OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

VSGCP-Q-85-001

DEPARTMENT OF OCEANOGRAPHY
SCHOOL OF SCIENCES AND HEALTH PROFESSIONS
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA 23508

# AN EVALUATION OF SOME PRIMARY HARVEST MANAGEMENT PROGRAMS FOR THE BLUE CRAB IN LOWER CHESAPEAKE BAY

By

Philip R. Mundy, Principal Investigator

and

Paul J. Anninos, Co-Principal Investigator

Final Report
For the period ending March 31, 1985

Prepared for the
Virginia Graduate Marine Science Consortium
University of Virginia
Charlottesville, Virginia 22903

Under
Research Grant VMSC-83-1185-700
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Submitted by the
Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, VA 23508

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## TABLE OF CONTENTS



## LIST OF TABLES

LIST OF TABLES - continued

LIST OF TABLES - continued

## Introduction

The management of crustacean fisheries has traditionally had goals which are very different from those established for the management of the best known marine bony fishes. David Cushing (1983) has compiled the literature record which defines the history of the development of the goals for teleostean management, but the goals for crab management seem more elusive. In a most thorough review of North American crab fisheries regulations, R.J. Miller (1976) cited no instance in which the actual size of the reproductive stock was of concern to the regulatory agency. For example Botsford et al (1983) display an ambiguity towards fishing mortality and natural mortality as causes of fluctuations in catches of Dungeness crab (Cancer magister) in northern California. The lack of concern for the fishery as a primary source of total mortality seems to be typical of crustacean management generally. So strong is the tradition of belief in the density independent population regulation of arthropods (Andrewartha and Birch 1954) that catch quotas and other limitations on the actual amount of crustaceans harvested are rarely imposed. In some cases, such as the blue crab fishery in Maryland and the Dungeness crab harvests in most jurisdictions, so-called 3-S management prevails, where the three S's are limitations on the size, sex and season of harvest without controls on the absolute number or weight harvested. The 3-S management contributes to the management objective of product quality, but it denies that control of the level of abundance of the populations is a legitimate objective of management.

The 3-S system usually leads to a passive management structure which is poorly equipped to specify the behavior of the fishery, let alone control the amount of crabs taken in a specific locality. Whether or not one believes in the ability of fisheries management to control or influence the abundance of crabs and other crustaceans through time, there are circumstances in which the ability to actively control the rate of harvest of crustaceans by locality is essential to proper management. For example the relation between size of penaeid shrimp and the unit price is well known. In order to maximize the economic value of a penaeid harvest through regulation, it would be necessary to know the time distribution of size classes in each fishing area (Paula 1983). Allocation of harvest among gear types or among user groups is another situation where active regulatory control might be necessary in any crustacean fishery. The ability to write regulations to accurately control harvest in the blue crab could one day be needed for economic, allocative, or even conservation purposes.

The Virginia Marine Resources Commission (VMRC) has the legislative mandate to protect and conserve the Commonwealth's valuable fisheries resources. The blue crab fishery in Virginia is clearly among its most important. In recent years, landings have been exceeded in quantity only by menhaden and in dockside value only by menhaden and oysters (of inshore/territorial sea fisheries). Virginia harvesters produce almost one-fourth of the total U. S. blue crab supply. In order to preserve its role as a leading producer, the Commonwealth must be willing to make a basic minimum commitment by developing rational harvest control measures and ensuring that adequate data exists for documenting the effectiveness of those implemented. It is likely that, ultimately, Virginia blue crab management plans will become part of a larger framework of bi-state or Chesapeake Bay management.

The theories and data relative to the management of any species are put to the ultimate test at the level of harvest control. Not only must an appropriate level or range of harvest levels be specified, but the understanding of the historical performance of the fishery must be focused to achieve the appropriate harvest level. Indeed if the operation of the various gear types cannot be directed to attain a specified level of harvest, the determination of maximum sustainable yield, total allowable catch, or any other harvest level becomes moot. The identification of information which is critical to the harvest control process necessarily requires an adequate knowledge of the life cycle of the target species in relation to its geographic distribution.

The combined results of Sea Grant investigations in Delaware, Maryland and Virginia provide a cohesive and compelling narrative of the life cycle of the blue crab (Callinectes sapidus) in the waters and estuaries of the Mid-Atlantic Bight (Sulkin et al 1982). Evidence relevant to the design of a harvest control information system is related to the mechanism of larval retention in the estuaries, since the probable closure of the population must be established before any meaningful harvest control program can be designed. The assumption of closure must be made before it is reasonable to postulate that the action of a fishery on one time interval could influence fishing success in subsequent time intervals.

The blue crab life history model upon which the harvest control study will proceed is summarized here from the Sea Grant studies previously cited. Blue crab larvae which originate at the mouth of the Chesapeake Bay are carried substantial distances away from the mouth over shelf waters. At the beginning of life the net direction of transport is probably south, however wind driven circulation in the near shore area is likely to figure prominently in the return of megalopae to the Bay. The success of a year class of Chesapeake Bay blue crabs depends upon the coincidence of larvae and post-larvae with wind driven events. Hence recruitment to the fishery is related to both stock and environment. Once the megalopae reach the Bay mouth they migrate up the Chesapeake Bay where they mature, mate and return to the Bay mouth to spawn. The exact amount of time required between the entry of a megalopa to the Bay and its return to the Bay mouth to spawn is unknown, as is the age composition of the commercial and recreational catches. Adult blue crabs in Chesapeake Bay are primarily descended from parents which matured, mated and spawned in the Cheasapeake Bay.

The concept of harvest control as a fisheries management specialty needs to be more fully explained. Harvest control has three objectives in order of priority; 1) attaining a specified level of harvest, 2) public safety, and 3) product quality. Public safety and product quality considerations are based upon a knowledge of the gear types and waters of the fishery and the processing and marketing of the product. The attainment of a specified harvest objective requires a detailed knowledge of the historical performance of the fishery and the performance data, typically catch and effort, must be gathered and analyzed before any regulations can be drafted. This proposal will not address public safety and product quality; we seek to determine the availability, and absence, of the data necessary to attain the primary objective of harvest control; distribution, timing, and abundance. The answers to the questions, "Where?, When?, and How many?" may be found in the historical records of catch and effort per unit time by statistical area. In an unknown number of cases the information will not exist, in which case the task becomes the definition of the necessary data type and how to obtain it.

The work at hand is the first step in determining whether current information is sufficient to permit rational regulation of harvest for Virginia's blue crab resource. Only future events will specify the purposes that might be attached to these regulations.

## Methods

All data pertaining to the Virginia blue crab fishery is collected at the state level. Commonwealth agencies participating in this effort are the Virginia Marine Resources Commission (VMRC) and the Virginia Institute of Marine Science (VIMS). Historical landings and harvester employment statistics are catalogued and stored by the National Marine Fisheries Service (NMFS). Prior to 1976, catch statistics were collected by NMFS port agents. The VMRC Fisheries Statistics Office has since assumed that responsibility. Catch statistics are collected monthly by a census of licensed seafood buyers' dockside sales receipts. Compliance with this reporting program is voluntary.

Monthly data is categorized by market category (hard, soft, and peeler), pounds landed, price paid at dockside, statistical area of harvest (approximately 70 water bodies although we have combined these into five statistical areas: 1) James River, 2) York River, 3) Rappahannock River, 4) Upper Bay, and 5) Lower Bay (Fig. 1) ) , gear employed (trotline, trap, scrape, dredge, and pot), and county of landing (approximately 39 political subdivisions). These data may be retrieved in any order or combination over any given time period for which data were collected (e.g., monthly landings/value of dredge catch in the lower Bay).

To describe catch as a function of time for each statistical area over all years of record the methods of Mundy (1982) were adapted

(Shively 1984). An average performance curve which is the cumulative average proportion of annual catch of hard and crabs in Virginia waters by month for calendar years (1960 - 1984) and for harvest years (December - November) (1972-1983) was prepared. Descriptive statistics were computed for the performance curves within and across years. In a companion report (Shively 1984) performance curves and descriptive statistics were computed by summer season (April - November) and winter dredge (December - March) for the five statistical areas.

The coefficient of variation is used to compare the variability in monthly harvests because the CV is independent of the magnitude of the harvests. The CV is also directly related to the magnitude of the confidence interval about the mean of the observation (Barth 1984); large CV's imply large confidence intervals, and conversely.

## INTRASEASON FORECAST METHODS

### Forecasts of annual abundance

The objective is to determine if historical performance of the time series of monthly catches from the commercial blue crab fishery in Virginia is useful for forecasting total annual harvests of hard blue crabs from Virginia waters. The catch data for the years 1973-1983 were taken from Shively (1984) and consist of monthly estimates of pounds of hard blue crab harvests. The original source of all data is the Virginia Marine Resources Commission, Newport News, Virginia.

To simplify the explanation of the forecasting methods the data are structured as an array with dimensions equal to the number of time increments in the season (12 months) and the number of years in the database (11). Also, since all methods relate directly to the cumulative performance of the data the following notation (Barth 1984) will be used;

$c'(i,j)$ = catch in month i, year j.

$c(i,j)$ = cumulative catch in month i, year j.

$p'(i,j)$ = proportion of catch in month i, year j.

$p(i,j)$ = cumulative proportion of catch in month i, year j.

where $i = 1,\ldots,12$; $j = 1,\ldots,11$.

The average timing model (ACP) relates the cumulative performance of catch in the current season to the average cumulative percentage performance in past seasons. The estimator is as follows:

$$\hat{C}(i,j)_{ACP} = c(i,j) \,/\, \bar{p}(i,j-1) \tag{1}$$

where,

$\hat{C}(i,j)_{ACP}$ = estimate of total catch for year j on month i by the average cumulative proportion model.

$\bar{p}(i,j-1)$ = average of cumulative proportions of catch on month i for all years prior to year j.

The second method for intraseason annual yield forecasting relates the cumulative catch for a given month to the total yield for that season by simple linear regression. The linear regression (LIN) estimator is:

$$\hat{C}(i,j)_{LIN} = a(i) + b(i)\, c(i,j) \tag{2}$$

where $a(i)$ and $b(i)$ are the least squares estimators of the intercept and slope of the regression of $C(j)$ on $c(i,j)$. Each time interval has a regression line whose parameter estimates, a(i) and b(i), are calculated from j-1 pairs of data. As the season progresses the coefficient of determination of the regression lines steadily increases until reaching one on the final time interval of the season since c(n,j) equals C(j).

Thus far the models underlying each of the estimators has not been mentioned. An examination of the methods reveals that each could be expressed by first order linear regression models. Formally stated the two basic models are;

$$Y(k) = B(i)\ X(i,k) + \epsilon(i,k) \tag{3}$$

$$Y(k) = A(i) + B(i)\ X(i,k) + \epsilon(i,k) \tag{4}$$

Where,

$Y(k) = C(k)$ = annual yield on year k.
$X(i,k) = c(i,k)$ = cumulative catch on time interval i year k.
$\epsilon(i,k)$ = forecasting error on time interval i year j
$k = 1,\ldots, j-1$

In either case the model is developed from a linear regression of annual catch on the cumulative catch for month i. Equations 3 and 4 correspond, respectively, to the ACP model and the LIN model. The ACP model is posed as a regression through the origin; a one paramter linear regression with slope intercept set equal to zero. The slope of the regression line, B(i), is estimated by the quantity,

$$1 / \bar{p}(i,j-1) .$$

In the linear regression model, Equation 4, the parameters, A(i) and B(i), are estimated by least squares methods. The basis for testing a two parameter linear regression model is the observation that poor catches in the early months of a harvest year do not necessarily presage a poor annual harvest. In mathematical terms this means that the slope intercept has been observed to be a non-zero positive number during much of the harvest season, contradicting a key assumption of Equation 3.

