THE QUEEN CONCH FISHERY OF BELIZE: AN ASSESSMENT OF THE RESOURCE, HARVEST SECTOR AND MANAGEMENT

By

SUSAN ANNE STRASDINE

B.Sc., The University of British Columbia, 1980

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES
(Interdisciplinary Studies, Resource Management Science)

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA
January 1988

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Department of Resource Management Science

The University of British Columbia
1956 Main Mall
Vancouver, Canada
V6T 1Y3

Date January 25, 1988

ABSTRACT

The primary goal of this study was to evaluate potential management options for the conch (Strombus gigas) fishery of Belize based on biological analyses of the present fishery. The specific objectives were to: 1) assess the condition of the stock; 2) estimate the possible yield of the resource; and 3) recommend viable alternatives for management. Information on population dynamics of Strombus gigas was obtained largely from the literature. A yield-per-recruit analysis was conducted to gain an understanding of how changes in the age of entry into the fishery and mortality and growth rates effect yield. Historical records on landings and fishing effort obtained from the fishing cooperatives were analyzed to assess the state of the stock. Landings-per-unit-effort was calculated in a manner unique to the quantity and quality of data available. The structure of the current management system, operations of the fishing cooperatives and routines of fishermen were also considered in the final evaluation of viable management options.

Conch was first exported by Belize around 1950 but the fishery remained small until 1967. Exports then climbed dramatically from 174,000 kg in 1967 to 562,634 kg in 1972. During the remainder of the 1970's, production declined due to a decline in stock biomass and subsequently, effort. Typical of all exploited populations, biomass decreased as the abundance of older adults declined and the size distribution of the catch shifted toward smaller individuals. The modification of harvest

rate thereafter is believed to be an operational response of the fleet to a mixed species resource. As the relative abundance, market value and distribution of lobster, conch and scale fish change, fishermen alter their harvesting strategy in order to maximize their economic returns per trip.

By the 1980's, the conch fishery was essentially seasonal with roughly one third of the year's total production being delivered within the first month (October) of the nine season. Size limits and a closed season were implemented in 1978 and the size of meats landed at the fishing cooperatives increased from an average of 66 gm in 1976 to 131 gm in 1985. Fishing effort for conch rose from 1980 to 1984 due to an increase in the absolute number of conch divers and remained high in 1985 and 1986. Landings per man-day (md) varied little between 1978 and 1984; average landings-per-unit-effort (LPUE) over this period (15.0 kg/md) was one third the LPUE of the late 1960's. However, in 1985 and 1986 LPUE dropped dramatically; a consequence most likely of recruitment variability and/or growth overfishing in intensely fished areas.

The current minimum limit on shell length (17.8 cm) is less than the predicted size of first capture at which yield-per-recruit is maximized (i.e., 21.7 cm shell length; 113 gm marketed meat weight). Present regulations also allow fishermen to harvest conch before they are capable of reproducing. It is recommended that more stringent measures be taken to reduce the possibility of recruitment overfishing until a more thorough assessment of the resource can be made. Improvements regarding the collection of data necessary for stock assessment are suggested.

The management options considered most appropriate for the conch fishery of Belize at present include, in order of importance: size limits, season closures and gear restrictions. A regulation prohibiting the harvest of nonlipped individuals would be most effective in protecting the breeding population. However, this measure is difficult to enforce because conch are cleaned at sea. Hence, a minimum size restriction on market-cleaned meats corresponding to the average meat yield of adults (120 gm; 4.2 oz) is suggested as well. Maintaining the current 3-month closed season and prohibition on harvesting using SCUBA offers additional protection in that these restrictions reduce the chances that fishermen will harvest spawning adults and adults which have migrated into deep-water refuges.

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ACKNOWLEDGEMENTS

Of the many Belizeans to whom thanks are due, I gratefully acknowledge the aid of the fishermen and the entire staff of the Belize Fisheries Department, the Cooperatives and Credit Unions Department, the fishing cooperatives and the Belize Fishermen Cooperatives Association. Special gratitude goes to Mr. Winston Miller, Mr. Norman Augustine, Mr. Robert Usher and Mr. Raymond Bradley.

The advice and support of my academic advisor, Dr. N. J. Wilimovsky, is greatly appreciated. The constructive comments made by Dr. R. Appeldoorn on earlier drafts of the manuscript and time devoted by my tutors in computer programing, Don Robinson and Barry Smith are also acknowledged. I owe sincere thanks to Philippe Barois for his encouragement, editing and fine cartography, and to Dr. W. H. L. Allsopp and Dr. G. Jamieson for their guidance from the very beginning, when this study was merely a dream.

Financial support for this study was received from the International Development Research Centre of Canada in the form of a Post Project Award for which I am most grateful.

CHAPTER ONE

Introduction

1.1 The Setting

Belize, formerly known as British Honduras, is positioned between the Caribbean Sea along its eastern coast, Mexico on the north and Guatemala to the west and south (Figure 1.1). It has been an independent nation since September 21, 1981 and is now a member of the British Commonwealth and the United Nations. The country has an area of nearly 23,000 square km (i.e., slightly larger than the State of Massachusetts) and its estimated population was 161,500 in 1984 (Government of Belize, 1985a). Creoles, an ethnic group of African origin, account for half of the population. The remainder is made up of Mayan Indians, Mestizos (Spanish-Maya), Garifunas (Afro-Carib) and peoples of European, East Indian and Asian descent (Belize Ministry of Education, 1984).

The land in the north of Belize is low and flat, but in the south-west there is a heavily forested mountain massif with a general elevation of between 600 m and 900 m. The coastal areas are low and swampy, and the mangrove coastline is sculptured by many salt and fresh water lagoons and some sandy beaches. The Belize continental shelf is approximately 250 km long and 15 to 50 km wide (Purdy *et al.*, 1975). It consists of a seaward reef-caye complex and a shoreward lagoon system. The barrier reef occurring along the seaward edge is said to be the largest

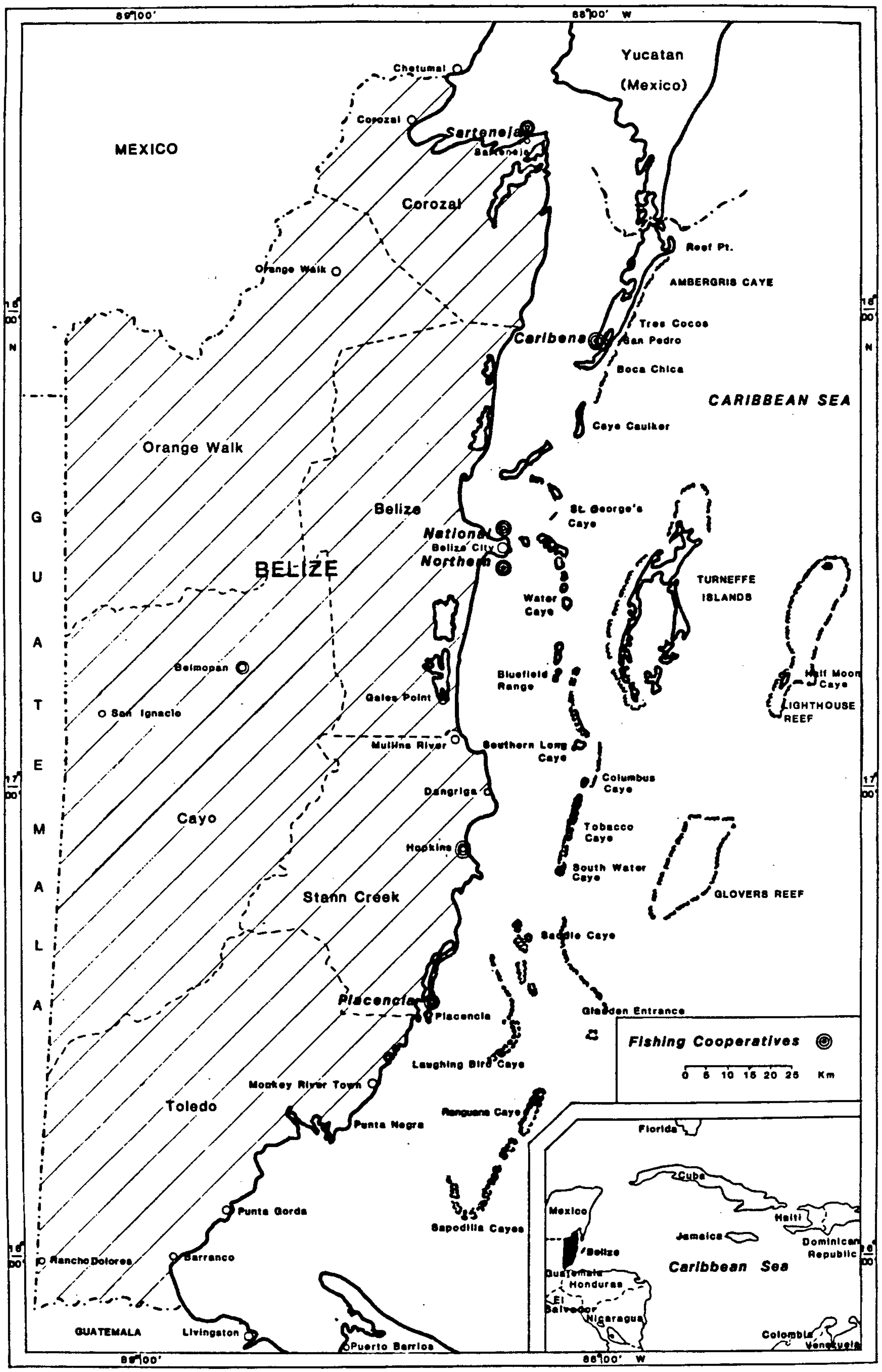


Figure 1.1 Map of Belize

continuous barrier reef in the West Indies (Smith, 1948). Outside the barrier reef there are three atolls: the Turneffe Islands, Glover's Reef and Lighthouse Reef.

The climate in Belize is tropical, tempered by north-easterly trade winds which blow consistently through the spring and summer. Temperatures in coastal districts may reach 35.6 degrees C in the hotter months of May through August. Between November and February there are cold spells lasting for three to four days during which the temperatures may fall to 10 degrees C. There are sharp annual variations of rainfall, but the average is generally around 190 cm in the north and 430 cm in the south. Hurricane season extends from June to November. The country has experienced four hurricanes in the past thirty years: one in 1961 (H. Hattie), two smaller hurricanes in 1974 and the most recent in September of 1978 (H. Greta).

The economy of Belize is predominantly agricultural with a narrow range of agricultural exports and a recurrent trade deficit. There is little industrialization and high unemployment. In 1984, the Gross Domestic Product (GDP) was estimated to be $365 million BZ at current prices and $2,260 BZ per capita ($1.00 BZ = $0.50 U.S.; United Nations, 1986a). Agriculture currently provides some 65% of the country's total foreign exchange earnings and employs around 30% of the labour force. The main export crops, in order of importance, are sugar, citrus and bananas. Maize, beans and rice are the main food crops cultivated and livestock production is on the increase.

Forest products were historically the country's most important export, but their relative importance has fallen.

Fish products are the fourth most valuable export items after sugar, garments and citrus (Table 1.1). They accounted for 7.3% of total domestic exports in 1984. The most important commodities are spiny lobster, conch (a gastropod), shrimp and "scale" fish (the latter is a colloquial term used by Belizeans to describe fin fish with scales). Fishing is centralized largely through fishermen-owned production and marketing cooperatives. The industry as a whole employs about 1200 full-time fishermen, 500 part-time fishermen, 200 fishing cooperative employees and many others in the services sector. Fish consumption per capita, although higher in coastal cities (22.7 kg/annum), is low in the country as a whole (Rabb and Adams, 1983). If the weight of fish products sold locally by the cooperatives in 1984 was doubled to account for unreported sales, estimated consumption for that year would be roughly two kg per person (304740 kg/161500 people). The natural resources of Belize and their importance to the country's economic development are reviewed by Setzekorn (1975), Perkins (1983), the Belize Ministry of Education (1984) and Bolland (1986).

National policies governing fisheries development in Belize are geared toward four goals (Government of Belize, 1983a):

"1) To investigate and establish as far as possible the state of the fish habitats, fish population and fishery resources of Belize and to restore where necessary, monitor and rationally utilize all of the fish resources of the country;

Table 1.1

Belize: Key economic indicators
(Money values in million $BZ)

	1981	1982	1983	1984
TRADE ACCOUNTS:				
Gross Imports	323.9	256.0	223.6	252.1
Gross Exports	238.0	182.0	155.5	191.7
Balance of Trade	-85.9	-74.0	-68.1	-60.4
Re-Exports	88.5	62.4	25.2	41.4
Domestic Exports	149.5	119.6	130.3	150.6
Retained Imports	235.3	193.6	198.4	211.0
EXPORTS:				
Sugar	85.3	65.7	68.3	78.4
Garments	22.1	12.7	16.8	29.9
Citrus Products	13.0	14.1	13.7	18.9
Fish Products*	13.4	12.3	13.9	13.3
Bananas	4.3	4.2	4.8	5.4
Molasses	2.4	1.8	1.9	3.4
Timber	2.6	3.8	2.7	2.1
Honey	0.5	0.3	0.4	0.5

Modified after Government of Belize, 1985a (Table 1).

* Value of fish exports as reported by the Fisheries Dept.

2) To improve processing and marketing capabilities within the fishing industry thereby increasing the supply of wholesome seafood products for both local and export markets;

3) To encourage the development of economically viable aquaculture industries; and

4) To improve and expand surveillance and enforcement capabilities in order to curtail the utilization of national resources by foreigners and the illegal exploitation and marketing by Belizeans."

This study is concerned with the first of the above national goals, and more specifically, the management of the queen conch (Strombus gigas) fishery. In terms of economic value, this fishery is the third most important in Belize. Conch exports accounted for roughly 10% of the total value of fish exports in 1986:

FISHERY EXPORTS, 1986

Commodity	Value ($ BZ)
Lobster	$9,372,048
Shrimp	$2,359,520
Conch	$1,436,850
Scale fish	
Whole fish	$852,198
Fillet	$273,190
Live shrimp (post larvae)	$39,341
SW Aquarium Fish	$32,700
Stone Crab Claws	$10,556
Dry Salted Fish	$6,606
TOTAL	$14,382,928

Source: Belize Fisheries Department

The conch resource is highly valued by the industry as a substitute source of income when the lobster season is closed and when the abundance of alternate species is low. The Government of Belize has been concerned about the state of the stock and the possibility of overfishing since conch were first exported to the United States on a large scale in 1967. Different management proposals have been considered but a proper assessment of the status of the fishery has not yet been made.

1.2 Previous Assessments of the Conch Resource

There have been three large research programs initiated in Belize to obtain the biological and statistical information needed to make recommendations regarding management of the resource. The first commenced in 1970 when the government considered implementing a quota system for conch. It involved the collection of fisheries statistics, tagging to determine the growth rate of conch and sampling to estimate the optimal meat yield/age ratio (Baird, 1971; Rosa, 1977). Results of this program are described in a FAO report by Baird (1973).

The second major research program was initiated in the mid-1970's following proposals to implement a closed season. Studies conducted dealt with: 1) growth; 2) morphometric development; 3) age at sexual maturity; 4) spawning and breeding periods and behavior; 5) environmental factors associated with periods of greatest sexual activity; and 6) population structure (Blakesley, 1976; Mitchell, 1976). A legal size limit and 3-month closed season were imposed soon after the results of these studies were summarized (Blakesley, 1977).

In 1980, the Fisheries Department launched another conch project with assistance from the International Development

Research Centre of Canada (IDRC). The objectives were to study the life history of the conch, to examine the biological basis for management and to explore the utilization of shells and the feasibility of conch mariculture (Gibson et al., 1983; Government of Belize, 1983b). A second phase of this project commenced in March of 1985, but little was accomplished during this extension. A genetic and demographic assessment of Strombus gigas fisheries was also initiated in Belize in 1985. This project, jointly funded by the Government of Belize and the United States Agency for International Development, led to the construction of a conch hatchery and research facility which is still in operation today. Results of studies conducted at the facility have not yet been published.

With the exception of Phase I of the IDRC study, the original data from the above studies are difficult to find. Some records were destroyed in the 1978 hurricane and others have simply been misplaced. Due to changing personnel and limited documentation in the past, those that can be located are difficult to interpret. Much of the data compiled were not evaluated and results were generally inconclusive. Some fisheries statistics were collected but no assessment of the stock was made and little feedback was provided on the adequacy of existing regulations. This study was undertaken to update what is known of the conch fishery in Belize and the resource on which it is based. In meeting the specific objectives stated below, this study also describes the nature of the fisheries management problem and the research needed to improve the quality of scientific advice available to managers.

1.3 Study Objectives and Thesis Outline

The primary goal of this study was to evaluate potential management options for the conch fishery of Belize based on biological analyses of the present fishery. To attain this goal, three objectives were proposed:

1) To assess the condition of the stock;
2) To estimate the potential yield of the resource; and
3) To recommend viable alternatives for management.

Information on population dynamics of Strombus gigas was obtained largely from the literature. A yield-per-recruit analysis was conducted to gain an understanding of how changes in the age of entry into the fishery, mortality and growth rates effect yield. Fisheries statistics obtained from the fishing cooperatives on landings and the number of active fishermen were analyzed and a means to assess stock status with the data available devised. The structure of current management system, operations of the fishing cooperatives and routines of fishermen were also considered in the final evaluation of potential management options.

This comprehensive review on the status of the fishery was undertaken as an interdisciplinary study. It incorporates information on the organization and development of the conch industry as well as that needed for biological assessments. The manuscript was written to address a wide audience. The thesis is divided as follows. Chapter Two outlines the various data sources and stock assessment techniques used in this study. Chapter Three concentrates on biological characteristics of the species and the dynamics of exploited conch populations. In Chapter Four, the state of development of Belize fisheries and fishing practices for conch are reviewed. An original analysis of historical landings and effort data to calculate an index of stock abundance and assess the present condition of the stock is presented in Chapter Five. The last chapter summarizes the institutional aspects of fisheries management in Belize. Management options considered viable for the conch fishery are evaluated and their requisite data reviewed. Modifications to the existing data collection system are also proposed.

CHAPTER TWO

Methodology

2.1 Sources of Information

Information on the conch fishery was obtained from four primary sources in Belize during a three-month visit to the country in the summer of 1985 (Appendix I):

1) Fisheries Department,
2) Cooperatives and Credit Unions Department,
3) Fishing Cooperative Societies, and
4) Belize Fishermen Cooperative Association (BFCA).

Four of the nine fishing cooperatives active in Belize export conch. These societies, and the cooperative that was active in Sarteneja until 1982, are the focus of this study. They are referred to in the text by the first part of their full title (Appendix I).

Literature was gathered from each of the above offices and government officials and executive secretaries of the cooperatives were interviewed. The 1985 Annual General Meeting of three of the fishing cooperatives was also attended. Morphometric and growth data used in this report were provided by the Fisheries Department; as a biologist of the Fisheries Department from 1981 to 1983, I was in charge of their collection (Strasdine, 1984). Methods used in the collection and analysis of these data are described in sections 2.2 and 2.3 of this chapter. Current data on landings-per-unit-effort and the size composition of landings were collected during a dockside survey conducted in June, 1985; sampling procedures are described in section 2.4. Section 2.5 pertains to the yield-per-recruit analysis and fisheries statistics collected from the above offices are outlined in section 2.6.

2.2 Morphometric Studies

Morphometric measurements were made of 204 conch collected from the Boca Chica study site in April and May of 1982 (Figure 1.1). The individuals sampled ranged in size from 13.3 to 26.3 cm. The sex of conch was determined by the presence of a verge in males and genital groove in females (Little, 1965). A conch was removed from its shell by severing the columellar muscle attachment from the shell axis. This process by which this is done (termed "knocking the conch") has been illustrated by Childress (1985). The weight of the animal's softparts is referred to hereafter as tissue weight. The following measurements were made and recorded for each conch sampled: total weight, shell weight, tissue weight (wet), marketed-meat weight (wet), maximum shell length and lip thickness. Specimens were drained briefly to remove excess water and weighed on a triple beam balance to the nearest gram. Length and lip-thickness measurements were made with vernier calipers to the nearest 0.1 cm.

To market clean conch, the viscera is discarded, the mantle, operculum, snout and eyes are skinned off the remaining softparts, and the esophagus is scraped clean. The meat of the conch, i.e., the foot and columellar muscle with a fragment of skin on it, is all that remains. In some countries, marketed-meat weight refers to the softparts minus the viscera only; in others, the foot and columellar muscle are fully skinned. The latter is customarily called a full-fillet.

In the analysis of morphometric data, geometric mean (GM) functional regressions of various weight-length relationships were calculated (Ricker, 1973). Symmetrical confidence limits were used for the GM regressions.

2.3 Growth Studies

2.3.1 Sampling procedures

Growth was studied in two conch populations located near the village of San Pedro, on Ambergris Caye (Figure 1.1). The first population was situated in a shallow back-reef area called Tres Cocos. The study site established there covered an area of 1.2 sq. km and was bordered on the east by the reef crest, the west by Ambergris Caye and on either end by natural channels cut through the reef. Water depth in the channels reached a maximum depth of 12.0 m but the average depth in the site was 2.2 m. Variation in substratum types within the site formed four distinct zones: the beach, sand, grass and rubble zones. The largest of these was the grass zone which accounted for 64.7% of the site's overall area. A stratified random sampling program was used to sample conch over the four substratum types. A grid system was designed to encompass the spatial range of the population. It consisted of fifteen transects placed 100 m apart and delineated by stakes positioned every 10 m. These transects ran perpendicular to the reef and shore. Conch were sampled by 100 sq. m quadrats (50 X 2 m) positioned randomly in the site. Sampling was repeated five times during the course of a year from June 30, 1982 to July 1, 1983. Samples were collected over a period of two to three weeks. The mid-point of a sampling period was the date used to place the sample on a time scale for length-frequency analyses.

The second study site was established in the Boca Chica region, a vast expanse of grass and sand flats off the southern tip of Ambergris Caye. The average water depth was 6 m. The bottom consisted of a mosaic of sand and seagrass beds. These were randomly distributed creating an overall homogeneous bottom, quite different from the sequential zonation observed at Tres Cocos. The sampling design at Boca Chica consisted of an array of nine circles, each 10 m in diameter. The first circle was randomly placed and the remaining circles were spaced in a 3 X 3 grid, each approximately 20 m apart. The number and size of conch in each circle were recorded once a month from October, 1981 to February, 1982 and again in May, 1982. Sampling was completed in one day.

2.3.2 Tagging procedures

Conch were collected by divers and brought to the surface to be measured and tagged. Siphonal length (tip of the spire to distal end of siphonal canal) was measured to the nearest 0.1 cm using vernier calipers. Spaghetti tags threaded by nylon-coated stainless steel wire were used to mark the animals. The wire tag was threaded through two holes drilled in the shell at the edge of the last whorl and secured on the outside by a crimped sleeve. Tags were further secured by new shell material laid over the holes by the conch. Upon subsequent sightings, tag number was recorded and shell dimensions remeasured.

During the course of sampling, 3000 conch were tagged at Tres Cocos and 800 at Boca Chica. Tagged animals recovered at Tres Cocos and Boca Chica were at large for variable lengths of time. Time of liberty for returns from Tres Cocos ranged from 10 to 235 days (n=100; $\bar{x}$=137; sd=60.0); at Boca Chica, the range was five to 196 days (n=53; $\bar{x}$=64; sd=49.9). Fishermen were not allowed to fish in these research sites.

Three other sets of tagging data for Belize were analyzed:

1) Recaptures from a population of juveniles near Water Caye;
2) Returns from fishermen following a coast-wide tagging program; and
3) Tag-recapture data collected by the Fisheries Department in 1976 & 1977.

Water Caye is situated 20 km southeast of Belize City (Figure 1.1). It was one of seven sites visited during a coast-wide tagging program conducted by the Fisheries Department in 1982 and 1983. At this site, 139 animals were tagged originally in July of 1982 and 11 were recovered on a subsequent sampling three months later. Few animals tagged by the Fisheries

Department were returned by fishermen and measurements of several of those that were, were incorrect (i.e., indicated negative growth). As a result, only 32 returns from fishermen were analyzed. Results for a tagging study conducted in Belize from April 1976 to November 1977 comprise the last set of data, and include measurements of growth for 82 adult conch.

2.3.3 Parameter estimation for growth model

In this study, the growth of an individual conch in a population is expressed by the von Bertalanffy growth formula (1938):

$$L(t) = L_{\infty} \; (1-e^{-K(t-t_o)}) \qquad (1)$$

where L(t) = length at age (t); L_{∞} = asymptotic maximum length; K = a constant which determines the rate at which the asymptotic weight is approached; and t-zero (t_o) = an arbitrary constant which is, in effect, the theoretical origin of the age-axis. Parameters of this model for Belize populations were derived by fitting the curve to length-at-age data obtained via length-frequency analyses and tag-recapture studies. Data available for the Boca Chica study site were excluded from the length-frequency analyses because sample size was not believed to be large enough to provide adequate estimates of the mean of underlying distributions. The length-frequency techniques are described below; tag returns were analyzed with Fabens' (1965) method.

Three methods were used to analyze size distributions of samples taken at Tres Cocos: the graphical methodology of Cassie (1954) and statistical methods of MacDonald and Pitcher (1979) and Schnute and Fournier (1980). The subroutine used for the Schnute and Fournier method was written by Barry Smith (U.B.C.) and incorporated into the SIMPLEX software package for the nonlinear estimation of von Bertalanffy parameters (Mittertreiner and Schnute, 1985). Length-at-age data were generated three different ways to ensure that the modes identified by the Schnute and Fournier method, and hence, von Bertalanffy parameters predicted, were reliable.

2.4 Dockside Survey

The dockside survey was conducted during the month of June in 1985, the last month of the 1984/85 fishing season for conch. This was an opportune time of year to conduct a survey for conch because the season for lobster was closed. Most divers active at this time are fishing solely conch and man-days (md) recorded on sales receipts refer to conch only. This is important since effort is not tallied by commodity on the statistical forms used in Belize but rather by fishing trip. Other advantages of sampling during the off-season for lobster are that more fishermen are available for interviews and sampling is easier logistically.

2.4.1 Interviews with fishermen

Conch fishermen were interviewed while landing their catch at the following cooperatives: National, Northern, Caribeña and Placencia (Figure 1.1). Fifty-one interviews in total were held and discussions with fishermen were informal (Appendix II). The dockside survey provided data for the calculation of landings/md and information on fishing routines, which in turn, were used to evaluate data extracted from the sales receipts collected by cooperatives (see section 2.6). Data were also collected at dockside by plant managers of Northern during the month of October, 1985 for this study. An outline of the information they were asked to collect is given in Appendix III.

2.4.2 Sampling of landings

The weight of conch meats sampled at each cooperative was roughly proportional to the cooperatives' relative production for June, 1985; 51% of the total sample came from National, 27% from Northern, 21% from Placencia and 1% from Caribeña. The landings of twenty-nine boats in total were sampled. On the days each cooperative was visited, all the boats delivering conch were sampled. No selection was made on the basis of boat type, excursion length or fishing ground.

Landings delivered by each boat were sampled randomly. This was done by removing an equal number of meats from each of the baskets used to carry the catch from the boat to the receiving room of the cooperative. Thus, meats were taken from the top through to the bottom of the ice box. Sample size was determined by the variance in individual meat weights (Mendenhall et al., 1971). Conch meats were weighed with a top-loading balance (HOMS model 28; 900 gm (32 oz) capacity) to the nearest 3.5 gm (1/8 oz). Conch sex was indicated on market-cleaned meats by a remnant of a verge on the male and a genital groove on the female.

2.4.3 Catch curve analysis

A catch curve analysis was undertaken to estimate total mortality (Z) in the conch populations of Belize. Size composition data from landings sampled in 1985 were combined to construct one length-frequency distribution for the catch. No special effort was made to include a certain number of conch in each weight class; the sample size (n=2369) was large enough that this was not considered necessary. The marketed-meat weights were converted to shell length using a pooled functional regression calculated from the conch (n=214) collected at Boca Chica for morphometric studies.

The calculated shell lengths were grouped into intervals of 0.5 cm and the log of the frequency in each size class was plotted against length. The instantaneous rate of total mortality was estimated from the slope of the descending right arm of the catch curve. Points of the left arm were not included because they represented incompletely selected and/or incompletely recruited animals. The main assumption of catch curves based on length frequencies is linearity in growth (Ricker, 1975). Given that absolute increase in mean length of conch between successive ages is not exactly uniform over the range of ages considered here, a length-converted catch curve (Pauly, 1984) was also considered. To construct this type of catch curve, the frequency of each length class is multiplied by the growth rate of fish in that class, logged and then plotted against the relative age corresponding to the length class.

2.5 Yield-Per-Recruit Analysis

The absolute rate of recruitment is not known for *Strombus gigas*, and so, the Beverton and Holt (1957) yield model was used to compute yield-per-recruit (YPR). Assumptions of this model are: 1) natural and fishing mortality are independent of age following recruitment into the fishery; 2) natural mortality and recruitment are independent of stock size; and 3) growth following recruitment approximates to the von Bertalanffy (1938) equation and the parameters of this equation are independent of stock size.

2.6 Statistics Collection

Since most Belizean fishermen produce more than one commodity within a year, statistics were collected for each of the three main fish commodities: lobster (*Panulirus argus*), conch (*Strombus gigas*) and scale fish. The various types of scale fish marketed in Belize are listed in Appendix IV. Lobster data pertain to first grade product only; data on second and third grade lobster and lobster meat (as opposed to tails) were not collected. Whole and filleted fish are grouped together and classified as scale fish unless otherwise indicated. Conch landed by fishermen are market-cleaned (refer to section 2.2). There are no commercial size categories and hence, no estimates of numbers of conch landed. The monetary unit cited in this report is the Belizean dollar. The rate of exchange on this currency was $1.00 BZ to $0.70 U.S. in 1967 and $1.00 BZ to $0.50 U.S. since 1976 (FAO, 1986). The Canadian equivalent to $1.00 BZ in 1985 was $0.68 (Customs & Excise Dept., 1985).

Statistics are compiled differently by the government offices and the fishing cooperatives. To obtain the most comprehensive and reliable database, one needs to know how the statistics were collected and possible sources of bias. The remainder of this chapter is dedicated to these topics.

2.6.1 Belize Fisheries Department

The Fisheries Department has been collecting statistics on the fishing industry since 1954 (Libby, 1969). Their data collection system is based on the payment receipts used by the fishing cooperatives and licensing of fishermen and their boats. On each sales receipt, fishermen are requested to record days and area fished, and the fishing method and boat type used (Appendix IV). The Department receives copies of each sales receipt but less than two percent have information on days and area fished. Nevertheless, data from completed forms have been used by the Department to calculate landings-per-unit-effort

(Gibson, 1981). These same data, and statistics on conch exports (1956-1986) and the monthly production and local sales of each cooperative (1976-1985) were collected from the Fisheries Department for use in this study.

Data collected by the Department through licensing are outlined in Part III of the Belize Fisheries Regulations (Government of Belize, 1977). The applications for fishing licenses shown in Appendix V (Forms A1 and B1) were photocopied for this study but not all could be found. To obtain an accurate estimate of the number of licenses issued, a ledger of license fees paid since 1978 was consulted.

Licensed fishermen are classified as cooperative fishermen when they are members of a fishing cooperative and independent fishermen when they are not. As a rule, cooperative fishermen sell their catch to the cooperatives and independents sell to the local markets; however, there are exceptions. Cooperative fishermen have been known to take lobster and conch rejected by their cooperative to the local market, and independents often sell their catch to the cooperatives via members to receive a higher price. Only data on sales by cooperative members to cooperatives are used in this study. The Fisheries Department has estimates of the annual harvest by independent fishermen but these are based on reported sales which are believed to underestimate true harvest. The same is true for the cooperatives' records of landings by independents. These data are of minimal use because the volume of conch delivered to cooperatives by nonmembers under members' names still remains unknown. There are no data on landings by foreign fishermen. The volume of conch taken for personal use is also unknown, but because of the high export market price for conch, is considered to be of little consequence.

2.6.2 Fishing cooperatives

Fishing cooperatives are required by law to keep accurate account of all their purchases and sales (Government of Belize, 1948 a & b). The sales receipt completed at dockside by fishermen or cooperative personnel is the basic unit of the cooperatives' book-keeping. These records of weight delivered are tallied for each member. An individual's production of each commodity over a fiscal year (April 1 - March 31) is entered on what is called a second payment schedule in Belize. Cooperatives also keep track of their total monthly production for each commodity and convey this information to the Belize Fishermen Cooperative Association and the Fisheries Department. Overall production for the fiscal year is published in the Cooperative's Financial Report. These reports are distributed at Annual General Meetings. Data for this study were collected from each type of cooperative account for the four largest cooperatives over the following time periods:

1) Records of all conch sales - March 15 to June 30, 1985 (off-season for lobster);
2) Records of members' individual deliveries - 1983 & 1984 (1/2 of each cooperative's membership sampled);
3) Second payment schedules - 1967 to 1984;
4) Monthly production by cooperatives - 1967 to 1985 for Northern and 1976 to 1985 for remaining cooperatives; and

5) Annual financial reports - late 1960's to 1985.

The Sarteneja Cooperative was officially declared defunct in 1982. However, statistics on conch harvest for the five years prior to its closure were available from the Department of Cooperatives and Credit Unions.

2.6.3 Landings data

Data on landings per year quoted in this report pertain to cooperative members only and were taken from the second payment schedules of the cooperatives unless otherwise stated. It was necessary to remove landings recorded for nonmembers from the cooperatives' accounts of total production to determine landings-per-unit-effort (LPUE). In the years for which second payments schedules were missing, totals quoted in the cooperatives' financial reports were used. These values are higher because they include production by nonmembers; significantly higher for Placencia as production by nonmembers comprises a major proportion of this cooperative's total landings, but only slightly higher for other cooperatives. If both the above references were unavailable, production figures tallied by the Fisheries Department were used. Unlike cooperative data which are based on a fiscal year, these pertain to a calendar year. This is clearly indicated whenever government data are used.

There is only one case in this report where data for fiscal and calendar years are combined. Information on annual exports was combined with that for total landings by fishing cooperatives to construct a longer time series of data on conch production (Chapter Five). Exports are slightly less than landings because: 1) cooperatives reserve 10% of their production for domestic sales and 2) losses are incurred during processing as a result of cleaning, spoilage and shrinkage. However, this difference is not obvious from values reported because exports are based on a calendar year and represent that of all fishermen, while harvest is based on a fiscal year and is harvest by members only. It should also be noted that conch meats were exported as full-fillets prior to 1967; therefore, exports for these earlier years are comparatively lower. Baird (1973) calculated that conch exports in the "market-cleaned" state yield about 15% more than full-fillets.

The terms "catch" and "landings" are both used in this report, but the weight of conch gathered from the sea bottom (catch) is greater than that delivered to the cooperatives (landings). Processing the conch at sea yields a landed product weighing roughly 40% of the total soft-parts. Landings are further reduced by an estimated 5% as a result of:

1) loss at sea, including meats lost overboard, used as fish bait or eaten;
2) self-consumption; and
3) rejection of poor quality and/or undersized meats by the cooperatives.

2.6.4 Fishing licenses

The cooperatives' membership lists and Fisheries Department records of licenses were used to estimate the number of fishermen in Belize. Members listed in the cooperatives' financial reports were separated by activity: producers and nonproducers. The names of producing members were verified by referring to the second payment schedules. A list of the country's cooperative fishermen was then compared with the Fisheries Department's list of licensed fishermen for each fiscal year. Licensed fishermen not included in the list of cooperative members were designated independent fishermen:

LICENSED FISHERMEN

Fiscal Year	Total	Cooperative Fishermen	Independent Fishermen	Unidentified (% of total)
1978	925	611	301	13 (1.4)
1979	938	607	317	14 (1.5)
1980	937	599	322	16 (1.7)
1981	1005	629	351	25 (2.5)
1982	1128	627	457	42 (3.7)
1983	1021	532	465	24 (2.3)
1984	1433	694	693	46 (3.2)

Four discrepancies were found in these data. First, some licenses were issued twice to the same name in one year; the extra licenses are labelled as unidentified in the table above. Second, some names occurred twice in the annual listings of cooperative members (2% of the total members). One man renewing a license for a friend or a fishermen beening listed by one cooperative as active and by another as inactive in the same year may explain such discrepancies but they may also simply be errors. Lastly, an average of 27.3% of cooperative members each year have been active but not licensed and 9.4% of licensed cooperative fishermen have not been active:

COOPERATIVE FISHERMEN

Fisc. Year	Total Active (A)	Licensed (B)	Licensed & active	Active but not licensed (% of A)	Licensed but not active (% of B)
1978	735	611	567	168 (22.9)	44 (7.2)
1979	720	607	536	184 (25.6)	71 (11.7)
1980	690	599	526	164 (23.8)	73 (12.2)
1981	755	629	556	199 (26.4)	73 (11.6)
1982	774	627	559	215 (27.8)	68 (10.8)
1983	814	532	500	314 (38.6)	32 (6.0)
1984	876	694	648	228 (26.0)	46 (6.6)

The total number of active independent fishermen was estimated from license information using the conversion factors calculated above. An example of the equation used follows:

Fisc. Year	total licensed	-	inactive fishermen	=	licensed & active	+	active but not licensed	=	total active
1978	301		(301*0.094=28)		273		(273*0.273=75)		348

The final estimates of active independents are:

INDEPENDENT FISHERMEN

Fisc. Year	Total licensed	Total active
1978	301	348
1979	317	365
1980	322	372
1981	351	405
1982	457	527
1983	465	536
1984	693	799

2.6.5 Effort Data

Unlike landings statistics, data on annual effort (man-days) are not available; therefore, effort was derived from landings-per-unit-effort (LPUE). LPUE was estimated using data obtained from six sources:

1) Records of daily production for Sartenejan fishermen (1978-1982);
2) Sales receipts collected during the off-season for lobster, 1985;
3) Interviews with fishermen at dockside in June, 1985;
4) Records of Northern's landings during October, 1985;
5) Cooperatives' second payment schedules (1967-1984); and
6) Sales receipts gathered by the Fisheries Department.

