Stock Assessments of Southeast Alaska Herring in 1994 and Forecasts for 1995 Abundance

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Regional Information Report[1] No. 1J96-05

Alaska Department of Fish and Game
Commercial Fisheries Management and Development Division
Juneau, Alaska

February 1996

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ABSTRACT

A total of 47,883 tons (43,432 metric tons) of mature herring is forecast to return to the major spawning grounds of Southeast Alaska in 1995. Of that, 28,993 tons (26,298 metric tons), are forecast to return to areas designated for sac-roe fisheries. The remaining biomass is forecast for areas designated for bait and/or pound, spawn-on-kelp fisheries. Overall, this forecast is slightly higher than the total estimated spawning biomass of 46,318 tons (42,019 metric tons) from 1994. Three designated sac-roe fishing areas, Sitka, Seymour Canal and Cat Island/Kah Shakes have 1995 forecasts above their respective thresholds, thereby allowing commercial fisheries in 1995. Herring biomass in the Lynn Canal area remains below threshold as it has since 1982. Sufficient biomass is forecast to allow spawn-on-kelp pound fisheries at Craig/Klawock and Hoonah Sound and food and bait fisheries at Port Houghton/Hobart Bay, Craig/Klawock, and Ernest Sound in 1995.

INTRODUCTION

This report describes the status of herring stocks in Southeast Alaska (Figure 1.) in 1994 and provides forecasts of biomass and estimates of harvest quotas for 1995. The research described in this report is the primary source of information for management of regional herring stocks. This work is critical for achieving the primary management objective of maintaining reproductively viable populations, as described in the regional herring management plan (Carlile et al., *in prep*.).

Herring are an important resource in Southeast Alaska. More than 6,900 tons of herring were harvested in the region in the 1993-94 season in three types of commercial fisheries: the food and bait fishery, the sac roe fishery, and the pound (spawn on kelp) fishery. The exvessel value of these commercial fisheries is estimated to exceed $6,300,000 (Larson et al. 1994). Herring are also an important resource for subsistence users and are important prey of many fish, bird, and mammal species.

Herring stock assessments are conducted annually. These assessments include an intensive sampling program and a mathematical analysis of population status based on the sample data. Samples of egg deposition, age, weight, length, sex, and general body condition are collected each year from the spawning grounds and from commercial and test fishery catches. Aerial and skiff surveys are conducted to document location and extent of spawning activity and other herring concentrations.

Analytical procedures include an age structured analysis (ASA) and a spawn deposition analysis. This is the first report of the application of these analytical methods to herring stock assessment in Southeast Alaska.

METHODS

Two models are used to assess abundance of herring in Southeast Alaska, spawn deposition and deterministic ASA. Spawn deposition analysis has historically been used to estimate and forecast abundance of mature herring in Southeast Alaska. Beginning in 1993 and continuing this year, ASA with auxiliary information is used to estimate the abundance of herring for four major southeastern herring fishery populations: Sitka, Seymour Canal, Revillagigedo Channel (Kah Shakes/Cat Island), and Craig/Klawock. The spawn deposition model was used to forecast abundance for the remaining areas. The two methods are not mutually exclusive. Spawn deposition data, upon which the spawn deposition analysis is dependent, is also an important element of ASA. A primary difference between the two methods is the amount of data needed to conduct the respective analyses. Spawn deposition analysis uses only the most recent spawn deposition data and no age composition or weight data to yield an estimate of current and future biomass. In contrast, the ASA uses a time series of age compositions and weights-at-age to estimate biomass. The four major fishing areas or populations mentioned above currently have sufficiently long time series of data to permit the use of ASA for estimating historical and future biomass.

Age Structured Analyses (ASA)

The principal objectives of the stock assessment and forecasting exercises are to estimate the current years' abundance of mature (age 3+) herring, and to forecast the abundance of mature herring for the following year. Abundance is estimated by accounting for additions to the mature fishable populations through recruitment, growth, maturation, and gear selectivity and by accounting for subtractions from the population via natural and fisheries-induced mortality. The ASA model reconstructs a historical time-series of age-specific abundance by estimating key parameters that either influence herring abundance or account for the values of relevant population variables (e.g., age composition) that are measured as part of the department's annual sampling of herring populations. The parameters are estimated using a least squares procedure that minimizes the deviations between observed egg deposition, spawning age and catch age compositions and the ASA-estimates of these variables. Besides the abundance time series, the model estimates survival, age-specific maturity and gear selectivity. The product of the natural mortality, age-specific maturity and the current year's abundance is a forecast of age-specific abundance of Age 4+ herring in the subsequent year. The median of the historical age 3 abundance estimates (from the ASA) is used to forecast Age 3 abundance. The specific ASA model used here was developed by Funk and Sandone 1990 (also see Deriso, et al. 1985)

Survival Model

The survival model used to estimate the age-specific abundance of herring relies on a difference equation to estimate the number (N) of fish of age a in a cohort in year y,
where S is the annual survival rate estimated by the ASA model, and $C_{a,y}$ is the catch of age a herring in year y (Appendix A).

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

For three areas, Sitka, Craig and Seymour Canal, $C_{a,y}$ was estimated as:

$$\hat{C}_{a,y} = p_{a,y} \frac{Y_y}{\sum \frac{p_{a,y}}{w_{a,y}}} \qquad (2)$$

where, $p_{a,y}$ is the estimated proportion of age a herring in the catch during year y (see Equation 4), Y_y is the total weight of the catch during year y, and $w_{a,y}$ is the mean estimated weight of age a herring during year y [Fritz Funk, Alaska Department of Fish and Game (ADF&G), personal communication]. The estimated catch, rather than the observed was used in the survival model for consistency, since age compositions were estimated rather than completely enumerated. Including catch in this form also accounts for the measurement error inherent in estimating catch but also makes ASA model estimates more vulnerable to process errors. Since the model does not account sufficiently for some aspect of the dynamics of the population, abundance estimates could be adversely affected.

Depending on the fishery, the catch is either seine or gillnet sac roe, or seine bait or pound. The number of fish in a cohort (N) includes mature and immature herring at a time after annulus formation occurs on the scales but before spawning.

The biomass of age a herring in year y was estimated as:

where $w_{a,y}$ is the weight of age a herring in year y (Appendix B), and r_a is the proportion mature at age a,

$$B_{a,y} = w_{a,y} [r_a N_{a,y} - C_{a,y}] \qquad (3)$$

estimated by the ASA model.

Observed Catch at Age

For all areas the numbers of fish caught at age a in year y ($C_{a,y}$) were estimated by transforming annual catch age compositions (by numbers) into catch-age composition by weight, using year-specific weights-at-age, and then applying the catch composition to the total catch values.

Estimation of the Age Composition of the Catch

Gear Selectivity. Year-specific catch-at-age ($C_{a,y}$) was estimated for each gear type as the product of the age-specific gear selectivity function (s_a) and the estimated abundance ($N_{a,y}$). The year-specific age composition of the catch ($p_{a,y}$) was estimated as:

As used in this equation, age-specific selectivity (s_a) accounts for factors that prevent fish from being captured by the fishing gear. These factors include fish not present on the fishing grounds (e.g., immature

$$p_{a,y} = \frac{s_a N_{a,y}}{\sum_a [s_a N_{a,y}]} \qquad (4)$$

fish), inherent selectivity of the gear (e.g., due to mesh size) and other conditions of the fishery (e.g., specific fishing locations). Two-parameter logistic functions were used to describe the relationship between gear selectivity and age:

where *a* and *b* are the parameters estimated by the ASA model.

Inherent in the use of this selectivity function is the assumption that selectivity increases asymptotically with

$$s_a = \frac{1}{1 + e^{[-\beta(a-\alpha)]}} \qquad (5)$$

age.

Comparing Estimated vs. Observed Age Compositions of the Catch

The degree of agreement between the observed and ASA model-estimated age compositions of the catch was computed as:

Because age compositions were expressed as proportions, arcsin transformations ($\sin^{-1}$) were used in

$$SSQ_{agecomp:catch} = \sum_y \sum_a [\sin^{-1}(\frac{C_{a,y}}{\sum_a C_{a,y}}) - \sin^{-1}(\hat{p}_{a,y})]^2 \qquad (6)$$

computing SSQs to normalize the error structure of the proportions. This SSQ was among three SSQs minimized by an optimization algorithm in the process of fitting estimated to observed age composition or abundance data.

Comparing Estimated vs. Observed Age Compositions of the Spawning Population

In addition to collecting data on the age composition of the catch, data on the age composition of the total spawning population have been collected annually. Commercial fishing gear is often size (weight and maturity) selective; therefore, independent sampling of spawning populations, distinct from catch sampling, is accomplished to provide estimates of age composition and size at age that are more representative of the entire spawning population. This sampling was primarily conducted with cast nets on the spawning grounds, although some sampling was conducted with trawls and seines during the 1970s and 80s. As with catch-age composition, a goodness-of-fit measure was used to calculate the level of agreement between the ASA model estimate of spawning age composition and that determined from sampling:

where $p_{a,y}^{spawn}$ is the observed proportion of age a fish in year y of the spawning population (Appendix C),

$$SSQ_{agecomp:spawn} = \sum_{y}\sum_{a}\left[\sin^{-1}\left(p_{a,y}^{spawn}\right) - \sin^{-1}\left(\frac{\rho_a N_{a,y}}{\sum_a(\rho_a N_{a,y})}\right)\right]^2 \qquad (7)$$

and r_a is the maturity-at-age, defined as the proportion of a cohort that spawned each year, was calculated as:

$$\rho_a = \frac{1}{1+e^{[-\beta(a-\alpha)]}} \qquad (8)$$

where a and b are the parameters estimated by the model. Maturity is modeled as a logistic function of age because, like gear selectivity, herring maturity should asymptote with increased age.

Maturity. The maturity function was applied when comparing abundance estimated from Equation 1, with spawn deposition surveys and spawning age compositions. The maturity-age relationship was assumed constant over time (years). The validity of this assumption was evaluated by examining the residuals of the spawn deposition surveys and spawning age compositions for time trends.

Total Egg Deposition

Annual spawn deposition surveys (see Equation 9) provided direct estimates of the total number of eggs deposited at different spawning areas. Year-specific estimates of total egg deposition, E_y, were computed as the product of the herring sex ratio (i.e., assumed 0.5), the estimated spawning population abundance and age-specific fecundity. Goodness of fit of the ASA model estimates of spawning numbers to the spawn deposition-based (i.e., observed) numbers was estimated as:

where $E_y^{spsurvey}$ is the total number of eggs estimated from the spawn deposition survey (Appendix D) and E_y^{est} is the ASA estimate of egg deposition in year y. For some earlier years, total egg deposition was determined based on an estimated 100,000,000 eggs per ton of herring, where tonnage was determined by

$$SSQ_{spawn} = \sum_{y} [\log_e(E_y^{spsurvey} + 1) - \log_e(E_y^{est} + 1)]^2 \qquad (9)$$

hydroacoustic estimates.

Parameter Estimation

Total Sum of Squares. A total sum of squares was computed by adding each of the aforementioned component sums-of-squares after an adjustment:

where the *l*'s are weights that may be assigned to each sum of squares component. For each of the four southeastern areas for which the ASA model was used, the weights for each SSQ were equal to one (1).

$$SSQ_{total} = \lambda_{spawn} SSQ^{adj.}_{spawn} + \lambda_{agecomp:catch} SSQ^{adj.}_{agecomp:catch} + \lambda_{agecomp:spawn} SSQ^{adj.}_{agecomp:spawn} \qquad (10)$$

The adjusted component *SSQ*s (e.g., SSQ^{adj}_{spawn}) are calculated as:

where the $SSQ_i^{current}$ are *SSQs* for component i calculated with parameter estimation influenced by all three data components simultaneously. The denominator term Max[SSQ_i @ [min(SSQ_j), min(SSQ_k)]], represents

$$SSQ_i^{adj} = \frac{SSQ_i^{current} - \min(SSQ_i)}{\max[SSQ_i \text{ @ } [\min(SSQ_{i_1}), \min(SSQ_{i_2}), \min(SSQ_{i_3}]] - \min(SSQ_i)}, \qquad (11)$$

the higher of the two values of SSQ_i (e.g. spawn deposition) that resulted from running the model influenced first only by component j (e.g., spawning age composition) and then only by component k (e.g. catch age composition). To obtain the SSQ_{total}, the three-components ASA model was run four separate times. It was run once to estimate the min(SSQ_i) for each of the three components and a final run which yielded the minimum SSQ_{total} and the final parameter estimates. The $SSQ_i^{current}s$ are calculated during the last of the four separate runs.

The SSQ_i^{adj} are used to scale the heterogeneous SSQ's that arise from the different units of measure used for the model components (e.g., age composition proportions, total number of eggs). This scaling reduces the tendency for one component of the model to have an inordinate, uncontrolled influence on parameter estimation relative to the other model components. Scaling is a standard practice used in optimization (Gill et al. 1981). The specific algorithm used here was suggested by Jeff Bromaghin (Alaska Dept. Fish & Game, pers. comm.). Different weights (l) may be applied to components if *a priori* information suggests greater reliability of one component compared to others. Lacking prior information to do otherwise, each component was given an equal weighting in all analyses conducted.

Minimization Methods

The Microsoft Excel (Microsoft 1992) spreadsheet optimizer was used to estimate the parameters which resulted in the minimized SSQ_{Total}. This is a non-linear least squares approach(e.g., see p. 83 in Bard 1974, also Gill et al. 1981), where deviations between observed and ASA model estimated values were minimized through iterative adjustment of the values of the parameters survival rate (S), initial abundance, and the logistic parameters defining the relationships between maturity-at-age and gear selectivity-at-age. The spreadsheet optimizer uses nonlinear programming methods to estimate parameters which minimize the SSQ_{Total}.

Biomass Forecast

The forecast biomass (tonnes) is estimated as:

$$B_{'95}^{forecast} = w_3^{forecast} N_3^{cent} \rho_3 + \sum_{a=4}^{8+} w_a^{forecast} N_{a,'95} \rho_a \qquad (12)$$

where $w_a^{forecast}$ is the forecast weight of Age a herring in 1995, N_3^{cent} is either the median or mean (depending on the area) ASA estimated number of Age 3 recruits for the years contributing data to the model, r_3 is the ASA estimate of Age 3 maturity, r_a is the ASA-estimated maturity of Age a herring (Eqn. 7.), and $N_{a,'95}$ is the ASA-estimated forecast number of Age a herring for 1995 (Equation 1).

Data Sources

Major shifts in spawning locations have been documented for herring in the Revillagigedo Channel, particularly since 1989. The current ASA model may not adequately account for these movements since the model is based only on data collected from the State-managed fisheries in the Kah Shakes and Cat Island areas, and does not yet include data collected at the Annette Island Reserve (AIR). The intent for this year's stock assessment was to incorporate data from both the State- and AIR-managed areas to try to account for these movements; however, delays in receiving the necessary stock assessment data from the AIR precluded this approach.

In 1992, 1993, and 1994, pound spawn-on-kelp fisheries were conducted at Craig. Harvest of fish to be placed in the pounds began on March 18, 1992, April 17, 1993 and April 5, 1994. During those years, the seine bait fisheries began on January 13, January 12, and December 8, respectively. Although some additional natural mortality of Craig herring undoubtedly occurred after bait and before the pound spawn-on-kelp fisheries, we assumed that this additional natural mortality was negligible and estimated only one survival rate for Craig.

The starting value for survival rates was 64% for Seymour Canal, Craig and Cat Island, as used by Funk and Sandone (1990). The starting value for the Sitka survival rate was 53%. This starting value was based on the 1993 Sitka ASA, which estimated a survival rate close to 53%. This lower initial value was used to promote a more rapid convergence of the ASA model. Starting values for abundance of Age 3 fish were estimated by fitting cohort survival through time, by eye, to spawn deposition and/or hydroacoustic-based estimates of egg deposition, using biologically reasonable starting values for maturity function parameters and the aforementioned survival rates. For some areas during the late 1970s, total egg estimates back-calculated from hydroacoustic biomass were used because actual spawn deposition estimates were unavailable. This back calculation is based on an estimated fecundity of 100,000,000 eggs per ton of hydroacoustically-estimated herring biomass. This preliminary fit-by-eye procedure was also used to fit starting values for Ages 4 to 8+ for the initial year represented in each areas' age composition time series. For Seymour Canal and Kah Shakes/Cat Island, the initial year was 1976, for Sitka it was 1971 and for Craig it was 1974. For each area, the initial year included in the ASA model was based on the earliest available and most reliable spawn deposition and/or age composition data.

Catch values for each area were obtained from ADF&G fish ticket records; however, the observed catch at age for the Cat Island/Kah Shakes fisheries were complicated in the 1990s by shifts in spawning locations around Revillagigedo Channel and the responses by the State and AIR fisheries managers to those shifts. In 1992, 416 tons of herring were caught in the commercial sac roe fishery at Annette Island. Because there was no significant spawn deposition in 1992 it is assumed that herring caught in Annette Island Reserve waters were intercepted enroute to spawning sites in the Cat Island area. In 1993, the Annette Island commercial catch was 403 tons. The first significant spawn deposition on Annette Island since 1988 also occurred in 1993. As of February 6, an official estimate of the commercial catch in Annette Island waters in 1994 was not available to ADF&G. A preliminary hearsay estimate of catch for 1994 was 347 tons.

The relatively close proximity of Annette Island to the Cat Island fishery, coupled with information on probable herring movement among the Kah Shakes, Cat Island and Annette Island areas, suggests that herring from the same spawning aggregation might have been harvested at both Annette Island and the Cat Island area. Recognition of this possibility resulted in the State reducing the 1992, 1993 and 1994 Cat Island harvest quotas by 150 tons, to reduce the chance of overharvesting herring. Since there was no significant spawning in Annette Island waters in 1992, the AIR fishery probably harvested from the same spawning aggregation subsequently exploited in the Cat Island area in 1992; therefore, in conducting the ASA for Kah Shakes/Cat Island, the AIR 1992 catch of 416 tons was included in the Cat Island catches for that year. Because there was significant spawn deposition in AIR waters in 1993 and 1994, it is less clear whether, or to what extent, the spawning aggregation harvested by the AIR fishery may have subsequently moved to the Cat Island area and been subjected to harvesting in the State managed fishery. Whether such movement may have occurred in 1994 may be particularly questionable. Gross observations and an actual catch below the 1994 State quota may suggest that some herring that formerly spawned in the Cat Island area prior to 1994 spawned at Annette Island in 1994. Although there is uncertainty whether herring subjected to harvest in AIR waters were subsequently subjected to further harvesting in the Cat Island area for 1993 and 1994, as a conservative measure, AIR catches for these years, as well as 1992, were added to the Cat Island catch.

Although herring used in pound fisheries are released following the fishery, some mortality occurs with mortality probably increasing with greater crowding. Although the actual mortality associated with the pounding operations varies and is unknown, to conduct the ASA we assumed a mortality rate of 75% for the pound fishery at Craig.

For Craig, since both the bait and pound harvests are conducted with seine gear, a single gear selectivity function was modeled. It was also assumed that any additional maturation of herring between the times of the bait and the pound fisheries was negligible and only one maturity function was defined. These simplifying assumptions, in addition to the single survival estimate for Craig, were made partly due to the relatively limited data available for Craig, compared to the other three areas for which ASA estimates were generated. The inclusion of a second survival and two additional maturity parameters in the model, to try to account for the time between the winter bait fishery and spring spawn deposition sampling, would tend to further decrease the already relatively low data/parameter ratio for the Craig ASA. A lower data/parameter ratio may tend to reduce both the accuracy and precision of parameter estimates.

For Seymour Canal, two gear selectivity functions were estimated based on the use of seines in the commercial fishery from 1976 to 1979, and gillnets from 1980 to the present.

For Seymour Canal, two separate maturity functions were estimated based on the two different sampling gears used to estimate spawning age composition. For the years 1976-79, seine gear was used to estimate spawning age composition. Since 1979, cast nets have been used to estimate spawning age composition.

Both the Sitka and Cat Island spawning populations display a historical cyclic recruit pattern, which would suggest a somewhat higher recruitment of age 3s in 1995. At Sitka this expectation was reinforced by results from age composition samples obtained during a winter test fishery conducted in January and February; therefore, the higher of two measures of central tendency, the mean rather than the median, was used as N_3^{cent} for these two areas. The Craig and Seymour Canal spawning populations do not display this cyclic recruitment pattern, so the expected recruitment for these areas is more uncertain than for Sitka and Cat Island; therefore, the lower of the two measures of central tendency, the median, was used as an estimate of N_3^{cent} for these areas. For Craig and Seymour Canal, the mean weights at age for 1993 and 1994 were used as most representative forecast weights-at-age (Appendix E). For Sitka, mean weights-at-age of herring sampled from the winter test fishery were used as forecast weights-at-age. The weights-at-age from the 1995 test fishery are substantially higher than the forecast weights based on the mean of the 1993 and 1994 Sitka weights-at-age. Forecast weights-at-age were calculated as the mean of historical weights-at-age for Cat Island. The mean of weights-at-age for all years were used for Cat Island because of the similar historical recruitment patterns at Cat Island and Sitka and the fact that preseason sampling at Sitka indicated higher weights-at-age than would be predicted using the mean of the 1993 and 1994 weights-at-age.

Spawn Deposition Surveys. Spawn surveys are conducted by SCUBA divers to estimate total annual egg deposition on the spawning grounds. Total egg deposition for a particular spawning ground (t_i) is estimated as:

$$t_i = a_i \bar{d}_i \qquad (13)$$

where a_i is the estimated total area (m^2) on which eggs have been deposited and $\bar{d}_i$ is the estimated mean density of eggs (eggs/m^2) at spawning area i. The total area on which eggs have been deposited (a_i) is estimated as:

where l_i is the total meters of shoreline receiving spawn (determined from aerial and skiff surveys) and $\bar{w}_i$ is the mean length of transects conducted at spawning area i.

$$a_i = l_i \bar{w}_i \qquad (14)$$

The mean density of eggs/m^2 at area i ($\bar{d}_i$) is estimated as:

where v_{hij} is the visual estimate of egg numbers by diver h, at area i, quadrate j. The c_h term refers to a diver-

$$\bar{d}_i = \left[\frac{\sum v_{hij} c_h}{\sum m_{hi}} \right]^{-0.1} \quad (15)$$

specific correction factor to adjust visual estimates made by diver h, and m_{hi} is the number of quadrates visually estimated by diver h at area i. Divers visually estimate egg density within 0.1 m quadrates. The 0.1 exponent expands the mean density from a 0.1 m^2 to a 1.0 m^2 unit basis. Diver-specific correction factors (c_h) are estimated as:

where v_h is the mean visual estimate of egg numbers for diver h and $\bar{k}_h$ is the mean laboratory count of egg

$$c_h = \frac{\bar{k}_h}{\bar{v}_h} \quad (16)$$

samples collected from quadrates visually estimated by diver h.

Given estimates of total egg deposition, an estimated fecundity of 100,000,000 eggs per ton of herring is then used to determine the annual escapement biomass. With the assumption that subsequent losses from the escapement biomass (i.e., natural mortality) are offset by gains (i.e., growth, maturation, recruitment), this escapement estimate is used as the forecast of mature biomass for the following year, for some areas. In 1994 those areas included: W. Behm Canal, Ernest Sound (Vixen Inlet/Union Bay), Port Houghton/Hobart Bay, Hoonah Sound, Lynn Canal, Lisianski Inlet, and Yakutat. Estimates of total egg deposition are also crucial data for application of ASA. Further details of spawn deposition surveys as well as age and growth methodology are provided in Larson et al. (1994).

Figure 1. Primary Southeast Alaska herring stock assessment locations.

RESULTS

Sitka

Model Parameter Estimates

The ASA model estimate of survival rate for Sitka was 59.6%. Parameter estimates (Appendix F) for the maturity function yielded maturities-at-age which ranged from 24% for Age 3 fish to 100% mature for Age 8+ (Figure 2).

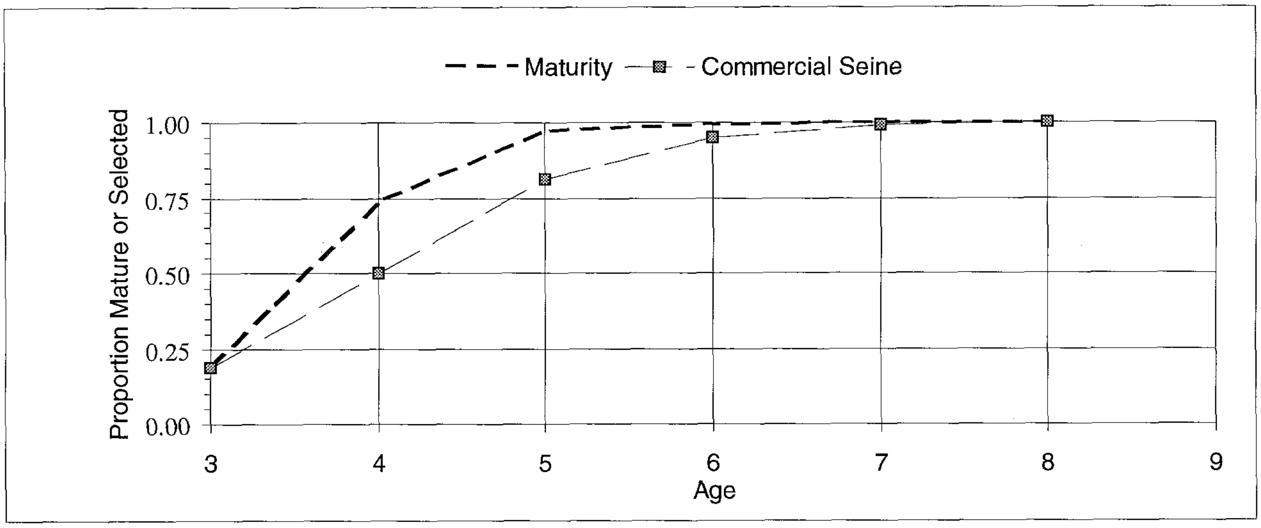

Figure 2. Sitka maturity and gear selectivity.

