C
```

```
      XOPN1=FCST1+((FU1*FUPR+ZMIS1)*ED11+(CRS1*VRAN1))
      XOPN2=FCST2+((FU2*FUPR+ZMIS2)*ED12+(CRS2*VRAN2))
      XOPN3=FCST3+((FU3*FUPR+ZMIS3)*ED13+(CRS3*VRAN3))
C
C    OPERATING COSTS IN SOUTHERN NEW JERSEY
C
      XOPS1=FCST1+((FU1*FUPR+ZMIS1)*ED21+(CRS1*VRAS1))
      XOPS2=FCST2+((FU2*FUPR+ZMIS2)*ED22+(CRS2*VRAS2))
      XOPS3=FCST3+((FU3*FUPR+ZMIS3)*ED23+(CRS3*VRAS3))
C
C    OPERATING COSTS IN DELMARVA
C
      XOPD1=FCST1+((FU1*FUPR+ZMIS1)*ED31+(CRS1*VRAD1))
      XOPD2=FCST2+((FU2*FUPR+ZMIS2)*ED32+(CRS1*VRAD2))
      XOPD3=FCST3+((FU3*FUPR+ZMIS3)*ED33+(CRS3*VRAD3))
C
C    CALCULATE TOTAL VESSEL COSTS FOR ALL VESSELS IN EACH REGION
C
C    NORTHERN NEW JERSEY
C
      TCSTN1=XOPN1*V11
      TCSTN2=XOPN2*V12
      TCSTN3=XOPN3*V13
C
C    AVERAGE VESSEL EARNINGS
C
      AERNN1=VRAN1-XOPN1
      AERNN2=VRAN2-XOPN2
      AERNN3=VRAN3-XOPN3
        IF(V11.EQ.0)AERNN1=0
        IF(V12.EQ.0)AERNN2=0
        IF(V13.EQ.0)AERNN3=0
C
C    FLEET EARNINGS BY VESSEL CLASS
C
      ERNN1=VRN1-TCSTN1
      ERNN2=VRN2-TCSTN2
      ERNN3=VRN3-TCSTN3
C
C    TOTAL NORTHERN JERSEY FLEET EARNINGS
C
      ERNNT=ERNN1+ERNN2+ERNN3
C
C    SOUTHERN JERSEY
C
      TCSTS1=XOPS1*V21
      TCSTS2=XOPS2*V22
      TCSTS3=XOPS3*V23
C
C    AVERAGE VESSEL EARNINGS
C
      AERNS1=VRAS1-XOPS1
      AERNS2=VRAS2-XOPS2
      AERNS3=VRAS3-XOPS3
```

```
         IF(V21.EQ.0)AERNS1=0
         IF(V22.EQ.0)AERNS2=0
         IF(V23.EQ.0)AERNS3=0
C
C     FLEET EARNINGS BY VESSEL CLASS
C
        ERNS1=VRS1-TCSTS1
        ERNS2=VRS2-TCSTS2
        ERNS3=VRS3-TCSTS3
C
C     TOTAL SOUTHERN NEW JERSEY FLEET EARNINGS
C
        ERNST=ERNS1+ERNS2+ERNS3
C
C     DELMARVA
C
        TCSTD1=XOPD1*V31
        TCSTD2=XOPD2*V32
        TCSTD3=XOPD3*V33
C
C     AVERAGE VESSEL EARNINGS
C
        AERND1=VRAD1-XOPD1
        AERND2=VRAD2-XOPD2
        AERND3=VRAD3-XOPD3
          IF(V31.EQ.0)AERND1=0
          IF(V32.EQ.0)AERND2=0
          IF(V33.EQ.0)AERND3=0
C
C     FLEET EARNINGS BY VESSEL CLASS
C
        ERND1=VRD1-TCSTD1
        ERND2=VRD2-TCSTD2
        ERND3=VRD3-TCSTD3
C
C     TOTAL DELMARVA FLEET EARNINGS
C
        ERNDT=ERND1+ERND2+ERND3
C
C     CALCULATE EARNINGS FOR THE ENTIRE MID-ATLANTIC FLEET
C
        TMAERN=ERNNT+ERNST+ERNDT
C
        RETURN
        END
C
        SUBROUTINE YRPRNT
C