The Fisheries Department's sample of sales receipts corresponded to four cooperatives over the following time periods:

Northern	July 1975 - June 1983
Caribeña	January 1976 - December 1982
Placencia	March 1978 - December 1982
National	November 1980 - March 1981

Direct estimates of conch abundance are impractical given the length of the coast and patchy distribution of conch along it. Hence, changes in LPUE were examined to estimate relative decline in conch abundance.

CHAPTER THREE

Biological Basis of the Fishery

Understanding the relation between fishing activity and potential sustainable catch requires knowledge of the species' biology and dynamics of the exploited populations. This chapter focuses largely on the estimation of parameters for the Beverton-Holt yield-per-recruit (YPR) model. Results of morphometric studies are presented in section 3.2 and the complications encountered in calculating asymptotic weight are addressed. Parameters of the von Bertalanffy growth formula are derived by fitting the growth curve to length-at-age data obtained from length-frequency analyses and tag-recapture studies. Results obtained for populations in Belize and elsewhere in the Caribbean are discussed in section 3.3. Rates of natural and fishing mortality for _S. gigas_ are presented in section 3.4. Other population parameters on which the Beverton and Holt model depends (eg., mean age at which fish are first recruited to the fishery (t_r); mean age at first capture (t_c); and longevity (t_{max})), are considered in section 3.5. The final section summarizes the results of the analysis on YPR.

3.1 Life History and Ecology of _Strombus gigas_

Strombus gigas (Linnaeus, 1758) is a large marine snail (Order Mesogastropoda) commonly referred to in many parts of the Caribbean as the queen conch. Although the Family Strombidae has an almost world-wide distribution in tropical waters, Strombus gigas occurs only in the western North Atlantic. It is found in Bermuda and south Florida, along Central America and northern South America to Brazil, and around all the West Indian islands (Warmke and Abbott, 1961). Other species of Strombus occurring within this range include S. costatus Gmelin (milk conch), S. pugilus Linnaeus (fighting conch), S. ranius Gmelin (hawk-wing conch), S. gallus Linnaeus (rooster-tail conch) and S. goliath Schroter. The latter, an indigenous Brazilian species, may grow to a length of 40 cm and is the largest Strombus in the world; the others range in length from about seven to 17 cm. Maximum length recorded for S. gigas is 30 cm and maximum total weight is 3.3 kg (Randall, 1964b). Conch (pronounced "konk") is a common name used for many different kinds of large spiral marine snails besides those of the genus Strombus. Among English speaking countries, the name queen or pink conch specifies S. gigas . Elsewhere in the Caribbean, the common name varies with the language spoken (Brownell and Stevely, 1981).

The physiology of S. gigas is described by Little (1965). Sexes are separate and fertilization is internal. The male has a verge (copulatory organ) located on the foot under the mantle, and the female has a genital groove transversing the right hand side of the foot. The sex ratio is 1:1 and females are generally greater in shell length than males by 1.0 to 2.0 cm (Randall, 1964b; Alcolado, 1976). Copulation may occur several weeks before spawning and more than one male may try to mate with a single female. Competition between males for access to a female is characteristic of Strombus species (Catteral and Poiner, 1983; Bradshaw-Hawkins and Sander, 1981).

Breeding habits, spawning and the formation of egg masses have been described by Robertson (1959), Randall (1964b), D'Asaro (1965) and Brownell (1977). Queen conch generally mate between March and September; exact times vary with geographic location. A tendency to migrate toward open sand to spawn has been noted by several researchers; preferred substrate conditions are described by Davis et al. (1984). Females engage in mating and egg laying many times in a single breeding season. Davis and Hesse (1983) estimated an average of eight egg masses per female are laid during a typical six month season. There are no data on age nor on size specific fecundity of conch. Each egg mass may contain from 310 to 750 thousand eggs and Berg and Olsen (in press) estimate that as many as six million larvae may be produced by a female each year. The rate of natural mortality of larvae is not known but assumed to be high.

The development of veligers from prehatching to premetamorphosis is described by D'Asaro (1965). Hatching occurs in approximately five days and the free-swimming veligers remain in the water column for about three weeks before settling to the bottom. The extent of larval dispersion is not known for certain (Berg et al., in press). Metamorphosis occurs roughly 10 days after settlement (Brownell, 1977). For the first year of their bottom dwelling existence, juveniles remain buried in the sand during the day and emerge at night to feed.

Juveniles grow in a spiral fashion until they are about three years old, then the pattern of growth changes. The animal ceases to grow in length and produces a flared shell lip instead. Growth in tissue weight continues but at a much slower rate. The lip is formed in roughly three months, and can grow to a thickness of 17-18 mm in one year (Appeldoorn and Ballantine, 1987). Conch reach sexual maturity at some time after lip formation. In Belize, Egan (1985) found most animals with ripe gonads had a lip thickness of at least 4 mm. He estimates, as does Appeldoorn and Ballantine (1987), that the age of first reproduction is close to four years, i.e., one year after the shell ceases to grow in length.

As the conch ages, overall thickness of the shell continues to increase and the space occupied by the softparts becomes smaller. The spire becomes worn and blunted, a pink nacre appears at the aperture and the flesh tends to darken. Shells are eventually weakened by the action of worms and certain boring organisms and maximum age is estimated to be six to seven years (Berg, 1976; Wefer and Killingley, 1980).

Shell characteristics such as size, thickness and volution, spine length and color vary widely in S. gigas (Alcolado, 1976). Differences in terminal size and occurrences of dwarf forms are frequently mentioned in the literature (Randall, 1964b; Robertson, 1959). The stunted form of S. gigas is called "samba", a name derived from earlier debates that the dwarf form may be a separate species, i.e., S. samba (Clench and Abbott, 1941; Verrill, 1948).

The queen conch is a herbivore. It is found in sandy habitats associated with coral reefs, usually amongst seagrasses where bottom disturbance and turbidity is low. The species occurs in the high tide level to depths of 35 m. Occurences in shallow water is attributed to availability of light for plant growth and optimal water temperatures (Roberston, 1961; Percharde, 1982). Notable conch predators include: Caretta caretta (loggerhead turtle), Dasyatis americana and Aetobatus narinari (rays), Petrochirus diogenes (hermit crab), Panulirus argus (lobster), Octopus vulgaris (octopus) and several carnivorous gastropods (eg., Fasciolaria tulipa , Plueroploca gigantica , Murex pomum and Cassis spp.). When approached by predators, conch may exhibit a behavior known as the escape response (Berg, 1974). This involves a kicking motion whereby conch may leap half their own length. Normally, the conch pulls itself around in an awkward and careening fashion by anchoring its operculum ahead of itself and contracting its columellar muscle (Parker, 1922).

Studies on movement and migrations of conch have been conducted by Hesse (1976) in the Turks and Caicos Islands. In the field, she determined the home-range (area over which conch habitually travelled while engaged in their usual activities) of conchs with shell lengths of 10-13 cm (1000 sq. m) and 13-16 cm (2500-5000 sq. m). Conch greater than 17 cm had larger, undetermined ranges. Maximum linear distance travelled was 100 m in 24 hours. Seasonal migration occurred with animals moving into shallower waters in the summer and deeper waters in the winter. The seasonal regularity of migrations increased with age. Hesse (1979) proposed that the movement offshore in the fall was to avoid surface swells and abrasion from winter storms and strong winds. Burying is another behavior characteristic of conch. Hesse (1979) has observed that individuals of all ages bury themselves in the substrate during winter storms. Long-term burying (up to six weeks) also occurs and is thought to represent a dormant period prior to the reproduction season.

Conch have a patchy distribution but little is known about the cause or the ecological significance of their aggregations. The types of aggregations noted in conch include (Catteral and Poiner, 1983):

1) Mating aggregation - concentration of copulating individuals;
2) Cluster - concentration of inactive individuals piled together in close contact;
3) Mixed age class colony - aggregation of individuals of all ages which persist over time and exhibit some coordinated movements; and
4) Juvenile colony - discrete and dense patch of juveniles.

Mass spawning activity in S. gigas is described by Hesse (1976) and Randall (1964b). The phenomenon of winter season clumping is described by Hesse (1976) and Strasdine (1984). Ecological mechanisms which could lead to aggregations of conchs, were considered by Catteral and Poiner (1983). From their work on S. luhunas, they concluded that intraspecific attraction is an important factor which maintains the spatial structure of all aggregations, while habitat specificity sets the larger area in which they move.

3.2 Morphometric Studies

Weight-length data were provided by the Fisheries Department and included measurements of 129 juveniles and 75 adults. In this report, 'adults' are conch having a fully formed lip greater than 10 mm thick. The ratio of females to males was essentially 1:1 for both juveniles and adults. The average size of adult conch measured, 22.1 cm (n=75; sd=2.0), is within the range noted for _S_. _gigas_ elsewhere in the Caribbean:

AVERAGE SIZES RECORDED FOR ADULT QUEEN CONCH

Location	Shell length (cm)	N	Reference
Virgin Isles	20.4	171	Randall (1964b)
St. John/Bimini	20.4	199	Berg (1976)
Turks & Caicos	21.3	23	Hesse (1976)
Venezuela	19.8	60	Brownell (1977)
Puerto Rico	24.1	1119	Appeldoorn and Ballantine (1987)
St. Croix	24.2	240	Coulston _et_ _al_. (in press)
Belize	22.1	75	This study

Geometric mean functional regressions of the relationships between shell length and weight (including total, shell, tissue and meat weight) and between shell lip-thickness and weight are given in Tables 3.1 and 3.2, respectively. Both shell deposition rate and allometric growth in tissue weight change when there is a shift from spiral shell growth to lip development. Length, though strongly correlated to juvenile tissue weight by sex, is not an adequate predictor of adult tissue weight. There is a

Table 3.1

Shell length-weight relationships for S. gigas.
Relationships between body parts determined using functional regression. All weights in grams and length in centimeters.

Relationship:	N	U	V	r^2	Mean (Y-values)	Mean (X-values)
Log(Total weight) = U + V Log(Length)						
Total Juveniles	129	-0.899	2.91	0.879	2.789	1.266
Juvenile Females	65	-0.868	2.89	0.913	2.830	1.280
Juvenile Males	52	-1.100	3.07	0.853	2.751	1.253
Total Adults	75	-0.579	2.85	0.569	3.249	1.343
Adult Females	38	-0.289	2.63	0.532	3.273	1.353
Adult Males	37	-0.995	3.16	0.561	3.223	1.333
Log(Shell weight) = U + V Log(Length)						
Total Juveniles	129	-0.969	2.88	0.842	2.675	1.266
Juvenile Females	65	-0.884	2.81	0.894	2.718	1.280
Juvenile Males	52	-1.230	3.08	0.796	2.633	1.253
Total Adults	75	-0.506	2.72	0.502	3.152	1.343
Adult Females	38	-0.176	2.47	0.461	3.173	1.353
Adult Males	37	-1.000	3.10	0.503	3.130	1.333
Log(Tissue weight) = U + V Log(Length)						
Total Juveniles	129	-1.750	3.07	0.875	2.136	1.266
Juvenile Females	65	-1.780	3.09	0.886	2.176	1.280
Juvenile Males	52	-1.910	3.19	0.859	2.097	1.253
Total Adults	75	-2.590	3.81	0.679	2.526	1.343
Adult Females	38	-2.660	3.86	0.613	2.558	1.353
Adult Males	37	-2.660	3.86	0.716	2.493	1.333
Log(Meat weight) = U + V Log(Length)						
Total Juveniles	129	-2.080	3.03	0.827	1.717	1.266
Juvenile Females	65	-1.980	2.92	0.840	1.763	1.280
Juvenile Males	52	-2.420	3.26	0.790	1.668	1.253
Total Adults	75	-3.820	4.44	0.622	2.142	1.343
Adult Females	38	-3.770	4.40	0.566	2.180	1.353
Adult Males	37	-4.050	4.61	0.636	2.104	1.333
Log(Meat weight) = U + V Log(Tissue weight)						
Total Juveniles	124	-0.404	0.99	0.913	1.715	2.134
Juvenile Females	65	-0.297	0.95	0.934	1.766	2.179
Juvenile Males	53	-0.502	1.03	0.885	1.664	2.094
Total Adults	75	-0.796	1.16	0.944	2.142	2.526
Adult Females	38	-0.736	1.14	0.945	2.180	2.558
Adult Males	37	-0.858	1.18	0.937	2.104	2.493

Table 3.2
Lip thickness-weight relationships for *S. gigas*
Relationships between body parts determined using functional regression. All weights in grams and lip thickness in millimeters.

Relationship:	N	U	V	r^2	Mean (Y-values)	Mean (X-values)
Log(Total weight) = U + V Log(Lip Thickness)						
Total Adults	75	2.99	0.27	0.242	3.249	0.982
Adult Females	38	2.96	0.31	0.250	3.273	1.011
Adult Males	37	2.99	0.24	0.224	3.223	0.952
Log(Shell weight) = U + V Log(Lip Thickness)						
Total Adults	75	2.90	0.25	0.277	3.152	0.982
Adult Females	38	2.88	0.29	0.295	3.173	1.011
Adult Males	37	2.91	0.24	0.253	3.130	0.952
Log(Tissue weight) = U + V Log(Lip Thickness)						
Total Adults	75	2.16	0.37	0.110	2.526	0.982
Adult Females	38	2.04	0.51	0.073	2.558	1.011
Adult Males	37	2.19	0.31	0.121	2.493	0.952
Log(Meat weight) = U + V Log(Lip Thickness)						
Total Adults	75	1.73	0.42	0.158	2.142	0.982
Adult Females	38	1.63	0.55	0.137	2.180	1.011
Adult Males	37	1.76	0.36	0.159	2.104	0.952

weak correlation between adult tissue weight and lip-thickness as well.

Because there are differences between the growth patterns of juveniles and adults, one cannot use pooled length-weight functions to convert the von Bertalanffy parameter L_∞ to W_∞. To predict adult weight, one must consider both the effect of length-growth plus the effect of lip growth. The latter was modelled in this study using an approach proposed by Appeldoorn and Ballantine (1987). For animals in Belize, "adult weight gain" (the difference between actual weights and predicted weights at onset of maturity) is related to lip thickness (mm) as follows ($n=75$; $r^2=0.40$):

For tissue weight:
log(adult wgt gain+100 gm) = 2.05 + 0.246 log(lip-thickness) (2)

For marketed-meat weight:
log(adult wgt gain+100 gm) = 1.98 + 0.175 log(lip-thickness) (3)

To avoid taking logs of negative numbers, 100 gm was added to values of adult weight gain. To obtain proper weights, 100 gm should be subtracted from the antilog of the predicted value. Asymptotic weight was calculated by summing the predicted weight for conch at onset of maturity and the maximum gain in weight of the adult. The former was based on the average length of adults in Belize (22.1 cm) and the latter on an estimate of asymptotic lip-thickness (54.9 mm) provided by Appeldoorn and Ballantine (1987). Asymptotic tissue weight was estimated to be 438 gm and asymptotic meat weight, 191 gm. The average adult tissue and meat weights recorded during morphometric studies were 356 gm (n=75; sd=119) and 150 gm (n=75; sd=57.9), respectively. Appeldoorn (unpubl.) has estimated the asymptotic meat weight of conch in Puerto Rico to be 275.0 gm; in the Turks and Caicos, Wood and Olsen (1983) estimated W_∞ to be 231.6 gm. In Belize, the value for average adult length may be biased low and asymptotic weight underestimated because there was a large number of dwarf conch (sambas) in the sample. Ideally, data from more than one area should be used in the estimation of asymptotic weight.

3.3 Growth Parameters

3.3.1 Literature review

Published estimates of mean shell length-at-age and von Bertalanffy parameters are presented in Tables 3.3 and 3.4, respectively. Most recent reports published on growth of Strombus gigas have pertained to juveniles (Berg, 1981; Higman, 1983; Siddall, 1984, Williams, in press). Length-frequency analyses and tagging studies have been used in studies of juvenile growth, but are not applicable in the case of adults due to determinant shell growth. Alternate methods used to age adults include lip-thickness-frequency analysis (Hesse, 1976; Wood and Olsen, 1983; Appeldoorn and Ballantine, 1987; Coulston et al., in press) and chemical analysis (Epstein and Lowenstam, 1953; Wefer and Killingley, 1980). Since conch are recruited to the fishery as juveniles, some combination of the methodologies above should be used to calculate a Ford-Brody growth coefficient (K) for modelling yield-per-recruit. This has not

Table 3.3

Mean lengths (cm) of the first, second and third size classes for <u>Strombus gigas</u> (based on length-frequency analyses)

Geographic Location	Date (D/M/Y)	N	Size Class* I	II	III	Source
Cabo Rojo, Puerto Rico	4/07/73	193	8.8 (1.5)	12.6 (1.5)	18.0 (1.5)	Berg, 1976
Los Roques, Venezuela	19/07/76	161	7.6	12.8	18.0	Brownell *et al.*, 1977
Turks & Caicos, B.W.I.	?/?/85	355	11.5	18.0	20.0	Olsen, 1985
St. Thomas, U.S.V.I.	?/09/81	334	9.0	12.6	15.7	Wood and Olsen, 1983
St. Croix, U.S.V.I.	?/?/84	273**	6.9 (0)	12.9 (2.2)	22.4 (1.9)	Coulston *et al.*, in press
Cuba:						
Cayo Anclitas	1/07/73	141	11.5	18.5	21.5	Alcolado, 1976
Diego Perez B	18/05/73	104	6.8	12.5	15.5	"
" " "	27/08/73	222	9.0	13.8	15.8	"
Diego Perez A	18/10/73	278	7.7	13.3	17.0	"
" " "	19/12/73	1063	10.3	14.3	17.3	"
Belize:						
Tres Cocos	7/07/82	566	8.9 (1.0)	13.3 (1.1)	17.1 (1.2)	This study

* (Standard deviation)
** 240 animals in this sample were estimated to be 4+ years old with a mean size of 24.2 cm (SD=1.5).

Table 3.4

Estimates of von Bertalanffy parameters derived from tagging data for *S. gigas*

Original Study (location)	N	L_∞	K	t_0	Size Range(cm)
Randall, 1964b (St. John, USVI)	104	26.0	0.516	0 *	
Berg, 1976 (St. Croix, USVI)	5	20.1	0.589	0	
Hesse, 1976 (Turks & Caicos, BWI)	108	31.8	0.381	-0.08 **	
	"	25.6	0.563	-0.16 ***	
Alcolado, 1976 (Cuba)	-	38.4	0.330	-0.05	
	-	38.1	0.287	-0.12	
	-	33.4	0.360	-0.13	
	-	26.0	0.571	-0.09	
	-	23.3	0.429	-0.09	
	-	20.8	0.442	-0.09	
Appeldoorn and Ballantine, 1987 (Puerto Rico)	141	46.0	0.250	-0.17	
Iverson *et al.*, 1987 (Berry Isles., Bahamas)	117	30.0	0.200	-0.65	
THIS STUDY: (Belize)					
Water Caye	11	26.9	0.290	0	7.1-13.3
Tres Cocos	100	24.2	0.286	0.03	7.3-18.3
Boca Chica	53	26.8	0.223	-0.05	7.8-21.1
Fishermen's rtns.	32	24.2	0.470	0	8.6-21.3
Blakesley, 1977	82	29.6	0.674	0	13.0-25.5

* Calculated by Berg (1976)
** Calculated by Berg and Olsen (in press)
*** Calculated by Appeldoorn (unpubl.)

yet been accomplished and hence, K values presented in the literature need to be critically interpreted.

The Belize populations for which growth data are available consist primarily of juveniles. Von Bertalanffy parameters based on these data are, therefore, considered less useful than those in the literature which cover a larger range of sizes. Results of analyses on Belize data are still presented to illustrate some of the difficulties encountered in parameter estimation for S. gigas. Length-frequency analyses and tagging studies are discussed separately below.

3.3.1 Length-frequency analyses

Three year classes are believed to be present in the Tres Cocos population, but the estimated number of animals within the third age class was small (Figure 3.1). This led to difficulties in establishing a third mode. Size-frequency data were analyzed with three different methods: Cassie (1954), MacDonald and Pitcher (1979) and Schnute and Fournier (1980). This measure was taken to ensure that length-at-age data generated by the latter method (and used in the estimation of von Bertalanffy parameters) were acceptable and not adversely biased by the the effects of partial recruitment and partial maturation (defined below). Mean shell lengths of the modal groups are presented in Table 3.5. Assuming July 1 represents mid-spawning season, mean lengths of one through three year olds in Tres Cocos are estimated to be 8.8, 13.3 and 17.1 cm, respectively.

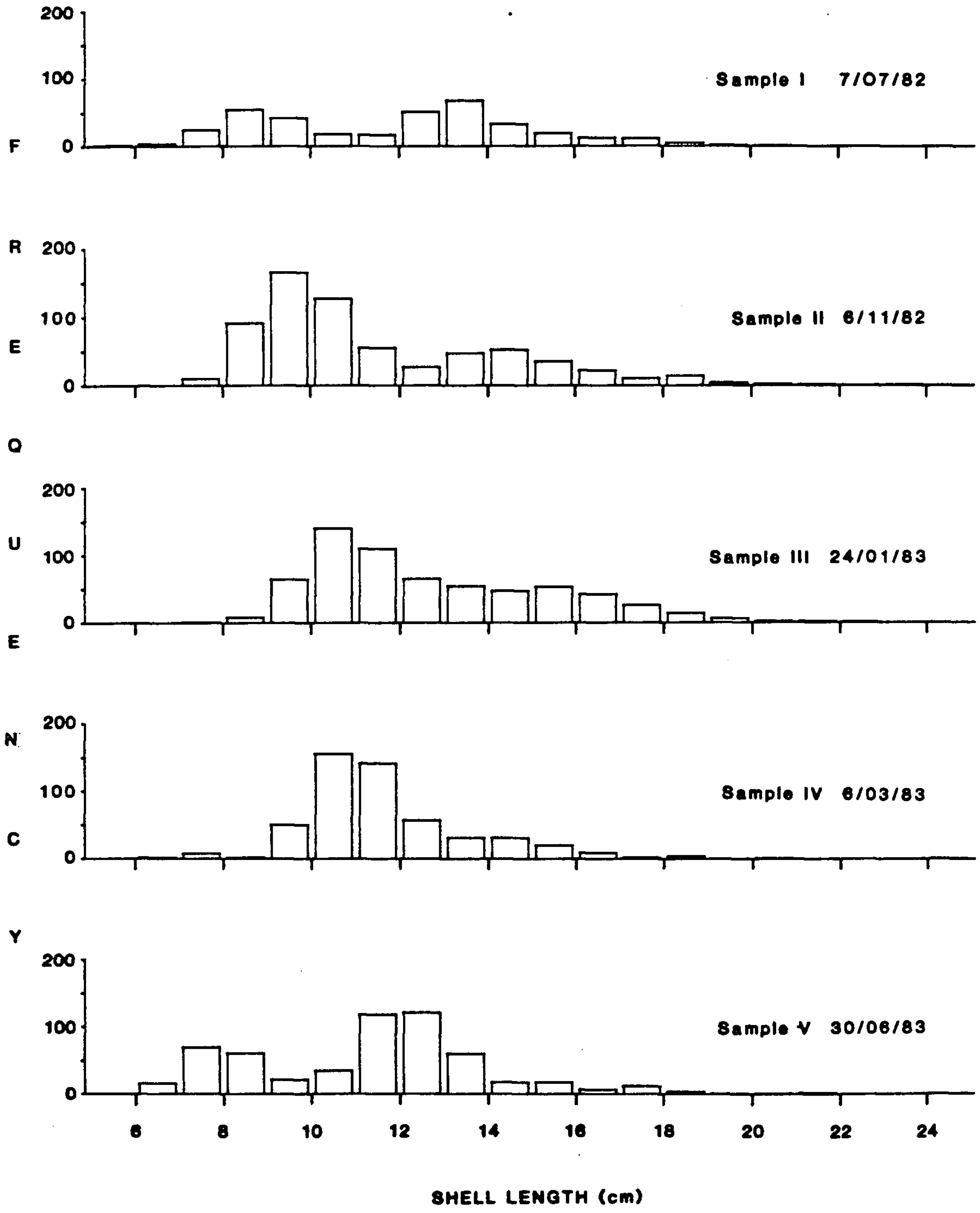


Figure 3.1 Size-frequency distributions for the Tres Cocos population.

Table 3.5

Mean lengths (cm) and estimated ages (yr) of modes identified by three different methods of size-frequency analysis in size-distributions of the Tres Cocos population.

	CASSIE					MACDONALD & PITCHER				SCHNUTE & FOURNIER			
SAMPLE SET I (7/07/82; n=363)													
Age	0.02	1.02	2.02	3.02	Age	0.02	1.02	2.02	3.02	0.02	1.02	2.02	3.02
Mean	-	8.3	12.9	16.5	Mean	-	8.8	13.4	17.2	-	8.8	13.3	17.1
SD	-	0.95	1.05	1.08	SD	-	1.06	1.10	1.10	-	1.03	1.14	1.22
Prop.	.005	.395	.500	.095	Prop.	.000	.395	.508	.097	-	.391	.510	.104
SAMPLE SET II (6/11/82; n=663)													
Age	0.35	1.35	2.35	3.35	Age	0.35	1.35	2.35	3.35	0.35	1.35	2.35	3.35
Mean	-	10.4	15.2	19.3	Mean	-	9.8	14.2	18.2	-	9.8	14.1	17.7
SD	-	1.05	1.18	0.93	SD	-	0.97	1.42	1.41	-	0.96	1.48	1.91
Prop.	.000	.700	.260	.038	Prop.	.000	.664	.282	.054	-	.659	.275	.070
SAMPLE SET III (24/01/83; n=635)													
Age	0.56	1.56	2.56	3.56	Age	0.56	1.56	2.56	3.56	0.56	1.56	2.56	3.56
Mean	-	10.8	15.6	-	Mean	-	10.9	14.9	17.7	-	10.7	14.6	21.5
SD	-	1.17	1.72	-	SD	-	1.02	1.69	2.09	-	0.90	0.99	1.11
Prop.	.000	.705	.291	.004	Prop.	.000	.588	.352	.059	-	.481	.493	.029
SAMPLE SET IV (6/03/83; n=516)													
Age	0.68	1.68	2.68	3.68	Age	0.68	1.68	2.68	3.68	0.68	1.68	2.68	3.68
Mean	-	10.6	14.2	-	Mean	-	11.0	14.6	17.0	7.1	10.9	13.4	-
SD	-	0.86	1.02	-	SD	-	1.12	0.93	1.97	0.08	0.79	2.34	-
Prop.	.020	.810	.156	.014	Prop.	.000	.800	.130	.070	.162	.655	.335	-
SAMPLE SET V (30/06/83; n=566)													
Age	1.00	2.00	3.00	4.00	Age	1.00	2.00	3.00	4.00	1.00	2.00	3.00	4.00
Mean	7.4	11.8	16.4	-	Mean	8.0	12.1	16.1	-	7.9	11.9	16.6	-
SD	0.73	1.24	1.21	-	SD	0.78	1.04	1.89	-	0.70	1.12	1.64	-
Prop.	.252	.655	.061	.004	Prop.	.290	.610	.100	-	.277	.637	.091	-

'Prop.' = proportion of the sample within each size class

Estimates of the von Bertalanffy parameters obtained for each Tres Cocos sample with the Schnute and Fournier method are given below:

RESULTS OF THE SCHNUTE & FOURNIER METHOD

Sample No.	N	L_∞ (cm)	K	t_0
I	363	35.6	0.187	-0.51
II	663	33.2	0.207	-0.33
III	635	-	-0.578	-
IV	516	18.2	0.442	-0.48
V	566	-	-0.068	-

The negative K value estimated for data sets III and V indicate the data do not conform well to the von Bertalanffy growth model. These results are believed to be a consequence of partial recruitment and partial maturation in sample IV (see Table 3.5). Non-representative sampling of the older size class in this sample likely arose from a size-determined migration of juveniles out of the grass beds.

When using length-frequency techniques to estimate fish growth, the following conditions should be met:

1) modal sizes represent age class cohorts and are not merely random concentrations of larval recruitment in time;
2) animals hatched in the same year tend to be of the same size range normally distributed around a modal size;
3) sampling is unbiased and representative; and
4) sample size is large enough for reliable calculation of mean length of all underlying distributions.

There are several aspects of conch biology which influence size class variability, and therefore, make it difficult to divide polymodal size-frequency samples into their component distributions. Among them are prolonged spawning, variable terminal size and different rates of growth between sexes. Too few observations have been made to determine the period over which spawning is most intense in Belize. However, elsewhere in the Caribbean, the spawning activity is prolonged. Spawning season in some areas extending from mid-spring to mid-fall (D'Asaro, 1965; Hesse, 1976; Davis et al., 1984; Weil and Laughlin, 1984; Coulston et al., in press).

Variation in terminal size is well recognized in Strombus gigas. Adults tagged by Alcolado (1976) in Cuba and by Weil and Laughlin (1984) in Venezuela ranged from 17-23 cm and 18-26 cm, respectively. Lipped individuals collected in Belize for the analysis of weight-length relations ranged from 16.7 to 26.3 cm (n=75; sd=2.01). Sambas comprised a relatively large percent (15%) of the sample collected in Boca Chica for morphometric studies. Therefore, their presence in the length-frequency samples and influence on size class variability are to be expected.

Different rates of growth in female and male conch may also increase the overlap between size classes. Observations that females are slightly larger than males is documented by Randall (1964b), Percharde (1968), Alcolado (1976) and Appeldoorn (in press (a)), and by Blakesley (1977) in Belize. In the sample used for morphometric studies, mean shell length of juvenile females was 19.2 cm (n=65; sd=2.5) as compared to 18.1 cm (n=52; sd=2.3) for males. Average length of adult females was 22.7 cm (n=38;sd=2.0) and males 21.6 cm (n=37; sd=1.9). The possibility of this form of sexual dimorphism leading to a misidentification of modes depends on the degree of overlap. With differences of 1 cm noted for Belize animals, it is not likely to be a problem.

Two other aspects of queen conch biology which cause difficulties when using size-frequency techniques are partial recruitment and determinant shell growth (Appeldoorn, in press (a)). These have an influence on whether all age groups will be sampled in proportion to true abundance. Sub-yearling conch (juveniles < 6-7 cm) bury beneath the substrate and are seldom seen by divers. As individuals grow, the year-class gradually emerges from the sand to be incorporated into the sampled population, but in the interim slow growing animals may be selectively undersampled. If so, mean length of the first year-class will be overestimated and abundance underestimated. A process which is essentially the reverse of partial recruitment, i.e., partial maturation, occurs when juveniles reach maturity and cease to grow in length. Large conch (fast growers) will be selectively removed from the sample as they become adults. The observed mean size of remaining individuals will be less than the real size and population growth rate represented by length-frequency analysis will be underestimated. Further explanation of how the transition of conch from juveniles to adults affects the location of the mode on the length-frequency histogram and its size is given by Appeldoorn (in press (a)).

3.3.2 Tag-recapture studies

Tagging data from Belize were analyzed with Fabens' (1965) method. Estimates of L_∞ derived from these data were within the range of previously documented values (Table 3.4). Estimates of K seem to be on the upper and lower ends of the spectrum. Those for the three juvenile populations ranged from 0.223 to 0.290 and data on returns from fishermen and animals tagged by the Fisheries Department in 1976 generated much larger values of K, i.e., 0.479 and 0.674. These results are believed to be artifacts of biased data; the first three populations biased toward small juveniles and the latter two data sets biased toward adults. Representative sampling is a common problem in tagging studies as conch are gregarious and often found in cohorts of similar sized animals.

Growth parameters derived from tagging data were different from those obtained via length-frequency analysis (LFA) for the Tres Cocos population:

PARAMETERS ESTIMATED FOR THE TRES COCOS POPULATION

	L_∞ (cm)	K	t_0	Age (yr) at Maturity
Tres Cocos - LFA				
(input=sample I)	35.6	0.187	-0.51	5.13
(input=sample II)	33.2	0.207	-0.33	4.96
Tres Cocos - Tagging	24.2	0.286	0.03	7.45

Slower growth was predicted by the tagging data due to a lack of large (fast growing) juveniles in the samples.

As explained at the beginning of this section, the von

Bertalanffy parameters used in the yield-per-recruit analysis were selected from published values due to a lack of suitable data for Belize populations. Parameters most commonly cited in the literature were chosen, i.e., those derived from Randall's (1964b) tagging data for the U.S. Virgin Islands (see Table 3.4).

3.4 Mortality in Conch Populations

Natural (M) and fishing (F) mortality rates may be estimated independently (Ricker, 1975; Pauly, 1984) or derived from the total mortality rate (Z=M+F). In this study, the latter approach had to be taken as there was insufficient data to do otherwise. F was derived from published estimates of M and a value of Z derived from a catch curve analysis.

3.4.1 Published values of natural mortality

Published natural mortality for Strombus gigas ranges from 0.08 to 8.62 (Table 3.6). The large variation stems from the fact that the mean age of populations studied and techniques of analysis used were different between researchers. The rate of M in conch decreases over a large portion of its life span (Appeldoorn, in press (b)). In light of this, only estimates of M corresponding to ages found in the Belize fishery are considered in this study. The objective being to meet the assumption of constant M over the fishable lifespan. The studies providing information on mortality corresponding to a fishable

Table 3.6

Values of published instantaneous natural mortality rate (M) for *Strombus gigas.* Corresponding average age (yr) calculated using Berg's (1976) von Bertalanffy growth parameters. Methods used to determine mortality were length-frequency analysis (LF) and tagging (T). (modified after Appeldoorn (in press(b)); Table 1)

SOURCE	LOCATION	M	AGE	METHOD
Randall, 1964a	Lameshur Bay, St. Johns, US. Virgin Islands	3.52	1.17	T
		3.40	1.39	T
		1.92	1.66	T
		2.55	1.91	T
Alcolado, 1976	S. Cuba, Diego Perez A	1.40	2.40	LF
		1.06	2.56	LF
	S. Cuba, Diego Perez B	1.39	2.40	LF
	S. Cuba, Cayo Anclitas	1.90	2.50	LF
	N. Cuba, Playa Cubanacan	1.39	2.50	LF
	S. Cuba, Cabo Cruz C	1.77	2.72	T
Baisre & Paez, 1981	Cuba	4.00	1.00	T
Iversen, 1983	Little Whale Cay, Berry Islands, Bahamas	2.90	1.50	T
Wood & Olsen, 1983	Western St. Thomas, USVI	0.19	1.75	LF
		0.04	2.75	LF
Laughlin & Weil, 1983	Venezuela	0.08	1.75	T
Olsen, 1985	Turks & Caicos Islands	0.08	1.50	LF
Appeldoorn, 1985	Media Luna, La Parguera, Puerto Rico	8.62	0.40	T
Appeldoorn, in press(c)	Media Luna, La Parguera, Puerto Rico	1.05	3.30	T
		0.52	4.25*	LF
Munoz *et al.*, in press	Venezuela	0.10	1.75	T

* Adults only

age (age> two years) include: the tagging experiments by Appeldoorn (in press (c)) and Alcolado (1976), and length-frequency analysis by Alcolado (1976) and Wood and Olsen (1983).

Values of M provided by Wood and Olsen (1983) are equal to Z obtained for prerecruits (ages 1 to 2). The average mortalities for the first two year-classes in the populations they studied (M=0.12 and M=0.08) were the lowest documented for conch. Alcolado (1976) claims there was no intense fishing in the populations for which he calculated mortality but his estimations of M were much higher for the same age classes (eg., 1.06 to 1.90). Appeldoorn (in press (c)) provided values of Z estimated during times of no fishing (Z=M=1.05) and when fishing was known to occur (Z=2.19). To discern which of the above estimates would be best for modelling, the techniques used were evaluated and the likelihood of some assumptions being violated considered. It was concluded that no one value is more reliable and that the best approach for modelling would be to select two different values within the range published (M=0.1 and 0.5) and compare the results. A discussion on the difficulties of assessing M for _S. gigas_ is presented below.

When estimating mortality from tag returns, it is important that sampling be unbiased, tag loss minimal, migration accounted for and that tagging in no way affects behavior in terms of growth, mortality or sampling (Seber, 1982). There are several factors that tend to reduce the number of tagged conch one is able to recover (Iversen, 1983). Conch may migrate from the search area or bury and be overlooked. The tags may be shed or not spotted due to algae and encrusting organisms on the shells. Lastly, larger tagged conch may be removed by fishermen and tags not returned.

Alcolado (1976) made little mention of his tagging experiment, though he conceded that his estimate of M (1.77) may be biased high because of possible incomplete recovery. Appeldoorn (in press (c)) claims there are no substantial departures from the assumptions of equal catchability and survival in his study. He noted characteristics of conch biology which may affect catchability and should be considered when deciding on a random sampling design. These included the aggregated distribution of conch and possibility that clusters may be characterized by distinct size groups. Habitat preferences of juveniles and the possibility that areas may be differentially characterized by the abundance of juveniles and adults are also noted. By working with conch of fishable size, his concern over juveniles burying, mortality decreasing with age and fishermen selecting certain sizes of conch was minimal. To correct for emigration, he estimated the instantaneous rate of annual emigration (E) and subtracted this figure (E=0.48) from his original estimate of M (1.53).

