FORECAST OF THE KAMISHAK HERRING STOCK IN 1994

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ABSTRACT

The 1994 abundance of Pacific Herring *Clupea pallasi* in the Kamishak Bay District of Lower Cook Inlet, Alaska, was forecasted for the first time from an age structured analysis model. This model estimates values of survival, maturity, gear selectivity, and initial population abundance that minimize differences between predicted and observed age composition and run biomass estimates. Estimated survival and adjusted initial population abundances were used to project the 1994 abundances. A regression model was used to predict 1994 weight at age from 1993 data.

The 1993 aerial surveys of run biomass were interrupted by bad weather. Therefore, the 1993 run biomass estimate was derived from daily aerial survey estimates of biomass divided by an estimate of expected daily proportion. The difference between the run biomass estimate, 32,439 tons, and the harvest, 3,570 tons, was escapement biomass. No late season age composition data was collected during 1993.

A biomass of 25 thousand tons of herring is forecast to return to the Kamishak Bay District in 1994. Herring mean weight is predicted to be 189 g. The 1988 year class is forecast to represent 70% of the run biomass and 69% of the individuals. The 1994 recommended total allowable harvest is 3.8 thousand tons and represents an exploitation rate of 15%. In accordance with the Kamishak Bay Herring Management Plan the harvest allocation is 3.4 thousand tons for the Kamishak spring sac roe fishery and 380 tons for the Shelikof Strait fall food and bait fishery.

KEY WORDS: *Clupea pallasi*, herring, forecast, Lower Cook Inlet, age structured analysis

INTRODUCTION

This report presents the forecast for the 1994 Kamishak Bay herring run biomass. This herring stock supports a spring sac roe fishery in the Kamishak Bay District (Lower Cook Inlet Management Area) and a fall food and bait fishery in Shelikof Strait (Kodiak Management Area; Figure 1).

Run biomass was defined as the segment of the herring population participating in the spring spawning migration and observed by aerial surveyors in the Kamishak Bay District between mid-April and June. Observed herring are considered recruited into the fishery and available to the sac roe fishing fleet even though harvest limits are typically achieved by mid-May. Escapement biomass was defined as the unharvested run biomass.

Stock assessment information such as age composition and aerial survey estimates of run biomass have been collected for the Kamishak Bay herring population since 1972. From this time series of biomass, mean weight-at-age, and age composition, biologists estimated annual abundances-at-age and mean survival rates. Forecast of future abundances and harvest allowances were then prepared using the previous year abundance estimates and the mean survival rate (Yuen and Bucher 1992, 1993).

Aerial survey estimates of biomass begin in early April when the nearshore area of Kamishak Bay District is surveyed daily from small aircraft to monitor relative abundance, distribution, and spawning of the herring population. Daily biomass estimates are derived from the number and size of herring schools observed. Run biomass estimates for each year largely rely on summing "peak" estimates from this time series of abundance observations. Because immigration to and emigration from the herring spawning grounds is likely a continuous process, aerial surveys tend to be conservative estimates of abundance.

In 1993, however, stock assessment activities were hampered by bad weather and turbidity for the third consecutive year of 'poor' aerial survey coverage when aerial surveyors were grounded for 12 consecutive days between 28 April and 9 May. Faced with the third year without a confirmed run biomass estimate from which to project ahead a year, we sought alternative methods to estimate 1994 abundance.

Age-structured analysis (ASA) was used this year for the first time in Kamishak Bay to model herring survival, age composition and biomass simultaneously. Although age and weight composition, obtained primarily from commercial purse seine catches and from test fish purse seine catches, are considered to be more precise than run biomass estimates, it was been treated separately from the aerial survey estimates of biomass until recently. Now, ASA employ nonlinear optimization algorithms to adjust all parameters simultaneously to minimize composite differences between predicted and observed age composition and run biomass. In the case of run biomass, the predicted biomass is scaled only to the observed aerial survey estimates of run biomass from years with "good" survey coverage. Thus, ASA methods are not as sensitive to missing data as was the historical forecast method.

While this approach removes much bias in abundance estimates by excluding aerial survey biomass estimates made during years having poor weather or inadequate geographic and temporal coverage, it only partially corrects the tendency for aerial surveys to be conservative. The ASA model estimates will still tend to underestimate true herring abundance since residence time of herring on the spawning grounds is not known and not all herring are observed, even during years with good surveys conditions.

The purpose of this report is to provide a forecast of herring returning to spawn in the Kamishak Bay District in 1994. Specific objectives are (1) to document data sources and methodology used for the 1994 forecast, (2) to document alternative forecasts, and (3) to present the 1994 forecast, and through application of Kamishak Bay Herring Management Plan (5 AAC 27.465), propose a harvest guideline for the 1994 commercial fishing season.

METHODS

In 1993, stock assessment activities were hampered by bad weather for the third consecutive year. Aerial surveyors were grounded for 12 consecutive days between 28 April and 9 May. Age composition samples were not obtained after the fishery ended in April. We were uncomfortable using the historical exponential decay model which relied on a prior year estimate of escapement biomass. Instead the 1994 forecast was chosen from one of three prepared; two using ASA models, (1) one in a spreadsheet and (2) the other in a FORTRAN program, in addition to (3) the historical exponential decay model (Yuen and Bucher 1992, 1993).

Database

Data for Kamishak herring run biomass observed as number of individuals at age and the herring harvests by age for purse seines from 1985 through 1993 (Appendix A and B) were obtained from the most recent abundance, age, and size report (Yuen and Bucher *in press*). All forecast models began with age-3, when Kamishak Bay herring first appear in the purse seine catch of sac roe herring. Although, age-1 and 2 herring have been captured with a trawl on the spawning grounds during the month of April, they are not considered recruited into the fishery as they rarely appear in the commercial harvest. Age composition estimates of the run biomass from 1985 through 1993 (Appendix C) were also obtained from Yuen and Bucher (*in press*).

During herring aerial surveys, observers estimate the surface area of herring schools arriving on the spawning grounds. Since 1989 surface areas have been converted to biomass estimates based on results of calibration samples from Togiak Bay in which entire herring schools were captured by purse seines after observers had estimated their surface area (Lebida and Whitmore 1985). Prior to 1989 the conversion of herring school surface area to biomass is undocumented. Biomass estimates from distinct spawning events are summed to obtain each annual run biomass. Distinct spawning events are defined as abundance peaks separated in space or time, having dissimilar age composition estimates, or showing differences in sexual maturity. Aerial survey estimates of run biomass from 1985 to 1993 were obtained from the most recent annual management reports (Bucher and Hammarstrom 1993) with the sole exception of 1989 where 27,855 tons (Appendix D) was used instead of 35,701 tons (Yuen et al. 1990).

The 1993 run biomass was estimated by dividing daily aerial survey estimates of run biomass by expected daily proportion. Expected daily proportions were obtained by averaging daily proportions across a 7-d period with the date in question being in the center of the period. The difference between the run biomass estimate, 32,439 tons, and the harvest, 3,570 tons, was escapement biomass (Yuen and Bucher *in press*). Age composition samples were not available after the fishery was completed in April.

Weight at Age

All forecast methods estimated age-specific numbers of individuals which needed be converted to biomass. Weight at age estimates for herring from 1985 through 1993 (Appendix E) were obtained from samples of herring from purse seine catches (Yuen and Bucher *in press*). Weight at age for herring, $\hat{w}_{a,y}$, in 1994 were estimated from previous age and weight data ($r^2 = 0.95$, d.f. = 89; Figure 2) using the linear regression model:

$$\hat{w}_{a,y} = 60.04989 + 1.50925(a-1) + 0.76936 w_{a-1,y-1} \; . \qquad (1)$$

Age-Structured-Analysis

The Kamishak Bay ASA models incorporates auxiliary information, similar to models developed by Deriso et al. (1985). Nonlinear least squares techniques are used to minimize a sum of squares constructed from heterogeneous types of auxiliary information which may incorporate many different sources of data. We developed two ASA models, one in an Excel spreadsheet with a vendor (Microsoft[1]) supplied nonlinear optimization function named SOLVER and the

[1]Vendor names are provided to document methods but do not constitute an endorsement by ADF&G

other written in FORTRAN incorporating Fletcher's non-linear optimization algorithm supplied by Hilborn and Walters (1992).

ASA models which incorporate heterogenous data have been reviewed by Hilborn and Walters (1992) and Megrey (1989). Whereas our primary goal was to generate a one-year-ahead forecast of herring abundance for 1994, the model also updated estimates of historical abundances for 1985-1993, and provided estimates of natural mortality and maturity. The Excel version also estimated gear selectivity for the purse seine fishery.

In our conceptual model of the annual cycle of events affecting the Kamishak Bay herring stock (Figure 3), we increment ages at the end of winter, coinciding with the approximate time of annulus formation. The population model begins accounting for herring at age 3, the first year a measurable proportion of a cohort usually return to spawn. Prior to spring, the conceptual model splits the "total" herring population into two components: an "immature" portion that will not return to spawn, and a "run" biomass that will return to inshore areas to spawn. Removals by the purse seine sac roe fishery are then deducted which leaves the "escapement" biomass that actually spawns. In this model configuration, we do not account for removals by the Shelikof Strait fall food and bait fishery, but these harvests are reflected in the survival rate estimate. These removals could be explicitly made when catch by age becomes available from these fisheries. However, because selectivity in this fishery may be highly variable and these harvests occur on mixed stocks, catch information from these fisheries may not provide useful "tuning" information for Kamishak ASA models.

The 1994 Kamishak herring biomass was forecast from the ASA estimate of 1993 total population size, adjusting for commercial removals, growth, mortality, maturity, and recruitment. Components used to prepare the forecast included estimates of: (1) the run biomass and commercial harvests, (2) age composition of the spawning biomass and harvest, and (3) weight-at-age. Initial parameter values for natural mortality, selectivity, maturity, and the number of age-3 herring for each cohort were provided before running the computer for each simulation model.

ASA Model In An Excel Spreadsheet

Survival

The survival component of our ASA model in an Excel spreadsheet used a difference equation to describe the number of herring (*N*) in a cohort aged *a* in year *y*:

$$\hat{N}_{a+1,y+1} = S\,(N_{a,y} - C_{a,y}) \qquad (2)$$

where S is the annual survival rate estimated by the ASA model and $C_{a,y}$ is the catch from the spring purse seine sac roe fishery. The number of herring in a cohort (N) includes both mature and immature herring present after annulus formation but before the spawning migration or spring roe fisheries occur (the "total population biomass" of Figure 3). The model starts accounting for herring at age 3. Herring age 11 and older were pooled into the "11+" category.

The starting value used in the model for annual survival rate was 70%, which is equivalent to a 0.35 instantaneous natural mortality rate (M). Values found in Yuen and Bucher (1992) were used as starting values for the abundance of the 1974-1990 year classes.

Estimated Catch Age Composition

Gear Selectivity. For purse seine catches an estimated age composition of the catch for each year ($\hat{p}_{a,y}$) was computed from a model which incorporated an age-specific gear selectivity function s_a and the estimated abundance $N_{a,y}$ from equation (2):

$$\hat{p}_{a,y} = \frac{s_a \hat{N}_{a,y}}{\sum_{a=3}^{11+} [s_a \hat{N}_{a,y}]} . \tag{3}$$

For our model, selectivity was defined as the proportion of the total population susceptible to capture by the fishing gear and includes the effect of immature herring not being present on the fishing grounds (partial recruitment or maturity), as well as active selection or avoidance of certain sizes classes of herring by the gear or fisher. Functions chosen to describe the relationship between gear selectivity and age were limited to two parameters because (1) it was desirable to minimize the number of parameters estimated by the model and (2) two parameters were the fewest that could adequately describe the age-selectivity relationship. The choice of a particular functional form represented an assumption which limited the possible range of selectivities. Purse seine gear was assumed to have an asymptotic selectivity and was represented by a logistic function:

$$s_a = \frac{1}{1 + e^{\beta(a - \alpha)}} , \tag{4}$$

where α is the age at which selectivity is equal to 50%, and β is a steepness parameter. Initial values for parameters used in equation 4 were chosen to give selectivities similar to those reported by Funk and Sandone (1990) for Prince William Sound.