C     THIS SUBROUTINE WRITES YEARLY OUTPUT TO THE USER'S TERMINAL
C     AND TO A FILE CALLED YROAT
C
        COMMON/HARV/HN11,HN21,HN31,HN41,HN51,HN61,HN12,HN22,HN32,HN42,
       CHN52,HN62,HN13,HN23,HN33,HN43,HN53,HN63,HS11,HS21,HS31,HS41,
       CHS51,HS61,HS12,HS22,HS32,HS42,HS52,HS62,HS13,HS23,HS33,HS43,
```

```
      CMS53,MS63,MD11,MD21,MD31,MD41,MD51,MD61,MD12,MD22,MD32,MD42,
      CMD52,MD62,MD13,MD23,MD33,MD43,MD53,MD63,V11,V12,V13,V21,V22,
      CV23,V31,V32,V33,ED11,ED12,ED13,ED21,ED22,ED23,ED31,ED32,ED33,
      CCA11,CA21,CA31,CA41,CA51,CA61,CA12,CA22,CA32,CA42,CA52,CA62,
      CCA13,CA23,CA33,CA43,CA53,CA63,XNCO1,XNCO2,XNCO3,XNCO4,XNCO5,
      CXNCO6,SCO1,SCO2,SCO3,SCO4,SCO5,SCO6,DCO1,DCO2,DCO3,DCO4,DCO5,
      CDCO6,XNLBT1,XNLBT2,XNLBT3,SLBT1,SLBT2,SLBT3,DLBT1,DLBT2,DLBT3,
      COTOT,MATOT,XLBTOT,SLBTOT,DLBTOT,XMALBS
       COMMON/GRW/Z11,Z12,Z13,Z14,Z15,Z16,Z21,Z22,Z23,Z24,Z25,Z26,Z31,
      CZ32,Z33,Z34,Z35,Z36,XLNN1,XLNN2,XLNN3,XLNN4,XLNN5,XLNN6,XLNS1,
CXLNS2,XLNS3,XLNS4,XLNS5,XLNS6,XLND1,XLND2,XLND3,XLND4,XLND5,XLND6,
      CIMO,IYRS,XWTN1,XWTN2,XWTN3,XWTN4,XWTN5,XWTN6,XWTS1,XWTS2,XWTS3,
CXWTS4,XWTS5,XWTS6,XWTD1,XWTD2,XWTD3,XWTD4,XWTD5,XWTD6,TWTN1,TWTN2,
CTWTN3,TWTN4,TWTN5,TWTN6,TWTS1,TWTS2,TWTS3,TWTS4,TWTS5,TWTS6,TWTD1,
      CTWTD2,TWTD3,TWTD4,TWTD5,TWTD6,TNPOP,TSPOP,TDPOP,TNWT,TSWT,TDWT,
      CTMPOP,TMWT,BNJ,BDEL,AVWT61,AVWT62,AVWT63
COMMON/VRET/ZLSCP,ZDCP,ZMCP,ZOYP,VRN1,VRN2,VRN3,VRAN1,VRAN2,VRAN3,
CTXL11,TXL12,TXL13,TXL21,TXL22,TXL23,TXL31,TXL32,TXL33,VRS1,VRS2,
CVRS3,VRAS1,VRAS2,VRAS3,VRD1,VRD2,VRD3,VRAD1,VRAD2,VRAD3,VRTN,VRTS,
CVRTD,VRMA,FCST1,FCST2,FCST3,CST11,CST21,CST31,CST41,CST51,CST12,
CCST22,CST32,CST42,CST52,CST13,CST23,CST33,CST43,CST53,FU1,FU2,FU3,
      CFUPR,ZMIS1,ZMIS2,ZMIS3,CRS1,CRS2,CRS3,CPS1,CPS2,CPS3,TCSTN1,
      CTCSTN2,TCSTN3,TCSTS1,TCSTS2,TCSTS3,TCSTD1,TCSTD2,TCSTD3,ERNN1,
CERNN2,ERNN3,ERNS1,ERNS2,ERNS3,ERND1,ERND2,ERND3,ERNNT,ERNST,ERNDT,
      CTMAERN,MGMT,SCP,CST61,CST62,CST63,EXFLR,
      CAERNN1,AERNN2,AERNN3,AERNS1,AERNS2,AERNS3,AERND1,AERND2,AERND3
COMMON/PRET/WSCST,SFCST,PRCST,BUP,PLBS,SHCST,TRNS,PAT,XLAB,ELEC,
      CFULD,PROP,PKG,DEPR,REPR,ZOVH,ZINS,ZLEGL,STRG,CHEM,TTRNS,TPAT,
CTXLAB,TELEC,TFULD,TPROP,TPKG,TDEPR,TZOVH,TZINS,TZLEGL,TSTRG,TCHEM,
      CTPROC,PFLR,TREV1,TREV2,TREV3,TREV4,TREV5,WPR1,WPR2,WPR3,WPR4,
      CWPR5,TREPR