To estimate total mortality from the decline in relative abundance of successive size classes of fish, one assumes that:

1) age can be estimated from length;
2) size classes are sampled in proportion to true abundance;

3) Z is the same in all age groups in question; and
4) age groups were equal in number at the time each was being recruited.

These assumptions however, may not be valid for Strombus gigas. It is difficult to determine age classes from a polymodal length-frequency because growth in shell length ceases when conch reach sexual maturity. The tendency of sub-yearling conch to bury will lead to an underestimation of abundance in earlier year classes and hence an underestimation of M (Appeldoorn, in press (a)). The decrease in M with age and temporal variability in recruitment of conch (Appeldoorn, in press (a); Alcolado, 1976) further complicates length-frequency analysis.

Alcolado's (1976) estimates of mortality for conch are based on fully recruited age classes, i.e., the last two annual classes. In Wood and Olsen's (1983) report, age classes were determined by probit analysis and age-class abundance was estimated after the method of Olsen and Koblich (1975). Appeldoorn (in press (b)) questioned Wood and Olsen's (1983) results claiming their calculations on the number of individuals within each mode are not a good match for their original length-frequency histogram. His recalculation of their data using a different method of analysis yielded a M of 1.03 at 1.75 years and 0.85 at 2.75 years. He also noted the possibility that the youngest year class may have been undersampled due to partial recruitment. If so, the first mortality figure would be increased further still.

3.4.2 Catch curve analysis

The instantaneous rate of total mortality (Z) is commonly defined by the expression:

$$N_t = N_o * e^{-Zt} \qquad (4)$$

where N_o = (initial) population size at time zero, N_t = number of fish remaining at the end of time 't' and e = mathematical constant 2.718 (Ricker, 1975). This relationship forms the basis for the catch curve analysis. If the age groups were equal in number at the time each was being recruited, Z can be calculated directly from the slope of a plot of log frequency of each age class on age. Techniques for estimating mortality via the analysis of catch curves and other methodologies (eg., mark-recapture experiments and cohort analysis) are reviewed by Ricker (1975), Seber (1982), Csirke and Caddy (1983), Jones (1984) and Pauly (1984).

Two catch curves were constructed with Belize data: 1) a plot of log frequency against length (Ricker, 1975), and 2) a length converted catch curve (Pauly, 1984). The size composition data used were collected during the dockside survey in June, 1985 and were considered representative of commercial catches. Sampling of the catch from each boat was random. It was assumed that the size distribution of conch landed differs little from month to month because fishermen are diving for conch in a variety of areas at any one time. The weights of market cleaned individuals sampled from the fishermen's landings ranged from 28.4 gm (1.0 oz) to 375.6 gm (13.3 oz). This corresponds to a range in shell lengths of 15.6 to 29.2 cm (Figure 3.2). The mode of the catch curve is situated at 23.0 cm which, using Berg's (1976) growth parameters, is equivalent to an age of 4.2 years. The regression describing the right hand limb of the first curve is given by the equation:

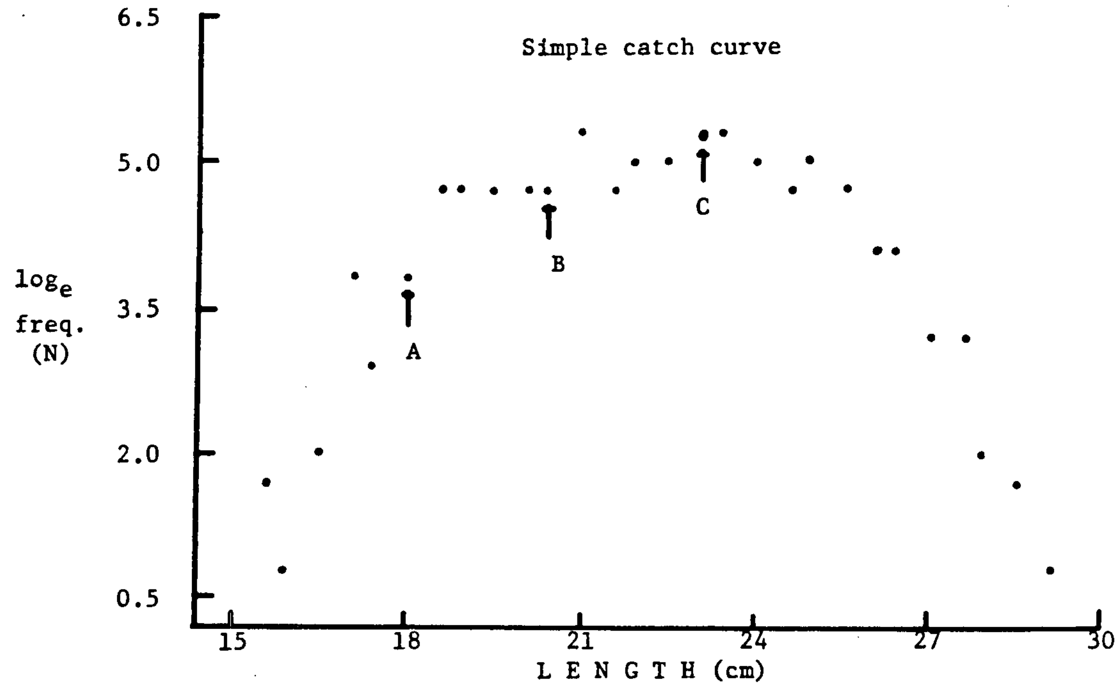
$$\log_e(\text{frequency}) = 22.5 - 0.72 \text{ Shell length (cm)} \qquad (5)$$

The confidence interval of the regression line is 0.72 $\pm$ 0.17 ($n=13$; $r^2=0.94$). The right arm of the length converted catch curve yields a line described by the following equation:

$$\log_e(N_i \frac{dl_i}{dt}) = 11.7 - 1.43 \log_e(t'_i) \qquad (6)$$

where N_i = frequency in age class i, dl/dt = growth rate of conch in i and t'_i = estimated age of the ith class. The confidence interval on the regression line is 1.43 $\pm$ 0.20 ($n=13$; $r^2=0.98$). If one assumes that conch increase in size by a constant absolute amount from year to year over the size range in question, the average value of Z for these year classes is estimated to be 0.72. However, if this assumption is wrong and growth rate is decreasing, this value will be an underestimate of Z. This is because of a piling-up effect where older size groups contain more age groups than do younger size groups. With Pauly's (1984) method, Z is estimated to be 1.43. This second approach takes the piling-up effect into account but as it requires the use of a juvenile von Bertalanffy growth formula to compute adult ages, it too is in question.

The final decision on which value of Z and M to use in modelling was made somewhat arbitrarily after examining the



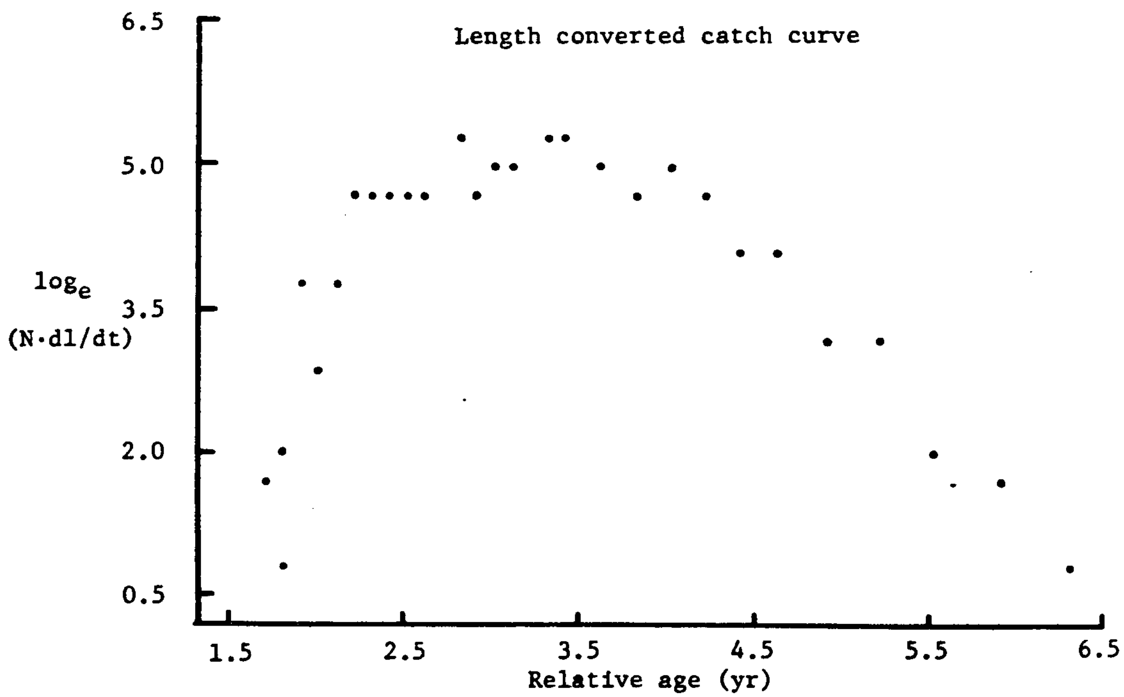


Figure 3.2 Catch curves constructed from size composition data on landings sampled in 1985. (A) regulation shell length, (B) regulation marketable meat weight, (C) mode at 23 cm.

results of several yield-per-recruit analyses, each conducted with a different value for M. I selected values Z=0.72 and M=0.10 and hence, predicted F to be around 0.62. Results of a YPR analysis using an M of 0.5 and a discussion on how variation in M and K influences YPR predictions are presented at the end of this chapter. I recognize the uncertainty likely to surround the results of a model based on a rough estimation of parameters, but in order to make judgements regarding management, have decided to select one set of parameters and describe potential variation of YPR thereafter.

3.5 Size and age composition of fishable populations

3.5.1 Average size of conch meats landed

The sex ratio of animals sampled during the dockside survey in 1985 was 1:1. Weights of marketed-meats ranged from 28.3 gm (1.0 oz) to 375.6 gm (13.3 oz). The average equalled 132.3 gm (4.7 oz); this is equivalent to 7.5 conch per kg or 3.4 per pound. Twenty-three percent of the meats in the sample were less than the minimum allowable meat weight of 85.1 gm (3.0 oz) (Figure 3.2). However, only three percent were less than 49.0 gm (1.7 oz) which corresponds to the minimum limit for shell length (17.8 cm) given a weight-length regression (functional) calculated for a pooled sample of juveniles and adults (n=214; r^2 =0.81; confidence interval for the regression line = 4.12 $\pm$ 0.24):

$$\log(\text{meat weight [gm]}) = -3.46 + 4.12 \log(\text{shell length [cm]}) \quad (7)$$

The discrepancy in the two size limits, therefore, allows fishermen to violate the minimum weight restriction.

The average weight of a market cleaned conch landed prior to the implementation of the size limit are cited as follows:

SOURCE	YEAR	MEAN SIZE in gm (and ounces)	CO-OP
Fisheries Department	1973	108.0 (3.8)	Placencia
" "	"	76.5 (2.7)	National
Blakesley (1976)	1976	66.0 (2.3)*	?
Brownell (1978)	1976	50.0 to 70.0 (1.8 to 2.5)	?
This study	1985	131.0 (4.7)	ave. for cooperatives

* Estimated weight given the average length of 19.1 cm quoted by Blakesley.

It would appear that the size restrictions have discouraged the harvest of juveniles; however, the number of undersize animals sold on the local market is unknown. The average meat size landed in the Turk and Caicos is higher than that quoted above for Belize. Olsen (1985) measured 4.6 conch per kg (2.1 conch per pound) in the catches he sampled. This is equivalent to an average meat weight of 215 gm (7.6 oz).

Among the cooperatives, Placencia landed the largest conch meats. The average meat size landed by all other cooperatives were relatively the same:

AVERAGE SIZE OF CONCH MEATS, 1985

Coop./Area	Ave. meat weight in grams	(sd)	N
CO-OP:			
Caribeña	128.1	(43.1)	43
Northern	126.4	(53.4)	660
National	129.4	(66.9)	1229
Placencia	150.0	(39.5)	437
AREA:			
San Pedro	128.1	(43.1)	43
Caye Caulker	161.0	(50.5)	148
Belize City	156.7	(56.2)	268
Placencia	152.9	(36.7)	279
Turneffe	171.5	(62.4)	119
Lighthouse Reef	93.8	(55.8)	539
Edge of reef	191.6	(56.7)	128

The largest meats measured during this study were delivered by two divers from National. These fishermen dove to depths of about 13 m in the channel of the main reef east of Belize City. Their landings were sampled on three days and the average meat weight of conch weighed was 191.6 gm (6.8 oz). Each conch captured was an adult with a thickened shell lip. Conversations with fishermen and examination of past landings receipts indicate that the intensity of fishing has been greatest in the Lighthouse Reef area (an outer atoll) and least along the outer edge of the main barrier reef. This probably explains the variation in average size of conch between these two areas; however, fishermen also believe that morphometric differences between the populations may also be a factor. They claim that lipped conch within the lagoons of Lighthouse Reef have always been smaller than those along the main reef. There are not enough data to say which areas within the inner reef are most heavily fished.

3.5.2 Mean age at recruitment

Mean age at recruitment (t_r) is defined as the time when conch are recruited to the exploited area, and are visible to the fishermen. The average age at which juveniles first emerge from the sand and appear in significant numbers is thought to approximate one year. This value of t_r is based on surveys conducted at Tres Cocos and assumption that the pulse of juveniles observed there in July, 1982 and June, 1983 are recruits of the previous year's spawning.

3.5.3 Mean age at first capture

Mean age at first capture is commonly regarded as the average minimum size at which the fish are capable of being retained by the fishing gear. Since conch are collected by hand, it is more appropriate to say that t_c is the mean minimum size selected by the fishermen. Landings composition data obtained from cooperatives for this study indicate a mean age of first capture of 2.2 years. This is the age corresponding to the minimum legal shell size of 17.8 cm. Having observed fishing operations at sea and the sale of sublegal sized animals on local markets, I suspect that a significant number of conch averaging 15 cm are caught. This means that the average age of capture may be as low as 1.7 years. However, since I have no data on conch landed outside the cooperatives, I have choosen a t_c of 2.2 years with which to model.

3.5.4 Longevity

Longevity of Strombus gigas has been estimated in a number of different ways. Berg (1976) calculated longevity using the von Bertalanffy formula whereby tmax is equated with the time required to reach 95% of the maximum length (Taylor, 1962). With this method, various estimates can be obtained for longevity depending on the K value used; Berg's (1976) estimate was 6.0 years using Randall's (1964b) data (K = 0.516). Another way of calculating longevity is to sum the time estimated for each stage of the life-cycle. Berg (1976) obtains a value of 5.7 years using this method. Hesse (1976) claimed lip-thickness could be equated with age. Based on a lip thickening rate of 1.25 mm/month (n=26), she estimated longevity to be 5.5 years. Coulston et al. (in press) observed a constant weight gain in adults and estimated mean longevity to be 12 years with a range of 8.4 to 26.0 years. Based on oxygen isotope studies of the conch shell, Wefer and Killingley (1980) estimated a longevity of 7.0 years for animals in Bermuda. The average of the above values (7.0 yr.) was used for modelling in this study.

3.6 Yield-Per-Recruit Analysis

Results of the Beverton-Holt yield-per-recruit computations for Strombus gigas, are given in Figure 3.3. The eumetric fishing curve, the eumetric yield curve and position of the Belize conch fishery in 1985 are also indicated on the yield

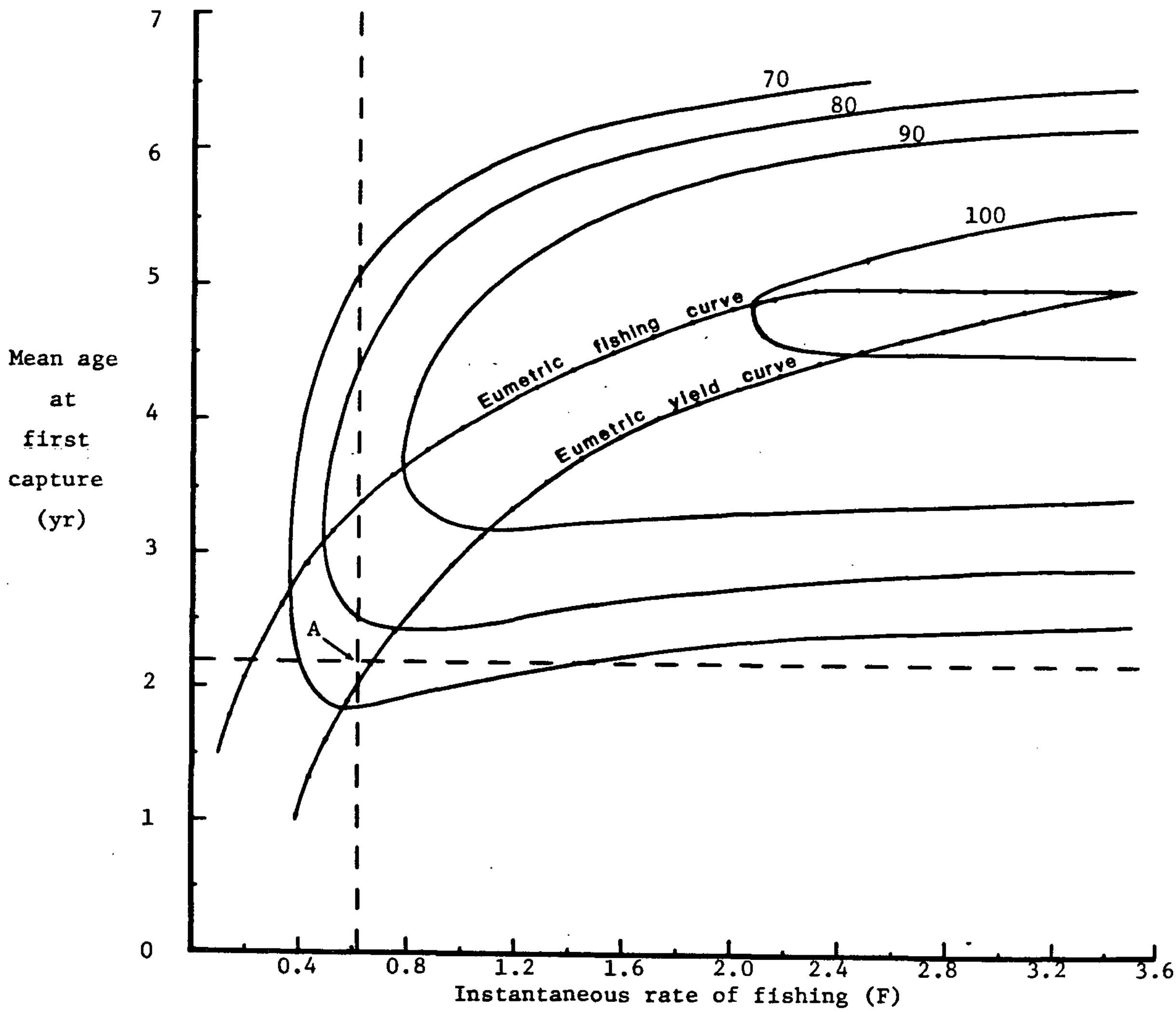


Figure 3.3 Yield contour diagram for Strombus gigas. (Yields shown are in grams per conch, computed by the Beverton-Holt method using t_r=1.0 yr, M=0.1, K=0.516, $W\infty$(marketable meat)=191 gm, t_o=0.0 yr and t_{max}=7.0 yr. Point A represents rate of fishing and mean age of first capture in 1985.)

isopleth diagram.

Assuming M=0.1, there is a sharp increase in yield at low fishing pressure. Thereafter, increases in yield are more gradual. Once F=0.8, the addition of fishing pressure for a given harvest size (t_c) has little effect on the yield function. Beyond the age of 3.0 years the gain in yield is minimal with increase in harvest size and below three years, yield is decreased significantly. The change in yield/recruit with age at first capture for the rate of fishing observed in Belize in 1985 (F=0.6) is as follows:

YIELD/RECRUIT @ F=0.6

t_c	YPR (gm)
1.0	52
1.5	64
2.0	73
2.5	80
3.0	84
3.5	85
4.0	83
4.5	78
5.0	70

Yield-per-recruit is expressed as a function of fishing mortality in Figure 3.4 and as a function of age at first capture in Figure 3.5. The maximum yield-per-recruit and corresponding fishing mortality (F) for a given mean age of entry (t_c) and the tangents of the eumetric fishing curve are given below:

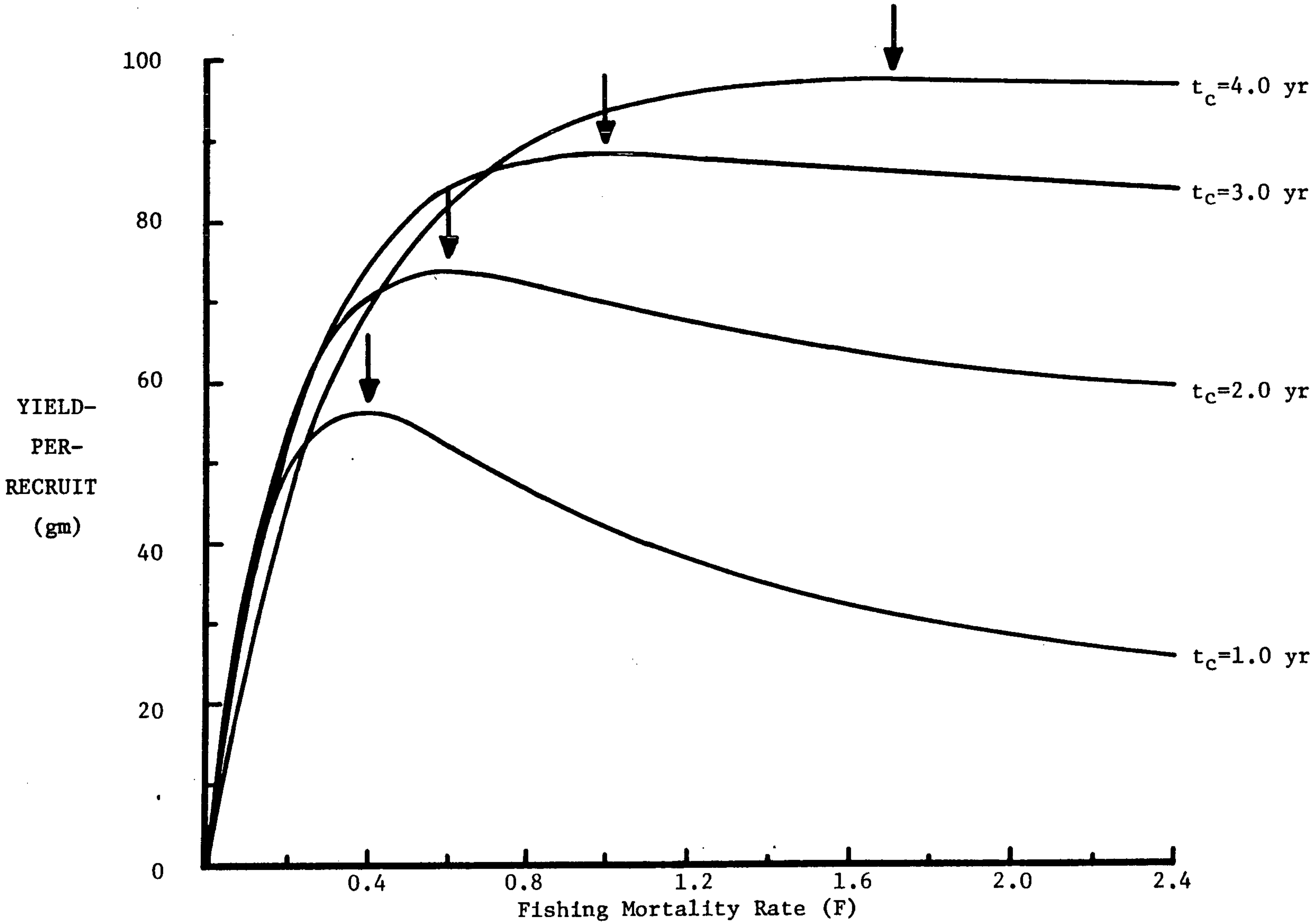


Figure 3.4 Yield-per-recruit as a function of fishing mortality; (↑) maxima

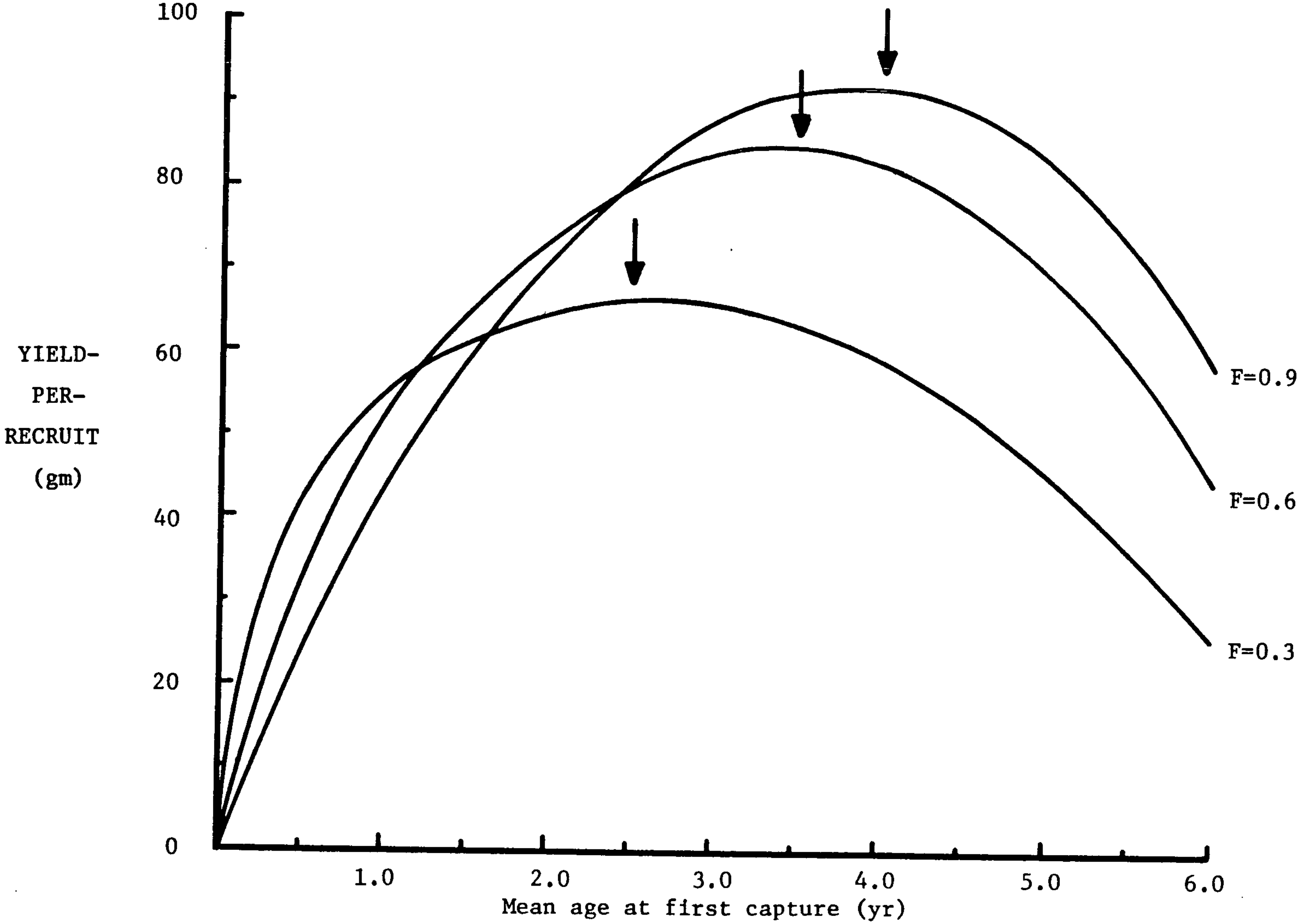


Figure 3.5 Yield-per-recruit as a function of age at first capture; (↑) maxima

TANGENTS OF THE EUMETRIC YIELD CURVE

t_c (yr)	Shell Length (cm)	YPR_{max} (gm)	F
1.0	10.4	56	0.4
1.5	14.0	65	0.5
2.0	16.7	73	0.6
2.5	18.8	81	0.8
3.0	20.4	88	1.0
3.5	21.7	94	1.3
4.0	22.7	98	1.7
4.5	23.4	100	2.5
5.0	24.0	101	3.5

TANGENTS OF THE EUMETRIC FISHING CURVE

Fishing Mortality	YPR_{max} (gm)	t_c (yr)	Shell length (cm)
0.1	35	1.5	14.0
0.2	54	2.0	16.7
0.3	67	2.5	18.8
0.4	75	3.0	20.4
0.5	80	3.0	20.4
0.6	85	3.5	21.7
0.7	88	3.5	21.7
0.8	90	3.5	21.7
0.9	92	4.0	22.7
1.0	94	4.0	22.7

The position of the conch fishery of Belize in 1985 is estimated to be at F=0.6 and t_c=2.2 years. To obtain a maximum yield using the observed t_c, this rate of fishing is appropriate. However, the best t_c for F=0.6 is 3.5 years. At the earlier t_c of 2.2 years, 88% of the maximum yield possible for F=0.6 is realized.

There is question as to how much confidence one can place in a yield computation based upon eight parameter values which were estimated from a limited amount of field data and accumulated knowledge on the species. The shape of the response surface generated by the model could be affected in any number of ways by errors in parameter estimation (Tester, 1952;

Gulland, 1983). The difficulties of estimating vital statistics of exploited tropical species by conventional techniques are well documented (Stevenson and Saila, 1977; Munro, 1979; Pauly, 1984). For Strombus gigas , inprecision of estimates of parameters K and M are most likely given the problems in describing growth and assessing M. Hence, both parameters were fluctuated to assess the potential variance in yield predictions. When yield-per-recruit is calculated with the coefficient of growth (K) varying between 0.4 and 0.6, the maximum YPR (tc=2.2) increases from 56.9 gm at K=0.4 to 89.1 gm at K=0.6 (Figure 3.6). If K increases relative to M, the cohort will maximize its biomass in a shorter time period. If M has been underestimated, a revision of the YPR analysis would suggest harvesting a smaller size at a greater rate (Figure 3.7). With an M of 0.5, YPR would be maximized at a F of 0.6 when tc = 2.0 years as opposed to 3.5 years as predicted with M = 0.1. Alternatively, if tc=2.2 years, the fishing mortality rate at which YPR is maximized at about 2.0 and not 0.6 as predicted for M=0.1. The absolute value of the yield would also decrease with a higher M:

YIELD-PER-RECRUIT ANALYSIS WITH M=0.5

Tangents of the Eumetric Yield Curve:

tc (yr)	Shell Length (cm)	YPRmax (gm)	F
1.0	10.4	25.5	0.7
1.5	14.0	29.8	1.0
2.0	16.7	30.0	2.0
2.5	18.8	34.5	4.8
3.0	20.4	33.6	5.8
3.5	21.7	30.9	6.5
4.0	22.7	27.2	6.8

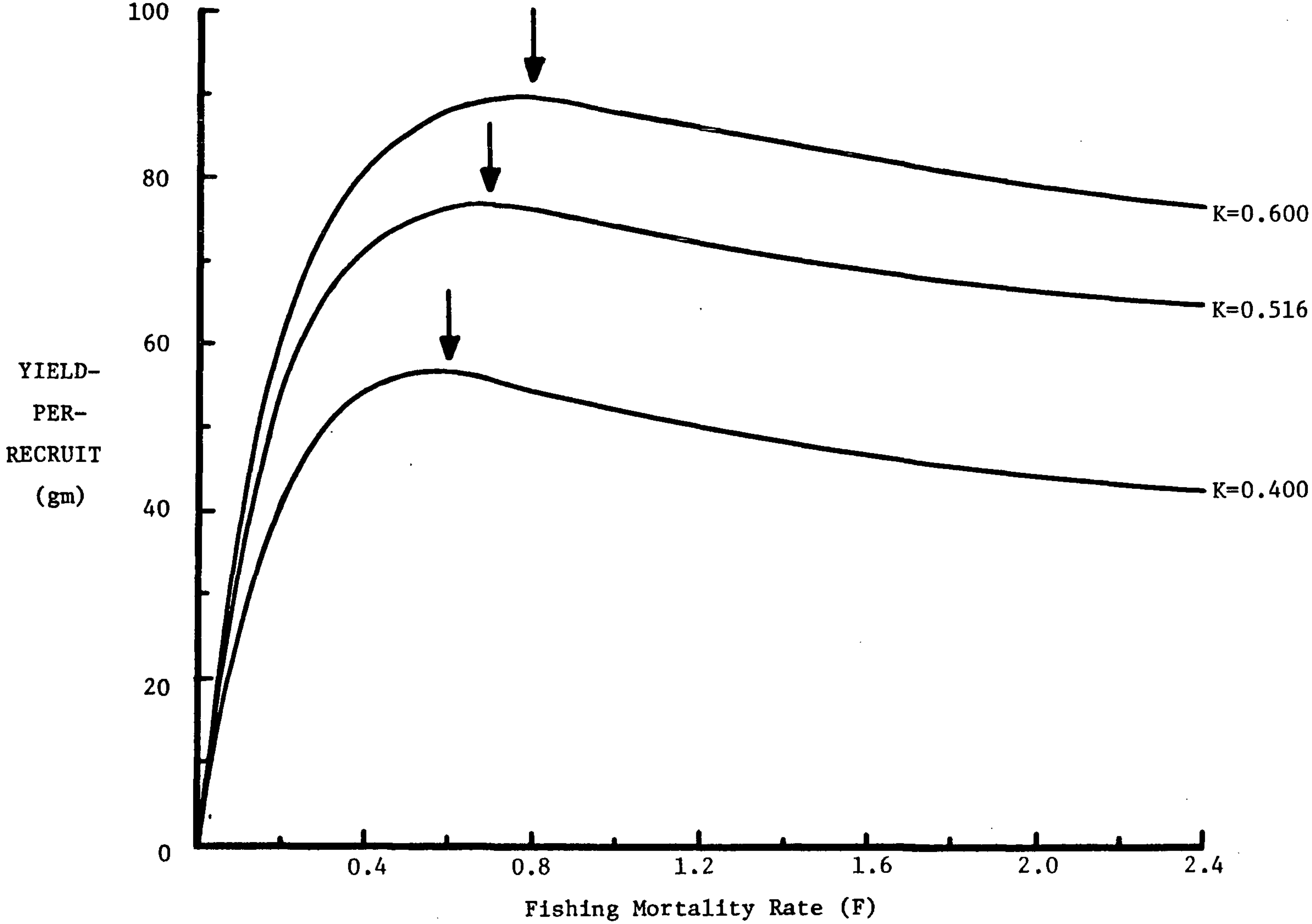


Figure 3.6 Change in yield-per-recruit with variation in K. Mean age at first capture = 2.2 yr; (↑) maxima

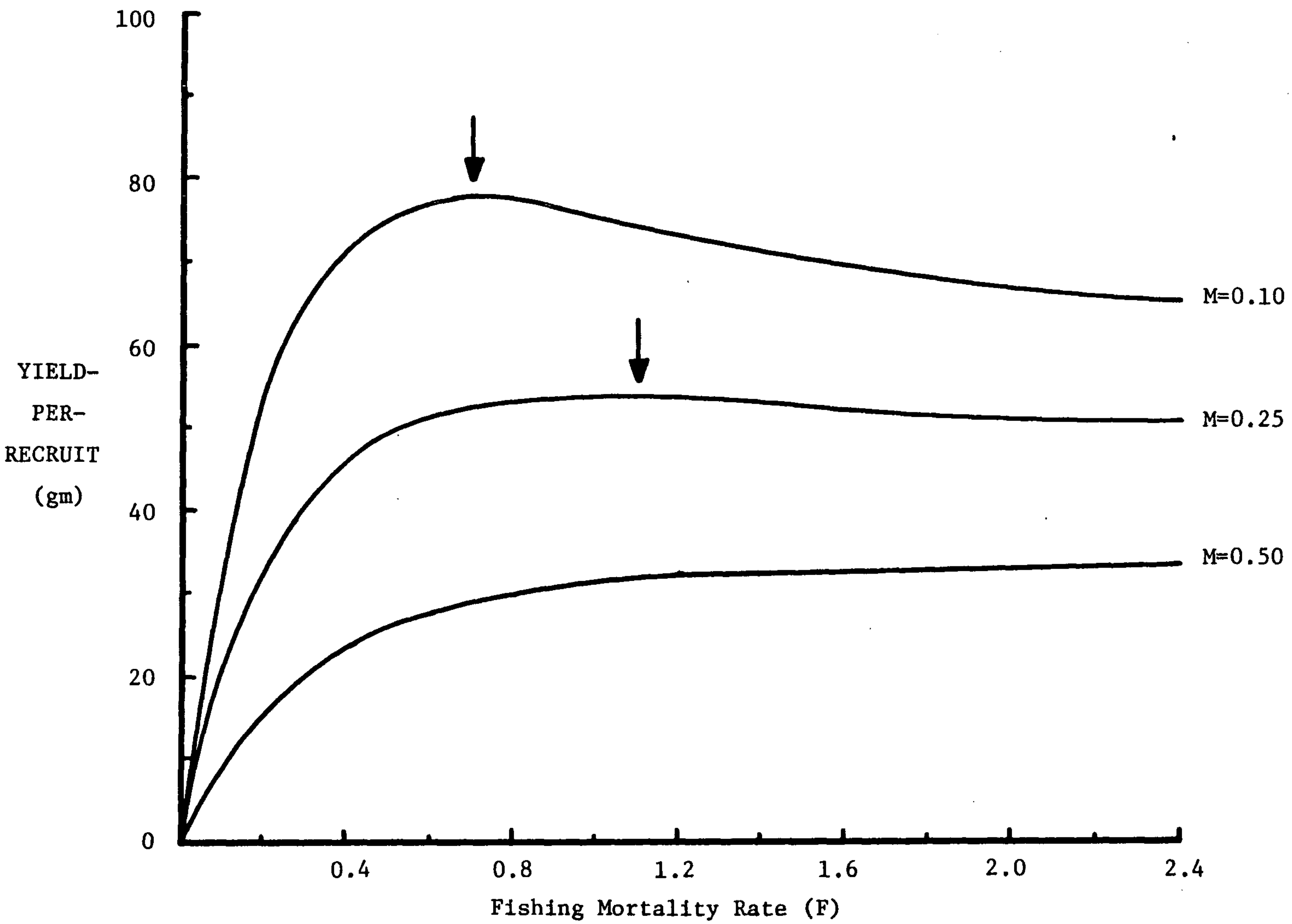


Figure 3.7 Change in Yield-per-recruit with variation in natural mortality (M)
Mean age at first capture = 2.2 yr; (↑) maxima

Tangents of the Eumetric Fishing Curve:

F	YPR_{max} (gm)	t_c (yr)	Shell Length (cm)
0.2	17.5	1.0	10.4
0.4	24.8	1.5	14.0
0.6	28.2	2.0	16.7
0.8	30.3	2.0	16.7
1.0	31.5	2.0	16.7
1.5	32.7	2.0	16.7
2.0	33.5	2.5	18.8
2.5	34.0	2.5	18.8
3.0	34.2	2.5	18.8

With a M/K value of 0.194 (0.1/0.516), the gain in biomass from growth is greater than the loss from mortality. The lower value of M would, therefore, predict that the stock would contain many relatively large conch in the absence of fishing. In terms of getting the best yield from a recruit level, it would pay to fish relatively lightly with a high size at first capture. The results of a YPR analysis with M=0.5 would on the other hand suggest fishing a small size at a high rate. The low values of YPR based on the higher value of M seem unrealistic. This suggests that either the parameters are poor estimates of true values or some assumptions of the model are violated. In sum, this model may be viewed as a qualitative description of what is happening. It can not be used to make quantitative predictions, for example, of the effect on the catch of changing the amount of fishing by 10%. However, it does provide a conceptual framework on which refinements can be made and the collection of relevant information, planned. The results and implications for management are discussed more fully at the end of Chapter Six.