SSQ Catch Age Composition. One measure of how well the ASA model fit actual data was obtained by comparing model age composition estimates for the commercial catch with actual estimates based on catch samples. For each gear, the sum of squares, SSQ, measuring the goodness of fit of the age composition of the catch was computed as:

$$SSQ_{agecomp:catch} = \sum_{y} \sum_{a} \left(\frac{C_{a,y}}{\sum_{a=3}^{11+} C_{a,y}} - \hat{p}_{a,y} \right)^2 , \qquad (5)$$

where $(\hat{p}_{a,y})$ was the estimated age composition of the catch from equation (3). A transformation, $\sin^{-1}$(square root), was applied to observed and estimated age composition proportions to stabilize the variance. Purse seine age composition was fit across all age groups (age 3 to 11^{+}) and years 1985 through 1993.

Maturity

Maturity was estimated for each age by the ASA model to estimate the proportion of the population which returned to spawn each year. The maturity function was applied when comparing abundances determined from equation (2) with aerial survey biomass estimates and run biomass age compositions. Because maturity is expected to be an asymptotic function, a logistic expression was used:

$$\rho_a = \frac{1}{1 + e^{\phi(a-\tau)}} , \qquad (6)$$

where τ is the age at which 50% of a cohort reach maturity, and ϕ is a steepness parameter. The maturity-age relationship was assumed to be constant over the range of years examined by the model. The validity of this assumption was investigated by examining run biomass age composition estimates to determine whether temporal trends in the sign or magnitude of their residuals were evident. Initial values supplied for maturity parameters set a 50% maturity at age 4 increasing to 100% maturity at age 7. Maturity based on ADF&G run age composition sampling is likely older than biological maturity because sampling tends to be curtailed at the end of the spawning run when younger fish are present.

We initially ran the ASA model without constraining the maturity function which compares abundances from both the aerial survey biomass and run biomass age composition estimates with model estimates. The resulting estimates were unrealistically low for older ages and suggested a need to constrain the maturity schedule. The actual age of full recruitment ($\rho_a \geq 0.98$) was unknown and the age we chose was based on our best opinion of Kamishak herring.

SSQ Biomass Estimates

Aerial survey data from 1985-1993 were rated based on coverage which included survey frequency, survey spatial and temporal coverage, and weather conditions (Table 1). Aerial surveys rated 'OK' (1986-1990) were considered for use in the ASA model as one of the surveys rated '?' (1986). One measure of how well the ASA model fit actual data was obtained by comparing model run biomass estimates with actual estimates based on aerial surveys. The sum of squares measuring the goodness of fit of the run biomass was based on the differences between ASA and aerial survey estimates of run biomass:

$$SSQ_{biomass} = \sum_{y=1986}^{1990} \{ \log_e (B_y^{survey}) - \log_e [\sum_{a=3}^{11+} \rho_a \, w_{a,y} \, \hat{N}_{a,y}] \}^2 , \qquad (7)$$

where B_y^{survey} is the aerial survey biomass estimate in year y, $w_{a,y}$ is the weight at age a in year y (Appendix E), ρ_a is the proportion mature at age a (equation 6) , and $N_{a,y}$ is the ASA estimate of total abundance at age a in year y (equation 2). Though there were too few abundance estimates to evaluate the appropriateness of the log transformation in equation (7), ASA models have been fit with and without the log transformation, with the results not being sensitive to this assumption (Funk et al. 1992). We chose to use a log transformation in our model because a lognormal error structure is commonly found when dealing with abundance data.

SSQ Run Age Composition

In addition to the time series of the catch by age, a time series of age composition estimates of the run biomass are available for 1985-1993 (Appendix C). The age composition of the run biomass was estimated using herring sampled from commercial fishery harvests as well as from areas where large concentrations of herring were sighted during aerial surveys or with vessel sonar. During fishery closures, departmental and volunteered commercial vessels made multiple purse seine sets to capture herring (hereafter referred to as test fishing). Samples were pooled whenever possible, in order to obtain sample sizes large enough (Yuen and Bucher *in press*) to represent the estimated biomass within area and time strata. For commercial harvests, samples were collected from tenders and fishing boats at the close of each fishing period. Both test fishing and commercial harvest samples were used to obtain data on herring age and size.

A measure of how well the ASA model fit actual data was obtained by comparing model run biomass age composition estimates with actual estimates based on samples. The sum of squares measuring the goodness of fit of the age composition of the run biomass was computed as:

$$SSQ_{agecomp:run} = \sum_y \sum_a [\, p_{a,y}^{run} - \frac{\rho_a \hat{N}_{a,y}}{\sum_a (\rho_a \hat{N}_{a,y})} \,]^2 \;, \tag{8}$$

where $p_{a,y}^{run}$ is the observed run age composition estimated for age a and year y. The $\sin^{-1}$(square root) transformation, was applied to observed and estimated age composition proportions to stabilize their variance. Only samples from 1986 and 1988 through 1990 were used in the SSQ of equation 8. Though sampling for run age composition began in 1985, years in which sampling did not occur on any but fishery days were excluded as they would be merely a duplicate of the harvest age composition.

Forecast Methodology

The forecast of herring run biomass for 1994 ($\hat{B}_{1994}^{Forecast}$) was based on projecting total abundance with the survival model (equation 2) modified by the ASA estimates of the proportion of mature herring expected for each age:

$$\hat{B}_{1994}^{Forecast} = \sum_a \rho_a \, \hat{w}_{a,1994} \, \hat{N}_{a,1994} \;, \tag{9}$$

where ρ_a is the proportion mature at age a from equation (6), $w_{a,1994}$ is weight at age a from the linear regression model of equation (1) and $N_{a,1994}$ is the ASA estimate of age-a herring for 1994 from equation (2). The above model was used to forecast the abundance of herring other than age 3, since we have no method to predict year class strength. For age-3 herring we used the median observed abundance of this age class, based on ASA estimates for the 1975-1990 year classes, to generate a 1994 forecast, $N_{3,1994}$. The median was thought to be more representative of recruitment in typical years than the mean year class strength, since the distribution of year class abundance at age 3 was very skewed.

The age composition of $\hat{B}_{1994}^{Forecast}$, ($p_{a,1994}$), was estimated using the maturity schedule estimated by the ASA model for the run biomass age composition, (ρ_a of equation 6), as:

$$\hat{p}_{a,1994} = \frac{\hat{N}_{a,1994} \, \rho_a}{\sum_a \hat{N}_{a,1994} \, \rho_a} \;. \tag{10}$$

Parameter Estimation

Total SSQ. A total sum of squares was computed by adding the adjusted sum of squares for each of the components (equations 5, 7, 8):

$$SSQ_{Total} = SSQ^{adjusted}_{agecomp:catch}\ \lambda_{agecomp:catch} + SSQ^{adjusted}_{biomass}\ \lambda_{biomass} + SSQ^{adjusted}_{agecomp:run}\ \lambda_{agecomp:run} \quad , \tag{11}$$

where the λ's are weights assigned to each sum of squares component. Each sum of squares component was scaled to a similar order of magnitude, so to contribute similarly to the total SSQ when λ's were equal. The method for adjusting the value of SSQ_j (from equations 5, 7, or 8) for the j sources of auxiliary information; (j=1) catch age composition, (j=2) aerial survey run biomass, and (j=3) run age composition was suggested by J. Bromaghim (ADF&G, Anchorage personal communication) as:

$$SSQ^{adjusted}_{j} = \frac{SSQ_j - Min(SSQ_{j,k}\ across\ all\ k)}{Max(SSQ_{j,k}\ across\ all\ k) - Min(SSQ_{j,k}\ across\ all\ k)} \quad , \tag{12}$$

where $SSQ_{j,k}$ is the estimated sum of squares for data source k when SSQ_{total} (equation 11) is estimated and λ is set equal to zero for all data sources except data source j. The λ's were used to assign ad hoc weights to each SSQ component reflecting our confidence in each component. An inverse variance weighting scheme could not be used, because the variance of the aerial survey abundance estimator was unknown. For the first year using this ASA model we felt we could not differentially weight data sources and set λ equal to one for all data sources.

Minimization Methods. The ASA model estimated a total of 21 parameters: 17 initial cohort sizes, two gear selectivity function parameters (α and β), and two maturity function parameters (ϕ and τ). The survival rate parameter (S) was fixed at 0.67. The three SSQ equations referred to 122 data observations with 101 degrees of freedom and a data to parameter ratio of approximately 5. However, not all observations were independent, so the amount of information contained in the data was considerably less than one could obtain from completely independent observations.

The Microsoft Excel[2] spreadsheet solver was used to estimate parameter values which minimized the total weighted sums of squares (equation 11). Parameter values manipulated by the solver were all scaled to a similar order of magnitude, as recommended by the software manufacturer. The solver obtained estimates of the variables in each one-dimensional search using linear extrapolation from a tangent vector (Tangent option), central differencing for estimates of partial derivatives, and a quasi-Newton method for computing the search direction (Microsoft 1992). The precision level was set at 0.00001. Population sizes for older herring ($\geq$ age 10) and all ages for 1993 were constrained to be greater than or equal to zero as negative population values were impossible and negative residuals cannot be $\sin^{-1}$ transformed.

Sensitivity Analysis. The sensitivity of the ASA model to our choice of age at full maturity ($\rho_a \geq 0.98$) needed to constrain the maturity schedule was investigated. Model simulations were done without the constraint and by varying full maturity from age 5 through age 8. For each choice of age at full maturity a model simulation was done constraining survival at 0.67 and then removing the constraint and allowing the model to estimate survival.

Goodness of Fit

The goodness of fit for our ASA model was assessed through evaluation of model residuals. A model's fit was rated as "good" if the residuals were small. The choice of model, i.e. it's functional form, was rated "good" if the residuals were randomly distributed about zero and did not form a pattern when plotted as a function of age, year, year class, or estimated values. For example, to choose a function to describe purse seine selectivity we examined residuals for purse seine age composition displayed against year or age to see if the function resulted in residuals distributed as a horizontal band. Another pattern or trend in residuals might indicate that the functional structure of the data changed through time or by age which would necessitate the use of a time period or age-specific function. Ideally, model residuals should have a normal distribution with zero mean. Essentially, we applied the same principles of goodness of fit used in applied regression analysis and examination of residuals (Draper and Smith 1981).

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[2] Company names are listed only for archival purposes and do not represent an endorsement of any kind by ADF&G.

Differences between the FORTRAN and Excel version are described below and summarized in Table 2.

Survival

The two versions had identical recursive survival models (equation 2) except that herring were aged out to 16 years of age in the FORTRAN version. Starting value of S was 0.7 for both (Table 3).

Estimated Catch Age Composition

The FORTRAN version did not model gear selectivity. Therefore, there is no equivalent of equations 3, 4, and 5 in the FORTRAN model.

Maturity

The two version were identical with respect to equation 6. Starting values of Φ and τ for the maturity curve in the FORTRAN version, however, were initiated with a cohort analysis where we began with all ages in the last data year and all of the oldest age groups for the earlier years and worked backwards toward age-3. The first backwards reconstruction incorporates S and ρ as:

$$\hat{N}_{a-1,y-1} = \frac{N_{a,y}}{S\ \rho_a} \qquad (13)$$

However, subsequent reconstruction working toward age 3 and the earliest year in the data set incorporates only S as:

$$\hat{N}_{a-1,y-1} = \frac{\hat{N}_{a,y}}{S} \quad . \qquad (14)$$

The initial cohort size of age 3 herring for the very last year was a special case,

$$\hat{N}_{3,last\ year} = \frac{N_{3,lastyear}}{\rho_3}. \tag{15}$$

The ratio of inshore spawning abundance to total population was:

$$\rho_{a,y} = \frac{N_{a,y,observed\ inshore}}{\hat{N}_{a,y}}. \tag{16}$$

A manually fit of a logistic curve through these ratios yielded Φ=-2 and τ=4.