Parameter estimates for the gear selectivity function resulted in age-specific gear selectivities ranging from 20% for Age 3 fish to 100% for Age 7+ fish (Figure 2). The time series of estimated Age 3 recruits exhibits a pattern of markedly strong year classes every four years, beginning with the 1976 year class (Figure 3; Appendix G).

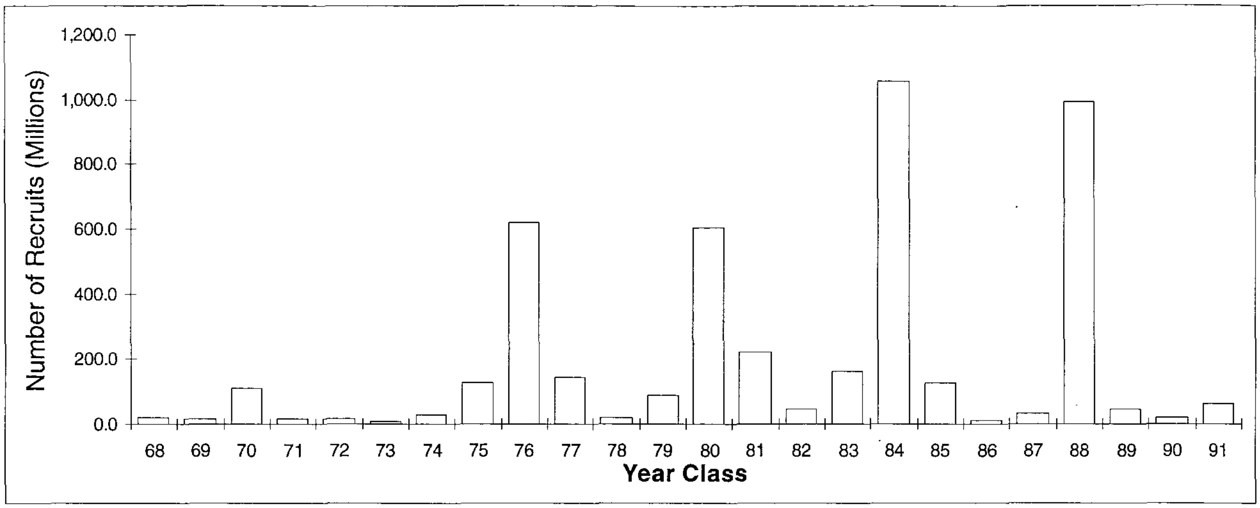

Figure 3. Sitka ASA-estimated herring Age 3 recruit strength.

This pattern is similar to (though somewhat more pronounced) than that seen in Prince William Sound (Funk 1994). Diagnostic graphics were used to evaluate the goodness of fit of ASA model estimates to observed data (Figure 4, and Appendices H.1-H.7).

Appendix H.1a and H.1b show how well the ASA model estimates of total egg deposition fit the spawn survey estimates. As shown in H.1.a, the pattern of interannual fluctuations in ASA estimates tracks the spawn survey estimates quite well in both direction and magnitude. The plot of residuals (H.1.b) does not display a pattern of ASA estimates consistently higher or lower than the spawn survey estimates. This suggests an acceptable ASA reconstruction of the population as reflected by total egg deposition.

The ASA estimates of spawning population age composition and the observed values are in close agreement, indicating a good fit of the model estimates to the observed data. Examples of the close agreement can be seen in the very similar patterns of observed and (ASA) estimated age compositions from 1991 through 1994. Plots of spawning run age composition residuals (Appendix H.3) provide information about potential lack of fit, or bias in ASA model estimates of spawning age composition. The apparent random fluctuation of positive and negative age composition residuals across years and age classes further suggests a reasonable fit of the ASA versus observed estimates, without noticeable bias. Plots of spawning age composition residuals versus age composition proportions do not suggest any consistent over- or under-estimate of age composition associated with the magnitude of the age composition. The model seems to fit the observed age compositions reasonably well whether a particular age class for a particular year comprises a large or small proportion of the annual age composition (Appendix H.4). As with spawning age compositions, for catch age compositions there is sufficiently close agreement between ASA estimated and observed age compositions (Appendix H.5), no consistent over- or underestimate of catch age compositions by year or age class (Appendix H.6), and no pattern of over- or underestimate of catch-age composition in relation to the magnitude of age composition (Appendix H.7).

Collectively these plots suggest that the ASA model provides a reasonably good fit to the observed data and, therefore, yields estimates of population parameters (e.g., survival and Age 3 recruits) useful for estimating historical abundance and forecasting future abundance. Similar diagnostic graphics are presented as appendices for the three other areas for which ASA was used.

1994 Stock Status

The ASA model estimates of 1994 pre fishery total abundance (numbers) declined 44% from 1993 estimates. The decline was influenced primarily by mortality of the still dominant 1988 year class (Age 6 in 1994) and the absence of other strong year classes. Decline in numbers was offset somewhat by growth of the dominant 1988 year class, resulting in only a 28% decline in biomass (Figure 4.).

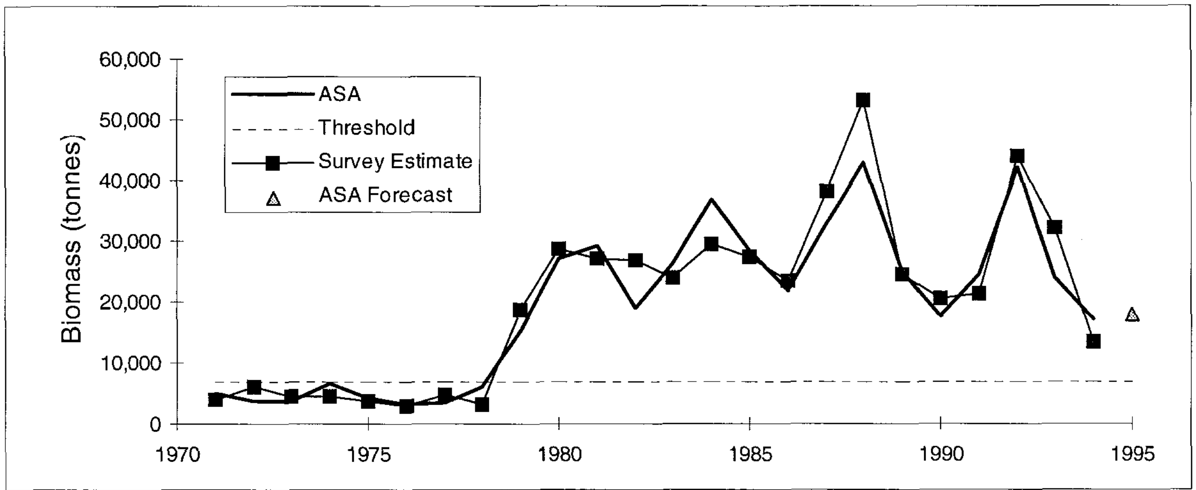

Figure 4. Spawn deposition and ASA estimates of Sitka biomass and ASA 1995 forecast.

Mean observed weights at all ages were higher in 1994 than in 1993 but below the 23 year (1971-1993) mean. The higher mean weights-at-age in 1994 interrupted a generally consistent, interannual pattern of declining weights-at-age of older (Ages 5+) herring that began during the mid-1980s (Appendix I).

1995 Forecast and Quota

The ASA estimated pre fishery forecast for mature herring in the Sitka area for 1995 is 14,505 short tons (13,156 tonnes, Table 1.). Under the current harvest strategy, this provides an allowable 11.9% exploitation rate and, therefore, a harvest quota of 1,561 tonnes (1,721 short tons). This forecast is based on use of the ASA estimated median number of age 3 recruits as a prediction of 1995 age 3 recruits; however, based on age samples collected from a winter test fishery, it appears that the 4-year cycle of high recruitment may continue, as it has for the past 15 years. There will likely be a higher proportion of Age 3 herring in 1995 than predicted based on the median; therefore, the forecast of Age 3 recruits will be based on the mean historical Age 3 recruitment. The composition of Age 4+ population will be dominated by Age 7 herring, the result of the strong 1988 year class.

Seymour Canal

ASA Model Parameter Estimates

The estimated survival rate for Seymour Canal was 77.1%. Estimated maturities-at-age, based on cast net samples (used for sampling from 1980 to 1993), ranged from 14% for Age 3 to 100% for Age 8+ fish (Figure 5.).

Figure 5. Seymour Canal maturity and gear selectivity.

Table 1. Herring thresholds, 1995 biomass forecasts, exploitation rates and harvest quotas for herring in Southeast Alaska.

Area	Gear/Fishery Type	Threshold		1995 Forecast		1995 Exploitation Rate	Final 1995 Quota		Biomass Estimation Method
		tonnes[a]	tons[b]	tonnes	tons		tonnes	tons	
Sitka	Seine - Sac roe	6,804	7,500	17,858	19,689	13.3%	2,366	2,609	ASA[c]
Seymour Canal	Gill net - Sac roe	2,722	3,000	2,839	3,130	10.1%	286	316	ASA
Cat Island/Kah Shakes	Gill net - Sac roe	5,443	6,000	5,601	6,174	10.1%	427	621	ASA
Craig	Seine - bait & pound[e]	4,536	5,000	6,148	6,778	10.7%	659	726	ASA
Hobart/Houghton	Seine - bait	1,814	2,000	2,189	2,414	10.4%	228	251	SPAWN DEP.[d]
Hoonah Sound	Seine - pound	907	1,000	2,222	2,450	0.5%	11	150[f]	SPAWN DEP.
Lisianski	Seine - bait	2,268	2,500	1,901	2,096	0.0%	0	0	SPAWN DEP.
Ernest Sound	Seine - bait	2,268	2,500	2,307	2,544	10.0%	232	255	SPAWN DEP.
West Behm Canal	Seine - bait	1,814	2,000	2,367	2,609	0.0%[g]	0	0	SPAWN DEP.
Tenakee Inlet	Seine - bait	2,721	3,000	0	0	0.0%	0	0	SPAWN DEP.
Lynn Canal	Seine - Sac roe	4,535	5,000	(Below threshold)		0.0%	0	0	SPAWN DEP.
Subtotal - sac roe				26,298	28,993		3,080	3,545	
Subtotal - bait				13,990	15,424		1,019	1,124	
Subtotal - pound				3,144	3,467		110	259	
TOTAL				**43,432**	**47,883**		**4,209**	**4,928**	

[a] Metric tons
[b] Short tons
[c] **A**ge **S**tructured **A**nalysis
[d] spawn deposition survey
[e] pound fisheries produce a spawn-on-kelp product
[f] fixed harvest quota of 150 tons of herring equals 12 tons of spawn-on-kelp product
[g] 0% exploitation due to uncertainty of Revillagigedo Channel herring wintering areas.

For the years 1976 to 1979 seine samples were used to collect representative AWL samples. The age-specific maturity for these years varied from 14% for Age 3 fish to 100% for Age 8+ (Figure 5). The age-specific maturity was essentially the same for both cast nets and seines. Gillnet (for the years 1980-1993) and seine (for 1976-1979) selectivity ranged from 0% to 100% for Ages 3 and 8+, respectively (Figure 5). Unlike the pattern exhibited for Sitka, there was no regular cycle of strong year classes evident in estimates of Age 3 recruits for Seymour Canal (Figure 6). As in Sitka, the 1988 year class was the most abundant in recent history.

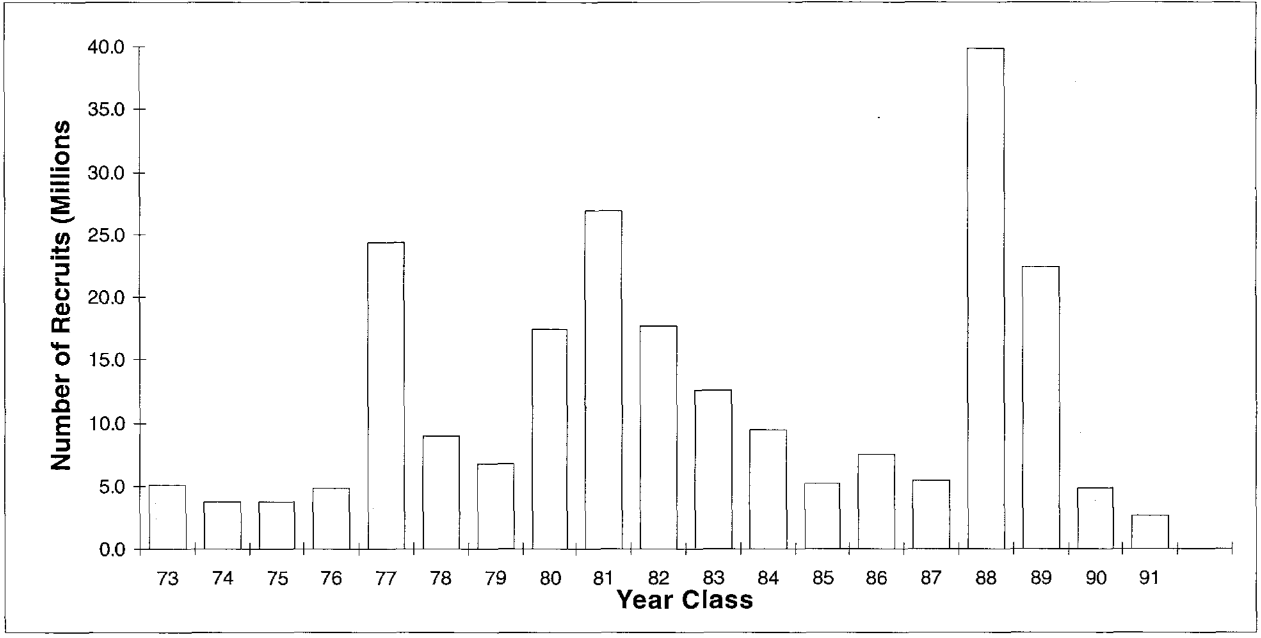

Figure 6. Seymour Canal, ASA-estimated herring Age 3 recruit strength.

Goodness of fit of ASA model estimates to observed data from Seymour Canal is depicted in Figure 7 and Appendices H.8-H.14.

1994 Stock Status

Model estimated abundance (numbers) and biomass (tonnes) of Seymour Canal herring decreased slightly from 1993 to 1994 (Figure 7 for biomass).

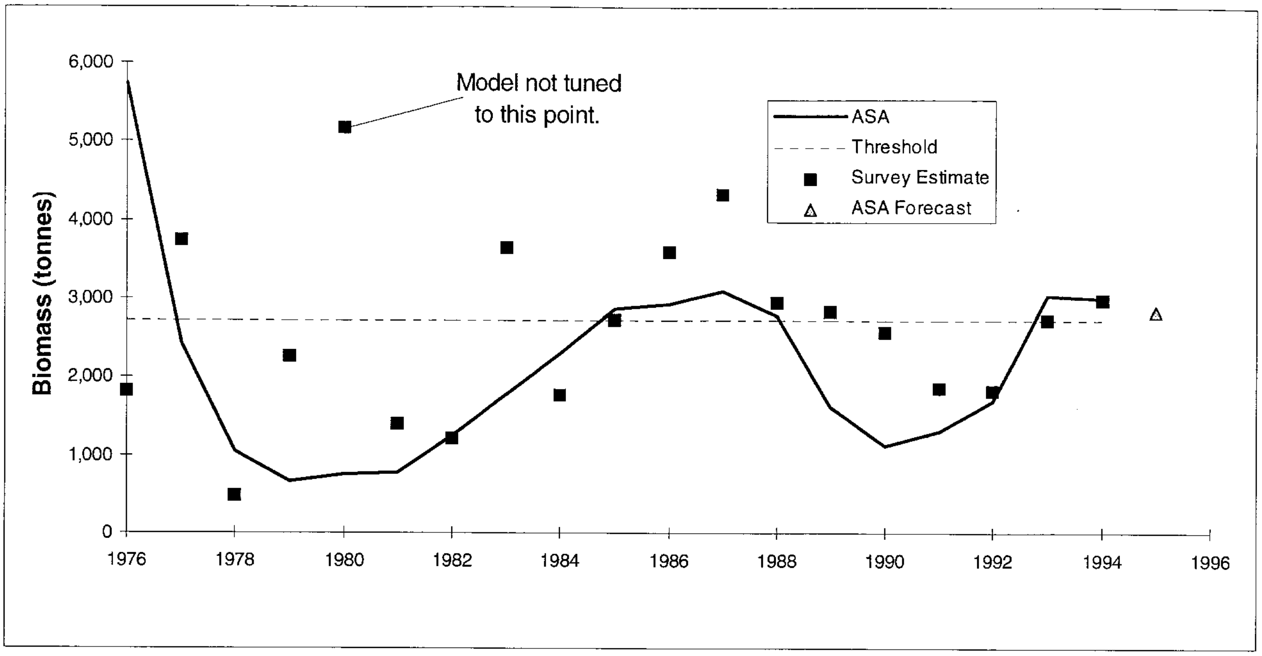

Figure 7. Spawn survey and ASA estimates of Seymour Canal biomass and ASA 1995 forecast.

The 1994 cohort was dominated primarily by Age 6 herring, and to a lesser extent Age 5 (Larson et al. 1994). The mean weights-at-age of the 1994 cohort were greater than in 1993 (Appendix I). In addition, the mean weights of Ages 3-4 herring were higher than the 18 year (1976-1993) mean, while the Age 5+ herring weighed less than the 18 year mean. The 1993 and 1994 mean weights-at-age reversed a general decline in annual weights-at-age that began in the mid-1980s, similar to the decline at Sitka (Appendix I)

1995 Forecast and Quota

The forecast of mature herring for Seymour Canal in 1995 is 3,130 tons (2,839 tonnes, Table 1). This exceeds the established threshold of 3,000 tons (2,721 tonnes) and allows an exploitation rate of 10.1%. This would provide an allowable harvest quota of 286 tonnes (316 short tons) at Seymour Canal in 1995.

Craig

ASA Model Parameter Estimates

The ASA model estimated survival rate for Craig herring was 68.4%. Maturities-at-age varied from 27% at Age 3 to 100% at Ages 8+ (Figure 8).

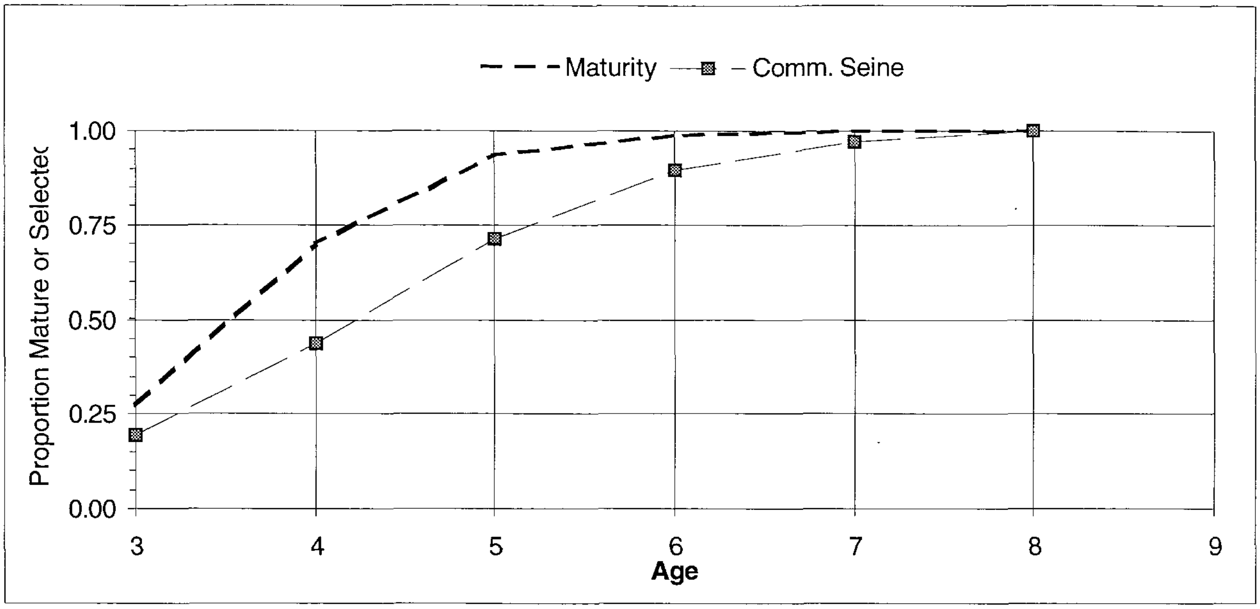

Figure 8. Craig maturity and gear selectivity.

Seine gear selectivities ranged from 19% for Age 3 to 100% for Age 8+ (Figure 8). The recruitment pattern for Craig lacks the obvious quadrennial cycle evident for Sitka. Like Sitka, the 1984 and 1988 year classes were pronounced at Craig; although the relative strength of the two year classes was reversed. As with Sitka, when processed the 1995 age samples may indicate whether the 1992 year class is stronger than the previous three years. If so, it may indicate the beginning (or continuation) of a Sitka-like, four-year recruitment cycle at Craig (Figure 9).

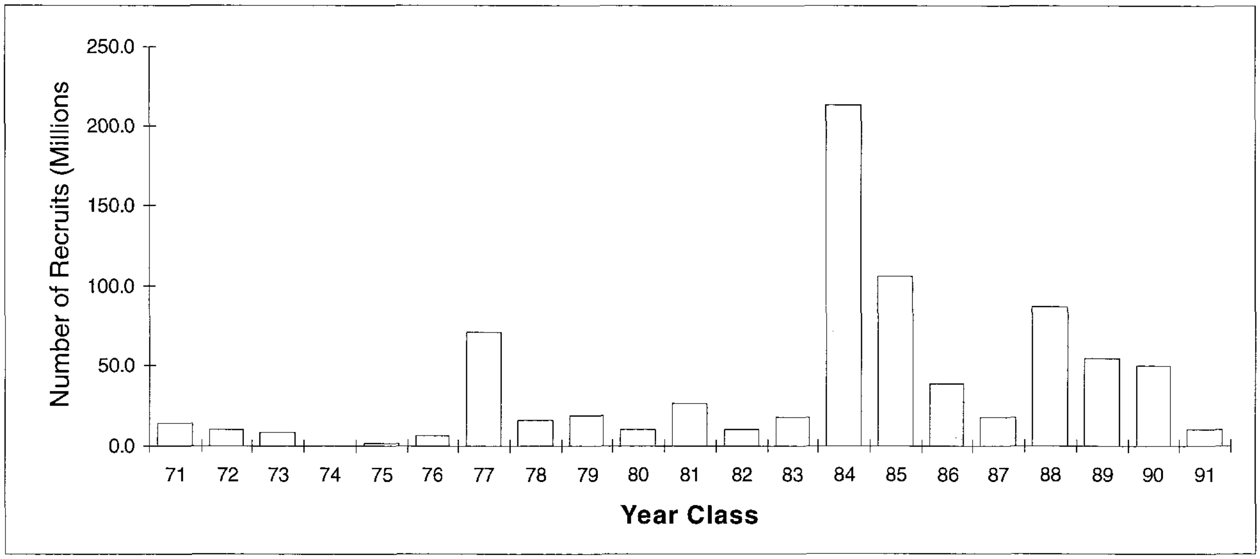

Figure 9. Craig ASA-estimated herring Age 3 recruit strength.

Goodness of fit of model estimates to observed data was evaluated using Figure. 9 and Appendices H.15-H.21.

1994 Stock Status

The 1994 ASA model estimated biomass of 7,252 short tons (6,578 tonnes, Table 1) was slightly less than the 1993 estimate of 7,495 short tons (6,798 tonnes, Fig. 10).

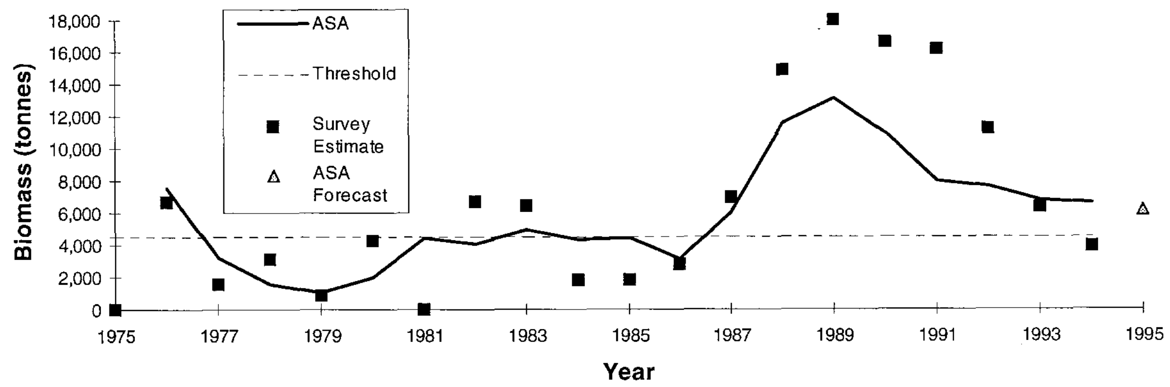

Figure 10. Spawn survey and ASA estimation of Craig herring biomass and 1995 ASA forecast.

Estimated numbers of herring also decreased from 79,000,000 in 1993 to 68,000,000 in 1994. Age 5 herring dominated the 1994 cohort, followed closely by Ages 4 and 6. Mean age-specific weights of 1994 Craig herring tended to be higher than both the 1993 and the 19-year (1974-1993) mean weights-at-age. As at Sitka and Seymour Canal, but to a lesser extent, the 1994 weights-at-age for Craig seemed to interrupt a slight downward trend in age-specific weights of most older age classes (i.e., Ages 4+) of herring that had prevailed at least since 1988 (Appendix I).