       COMMON/ENEX/XMVAL1,XMVAL2,XMVAL3,ARATE1,ARATE2,ARATE3,VINC1,
      CVINC2,VINC3,VDEC1,VDEC2,VDEC3
COMMON/EFRT/EHRS1,EHRS2,EHRS3,WUTIL1,WUTIL2,WUTIL3,SUTIL1,SUTIL2,
      CSUTIL3
COMMON/QUOT/RHRS1,RHRS2,RHRS3,QUOTA1,QUOTA2,QUOTA3,SEHRT1,SEHRT2,
      CSEHRT3,SEHRT4,QUOTA4,QUOTA
       COMMON/SWTCH/SWTCH1,SWTCH2,SWTCH3,RCVTM1,RCVTM2,RCVTM3
COMMON/YRLY/AED11,AED12,AED13,AED21,AED22,AED23,AED31,AED32,AED33,
      CAEDMA1,AEDMA2,AEDMA3,ANLBT1,ANLBT2,ANLBT3,ASLBT1,ASLBT2,ASLBT3,
```

```
     CADLBT1,ADLBT2,ADLBT3,AMALB1,AMALB2,AMALB3,YERNN1,YERNN2,YERNN3,
     CYERNS1,YERNS2,YERNS3,YERND1,YERND2,YERND3,ATWTN6,ATWTS6,ATWTD6,
     CAXNCD6,AXSCD6,AXDCD6,ABUN,ABUS,ABUD,APLBS,APROC,
     CASHCST,ATRNS,APAT,AXLAB,AELEC,AFULC,APROP,APKG,ADEPR,ACVH,AINS,
     CALEGL,ASTRG,ACHEM,AWPR1,AWPR2,AWPR3,AWPR4,AWPR5
C
C
      WRITE(7,10) IYRS
      WRITE(1,10) IYRS
10    FORMAT('1','ANNUAL SUMMARY FOR END OF YEAR',1X,I1)
      WRITE(7,11)
      WRITE(1,11)
11    FORMAT('0','FISHING SECTOR SUMMARY')
      WRITE(7,12)
      WRITE(1,12)
12    FORMAT(1X,'REGION'22X,'NNJ',12X,'SNJ',7X,'DELMARVA',3X,'MID
ATLANT
     CIC')
      TT1=V11+V21+V31
      WRITE(7,13) V11,V21,V31,TT1
      WRITE(1,13) V11,V21,V31,TT1
13    FORMAT(1X,'CLASS I
VESSELS',12X,F4.0,11X,F4.0,11X,F4.0,11X,F4.0)
      WRITE(7,14) AED11,AED21,AED31
      WRITE(1,14) AED11,AED21,AED31
14    FORMAT(1X,1X,'EFFORT DAYS',13X,F6.2,9X,F6.2,9X,F6.2)
      TT3=ANLBT1+ASLBT1+ADLBT1
      WRITE(7,15) ANLBT1,ASLBT1,ADLBT1,TT3
      WRITE(1,15) ANLBT1,ASLBT1,ADLBT1,TT3
15    FORMAT(1X,1X,'TOTAL HARVEST (LBS)',1X,G14.7,T38,G14.7,T53,
     CG14.7,T67,G14.7)
      TT4=ANLBT1/17.0
      TT5=ASLBT1/17.0
      TT6=ADLBT1/17.0
      TT7=TT3/17.0
      WRITE(7,16) TT4,TT5,TT6,TT7
      WRITE(1,16) TT4,TT5,TT6,TT7
16    FORMAT(1X,1X,'TOTAL HARVEST (BU)',2X,G14.7,T38,G14.7,T53,
     CG14.7,T67,G14.7)
      WRITE(7,17)
      WRITE(1,17)
17    FORMAT(1X,1X,'TOTAL FLEET')
      TT8=YERNN1+YERNS1+YERND1
      WRITE(7,18) YERNN1,YERNS1,YERND1,TT8
      WRITE(1,18) YERNN1,YERNS1,YERND1,TT8
18    FORMAT(1X,1X,'PROFITS ($)',9X,G14.7,T38,G14.7,T53,
     CG14.7,T67,G14.7)
      TT9=V12+V22+V32
      WRITE(7,19) V12,V22,V32,TT9
      WRITE(1,19) V12,V22,V32,TT9
19    FORMAT(1X,'CLASS II
VESSELS',11X,F4.0,11X,F4.0,11X,F4.0,11X,F4.0)
      WRITE(7,14)AED12,AED22,AED32
      WRITE(1,14) AED12,AED22,AED32