SSQ Biomass Estimates

Aerial surveys rated either 'OK' (1986-1990) or '?' (1985-1986) were considered for use. Differences between observed and predicted run biomass was calculated as

$$SSQ_{biomass} = \sum_{y=1985}^{1990} \left(\log_e(B_y^{survey}) - \log_e(\sum_{a=4}^{16} [\rho_a \hat{w}_{a,y} \hat{N}_{a,y}]) \right)^2 . \tag{17}$$

Run Age Composition

$SSQ_{agecomp:run}$ differed from equation 8 in that a simple arcsin transformation was used instead:

$$SSQ_{agecomp:run} = \sum_{y=1985}^{1990} \sum_{a=3}^{16} \left(\arcsin(p_{a,y}^{run}) - \arcsin\left(\frac{\rho_a \hat{N}_{a,y}}{\sum_{a=4}^{16} [\rho_a \hat{N}_{a,y}]} \right) \right)^2 . \tag{18}$$

Forecast Methodology

The forwards prediction for each year class begins with age 4 for all years and all ages for the second year in the data set as:

$$\hat{N}_4 = \hat{N}_{initial\ population\ size}\ S\ \rho_4\ . \tag{19}$$

All other predictions are based on the previous predictions

$$\hat{N}_5 = \hat{N}_4\ S\ \rho_4\ . \tag{20}$$

Both versions used equation 9 to convert population abundance to biomass.

Parameter Estimation

Total SSQ. The FORTRAN program adjusted starting parameter values for Φ, τ, and S only when solving for

$$\min\ SSQ_{total} = \min\ [SSQ_{biomass} + SSQ_{agecomp:run}]. \tag{21}$$

SSQ_{age} was weighted to place it on the same order of magnitude as $SSQ_{biomass}$.

Minimization Methods. Initial cohort sizes were not parameters to be solved for in the FORTRAN version. There were 18 starting values of initial cohort sizes in the FORTRAN version that were obtained from the cohort analysis (equations 13, 14, and 15) at the start of the analysis when S was set to a value of 0.7. Current estimates of initial cohort sizes were restated to reflect the current value of S.

The optimization algorithm in the FORTRAN model simultaneously solved for 3 parameters: S, Φ, and τ. In the FORTRAN ASA model aerial surveys ($\hat{B}_y$) for the years between 1986 and 1990 were used in the calculation of $SSQ_{biomass}$ and 60 values of $\hat{N}_{a,y}$ in the calculation of SSQ_{age} for a total 65 data observations and a data parameter ratio of 22.

Exponential Decay Model

Through 1993, an exponential decay model,

$$\hat{Q}_{a,y}=(Q_{a-1,y-1}-C_{a-1,y-1})e^{-(\bar{M}_{a-1}+\bar{R}_{a-1})} \tag{22}$$

was used to predict the number of individuals, $Q_{a,y}$, of age-a herring returning in year y to spawn from age-specific natural mortality and recruitment rates $M_{a-1}+R_{a-1}$ and previous year escapement abundance ($Q_{a-1,y-1}$- $C_{a-1,y-1}$), where C is the catch of the purse seine sac roe fishery. For the 1994 forecast, $Q_{a-1,y-1}$ was estimated by dividing 1993 daily aerial survey estimates of run biomass by the mean expected daily proportion and taking the average. This differs from $N_{a,y}$ in the ASA model of equation 2 as this represents only mature herring in the run biomass after separating from the immature biomass to begin the inshore spawning run (Figure 3).

Age-specific number of individuals, $Q_{a,y}$, were converted to biomass $\hat{B}_a$ using predicted mean weight-at-age, $\hat{w}_{a,y}$ as:

$$\hat{B}_{a,y}=\hat{Q}_{a,y}\hat{w}_{a,y} \tag{23}$$

and run biomass became the sum of the age-specific biomass,

$$\hat{B}_y=\sum_{a=3}^{16}\hat{B}_{a,y} \quad . \tag{24}$$

Because the sac roe fishery occurred once a year and for a very short period, we used $M_{a,y}+R_{a,y}$ values from the 1993 forecast (Yuen and Bucher 1992) estimated as:

$$M_{a,y}+R_{a,y}=-\ln\frac{Q_{a+1,y+1}}{Q_{a,y}-C_{a,y}} \tag{25}$$

where $Q_{a,y}$-$C_{a,y}$ is the abundance of age a herring in year y immediately after the fishery called the escapement, and $Q_{a+1,y+1}$ is the abundance of age $a+1$ fish in year $y+1$ immediately before the fishery, and includes the over winter survivors from the previous year spawning population plus any new recruits (Ricker 1975).

Natural mortality and recruitment $M_{a,y}+R_{a,y}$ were positive whenever herring aged a are fully recruited, that is, the loss of age a herring, $M_{a,y}$, exceeded any gain through recruitment, $R_{a,y}$, of individuals into the spawning population. In contrast, when $M_{a,y}+R_{a,y}$ is negative the opposite is true. Only positive estimates of $M_{a,y}+R_{a,y}$ for age-8 and older were considered while mixed values of $M_{a,y}+R_{a,y}$ for ages-7 and younger were allowed. A moving average of $M_{a,y}+R_{a,y}$ over the most recent 2 of 4, 3 of 5, or 4 of 8 estimates was used because the recent values tend to be greater as,

$$\bar{M}_a+\bar{R}_a=\frac{\sum_{y=(Y/2)+0.5}^{Y} M_{a,y}+R_{a,y}}{Y}, \tag{26}$$

where Y is the total number years. This was expected for the older age classes as they tend to be rare and become more so over time as they are removed by the fishery.

Projected Harvest

The Kamishak Bay Herring Management Plan (5 AAC 27.465) stipulates both fisheries will be closed if the Kamishak Bay herring run biomass forecast is less than 8,000 tons. If the projected biomass is more than 8,000 tons but less than 20,000 tons, harvest rates will be 9% of the forecast for the spring Kamishak sac roe fishery and 1% for the Shelikof Strait fall food and bait fishery for a total exploitation rate of 10%. If the forecast is more than 20,000 tons but less than 30,000 tons, total exploitation rate increases to 15%. If the forecast is more than 30,000 tons, total exploitation rate is 20%. The relative allocation between the two fisheries remains the same.

RESULTS

All three models produced dissimilar forecasts for 1994. The Excel version of the ASA model produced the most conservative estimate of 25,344 tons where SSQ_{total} = 0.166. The FORTRAN version produced the most optimistic outlook at 32,584 tons where SSQ_{total} = 0.244. The Exponential decay model was in between with a forecast of 27,753 tons. The forecast derived from the Excel version of the ASA model had the lower SSQ_{total} and was selected for the 1994 harvest projections.

When ASA models were fit with survival either estimated or fixed in combination with constraints on the maturity schedule (Table 4, model 1-10), results varied mainly in run biomass estimates for 1991 through 1994 (Figures 4 and 5). Because all models used 1986 through 1990 aerial surveys differences between maximum and minimum biomass estimates increased only after 1989 to 17 thousand tons. Biomass estimates were lowest when survival was fixed (models 1, 3, and 5, Figure 4) and within that group increased with increasing age at which maturity was fixed (0.98). When maturity was not constrained (models 8-10, 12) biomass estimates were similar and higher when survival was fixed. Estimates were lower when 1991 through 1993 aerial survey estimates were included (model 11, 12, Figure 5). We chose model 3 to be our 1994 forecast. Though it did not have the smallest total sum of squares we felt it was more important that the functional form of the model make biological sense necessitating the constraint on survival and maturity.

The ASA model used for the 1994 forecast fixed survival rate at 0.67 which is an instantaneous mortality rate of 0.4 (Table 5). The maturity schedule was also constrained accepting only those parameter values estimating the percent mature at age 6 to be $\geq$ 0.98 (Figure 6). In contrast values for purse seine selectivity estimated by the model were much lower at age with only 72% of the age-6 herring available to the gear. Herring were not fully selected for until age 8 (s_7=0.973).

Residuals of the purse seine catch age composition from the ASA model formed a fairly horizontal band centered close to zero when displayed as a function of age (Figure 6). The variability seems greater for age -3 and -4 herring and perhaps more negative residuals for the oldest and youngest ages. No strong trend was seen in residuals plotted by age for each year. The age composition of the purse seine catch estimated from the ASA model agreed well with the observed age composition of catch samples (Figure 7).

Pooled residuals of the run biomass age composition did not form a horizontal band when displayed as a function of age (Figure 6). Residuals for ages 4-6 were predominately negative followed by nearly all positive residuals for ages 7-11. This pattern was fairly consistent for all years in the model. Again the age compositions of the run biomass estimated from the ASA model agreed fairly well with that observed; with notable exceptions being the differences between estimated and observed age-7 herring in 1991 and age-5 herring in 1993 (Figure 8).

Run biomass estimates obtained from the ASA model compared well with the four aerial surveys used as auxiliary data (Figure 6). The poorest fit was through 1986 and the best through 1990.

ASA Model In An FORTRAN Program

Predicted run biomass varied depending on our assumption of survival and maturity (Figure 9). We initially ran a simple model, $SSQ_{total} = SSQ_{biomass}$, to test the effect of estimating S. Here, $SSQ_{biomass}$ decreased from 0.367 to 0.085, and the age at which 90% of herring were mature decreased from age 7 to age 5, with a final estimate of S = 0.751.

We then ran a more complex model, $SSQ_{total} = SSQ_{biomass} + SSQ_{agecomp:run}$, and $SSQ_{biomass}$ increased to 0.110, age at which 90% of herring were mature increase to age 9 with a final estimate of S = 0.564. While the model appeared to duplicate the trends, all versions underforecast the observed run biomass maximum and overforecast the observed minimums. Hence, our decision to not used this model.

Forecast

A biomass of 25 thousand tons of herring is expected to return to the Kamishak Bay District in 1994 (Table 6). Herring mean weight is predicted to be 189 g. The 1988 year class is forecast to represent 70% of the run biomass where 69% of the individuals would be age-6 herring (Figure 10).

Projected Harvest

Total allowable harvest is projected to be 3.8 thousand tons based on an exploitation rate of 15% of the forecast. Harvest allocation is 3.4 thousand tons for the Kamishak spring sac roe fishery and 380 tons for the Shelikof Strait fall food and bait fishery (Table 7).

DISCUSSION

The success of the aerial surveys is very important to the success of the forecast. All of the Kamishak Bay District forecast through 1993 have been the collective products of the previous year abundances by age and age-specific natural mortality and recruitment (M+R) rates. Faced with the third year of unconfirmed run biomass estimates, we turned to age structured analysis to prepare the 1994 forecast.

Both methods required an estimate of initial population size. For the older model this was spawning population from the previous year. However, without a successful aerial survey of run biomass in 1993, the 1994 forecast became an extension of the 1993 forecast made from 1992 data. We would, of course, adjust the 1993 forecast age composition to match the observed 1993 age composition before we made the 1994 forecast. However, we did not have the options of adjusting the magnitude of the 1993 forecast, or updating our M+R rates. Because, 1993 was the third year of frustrated aerial surveys, we were essentially making a 4 year forecast from the 1990 data, the last year with a successful aerial survey program.

ASA models, on the other hand, were designed to use the observed 1993 age composition, along will all other observed age compositions, to adjust the initial abundance estimates of age-3 herring. Because year class abundances would change, M+R rates would also change as we tried to minimize the difference between observed and predicted run biomass and age composition. That chain of events would revise the 1994 forecast in a manner that the old method could not easily do. This was the reason we changed our forecast methods. Nevertheless, this was a new and untried method for Lower Cook Inlet herring and therefore the more conservative of the two ASA predictions was selected.