1995 Forecast and Quota

The 1995 ASA forecast estimate of biomass for Craig is 6,778 tons (6,148 tonnes). Considering the established 5,000 tons (4,536 tonnes) threshold, a 10.6% exploitation rate will be permitted. This will yield a 1995 harvest quota of 726 short tons (659 tonnes) for Craig in 1995. Based on current regulation (ADF&G 1994), 85% or 617 tons (560 tonnes), will be allotted to the Craig bait fishery and the remaining 15%, or 109 tons (99 tonnes) to the pound fishery.

ASA Model Parameter Estimates

The estimated survival rate for the Cat Island area herring population was 68.5%. The age-specific maturities ranged from 45% at Age 3 to 100% for Ages 6+ (Figure 11)

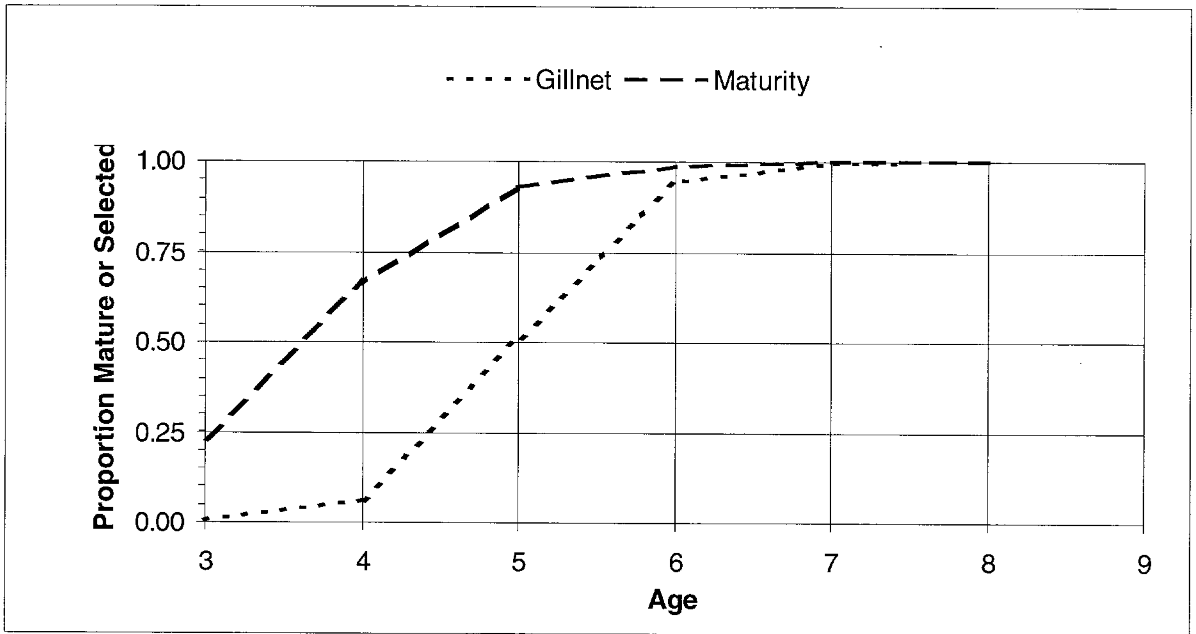

Figure 11. Kah Shakes/Cat Island maturity and gear selectivity.

Gillnet gear selectivity ranged from 1% at Age 3 to 100% at Ages 7+ (Figure 11). Estimates of recruit strength at Age 3 suggest a possible, approximately four year cycle similar to that exhibited in the Sitka area (Figure 12).

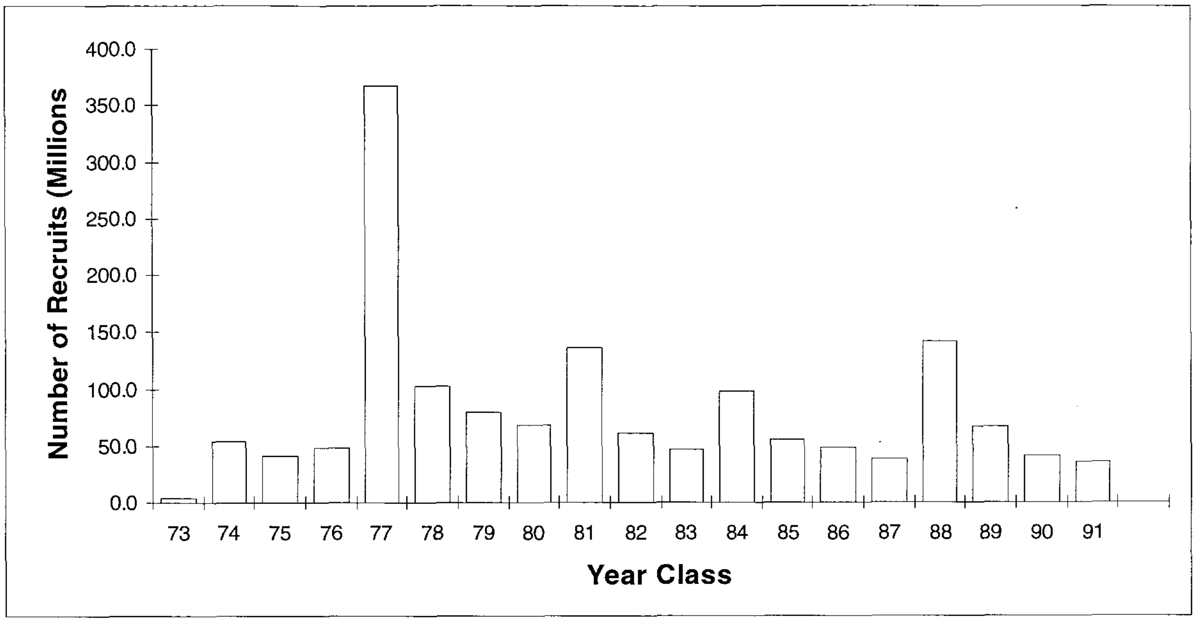

Figure 12. Kah Shakes/Cat Island, ASA-estimated herring Age 3 recruit strength.

However, the first markedly strong year class occurs in 1977 rather than 1976, and the quadrennial nature of the cycle is interrupted by strong 1981 and 1984 year classes, with only two, rather than three years between those strong year classes. Diagnostic graphics depicting the goodness of fit of ASA model predictions to observed data are included in Figure 13 and Appendix Figsures H.22 to H.28.

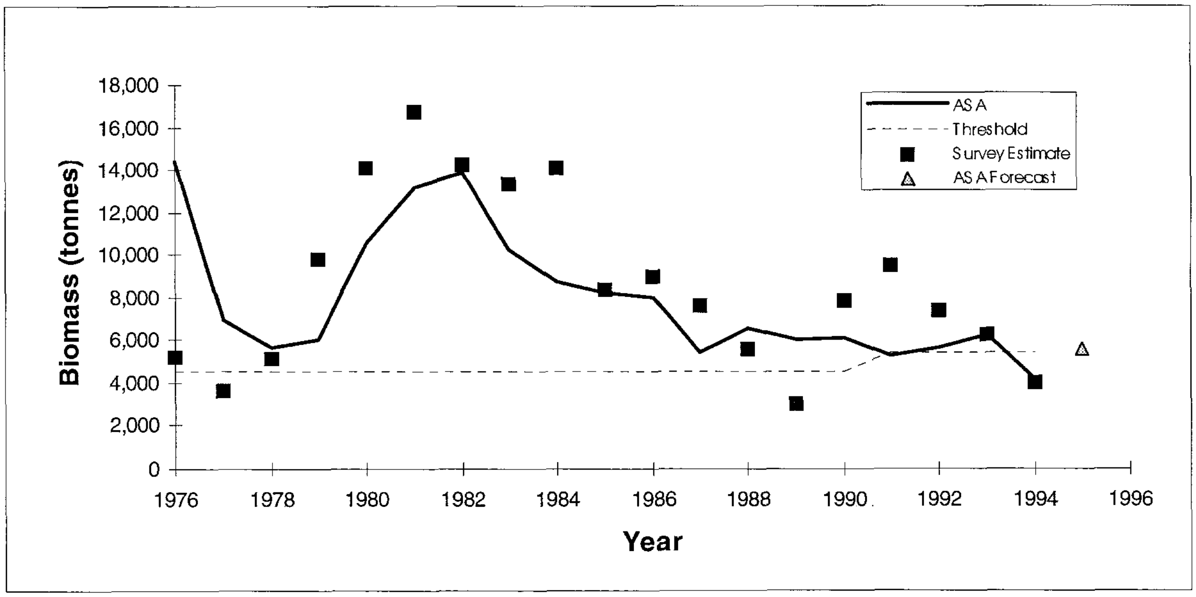

Figure 13. Spawn survey and ASA estimates of Kah Shakes/Cat Island biomass and ASA 1995 forecast.

1994 Stock Status

The 1994 ASA estimated biomass was 4,579 tons (4,154 tonnes) This represented a 34% decline in estimated biomass from the 1993 estimate of 6,906 tons (6,264 tonnes). This decline may be partially accounted for by some herring spawning outside of the Cat Island area at Annette Island. The 1994 cohort was dominated slightly by Age 5 fish (29.8%), followed by Ages 4 (24.3%), 6 (22.3%) and 3 (19.4%). Mean age-specific weights in 1994 averaged 12% lower than in 1993 and were also lower than the 19 year mean.

1995 Forecast and Quota

The ASA model forecast of mature herring for the Cat Island area in 1995 is 6,174 t (5,601 tonnes; Table 1). Given a threshold of 6,000 tons (5,443 tonnes), the allowable 10.1% exploitation rate results in a 1995 quota of 621 tons. The threshold was increased from 5,000 tons in 1991 to account for a shift in the primary spawning location and resultant expansion of harvest area. As in 1994, this quota was not reduced in 1995 to account for potential harvest of herring on Annette Island. Without significant recruitment in 1995, the age composition of the population is expected to be comprised predominantly of Ages 4, 5, 6 and 7 herring; however, as at Sitka there are some indications of a 4 year cycle of higher recruitment at Cat Island/Kah Shakes. If such a cycle continues, stronger than normal recruitment may be expected in the Cat Island/Kah Shakes area.

West Behm Canal

1994 Stock Status

Spawn deposition sampling in West Behm Canal indicated a spawning biomass of 2,609 tons (2,367 tonnes). This is a decline from the 1993 estimate of 3,854 tons (3,496 tonnes) but still above the biomasses estimated for 1990-92 (Figure 14).

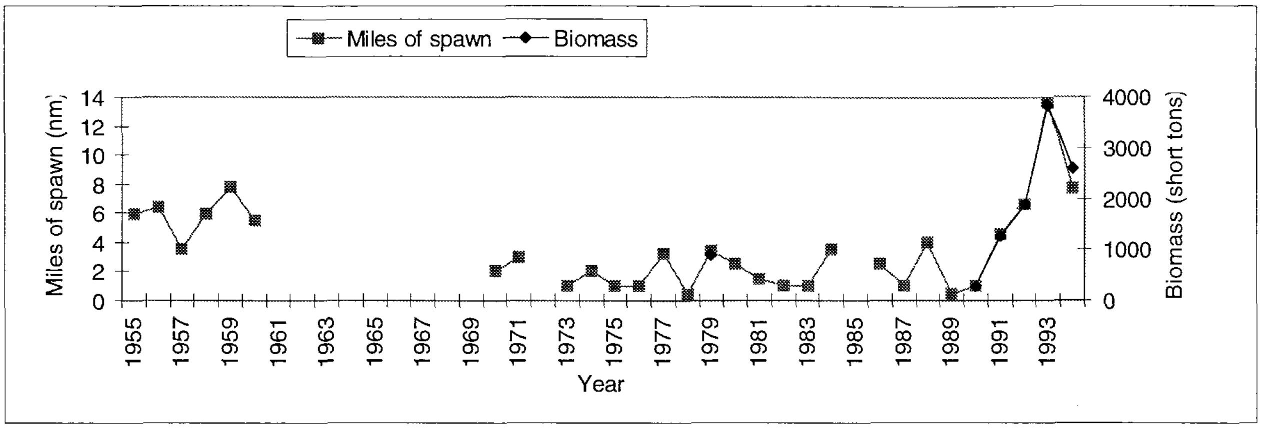

Figure 14. Spawn survey estimates of miles of spawn and biomass, West Behm Canal.

The spawning age composition, as determined by cast net samples, was dominated by Ages 3, 4 and 5 herring.

1995 Forecast and Quota

Assuming that natural mortality losses from the 1994 spawning biomass equal the gains attributable to recruitment and growth and maturation, the 1995 forecast spawning biomass for West Behm Canal is 2,609 tons (2,367 tonnes). Given the current threshold of 2,000 tons (1,814 tonnes), this forecast spawning biomass could provide for a bait harvest in West Behm Canal. However, uncertainty about the wintering locations of fish that spawn in the West Behm Canal, Cat Island and Annette Island areas raise the possibility of exceeding allowable harvest rates at one or more of these areas if a winter bait fishery is permitted at West Behm Canal. Hence, no harvest is allowed at West Behm Canal in 1995 (Table 1).

Ernest Sound (Vixen Inlet/Union Bay)

1994 Stock Status

Spawn sampling in Ernest Sound in 1994 indicated a spawning biomass of 2,544 short tons (2,308 tonnes). This is a dramatic increase compared to 1993, but is very close to the estimated 1992 biomass. The marked change in Ernest Sound herring biomass between 1992 and 1994 is attributable to the much lower egg density in 1993. Miles of spawn declined from 10 to 9 miles from 1992 to 1993 and further declined to about 8 miles in 1994 (Figure 15).

The 1994 age composition of herring from Ernest Sound was composed primarily of Ages 5 (36.5%), 3 (23%) and 4 (21.2%).

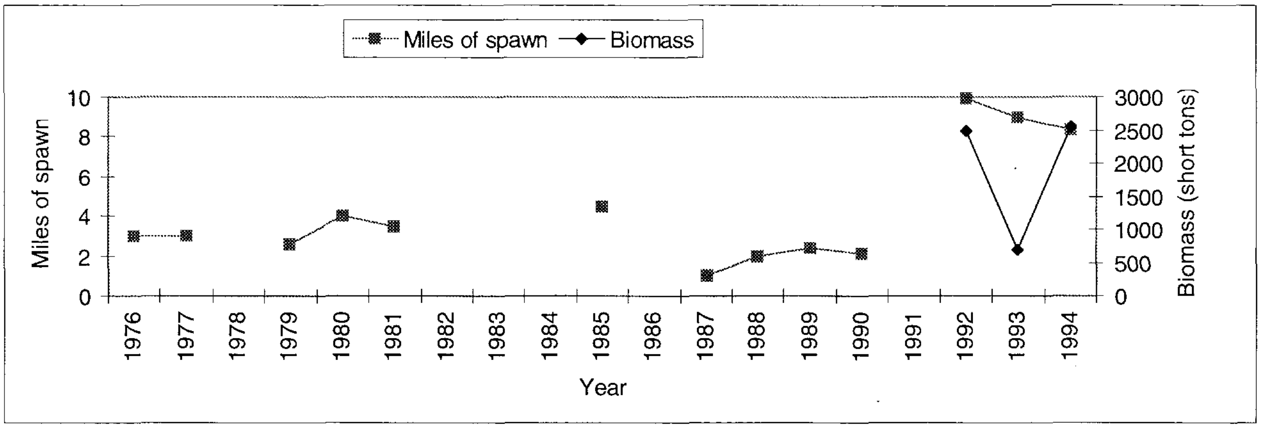

Figure 15. Spawn survey estimates of miles of spawn and biomass, Ernest Sound (Vixen Inlet/Union Bay).

1995 Forecast and Quota

Assuming that natural mortality losses from the 1994 spawning biomass equal the gains attributable to recruitment growth and maturation, the 1995 forecast spawning biomass is 2,544 short tons (2,308 tonnes). Because this biomass is above the threshold of 2,500 short tons (2,268 tonnes), the harvest quota will be 255 tons (232 tonnes) for 1995 (Table 1).

Assuming age composition and recruitment are similar to 1994, the age composition of Ernest Sound herring in 1995 is expected to include primarily Ages 4, 5 and 6 herring.

Hobart Bay/Port Houghton

1994 Stock Status

Spawn deposition sampling in 1994 resulted in a mature spawning biomass estimate of 2,189 tonnes (2,414 short tons). This does not include the harvest of 229 tons from the bait fishery conducted in February. The estimated biomass represents a decrease from 1993 to about the level estimated in 1992 (Figure 16).

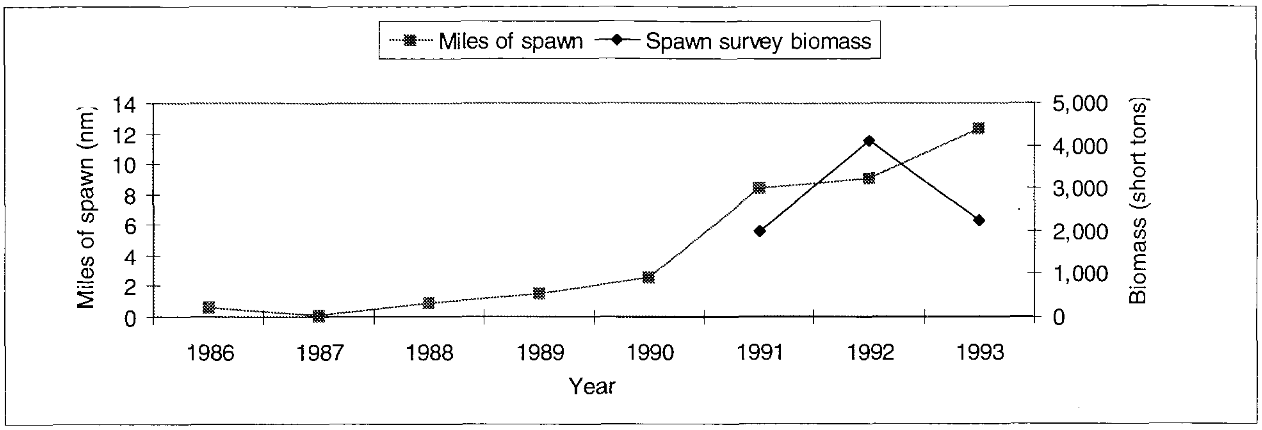

Figure 16. Spawn survey estimates of miles of spawn and biomass, Port Houghton/Hobart Bay.

The 1994 cohort was dominated by Ages 6 (57%) and 5 (26%) herring.

1995 Forecast and Quota

Assuming that natural mortality losses from the 1994 spawning biomass are exactly offset by gains due to recruitment, growth and maturation, the forecast of 1995 spawning biomass is 2,414 short tons (2,189 tonnes). Given a threshold of 2,000 short tons (1,814 tonnes) this would provide a 10.4% exploitation rate and an allowable quota of 251 short tons (228 tonnes; Table 1). We expect the 1995 cohort to be dominated primarily by Ages 6 and 7 herring.

Tenakee Inlet

1994 Stock Status

There was very little spawning activity documented in Tenakee Inlet in 1994 (approximately 0.25 nm of spawn). This is a marked decline in spawning activity compared to the previous years but consistent with levels of spawning activity seen during 1991 and 1992 (Figure 17).

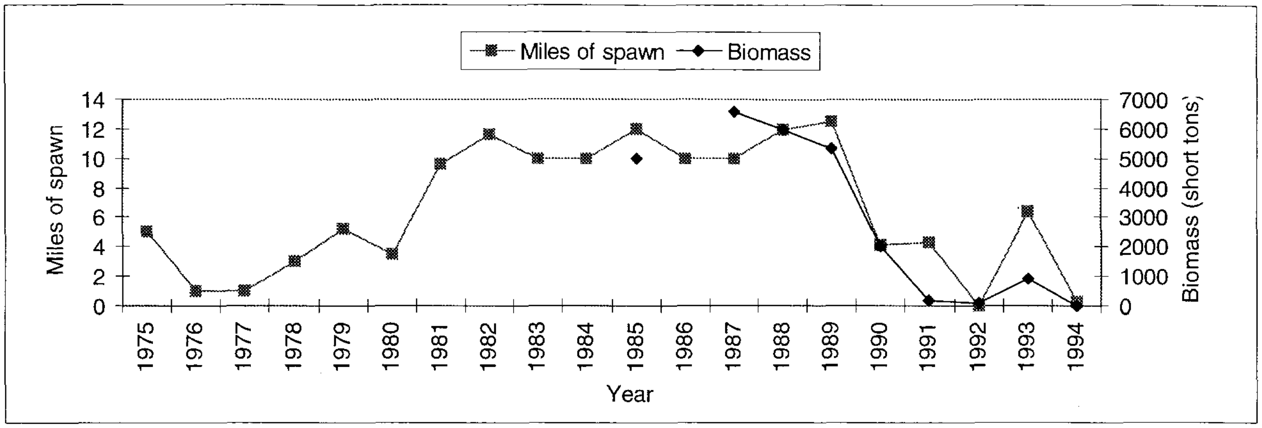

Figure 17. Spawn survey estimates of miles of spawn and biomass, Tenakee Inlet.

Because of the very limited spawning activity, neither spawn nor age-weight-length sampling was conducted at Tenakee Inlet in 1994.

1995 Forecast and Quota

The minimum biomass needed to allow a fishery in Tenakee Inlet is 3,000 short tons (2,721 tonnes). Given the extremely limited spawning activity observed in Tenakee in 1994, it is highly unlikely that the 3,000 threshold would be achieved in 1995; therefore, there will be no fishery in Tenakee Inlet in 1995 (Table 1).

Necker and Whale Bays

1994 Stock Status

Aerial surveys to document spawning activities were conducted at Necker or Whale Bays on April 7 and 18 and May 2, 1994. No pre spawning herring or active spawn was observed; however, a very limited sonar survey of the areas suggested a probable biomass of at least 2,000 short tons of herring (Bob DeJong, ADF&G, personal communication). No herring samples were collected to estimate size or age composition. Because of budget limitations, formal spawn and AWL surveys have been intermittent at Necker and Whale Bays, making assessment of population trends in these areas difficult (Figure 18).

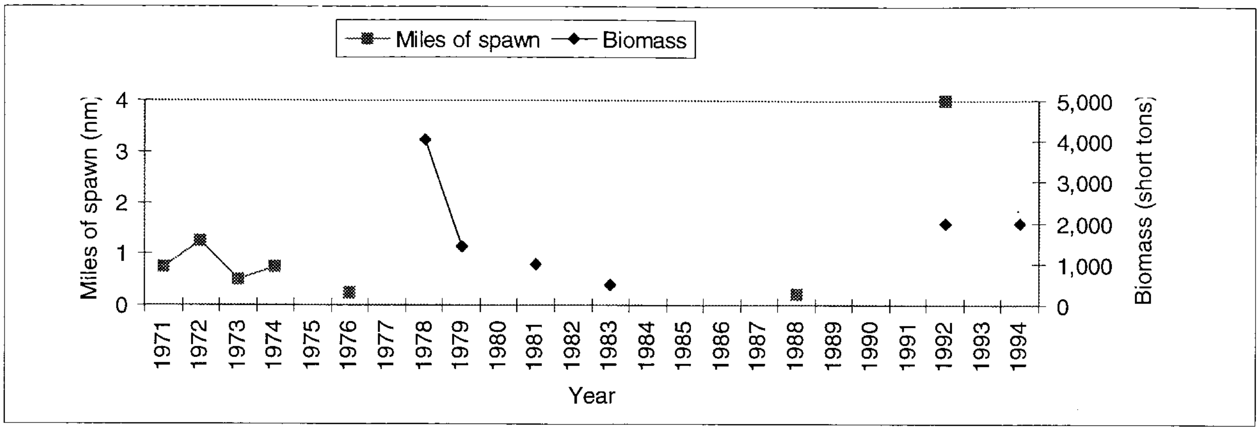

Figure 18. Spawn survey estimates of miles of spawn and biomass, Necker and Whale Bays.

1995 Forecast and Quota

As in 1994, aerial surveys may be conducted during the winter of 1994-95 to determine whether a 2,000 ton minimum biomass is available. If so, a bait harvest may be conducted during the winter of 1994-95.

Hoonah Sound

1994 Stock Status

The estimated spawning escapement for Hoonah Sound in 1994 was 2,450 short tons (2,222 tonnes). This represents a 55% increase above the 1993 biomass of 1,099 tons, but is still well below the record high 5,714 ton biomass from 1992 (Figure 19).

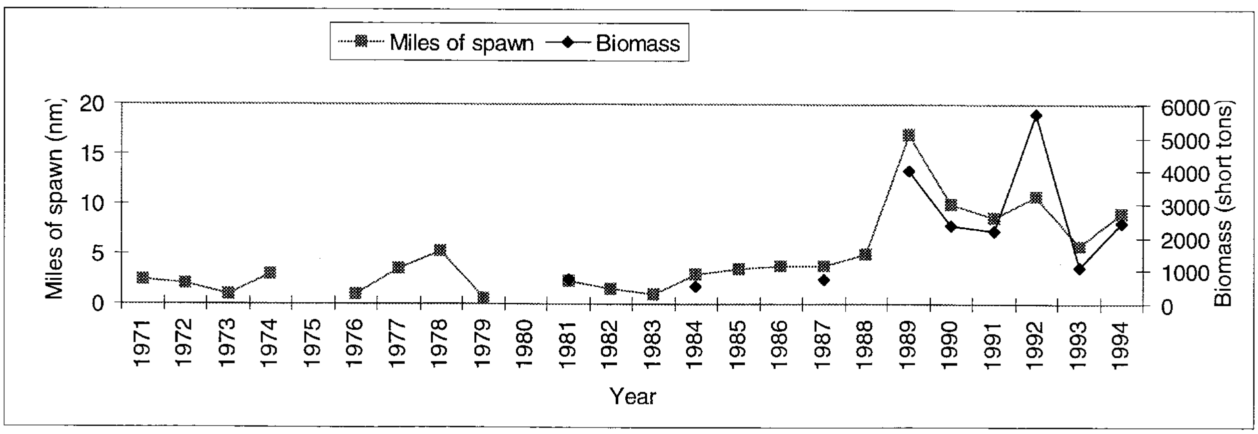

Figure 19. Spawn survey estimates of miles of spawn and biomass, Hoonah Sound.