## Forecasts for Each Month

The objective is to determine if historical performance of the time series of monthly catches from the commercial blue crab fishery in Virginia is useful for forecasting monthly harvests of hard blue crabs from Virginia waters. Projections of monthly catches can be derived from average performance information or by a variation of the linear regression model. Monthly forecasts could be made by the average performance model,

$$\hat{c}'(i+m,j) = \hat{C}(i,j)_{ACP}\ \ \bar{p}'(i+m,j-1) \tag{5}$$

where m is the number of months projected ahead and the projection of catch for month i+m as calculated on month i is,

$$\hat{c}'(i+m,j)$$

However Eby and O'Neill (1977) suggest projecting only one time interval ahead, and restricting the method to the use of cumulative proportions in the following manner,

$$\hat{c}(i+1,j)_{ACP} = \hat{C}(i,j)_{ACP} \ \bar{p}(i+1,j-1) \tag{6}$$

where the projection of cumulative catch for month i+1, as calculated on increment i is,

$$\hat{c}(i+1,j)_{ACP}$$

The estimated period catch is the projection of cumulative catch on month i+1 minus the the observed cumulative catch in month i or,

$$\hat{c}'(i+1,j)_{ACP\ PF} = \hat{c}(i+1,j) - c(i,j) \tag{7}$$

Eby and O'Neill's (1977) method (Equation 7) is used to project period catches by the average performance model.

Forecasts of cumulative catch on a future time interval can be estimated by linear regression in the same manner as total yield. The projection of period yield is derived from the following estimator:

$$\hat{c}(i+m,j)_{LIN} = a(i) + b(i)\ c(i,j) \tag{8}$$

where a(i) and b(i) are estimated from the regression of c(i+m,j) on c(i,j). Projections by this linear model were also only calculated for the next time interval in the season (m = 1),

$$\hat{c}'(i+1,j)_{LIN\ PF} = \hat{c}(i+1,j) - c(i,j) \tag{9}$$

Assessment of Accuracy

Ultimately the accuracy of the estimators should be judged by their ability to predict the value being forecasted. In the evaluation of forecasts by Saila et al (1980) the criteria for judgement were the residuals,

$$C(j) - \hat{C}(j)$$

and a measure of the fit of the modeled data to observed data. The fit of expected to observed is analogous to the coefficient of determination in linear regression. Since our forecasts are made for purposes different from those of Saila et al (1980), another statistic was chosen to compare the effectiveness of the forecast models, the absolute percentage error (APE). The residual, $\epsilon(i,j)$ , or in forecasting terminology, the forecasting error, is expressed as a percentage of the observed value;

$$APE(i,j) / 100 = | \epsilon(i,j) | / C(j) = | C(j) - \hat{C}(i,j) | \; / \; C(j) \qquad (10)$$

where,

$APE(i,j)$ = absolute value of the percentage error of the forecast of annual yield in month i, year j.
$\epsilon(i,j)$ = forecasting error (residual)

Roff (1983) used the mean absolute percentage error (MAPE) of several years of forecasts to evaluate medium term forecasts of annual yield. Although MAPE is a good indicator of the success of an estimator, it can not be used to make approximate precision bounds on a forecast. Therefore it is more informative to use a statistic which relates forecasting error as a percentage of the forecast instead of as a percentage of the observed value. As such the mean absolute percentage deviation can be defined as;

$$MAPD(i) = [\ 100 / (n-1)\ ] \sum_{j=1}^{n} | \epsilon(i,j) | / \hat{C}(i,j) \qquad (11)$$

The interpretation of MAPD, like MAPE, is straightforward in that smaller values indicate successful forecasts and large values indicate inaccurate forecasts. Since the forecast models are usually judged on their empirical performance, it is desirable to express the relative error as statistics which are easily understood.

Of immediate interest is the relative accuracy of the estimators as the fishing season progresses. The estimators were used to back-forecast monthly and annual catches for the years 1979-1980. Forecasts were based on data from all years prior to the year being forecasted. For example, 1980 yields were forecasted on the basis of the previous seven years (1973-1979). A mean absolute pecentage deviation (MAPD) was then calculated, from the five years of back-forecasts, for each time interval of the season. The resulting time series of relative errors will provide a important measure of the utility of the forecasting methods.

The coefficients of variation (CV) of the average cumulative proportions are also indicators of the precision of the ACP model as the season progresses,

$$(s/\bar{p}(i,j-1))\ 100$$

As a general rule of thumb the following equation can be used:

$$P(\ APE(i,j) > k\ CV\ ) \le [\ 1 / k^2\ ] \qquad (12)$$

or approximately, the probability that the absolute percentage error is greater than k times the coefficient of variation is less than $1/k^2$ For example, if k equals two and the CV equals

50 then the probability that the absolute percentage error is greater than 100 is less than or equal to 0.25. If the p(i,j) are approximately normally distributed then this probability would be closer to 0.05. Notice that these inferences can not be extended to a forecast in future years unless it is assumed that the standard deviation of p(i,j) is approximately the same as was calculated for past years.

Prediction intervals can be calculated for forecasts when they are posed as linear regression estimates. Such prediction intervals are more satisfactory as measures of precision since they are more statistically appropriate. Consult standard regression texts for interval formulas. The methods of Neter and Wasserman (1974) were followed for this study.

MAPD's, MAPE's, CV's and the correlation coefficients of the regression models may all serve as useful indicators of the accuracy of both annual and period forecasts on a given month for the blue crab fishery. A comparison of the two methods which summarizes the accuracy of each estimator for each fishery can be achieved by two statistics, the MAPD of forecasts on the mean date of the fishing season, and the MAPD of all forecasts made on or before the mean date. The mean date of the fishing season is a standard reference point within a fishing season which is frequently the half-way point for a season. Intraseason forecasts are the most useful during the first half of a season, therefore these measures of forecast accuracy for the early portion of a season should be a good measure of a method's utility as a forecasting tool.

It would also be desirable to compare the results for intraseason forecasts and for pre-season forecasts in order to see if the intraseason forecast models actually contribute more accurate information than the pre-season forecasts. But, unfortunately, quantifiable pre-season forecasts were not available. As a simple alternative a five year moving average (MA) was used in place of a pre-season estimate of annual performance,

$$C(j+1) = (1/5) \sum_{k=j-4}^{j} C(k) \qquad (13)$$

The MA is also the means to evaluate the relative value of the more complex forecasting schemes previously described. If the complex forecasting schemes cannot better the average error of the MA, then the utility of the complex forecasting methods to management is low, and the effort required to generate such forecasts is not readily justified.

Part of the study involved examining the current data collection procedures in Virginia for consistency with fishing success methods of estimating stock size and with the methods of stock-recruitment modeling. Our procedure was to compare existing studies and methods to our understanding of Virginia's catch reporting system.

The concept that a percentage decline in catch per unit effort, CPUE, is representative of a comparable percentage decline in the total population size has been useful in population dynamics for many years (Leslie and Davis 1939 and DeLury 1947 in Seber 1973). The method is applicable to a closed population or to one with known rates of emigration and immigration where units of gear function independently and additively in removing stock. The work of Applegate (1983) was especially important for evaluating the applicability of current data in fishing success methods.

In the area of the relation between blue crab spawning stock and its resultant recruitment to the fishery, both Applegate (1983) and Hester (1983) were important references, with Applegate taking the more traditional approach, while Hester emphasized the implications of the relation between life history and oceanographic processes.

## Results

### Timing of Harvests

The timing of the blue crab harvests is remarkably stable, both within the year and across years, regardless of whether the catch data are arranged in a calendar year format (Tables CY1 - CY4) or in a harvest year format (Tables HY1 - HY4). Shively (1984) found the same stability in a preliminary study in which the catch data were grouped into summer seasons and winter seasons.

### Calendar Year Timing

The average monthly catch (1960 - 1984) is 3.6 million pounds of hard crabs with a coefficient of variation (CV) of 52% (see Grand Statistics, Table CY1). It is not surprising that the monthly harvests are above this grand average in the summer and fall months (June - October), and below the grand mean in the winter and spring (November - May; see Monthly Statistics, Table CY1). It is notable that the CV's of the mean monthly catches in the heart of the summer-fall seasons (July - October) are less than half the CV of the grand mean. The mean catch for the first month of the winter dredge season, December, also has a low CV (26%) relative to that of the grand mean. In the face of all the environmental conditions and blue crab stock levels encountered during this 25 year period, the pot, trot line, and winter dredge fisheries managed to maintain production during times of peak demand within remarkably small bounds. In the transition months of January - June and November, the variability in monthly harvest is quite high, as measured either by the standard deviation of monthly harvest or by the CV.

Variability of the monthly blue crab catches within the year shows substantial change from year to year (Annual Statistics, Table CY1). In an arbitrary grouping, the years 1960, 1969, 1975, 1977, and 1983 were years of highly variable monthly catches with CV's greater than or equal to 60%, while the years 1963, 1968, 1976, 1978, 1979, 1981, 1982, and 1984 were years of high to moderate monthly variability with CV's greater than 50% but less than 60%, and the years 1961, 1962, 1964, 1965-1967, 1970-1974, and 1980 were years of moderate to low variability with CV's less than or equal to 50%. It comes as no surprise that 1977 is the year with the maximum variability in monthly catches due to extreme weather conditions, but it is remarkable that all but one of the ten most recent years of record (1975-1984) have CV's greater than 50%.

The cumulative progress in monthly catches grouped by calendar year (1960 - 1984) also shows remarkable stability (Table CY2). There is a steady decline in the CV of cumulative monthly mean catches of hard crabs which point toward a very low CV in total annual harvest (December column, rightmost, Table CY2) of only 17.6%. Slow starts early in the harvest season are compensated for later on in the season in most years.

Monthly percentages of annual harvest permit an understanding of the rate of blue crab harvest for the calendar years 1960-1984. The expected fraction of the monthly harvest is obviously 1/12, or 8.33% (Table CY3), and the CV of the grand mean monthly percentage harvested, 50%, is only slightly less than that of the grand mean monthly pounds (Table CY1). Note that monthly mean percentages for the peak season months of July - October and December have CV's which are less than half that of the grand mean percentage (Table CY3), which is analogous to the situation for monthly pounds (Table CY1). That the variability in monthly <u>rate</u> of harvest should be so similar to the variability in actual monthly harvest is another indication of the relative lack of variability in total annual blue crab harvests.

The CV's of the annual monthly percentages (rightmost column, Table CY3) are mathematically identical to those of the annual monthly catches (Table CY1), so these results have already been reported.

The cumulative monthly percentages of catches (Table CY4) provide a convenient means of guaging the progress of total annual harvest which is less variable than the cumulative monthly catches (Table CY2), as judged by comparison of the CV's of the means. Even so the difference between the CV's of mean monthly numerical and percentage catches is probably inconsequential for harvest control purposes as will be seen later in the evaluation of forecast methods (Tables HY5 & HY6). By the end of June an average of 37% of the annual blue crab harvest has been taken, and by the end of July it is fairly certain that half the annual harvest has been taken, although the actual percent of the annual harvest taken by the end of July has varied from 34% in

1969 to 61% in 1967 (Table CY4). A reasonable approximation to a 99% confidence interval on the fraction of the annual blue crab harvest expected by the end of July is 40% - 60%.

