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An Examination of the Variability of Migratory Timing Statistics Estimated From Catch and Effort Observations

Arthur J. Butt
Old Dominion University

AN EXAMINATION OFTHE VARIABILITY OF MIGRATORY TIMING

STATISTICS ESTIMATED FROM CATCH AND EFFORT OBSERVATIONS

by

Arthur J. Butt
B.S. May 1971, University of West Florida at Pensacola
M.S. June 1974, University of West Florida at Pensacola

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Phillip R. Mundy (Director)

ABSTRACT

AN EXAMINATION OF THE VARIABILITY OF MIGRATORY TIMING STATISTICS ESTIMATED FROM CATCH AND EFFORT OBSERVATIONS

Arthur Jordan Butt
Old Dominion Universtiy
Director: Dr. Phillip R. Mundy

The estimate of the mean arrival time based on catch or CPUE of fishes migrating into a fixed harvest area is a function of the number of days fished. Simulation studies using chinook salmon catch and effort data from the Yukon River delta, Alaska indicate that fishing effort concentrated at the tails of the migratory distribution which would tend to erroneously weigh the estimated mean arrival time in the direction of the sample, away from the true mean, is only a significant problem when the number of days open to fishing is small, covering less than 12 % of the total duration of the migration. At sampling rates of the time domain greater than 12 %, estimated mean arrival times are usually within 50 % of the true mean.

The variance of the ratio estimator and the mean square error (biased MSE) for the ratio estimator both allow for the construction of confidence limits for an estimated arrival time based on commercial catch and CPUE data. Arrival time estimates for migrations with large variances and with fewer than 12 % of the time domain of the migration sampled have narrower 95 % confidence intervals than the same methods produced for arrival time estimates for migrations of small variances. The variance of the ratio estimator is more conservative with sampling rates below 12 %, however, it closely matches the biased MSE when sampling greater than 12 % of the time domain of the migration. Once about a quarter of the migratory time span is fished, the confidence interval is greatly reduced. This is particularly true for migrations of small variance where the proportions of the population sampled tend to be quite concentrated about the central mass of the time distribution

of abundance.

Sampling from the average empirical proportion of catch yields a narrower confidence interval on the mean arrival time than does sampling from CPUE data. However, samples from annual daily proportions of CPUE with broader variances yield stronger confidence in arrival time estimates than do samples from migrations of average to small variances. There appears to be little distinction between the annual mean arrival time estimates based on both catch and CPUE observations when sampling 12.5 - 30.5 % of the migration for early migrations. However, once 30 % or more of the migration is fished, daily proportions of catch offer more confidence for annual arrival time estimates.

The higher order distributional parameters which estimate the variance, skewness and kurtosis may be too volatile to adequately describe the migratory distribution based solely on commercial catch data. Estimates of skewness and kurtosis are extremely difficult to estimate within the context of the data examined

This is dedicated to my teacher,

Maharishi Mahesh Yogi

and to his teacher, Guru Dev.

KNOWLEDGE IS STRUCTURED IN CONSCIOUSNESS
Rig Veda

JAI GURU DEV

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CHAPTER 1

INTRODUCTION

The fisheries literature abounds with examples of uses for quantitative analyses of migratory timing (Royce 1965; Preston 1966; Mathisen and Berg 1968; Rothschild and Balsiger 1971; Lord 1973; Roberson and Fridgen 1974; Walters and Buckingham 1975; Mobrand 1977; Mundy 1979, 1982; Mundy and Mathisen 1981). Such abundance is not surprising since the study of migrations and its consequent knowledge of the arrival time of the migration are essential to the harvest control operations of many fisheries. However, given the present literature and the current needs, bounded estimates of the migratory timing statistics of individual years have not been constructed.

Mundy (1979, 1982, 1984) has characterized migrations by the mean and variance of the arrival times of the individuals, but he offered no confidence intervals for the estimates of an individual year. Leggett (1977) warned that catch data, "frequently provide more information on the distribution of fishing effort than on the distribution of fish and thus requires great care in interpretation."

Interpretation of migratory timing information is limited by the inability to make quantitive statements regarding the accuracy of statistical parameters based on commercial catch data. Fisheries do not sample at random with respect to the timing of a migration, so we do not have simple random samples of the migratory event; however, simulation studies employing random sampling should yield useful information concerning estimates of statistics of arrival timing with associated confidence intervals for practical purposes.

Migratory timing, or the arrival time of stocks into the harvest area, has been used to segregate stocks in many systems including the salmonids of the Yukon River (Buklis 1981). Migratory behavior is conserved across generations; therefore, the stocks migrate on a predictable schedule of movement which is genetically transmitted (Killick 1955; Hoar 1976; Mundy 1982, 1984). When the migratory timing is associated with a specified time interval measured from a fixed geographic time frame, that proportion of the population within the time interval defines its probability of occurrence. The proportion of the migration as a function of time is a probability density function, the time density (Mundy 1979).

Information on timing is equated to catch data taken over discrete time intervals from a fixed spatial reference point or within a fixed geographic reference frame. However, catch data, even when proportional to total abundance, does not necessarily represent the entire duration or domain of the migratory event. Therefore, an empirical probability density function and its descriptive parameters are employed to estimate the true behavior of the population. The time density has descriptive statistics such as the first four moments about the mean that aid in describing the probability density function. It is recognized that estimation of the statistics of skewness and kurtosis may be difficult, if not impossible, given the fragmentary nature of fisheries data.

Estimates of the descriptive parameters of migration are derived from a set of historical catch data which constitutes a sample across the time density. In commercial fisheries where millions of dollars are made or lost on regulatory decisions in any one day, such quantitative measures must be made for the fishery, and related industries, to maximize profits and to insure conservation. It is the goal of fisheries management to arrange the maximum sustainable benefit to the harvester (i.e. to insure profit to the fishery by maximizing catch) and to maintain the levels of exploitable stock to reproducible levels, since success in biological terms is measured by the ability of the species to have grandchildren.

As fisheries mature, fewer days are fished in each subsequent year due to the increased efficiency of harvest operations. The result is censorship and truncation of our knowledge of the time distribution of abundance. Consequently, less information is available for adequate estimates of migratory timing and abundance estimation. Both factors, timing and abundance, are important to the survival of the private fishing industry, for few benefit from abundance estimates once the population has migrated past the fishery without harvest.

The central question is, " With what assuredness can managers employ migratory timing parameters based on commercial catch data ?" In order to answer the question, a knowledge of the error of estimation as a function of the number of sampling days (days fished) must be approached. There are a finite number of ways of estimating the migratory timing based on the number of days fished from a distribution of a known duration. Fewer days fished yield larger numbers of potentially inaccurate migratory timing estimates. Therefore, the ability of the estimators to accurately characterize the true migratory behavior of the population should decline as the number of days open to fishing declines.

The objective is to estimate the timing behavior of a population by means of the migratory time density and its associated descriptive parameters. The purpose of this research is to address the problems of the adequacy of these estimators of migratory behavior through computerized sampling of actual and hypothetical migratory time densities.

CHAPTER 2

ESTIMATION OF MIGRATORY BEHAVIOR

The migration of most animals is a movement to and from their breeding grounds. This movement reflects some spatial displacement by the individual or population relative to some other object and the change occurs over some specified time interval (Baker 1978). Therefore, it is most advantageous to establish a fixed geographic reference frame. In catadromous and anadromous fishes migratory behavior of one or more species can be studied from tactically advantageous locations where the route of migration passes through waters adjacent to land. Fisheries such as those for adult salmon, striped bass and American eels are often located within rivers and/or estuaries, allowing for such studies. Among teleostean fishes, breeding is usually an annual event, and in the mathematical sense of recurring at regular intervals, the length of period is generally one year.

Population sizes rarely remain stationary during any given year, particulary where recruits and harvests are known to vary from year to year. Comparisons of total abundance from year to year is not useful for populations which demonstrate large variations in annual abundance. Proportions of total abundance as a function of time, the time density, are often more stable than the time series of abundance. The concept of quantifying migration in terms of its time density is developed by Mundy (1979, 1982). The migration of a species may be solely dimensioned with respect to time which does not, however, imply that time regulates or determines the migration. Time is a conveniently measured covariate of variables which do influence the migration.

Estimates of the time of arrival of members of a migration over time are biological parameters indispensible to management purposes (Vaughan 1954). When the probability assigned to each time interval (i.e. day) of the migration is the proportion of the total population arriving on that given time interval, the mean and variance of the time density distribution are defined by standard statistical procedures. Simulation procedures that estimate migratory behavior from a random sample of time intervals from a known distribution may allow probability statements concerning the range of values assumed by the descriptive parameters. In particular, the performance of two of the moments of the time density, namely the mean and variance, can be viewed for reliability by such methods.

Migratory time densities have been defined for populations of commercial species of fishes and crustaceans (Mundy 1979, 1982; Mundy and Mathisen, 1981; Babcock and Mundy in press; and others). The time density model provides a mathematical description of migratory timing which establishes an objective basis for comparison of migratory behavior between years and species. Expressing abundance as a function of time is potentially conceptually misleading (Mundy 1979). Migratory behavior is dependent upon endogenous factors which in turn are mediated by exogenous ones (Banks 1969; Leggett 1977). Therefore, abundance and time of migratory behavior are related by the characteristic time density of the population as mentioned above.

Migratory timing is a dynamic annual event which may be objectively categorized into various discrete groupings such as "early", "average" or "late" migrations based upon the grand mean and its sampling distribution for all years of catch data as was done with chinook salmon (~~Onchorhynchus tshawytscha~~) from the Yukon River delta (Mundy 1982). Among the species studied, a migration is characterized as "slow" or "fast", and the resultant dispersion of the migration through time, as measured by the variance, may be correspondingly broad or narrow.

The migratory behavior of salmon for any given year is composed of the behavior of numerous geographic isolates, each having a characteristic migratory timing (Killick 1955). Each year an annual target level of catch is sought for that migratory run. In order to avoid harvesting any one stock disproportionately, and to insure survival of a spawning escapement from each time segment, the number of fishing days is often restricted. Therefore, the optimun strategy is to spread the catch proportionately across all time segements of the migration.

Each year maturing chinook salmon migrate through the waters of the Yukon River delta from the end of May to the first of September. Although the vast majority of migration (2.5 - 97.5 %) occurs over on an average of 29 days, the central half of the population (25 - 75 %) pass through the harvest area within a much narrower window of time. The central 50% of an early migration is expected to cover 13 days, while in a very fast, or late migration, the central 50% may occupy only 8 days (Mundy 1982). As a result, the estimates of abundance, migratory timing and harvest timing become very crucial to the decision making process and the need for precision information in harvest control during temporally compressed migrations is heightened.

To establish a forecasting tool, a model of the daily or cumulative proportions of total abundance is prepared by averaging past years' proportions over each day of the migration (Walters and Buckingham 1975; Hornberger et al. 1979; Mundy 1979). Both daily and total catch from observed cumulative catch can then be compared to this historical performance to estimate total abundance or yield throughout the season providing management with a dynamic method of interseason estimates. Such estimates can be wildly inaccurate when shifts in timing go undetected (Barth 1984).

As the fishing season progresses the current cumulative catch is compared to the historical performance contained in the average cumulative time density. As long as the harvest level at a given date is consistent with the established guidelines, the harvest will continue. A cumulative catch which amasses a rate which is over or below the target level means a re-adjustment of the number of open fishing days (openers).

The classic dilemma for managers is to distinguish between fluctuations in abundance and shifts in timing. Are the catches to date smaller than average due to a small migration, or is the migration late? Is the migration more abundant than average, or did the migration start early ? (Mundy 1979).

A study of sampling problems with respect to migratory behavior and fixed geographic areas should improve the understanding and utility of predictive methods employing estimators based on migratory time densities. It will contribute toward answering the question of whether variation observed in timing is due to sampling error or due to real fluctuations in the timing of the migration.

Simulation procedures which estimate migratory behavior from a sample of fixed distribution with respect to some family of distributions should defeat the analytical problems posed by our inability to control the "sampling" of migrations by commercial fisheries. Such sampling is not random with respect to the migration. Harvesters have historically concentrated fishing operations in the center of each migration while regulators permit harvests at regularly fixed intervals on this central span of the migration. By sampling a variable fraction of a known distribution at intervals which approximate the behavior of a commercial fishery, the limits to the accuracy of migratory timing statistics can be understood.

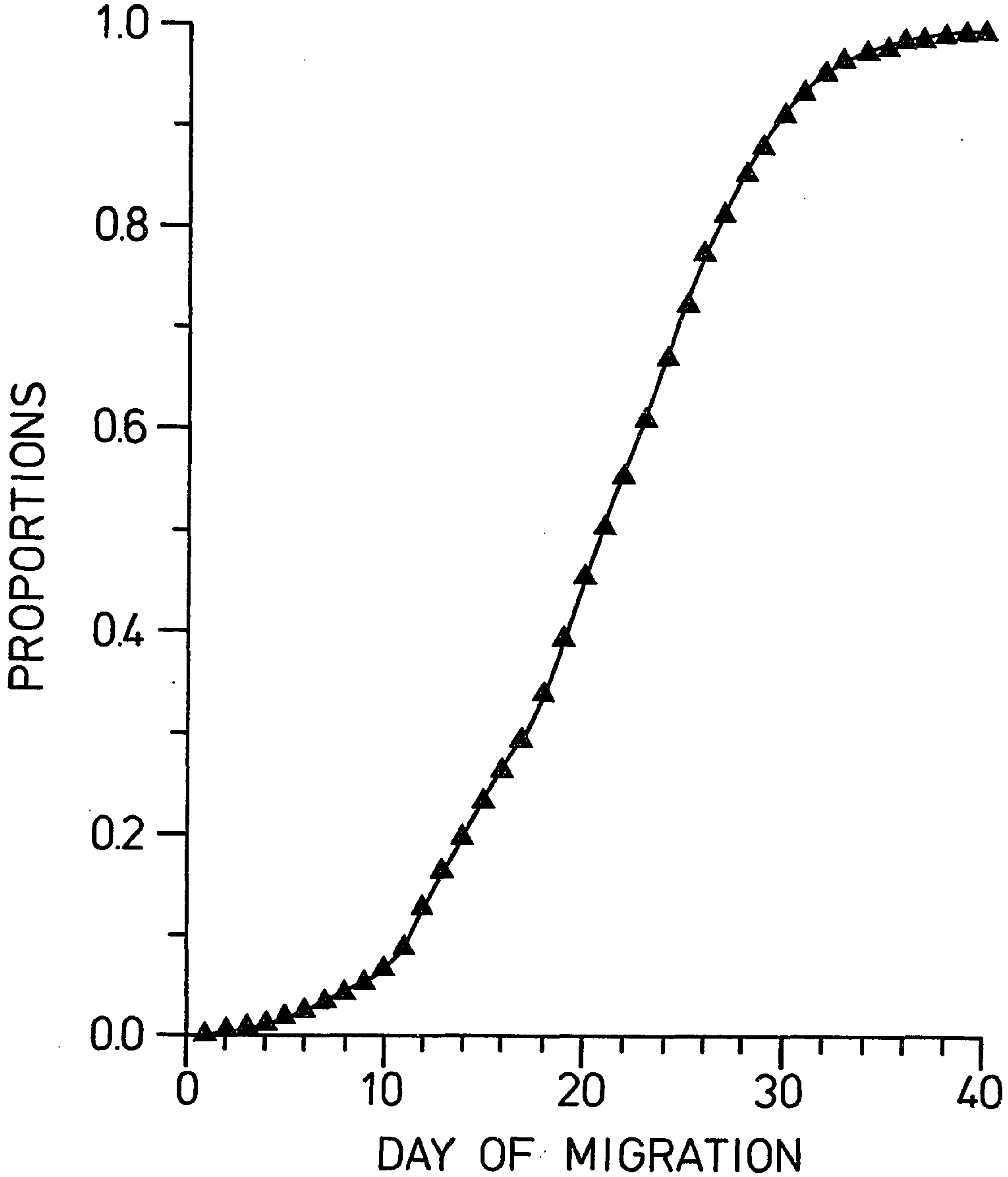
CHAPTER 3

METHODS

Data which can be used to validate the simulation study are available in the form of daily catch data records of chinook salmon from the Yukon Area Annual Management Report (AMR), Alaskan Department of Fish and Game where records of commercial catch by date are available since 1961. The cumulative time density (CTD) (i.e. the time series which is the sum of the proportions for a time density) yields a sigmoidal curve reminiscent of the family of symmetric cumulative probability density functions such as the logistic model (Fig. 1). The normal probability density function (PDF) is used to quantify the time density (assuming a homogenous population or subpopulation of chinook salmon) (Fig. 2).

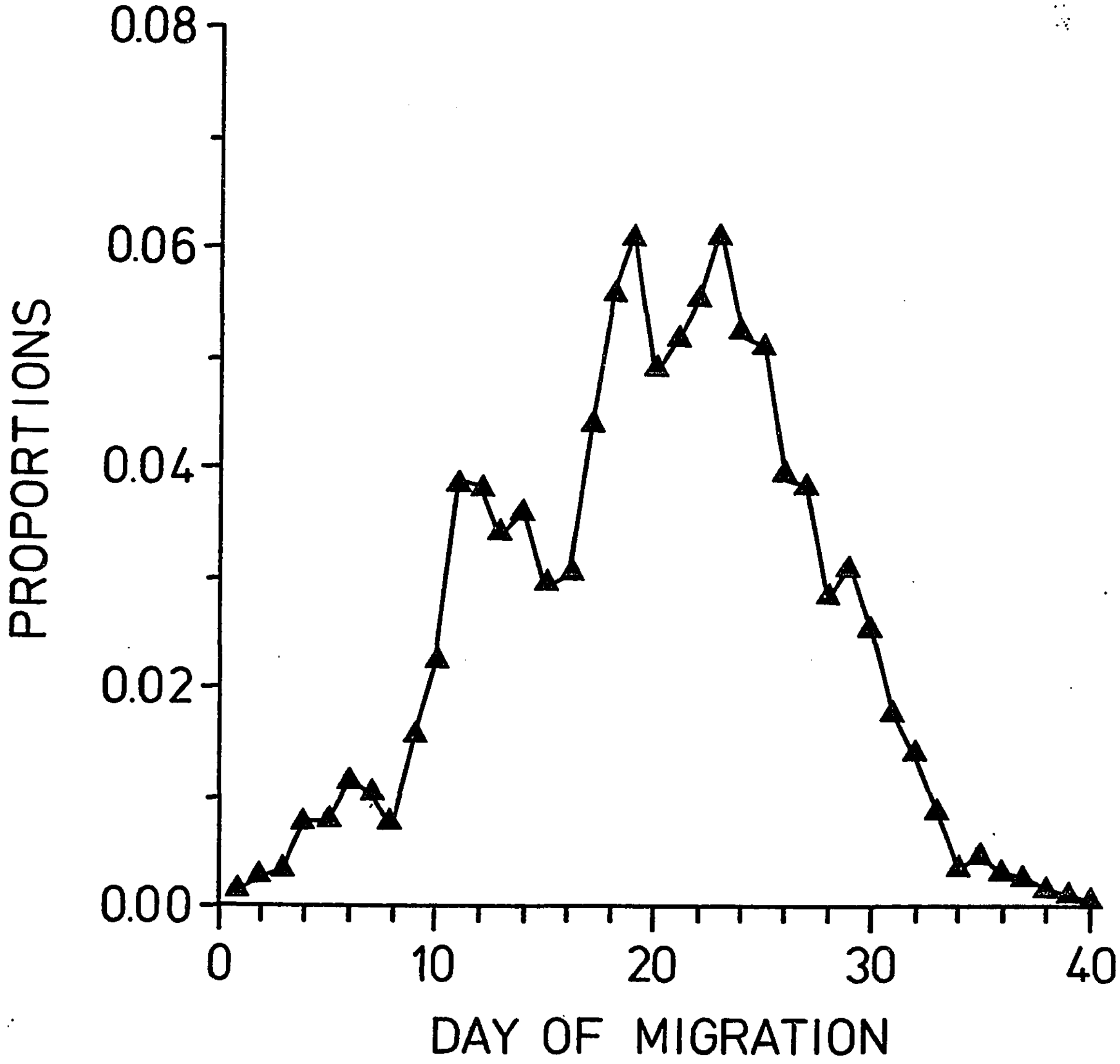
Arrival time in the time density model is a discrete random variable. The model prescribes the probability of realizing a single time of arrival within a given migration. To simulate a migratory sequence a simple random sampling procedure is sought. The sampling must be without replacement because a day of the migration can not be repeated. The population or subpopulation to be sampled is assigned integers ($t = 1, 2, \cdots m$) in an array. The problem of taking a random sample becomes a problem of generating j random integers between 1 and m. Each of the j integers must be unique; no two must have the same

Figure 1. The average cumulative proportion of total catch as a function of time (days) for chinook salmon in June and July, 1961-1980 (after Mundy 1982).



1.0
0.8
0.6
0.4
0.2
0.0
PROPORTIONS
0
10
20
30
40
DAY OF MIGRATION

Figure 2. The average of the daily proportion of catch for chinook salmon in June and July, 1961-1980 (after Mundy 1982).


0.08
0.06
0.04
0.02
0.00
PROPORTIONS
0
10
20
30
40
DAY OF MIGRATION

value. A simple Monte Carlo method is employed to choose integers between 1 and m. A nonsequential procedure is employed to allow for more flexibility of the selection process with a small sample size, or where the total migration occurs over a discrete time interval. This is accomplished by generating a number U_k from Uniform (0,1) and taking $[U_k \cdot m] + 1$ (Kennedy and Gentle 1980). Each new number is then checked for uniqueness against those values already selected. In this way the j days of the migration were randomly selected for sampling without replacement.

The question of randomness of the number generating process is moot according to Lehmer (1951) and Martin-Löf (1969). Although the number selection is not completly random, numbers generated are created from a random number seed. For this purpose I adopt the attitude of Lehmer (1951) toward random sequences "a vague notion embodying the idea of a sequence in which each term is unpredictable to the uninitiated and whose digits pass a certain number of tests traditional with statisticians and depending some what on the use to which the sequence is to be put."

Time Density and The Ratio Estimator

The time density is the time series of proportions produced from the time series of abundances per unit time divided by total abundance for the year. Therefore, the time density is the relative abundance of a migrating population as a function of time. The migratory behavior is such that the probability of occurrence of any given arrival time is dependent upon the location of that arrival time relative to the central day of migration (mean) which is determined by the dispersion of the migration through time (variance). The empirical time density for the time series of daily proportions (P_t) is calculated as follows:

$$P_t = n_t / N \qquad (1)$$

where

n_t = abundance, catch, or CPUE on time interval t,

N = total annual abundance, catch, or CPUE

Catch data, even when proportional to total abundance, cannot represent the entire duration or domain of the migratory event unless fishing is continuous throughout the migration. The annual mean ($\bar{t}$) of the catch occuring over a time span of m days is the sum of the products of the daily proportions during each discrete interval (P_t) and the time interval (t). The variance of the catch is represented by S_t^2.

$$g_t = t \cdot P_t \qquad (2)$$

$$\bar{t} = \sum_{t=1}^{m} g_t \qquad (3)$$

$$S_t^2 = \sum_{t=1}^{m} (t - \bar{t})^2 P_t \qquad (4)$$

The square root of S_t^2, S_t, is called the standard deviation.

The grand mean for all years of catch data is the average of all the $\bar{t}$. The result is a historical performance curve (Fig. 2). Since the migratory behavior is conserved across generations, the migratory timing is objectively divided into early, average, or late categories based on a 95% confidence interval about the grand mean for all years (Mundy 1982).

Previous salmon migration studies indicate that average proportions over day of run is the optimal stragetgy to pursue for more accurate estimates of migratory behavior (Hornberger et al. 1979; Hornberger and Mathisen 1980, 1981; Brannian 1982). However, average daily proportionate data does not sum to unity, so it cannot fulfill that requisite property of the PDF. In order to retrieve the daily proportions (P_t) differencing of the average cumulative distribution is employed:

$$P_t = [\ Y(t+1) - Y(t)\ ] \tag{5}$$

where

$Y(t)$ = average cumulative proportion on day t, and

$Y(t+1)$ = average cumulative proportion on day t+1

The derived daily proportions in the test are referred to as the empirical average distribution.

For any given year migratory timing is usually viewed with regard to commercial catch data, which is analogous to censored sampling of the entire migraton. The problem of censored sampling can be approached by sampling a known distribution (PDF) in order to examin the behavior of the estimates of the statistics of the time densities.

These estimates must be scaled to reflect the fact that the sample includes only a fraction of the PDF, and are referred to as ratio estimators. If t_i, ···, t_j denotes a sequence of randomly selected dates (days) of the migration, not necessarily incremented by one, 1, 2, 3 ··· ; and the t_i are randomly selected integer numbers such that $1 \leq t_i \leq m$, where m is the actual duration of the migration. The estimated mean and variance for a random sample of j many time intervals are as follows;

$$\bar{t}_j = \sum_{i=1}^{j} t_i H_i \qquad (6)$$

$$S_j^2 = \sum_{i=1}^{j} (t_i - \bar{t}_j)^2 H_i \qquad (7)$$

where:

$$H_i = [P_{t_i} / \sum_{i=1}^{j} P_{t_i}] \qquad (7A)$$

The P_{t_i} may be drawn from a known distribution, empirical or theoretical, because sampling from a time density or sampling actual numerical migratory timing is computationally the same.

Since it is assumed that catch is proportional to total abundance, there is no difference between the time series of catch and the time series of total abundance when converted to proportions. Similarly, there is no difference between the time series of proportions, H_i, derived from sampling the time density and that time series of proportions which would have been derived from catches. The time series of catches, C_t, is the product of the instantaneous fishing mortality, the daily proportions, and the total annual abundance.

$$C_t = F\,[\,N \cdot P_t]$$

since F and N are constant let $F \cdot N = k$;

$$C_t = k \cdot P_t$$

the daily proportion is: $k\,P_t \,/\, \sum k\,P_t = H_t$

See Equation 7A above. Note that the first of the j elements, i = 1, is not necessarily the first time interval of the empirical PDF.

Moments

The first four moments play an important role in fitting empirical distributions and approximating the distributions of a random variable (Hahn and Shapiro 1967). They can be used to measure how much an observed frequency distribution (i.e. a continuous probability distribution) departs from normality by describing the spread, symmetry (or asymmetry) and peakedness of the distribution. The normal probability density function is used to quantify the time density of a hypothetically homogeneous population of chinook salmon. A brief discussion of the first and second moments (i.e. the mean and variance, respectively) is outlined above. The third moment about the mean,

$$u_3 = \sum_{t=1}^{m} (t - \bar{t})^3 \; P_t \tag{8}$$

is divided by the cube of the standard deviation to yield a_3 a measure of skewness. It describes the symmetry of the frequency distribution.

$$a_3 = u_3 \,/\, S^3 \tag{8A}$$

The fourth moment about the mean,

$$u_4 = \sum_{t=1}^{m} (t - \bar{t})^4 \; P_t \tag{9}$$

is divided by S^4 to describe the peakedness or kurtosis of the frequency distribution.

$$a_4 = u_4 \,/\, S^4 \tag{9A}$$

In conjunction with the variance, the third and forth moments provide information about the stability of the shape of the time density. For example if $a_3 < 0$, the unimodal (i.e. a single peaked) time density distribution attenuates to the left, and it is designated negatively skewed. Attenuation to the right is positively skewed ($a_3 > 0$) and for symmetric distributions $a_3 = 0$. A normal distribution has a kurtosis of 3; therefore, $a_4 > 3$ appears sharply peaked and is termed leptokurtic. A leptokurtic time density is indicative of a fast migration where the migration is concentrated on a few time intervals. In a much slower (or "early") migration the distribution is platykurtic, or flat in appearance ($a_4 < 3$).

Variance Estimates

The objective of survey sampling is to draw inferences about a population based on information contained in a subsample or component part of the population. In order to make such inferences, estimates are made for certain population parameters utilizing the subsample data collected. The basic assumption is that the commercial catch is randomly sampled over the complete duration of the migratory event, thus making it analogous to a survey sampling technique. The statistics sought most frequently for population estimates are the population mean and variance (Equations 3 and 4, respectively) (Mendenhal, Ott and Schaeffer 1971).

It is desirable for the estimated mean, $\cdot\bar{t}_j$, to be equal to the true population parameter, $\bar{t}$:

$$E(\cdot\bar{t}_j) = \bar{t} \qquad (10)$$

If such a condition exists, the estimate is unbiased. Otherwise, it is said to be biased. It is advantageous for a biased estimator to have expected value at least close to the parameter ($\bar{t}$), and as small a variance as possible. With a random sample of a fixed sample size (j), a minimal difference between the value of the estimate and the parameter is sought. The statistic $\cdot\bar{t}_j$ that minimizes $E[(\cdot\bar{t}_j - \bar{t})^2]$ is the one with the minimum mean square error (MSE):

$$MSE = \sum_{j=1}^{m} \frac{\sum_{b=1}^{c} (\cdot\bar{t}_{b_j} - \bar{t})^2}{c} \qquad (11)$$

where c is the number of times $\cdot\bar{t}_j$ is calculated (i.e. b = 1, 2, ··· c). The MSE is given by:

$$MSE = Variance + (Bias)^2 \qquad (12)$$

The bias is calculated as:

$$bias = \sum_{j=1}^{m} \frac{\sum_{b=1}^{c} \bar{t}_{b_j} - \bar{t}}{c} \qquad (13)$$

If the bias is relatively small and the MSE approximates the variance (Equation 20), an approxiate 95% confidence interval for the average arrival time can be calculated as,

$$\bar{t} \pm 2 \, [\, MSE \,]^{1/2} \qquad (14)$$

The sample variance of the finite population ($t \cdot P_t = g_t$) is defined as:

$$S_g^2 = \sum_{t=1}^{m} (g_t - \bar{G})^2 \quad / \ (m - 1) \tag{15}$$

where

$$\bar{G} = \frac{\bar{t}}{m}$$

There are a finite number of ways of estimating $\bar{t}$ based on j many samples of the distribution. From a sample of 39 out of a possible 40 dates, there are 40 ways of calculating the estimate, $\cdot\bar{t}_j$; there are 780 ways of estimating $\bar{t}$ from a sample of 38 dates, and as the number of dates sampled decreases, the number of possible combinations increases. The number of distinct subsets or possible combinations of j elements from a set of m elements is described by the basic combinatorial theorem, ${}_mC_j$, where:

$${}_mC_j = \frac{m!}{(m-j)!\ j!} = \binom{m}{j} \tag{16}$$

The variance of the mean $\bar{g}$ from a simple random sample is taken over all ${}_mC_j$ samples, as follows;

$$V(\bar{g}) = E\ (\bar{g} - \bar{G})^2 = \frac{S_g^2}{j}\ (1-f) \qquad (17)$$

The variance, S_g^2, is calcualted from Equation 15, and f is the sampling fraction (j/m). For a random sample of size j, from a finite population, the finite population correcton equation (1-f) is used.

Frequently, the quantity that is estimated from a simple random sample is the ratio of two variables both of which vary from unit to unit. The population parameter to be estimated is the ratio;

$$\bar{t} = \frac{\sum_{t=1}^{m} g_t}{\sum_{t=1}^{m} P_t} \qquad (18)$$

The corresponding sample estimate (ratio estimator) is:

$$\cdot\bar{t}_j = \frac{\bar{g}}{\bar{P}} = \frac{\sum_{i=1}^{j} g_i}{\sum_{i=1}^{j} P_i} \qquad (19)$$

from equations 3 and 6, respectively.

According to Cochran (1977), if there is a correlation between g_t and P_t, the ratio estimator ($\cdot\bar{t}_j$) allows for increased precision of the estimator from a randomly selected sample by taking advantage of the correlation. Since $\bar{g}$ and $\bar{P}$ vary from sample to sample, the sampling distribution of $\cdot\bar{t}_j$ is more complicated than that of $\bar{g}$. In small samples the distribution of $\cdot\bar{t}_j$ may be skewed, and it is usually a biased estimate of $\bar{t}$. In large samples $\cdot\bar{t}_j$ tends towards normality and bias becomes negligible.

The question remains, "How confident are we in the estimates of $\bar{t}$?" In this particular case, the subsample is the commercial catch data and it is randomly sampled. The known distribution is the annual catch data as described above. The variance of the ratio estimator, $V(\cdot\bar{t}_j)$, and the confidence limits of the estimated mean of the subsampled catch data $(\cdot\bar{t}_j)$ are calculated as follows from Cochran (1977):

$$V(\cdot\bar{t}_j) = \frac{1 - f}{j \cdot \bar{X}^2} \sum_{t=1}^{m} \frac{(g_t - R \cdot x_t)^2}{m - 1} \qquad (20)$$

where

$$f = j/m$$

$$R = \bar{t}$$

$$x_t = P_t$$

$$\bar{X}^2 = [\sum_{t=1}^{m} P_t \; / \; m]^2$$

Note that the cumulative sum of $P_t = 1$ where $t = 1, 2 \cdots m$ because sampling is made from the historical distribution of a known duration, m. Therefore, the value $\bar{X}^2$ equals the ratio of one divided by the square of the duration of the migratory event $(1/m)^2$.