The spawning age composition, as determined by cast net sampling, was dominated by Ages 6 (42%) and 5 (35%) herring (Larson et al. 1994).

1995 Forecast and Quota

The threshold for Hoonah Sound is 1,000 short tons (907 tonnes). If biomass gains offset losses between 1994 and 1995, the forecast 1995 spawning population would be 2,450 short tons (2,222 tonnes); well above the threshold. So, as provided for in regulation, a 12 ton quota will be available for harvest for the 1995 spawn-on-kelp pound fishery in Hoonah Sound (Table 1).

Lisianski Inlet

1994 Stock Status

The 1994 spawn deposition sampling at Lisianski Inlet yielded an estimate of 2,096 short tons (1,901 tonnes) of mature herring. This represents a substantial increase over the 522 short tons estimated in 1993, but is still well below the 5,750 short tons estimated for 1992 (Figure 20).

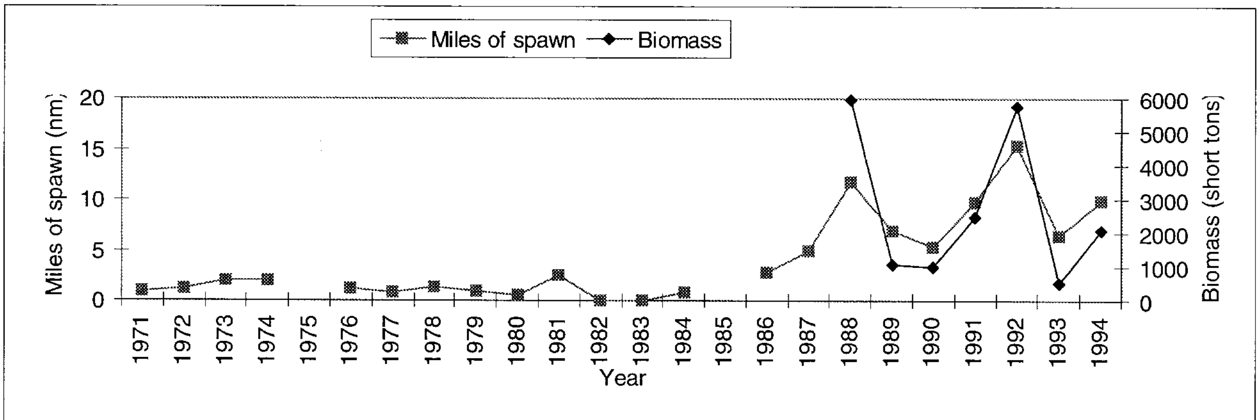

Figure 20. Spawn survey estimates of miles of spawn and biomass, Lisianski Inlet.

No sampling for age or sex composition or weights-at-age was conducted at Lisianski Inlet in 1994.

1995 Forecast and Quota

Assuming that population losses would be offset by population gains, the forecast mature spawning biomass for Lisianski Inlet in 1995 would be 2,096 short tons (1,901 tonnes). This is below the 2,500 short ton (2,268 tonnes) threshold for Lisianski, precluding a fishery at Lisianski in 1995 (Table 1).

Lynn Canal

1994 Stock Status

A total of 4.3 nm of spawn were observed from aerial surveys flown between Auke Bay and Berners Bay. This was a slight increase in spawning activity over the 3.2 nm documented in 1993, but similar to the 4.0 nm seen in 1992 (Figure 21).

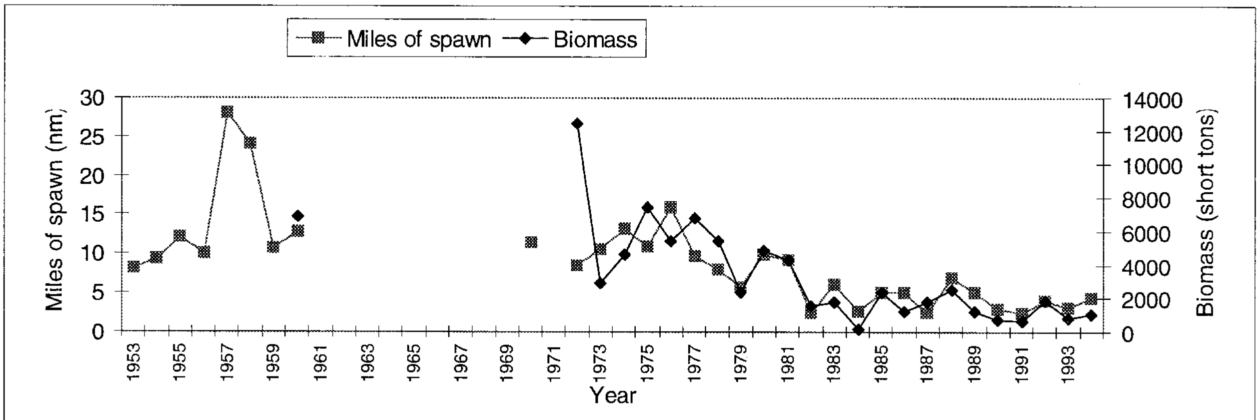

Figure 21. Spawn survey estimates of miles of spawn and biomass, Lynn Canal.

As in several other areas, Ages 6 (40%) and 5 (37%) comprised the majority of the spawning population (see Larson et al. 1994).

1995 Forecast and Quota

As it has since 1982, the amount of spawn noted in the Lynn Canal area indicated inadequate mature herring biomass to warrant a fishery in 1995 (Table 1).

Yakutat

1994 Stock Status

An aerial survey of spawn indicated 0.3 nm of spawn in the Yakutat area. This is a decline from the 1.1 nm of spawn observed in 1993. The age composition of Yakutat herring from cast net samples was composed primarily of Ages 3 (46%) and 2 (32%) herring.

1995 Forecast and Quota

The minor spawn observed in the Yakutat area indicates spawning biomass below the established threshold of 2,000 short tons (1,814 tonnes). Therefore no commercial herring fishery will be allowed at Yakutat in 1995.

DISCUSSION

At the major southeast Alaska herring spawning locations sampled by the Department, the 1995 mature spawning biomass of herring is forecast to be 47,883 tons (43,432 tonnes). This forecast is approximately 3% higher than the estimated 1994 spawning biomass of 46,318 tons (42,019 tonnes). This increase can be attributed primarily to the marked increases in forecast ASA estimated biomass for the Sitka herring population. Declines in forecast abundance at Cat Island, Craig and Seymour Canal can be attributed, to varying degrees, to the decline of the strong 1988 year class and the apparent absence of subsequent strong year classes. The apparent declines at Cat Island, Craig and Seymour Canal are of interest, but are not a cause for concern. Herring populations exhibit large, natural fluctuations in abundance (e.g., Wespestad and Gunderson 1991, Zebdi 1991) and recovery from major declines in abundance are well documented (e.g., Hourston 1980). Among areas sampled in 1994, the Sitka herring population alone accounted for approximately 40% of the mature, spawning biomass for all areas combined. Within the past 15 years, the Sitka herring population has experienced interannual declines of over 40% (e.g., 1988 versus 1989) and still rebounded to subsequent high abundance (e.g., 1992). In addition, the herring population fished at Seymour Canal had sufficiently rebounded from below-threshold abundance during 1990-1993 to allow fisheries in 1994 and again for the upcoming 1995 spawning season.

While the apparent recent declines at Cat Island, Craig and Seymour Canal are not cause for undue concern, continued close monitoring of southeast herring populations is obviously needed. An adequate stock assessment program must be maintained to assure that population levels can be properly monitored, and potential impacts of fisheries and other human activities evaluated. Particularly at Sitka, 1995 will be a pivotal year, providing an indication of whether the 4-year cycle of high recruitment that has prevailed for the past 15 years will continue. Sampling during a winter test fishery in January and February 1995 provided a preliminary indication of a increased recruitment as well as an increase in the mean weights-at-age. At several areas, notably Sitka, Seymour Canal and Craig, higher, mean weights-at-age in 1994 than in 1993 interrupted downward trends in annual weights-at-age that had prevailed, in some cases, since the mid-1980s. This may signify at least a stabilization in growth rates, if not an actual reversal of the downward trends in mean herring weights.

Continued stock assessment sampling, at least at the current levels, will gradually allow application of ASA methods to additional areas, beyond the four locations for which it was used in 1994. In particular, Lisianski Inlet, Tenakee Inlet and Hoonah Sound may have sufficiently long time series of spawn deposition data to explore the use of ASA methods as the primary analytical stock assessment tool for these areas. This method provides a much improved approach to biomass estimation and forecasting. The method uses the full suite of historical data commonly collected to evaluate population dynamics rather than solely the most recent years' spawn deposition data. Preferably, continuous spawn deposition and age composition data documenting at least one complete cohort (i.e., 6 years) should be available before trying to apply ASA techniques for southeast herring. Accordingly, in 1995 it may be useful to use ASA methods for areas such as Lisianski Inlet and Hoonah Sound.

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Appendix A. Observed abundance of herring catch (millions) for Sitka, Seymour Canal, Craig and. Cat Island/Kah Shakes.

Sitka

YEAR	Age 3	4	5	6	7	8+
1971	0.32	0.97	1.43	0.46	0.79	0.65
1972	0.23	1.14	0.68	0.76	0.27	0.65
1973	5.65	0.44	0.45	0.11	0.09	0.04
1974	0.17	4.01	0.56	0.39	0.17	0.22
1975	1.39	1.14	6.82	2.15	0.88	0.25
1976	0.12	1.01	0.95	3.02	0.65	0.12
1977	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.93	0.44	0.11	0.03	0.02	0.05
1979	16.44	8.21	1.05	0.36	0.09	0.18
1980	7.64	33.18	6.07	0.59	0.12	0.00
1981	0.00	2.11	18.99	4.75	0.53	0.00
1982	6.31	1.05	4.56	15.42	5.26	0.00
1983	14.93	2.30	0.77	3.06	15.70	1.53
1984	7.40	33.03	3.45	3.45	1.97	0.49
1985	0.57	9.05	35.65	5.66	2.83	2.83
1986	1.94	1.29	10.04	17.16	1.62	0.32
1987	21.87	7.11	1.69	3.90	5.67	0.62
1988	2.11	89.85	6.34	3.17	3.17	1.06
1989	4.04	32.34	88.94	4.04	2.70	0.00
1990	0.32	0.32	4.77	24.17	1.91	0.64
1991	17.11	0.70	0.23	0.70	4.69	0.23
1992	1.10	47.45	1.66	0.55	0.55	3.86
1993	1.26	4.04	87.18	1.77	0.76	2.78
1994	1.10	0.62	3.24	27.82	1.04	1.45

Seymour Canal

YEAR	Age 3	4	5	6	7	8+
1976	0.00	0.15	0.35	0.24	0.23	0.95
1977	0.00	0.18	0.29	1.39	0.44	1.39
1978	0.53	1.13	0.99	0.53	1.19	2.19
1979	0.08	0.31	0.40	0.17	0.10	1.07
1980	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.52	1.45	1.14	0.68	2.05
1982	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.20	0.60	0.52	0.88	1.77	0.04
1985	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.01	0.10	0.68	0.67	0.39	0.68
1987	0.01	0.06	0.30	1.01	0.46	0.43
1988	0.00	0.09	0.44	1.11	1.76	0.87
1989	0.01	0.05	0.50	1.15	1.30	1.58
1990	0.01	0.10	0.17	0.83	0.81	1.11
1991	0.00	0.00	0.00	0.00	0.00	0.00
1992	0.00	0.00	0.00	0.00	0.00	0.00
1993	0.00	0.00	0.00	0.00	0.00	0.00
1994	0.00	0.02	0.69	2.11	0.24	0.26

Craig

YEAR	Age 3	4	5	6	7	8+
1975	0	0.246	0.512	0.266	0.389	0.635
1976	0	0.012	0.108	0.156	0.323	0.587
1977	0	0.114	0.227	0.493	0.796	2.122
1978	0.009	0.043	0.052	0.058	0.034	0.019
1979	0	0	0	0	0	0
1980	1.187	0.099	0.02	0.059	0.257	0.336
1981	0	0	0	0	0	0
1982	***0.84***	***0.56***	***1.72***	***1.01***	***0.69***	***0.31***
1983	***0.08***	***0.4***	***0.15***	***0.28***	***0.14***	***0.09***
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0.029	0.058	0.641	0.248	0.248	0.233
1987	***3.3***	***5.99***	***1***	***1.35***	***0.31***	***0.48***
1988	2.425	9.525	1.559	1.732	1.212	0.866
1989	***0.98***	***6.62***	***6.32***	***0.67***	***0.78***	***0.43***
1990	0.452	2.65	7.545	10.04	1.948	1.772
1991	10.32	1.953	2.511	5.58	6.696	0.558
1992	3.029	10.6	1.082	1.514	3.245	1.947
1993	1.877	1.944	1.81	0.402	0.268	0.335
1994	0.272	1.602	2.29	1.217	0.288	0.849

Cat Island/Kah Shakes

YEAR	Age 3	4	5	6	7	8+
1977	0.00	0.03	0.41	2.28	1.72	0.74
1978	***0.01***	***0.08***	***0.07***	***0.30***	***0.59***	***0.06***
1979	***0.05***	***0.32***	***0.88***	***0.36***	***0.70***	***0.65***
1980	***1.14***	***0.64***	***1.94***	***2.31***	***0.39***	***0.36***
1981	0.00	6.32	2.98	3.10	1.16	0.91
1982	0.04	1.43	12.80	2.38	0.83	0.16
1983	0.00	2.03	6.95	13.91	0.48	0.27
1984	0.00	0.61	3.21	5.50	5.65	0.15
1985	***0.16***	***2.93***	***4.20***	***5.91***	***0.00***	***2.62***
1986	0.11	1.21	6.83	2.09	0.66	0.11
1987	0.51	2.27	4.42	4.55	0.76	0.00
1988	***0.14***	***2.23***	***1.42***	***1.44***	***2.76***	***0.35***
1989	***0.00***	***0.41***	***2.92***	***0.74***	***0.27***	***0.25***
1990	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.18	0.26	1.32	1.27	0.88	0.48
1992	0.11	2.09	2.53	3.33	2.04	0.91
1993	0.00	0.56	4.46	1.42	0.94	0.48
1994	0.00	0.21	1.54	2.67	0.53	0.17

NOTE: Abundances in bold italics were estimated. No commercial samples taken for those years.

Appendix B. Observed mean weights-at-age (g) of herring at Sitka, Seymour Canal, Craig and. Cat Island/Kah Shakes.

Sitka

	Age					
YEAR	3	4	5	6	7	8+
1971	85	113	131	137	155	170
1972	85	110	128	153	154	177
1973	67	85.6	108.6	137.2	172	186
1974	67	102	119	153	166	190
1975	76	85	114	121	129	153
1976	73	100	116	129	137	160
1977	83	106	134	146	156	158
1978	85	109	130	164	177	194
1979	70	84	97	116	131	161
1980	65	84	97	116	153	169
1981	56	90	121	131	136	174.5
1982	75	87	114	128	149	174.5
1983	88	113	121	146	163	180
1984	74	100	131	159	173	182
1985	51	96	118	130	153	179
1986	80	93	121	139	177	185
1987	67	88	108	134	152	177
1988	65	77	99	122	140	163
1989	54	67	87	114	129	160
1990	74	86	105	113	127	158
1991	58	72	101	111.5	122	137
1992	69	83	95	106.8	118.5	144
1993	64	81	94	101	115	137
1994	69.25	87.78	115.5	128	137.6	151.3

Seymour Canal

	Age					
YEAR	3	4	5	6	7	8+
1976	61.3	72.8	90.4	106.2	124.8	136.5
1977	61.3	72.8	90.4	106.2	124.8	136.5
1978	61.3	72.8	90.4	106.2	124.8	136.5
1979	61.3	72.8	90.4	106.2	124.8	136.5
1980	61.3	72.8	90.4	106.2	124.8	136.5
1981	57	79	100	101	146	136.5
1982	54	62	79	103	139	136.5
1983	68	77	86	95	106	136.5
1984	64	90	102	120	133	152
1985	68	76	99	115	127	123
1986	67.5	78	95	124	129	149
1987	67	75	94	116	138	150
1988	61.3	94	101	118	126	144
1989	39	62	77	91	112	128
1990	58	69	91	101	106	120
1991	49	60	81	96	112	126
1992	44	55	74	84	99	105
1993	49.92	74.38	90.93	103.8	110.1	143.3
1994	60.6	77	87.5	100.9	113.1	141.1

Craig

	Age					
YEAR	3	4	5	6	7	8+
1974	63.58	86.36	105.6	123.9	141.4	150.8
1975	63.58	86.36	105.6	123.9	141.4	150.8
1976	63.58	86.36	105.6	123.9	141.4	150.8
1977	63.58	86.36	105.6	123.9	141.4	150.8
1978	63.58	86.36	105.6	123.9	141.4	150.8
1979	63.58	86.36	105.6	123.9	141.4	150.8
1980	63.58	86.36	105.6	123.9	141.4	150.8
1981	63.58	105	134	142	188	150.8
1982	63.58	86.36	105.6	123.9	141.4	150.8
1983	63.58	86.36	105.6	123.9	141.4	150.8
1984	63.58	86.36	105.6	123.9	141.4	150.8
1985	63.58	86.36	105.6	123.9	141.4	150.8
1986	63.58	86.36	105.6	123.9	141.4	150.8
1987	63.58	86.36	105.6	123.9	141.4	150.8
1988	66	91	102	127	147	168
1989	61	86	103	123	137	152
1990	68	92	110	121	140	165
1991	66	75	102	117	129	145
1992	62.5	84.5	97	122.5	128	140.5
1993	58	71	91	115	121	134
1994	50.32	74.13	98.88	115.1	137	154.2

Cat Island/Kah Shakes

	Age					
YEAR	3	4	5	6	7	8+
1976	101	136	152	169	192	227
1977	79	104	124	140	148	157
1978	75	98	120	138	144	164
1979	95	120	138	170	171	198
1980	80	95	137	166	179	195
1981	65	83	111	144	137	160
1982	78	91	112	144	159	163
1983	77	101	118	128	174	184
1984	75	93	115	125	148	187
1985	67	92	114	135	158	179
1986	89	113	122	141	148	171
1987	59	76	104	115	135	164
1988	78	96	111	136	149	153
1989	71	88	109	129	151	176
1990	85	99	116	127	145	162
1991	59	69	92	112	110	129
1992	58	74	85	113	143	129
1993	70	84	95	108	144	140
1994	57	78	92	101	110	121

Appendix C. Observed age compositions (%) of mature herring at Sitka, Seymour Canal, Craig and. Cat Island/Kah Shakes.

Sitka

YEAR	Age 3	4	5	6	7	8+
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978	36%	27%	6%	12%	8%	11%
1979	62%	30%	4%	2%	1%	1%
1980	17%	71%	11%	1%	0%	0%
1981	2%	25%	62%	11%	1%	0%
1982	12%	2%	21%	60%	5%	1%
1983	67%	10%	2%	4%	15%	1%
1984	12%	69%	7%	5%	5%	2%
1985	6%	43%	48%	3%	1%	1%
1986	31%	6%	22%	34%	4%	4%
1987	53%	17%	4%	10%	14%	1%
1988	2%	85%	6%	3%	3%	1%
1989	1%	19%	75%	2%	1%	1%
1990	2%	1%	15%	70%	9%	3%
1991	74%	5%	1%	4%	15%	1%
1992	2%	89%	4%	0%	2%	4%
1993	2%	2%	87%	3%	0%	6%
1994	11%	6%	9%	65%	4%	4%

Seymour Canal

YEAR	Age 3	4	5	6	7	8+
1976	0%	8%	18%	13%	12%	50%
1977	0%	5%	8%	38%	12%	38%
1978	8%	17%	15%	8%	18%	33%
1979	4%	15%	19%	8%	5%	50%
1980	53%	25%	11%	3%	8%	0%
1981	6%	72%	18%	2%	2%	0%
1982	1%	16%	73%	9%	1%	0%
1983	20%	2%	11%	59%	8%	0%
1984	18%	11%	10%	28%	30%	3%
1985	5%	35%	19%	15%	16%	11%
1986	6%	11%	47%	17%	11%	8%
1987	6%	13%	28%	30%	15%	8%
1988	2%	9%	16%	27%	23%	23%
1989	28%	30%	20%	14%	5%	3%
1990	8%	23%	8%	19%	13%	30%
1991	52%	9%	11%	5%	6%	17%
1992	18%	55%	10%	7%	3%	7%
1993	3%	25%	56%	6%	5%	6%
1994	1%	5%	31%	45%	10%	9%

Craig

YEAR	Age 3	4	5	6	7	8+
1974						
1975						
1976						
1977						
1978						
1979						
1980	21.8%	65.4%	12.8%	0.0%	0.0%	0.0%
1981	0.0%	86.0%	10.0%	2.0%	1.0%	0.0%
1982						
1983	56.7%	8.6%	11.8%	15.1%	6.5%	1.2%
1984	10.0%	10.0%	32.0%	30.0%	17.0%	2.0%
1985						
1986						
1987						
1988	16.0%	67.0%	6.0%	5.0%	3.0%	2.0%
1989	3.0%	28.0%	57.0%	7.0%	2.0%	2.0%
1990	2.0%	12.0%	34.0%	40.0%	9.0%	3.0%
1991	44.0%	6.0%	7.0%	21.0%	17.0%	5.0%
1992	10.0%	41.7%	8.5%	12.3%	12.8%	14.8%
1993	17.0%	21.0%	34.0%	5.0%	9.0%	14.0%
1994	4.2%	24.6%	35.1%	18.7%	4.4%	13.0%

Cat Island/Kah Shakes

YEAR	Age 3	4	5	6	7	8+
1976	1%	17%	61%	11%	7%	3%
1977	12%	5%	17%	42%	15%	8%
1978	8%	26%	8%	24%	27%	7%
1979	12%	13%	30%	9%	22%	14%
1980	72%	11%	4%	2%	3%	8%
1981	3%	87%	4%	4%	1%	1%
1982	21%	11%	64%	4%	0%	0%
1983	18%	25%	12%	41%	2%	1%
1984	26%	24%	22%	18%	9%	0%
1985	8%	48%	25%	14%	5%	0%
1986	5%	20%	56%	14%	4%	1%
1987	54%	17%	10%	15%	4%	0%
1988	17%	50%	14%	8%	7%	4%
1989	11%	34%	39%	12%	3%	1%
1990	2%	21%	26%	31%	11%	9%
1991	74%	14%	6%	2%	2%	2%
1992	22%	59%	9%	4%	3%	2%
1993	27%	33%	36%	3%	1%	1%
1994	19%	24%	30%	22%	2%	2%

Appendix D. Observed total herring egg depositions (trillions) for Sitka, Seymour Canal, Craig, and Cat Island/Kah Shakes.

	AREA			
YEAR	**Sitka**	**Seymour Canal**	**Craig**	**Cat Island/Kah Shakes**
1971	***0.425***			
1972	***0.675***			
1973	***0.500***			
1974	***0.500***			
1975	***0.400***			
1976	***0.308***	0.200	***0.740***	0.4505
1977	***0.523***	0.412	***0.169***	0.2855
1978	0.341	0.053	***0.345***	0.5600
1979	2.050	0.250	***0.099***	1.0325
1980	3.150	0.570	***0.470***	1.3400
1981	3.000	0.155		1.6255
1982	2.972	0.134	***0.735***	1.3570
1983	2.630	0.402	***0.710***	1.1435
1984	3.250	0.195	***0.200***	1.3350
1985	3.025	0.300	***0.200***	0.9235
1986	2.580	0.395	***0.305***	0.9850
1987	4.201	0.478	***0.763***	0.8390
1988	5.871	0.325	1.635	0.6160
1989	2.700	0.312	1.980	0.3080
1990	2.273	0.285	1.835	0.6400
1991	2.346	0.205	1.780	1.0450
1992	4.843	0.200	1.235	0.8103
1993	3.530	0.301	0.696	0.6931
1994	1.471	0.329	0.432	0.4413

NOTE:Numbers in bold italics represent estimates back calculated from hydroacoustic estimates of abundance.

Appendix E. Forecast weights-at-age for 1995.

AREA	Age					
	3	4	5	6	7	8+
Sitka[1]	78.2	92.8	113.0	129.2	149.8	149.4
Seymour Canal	55.3	75.7	89.2	102.3	111.6	142.2
Cat Island/Kah Shakes	73.3	92.2	112.4	133.2	147.4	162.9
Craig	54.2	72.6	94.9	115.1	129.0	144.1

[1]Forecast weights at age determined from January/February 1995 winter test fishery.

Appendix F. Parameter estimates for two-parameter logistic functions[1] defining partial recruitment and gear selectivity for Sitka, Seymour Canal, Craig and Cat Island/Kah Shakes.

		Parameter Estimate	
Area	Function	α	β
Sitka	Partial recruitment	3.4581	2.4730
	Gear Selectivity	3.8122	1.6973
Seymour Canal	Partial recruitment (seine)	4.1380	1.5820
	Partial recruitment (cast net)	4.1400	1.5820
	Gear Selectivity (gill net)	5.1622	2.5332
	Gear Selectivity (seine)	4.7650	0.9578
Craig	Partial recruitment	3.5864	1.7059
	Gear Selectivity	4.2844	1.1390
Cat Island/Kah Shakes	Partial recruitment	3.6405	1.8870
	Gear Selectivity	4.9842	2.7652

1 $$\frac{1}{1+e^{[-\beta(a-\alpha)]}}$$

Appendix G. ASA estimates of initial cohort abundance (millions) for Sitka, Seymour Canal, Craig and Cat Island/Kah Shakes.