The overall timing of the blue crab fishery of Virginia in a calendar year can be summarized by descriptive statistics (Table CY5). The grand mean or central date of the harvest is July 8, with 95% confidence interval July 3 - July 13. The distribution is fairly symmetric about the mean because the median date of catch (the 50% point in harvest) usually occurs during July (Table CY4). By grouping the annual mean dates of harvest with respect to the 95% confidence interval about the grand mean date of harvest, early, average and late timing categories can be defined (Table CY5). The eight early years are 1961-1963, 1974, 1976, and 1982-1984, while the 10 average years are 1964-1966, 1968, 1970, 1972-1973, 1975, and 1980-1981. The seven late years are 1960, 1967, 1969,1971, and 1977-1979. Even though the years are fairly evenly distributed among the timing categories, there is a tendency for runs of a timing category to occur; the effects which produce deviations in timing do not appear to be independent. Note the two sets of three early years in a row, 1961 - 1963, and 1982 - 1984.

Harvest Year Timing

The analysis for harvest years contains only the time intervals December 1972 - November 1984, so the comparison between calendar years and harvest years is not exact, however there is little real difference in variability between the two methods of arranging the data. The historical data 1960 - 1971 contained only hard crabs, more recent data gives total crab harvested. The monthly mean harvest is 3.3 million pounds of hard and soft crab (Table HY1), only slightly less than the mean found for hard crab in the 25 year period (Table CY1). The pattern observed in the CV's is maintained, the CV of the grand mean being 57% with the CV's of the peak harvest months July - October and December being about half or less the CV of the grand mean (Table HY1).

The general decline in the CV of mean cumulative monthly catch which was observed in the calendar year data (Table CY2) is also seen in the harvest year data (Table HY2). Similarly, the monthly percentage catch information (Table HY3) adds nothing new relative to the calendar year data (Table CY3), nor does the pattern of the cumulative percentage of harvest in the harvest year (Table HY4) differ much from that of the calendar year (Table CY4). The descriptive statistics of timing in the harvest year format are about what would be expected from shifting the calendar year back a month (Table HY4A). The grand mean date of catch for the harvest years 1972 - 1983 was June 7, as opposed to a grand mean date of July 8 for the calendar year. Note that in the forecasting section which follows the grand mean date of the harvest years 1972 - 1979, June 12, was used, since the intention was to test the forecasting methods using only information available at the beginning of harvest year 1980.

Since there was not much difference between harvest year and calendar year formats, the harvest year was chosen for forecasting in order to avoid placing the data from a single winter fishery into two different statistical years.

## Forecasting

Forecasting total abundance was reasonably successful with all of the models tested with the linear regression (LIN) model being much more reliable than the others for most of the year (Table HY5). The month by month forecasts were less successful than the total annual forecasts (Table HY5), and very little difference was observed between the monthly version of the average cumulative proportion ACP PF, and the monthly linear model, LIN PF. Reading Table HY5 takes some care, but it is worth the effort since it contains an enormous amount of information. In the upper half of the table are the errors of the estimates by model for each month. For example, using the catch data available at the end of March with an average of 18.6% of the total harvest over (see column p(i,j) ), the LIN model has an average error of 15.3% in forecasting total annual catch, whereas the ACP model had almost three times the error at 43.3%. In forecasting monthly harvests in the same month, the LIN PF model at 42.7% was better than the ACP PF model which erred an average of 49.3%. All of the models do well after the mean of the season, marked as June 12 on the table.

Note that the expected cumulative percent (column p(i,j) ) here is different from that of Table HY4, since the model was tested using only the average of harvest years 1972-1978. The forecasting test started in harvest year 1979 using only the information which would have been available at the start of that harvest year. The standard deviations of the forecasts appear in the lower half the table (HY5), and these generally correspond to the magnitude of the errors reported above.

To summarize the performance of the models, the errors have been averaged up to the mean date of the season, and recorded on the mean date (Table HY6). For comparison of the performance of the models a five year moving average model of the total annual catch has also been run and the error (MAPD) recorded. It is easy to see that up until the middle of the harvest year, the LIN model with an average error of 14.52% is clearly superior its next closest competitor, Cochran's censored ratio, CR, at 19.86% error. But at the mean date of the season the LIN model is bested by all models except the CR, although all of the errors are quite small at this point in the season.

A real shock comes when the errors of these clever models are compared to the error of the simple five year moving average model. At a MAPD of 13.26% (Table HY6) the moving average model is clearly superior to all of the models up to the middle of the season, about July 12 . After June 12, the ACP model is a good choice for forecasting total annual yield due to ease of computation, not superior accuracy. Each of the models does a much better job than the five year moving average of forecasting total annual harvest after June 12 (Table HY5).

Fishing Success Methods

Applegate (1983) worked with individual winter dredge vessel catch records collected by Van Engel and himself by working directly with individual processors. This remarkable data set covered part of the fleet for the time period December 1, 1931 to February 23, 1982. Applegate was perhaps able to exclude the effects of legally imposed quotas on the catch per vessel day by excluding CPUE's from dates on which more than two-thirds of his sample vessels reached the legal quota from his regression, although the catches were necessarily added into the cumulative catch calculation. Another assumption which Applegate was required to make was that the catch of his sample vessels was representative of the other licensed dredge vessels. The catch per vessel (actually per license) in the sample fleet was assumed to estimate the catch per winter crab-dredge license in the fleet at large in order to estimate total catch which implies the uniform distribution of crab with respect to the dredge fleet.

Stock and recruitment

For stock-recruitment modeling Applegate (1983) was required to make further assumptions regarding the life history of the blue crab; 1) That no natural mortality occurred between the end of the dredge season and the start of spawning, 2) that fishing mortality did not reduce the spawning population during the course of the spring and summer while spawning was occurring, 3) spawning closure of the Chesapeake Bay stocks with respect to emigration of mature females, immigration of larvae, megalopae, and other immature life history stages, and 4) a simple two year life cycle in which a female crab spawned during the spring and summer of one year would recruit to the dredge fishery in the late fall of the following year, and in which all females die in the year after spawning.

Hester and Mundy (1982) and Hester (1983) employed a somewhat different life history model in studying the population dynamics of the blue crab which was more closely attuned to recent oceanographic surveys near the Bay mouth. Since blue crab larvae were found by McConaugha et al (in press) in the neuston off the Chesapeake Bay all during the spring and summer, it was assumed that crabs could start life either in May at the earliest, or in August at the latest. If females mature at about eighteen months of age, a female which hatched in August might not mature in time to mate and recruit to the dredge fishery late in the following year. In order to set up an equilibrium population with cohorts originating each year in May and in August it was necessary to assign different instantaneous rates of both natural and fishing mortality to each of the two annual cohorts. The cohorts are defined in terms of the year and month (May or August) of spawning, and different values of natural and fishing mortality are applied to the May and August cohorts in the exponential depletion model to achieve an equilibrium.It was also clear that these equilibrium mortality rates would be very different depending on whether a constant fishable life span or a terminal spawning in which all females die the September after spawning was assumed for each cohort.

Hester (1983) also modeled the effect of wind stress in returning larvae shoreward toward the Chesapeake Bay as part of her stock-recruitment model. The initial production of larvae by a cohort of spawners is a linear function of the number of female spawners, and the initial number of larvae is depreciated over time via an exponential depletion model. In this model larvae are broadcast at the mouth of the Chesapeake Bay and drift offshore, to be returned only as climatologic and physical oceanographic conditions permit.

## Discussion

The stability of the timing of the harvests of the blue crab in Virginia raises some interesting questions about the reasons for the similarity in monthly catches during peak months (July - October and December) and in the total annual catches. One possibility is that the exploitation rate is very low so that availability of crabs hardly ever limits the magnitude of catch. As pointed out in the Introduction, questions of overfishing are realy not directly raised in North American crab regulatory programs. In the case of the blue crab of Virginia's Chesapeake Bay overfishing would appear to pose no threat under current environmental and economic conditions.

The support for the low exploitation rate hypothesis comes from both basic biological evidence and the behavior of the fishery. The blue crab is an arthropod with an average of one million eggs per female, rapid growth and a short life cycle whose life history stages occupy a broad range of estuarine and oceanic habitat. In this hypothesis the blue crab is a classic "r strategist" which can use its explosive reproductive potential and rapid growth rate to defeat environmental uncertainty and to offset the effects of new predators such as humans. Furthermore the oceanic distribution of the blue crab larvae makes recolonization of Chesapeake Bay from more northerly populations a distinct possibility, and adults are known to exist outside of estuaries, e.g. "ocean-run" crabs. Complete closure of the Chesapeake Bay blue crab populations seems highly unlikely.

To explain the timing behavior the fishery is characterized as weather and market driven. The catch, and particularly the proportion of catch, as a function of time is a reflection of the action of three key variables; the behaviors of the 1) crabs, 2) harvesters, and 3) markets. Given that the abundance of crabs usually does not hinder the accumulation of catch, delays in the spring can be caused by unusually cold weather, or spring catches can be accelerated by unusually warm weather. Increases or decreases in the rate of harvest at any time of the year can be caused by increases or decreases in unit prices. Thus the mean date of the annual harvest (Tables CY5 and HY4A) remains stable because harvesters can easily make up shortages caused by a cool spring once the weather warms up, and abundant supplies permitted by a warm spring will ultimately depress prices and reduce the rate of harvest.

The largest variabilities in monthly catches (Tables CY1 & HY1) and in monthly percentages of catch (Tables CY3 and HY3) occurs in those months when weather is most likely to hamper the operations of harvesters or when unit price or catch quotas and other regulations may be factors; November and January - June. That the annual timing of catch remains relatively constant in the face of fluctuations in the environment and prices paid to harvesters is a tribute to the the productivity of the blue crab.

Forecasting total annual harvest is relatively easy due to the stability of the timing of catch. The five year moving average of harvest should be used through the end of May, followed by the two parameter linear regression which models total annual catch as a function of cumulative monthly catch for June - November. Higher resolution in forecasting coulkd be obtained by working with weekly catch records. For example excellent accuracy in forecasting total annual catch could be achieved by using the catch obtained by the end of the first week June in the LIN model (Table HY5), but under current data collection procedures this could not be done in a timely or effective manner.

Forecasting monthly catch is difficult for January - May, and easy for the rest of the year (Table HY5). Both the average cumulative proportion and linear models provide good estimates of monthly harvests for June - November.

A most interesting question is raised by the forecasting success of the linear model. The linear model, in words, contends that the total harvest for a harvest year is a function of the cumulative catch for the month. There are 12 two parameter models set up for predicting the harvest based on the cumulative catch through each month. The question is this, "Why should the catch in the winter dredge fishery be a predictor of the harvest in the pot and trot line fisheries of the following spring, summer and fall?" There may be explanantions in terms of basic biological circumstances or there may economic causes, but the relation exists and it remains to be explained.

A number of basic data reporting problems exist. Catches from some areas may be under-reported due to inconsistencies in availability of field statisticians. Substantial evidence of under-reporting of catch is developed by Shabman and Vance (1983) and the concern for the accuracy of the catch reporting system in Maryland motivated the work of Summers et al (1983). Under-reporting in Virginia is a certainty, since the recreational harvest is not documented.

Statistical areas and gear categorizations are, for the most part, adequate. Reporting time intervals for the dredge fishery (monthly), however, are probably too long for the purposes of both fishing success methods and forecasting of catch. In the case of both winter and summer fisheries weekly reporting would bring improvements in forecasting and control. For the winter dredge, daily reporting by vessel is the ideal, but it could be approximated by daily reporting of a fraction of the fleet.