The variance of the ratio estimate above can be simplified to yield:

$$V(\cdot\bar{t}_j) = \frac{m(m-j)}{j} \sum_{t=1}^{m} \frac{P_t^2 \, (t - \bar{t})^2}{m - 1} \tag{21}$$

The above equation is composed of the product of two basic quantities. One is a function of the ratio of the number of days in the migration (m) time the difference between m and the subsample size j, (m-j), all divided by the subsample size j. The second is the sum of the products of the daily proportion (P_t) and the sample estimate of the variance of the total catch variance (Equation 4) all divided by the total number of days in the migration (m) minus 1.

The approximate 95% confidence limits (or error bounds) for the estimated subsample mean (Equation 6) is:

$$\cdot\bar{t}_j \pm 2 \, [\, V(\cdot\bar{t}_j) \,]^{1/2} \tag{22}$$

Normal Distribution

A family of distributions calculated from the normal probability density function, $N(t, \mu, \sigma^2)$ is used to study confidence limits associated with time density estimates.

$$P_t = \frac{1}{\sigma \, (2 \cdot \pi)^{1/2}} \, e^{-(t-\mu)^2 / 2\sigma^2} \qquad -\infty < t < \infty \tag{23}$$

The dependent variable, P_t, of the curve for any given value of the time variable (i.e. day) is the density. Density refers to the relative concentration or frequency of the variate along the Y-axis (refer to Fig. 2). In this expression density is a function of the variable m, as defined earlier. The remainder of the equation is composed of two constants and two parameters. The constants are π, and e, the base of natural logrithms. The parameters in the normal probability function are the mean, μ, and standard deviation, σ. They determine the location and shape of the distribution. A biologically realistic range of parameter values is used to simulate the time densities of Pacific salmon.

CHAPTER 4

RESULTS

The following is a description of results of estimates based on samples from daily proportions of empirical catch data, a family of distributions, $(N(t,\mu,\sigma^2))$, and empirical CPUE data. The studies are divided into three general categories. The first section deals with results pertaining to the historical performance data for chinook salmon of the Yukon River delta, the empirical probability density function. Section two contains the results based on estimates made by sampling distributions generated by variation of the parameters of the normal curve (Equation 23). Section three deals specifically with placing a confidence interval on estimates of the mean dates of migration for Yukon River chinook, 1961-1980 by reference to the annual empirical time densities. The methods employed on each distribution (average empirical, normal, and annual empirical) are the same.

Statistics Based on Empirical Average Migratory Time Densities for Chinook Salmon

A random sample of days (j) is taken from a population whose distribution is established from historical catches by differencing the average cumulative proportion of chinook catch for the Yukon River, 1961-1980 (Mundy 1982, Table 1, column Average). Both the population mean and variance are known, as well as the duration of the migration (m = 40) (Table 1). An example of a sample is presented to compare estimated values of statistics of migratory behavior (Table 2). In this particular sample series eleven days (j = 11) constitutes the total information available for the estimation of the statistics of migration for the "migratory year". As seen in Table 2, the sample contains only 28% of the actual total migration for the year sampled. All other figures and tables reflect this basic format where $j = 1, 2 \cdots m$, and m is the total number of days during which the migration is in the area of the fishery. The estimates of the mean, variance, skewness and kurtosis for a single sample representing each of the possible number of days sampled ($j = 1, 2 \cdots 40$) is presented in Table 3 for comparison.

The estimated mean date of migration as a function of the number of migratory days randomly sampled roughly resembles a sine function (Fig. 3). The function has a horizontal shift of π units dependent on the numbers of days randomly sampled. When j is small and the days selected are at the tails of the frequency distribution, the mean of the sample

Table 1. The empirical average distribution for catches of chinook salmon from the Yukon delta (1961-1980) with a mean = 19.98, variance = 48.32, skewness = -0.1468 and kurtosis = 2.599 (after Mundy 1982).

mig day	daily proportion	cumulative proportion
1	.00130	.00130
2	.00250	.00380
3	.00300	.00680
4	.00770	.01450
5	.00750	.02200
6	.01140	.03340
7	.01020	.04360
8	.00720	.05080
9	.01550	.06630
10	.02230	.08860
11	.03870	.12730
12	.03810	.16540
13	.03360	.19900
14	.03610	.23510
15	.02890	.26400
16	.03010	.29410
17	.04370	.33780
18	.05570	.39350
19	.06150	.45500
20	.04820	.50320
21	.05130	.55450
22	.05530	.60980
23	.06150	.67130
24	.05180	.72310
25	.05100	.77410
26	.03890	.81300
27	.03840	.85140
28	.02770	.87910
29	.03110	.91020
30	.02520	.93540
31	.01750	.95290
32	.01370	.96660
33	.00840	.97500
34	.00320	.97820
35	.00470	.98290
36	.00300	.98590
37	.00250	.98840
38	.00130	.98970
39	.00090	.99060
40	.00030	.99090

Table 2. Eleven days (j = 11) randomly sampled from the empirical average distribution of chinook salmon from the Yukon delta, 1961-1980, and the statistics of the sample.

day sampled	daily proportion	cumulative proportion
7	.01020	.01020
11	.03870	.04890
13	.03360	.08250
14	.03610	.11860
16	.03010	.14870
24	.05180	.20050
25	.05100	.25150
30	.02520	.27670
36	.00300	.27970
38	.00130	.28100
40	.00030	.28130

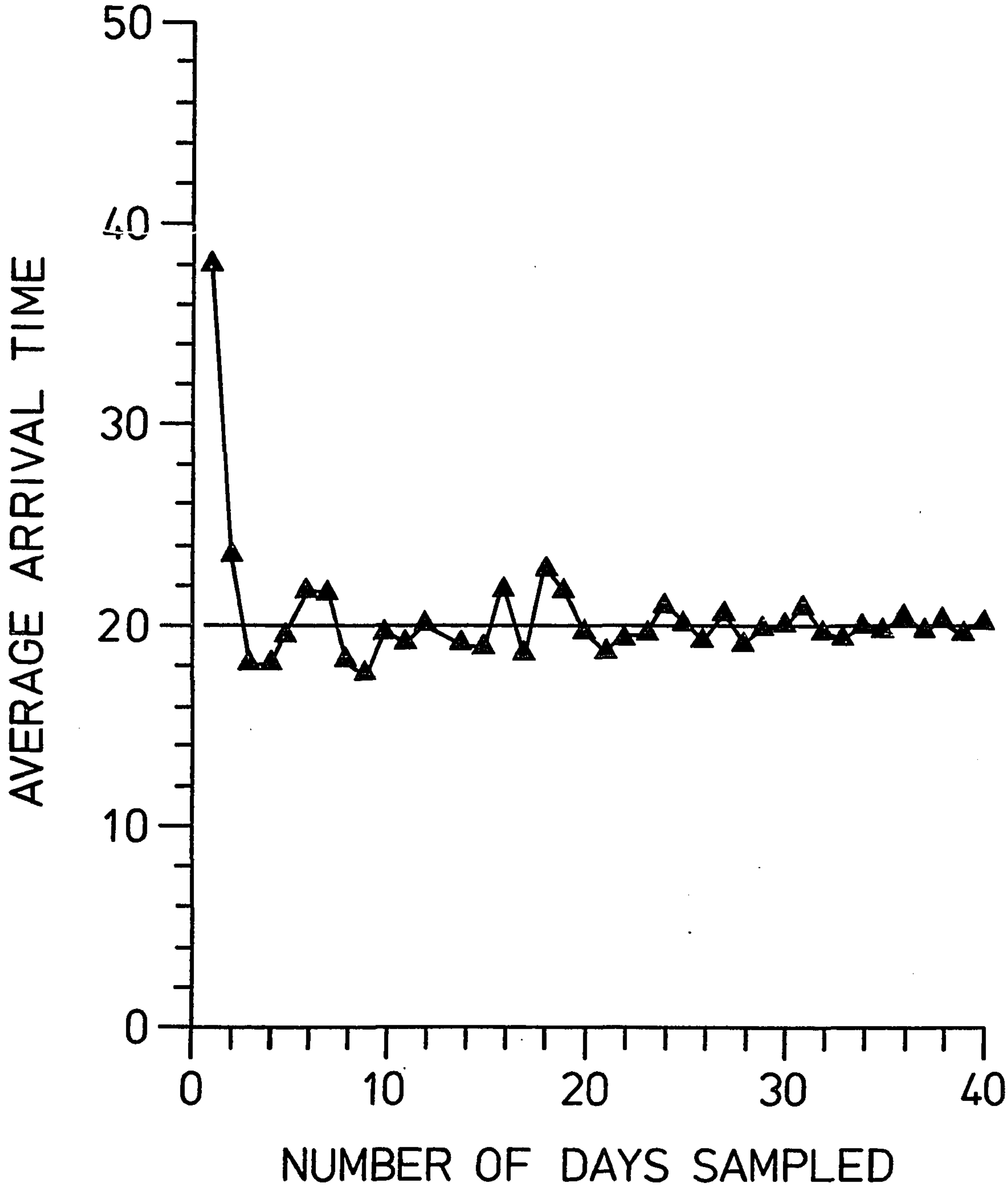
Sample Mean = 19.07
Sample Variance = 49.68
Sample Skewness = 0.0699
Sample Kurtosis = 0.5578

Table 3. Estimates of the mean, variance, skewness and kurtosis, and the proportion actually samapled for a single sample of variable number of days, j (j = 1, 2, •••40) randomly sampled from the average empirical time density of Table 1.

numb samp	mean	variance	proport sampled	skewness	kurtosis
1	38.00*	0.00000	.00130	0.0000	0.0000
2	23.45*	0.24817	.11330	0.0195	0.1166
3	18.01	49.56530	.07320	-0.0898	0.1878
4	17.98*	42.63885	.10720	0.0283	0.3715
5	19.81	15.41090	.20030	0.0492	1.1171
6	21.77	35.55632	.16140	-0.0368	0.5154
7	21.70	36.17059	.21590	-0.1237	0.5814
8	18.11	61.99905	.16220	0.0680	0.3655
9	17.45*	34.98511	.25390	-0.0081	0.8544
10	19.69	50.16952	.27840	-0.0785	0.5733
11	19.07	49.68363	.28130	0.0699	0.5578
12	20.01	45.71186	.34800	0.0603	0.7182
13	19.60	54.55591	.27040	0.0779	0.6137
14	19.04	62.44611	.36220	0.0135	0.6158
15	18.90	44.48259	.40880	-0.0614	1.0447
16	22.06*	45.46752	.41090	-0.3837	1.4014
17	18.50	44.41541	.40140	-0.0042	1.2990
18	22.90*	46.13504	.42190	-0.3643	1.3914
19	21.66	34.84987	.54050	-0.1883	1.5850
20	19.72	47.53914	.51370	-0.3087	1.4566
21	18.63	47.95924	.44270	0.0565	1.3768
22	19.46	48.35612	.55620	0.0345	1.3865
23	19.44	46.96298	.63730	0.1017	1.6265
24	21.05	43.91569	.50250	-0.1757	1.9066
25	20.22	55.88401	.58040	-0.1225	1.3985
26	19.15	43.84364	.72060	0.0271	2.0269
27	20.58	45.11890	.79620	-0.1470	1.9880
28	19.09	48.16703	.72440	-0.0736	1.8393
29	19.74	43.31541	.78720	-0.1499	2.1373
30	19.82	48.79308	.75240	-0.1465	1.8931
31	20.96	44.44000	.83340	-0.3583	2.4419
32	19.58	54.75487	.72230	-0.0211	1.6454
33	19.39	45.05930	.86780	0.0027	2.3696
34	19.92	51.84190	.83390	-0.0693	2.0275
35	19.79	53.18855	.79760	-0.1091	2.0137
36	20.50	49.93339	.85720	-0.2067	2.2861
37	19.76	51.14442	.87610	0.0232	2.1209
38	20.00	49.07147	.93880	-0.2030	2.4217
39	19.69	47.16466	.95980	-0.1001	2.6088
40	19.98	48.32053	.99090	-0.1468	2.5999

* value exceeds or falls below the approximate 95% confidence interval on the true mean; 18-22.

Figure 3. The mean time densities ($\cdot\bar{t}_{j}$) corresponding to the possible number of days randomly sampled, j (j = 1, 2, ··· 40) and the calculated grand mean ($\bar{t}_{m}$) of the populataion (19.98).


50
40
30
20
10
0
AVERAGE ARRIVAL TIME
0
10
20
30
40
NUMBER OF DAYS SAMPLED

time density ($\cdot\bar{t}_j$) may be well above or below the population mean of the distribution resulting in a broader amplitude. As the number of days sampled approaches the population size, m, the wave function dampens and the observed values match the expected population mean (j = m).

Following the procedures of Mundy (1982), the estimated means can be used to objectively divide the annual migrations of "early", "average", or "late" categories based on the approximate 95% condidence interval about the grand mean which is 18 - 22 in this case. Estimated mean values below the lower bound are considered "early", while means above the upper bound are categorized as "late". Means that fall inside the interval are considered "average". There are six examples of sample means that fall outside the "average" category (Table 3). The first four series ($j < 5$) may not be expected to show conservation of the estimates because of the small sample size. However, in this particular series of randomly sampled "fishing years", one of the first four estimates happens to fall within the expected interval. When $j \geq 5$, the mean time densities usually fall within the confidence interval. The other three estimates that lie outside the 95% interval represent random samples which happen to fall at the tails of the migratory distribution . If a sample(s) is taken very early in the distribution, an early migration is estimated. On the other hand, if the sample(s) is taken more toward the end of the migration, the estimated means fall within the "late" category. Therefore, samples taken at either end of the distribution tend to weigh the time density in the direction of the sample which is particularly likely to occur when the sample size is small, say less than 5. The spread between the range limits of $\cdot\bar{t}_j$ is broadest when the sample size is small due to the combinatorial properties (Equation 16) (Fig. 4). However, as the number of combinations (${}_mC_j$) decreases with increasing sample size, the spread of $\cdot\bar{t}_j$ decreases.

Deviations from the expected values (residuals) for a series of runs where j = 1, 2, ··· 40 is shown in Table 4 (Fig. 5). It is a mirror image of the mean time density graph (Fig. 3). The standard error (standard deviation of the mean) shows a decrease similar to an exponential decay as the sample size (j) increases (Fig. 6). There is an initial wide displacement of the standard error limits with only a few obserable days recorded. Once 10 or 11 days are sampled the curve becomes more conservative and stable.

The estimates of the variance the migration are not as conservative as the estimates of the mean (Fig. 7). There is a broad vertical shift above and below the population variance of 48.32. The limits range form $S^2 = 15$ to $S^2 > 62$ for $j < 20$. It is not until 50% of the entire distribution is sampled that the variance settles to the narrower limits of S^2 between 43 and 56. The corresponding residuals of the variance are seen in Figure 8.

The estimates of skewness show little conservation (Fig. 9). The values tend to oscillate about the normal ($a_3 = 0$) showing the weighting influence of days sampled at the tails of the distribution. The kurtosis shows a flattened appearance with small sample sizes and approaches a normal ($a_4 = 3$) only as the sample size (j) approaches 40 (Table 3)(Fig. 10). The chinook distribution is slightly platykurtic (Fig. 2); therefore, any sample size would show an exaggeration of the flattness of the distribution due to sampling censorship.

The mean square error (MSE) is equal to the variance plus the

Figure 4. Twenty random combinations of $\cdot\bar{t}_j$ ($j = 1, 2, \cdots 40$) for the distribution of chinook salmon, 1961-1980 (mean = 19.98, variance = 48.32).

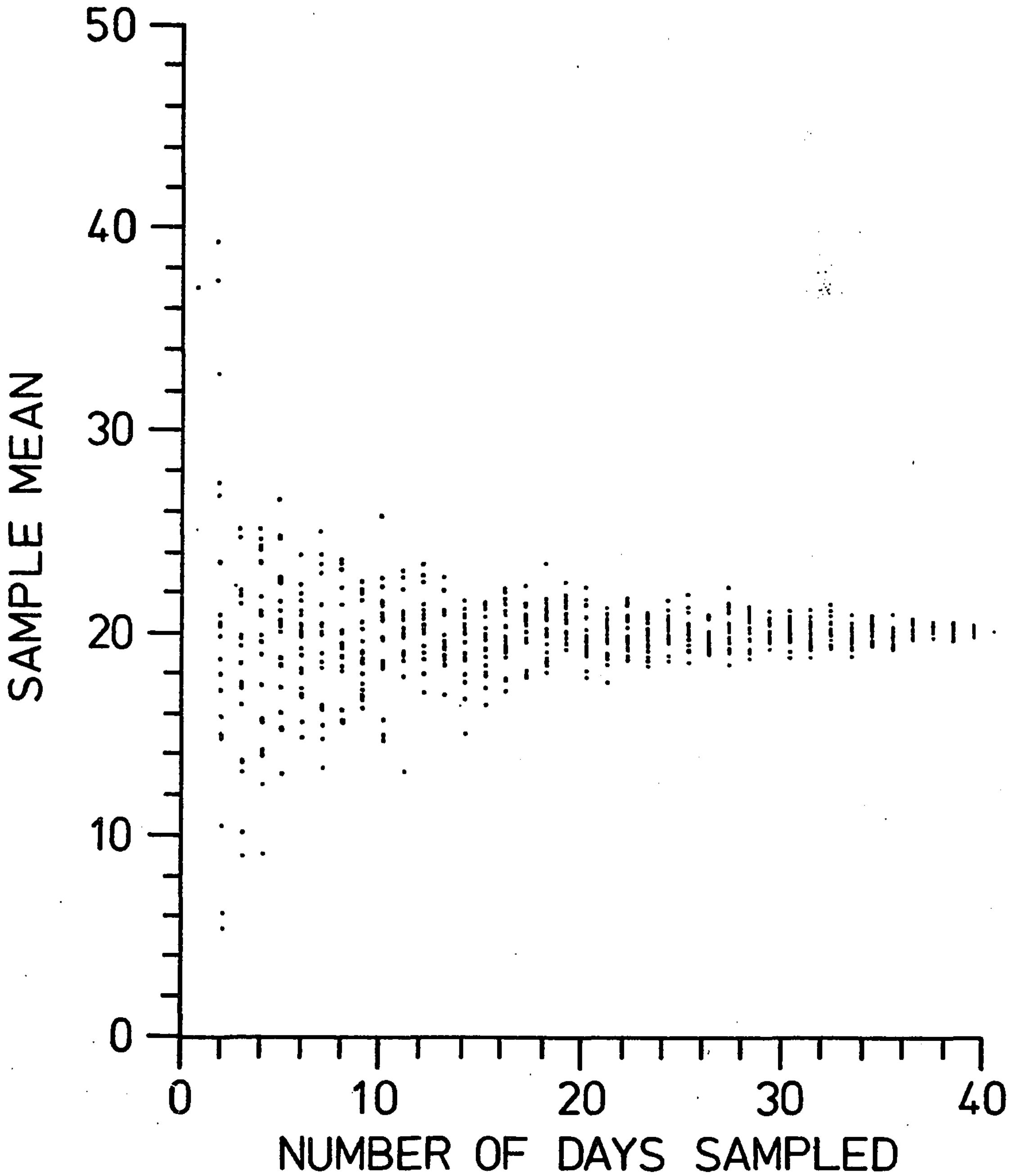

SAMPLE MEAN
50
40
30
20
10
0
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Table 4. Estimates of the standard deviation (error) of the mean, residual of the mean, and residuals of the variance for a single sample of variable number of days, j (j = 1, 2, ··· 40) randomly sampled from the empirical distribution.

numb samp	mean	standard error	mean residual	variance residual
1	38.00	0.00000	-18.01978	48.32053
2	23.45	0.35226	-3.47697	48.07236
3	18.01	4.06470	1.96383	-1.24477
4	17.98	3.26492	1.99235	5.68168
5	19.81	1.75561	0.16844	32.90963
6	21.77	2.43435	-1.79425	12.76421
7	21.70	2.27315	-1.72103	12.14994
8	18.11	2.78386	1.87048	-13.67852
9	17.45	1.97161	2.53477	13.33542
10	19.69	2.23986	0.28877	-1.84899
11	19.07	2.12525	0.90983	-1.36310
12	20.01	1.95175	-0.03415	2.60867
13	19.60	2.04856	0.38444	-6.23538
14	19.04	2.11197	0.94240	-14.12558
15	18.90	1.72206	1.08296	3.83794
16	22.06	1.68574	-2.08208	2.85301
17	18.50	1.61638	1.47698	3.90512
18	22.90	1.60096	-2.92331	2.18549
19	21.66	1.35433	-1.67824	13.47066
20	19.72	1.54174	0.25626	0.78139
21	18.63	1.51122	1.35519	0.36129
22	19.46	1.48257	0.52211	-0.03559
23	19.44	1.42894	0.54432	1.35755
24	21.05	1.35271	-1.07192	4.40484
25	20.22	1.49511	-0.23515	-7.56348
26	19.15	1.29857	0.82812	4.47689
27	20.58	1.29270	-0.59891	3.20163
28	19.09	1.31158	0.88842	0.15350
29	19.74	1.22214	0.24191	5.00512
30	19.82	1.27532	0.15951	-0.47255
31	20.96	1.19731	-0.97730	3.88053
32	19.58	1.30809	0.40456	-6.43434
33	19.39	1.16852	0.59015	3.26123
34	19.92	1.23481	0.06392	-3.52137
35	19.79	1.23275	0.19211	-4.86802
36	20.50	1.17773	-0.51861	-1.61286
37	19.76	1.17570	0.22471	-2.82389
38	20.00	1.13638	-0.02223	-0.75094
39	19.69	1.09970	0.29226	1.15587
40	19.98	1.09910	0.00000	0.00000

Figure 5. The residuals for the mean time densities ($\cdot\bar{t}_j$) about the population mean ($\bar{t}_m$) of 19.98 for chinook salmon (1961-1980).

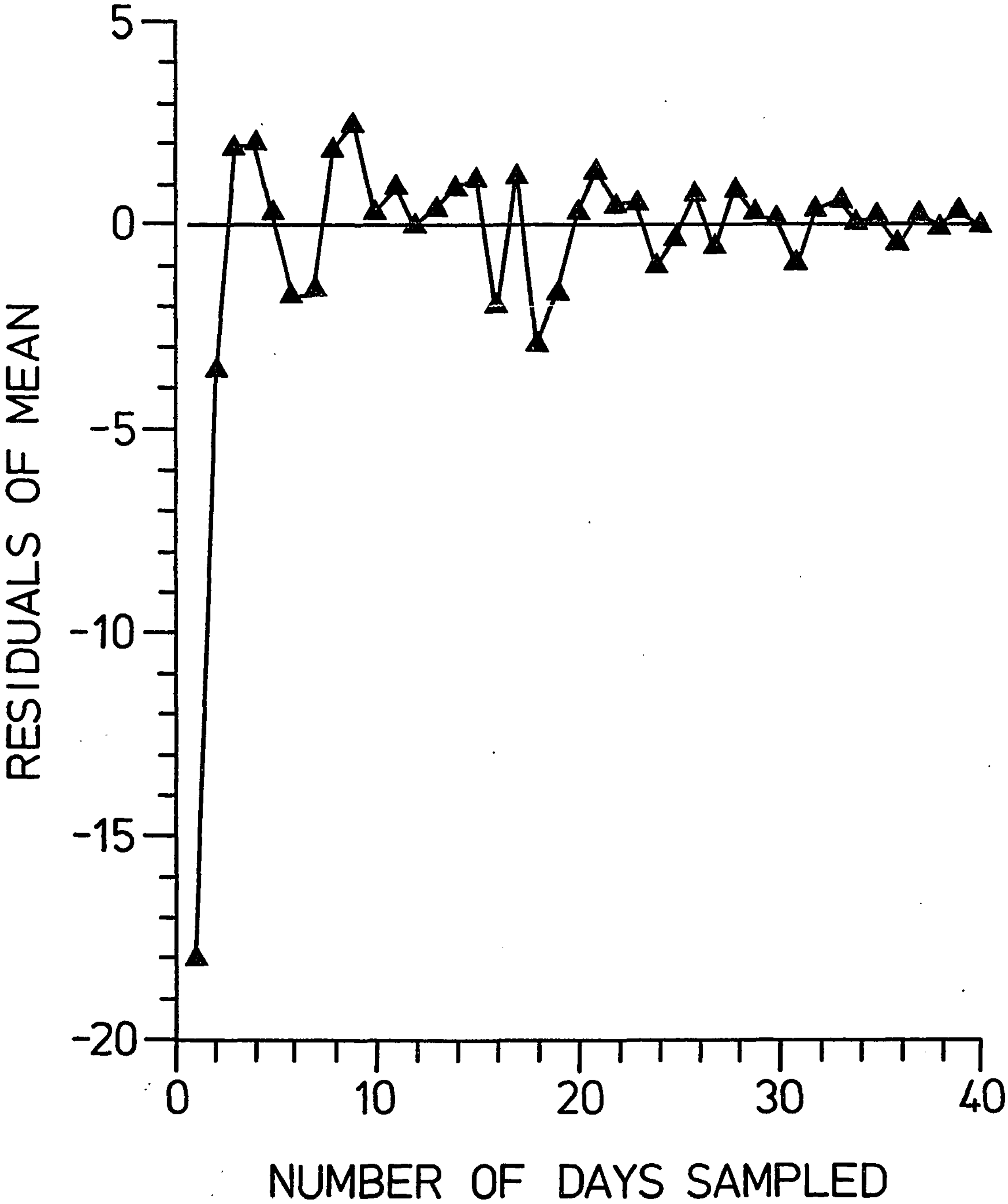

5
0
-5
-10
-15
-20
RESIDUALS OF MEAN
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 6. The population mean ($\bar{t}_m$ = 19.98) of chinook salmon and the standard deviation of the mean (standard error) for the number of migratory days randomly sampled.

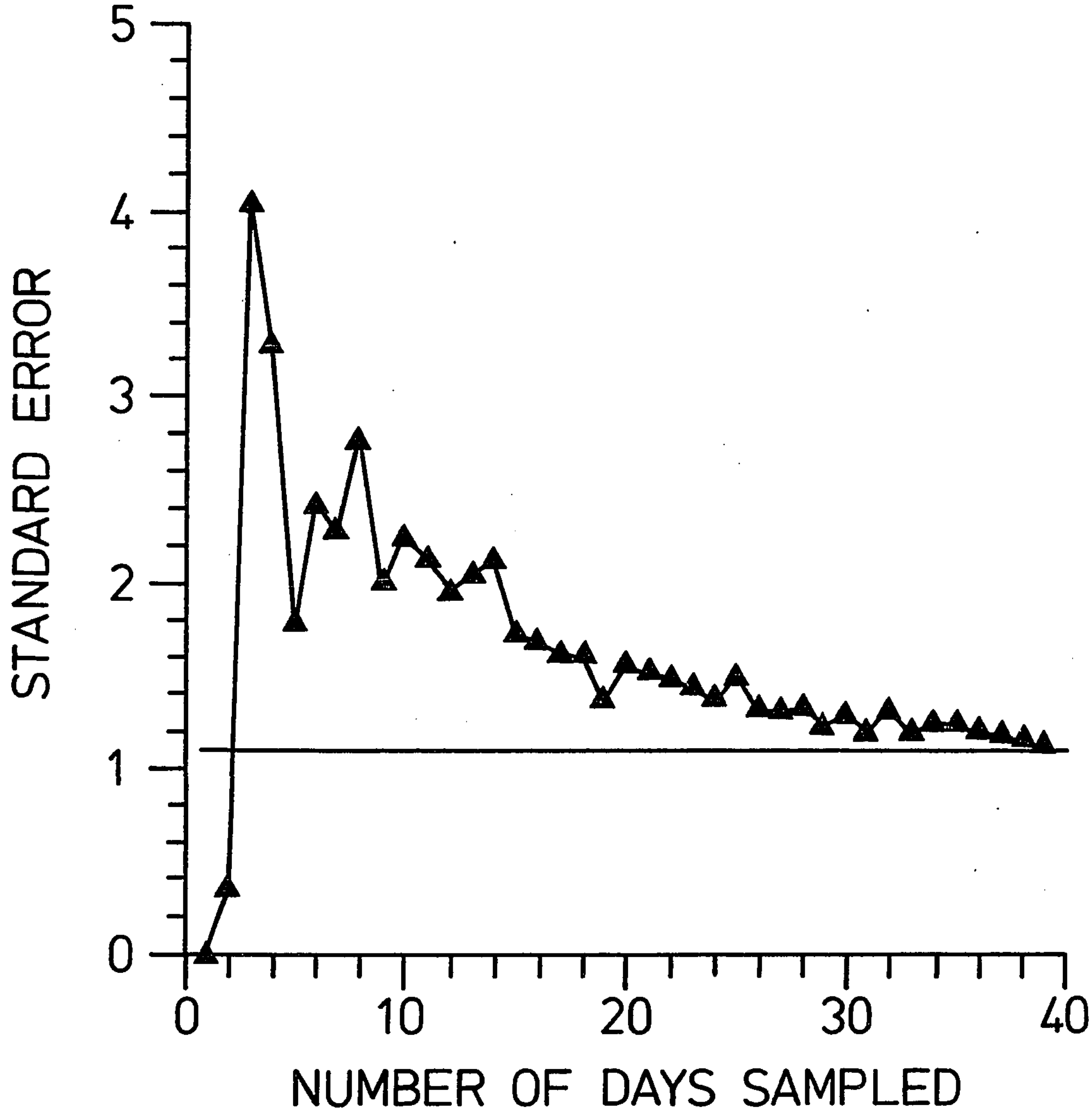

STANDARD ERROR
NUMBER OF DAYS SAMPLED
0
1
2
3
4
5
10
20
30
40

Figure 7. The degree of dispersion of migration through time ($\cdot S_i^2$) about the population variance (S_m^2 = 48.330) for chinook salmon (1961-1980).

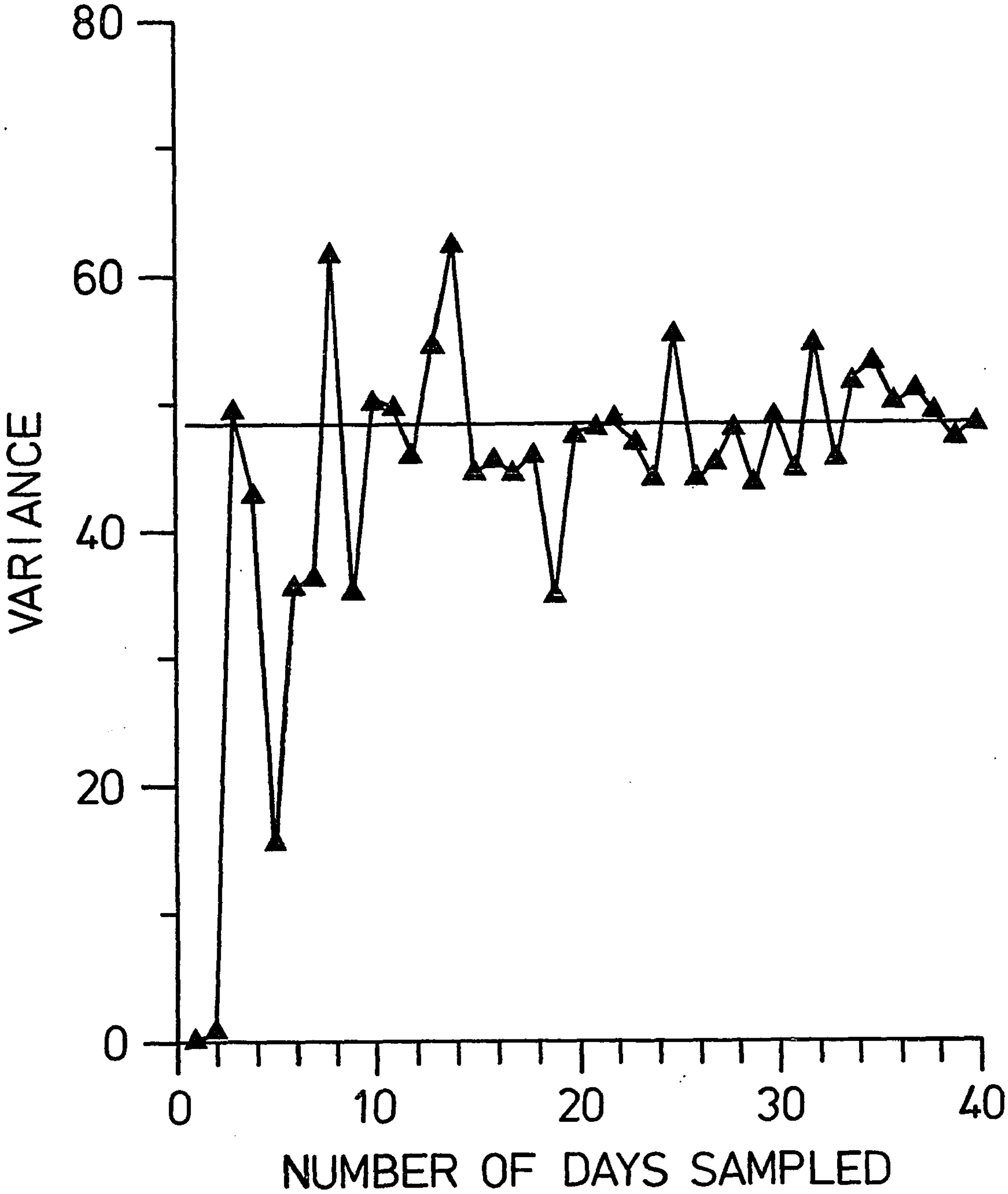

80
60
40
20
0
VARIANCE
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 8. The residuals of the variance ($\cdot S_j^2$) about the population variance (S_m^2) for chinook salmon (1961-1980).