CHAPTER FOUR

The Harvest Sector

4.1 Development of the Small-Scale Fisheries of Belize

The fishing industry of Belize was centered largely around a trap fishery for lobster until the 1960's (Thompson, 1945; Idyll, 1962; Vega, 1977). Thereafter, it boomed with the formation of fishing cooperatives, development of markets in the United States and advances in diving technology (i.e., introduction of mask and fins). Both the number of species exported and the area fished increased. By the mid-1960's, cooperatives were exporting lobster, conch, shrimp and filleted scale fish, and to a lesser extent, turtle (shell and meat). Skindiving became popular and the area of fishing was no longer contained to the northern lagoon where conditions for lobster trapping were best (Idyll, 1962). Fishermen began to fish in deeper waters and along the margins of patch reefs and cayes in the southern lagoon, the barrier reef and outer atolls.

Shortly after this sudden expansion in the industry, the Government of Belize established a lobster management system (Allsopp, 1968). Harvest restrictions implemented through this system included a size limit, closed season and quota. These were observed by the cooperatives and hence, set precedence for fisheries management in Belize. Another important event influencing the course of fisheries development was the introduction of a government policy in 1965 which allowed the fishing cooperatives only to export lobster and conch.

Since the 1970's, efforts have been made to diversify fisheries to increase employment opportunities and lessen the intensity of fishing on lobster and conch. Progress was first made in the scale fish industry with the establishment of an export market for whole fish in 1974. Six shrimp trawlers were also acquired in the early 1970's, but shrimp exports remained low and over the years eventually dropped to zero because of no fishing (Government of Belize, 1983a). This industry was re-established in 1985 through joint ventures with foreign shrimping companies and is now the second most important in terms of economic value (BFCA, 1985a). There has been much interest in a deep sea finfish industry but little progress made in its development (BFCA, 1983a; CARE, 1983; The Reporter, 1985).

At present cooperatives are trying to establish markets for a variety of products including stone crab claws, clams and shark. In 1985, they were successful in finding a market for fresh fish, and fillet production has subsequently increased. The potential of other fisheries (eg., sponges, mangrove oysters, mussels, seaweed and aquarium fish) are being investigated by the Fisheries Department and private entrepreneurs. Plans to farm freshwater products (eg., prawns, Tilapia and catfish) are also materializing. The government advocates development in aquaculture and the interest of investors is apparently high. Latest accounts of the status of fisheries in Belize include those by Gibson (1978), Government of Belize (1982a), Perkins (1983) and Shusterich (1984).

The accomplishments Belize has made in small-scale fisheries development through the efforts of the government, the dedication of fishermen and establishment of fishermen-owned cooperatives are well recognized (Eberle, 1977; Brownell, 1978; Gibson, 1978; FAO, 1979). The sale of luxury items directly to wholesale firms in the United States and the availability of financing through the cooperatives have transformed what was once a subsistence fishing economy into a modern commercial one. Belizean fishermen still concentrate on inshore fisheries and use small vessel sizes (3 to 10 m) and simple gear types (skindiving, handmade traps, handlines). However, they also own outboard motors, keep their catch on ice while at sea, and receive prices on par with American fishermen for their exported commodities. The fishing cooperative system, operations within each cooperative and gross earnings of cooperative members are described in the section to follow.

4.2 Fishing Cooperatives

Twelve fishing cooperatives have been registered in Belize; Northern was the first cooperative to be formed in 1959 followed by Placencia, Caribeña, National and finally, Sarteneja. With the exception of Placencia, these cooperatives are located in northern Belize (Figure 1.1). The Sarteneja cooperative was registered in 1969, started exporting conch in 1971, and was closed in 1982 due to financial difficulties.

The remaining registered cooperatives are in the south of Belize. Two are no longer active: Toledo Fishermen Cooperative in Punta Gorda and Freshwater Fishermen Society Ltd. in Rancho Dolores. The three cooperatives in operation the longest include: Southern Foreshore Cooperative in Punta Gorda (registered in 1971), Central Fishermen Cooperative in Dangriga (registered in 1973) and the Barranco Fishermen Cooperative also in the Toledo District (registered in 1983). These cooperatives have no freezing facilities and their products, mainly scale fish, are sold exclusively on the local market (Government of Belize, 1982a). Their membership in 1984 was 40, 30 and 19, respectively. The most recently established cooperatives are located in the villages of Hopkins and Independence in the Stann Creek District.

The major objective of the fishing cooperatives in Belize is "to promote the economic and cultural welfare of its members by utilizing their united funds and united efforts for the more efficient production, distribution, processing and sale of the products of their skill and labours" (National, 1958). The facilities, and processing and marketing systems of the exporting cooperatives are reviewed by Tengberg-Hansen (1968), Synder (1976) and Seeman (1977). Each cooperative has refrigeration facilities (ice making machine, cold storage space and blast freezers), unloading docks, a processing plant, office, marine fueling station and store (for gear sales). Most products, eg., lobster tails, market cleaned conch, shrimp tails, whole fish and fish fillets are frozen.

The cooperatives are well organized. Each one has an elected governing body (management committee) drawn from the member fishermen and an Executive Secretary. The latter is responsible for recording the whole of the financial transactions of the registered society (Vasquez, 1982). Specific duties of the management committee are outlined in each cooperative's By-laws. In brief, they plan and control the use of the cooperative's resources including the funds, materials and machinery.

Entrance requirements to join a cooperative are generally the same for each cooperative. Prospective members must be at least 18 years old, and a bona fide national or legal resident of Belize. If they have previously been a member of another cooperative, they must have resigned in good standing. Upon entering the cooperative, members are required to purchase shares in the cooperative and pledge to buy more over a given period of time. The number of shares varies with cooperative. Once accepted, the member is placed on probation and must meet certain production requirements. Members should also reside and fish within the cooperative's area of operation which is specified when a cooperative is formed. However, this law is disregarded generally. Fishermen work in areas all along the reef, and on occasion, are found to be members of a cooperative other than the one in their home town. Cooperatives strongly encourage their members to remain loyal, especially in small cooperatives for which production is low and overhead high.

The cooperatives purchase and then process the products from their members. At the end of a financial year, after operating expenses have been deducted, the members are given a second payment which is based on each fisherman's proportion of total catch. Each cooperative secures its own export markets and negotiates its own prices. The first payment is based on the going price as stated in the Fishery Market News Reports of the U.S. National Marine Fisheries Service. The average foreign market prices received by the cooperatives in Belize over the years are given in Table 4.1. The same first payment is given by all cooperatives to discourage members from selling to cooperatives other than their own. For the fiscal year of 1985, first payment for lobster was $13.23 BZ/kg ($6.00 BZ/lb) and for conch, $4.96 BZ/kg ($2.25 BZ/lb). Price per kg for scale fish varies for the class of fish (Appendix IV). In May 1985, whole fish ranged from $1.46 BZ/kg ($0.66 BZ/lb) for Class C species to $2.76 BZ/kg ($1.25 BZ/lb) for Class A species; fish fillet ranged from $2.20 BZ/kg ($1.00 BZ/lb) to $3.86 BZ/kg ($1.75 BZ/lb). Prices have increased in recent years with the first payment for lobster and conch set at $15.56 BZ/kg ($7.00 BZ/lb) and $6.67 BZ/kg ($3.00 BZ/lb), respectively in the fiscal year of 1987.

Second payment varies among cooperatives as it is based on

Table 4.1

Exports of major fish commodities and average price received on the foreign market

CAL. YEAR	Weight Exported (kg) CONCH	LOBSTER	FISH	SHRIMP	Price/kg* CONCH	LOBSTER	FISH	SHRIMP
1956	7393F	72375	40654	0	0.26	1.72	0.42	-
1957	12755F	107371	50077	0	0.37	1.57	0.37	-
1958	5478F	166257	50161	0	0.29	1.34	0.37	-
1959	4346F	181913	51613	0	0.29	1.32	0.44	-
1960	1725F	164983	58212	0	0.33	1.68	0.42	-
1961	47533F	120802	62715	0	0.75	1.37	0.55	-
1962	25812F	131366	79253	0	0.53	1.48	0.57	-
1963	39150F	156655	108417	0	0.53	1.76	0.49	-
1964	54840F	182800	43772	0	0.49	2.62	0.60	-
1965	35789F	195728	72712	0	0.46	3.33	0.60	-
1966	61644F	175951	94757	10478	0.57	3.22	0.55	1.90
1967	174545F	143777	138577	103420	0.49	2.82	0.55	2.12
1968	217773	180472	181440	63821	0.68	3.75	0.55	2.23
1969	359666	188952	108638	48517	0.88	7.72	0.95	2.27
1970	364819	183755	111816	1896	0.99	7.72	0.99	3.31
1971	477169	210869	95315	17431	1.30	9.33	1.37	3.31
1972	562634	227928	52018	11227	1.34	11.27	1.32	3.97
1973	506653	156904	47922	6495	1.43	11.86	1.26	4.48
1974	443008	214256	61433	6994	1.43	13.23	1.23	3.97
1975	406711	219655	95569	12803	3.09	17.39	2.43	7.72
1976	359750	210796	190261	28644	3.97	18.74	2.07	8.82
1977	245306	167532	208846	32931	3.97	18.74	2.27	8.82
1978	208996	172141	191577	29325	4.41	22.05	2.56	8.82
1979	183209	201069	128985	20797	7.16	29.76	2.84	13.23
1980	140071	176876	161675	15785	7.72	30.86	3.59	17.09
1981	113853	305817	205765	10296	9.94	36.38	3.44	17.09
1982	154836	276745	219543	3424	8.62	36.38	3.53	22.05
1983	181249	286457	294649	3220	9.37	38.58	3.68	25.35
1984	239368	264031	137894	0	10.71	38.36	4.30	-
1985	167968	315143	89318	45713	12.13	36.60	4.39	15.43
1986	105462	221992	171928	107027	13.62	42.22	6.55	22.05

$$\text{*Price/kg} = \frac{\text{total value of exports (\$BZ)}}{\text{total weight exported}}$$

F Conch fillets (vs market-cleaned meats)

SOURCE: Belize Fisheries Department

the profitability of each and distribution of overhead among the products handled. The final value is decided upon by the individual management committees. The larger cooperatives can usually afford to give their members a higher second payment:

SECOND PAYMENT MADE TO FISHERMEN
($BZ/kg)

Cooperative	1984/85		1985/86		1986/87	
	Lobs.	Con.	Lobs.	Con.	Lobs.	Con.
Northern	$19.29	$0.95	$15.87	$0.84	$21.50	$2.31
National	$16.53	$1.65	-	-	$21.50	$2.76
Caribeña	$6.61	$1.43	$8.82	$1.32	$9.37	$1.32
Placencia	$2.20	$0.33	-	-	-	-

Among the principal fish products exported, lobster has by far been the greatest money earner. During the 1970's, lobster accounted for roughly 70% of the total value of fish exports while conch accounted for 20%, scale fish 5% and shrimp 2.5%. The distribution of total value of a cooperative's production of lobster, conch and scale fish by species group for 1984 was as follows:

PERCENT OF TOTAL SALES OF THE THREE MAJOR
FISH COMMODITIES BY SPECIES FOR 1984

	Lobster	Conch	Fish
National	68	28	4
Northern	87	8	5
Caribeña	75	16	9
Placencia	48	27	25

An increase in price for conch on the export market has kept the value of exports high despite the decrease in terms of weight. The rate of increase in price received for conch exports has been greatest among the commodities. From 1982 to 1986 alone, export prices increased by nearly 60% (i.e., from $8.62 BZ/kg to $13.62 BZ/kg). In comparison, the price of lobster increased by 16% from $36.38 BZ/kg in 1982 to $42.22 BZ/kg in 1986. Fish increased in price significantly over this period but the absolute amount still remains low (eg., $6.55 BZ/kg in 1986).

To ensure that some of the production of the highly priced export items are kept for domestic consumption, the Belizean Government requires that the cooperatives sell 5% (by weight) of their lobster, 10% (by weight) of their conch and a prescribed poundage of scale fish on the local market at controlled prices. In 1985, the ceiling prices for conch and lobster were $3.31 BZ/kg ($1.50 BZ/lb) and $6.61 BZ/kg ($3.00 BZ/lb), respectively. This is far lower than what cooperatives pay fishermen for lobster and conch. As a result, cooperatives are reluctant to sell top grade product on the local market. In 1984, 6.2% of lobster and 4.4% of conch processed by cooperatives remained in Belize:

PERCENT OF COOPERATIVE PRODUCTION SOLD LOCALLY

YEAR	Lobster	Conch	Fish	Shrimp
1980	5.9	12.6	44.8	38.0
1981	3.6	7.5	43.4	45.2
1982	3.5	4.9	36.0	38.4
1983	4.5	6.7	28.2	31.8
1984	6.2	4.4	45.4	100.0

Prior to a resurgence of shrimp production in 1985, landings of this commodity was too poor to maintain exports. Nearly half of the scale fish produced in Belize is sold locally; the rest is exported to markets in the U.S.A., Jamaica, Honduras and Guatemala.

Studies on the economics of fishing in Belize are limited. CARE (Cooperative for American Relief Everywhere Inc., 1982) has conducted a study on the financial status of the fishing cooperatives which pinpoints the central issues in cooperative management. McElroy (1965) presented a profit analysis of lobster trap fishermen and Baird (1973) made an assessment of a proposed snapper fishery. There is no documentation of the costs entailed fishing conch. Such research was beyond the scope of this study. However, it was possible to determine the average gross income of fishermen from cooperative records of the annual production of each member and an estimate of the price paid to fishermen (Table 4.2). The average gross earnings made by each member of National are given below. The variance around each figure is high because many members fish on a part-time basis and others record the catch of independent fishermen under their name. Earnings from conch alone were separated from those generated through the sale of all three major commodities:

AVERAGE GROSS INCOME OF FISHERMEN *

Fiscal Year	Average for membership (N)	Average earnings from the sale of conch (N)
1979	$10,408 (156)	$3,135 (102)
1980	$11,250 (141)	$2,569 (90)
1981	$19,117 (181)	$2,841 (120)
1982	$14,512 (226)	$2,690 (155)
1983	$15,190 (281)	$2,865 (214)
1984	$12,966 (302)	$3,637 (241)

* Values given in $BZ and number of fishermen represented indicated in brackets.

The average annual income of paid employees in Belize is estimated to be $6,000 BZ (Bolland, 1986). The self-employed

Table 4.2

Prices/kg received by fishermen for major fish commodities

FISCAL YEAR	CONCH	LOBSTER	FILLET	WHOLE FISH
1967	0.40	3.92	0.68	-
1968	0.53+	4.48+	1.21+	-
1969	0.64	5.00	1.26	-
1970	0.88*	7.21*	1.06	-
1971	1.15	9.61	1.23	-
1972	1.32	9.52	1.76	-
1973	1.65+	11.84+	1.74+	-
1974	1.98	14.18	1.72	1.32
1975	3.00	17.15	2.87	1.32
1976	3.26	19.84	3.48	1.41
1977	3.68	17.70	3.88	1.28
1978	3.70	20.94	4.10	1.28
1979	3.81	22.20	4.45	1.59
1980	5.49	23.15	5.40	1.83
1981	6.55	30.31	5.49	2.29
1982	6.77	28.11	5.34	2.49
1983	6.39	30.31	5.49	2.58
1984	6.75	27.54	5.93	2.56

Price/kg = cost of sales ($BZ)/ total production
Cost of sales = initial purchases + second payment
Production = exports and weight sold locally

Source: Profit and Loss Statement,
National Cooperative Financial Reports

* only exports known; value overestimated

+ data not available; value = extrapolation fisherman earns twice as much, but these gross earnings do not account for the investment in boats, and cost of fuel, ice and repairs.

4.3 The Conch Fishery

The conch fishery in Belize has two components: the day fishery and the trip fishery. To standardize units of the fishing effort, differences between the fishing strategies of "day" and "trip" fishermen had to be identified. Notable characteristics of the fishery and variation in the activities of conch fishermen are described below.

4.3.1 The fishing fleet

Three boat types dominate among the fishing vessels of Belize: the skiff, dugout canoe and sailboat. Their design and construction are reviewed by Shawyer (1975). Skiffs (Figure 4.1) were introduced in Belize in the early 1960's. They range in length from 4 to 6 m and are outboard powered by engines of generally 20 to 40 hp. They are fast and maneuverable and used almost exclusively for short-range fisheries. Popular among fishermen who trap lobster, this type of boat is found primarily in the Northern waters of Belize.

A wide variety of dugout canoes are used by fishermen in Belize (Craig, 1966). In this report a distinction is made between canoes greater and less than 5 m. The small canoes

Figure 4.1 V-bottom skiff (outboard)

Figure 4.2 Small dugout canoe (LOA<5m)

(Figure 4.2) are taken on sailing trips. The large dugout canoes may reach up to 10 m and are outboard powered with 9.9 to 25 hp engines (Figure 4.3). Some may also have sails. This larger variety is used in both the day and trip fishery for conch. On fishing trips, fishermen equip the dugout with a small ice box and may remain at sea (or camp on an island near their fishing grounds) for up to five days. Dugouts are slower than skiffs but less expensive in the long run. Unlike skiffs with an average longevity of four years, dugout canoes will last more than a decade. The canoes, or "dories" as they are called in Belize, are most popular in Carib fishing communities in southern Belize. Boat type is one of the many differences in fishing practices between the ethnic groups of Belize. Other differences between the Mestizos in the north, Creoles centered around Belize City and the Garifunas in the south are reviewed by Craig (1966) and Price (1986).

Sailboats are the largest of the three boat types ranging in length from 7 to 11 m and drawing 0.8 to 1.3 m of water (Figure 4.4). Sails are fore and aft rigged with a jib and main sail. Most boats have an outboard (9.9 - 30 hp) as an auxiliary source of power, and in recent years, several boat owners have had inboard diesel engines installed. There are two basic types of sailboats used by fishermen in Belize: the smack and "dry-boat". The smack is characterized by a live well incorporated amidships and is used most commonly in the fishing of scale fish (Craig, 1966). The dry-boat first appeared in the 1960's when fishermen began to store their catch in ice (Price, 1986).

Figure 4.3 Large dugout canoe or "dory" (LOA> 5m)

Figure 4.4 Sailing craft ("dry-boat")

Instead of a live well, the dry-boat has an icebox amidships. Somewhere between 800 to 1100 kg of ice is loaded per trip. This ice will last approximately 10 days in the insulated fish boxes.

The main advantage of the sailboat is that it can accommodate five to six men on extended fishing trips. Once a fishing ground is reached, the sailboat is anchored and used at the local base where men store their catch, cook and sleep. Small dugouts, one per crewman, are used for the actual collection of conch. Sailboats may last for 15 years when kept in good condition. Maintenance requires hauling the boat on the average of twice a year for painting and repairs. To cover the costs entailed as well as the initial purchase of the boat, sailboat owners are awarded an extra share of the catch each trip. The cost of fuel, food and ice is shared evenly among the men aboard.

Applications for boat licenses were examined to determine the number of skiffs, canoes and sailboats licensed each year since 1978. The number of each boat type is based on the relative percent among the original applications found:

BOAT LICENSES

Cal. Year	Total	Skiffs	Canoes	Sailbt.	Other	Proportion of applic. sampled
1978	595	317	82	189	7	0.89
1979	280	151	37	90	2	0.89
1980	325	139	64	121	1	0.85
1981	245	96	57	92	0	0.77
1982	344	121	81	139	3	0.86
1983	597	374	114	103	6	0.61
1984	579	350	134	95	0	0.28

The main trend noted is an increase in the use of skiffs. In

1983 and 1984, skiffs comprised about 60% of the boat applications sampled, and sailboats less than 20%. License applications available for the first half of 1985, show the same trend: 57% were for skiffs and 15% for sailboats. This recent development may be related to increased activity in the lobster trap fishery (Price, 1986). Engine power of the fleet has also increased. In a survey made in Belize in 1966, Allsopp (1967) estimated the total number of skiffs used by Belizean fishermen to be 102, dugout canoes 12 and sailboats 150; 153 outboard engines were also inventoried. If each skiff was outboard powered, then only 50 motors were shared among three times that many sailboats. Today, sailboats which rely solely on sail power are rarely seen.

4.3.2 Crewmen

Crew size varies with boat size. Generally one to two men will go out in a skiff on a day excursion. The same is true for the large dugouts unless fishermen journey far from port for a period of two or more days. On these trips, up to three men may accompany the boat-owner and small canoes are brought along. A sailboat crew consists usually of four to five men. The range noted during the dockside survey in 1985 was three to eight men per boat. Most of the time the boat-owner accompanies the crew, but on occasion a captain is appointed instead. Crewmen change boats over the course of the year and may participate in both the day and trip fishery within a season.

Members of the crew generally have equal status but there are some situations where a fisherman is assisted by a helper. The helper will not receive an equal share of the catch but rather a flat sum for the day. Young sons accompanying their fathers are often of this category. When crewmen are partners, the catch is divided into equal shares: one for each of the fishermen and one for the boat. The boat's share will be an extra share for the boat-owner if he made the trip. When sold to the cooperative, each share is entered under the member's name so that a second payment can be received. In southern Belize, some of the fishermen have a different arrangement for sharing the catch. Instead of working as a team, a strict account of each man's production is kept. A spring balance is taken on the trip and individual fishermen weigh their catch at the end of each day.

4.3.3 Time at sea

The length of a fishing excursion is what differentiates the day and trip fisheries. Day-men are those fishermen who fish within an hour or two's distance from port. Trip-men are those fishermen who journey far from their home port and may not return for two to five days. They include primarily sailboat crews and fishermen who stay at fish camps. The latter is common among Placencia fishermen, and Belize City fishermen who fish in the Turneffe Islands approximately 40 km southeast of their home port.

On sailing trips, seven to ten days are generally spent at sea. The maximum time away from port is determined by how long the ice in the vessel hold lasts. The lower limit on trip length is set by profitability. Men keep account of their landings and remain at sea until they are sure their costs are covered. Within this range, time spent at sea is determined by the interplay of two factors: weather and fishing success. During stormy weather, both the mobility of the boats and efficiency of the divers decrease. Capture efficiency is influenced primarily by cold temperatures and reduced visibility. If the weather turns poor during a trip, the men will either: 1) anchor in the lee of an island until fishing conditions improve, which will lengthen the time they spend at sea, or 2) return to port, thereby shortening their time at sea. This decision in turn will depend on their success at fishing prior to the bad weather. If fishing is poor, they would be more likely to remain at sea until the weather improves.

4.3.4 Areas fished

Conch are distributed throughout the reef-caye complex along the barrier reef of Belize. The fishery is concentrated in shallow water not exceeding 18 m in depth. The stock is believed to extend into reef communities on the edge of the continental shelf to depths of approximately 35 m. From conversations with fishermen, there does not appear to be any virgin populations left; all areas in the inner reef have been fished at sometime in the past. "Stock" is defined here as legal sized conch in all areas accessible to the fishery. More than one unit stock may exist along the coast and reefs of the outer atolls, but in absence of better information on stock identity, one stock is assumed.

In general, day-men fish in grounds close to their homes and trip-men are found in distant areas such as the Turneffe Islands, the outer atolls, Gladden Entrance and the Sapodilla Cayes (Figure 1.1). General information on where the day- and trip-men of each cooperative dive for conch was obtained from sales receipts and is outlined below:

COOPERATIVE	AREA FISHED	
	Day-men	Trip-men
Sarteneja	(Not Applicable)	All along the main reef as far south as Lighthouse Reef
Caribeña	Reef Pt. to Caye Caulker	Turneffe Islands, Lighthouse and Glovers Reefs
Northern	Caye Caulker and South of Belize City to the Bluefield Range	South of Belize City to Gladden Entrance
National	St. George's Caye to the Bluefield Range	South of Belize City to Ranguana Caye
Placencia	Cayes inside the main reef from Saddle Caye to Laughing Bird Caye	Cayes on the main reef east of Dangriga and south to the Sapodilla Cayes

From interviews with conch producers it appears that the most popular fishing grounds for conch are the outer atolls (Lighthouse and Glover's Reef) and the Southern Cayes. The Southern Cayes most commonly mentioned included: South Water, South Long, Columbus, Tobacco, Silk, Ranguana, Sapodilla and Hunting.

The location of a cooperative with respect to the fishing grounds is the main factor that determines its ratio of day:trip fishermen. Daily production records indicate that all of Sarteneja's conch divers fished on a trip basis. A high proportion (estimated 90%) of the conch divers from National and Caribeña are trip-men also. Approximately 75% of the man-days fished for conch by Placencia fishermen are attributed to trip-men each season. Due to the large number of day-men located on Caye Caulker, 40% of Northern's conch fishermen are thought to fish on a daily basis. The ratios mentioned above for Placencia and Sarteneja fishermen remain the same throughout the year. In the other three cooperatives, the proportion of day:trip fishermen changes for the last three and a half months of the conch season. Sailboats are usually hauled for repairs from April to June in preparation for the lobster season. Crewmen from these boats who continue to fish conch will do so on a daily basis. Taking the entire season and all cooperatives into account, I estimate that cooperative fishermen fish conch on a daily basis 30% of the time each season, and on a trip basis for the remaining 70%.

4.3.5 Methods of capture

Skindiving is believed to have replaced hooking as the primary means of fishing conch by 1967. The apparatus used to hook conch included a long (6-9 m) pole with two tines attached to one end and a sea-glass. The looking glass consisted of a water tight box sealed with a pane of glass at one end and left open at the other end for viewing. It was used on windy days when the seas were too choppy to see the bottom. Once spotted, conch were lifted to the surface by inserting the curved tines of the hook into the aperture of their shells (Doran, 1958; Randall, 1963). The method of hooking is still used to a limited degree in the Bahamas, Bermuda and the Turks and Caicos Islands (Brownell and Stevely, 1981). Attempts have also been made to dredge for conch in Belize but only on an experimental basis (Baird, 1973). SCUBA diving and hookah are used in a number of countries, eg., Antigua and Barbuda, Grenada, St. Lucia, Puerto Rico and Dominican Republic, but are prohibited in Belize (Brownell and Stevely, 1981).

Lobster and fish may be collected at the same time a diver gathers conch. Fishing methods for these commodities were studied to better understand what decisions a fisherman may make in allocating his effort among the species. Descriptions of lobster fishing methods are given by Price (1986). Details on the species of fish harvested commercially in Belize and fishing techniques used for each are given by Thompson (1945), Auxillou (1967) and Bradley (1978).

CHAPTER FIVE

Trends in Landings and Effort

The basis of management of a fishery resource depends on accurate and complete statistics of landings, fishing effort and sizes of fish caught. Several years of records are required before trends which may warn of depletion or encourage expansion, can be detected. Trends observed in conch landings by the major fishing cooperatives in Belize are described in section 5.1 of this chapter. Changes in annual production over time, differences between cooperatives, and seasonal patterns in production are described. In section 5.2, the total number of commercial fishermen in Belize and proportion that dive for conch are estimated. An index of stock abundance, namely the weight of conch landed per man-day by the country's top conch producers, is used to assess the condition of the stock. The manner in which total effort was subsequently estimated is given in section 5.4. Results of the above analyses are summarized in section 5.5.

5.1 Conch Landings

The first significant increase in conch production occurred in 1967 (Figure 5.1). This is thought to mark the beginning of a largely commercial, as opposed to subsistence, fishery. Exports climbed dramatically in the five years to follow, from 174,545

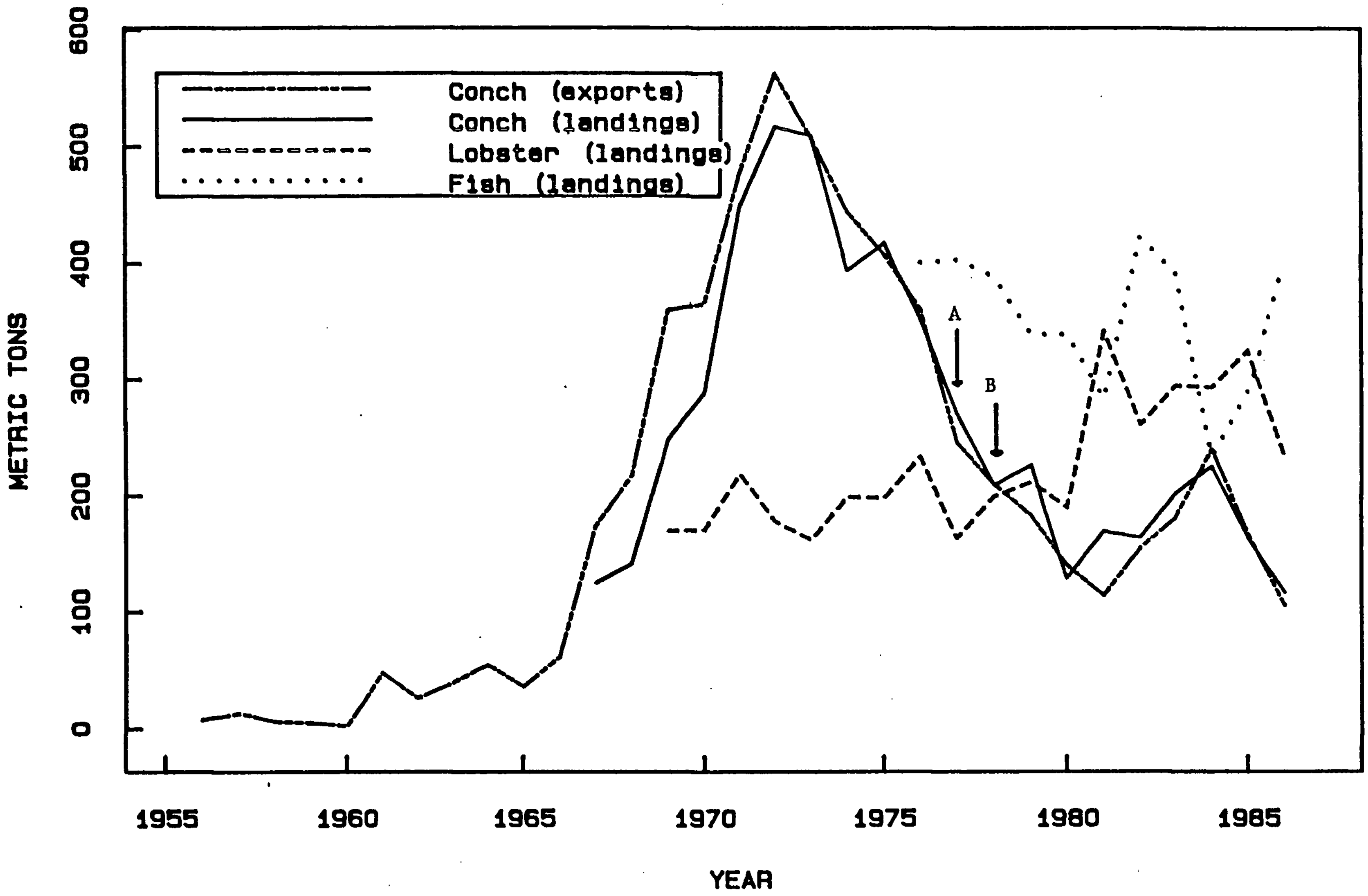


Figure 5.1 Conch exports (calendar yr) and production (fiscal yr).
(A) Closed season introduced, 1977; (B) Size limits introduced, 1978.
Data presented in Table 4.1 and Appendix VI

kg in 1967 to 562,634 kg in 1972. Thereafter, production declined and continued to do so for the next eight years. By fiscal year 1980, cooperative production was at a historical low of 128,315 kg. Conch landings improved from 1981 to 1984 but then declined again in 1985 and 1986. Production in 1986 (110,232 kg) was the lowest it has been in 20 years. Landings of lobster and scale fish are plotted in Figure 5.1 for comparison.