The assumptions of fishing success methods are obviously difficult to meet for blue crab fisheries on Chesapeake except in the case of the winter dredge fishery. Due to the relatively short duration of the dredge fishery (December through March), it is desirable to document daily catch by vessel, including the time required to harvest the daily catch limit. Generally, this data is available in seafood buyers' records; its collection, however, could be made a less than a burdensome and time-consuming task by designing a standard for the records which would facilitate data entry. In Alaska for example tens of thousands of fish tickets from commercial salmon fisheries are entered on microcomputers at the site of the fishery, and then the tickets are sent via diskette to a central site.

Estimates of harvester employment and vessel usage in the dredge fishery are developed, annually, via analysis of VMRC commercial fishermen licenses and U. S. Coast Guard Documentation records. Data availability and adequacy are discussed by Rothschild et al (1981), Anninos and Burch (1982), and Austin (1982).

Data which can link catch to climatic events or stock to recruitment (see Austin et al 1982) were not available. The age structure data were identified as essential in a recent simulation study of population dynamics of the blue crab (Hester and Mundy 1982). The simulation study has also identified the month as the minimum acceptable unit of time for such blue crab models. Sampling programs which develop a size frequency distribution are necessary before progress can be made in environmental models.

The modeling of Hester and Mundy (1982) and Hester (1983) served to point out that there were certain inadequacies in the knowledge of the life history of the blue crab with respect to fisheries management activities. If climatic events are to be related to recruitment then the time from spawning to recruitment must be known to within a month or two so that the lag time between the cause and effect can be established. There are larval stages of blue crabs in the waters adjacent to Chesapeake Bay for a period of about four months, so to assume all apawning takes place in the spring will overly simplify the resulting model of the population dynamics. The theory that there is an age structure to the recruited female population whose unit time is a month or less appears to be most reasonable.

Given that crabs spawn from May to August (McConaugha et al in press), the length of time the individual is vulnerable to the various gear types could vary substantially as a function of the month of birth. Furthermore the age structure of the catch could vary substantially depending upon which of two hypotheses is ultimately validated regarding the length of life as members of the fishable stock; the constant fishable life span hypothesis, or the terminal molt hypothesis (Hester and Mundy 1982). Under the constant fishable life span hypothesis, the female crabs remain available to the fishery after spawning, while under the terminal molt hypothesis the females all disappear at the end of the September after spawning. The consequences of the model argue strongly for age composition data from the commercial fishery. Other consequences of interest to harvest control and general fisheries management remain to be revealed as the model is developed further.

Catch sampling to establish size frequency categories is necessary if these hypotheses are to be tested. It is an unfortunate circumstance that after 350 years of exploitation, most of the hypotheses regarding the life cycle of the blue crab in Chesapeake Bay remain untested.

## Conclusions and Recommendations

1) Without considering the absolute accuracy of the the catch reporting system there are two improvements in catch reporting which would increase the fisheries management capabilities of VMRC

a) for fishing success methods

collect daily records from some fraction of the dredge vessel operators. A study would be necessary to determine the size of the fraction

b) for forecasting total and monthly catches

collect weekly catch figures

2) A catch sampling program for size frequency by sex would contribute to unraveling some of the remaining mysteries of the blue crab life cycle

3) If a quota form of management should become necessary, the five major areas (see Figure) could be readily regulated by controlling the amount of time open to fishing. The minimum amount of time for a viable regulation would depend on the catch reporting time step. For example if monthly data are available then the opening for the next month would depend on the cumulative catch through the end of the current month. For a summer or winter fishery the proportion of the harvest expected on the next time interval could be found in the performance curves of Shively (1984, Appendix). The LIN PF model could also be used with the data of Shively (1984) for an area by area quota management system.

Our research constitutes a logical extension of recent advances in knowledge of the life history of the blue crab to the applied fisheries management specialty of harvest control. The Sea Grant studies summarized by Sulkin et al. (1982) were logical extensions of many years of research within Chesapeake Bay by Van Engel, Cronin, and others. The Maryland Department of Natural Resources has devoted substantial resources to the data and methods of management for the blue crab (Summers et al 1983a & 1983b) and it is our hope that this work has taken the Virginia Marine Resources Commission one step closer to being able to complement Maryland's work in the lower Chesapeake Bay.

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## Acknowledgments

The material and intellectual contributions of the following people are gratefully noted; Erik Barth, Beth Hester, Louis Rugolo, and Dale Shively. Without their hard work and dedication this work would have been far less.

TABLES: Calendar Year Format

Table CY1. Monthly catches of hard blue crabs (million lbs) for the calendar years 1960 - 1984 and the monthly and annual mean catches and their standard deviations (SD) and coefficients of variation, CV, (percent) for the Virginia portion of the Chesapeake Bay.

| | Monthly catches | | | | | | | | | | | | Annual Statistics | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yr | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean | SD | CV |
| 60 | 0.840 | 0.875 | 0.664 | 1.082 | 2.245 | 2.508 | 4.338 | 5.128 | 6.277 | 3.716 | 2.067 | 4.448 | 2.849 | 1.892 | 66.42 |
| 61 | 2.627 | 2.896 | 2.478 | 2.951 | 2.898 | 5.127 | 6.118 | 5.236 | 4.437 | 4.498 | 1.823 | 4.464 | 3.796 | 1.345 | 35.44 |
| 62 | 3.007 | 2.405 | 2.360 | 4.628 | 5.169 | 6.368 | 5.531 | 6.522 | 4.524 | 5.330 | 0.978 | 4.626 | 4.287 | 1.729 | 40.32 |
| 63 | 6.150 | 4.258 | 0.864 | 1.360 | 2.260 | 2.340 | 4.531 | 6.859 | 6.140 | 6.760 | 1.461 | 4.969 | 3.996 | 2.242 | 56.12 |
| 64 | 4.233 | 1.555 | 1.237 | 2.020 | 5.257 | 4.382 | 6.742 | 5.543 | 5.043 | 5.383 | 2.727 | 4.746 | 4.072 | 1.767 | 43.38 |
| 65 | 2.444 | 3.464 | 0.960 | 2.884 | 5.218 | 6.338 | 6.735 | 4.323 | 5.693 | 5.826 | 3.197 | 5.387 | 4.372 | 1.780 | 40.70 |
| 66 | 3.738 | 2.167 | 2.044 | 4.785 | 5.571 | 6.388 | 6.963 | 7.724 | 7.480 | 6.233 | 3.316 | 6.028 | 5.203 | 1.977 | 38.00 |
| 67 | 4.209 | 2.130 | 2.493 | 4.044 | 5.513 | 7.146 | 7.921 | 7.212 | 5.219 | 4.083 | 1.146 | 3.650 | 4.564 | 2.124 | 46.55 |
| 68 | 3.116 | 1.107 | 1.312 | 1.536 | 3.105 | 4.523 | 5.890 | 6.394 | 6.274 | 5.171 | 1.930 | 3.358 | 3.643 | 1.966 | 53.98 |
| 69 | 2.164 | 2.307 | 0.683 | 0.909 | 1.076 | 2.369 | 2.258 | 3.901 | 4.893 | 6.808 | 3.689 | 3.878 | 2.911 | 1.799 | 61.81 |
| 70 | 1.737 | 2.376 | 2.136 | 1.545 | 4.076 | 4.235 | 4.542 | 5.981 | 4.311 | 5.018 | 2.759 | 3.769 | 3.540 | 1.406 | 39.70 |
| 71 | 1.444 | 2.239 | 1.369 | 2.400 | 5.281 | 4.859 | 5.530 | 5.705 | 4.965 | 4.560 | 3.262 | 6.056 | 3.973 | 1.725 | 43.44 |
| 72 | 2.694 | 2.033 | 2.166 | 3.662 | 4.202 | 5.107 | 4.800 | 6.825 | 4.740 | 4.419 | 3.363 | 4.338 | 4.029 | 1.354 | 33.61 |
| 73 | 2.579 | 2.033 | 1.157 | 2.192 | 2.513 | 3.842 | 4.738 | 5.460 | 4.743 | 3.946 | 1.225 | 3.301 | 3.144 | 1.418 | 45.09 |
| 74 | 2.533 | 1.178 | 1.020 | 3.519 | 4.728 | 5.141 | 5.198 | 4.985 | 4.324 | 3.812 | 1.643 | 3.580 | 3.472 | 1.537 | 44.27 |
| 75 | 1.414 | 0.724 | 0.514 | 2.175 | 4.088 | 5.973 | 5.433 | 4.142 | 4.199 | 3.164 | 1.861 | 1.885 | 2.964 | 1.804 | 60.85 |
| 76 | 1.970 | 0.953 | 1.509 | 1.403 | 1.240 | 3.341 | 4.155 | 3.087 | 2.819 | 2.681 | 0.341 | 3.023 | 2.210 | 1.140 | 51.59 |
| 77 | 0.649 | 0.815 | 0.187 | 0.461 | 1.738 | 3.707 | 6.292 | 6.992 | 5.494 | 4.597 | 2.855 | 4.085 | 3.156 | 2.397 | 75.95 |
| 78 | 1.994 | 1.364 | 0.755 | 0.816 | 2.336 | 4.044 | 5.344 | 6.123 | 4.957 | 3.887 | 2.530 | 2.510 | 3.055 | 1.792 | 58.65 |
| 79 | 1.014 | 0.969 | 1.058 | 1.661 | 3.960 | 5.928 | 6.209 | 5.928 | 3.551 | 4.035 | 2.413 | 4.161 | 3.407 | 1.979 | 58.08 |
| 80 | 1.963 | 2.038 | 1.319 | 3.019 | 2.842 | 4.032 | 4.896 | 5.483 | 4.277 | 3.273 | 0.996 | 4.186 | 3.194 | 1.426 | 44.64 |
| 81 | 4.409 | 1.739 | 0.318 | 1.430 | 1.938 | 3.403 | 5.649 | 6.290 | 5.276 | 4.996 | 1.961 | 3.771 | 3.432 | 1.930 | 56.24 |
| 82 | 3.187 | 1.525 | 0.960 | 2.479 | 4.463 | 5.052 | 6.529 | 6.530 | 5.759 | 4.148 | 1.588 | 1.837 | 3.671 | 2.018 | 54.95 |
| 83 | 0.820 | 0.744 | 0.556 | 2.185 | 2.683 | 5.513 | 6.596 | 8.179 | 6.988 | 5.037 | 2.470 | 4.269 | 3.837 | 2.632 | 68.60 |
| 84 | 3.721 | 2.091 | 0.829 | 2.301 | 4.063 | 8.266 | 5.737 | 4.580 | 4.097 | 4.099 | 1.360 | 4.375 | 3.793 | 2.019 | 53.22 |

| | Monthly Statistics | | | | | | | | | | | | Grand Statistics | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| St | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean | SD | CV |
| Mn | 2.586 | 1.839 | 1.238 | 2.298 | 3.539 | 4.797 | 5.547 | 5.805 | 5.059 | 4.619 | 2.118 | 4.028 | 3.623 | 1.872 | 51.67 |
| SD | 1.322 | 0.874 | 0.682 | 1.162 | 1.415 | 1.494 | 1.157 | 1.222 | 1.050 | 1.053 | 0.886 | 1.053 | | | |
| CV | 51.11 | 47.50 | 55.06 | 50.59 | 39.98 | 31.14 | 20.85 | 21.06 | 20.75 | 22.80 | 41.80 | 26.13 | | | |

Table CY2. Cumulative monthly catches of hard blue crabs (million lbs) for the calendar years 1960 - 1984 and the monthly mean cumulative catches and their standard deviations (SD) and coefficients of variation, CV, (percent) for the Virginia portion of the Chesapeake Bay.