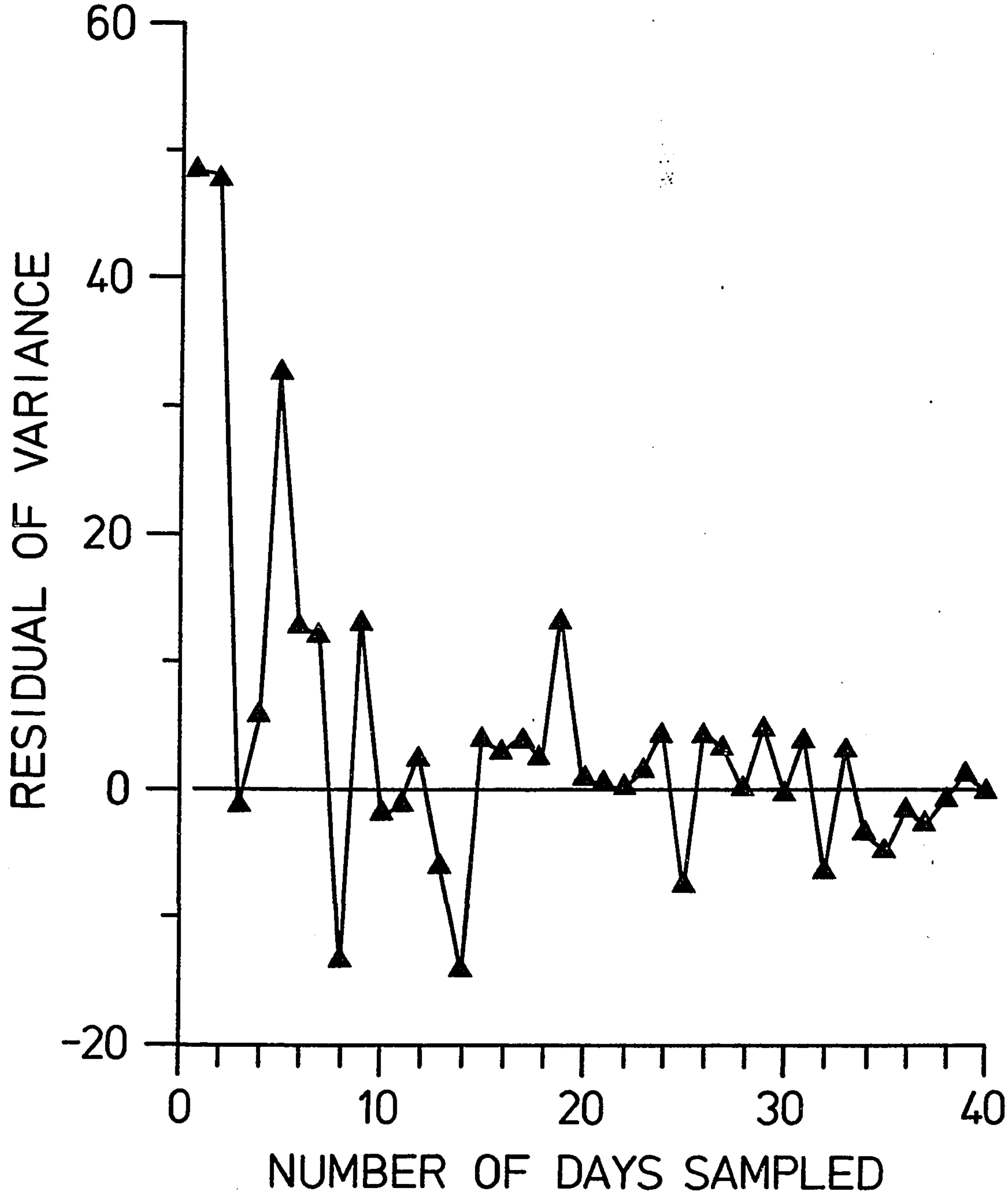

60
40
20
0
-20
RESIDUAL OF VARIANCE
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 9. Skewness values for the number of randomly sampled days j (j = 1, 2 ··· 40) vs the third moments about the population mean (-0.1468) value for chinook, 1961-1980.

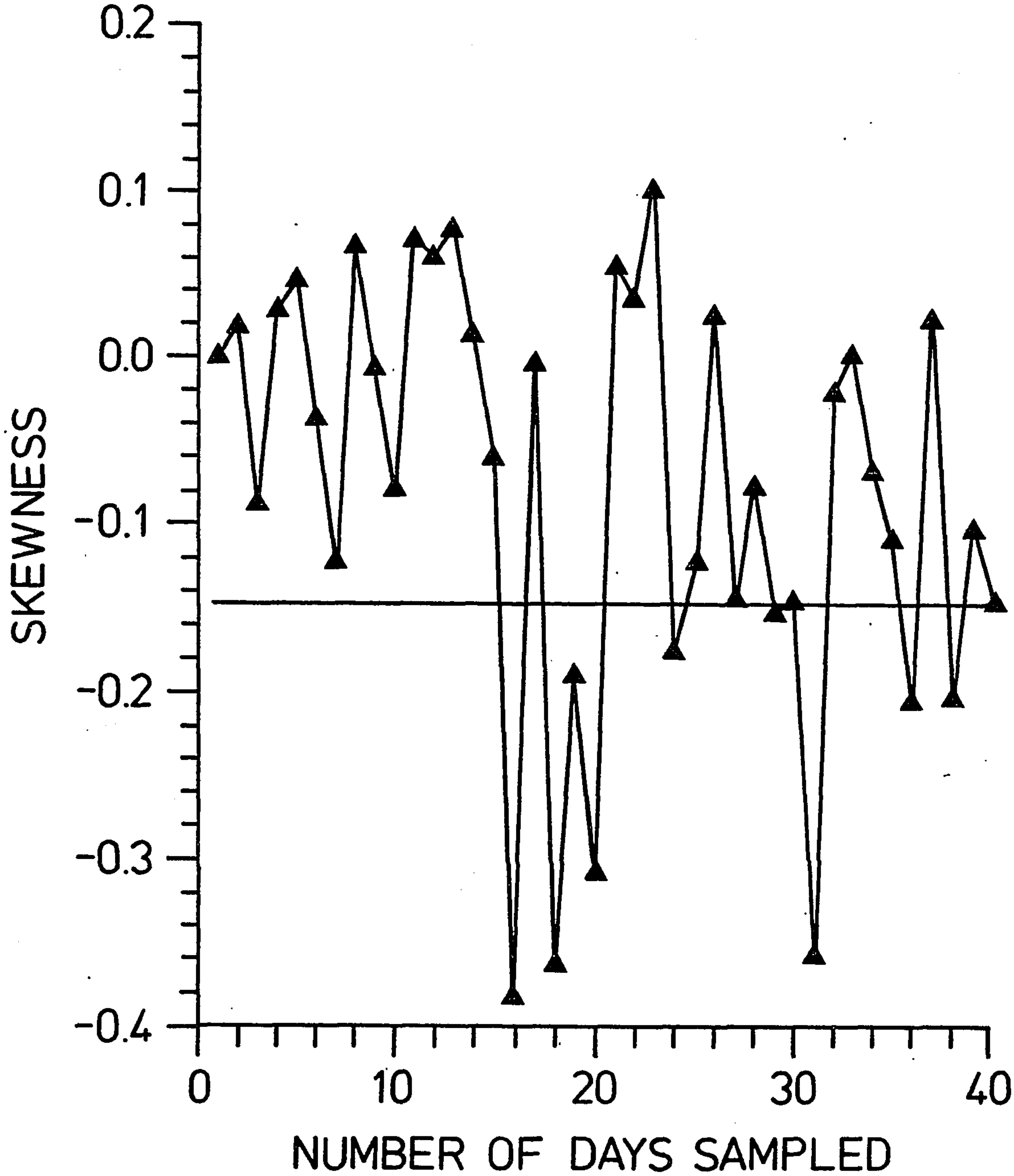
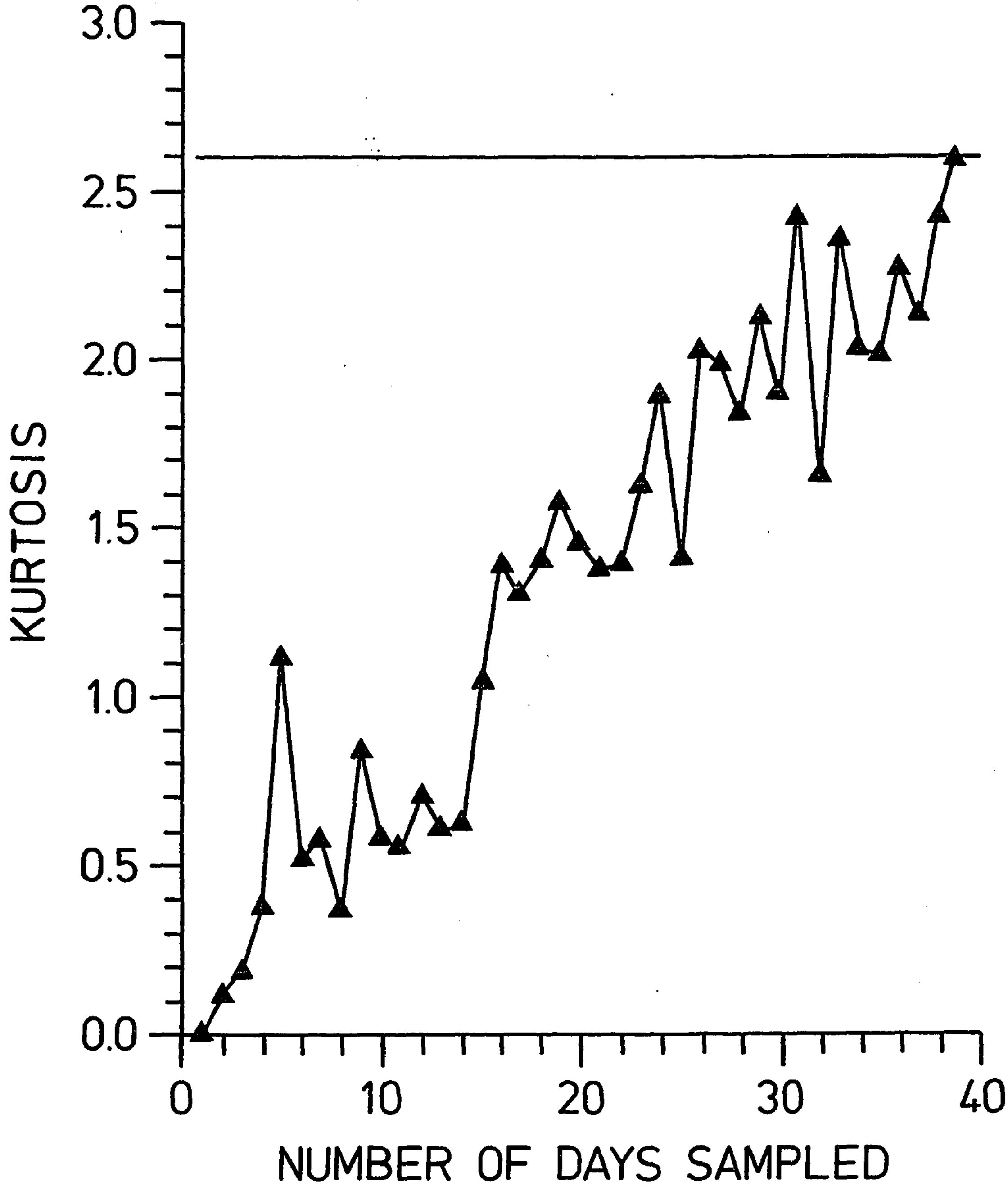

0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
SKEWNESS
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 10. Kurtosis values for the number of randomly sampled days j (j = 1, 2 ··· 40) vs the fourth moments about the population mean (2.599) for chinook salmon, 1961-1980.



3.0
2.5
2.0
1.5
1.0
0.5
0.0
KURTOSIS
0
10
20
30
40
NUMBER OF DAYS SAMPLED

square of a bias calculation (Equation 12). If the bias is small, the MSE of a biased estimator can be a better approximation of the variance. Based on multiple repetitons seen in Table 5 the MSE rapidly becomes minimal and stable when as few as six or seven days are randomly sampled (Fig. 11). The bias remains relatively conservative with range limits between -0.4 and 0.3 (Fig. 12). The limits settle to within $\pm$ 0.1 after $j > 10$. Therefore, the biased estimate of the MSE is a better estimate (Fig. 13) than the sample variance because it minimizes the difference between the observed and the expected values of the average arrival time. As result, a reliable range or 95% confidence interval (Equation 14) is constructed to encompass the expected average arrival time of the migration (Fig. 14).

The ratio estimator is a biased estimator according to Cochran (1977). There is a good correlation between g_t and P_t (Fig. 15). The variance estimate, $V(\cdot\bar{t}_j)$, from Equations 20 and 21, also is an appropriate estimator (Table 6) for this study even though it is generally associated with large sample sizes. It offers a much narrower confidence with 12 % or less of the migratory days sampled than the biased MSE of the ratio estimate above. Otherwise, the variance of the ratio estimator is only slightly more conservative than the biased MSE estimate for random samples greater than 12 %.

Table 5. Calculations from 300 repetitions for the mean time density ($\cdot\bar{t}_j$), cumulative proportions, bias and mean square error (MSE) of the ratio estimator, and the MSE for the unbiased estimator of the population total (sample variance).

num days samp	mean	cum propor	bias	MSE biased	MSE unbiased
1	20.237	0.02482	0.257	143.693	308.503
2	19.568	0.05133	-0.412	44.617	150.296
3	20.074	0.07607	0.094	21.519	97.561
4	19.775	0.10179	-0.205	13.112	71.193
5	19.757	0.12603	-0.223	10.192	55.372
6	19.681	0.15117	-0.299	7.683	44.825
7	19.825	0.16917	-0.155	6.467	37.292
8	19.923	0.19527	-0.057	5.689	31.641
9	20.144	0.22850	0.164	4.362	27.247
10	19.901	0.24309	-0.079	3.858	23.731
11	20.032	0.27294	0.052	3.010	20.854
12	20.043	0.29589	0.063	2.949	18.457
13	20.001	0.31400	0.021	2.525	16.429
14	20.011	0.34817	0.031	2.551	14.691
15	20.049	0.37339	0.069	2.099	13.184
16	19.926	0.39856	-0.054	1.825	11.865
17	19.926	0.42282	-0.054	1.844	10.702
18	19.956	0.44073	-0.024	1.482	9.668
19	20.038	0.46429	0.058	1.395	8.743
20	19.997	0.49880	0.017	1.228	7.910
21	19.945	0.52128	-0.035	1.151	7.157
22	19.991	0.54958	0.011	1.001	6.472
23	20.001	0.56940	0.021	0.873	5.847
24	19.965	0.59572	-0.015	0.800	5.274
25	19.870	0.61727	-0.110	0.909	4.746
26	20.004	0.63982	0.024	0.607	4.259
27	19.957	0.66841	-0.023	0.546	3.809
28	19.976	0.69213	-0.004	0.482	3.390
29	19.982	0.72016	0.002	0.458	3.000
30	19.908	0.74182	-0.072	0.352	2.637
31	20.018	0.76876	0.038	0.330	2.297
32	19.957	0.79020	-0.023	0.328	1.978
33	20.010	0.81815	0.030	0.250	1.678
34	19.965	0.84253	-0.015	0.176	1.396
35	19.961	0.86809	-0.019	0.171	1.130
36	19.974	0.89307	-0.006	0.136	0.879
37	19.991	0.91653	0.011	0.096	0.641
38	19.976	0.93946	-0.004	0.057	0.416
39	19.993	0.96817	0.013	0.029	0.203
40	19.980	0.99090	0.000	0.000	0.000

Figure 11. The mean square error for simulation runs (300 repetitions) of $\cdot\bar{t}_j$ (j = 1, 2 ··· 40) for chinook salmon, 1961-1980.

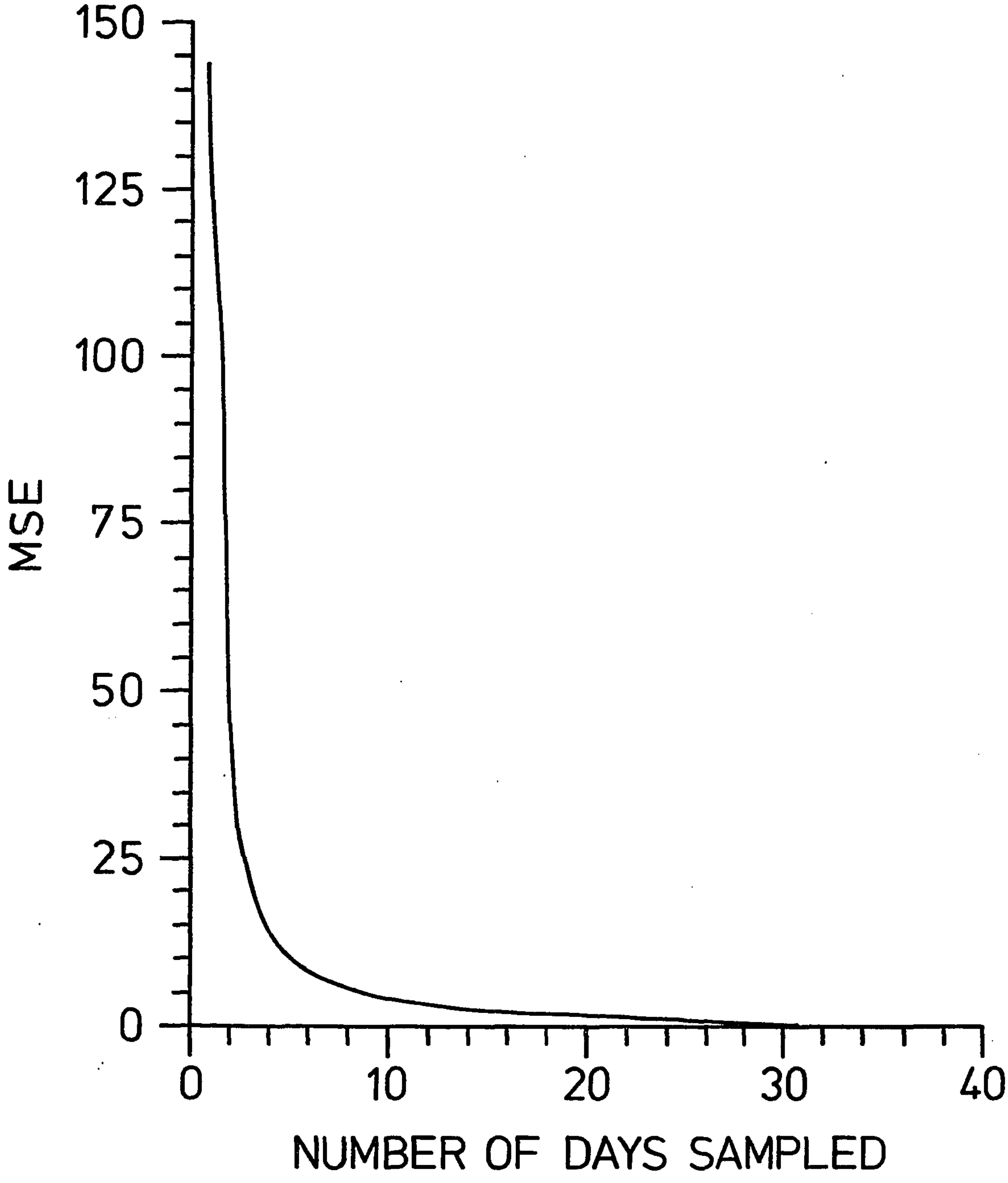

150
125
100
75
50
25
0
MSE
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 12. The bias of the ratio estimator for $\cdot\bar{t}_j$, as j = 1, 2 ··· 40 for chinook salmon.

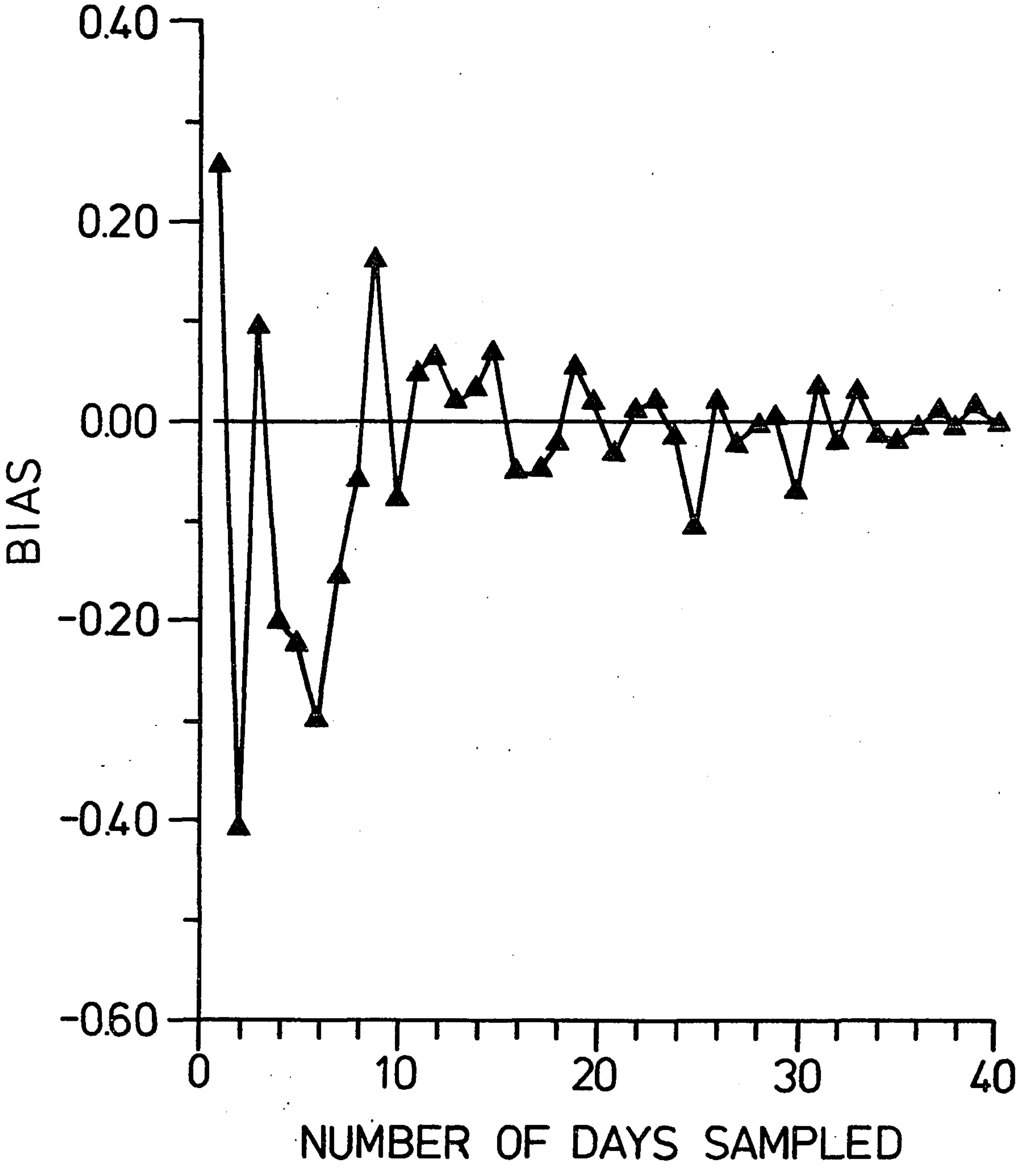
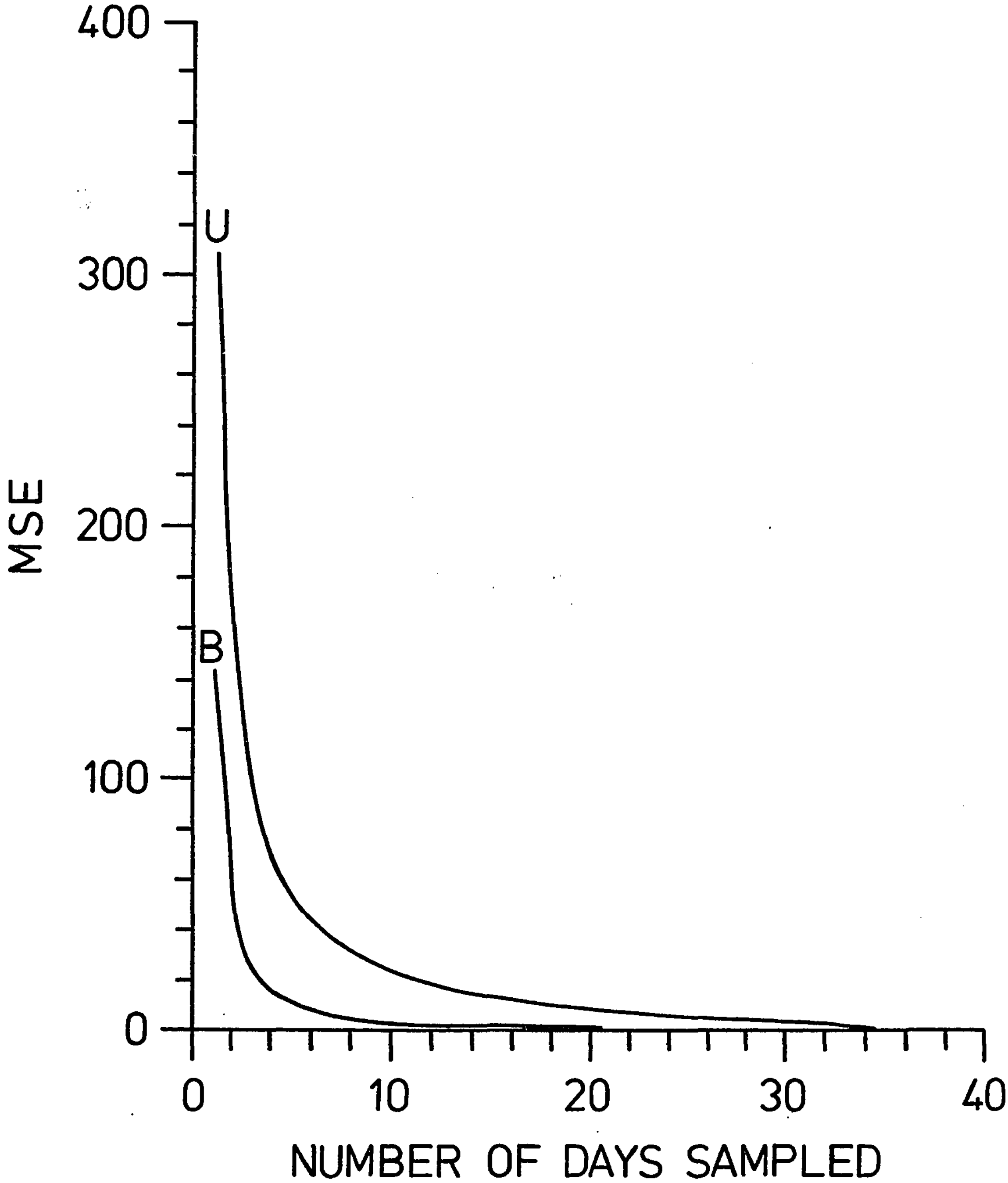
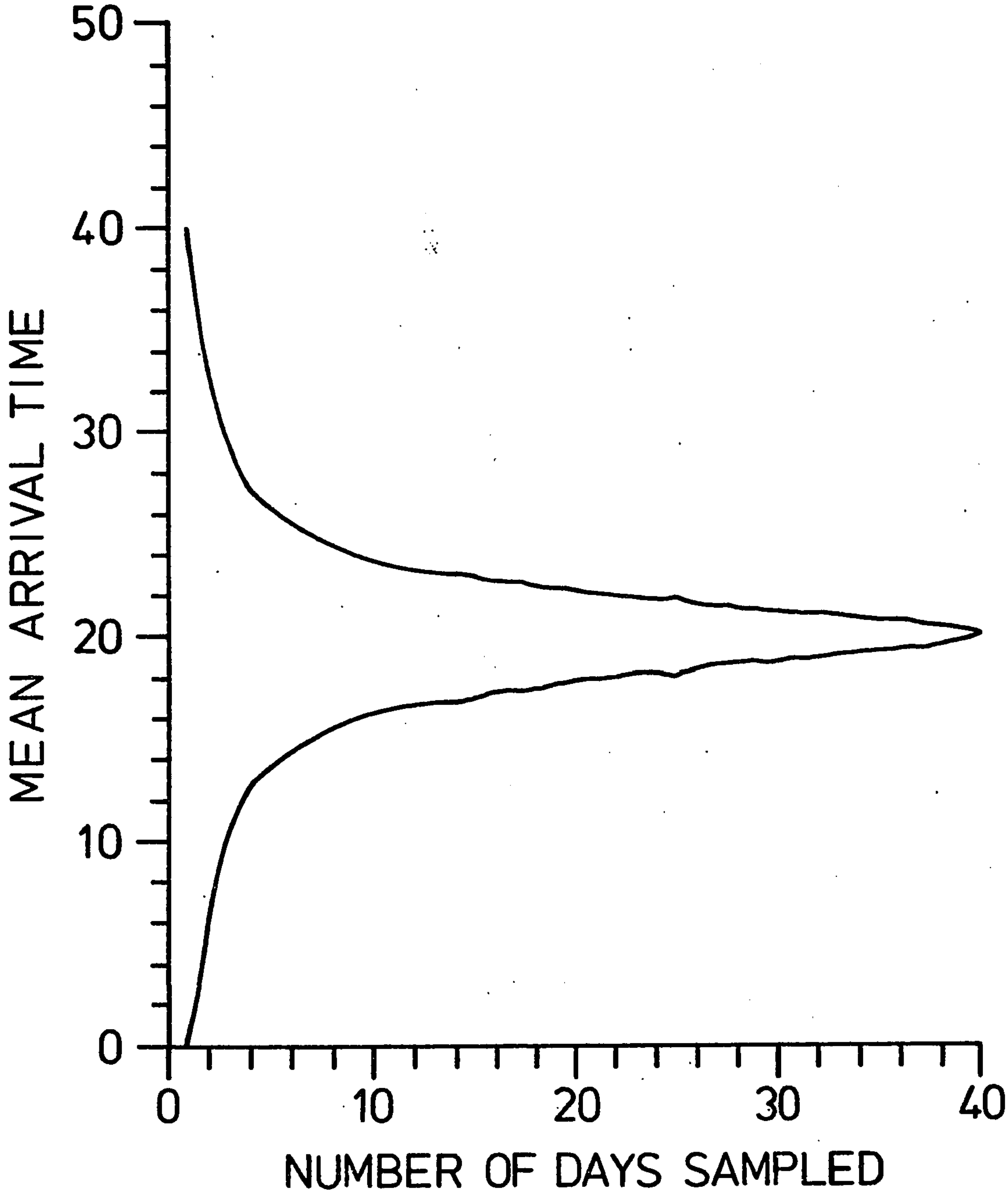

0.40
0.20
0.00
-0.20
-0.40
-0.60
BIAS
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 13. Comparison of the bias MSE and the unbias sample variance of the average arrival time for chinook salmon, 1961-1980.



400
300
200
100
0
MSE
U
B
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 14. The approximate 95% confidence interval for the average arrival time of chinook salmon, 1961-1980, based on the biased estimate of the MSE.



50
40
30
20
10
0
MEAN ARRIVAL TIME
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 15. Correlation diagram of g_t vs P_t for each of the time intervals t for chinook salmon.