Total landings of conch, lobster and scale fish have differed among cooperatives (Figures 5.2, 5.3 & 5.4; Appendix VI). Relative production of each commodity among the cooperatives depends on the size of the cooperative and its interest in the commodity. The membership of each cooperative (Table 5.1) and proportion of it delivering conch (Table 5.2) are discussed later on. National has consistently been the largest producer of conch accounting for 30 to 60% of the total production by cooperatives. Sarteneja was generally in second place over the course of its existence but in 1978 and 1981 actually surpassed National in conch production. Prior to 1974, Caribeña was also interested in conch but since then has contributed less and less to the country's total production. Despite its small size, Placencia has ranked third in conch production over the last decade. Fishermen of the Northern Cooperative have shown little interest in conch relative to lobster. This cooperative has been the second largest conch producer since 1982 simply because it has far more members than the other cooperatives. Each cooperative tends to specialize in one commodity. National and Sarteneja are recognized for their

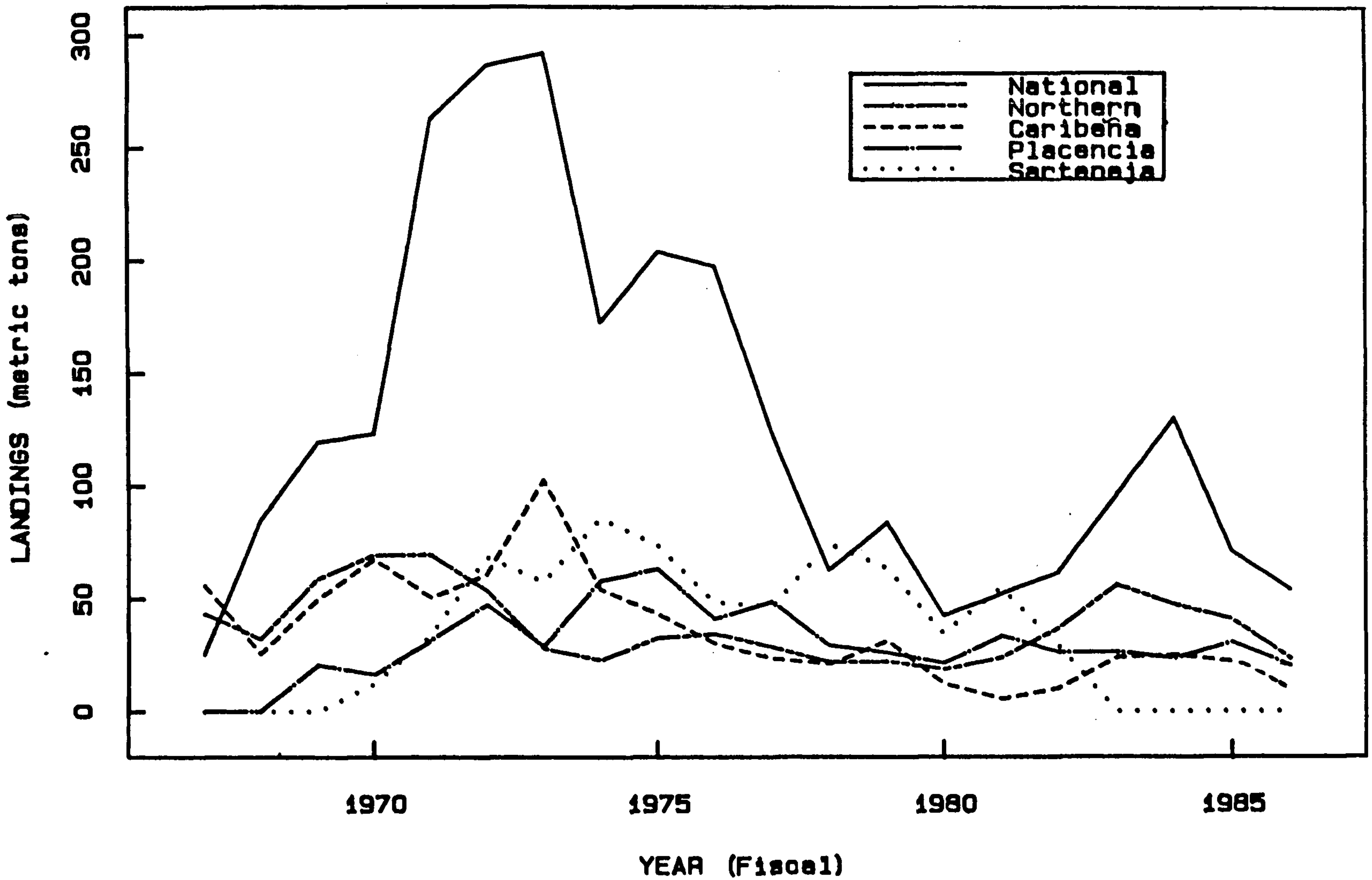


Figure 5.2 Conch production by each cooperative.
Data presented in Appendix VI

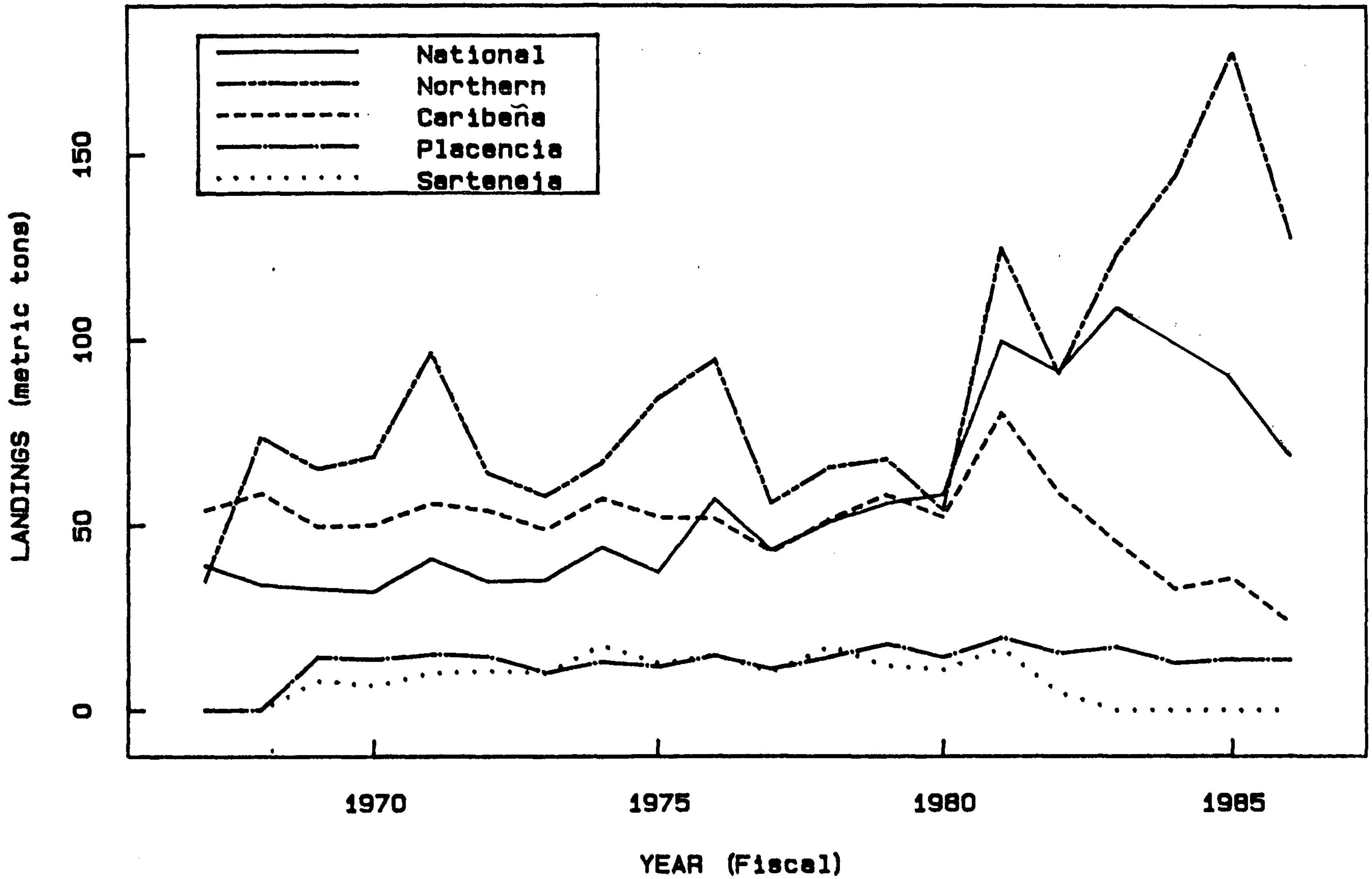


Figure 5.3 Lobster production by each cooperative.
Data presented in Appendix VI

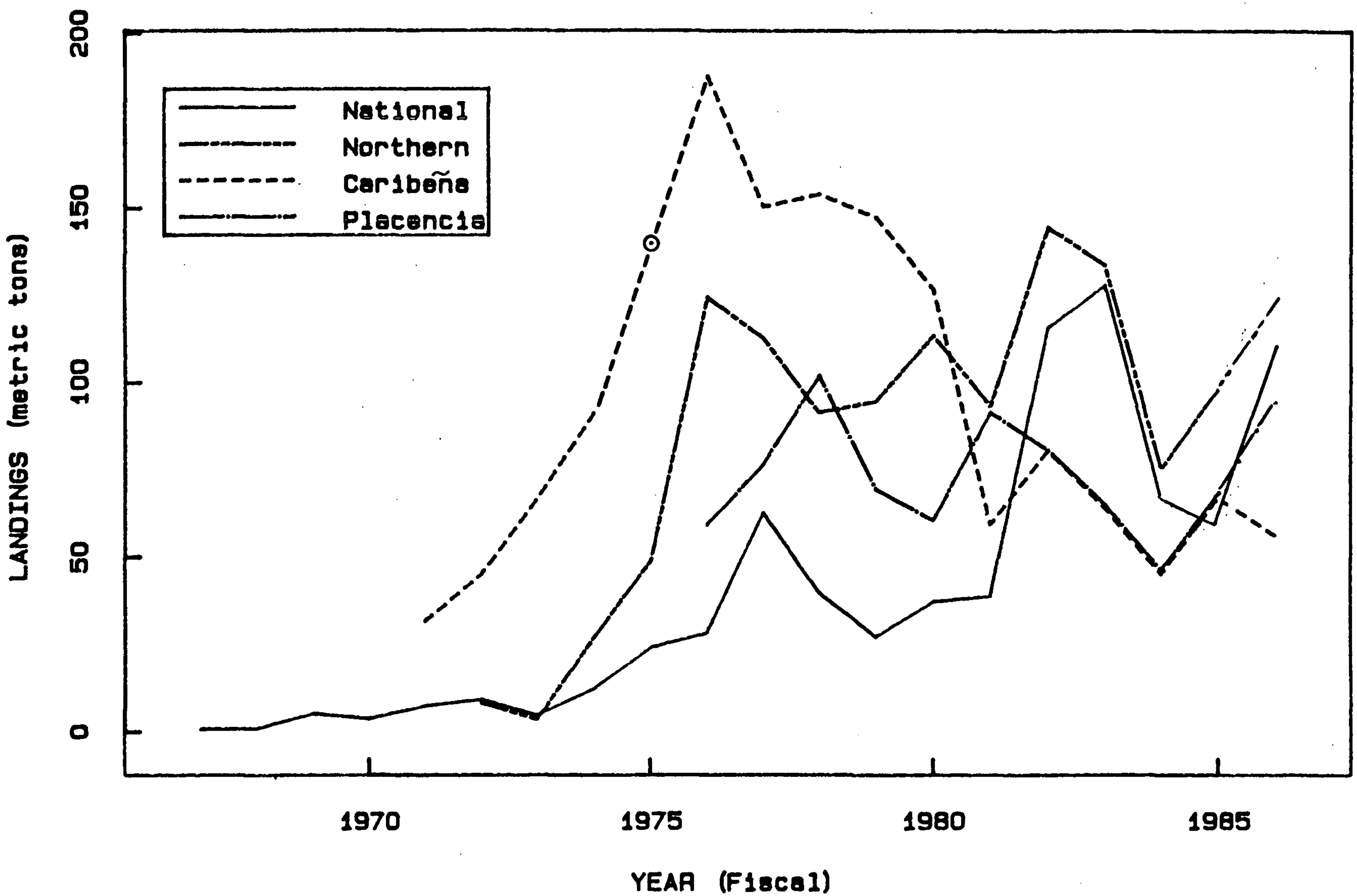


Figure 5.4 Scale fish production by each cooperative.
(0) data unavailable - value extrapolated.
Data presented in Appendix VI

Table 5.1

Number of cooperative fishermen:
Total membership (T) and active members (A).

FISC.	NATIONAL		NORTHERN		CARIBEÑA		PLACENCIA		SARTENEJA		TOTALS	
YEAR	T	A	T	A	T	A	T	A	T	A	T	A
1965	152	-	143	-	135	-	75	-	0	0	505	-
1966	-	-	-	-	-	-	-	-	0	0	-	-
1967	158	97	-	-	-	-	-	-	54	-	212	-
1968	184	105	-	-	-	-	75	-	41	-	300	-
1969	185	110	145	-	161	-	64	-	49	-	604	-
1970	195	108	157	-	177	122	82	-	49	-	660	-
1971	219	138	158	-	186	126	82	-	61	-	706	-
1972	260	177	163	103	210	163	78	47	52	40	763	530
1973	194+	187	160	106	222	176	80	48	52	40	708	557
1974	206	189	163	112	221	179	89	56	142	111	821	647
1975	208	174	169	122	213	158	87	72	150	118	827	644
1976	211	191	178	152	213	158	94	83	135	82+	831	666
1977	219	188	183	164	234	191	94	78	159	101+	889	722
1978	202	170	191	171	237	187	86	76	155	131	871	735
1979	197	156	199	176	233	188	92	68	159	132	880	720
1980	194	148	211	192	229	177	82	62	141	111	857	690
1981	227	181	240	209	234	179	79	66	140	120	920	755
1982	265	226	295	261	225	175	88	71	41	41	914	774
1983	326	281	339	296	214	160	96	77	0	0	975	814
1984	361	302	372	334	200	154	99	86	0	0	1032	876
1985	353	305	421	372	178	147	98	76	0	0	1050	900
1986	410	320	432	355	167	134	81	63+	0	0	1090	872

- data not available
+ figure thought to be slightly underestimated

Table 5.2

Relative percentage of cooperative fishermen delivering conch. Absolute number (#) and percentage (%) of the cooperative's total number of producers.

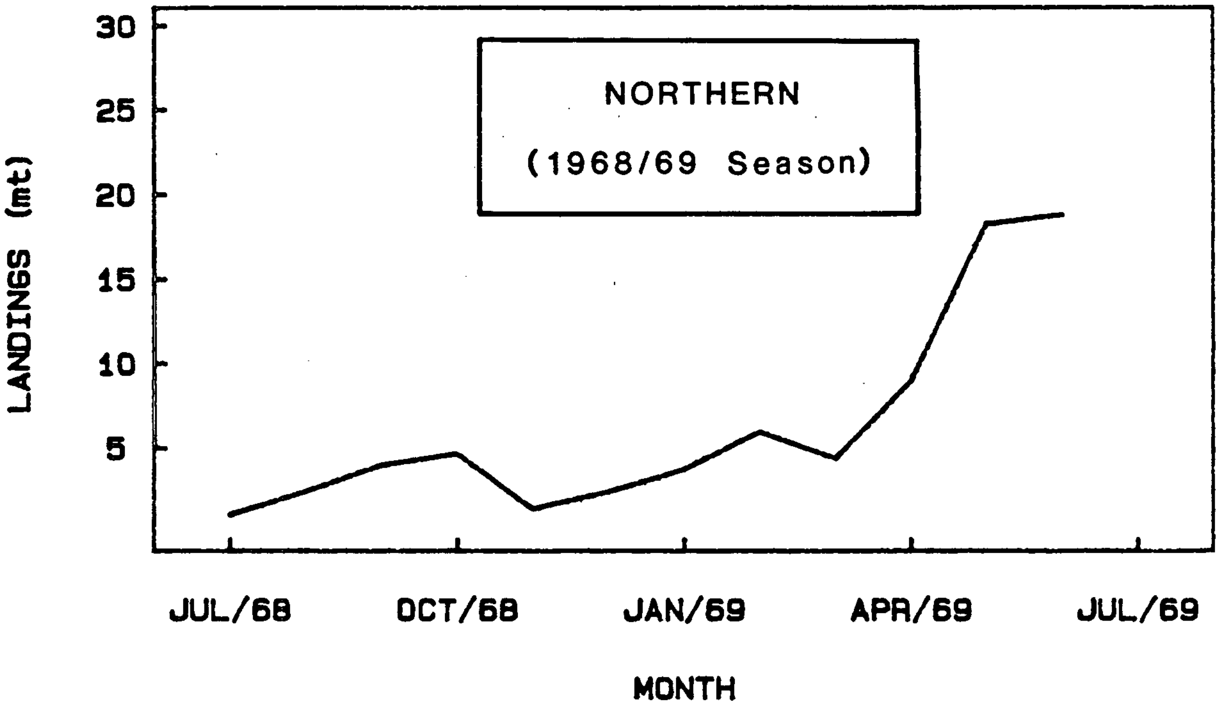
FISC. YEAR	NATIONAL #	NATIONAL %	NORTHERN #	NORTHERN %	CARIBEÑA #	CARIBEÑA %	PLACENCIA #	PLACENCIA %	SARTENEJA #	SARTENEJA %	TOTAL #	TOTAL %
1967	24	25	-	-	-	-	0	0	0	0	-	-
1968	68	65	-	-	-	-	-	-	0	0	-	-
1969	74	67	-	-	-	-	-	-	-	-	-	-
1970	73	68	-	-	-	-	-	-	-	-	-	-
1971	106	77	-	-	96	76	-	-	-	-	-	-
1972	144	81	31	30	122	75	-	-	-	-	-	-
1973	154	82	29	27	138	78	-	-	-	-	-	-
1974	153	81	39	35	143	80	-	-	-	-	-	-
1975	155	90	53	43	-	-	-	-	-	-	-	-
1976	156	82	50	33	-	-	-	-	-	-	-	-
1977	150	80	69	42	136	71	-	-	-	-	-	-
1978	114	67	58	34	143	76	65	86	127	97	507	69
1979	102	65	70	40	150	80	58	85	129	98	509	71
1980	90	61	99	52	125	68	53	85	105	95	472	68
1981	120	66	89	43	105	59	56	85	111	93	481	64
1982	155	69	143	55	116	66	62	87	41	100	517	67
1983	214	76	190	64	116	73	66	86	0	0	586	72
1984	241	80	214	64	102	66	71	83	0	0	628	72
1985	-	-	265	71	118	80	-	-	0	0	-	-
1986	221	69	174	49	114	85	-	-	0	0	-	-

- Data not available

conch production and Northern and Caribeña for their lobster and fish production. Caribeña has the highest proportion of members interested in fish but follows National in total production because of a difference in absolute size. Placencia fishermen appear to be equally interested in all three commodities.

The pattern of production of conch within a year has changed over the years for all cooperatives. In the 1960's, fishermen landed conch primarily during the off-season for lobster. From 1970 to 1973, conch was fished heavily all year round except during holidays (eg. Christmas and Easter) and when lobster was most abundant (eg., when the lobster season first opened) (Figure 5.5). For the next four years, conch landings were greatest in the months of August through October. After the closed season was introduced in 1978, landings for these three month were essentially condensed into one. From 1978 to 1984 an average of 30% of the year's total was delivered in October (Figure 5.6). Another 40% was delivered during the off-season for lobster which extends 107 days. The last 30% of the landings was delivered in the remaining 136 days of the season. In 1985, conch landings for October averaged 39% of the year's total while those during the off-season for lobster averaged 25%.

Unlike that for conch, the pattern in monthly production of scale fish and lobster has remained the same from year to year; only the magnitude of landings has changed. The scale fish fishery is highly seasonal with fillet production peaking during the spawning seasons for grouper which occurs sometime between



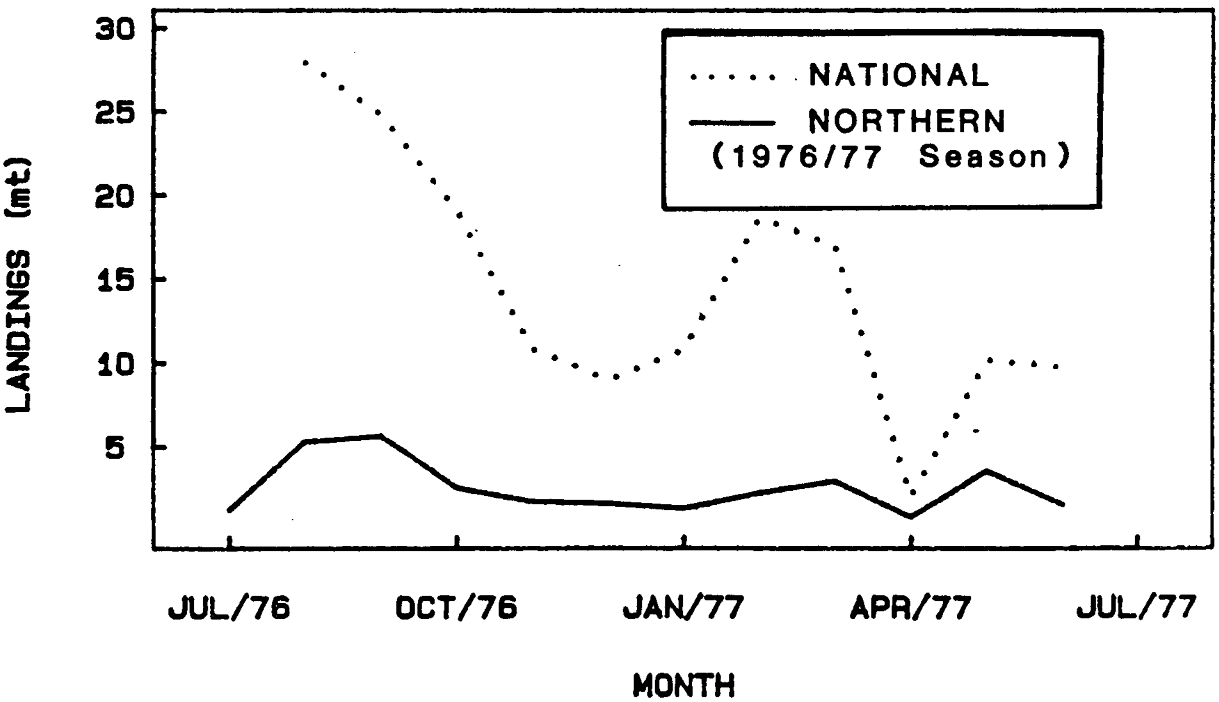
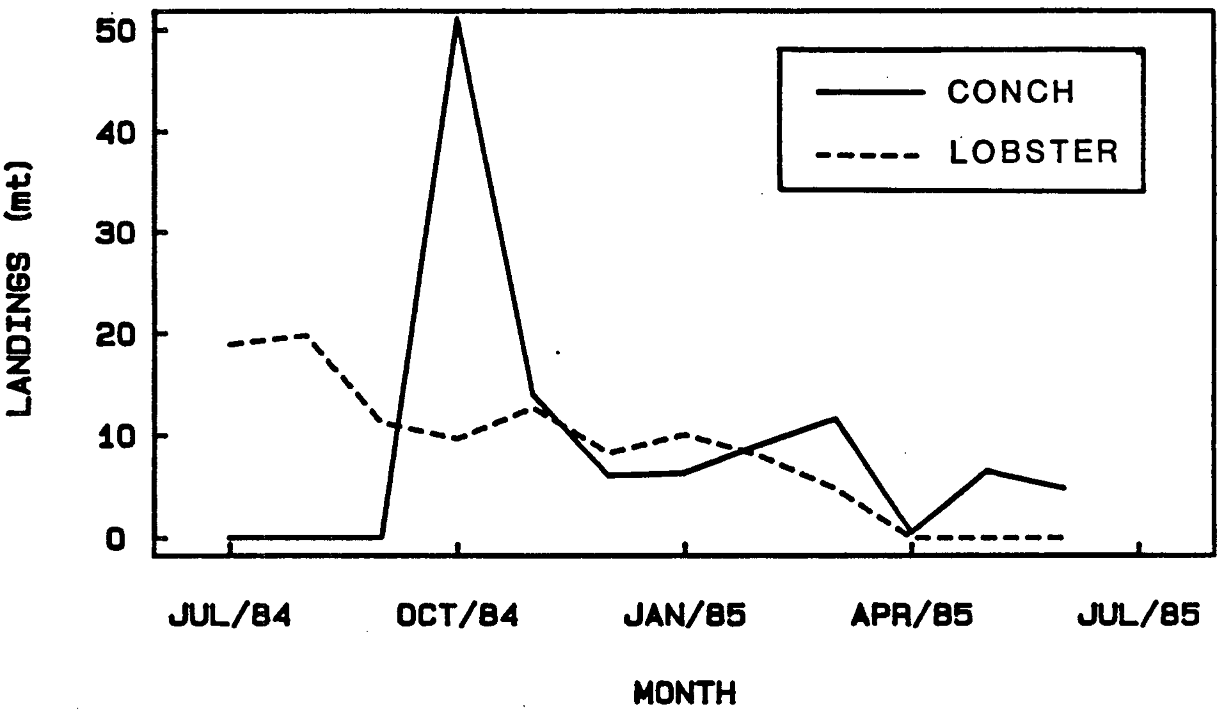


Figure 5.5 Monthly landings of conch in fiscal years 1968 and 1976.



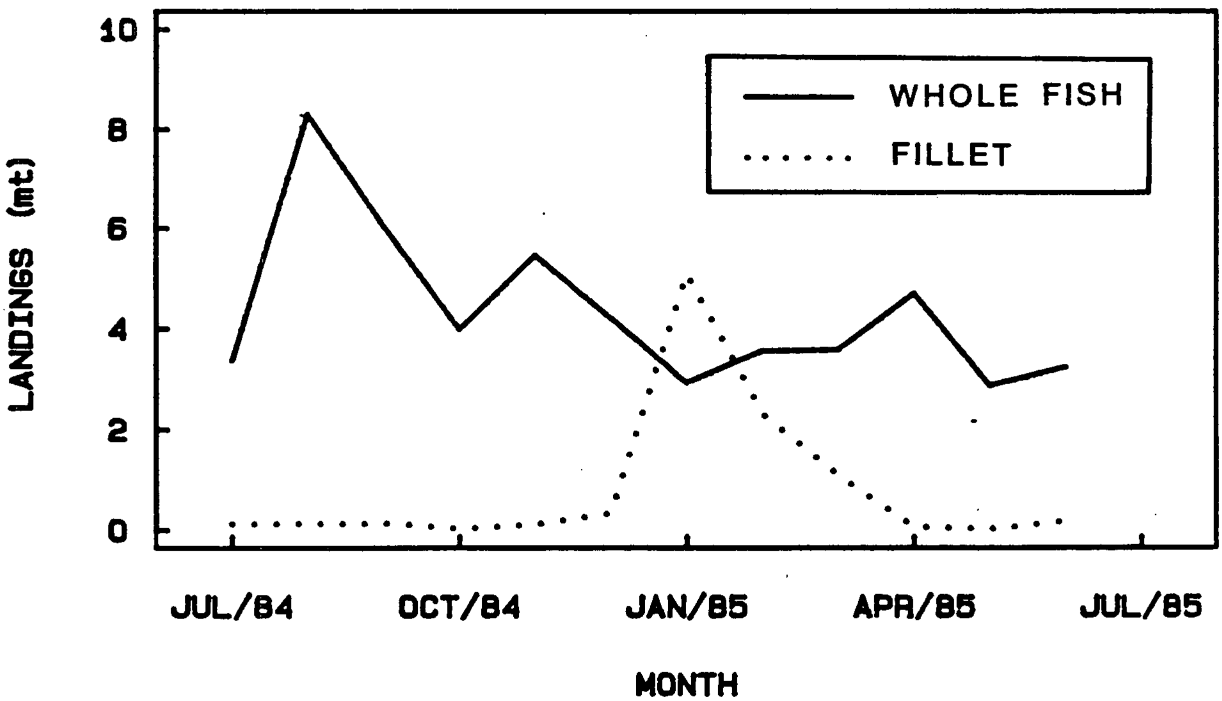


Figure 5.6 Monthly production of conch, lobster and scale fish in 1984 (National Cooperative).

December and February (Dres and Meyers, 1965; Miller, 1984). Most of the lobster is caught during the first five months of the season. McElroy (1965) claimed this is because trap yields increase with moulting and feeding activity in the warmer months (July through August) and with migrations in the rough weather months (November through December). The inshore migrations he refers to are known as "lobster runs". They usually occur after a "northern" which is a strong, cold north wind lasting three to four days. Low landings of lobster in September may be the result of combination of factors: high rainfall, two national holidays and school-age fishermen returning to classes. Trap yields as well as effort are reduced by heavy rains because lobster generally migrate away from the shallow-water trapping areas when salinity decreases sharply (Gibson, 1980). There is a quota on lobster limiting annual exports to 244,944 kg (540,000 lb) but I do not think it influences the pattern of production. The quota was not reached until 1981, and since then, has been increased. It does not appear that fishermen are concerned about getting a share of the resource before the quota is filled.

Today's seasonal pattern in conch production appears to be defined by the species' abundance relative to lobster and fish. Now that conch are difficult to find, most fishermen only dive for them when the fishing season first opens. By the end of a month, the density of conch in the popular fishing grounds is low and most fishermen switch back to lobster leaving what conch remain in these areas and in less productive areas to specialists who dive for conch year round. Fishermen diving for lobster and fish will continue to take conch but only when they happen to come across them.

5.2 Number of fishermen landing conch

5.2.1 Total number of fishermen in Belize

The total number of active fishermen in Belize from 1978 to 1984 is estimated to have been the following:

NUMBER OF FISHERMEN

Fiscal Year	Total active coop. men	Estimated total indep. men	Grand total
1978	735	348	1083
1979	720	365	1085
1980	690	372	1062
1981	755	405	1160
1982	774	527	1301
1983	814	536	1350
1984	876	799	1675

There has been a large and sudden increase in the number of fishermen in the 1980's. Between 1981 and 1984, the total increased by 44% from 1160 to 1675. The rate of increase in the number of independent fishermen was greater than that for cooperative fishermen. In 1981, independents comprised 35% of the total; by 1984 they comprised 48%. In comparison, the number of registered fishermen in the Turks and Caicos Islands which exports far more conch than Belize to the United States, was 300 in 1982 (Hamaludin, 1982).

The number of boat licenses issued over the above period was also estimated:

BOAT LICENSES

Cal. Year	Total issued	Number issued to independents	Proportion of applic. available
1978	595	84	0.79
1979	280	52	0.80
1980	325	68	0.75
1981	245	77	0.70
1982	344	81	0.79
1983	597	147	0.55
1984	579	138	0.26

The proportion of licenses issued to independents was determined from the applications for boat licenses (Appendix V; Form A1). The estimated number of independent fishermen purchasing boat licenses in 1983 and 1984 was double the average for earlier years, but it is difficult to be certain of the true number of fishing boats in operation. This is because few men renew their boat licenses on a yearly basis as regulations require. Most wait until they go to renew their fishermen licenses which may be once every five years. The increase in boat licenses in 1983 therefore, may be related to the renewal of licenses issued in 1978.

The sudden increase in the number of participants in the fishing industry in the 1980's may be explained by two events. One is the recent influx of refugees from neighbouring countries and the other is lay-offs in the sugar industry. Between 1980 and 1983 about 5,000 refugees from Guatemala and El Salvador settled in Belize (Bollard, 1986). In 1984, the Government of Belize offered the refugees alien residency through a 90 day amnesty period (Government of Belize, 1984b). Since then, forty aliens have applied for fishing licenses. The actual number of aliens fishing in Belize however, is probably much greater because Belizean fishermen have been recruiting aliens as crew for years (BFCA, 1983b). The incentive being that foreign helpers settle for lower wages than their Belizean counterparts. The employment situation in other sectors of the economy may also influence the number of people entering the fishing industry. Shifts in demand for sugar since 1980 has lead to economic difficulties among the cane growers in Belize. As a consequence, hundreds of people have been laid off (Bollard, 1986). In northern towns and villages, for example Sarteneja, many people work in the sugar as well as the fishing industry. The lack of employment in the former may have steered more individuals toward fishing for a livelihood.

5.2.2 Proportion of fishermen delivering conch

With no catch data for independent fishermen, license applications had to be used to determine the proportion of those who dive, and therefore, likely to fish conch. Information on applications may be up to five years old, but it is assumed that fishermen will remain divers over this period of time. The sample of applications completed by independents between 1978 and July, 1985 totalled 668. Sixty percent of the applicants claimed they were divers, and nearly half of these were 17 years of age or younger. In September of 1984, the Fishery Advisory Board proclaimed that all fishermen 12 years and older had to be licensed. I believe this is why such a high proportion of licenses were issued to young divers. Since diving is more common among young fishermen than older ones, the above ratio of divers to nondivers is believed to be biased high and it is predicted that closer to 50% of the independent fishermen dive for conch.

License information also indicated that much of the conch landed by independents is channelled through the cooperatives. Independents regularly name a cooperative as their normal place of landing catch on their license applications. Their serving as crew for cooperative members may also explain the small number of boat licenses issued to independents. A time lag between the minimum license age (12 years) and minimum age of entry into a cooperative (18 years) means that young divers will be classed as independents. From a dockside survey and interviews with staff at the cooperatives, it is apparent that most of these young divers fish with relatives affiliated with a cooperative. Finally, cooperative produce vouchers on which members are identified as the sellers but nonmembers have signed for the cash are common. This observation further supports the hypothesis that independent fishermen work with cooperative members and place their catch under the name of a registered member on a regular basis.

A significant number of men in each cooperative dive for conch, but the degree to which each cooperative benefits from conch differs. The number of.men landing conch each year was determined from second payment schedules (Table 5.2). From 1972 to 1976, National had the largest proportion (83%) of active members delivering conch, and Northern, the smallest (34%). In the 1980's, the difference between the two cooperatives was less. The percent of National's members interested in conch dropped to 70% and Northern's increased to 56%. Caribeña's interest in conch has changed little over the years. The number of members delivering conch dropped by 10% in the 1980's to an average of 66% of the total membership. Data are limited for Sarteneja and Placencia but indicate that these cooperatives have the greatest dependence on conch. An average of 96% of Sarteneja's membership delivered conch from 1978 to 1982. The average for Placencia is in the neighbourhood of 85%. Changes in the proportion of National and Northern's membership landing conch in the 1970's resulted from an exchange between memberships with Sarteneja and Caribeña (Figure 5.7). From 1980 to 1984, Northern granted membership to 20 fishermen from Caribeña and 10 from Sarteneja. National took in two fishermen from Caribeña and 60 from Sarteneja. The dissolution of Sarteneja in 1982, financial difficulties experienced by Caribeña in 1983 and tendency for fishermen to transfer to cooperatives allocating higher second payments are the main factors leading to the exchange.

To calculate the grand total of fishermen that dive for conch each year, the number of fishermen within the cooperatives who land conch (see Table 5.2) was added to an estimate of the number of independents who dive (i.e., 50% of the licensed

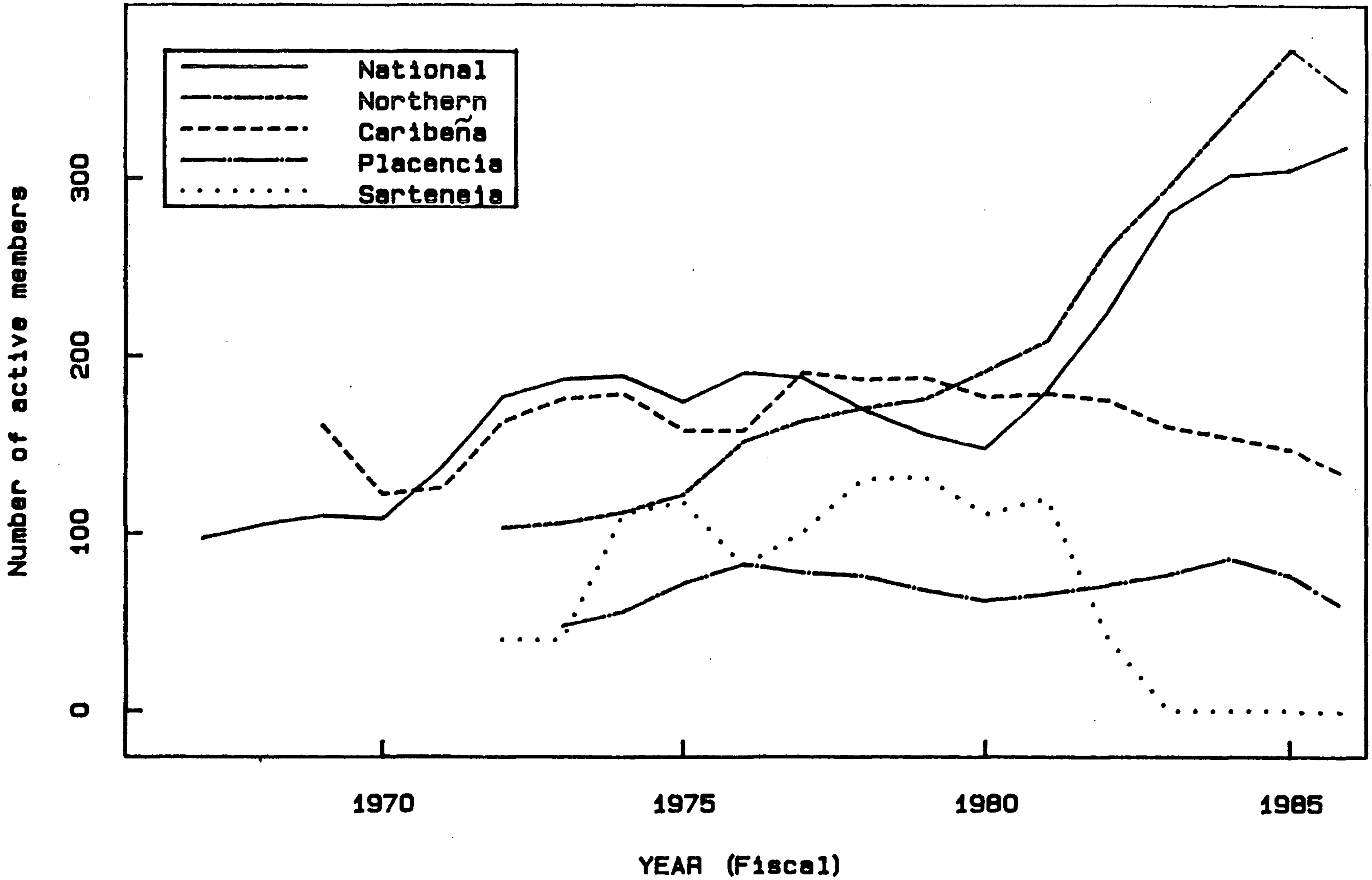


Figure 5.7 Number of active fishermen in each cooperative.
Data presented in Table 5.1.

independent fishermen; see section 5.2.1):

NUMBER OF FISHERMEN WHO DIVE FOR CONCH

Fiscal Year	Coop. members	Independents	Total (% of total fishermen)
1978	507	174	681 (63)
1979	509	183	692 (64)
1980	472	186	658 (62)
1981	481	203	684 (60)
1982	517	264	781 (60)
1983	586	268	854 (64)
1984	628	400	1028 (61)

These figures indicate that many more cooperative fishermen dive for conch than independents and the number of men diving for conch is on the increase. The proportion of total fishermen interested in conch has remained the same at an average of about 62%. An average of about 31% of the fishermen believed to dive for conch are independents. It is not possible to estimate their production given this percentage and knowledge of what cooperative fishermen produce because many independents deliver their catch to the cooperatives under a member's name in the first place.

5.3 Standardization of effort data

5.3.1 Man-days fished by trip fishermen

Extracting information on the catch and effort of trip fishermen from cooperative sales receipts is difficult due to the system of shares. The sales receipt which is made out to each cooperative member may not be representative of one man's catch. The weight of conch recorded under a trip fisherman's name upon delivery may actually be a share of the boat's total production. If so, this figure will be less than what he really caught over the course of the trip. Alternatively, if the sales receipt is a boatowner's, then the landings per man recorded will be overestimated. Data are also biased high if the receipt belongs to a member of the crew with an additional man's share under his name. The unidentified share may belong to another member or a nonmember. Members trying to slow their repayment of loans received from the cooperative will put their production in another's name. This way their loan payment which is deducted automatically from their account will amount to less. Such transactions are also common among boat-owners wishing to remain within a certain tax bracket. By distributing their production amongst the crew, captains with high earnings may lower the income value recorded under their name in the cooperative files. Finally, fishermen not eligible for membership because they are underage, not Belizean citizens, or in poor standing with another cooperative, may put their catch in a member's name to receive a second payment.