We performed a cursory analysis of the differences in the two ASA models. The major difference was the Excel version adjusted estimates of initial cohort size in an effort to minimize SSQ whereas the FORTRAN version adjusted S instead. Some of the differences in results may also be related to differences in how the data was handled. For example, the FORTRAN version may have had lower estimates of ρ because of an age-15 outlier in the data set (Figure 11). The Excel version did not encounter this outlier because age-11 through 16 were combined as a single group and ρ for all ages older than the age-of-full-recruitment was 100%.

The abundance and biomass of Kamishak herring peaked in 1987. The downturn that followed may have reversed itself during 1990 (Figure 12). The recent upturn is expected to continue in 1994 because of the strong recruitment of age-4 herring in 1992. Forecasts made since 1988 have tracked the observed biomass except for the low forecast in 1992.

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Table 1. Rating of aerial surveys for use in Kamishak herring ASA models.

Harvest[a] Year	Months Surveyed	Longest Period Without Aerial Survey (days)	Date(s) of Longest Period Without Data	Coverage
85				?
86				?
87	April May	7	5/17-5/23	OK
88	April May June	4	4/24-27, 5/3-5/6, 5/27-5/30	OK
89	April May	4	5/13-5/16	OK
90	April May June	6	5/23-5/29	OK
91	April May June	20	4/25-5/14	poor
92	April May June	17	5/2-20	poor
93	April May June	12	4/28-5/9	poor

[a]original aerial survey data forms for 1985 and 1986 were not available.

Table 2. Differences between the Excel and FORTRAN version of Kamishak herring ASA models.

	Excel	FORTRAN
optimization algorithm source:	Microsoft[3]	Hilborn and Walters (1992)
projected abundance of age-3 herring for 1994:	98.44	13.8 million
SSQ_{age}:	separate terms for catch and run biomass	single term for run biomass
maturity schedule:	used age composition and observed values of run biomass	used catch samples and run biomass from aerial surveys
selectivity schedule:	used age composition of purse seine catch	not used
age groups:	3 - 11+	3-16
aerial survey:	1986-1990	1985-1990
constraints:	$p_6 \geq 0.98$ $S = 0.67$	none
initial cohort size	changed by optimization algorithm to min SSQ	restated when ever S changed
total number of parameters estimated by ASA model:	21	3
parameters estimated outside the ASA model:	1	18
number of observations used	122	65

[3] Vendor names are provided to document methods but do not constitute and endorsement by ADF&G.

Table 3. Starting values of parameter estimates for ASA models.

Starting Values of Parameter estimates for EXCEL ASA Model

			remarks:
s	0.67		
b	-1.373		catch sample age composition
k	5.165		catch sample age composition
b	-1.682		reconstructed total population age composition
k	4.199		reconstructed total population age composition

Intial Cohort Size (x 1,000 herring)

	Age	
Year	3	4
78	103.12	109.04
79	155.66	
80	265.01	
81	134.23	
82	148.30	
83	101.74	
84	120.04	
85	23.04	
86	124.27	
87	161.47	
88	27.29	
89	25.70	
90	47.91	
91	305.48	
92	14.49	
93	6.80	

Starting Values of Parameters for FORTRAN ASA Model

s	0.70
b	-2.000
k	4.000

Intial Cohort Size (x 1,000 herring)

	Age										
Year	3	4	5	6	7	8	9	10	11	12	13
85	24,644	56,531	31,975	29,700	25,087	18,762	6,613	2,284	2,248	552	147
86	122,160										
87	210,164										
88	57,885										
89	39,515										
90	68,644										
91	255,473										
92	9,635										
93	1,988										

Table 4. Combination of constraints on survival, maturity at age, and aerial surveys used to examine the sensitivity of ASA model results in an Excel spreadsheet.

Model No.	Fixed	Survival Value	Maturity at Age: Age	Maturity at Age: Value	Aerial Surveys	Total Sum of Squares	Estimated Run Biomass (Tons): 1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	Yes	0.67	5	0.98	86-90	0.219	38,677	33,955	34,400	31,468	25,241	17,896	18,488	28,179	25,877	21,446
2	No	0.77	5	0.98	86-90	0.144	28,606	28,262	31,297	29,810	25,913	20,595	24,285	37,696	37,990	36,040
3	Yes	0.67	6	0.98	86-90	0.166	36,718	33,762	32,968	29,504	25,603	19,022	19,792	26,662	28,256	25,344
4	No	0.75	6	0.98	86-90	0.122	29,185	29,211	30,994	28,705	26,022	20,975	24,295	33,751	36,894	36,216
5	Yes	0.67	7	0.98	86-90	0.120	35,051	33,097	32,214	28,161	25,529	20,166	21,461	26,619	29,751	29,411
6	No	0.73	7	0.98	86-90	0.098	29,836	29,909	30,975	27,884	25,858	21,402	24,571	31,455	35,398	36,567
7	Yes	0.67	8	0.98	86-90	0.097	33,717	32,451	31,860	27,419	25,321	21,090	23,117	27,097	30,245	32,264
8	Yes	0.67	Not fixed[a]		86-90	0.168	29,840	30,142	31,079	26,902	25,191	22,657	27,824	30,977	32,522	37,141
9	Yes	0.67	Not fixed		86-90	0.244	29,370	29,801	30,880	26,850	25,272	22,588	28,321	31,681	33,434	38,334
10	No	0.62	Not fixed		86-90	0.238	31,263	30,909	31,275	26,797	24,967	22,619	28,065	30,447	31,158	35,729
11	Yes	0.67	6	0.95	86-93	0.154	35,767	33,355	32,042	29,098	25,105	19,179	19,724	25,298	28,568	27,321
12	Yes	0.67	Not fixed		86-93	0.316	32,427	31,491	30,894	26,213	24,063	20,312	22,049	25,094	27,827	30,604
						Minimum	28,606	28,262	30,880	26,213	24,063	17,896	18,488	25,094	25,877	21,446
						Maximum	38,677	33,955	34,400	31,468	26,022	22,657	28,321	37,696	37,990	38,334
						Average	32,538	31,362	31,740	28,234	25,340	20,708	23,499	29,580	31,493	32,201
						Range	10,071	5,693	3,520	5,255	1,959	4,761	9,833	12,602	12,113	16,888

[a] Selectivity of purse seine fishery constrained to be fully selective at age 8.

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Table 5. Final parameter estimates for ASA models.

Final Parameter Estimates for EXCEL ASA Model

		remarks:
s	0.67	constrained to be 0.67
b	-1.311	catch sample age composition
k	5.277	catch sample age composition
b	-1.903	reconstructed total population age composition
k	3.955	reconstructed total population age composition

Intial Cohort Size (x 1,000 herring)

	Age	
Year	3	4
78	83.92	83.82
79	123.31	
80	216.97	
81	110.93	
82	127.02	
83	89.32	
84	107.56	
85	20.70	
86	117.58	
87	154.96	
88	25.94	
89	25.69	
90	50.05	
91	319.98	
92	14.72	
93	2.43	

Final Parameter Estimates for FORTRAN ASA Model

s	0.56
b	-0.886
k	6.492

Intial Cohort Size (x 1,000 herring)

	Age										
Year	3	4	5	6	7	8	9	10	11	12	13
85	126,624	152,803	80,444	71,284	71,420	34,870	11,203	3,562	3,930	870	182
86	440,536										
87	717,725										
88	202,349										
89	144,581										
90	311,034										
91	1,382,269										
92	59,810										
93	5,458										

Table 6. Forecast of 1994 Kamishak Bay District herring abundance and projected harvest by age class.

Age	1994 Forecast No. of fish (x 1,000)	Proportion by Numbers	Predicted Mean Weight(g)	1994 Forecast Biomass (tons)	Harvest Rate	1994 Total Allowable Harvest	Proportion by Weight
3	13,768	0.11	88	1,336	0.15	200	0.05
4	843	0.01	129	120	0.15	18	0.00
5	5,570	0.05	152	933	0.15	140	0.04
6	83,431	0.68	193	17,763	0.15	2,664	0.70
7	7,413	0.06	230	1,876	0.15	281	0.07
8	2,160	0.02	244	582	0.15	87	0.02
9	1,047	0.01	259	299	0.15	45	0.01
10	3,867	0.03	291	1,239	0.15	186	0.05
11+	3,390	0.03	320	1,197	0.15	180	0.05
Total	121,488		189	25,344		3,802	

Table 7. Allocation of the projected 1994 Kamishak Bay herring harvest.

	Exploitation Rate	Harvest (tons)
Kamishak Bay Sac Roe Fishery	0.135	3,422
Shelikof Strait Food and Bait Fishery	0.015	380
Total	0.150	3,802

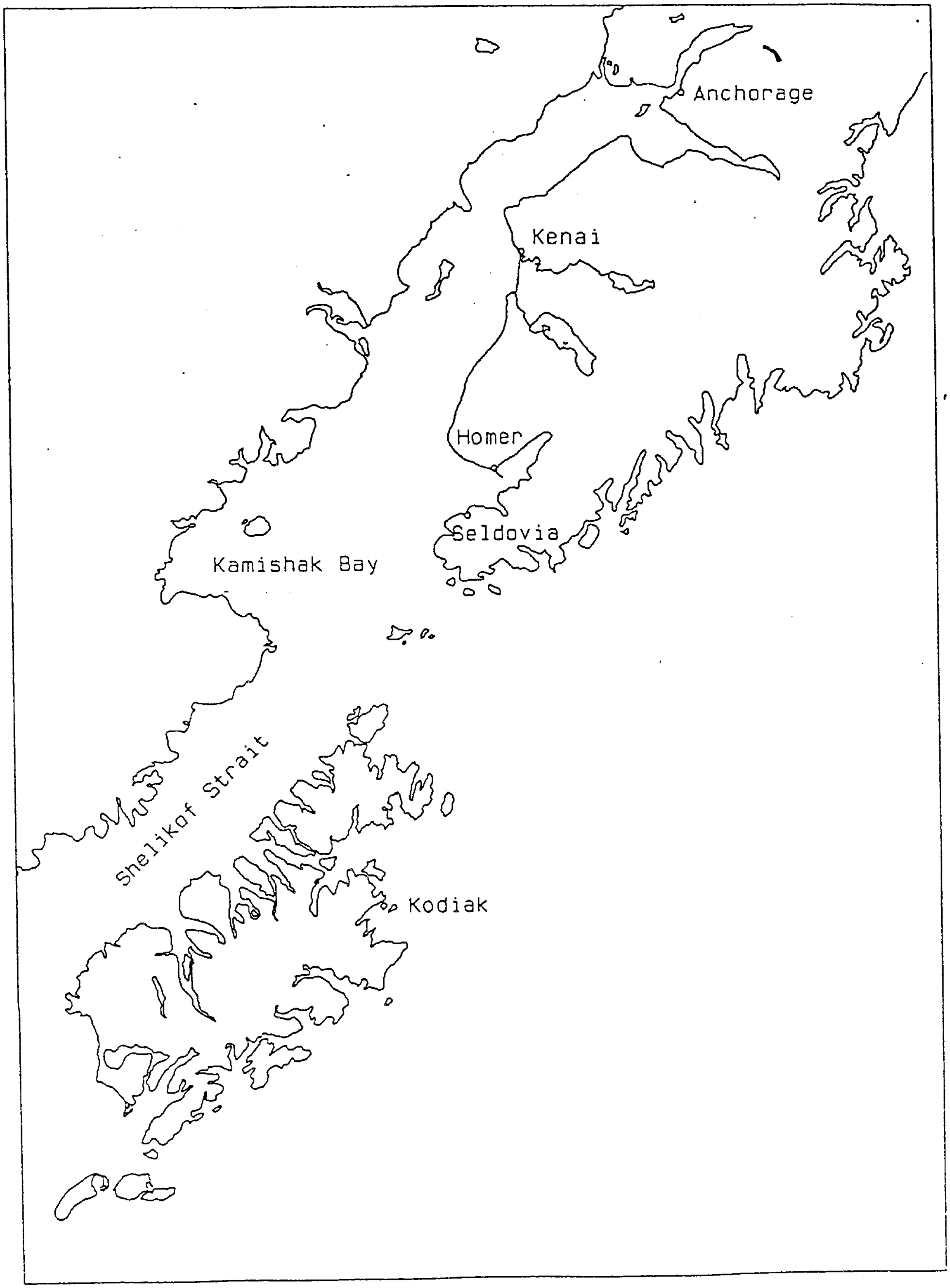


Figure 1. Kamishak Bay and Shelikof Strait, Alaska.