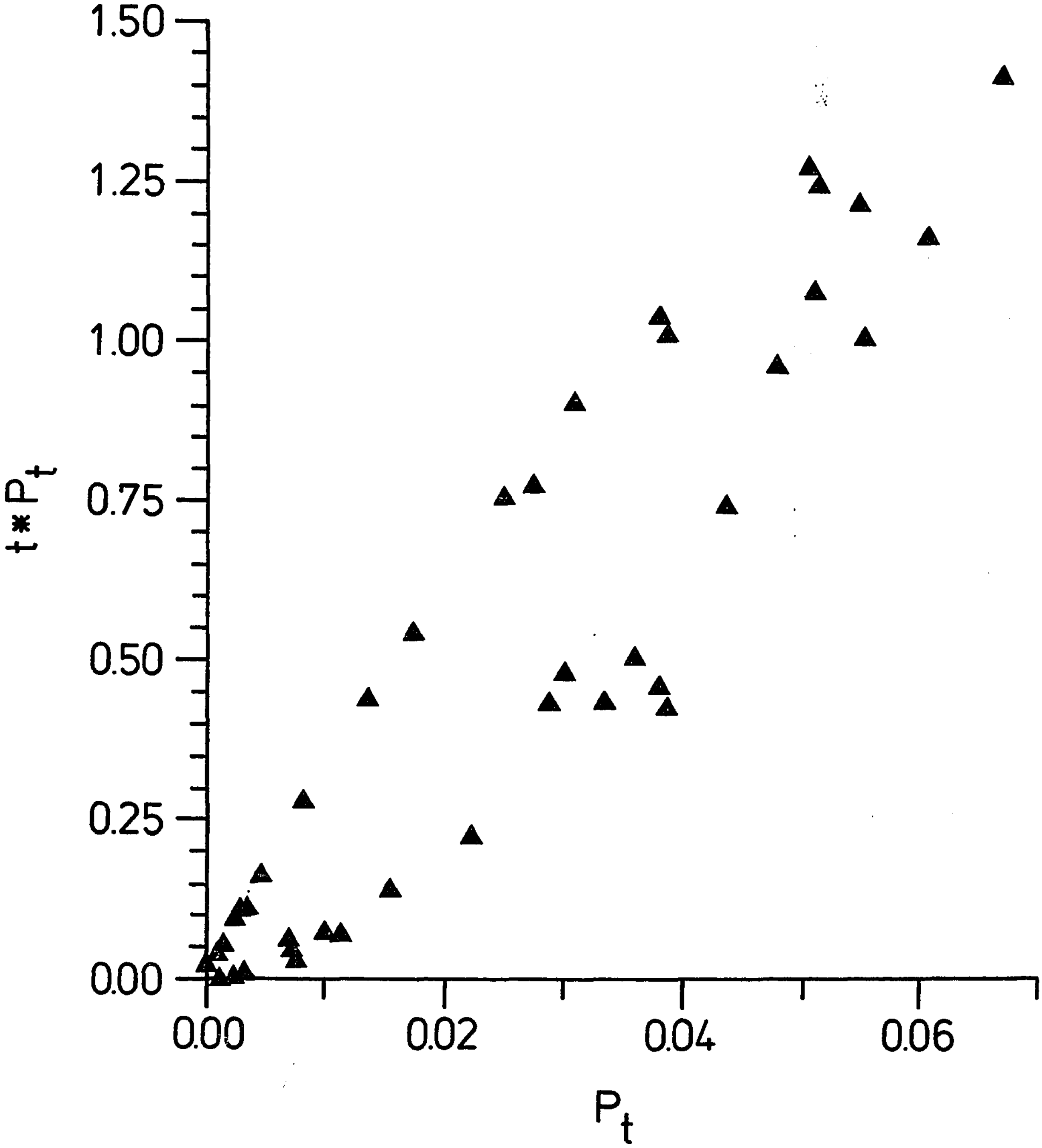

1.50
1.25
1.00
0.75
0.50
0.25
0.00
t * P_t
0.00
0.02
0.04
0.06
P_t

Table 6: The bound on the error of estimation for the average arrival time for the empirical average distribution (mean = 19.98, variance = 48.32) with the lower and upper bounds and the variance estimator, $V(\cdot\bar{t}_j)$ for a single sample of a variable number of days, j (j = 1, 2, ··· 40) from the empirical distritution.

numb sampl	mean	lower bound	upper bound	variance estimator
1	38.000*	6.609	33.351	44.694
2	23.457	10.648	29.313	21.774
3	18.016	12.461	27.499	14.134
4	17.988	13.557	26.403	10.314
5	19.812	14.316	25.645	8.022
6	21.774	14.884	25.077	6.494
7	21.701	15.332	24.629	5.403
8	18.110	15.698	24.262	4.584
9	17.445	16.007	23.954	3.947
10	19.691	16.272	23.689	3.438
11	19.070	16.504	23.457	3.021
12	20.014	16.710	23.251	2.674
13	19.596	16.895	23.066	2.380
14	19.038	17.062	22.898	2.128
15	18.897	17.216	22.744	1.910
16	22.062	17.358	22.602	1.719
17	18.503	17.490	22.471	1.550
18	22.904	17.613	22.347	1.401
19	21.658	17.729	22.231	1.267
20	19.724	17.839	22.121	1.146
21	18.625	17.944	22.017	1.037
22	19.458	18.044	21.917	0.938
23	19.436	18.140	21.821	0.847
24	21.052	18.232	21.728	0.764
25	20.215	18.322	21.639	0.688
26	19.152	18.409	21.551	0.617
27	20.579	18.495	21.466	0.552
28	19.092	18.579	21.382	0.491
29	19.738	18.662	21.299	0.435
30	19.821	18.744	21.216	0.382
31	20.958	18.827	21.134	0.333
32	19.576	18.910	21.051	0.287
33	19.390	18.994	20.966	0.243
34	19.916	19.081	20.880	0.202
35	19.788	19.171	20.789	0.164
36	20.499	19.267	20.694	0.127
37	19.756	19.371	20.590	0.093
38	20.002	19.489	20.471	0.060
39	19.688	19.637	20.323	0.029
40	19.980	19.980	19.980	0.000

* value exceeds or falls below the approxiate 95% confident level of the true mean, 18-22.

Simulations Based on Variations of the Parameters of a Normal Curve

The migratory time density of the salmon populations in question is slightly skewed to the right and platykurtic; however, it has a migatory arrival time that is distributed "normally". The daily proportions calculated from the normal curve in Table 7 have the same mean (19.98) and variance (48.32) as that of the daily abundances taken from the average catch data (Table 1) for chinook salmon is a fairly good approximation of the empirical case (Fig. 16). A family of normal distributions is then used to simulate migrations as may be anticipated in a real fishery for early or late migrations.

In this procedure the mean is fixed at 19.98, while the variance is allowed to vary within the biologically realistic limits of 4 and 81 (Table 8). Truncation is simulated by selecting only a limited number of dates, form 1 to 40, from which to estimate the moments of migratory timing. (Truncation in practice occurs when the fishery begins after the migration has already begun to pass through the fishery and/or ends before the end of the migration). At a variance greater than 16, the third and fourth moments start straying from "normality". An average migration corresponds to $S^2 = 36$, with $S^2 = 81$ as an early migration and $S^2 = 4$ as a fast or late migration (Fig. 17).

A series of random samples is taken from a simulated early migration (S2 = 81), in conjunction with the first four moments for each series (Table 9). The simulated run shows a pattern similar to the empirical catch data for the mean time densities, $\cdot\bar{t}_j$. When $j \leq 5$, $\cdot\bar{t}_j$

Table 7. The theoretical daily and cumulative proportions for the normal distribution with a mean of 19.98 and a variance of 48.32 (skewness = 0.0227, kurtosis = 2.5729) for each day of the migration.

migr day	daily proport	cum proport
1	.00138	.00138
2	.00202	.00340
3	.00290	.00631
4	.00409	.01039
5	.00563	.01602
6	.00759	.02361
7	.01004	.03365
8	.01300	.04665
9	.01648	.06313
10	.02048	.08361
11	.02491	.10852
12	.02969	.13822
13	.03467	.17288
14	.03964	.21252
15	.04440	.25692
16	.04872	.30564
17	.05235	.35800
18	.05511	.41311
19	.05683	.46993
20	.05739	.52733
21	.05678	.58410
22	.05502	.63913
23	.05222	.69135
24	.04855	.73990
25	.04422	.78412
26	.03944	.82357
27	.03447	.85803
28	.02950	.88753
29	.02473	.91226
30	.02031	.93257
31	.01633	.94890
32	.01287	.96177
33	.00993	.97170
34	.00751	.97921
35	.00556	.98477
36	.00403	.98880
37	.00286	.99166
38	.00199	.99365
39	.00136	.99501
40	.00091	.99592

Figure 16. The average empirical distribution for chinook salmon (1961-1980) and the theoretical daily proportions from the normal distribution (mean = 19.98, variance = 48.32).

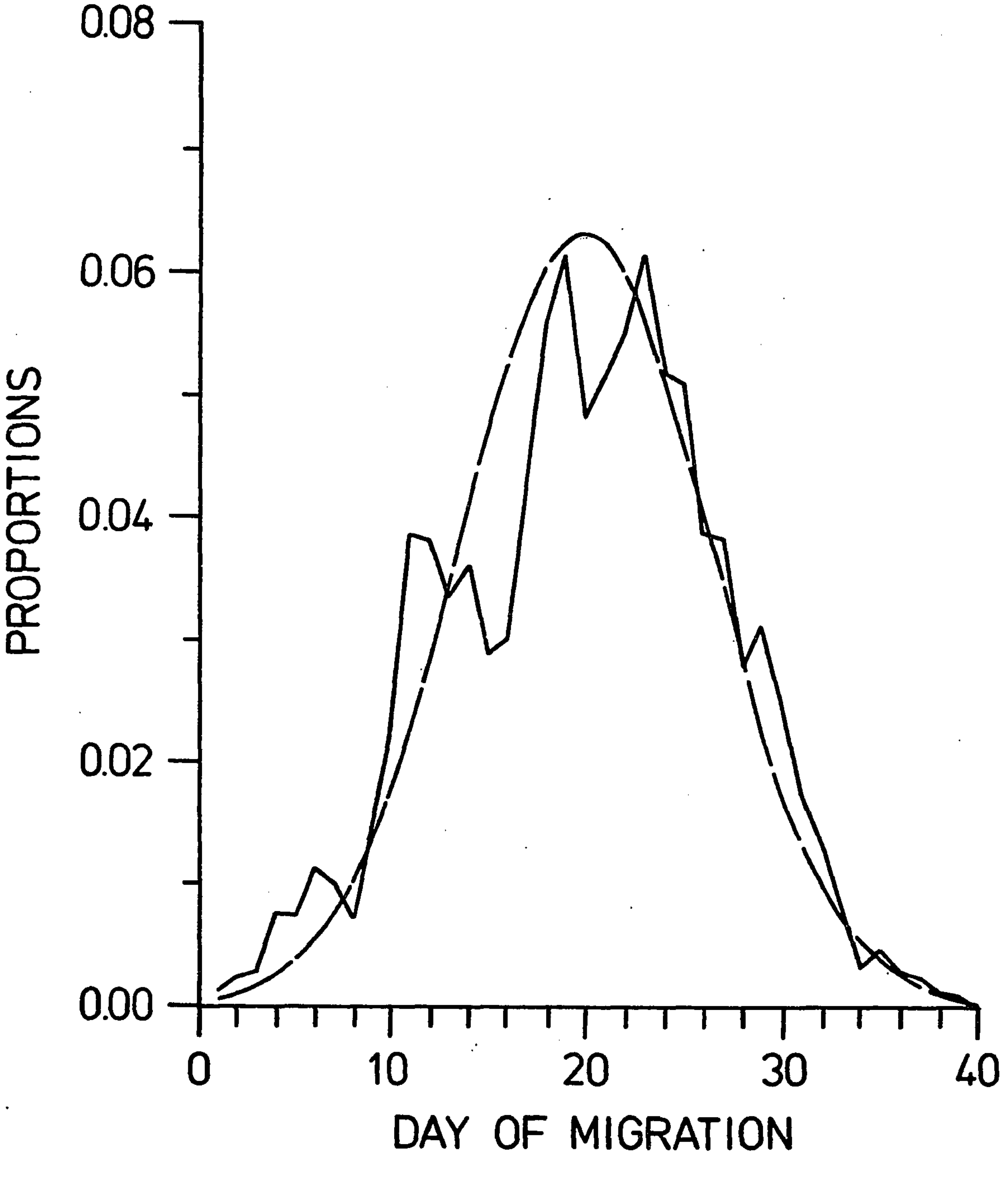

0.08
0.06
0.04
0.02
0.00
PROPORTIONS
0
10
20
30
40
DAY OF MIGRATION

Table 8. The skewness and kurtosis of a simulation runs sampling from the normal distribution with variable variances and fixed mean.

run	variance	skewness	kurtosis
1	4.00	0.0000	3.0000
2	6.25	0.0000	3.0000
3	9.00	0.0000	3.0000
4	12.25	0.0000	3.0000
5	16.00	0.0000	2.9995
6	20.25	0.0004	2.9956
7	25.00	0.0018	2.9787
8	30.25	0.0049	2.9344
9	36.00	0.0099	2.8502
10	42.25	0.0164	2.7221
11	49.00	0.0233	2.5551
12	56.25	0.0300	2.3602
13	64.00	0.0356	2.1503
14	72.25	0.0399	1.9368
15	81.00	0.0428	1.7288

Figure 17. The degree of dispersion for the simulation of the normal distribution with a mean of 19.98 and a varying variance of 4, 36 & 81.

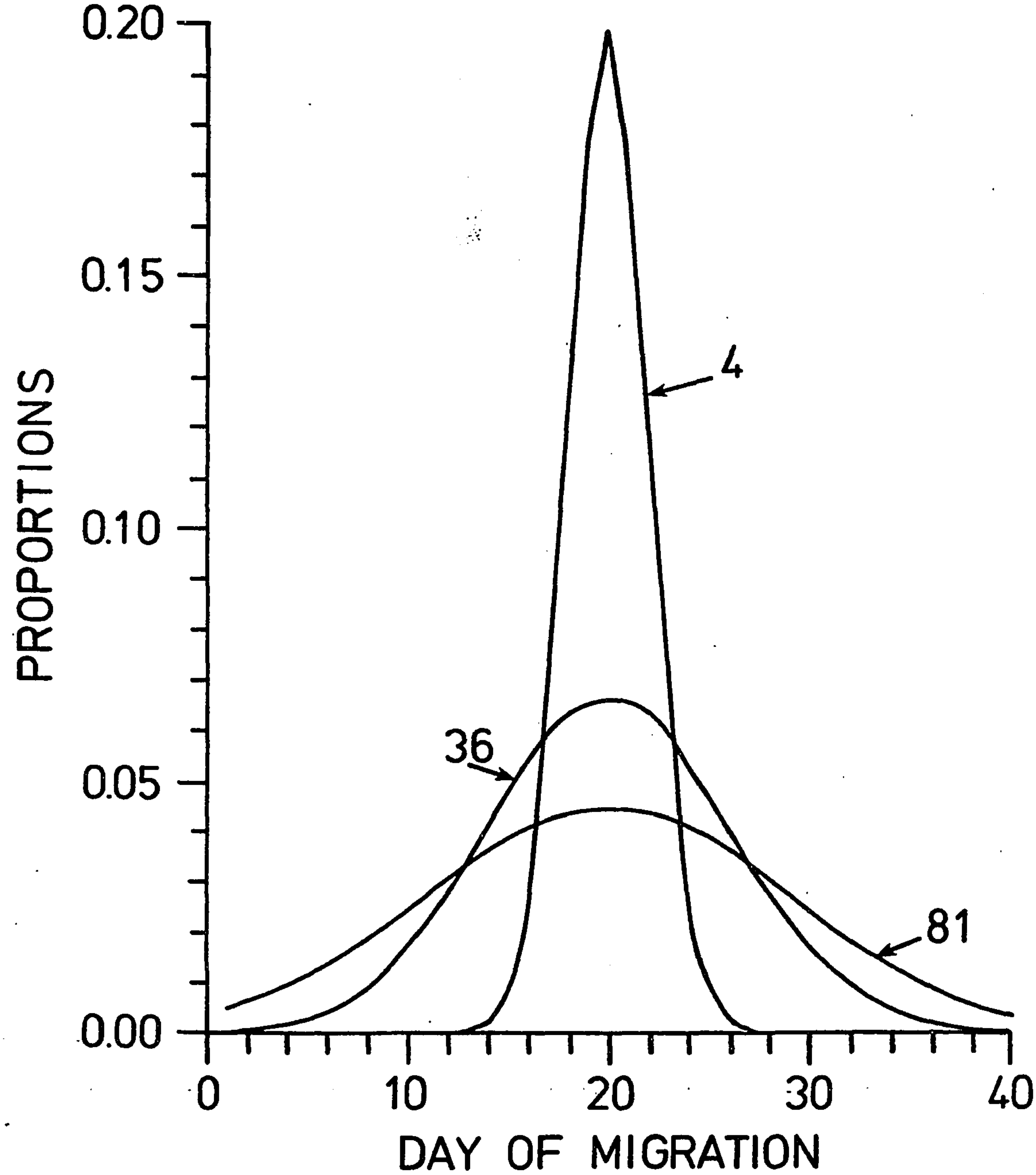

0.20
0.15
0.10
0.05
0.00
PROPORTIONS
4
36
81
0
10
20
30
40
DAY OF MIGRATION

Table 9. Estimates of the mean, variance, skewness and kurtosis, and the actual proportion sampled for a single sample of a variable number of days, j (j = 1, 2, ··· 40) from the normal (N(19.98, 81)).

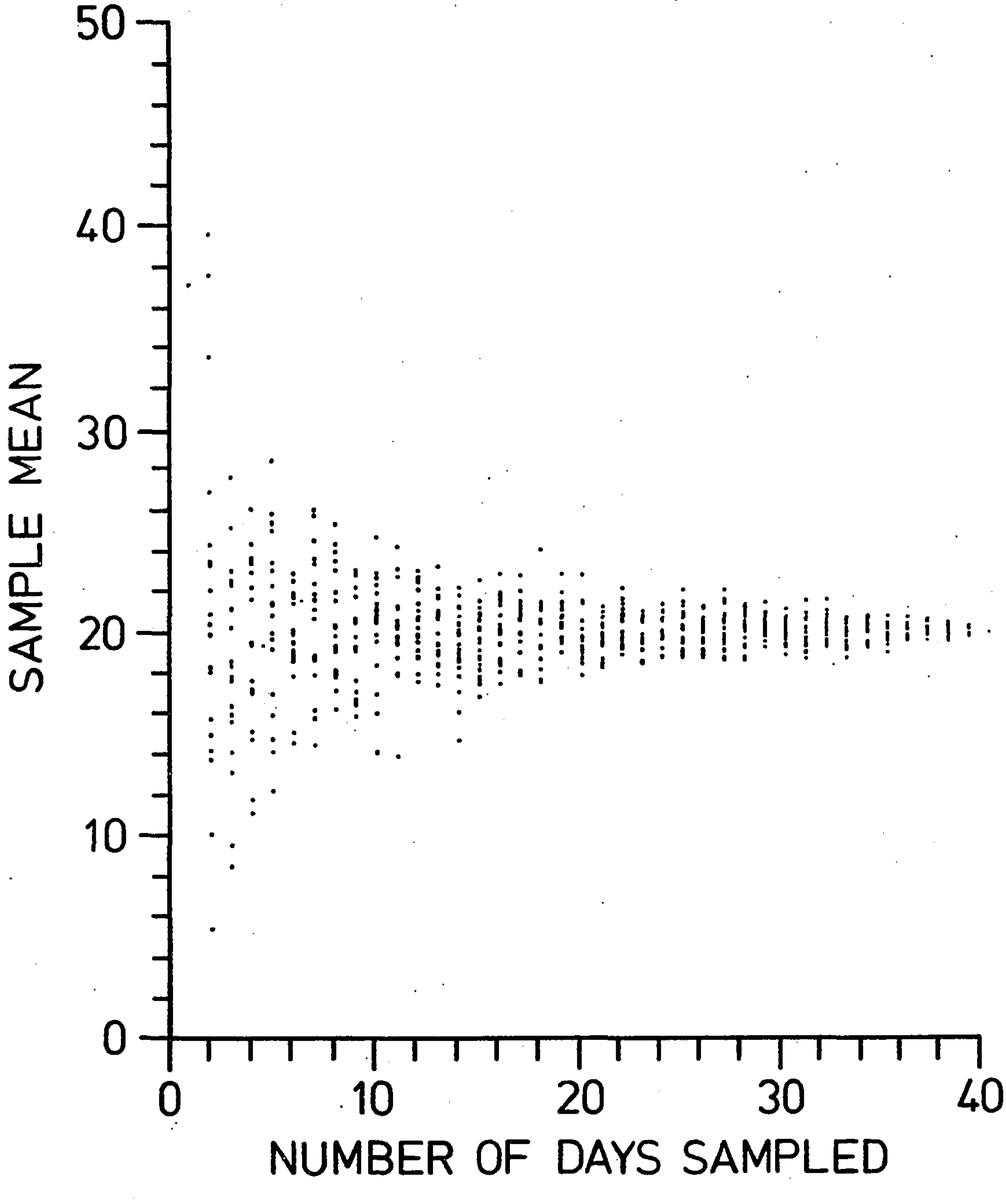
numb samp	mean	variance	cum proport	skewness	kurtosis
1	38.00*	0.00000	.00597	0.0000	0.0000
2	23.49*	0.24988	.08202	0.0036	0.0822
3	16.12*	60.88733	.06806	-0.0409	0.0966
4	18.59	58.47407	.10842	0.0385	0.2988
5	19.38	26.07786	.17974	-0.0597	0.6929
6	21.12	50.71992	.16204	-0.0143	0.5453
7	20.52	54.05957	.19725	-0.1237	0.4984
8	17.95*	84.00241	.18046	0.0877	0.3717
9	17.12*	45.68141	.24376	0.0422	0.8473
10	19.29	63.54867	.25644	-0.0393	0.5878
11	19.51	66.30579	.27188	0.1558	0.6804
12	19.67	58.07852	.33908	0.0521	0.7220
13	20.47	79.83409	.27231	0.0855	0.6518
14	19.66	75.25538	.34554	0.0265	0.6345
15	18.77	59.47541	.38909	0.0200	1.0435
16	21.51	64.21320	.39920	-0.2292	1.1093
17	19.20	70.43275	.40189	0.1234	1.0958
18	22.26*	67.87337	.42936	-0.2064	1.1234
19	22.16*	51.76008	.49345	-0.1243	1.6139
20	18.89	66.39848	.48403	-0.0934	1.2141
21	19.50	77.80145	.45518	0.1436	1.1945
22	19.66	66.46213	.54902	0.1003	1.3526
23	19.93	62.40416	.60556	0.1101	1.4707
24	21.54*	73.10823	.51822	-0.0983	1.5021
25	20.76	79.03404	.55729	-0.1022	1.2859
26	19.22	59.90459	.70187	0.1155	1.7557
27	20.76	59.48333	.72386	-0.0873	1.7818
28	18.99	65.73619	.70558	0.0363	1.6982
29	19.56	60.67577	.74848	0.0106	2.0173
30	19.60	68.05205	.73164	0.0133	1.8173
31	20.63	62.12874	.80069	-0.2343	2.1093
32	19.77	75.76431	.74350	0.1160	1.6746
33	19.45	62.24505	.83405	0.1327	2.2844
34	20.18	71.86739	.81507	0.0300	1.8906
35	20.02	77.48796	.79196	0.0129	1.8354
36	20.68	72.10738	.84455	-0.0746	2.0606
37	19.95	72.08089	.88105	0.1158	2.0674
38	19.98	69.49659	.91603	-0.0037	2.2552
39	19.81	68.08844	.94673	0.0801	2.4126
40	20.06	68.47686	.97356	0.0268	2.4174

* value exceeds or falls below the approximate 95% confidence interval on the true mean, 18 - 22.

does not fall within the approximate 95% interval for an average category. Three additional series (those with 9, 18, and 24 randomly sampled days) also fall outside the average limits (two being below and the other above the interval). As with the empirical data, random samples taken at either tail of the distribution tend to weigh the time density away from the central mass of the distribution. As the number of randomly selected days increases, the spread of $\cdot\bar{t}_j$'s decreased and they become clustered about the population mean, $\bar{t}$, with fewer outliers (Fig. 18). As with the chinook salmon data, the S^2 and a_3 values have broad fluctuations with the changing sample sizes. The fourth moment, a_4, approaches normality, but truncation of the data prevents it from reaching the value $a_4 = 3$, for a normal curve. It is important to note that with truncation of the distribution the mean time density remains relatively unchanged (20.06 to 19.98). This conservation is due to the symmetry of the distribution; however, there appears to be an under estimation of the dispersion of the distribution. The variance is calculated at $S^2 = 68.5$ rather than the variance of 81. This may be expected from a truncated data set.

A series of random samples taken from a simulated "late" migration ($S^2 = 4$) are presented in Table 10 with $j = 1, 2, \cdots 40$. In this particular series, only five (5) of the forty series have mean time densities outside the "average" category. Those five outliers all occur when seven or fewer days are randomly sampled ($j \leq 7$). All but one of the examples falls below the "average" time density. This is due to sampling at the tails of the distribution where no catch is reported (i.e. $P_t = 0$), and $g_t = 0$ for that time interval. The spread of the sample means for the possible combinations ($_mC_j$) about the population

Figure 18. Twenty (20) random combinations for each $\cdot\bar{t}_j$ as j = 1, 2 ··· 40 for the normal distribution (mean = 19.98, variance = 81).



50
40
30
20
10
0
SAMPLE MEAN
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Table 10. Estimates of the mean, variance, skewness and kurtosis, and the actual proportion sampled for a single sample of a variable number of days, j (j = 1, 2, ··· 40) from the normal (N(19.98, 4)).

numb samp	mean	variance	cum proport	skewness	kurtosis
1	21.00	0.00000	.17515	0.0000	0.0000
2	12.00*	0.00000	.00007	94.9039	129328308.0000
3	11.00*	0.00028	.00001	0.0116	15.9889
4	16.67*	0.62973	.07700	-0.1682	0.4773
5	25.62*	5.95095	.00228	-0.0121	0.0679
6	21.52	3.26838	.12918	-0.4095	1.5648
7	16.00*	1.99212	.03024	0.1935	1.5690
8	20.37	3.49256	.36335	-0.0033	0.7635
9	19.25	1.70962	.26533	-0.2942	0.8006
10	20.66	3.18983	.36283	-0.0654	0.8254
11	19.52	3.00374	.52826	0.2418	1.8193
12	19.73	16.98001	.05670	0.0050	0.0616
13	20.92	1.35168	.44738	0.6890	2.3911
14	19.72	3.89044	.33322	-0.1335	0.8645
15	20.08	3.32999	.59900	-0.7475	2.2338
16	20.57	7.79787	.28585	-0.1753	0.4979
17	21.00	6.59842	.26107	-0.2343	0.6505
18	20.02	1.55487	.57163	0.2590	6.2520
19	21.90	1.17698	.39431	0.0606	3.6855
20	20.80	4.25809	.48645	-0.1489	1.3616
21	20.51	3.57914	.53882	-0.1636	2.0647
22	20.12	2.29950	.82445	0.2859	3.1057
23	19.88	4.90713	.57758	0.2780	1.1181
24	20.09	6.88213	.34722	-0.0992	0.6199
25	20.03	7.55786	.43641	0.0042	0.6444
26	19.60	3.06675	.47972	-0.5733	1.7658
27	20.24	4.34853	.81397	-0.1752	2.2146
28	20.17	3.68644	.72929	0.3128	2.2400
29	20.38	4.77664	.52247	-0.3954	1.4691
30	20.05	3.50806	.81165	-0.1444	3.0669
31	20.02	3.47318	.81099	-0.2549	2.9969
32	20.07	3.27808	.90774	-0.1497	3.3317
33	19.82	2.97020	.89797	-0.0645	3.0541
34	19.99	3.90745	.99729	0.0275	2.8815
35	19.70	3.91351	.88022	0.2418	3.0359
36	20.02	4.19524	.67363	0.0108	2.0491
37	20.09	3.64755	.97239	0.0811	3.0274
38	19.77	3.60876	.93621	0.0491	3.2335
39	19.98	3.99584	.99993	0.0036	2.9886
40	19.98	4.00000	1.00000	0.0000	3.0000

* value exceeds or falls below approximate 95% confidence interval on the true mean; 18 - 22.

mean of 19.98 is broad (Fig. 19). Values for the mean are initially more variable for a late migration than an average one; however, once about 10 days have been sampled, the late migration has more conservative values (Fig. 20). The variance values show far more conservation for a narrow dispersion than for the broader variance (Fig. 21). The values for the moments a_3 and a_4 oscillate more radically with changing sample size for fast migrations as compared to the average or early migrations (Figures 22 & 23, respectively). It should be noted that the relative magnitude of the kurtosis values mean little. What is important is if the a_4 values are above or below the expected, $a_4 = 3$.

The biased estimate of the MSE for multiple repetitions of catch data for the normal (N(19.98, 81)) (Table 11) is very similar to that for chinook presented in Table 6, above. The approximate 95% confidence interval based on the biased MSE also is similar in shape (Fig. 24). On the other hand, the MSE of a biased estimate for a late migration initailly is broader than either an early or average migration (Table 12). However, it rapidly becomes more conservative (Fig. 25) and the confidence interval for the late migration lies within the interval for an average or early migration when there are as few as 9 or 10 randomly sampled days (Fig. 26). On the other hand, the variance estimates for an early migration based on catch proportions from the normal (N(19.98, 81)) remain much larger as compared to variance estimates for a late migration (N (19.98, 4)) (Table 13).

The slope of the cumulative (performance) curve is related to the variance of the time distribution of catch. The wider variances show a shallower slope as compared to the steep slope of a small variance (Fig. 27).

Figure 19. Twenty (20) random combinations for each $\cdot\bar{t}_j$ as $j = 1, 2 \cdots 40$ from the normal distribution (mean = 19.98, variance = 4).

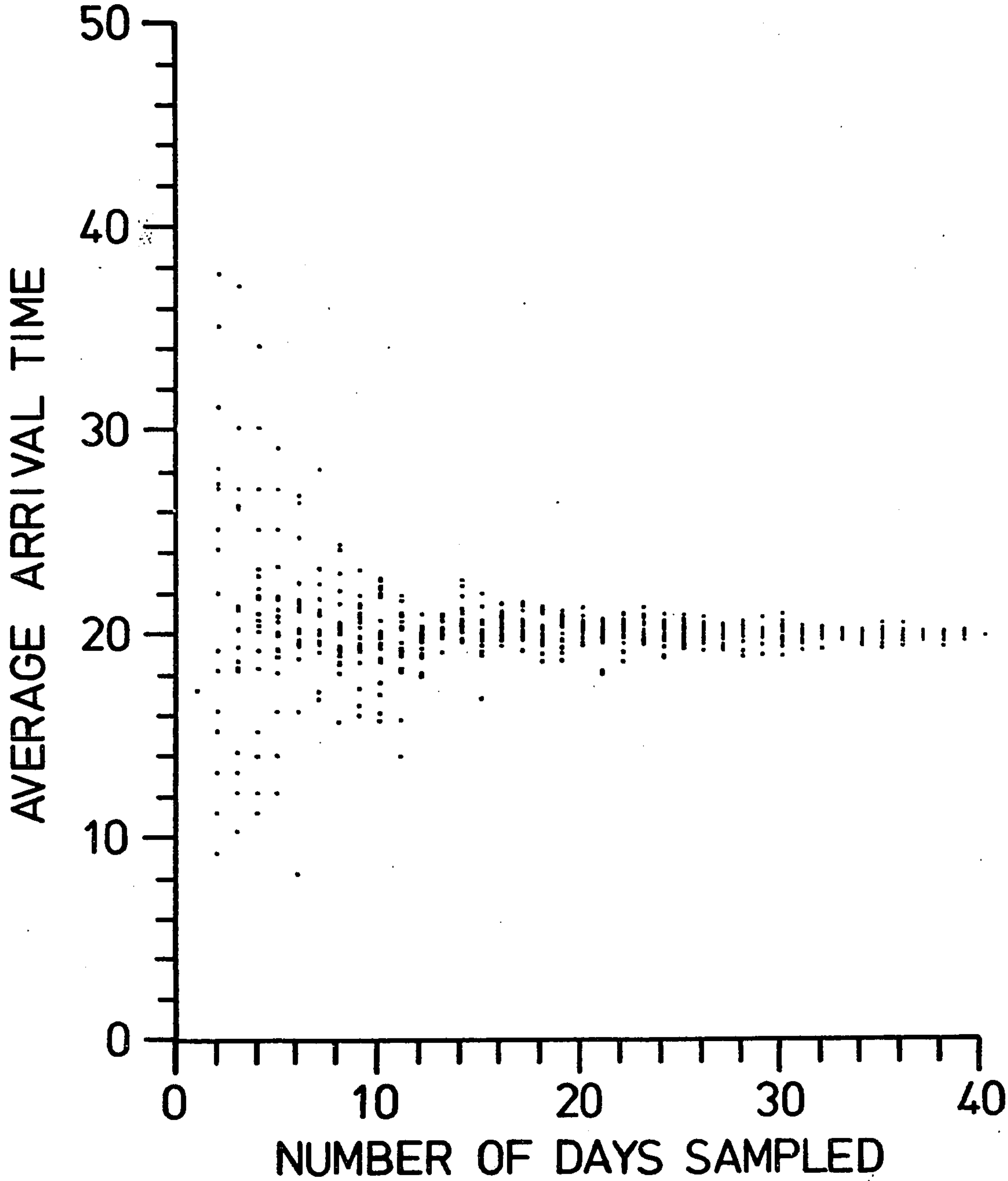

AVERAGE ARRIVAL TIME
50
40
30
20
10
0
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 20. Sample means, $\bar{t}_{\cdot j}$ (j = 1, 2 ··· 40) from sampled data sets for the normal distribution with a mean of 19.98 and variances of 4 and 81.