Sitka

YEAR	Age 3	4	5	6	7	8+
1971	21.5	10.9	11.5	3.7	8.5	4.5
1972	16.6					
1973	109.7					
1974	16.1					
1975	19.0					
1976	8.4					
1977	32.1					
1978	126.7					
1979	622.9					
1980	144.3					
1981	23.2					
1982	90.6					
1983	603.9					
1984	222.0					
1985	48.6					
1986	162.2					
1987	1057.0					
1988	128.6					
1989	11.9					
1990	33.4					
1991	995.0					
1992	47.1					
1993	23.2					
1994	62.9					

Seymour Canal

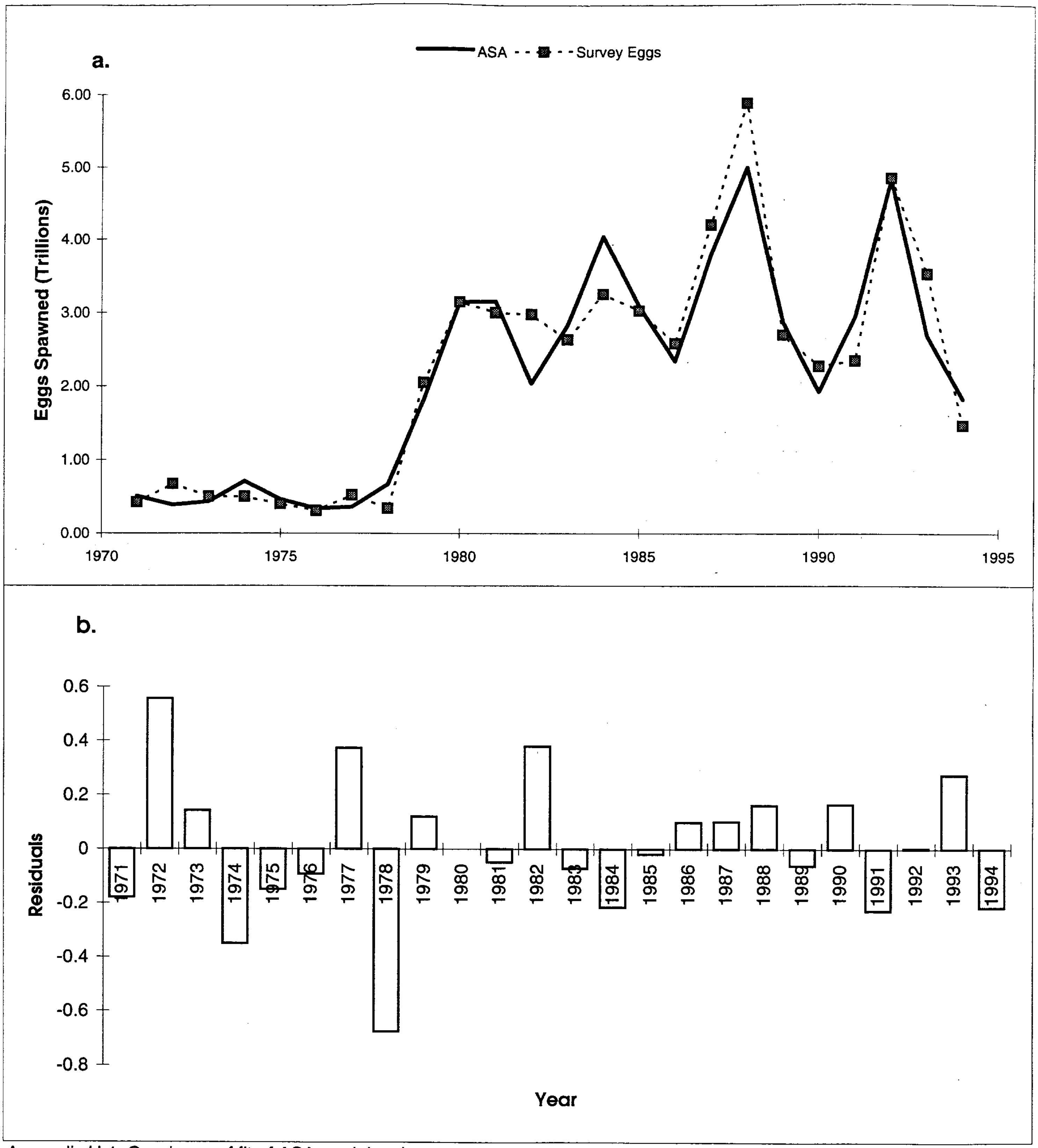
YEAR	Age 3	4	5	6	7	8+
1976	5.1	2.697	12.09	7.174	9.544	22.12
1977	3.8					
1978	3.8					
1979	4.9					
1980	24.4					
1981	9.0					
1982	6.8					
1983	17.4					
1984	26.9					
1985	17.6					
1986	12.6					
1987	9.4					
1988	5.2					
1989	7.6					
1990	5.4					
1991	39.9					
1992	22.4					
1993	4.9					
1994	2.7					

Craig

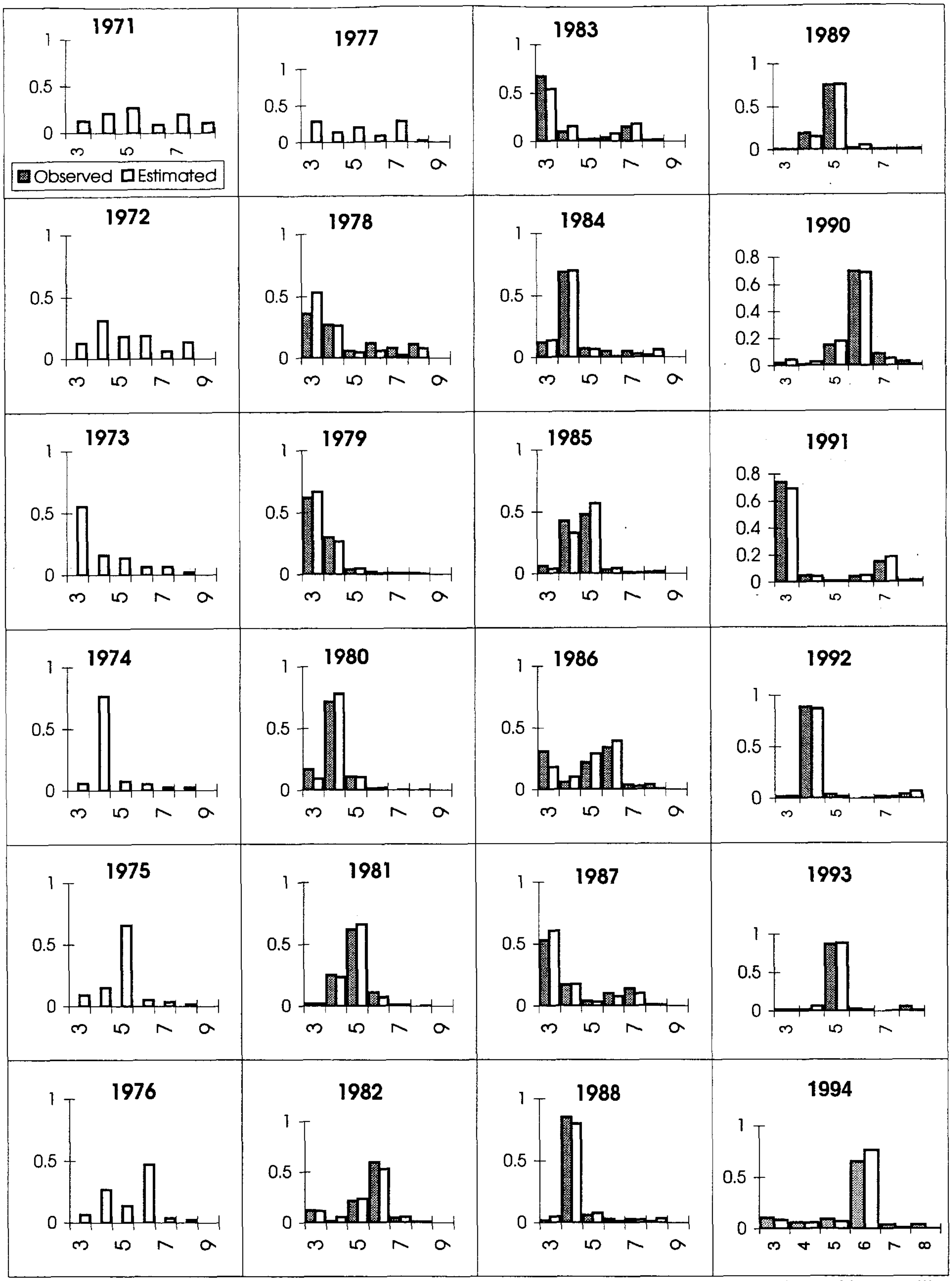
YEAR	Age 3	4	5	6	7	8+
1974	14.7	16.7	36.2	49.9	55.8	2.0
1975	11.3					
1976	8.6					
1977	0.0					
1978	2.4					
1979	7.1					
1980	73.0					
1981	16.5					
1982	20.2					
1983	11.5					
1984	27.6					
1985	10.5					
1986	18.2					
1987	219.4					
1988	109.1					
1989	38.8					
1990	20.1					
1991	92.7					
1992	55.0					
1993	49.2					
1994	12.0					

Cat Island/Kah Shakes

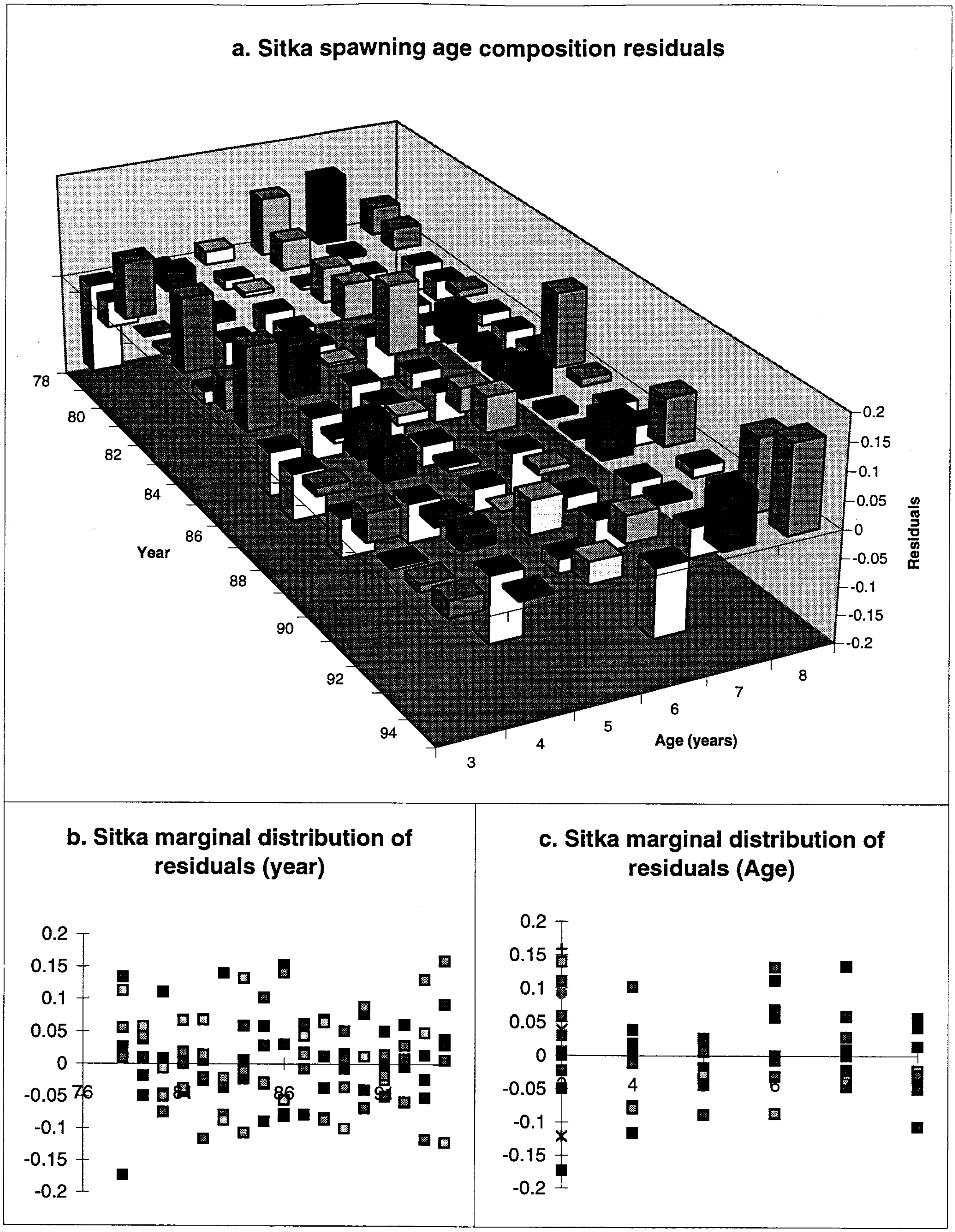
YEAR	Age 3	4	5	6	7	8+
1976	9.2	9.6	21.1	13.1	17.0	6.9
1977	23.1					
1978	23.8					
1979	24.3					
1980	171.5					
1981	50.7					
1982	37.9					
1983	36.1					
1984	68.1					
1985	31.6					
1986	26.1					
1987	42.5					
1988	25.3					
1989	24.2					
1990	19.9					
1991	66.9					
1992	31.2					
1993	20.3					
1994	15.0					



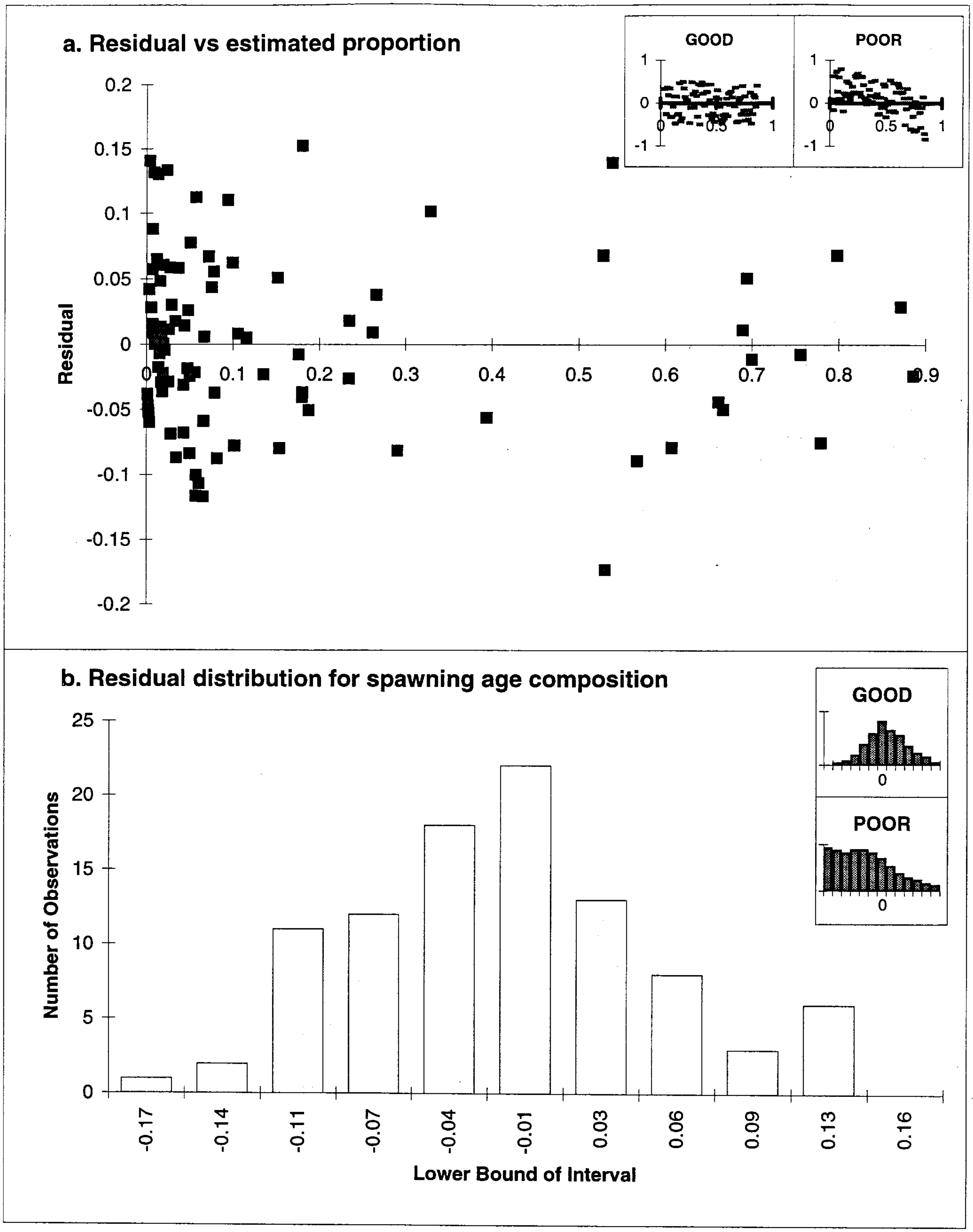
Appendix H.1 Goodness of fit of ASA model estimates to spawn survey estimates of total eggs and mature biomass. a. ASA vs. survey estimates of total egg deposition. b. Residuals for total egg production (i.e. ASA estimate - survey estimate).



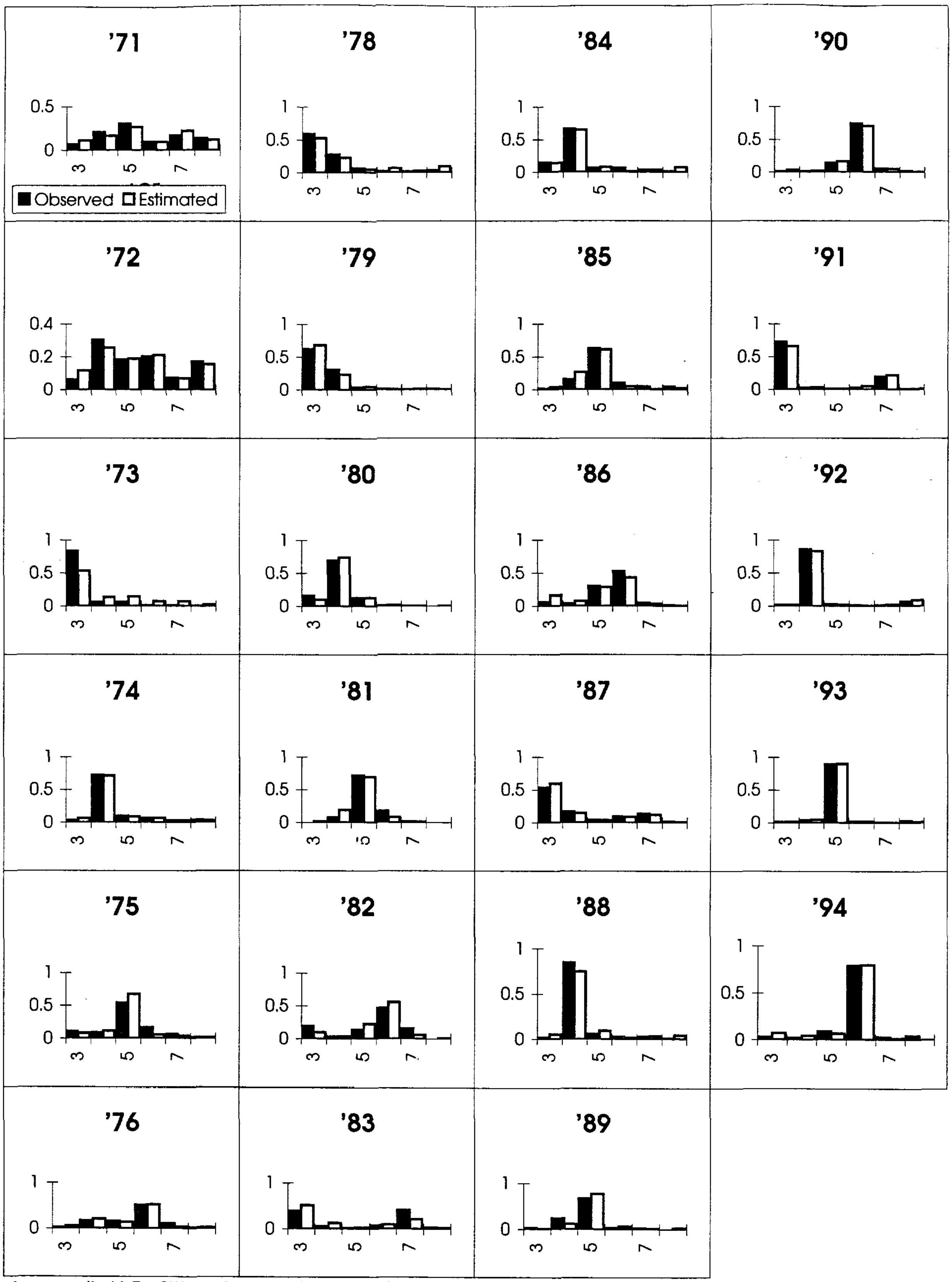
Appendix H.2. Sitka observed and ASA-estimated spawning run age compositions. Years without observed data were not used to tune the model, due to the absence of samples representative of the spawning population.



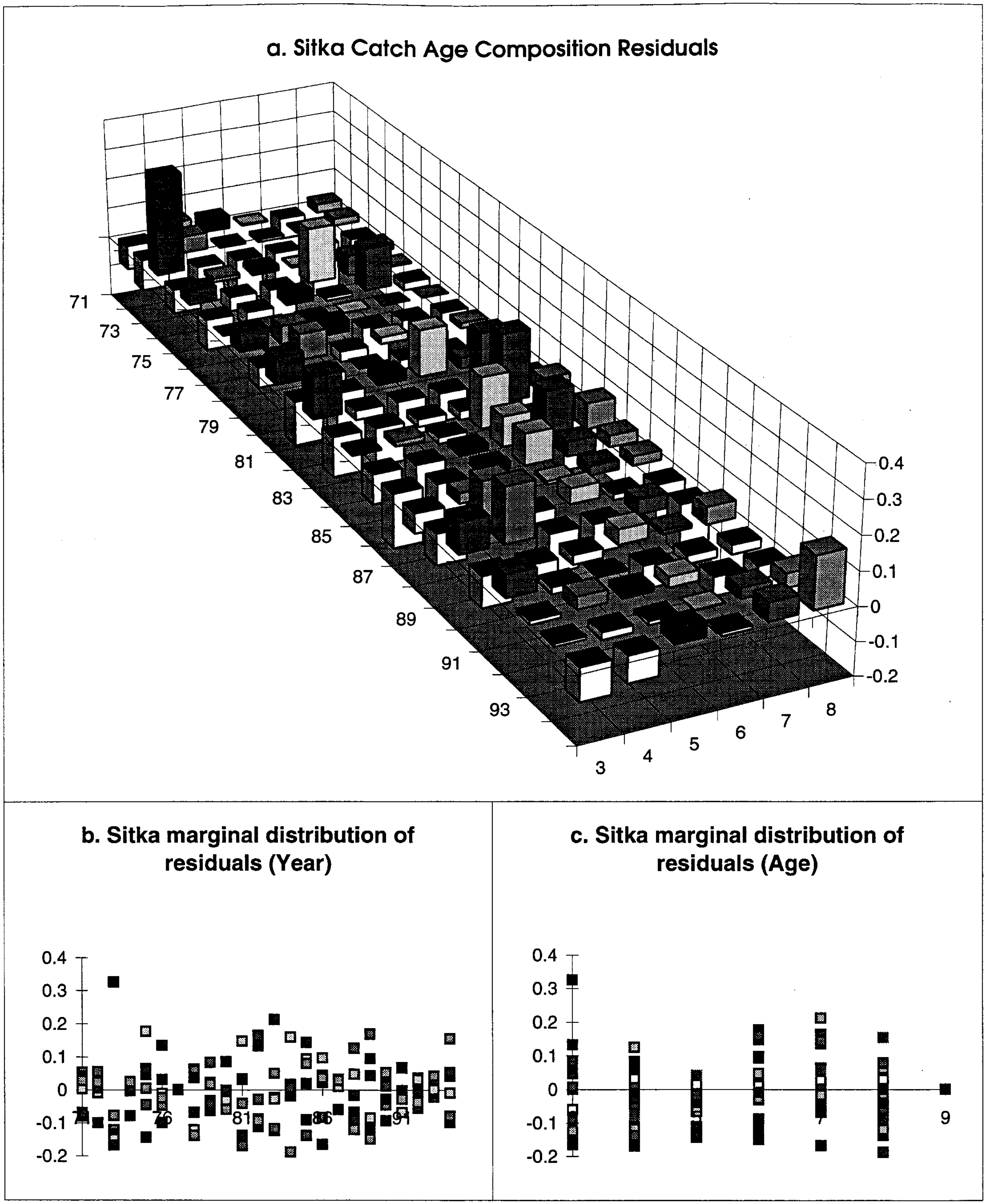
Appendix H.3. Spawning age composition residuals for Sitka. These residuals are the deviations of the arcsine transformed ASA-estimated spawning run age compositions from the arcsine transformed observed age compositions.