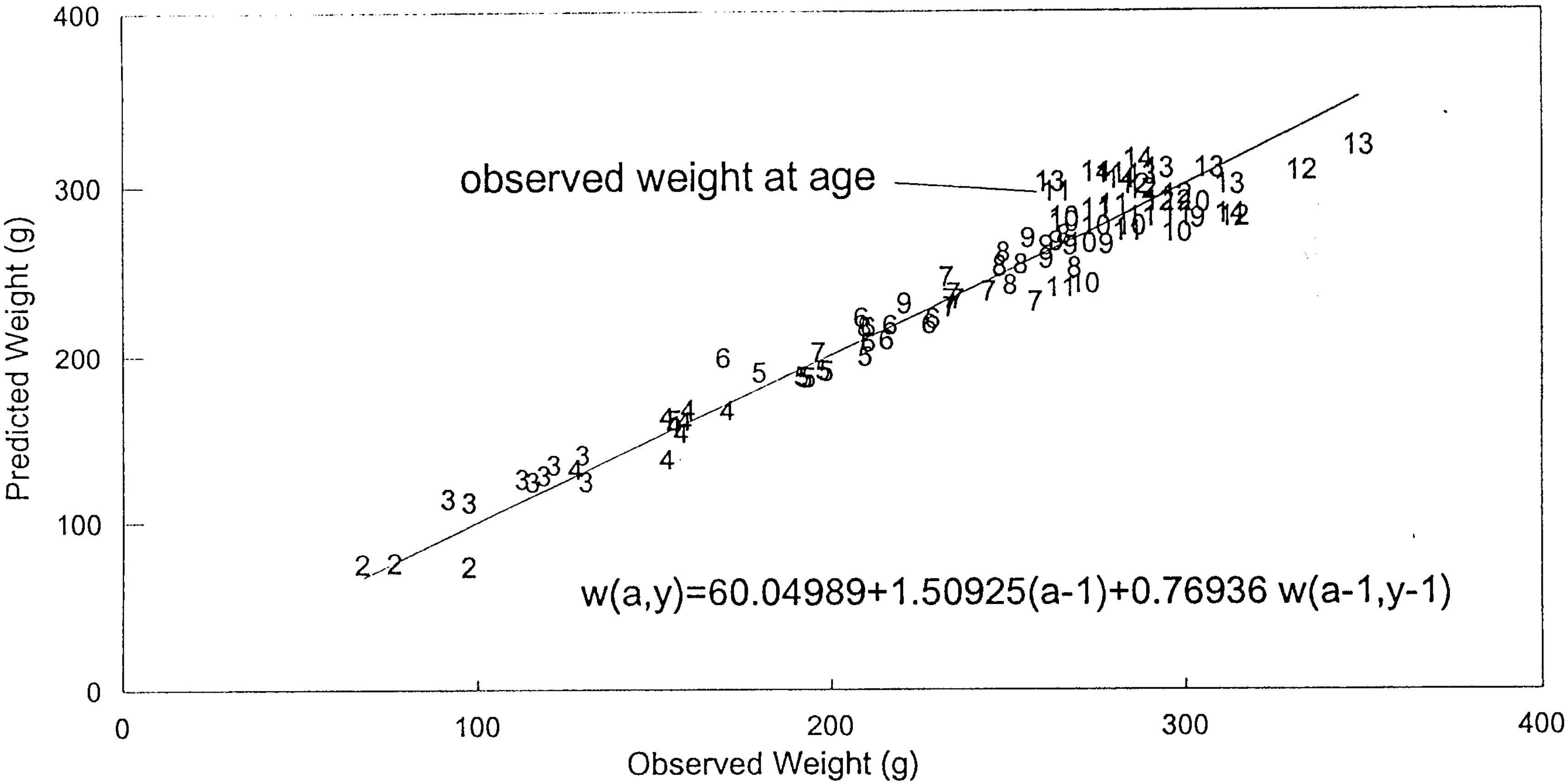


Figure 2. Observed and predicted weights from previous weight and age data for Kamishak Bay District Herring.

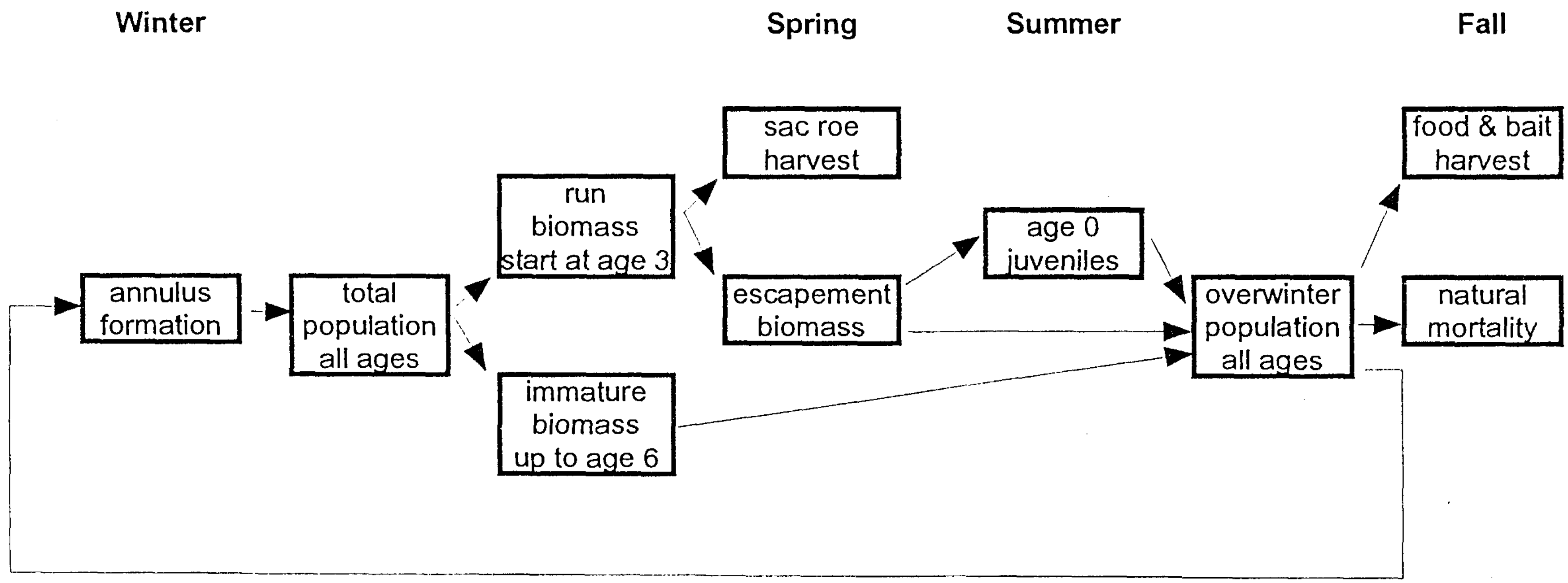


Figure 3. Conceptual model of the annual cycle of events affecting the Kamishak herring population.

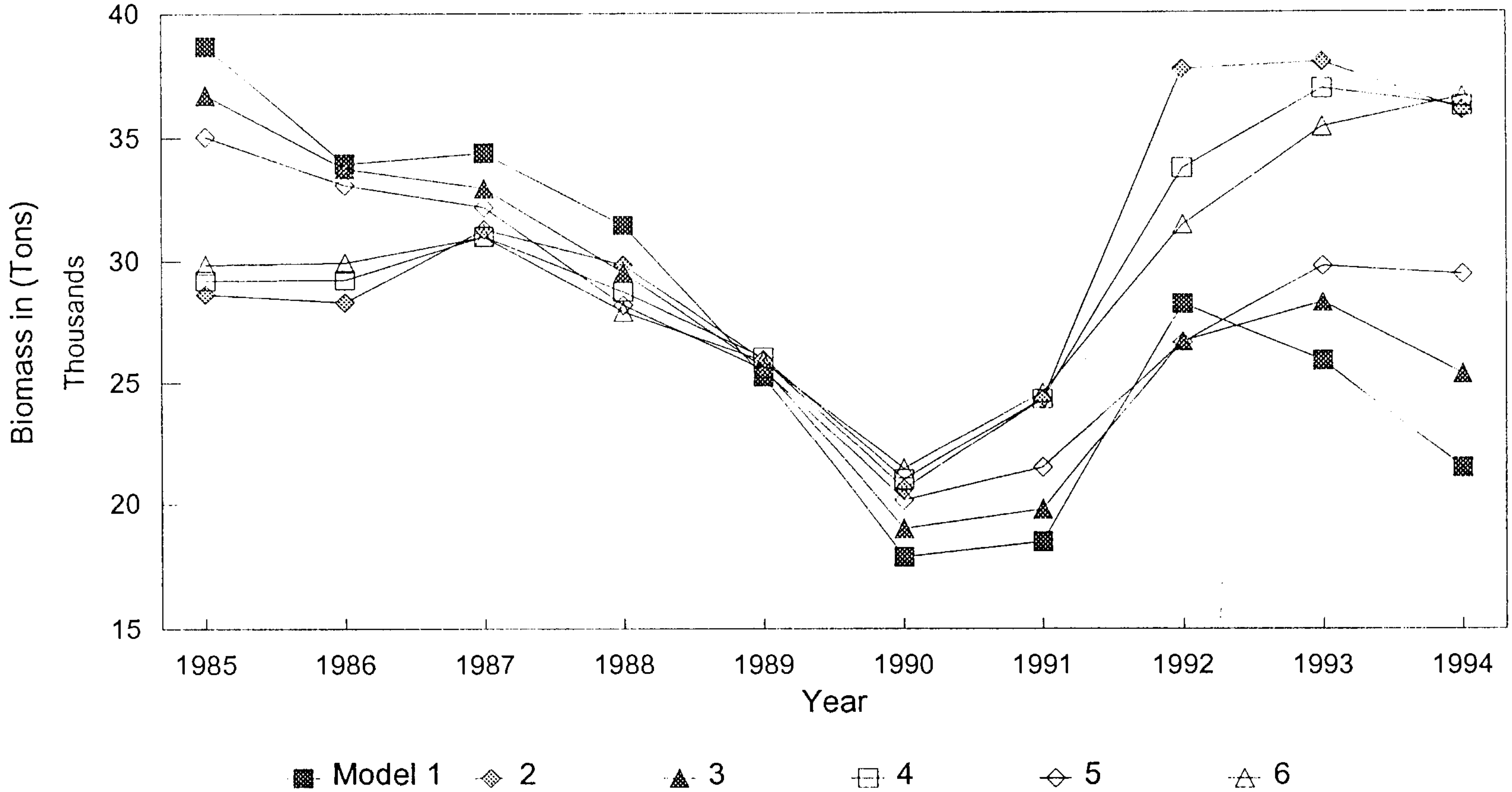


Figure 4. Estimates of run biomass from ASA models using different assumptions on survival and maturity.