```

```
      TT11=ANLBT2+ASLBT2+ADLBT2
      WRITE(7,15) ANLBT2,ASLBT2,ADLBT2,TT11
      WRITE(1,15) ANLBT2,ASLBT2,ADLBT2,TT11
      TT12=ANLBT2/17.0
      TT13=ASLBT2/17.0
      TT14=ADLBT2/17.0
      TT15=TT11/17.0
      WRITE(7,16)TT12,TT13,TT14,TT15
      WRITE(1,16) TT12,TT13,TT14,TT15
      WRITE(7,17)
      WRITE(1,17)
      TT16=YERNN2+YERNS2+YERND2
      WRITE(7,18) YERNN2,YERNS2,YERND2,TT16
      WRITE(1,18) YERNN2,YERNS2,YERND2,TT16
      TT17=V13+V23+V33
      WRITE(7,20) V13,V23,V33,TT17
      WRITE(1,20) V13,V23,V33,TT17
20    FORMAT(1X,'CLASS III
VESSELS',10X,F4.0,11X,F4.0,11X,F4.0,11X,F4.0)
      WRITE(7,14)AED13,AED23,AED33
      WRITE(1,14) AED13,AED23,AED33
      TT19=ANLBT3+ASLBT3+ADLBT3
      WRITE(7,15) ANLBT3,ASLBT3,ADLBT3,TT19
      WRITE(1,15) ANLBT3,ASLBT3,ADLBT3,TT19
      TT20=ANLBT3/17.0
      TT21=ASLBT3/17.0
      TT22=ADLBT3/17.0
      TT23=TT19/17.0
      WRITE(7,16) TT20,TT21,TT22,TT23
      WRITE(1,16) TT20,TT21,TT22,TT23
      TT24=YERNN3+YERNS3+YERND3
      WRITE(7,17)
      WRITE(1,17)
      WRITE(7,18) YERNN3,YERNS3,YERND3,TT24
      WRITE(1,18) YERNN3,YERNS3,YERND3,TT24
      WRITE(7,21)
      WRITE(1,21)
21    FORMAT('0','TOTAL MID ATLANTIC STATISTICS')
      TT25=TT1+TT9+TT17
      WRITE(7,23) TT25
      WRITE(1,23) TT25
23    FORMAT(1X,1X,'NUMBER OF VESSELS',T33,F5.0)
      TT27=AMALB1+AMALB2+AMALB3
      WRITE(7,25) TT27
      WRITE(1,25) TT27
25    FORMAT(1X,1X,'TOTAL HARVEST (LBS)',T33,G14.7)
      TT28=TT23+TT15+TT7
      WRITE(7,26) TT28
      WRITE(1,26) TT28
26    FORMAT(1X,1X,'TOTAL HARVEST (BU)',T33,G14.7)
      TT29=TT8+TT16+TT24
      WRITE(7,17)
      WRITE(1,17)
      WRITE(7,27) TT29
```

```
      WRITE(1,27) TT29
27    FORMAT(1X,1X,'PROFITS ($)',T33,G14.7)
      WRITE(7,28)
      WRITE(1,28)
28    FORMAT('0','BIOLOGICAL SUMMARY')
      WRITE(7,29)
      WRITE(1,29)
29    FORMAT(1X,23X,'INDIVIDUALS',11X,'POUNDS')
      WRITE(7,30) TNPOP,TNWT
      WRITE(1,30) TNPOP,TNWT
30    FORMAT(1X,2X,'NORTHERN JERSEY',3X,G14.7,3X,G14.7)
      WRITE(7,31) XNCO1,TWTN1
      WRITE(1,31) XNCO1,TWTN1
31    FORMAT(1X,3X,'COHORT 1',9X,G14.7,3X,G14.7)
      WRITE(7,32) XNCO2,TWTN2
      WRITE(1,32) XNCO2,TWTN2
32    FORMAT(1X,3X,'COHORT 2',9X,G14.7,3X,G14.7)
      WRITE(7,33) XNCO3,TWTN3
      WRITE(1,33) XNCO3,TWTN3