Cumulative monthly catches

| Yr | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 0.84 | 1.71 | 2.38 | 3.46 | 5.71 | 8.21 | 12.55 | 17.68 | 23.96 | 27.67 | 29.74 | 34.19 |
| 61 | 2.63 | 5.52 | 8.00 | 10.95 | 13.85 | 18.98 | 25.09 | 30.33 | 34.77 | 39.27 | 41.09 | 45.55 |
| 62 | 3.01 | 5.41 | 7.77 | 12.40 | 17.57 | 23.94 | 29.47 | 35.99 | 40.51 | 45.84 | 46.82 | 51.45 |
| 63 | 6.15 | 10.41 | 11.27 | 12.63 | 14.89 | 17.23 | 21.76 | 28.62 | 34.76 | 41.52 | 42.98 | 47.95 |
| 64 | 4.23 | 5.79 | 7.02 | 9.04 | 14.30 | 18.68 | 25.43 | 30.97 | 36.01 | 41.40 | 44.12 | 48.87 |
| 65 | 2.44 | 5.91 | 6.87 | 9.75 | 14.97 | 21.31 | 28.04 | 32.37 | 38.06 | 43.88 | 47.08 | 52.47 |
| 66 | 3.74 | 5.90 | 7.95 | 12.73 | 18.30 | 24.69 | 31.66 | 39.38 | 46.86 | 53.09 | 56.41 | 62.44 |
| 67 | 4.21 | 6.34 | 8.83 | 12.88 | 18.39 | 25.54 | 33.46 | 40.67 | 45.89 | 49.97 | 51.12 | 54.77 |
| 68 | 3.12 | 4.22 | 5.53 | 7.07 | 10.18 | 14.70 | 20.59 | 26.98 | 33.26 | 38.43 | 40.36 | 43.72 |
| 69 | 2.16 | 4.47 | 5.15 | 6.06 | 7.14 | 9.51 | 11.77 | 15.67 | 20.56 | 27.37 | 31.06 | 34.93 |
| 70 | 1.74 | 4.11 | 6.25 | 7.79 | 11.87 | 16.11 | 20.65 | 26.63 | 30.94 | 35.96 | 38.72 | 42.49 |
| 71 | 1.44 | 3.68 | 5.05 | 7.45 | 12.73 | 17.59 | 23.12 | 28.83 | 33.79 | 38.35 | 41.61 | 47.67 |
| 72 | 2.69 | 4.73 | 6.89 | 10.55 | 14.76 | 19.86 | 24.66 | 31.49 | 36.23 | 40.65 | 44.01 | 48.35 |
| 73 | 2.58 | 4.61 | 5.77 | 7.96 | 10.47 | 14.32 | 19.05 | 24.51 | 29.26 | 33.20 | 34.43 | 37.73 |
| 74 | 2.53 | 3.71 | 4.73 | 8.25 | 12.98 | 18.12 | 23.32 | 28.30 | 32.63 | 36.44 | 38.08 | 41.66 |
| 75 | 1.41 | 2.14 | 2.65 | 4.83 | 8.91 | 14.89 | 20.32 | 24.46 | 28.66 | 31.83 | 33.69 | 35.57 |
| 76 | 1.97 | 2.92 | 4.43 | 5.83 | 7.07 | 10.42 | 14.57 | 17.66 | 20.48 | 23.16 | 23.50 | 26.52 |
| 77 | 0.65 | 1.46 | 1.65 | 2.11 | 3.85 | 7.56 | 13.85 | 20.84 | 26.33 | 30.93 | 33.79 | 37.87 |
| 78 | 1.99 | 3.36 | 4.11 | 4.93 | 7.26 | 11.31 | 16.65 | 22.78 | 27.73 | 31.62 | 34.15 | 36.66 |
| 79 | 1.01 | 1.98 | 3.04 | 4.70 | 8.66 | 14.59 | 20.80 | 26.73 | 30.28 | 34.31 | 36.73 | 40.89 |
| 80 | 1.96 | 4.00 | 5.32 | 8.34 | 11.18 | 15.21 | 20.11 | 25.59 | 29.87 | 33.14 | 34.14 | 38.32 |
| 81 | 4.41 | 6.15 | 6.47 | 7.90 | 9.83 | 13.24 | 18.89 | 25.18 | 30.45 | 35.45 | 37.41 | 41.18 |
| 82 | 3.19 | 4.72 | 5.67 | 8.15 | 12.61 | 17.67 | 24.19 | 30.72 | 36.48 | 40.63 | 42.22 | 44.06 |
| 83 | 0.82 | 1.56 | 2.12 | 4.30 | 6.99 | 12.50 | 19.10 | 27.28 | 34.26 | 39.30 | 41.77 | 46.04 |
| 84 | 3.72 | 5.81 | 6.64 | 8.94 | 13.01 | 21.27 | 27.01 | 31.59 | 35.69 | 39.78 | 41.14 | 45.52 |

Cumulative monthly statistics

| St | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mn | 2.59 | 4.42 | 5.66 | 7.96 | 11.50 | 16.30 | 21.84 | 27.65 | 32.71 | 37.33 | 39.45 | 43.47 |
| SD | 1.32 | 1.97 | 2.28 | 3.00 | 3.95 | 4.92 | 5.63 | 6.14 | 6.49 | 6.90 | 7.06 | 7.64 |
| CV | 51.1 | 44.6 | 40.2 | 37.7 | 34.4 | 30.2 | 25.8 | 22.2 | 19.9 | 18.5 | 17.9 | 17.6 |

Table CY3. Monthly percentages of catches of hard blue crabs for the calendar years 1960 - 1984 and the monthly and annual mean percentages of catch, and their standard deviations x 100 (SD) and coefficients of variation, CV, (percent) for the Virginia portion of the Chesapeake Bay.

| | Monthly catches | | | | | | | | | | | | Annual Statistics | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yr | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean | SD | CV |
| 60 | 2.46 | 2.56 | 1.94 | 3.16 | 6.57 | 7.34 | 12.69 | 15.00 | 18.36 | 10.87 | 6.05 | 13.01 | 8.33 | 5.54 | 66.42 |
| 61 | 5.77 | 6.36 | 5.44 | 6.48 | 6.36 | 11.26 | 13.43 | 11.49 | 9.74 | 9.87 | 4.00 | 9.80 | 8.33 | 2.95 | 35.44 |
| 62 | 5.84 | 4.67 | 4.59 | 9.00 | 10.05 | 12.38 | 10.75 | 12.68 | 8.79 | 10.36 | 1.90 | 8.99 | 8.33 | 3.36 | 40.34 |
| 63 | 12.83 | 8.88 | 1.80 | 2.84 | 4.71 | 4.88 | 9.45 | 14.30 | 12.80 | 14.10 | 3.05 | 10.36 | 8.33 | 4.68 | 56.11 |
| 64 | 8.66 | 3.18 | 2.53 | 4.13 | 10.76 | 8.97 | 13.80 | 11.34 | 10.32 | 11.02 | 5.58 | 9.71 | 8.33 | 3.62 | 43.40 |
| 65 | 4.66 | 6.60 | 1.83 | 5.50 | 9.94 | 12.08 | 12.84 | 8.24 | 10.85 | 11.10 | 6.09 | 10.27 | 8.33 | 3.39 | 40.70 |
| 66 | 5.99 | 3.47 | 3.27 | 7.66 | 8.92 | 10.23 | 11.15 | 12.37 | 11.98 | 9.98 | 5.31 | 9.65 | 8.33 | 3.17 | 38.00 |
| 67 | 7.69 | 3.89 | 4.55 | 7.38 | 10.07 | 13.05 | 14.46 | 13.17 | 9.53 | 7.46 | 2.09 | 6.66 | 8.33 | 3.88 | 46.55 |
| 68 | 7.13 | 2.53 | 3.00 | 3.51 | 7.10 | 10.35 | 13.47 | 14.63 | 14.35 | 11.83 | 4.41 | 7.68 | 8.33 | 4.50 | 54.00 |
| 69 | 6.19 | 6.60 | 1.96 | 2.60 | 3.08 | 6.78 | 6.46 | 11.17 | 14.01 | 19.49 | 10.56 | 11.10 | 8.33 | 5.15 | 61.82 |
| 70 | 4.09 | 5.59 | 5.03 | 3.64 | 9.59 | 9.97 | 10.69 | 14.08 | 10.15 | 11.81 | 6.49 | 8.87 | 8.33 | 3.31 | 39.70 |
| 71 | 3.03 | 4.70 | 2.87 | 5.03 | 11.08 | 10.19 | 11.60 | 11.97 | 10.42 | 9.57 | 6.84 | 12.70 | 8.33 | 3.62 | 43.44 |
| 72 | 5.57 | 4.20 | 4.48 | 7.57 | 8.69 | 10.56 | 9.93 | 14.12 | 9.80 | 9.14 | 6.96 | 8.97 | 8.33 | 2.80 | 33.63 |
| 73 | 6.84 | 5.39 | 3.07 | 5.81 | 6.66 | 10.18 | 12.56 | 14.47 | 12.57 | 10.46 | 3.25 | 8.75 | 8.33 | 3.76 | 45.07 |
| 74 | 6.08 | 2.83 | 2.45 | 8.45 | 11.35 | 12.34 | 12.48 | 11.97 | 10.38 | 9.15 | 3.94 | 8.59 | 8.33 | 3.69 | 44.28 |
| 75 | 3.98 | 2.04 | 1.44 | 6.11 | 11.49 | 16.79 | 15.27 | 11.64 | 11.80 | 8.89 | 5.23 | 5.30 | 8.33 | 5.07 | 60.85 |
| 76 | 7.43 | 3.59 | 5.69 | 5.29 | 4.68 | 12.60 | 15.67 | 11.64 | 10.63 | 10.11 | 1.29 | 11.40 | 8.34 | 4.30 | 51.58 |
| 77 | 1.71 | 2.15 | 0.49 | 1.22 | 4.59 | 9.79 | 16.61 | 18.46 | 14.51 | 12.14 | 7.54 | 10.79 | 8.33 | 6.33 | 75.96 |
| 78 | 5.44 | 3.72 | 2.06 | 2.23 | 6.37 | 11.03 | 14.58 | 16.70 | 13.52 | 10.60 | 6.90 | 6.85 | 8.33 | 4.89 | 58.64 |
| 79 | 2.48 | 2.37 | 2.59 | 4.06 | 9.69 | 14.50 | 15.19 | 14.50 | 8.68 | 9.87 | 5.90 | 10.18 | 8.33 | 4.84 | 58.09 |
| 80 | 5.12 | 5.32 | 3.44 | 7.88 | 7.42 | 10.52 | 12.78 | 14.31 | 11.16 | 8.54 | 2.60 | 10.92 | 8.33 | 3.72 | 44.64 |
| 81 | 10.71 | 4.22 | 0.77 | 3.47 | 4.71 | 8.26 | 13.72 | 15.27 | 12.81 | 12.13 | 4.76 | 9.16 | 8.33 | 4.69 | 56.24 |
| 82 | 7.23 | 3.46 | 2.18 | 5.63 | 10.13 | 11.47 | 14.82 | 14.82 | 13.07 | 9.42 | 3.60 | 4.17 | 8.33 | 4.58 | 54.96 |
| 83 | 1.78 | 1.62 | 1.21 | 4.75 | 5.83 | 11.97 | 14.33 | 17.76 | 15.18 | 10.94 | 5.36 | 9.27 | 8.33 | 5.72 | 68.58 |
| 84 | 8.17 | 4.59 | 1.82 | 5.06 | 8.93 | 18.16 | 12.60 | 10.06 | 9.00 | 9.01 | 2.99 | 9.61 | 8.33 | 4.44 | 53.22 |

| | Monthly Statistics | | | | | | | | | | | | Grand Statistics | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| St | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean | SD | CV |
| Mn | 5.88 | 4.18 | 2.82 | 5.14 | 7.95 | 11.03 | 12.85 | 13.45 | 11.78 | 10.71 | 4.91 | 9.31 | 8.33 | 4.16 | 49.86 |
| SD | 2.66 | 1.74 | 1.44 | 2.08 | 2.49 | 2.85 | 2.26 | 2.35 | 2.34 | 2.30 | 2.11 | 2.05 | | | |
| CV | 45.23 | 41.53 | 50.91 | 40.47 | 31.27 | 25.88 | 17.56 | 17.48 | 19.91 | 21.49 | 43.01 | 21.97 | | | |

TABLES: Calendar Year Format

Table CY4. Cumulative monthly percentages of catches of hard blue crabs for the calendar years 1960 - 1984 and the monthly mean cumulative percentage of catch and their standard deviations x 100 (SD) and coefficients of variation, CV, (percent) for the Virginia portion of the Chesapeake Bay.