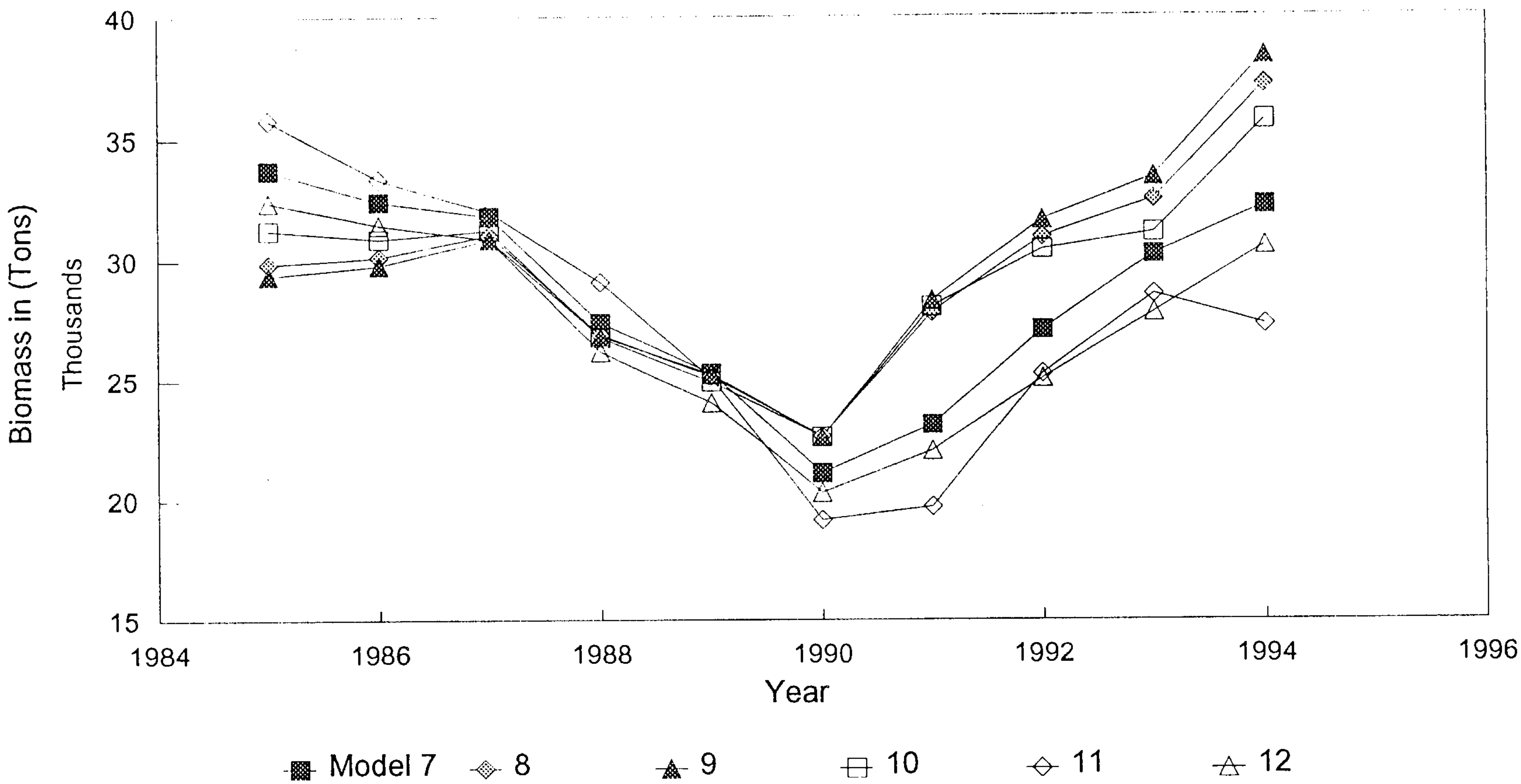
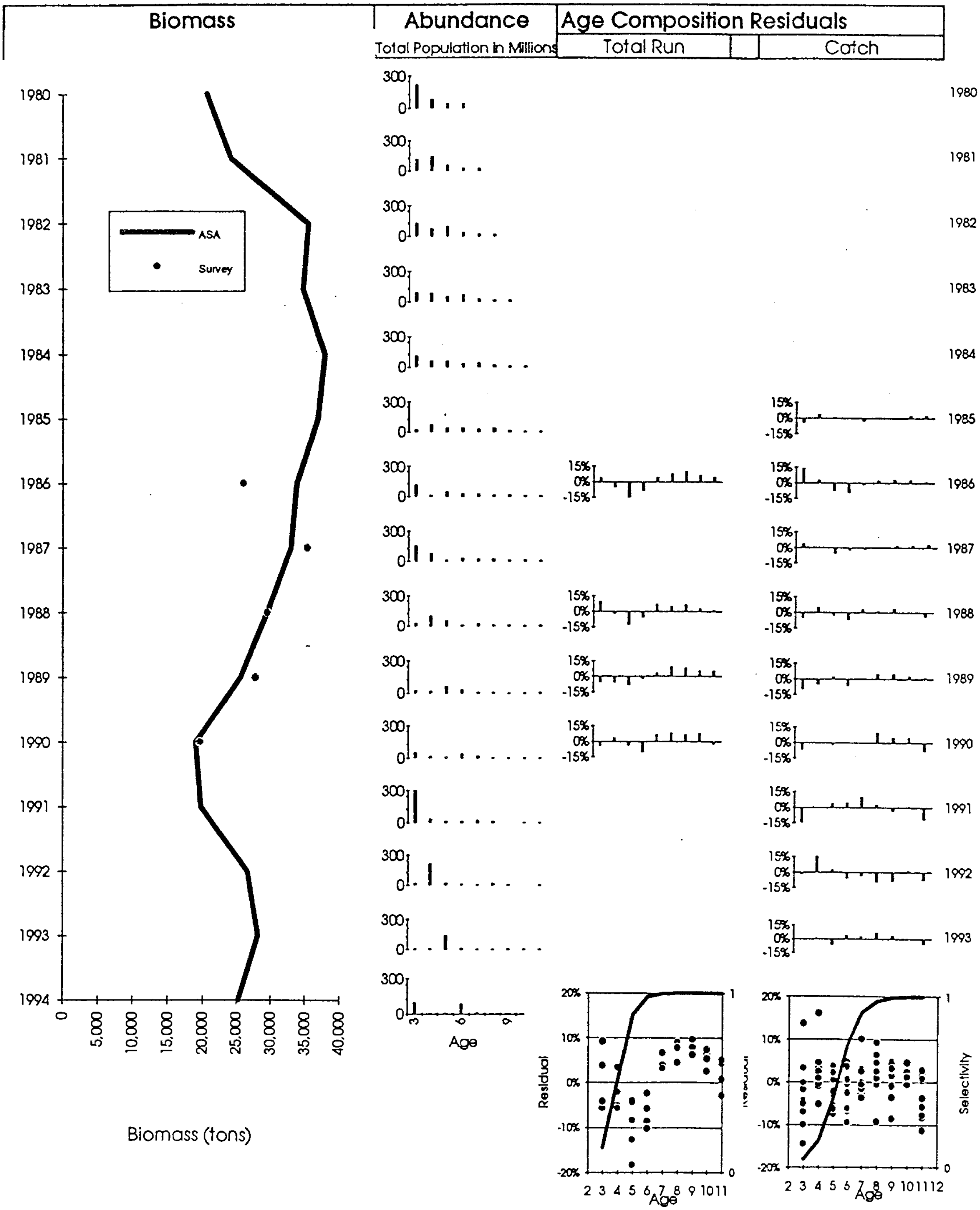


Figure 5. Estimates of run biomass from ASA models using different assumptions on survival and maturity and different subsets of aerial surveys.



	Aerial Biomass	Total	Run Agecomp		Catch AgeComp
Sum of Squares	0.081	0.166	0.176		0.225
Weights (lambdas):	1.000		1.000		1.000
Survival Rate: 67.00%					

Figure 6. Observed versus estimated run biomass, age composition residuals, maturity, and selectivity curves for the Excel spreadsheet version ASA model for Kamishak herring.

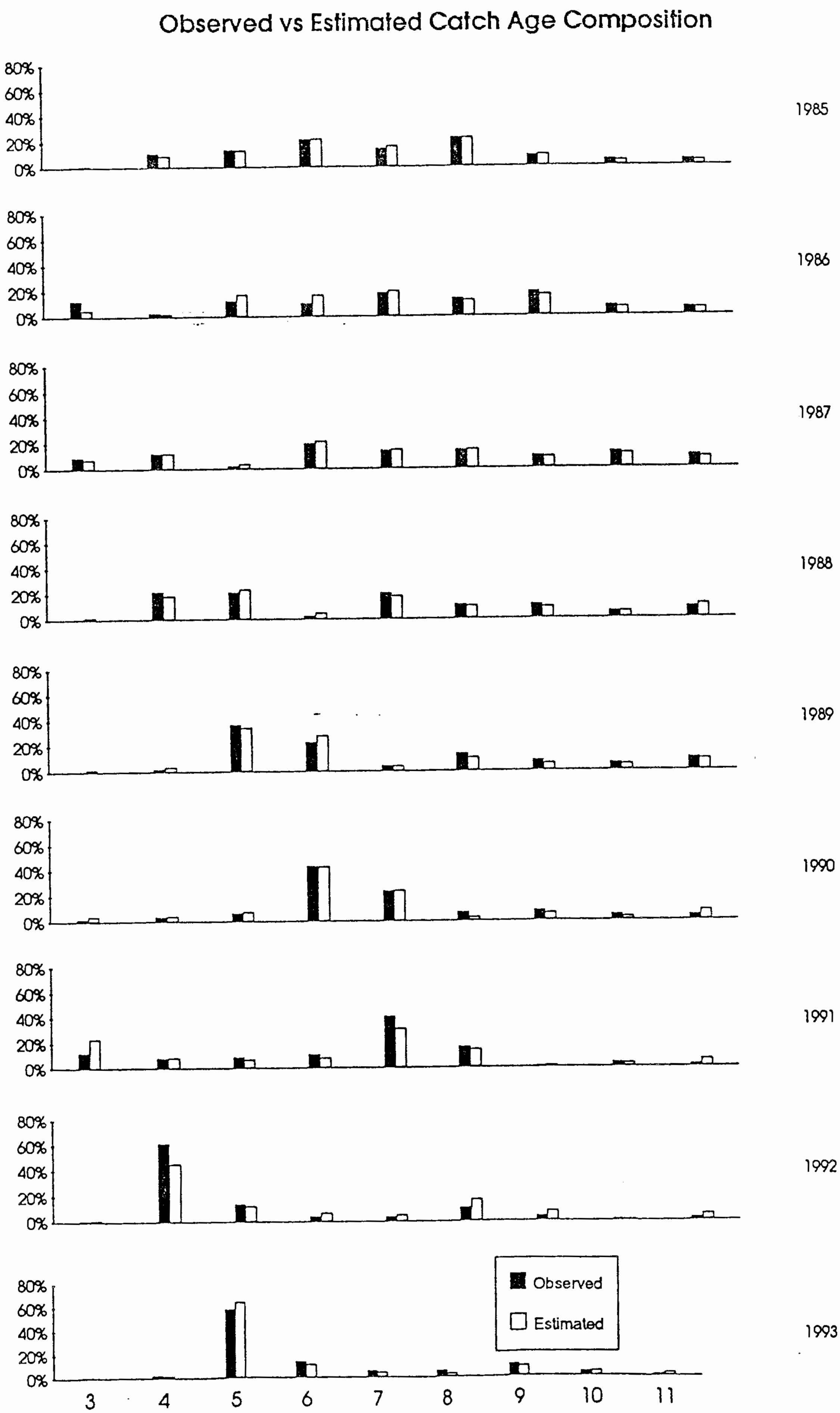


Figure 7. Observed age composition of the purse seine catch versus that estimated to be available by the Excel ASA model for Kamishak herring.