33    FORMAT(1X,3X,'COHORT 3',9X,G14.7,3X,G14.7)
      WRITE(7,34) XNCO4,TWTN4
      WRITE(1,34) XNCO4,TWTN4
34    FORMAT(1X,3X,'COHORT 4',9X,G14.7,3X,G14.7)
      WRITE(7,35) XNCO5,TWTN5
      WRITE(1,35) XNCO5,TWTN5
35    FORMAT(1X,3X,'COHORT 5',9X,G14.7,3X,G14.7)
      WRITE(7,36) XNCO6,TWTN6
      WRITE(1,36) XNCO6,TWTN6
36    FORMAT(1X,3X,'COHORT 6',9X,G14.7,3X,G14.7)
      WRITE(7,37) TSPOP,TSWT
      WRITE(1,37) TSPOP,TSWT
37    FORMAT(1X,2X,'SOUTHERN JERSEY',3X,G14.7,3X,G14.7)
      WRITE(7,31) SCO1,TWTS1
      WRITE(1,31) SCO1,TWTS1
      WRITE(7,32) SCO2,TWTS2
      WRITE(1,32) SCO2,TWTS2
      WRITE(7,33) SCO3,TWTS3
      WRITE(1,33) SCO3,TWTS3
      WRITE(7,34) SCO4,TWTS4
      WRITE(1,34) SCO4,TWTS4
      WRITE(7,35) SCO5,TWTS5
      WRITE(1,35) SCO5,TWTS5
      WRITE(7,36) SCO6,TWTS6
      WRITE(1,36) SCO6,TWTS6
      WRITE(7,38) TDPOP, TDWT
      WRITE(1,38) TDPOP,TDWT
38    FORMAT(1X,2X,'DELMARVA',10X,G14.7,3X,G14.7)
      WRITE(7,31) DCO1,TWTD1
      WRITE(1,31) DCO1,TWTD1
      WRITE(7,32) DCO2,TWTD2
      WRITE(1,32) DCO2,TWTD2
      WRITE(7,33) DCO3,TWTD3
      WRITE(1,33) DCO3,TWTD3
      WRITE(7,34) DCO4,TWTD4
```

```
      WRITE(1,34) DCD4,TWTD4
      WRITE(7,35) DCD5,TWTD5
      WRITE(1,35) DCD5,TWTD5
      WRITE(7,36) DCD6,TWTD6
      WRITE(1,36) DCD6,TWTD6
      WRITE(7,39) TMPOP,TMWT
      WRITE(1,39) TMPOP,TMWT
39    FORMAT(1X,2X,'MID ATLANTIC',6X,G14.7,3X,G14.7)
      TMCD1=XNCD1+SCD1+DCD1
      TMCD2=XNCD2+SCD2+DCD2
      TMCD3=XNCD3+SCD3+DCD3
      TMCD4=XNCD4+SCD4+DCD4
      TMCD5=XNCD5+SCD5+DCD5
      TMCD6=XNCD6+SCD6+DCD6
      TMWT1=TWTN1+TWTS1+TWTD1
      TMWT2=TWTN2+TWTS2+TWTD2
      TMWT3=TWTN3+TWTS3+TWTD3
      TMWT4=TWTN4+TWTS4+TWTD4
      TMWT5=TWTN5+TWTS5+TWTD5
      TMWT6=TWTN6+TWTS6+TWTD6
      WRITE(7,31) TMCD1,TMWT1
      WRITE(1,31) TMCD1,TMWT1
      WRITE(7,32) TMCD2,TMWT2
      WRITE(1,32) TMCD2,TMWT2
      WRITE(7,33) TMCD3,TMWT3
      WRITE(1,33) TMCD3,TMWT3
      WRITE(7,63) TMCD4,TMWT4
      WRITE(1,63) TMCD4,TMWT4
      WRITE(7,35) TMCD5,TMWT5
      WRITE(1,35) TMCD5,TMWT5
      WRITE(7,36) TMCD6,TMWT6
      WRITE(1,36) TMCD6,TMWT6
      WRITE(7,40)
      WRITE(1,40)
40    FORMAT('0','PROCESSING SECTOR SUMMARY')
      WRITE(7,41) APROC
      WRITE(1,41) APROC
41    FORMAT(1X,2X,'TOTAL PROCESSING COSTS FOR MID ATLANTIC
($)',2X,G14.