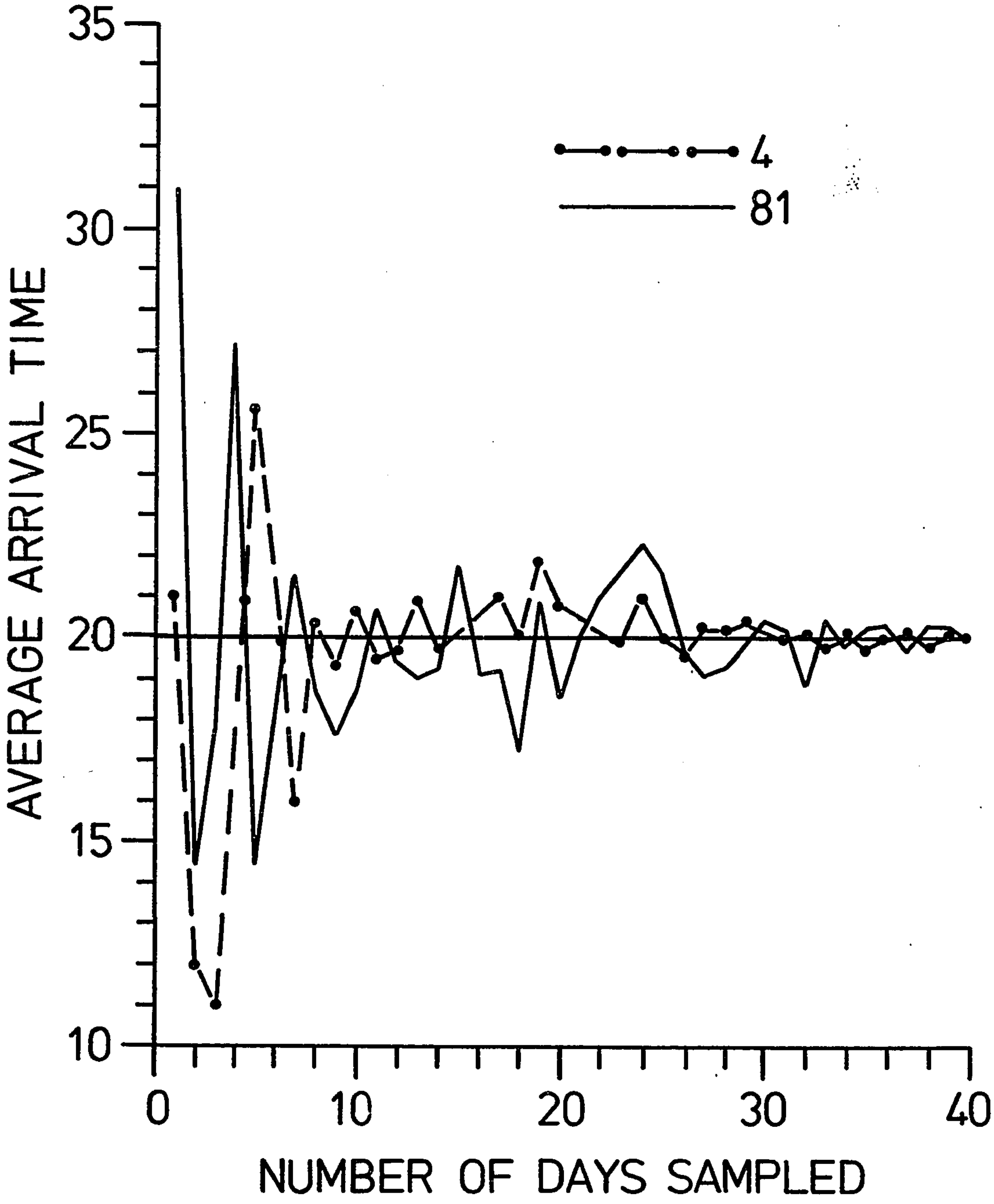
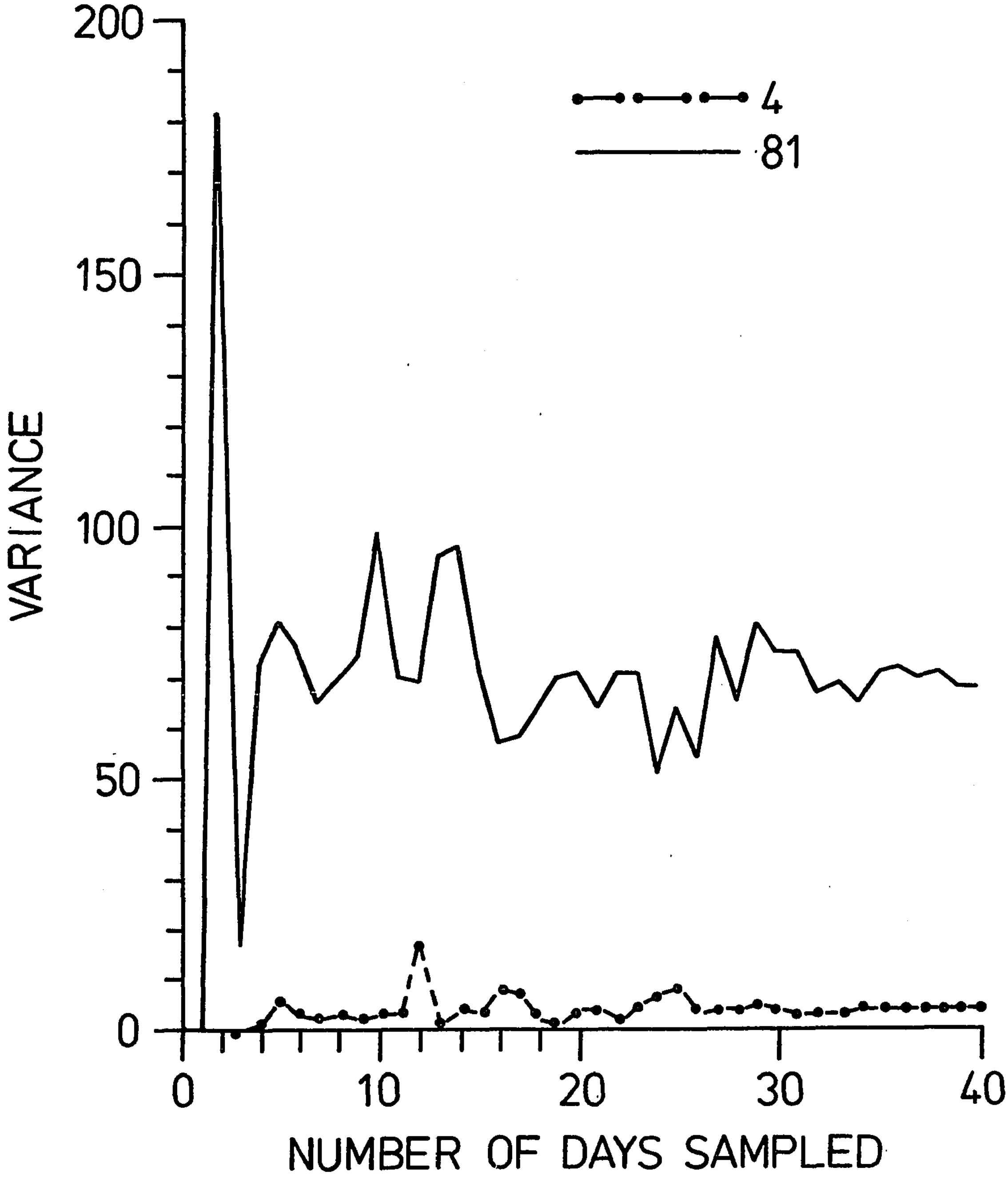
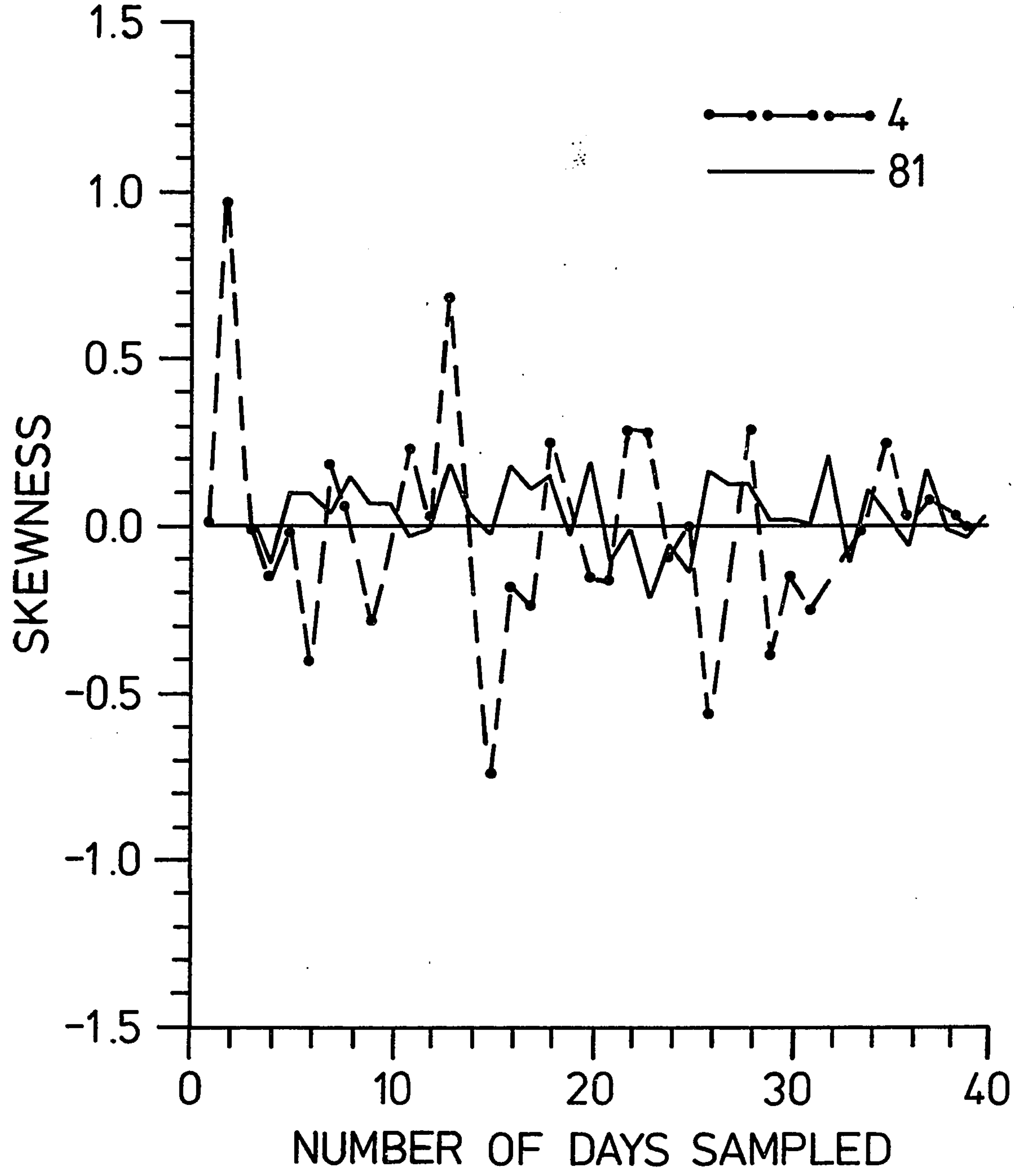

35
30
25
20
15
10
AVERAGE ARRIVAL TIME
0
10
20
30
40
NUMBER OF DAYS SAMPLED
4
81

Figure 21. Sample variances, $\cdot S_j^2$ where j = 1, 2 ··· 40) from sampled data sets of the normal distribution with a population mean of 19.98 and variances of 4 and 81.



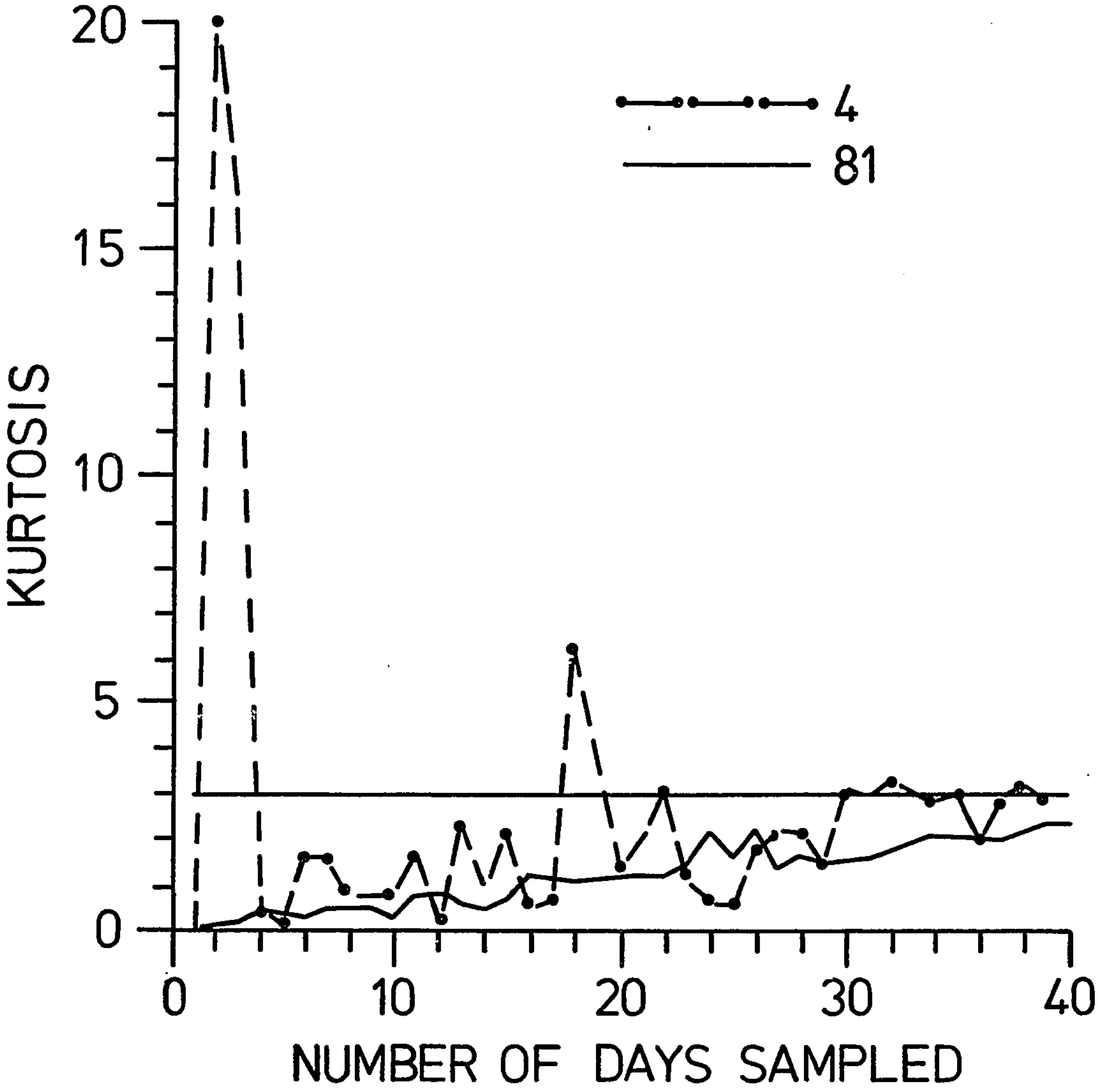
200
150
100
50
0
VARIANCE
4
81
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 22. Third moments (a_3) about the mean from sampled data sets j (j = 1, 2 ··· 40) of the normal distribution with a mean of 19.98 and varying variances of 4 and 81.



1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
SKEWNESS
4
81
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Figure 23. Fourth moments (a_4) about the mean from sampled data sets j (j = 1, 2 ... 40) of the normal distribution with a mean of 19.98 and varying variances of 4 and 81.

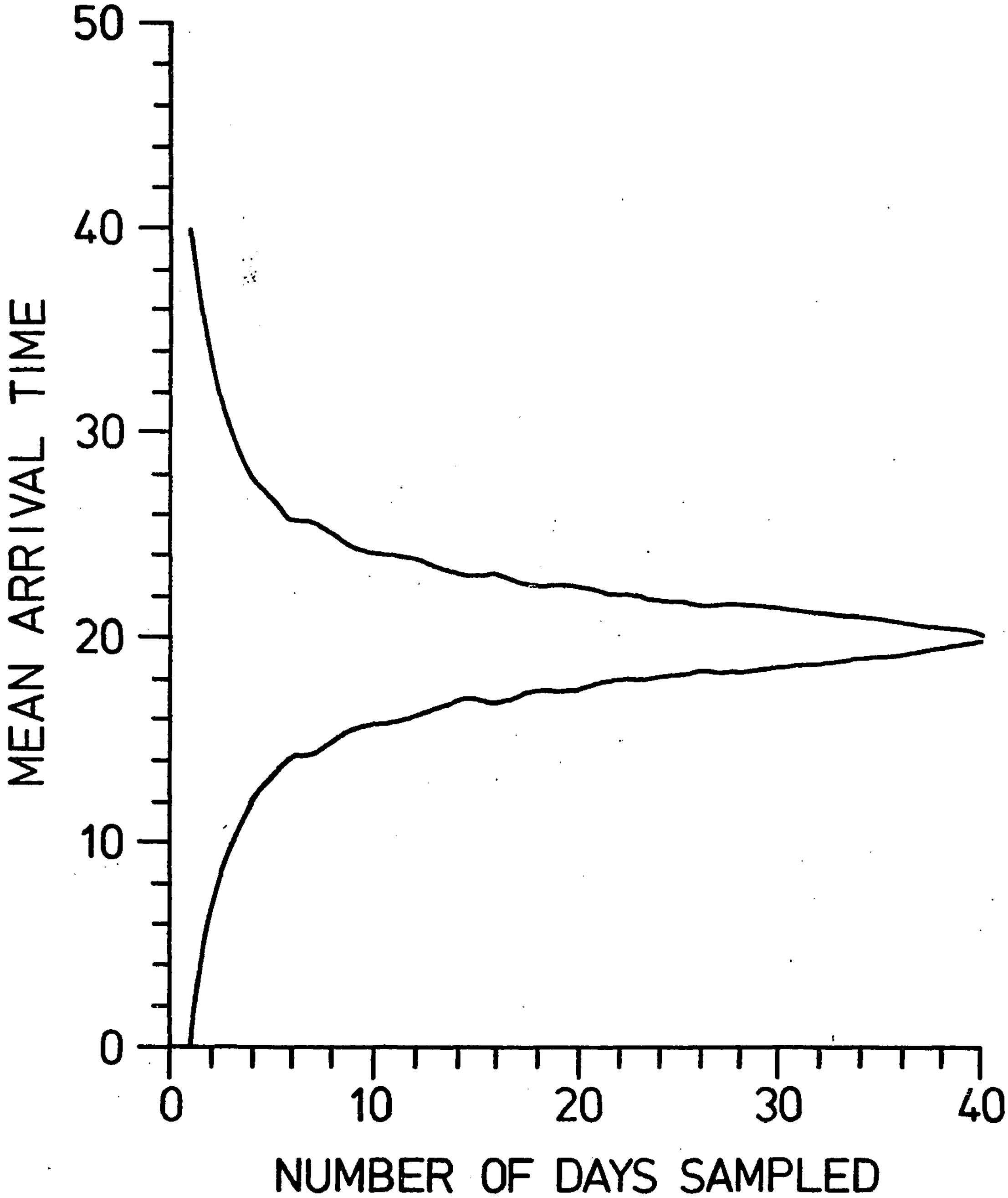


KURTOSIS
NUMBER OF DAYS SAMPLED
4
81
0
5
10
15
20
0
10
20
30
40

Table 11. The average time of arrival ($\cdot\bar{t}_j$), cumulative proportions, bias, mean square error (MSE), and the approximate 95% confidence interval ($\bar{t} \pm 2[MSE]^{1/2}$) as sampled from the normal (N(19.98, 81)) to simulate 300 years of catch data for each number of days sampled.

numb sampl days	aver mean	cum proport	bias	MSE	confidence interval lower	confidence interval upper
1	19.817	0.02421	-0.163	135.510	0.000	40.000
2	20.397	0.04637	0.417	46.000	6.415	33.545
3	20.192	0.06971	0.212	28.554	9.293	30.667
4	19.768	0.10019	-0.212	15.592	12.083	27.877
5	20.394	0.12064	0.414	11.918	13.075	26.885
6	20.070	0.14786	0.090	8.337	14.205	25.755
7	20.022	0.16848	0.042	7.920	14.352	25.608
8	20.115	0.19835	0.135	6.423	14.911	25.049
9	19.942	0.22283	-0.038	4.834	15.583	24.377
10	19.946	0.24360	-0.034	4.419	15.776	24.184
11	20.028	0.27075	0.048	4.214	15.875	24.085
12	20.244	0.29268	0.264	3.663	16.152	23.808
13	20.074	0.31754	0.094	2.916	16.565	23.395
14	20.047	0.34462	0.067	2.356	16.910	23.050
15	20.049	0.36913	0.069	2.360	16.908	23.052
16	19.979	0.38528	-0.001	2.556	16.782	23.178
17	20.140	0.40625	0.160	1.827	17.277	22.683
18	20.123	0.43839	0.143	1.659	17.404	22.556
19	20.104	0.46247	0.124	1.752	17.333	22.627
20	19.922	0.48421	-0.058	1.484	17.543	22.417
21	20.080	0.50748	0.100	1.195	17.794	22.166
22	20.049	0.53924	0.069	1.019	17.961	21.999
23	20.120	0.56094	0.140	1.031	17.949	22.011
24	20.039	0.58280	0.059	0.871	18.113	21.847
25	20.006	0.60807	0.026	0.826	18.163	21.797
26	20.132	0.63505	0.152	0.626	18.398	21.562
27	20.068	0.65905	0.088	0.700	18.307	21.653
28	20.039	0.68085	0.059	0.605	18.424	21.536
29	20.018	0.70815	0.038	0.564	18.478	21.482
30	20.073	0.72950	0.093	0.523	18.534	21.426
31	20.098	0.75524	0.118	0.386	18.738	21.222
32	20.042	0.77558	0.062	0.352	18.794	21.166
33	20.084	0.80616	0.104	0.280	18.921	21.039
34	20.051	0.82473	0.071	0.255	18.971	20.989
35	20.071	0.85237	0.091	0.197	19.092	20.868
36	20.075	0.87690	0.095	0.133	19.252	20.708
37	20.029	0.90178	0.049	0.107	19.326	20.634
38	20.066	0.92558	0.086	0.078	19.421	20.539
39	20.065	0.94871	0.085	0.040	19.579	20.381
40	20.060	0.97362	0.080	0.006	19.820	20.140

Figure 24. The approximate 95% confidence interval for the normal (N(19.98,81) based on the biased estimate of the MSE.

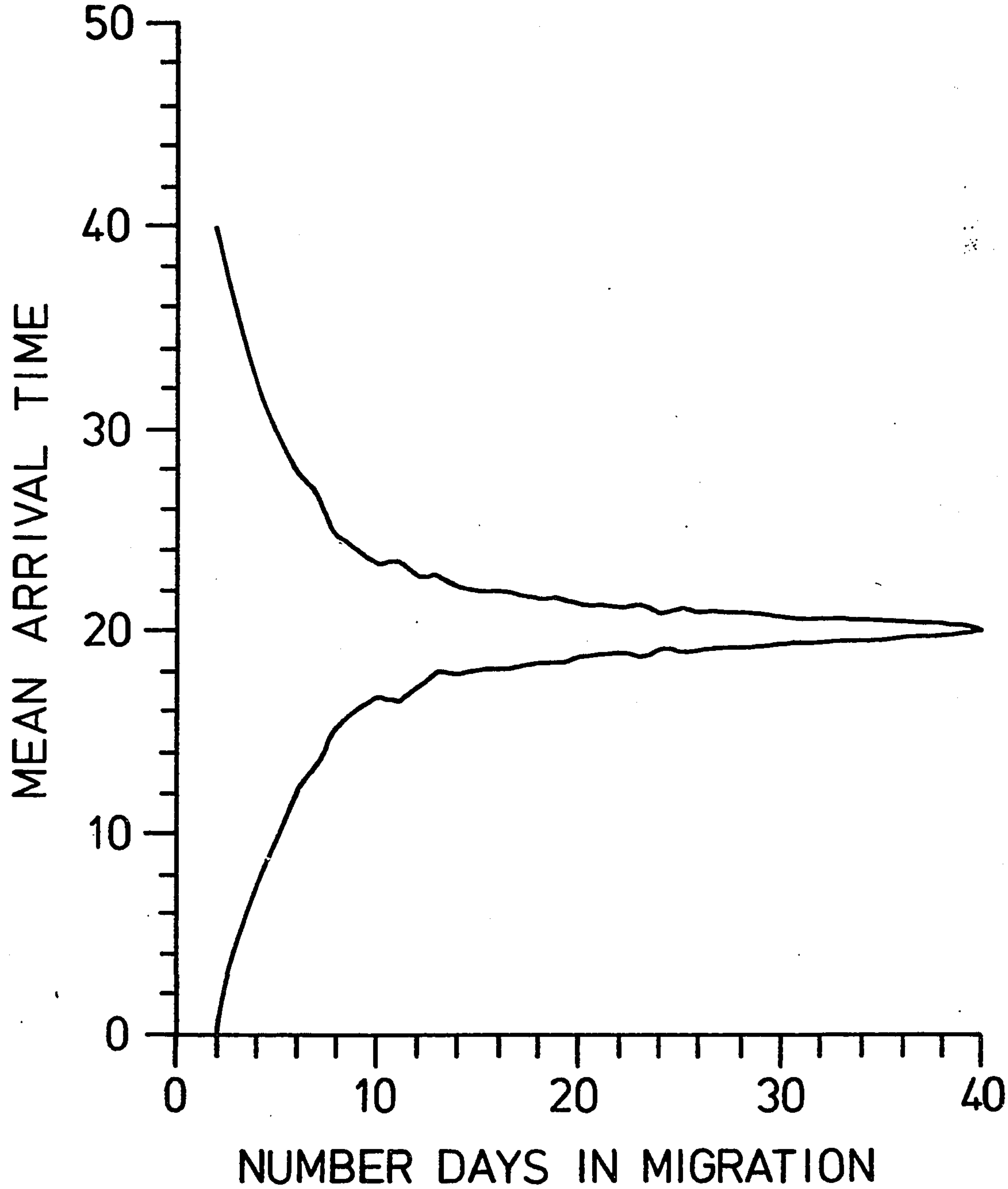


50
40
30
20
10
0
MEAN ARRIVAL TIME
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Table 12. The average time of arrival ($\cdot\bar{t}_j$), cumulative proportions, bias, mean square error (MSE), and an approximate 95% confidence interval ($\bar{t} \pm 2[MSE]^{1/2}$) as sampled from the normal (N(19.98, 4)) to simulate 300 years of catch data for each number of days sampled.

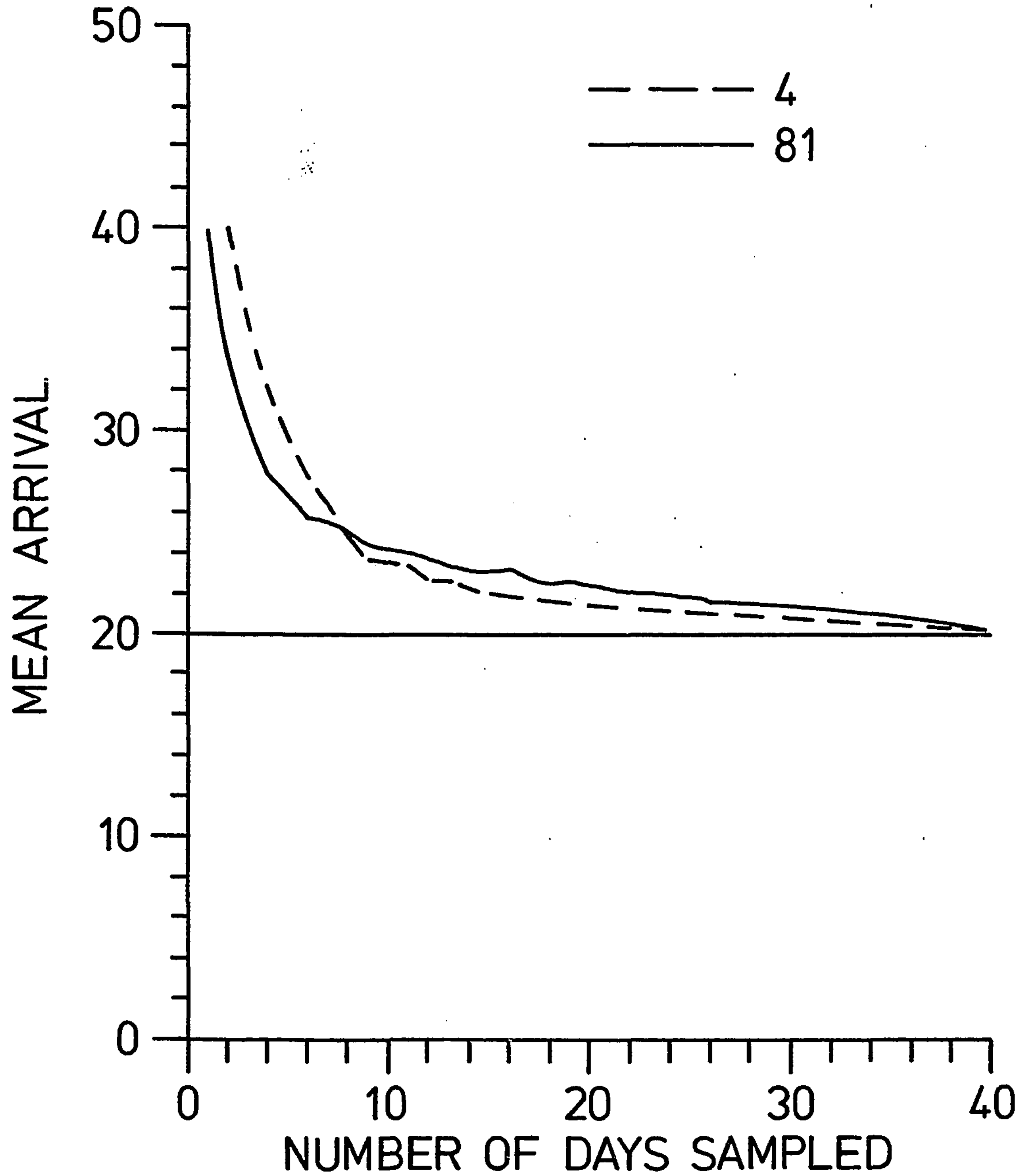
numb sampl days	aver mean	cum proport	bias	MSE	confidence interval lower	upper
1	9.447	0.02338	-10.533	216.165	0.000	40.000
2	14.234	0.05238	- 5.746	129.354	0.000	40.000
3	17.919	0.07775	- 2.061	57.924	4.758	35.200
4	19.355	0.10506	- 0.625	37.072	7.803	32.157
5	19.215	0.12604	- 0.795	24.088	10.164	29.796
6	19.791	0.13631	- 0.189	15.417	12.127	27.833
7	19.740	0.16580	- 0.240	11.208	13.284	26.676
8	19.734	0.21185	- 0.246	5.613	15.242	24.718
9	20.118	0.22820	0.138	4.058	15.951	24.001
10	19.967	0.24806	- 0.013	2.671	16.711	23.249
11	19.834	0.27811	- 0.146	3.083	16.468	23.492
12	19.937	0.29533	- 0.043	1.863	17.250	22.710
13	19.820	0.31801	- 0.160	2.002	17.98	22.810
14	19.994	0.36988	0.014	1.157	17.829	22.131
15	19.981	0.38400	0.001	0.921	18.061	21.899
16	20.008	0.40518	0.028	0.835	18.046	21.914
17	19.954	0.44326	- 0.026	0.790	18.202	21.758
18	19.921	0.45788	- 0.059	0.625	18.399	21.561
19	19.998	0.47476	0.018	0.653	18.364	21.596
20	19.950	0.51838	- 0.030	0.405	18.707	21.252
21	20.054	0.51009	0.074	0.407	18.704	21.256
22	19.972	0.56110	- 0.008	0.305	18.875	21.085
23	19.969	0.57167	- 0.011	0.396	18.721	21.239
24	19.976	0.61294	- 0.004	0.207	19.070	21.890
25	19.950	0.62395	- 0.030	0.297	18.890	21.070
26	19.968	0.65003	- 0.012	0.226	19.030	20.930
27	19.979	0.66842	- 0.001	0.199	19.080	20.870
28	19.964	0.70090	- 0.016	0.184	19.122	20.840
29	19.955	0.72335	- 0.025	0.162	19.175	20.785
30	19.968	0.75974	- 0.012	0.116	19.299	20.661
31	19.974	0.77372	- 0.006	0.095	19.364	20.596
32	19.985	0.79482	0.005	0.093	19.370	20.590
33	19.994	0.82195	0.014	0.075	19.432	20.528
34	19.966	0.84945	- 0.014	0.069	19.455	20.505
35	19.956	0.88141	- 0.024	0.049	19.537	20.423
36	19.992	0.89636	0.012	0.035	19.606	20.354
37	19.958	0.92772	- 0.022	0.029	19.639	20.321
38	19.982	0.94210	0.002	0.023	19.677	20.280
39	19.983	0.97479	0.003	0.009	19.790	20.170
40	19.980	1.00000	0.000	0.000	19.980	19.980

Figure 25. The approximate 95% confidence interval for the normal (N(19.98,4) based on the biased estimate of the MSE.