The problem of not knowing how many shares one receipt accounts for, can be resolved by ensuring that sales receipts are kept in sequence, i.e., ordered by time of delivery or receipt number. The number of equally sized shares attributed to each trip can then be identified and counted. The number of men aboard equals the number of shares minus one for the boat. The weight of conch delivered by the boat is then divided by the total number of men aboard to estimate true landings per man-trip.

Errors in the estimates of days fished per trip is another problem encountered when estimating effort from sales receipts. Most often than not, trip fishermen record the number of days they are away from port. These figures will overestimate days fished because they include time spent travelling. The main difference in travelling time between day and trip fishermen is the extra time it takes the trip-men to sail to and from their fishing grounds. Once there, trip-men expend as much time moving their sailboats from one conch bed to the next as day-men spend travelling to and from their fishing site within a day. In this report, an average of two days travelling time per trip was allotted for sailboats and one day for dugout canoes to standardized man-days. Variation in the form of propulsion (eg., 9.5 hp versus 40 hp) was not taken into account.

5.3.2 Allocation of effort among species

The proportion of man-days (md) fished for each major commodity has differed over the years. Before trends could be identified in the conch fishery, this had to be taken into account. To investigate the relationship between the three commodities, fishermen delivering conch were separated into three sub-groups: 1) men delivering lobster, conch and fish together in a year; 2) men delivering conch and one other commodity in a year; and 3) men delivering conch only. The relative percent of each group at National is plotted in Figure

5.8. For many years fishermen concentrated mainly on lobster and conch. Then in 1974, when an export market was established for whole fish, there was a switch: more fishermen began to fish all three commodities within a year. With more effort diverted toward fish, less time was spent diving for conch.

On a trip basis, divers generally concentrate on one commodity and deliver an incidental amount of other fish products. They fish in areas where the targetted species is most abundant. In the case of lobster and fish, that is near the reef crest. Conch, on the other hand, is found in sea-grass beds set back from the reef. If time is devoted equally among the commodities fished, it is usually because abundance of the fish-type first aimed for was found to be low. Man-days devoted to each species are not recorded on the sales receipts. Therefore, care must be taken to separate data on trips made for conch only from those on trips during which more than one commodity is fished. Knowing the number of hours fished per day would provide more accurate estimations of effort, but data of this sort is more difficult to gather and may require the use of onboard observers.

5.4 Landings-per-unit-effort (LPUE)

Estimates of the weight of conch landed per man-day were calculated to study the decline in conch abundance. The results are presented below and ordered by data source. The best sources of effort data were the daily production records for the

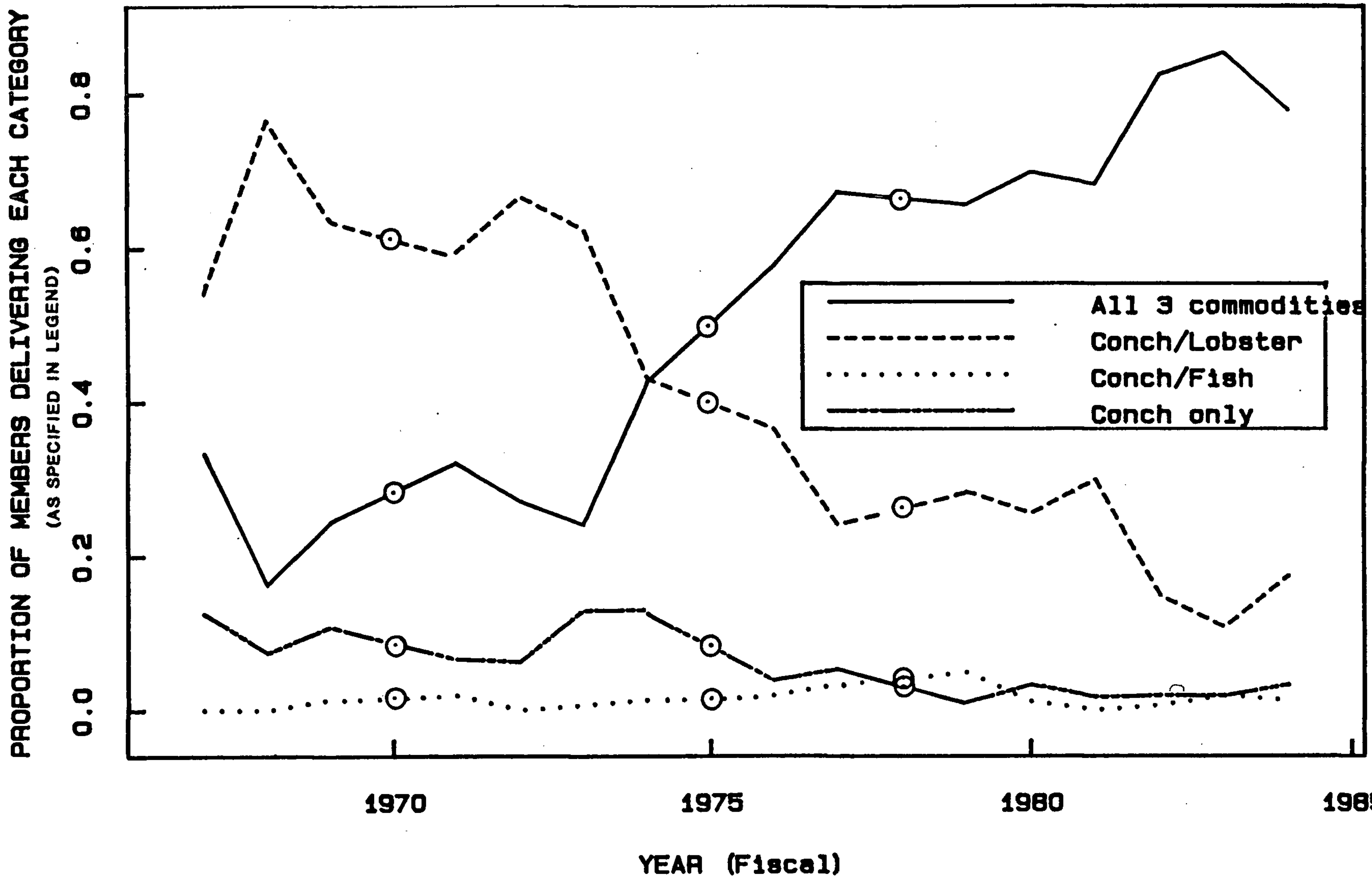


Figure 5.8 Conch fishermen's interest in other commodities (National Co-op.).
(0) data unavailable - value extrapolated

Sarteneja Cooperative and the dockside survey. However, these provided information for only one to four years. To obtain a longer time series of LPUE values, a rough and ready method of estimating LPUE from landings statistics alone had to be devised. These estimates of average LPUE for the year are used primarily to identify trends.

5.4.1 Sarteneja Cooperative (1978-1982)

The average LPUE of Sarteneja fishermen was calculated for the years 1978 through 1982. Records of production by these trip-men were kept in order so that shares could be identified (see section 5.3.1). Man-days (md) per trip was calculated by assuming that the average number of days fished per trip was seven. Effort was summed over all trips to arrive at total annual effort. Trips during which only conch was fished are termed "conch-only" trips; those during which lobster and conch were both caught are referred to as "conch-plus" trips. Sarteneja fishermen did not deliver fish to their cooperative over the time period considered here. LPUE varied little over the last four years for which the cooperative was in operation (Table 5.3A). Much more time was devoted to conch-only trips. On trips when lobster was also caught, only a third of the man-days was devoted to conch. Average monthly LPUE was also calculated for Sarteneja fishermen but no within-year trend could be discerned. This is likely because fishermen changed fishing areas throughout the season.

Table 5.3

Variation in estimates of landings-per-unit-effort (LPUE)

A. LPUE (kg/md) OF SARTENEJAN FISHERMEN

Fiscal Year	Conch-only Trips Landings (kg)	md	LPUE	Conch-plus Trips Landings (kg)	md	LPUE
1978	73362	4443	16.5	12285	2031	6.0
1979	61165	4100	14.9	3821	840	4.5
1980	30790	2464	12.5	4729	1064	4.4
1981	49794	3640	13.7	6811	1413	4.8
1982	13218	924	14.3	0	0	-

N.B. Landings include those by nonmembers also.

B. LPUE (kg/md) DURING THE OFF-SEASON FOR LOBSTER, 1985: Differences between day- and trip-fishermen.

COOPERATIVE	DAY-MEN Landings (kg)	md	LPUE	TRIP-MEN Landings (kg)	md	LPUE
Caribeña	4487	439	10.2	-	not fishing	-
Northern						
C. Caulker	2147	202	10.6	-	none	-
Belize City	266	21	12.7	10084	765	13.2
National	2522	249	10.1	18335	1684	10.9
Placencia	2847	211	13.5	-	not known	-

C. LPUE (kg/md) DURING THE OFF-SEASON FOR LOBSTER, 1985: Bias introduced when man-days are overestimated

COOPERATIVE	CONCH-ONLY* Landings (kg)	md	LPUE	CONCH-PLUS-FISH Landings (kg)	md	LPUE
Caribeña	4487	439	10.2	1491	227	6.6
Northern						
C. Caulker	2147	202	10.6	577	65	8.9
Belize City	10350	786	13.2	1076	189	5.7
National	20857	1933	10.8	425	83	5.1
Placencia	- totals for trip men not known -					

* includes deliveries by trip- and day-men

5.4.2 Other cooperatives (1984 fishing season)

Sales receipts for conch were collected during the off-season for lobster in 1985. Landings and man-days were tallied for this period and used to calculate an average LPUE (Table 5.3B). These data tend to indicate that LPUE in the southern regions is higher. Although data were insufficient to discern man-days fished by Placencia trip-men in 1985, records of daily deliveries for the previous year show that they landed an average of 13.7 kg/md (30.3 lb/md). Trip-men diving in the Southern Cayes in June, 1985 had an average LPUE of 14.6 kg/md (32.1 lb/md).

It is evident from Table 5.3B that trip-men deliver the majority of the catch and that National was most active in the trip fishery. During the closed season for lobster, Caribeña is active in the day fishery but not in the trip fishery. There are essentially no trip-men stationed at Caye Caulker. It is difficult to say if LPUE for day-men is the same as that for trip-men. It depends where the fishermen fish. If trip-men venture south, their LPUE will probably be greater than a day-man's in northern waters. However, if a day-man is fishing just outside the barrier reef in deeper waters not previously fished, his LPUE may be greater than a trip-man's. LPUE estimates based on data collected during the dockside survey were 13.6 kg/md (29.9 lb/md) for day-men and 13.3 kg/md (29.3 lb/md) for trip-men, but day-men fishing deep-water populations were included in the sample which probably explains the similarity in values (see section 3.5 of Chapter Three).

In 1985, most of the deliveries made during the off-season for lobster consisted of conch only (Table 5.3C). As noted earlier, the LPUE for a conch-plus excursion is much lower because the estimate is based on the total number of days spent fishing and not those aimed specifically at conch.

Statistics on deliveries of conch made in October, 1985 were obtained from Northern's receiving station on Caye Caulker. Landings totalled 1,591 kg for the month and were delivered by day-men only. The number of man-days allocated to excursions for more than one commodity equalled that for conch only, i.e., 118 md. The LPUE of men diving solely for conch was 8.8 kg/md (19.5 lb/md). Men fishing more than the one commodity on the same day landed 4.7 kg (10.3 lb) of conch per man-day.

From the calculations above, it is evident which cooperative is most interested in conch and what the relative contribution of each is to the day and trip fisheries. The importance of separating sales receipts by the type of trip (conch-only or conch-plus) is clearly illustrated.

5.4.3 Fisheries Department data

LPUE data for the conch fishery in Belize was derived from cooperative sales receipts by the Fisheries Department for the years 1976 through 1983 (Gibson, 1981). The receipts used included those on which days fished, area fished and weight landed were all recorded. It is not known if they correspond to deliveries of conch only or that of one man. LPUE was calculated from these data for this report by dividing the sum of landings recorded on these receipts by the sum of man-days (Table 5.4). The results indicate a decline in LPUE from 30.5 kg/md (67.3 lb/md) in 1976 to 12.2 kg/md (26.8 lb/md) in 1983. However, since conch-plus excursions are included in the calculations and there was no way to account for the trend toward fewer days fished for conch relative to fish, I suspect that these results overestimate the decline in LPUE.

Data were grouped by area so changes in LPUE in one area over time could also be assessed (Table 5.5). Although there is some variability within area over the years, it appears LPUE is greater in the southern fishing grounds (eg., Glover's Reef, Placencia and Ranguana Caye). The largest amount of data are available for Caye Caulker and estimates of LPUE for this area varied little from 1978 to 1984.

5.4.4 Annual landings statistics

LPUE in past years was also derived from statistics on the annual production of conch by each cooperative member. To use this information, the assumption was made that conch fishermen are comprised of three kinds: men fishing conch intensely throughout the year; those interested in conch primarily in October and/or the off-season for lobster; and men fishing conch

Table 5.4

Estimated average LPUE (kg/md) for the year based on cooperative landings statistics and Fisheries Department data

DATA SOURCE:	COOPERATIVES						FISHERIES DEPT.	
FISCAL YEAR	NAT.	NOR.	CAR.	PLA.	SAR.	AVE. FOR COUNTRY+	AVE. FOR COUNTRY	(N)
1967	21.9	-	-	-	-	21.9	-	
1968	32.4	-	-	-	-	32.4	-	
1969	45.5	-	-	-	-	45.5	-	
1970	46.5	-	-	-	-	46.5	-	
1971	58.2	-	12.1	-	-	36.0*	-	
1972	52.1	73.8	14.8	-	-	38.7	-	
1973	45.7	30.2	23.5	-	-	36.2	-	
1974	32.7	22.5	12.6	-	-	23.6	-	
1975	49.4	31.7	-	-	-	45.8*	-	
1976	39.3	32.4	-	-	-	38.1*	30.5	(448)
1977	29.7	19.2	5.9	-	-	18.2	13.6	(371)
1978	23.4	24.0	6.7	-	13.7	14.8	23.9	(665)
1979	30.8	22.0	7.7	14.5	14.0	16.1	22.0	(475)
1980	23.4	14.0	-	-	11.1	15.2	17.4	(781)
1981	22.5	19.0	2.3	-	16.0	14.6	14.2	(988)
1982	18.0	13.8	3.8	14.6	0	15.5	11.4	(2019)
1983	18.8	13.8	8.1	12.5	0	14.2	12.2	(570)
1984	22.1	9.8	10.5	10.3	0	14.7	-	
1985	-	7.4	7.6	-	0	7.5*	-	
1986	8.8	5.1	5.6	-	0	6.9	-	

Nat. - National Cooperative
Nor. - Northern Cooperative
Car. - Carībeña Cooperative
Pla. - Placencia Cooperative
Sar. - Sarteneja Cooperative

* values changed in the final estimation of effort (see Table 5.6)

N number of sales receipts used in estimation of LPUE

$$+ \text{ Average LPUE} = \frac{\text{Total landings (all co-ops)}}{\text{Sum of effort per co-op}}$$

$$\text{Effort/co-op} = \frac{\text{cooperative's landings}}{\text{LPUE for cooperative}}$$

Table 5.5

LPUE (kg/md) in major fishing grounds of Belize
(Number of sales receipts used in the calculations)

Cal. Year	C.C.	Bz.C.	Trnf.	HMC	Glovers	Plac.	Rang.
1976	-	-	227.3 (2)	66.7 (11)	26.4 (11)	-	-
1977	11.7 (184)	14.3 (48)	9.1 (31)	16.4 (21)	15.4 (27)	-	-
1978	8.4 (127)	19.7 (95)	15.2 (19)	25.6 (10)	29.7 (20)	31.1 (109)	23.6 (26)
1979	12.8 (55)	13.8 (51)	21.5 (13)	47.6 (10)	44.7 (25)	14.7 (43)	18.6 (17)
1980	10.2 (203)	13.4 (17)	14.0 (16)	28.8 (18)	14.2 (79)	21.4 (69)	13.3 (27)
1981	7.3 (108)	9.1 (160)	8.4 (10)	13.5 (6)	15.2 (25)	17.4 (74)	27.5 (8)
1982	10.4 (165)	9.1 (252)	3.3 (24)	9.1 (1)	-	19.1 (74)	21.5 (9)
1983	8.6 (173)	11.6 (219)	5.6 (13)	-	-	-	-
1984*	10.6 (202)	10.1 (249)	10.1 (2)	12.5 (4)	-	13.5 (211)	-
1985*	8.8 (68)	10.3 (62)	-	-	-	-	-

1984* = average over off-season for lobster (March-June, 1985)
1985* = average for month of October, 1985

C.C. - Caye Caulker
Bz.C. - Islands near Belize City
Trnf. - Turneffe Islands
HMC - Half Moon Caye, Lighthouse Reef
+Glovers - Glovers Reef
+Plac. - Islands near Placencia
+Rang. - Ranguana Caye
(+ Southern areas)

incidentally all year long. The first group was used in the calculation of LPUE because this was the only one for which days fished/year could be estimated. These fishermen were also less likely to have reduced the days/year they spent fishing conch over the years. The top 10% of fishermen in each cooperative with the highest annual production of conch were considered representative of this group.

The maximum possible number of days that each of these men could have fished conch in a year was calculated by subtracting an estimate of time spent in port and travelling (Appendix VII). Dividing the mean annual production of top producers by this estimate of days fished yielded an average value of LPUE for the year. The cooperative's total landings was then divided by this LPUE to calculate the effort exerted by the cooperative. Because these calculations are only applicable to top producers for which days fished per year can be estimated, an underlying assumption is made that the average LPUE derived from the best conch producers is the same for all conch producers in the cooperative. Effort may, therefore, be slightly underestimated.

In estimating how many days/year conch fishermen were likely to spend fishing, it was assumed that they remained ashore 228 days per year for the following reasons (Appendix VII):

1. The season for conch is closed from July 1 to September 30;
2. Cooperatives are closed on Sundays;
3. Fishermen take time off when -
   a) its a major holiday (eg. Easter, Christmas, and Saint George's Day and Independence Day in September)
   b) they receive their second payment in May, and

c) Cooperatives hold their Annual Meeting in June;
4. Boat are hauled ashore for repairs on an average of four weeks a year;
5. Five days per month are lost to unfavorable weather conditions.

Time allotted to the last three items was based on personal estimates. The final estimate of days at sea was 137 per year. When there was no closed season for conch, fishermen could spend 189 days at sea. For men in the day fishery, this time is equivalent to time spent fishing. However, for men in the trip fishery turn-over time in port between trips and travelling time to and fro distant fishing grounds must be subtracted. The time needed between each fishing trip to unload catch and replenish stores of food, ice and fuel is estimated to be two days. The same amount was allotted for travel time per trip. Conch fishermen in Belize fish on a trip basis approximately 70% of the time during a season (see Chapter Four). Based on this ratio, men in the trip fishery, as of 1978, could make nine trips a season. Removal of four days per trip for turn-around and travel from time devoted to the trip fishery results in a total of 61 days fishing per year. In total, an estimated 102 days could be spent fishing conch: 61 days on a trip basis plus 41 days on a day basis. Based on the same method of calculation, an estimated 141 days could have been spent fishing conch each year prior to 1978.

Values of LPUE derived from the method above are presented for each cooperative in Table 5.3. On the whole, they tend to agree with the trend indicated by the LPUE values estimated from the Sarteneja data and from the Fisheries Department's data for individual areas. The drawback with this method is evident by the variability in LPUE among cooperatives. The accuracy of the average LPUE calculated for the top conch producers depends on the data extracted from the original sales receipts. If more than one man's share per trip is routinely entered, the LPUE calculated will be overestimated. If the top producers are landing other commodities besides conch during the conch season, this estimate of days fished/year will overestimate the true number of man-days and LPUE will be underestimated. When LPUE values estimated for top producers in 1984 are compared with true values calculated directly from sales receipts, it is evident that annual landings recorded for National's top producers are biased high:

LPUE (kg/md) FOR 1984
(ave. for day & trip-men)

	COOPERATIVE			
LPUE TYPE	National	Northern	Caribena	Placencia
Top 10% of Producers (ave. for year)	22.1	9.8	10.5	10.3
Sales Receipts (end of season)	10.8	12.7	10.2	13.5

Observations made at dockside support the hypothesis that producers at National deliver more than one man's share in their name. In June, 1985 landings delivered by 10 boats were sampled. This represented the catch of 33 fishermen. However, only 19 sales receipts were made out. The remaining 14 men delivering their catch in another's name were not members of National.

There is less of a discrepancy between true and estimated values of LPUE for Sarteneja:

LPUE (kg/md) BY SARTENEJAN FISHERMEN

Fiscal Year	Based on records of daily deliveries (True)	Based on production of top conch producers (Estimated)
1978	16.3	13.7
1979	15.0	14.0
1980	12.5	11.1
1981	13.8	16.1
1982	14.3	?

This is more likely because the biases described in the above paragraph cancel each other; not because more of the data pertain to single fishermen diving for conch the full 102 days.

As long as the top producers maintain their routine and there is a the same amount of bias each year, the results of this last method will illustrate the trend in LPUE. Based on this assumption, the results indicate that LPUE dropped dramatically between 1971 and 1978, remained stable until 1984 and then dropped abruptly for a second time in 1985 and 1986. How well these changes in LPUE reflect those in the abundance of _S._ _gigas_, a semi-mobile species known to have a patchy distribution, is debatable. The quality of the index depends on the degree of spatial and temporal variation in catchability. Possible change in catchability are outlined below, but as there are no data with which to quantify their effect, I have based my conclusions regarding stock condition on trends observed in LPUE.

One of the reasons why estimated statistics may not truly represent what is happening in the conch stocks is because only part of the stock is accessible to the fishery - populations located at depths less than 18 m. The abundance of animals at greater depths is not known but reports from sport-divers in Belize suggest that the number of deep water populations may be significant. Their exclusion from the exploitable stock means LPUE is at best an index of apparent abundance and not true abundance (Marr, 1951).

The use of LPUE as an index of abundance is also difficult because Strombus gigas have a contagious distribution. As a result of this spatial heterogeneity there may be a hyperstability in catchability (q); abundance may be dropping with the number of clumps while LPUE remains stable. If there are two distinct types of density - a large, low density of animals overall with small, dense patches scattered among them - abundance would be misrepresented by LPUE in a different way. As long as fishermen could find clumps, their LPUE would remain high. Once these patches were removed, LPUE would drop suddenly with the change in spatial distribution even though abundance may still be high. Conversations with fishermen indicate that they concentrate on clumps of conch to maximize yield/unit time. There also appears to be a minimum LPUE below which they cannot be bothered to search for conch. The probability of capture of each individual is therefore not the same because effort is distributed in relation to a population density gradient. LPUE may be more a reflection of the availability of concentrations of animals than the average density within a population.

Another reason why the trend in LPUE may not be analogous to that in stock density is year-to-year variation in the distribution of fishing. In Belize, there may have been a spatial variation in catchability as the fleet gradually moved from the traditional fishing grounds in the north to the southern cayes where stocks were less depleted. The greater proportion of men diving in deeper water may also have helped the LPUE remain stable between 1978 and 1984.

Changes over time in the amount of fishing power exerted during a man-day is an example of a temporal variation in catchability. Improvements in the gear's ability to catch conch and changes in the search time/handling time index would both affect fishing power. During the first years of the commercial conch fishery, LPUE increased with effort. This is a good indication that men were improving their skill at locating conch populations and diving. With the exception of this learning factor, capture efficiency is thought to have remained the same over the period studied. The transition of hooking to skindiving occurred in the 1960's and there are very few accounts of SCUBA being used; therefore, one method of fishing is believed to dominate the fishery. What has changed however, is the relative amount of time budgetted to each part of the catching process (travel, search, gather and clean). Although trip fishermen still work roughly seven hours per day, the actual number of hours per day a diver operates underwater has increased. From personal observations of handling time, it is estimated that fishermen landing 45.4 kg (100 lb) of conch per day in the past spent two hours collecting the animals and five hours cleaning them. In 1985, with the LPUE being closer to 13.6 kg/md (30 lb/md), it took 5.5 hours to search for the animals and 1.5 hours to clean them. To quantify the variations in q noted above, better documentation of the time and area fished is needed. Suggested modifications to the existing data collection system in Belize are given at the end of Chapter Six.

5.5 Total Annual Effort

Man-days fished by the membership of each cooperative was predicted by dividing the cooperative's total production by the average value of LPUE for its top producers. This kind of LPUE estimate was used because these values were available for the longest time period. Annual effort was summed over the cooperatives and divided into the corresponding total landings to arrive at an average LPUE for the country (Table 5.3). Data were lacking for the years 1971, 1975, 1976 and 1985; hence, effort was calculated by dividing total landings by an extrapolated value of LPUE. The estimates of total annual effort are presented in Table 5.6.

There have been two periods of expansion in the conch fishery: an initial period of development from 1968 to 1973, and a recent expansion in the fishery from 1980 to 1984 (Figure 5.9) Catch increased with effort during both these periods, but the

Table 5.6

Estimated total annual effort

FISCAL YEAR	AVERAGE LPUE (kg/md)	TOTAL LANDINGS (kg)	TOTAL EFFORT (md)
1967	21.9	124939	5717.2
1968	32.4	142036	4381.7
1969	45.5	248820	5466.6
1970	46.5	288690	6201.5
1971	42.6*	448302	10514.1*
1972	38.7	517073	13352.2
1973	36.2	508672	14039.9
1974	23.6	393015	16664.5
1975	21.8*	417229	19162.9*
1976	20.0*	351117	17592.5*
1977	18.2	270382	14854.9
1978	14.8	208348	14042.7
1979	16.1	226474	14078.6
1980	15.3	128315	8396.1
1981	14.6	169449	11620.2
1982	15.5	163438	10561.4
1983	14.2	201907	14186.3
1984	14.7	225247	15331.2
1985	10.8*	164239	15207.3
1986	6.9	110232	15975.7

'*' substituted values based on extrapolation

Note: Values of LPUE used in the estimation of effort rounded to one decimal point in column 2 above.

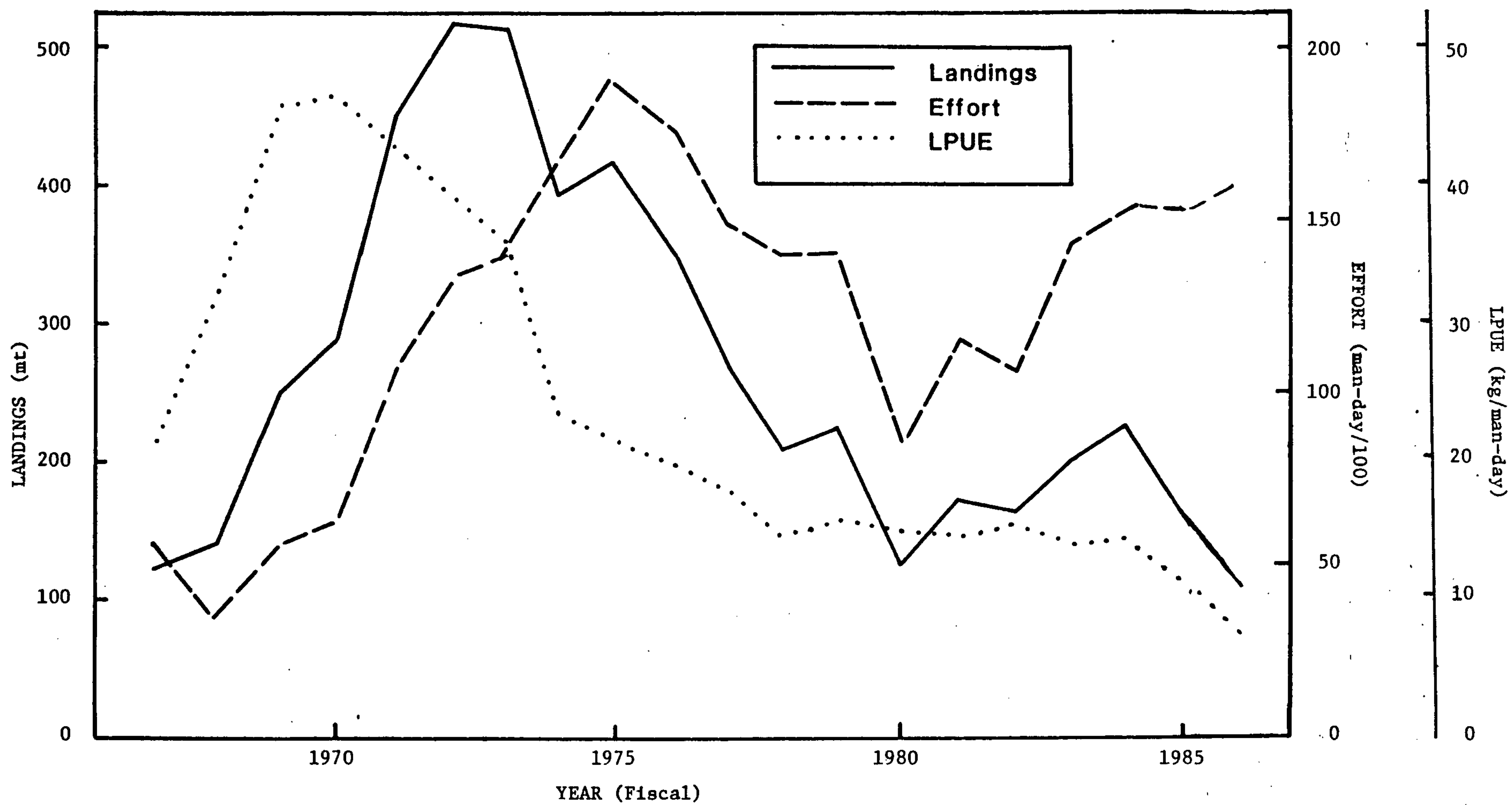


Figure 5.9 Estimated total annual landings and effort, and average LPUE (1967-1986). Data presented in Table 5.6.

relative increase in landings was much greater in the early stages of the fishery because larger stocks were being exploited (Figure 5.10). Landings in 1983 totalled 201,852 kg; this is roughly 40% of what was landed in 1973 for the same amount of effort. LPUE remained stable with the increase in effort in the 1980's until 1984 and then declined.

The potential for effort to expand given the current number of fishermen and season length is great. Each member at National spent an average of 37 of a possible 102 days fishing conch in 1984:

AVE. NUMBER OF DAYS FISHED FOR CONCH PER MAN-YEAR*

Fiscal Year	Total Effort (MDF)	No. of members delivering conch	Ave. MDF/member
1978	4,212	114	36.9
1979	5,207	102	50.1
1980	2,755	90	30.6
1981	3,576	120	29.8
1982	3,983	155	25.7
1983	6,735	214	31.5
1984	8,841	241	36.7

* Total effort for National/number of men delivering conch.

The significance of this latent effort is discussed in the following section.

5.6 Synopsis of the Conch Fishery's Development

The conch fishery has passed through four phases in its development over the last 20 years. The first significant increase in conch production occurred in 1967. By this time all five cooperatives were in operation and overseas markets were established for conch. Conch were abundant, easy to catch and

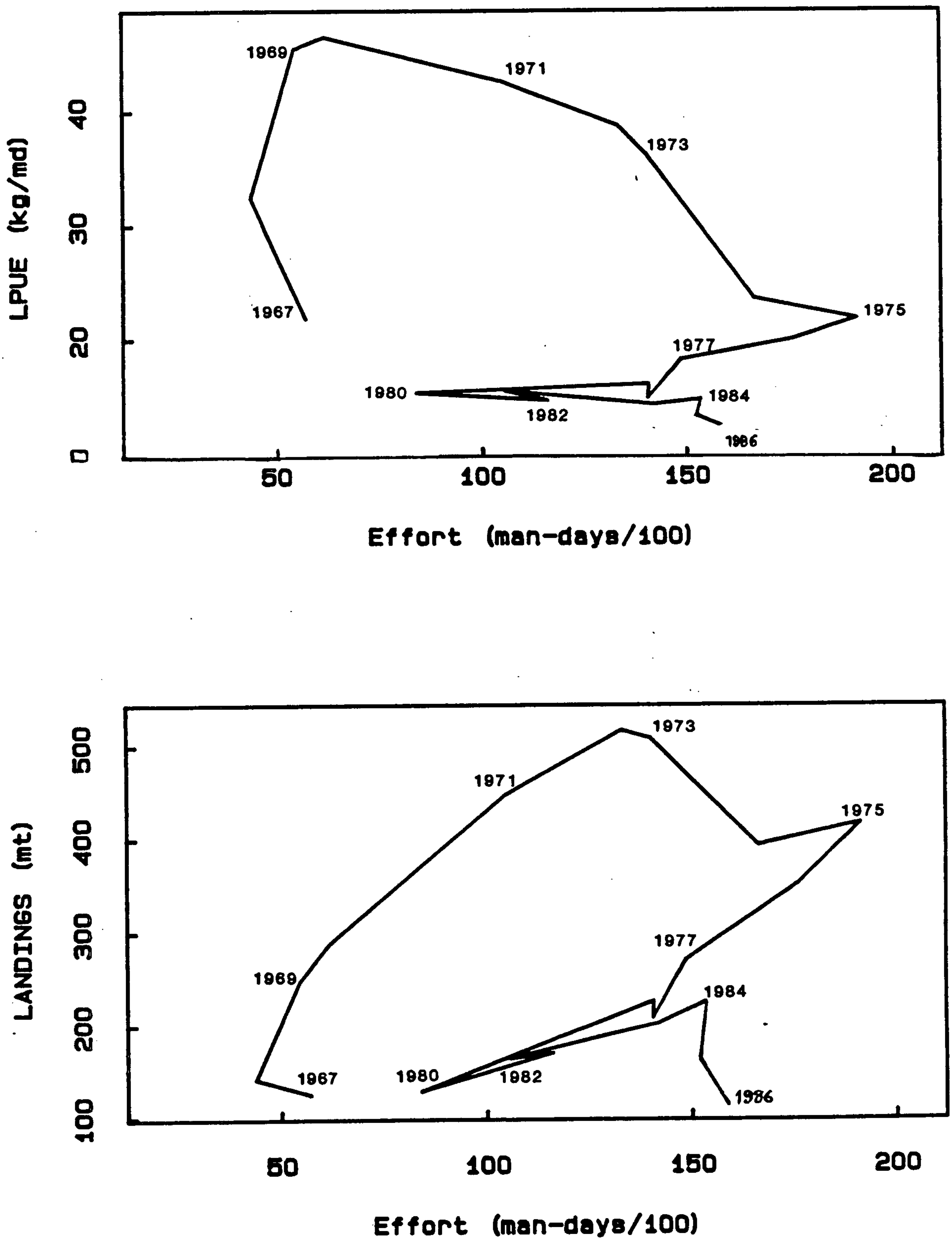


Figure 5.10 Landings and LPUE as a function of effort.

had the highest dockside price next to lobster. Effort was low for the first four years of this phase but as skindivers turned their attention to conch and became more efficient at locating the conch beds and pinpointing the most productive ones, LPUE rose rapidly and so did catch. By 1971, it was apparent that money could be made from the resource and effort jumped markedly. Production by National, Placencia and Sarteneja this year was double what it was the year before. Divers would switch to fishing conch whenever lobster was difficult to find. Though not obvious from LPUE due to changes in catchability, conch abundance probably declined during this phase. However, as the removals were relatively small, it is doubtful they had an effect on the stock.

The second phase identified in the fishery's development extends from 1971 to 1975. During this period, effort continued to increase as divers entered the fishery. National was already well established in the fishery and the number of its members landing conch remained the stable. Sarteneja and Placencia, on the otherhand, showed the most significant growth over these years. Caribeña's peak conch production occurred in 1973, Sarteneja's in 1974 and Placencia's in 1975 (Appendix VI). As the conch fishery expanded, lobster production by all cooperatives, except Northern, remained relatively stable. This supports the hypothesis that mainly divers, as opposed to lobster trap fishermen, were entering the fishing industry at this time and most were targetting on conch.

It was during the second phase that the fishery began to take its toll on the conch stock. Landings continued to climb with the increase in effort but at less than proportionate rate of increase. The average size of individuals in the stock was shifting with a reduction in the reserves of adults. A decrease in both number of conch and average weight per individual explaining the dramatic decline in LPUE in 1974. LPUE decreased from an estimated 45.4 kg/md (100 lb/md) in 1971 to approximately 22.7 kg/md (50 lb/md) in 1975. The fleet moved into the more distant southern waters in search for the last of the virgin conch beds around the mid-1970's (FAB Meeting, 1973).

During the third phase of the fishery from 1976 to 1980, LPUE was still dropping but at a much slower rate than in previous years. Despite a decline in effort, catch was still high and it seems more individuals were taken than the stock could produce; the result being a net reduction in stock size. The rate of decline in landings was increased by a reduction in effort. Even though the number of fishermen delivering conch remained the same, man-days fished for conch decreased. The reduction in time spent fishing conch was related to a combination of factors. In 1974, more fishermen began to deliver fish as well as lobster and conch which meant that fewer trips were made for conch only. Closing the conch fishery for three months in 1978 further reduced the time they would spend fishing. Although the shorter season had little effect on the effort initially, it may have been partly responsible for the drop in number of conch fishermen between 1978 and 1980.