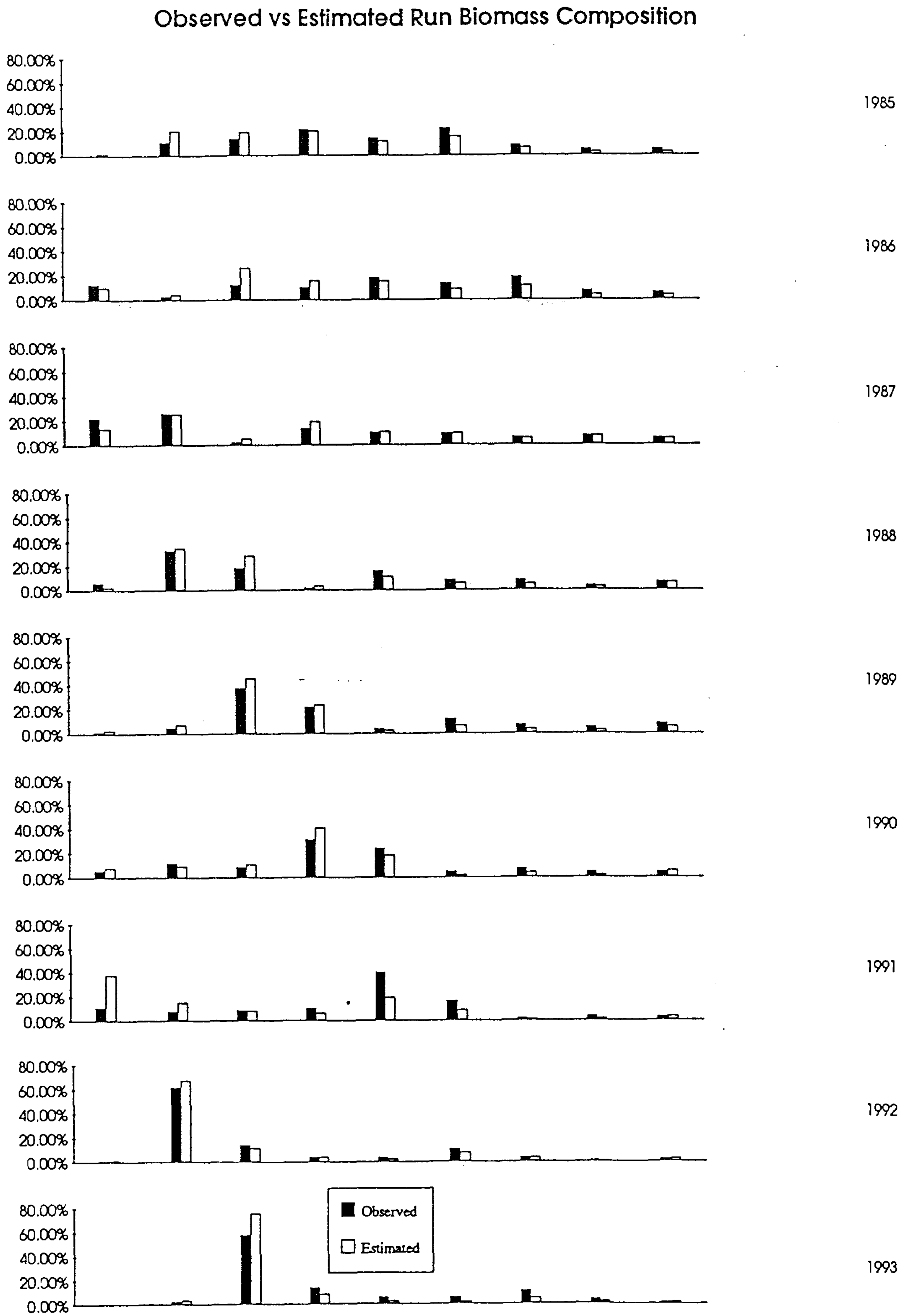


Figure 8. Observed age composition of the run biomass versus that estimated to be available by the Excel ASA model for Kamishak herring.

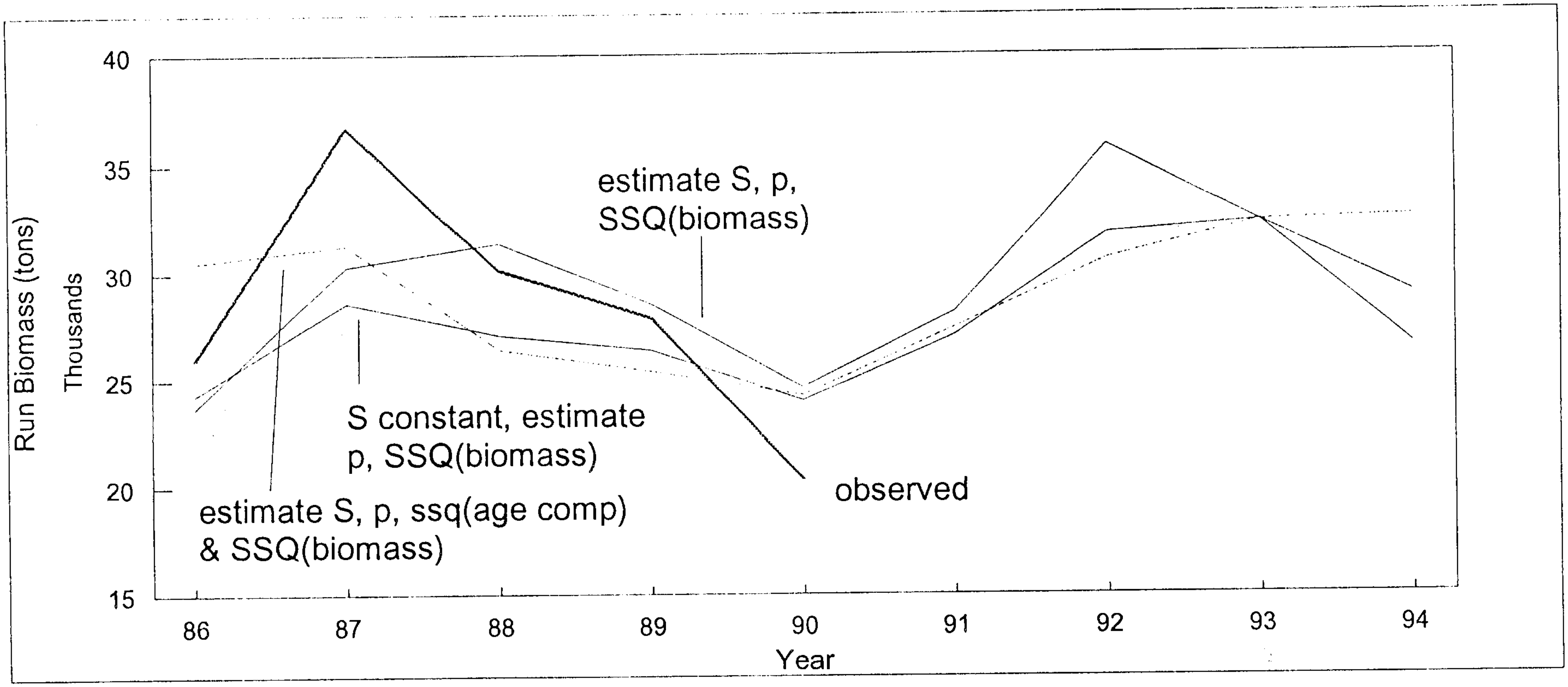


Figure 9. Estimates of run biomass from ASA model in FORTRAN program using different assumptions on survival and maturity.

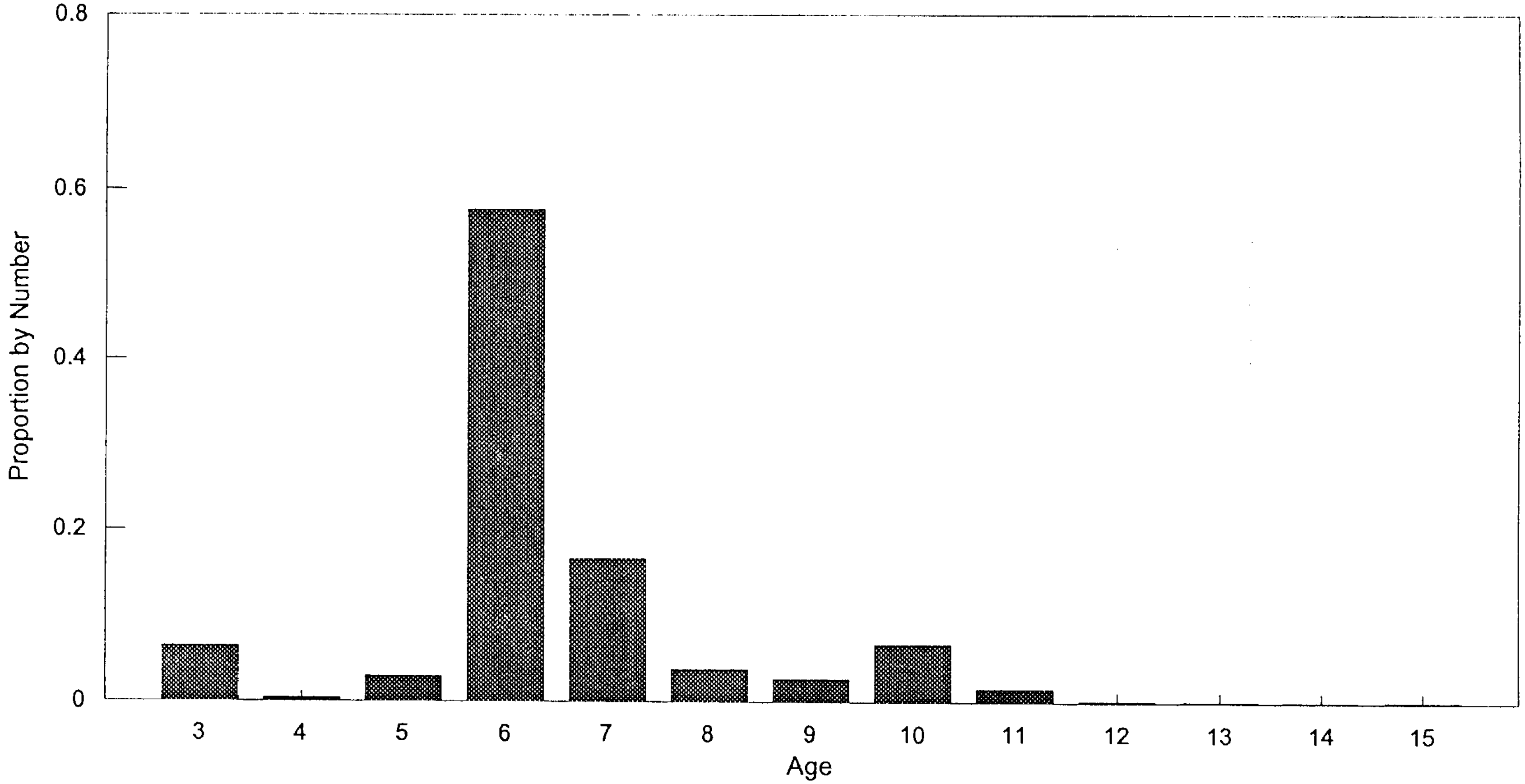


Figure 10. Kamishak Bay District age composition by number forecast for 1994.