MEAN ARRIVAL TIME
NUMBER DAYS IN MIGRATION
0
10
20
30
40
50

Figure 26. Comparison of the upper bounds for the 95% confidence intervals from the biased estimate of the MSE for the normal (mean = 19.98) with varying variances of 4 and 81.



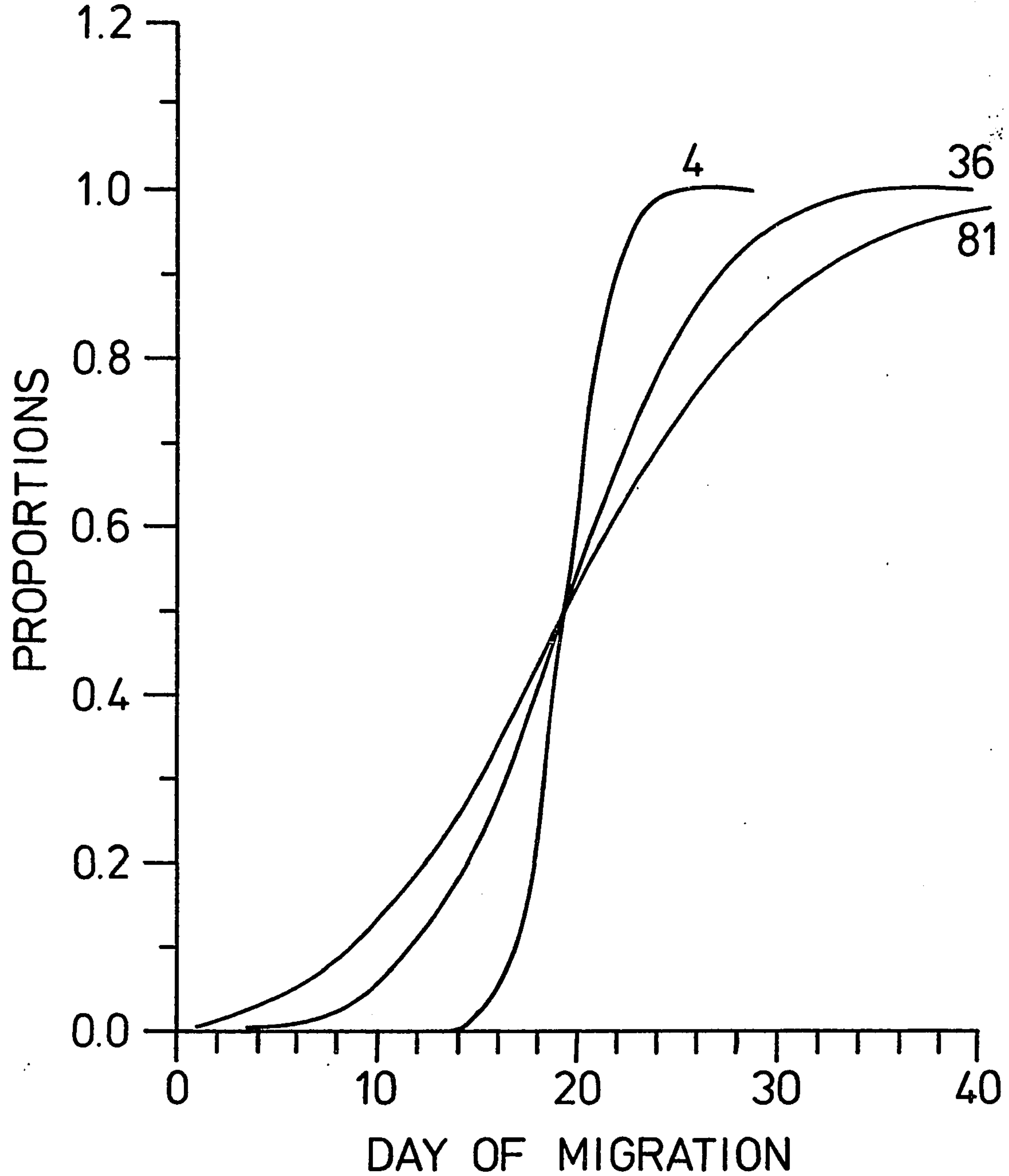
50
40
30
20
10
0
MEAN ARRIVAL
4
81
0
10
20
30
40
NUMBER OF DAYS SAMPLED

Table 13. The error bounds for the normal distributions with a mean = 19.98, and varying variances of 81 and 4, with the estimated arrival times calculated from randomly sampled days, j (j = 1, 2, ··· 40), approximate 95% confidence intervals and the corresponding variance estimates (VE).

numb days sampl	81				4			
	mean	95% L	95% U	VE	mean	95% L	95% U	VE
1	38.00*	5.83	34.13	50.03	21.00	13.26	26.70	11.28
2	23.49	10.11	29.85	24.37	12.00*	15.29	24.67	5.50
3	16.12*	12.03	27.94	15.82	11.00*	16.20	23.76	3.57
4	18.59	13.18	26.78	11.55	16.68*	16.75	23.21	2.60
5	19.38	13.99	25.97	8.98	25.63*	17.13	22.83	2.03
6	21.12	14.59	25.37	7.27	21.53	17.42	22.54	1.64
7	20.52	15.06	24.90	6.05	16.00*	17.64	22.32	1.36
8	17.95	15.45	24.51	5.13	20.37	17.83	22.13	1.16
9	17.13	15.78	24.18	4.42	19.28	17.98	21.98	1.00
10	19.29	16.06	23.90	3.85	20.66	18.12	21.84	0.87
11	19.51	16.30	23.66	3.38	19.53	18.23	21.73	0.76
12	19.67	16.52	23.44	2.99	19.73	18.34	21.62	0.68
13	20.47	16.72	23.24	2.66	20.92	18.43	21.45	0.60
14	19.66	16.89	23.07	2.38	19.72	18.51	21.45	0.54
15	18.77	17.06	22.90	2.14	20.08	18.59	21.37	0.48
16	21.51	17.21	22.75	1.92	20.57	18.66	21.30	0.43
17	19.20	17.34	22.62	1.74	21.01	18.73	21.23	0.39
18	22.27*	17.48	22.48	1.57	20.02	18.79	21.17	0.35
19	22.16*	17.60	22.36	1.42	21.91	18.85	21.11	0.32
20	18.89	17.72	22.25	1.28	20.81	18.90	21.06	0.29
21	19.50	17.83	22.14	1.16	20.51	18.96	21.00	0.26
22	19.66	17.93	22.03	1.05	20.12	19.01	20.95	0.24
23	19.93	18.03	21.93	0.95	19.89	19.06	20.91	0.21
24	21.54	18.13	21.83	0.86	20.10	19.10	20.86	0.19
25	20.76	18.23	21.74	0.77	20.03	19.15	20.81	0.17
26	19.23	18.32	21.64	0.69	19.61	19.19	20.77	0.16
27	20.76	18.41	21.55	0.62	20.25	19.23	20.73	0.14
28	18.99	18.50	21.46	0.55	20.17	19.28	20.68	0.12
29	19.57	18.59	21.38	0.49	20.39	19.32	20.64	0.11
30	19.60	18.67	21.29	0.43	20.06	19.36	20.60	0.10
31	20.63	18.76	21.20	0.37	20.03	19.40	20.56	0.08
32	19.78	18.85	21.11	0.32	20.09	19.44	20.52	0.07
33	19.45	18.94	21.02	0.27	19.83	19.49	20.46	0.06
34	20.18	19.03	20.94	0.23	19.99	19.53	20.43	0.05
35	20.02	19.12	20.84	0.18	19.71	19.57	20.39	0.04
36	20.68	19.23	20.74	0.14	20.02	19.62	20.34	0.03
37	19.95	19.34	20.63	0.10	20.09	19.67	20.29	0.02
38	19.98	19.46	20.50	0.07	19.77	19.73	20.23	0.02
39	19.81	19.62	20.34	0.03	19.98	19.81	20.15	0.01
40	19.98	19.98	19.98	0.00	19.98	19.98	19.98	0.00

* values that exceed or falls below the 95% confidence interval for the mean arrival time, 18 - 22.

Figure 27. The cumulative proportions (performance curves) for the simulation calculations from the normal distribution (mean = 19.98, variances = 4, 36 & 81).


1.2
1.0
0.8
0.6
0.4
0.2
0.0
PROPORTIONS
4
36
81
0
10
20
30
40
DAY OF MIGRATION

~~Statistics Based on CPUE Data for Chinook Salmon from the Yukon River Delta, 1961-1982~~

A normal distribution was developed for each year from the reported mean and variance of the chinook of the lower Yukon River delta from 1961-1982. Each distribution was then sampled randomly for the number of days j (j = 1, 2, ··· 40) represented by the true number of openers allowed from June 1 through July 10, inclusive, for each of the respective years studied (Table 14). The number of openers (or "fishing days") was calculated by taking the cumulative hours fished between June 1 and July 10 (inclusive) for each year and dividing the total by twenty-four (rounding-off to the nearest day). The mean square error (MSE) and a confidence interval (approximately 95%) were calculated for each years' openers based on 300 repetitions for each of the j days.

Although the true migration and fishing may have extend beyond the end of July 10 (m = 40) the bulk of each migration (2.5 - 97.5 %) was expected to clear the harvest area by day 40 (Mundy 1982). The average empirical cumulative proportion of CPUE accounted for better than 95% of the reported catch by July 10 in 20 of the 22 years studied. During 1976 93.6% of the cumulative CPUE was recorded by day 40; however, in 1971 only 88.2% of the cumulative proportion of CPUE was obtained during the specified time span. In 1971 fishing began on day 11 (June 11) with an estimated arrival time on day 29.08 ("late"). Fishing, however, continued through the middle of August with 21% of the total catch reported from a single day on June 30. As a result, 1971 had the

Table 14. The number of openers (June 1 - July 10), the mean and variance for each year of CPUE data for chinook salmon (1961-1980) and the average mean, lower and upper limits of the approximate 95% confidence interval calculated from the biased MSE of the ratio estimator from 40 repetitions, and the biased MSE for the number of possible days randomly sampled.

year	number of openers	mean CPUE	mean sample	95% lower	95% upper	CPUE variance	MSE
1982	9	23.660	23.333	20.301	27.019	41.430	3.055
1981	10	14.420	15.286	10.177	18.663	54.080	4.348
1980	7	19.330	19.298	13.471	25.189	51.120	6.506
1979	10	16.560	17.694	10.808	22.312	86.790	6.370
1978	10	20.480	20.646	16.210	24.750	66.830	4.385
1977	9	25.540	25.432	22.111	28.969	42.050	3.160
1976	10	28.370	27.296	22.261	34.479	54.000	6.817
1975	10	24.690	24.157	21.615	27.765	45.910	2.626
1974	14	16.400	17.036	12.880	19.920	87.290	3.297
1973	11	19.410	19.511	16.435	22.385	67.500	2.474
1972	9	24.170	23.180	20.808	27.532	47.880	3.060
1971	9	29.080	27.170	22.487	35.673	98.150	7.404
1970	12	20.970	20.976	17.461	24.479	45.670	3.280
1969	8	15.020	15.889	9.289	20.751	61.070	6.344
1968	16	19.910	20.188	17.763	22.057	46.450	1.215
1967	15	13.730	14.242	10.942	16.518	51.750	2.188
1966	12	22.230	21.988	19.587	24.873	26.790	1.966
1965	16	20.250	20.023	17.793	22.707	31.280	1.682
1964	14	26.840	26.481	24.379	29.301	25.250	1.688
1963	18	18.950	18.808	16.725	21.175	54.930	1.331
1962	17	22.260	22.370	19.375	25.145	36.490	2.336
1961	20	17.640	17.640	15.582	19.698	52.160	1.084

broadest recorded variance (S^2 = 98.15) of the 22 years of available data.

The MSE was largest in 1971 as compared to all other years. The other large MSE values occurred during years when the number of days fished fell below 11, and the variances were greater than 54.0. The most conservative confidence intervals for an estimated arrival time were made prior to 1969 when the number of openers exceeded 11 days out of the possible 40. In those cases, the estimated arrival times fell discretely within one of the three categories of "early", "average", or "late". However, as the number of days fished declined after 1968, there was a loss of confidence in the estimates. Based on the MSE calculations and the corresponding approximate 95% confidence interval, an early estimate also fell within an average category based on the grand mean for all years as mentioned above (18 - 22). This overlapping of categories extended to an average estimate being either early, average or late, and a late estimate overlapping an average domain.

In order to better understand the component performances based on empirical data, the average empirical proportions of CPUE and empirical daily proportions of CPUE for one of each category were tested. The average empirical distribution of CPUE for the 22 years in Table 15 showed a slightly earlier arrival time of 19.788 as compared to that of catch with the arrival time of 19.98 (Table 5). A broader variance (S^2 = 53.403) was also calculated for the CPUE as compared to S^2 = 48.32 for the average catch data. The MSE values for the average empirical proportion of catch (Table 5) were slightly more conservative when compared to the average proportion of CPUE for the same years. Similar

Table 15. The average arrival time ($\cdot\bar{t}_j$) from a number of randomly sampled days, j (j = 1, 2, ··· 40), the approximate 95% confidence interval from the biased MSE, the MSE (based on 300 repetitions for each j), bias, and the average cumulative proportions from the empirical average proportions of CPUE of chinook salmon from June 1 through July 10 for 1961-1980, with the mean = 19.788 and variance = 53.403.

numb of days	mean	95% lower	95% upper	MSE	bias	cumulat proport
1	20.047	-2.804	42.380	127.598	0.2587	0.02588
2	19.562	6.620	32.956	43.346	-0.2264	0.04947
3	19.340	9.624	29.952	25.827	-0.4481	0.07482
4	19.370	11.987	27.589	15.214	-0.4176	0.09840
5	19.697	12.879	26.697	11.932	-0.0912	0.12367
6	19.806	13.512	26.064	9.847	0.0183	0.14295
7	19.520	14.534	25.042	6.901	-0.2680	0.17565
8	19.681	15.092	24.484	5.513	-0.1070	0.19966
9	19.736	15.344	24.232	4.937	-0.0525	0.22277
10	19.597	15.727	23.849	4.123	-0.1909	0.24691
11	19.774	15.915	23.661	3.749	-0.0138	0.26834
12	19.742	15.974	23.602	3.636	-0.0460	0.29361
13	19.870	16.327	23.249	2.995	0.0818	0.32109
14	19.593	16.413	23.163	2.848	-0.1952	0.34569
15	19.774	16.731	22.845	2.336	-0.0140	0.37419
16	19.842	16.928	22.648	2.045	0.0537	0.39840
17	19.699	17.128	22.448	1.769	-0.0891	0.41791
18	19.699	17.062	22.514	1.857	-0.0888	0.44072
19	19.649	17.257	22.319	1.602	-0.1387	0.47235
20	19.688	17.372	22.204	1.459	-0.1004	0.49132
21	19.899	17.386	22.190	1.442	0.1106	0.51668
22	19.704	17.599	21.977	1.198	-0.0840	0.53823
23	19.791	17.776	21.800	1.012	0.0028	0.56967
24	19.741	17.844	21.732	0.945	-0.0474	0.58953
25	19.818	18.043	21.533	0.761	0.0300	0.61909
26	19.748	18.097	21.479	0.715	-0.0403	0.63968
27	19.794	18.159	21.417	0.664	0.0056	0.66702
28	19.832	18.180	21.396	0.646	0.0443	0.69159
29	19.750	18.305	21.271	0.550	-0.0378	0.71345
30	19.776	18.426	21.150	0.464	-0.0119	0.74532
31	19.743	18.543	21.033	0.387	-0.0446	0.76621
32	19.805	18.624	20.952	0.339	0.0174	0.79240
33	19.841	18.690	20.886	0.302	0.0531	0.81951
34	19.772	18.821	20.755	0.234	-0.0156	0.83632
35	19.790	18.907	20.669	0.194	0.0020	0.86118
36	19.768	19.037	20.539	0.141	-0.0203	0.88313
37	19.800	19.073	20.503	0.128	0.0124	0.91323
38	19.780	19.248	20.328	0.073	-0.0075	0.93853
39	19.780	19.397	20.179	0.038	-0.0083	0.95949
40	19.788	19.788	19.788	0.000	0.0001	0.98720

results were obtained with the variance of the ratio estimator between the catch and effort data (Table 16).

An annual estimate based on CPUE data for each of the three categories was tested. One example from each of the categories (i.e. "early", "average" and "late") was taken from Table 14. The year 1967 was obviously an "early" migration with an estimated arrival time of 13.73, 1970 an "average" ($\cdot\bar{t}_j$ = 20.97), and 1976 a "late" run with 28.37 as the estimated average arrival time. The daily proportions for each year served as the pdf with the migration occuring from June 1 through July 10. As a result, the means were recalculated for each category based on the proportions of CPUE inclusive of those dates, and the MSE calculated.

Initially, the biased estimate of the MSE for all three categories was large with the more conservative values for the early (Table 17), followed by the average (Table 18) and late (Table 19), respectively. However, as demonstrated by the simulations with the normal, the MSE for a late migration fell below the other two categories when as few as 6 days were randomly sampled. However, almost a quarter of the migration was sampled before the confidence interval fell outside the range for the average domain based on the grand mean of the population (18 - 22). The other two categories maintained large MSE values until 50% of the number of migratory days were sampled.

The daily proportions of catch for each of the three years outlined above (Table 20) were used to compared estimate performances to those of effort (CPUE). The MSE values for the daily proportions of catch and effort were about the same for 1969 ("early") when as little as 12.5 - 30.5 % of the distribution was sampled. However, as a larger fraction

Table 16. The bound on the error of estimation about the average arrival time for the empirical average daily proportions of CPUE (from Table 2, Mundy 1982) (mean = 19.79, variance = 53.40) with the lower and upper bounds and the variance estimator, $V(\cdot\bar{t}_j)$ for a single sample of a variable number of days j (j = 1, 2, ··· 40).

numb sample	mean	95 % lower	95 % upper	variance estimator
1	31.00*	5.53	35.05	50.85
2	9.82*	9.83	29.74	24.77
3	18.57	11.77	27.81	16.08
4	28.02*	12.94	26.64	11.73
5	12.91*	13.75	25.83	9.13
6	16.93*	14.35	25.22	7.39
7	20.73	14.83	24.75	6.15
8	18.04	15.22	24.36	5.22
9	17.38*	15.55	24.03	4.49
10	17.52*	15.83	23.74	3.91
11	20.94	16.08	23.50	3.43
12	18.39	16.30	23.28	3.04
13	17.35	16.50	23.08	2.71
14	19.08	16.68	22.90	2.42
15	21.65	16.84	22.74	2.17
16	19.11	16.99	22.59	1.96
17	19.13	17.13	22.44	1.76
18	17.49*	17.26	22.31	1.59
19	20.29	17.39	22.19	1.44
20	17.68*	17.50	22.07	1.30
21	20.20	17.61	21.96	1.18
22	20.96	17.72	21.85	1.07
23	21.60	17.83	21.75	0.96
24	21.68	17.92	21.65	0.87
25	20.91	18.02	21.56	0.78
26	19.69	18.11	21.46	0.70
27	19.31	18.20	21.37	0.63
28	19.31	18.29	21.28	0.56
29	20.09	18.38	21.19	0.50
30	19.89	18.47	21.11	0.44
31	19.89	18.56	21.02	0.38
32	18.82	18.65	20.93	0.33
33	20.17	18.74	20.84	0.28
34	19.59	18.83	20.75	0.23
35	19.65	18.93	20.65	0.19
36	20.13	19.03	20.55	0.15
37	19.29	19.14	20.44	0.11
38	20.13	19.26	20.31	0.07
39	20.17	19.42	20.15	0.03
40	19.79	19.79	19.79	0.00

* value exceeds or falls below the approximate 95% confidence level of the true mean, 18 - 22.

Table 17. Estimates of parameters from a late migration of chinook salmon (1976). The calculated mean (from a sample size of 300 repetitions), approximate 95% confidence interval, biased MSE of the ratio estimator, bias and average cumulative proportions for each of the randomly sampled days, j (j = 5, 6, ··· 25) from daily proportions of CPUE.

numb of days	mean	95% lower	95% upper	MSE	bias	cumulat proport
5	25.353	14.011	39.963	42.096	-1.6338	0.11229
6	26.624	18.775	35.199	16.861	-0.3631	0.14603
7	26.265	18.998	34.976	15.956	-0.7223	0.15959
8	26.670	20.637	33.337	10.082	-0.3168	0.18329
9	26.779	22.086	31.888	6.004	-0.2078	0.21279
10	26.932	21.917	32.057	6.426	-0.0548	0.23296
11	26.884	22.621	31.353	4.765	-0.1027	0.25840
12	27.002	23.297	30.677	3.405	0.0149	0.28439
13	26.893	23.579	30.395	2.904	-0.0940	0.30893
14	26.849	23.833	30.141	2.487	-0.1380	0.32717
15	26.892	23.748	30.226	2.623	-0.0950	0.35332
16	27.002	23.836	30.138	2.482	0.0153	0.36249
17	26.754	23.891	30.083	2.396	-0.2333	0.39901
18	26.874	24.165	29.809	1.991	-0.1134	0.41481
19	27.050	24.508	29.466	1.536	0.0632	0.44158
20	26.847	24.581	29.393	1.447	-0.1404	0.46031
21	27.021	24.530	29.444	1.510	0.0338	0.48880
22	27.023	24.788	29.186	1.209	0.0361	0.50620
23	26.961	24.837	29.137	1.156	-0.0255	0.53952
24	26.915	24.886	29.088	1.103	-0.0722	0.55983
25	27.037	25.126	28.848	0.866	0.0496	0.59285

mean = 26.987　　skewness = 0.1212
variance = 25.262　　kurtosis = 2.5700

Table 18. Parameter estimates of an average migration of chinook salmon (1970). The calculated mean (from a sample size of 300 repetitions), approximate 95% confidence interval, biased MSE for the ratio estimator, bias and average cumulative proportions for each of the randomly sampled days, j (j = 5, 6, ··· 25) from daily proportions of CPUE.

numb of days	mean	95% lower	95% upper	MSE	bias	cumulat proport
5	20.2955	10.518	30.994	26.205	-0.4608	0.12420
6	20.3819	12.362	29.151	17.618	-0.3744	0.15082
7	21.0224	13.893	27.620	11.778	0.2661	0.17489
8	20.8841	14.350	27.163	10.261	0.1278	0.20261
9	20.7477	14.547	26.966	9.639	-0.0086	0.22777
10	20.7551	15.345	26.168	7.320	-0.0012	0.24280
11	20.6963	15.911	25.601	5.869	-0.0600	0.28011
12	20.6682	16.250	25.262	5.076	-0.0881	0.29718
13	20.5520	16.461	25.051	4.612	-0.2043	0.32391
14	20.6412	16.843	24.669	3.828	-0.1151	0.34793
15	20.5276	16.940	24.572	3.641	-0.2287	0.38047
16	20.8432	17.266	24.247	3.046	0.0869	0.39780
17	20.7279	17.453	24.059	2.728	-0.0284	0.42594
18	20.6639	17.658	23.855	2.400	-0.0924	0.45728
19	20.5376	17.608	23.905	2.479	-0.2187	0.46991
20	20.8651	17.848	23.665	2.114	0.1088	0.50059
21	20.8251	18.073	23.440	1.800	0.0688	0.52000
22	20.6570	18.110	23.403	1.751	-0.0993	0.54140
23	20.7286	18.407	23.106	1.380	-0.0277	0.56554
24	20.6644	18.553	22.960	1.214	-0.0919	0.59807
25	20.8131	18.603	22.909	1.159	0.0568	0.62034

mean = 20.756　　skewness = 0.1138
variance = 36.8065　　kurtosis = 2.2190

Table 19. Parameter estimates from an early migration of chinook salmon (1976). The calculated mean (from a sample size of 300 repetitions), approximate 95% confidence interval, MSE for the ratio estimator, bias and average cumulative proportions for each of the randomly sampled days, j (j = 5, 6, ··· 25) from daily proportions of CPUE.

numb of days	mean	95% lower	95% upper	MSE	bias	cumulat proport
5	14.206	3.730	23.670	24.848	0.5062	0.12478
6	14.034	5.071	22.329	18.616	0.3336	0.15578
7	14.052	4.817	22.583	19.729	0.3523	0.17690
8	14.285	5.544	21.856	16.629	0.5845	0.20394
9	14.291	5.911	21.489	15.168	0.5905	0.22768
10	14.266	7.192	20.208	10.589	0.5659	0.24722
11	14.166	6.642	20.758	12.454	0.4663	0.27105
12	14.126	7.402	19.998	9.917	0.4260	0.30207
13	13.832	7.955	19.445	8.252	0.1323	0.32700
14	13.905	8.359	19.041	7.130	0.2051	0.34633
15	13.974	8.485	18.915	6.800	0.2738	0.37663
16	13.976	8.836	18.564	5.914	0.2764	0.40994
17	13.888	9.134	18.266	5.211	0.1884	0.42959
18	13.988	9.374	18.026	4.680	0.2884	0.45159
19	13.876	9.370	18.030	4.687	0.1763	0.47596
20	13.905	9.466	17.934	4.481	0.2053	0.50493
21	13.757	9.614	17.786	4.173	0.0568	0.52157
22	13.865	10.390	17.010	2.739	0.1646	0.54923
23	13.888	10.225	17.175	3.019	0.1884	0.57534
24	13.801	10.267	17.133	2.947	0.1010	0.59007
25	13.989	10.415	16.985	2.698	0.2886	0.61695

mean = 13.700 skewness = 0.3618
variance = 50.071 kurtosis = 1.8033

Table 20. The biased MSE of the estimator (from 300 repetitions) calculated from a number of randomly sampled days, j (j = 5, 6, ·· 25) for the years - 1976 (late), 1970 (average), and 1967 (early) based upon empirical catch data from June 1 - July 10, inclusive, for each year.

number of days sampled	1976 (late)	1970 (average)	1967 (early)
5	33.806	29.870	30.405
6	29.296	20.385	23.143
7	11.075	15.389	19.811
8	13.859	14.121	16.366
9	9.836	9.859	12.833
10	6.868	7.780	13.044
11	6.877	8.282	10.101
12	4.119	6.080	9.062
13	4.613	5.449	6.697
14	3.949	5.744	6.819
15	3.841	4.636	7.033
16	3.220	4.106	5.645
17	3.048	2.842	4.591
18	2.563	2.908	4.294
19	2.265	2.452	3.764
20	1.883	2.887	3.957
21	1.576	2.161	3.142
22	1.914	1.435	3.012
23	1.361	1.435	2.432
24	1.500	1.404	2.309
25	1.359	1.171	2.208
mean	27.610	21.978	14.056
variance	21.369	25.289	51.189
skewness	0.0050	0.2272	0.1805
kurtosis	2.4928	2.7098	1.7605

was sampled ($j > 12$) catch data offered slightly more confidence to the estimate of arrival time. The variances were about equal. The daily proportions of CPUE for the other two years studied, namely 1970 ("average") and 1967 ("late"), resulted in smaller MSE values across the sampling regimes ($j = 5, 6, \cdots 25$). A broader dispersion of the distribution was represented by both distributions, as well.

CHAPTER 4

DISCUSSION

Much of what is known today concerning the migrations of fishes is derived from the study of commercial catch data (Leggett 1977). A standard harvest control objective in Alaskan salmon net fisheries is to spread the catch proportionately across all time segments of the migration. Failure to meet this objective can result in severe censorship of the catch data that is used in estimating the parameters of migratory timing.

The use of simulation techniques has shown the estimates of mean arrival time based on severely censored, and often truncated, data sets to be amazingly accurate. However, estimates of the variance and higher order moments from the same data are rather volatile, being very sensitive to sampling error.

It was not surprising that commercial catch taken at the tails of the migratory distribution tend to weigh the expected arrival time in the direction of the sample, away from the true mean. However, in many marine fisheries, the actual tendency is to concentrate harvest efforts during the first half of a migration. In other fisheries the management stategy forces the industry to wait until the central mass of the population has passed through the harvest area before they begin their fishing operations. Therefore, if the number of openers is small, say less than 8/40, and concentrated near the left hand tail or shoulder of the distribution, an early migration may be erroneously estimated. On the other hand, forestalling fishing operations until the migration is well established causes erroneous estimates of late migrations. But even so, when enough years of data are combined, even a fishery with a small number of contagiously distributed annual openers can yield an excellant estimate of migratory timing (Table 5).

Simulation studies based on the normal distribution support and expand the experience gained from sampling the empirical distribution. Arrival time estimates from small samples ($j < 10$) of a broad-variance distribution are more stable in comparison to those for fast (narrow-variance) runs that occur over very short time intervals. However, as the number of days sampled approaches ten (10), the chances of sampling the larger proportions which are concentrated about the central mass of the narrow-variance distribution increases and our confidence in the estimate of the mean arrival time is improved. As a result, better estimates of the mean arrival time for a fast migration are superior to those of a broad-variance migration when 25 - 50 % of the time domain is sampled.

It is important to note that daily proportions of both catch and effort supply good data bases for estimating mean arrival times of Yukon chinook with adequate sample sizes. Both the variance estimate of the ratio estimator and the biased estimate of the MSE of the ratio estimator offer reliable confidence limits; however, the former maintains a much narrower interval when sampling less than 12 % of the migration.

It is often very difficult if not impossible to know the first or last dates of a migration. Many fishermen rely on intuitive methods for such information; however, managers and fisheries biologists seek more precise scientific methods. The division of annual migrations into the timing categories is important because it allows a means for scheduling dates of commercial fishing with some concept of the expected catch. The MSE for the ratio estimator is a better method for studying estimates of the dispersion of the migration than the sample variance of the population total. It is not until about 50% of the entire distribution is sampled that the sample variance of the migration settles to a reliable range. The sample variance is far more easily estimated for a late (small-variance) migration than for the earlier (large-variance) ones based on simulations. However, truncation of data can result in narrower variance estimate due to a lack of observations from the distributional tails. As a result, commercial catch may not be an appropriate data source for characterizing seasonal dispersion.

The purpose of calculating variability of the mean of a time density is to allow comparisons between years. In contrast to the mean, the stability of the shape of the time density as measured by the skewness and kurtosis is very poor for fast migrations, as compared to the average or early migrations. Therefore, inadequate sample size causes widely fluctuating estimates of S^2, a_3, and a_4, resulting in difficult characterization of these statistics from commercial catch.

The best possible estimate for characterizing migratory behavior is to sample the entire distribution of the actual migration; however, this may be impractical with respect to the commercial harvest for reasons of continually increasing efficiency. While chinook stocks on the Yukon were sampled commercially 5 out of every 7 days in 1961, sampling had dropped to one day out of 7 by 1982. As a result, the performance curve(s) based on commercial catch data are now based on little data to serve as an adequate measure of annual migratory timing. Test fisheries on the Yukon offer the only viable alternative to commercial catch data until sonar is fully developed. As mentioned above, daily catch data from every date is the optimal method.

Test fisheries are not as susceptible to censorship of the sample of the time domain of the migration, and the "continuous" frequency distribution in association with the ratio estimator appears to be the only reliable source for adequate estimation of the moments. As a result, test fisheries become increasingly more important as the only viable source of performance curve data. It is possible that truncation of the test fishery can occur. This too may cause the sample variance to underestimate the true dispersion of the migration.

Unfortunately, test fisheries are expensive to operate and maintain. So, commercial catch remains the only available data for study among many marine fisheries. The cost of the test fishery must be measured against the risk of errors in harvest control caused by faulty timing information. As presented above, commercial catch and CPUE data can provide good objective determinants for annual estimates of mean arrival, given even a limited (25%) number of dates.