Cumulative monthly percentages

| Yr | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 2.46 | 5.02 | 6.96 | 10.12 | 16.69 | 24.03 | 36.71 | 51.71 | 70.07 | 80.94 | 86.99 | 100.00 |
| 61 | 5.77 | 12.12 | 17.56 | 24.04 | 30.40 | 41.66 | 55.09 | 66.58 | 76.32 | 86.20 | 90.20 | 100.00 |
| 62 | 5.84 | 10.52 | 15.11 | 24.10 | 34.15 | 46.53 | 57.28 | 69.95 | 78.75 | 89.11 | 91.01 | 100.00 |
| 63 | 12.83 | 21.71 | 23.51 | 26.34 | 31.06 | 35.94 | 45.38 | 59.69 | 72.49 | 86.59 | 89.64 | 100.00 |
| 64 | 8.66 | 11.84 | 14.38 | 18.51 | 29.27 | 38.23 | 52.03 | 63.37 | 73.69 | 84.71 | 90.29 | 100.00 |
| 65 | 4.66 | 11.26 | 13.09 | 18.59 | 28.53 | 40.61 | 53.45 | 61.69 | 72.54 | 83.64 | 89.73 | 100.00 |
| 66 | 5.99 | 9.46 | 12.73 | 20.39 | 29.32 | 39.55 | 50.70 | 63.07 | 75.05 | 85.03 | 90.35 | 100.00 |
| 67 | 7.69 | 11.57 | 16.13 | 23.51 | 33.58 | 46.63 | 61.09 | 74.26 | 83.79 | 91.24 | 93.34 | 100.00 |
| 68 | 7.13 | 9.66 | 12.66 | 16.17 | 23.28 | 33.62 | 47.10 | 61.72 | 76.08 | 87.90 | 92.32 | 100.00 |
| 69 | 6.19 | 12.80 | 14.75 | 17.36 | 20.44 | 27.22 | 33.68 | 44.85 | 58.85 | 78.34 | 88.90 | 100.00 |
| 70 | 4.09 | 9.68 | 14.71 | 18.35 | 27.94 | 37.91 | 48.60 | 62.68 | 72.82 | 84.63 | 91.13 | 100.00 |
| 71 | 3.03 | 7.73 | 10.60 | 15.63 | 26.71 | 36.90 | 48.50 | 60.47 | 70.89 | 80.45 | 87.30 | 100.00 |
| 72 | 5.57 | 9.78 | 14.26 | 21.83 | 30.52 | 41.08 | 51.01 | 65.13 | 74.93 | 84.07 | 91.03 | 100.00 |
| 73 | 6.84 | 12.22 | 15.29 | 21.10 | 27.76 | 37.94 | 50.50 | 64.97 | 77.55 | 88.00 | 91.25 | 100.00 |
| 74 | 6.08 | 8.91 | 11.36 | 19.80 | 31.15 | 43.49 | 55.97 | 67.93 | 78.31 | 87.46 | 91.41 | 100.00 |
| 75 | 3.98 | 6.01 | 7.46 | 13.57 | 25.06 | 41.85 | 57.13 | 68.77 | 80.57 | 89.47 | 94.70 | 100.00 |
| 76 | 7.43 | 11.02 | 16.71 | 22.00 | 26.68 | 39.27 | 54.94 | 66.58 | 77.21 | 87.32 | 88.60 | 100.00 |
| 77 | 1.71 | 3.87 | 4.36 | 5.58 | 10.17 | 19.95 | 36.57 | 55.03 | 69.54 | 81.68 | 89.21 | 100.00 |
| 78 | 5.44 | 9.16 | 11.22 | 13.45 | 19.82 | 30.85 | 45.43 | 62.13 | 75.65 | 86.25 | 93.15 | 100.00 |
| 79 | 2.48 | 4.85 | 7.44 | 11.50 | 21.19 | 35.68 | 50.87 | 65.37 | 74.05 | 83.92 | 89.82 | 100.00 |
| 80 | 5.12 | 10.44 | 13.88 | 21.76 | 29.17 | 39.70 | 52.47 | 66.78 | 77.94 | 86.48 | 89.08 | 100.00 |
| 81 | 10.71 | 14.93 | 15.70 | 19.17 | 23.88 | 32.14 | 45.86 | 61.14 | 73.95 | 86.08 | 90.84 | 100.00 |
| 82 | 7.23 | 10.70 | 12.87 | 18.50 | 28.63 | 40.10 | 54.92 | 69.74 | 82.81 | 92.23 | 95.83 | 100.00 |
| 83 | 1.78 | 3.40 | 4.60 | 9.35 | 15.18 | 27.15 | 41.48 | 59.24 | 74.42 | 85.36 | 90.73 | 100.00 |
| 84 | 8.17 | 12.77 | 14.59 | 19.64 | 28.57 | 46.73 | 59.33 | 69.40 | 78.40 | 87.40 | 90.39 | 100.00 |

Cumulative monthly statistics

| St | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mn | 5.88 | 10.06 | 12.88 | 18.01 | 25.97 | 36.99 | 49.84 | 63.29 | 75.07 | 85.78 | 90.69 | 100.00 |
| SD | 2.66 | 3.83 | 4.28 | 5.10 | 5.90 | 6.94 | 7.12 | 6.23 | 4.92 | 3.25 | 2.05 | 0.00 |
| CV | 45.23 | 38.06 | 33.23 | 28.33 | 22.71 | 18.75 | 14.28 | 9.84 | 6.56 | 3.79 | 2.26 | 0.00 |

## Calendar Year Format

Table CY5. Annual mean date of hard blue crab catch in calendar and coded notation, the variance of the timing of catch, and the coefficient of variation of the timing of catch (percent) for the Virginia portion of the Chesapeake Bay. The years are classified as early (E), late (L), or average (A) with respect to the 95% confidence interval about the long term average timing which is given at the foot of the table.

| Yr | | Mean date Cal | Mean date Cd | Var | CV |
|---|---|---|---|---|---|
| 60 | L | Aug 3 | 8.1 | 7.37 | 34 |
| 61 | E | Jun 27 | 6.9 | 9.97 | 46 |
| 62 | E | Jun 24 | 6.8 | 9.26 | 45 |
| 63 | E | Jun 27 | 6.9 | 12.62 | 51 |
| 64 | A | Jul 6 | 7.2 | 10.03 | 44 |
| 65 | A | Jul 6 | 7.2 | 9.64 | 43 |
| 66 | A | Jul 6 | 7.2 | 9.43 | 43 |
| 67 | L | Jun 18 | 6.6 | 8.67 | 45 |
| 68 | A | Jul 9 | 7.3 | 8.69 | 40 |
| 69 | L | Aug 1 | 8.0 | 10.58 | 41 |
| 70 | A | Jul 9 | 7.3 | 9.28 | 42 |
| 71 | L | Jul 15 | 7.5 | 9.12 | 40 |
| 72 | A | Jul 3 | 7.1 | 9.61 | 44 |
| 73 | A | Jul 3 | 7.1 | 9.48 | 44 |
| 74 | E | Jul 1 | 7.0 | 8.76 | 42 |
| 75 | A | Jul 3 | 7.1 | 6.89 | 37 |
| 76 | E | Jul 1 | 7.0 | 9.78 | 45 |
| 77 | L | Aug 6 | 8.2 | 5.89 | 29 |
| 78 | L | Jul 15 | 7.5 | 8.04 | 38 |
| 79 | L | Jul 15 | 7.5 | 7.39 | 36 |
| 80 | A | Jul 3 | 7.1 | 9.33 | 43 |
| 81 | A | Jul 9 | 7.3 | 10.36 | 44 |
| 82 | E | Jun 27 | 6.9 | 7.96 | 41 |
| 83 | E | Jun 27 | 7.9 | 6.20 | 32 |
| 84 | E | Jun 24 | 6.8 | 9.51 | 45 |

Grand statistics

| Grand mean | SD | 95% Confidence interval bounds: Lower | 95% Confidence interval bounds: Upper |
|---|---|---|---|
| July 8: 7.26 | 0.42 | July 3: 7.08 | July 13: 7.43 |

Student's t(24,0.05) = 2.064

Table HY1. Monthly catches of hard and soft blue crabs (lbs/100 000) for the harvest years 1972-73 - 1983-84 and the monthly and annual mean catches x 1/100 000 and their standard deviations x 1/100 000 (SD) and coefficients of variation, CV, (percent) for the Virginia portion of the Chesapeake Bay.

| | Monthly catches | | | | | | | | | | | | Annual Statistics | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yr | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Mean | SD | CV |
| 72 | 43.38 | 25.79 | 20.33 | 11.57 | 21.92 | 25.13 | 38.42 | 47.38 | 54.60 | 47.43 | 39.46 | 12.25 | 32.31 | 14.59 | 45.17 |
| 73 | 33.01 | 25.33 | 11.78 | 10.20 | 35.19 | 47.28 | 51.41 | 51.98 | 49.85 | 43.24 | 38.12 | 16.43 | 34.49 | 15.37 | 44.58 |
| 74 | 35.80 | 14.14 | 7.24 | 5.14 | 21.75 | 40.88 | 59.73 | 54.33 | 41.42 | 41.99 | 31.64 | 18.61 | 31.06 | 17.78 | 57.24 |
| 75 | 18.85 | 19.70 | 9.53 | 15.09 | 14.03 | 12.40 | 33.41 | 41.55 | 30.87 | 28.19 | 26.81 | 3.41 | 21.15 | 11.13 | 52.63 |
| 76 | 30.23 | 6.49 | 8.15 | 1.87 | 4.61 | 17.38 | 37.07 | 62.92 | 69.92 | 54.94 | 45.97 | 28.55 | 30.68 | 23.79 | 77.56 |
| 77 | 40.85 | 19.94 | 13.64 | 7.55 | 8.16 | 23.36 | 40.44 | 53.44 | 61.23 | 49.57 | 38.87 | 25.30 | 31.86 | 18.06 | 56.68 |
| 78 | 25.10 | 10.14 | 9.69 | 10.58 | 16.61 | 39.60 | 59.28 | 62.09 | 59.28 | 35.51 | 40.35 | 24.13 | 32.70 | 19.79 | 60.53 |
| 79 | 41.61 | 19.63 | 20.38 | 13.19 | 30.19 | 28.42 | 40.32 | 48.96 | 54.83 | 42.77 | 32.73 | 9.96 | 31.92 | 14.24 | 44.62 |
| 80 | 41.86 | 44.69 | 17.39 | 3.21 | 14.28 | 20.44 | 43.52 | 57.73 | 64.44 | 53.29 | 49.97 | 19.61 | 35.87 | 19.88 | 55.42 |
| 81 | 37.71 | 31.87 | 15.25 | 9.60 | 24.79 | 46.81 | 51.82 | 66.94 | 66.92 | 58.73 | 41.49 | 15.88 | 38.98 | 20.00 | 51.29 |
| 82 | 18.37 | 8.20 | 7.44 | 5.56 | 22.35 | 28.46 | 56.65 | 67.75 | 84.84 | 69.20 | 50.47 | 24.81 | 37.01 | 27.49 | 74.28 |
| 83 | 42.69 | 37.21 | 20.91 | 8.29 | 23.02 | 43.23 | 84.28 | 59.13 | 47.83 | 41.64 | 41.02 | 13.60 | 38.57 | 20.78 | 53.86 |
| | Monthly Statistics | | | | | | | | | | | | Grand Statistics | | |
| St | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Mean | SD | CV |
| Mn | 34.12 | 21.93 | 13.48 | 8.49 | 19.74 | 31.12 | 49.70 | 56.18 | 57.17 | 47.21 | 39.74 | 17.71 | 33.05 | 18.87 | 57.08 |
| SD | 9.12 | 11.74 | 5.26 | 4.00 | 8.71 | 12.00 | 14.17 | 8.05 | 14.11 | 10.92 | 7.07 | 7.31 | | | |
| CV | 26.73 | 53.56 | 39.04 | 47.14 | 44.14 | 38.58 | 28.51 | 14.33 | 24.68 | 23.12 | 17.78 | 41.25 | | | |