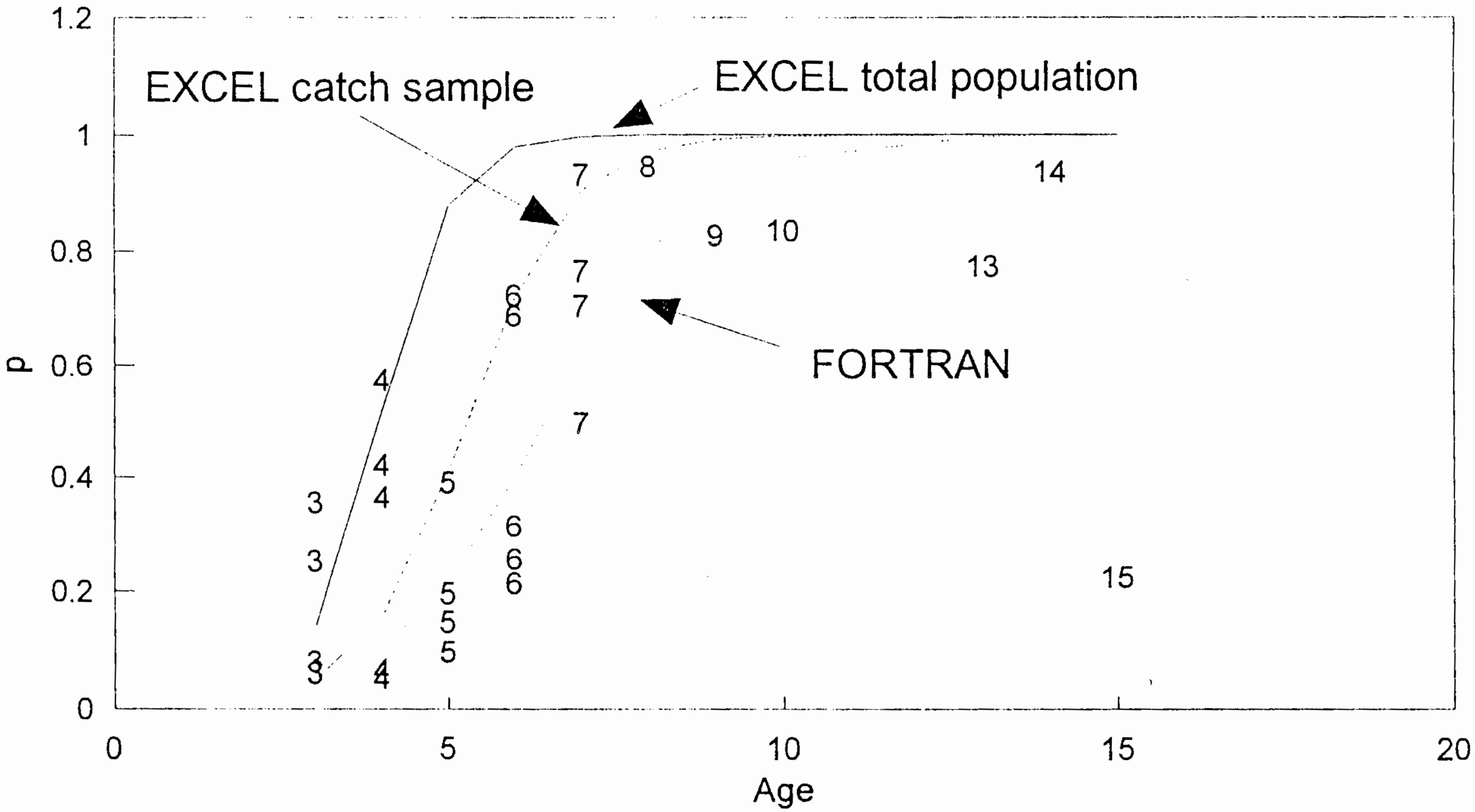


Figure 11. Observed and predicted maturity where observed maturity was estimated from equation 16 and predicted values were calculated from parameters in Table 4.

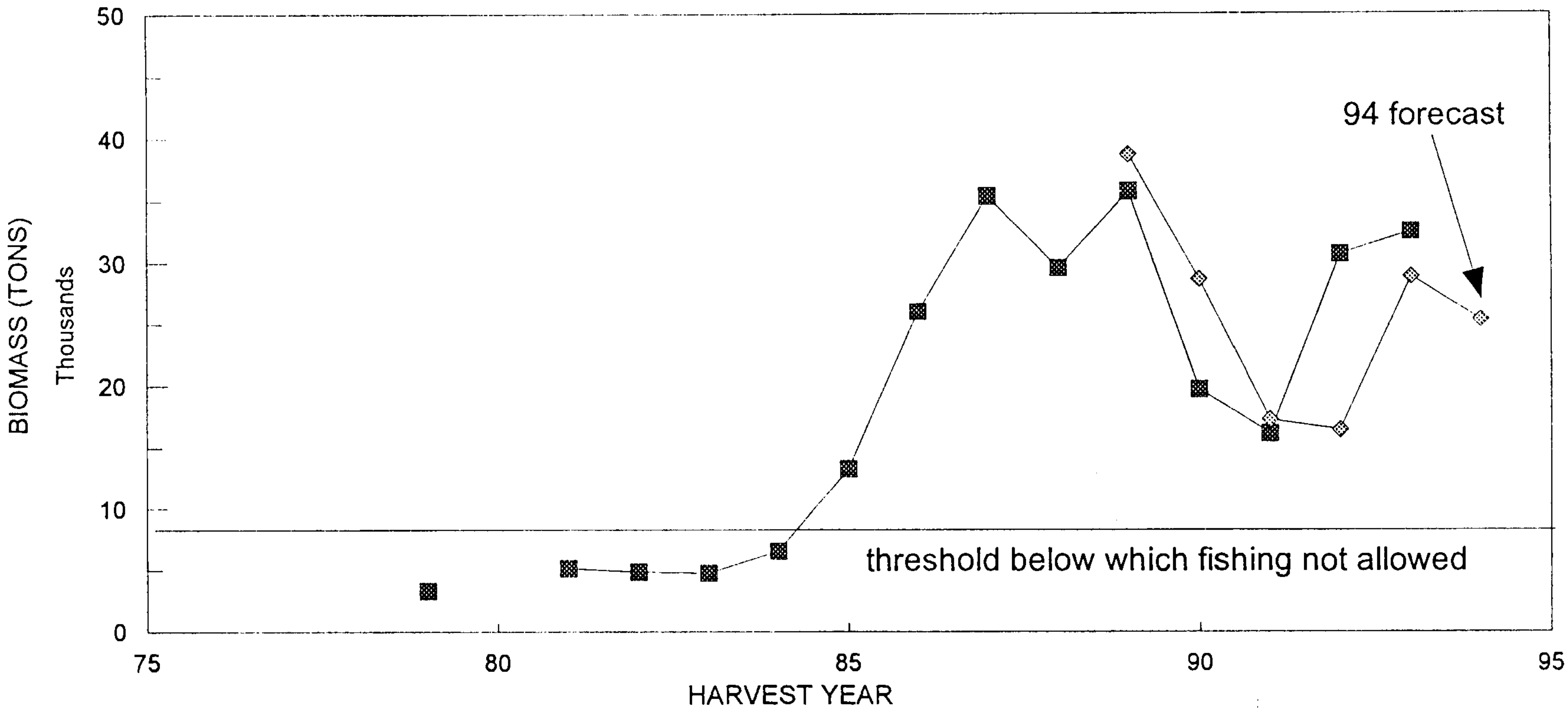


Figure 12. Kamishak Bay District herring biomass by year, 1979-1993, and forecast by year 1989-1994.

Appendix A. Kamishak Bay District observed prefishery mature abundance (x 1,000) by age and year of harvest, 1985-1993[a].

						Age								
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16
85	111	6693	8237	13252	8696	13843	5097	2980	2408	574	0	0	0	0
86	14513	3015	13645	11805	21054	15791	21361	8586	3321	2606	767	103	0	0
87	41071	48226	3622	25570	18774	17647	10645	13805	5498	2294	2026	445	37	0
88	9071	49857	27515	2809	24120	12423	12567	5644	6810	2202	420	475	66	0
89	1544	5756	47063	27215	4947	14965	8586	6121	4878	3414	1219	272	299	194
90	5225	10739	7897	29131	22438	4400	6445	4188	2050	856	490	294	157	43
91	34981	16199	11485	8864	14029	6477	1767	1939	1035	528	360	177	0	0
92	1167	111689	24878	6969	6600	19016	6606	1551	2328	390	388	774	0	0
93	237	3342	91692	21464	8589	8599	17402	5719	954	475	238	237	0	0

[a] These estimates of abundance by age were derived in part from aerial survey estimates of total run biomass. The estimates between 1990 and 1993 were used in a cohort analysis to back-calculate starting values of initial populations sizes (Eq. 12) by the ASA models.

Appendix B. Kamishak Bay District herring catch (x 1,000) by age and year of harvest, 1985-1993.

						Age								
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16
85	10	569	700	1124	739	1177	433	253	204	49	0	0	0	0
86	1093	227	1028	889	1586	1190	1609	647	250	196	58	8	0	0
87	2342	3098	476	5133	3612	3696	2454	3182	1335	579	476	112	9	0
88	120	5593	5338	592	5160	2687	2743	1231	1485	481	92	103	14	0
89	12	388	7599	4704	825	2796	1615	1168	938	662	234	51	57	37
90	154	364	603	4327	2333	647	789	444	211	94	34	26	2	15
91	1102	697	787	945	3690	1462	45	270	112	22	22	0	0	0
92	87	8344	1848	520	491	1415	491	115	173	29	29	58	0	0
93	26	367	10077	2362	945	945	1916	630	105	52	26	26	0	0

Appendix C. Kamishak Bay District herring observed age composition (%) of the run biomass by year of harvest, 1985-1993.

					Age				
Year	3	4	5	6	7	8	9	10	11+
1985	0.016	0.202	0.190	0.201	0.120	0.157	0.060	0.027	0.027
1986	0.101	0.044	0.258	0.158	0.152	0.089	0.115	0.044	0.040
1987	0.133	0.250	0.049	0.189	0.105	0.096	0.055	0.071	0.051
1988	0.023	0.344	0.285	0.037	0.113	0.058	0.051	0.028	0.061
1989	0.028	0.072	0.454	0.235	0.028	0.066	0.034	0.028	0.056
1990	0.076	0.093	0.108	0.407	0.184	0.019	0.040	0.019	0.053
1991	0.379	0.148	0.081	0.060	0.193	0.083	0.006	0.017	0.033
1992	0.012	0.671	0.116	0.040	0.025	0.077	0.034	0.003	0.022
1993	0.002	0.032	0.757	0.083	0.026	0.015	0.048	0.021	0.016

Appendix D. Run biomass estimates of Kamishak Bay herring as estimated from aerial survey.

Year	Run Biomass (tons)
1985	13,320
1986	26,001
1987	35,332
1988	29,548
1989	27,855
1990	19,650
1991	18,163
1992	24,077
1993	30,522

Appendix E. Kamishak Bay District herring mean weight (kg) by age and year of harvest, 1985-1993.

	Age													
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16
85	.064	.125	.155	.182	.205	.220	.238	.248	.255	.275	.000	.000	.000	.000
86	.088	.104	.155	.189	.215	.233	.249	.261	.272	.281	.292	.295	.000	.000
87	.091	.134	.162	.198	.218	.241	.251	.267	.276	.275	.288	.288	.287	.000
88	.084	.123	.163	.196	.218	.236	.248	.261	.266	.280	.298	.262	.282	.000
89	.098	.131	.158	.199	.228	.245	.254	.268	.285	.288	.298	.293	.313	.296
90	.090	.135	.162	.182	.220	.245	.256	.273	.289	.303	.310	.333	.269	.299
91	.079	.118	.172	.208	.214	.259	.267	.288	.280	.229	.413	.313	.000	.000
92	.099	.116	.156	.210	.229	.234	.266	.304	.303	.279	.333	.349	.000	.000
93	.078	.111	.148	.179	.204	.225	.241	.254	.273	.317	.382	.318	.000	.000
94	.088	.129	.152	.193	.230	.244	.259	.291	.320					