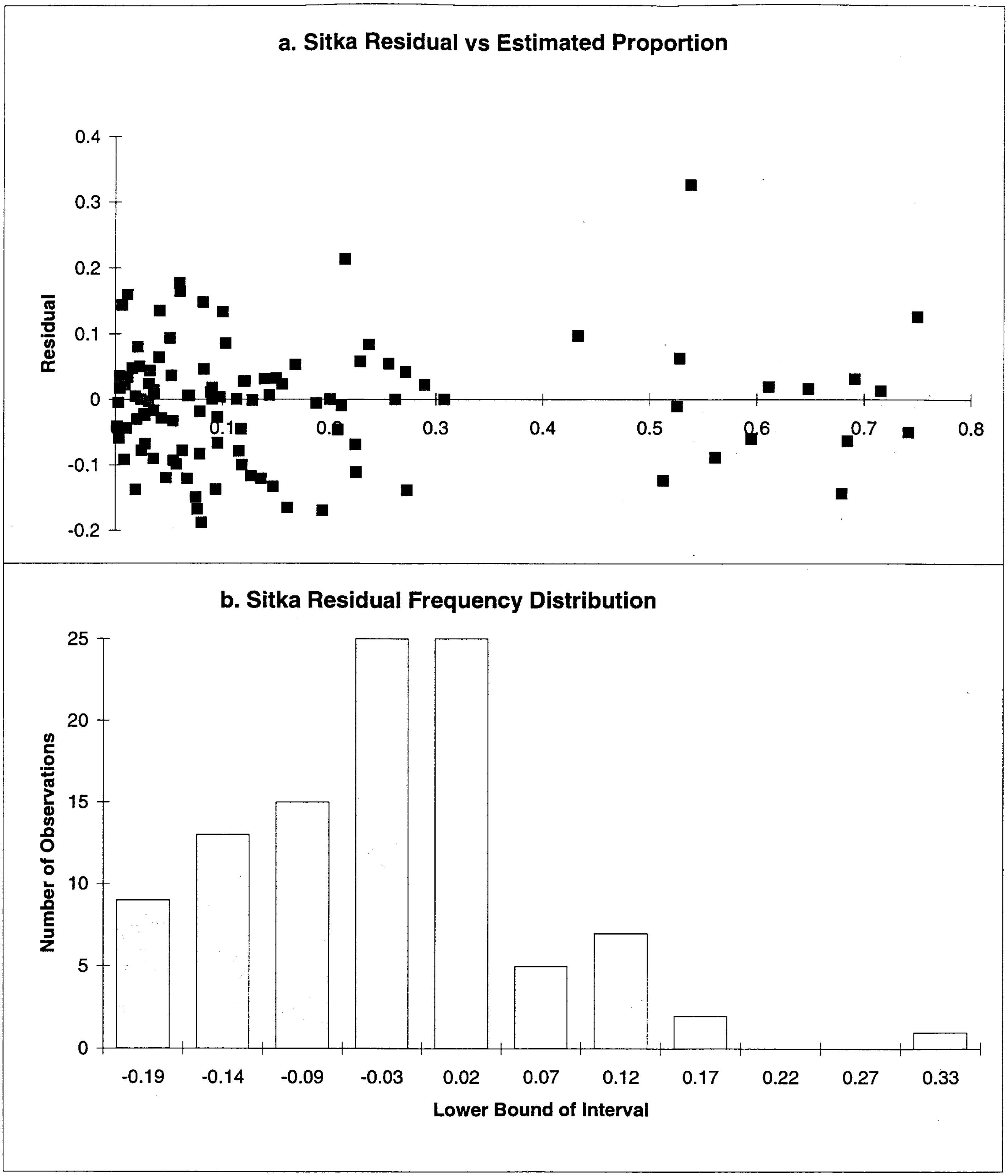
Appendix H.4. Sitka spawning age composition residual diagnostics. Panel a. Distribution of residuals plotted against magnitude of proportions in age classes. Reference plots in upper right corner show examples of good and poor residual patterns to aid interpretation of plots. Panel b. Frequency distribution of residuals. Again, reference plots in upper right of the panel indicate good and poor residual distributions to help evaluate model performance.



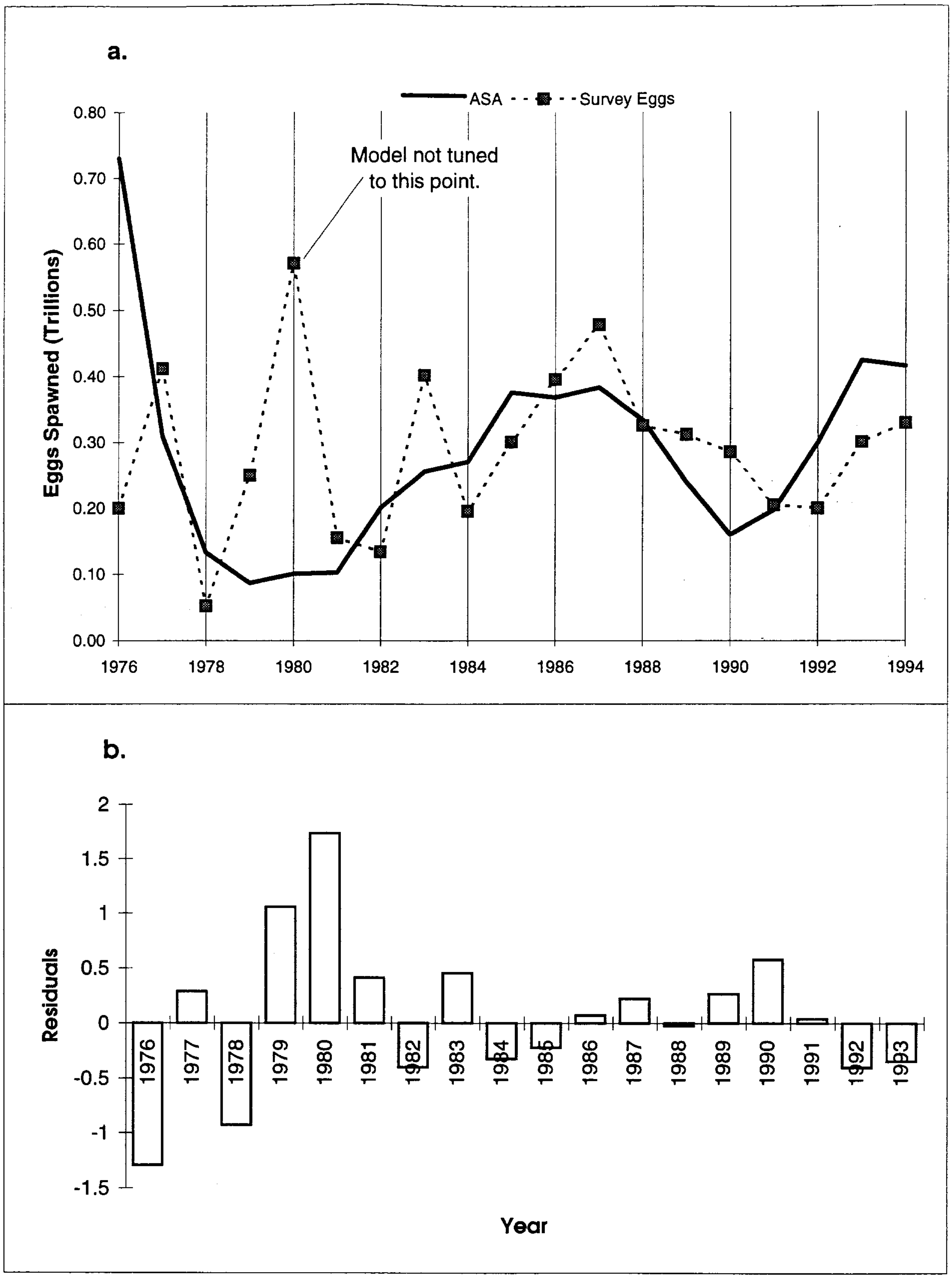
Appendix H.5. Sitka observed and ASA-estimated catch age compositions. Used to assess goodness of fit of ASA model-estimated catch-at-age proportions to observed catch-at-age proportions.



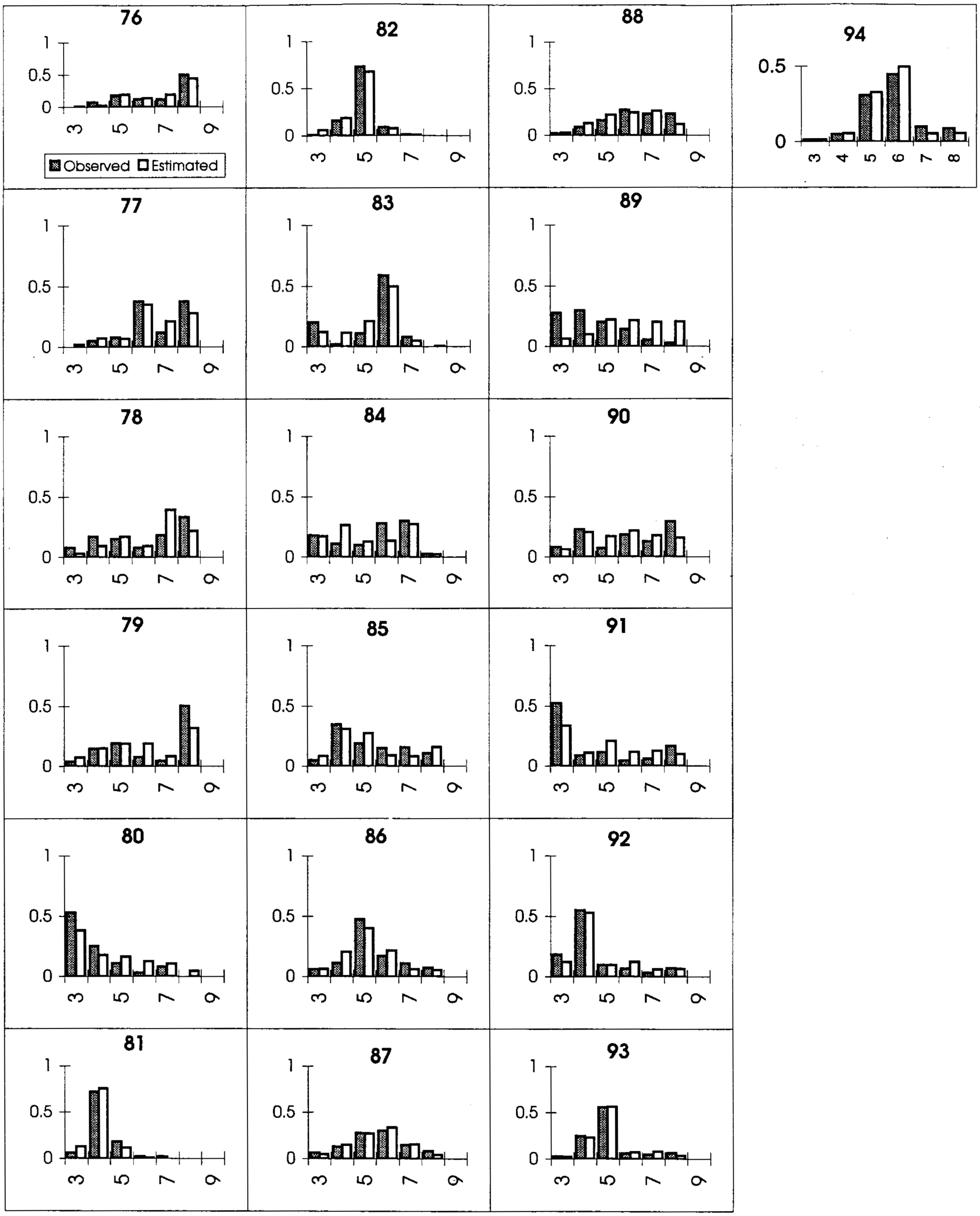
Appendix H.6. Catch age composition residuals for Sitka. These residuals are the deviations fo the arcsine transformed ASA-estimated catch age compositions from the arcsine transformed observed catch age compositions.



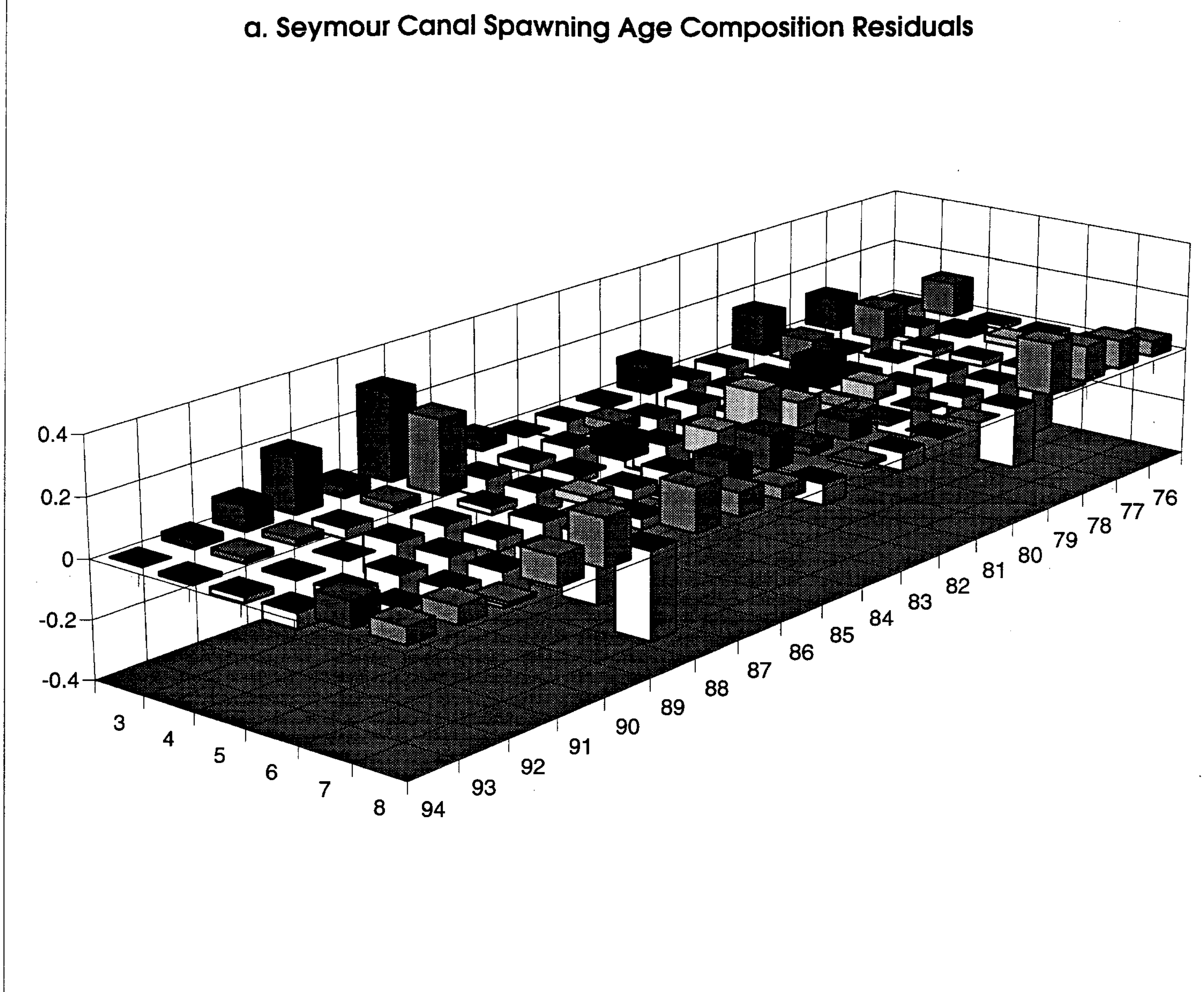
Appendix H.7. Sitka catch age composition diagnostics to assess normality of residuals. Panel a. Distributior of residuals versus magnitude of proportions in age classes. Panel b. Frequency distribution of residuals

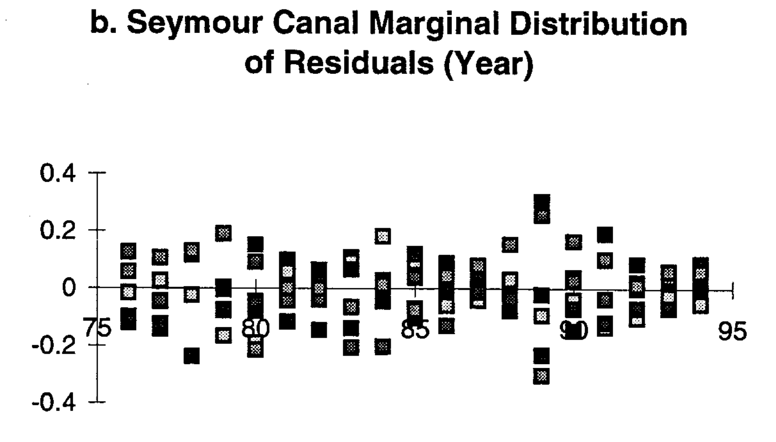


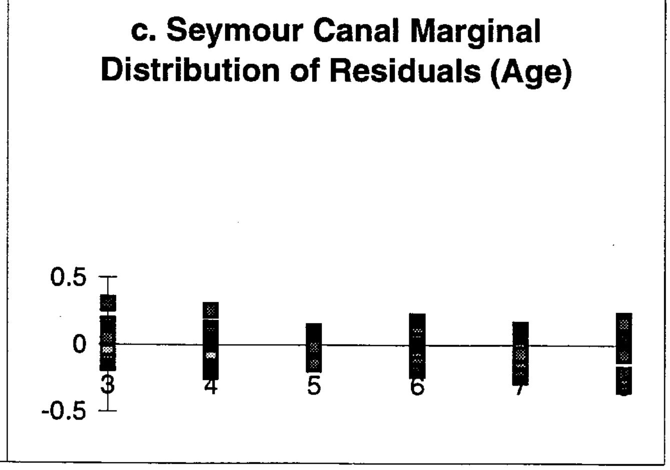
Appendix H.8. Goodness of fit of ASA model estimates to spawn survey estimates of total eggs. a. ASA vs. survey estimates of total egg deposition. b. Residuals for total egg deposition (i.e. ASA estimate - survey estimate).



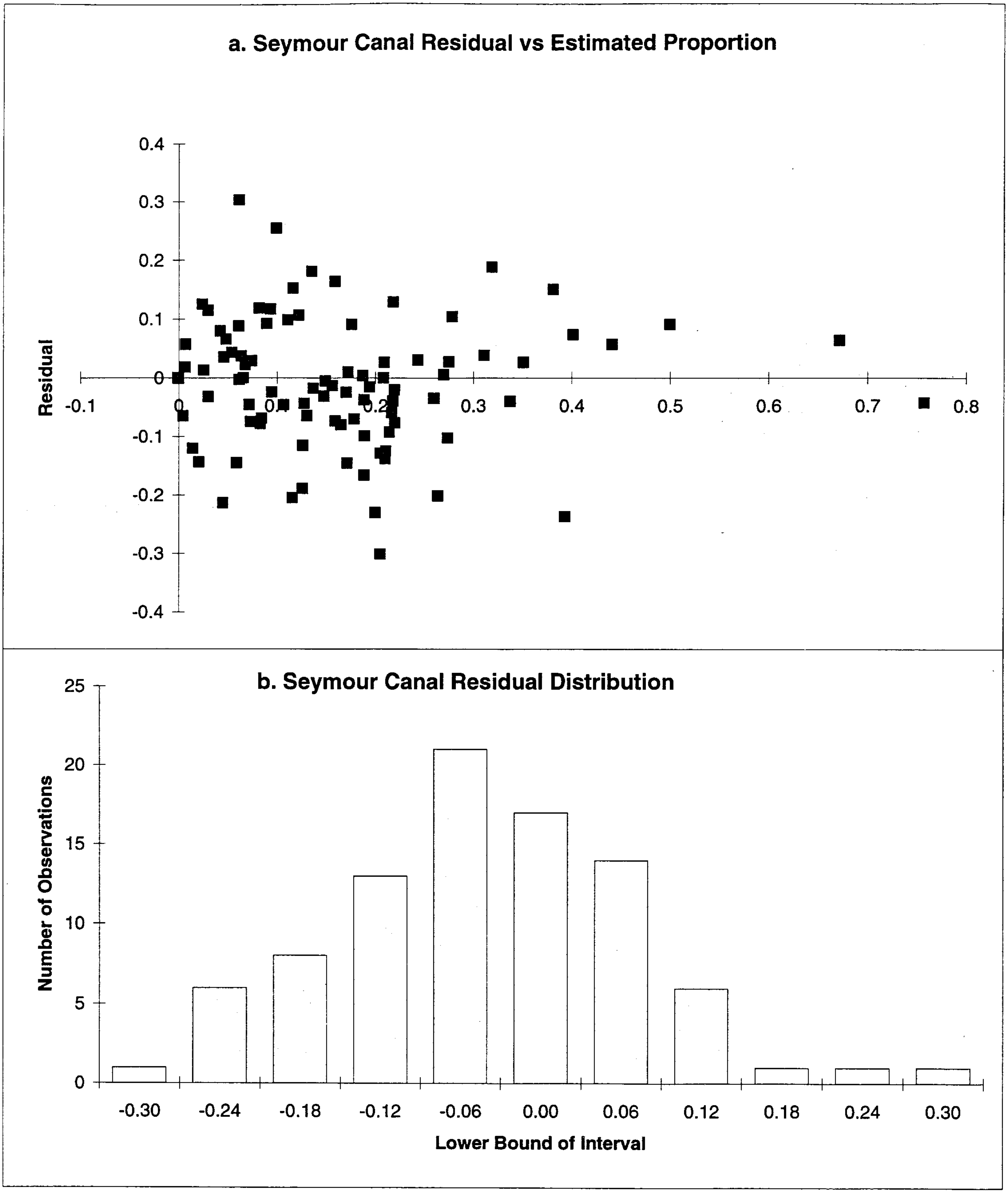
Appendix H.9. Seymour Canal observed and ASA-estimated spawning age compositions.



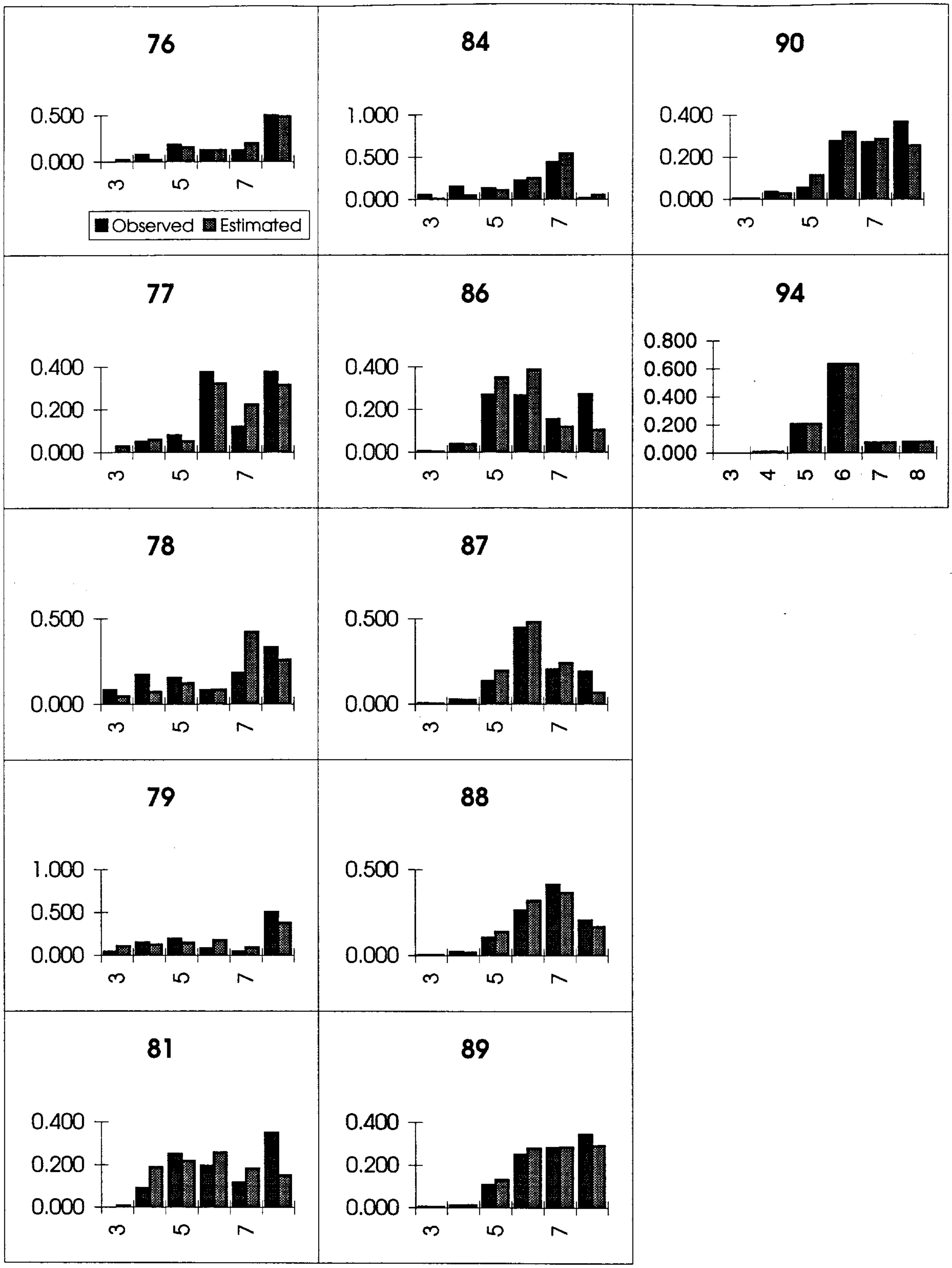




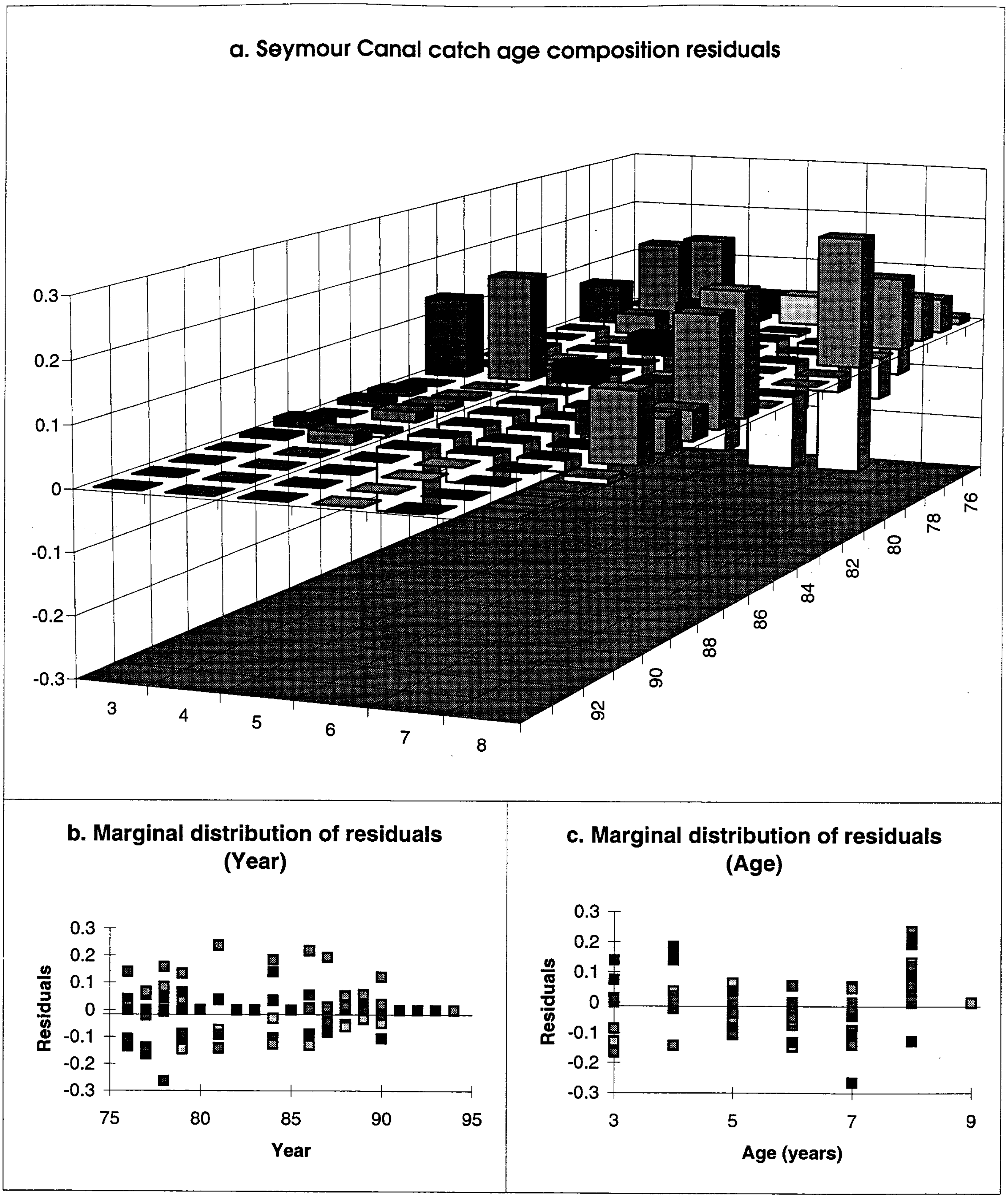
Appendix H.10. Spawning age composition residuals for Seymour Canal. These residuals are the deviations of the arcsine transformed ASA-estimated spawning run age compositions from the arcsine transformed observed age compositions.