Table HY2. Cumulative monthly catches of hard and soft blue crabs (lbs/100 000) for the harvest years 1972-73 - 1983-84 and the monthly mean cumulative catches x 1/100 000 and their standard deviations x 1/100 000 (SD) and coefficients of variation, CV, (percent) for the Virginia portion of the Chesapeake Bay.

Cumulative monthly catches

| Yr | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72 | 43.4 | 69.2 | 89.5 | 101.1 | 123.0 | 148.1 | 186.5 | 233.9 | 288.5 | 336.0 | 375.4 | 387.7 |
| 73 | 33.0 | 58.3 | 70.1 | 80.3 | 115.5 | 162.8 | 214.2 | 266.2 | 316.0 | 359.3 | 397.4 | 413.8 |
| 74 | 35.8 | 49.9 | 57.2 | 62.3 | 84.1 | 125.0 | 184.7 | 239.0 | 280.4 | 322.4 | 354.1 | 372.7 |
| 75 | 18.8 | 38.5 | 48.1 | 63.2 | 77.2 | 89.6 | 123.0 | 164.6 | 195.4 | 223.6 | 250.4 | 253.8 |
| 76 | 30.2 | 36.7 | 44.9 | 46.7 | 51.4 | 68.7 | 105.8 | 168.7 | 238.6 | 293.6 | 339.6 | 368.1 |
| 77 | 40.9 | 60.8 | 74.4 | 82.0 | 90.1 | 113.5 | 153.9 | 207.4 | 268.6 | 318.2 | 357.1 | 382.4 |
| 78 | 25.1 | 35.2 | 44.9 | 55.5 | 72.1 | 111.7 | 171.0 | 233.1 | 292.4 | 327.9 | 368.2 | 392.3 |
| 79 | 41.6 | 61.2 | 81.6 | 94.8 | 125.0 | 153.4 | 193.7 | 242.7 | 297.5 | 340.3 | 373.0 | 383.0 |
| 80 | 41.9 | 86.5 | 103.9 | 107.1 | 121.4 | 141.9 | 185.4 | 243.1 | 307.6 | 360.8 | 410.8 | 430.4 |
| 81 | 37.7 | 69.6 | 84.8 | 94.4 | 119.2 | 166.0 | 217.8 | 284.8 | 351.7 | 410.4 | 451.9 | 467.8 |
| 82 | 18.4 | 26.6 | 34.0 | 39.6 | 61.9 | 90.4 | 147.0 | 214.8 | 299.6 | 368.8 | 419.3 | 444.1 |
| 83 | 42.7 | 79.9 | 100.8 | 109.1 | 132.1 | 175.4 | 259.6 | 318.8 | 366.6 | 408.2 | 449.3 | 462.9 |

Cumulative monthly statistics

| St | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mn | 34.1 | 56.0 | 69.5 | 78.0 | 97.8 | 128.9 | 178.6 | 234.8 | 291.9 | 339.1 | 378.9 | 396.6 |
| SD | 9.1 | 18.9 | 23.5 | 24.0 | 28.1 | 34.4 | 42.4 | 43.8 | 45.6 | 50.4 | 54.4 | 56.7 |
| CV | 26.7 | 33.7 | 33.7 | 30.8 | 28.7 | 26.7 | 23.8 | 18.7 | 15.6 | 14.8 | 14.4 | 14.3 |

Table HY3. Monthly percentages of catches of hard and soft blue crabs for the harvest years 1972-73 - 1983-84 and the monthly and annual mean percentages of catch, and their standard deviations x 100 (SD) and coefficients of variation, CV, (percent) for the Virginia portion of the Chesapeake Bay.

| | Monthly catches | | | | | | | | | | | | Annual Statistics | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yr | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Mean | SD | CV |
| 72 | 11.19 | 6.65 | 5.24 | 2.98 | 5.65 | 6.48 | 9.91 | 12.22 | 14.09 | 12.24 | 10.18 | 3.16 | 8.33 | 3.77 | 45.20 |
| 73 | 7.98 | 6.12 | 2.85 | 2.47 | 8.50 | 11.43 | 12.42 | 12.56 | 12.05 | 10.45 | 9.21 | 3.97 | 8.33 | 3.71 | 44.57 |
| 74 | 9.61 | 3.79 | 1.94 | 1.38 | 5.84 | 10.97 | 16.03 | 14.58 | 11.11 | 11.27 | 8.49 | 4.99 | 8.33 | 4.77 | 57.26 |
| 75 | 7.42 | 7.76 | 3.76 | 5.94 | 5.53 | 4.89 | 13.16 | 16.37 | 12.16 | 11.11 | 10.56 | 1.34 | 8.33 | 4.39 | 52.63 |
| 76 | 8.21 | 1.76 | 2.22 | 0.51 | 1.25 | 4.72 | 10.07 | 17.09 | 18.99 | 14.92 | 12.49 | 7.76 | 8.33 | 6.46 | 77.55 |
| 77 | 10.68 | 5.21 | 3.57 | 1.98 | 2.13 | 6.11 | 10.58 | 13.98 | 16.01 | 12.96 | 10.17 | 6.62 | 8.33 | 4.72 | 56.67 |
| 78 | 6.40 | 2.58 | 2.47 | 2.70 | 4.23 | 10.09 | 15.11 | 15.82 | 15.11 | 9.05 | 10.28 | 6.15 | 8.33 | 5.04 | 60.53 |
| 79 | 10.86 | 5.12 | 5.32 | 3.44 | 7.88 | 7.42 | 10.53 | 12.78 | 14.32 | 11.17 | 8.55 | 2.60 | 8.33 | 3.72 | 44.64 |
| 80 | 9.73 | 10.38 | 4.04 | 0.74 | 3.32 | 4.75 | 10.11 | 13.41 | 14.97 | 12.38 | 11.61 | 4.56 | 8.33 | 4.62 | 55.41 |
| 81 | 8.06 | 6.81 | 3.26 | 2.05 | 5.30 | 10.01 | 11.08 | 14.31 | 14.31 | 12.55 | 8.87 | 3.39 | 8.33 | 4.28 | 51.31 |
| 82 | 4.14 | 1.85 | 1.68 | 1.25 | 5.03 | 6.41 | 12.76 | 15.26 | 19.10 | 15.58 | 11.36 | 5.59 | 8.33 | 6.19 | 74.26 |
| 83 | 9.22 | 8.04 | 4.52 | 1.79 | 4.97 | 9.34 | 18.21 | 12.77 | 10.33 | 9.00 | 8.86 | 2.94 | 8.33 | 4.49 | 53.86 |

| | Monthly Statistics | | | | | | | | | | | | Grand Statistics | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| St | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Mean | SD | CV |
| Mn | 8.63 | 5.51 | 3.41 | 2.27 | 4.97 | 7.72 | 12.50 | 14.26 | 14.38 | 11.89 | 10.05 | 4.42 | 8.33 | 4.57 | 54.83 |
| SD | 2.04 | 2.66 | 1.23 | 1.45 | 2.08 | 2.51 | 2.70 | 1.60 | 2.77 | 2.02 | 1.30 | 1.87 | | | |
| CV | 23.65 | 48.30 | 36.03 | 64.00 | 41.93 | 32.58 | 21.62 | 11.24 | 19.29 | 16.96 | 12.95 | 42.33 | | | |

Table HY4. Cumulative monthly percentages of catches of hard and soft blue crabs for the harvest years 1972-73 - 1983-84 and the monthly mean cumulative percentage of catch and their standard deviations x 100 (SD) and coefficients of variation, CV, (percent) for the Virginia portion of the Chesapeake Bay.

Cumulative monthly percentages

| Yr | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72 | 11.19 | 17.84 | 23.09 | 26.07 | 31.72 | 38.21 | 48.12 | 60.34 | 74.43 | 86.66 | 96.84 | 100.00 |
| 73 | 7.98 | 14.10 | 16.94 | 19.41 | 27.91 | 39.34 | 51.76 | 64.32 | 76.37 | 86.82 | 96.03 | 100.00 |
| 74 | 9.61 | 13.40 | 15.34 | 16.72 | 22.56 | 33.53 | 49.56 | 64.14 | 75.25 | 86.52 | 95.01 | 100.00 |
| 75 | 7.42 | 15.18 | 18.94 | 24.88 | 30.41 | 35.30 | 48.46 | 64.83 | 76.99 | 88.10 | 98.66 | 100.00 |
| 76 | 8.21 | 9.98 | 12.19 | 12.70 | 13.95 | 18.67 | 28.74 | 45.84 | 64.83 | 79.76 | 92.24 | 100.00 |
| 77 | 10.68 | 15.90 | 19.47 | 21.44 | 23.57 | 29.68 | 40.26 | 54.24 | 70.25 | 83.22 | 93.38 | 100.00 |
| 78 | 6.40 | 8.98 | 11.45 | 14.15 | 18.38 | 28.47 | 43.58 | 59.41 | 74.52 | 83.57 | 93.85 | 100.00 |
| 79 | 10.86 | 15.99 | 21.31 | 24.75 | 32.64 | 40.06 | 50.59 | 63.37 | 77.69 | 88.85 | 97.40 | 100.00 |
| 80 | 9.73 | 20.11 | 24.15 | 24.89 | 28.21 | 32.96 | 43.07 | 56.48 | 71.45 | 83.83 | 95.44 | 100.00 |
| 81 | 8.06 | 14.87 | 18.13 | 20.18 | 25.48 | 35.49 | 46.57 | 60.88 | 75.18 | 87.73 | 96.61 | 100.00 |
| 82 | 4.14 | 5.98 | 7.66 | 8.91 | 13.95 | 20.35 | 33.11 | 48.37 | 67.47 | 83.05 | 94.41 | 100.00 |
| 83 | 9.22 | 17.26 | 21.78 | 23.57 | 28.55 | 37.89 | 56.09 | 68.87 | 79.20 | 88.20 | 97.06 | 100.00 |