     C7)
      WRITE(7,42) ASHCST
      WRITE(1,42) ASHCST
42    FORMAT(1X,4X,'SHELL-STOCK COSTS',3X,G14.7)
      WRITE(7,43) ATRNS
      WRITE(1,43) ATRNS
43    FORMAT(1X,4X,'TRANSPORTATION',6X,G14.7)
      WRITE(7,44) APAT
      WRITE(1,44) APAT
44    FORMAT(1X,4X,'PATENTS',13X,G14.7)
      WRITE(7,45) AXLAB
      WRITE(1,45) AXLAB
45    FORMAT(1X,4X,'LABOR',15X,G14.7)
      WRITE(7,46) AELEC
      WRITE(1,46) AELEC
```

```
46      FORMAT(1X,4X,'ELECTRICITY',9X,G14.7)
        WRITE(7,47) AFULO
        WRITE(1,47) AFULO
47      FORMAT(1X,4X,'FUEL OIL',12X,G14.7)
        WRITE(7,48) APROP
        WRITE(1,48) APROP
48      FORMAT(1X,4X,'PROPANE',13X,G14.7)
        WRITE(7,49) APKG
        WRITE(1,49) APKG
49      FORMAT(1X,4X,'PACKAGING',11X,G14.7)
        WRITE(7,50) ADEPR
        WRITE(1,50) ADEPR
50      FORMAT(1X,4X,'DEPRECIATION',8X,G14.7)
        WRITE(7,51) AOVH
        WRITE(1,51) AOVH
51      FORMAT(1X,4X,'OVERHEAD',12X,G14.7)
        WRITE(7,52) AINS
        WRITE(1,52) AINS
52      FORMAT(1X,4X,'INSURANCE',11X,G14.7)
        WRITE(7,53) ALEGL
        WRITE(1,53) ALEGL
53      FORMAT(1X,4X,'LEGAL-ACCOUNTING',4X,G14.7)
        WRITE(7,54) ASTRG
        WRITE(1,54) ASTRG
54      FORMAT(1X,4X,'STORAGE',13X,G14.7)
        WRITE(7,55) ACHEM
        WRITE(1,55) ACHEM
55      FORMAT(1X,4X,'CHEMICALS',11X,G14.7)
        APP=AMALB1+AMALB2+AMALB3
        ABP=APP/17.0
        WRITE(7,56) ABP
        WRITE(1,56) ABP
56      FORMAT(1X,2X,'BUSHELS PROCESSED',5X,G14.7)
        WRITE(1,57) APLBS
        WRITE(7,57) APLBS
57      FORMAT(1X,2X,'LBS OF MEAT PRODUCED',2X,G14.7)
        WRITE(7,58) AWPR1
        WRITE(1,58) AWPR1
58      FORMAT('0',2X,'BREAK EVEN WHOLESALE PRICE PER POUND
($)',3X,F7.2)
        WRITE(7,59) AWPR2
        WRITE(1,59) AWPR2
59      FORMAT(1X,2X,'WHOLESALE PRICE AT 5% RETURN ($)',11X,F7.2)
        WRITE(7,60) AWPR3
        WRITE(1,60) AWPR3
60      FORMAT(1X,2X,'WHOLESALE PRICE AT 10% RETURN ($)',10X,F7.2)
        WRITE(7,61) AWPR4
        WRITE(1,61) AWPR4
61      FORMAT(1X,2X,'WHOLESALE PRICE AT 15% RETURN ($)',10X,F7.2)
        WRITE(7,62) AWPR5
        WRITE(1,62) AWPR5
62      FORMAT(1X,2X,'WHOLESALE PRICE AT 20% RETURN ($)',10X,F7.2)
63        FORMAT('1',3X,'COHORT 4',9X,G14.7,3X,G14.7)
C
```

```
RETURN
END
```

Appendix B

This appendix contains the survey questionnaires distributed to surf clam fishermen and processors. Longer questionnaires not included in this appendix were used for selected interviews and distribution.

CHARTERED 1693
COLLEGE OF WILLIAM AND MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

Gloucester Point, Virginia [illegible]
Phone (804) 642-2111

Dear Sir:

A research project is currently in progress at the Virginia Institute of Marine Science to gather important information about the surf clam/ocean quahog fishing and processing industry. The purpose of this study is to examine the economic health of the industry, and to understand whether different fishery management approaches could improve the economic return to clam fishermen and processors.

I am conducting the study through personal confidential interviews and written responses to a confidential survey. I ask that you take a small amount of time to complete the enclosed questionnaire and return it to me in the enclosed envelope. This is your chance to provide valuable information that will give resource managers a better understanding of your economic problems and priorities.

The results of the study will be made available to you and to the Mid-Atlantic Fisheries Management Council. Summarizing statistics will be used in the final report, thereby maintaining the confidentiality of all information collected from individual participants in the study.