Simulation studies typically make certain basic assumptions in order to function. Throughout this study there was random sampling and the catches were exactly proportional to the total abundance. In practice, scheduling of fishing days is rarely random. On the contrary, most of the large salmon fisheries operate on guidelines obtained from predetermined schedules as mentioned earlier. Therefore, estimation of a current years' timing and abundance compared to similar historical performances should yield more reliable results due to concentration of fishing near the center of the migration. However, it is well known that catchability is inversely proportional to effort in gill net fisheries for adult salmon (Brannian 1983; Schaller 1984) so the lack of the proportionality of catch to effort is a potential source of error.

As stated above, Alaskan salmon managers of net fisheries try to spread the catch proportionately across all time segements of the migration. This may appear deceptively simple with symmetrical distributions, but estimating proportions with a skewed distribution is even more difficult, particularly in light of the fact that characterization of parameters of the migration other than the average arrival time may be misleading.

Modeling and simulation studies by their nature have an inherent rigidity with respect to the true nature of the organism(s) under investigation. Migratory timing is equated to catch taken from a population of fish moving in a unidirectional fashion at a constant average rate of speed. It is likely that few organisms exhibit such a concentrated effort, and in fact, considerable wandering should be expected (Ellis 1962; Alabaster 1970; Leggett 1977; Grays and Haynes 1979). However, it is resonable to assume that less wandering occurs during fast runs as compared to slow, or "early", migrations.

Let me emphasize that migratory timing is not time dependent. It is the genetic elasticity of salmonid stocks and the consequent adaptive plasticity that enables them to respond to ambient physical factors throughout their life cycle (Banks 1969; Bams 1976; Hoar 1976; Leggett 1977; to name a few), and it is the physical factors that probably explain the variations in the timing of salmon migrations. Time is a covariate of these and until extensive oceanographic studies are combined with complete life history studies, the precise characterizaton of salmonid migratory timing will remain unsolved.

The procedures utilized in estimating the average arrival time of chinook salmon is not limited soley to that particular fish species. On the contrary, the ratio estimator is a viable method in estimating the averge migratory arrival of any population. The salmon of the Yukon River delta offered a good continuous historical data base to test the methods described above.

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APPENDIX A

FISHING HOURS

CHINOOK SALMON: the daily fishing hours from the Yukon River delta for each year (1961 - 1982) from June 1 - July 10, inclusive.

Table Al. Subdistrict 334-11, 1961: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
5	605	24	0.0506	24	0.0506
6	606	24	0.0506	48	0.1013
7	607	24	0.0506	72	0.1519
8	608	18	0.0380	90	0.1899
9	609	0	0.0000	90	0.1899
10	610	0	0.0000	90	0.1899
11	611	6	0.0127	96	0.2025
12	612	24	0.0506	120	0.2532
13	613	24	0.0506	144	0.3038
14	614	24	0.0506	168	0.3544
15	615	18	0.0380	186	0.3924
16	616	0	0.0000	186	0.3924
17	617	0	0.0000	186	0.3924
18	618	6	0.0127	192	0.4051
19	619	24	0.0506	216	0.4557
20	620	24	0.0506	240	0.5063
21	621	24	0.0506	264	0.5570
22	622	18	0.0380	282	0.5949
23	623	0	0.0000	282	0.5949
24	624	0	0.0000	282	0.5949
25	625	6	0.0127	288	0.6076
26	626	24	0.0506	312	0.6582
27	627	24	0.0506	336	0.7089
28	628	24	0.0506	360	0.7595
29	629	18	0.0380	378	0.7975
30	630	0	0.0000	378	0.7975
31	701	0	0.0000	378	0.7975
32	702	6	0.0127	384	0.8101
33	703	24	0.0506	408	0.8608
34	704	24	0.0506	432	0.9114
35	705	24	0.0506	456	0.9620
36	706	18	0.0380	474	1.0000

Mean Date: 20.4557 Variance: 98.3113
Skewness: -.306502 Kurtosis: -1.23083

Table A2. Subdistrict 334-11, 1962: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
11	611	24	0.0580	24	0.0580
12	612	24	0.0580	48	0.1159
13	613	24	0.0580	72	0.1739
14	614	18	0.0435	90	0.2174
15	615	0	0.0000	90	0.2174
16	616	0	0.0000	90	0.2174
17	617	6	0.0145	96	0.2319
18	618	24	0.0580	120	0.2899
19	619	24	0.0580	144	0.3478
20	620	24	0.0580	168	0.4058
21	621	18	0.0435	186	0.4493
22	622	6	0.0145	192	0.4638
23	623	24	0.0580	216	0.5217
24	624	12	0.0290	228	0.5507
25	625	24	0.0580	252	0.6087
26	626	24	0.0580	276	0.6667
27	627	24	0.0580	300	0.7246
28	628	18	0.0435	318	0.7681
29	629	0	0.0000	318	0.7681
30	630	0	0.0000	318	0.7681
31	701	6	0.0145	324	0.7826
32	702	24	0.0580	348	0.8406
33	703	24	0.0580	372	0.8986
34	704	24	0.0580	396	0.9565
35	705	18	0.0435	414	1.0000

Mean Date: 22.9565 Variance: 56.7807
Skewness: -.404188 Kurtosis: -1.08902

Table A3. Subdistrict 334-11, 1963: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
3	603	18	0.0417	18	0.0417
4	604	24	0.0556	42	0.0972
5	605	6	0.0139	48	0.1111
6	606	6	0.0139	54	0.1250
7	607	24	0.0556	78	0.1806
8	608	18	0.0417	96	0.2222
9	609	0	0.0000	96	0.2222
10	610	18	0.0417	114	0.2639
11	611	24	0.0556	138	0.3194
12	612	6	0.0139	144	0.3333
13	613	6	0.0139	150	0.3472
14	614	24	0.0556	174	0.4028
15	615	18	0.0417	192	0.4444
16	616	0	0.0000	192	0.4444
17	617	18	0.0417	210	0.4861
18	618	24	0.0556	234	0.5417
19	619	6	0.0139	240	0.5556
20	620	6	0.0139	246	0.5694
21	621	24	0.0556	270	0.6250
22	622	18	0.0417	288	0.6667
23	623	0	0.0000	288	0.6667
24	624	18	0.0417	306	0.7083
25	625	24	0.0556	330	0.7639
26	626	6	0.0139	336	0.7778
27	627	6	0.0139	342	0.7917
28	628	24	0.0556	366	0.8472
29	629	18	0.0417	384	0.8889
30	630	0	0.0000	384	0.8889
31	701	18	0.0417	402	0.9306
32	702	24	0.0556	426	0.9861
33	703	6	0.0139	432	1.0000

Mean Date: 17.75 Variance: 83.1042
Skewness: -.326433 Kurtosis: -1.18813

Table A4. Subdistrict 334-11, 1964: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
15	615	18	0.0536	18	0.0536
16	616	24	0.0714	42	0.1250
17	617	6	0.0179	48	0.1429
18	618	0	0.0000	48	0.1429
19	619	30	0.0893	78	0.2321
20	620	18	0.0536	96	0.2857
21	621	0	0.0000	96	0.2857
22	622	18	0.0536	114	0.3393
23	623	24	0.0714	138	0.4107
24	624	6	0.0179	144	0.4286
25	625	6	0.0179	150	0.4464
26	626	24	0.0714	174	0.5179
27	627	18	0.0536	192	0.5714
28	628	0	0.0000	192	0.5714
29	629	18	0.0536	210	0.6250
30	630	24	0.0714	234	0.6964
31	701	6	0.0179	240	0.7143
32	702	6	0.0179	246	0.7321
33	703	24	0.0714	270	0.8036
34	704	18	0.0536	288	0.8571
35	705	0	0.0000	288	0.8571
36	706	18	0.0536	306	0.9107
37	707	24	0.0714	330	0.9821
38	708	6	0.0179	336	1.0000

Mean Date: 26.2679 Variance: 50.1604
Skewness: -.416262 Kurtosis: -1.17539

Table A5. Subdistrict 334-11, 1965: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
7	607	18	0.0469	18	0.0469
8	608	24	0.0625	42	0.1094
9	609	6	0.0156	48	0.1250
10	610	6	0.0156	54	0.1406
11	611	24	0.0625	78	0.2031
12	612	18	0.0469	96	0.2500
13	613	0	0.0000	96	0.2500
14	614	18	0.0469	114	0.2969
15	615	24	0.0625	138	0.3594
16	616	6	0.0156	144	0.3750
17	617	6	0.0156	150	0.3906
18	618	24	0.0625	174	0.4531
19	619	18	0.0469	192	0.5000
20	620	0	0.0000	192	0.5000
21	621	18	0.0469	210	0.5469
22	622	24	0.0625	234	0.6094
23	623	6	0.0156	240	0.6250
24	624	6	0.0156	246	0.6406
25	625	24	0.0625	270	0.7031
26	626	18	0.0469	288	0.7500
27	627	0	0.0000	288	0.7500
28	628	18	0.0469	306	0.7969
29	629	24	0.0625	330	0.8594
30	630	6	0.0156	336	0.8750
31	701	6	0.0156	342	0.8906
32	702	24	0.0625	366	0.9531
33	703	18	0.0469	384	1.0000

Mean Date: 20.0 Variance: 65.75
Skewness: -.366225 Kurtosis: -1.1852

Table A6. Subdistrict 334-11, 1966: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
10	610	24	0.0816	24	0.0816
11	611	18	0.0612	42	0.1429
12	612	0	0.0000	42	0.1429
13	613	18	0.0612	60	0.2041
14	614	24	0.0816	84	0.2857
15	615	6	0.0204	90	0.3061
16	616	6	0.0204	96	0.3265
17	617	24	0.0816	120	0.4082
18	618	18	0.0612	138	0.4694
19	619	0	0.0000	138	0.4694
20	620	18	0.0612	156	0.5306
21	621	24	0.0816	180	0.6122
22	622	6	0.0204	186	0.6327
23	623	6	0.0204	192	0.6531
24	624	24	0.0816	216	0.7347
25	625	6	0.0204	222	0.7551
26	626	0	0.0000	222	0.7551
27	627	18	0.0612	240	0.8163
28	628	18	0.0612	258	0.8776
29	629	0	0.0000	258	0.8776
30	630	6	0.0204	264	0.8980
31	701	24	0.0816	288	0.9796
32	702	6	0.0204	294	1.0000

Mean Date: 20.0408 Variance: 45.8147
Skewness: -.28099 Kurtosis: -1.17976

Table A7. Subdistrict 334-11, 1967: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
2	602	24	0.0678	24	0.0678
3	603	18	0.0508	42	0.1186
4	604	0	0.0000	42	0.1186
5	605	18	0.0508	60	0.1695
6	606	24	0.0678	84	0.2373
7	607	6	0.0169	90	0.2542
8	608	6	0.0169	96	0.2712
9	609	24	0.0678	120	0.3390
10	610	18	0.0508	138	0.3898
11	611	0	0.0000	138	0.3898
12	612	18	0.0508	156	0.4407
13	613	24	0.0678	180	0.5085
14	614	6	0.0169	186	0.5254
15	615	6	0.0169	192	0.5424
16	616	24	0.0678	216	0.6102
17	617	18	0.0508	234	0.6610
18	618	0	0.0000	234	0.6610
19	619	18	0.0508	252	0.7119
20	620	24	0.0678	276	0.7797
21	621	6	0.0169	282	0.7966
22	622	6	0.0169	288	0.8136
23	623	24	0.0678	312	0.8814
24	624	18	0.0508	330	0.9322
25	625	0	0.0000	330	0.9322
26	626	18	0.0508	348	0.9831
27	627	6	0.0169	354	1.0000

Mean Date: 13.8644 Variance: 56.7104
Skewness: -.376894 Kurtosis: -1.16187

Table A8. Subdistrict 334-11, 1968: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
3	603	6	0.0161	6	0.0161
4	604	24	0.0645	30	0.0806
5	605	6	0.0161	36	0.0968
6	606	6	0.0161	42	0.1129
7	607	24	0.0645	66	0.1774
8	608	18	0.0484	84	0.2258
9	609	0	0.0000	84	0.2258
10	610	6	0.0161	90	0.2419
11	611	24	0.0645	114	0.3065
12	612	6	0.0161	120	0.3226
13	613	6	0.0161	126	0.3387
14	614	24	0.0645	150	0.4032
15	615	18	0.0484	168	0.4516
16	616	0	0.0000	168	0.4516
17	617	6	0.0161	174	0.4677
18	618	24	0.0645	198	0.5323
19	619	6	0.0161	204	0.5484
20	620	6	0.0161	210	0.5645
21	621	24	0.0645	234	0.6290
22	622	18	0.0484	252	0.6774
23	623	0	0.0000	252	0.6774
24	624	6	0.0161	258	0.6935
25	625	24	0.0645	282	0.7581
26	626	6	0.0161	288	0.7742
27	627	6	0.0161	294	0.7903
28	628	24	0.0645	318	0.8548
29	629	18	0.0484	336	0.9032
30	630	0	0.0000	336	0.9032
31	701	6	0.0161	342	0.9194
32	702	24	0.0645	366	0.9839
33	703	6	0.0161	372	1.0000

Mean Date: 17.871 Variance: 80.435
Skewness: -.322282 Kurtosis: -1.18979

Table A9. Subdistrict 334-11, 1969: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; 4) Cumulative proportion of fishing hours.
1

DAY	DATE	(1)	(2)	(3)	(4)
6	606	24	0.1333	24	0.1333
7	607	18	0.1000	42	0.2333
8	608	0	0.0000	42	0.2333
9	609	0	0.0000	42	0.2333
10	610	6	0.0333	48	0.2667
11	611	6	0.0333	54	0.3000
12	612	0	0.0000	54	0.3000
13	613	24	0.1333	78	0.4333
14	614	18	0.1000	96	0.5333
15	615	0	0.0000	96	0.5333
16	616	6	0.0333	102	0.5667
17	617	24	0.1333	126	0.7000
18	618	0	0.0000	126	0.7000
19	619	0	0.0000	126	0.7000
20	620	18	0.1000	144	0.8000
21	621	0	0.0000	144	0.8000
22	622	0	0.0000	144	0.8000
23	623	0	0.0000	144	0.8000
24	624	18	0.1000	162	0.9000
25	625	0	0.0000	162	0.9000
26	626	0	0.0000	162	0.9000
27	627	0	0.0000	162	0.9000
28	628	18	0.1000	180	1.0000

Mean Date: 15.3333 Variance: 48.1556
Skewness: -.117683 Kurtosis: -1.01839

Table A10. Subdistrict 334-11, 1970: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
6	606	18	0.0612	18	0.0612
7	607	0	0.0000	18	0.0612
8	608	0	0.0000	18	0.0612
9	609	24	0.0816	42	0.1429
10	610	6	0.0204	48	0.1633
11	611	6	0.0204	54	0.1837
12	612	24	0.0816	78	0.2653
13	613	18	0.0612	96	0.3265
14	614	0	0.0000	96	0.3265
15	615	6	0.0204	102	0.3469
16	616	24	0.0816	126	0.4286
17	617	6	0.0204	132	0.4490
18	618	6	0.0204	138	0.4694
19	619	24	0.0816	162	0.5510
20	620	18	0.0612	180	0.6122
21	621	0	0.0000	180	0.6122
22	622	6	0.0204	186	0.6327
23	623	24	0.0816	210	0.7143
24	624	6	0.0204	216	0.7347
25	625	0	0.0000	216	0.7347
26	626	18	0.0612	234	0.7959
27	627	0	0.0000	234	0.7959
28	628	0	0.0000	234	0.7959
29	629	6	0.0204	240	0.8163
30	630	24	0.0816	264	0.8980
31	701	6	0.0204	270	0.9184
32	702	6	0.0204	276	0.9388
33	703	18	0.0612	294	1.0000

Mean Date: 19.1633 Variance: 65.1774
Skewness: -.19918 Kurtosis: -1.12325

Table All. Subdistrict 334-11, 1971: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
18	618	24	0.1143	24	0.1143
19	619	18	0.0857	42	0.2000
20	620	0	0.0000	42	0.2000
21	621	6	0.0286	48	0.2286
22	622	24	0.1143	72	0.3429
23	623	6	0.0286	78	0.3714
24	624	6	0.0286	84	0.4000
25	625	24	0.1143	108	0.5143
26	626	18	0.0857	126	0.6000
27	627	0	0.0000	126	0.6000
28	628	6	0.0286	132	0.6286
29	629	24	0.1143	156	0.7429
30	630	6	0.0286	162	0.7714
31	701	6	0.0286	168	0.8000
32	702	24	0.1143	192	0.9143
33	703	18	0.0857	210	1.0000

Mean Date: 25.5714 Variance: 25.9878
Skewness: -.610441 Kurtosis: -1.15316

Table A12. Subdistrict 334-11, 1972: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
14	614	6	0.0286	6	0.0286
15	615	6	0.0286	12	0.0571
16	616	24	0.1143	36	0.1714
17	617	18	0.0857	54	0.2571
18	618	0	0.0000	54	0.2571
19	619	0	0.0000	54	0.2571
20	620	24	0.1143	78	0.3714
21	621	6	0.0286	84	0.4000
22	622	0	0.0000	84	0.4000
23	623	24	0.1143	108	0.5143
24	624	18	0.0857	126	0.6000
25	625	0	0.0000	126	0.6000
26	626	6	0.0286	132	0.6286
27	627	24	0.1143	156	0.7429
28	628	6	0.0286	162	0.7714
29	629	6	0.0286	168	0.8000
30	630	24	0.1143	192	0.9143
31	701	18	0.0857	210	1.0000

Mean Date: 23.2286 Variance: 29.9192
Skewness: -.629902 Kurtosis: -1.15397

Table A13. Subdistrict 334-11, 1973: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
12	612	24	0.0909	24	0.0909
13	613	6	0.0227	30	0.1136
14	614	0	0.0000	30	0.1136
15	615	24	0.0909	54	0.2045
16	616	18	0.0682	72	0.2727
17	617	0	0.0000	72	0.2727
18	618	6	0.0227	78	0.2955
19	619	24	0.0909	102	0.3864
20	620	6	0.0227	108	0.4091
21	621	6	0.0227	114	0.4318
22	622	24	0.0909	138	0.5227
23	623	18	0.0682	156	0.5909
24	624	0	0.0000	156	0.5909
25	625	6	0.0227	162	0.6136
26	626	24	0.0909	186	0.7045
27	627	6	0.0227	192	0.7273
28	628	0	0.0000	192	0.7273
29	629	0	0.0000	192	0.7273
30	630	0	0.0000	192	0.7273
31	701	0	0.0000	192	0.7273
32	702	0	0.0000	192	0.7273
33	703	0	0.0000	192	0.7273
34	704	0	0.0000	192	0.7273
35	705	6	0.0227	198	0.7500
36	706	24	0.0909	222	0.8409
37	707	18	0.0682	240	0.9091
38	708	0	0.0000	240	0.9091
39	709	0	0.0000	240	0.9091
40	710	24	0.0909	264	1.0000

Mean Date: 24.25 Variance: 83.8239
Skewness: .119354 Kurtosis: -1.28123

Table A14. Subdistrict 334-11, 1974
(1) Daily fishing hours; (2) Daily Proportion of fishing hours;
(3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
3	603	6	0.0175	6	0.0175
4	604	24	0.0702	30	0.0877
5	605	6	0.0175	36	0.1053
6	606	6	0.0175	42	0.1228
7	607	24	0.0702	66	0.1930
8	608	6	0.0175	72	0.2105
9	609	0	0.0000	72	0.2105
10	610	0	0.0000	72	0.2105
11	611	24	0.0702	96	0.2807
12	612	6	0.0175	102	0.2982
13	613	0	0.0000	102	0.2982
14	614	24	0.0702	126	0.3684
15	615	6	0.0175	132	0.3860
16	616	0	0.0000	132	0.3860
17	617	0	0.0000	132	0.3860
18	618	24	0.0702	156	0.4561
19	619	6	0.0175	162	0.4737
20	620	6	0.0175	168	0.4912
21	621	24	0.0702	192	0.5614
22	622	6	0.0175	198	0.5789
23	623	0	0.0000	198	0.5789
24	624	6	0.0175	204	0.5965
25	625	24	0.0702	228	0.6667
26	626	6	0.0175	234	0.6842
27	627	6	0.0175	240	0.7018
28	628	24	0.0702	264	0.7719
29	629	6	0.0175	270	0.7895
30	630	0	0.0000	270	0.7895
31	701	0	0.0000	270	0.7895
32	702	0	0.0000	270	0.7895
33	703	0	0.0000	270	0.7895
34	704	6	0.0175	276	0.8070
35	705	24	0.0702	300	0.8772
36	706	6	0.0175	306	0.8947
37	707	0	0.0000	306	0.8947
38	708	6	0.0175	312	0.9123
39	709	24	0.0702	336	0.9825
40	710	6	0.0175	342	1.0000

Mean Date: 20.5614 Variance: 126.895
Skewness: -.129398 Kurtosis: -1.16024

Table A15. Subdistrict 334-11, 1975: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
13	613	24	0.1026	24	0.1026
14	614	0	0.0000	24	0.1026
15	615	0	0.0000	24	0.1026
16	616	6	0.0256	30	0.1282
17	617	24	0.1026	54	0.2308
18	618	6	0.0256	60	0.2564
19	619	6	0.0256	66	0.2821
20	620	24	0.1026	90	0.3846
21	621	6	0.0256	96	0.4103
22	622	0	0.0000	96	0.4103
23	623	6	0.0256	102	0.4359
24	624	24	0.1026	126	0.5385
25	625	6	0.0256	132	0.5641
26	626	6	0.0256	138	0.5897
27	627	18	0.0769	156	0.6667
28	628	0	0.0000	156	0.6667
29	629	0	0.0000	156	0.6667
30	630	6	0.0256	162	0.6923
31	701	18	0.0769	180	0.7692
32	702	0	0.0000	180	0.7692
33	703	0	0.0000	180	0.7692
34	704	18	0.0769	198	0.8462
35	705	0	0.0000	198	0.8462
36	706	0	0.0000	198	0.8462
37	707	6	0.0256	204	0.8718
38	708	24	0.1026	228	0.9744
39	709	6	0.0256	234	1.0000

Mean Date: 25.0769 Variance: 65.7889
Skewness: -.133652 Kurtosis: -1.19743

Table A16. Subdistrict 334-11, 1976: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
15	615	24	0.1000	24	0.1000
16	616	6	0.0250	30	0.1250
17	617	6	0.0250	36	0.1500
18	618	24	0.1000	60	0.2500
19	619	6	0.0250	66	0.2750
20	620	0	0.0000	66	0.2750
21	621	6	0.0250	72	0.3000
22	622	24	0.1000	96	0.4000
23	623	6	0.0250	102	0.4250
24	624	6	0.0250	108	0.4500
25	625	24	0.1000	132	0.5500
26	626	6	0.0250	138	0.5750
27	627	0	0.0000	138	0.5750
28	628	6	0.0250	144	0.6000
29	629	24	0.1000	168	0.7000
30	630	6	0.0250	174	0.7250
31	701	6	0.0250	180	0.7500
32	702	18	0.0750	198	0.8250
33	703	0	0.0000	198	0.8250
34	704	0	0.0000	198	0.8250
35	705	0	0.0000	198	0.8250
36	706	18	0.0750	216	0.9000
37	707	0	0.0000	216	0.9000
38	708	6	0.0250	222	0.9250
39	709	18	0.0750	240	1.0000

Mean Date: 25.75 Variance: 56.3375
Skewness: -.15441 Kurtosis: -1.1295

Table A17. Subdistrict 334-11, 1977: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
16	616	6	0.0294	6	0.0294
17	617	24	0.1176	30	0.1471
18	618	6	0.0294	36	0.1765
19	619	0	0.0000	36	0.1765
20	620	6	0.0294	42	0.2059
21	621	18	0.0882	60	0.2941
22	622	0	0.0000	60	0.2941
23	623	6	0.0294	66	0.3235
24	624	24	0.1176	90	0.4412
25	625	6	0.0294	96	0.4706
26	626	0	0.0000	96	0.4706
27	627	6	0.0294	102	0.5000
28	628	18	0.0882	120	0.5882
29	629	0	0.0000	120	0.5882
30	630	6	0.0294	126	0.6176
31	701	18	0.0882	144	0.7059
32	702	0	0.0000	144	0.7059
33	703	0	0.0000	144	0.7059
34	704	6	0.0294	150	0.7353
35	705	18	0.0882	168	0.8235
36	706	0	0.0000	168	0.8235
37	707	6	0.0294	174	0.8529
38	708	24	0.1176	198	0.9706
39	709	6	0.0294	204	1.0000

Mean Date: 27.3529 Variance: 55.1107
Skewness: -.329312 Kurtosis: -1.28245

Table A18. Subdistrict 334-11, 1978: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
8	608	6	0.0250	6	0.0250
9	609	18	0.0750	24	0.1000
10	610	0	0.0000	24	0.1000
11	611	0	0.0000	24	0.1000
12	612	6	0.0250	30	0.1250
13	613	18	0.0750	48	0.2000
14	614	0	0.0000	48	0.2000
15	615	0	0.0000	48	0.2000
16	616	24	0.1000	72	0.3000
17	617	6	0.0250	78	0.3250
18	618	0	0.0000	78	0.3250
19	619	6	0.0250	84	0.3500
20	620	18	0.0750	102	0.4250
21	621	0	0.0000	102	0.4250
22	622	6	0.0250	108	0.4500
23	623	24	0.1000	132	0.5500
24	624	6	0.0250	138	0.5750
25	625	0	0.0000	138	0.5750
26	626	6	0.0250	144	0.6000
27	627	18	0.0750	162	0.6750
28	628	0	0.0000	162	0.6750
29	629	6	0.0250	168	0.7000
30	630	24	0.1000	192	0.8000
31	701	6	0.0250	198	0.8250
32	702	0	0.0000	198	0.8250
33	703	0	0.0000	198	0.8250
34	704	18	0.0750	216	0.9000
35	705	0	0.0000	216	0.9000
36	706	0	0.0000	216	0.9000
37	707	24	0.1000	240	1.0000

Mean Date: 23.025 Variance: 76.2744
Skewness: -.363351 Kurtosis: -1.04076

Table A19. Subdistrict 334-11, 1979: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
4	604	6	0.0256	6	0.0256
5	605	18	0.0769	24	0.1026
6	606	0	0.0000	24	0.1026
7	607	6	0.0256	30	0.1282
8	608	18	0.0769	48	0.2051
9	609	0	0.0000	48	0.2051
10	610	0	0.0000	48	0.2051
11	611	6	0.0256	54	0.2308
12	612	18	0.0769	72	0.3077
13	613	0	0.0000	72	0.3077
14	614	6	0.0256	78	0.3333
15	615	24	0.1026	102	0.4359
16	616	6	0.0256	108	0.4615
17	617	0	0.0000	108	0.4615
18	618	0	0.0000	108	0.4615
19	619	18	0.0769	126	0.5385
20	620	0	0.0000	126	0.5385
21	621	0	0.0000	126	0.5385
22	622	18	0.0769	144	0.6154
23	623	0	0.0000	144	0.6154
24	624	0	0.0000	144	0.6154
25	625	0	0.0000	144	0.6154
26	626	18	0.0769	162	0.6923
27	627	0	0.0000	162	0.6923
28	628	6	0.0256	168	0.7179
29	629	18	0.0769	186	0.7949
30	630	0	0.0000	186	0.7949
31	701	0	0.0000	186	0.7949
32	702	0	0.0000	186	0.7949
33	703	18	0.0769	204	0.8718
34	704	0	0.0000	204	0.8718
35	705	0	0.0000	204	0.8718
36	706	24	0.1026	228	0.9744
37	707	6	0.0256	234	1.0000

Mean Date: 20.0769 Variance: 108.866
Skewness: -.158491 Kurtosis: -1.28871

Table A20. Subdistrict 334-11, 1980: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
9	609	6	0.0385	6	0.0385
10	610	18	0.1154	24	0.1538
11	611	0	0.0000	24	0.1538
12	612	6	0.0385	30	0.1923
13	613	24	0.1538	54	0.3462
14	614	6	0.0385	60	0.3846
15	615	0	0.0000	60	0.3846
16	616	6	0.0385	66	0.4231
17	617	0	0.0000	66	0.4231
18	618	0	0.0000	66	0.4231
19	619	6	0.0385	72	0.4615
20	620	24	0.1538	96	0.6154
21	621	6	0.0385	102	0.6538
22	622	0	0.0000	102	0.6538
23	623	6	0.0385	108	0.6923
24	624	0	0.0000	108	0.6923
25	625	0	0.0000	108	0.6923
26	626	0	0.0000	108	0.6923
27	627	18	0.1154	126	0.8077
28	628	0	0.0000	126	0.8077
29	629	0	0.0000	126	0.8077
30	630	0	0.0000	126	0.8077
31	701	0	0.0000	126	0.8077
32	702	0	0.0000	126	0.8077
33	703	24	0.1538	150	0.9615
34	704	6	0.0385	156	1.0000

Mean Date: 20.1154 Variance: 68.7944
Skewness: .0113812 Kurtosis: -1.32719

Table A21. Subdistrict 334-11, 1981: (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
5	605	24	0.1000	24	0.1000
6	606	0	0.0000	24	0.1000
7	607	0	0.0000	24	0.1000
8	608	24	0.1000	48	0.2000
9	609	0	0.0000	48	0.2000
10	610	0	0.0000	48	0.2000
11	611	24	0.1000	72	0.3000
12	612	0	0.0000	72	0.3000
13	613	0	0.0000	72	0.3000
14	614	0	0.0000	72	0.3000
15	615	24	0.1000	96	0.4000
16	616	0	0.0000	96	0.4000
17	617	0	0.0000	96	0.4000
18	618	24	0.1000	120	0.5000
19	619	0	0.0000	120	0.5000
20	620	0	0.0000	120	0.5000
21	621	0	0.0000	120	0.5000
22	622	24	0.1000	144	0.6000
23	623	0	0.0000	144	0.6000
24	624	0	0.0000	144	0.6000
25	625	24	0.1000	168	0.7000
26	626	0	0.0000	168	0.7000
27	627	0	0.0000	168	0.7000
28	628	0	0.0000	168	0.7000
29	629	24	0.1000	192	0.8000
30	630	0	0.0000	192	0.8000
31	701	0	0.0000	192	0.8000
32	702	24	0.1000	216	0.9000
33	703	0	0.0000	216	0.9000
34	704	0	0.0000	216	0.9000
35	705	0	0.0000	216	0.9000
36	706	0	0.0000	216	0.9000
37	707	0	0.0000	216	0.9000
38	708	0	0.0000	216	0.9000
39	709	24	0.1000	240	1.0000

Mean Date: 20.4 Variance: 110.24
Skewness: -.0963079 Kurtosis: -1.10603

Table A22. Subdistrict 334-11, 1982 (1) Daily fishing hours; (2) Daily Proportion of fishing hours; (3) Cumulative fishing hours; (4) Cumulative proportion of fishing hours.

DAY	DATE	(1)	(2)	(3)	(4)
14	614	24	0.1176	24	0.1176
15	615	0	0.0000	24	0.1176
16	616	0	0.0000	24	0.1176
17	617	24	0.1176	48	0.2353
18	618	0	0.0000	48	0.2353
19	619	0	0.0000	48	0.2353
20	620	0	0.0000	48	0.2353
21	621	24	0.1176	72	0.3529
22	622	0	0.0000	72	0.3529
23	623	0	0.0000	72	0.3529
24	624	24	0.1176	96	0.4706
25	625	0	0.0000	96	0.4706
26	626	0	0.0000	96	0.4706
27	627	0	0.0000	96	0.4706
28	628	24	0.1176	120	0.5882
29	629	0	0.0000	120	0.5882
30	630	0	0.0000	120	0.5882
31	701	24	0.1176	144	0.7059
32	702	0	0.0000	144	0.7059
33	703	0	0.0000	144	0.7059
34	704	0	0.0000	144	0.7059
35	705	24	0.1176	168	0.8235
36	706	0	0.0000	168	0.8235
37	707	0	0.0000	168	0.8235
38	708	36	0.1765	204	1.0000

Mean Date: 26.7059 Variance: 68.737
Skewness: -.432297 Kurtosis: -1.24634

APPENDIX B

PROGRAM LIST

MTV2EB.FOR, error bound calculations for varying means and variances using the normal distribution.

MTR4.FOR, simulation program for calculating repetitions of $\bar{t}_j$ where j = 1, 2 ··· 40 with MSE calculations.