Cumulative monthly statistics

| St | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mn | 8.63 | 14.13 | 17.54 | 19.81 | 24.78 | 32.50 | 44.99 | 59.26 | 73.64 | 85.53 | 95.58 | 100.00 |
| SD | 2.04 | 4.03 | 5.06 | 5.59 | 6.47 | 7.05 | 7.86 | 6.91 | 4.31 | 2.78 | 1.87 | 0.00 |
| CV | 23.65 | 28.49 | 28.83 | 28.20 | 26.09 | 21.70 | 17.46 | 11.66 | 5.85 | 3.25 | 1.96 | 0.00 |

**TABLES: Harvest Year Format**

Table HY4A. Mean date of Virginia's blue crab harvest, the coded mean date of harvest, and the variance and coefficient of variation in timing of harvest for the harvest years 1972-73 - 1983-84.

| Yr | Mean | Coded mean | Var | CV |
|---|---|---|---|---|
| 72 | May 27 | 6.855 | 11.275 | 49 |
| 73 | Jun 1 | 6.990 | 9.548 | 44 |
| 74 | Jun 6 | 7.184 | 9.362 | 43 |
| 75 | May 27 | 6.908 | 9.686 | 45 |
| 76 | Jul 3 | 8.129 | 8.832 | 37 |
| 77 | Jun 12 | 7.379 | 11.130 | 45 |
| 78 | Jun 18 | 7.572 | 8.289 | 30 |
| 79 | May 24 | 6.765 | 10.411 | 48 |
| 80 | June 3 | 7.097 | 11.825 | 49 |
| 81 | June 3 | 7.108 | 9.725 | 44 |
| 82 | Jul 3 | 8.126 | 6.863 | 32 |
| 83 | May 21 | 6.723 | 9.934 | 47 |

TABLES: Harvest Year Format

Table HY5. Forecast method evaluation summary. The mean absolute percentage deviation (MAPD) and its standard deviation (MAPDSD) for monthly estimates of total Virginia blue crab harvest by the forecast models, average cumulative proportion (ACP), Cochran's ratio (RAT), Cochran's censored ratio (CR), and Cochran's regression (REG), a standard two-parameter linear regression (LIN), and a one parameter linear regression (ADJ LIN), and the MAPD and MAPDSD for forecasts of each month's blue crab harvest by the ACP and LIN models for theVirginia portion of the Cheasapeake Bay for the four (4) harvest years beginning in December, 1979. The expected cumulative percent of harvest is shown in the column p(i,j).

Mean absolute percentage deviation

| | | Total annual catch forecasts | | | | | | Mon. fcst. | |
|---|---|---|---|---|---|---|---|---|---|
| Month | p(i,j) | ACP | RAT | CR | REG | LIN | ADJ LIN | ACP PF | LIN PF |
| Dec | 7.8 | 40.1 | 40.5 | 24.3 | | 19.6 | 42.0 | 42.0 | 45.0 |
| Jan | 13.2 | 50.4 | 50.7 | 17.4 | | 15.9 | 53.5 | 22.0 | 27.1 |
| Feb | 16.5 | 48.0 | 48.3 | 17.7 | 44.3 | 15.7 | 51.7 | 37.6 | 42.5 |
| Mar | 18.6 | 43.3 | 43.1 | 4.6 | 45.6 | 15.3 | 45.8 | 49.3 | 42.7 |
| Apr | 23.7 | 31.2 | 31.2 | 34.2 | 37.9 | 14.8 | 33.4 | 49.5 | 40.7 |
| May | 31.5 | 21.0 | 21.0 | 31.0 | 20.6 | 13.6 | 22.7 | 36.5 | 21.9 |
| Jun | 43.4 | 11.8 | 11.8 | 14.5 | 8.5 | 11.2 | 12.6 | 17.3 | 18.4 |
| June 12 | | | | | | | | | |
| Jul | 57.7 | 7.7 | 7.8 | 8.1 | 6.4 | 8.1 | 7.6 | 18.1 | 23.8 |
| Aug | 73.3 | 4.5 | 4.5 | 4.4 | 4.3 | 4.1 | 4.5 | 19.2 | 21.9 |
| Sep | 85.4 | 2.8 | 2.8 | 2.8 | 3.2 | 2.9 | 2.8 | 14.6 | 16.3 |
| Oct | 95.5 | 1.3 | 1.3 | 1.3 | 2.1 | 1.5 | 1.3 | 27.3 | 29.6 |
| Nov | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

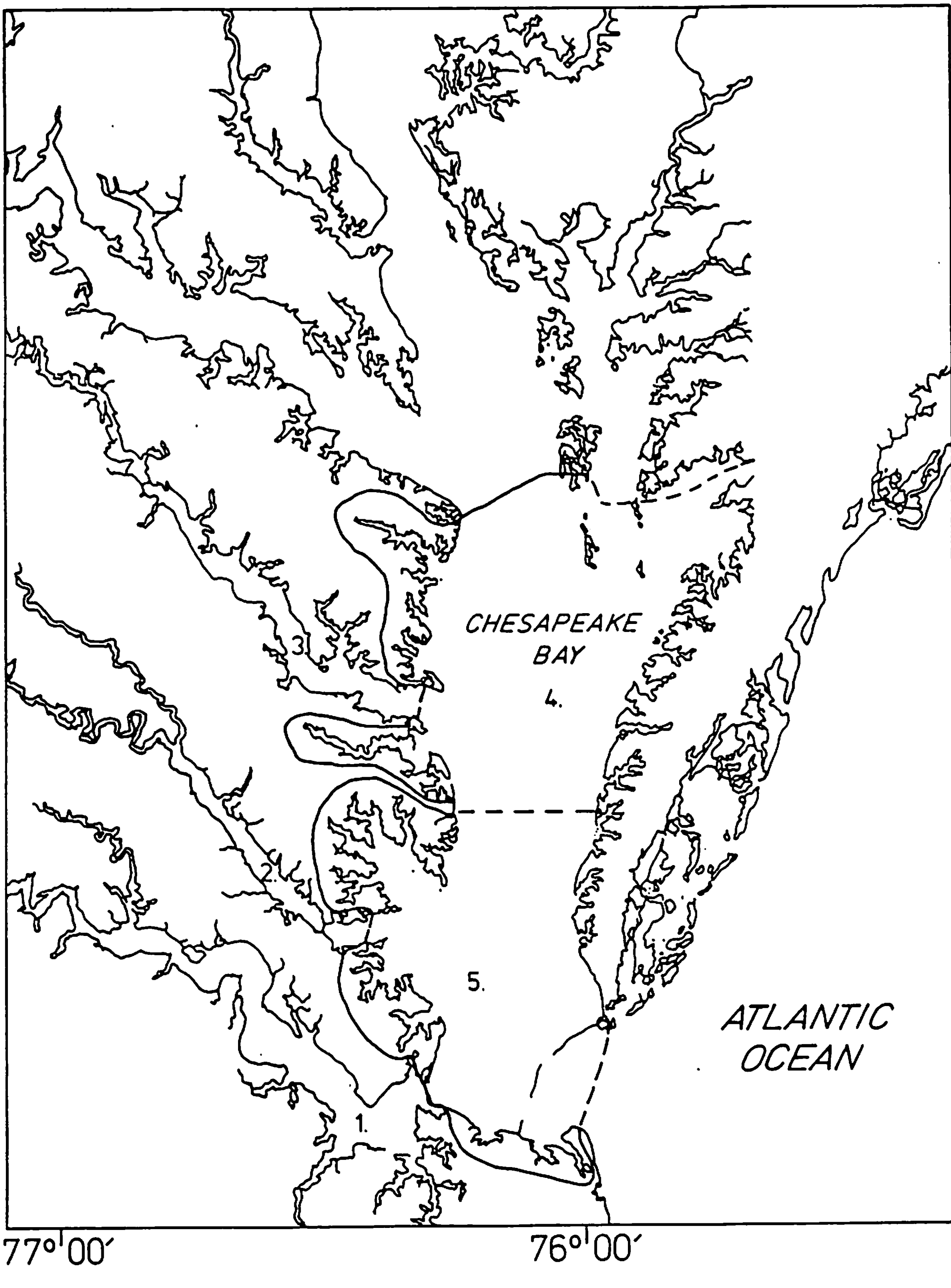
Standard deviation of mean absolute percentage deviation

| | | Total annual catch forecasts | | | | | | Mon. fcst. | |
|---|---|---|---|---|---|---|---|---|---|
| Month | p(i,j) | ACP | RAT | CR | REG | LIN | ADJ LIN | ACP PF | LIN PF |
| Dec | 2.7 | 45.6 | 46.0 | 24.0 | — | 14.7 | 49.4 | 32.6 | 44.1 |
| Jan | 5.7 | 57.0 | 57.4 | 22.1 | — | 15.7 | 63.2 | 13.3 | 17.9 |
| Feb | 6.8 | 53.0 | 53.2 | 21.2 | 51.4 | 13.5 | 58.4 | 32.2 | 22.7 |
| Mar | 7.0 | 50.7 | 50.3 | 1.0 | 52.4 | 12.2 | 54.6 | 49.0 | 30.0 |
| Apr | 7.5 | 32.0 | 31.6 | 37.5 | 40.3 | 9.4 | 35.4 | 21.7 | 24.0 |
| May | 7.5 | 24.7 | 24.9 | 25.9 | 25.9 | 9.6 | 26.9 | 24.4 | 15.3 |
| Jun | 6.5 | 14.2 | 14.2 | 18.0 | 9.4 | 8.4 | 15.0 | 17.7 | 9.3 |
| June 12 | | | | | | | | | |
| Jul | 5.8 | 8.7 | 8.6 | 8.7 | 6.0 | 7.4 | 9.2 | 25.8 | 19.3 |
| Aug | 3.9 | 3.0 | 3.0 | 3.4 | 2.5 | 3.8 | 3.1 | 16.3 | 15.2 |
| Sep | 2.7 | 1.0 | 1.1 | 1.4 | 1.4 | 1.0 | 1.1 | 6.8 | 8.3 |
| Oct | 1.5 | 0.8 | 0.8 | 1.0 | 1.2 | 0.8 | 0.8 | 17.3 | 15.1 |
| Nov | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Table HY6. The average mean absolute percent deviation for annual and one-month estimates of Virginia's blue crab harvest up to the grand mean date of catch (Month number 7.4; June 12, standard deviation 0.5477) and its standard deviation, and the same statistics for estimates made at the mean date of catch. The MAPD for the five year moving average estimate and the average annual catch and their standard deviations are presented for comparison.

| | Up to Mean Date | | At Mean Date | |
|---|---|---|---|---|
| | MAPD | S.D. | MAPD | S.D. |
| **Annual estimates** | | | | |
| Average Timing (ACP) | 32.26 | 34.69 | 8.85 | 8.88 |
| Ratio Estimator (RAT) | 32.37 | 34.72 | 8.90 | 8.72 |
| Censored Ratio (CR) | 19.86 | 20.78 | 10.51 | 9.41 |
| Regression Estimator (REG) | 27.85 | 30.10 | 6.89 | 6.40 |
| Linear Regression (LIN) | 14.52 | 10.88 | 9.70 | 7.41 |
| LIN Through Origin (ADJ LIN) | 34.20 | 38.07 | 8.50 | 9.31 |
| **Estimates of monthly catch** | | | | |
| ACP c'(i+1,j) - (ACP PF) | 35.75 | 14.50 | 20.03 | 25.95 |
| LIN c'(i+1,j) - (LIN PF) | 33.92 | 10.64 | 23.69 | 19.88 |

Average yield, 42,500,000 lbs.; standard deviation, 3,550,000
Five year moving average MAPD, 13.2566; standard deviation, 6.42788


CHESAPEAKE
BAY
ATLANTIC
OCEAN
1.
2.
3.
4.
5.
38°
00′
37°
00′
77° 00′
76° 00′