If you have any questions regarding this survey or the study, please call me at the Virginia Institute of Marine Science (804)-642-2111, extension 196. Full participation in the study is extremely important. Please assist me by completing and returning the brief questionnaire enclosed. Thank you very much.

Sincerely,

Thomas M. Armitage

CONFIDENTIAL

Virginia Institute of Marine Science

SURVEY OF SURF CLAM/OCEAN QUAHOG FISHING INDUSTRY

I. OWNER/OPERATOR INFORMATION

1. How many surf clam or ocean quahog fishing vessels do you currently own? (if vessels are company owned indicate how many)

2. Are you a captain of any of these vessels?

3. What were your home ports during the 1981 season?

4. If you have worked out of any other ports during the past 10 years, please indicate the port and the year you worked there.

II. BUSINESS STRUCTURE

1. Is your business a(n) individual proprietorship____ Partnership__ Corporation____. If a corporation please indicate how many stockholders____.

2. Please describe the employees involved in your fishing operation.

	Number	% share or salary per year or salary/ trip
Crew	____	____
Skipper	____	____
(note captain's bonus if any)		
Office help	____	____
Other (describe)		
____	____	____
____	____	____
____	____	____
____	____	____
____	____	____
____	____	____

3. Other employee benefits paid.
Health insurance____% Unemployment tax____% Other____%

4. Please estimate your total labor costs (wages/year or wages/trip):

Currently 1981 1979 1977 1975 1973 1971

III. <u>VESSEL CHARACTERISTICS</u>
For each of your vessels, please identify the characteristics listed on the following table.

VESSEL #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Length															
Displacement															
Fuel Capacity															
Cruising Range															
Age															
Draft															
Hull Material															
Max. Load Capacity															
<u>Engine</u>															
Rated H.P.															
Type															
Age															
Year Last Rebuilt															
<u>Gear</u>															
# of Dredges															
Blade Widths															
<u>Navigation Equipment</u> Indicate if boat has:															
Radar															
Fathometer															
Ship to shore Radio															
Loran A or C															
Please specify other equipment															

VESSEL #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Other Info.															
Present Market Value of Boat															
Cost of New Engine															
Engine Life With Overhauls															
How Many Overhauls															
Average Cost per Overhaul															
Number of Crew Members															
1981 Cost of Vessel Insurance															
1981 Cost of Vessel Repair and Maintenance															
1981 Taxes Paid on Vessel															
Average # of Gallons of Fuel Required per Trip															
1981 Cost of Food per Trip															
1981 Cost of Supplies per Trip															
Auxillary Engine Horsepower															
Pump Power															
Maximum Dredge Depth															

2. Approximately how much have you invested in navigation equipment?

3. What would this equipment cost new?

4. How long do you expect to use this equipment?

IV. ECONOMIC INFORMATION

1. Please estimate the current cost per trip of the following items, and if they have changed indicate what these costs were in the previous years listed.

a) Fuel and Oil
Currently 1981 1979 1977 1975 1973 1971

b) Please list and estimate any other costs of fishing trips for the years indicated below
Cost Currently 1981 1979 1977 1975 1973 1971

2. Please estimate the current cost per year of the following items, and if they have changed indicate what these costs were in the previous years listed.

a) Boat Repair and Maintenance
Currently 1981 1979 1977 1975 1973 1971

b) Port Fees
Currently 1981 1979 1977 1975 1973 1971

c) Loan Payments
Currently 1981 1979 1977 1975 1973 1971

d) Legal-Accounting Fees
Currently 1981 1979 1977 1975 1973 1971

3. How much would it cost to replace your fishing gear?

	Replacement Cost	Years of Usefulness
Clam Dredges		
Pumps		
Other Gear (please list)		

4. What was your total gross revenue from fishing operations for the following years?
Current year to date 1981 1979 1977 1975 1973 1971

5. What was your net income from fishing operations for the following years?
Current year to date 1981 1979 1977 1975 1973 1971

6. What percentage of your catch is surf clams, and what percentage is ocean quahogs?
Currently 1981 1979 1977 1975 1973 1971

Surf Clam
Ocean Quahog

CONFIDENTIAL

Virginia Institute of Marine Science

SURVEY OF CLAM PROCESSING INDUSTRY

I. SUPPLY SOURCES AND PROCESSING ACTIVITY

A. Products

1. List the seafood species that you process (surf clam, ocean quahog, other fish and shellfish)

2. Please estimate the percentage of raw product that each species has contributed to your business in each of the following years:

Species	Currently	1981	1979	1977	1975	1973	1971