Finally, the price of lobster was far above that for conch. In 1980, the dockside price for conch was $5.49 BZ/kg ($2.49 BZ/lb) while that for lobster was $23.15 BZ/kg ($10.50 BZ/lb).

Together, the high price of lobster, alternative opportunities in the scale fish industry and decrease in abundance of conch were shifting fishing effort away from conch. With the economic return per unit of effort higher for other species, it was not worth it to fishermen to dive for conch on a regular basis. Seasonal mobility from one species to another became a more economically efficient strategy. Following the reduction in effort in the late 1970's, stability in stock size returned. The adult reserves are gone, but the fact that LPUE remained unchanged from 1978 to 1984 suggests that it may be possible to sustain the stock at a lower level. This interpretation, of course, is subject to the condition that catch rates adequately reflect S. gigas abundance.

During the fourth phase in the 1980's, production and effort increased steadily with a boom in the number of fishermen in Belize. Interest in conch changed little since 1978. Both the percentage of active fishermen delivering conch and the average number of days fished per man-year remained the same. However, licensed fishermen delivering conch are estimated to have increased by 56% between the years of 1980 and 1984 from 658 to 1028. Effort in 1984 was only 20% less than the all time high of 1975. Data are limited for the years 1985 and 1986, but it appears that effort remained high from 1984 through 1986 and the decrease in conch landings from 225,247 kg in 1984 to 110,232 kg in 1986 was due to a drop in LPUE.

There are two probable explanations for the recent decline in LPUE assuming that LPUE adequately reflects conch abundance; namely, variable recruitment and growth overfishing. With the reserves of older animals gone, there is a higher proportion of newly recruited animals in the catch and differences in year class strength will be more noticeable. Growth overfishing may also have occurred in some fishing grounds as a result of the removal of animals with less than the legal meat weight and increases in fishing mortality rate due to growth in the industry.

These trends in LPUE and fishing effort, coupled with the facts that: 1) the mean age of first capture (2.2 yr) is less than that for reproduction (4.0 yr) and 2) there is potential for fishing effort to increase suddenly with changes in the price and abundance of conch relative to lobster and scale fish, raise concerns regarding the possibility of recruitment overfishing. Precautions which may reduce the chances of recruitment overfishing are discussed in the following chapter.

CHAPTER SIX

Management

6.1 Historical Overview

Progress towards management of the conch fishery in Belize was slow. The fishery was well established by 1967 but management was not enacted until 1977. The first management measures were contemplated around 1970 and included a quota and minimum size limit (Baird, 1971). Though accurate projections as to the level of a quota could not be made, the Fisheries Department realized that even an arbitrary quota could yield results on which future planning of regulations could be based, or at least, lessen the chances of overexploitation. If the quota was set low enough to limit the extent of commercial exploitation and recruitment was reasonably constant, a decrease in the effort needed to attain the quota over the years would indicate that abundance was increasing. The uncertainty generated by variable recruitment was recognized and a continual survey of sizes of conch landed, recommended. A minimum size limit was proposed to control exploitation until more information could be gathered through the quota system. A marketed-meat weight restriction of 57.0 gm (2.0 oz) was suggested initially but as more became known of the growth and mortality rates of _Strombus gigas_, this value was increased.

In 1973, the Minister responsible for fisheries accepted a proposal for a landings quota of 294,840 kg/annum (650,000 lb/annum) (Baird, 1973). This amount was equivalent to 80% of the average for annual landings in the previous three years. A decision on how the quota was to be allocated among the fishing cooperatives was also made but the regulation was not implemented. It appears that management objectives at this time were more in favor of maintaining employment than preserving the resource (Robertson, 1975). The cooperatives lobbied strongly against harvest restrictions as they believed that efforts to conserve the resource would be futile as long as conch were being removed by foreigners and poachers in the interim (FAB Meeting, 16 May 1973). They argued that the stock could endure the rate of fishing being exerted at the time based on the fact that production was increasing with effort and the assumption that the recruitment from reserves of adults in water too deep for divers to access, was likely replenishing the shallow water portion of the stock.

It was not until 1975, after harvest had declined that management objectives were changed and more stringent measures to protect the conch stock were adopted (FAB Meeting, 11 Aug. 1975). The third management option to be proposed for conch - a closed season - originated at this time. The rationale for this measure centered on the belief that conch exhibit a seasonal breeding migration (Robertson, 1975). As explained by the Fisheries Department, a closed season would allow conch to congregate for mating in an undisturbed environment and allow a rest and recovery period during which the smaller individuals would have a chance to grow (Mitchell, 1976). An agreement for a closed season from July 15 to October 15 was reached during a Fishery Advisory Board meeting on September 8, 1975 (Synder, 1976). However, as with the quota system, this regulatory measure was not made law until 1977; a size limit was introduced the following year. Current regulations are described in the next section.

In the last 10 years, the system of management in Belize has improved. Goals for fisheries development are outlined in a national plan and a network of committees advises the Minister on relevant matters. A legal framework for management has been developed and though improvements are still needed in enforcement, there has been progress in this area as well.

6.2 Existing Management System

6.2.1 Management objectives

Detailed documentation of the objectives of management on a fishery basis is seldom available for small-scale fisheries (Proude, 1973; Emmerson, 1980; Panayotou, 1982). There is often a variety of fishery management objectives and conflicts among them. If there is no plan identifying which objective is considered most important, it is difficult to evaluate alternative management approaches (Alverson and Paulik, 1973;

Roedel, 1975; Everett, 1983). Belize's National Fisheries Development Plan identifies optimum sustainable yield (OSY) as the goal of fisheries management, but it is not stipulated which of the objectives underlying this goal takes priority in the management of the conch fishery. The general objectives are (Miller, 1978; BFCA, 1985b & 1985c):

1) Rationally utilize resources so to ensure continuation of the stocks.
2) Ensure maximum returns to the industry through efficient harvesting, and utilization and marketing of fish products; and
3) Diversify fisheries so to ensure future stability in the industry and maintain employment opportunities for fishermen.

Based on interviews with government and industry officials, the primary interest of managers overseeing the conch fishery seems to be maintaining the stock at its most productive level. Maintaining the best average gross yield will subsequently lead to the other benefits sought from the resource including the increases in exports, employment and the amount of food available locally. Though admirable, this objective is still not well defined for it is not known what level is most productive. It might be more appropriate to state the objective as one of maximizing yield from a fluctuating abundance.

6.2.2 Management authorities

In Belize, a relatively sophisticated institutional framework has evolved to govern fisheries development and management. The primary entities overseeing management include: the Fisheries Department, the Cooperatives and Credit Unions

Department, the Belize Fishermen Cooperative Association and the Fishery Advisory Board. The Department of Fisheries originated in 1965 and is presently under the Ministry of Agriculture. Its operations are centered in Belize City and its staff numbers 12. The Department's main activities include:

1) Fisheries extension services providing social and organizational assistance to fishermen;
2) Research on commercial species;
3) Quality control of fish products and marketing programs for fisheries development;
4) Collection of statistics;
5) Licensing; and
6) Enforcement.

The Cooperatives and Credit Unions Department was established in 1953 and is involved in the development of the fishing industry to the extent that it gives managerial assistance to the fishing cooperatives. In general, it is charged with the responsibility of "promoting, organizing, registering, supervising and dissolving cooperative societies" (Cooperatives and Credit Unions Department, 1980).

The cooperatives compliance with the Fisheries Ordinance is fundamental to the management system. Their maintenance of accurate records on sales and purchases, and respect for fisheries regulations are essential for management. Annual General Meetings hosted by the cooperatives further assist management efforts by providing a forum for general discussion. Fishermen and industry representatives brought together for these meetings have an opportunity to consult on issues related to fisheries. Finally, cooperatives maintain a high quality of seafood to meet the standards of the U.S. Food and Drug

Administration and companies purchasing the products. This is an assistance to the Fisheries Department which is too under-staffed to oversee quality control on its own.

Fishing cooperatives are represented by the Belize Fishermen Cooperative Association (BFCA), an organization in existence since 1970. Its efforts in the past have been concentrated in four areas (BFCA, 1983b):

"... 1) Fostering, strengthening and maintaining closer cooperation among the cooperatives;
2) Providing information to member societies pertaining to anything that affected the industry especially efforts that threatened the protected interest of the producers and their relative control over the commercial fishery;
3) Keeping watch over the fisheries' laws and regulations and influencing changes for the protection and preservation of the industry; and
4) Assisting the cooperatives in areas that would enhance their productivity and viability."

The BFCA was administered by one man until it joined forces with the Ministry of Cooperatives and CARE to work on a fisheries management training and resource development project in 1984 (BFCA, 1984b; Government of Belize, 1984b). It subsequently acquired its own office with a full-time Executive Secretary. It now publishes a quarterly newsletter on current issues in the fishing industry and hosts various seminars for cooperative directors and educational programs for fishermen. As a spokesman for its member societies on the Fishery Advisory Board, BFCA plays an active role in fisheries management.

A Fishery Advisory Board (FAB) was created in 1965. It is responsible for providing advice to the Minister in relation to the organization, improvement, management and continued development of the fishing industry (Government of Belize, nd.). The FAB is essentially the decision-making component of the fisheries management system. It oversees the formulation of National Fisheries Development Plans, amendments to the laws and regulations governing the industry, and proposals for various types of business ventures concerning fisheries. Ten members are appointed to the board by the Minister responsible for fisheries. They generally include the Fisheries Administrator, the Registrar of Cooperatives, representatives of the BFCA, Belize Defense Force, and the Police department, and members of the business community.

6.2.3 Current Regulations

Several different regulatory measures have been taken by the Government of Belize to control the harvest of conch. The present ordinance reads as follows:

> "No person shall take in the waters of Belize or buy, sell or have in his possession -
>
> (a) any conch between the 1st day of July and the 30th day of September, inclusive, in any year;
> (b) at any time, conch the overall shell length of which does not exceed 7 inches or the weight of the market clean conch taken from which does not exceed 3 ounces."

Source: Belize Statutory Instrument No. 66 of 1977, Fisheries Regulations, 1977 and Belize Statutory Instrument No. 71 of 1978, Fisheries (Amendment) Regulations, 1978, (Government of Belize, 1977 & 1978).

Conch exports per year are limited to 295,029 kg (650,000 lb) of marketed-meats. Licensing of commercial fishermen and boats is mandatory and SCUBA is prohibited for commercial harvesting.

These last two measures were imposed in the mid-1960's with the establishment of the lobster management system. A legislation passed in 1982 which gives the Ministry responsible for Fisheries power to declare marine reserves, presents new opportunities for conch management (Government of Belize, 1982b). A series of discussions aimed at investigating this avenue and new conch management regulations such as prohibiting the harvest of non-lipped animals were recently initiated by the Fisheries Department (The Beacon, 1987). All options are discussed in more detail in section 6.3.

Upon comparing regulatory measures used in Belize and other countries in the Caribbean, it becomes evident that many countries have no restrictions at all on harvesting *S. gigas* (Brownell and Stevely, 1981; Wells *et al.*, 1983; Shusterich, 1984; Dubois, 1985; Berg and Olsen, in press). Those that do, imposed their controls on fishing only after stocks began to exhibit signs of overfishing. The Bahamas is the only country known to have established a conch management program before 1970. In the Turks and Caicos Islands, as in Belize, licenses are mandatory, a size limit is imposed and SCUBA is prohibited (Nardi, 1982). Venezuela and Bonaire have also established a licensing system. Countries known to have a closed season other than Belize include Cuba (March through September), Venezuela (December through April) and Haiti. Area closures are utilized by Columbia (Moncaleano A., 1978) and Bonaire. Fishery quotas have been set in Belize, Cuba and Mexico. Since 1971, Florida has imposed a daily catch quota (10 conch/person) and is considering a size limit of 22.5 cm which, it is estimated, will protect 50% of the flared lipped population and 90% of the juveniles (Hunt, in press). The Government of Mexico is also investigating the possibility of a minimum size limit of 20 cm, as well as a closed season (Torre Alegria, 1984). To insure maximum local utilization of the resource, export of Bahamian conch meat is prohibited and licenses are granted for export of processed products. More stringent management measures (eg. moratoriums) have been taken in Venezuela, Bonaire, Cuba and Columbia. In Bermuda, *Strombus gigas* is a protected species.

The Organization of Eastern Caribbean States is presently examining a proposal to coordinate regulations for conch among the Lesser Antilles Region (OECS, 1983). The regulations proposed include restrictions on the harvest of conch which do not have a shell with a broad, thickened flared lip, a marketed-meat greater than 225 gm (8 oz), or a shell greater than 18 cm (7 inches) in length. The use of SCUBA for commercial collection would not be allowed and a closed season would be implemented to span the longest recorded breeding season (March to October). It is also recommended that the harvest of egg-laying females or copulating pairs be prohibited at all times and that closed areas, eg. breeding sites and/or over-exploited fishing grounds, be promoted (K. Nichols, pers. comm., 1986).

6.2.4 Enforcement

At present, Belize severely lacks the human and financial resources to establish a surveillance and enforcement system. The legal framework for fisheries management exists in Belize but the Fisheries Department has no law enforcement division. Violators of the Fisheries Ordinance are prosecuted by the Fisheries Administrator personally in his official capacity. There is only one Fisheries Inspector on staff. He is assisted by one or two Fisheries Officers and is in charge of conducting spot checks at the cooperatives, local markets and eating establishments to ensure no undersize and/or out of season fish products are being sold. The Department relies on the assistance of the Belize Defense Force and the Police Department for their surveillance at sea. A preliminary study on fisheries surveillance in Belize was conducted by the Overseas Development Administration (ODA) in October of 1981. An integrated air and sea surveillance system was subsequently recommended and its cost was estimated at $1.15 m BZ (FAB Meeting, 2 Oct. 1981). This amount would cover the cost of high speed patrol crafts, VHF radios, cameras and armament, the rental of a plane and training of special personnel. It is impossible for Belize to finance such an operation at this time. As a result, the managers have had to rely on existing systems as described below.

The Fisheries Department has taken several approaches to improve the enforcement situation in Belize. The first was to work in collaboration with other law enforcement divisions of the government. The Police Department acquired three patrol boats in 1982, and the Marine Arm of the Belize Defense Force received patrol boats and an aircraft in mid-1984. The Fisheries Department has made arrangements to use these vessels for fisheries surveillance by having Fisheries Officers taken on patrol. Another approach was to appoint members of the cooperatives' management committees as fisheries officers (BFCA, 1984b). This option was proposed by the BFCA and incorporated into the Fisheries Ordinance in 1982. The fishermen's assistance in policing regulations could be very valuable but the success of the program depends on the fishermen's willingness to reprimand a fellow fishermen. Belize is a small country and the community of fishermen is tightly knit. It is not unlikely a Fisheries Officer will encounter friends or family members fishing illegally. If the law is upheld, animosity among fishermen is inevitable and this may generate problems of another kind. A less direct approach to curtailing illegal fishing has been to impose stricter penalties for those convicted for contraventions of the fisheries laws. Penalties included any one or a combination of, a jail sentence, fine, or confiscation of the fisherman's catch, gear or boat.

The vigilance and understanding of fishermen, as exemplified by the success of the lobster management system, is the key factor in the effectiveness of regulations in Belize. Recognizing this and hopeful of instilling an awareness among fishermen of the necessity and benefits of conservation policies, the Fisheries Department and the BFCA have organized a number of education programs. Given the cooperative spirit observed in fishermen and limited resources available for enforcement, the author believes this is an avenue which has potential and should be pursued.

6.3 Management Options

There are several factors to consider in the evaluation of management options for the queen conch fishery in Belize. The main ones include the following:

1) The desired harvest strategy;
2) How certain one is of stock abundance, expected effort and catchability;
3) Consequences of not achieving the target catch for a particular strategy;
4) Characteristics of the species' biology;
5) How the fishery operates; and
6) The information requirements and costs of implementing each option.

All these factors work synergistically. It is difficult to know how the system works as a whole, which variables are most important and what the consequences of managing under uncertainty are without building a sensitivity model (Hilborn, 1986). However, before one can venture to that level of analysis, the variables of the model need to be identified and the accuracy with which they are likely to be estimated assessed. This is the stage managers are at with the conch fishery in Belize.

In this study, a preliminary evaluation of management options is conducted. Since the management objectives of managers in Belize are not specifically stated, three possible types of harvest strategies are considered: constant catch, fixed escapement and constant harvest rate. The likely outcome of six options that may be used to implement these strategies are predicted; some of the options presented are already in use in Belize. Requirements for implementing the different controls and the effects they are likely to have on the industry are also discussed.

6.3.1 Effectiveness of options in meeting harvest strategies

6.3.1.1 Quota

The quota system used in Belize applies to the fishery as a whole; there is no allocation among individual fishermen. Because there is only a limited internal market for conch, the quota was designed to limit of the quantity permitted for export which is far easier to monitor. The quota was implemented originally as a preemptive quota (Sissenwine and Kirkley, 1982). There is no evidence that it was used specifically to keep the stocks at a level that would maximize sustainable yield. Exports by cooperatives from 1978 through 1986 averaged about 166,112 kg which is notably lower than the ceiling of 295,029 kg (650,000 lb).

If the quota in Belize was used to reduce fluctuations in annual catch, it would have to be lowered. This option would provide stability in the income of fishermen and make it easier for cooperatives to plan their operations. However, it would not stop an increase in the size of the fleet or changes in fishing methods. There would still be the danger of overcapitalization. It is also questionable whether a lower quota would allow adequate escapement. Predicting the level of a quota with little knowledge of stock size, is a high risk to take. If the quota is based on an overestimate of stock size, yield will be lost the current year due to growth overfishing and possibly in the future due to recruitment overfishing. If stock size is underestimated, not all the allowable yield will be taken and future recruitment may also be affected if the stock/recruitment relationship abides by the Ricker (1975) model. Costs of underestimating optimum yield will also be influenced by the natural mortality rate (M). If M is low, benefits lost one year can be regained the following year. This is less likely to be the case if M is high.

6.3.1.2 Closed season

A closed season was imposed on the conch fishery of Belize for biological reasons; economic concerns, eg., maintaining product quality or allocating effort between user groups, were not an issue. The aim of the closure from July through September was to protect conch during their seasonal breeding migration and to allow further growth of smaller individuals. This rationale is based on the understanding that: 1) this period coincides with the height of the breeding season, 2) conch are more vulnerable during their breeding season because they migrate into shallow water and cluster to mate, and 3) conch go through a rapid increase in growth and weight just prior to reaching the minimum legal limit. In their studies on the reproductive cycles of conch in Belize, Blakesley (1977) and Egan (1985) found that conch are capable of breeding year round. They did not however, indicate at what time of year spawning was more intense. Therefore, an addition assumption has been made, i.e., that conch in Belize, like those elsewhere in the Caribbean, spawn more frequently during the warmer months of the year. A season closure would give juveniles extra time to grow, but a well enforced size restriction would be a more effective means of ensuring the cohort is harvested at the appropriate age to maximize yield.

Hilborn (1986) notes that restricting the time allowed for fishing via season closures may be a preferred option for invertebrate fisheries if fixed escapement strategy is desired and there is uncertainty regarding stock size. With a fixed season, one would expect the harvest rate to rise with stock abundance if effort can be increased by either fishing when fishing is good, or by the entry of fishermen from outside areas. Alternatively, at low stock densities harvest rate declines and escapement improves.

The numerical response of fishermen is strong in Belize with the availability of alternate species. Fishermen are apt to switch to another commodity when the economic return per unit of effort received for conch decreases relative to other species, and hence, one might expect escapement to improve at low stock densities. This is an advantage as long as what remains after fishermen switch off is sufficient to sustain the stock. The stability observed in LPUE between 1978 and 1984 tends to suggest that the average harvest rate reached by the fishery during this time was within optimal levels. However, the drop in LPUE in recent years indicates that the season length is too long for the number of participants in the fishery. It allows the harvest rate to increase with stock size at too great a rate. The season could be shortened but as long as there is unlimited entry, restricting the time allowed for fishing will be an ineffective means of controlling effort in the long term. Extending the closed season will be useful primarily in providing the fishery managers with extra time to develop more effective management schemes.

Increasing the duration of the closed season to include October would be the easiest way to lower the upper limit the season length imposes on fishing effort. October is the one month when fishermen are not especially keen on fishing another commodity or busy with other community or fishing activities. The opening of the lobster season in July deters most fishermen from diving conch despite the closed season. The fishermen's interest in conch is also less during the rough weather months, when snapper and grouper are spawning, around Easter and Christmas, and when men haul their boats for repairs in anticipation for the lobster season. It is better to extend the season into October than June because fishermen have cash on hand then; in June, fishermen are low on funds and rely on conch as a source of income until the lobster season reopens.

6.3.1.3 Limiting entry

Theoretically, a limitation of the number of fishermen would be the most effective means of controlling the harvest rate. With effort restricted at a certain level, catch would increase with stock size at a constant rate. This option is optimal if YPR is to be maximized; however, it will not stop fishermen from fishing at low stock sizes which may be a problem if recruitment overfishing is a concern. Still, this option is a safer approach than a quota given the uncertainty with which stock size is likely to be estimated. With a quota, the harvest rate will increase as abundance declines. At the other extreme, i.e., high stock sizes, limiting effort may inhibit the removal of the stock's total surplus production. At present, effort is free to expand during the season to take advantage of what is available.

Though limiting entry may in theory be an effective management option, it is not thought to be politically acceptable in Belize nor practically applicable to enforce. Limiting the number of fishermen to those currently in the conch fishery would be difficult. It is most likely that all licensed fishermen will claim they have some sort of investment (eg., financial) in the fishery, and therefore, have the right to be issued a license to dive conch. Even if access could be limited to the estimated 62% of divers presently delivering conch, there may still be too many people in the fishery. It will depend on the potential effort part-time fishermen are capable of exerting should they decide to fish conch full-time.

6.3.1.4 Gear restriction

The rationale for banning the use of SCUBA for commercial fishing in Belize was to reduce the fishing mortality rate, particularly that on lobster. However, controlling the efficiency of harvest did not prevent more divers from entering the fishery and effort from increasing. Though prohibiting SCUBA does little to keep the harvest rate or catch constant, it does succeed in protecting the deep water reserves of conch. If these populations are proven to be the main source of new recruits, this option will be of particular value in preserving the spawning stock.

6.3.1.5 Size limits

Size limits control the age of entry of animals into the fishery. The rationale for using this measure in Belize was to protect premature conch so that they may grow to an economical size and increase the proportion of individuals of each cohort that survive to spawn. As with the gear restriction, this option modifies the harvest capacity of each vessel and is an indirect means of meeting the harvest strategies considered here.

In Belize, the minimum allowable shell length for conch is seven inches (17.8 cm) and the minimum marketed-meat weight is three ounces (85.1 gm). Based on the weight-length regressions obtained in this study, these measurements do not equate to an individual of equal size. The shell length corresponding to the minimum meat weight is 20.3 cm not 17.8 cm. Increasing the length limit and strict enforcement of the current weight regulation would shift the average time of first capture (t_c) from its current estimated position of 2.2 years to 3.0 years, but this is still lower than the predicted optimum tc of 3.5 years. The size of capture at which YPR is the highest for the fishing mortality rate estimated for Belize (F=0.6) is 21.7 cm. To maximize YPR, it is estimated that the meat size limit would have to be increased to 113.0 gm (4 oz). It is noted however, that the increase in YPR with increase in tc is minimal after 3.0 years.

Meats less than four ounces comprised 23% of the landings (by weight) sampled at the cooperatives in 1985. An increase in the minimum allowable size would therefore, decrease yield significantly in the short term. It would take six months for animals weighing 85.1 gm to reach 113.0 gm, thereafter, YPR would be increased by an estimated 12% (F=0.6;M=0.1). Improving enforcement of the present meat weight regulation would increase YPR by 11% with only an 11% loss in weight of animals landed. This option would therefore have a smaller impact on fishermen economically.

Trying to obtain the best yield from a cohort is an adequate management strategy if recruitment in the species fluctuates independently of stock size. If the stock-recruit (S/R) relationship on the other hand is strong, basing a size limit on a YPR analysis may not be a good approach because it does not take recruitment, the controlling variable, into account. Fishing mortality rates and size limits that give high YPR might result in low egg production. For instance, if adult mortality rate is low and fecundity in large individuals high, the relative reproductive value of old, large adults would be great; their removal would have a large impact on egg production. Hence, the consequence of assuming no S/R relationship exists, when in fact one does, could be severe. Even if the S/R relationship is not known, it is wise to conduct a fecundity-per-recruit analysis and compare the results with YPR calculations (Jamieson and Caddy, 1986). Building a model to examine production of eggs during the life of the cohort requires knowledge of the species age-specific fecundity (Sluckanowski, 1986). Since there is no information on this topic for S. gigas, such an analysis could not be performed in this study.

Size restrictions based on length provide minimal protection of the reproductive capacity of conch stocks because length is a poor indicator of maturity and there is large variation in size at age. It takes roughly one year after reaching maximum length to reach sexual maturity. In the Belize fishery, there may be a span of up to two years from the time conch enter the fishery (tc=2.2 yr) to the time they are able to reproduce at an estimated age of 4.0 yr. In regard to variance in terminal size, adult conch in Belize range from 16.7 to 26.3 cm and females are generally larger than males. As a result, selective harvesting on the basis of size may introduce a bias toward the removal of fast growing individuals and females may be fished more intensely than males. The only breeders protected by the current limit are the dwarf form of S. gigas, the Sambas.

With time of capture set below the age of first reproduction, recruitment overfishing is a concern and more conservative size limits should be considered. Imposition of a regulation requiring a fully developed lip will cause uniform random cropping of the breeding stock. However, enforcement will be difficult as fishermen clean their catch at sea and given the wide range of adult sizes, there is no way to identify lipped and nonlipped animals from marketed-meat weight alone. Fishermen will have to deliver conch live (which is feasible for day-men only) and then there will be questions concerning the return of undersized individuals and disposal of the shells of lipped conch (the latter may be a problem for cooperatives based in Belize City).

Another option is to raise the minimum allowable meat weight to correspond with the average weight of adults. The average weight of adults collected for morphometric studies in this study was 120 gm (4.2 oz). Conch of different areas may vary in terminal size, but a uniform size limit, as opposed to area specific size limits, would be easier to administer and police. Because the proportion of sambas in the stock is unknown and there is little information on the factors controlling the growth of this dwarf form, I have not addressed the question of how an increase in the size limit may change the size distribution of the stock.

6.3.1.6 Closed areas

The spatial restriction of fishing activity is another possible management alternative. In 1982, the Minister responsible for fisheries was authorized to declare any area within the fishing limits of Belize, a marine reserve. The rationale for closing an area as stated in the Fisheries (Amendment) Act, 1982 (Government of Belize, 1982b) is to:

"... a) afford special protection to the aquatic flora and fauna of such areas and to protect and preserve the natural breeding grounds and habitats of aquatic life;
b) allow for the natural regeneration of aquatic life in areas where such life has been depleted;
c) promote scientific study and research in respect of such areas; or
d) preserve and enhance the natural beauty of such areas."

The first marine reserve (Hol Chan) was designated in the fall of 1987; it is located on the main reef near the town of San Pedro on Ambergris Caye. Creation of national marine reserves through the the National Park System Act of 1981 is another avenue by which fishing may be restricted. Half Moon Caye (Figure 1.1) is the only national park presently closed to fishing, but several others have been proposed (Deshler, 1978; BFCA, 1984c).

In regard to stock rejuvenation, large area closures would be a less costly alternative than closing nursery areas and individual breeding grounds. If the objective is to protect juveniles so they may reach the optimal size for harvesting, a size restriction would be a more direct approach. Closing breeding grounds to protect the brood stock will require predicting exactly where *S. gigas* spawn as well as when. A considerable amount of manpower would also be needed to guard the spawning grounds and/or collect the adults and place them in designated protected areas. Closing the fishery during the breeding season as is currently done is easier logistically.

If blanket closures of overfished areas, eg., Half Moon Caye, are implemented to aid stock rejuvenation, fishing for all species in each area will have to be restricted unless enforcement practices are rigorous enough to include vessel hold inspections. This may lead to controversies if other species are underfished. Decisions will also have to be made on whether the closure should be on a short term basis or permanent basis. If rotational area closures were used, other regulations, eg., size limits, will still be needed to ensure the area is not overfished again. Long term closures may result in overstocking of sanctuaries and understocking of unprotected areas.

6.3.1.7 Economic measures

There are a number of economic measures taken by the government which could potentially influence the fishing mortality rate exerted by the conch fishermen. These include the price control on the sale of conch in local markets, the tax on fish exports (5% ad valoreum) and the fees applied to fishing and boat licenses. Incentive and disincentive plans such as these are not evaluated in this report due to a lack of economic data on the fishery. However, the purpose of a price control with the ceiling price set much lower than that received by fishermen at dockside is questioned (refer to chapter four; section 4.2). Having the cooperatives subsidize local families with conch when this commodity fetches such a high price on foreign markets and can be exchanged for foods with greater nutritional value per dollar, seems illogical from an economic standpoint.

6.3.2 Information requirements, implementation and enforcement

To accurately assess the level of a catch quota used to maximize yield from a fluctuating abundance, researchers in Belize will need to be able to predict maximum sustainable yield and forecast incoming recruitment. Information on the size of the resource and the regulation based on it, would have to be continually updated for the regulation to be flexible enough to account for variability in recruitment. Adjusting the regulation quickly enough to respond to the condition of resource will be particularly important if new recruits constitute a major part of the catch and/or recruitment is highly variable.

A quota on cooperative production would be administratively simple but establishing a network to monitor landings outside the cooperatives would be difficult as landings sites are dispersed. An export quota would be easier to enforce than a restriction on total allowable catch but one cannot assume sales on the local markets are fixed. The problem of illegal exportation to neighbouring countries could escalate since enforcement at sea is limited. The best way to ensure the regulation is effective is to prohibit all conch fishing once a quota is met.

To use the season closures to control harvest rate, managers must know the fishing mortality rate (F) they wish to target upon and the relation between F and effort. Prerequisite data needed to acquire this information is severely limited at present. Prohibiting cooperatives from processing during the closed season would be simple, but surveillance, either at sea or local markets, would still be needed.

The least disruptive approaches to limiting entry would be to: 1) restrict licenses to fishermen already in the industry; 2) require that license holders be full-time fishermen; and/or 3) increase license fees. Managers in Belize would have to define the criteria by which one classifies a fisherman as a full-time conch diver. It would be difficult to identify full-time independent fishermen because there are no records of their landings. Requiring that all fishermen be members of cooperatives may simplify matters. Managers would also have to design a new licensing system because a different license would be needed for each species. Commercial fishermen are already required to have a valid license on their person and the registration number of their boat clearly marked. However, surveillance at sea will still be complicated by the presence of unmarked cargo, passenger and sport-fishing boats.

Implementing a regulation banning the use of SCUBA for commercial harvesting was easy largely because few fishermen are interested in adopting this harvest technique. Diving with tanks is far more costly and dangerous than skindiving. There is also the time consuming task of maintaining the equipment and refilling tanks. This lack of interest in SCUBA makes enforcement easier in one sense, but surveillance at sea is still necessary.

To calculate the best minimum size based on YPR and fecundity-per-recruit, better information is needed on the growth, mortality and fecundity of S. gigas. Weight-length relations of conch in various populations throughout Belize should also be studied. As was demonstrated in Chapter Three, obtaining such data and estimating model parameters is subject to many complications. Restrictions on meat weight would be easiest to implement since fishermen land cleaned conch. Prohibiting the harvest of non-lipped animals would be difficult to enforce; managers will have to rely largely on the vigilance and cooperation of fishermen.

If managers anticipate having either the cooperation of fishermen or sufficient seaborne patrols to make closing an area a viable management alternative, they should consider: 1) which area(s) and how large an area to close, 2) the duration of the closure, and 3) what other species are in the area. Selecting an area on the basis of how easy it will be to patrol and dealing with the general problems of enforcement, eg., encroachment, are additional considerations.

6.3.3 Regulations from the industry's perspective

There is no opposition of the quota from the industry at present because it does not limit exploitation. If it did prohibit fishermen from taking conch, cooperatives would no longer be able to capitalize on increases in demand and prices. If the fishing season is shortened due to the desire of individual fishermen to catch as much as they can before the quota is met, cooperatives may also experience problems in handling the product. In addition, fishermen may run into financial difficulties if they are not allowed to fish conch during the closed season for lobster because the quota for conch has already been filled.

The closed season is not a new approach in Belize. Fishermen seem readily acceptant of this measure as a means to protect conch from overexploitation. This and the fact that the closure extension suggested is for only one month and at a time of year (October) when fishermen are not particularly short of cash may mean there will be little opposition. When deciding on an extension, fishery managers should take into consideration that effort on lobster and scale fish may increase and that the impact this measure has on decreasing effort on conch is only known qualitatively. Accurate monitoring of effort is a prerequisite for proper evaluation of this option. Further study is needed to determine how a change in the timing of a closed season would effect marketing of conch. Belize's largest competitor on the international markets (Turks and Caicos Isles) has no closed season at present.

If the suggestions for limiting entry presented in section 6.3.2 are considered, managers can anticipate controversy over the exclusion of part-time fishermen from the fishery and increases in the costs of fishing caused by raising the license fee. Belizeans will also have to change their perspective regarding the ownership of natural resources. Fisheries resources will no longer be common property; some Belizeans will be denied the opportunity to earn a living from fishing conch. The government will have to decide if they can restrict licenses; it may not be justified in Belize as the need for employment is great.

Though the ban on SCUBA reduces the capture efficiency of the harvester, there appears to be little objection. Fishermen are deterred from adopting this method of fishing due to the high initial and operational costs of SCUBA. Safety is also a concern as there is no formal training programs, decompression chambers nor regulations regarding dive operations and purity of compressed air.

The degree to which fishermen will object to a change in size limits will depend on their desire to invest in the resource. In other words, how willing they are to trade immediate gains for larger future ones. Explaining the biological basis for these changes may convince some fishermen, but their concern that poachers will reap the benefits gained before they do, lessens the chance they will abide by the regulation.

One of the industry's main concerns with closed areas will be how the areas are distributed with regard to each cooperative's location. Fishermen not allowed to fish in an area close to their home port will feel deprived if another cooperative is not subject to the same inconvenience and higher costs incurred with travelling to alternate sites. Rotating closed areas may help resolve this problem.

6.3.4 Recommended approach

If a manager's aim was simply to achieve the target catch of one of the three harvest strategies considered here, the following options would be the best:

Harvest Strategy	Best Option(s)
Constant catch	Quota
Fixed escapement	Size limits, season and area closures
Constant harvest rate	Effort limitation

Likewise, when considering which strategy would be best for a given objective, it is recommended that a constant catch strategy be considered first if the objective is to minimize year-to-year variability; a fixed escapement strategy, if the desire is to optimize long term average yield; and finally, a fix harvest rate if the goal is to maximize YPR and recruitment overfishing was not a concern.

The management situation in Belize however, is not as simple as this. Harvest strategies are not documented and there is no information on what level of yield, fishing mortality rate or escapement managers should target for. The Fisheries Department has limited resources (financial and human) with which to monitor stock condition, implement options or enforce regulations. In addition to these management constraints, there are also aspects of the species' biology that raise the risks and costs of mismanagement. The conch's tendency to clump increases catchability and may lead to a hyperstability in LPUE. Determinant shell growth leads to difficulties in estimating vital parameters, and hence, changes in YPR with age of entry into the fishery and F can not be modelled with any certainty. There is also a long immature phase during which conch are potentially exploitable.

Under these circumstances, adopting management strategies such as a quota system and limited entry program are not recommended. Information requirements are too demanding. Managers would need to estimate the long term target, and then determine whether the current exploitation rate should be reduced or allowed to rise and at what rate the target should be approached. In general, these regulations would be the most difficult to implement properly and monitor in Belize. Maintaining the fishery at its present magnitude (status quo policy) and improving the Fisheries Department's capabilities of monitoring stock condition would be a better approach.

Given that the chances of recruitment overfishing are increased with time of first capture being less than time of first reproduction, it is recommended managers take a more conservative approach toward management. Given the possibility that a strong relationship may exist between stock size and recruitment, they should safeguard against recruitment overfishing by adopting a fixed escapement strategy. Of the harvest strategies considered above, this would be the best at minimizing the risk of the fishery collapsing from excessive fishing.

The management options considered most appropriate in this regard include, in order of importance, size limits, season closures and gear restrictions. As explained in the section 6.3.1.5, a regulation prohibiting the harvest of nonlipped individuals and a minimum size restriction on market-cleaned meats corresponding to the average meat yield adults (120 gm; 4.2 oz) are necessary to protect the breeding population until a more thorough assessment of stock condition can be made. Maintaining the current three-month closed season which extends over the warmest months of the year when spawning is thought to be most intense and prohibiting the harvest of adults which have migrated into areas too deep for free-divers to access are considered the next best management options. Size limits are most important because damage to the stock would be greatest if they were not imposed. Fishermen would target on the smaller conch as they are found in dense clusters, and therefore, easier to fish. The exclusion of the closed season would not be as detrimental because the economics of fishing conch would still control the rate of harvest to some extent. Gear restrictions are not as essential as size limits because the lack of interest in SCUBA due to the costs involved would lessen the effects of lifting the ban on SCUBA.