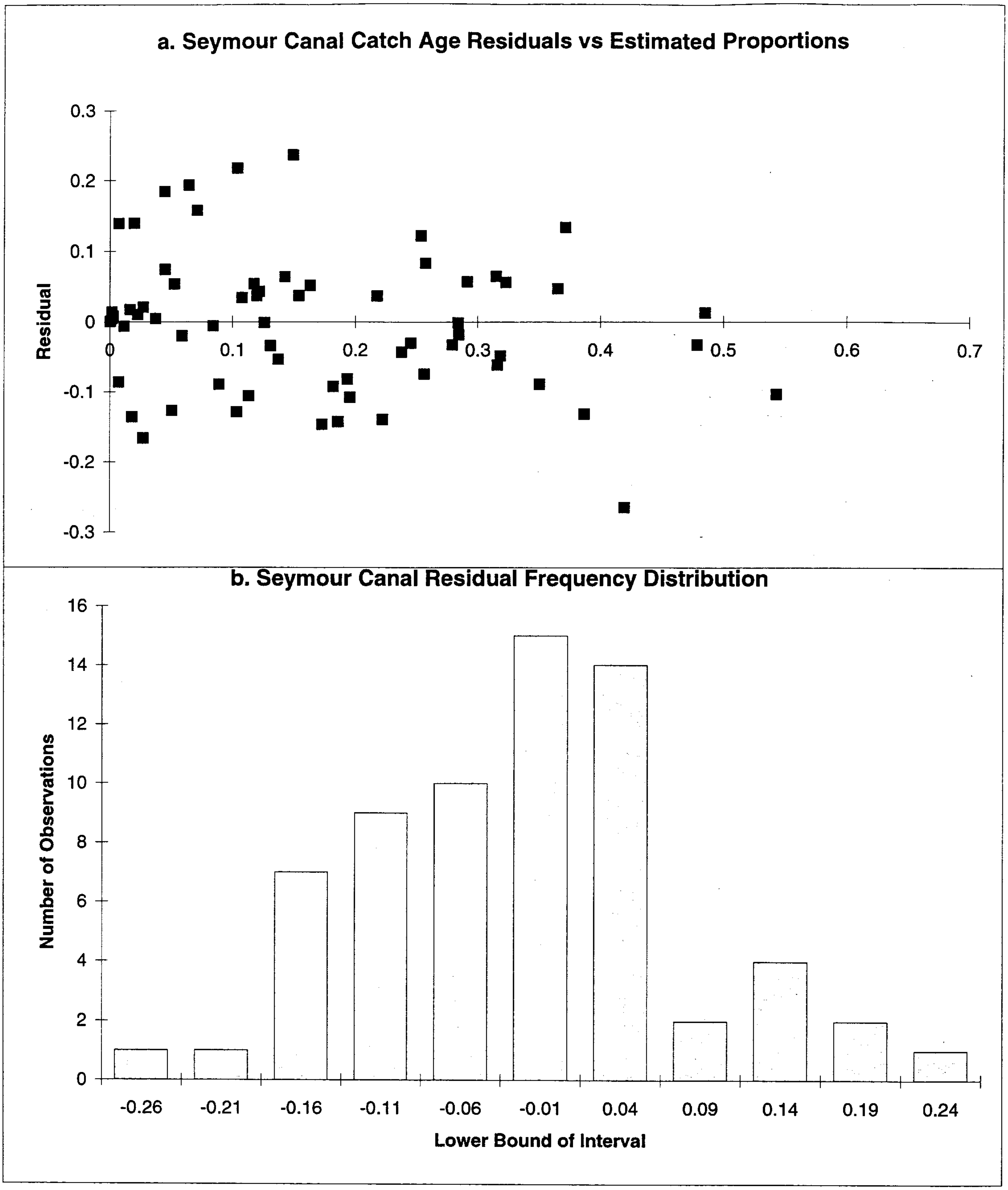
Appendix H.11. Seymour Canal spawning age composition residual diagnostics. Panel a. Distributior of residuals versus magnitude of proportions in age class. Panel b. Frequency distribution of residuals



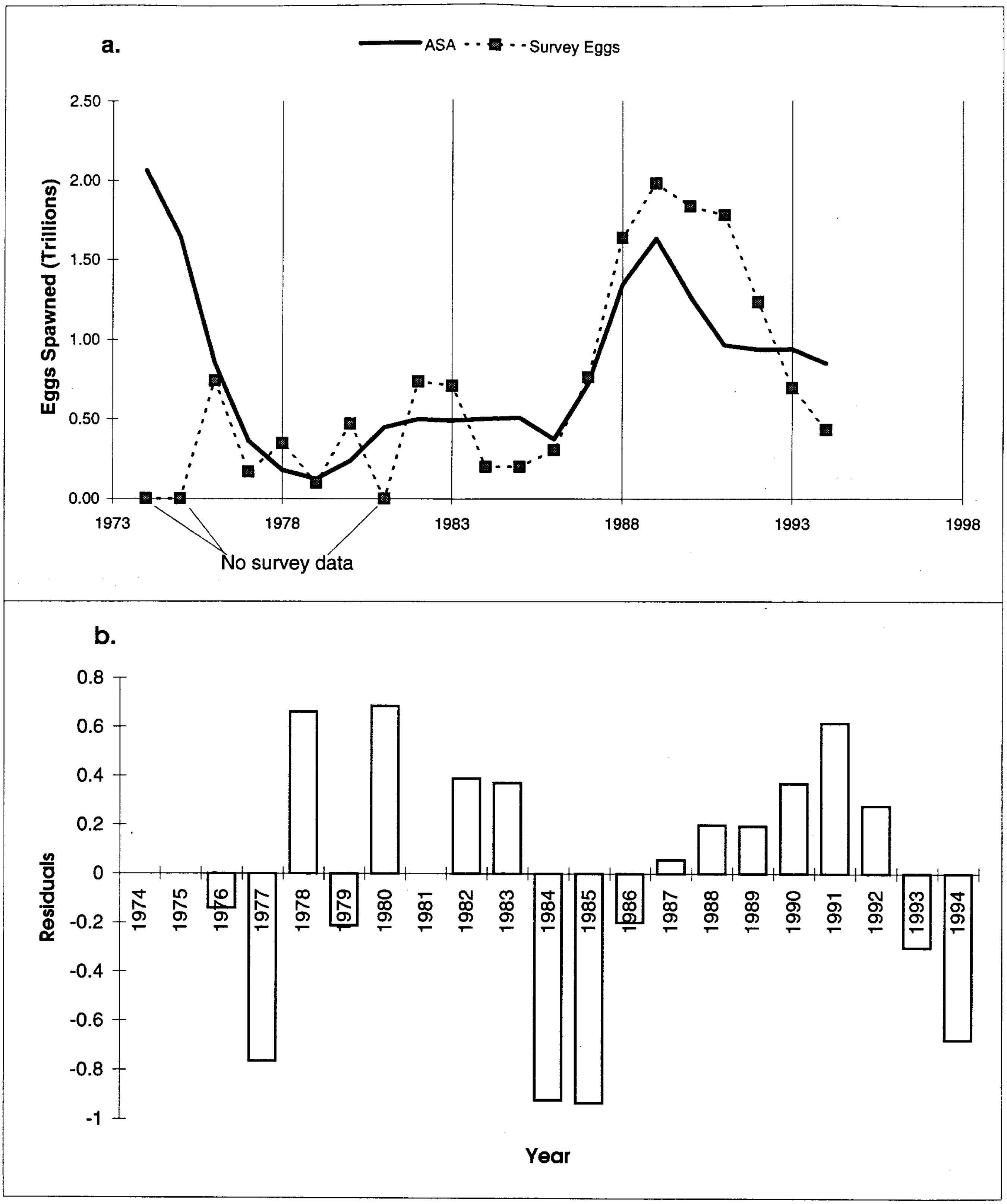
Appendix H.12. Seymour Canal observed and ASA-estimated catch-at-age compositions. Years within the above sequence not shown are years without commercial catch. Observed and model-estimated age composition for 1994 coincide exactly because model -estimated values used for both due to lack of sampling of catch in 1994.



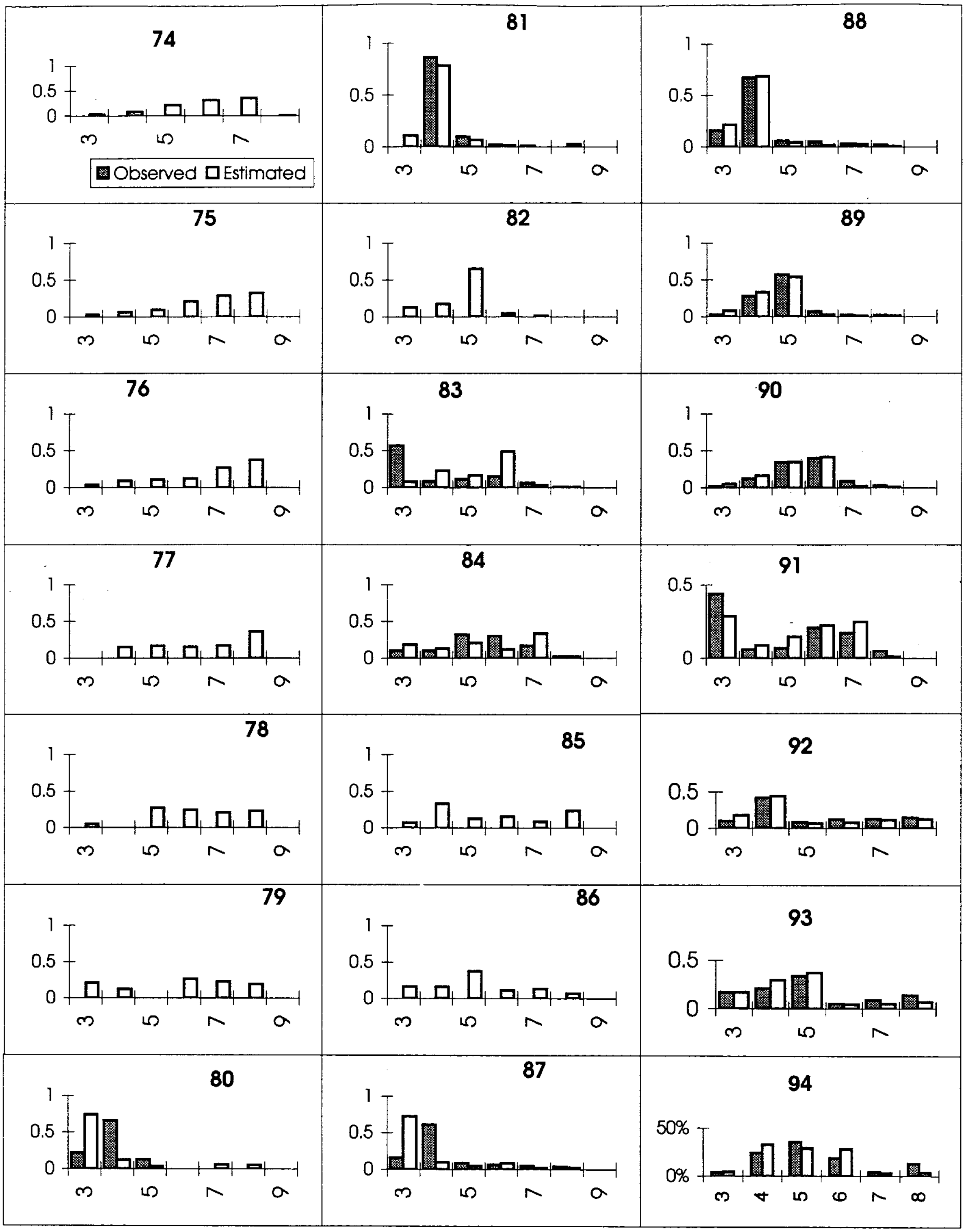
Appendix H.13. Catch age composition residuals for Seymour Canal. These residuals are the deviations o the arcsine transformed ASA-estimated catch age compositions from the arcsine transformed observed catch age compositions.



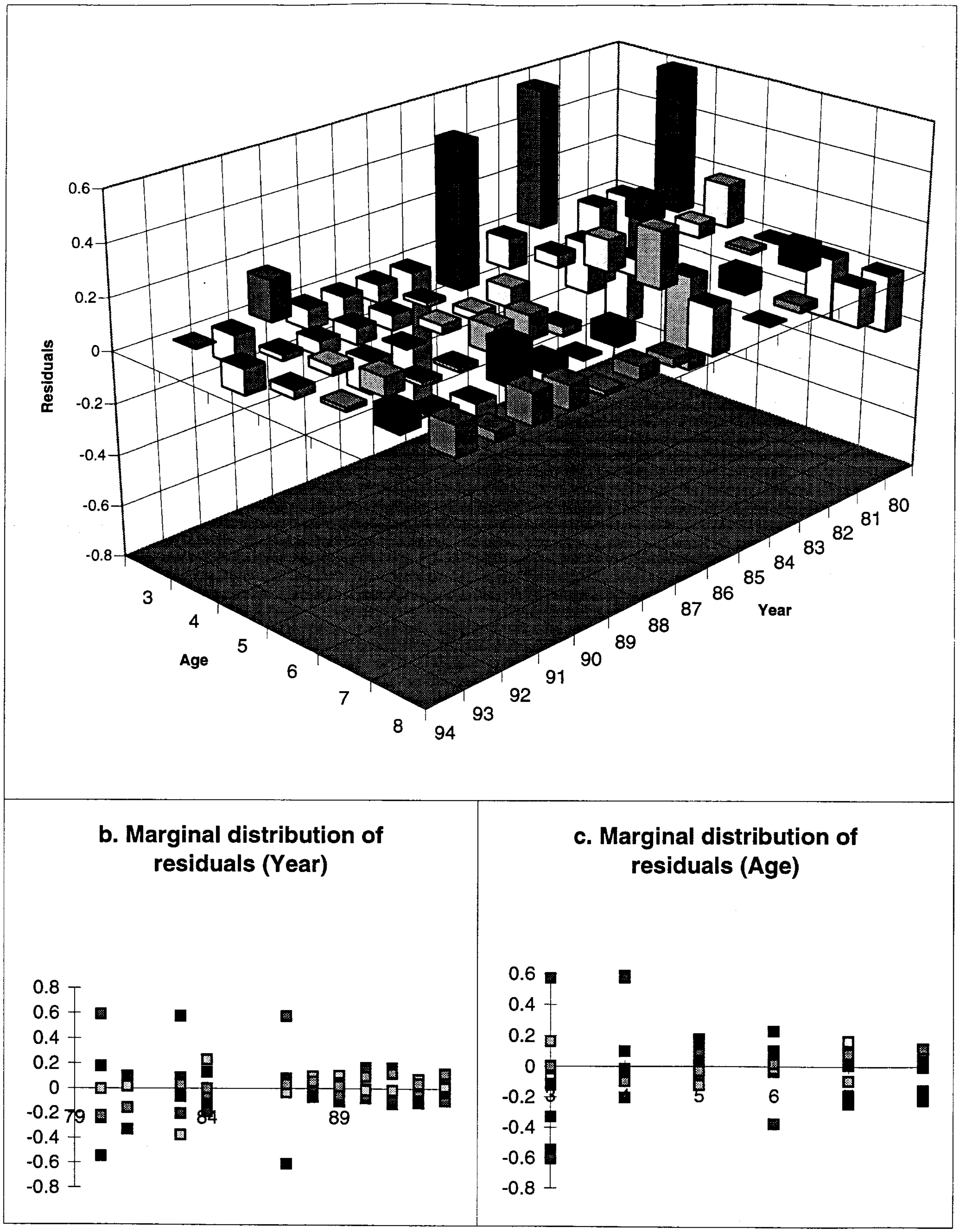
Appendix H.14. Seymour Canal catch age composition residual diagnostics. Panel. a. Distributions of residuals vs magnitude of proportions in age classes. Panel b. Frequency distribution of residuals.



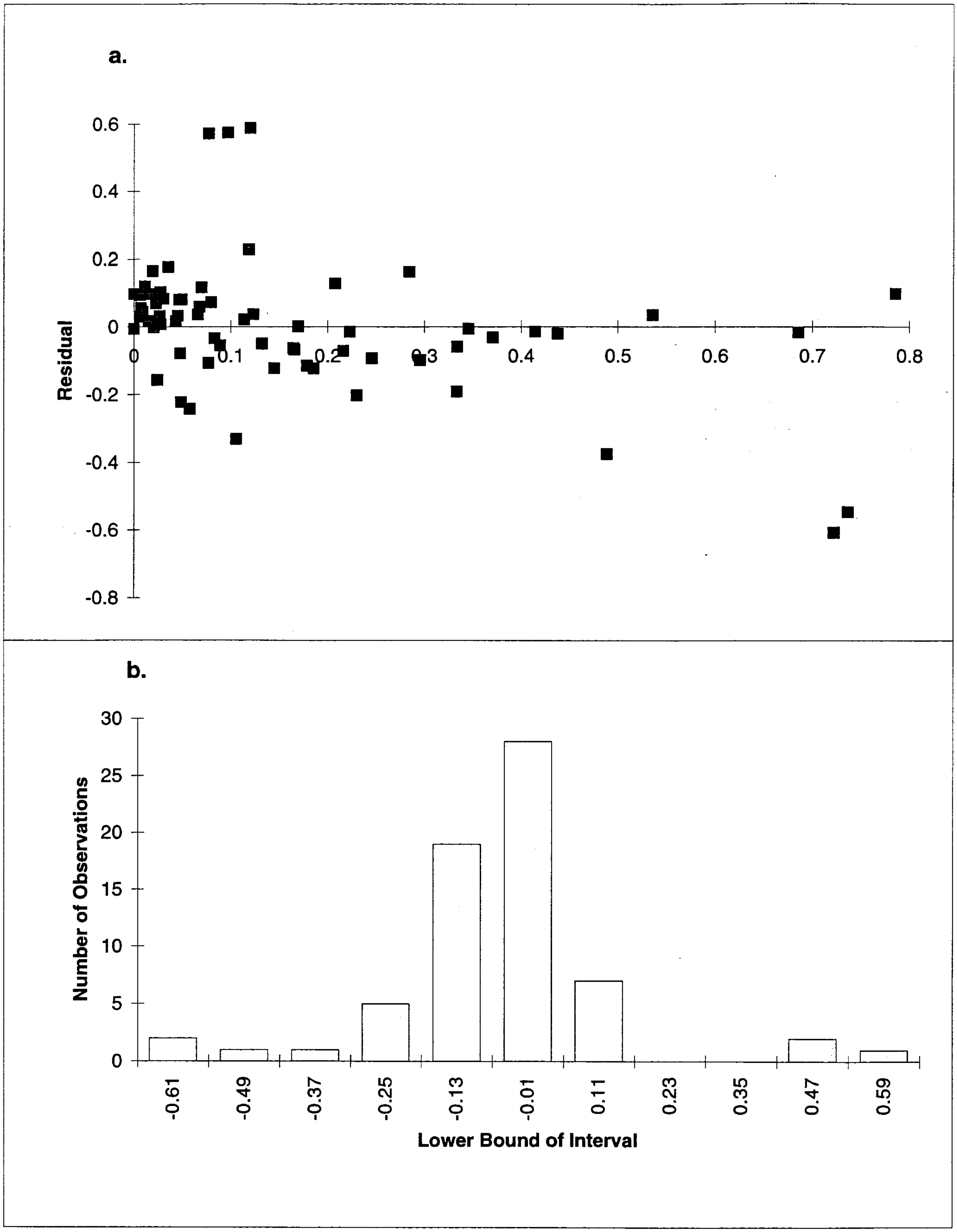
Appendix H.15. Goodness of fit of ASA model estimates to spawn survey estimates of totatl eggs for Cragi herrin(
a. ASA vs. survey estimates of total egg deposition. b. Residuals for total egg deposition
(i.e. ASA estimate - survey estimate).



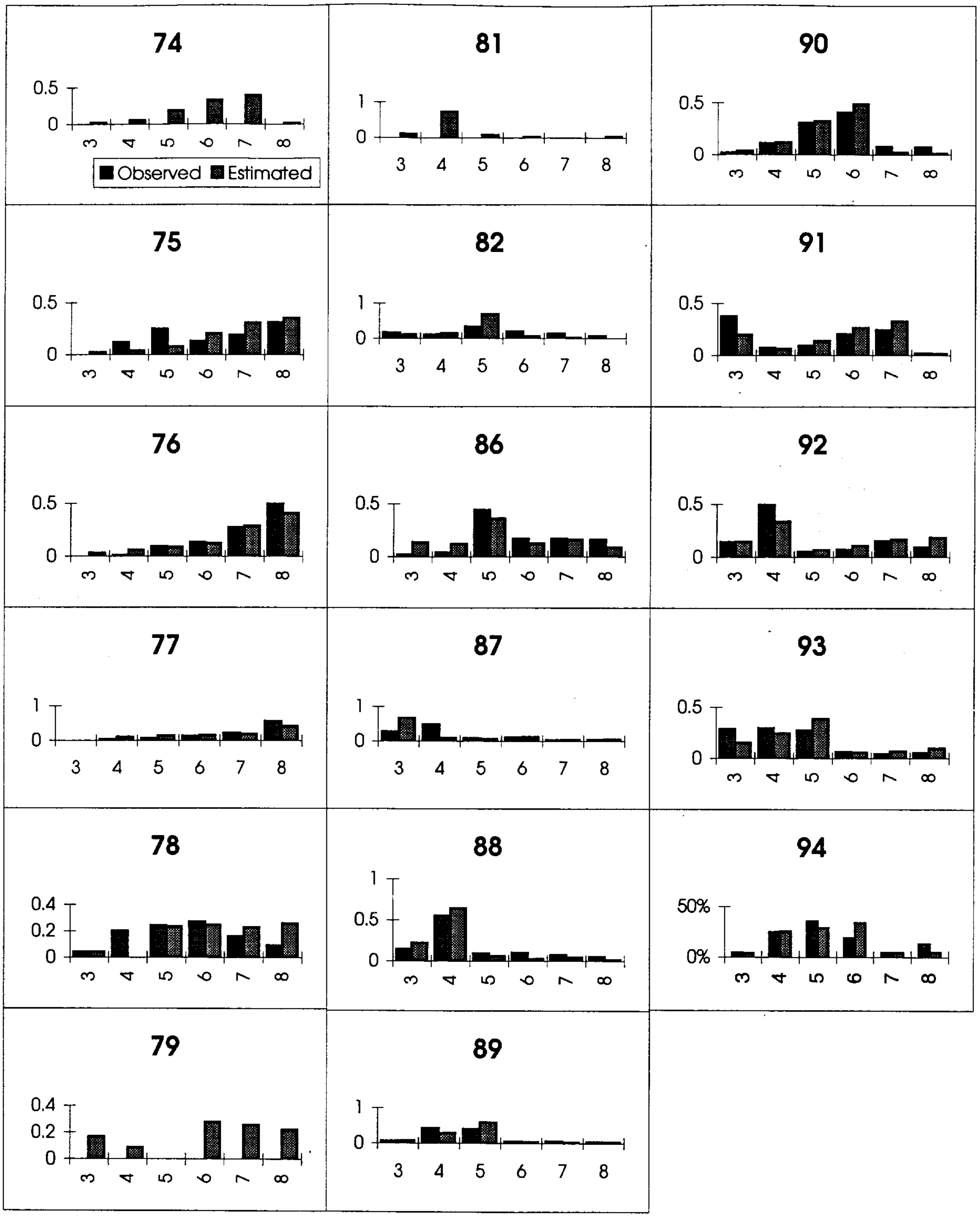
Appendix H.16. Craig observed and ASA-estimated spawning age compositions. Years without observed data were not used to tune the model, due to the absence of samples representative of the spawning population.