MTVEB2.FOR

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                      C
C   MIGRATORY TIMING VARIATIONS        C
C             FOR                      C
C        THE NORMAL CURVE              C
C ------------------------------------ C
C  CALCULATIONS OF PROPORTIONS         C
C       WITH OPTIONS :                 C
C         VARY THE MEAN OR VARIANCE    C
C         WITH ERROR BOUNDS FROM       C
C            RATIO ESTIMATOR           C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C   ------ DIRECTORY  -------------
C
C   L - # OF DAYS IN OBS - MOMENTS
C   D1 - DAY OF OBS - CALCULATING MEAN OF TIME DENSITY
C   P2 - ABUNDANCE OF PROP- DAILY PROP CALCULATED FROM AVG CUM
C
C
C   ISER - SINGLE MOMENTS RUN - 1 OR MULTIPLE RUNS
C   IRUN - # OF MULTIPLE SINGLE MOMENTS RUNS
C   RUN - RE-EXECUTE PROGRAM
C   FILE - FOR OUTPUT FILES
C
C   AL -  AVG FOR THE COMPLETE SEQ. - POP. MEAN
C   VL -  VARIANCE - POP. VARIANCE
C   CSUM - CUMULATIVE PROPORTION OF TOTAL CATCH
C   AVGT  - MEAN TIME DENSITY
C   VART  - VARIANCE OF TIME DENSIY
C
C   STD - STD.DEVIATION FROM STAT2
C    G  - SKEWNESS FROM STAT2
C   GG  - KURTOSIS FROM STAT2
C
C
C
C       UNIT=01 - DAILY PROPORTIONS GENERATED FROM FORMULA
C
C
        DIMENSION DAY(41),DAY2(41),PROP(41),PROP2(41)
        DIMENSION KK(41),JKL(41)
        DIMENSION D1(41),P1(41),P2(41)
        DIMENSION DAYS(41),A(41),V(41),C(41),S(41)
        INTEGER L,RUN,DEC,PTT,LDAY
        TYPE 10010
C              INITIALIZE ACCEPT STATMENTS FOR EACH RUN
10      RUN=0
        ERROR=0
        FILE=0
        IRUN=0
```

```
      ISER=0
      SDM1=0.
      SDM2=0.
      SDM=0.
      AVGT=0.
      STD=0.
      STEP=0.
      FIX=0
      PI=3.14159
C
C
C     ##############################################################
C######## ############ ############## #############
###########
      TYPE 10190
      ACCEPT *, L
C
C
c
c
c            BEGIN SINGLE RUN SERIES OF CALCULATIONS
      TYPE 248
      ACCEPT *,ISER
248   FORMAT(/5x,'You have option of making a single sampling run',
      1 /5x,'with a single mean and variance you select, and ',
      2 /5x,'calculate the daily proportions from the normal dist.',
      3 /5x,'OR you can fix either the mean or the variance, and',
      4 /5x,'let the other moment vary about some limits.  You must',
      5 /5x,'begin at the lowest value and set the increments you',
      6 /5x,'need. The upper limit of the varing parameter is set',
      7 /5x,'by the number of runs you set.  ',
      1 //5X,'NOTE: THE PROPORTIONS GENERATEED WILL GO TO A R-W ',
      2 /5X,'        FILE NAMED F28.DAT - TO BE ENTERED BELOW',
      3 //5X,'NOTE: ALL NUMBERS ENTERED MUST BE REAL NUMBERS',
      5 //5x,'Type - 1 - 1 single  run of n migratory days',
      6 //5x,'       2 - Fix one moment and vary the other - with',
      7 /5X,'           MOMENTS TABLES ONLY!!!',
      1 //5x,'       3 - Same as 2 above, with',
      8 /5X,'         - MOMENTS TABLE AND SEQUENCE OF EACH RUN,',
      9 /5X,'           SAVED, BUT EACH IN A SEPARATE FILE.',
      1 /5X,'           MOMENTS TABLE ONLY VIEWED ON SCREEN!!')
      TYPE 10200
      ACCEPT *,FILE
      GO TO (260,220,220) ISER
220   TYPE 100
      ACCEPT *, FIX
100   FORMAT(/5X,'YOU HAVE THE OPTION OF FIXING EITHER THE MEAN ',
      1 /5X,'OR VARIANCE OF THE DISTRIBUTION, AND LET THE OTHER',
      2 /5X,'VARY BETWEEN SOME DESIGNATED RANGE -  CHOOSE -',
      5 /5X,'NOTE: ERROR BOUND ESTIMATE IS THE SAME FOR ALL RUNS',
      6 /5X,'      IF VARIANCE IS FIXED AND CAN BE CAL. ON MT.FOR',
      3 //10X,'FIXED MEAN - 1',
      4 /10X,'FIXED VARIANCE - 2 ')
      IF (FIX.EQ.2) GO TO 20
```

```
         TYPE 120
         ACCEPT *, AVGT
120      FORMAT(//5X,'PLEASE TYPE IN THE FIXED MEAN TIME DENSITY -')
         TYPE 130
         ACCEPT *, STD
C
130      FORMAT(//5X,'TYPE IN THE BEGINING STD VALUE ')
         GO TO 30
20       CONTINUE
         TYPE 140
         ACCEPT *, STD
140      FORMAT(//5X,'PLEASE TYPE IN THE FIXED STD FROM THE VARIANCE',
         1  /5X,'OF THE TIME DENSITY-')
         TYPE 150
         ACCEPT *, AVGT
150      FORMAT(//5X,'TYPE IN THE BEGINING VALUE FOR THE MEAN ')
30       CONTINUE
         TYPE 160
         ACCEPT *, STEP
160      FORMAT(///5X,'WHAT STEP INCREMENT DO YOU WANT ?')
         TYPE 250
         ACCEPT *, IRUN
250      FORMAT(//5X,'How many INCREMENT STEPS do you want ¼1-40½?')
         IF(FIX.EQ.2) GO TO 251
         TYPE 200
         ACCEPT *,EB
200      FORMAT(//5X,'Do you want the ERROR BOUNDS calculated for',
         1  /5x,'for each distribution generated ? Must have outside',
         2  /5x,'file !!!',
         3  /5x,'Type - 1 - yes',
         4  /5x,'     - 2 - NO')
251      IF(FILE.EQ.2) GO TO 254
         GO TO (260,253,252) ISER
252      TYPE 10210
         OPEN(UNIT=21,ACCESS='SEQOUT',MODE='ASCII',DIALOG)
253      TYPE 10211
         OPEN(UNIT=22,ACCESS='SEQOUT',MODE='ASCII',DIALOG)
         IF(EB.EQ.2) GO TO 254
         TYPE 10212
         OPEN(UNIT=23,ACCESS='SEQOUT',MODE='ASCII',DIALOG)
         WRITE(23,10181) L
         IF(FIX.EQ.2) GO TO 210
         WRITE(23,209) AVGT
209      FORMAT(5X,'Mean Time Density -',f7.3)

         WRITE(23,10465)
         GO TO 254
210      WRITE(23,211) Std
211      FORMAT(5X,'Std. deviation -',F7.3)
         WRITE(23,10464)
254      CONTINUE
         if(ISER.EQ.2) GO TO 260
260      GO TO (269,261,261) ISER
261      GO TO (262,263) FILE
```

```
262     WRITE(22,10181) L
        WRITE(22,10182)
263     WRITE(5,10182)
C
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C       XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C          BEGIN RUN
C   ----------------------
C
        go to (269,268,268) iser
268     do 565 is=1,IRUN
        WRITE(21,*) IS
        GO TO 285
269     IF(FILE.EQ.2) GO TO 270
        TYPE 10210
        OPEN(UNIT=21,ACCESS='SEQOUT',MODE='ASCII',DIALOG)
270     TYPE 275
        ACCEPT *, AVGT,STD
275     FORMAT(//5X,'TYPE IN THE MEAN AND STANDARD DEVIATION -')
285     CONTINUE
        OPEN(UNIT=01,FILE='F28.DAT')
        CSUM=0.
        VART=STD**2
        TS=0.
        TK=0.
        G=0.
        GG=0.
        T2A=0.
C
C      BEGIN FOR # OF DAYS WANTED TO OBSERVE
C
C      GENERATE NUMBERS - SAME AS ABOVE
C      MAKES SURE NO NUMBER IS REPEATED (JKL(PPT)=-1)
C
C
C
        IF (FILE.EQ.2)  GO TO 350
        WRITE(21,330)
330     FORMAT(/2X,'DAILY PROPORTION OF CATCH FROM NORMAL',
        1  /2X,'(1)-DAY OF MIGRATION',
        2  /2X,'(2)-DAILY ABUNDANCE',
        3  /2X,'(3)- CUMULATIVE ABUNDANCE - F¼X½',
        3  /1X,'--------------------------------------------',
        1  /1X,'  1       2       3         ',
        2  /1X,'---------------------------------------------')
350     CONTINUE
C
C       UNIT 01 - DAILY PROP OF CATCH, CALCULATED FROM AVG CUM PROP (Y)
C
C
        IF(ISER.GT.1) GO TO 390
        IF (SCREEN.EQ.2)  GO TO 390
        WRITE(5,330)
C
```

```
390     CONTINUE
C
C       READ 01 - DAILY PROP OF CATCH FROM CUM DATA
C
C
C
C       D1 - DAYS OF OBS-CUM MEAN TIME DENSITY
C       P2 - DAILY ABUNDANCE OF PROP - FORM CUM - TIME DENSITY
C
C
        DO 430 J=1,L
        EX1=0.
        DP=0.
        EX=0.
        T1=0.
        T1A=0.
        T2=0.
        T2A=0.
        XJ=FLOAT(J)
        DP=(1.0/(STD*(SQRT(2.0*PI))))
        EX1=((XJ-AVGT)/STD)**2
        EX=EXP(-(0.5)*EX1)
        P2(J)=DP*EX
        IF(ISER.EQ.2) GO TO 409
        WRITE(01,*) J,P2(J)
 409    CSUM=CSUM+P2(J)
C
C
        IF(ISER.EQ.2) GO TO 420
        IF(FILE.EQ.2)  GO TO 410
        WRITE(21,10310) J,P2(J),CSUM
410     CONTINUE
        IF(ISER.GT.1) GO TO 420
        WRITE(5,10310) J,P2(J),CSUM
420     CONTINUE
        T1=(XJ-AVGT)**3
        T1A=T1*P2(J)
        TS=TS+T1A
        T2A=(XJ-AVGT)**4
        T2=T2A*P2(J)
        TK=TK+T2
430     CONTINUE
C
C
        G=TS/(STD**3)
        GG=TK/(STD**4)
C
C   X X X X X X ERROR BOUNDS X X X X X
C
        IF(EB.EQ.2) GO TO 579
C
        SUM1=0.
        SUM1A=0.
        SUM2=0.
```

```
      SUM2A=0.
      SUM3=0.
      SUM3A=0.
      R1=0.
      R2=0.
      SUMD=0.
      VE=0.
      RE1=0.
      RE2=0.
      OUT1=0.
      OUT2=0.
      CAL3=0.
      CAL2=0.
      OUTA=0.
      CAL1=0.
      CALA=0.
      REWIND 01
      DO 576 IJ=1,L
      READ(01,*) DAY2(IJ),P2(IJ)
      XL=FLOAT(L)
      SUM1=(DAY2(IJ)*P2(IJ))**2
      SUM1A=SUM1A+SUM1
      SUM2=(DAY2(IJ)*(P2(IJ)**2))
      SUM2A=SUM2A+SUM2
      SUM3=(P2(IJ)**2)
      SUM3A=SUM3A+SUM3
      R1=(DAY2(IJ)*P2(IJ))
      R2=R2+R1
      SUMD=SUMD+P2(IJ)
576   CONTINUE
      DO 577 JI=1,L
      XJI=FLOAT(JI)
      OUTA=(XL*(XL-XJI))/XJI
      CAL2=(2.0*R2*SUM2A)
      CAL3=((R2**2)*SUM3A)
      CAL1=(SUM1A-CAL2+CAL3)
      CALA=(CAL1/(XL-1.0))
      VE=OUTA*CALA
      RE1=AVGT+(2.0*(SQRT(VE)))
      RE2=AVGT-(2.0*(SQRT(VE)))
      VART=STD**2
      IF(FIX.EQ.2) GO TO 588
      WRITE(23,10467) JI,RE1,RE2,VART,VE
588   CONTINUE
577   CONTINUE
      CLOSE(UNIT=01)
C
C - - -  END OF BOUND OF ERROR RUN
C
579   CONTINUE
C
C
C       SKIP OUTPUT TO CRT AND GO TO SMR
C
```

```
      IF(ISER.GT.1) GO TO 480
C
C
      WRITE(5,10360) L
      TYPE 10380, G,GG
      GO TO 475
470   WRITE(5,10390) L,AVGT,VART,CSUM,G,GG
475   CONTINUE
C
C     FILE - OUTPUT FROM SINGLE TO OUTSIDE FILE UNIT=21
C     IF FILE=2, NO OUTPUT
C
C
C
      GO TO 486
C
C           multiple runs of single moments
480   GO TO  (481,482) FILE
481   WRITE(22,10390) IS,AVGT,VART,G,GG
482   WRITE(5,10390) IS,AVGT,VART,G,GG
C
c
486   continue
c
      IF(FILE.EQ.2)  GO TO 540
490   CONTINUE
      WRITE(21,500) AVGT,VART,CSUM
500   FORMAT(/1X,'MEAN TIME DENSITY= ',F9.4,
      1  /1X,'VARIANCE OF TIME DENSITY= ',F10.4,
      1  /1X,' CUMULATIVE TOTAL - F¼X½= ',F7.5)
510   CONTINUE
      WRITE(21,520) L,G,GG
520   FORMAT(/1X,'NUMBER OF DAYS IN MIGRATION = ',I2,
      3  /1X,'SKEWNESS = ',F9.4,
      4  /1X,'KURTOSIS = ',F9.4)
C
C
C
C
540   CONTINUE
C
C
C
      IF(FIX.EQ.2) GO TO 295
      STD=STD+STEP
      GO TO 300
295   AVGT=AVGT+STEP
300   CONTINUE
565   continue
c
c                      end of run for single moments run
c
570   CONTINUE
C
```

```
C # # # # # # # # # #  E N D   OF  S E Q U E N C E   R U N S  # # # # # #
C # # # # # # # # # # # # # #  ### ##  # # # # # # # # # # # # # # # # # #
C      ################################################################
C######################################################################
C######################################################################
C
C
C   - - - -  RE-USE R/W FILES
C
       CLOSE(UNIT=01)
       CLOSE(UNIT=20)
       CLOSE(UNIT=23)
       CLOSE(UNIT=24)
       CLOSE(UNIT=21)
C
C
C
       TYPE 574
       ACCEPT *,ISMR
574    FORMAT(/5X,'DO YOU WANT TO MAKE ANOTHER RUN AS BEFORE ?',
       1  /5X,'TYPE - 1 - YES',
       2  /5X,'        2 - NO !!')
       IF(ISMR.EQ.9) GO TO 711
       GO TO (10,700) ISMR
C---------------------------------------------------------------------
C
700    CONTINUE
       TYPE 10670
       ACCEPT *, RUN
       IF (RUN.EQ.1)  GO TO 10
710    CONTINUE
       TYPE 10680
       ACCEPT *,HLP
       IF(HLP.LT.1)  GO TO 10
711    CLOSE(UNIT=20)
       CLOSE(UNIT=21)
       CLOSE(UNIT=23)
       CLOSE(UNIT=24)
       STOP
C
10010  FORMAT(///5X,'###################################',
       1  //12X,'A SIMULATION MODEL',
       2  //6X,'MIGRATORY TIMING VARIATIONS',
       3  //5X,'###################################')
10181  FORMAT(/5X,'NO. OF MIGRATORY DAYS -',I4)
10182  FORMAT(/5x,'Daily Proportion of Catch',
       1  /5x,'1 - # of runs      2 - Mean Time Density',
       2  /5x,'3 - Variance of Time Density',
       4  /5x,'4 - Skewness',
       5  /5x,'5 - Kurtosis',
       6  /1x,'--------------------------------------------------',
       7  /1x,' 1      2          3            4         5        ',
       8  /1x,'--------------------------------------------------')
10190  FORMAT(/5X,'HOW MANY  DAYS ¼n½  ARE IN THE MIGRATION? (1-40)')
```

```
10200   FORMAT(/5X,'DO YOU WANT THE OUTPUT TO GO TO AN OUTSIDE FILE',
        1  /5X,'FOR LATER USE?',
        2  /5X,'TYPE - 1 - YES',
        3  /5X,'      - 2 - NO')
10210   FORMAT(/5X,'PLEASE TYPE THE NAME OF THE OUTPUT FILE-',
        1  /5X,'NOTE-THIS FILE IS FOR THE RUN SERIES',
        2  /11X,'WITH DAILY PROPORTIONATE DATA')
10211   FORMAT(//5X,'THIS FILE IS FOR THE MOMENTS TABLE FOR THE RUN',
        1  /5X,'SERIES.  PLEASE TYPE THE OUTPUT FILE NAME -')
10212   FORMAT(//5X,'This file is for error bounds for each
distribution',
        1  /5x,'generated.  Type file name -')
10310   FORMAT(2X,I2,2(2X,F7.5))
10360   FORMAT(/1X,'NUMBER OF MIGRATORY DAYS = ',I2)
10380   FORMAT(/2X,'SKEWNESS = ',F9.4,
        1  /2X,'KURTOSIS = ',F9.4)
10390   FORMAT(1X,I2,2X,F8.4,2X,F9.4,2(2X,F9.4))
10464   FORMAT(/5X,'Bound on error of estimation',
        1  /5x,'from normal distribution',
        2  /5x,'1- number of days sampled',
        3  /5x,'2- mean time density',
        4  /5x,'3- UPPER bound   4- LOWER bound',
        5  /5x,'5- variance estimator',
        6  /2x,'-----------------------------------------------------',
        8  /2x,'-----------------------------------------------------')
10465   FORMAT(/5X,'BOUND ON THE ERROR OF ESTIMATION',
        1  /5X,'DAILY PROPORTION OF CATCH',
        5  /5x,'from normal distribution',
        2  /5X,'1- NO. OF DAYS SAMPLED',
        5  /5X,'2- UPPER BOUND   3- LOWER BOUND',
        4  /5X,'4- VARIANCE OF TIME DENSITY',
        1  /5X,'5- VARIANCE ESTIMATOR',
        6  /2X,'------------------------------------------------------------',
        8  /2X,'------------------------------------------------------------')
10466   FORMAT(3X,I2,2X,F6.3,2X,F7.3,2(2X,F7.3))
10467   FORMAT(3X,I2,4(2X,F7.3))
10670   FORMAT(/5X,'DO YOU WANT TO TRY AGAIN?',
        1  /5X,'TYPE (1) IF YOU WANT TO START AGAIN',
        2  /5X,'TYPE (2) IF YOU WANT TO END IT ALL!!!')
10680   FORMAT(/5X,'PLOT FILES CAN BE PREPARED USING THE FOLLOWING-',
        1  //5X,'PLTMOM.FOR - TIME DENSITY AND PROPORTIONS DATA',
        2  /5X,'PLTMV2.FOR - MOMENTS TABLES, AND DAYS DENERATED AS',
        3  /5x,'              STD.ERROR AND RESIDUAL DATA',
        4  //5x,'A guide to file transfer to the VECTOR diskett',
        5  /5x,'usage is avialable in the USER GUIDE',
        6  //5X,'TYPE - 1 - WHEN YOU WISH TO END EXECUTION-')
        END
```

MTR4.FOR

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                         C
C         MIGRATORY TIMING                C
C         WITH REPETITIONS                C
C-----------------------------------------C
C              OPTIONS:                   C
C    MSE AND BIASNESS CALCULATIONS        C
C    RANDOM MEAN TIME DENSITIES           C
C               FROM                      C
C      CHINOOK SALMON DATA    OR          C
C      NORMAL CURVE DATA                  C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C       CH - CHOOSE RANDOM LISTING OR MAX-MIN
C       DEC - CHOOSE MSE OR RANDON NUMBER LISTINGS
C       IC - INCREMENTS (DAY, OR EVERY 5 DAYS, ETC.)
C       IB - BEGIN DAY SAMPLED
C       IE - END OF DAYS SAMPLED
C       IRUN - # OF REPITITIONS
C       M - # MIG. DAYS
C       OUT - OUTSIDE FILE
C       R - POP MEAN TIME DENSITY
C       VSRTA - IMSL subroutine
C       STAT2 - subroutine to calculate moments
C
        DIMENSION KK(1001),JKL(1001),DAY(1001),D1(1001),P1(1001)
        DIMENSION DAY2(1001),D2(1001),P2(1001),ER(1001),TV(1001)
        DIMENSION TD(1001),TD1(1001),A(1001)
        REAL MSE
1       TYPE 10100
        OPEN(UNIT=20,ACCESS='SEQIN',MODE='ASCII',DIALOG)
10100   FORMAT(/5X,'PLEASE ENTER NAME OF FILE -',
        1  /5X,'DAILY PROPORTIONS OF CHINOOK - FOR01.DAT',
        2  /5X,'CPUE - CHINOOK               - FOR23.DAT',
        3  /5X,'OTHER SUCH AS NORMAL         - F28.DAT')
        M=0
        IRUN=0
        IB=0.
        IE=0
        IC=0
        R=0.
        TSUM=0.
        MSE=0.
        BIAS=0.
        B=0.
        US2=0.
        B2=0.
        B1=0.
        B3=0.
        TYPE 10110
        ACCEPT *,M
```

```
10110   FORMAT(//5X,'HOW MANY DAYS IN MIGRATION ?')
        TYPE 10120
        ACCEPT *,IRUN
10120   FORMAT(//5X,'HOW MANY REPITITIONS FOR EACH OF THE DAYS ',
        1  /5X,'SAMPLED DO YOU WANT ?')
        TYPE 10130
        ACCEPT *, R
10130   FORMAT(//5X,'TYPE IN THE MEAN TIME DENSITY -')
        CALL TIME(X,Y)
        IY=IFIX(Y*100)
        CALL SETRAN(IY)
        TYPE 10132
        ACCEPT *, IB,IE,IC
10132   FORMAT(//5X,'TYPE IN THE BEGINNING DAY SAMPLED -',
        1  /5X,'TYPE THE LAST DAY SAMPLED OREND OF MIGRATION ¼40½',
        2  /5X,'AND THE INCREMENTS YOU WANT ¼1-EVERY DAY, 5-EVERY 5')
        TYPE 10135
        ACCEPT *, DEC
10135   FORMAT(//5X,'CHOOSE -  BIAS AND MSE CALCULATIONS - 1 -',
        1  /5X,'        - RANDOM MEAN TIME DENSITY - 2')
        TYPE 10140
        ACCEPT *,OUT
10140   FORMAT(//5X,'DO YOU WANT OUTSIDE FILE ?',
        1  /5X,'TYPE - 1 - YES',
        2  /5X,'     - 2 - NO !!')
        IF(OUT.GT.1) GO TO 4
        IF(DEC.GT.1) GO TO 2
        TYPE 10150
        OPEN(UNIT=21,ACCESS='SEQOUT',MODE='ASCII',DIALOG)
10150   FORMAT(///5X,'TYPE FILE NAME FOR BIAS AND MSE -')
        GO TO 4
2       TYPE 10152
        ACCEPT *, CH
10152   FORMAT(////5X,'CHOOSE ---',
        1  /5X,'1 - LISTINGS OF RANDOM MEANS TO OUTSIDE FILE -',
        2  /5X,'2 - MEAN, MIN, MAX & VARIANCE OF RANDOM SEQUENCE',
        3  /5X,'3 - BOTH -note, no 2 seen on screen ')
        IF(CH.EQ.2) GO TO 3
        TYPE 10155
        OPEN(UNIT=22,ACCESS='SEQOUT',MODE='ASCII',DIALOG)
10155   FORMAT(/5X,'TYPE FILE NAME FOR RANDOM MEAN  -')
        IF(CH.EQ.1) GO TO 4
3       TYPE 10156
        OPEN(UNIT=21,ACCESS='SEQOUT',MODE='ASCII',DIALOG)
10156   FORMAT(//5X,'TYPE FILE NAME FOR MEAN AND VARIANCE OF',
        1  /5X,'TIME DENSITIES GENERATED - ERASE.ME')
4       CONTINUE
        WRITE(5,10160)
        WRITE(5,10161) M,IRUN,R
        if(dec.eq.1) go to 6
        if(CH.EQ.1) go to 5
        WRITE(5,10172)
10161   FORMAT(6X,I2,2X,I4,4X,F6.3)
        IF(OUT.EQ.2) go to 8
```

```
      GO TO 7
5     CONTINUE
      WRITE(5,10165)
      GO TO 7
6     CONTINUE
      WRITE(5,10170)
      IF(OUT.GT.1) GO TO 8
      WRITE(21,10170)
      GO TO 8
7     GO TO (11,12,11) CH
11    WRITE(22,10160)
      WRITE(22,10161) M,IRUN,R
      write(22,10165)
      IF(CH.EQ.1) GO TO 8
12    WRITE(21,10160)
      WRITE(21,10161) M,IRUN,R
      WRITE(21,10172)
8     CONTINUE
C
C     CALCULATIONS FOR VARIANCE ESTIMATE OF POP TOTAL
C
      REWIND 20
      B2=0.
      B=0.
      DO 15 JL=1,M
15    READ(20,*) D1(JL),P1(JL)
      DO 18 J=1,M
      B1=0.
      XM=FLOAT(M)
      A(J)=D1(J)*P1(J)
      B1=A(J)*A(J)
      B2=B2+B1
      B3=B3+A(J)
18    CONTINUE
      B=((B3)**2)/XM
      US2=(B2-B)/(XM-1.)
19    CONTINUE
C
C     X X X X X X X X X X X X X X X X X X X X X X X X X X X X X  X X
C     BEGIN # OF RANDOM SAMPLED DAYS
      DO 100 L=IB,IE,IC
C
      REWIND 20
C
      XL=FLOAT(L)
      XM=FLOAT(M)
      AVGT=0.
      AAVGT=0.
      S11=0.
      S2=0.
      TS=0.
      T0=0.
      T1=0.
      TTS=0.
```

```
      TSUM=0.
      MSE=0.
      BIAS=0.
      VART=0.
      SMSE=0.
      ER(IIS)=0.
      TCSUM=0.
C
C
C-------------------------------------------------------------
C     BEGIN REPITITION FOR EACH RANDOMLY SAMPLED DAY
C     ------------------------------------------------
C
      DO 85 IS=1,IRUN
      TOT=0.
      S1=0.
      CSUM=0.
      EMSE=0.
      AVGT=0.
      KK(I)=0.
      JKL(I)=I
      AVG=0.
      D1(III)=0.
      VAR=0.
      JKL(I)=I
      DO 20 I=1,M
      JKL(I)=I
20    KK(I)=0.
C
C
C     MONTE CARLO
C
      DO 30 II=1,L
35    PTT=40*RAN(0)+1
      IF(JKL(PTT).EQ.-1) GO TO 35
      KK(II)=PTT
      JKL(PTT)=-1
30    CONTINUE
      LR=L
      CALL VSRTA(KK,LR)
      DAY(1)=0
      DO 40 IIJ=1,M
40    DAY(IIJ)=DAY(IIJ-1)+1
c     DO 50 JJJ=1,M
c50   READ(20,*) D1(JJJ),P1(JJJ)
      DO 60 III=1,L
      D1(III)=DAY(KK(III))
      P2(III)=P1(KK(III))
60    CSUM=CSUM+P2(III)
C
C
C     SCALE TIME DENSITY
C
      DO 70 I=1,L
```

```
        AVG=0.
        AVG=D1(I)*(P2(I)/CSUM)
70      AVGT=AVGT+AVG
C       DO 80 J=1,L
C       VAR=((D1(J)-AVGT)**2)*(P2(J)/CSUM)
C80     VART=VART+VAR
        ER(IS)=AVGT
        TV(IS)=VART
C
C       ESTIMATES OF MSE
C
        TCSUM=TCSUM+CSUM
        TAVG=TAVG+ER(IS)
        S1=ER(IS)**2
        S11=S11+S1
        IF(DEC.EQ.1) GO TO 80
        WRITE(22,*) L,ER(IS)
80      CONTINUE
85      CONTINUE
C
CX X X X X X X   END OF REPETITIONS  X X X X X X X X X X X X X
C = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
        CALL VSRTA(ER,IRUN)
        DO 74 II=1,IRUN
        RMIN=ER(1)
        RMAX=ER(IRUN)
74      CONTINUE
        TD(1)=0
        RUN=IRUN
C
        TSUM=TCSUM/RUN
        AAVGT=TAVG/RUN
        TO=TAVG*TAVG
        T1=TO/RUN
        S2=(S11-T1)/(RUN-1.0)
        BIAS=AAVGT-R
C

        IF(DEC.EQ.1) GO TO 89
        WRITE(5,10175) L,AAVGT,RMIN,RMAX,S2
        WRITE(21,10175) L,AAVGT,RMIN,RMAX,S2
        GO TO 96
89      DO 90 IIS=1,IRUN
        TS=0.
        TS=(ER(IIS)-R)**2
90      TTS=TS+TTS
        MSE=TTS/RUN
        STD=SQRT(MSE)
        VG1=((M**2)*US2)/XL
        VG2=1.-(XL/XM)
        VG=VG1*VG2
        IF(OUT.GT.1) GO TO 95
        WRITE(21,10180) L,AAVGT,TSUM,BIAS,MSE,VG
95      WRITE(5,10180) L,AAVGT,TSUM,BIAS,MSE,VG
```

```
96      CONTINUE
C
C
100     CONTINUE
C   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C  X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
        CLOSE(UNIT=21)
        CLOSE(UNIT=22)
        TYPE 10200
        ACCEPT *,REP
10200   FORMAT(//5X,'DO YOU WANT TO TRY AGAIN ?',
        1  /5X,'TYPE - 1 - YES',
        2  /5X,'     - 2 - NO, END EXECUTION !!')
        IF(REP.EQ.1) GO TO 1
10160   FORMAT(/5X,'NUMBER OF',
        1  /5X,'DAYS   REPS   MTD')
10165   format(/5x,'number of days sampled & mean time density',
        1  /5X,'---------------------------------------------',
        2  /5X,'                     ',
        3  /5X,'---------------------------------------------')
10170   format(/5x,' The mean- cumulative proportion- bias and MSE',
        1  /5x,'of a biased estimator and MSE of unbias estimator,'
        2  /5x,'of the population total fro a number of possible,'
        3  /5x,'days ½j½ randomly sampled,'
        5  /1X,'----------------------------------------',
        6  /1x,'num    mean    cum    bias    bias     unbias,'
        8  /1x,'days           prop           MSE       MSE,'
        7  /1X,'----------------------------------------')
10172   FORMAT(/5X,'A simulation run of possible means based on',
        1  /5x,'    repititions with the minimum and maximum mean time',
        2  /5x,'densities and their variance from random numbers of ',
        3  /5x,'possible days j where j= 1 --- 40 ',
        4  /1X,'----------------------------------------',
        5  /5x,'numb   mean   min   max     SAMPLE',
        7  /5x,'sampl         MEAN  MEAN    VARIANCE',
        6  /1X,'----------------------------------------')
10175   format(5x,I2,3(5x,F6.3),5x,F8.3)
10180   FORMAT(2X,I2,2X,F6.3,2X,F8.5,2X,F7.3,2(2X,F8.3))
        END
```

VITA

Arthur Jordan Butt was born in New Orleans, Louisiana, on February 3, 1949. He received a Bachelor of Science in Biology from the University of West Florida, Pensacola, in 1971 and a Master of Science in Marince Science from the same university in 1974. He has held teaching and research assistantships at the University of West Florida, as well as, Old Dominion University. Since 1982 he has managed the Environmental Pollution Laboratory, ODU, and was appointed Operations Manager of the Applied Marine Research Laboratory in 1984. He has published the following:

1978 A Cladistic Approach to the Evolutionary History of some Mazocraeid Trematodes. Virginia Aacademy of Science (abs)

1978 Emergent Vegetation as Indicators of Estimation of the Mean High Water Level of Freshwater Lacustrine Systems. (co-author M. C. Applegate) ASB Bull., Vol. 25, no. 2. (abs)

1978 Estuarine Shoreline Vegetation as Indicators of the Mean High Water Line. (co-author M. C. Applegate) ASB Bull., Vol 25, no. 2. (abs)

1978 Host-specificity and Zoogeography among Monogenetic Trematodes of the Family Mazocraeidae. ASB Bull., Vol 25, no. 2. (abs)

1976 Coastal Development Along Estuarine Shorelines. (co-author M. C. Applegate), Coastal Zone Management Symposium.

1976 Management of Coastal Wetlands: Perspective Enforcement of State Regulations Governing Dredging and Filling in Wetlands. (co-author M. C. Applegate), Coastal Zone Management Symposium.

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1973 Notes on a Trematode (Monogenea: Mazocraeidae) and its Host, *Stromateus stellatus* (Pisces: Stromateoide). Quart. J. Florida Academy of Science, Vol 35. (abs)

Academic Awards:

1. University Grant, 1978, Old Dominion University, Norfolk
2. University Scholarship, 1976-1977, Old Dominion University, Norfolk
3. University Scholarship, 1972, University of West Florida, Pensacola