3. What percentage of your clams do you obtain from independent fishermen?

Species	Currently	1981	1979	1977	1975	1973	1971

4. What percentage of your clams do you obtain from other processors or shucking houses?

Species	Currently	1981	1979	1977	1975	1973	1971

5. How many days per week are clams or other raw product delivered to your plant?

surf clams______ ocean quahogs_____ other (specify) ________

B. Facilities

1. Do you own boats? If yes, how many did you own in each of the following years?

Currently	1981	1979	1977	1975	1973	1971

C. Price Paid

1. Do you pay a price differential for different size surf clams? If yes, what is the differential and why do you pay it (processing cost, products produced, etc.)

2. How do you determine what you will pay for raw product? What factors are involved? Who sets prices?

3. What are the average prices that you must pay for the different sizes of surf clams and ocean quahogs?

Surf clam	Currently	1981	1979	1977	1975	1973	1971
Medium							
Large							
Ocean quahog							

D. Processing

Please indicate the types of processed products you sell (i.e. raw shucked, raw cooked, frozen breaded, canned, chowder, etc.) and estimate the quantity and dollars sold of each in 1981.

Type product	1981 Quantity	1981 dollars sold

2. What is the total number of people employed in your clam processing operation?

Total employees	Currently	1981	1979	1977	1975	1973	1971
Salaried							
Hourly							
Piece Work							

3. What is the current average wage you must pay salaried workers and piece work employees (for piece work indicate rate per amount produced)?

4. How do you dispose of shell, belly, or other waste products?

5. How do you treat your waste water? How do you dispose of it? Please estimate the added cost that this requires.

6. Please try to estimate the amount of fresh water you use per day of operation.
   Fresh water use per day__________
   Bushels of clams processed per day__________ or pounds_______
   Pounds of finished product processed per day__________

7. Do you obtain water from a well or purchase it from a municipality?

8. Please describe the water use quotes with which you must comply.

9. Do these quotas ever present a problem for you? Explain.

10. The following costs have been identified as major costs for a clam processing operation. Please try to estimate the percentage that each contributes to your total cost of operation, and also estimate each cost in cents per pound of clam meat processed. If you have additional costs, or use alternative cost categories, please add them at the end of the list.

	% of Total Cost	Cost per pound of surf clam meat processed	Cost per pound of quahog mea (if different)
Raw Product			
Transportation - in			
Machinery to remove belly, or other royalties			
Labor			
Payroll tax			
Salt or other chemicals			
Fuel (diesel)			
Other fuel			
Propane for shucking machines or forklifts			
Packaging			
Electricity			
Depreciation			
Repair & Maintenance			
Freight - out			
Overhead			
Insurance			
Other (specify)			
________			
________			
________			
________			

11. Please estimate the total cost ($/lb.) of processing a pound of clam meat.
Total cost for quahogs ___________
Total cost for surf clams _________

II. GROWTH

1. What is the plant capacity (lbs/day) of your processing operation?

2. How many shifts do you work per day (specify the number of cleaning and processing shifts)

3. What are the limiting factors that impede your clam processing operation from running at full capacity?

4. What do you consider to be the most serious problem(s) presently confronting the clam processing industry?

5. What are your feelings about the management plan for surf clams and ocean quahogs? (has it hurt you, what are its weaknesses, how would you improve the plan)

6. Which seafood products do you feel represent the greatest competition in the marketplace for your products?

7. Are you a sole entity, subsidiary, or parent corporation?
If subsidiary, of whom?
If parent, of whom?

8. Do you attempt to maintain price at a percentage markup or margin over cost?
________% or _______dollars

VITA

Thomas M. Armitage

Born in Chester, Pennsylvania, January 13, 1952. Graduated from Penncrest High School in Lima, Pennsylvania, June 1970. Received B.A. in biology from the University of Pennsylvania, Philadelphia, Pa. in 1974; M.B.A. from Temple University, Philadelphia, Pa. in 1977; and M.S. in marine biology from the Florida Institute of Technology, Melbourne Florida, in 1979.

Entered the School of Marine Science as a graduate research assistant in 1979. Awarded Sea Grant Fellowship to serve as fisheries advisor on staff of U.S. Senator Ted Stevens (Alaska), 1984-1985. Currently employed as a staff scientist, Ecological Effects Branch, U.S. Environmental Protection Agency, Washington, D.C.