The above options are passive controls with regard to effort. Given that fishermen have the potential to exert far greater effort than they currently do, it would be wise to have a contingency plan in case changes in prices and/or decreases in the abundance of other species trigger fishermen to target on conch. Two options are considered feasible: closed areas and a shift in the closed season. Closing areas which show signs of overfishing (eg., declining LPUE and mean size of individuals in the catch) should be a first step. An area closure is easier to enforce because it affects only the fishermen who routinely fish in the area. Shifting the closed season to include October would be more successful at limiting effort but may also have a much stronger financial impact on fishermen. This may be considered as a last resort.

Fishermen are accustomed to the three options considered above for immediate action, i.e., size limits, closed season and gear restriction. Given a clear explanation of the stock's condition and biological basis of these measures, they may be encouraged to abide by the recommended changes and participate in conservation programs. Soliciting the assistance of fishermen in data collection and enforcement is crucial in Belize due to the limited resources of the Fisheries Department. Their involvement at the decision-making level would also benefit management. Progress has been made by including the BFCA on the Fishery Advisory Board and recent decision to appoint members of the cooperatives' management committees as fishery officers. Little work, however, has been done at dockside. A new approach to collecting data on catch and effort from the fishermen is proposed in section 6.4.

Monitoring the effects of the changes made in fisheries regulations go hand in hand with their implementation. A trial period of three years for new regulations should be considered.

Size composition data on fished and unfished populations as well as time series data on catch and effort by area are most needed for an evaluation of the recommended measures. The subject of data collection as a whole is addressed below.

6.4 Suggestions for data collection

Through-out this study, various types of data needed by fishery managers in Belize have been noted. They may be categorized into three main groups: conventional fisheries data, economic data and data pertaining to basic biological parameters. The first group encompasses statistics on landings and effort by time and location and the composition of the catch by size. Knowledge of the operations of the fleet and how to standardize effort for variation in fishing power also falls into this category. Historical data on prices, earnings, costs and incomes are needed to understand the economics of fishing conch, i.e., whether the conch fishery has reached economic equilibrium and to what extent the presence of alternatives deters fishermen from exerting more effort on the conch stock. The last category includes data from tagging investigations and research vessel surveys, i.e., that pertaining to growth and mortality rates, the spatial heterogeneity of S. gigas, selectivity of fishing operations, stock size and pre-recruit abundance.

Time series of catch and effort data are the most useful for stock assessment purposes. The other data types are thought to have a lower priority in Belize at present. Economic data will certainly add to the burden of data collection. Research in the field (eg., surveys of conch biomass) would be costly because of the species' wide occurrence and patchy distribution, and the requirement of divers. Sampling juveniles would be even more problematic due to their clumped distribution, their habitat preferences which differ from adults, and their tendency to bury.

In planning a new data collection program, the government might first consider separating the Fisheries Department into two different divisions - one for licensing and policing (eg. protection branch), and another for research and extension (eg. development branch). As it is, there is a conflict of interest. Managers who establish and ensure that regulations are effective, are also involved with the collection and analysis of catch and effort data. For fishermen to cooperate with biologists, a clear distinction should be made between the two functions. The Fisheries Department may be too small at present to have two separate offices but effort could be made to establish a rapport with fishermen and ensure confidentially. Communication with fishermen at all stages of data collection is important; biologists should explain to fishermen why the statistics are needed and report on the findings.

Another step to be taken in improving the data collection system is to introduce a new type of statistical form. Instead of trying to determine landings per man from individual sales receipts, it would be better to estimate landings per boat (Appendix V). With this approach, only the captains would need to complete the data forms and the paperwork involved in analyzing the data would be reduced. This method would provide an estimation of the number of men aboard and days fished; and hence, improve resultant LPUE estimates. Trips made primarily for conch, i.e., with nil or incidental landings of other species, should be focussed upon. If other commodities are fished, an attempt should be made to estimate how many days (or hours) were devoted to conch. The new statistical forms could be adapted to include information on the number of foreign boats observed in fishing grounds of Belize. This would be a simple means of assessing the magnitude of illegal fishing. The fishermen should be provided with instructions on how to complete the new forms properly, eg., that man-days per trip does not include travelling time. Posting a schematic diagram of fishing areas (perhaps a prototype of statistical fishing areas) may facilitate the identification of area fished recorded on data forms.

Data on catch and effort gathered directly from the fishermen can be used to correct for biases in the above 'log-book' data. Dockside surveys to supplement the log-book information and sample landings should be made on a routine basis, eg., twice a month at all cooperatives. Fisheries staff will need to be briefed on how to collect the supplementary statistical information and sample landings randomly (see Chapter Two). Periodic sampling to identify how many independent fishermen deliver to the cooperatives could be done at the same time.

Unlike catch and effort statistics which indicate the effect fishing has on the stock indirectly through an apparent change in abundance, data on the size composition of the catch indicate how the stock is affected by fishing. Biological variables such as mean size and sex ratio are, therefore, intrinsic indices of stock status (Caddy, 1986). The importance of collecting such data in Belize rests with their value in the detection of recruitment overfishing and ease of collection through the cooperatives' processing plants. Morphometric data could be gathered at the same time if arrangements were made for some day-men to delivered conch live.

Past statistics can be standardized by using the plant manager's records of daily landings. These tallies have deliveries listed in chronological order. Hence, it is easier to identify deliveries per boat, and thereby, correct for bias introduced by the shares system and deliveries made by nonmembers (see Chapter Five). License information will also be needed to estimate the number of fishermen in Belize and obtain more data on fishing operations by independent fishermen. It is important that the license forms, even renewals, be complete.

More data will not be of use to scientists in their assessment of stock condition and changes in fishing activity unless they can be analyzed. Thus, improvements in the analysis of catch and effort data must parallel those in the collection system. In the interim, data should be well documented and organized (i.e., by time and location), and recorded accurately and neatly. Much of the tabulation and even analysis can be done with a hand calculator (Pauly, 1984). Computer assisted analyses may also be possible through arrangements with other countries having the facilities. Countries with conch fisheries of their own and research programs established in the Fisheries Department and/or universities (eg., U.S. and Puerto Rico) are apt to be the most interested in such a cooperative program. Collaboration of this sort was promoted at the last international meeting on conch fisheries held by the Gulf and Caribbean Fisheries Institute (Williams, in press).

CONCLUSIONS

1. Prior to the establishment of fishing cooperatives in Belize in the 1960's, exports of queen conch (Strombus gigas) were minimal compared to those for lobster, scale fish and turtle. Harvesting of conch on a large scale did not commence until 1967. For the following 20 years, the fishery was the country's second most important next to lobster in terms of economic value.

2. Expansion of the small-scale fisheries of Belize is attributed largely to the centralization of fishing through cooperatives. The system of fishermen-owned production and marketing cooperatives facilitates improvements in harvesting methodology, processing and marketing, and contributes to the monitoring and regulation of fishing activities.

3. Until 1978, National was the cooperative with the largest conch production. During the peak years of the fishery (1971-1977), this cooperative accounted for approximately 50% of the country's total landings. Roughly 82% of its members delivered conch each season. From 1978 to 1982, Sarteneja matched National in the production of conch with 95% of its members fishing for the species. Since 1982, National and Northern have been both the largest cooperatives and conch producers. Placencia has the largest portion of its total sales (25%) attributed to conch. Approximately, 85% of its members deliver conch within a season.

4. The average export price received for conch by the fishing cooperatives has increased from $8.62 BZ/kg in 1982 to $13.62 BZ/kg in 1986. Lobster and scale fish in comparision, averaged

\$42.22 BZ/kg and \$6.55 BZ/kg in 1986, respectively. Average export price for shrimp was \$22.05 BZ/kg in 1986. Most of the conch processed by the cooperatives is sold to the United States; only 4.4% of the production by the four largest cooperatives was retained for sale on the local market in 1984.

5. The conch resource serves as a substitute source of income for fishermen when the lobster season is closed and when the abundance of alternate species is low. National's conch divers on average earned \$2,500 BZ to \$3,600 BZ annually from their sales of conch between 1979 and 1984. Total gross annual income of National's producers was estimated to range from \$10,400 BZ to \$19,000 BZ over the same period. Variance in gross income between fishermen is high because many men fish on a part-time basis and others have more than one man's catch recorded under their name.

6. Conch landings by exporting cooperatives increased steadily from 1967 and peaked at 517,073 kg in 1972. Harvest dropped until 1980 due to a decline in stock biomass and subsequently, effort. LPUE (kg/man-day) decreased as abundance of older adults declined and the size distribution of the catch shifted toward smaller individuals. The modification of harvest rate with abundance is believed to be an operational response of the fleet to a mixed species resource. More data are needed for verification, but it appears that fishermen try to maximize their economic returns per trip by seeking the most opportune mix of species depending on their relative abundance, market value and distribution.

7. By the 1980's, the conch fishery was essentially seasonal

with roughly one third of the year's total production being delivered within the first month of the season (October). Relatively few divers fish conch on a full-time basis, but when targetting for other species, all divers will take the conch they encounter.

8. LPUE averaged roughly 15.0 kg/md between 1978 and 1984. This is one third of what the catch rate was in the late 1960's. The reduction in effort in the late 1970's due to the poor economics of fishing conch relative to lobster, and the implementation of size limits and a closed season are thought to have given the stock an opportunity of rebuild its reserves. As a result, the stock was able to sustain the second upswing in effort from 1980 to 1984.

9. The drop in LPUE in 1985 and 1986 while effort remained relatively constant may be a consequence of variability in year class strength and/or growth overfishing.

10. The reliability of LPUE as an index of conch abundance maybe subject to a number of temporal and spatial variations in catchability.

11. Fishing effort for conch increased from 1980 to 1984 due to an increase in the absolute number of conch divers (from 658 to 1028). The proportion of total fishermen in Belize delivering conch and the effort per man varied little over this period. Fishing mortality may have increased with the general expansion of the fishing industry.

12. A total of 1675 fishermen were active in Belize in 1984. The rate of increase in the number of independent fishermen has been greater than that for cooperative fishermen in recent years. In

1981, independents comprised 35% of the total fishermen in Belize; by 1984, they comprised 48%.

13. Approximately one third of conch divers are independent fishermen. Little is known about these fishermen as their catch is not recorded. It is suspected that most deliver their catch to cooperatives under a member's name.

14. The majority of the year's total landings is delivered by trip-fishermen as opposed to day-fishermen. It is estimated that conch divers fish on a trip basis 70% of the time.

15. Conch populations are believed to be fully exploited within their geographic distribution in Belize. The only areas not yet fished are those beyond the maximum depth for free-diving (18m). The fishing grounds yielding the largest conch at the greatest densities are found among the southern Cayes.

16. Fishing grounds near Half Moon Caye are showing signs of overfishing; LPUE has decreased and the average weight of meats landed is the lowest amongst the fishing grounds studied. Fishermen diving in these areas in June, 1985 were landing conch with an average meat weight of 94 gm (3.3 oz). In comparision, average meat weight of conch taken from areas along the main reef ranged from a low of 128 gm (4.5 oz) in the northern areas to 161 gm (5.7 oz) in the southern areas.

17. The current minimum size limits in Belize are a shell length of 17.8 cm and a marketed-meat weight of 85 gm (3.0 oz). Weight/length relationships determined in this study demonstrate that these values are contradictory; conch with a shell length of 17.8 cm weigh less than 85 gm. Hence, fishermen fishing animals of legal shell size may land meats as small as 49 gm

(1.7 oz); equivalent to an age of 2.2 years. A survey in 1985 indicated that 23% of the conch meats landed at the cooperatives were less than the regulation meat weight.

18. Vital parameters for Strombus gigas were difficult to estimate from the limited field data available on Belize populations. The cryptic nature of juveniles, varied habitat preferences of different size classes and clumped pattern of distribution make representative sampling difficult. Determinant shell growth complicates the calculation of asymptotic weight and the use of length-frequency analyses to estimate growth parameters and mortality.

19. Published estimates of M and K vary substantially for S. gigas. Based on a yield-per-recruit (YPR) analysis using M=0.1, F=0.6 and K=0.516, YPR is maximized at a mean age of first capture (t_c) of 3.5 years, equivalent to a length of 21.7 cm and meat weight of 113 gm (4.0 oz). However, the increase in YPR with time of harvest after 3.0 years is minimal; the average meat weight of 3.0 year old animals approximates the current minimum legal limit, i.e., 85gm (3.0 oz). With M=0.1, results of the analysis suggest fishing relatively lightly at a high size at first capture. When M is increased, eg. M=0.5, the best option in terms of getting the maximum yield from a recruit level is to fish smaller individuals (t_c=2.5) at a high rate of harvest (F=2.0). These results indicate that the current tc (2.2 years) in Belize is too low to maximize the yield available from the population.

20. Conch reach terminal shell size roughly one year before they are sexually mature. As a consequence of this determinant shell

growth, there is a long immature phase during which the species is potentially exploitable. If stock size is related strongly to recruitment, managing on the basis of YPR could increase the chances of recruitment overfishing.

21. The management options considered most appropriate for the conch fishery of Belize at present include, in order of importance, size limits, season closures and gear restrictions. A regulation prohibiting the harvest of nonlipped individuals and a minimum size restriction on market-cleaned meats corresponding to the average size of adults (120 gm; 4.2 oz) are necessary to protect the breeding population. Maintaining the current three-month closed season which extends over the warmest months of the year when spawning is thought to be most intense and prohibiting the harvest of adults which have migrated into areas too deep for free-divers to access are considered the next best management options.

22. Area closures would be effective in rejuvenating the stock in localized areas and extending the closed season to include October would slow the increase in total fishing effort.

23. Conventional fisheries data, particularly those on size composition of the catch, landings and effort by area are those most needed in Belize to monitor stock status. Routine dockside surveys to supplement logbook information on catch and effort and sample landings are recommended. Methods of compiling statistical data, sampling landings randomly and extracting required information from the data could be updated and documented for use by the Fisheries Department.

24. LPUE is difficult to calculate from data on the statistical

forms currently used. An improved statistical form to be completed by the captain of each boat is suggested. Tallying the landings and divers per boat will yield more accurate estimates of LPUE and lessen the paperwork involved in analyzing the statistics.

25. The involvement of fishermen at all levels of management is encouraged. Their fishing skills, knowledge of the species' habits and distribution, and the time they spend at sea are valuable assets toward data collection and enforcement. The participation of fishermen in the decision-making process will also increase a management program's chances of success.

SUMMARY

Lobster, conch and scale fish have traditionally been the most important fisheries in Belize. Queen conch (*Strombus gigas*) was first harvested for export on a large scale in 1967, shortly after fishing cooperatives were established. Lobster has always been the highest priced commodity, but conch has value as a secondary source of income when the lobster fishing season is closed or when alternative species are scarce. Conch accounted for 10% of the total value of fish exports in 1986, and it is estimated that about 62% of the commercial fishermen in Belize dive for conch.

The success Belize has had in small-scale fisheries development is attributed largely to the centralization of fishing through cooperatives. The cooperative system facilitates improvements in harvesting methodology, processing and marketing, and contributes to the monitoring and regulation of fishing activities. There are nine fishing cooperatives currently active in Belize and four of these export fish products. The largest cooperatives are situated in northern Belize in or near the main commercial centre (Belize City). The smaller cooperatives are located in fishing villages scattered along the southern coast. The fishermen-owned production and marketing cooperatives secure export markets for Belizean products and provide low interest loans for their membership.

The fishermen of Belize are skilled and versatile; each may fish a number of species, a variety of ways. They may work only part-time as a crewman or own more than one sailboat and hire additional crew. Some fishermen work solely on a day basis (eg., conch divers residing on Caye Caulker), and others, on a trip basis (eg. Sartenejan divers). Fishermen may change their speciality during their fishing careers, and hence, there is a high turnover in crews, boats and equipment. General licensing of fishermen and boats is used by the Fisheries Department to monitor fishing activities.

As prices for the exported fish commodities rise and the unemployment situation in Belize becomes worse, more people are attracted to the fishing industry. The number of active fishermen in Belize is estimated to have increased from 1083 in 1978 to 1675 in 1984. Licensed commercial fishermen not affiliated with the cooperatives (independent fishermen) have shown the greatest increase in number. Today, they comprise approximately 50% of the active fishermen in Belize and 33% of the conch divers. There are no records of their production, but there is evidence to suggest that many deliver their catch to the cooperatives, and that their landings are accounted for in the cooperatives' statistics.

A study of catch statistics for the five largest cooperatives demonstrated that each cooperative's production of conch varied in relation to the membership's size and interest in the commodity. Prior to 1980, National and Caribeña had the greatest number of active fishermen. Sarteneja was the fourth largest cooperative and about 95% of its membership was delivering conch. Since the Sarteneja cooperative closed in 1982, both Northern and National have expanded with the amalgamation of ex-Sarteneja members and growth in the industry as a whole. In 1985, their memberships totalled 421 and 353 respectively.

National has always been the largest producer of conch. From 1971 to 1977 its production accounted for 56% of the total recorded landings. During this time, the number of its fishermen delivering conch remained relatively consistent but effort per man was steadily decreasing. By the time the closed season was implemented in 1978, the absolute number of fishermen and the proportion of members diving for conch had also declined. This trend was reversed in 1981. By 1984, National once again accounted for 58% of the total conch production by the exporting cooperatives and 80% of its producing members delivered conch.

Northern is the second largest producer of conch, but its main interest is in the lobster fishery. Before 1980, only 35% of its producers fished for conch and though higher today (56%), this percentage is still the lowest among the cooperatives. A notable percentage of Caribeña's members deliver conch but very few fish the species on a regular basis. These fishermen are better known for their lobster and fish production. Placencia is located in a region where trapping for lobster is difficult. Fishermen of this cooperative are primarily skin-divers and depend greatly on conch for a livelihood. Approximately, 85% of its producing members dive for conch and though this is the smallest exporting cooperative, it ranks third in conch production.

The conch fishery has passed through four stages in its development. The first marks the period when fishermen discovered that conch fishing could be profitable. From 1967 to 1971, the percentage of fishermen at National delivering conch increased from 25% to 77% of the total producing membership. Conch landings by exporting cooperatives peaked in 1972 at 517,073 kg. During the second phase in the mid-1970's, fishing effort continued to increase but landings-per-unit-effort (LPUE) fell from an estimated 45.4 to 22.7 kg/man-day. This was caused by a decrease in both the number and average size of individuals in the stock. The average size of animals landed in 1976 was roughly 66 gm (2.3 oz). This is less than half the size of conch in the relatively unfished populations that remain today, i.e., those found in waters too deep for skindiving.

With the abrupt drop in catch rate and the establishment of new export markets for scale fish in 1974, fishermen decreased the time they spent fishing conch and turned their attention to other species. This is characteristic of a fleet's operation when there is a mixed species resource. Although economic data were limited for this study, it appears that Belize fishermen try to maximize their economic returns per trip by seeking out the most opportune mix of lobster, conch and scale fish depending on the relative abundance, market value and distribution of these species. Season and size restrictions were also implemented during the third phase of the fishery and the average size of conch landed at the cooperative gradually increased. These management measures and the decline in effort during the late 1970's are believed to have enabled the conch stock to rebuild its reserves.

In the last phase identified (1981-1984), fishermen were landing one third of the year's annual production of conch in the first month of the season (October). Days-fished per man-year remained low but the number of fishermen fishing conch rose from an estimated 684 in 1981 to 1028 in 1984. Effort exerted in the conch fishery in 1984 was the highest it had been in eight years and only 20% less than the record high of 1975. During the re-expansion of the fishery, LPUE remained stable at 15.0 kg/md (which is one third of what it was in the late 1960's) until 1984.

Production by the exporting cooperatives has declined in recent years while effort has remained fairly stable. Total landings for 1986 was 110,232 kg, the lowest it has been in 20 years. Variability in recruitment and growth overfishing are probable causes for the decline in abundance but it is difficult to discern which one is most responsible given the limited data avaiable for stock assessment.

The above evaluation of stock status is based on the assumption that LPUE reflects conch abundance. There are no data to refute this assumption, but it is noted that certain aspects of the species' biology and the fishery may influence catchability. For instance, conch are readily detectable, have a clumped distribution and congregate to breed. These characteristics tend to increase catchability. Migration of conch into deep waters and their tendency to bury on the other hand, lessens the chances of their being caught by free-divers. Characteristics of the fishery which affects how well the trend in LPUE represents that in abundance include year-to-year variation in the distribution of fishing and changes in the hours fished per day. Since the 1960's, conch fishing has gradually moved from northern Belize to the outer atolls and the southern cayes. As stock density decreases in the current fishing grounds, fishermen will continue to search for less heavily fished populations (eg., those along the outer edge of the main reef). As a result, LPUE may overestimate true abundance. In contrast, LPUE may underestimate abundance because the number of hours per day a diver operates underwater has increased over time. In the early 1970's, the search time/handling time index was small. Today, landings per day are not limited by how many conch fishermen can clean; it is limited by how many they can find.

The key issue regarding the management of the conch fishery in Belize is the harvest of animals before they are capable of reproducing. Given the results of the YPR analysis, it appears fishermen are also removing animals of an age less than that considered optimum for maximizing YPR (estimated to be between 3.0 and 3.5 years). With declining LPUE and the increasing number of fishermen diving conch, there is need for immediate action. Size limits, season closures and gear restrictions are the management options that the author believes will be most successful in ensuring that there is adequate escapement and preventing a collapse of the fishery due to recruitment overfishing. Area closures and an extension of the closed season were proposed as secondary options should the occurences of growth overfishing increase. These types of controls are passive and not the best for controlling the fishing mortality rate. However, for active forms of regulation (eg., limiting entry) to be effective, one needs more scientific information and enforcement than the Belize Fisheries Department is presently capable of supplying.

Management of the conch resource in Belize is hindered by primarily one thing - lack of money. As a developing country, Belize does not have the finances to provide the Fisheries Department with the equipment and manpower that is needed to conduct baseline research and enforce regulations. With a staff of 12 and no law enforcement division, the Fisheries Department is hard pressed to control illegal fishing on a species which is fished by approximately 1028 fishermen along a barrier reef 240 km long. Lack of conventional fisheries data is considered to be the primary management constraint. It is recommended the Fisheries Department direct more of its finances and manpower toward monitoring the stock's condition via effort assessment (i.e., obtaining data on landings, fishing effort and size composition of the landings by area). Biological studies pertaining to population dynamics, catchability and recruitment are of lower priority as they are costly and do not meet the immediate information needs for management. With fishing centralized through the cooperatives, the costs of a statistical survey in comparision could be kept at a minimum.

The cooperation of fishermen is crucial to both data collection and enforcement. This is especially true for Belize due to the limited funds the Fisheries Department has available for research surveys and fisheries surveillance. Opening channels of communication with fishermen to gain their support in management is recommended. Progress made thus far includes the representation of the BFCA on the Fishery Advisory Board and appointment of fishermen as fishery officers. Educational programs aimed at convincing the users and general public of the need to conserve natural resources have also been initiated. However, more interaction between the biologist and fishermen at dockside is still needed. The fishermen's cooperation in providing data will be minimal as long as they associate the Fisheries Department with law enforcement. Separating the development and management division of the department from the fisheries protection division when feasible and ensuring confidentiality in the meantime will facilitate data collection.

LPUE is difficult to calculate from data on the statistical forms currently used. The cooperatives' produce vouchers must be kept in chronological order so that true landings per man can be back calculated from the shares recorded, and sales receipts corresponding to more than one man's delivery can thus be identified. Corrections must also be made to calculate days-fished from days-at-sea recorded by trip-men. The bias in statistical records due to species preference may be accounted for by focussing on skippers who are specialists in fishing conch and more likely to concentrate on this species irrespective of changes in abundance of other species. Hence, records of deliveries of more than one species should be separated from those corresponding to conch-only deliveries.

To avoid the above problems, it is suggested that a new format be used on the statistical forms so that landings/boat and men/boat are recorded instead of each individual crewman's landings. One form would be completed by the captain of each boat and hence, the paperwork, for fishermen and biologists alike, reduced. Assistance of cooperative personnel to ensure the forms are completed when the delivery is made may be necessary. Provision should also be made in the data collection system for the analysis of data and the documentation and presentation of results.

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Appendix I

Sources of fisheries information
(representatives interviewed)

BELIZE FISHERIES DEPARTMENT
P.O. Box 148, Belize City (Tel: 44552)
(Minister of Fisheries - Mr. Eduardo Juan*)
(Fisheries Administrator - Mr. Winston Miller*)

BELIZE COOPERATIVES & CREDIT UNIONS DEPARTMENT
P.O. Box 159, Belize City (Tel: 7401)
(Registrar of Cooperatives - Mr. Norman Augustine*)

BELIZE FISHERMEN COOPERATIVE ASSOCIATION LTD.
P.O. Box 751, Belize City (Tel: 45267)
(Chairman - Mr. Eddie Young*)

NATIONAL FISHERMEN PRODUCER'S COOPERATIVE SOCIETY LTD.
P.O. Box 316, Belize City (Tel: 3165)
(Executive Secretary - Mr. Raymond Bradley)

NORTHERN FISHERMEN COOPERATIVE SOCIETY LTD.
P.O. Box 647, Belize City (Tel: 44460)
(Executive Secretary - Mr. Robert Usher)

CARIBEÑA PRODUCER'S COOPERATIVE SOCIETY LTD.
San Pedro, Ambergris Caye (Tel: 026-2011)
or P.O. Box 322, Belize City
(Executive Secretary - Mr. Ruben Paz)

PLACENCIA PRODUCER'S COOPERATIVE SOCIETY LTD.
Point Placencia, Stann Creek District (Tel: 06-2046-2116)
(Executive Secretary - Mr. William Faux)

FISHERY ADVISORY BOARD
Fisheries Department, P.O. Box 148, Belize City.
(Secretary - Mrs. J. Gibson)

SOURCES OF ECONOMIC INFORMATION:

Central Bank of Belize - Treasury Bldg., Belize City
Office of Economic Development - P.O. Box 42, Belmopan
Chamber of Commerce & Industry - P.O. Box 291, Belize City
American Embassy - P.O. Box 286, Belize City

* no longer in office

Appendix II

Information gathered during interviews with fishermen

FISHERMAN:
- name, residence, cooperative
- number of years in the conch fishery (full-time or part-time basis)
- other commodities fished; how; when
- other jobs besides fishing

CREW:
- average size

BOAT AND MOTOR:
- type, size, age
- icebox capacity

EXPENSES PER TRIP:
- for gas, ice, food, other supplies
- cost of boat and gear
- system of sharing the catch

FISHING AREA:
- grounds fished on last excursion, over the course of the season and in past years

TIME SPENT FISHING:
- average number of days at sea
- activities while at sea and time devoted to each (eg., travelling, turn-around, and searching, gathering and cleaning the catch)
- time spent at port (eg., for hauling the boat and holidays)
- type of excursion usually made (eg., day, sailing or camping trip)

THE AFFECT WEATHER HAS ON FISHING:
- when are conditions too poor to dive (re: wind, rain, temperature and "Northerns")
- is a radio (AM) taken to sea

PRODUCTION:
- unit of measure (eg., pig-tail bucket, sack, basket, dory)
- today's delivery of conch, number of men aboard and days spent fishing
- weight of other products delivered
- losses between capture and landing of conch (eg., eaten by crew, given to friends/family, sold at local market)
- weight of meats rejected by cooperative
- average day's catch this season; in the past

DISTRIBUTION AND AVAILABILITY:

- where are conch found (depth, bottom type, inside/outside the reef)
- how are individuals distributed (clumped or dispersed)
- abundance of juveniles less than 10 cm
- proportion of catch comprised of lipped animals
- fishermens knowledge of the species' life-history
- local names for Strombus gigas

OBERVATIONS OF FOREIGN FISHERY

Number of members interviewed at each cooperative:

National	13
Northern	17
Caribeña	9
Placencia	12
TOTAL	51

Appendix III

Recording Daily Landings of Conch: Suggestions regarding the collection of fisheries data for the calculation of LPUE (kg/man-day)

DATE
- the day the catch was landed; note this is not necessarily when the sales receipt was cashed.

LANDINGS
- total weight of conch landed by the crew as a whole, i.e., landings per boat-trip.

NUMBER OF MEN ABOARD
- all those men who fished conch including men who are not members of the cooperative.
- do not simply record names of individuals who received a sales receipt.

NUMBER OF DAYS FISHED
- number of days spent fishing on the grounds.
- does not include travelling and turn-around time.

LANDINGS OF OTHER SPECIES
- if other species were caught on the same fishing trip, note the number of days devoted to fishing each commodity.

AREA FISHED
- fishing grounds visited.

Appendix IV

Cooperative Produce Voucher

Placencia Producers Co-operative Society Ltd.

PRODUCE VOUCHER

DATE:________________19____

Seller's Name ______________________________

Name of Boat ______________ Days Fished: ________ 27369

Method: Area Fished:

Commodity	Weight Lbs.	Rate		Amount:	
LOBSTER TAILS					
CONCH					
MUTTON SNAPPER CLASS "A"					
LANE SNAPPER					
REEF SNAPPER					
BLACK SNAPPER					
YELLOW TAIL					
HOG SNAPPER					
DEEP WATER SILK					
GOAT FISH					
KING FISH					
FISH CLASS "B"					
BARRACUDA					
MACKEREL					
GROUPER					
JACK					
FISH CLASS "C"					
GRUNT					
PORGY					
TRIGGER FISH					
DOCTOR FISH					
TOTAL			$		

Received the sum of $: in payment for the above commodity

____________________ ____________________

Seller's Signature Receiving Clerk

Appendix V

Fishing Licence Applications
(Source: Belize Fisheries Regulations, 1977)

SCHEDULE 2.

Form A1.

. Fisheries Ordinance Chapter 133

APPLICATION FOR A LICENCE TO FISH (BOATS) OR RENEWAL THEREOF

To: The Fisheries Administrator.

I (We) (Name(s) of owner in full): ______________________
(Please Print)

of (Full Postal Address of owner) ______________________
(Please Print)

The owner(s) of the undermentioned fishing boat, hereby apply to register the said boat to be used for taking of fish for sale.

Name of Boat " ______________________ "

Port of Domicile (Place where boat is based) ______________________

Type of Boat: *Smack* (   ) *Dry Boat* (   )
Out Board (   ) *Inboard* (   )
Dorey over 14 feet (   )

Description of Boat:
Overall Length __________ feet __________ inches

Beam __________ feet __________ inches

Draught __________ feet __________ inches

Engine Make:
Horsepower: ______________________

Type of Fuel: ______________________

Date of Application ______________________ Signature ______________________

FOR OFFICE USE ONLY

Date Received ______________________ Licence No. ______________________

Registration Mark Allocated __________ Date Issued ______________________

Fee Paid and Receipt Number ______________________

SCHEDULE 2

Form B1.

APPLICATION FOR A FISHERMAN'S LICENCE OR RENEWAL THEREOF

Part A to be completed in full and accompanied by two full face Photographs of the applicant not exceeding one and one half inches by one inch in size. For first issue money should not be sent with the form. For first issue proof of citizenship or valid work permit must be furnished with the application or at the time of actual issue of the licence.

To: The Fisheries Administrator.

PART A.

I hereby apply for a first issue/renewal of a fisherman's licence.

Name ______________________ Age __________ years
(block capitals)

Fishing experience __________ years (full time __________ Part Time __________ yrs)

Home Address ______________________ I am a boat owner __________ yes/no
______________________ boat operator __________ yes/no
______________________ crewman __________ yes/no

I am/am not a member of a fishermen's co-operative society

Name of Co-operative if a member ______________________

Membership No. ______________________ Previous fishermen's licenceNo. __________

Date Issued ______________________

PART B.

To be Completed in full for first issue and on renewal only if a change in the details given in the first issue application have taken place)

Type of fishing in which engaged and methods used. Please enter a tick against the appropriate method and enter the number of units applicable in the spaces provided.

	Lobster		*Scale Fish*			*Conch*	*Other*
Traps	( )	No. ( )	Seine nets	( )	No. ( )	Diving ( )	Product
Drums	( )	No. (	Cast nets	( )	No. ( )		______
Beach			Set nets	( )	No. ( )		Method
Traps	( )	No. ( )	Tangle nets	( )	No. ( )		______
Diving	( )	No. ( )	Gill nets	( )	No. ( )		No. of Units
Other	( )		Trammel net	( )	No. ( )— —1 or 2 wall		______
			Beach traps	( )	No. ( )—shore or open sea based		
			Fish pots	( )	No. ( )—any type		
			Drop lines	( )			
			Long Lines	( )	No. ( )—indicate hooks/100 yards.		

Other methods specify ______________________

Approximate value of gear __________ Place of normal landing of catch __________

____

Date of application __________ Signature of Applicant __________

THIS PART FOR OFFICE USE ONLY: Passport No. __________ (   )

Received in Office __________ Work permit __________ (   )

Fee received __________ ( ) Birth Cert. __________ (   )

Appendix VI

Annual Production (kg) of conch, lobster and scale fish by each fishing cooperative (fiscal year)

CONCH

YEAR	NATIONAL	NORTHERN	CARIBEÑA	PLACENCIA	SARTENEJA	TOTAL
1967	25596	43384	55968	0	0	124939
1968	84684	31893	25458	-	0	142036
1969	119531	58884	49781	20623*	-	248820
1970	123349	69459	67659	16065*	12156	288690
1971	262740	69656	50511	31729*	33663*	448302
1972	286525	53450	61018	47559*	68519	517073
1973	292062	27836	102563	28766*	57442	508672
1974	172270	22707	54208	58132*	85695	393015
1975	203992	32767	43333	63449*	73687	417229
1976	197210	34475	30093	40982*	48356	351117
1977	123426	28366	23279	48949*	46360	270382
1978	62477	21695	20901	29075*	74198	208348
1979	83850	22024	31224	25845	63529	226474
1980	42112	18440	12125	21166*	34470	128315
1981	52067	23827	5330	33443*	54779	169449
1982	61606	36806	10177	25907	28940*	163438
1983	95920	55994	23784	26207	0	201907
1984	129930	47196	24910	23209	0	225247
1985	70840*	40722	21917	30759*	0	164239
1986	52468*	20794+	15602	21368*	0	116232

LOBSTER

YEAR	NATIONAL	NORTHERN	CARIBEÑA	PLACENCIA	SARTENEJA	TOTAL
1967	38923	34968	54006	0	0	127898
1968	33712	73669	58565	-	0	165947
1969	32636	65043	49460	14333*	7936	169410
1970	31859	68550	50072	13660*	6511	170655
1971	40960	96429	55882	15174*	10100	218548
1972	34629	63876	53829	14557*	10684	177578
1973	35156	57778	48736	10157*	9953	161783
1974	44208	66881	57232	13182*	17471	198976
1975	37124	84228	52123	11704*	12681	197862
1976	57225	94801	51743	14896*	14998	233665
1977	43127	56005	42766	11100*	10307	163307
1978	50783	65621	51399	14399+	17181	199384
1979	55885	67796	58206	17985	11977	211851
1980	58312	54011	52093+	14288*	10991	189697
1981	99742	124707	80206	19665	16844	341166
1982	91265	90856	58564	15420	4790	260897
1983	108795	123075	45373	17205	0	294448
1984	103060	144238	32766	12715	0	292780
1985	89428	177738	36458*	13835*	0	317459
1986	67882*	126427	21468*	14481*	0	230258

FISH

YEAR	NATIONAL	NORTHERN	CARIBEÑA	PLACENCIA	SARTENEJA	TOTAL
1967	686	-	-	0	0	-
1968	1003	-	-	-	0	-
1969	5303	-	-	0	-	
1970	3674*	-	-	0	-	
1971	7411	-	31708	-	0	-
1972	9342	8242	45059	-	0	-
1973	4597	3456	66744	-	0	-
1974	12482	27122	91359	-	0	-
1975	24157*	48957	-	-	0	-
1976	28440*	124489	187774*	59380	0	400085
1977	62991*	112747	150423	76572+	0	402735
1978	39823*	91479	154026	102006+	0	387335
1979	27052	94714	147231	69413	0	338412
1980	37342	113540	126759+	60525+	0	338166
1981	38987	93348	59340	91604	0	283280
1982	115954	144663	80669	80742	0	422029
1983	128209	133766	64327	65288	0	391591
1984	66377	75310	45149	46412	0	233249
1985	58431*	98258	66989	68463*	0	289573
1986	115174*	122644	57365*	95169*	0	390352

* Includes production of non-members
\+ Based on calendar year
\- Data not available

Appendix VII

Estimation of the maximum number of days per year that could be spent fishing conch.

Seasons:	Closed for Conch July 1-Sept.30 (as of 1978)	Oct.1-Mar.14	Closed for Lobster Mar.15-June 30
Total Days:	92	166	107
Time Subtracted:			
Holidays	5	15	15
Sundays	13	23	16
Bad Weather	15	28	18
Boat Repairs	7	14	7
TOTAL	40	80	56
Maximum days at sea:	52	86	51

SUBTRACTION OF TRAVELLING AND TURN-AROUND TIME OF TRIP-MEN:

A. Total days at sea since 1978 = 137

1. Time allocated to day fishery = 137 * 0.3 = 41.1 days

2. Time allocated to trip fishery = 137 * 0.7 = 95.9 days
   Trip length from time of loading to unloading = 11 days
   Number of trips per year = 95.9 / 11 = 8.7
   Travelling and turn-around time = 4 * 8.7 = 34.9 days

   Time allocated to trip fishery = 95.9 - 34.9 = 61.0 days

   Estimated maximum number of days/year that could be spent fishing conch (since 1978) = 102 days

B. Total days at sea prior to 1978 = 189

1. Day fishery = 189 * 0.3 = 56.7 days

2. Trip fishery = 189 * 0.7 = 132.3 days
   Time spent fishing = 132.3- [(132.3/11)*4] = 84.3 days

   Estimated maximum number of days/year a fisherman could have spent fishing conch prior to 1978 = 141 days