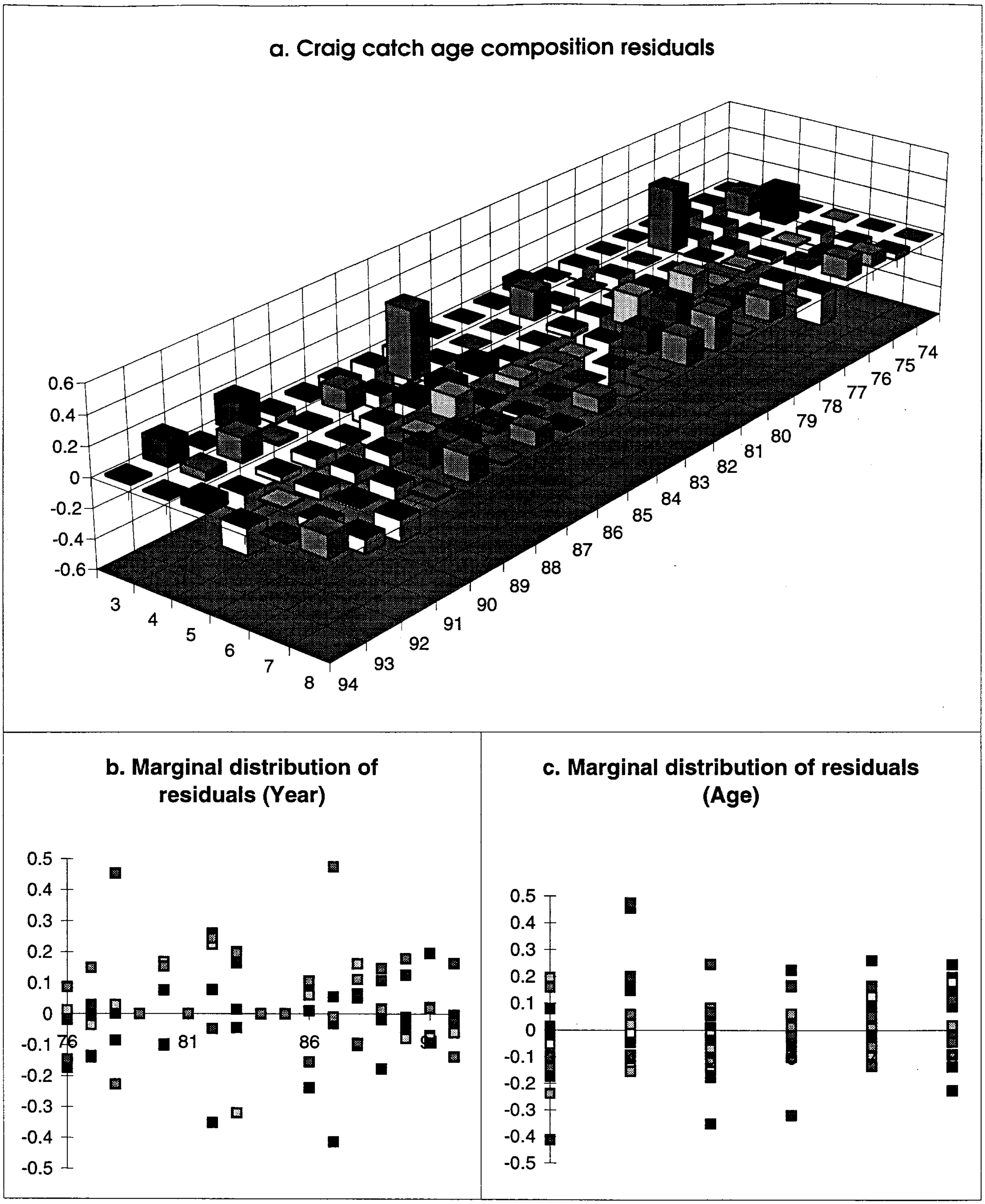
Appendix H.17. Spawning age composition residuals for Craig. These residuals are the deviations of the arcsine transformed ASA-estimated spawning run age compositions from the arcsine transformed observed age compositions.



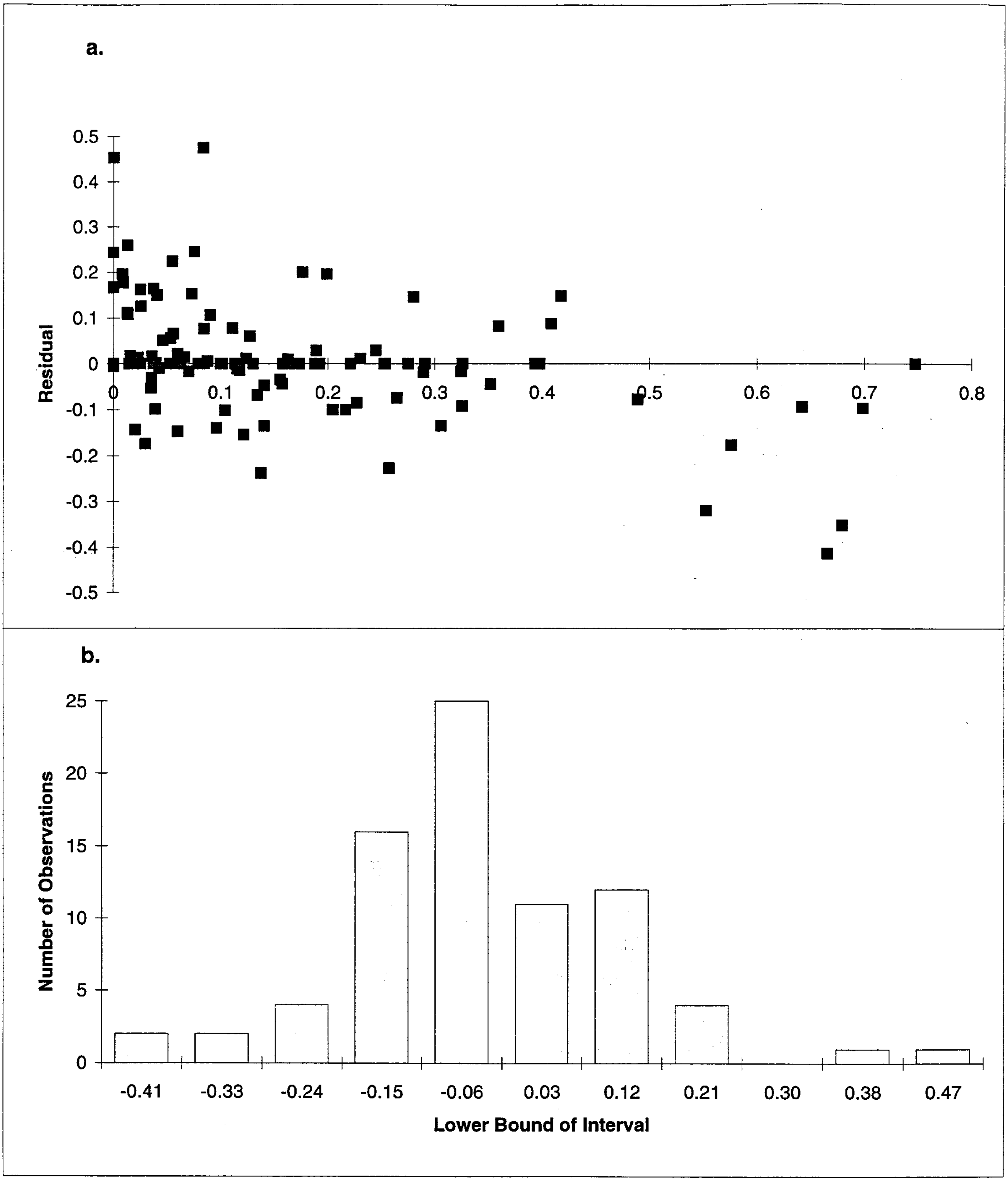
Appendix H.18. Craig spawning age composition residual diagnostics. a. Distribution of residuals vs. magnitude o proportions in age classes. b. Frequency distritbution of residuals.



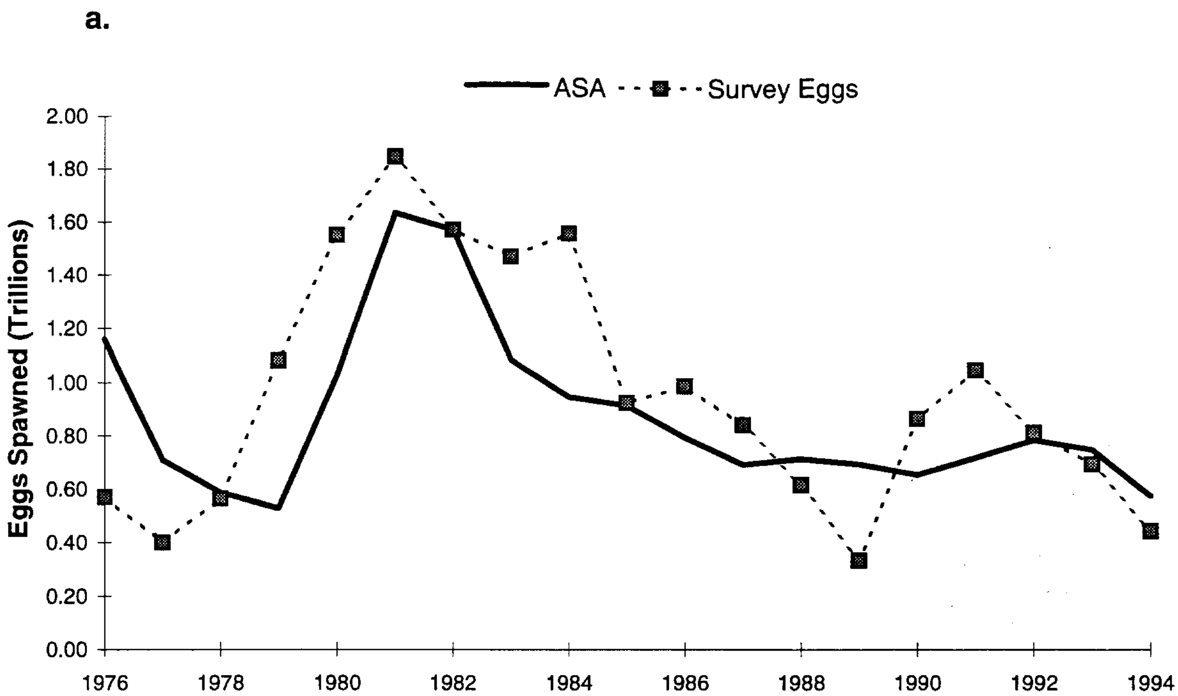
Appendix H.19. Craig observed and ASA-estimated catch age compositions. Years betwe
1974 and 1994 that are not shown had no commercial catches.

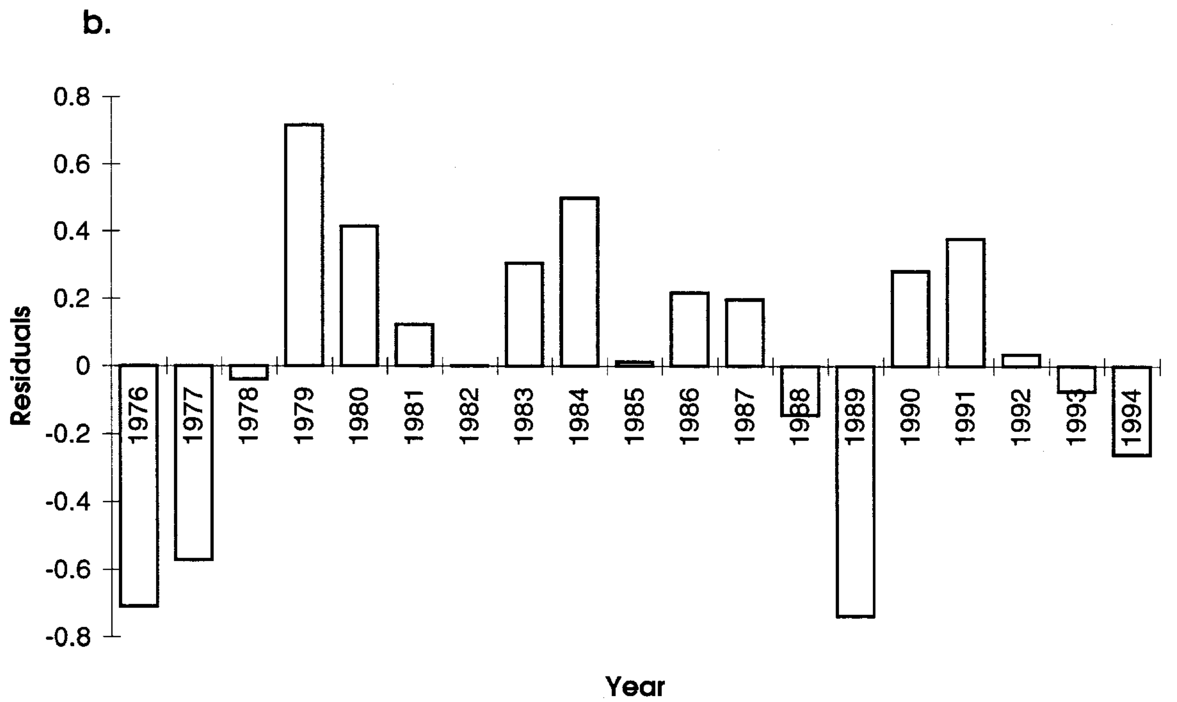


Appendix H.20. Catch age composition residuals for Craig. These residuals are the deviations of the arcsine-transformed ASA-estimated catch age compositions from the arcsine-transformed observed catch age compositions.

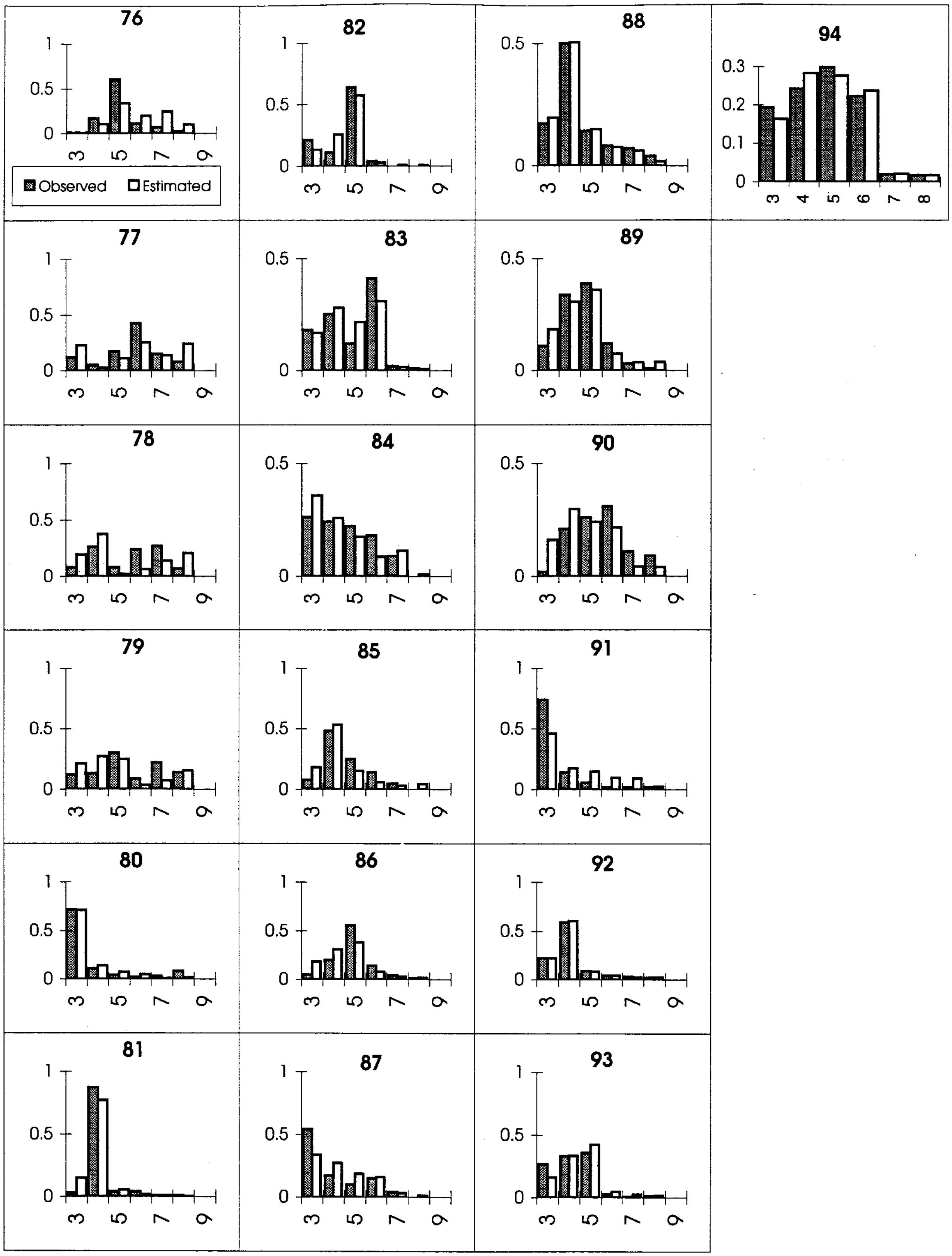


Appendix H.21. Craig catch age composition diagnostics to assess normality and trend in residuals Panel a. Distribution of residuals versus magnitude of proportions in age classes. Panel b. Frequency distribution of residuals.

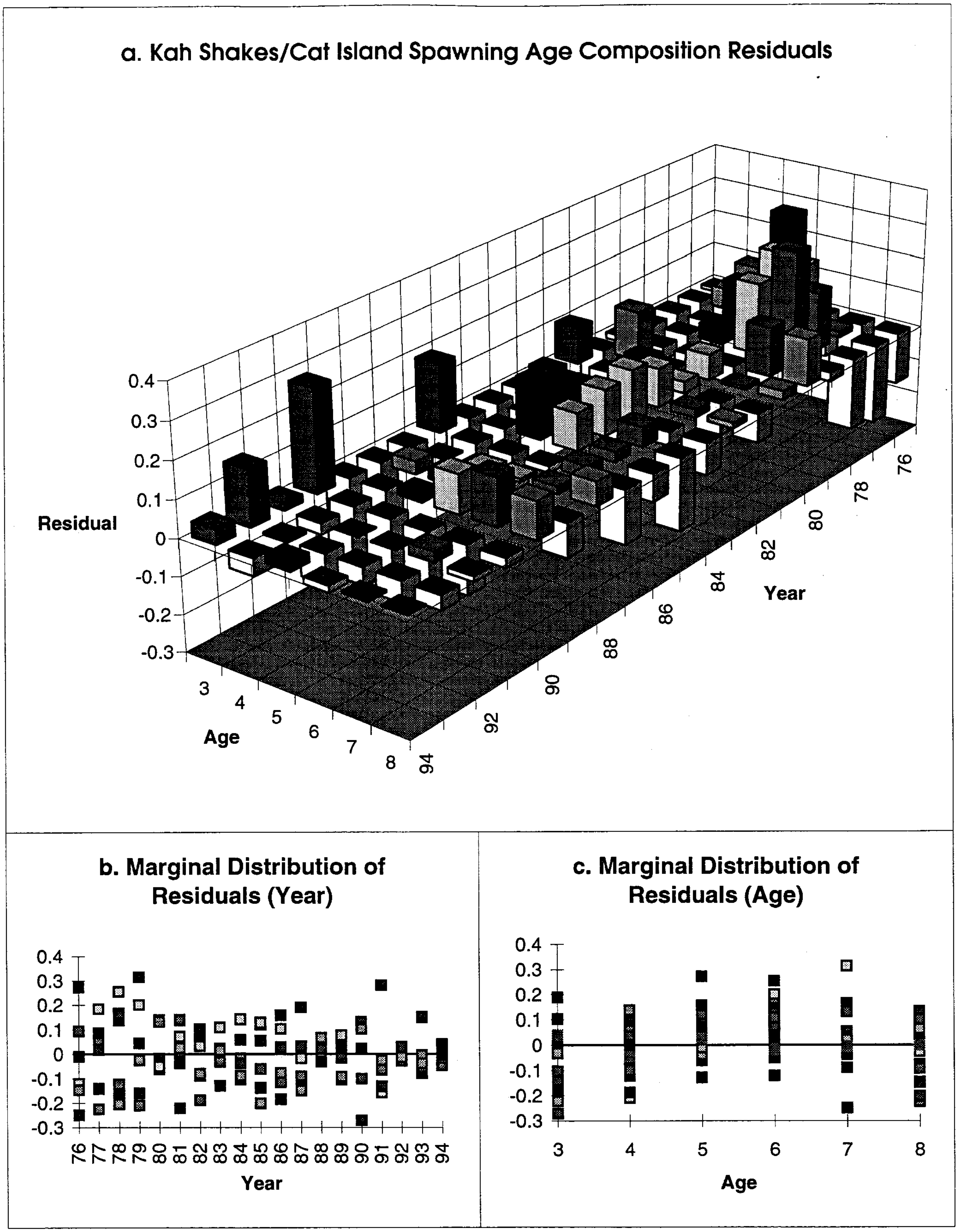




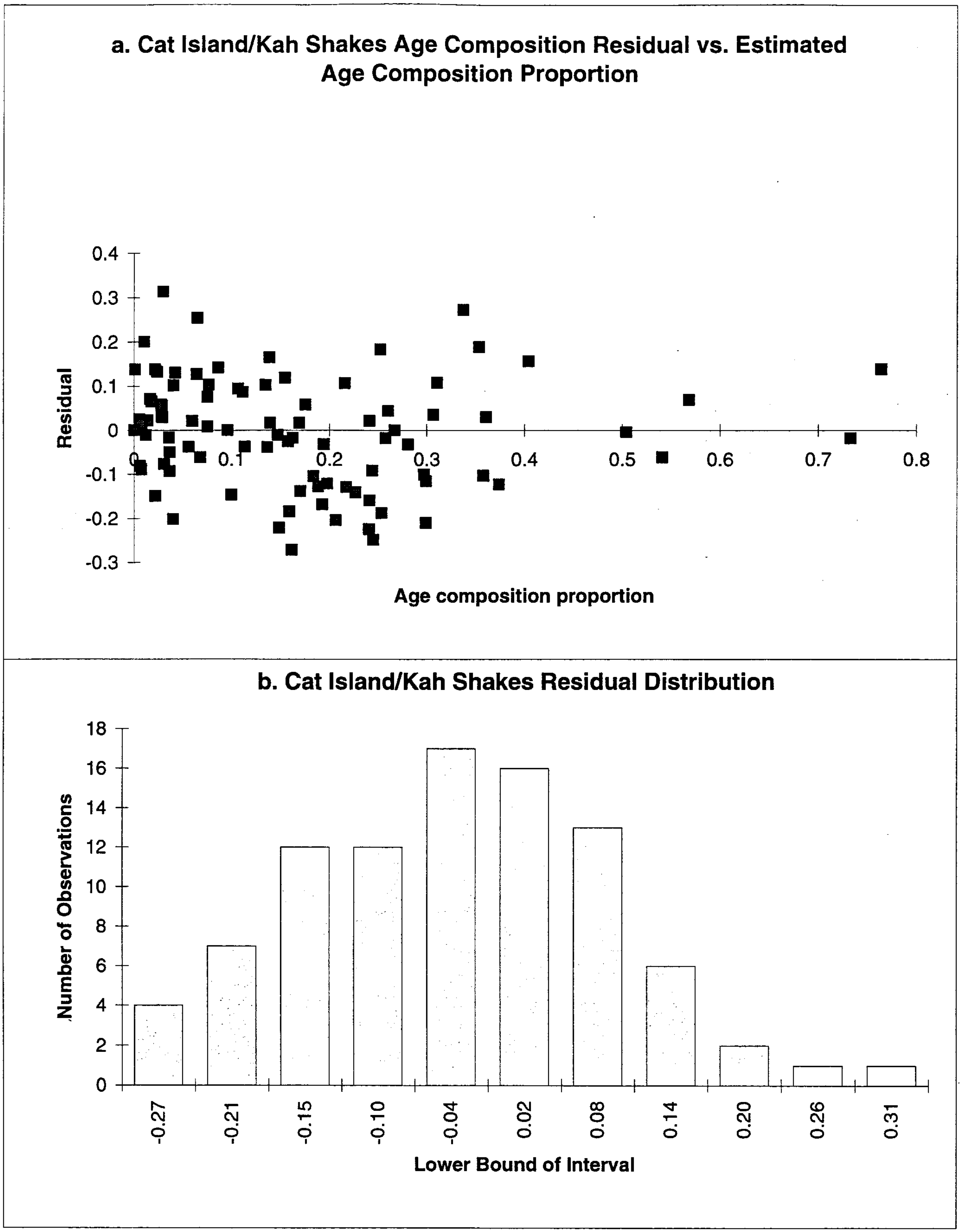
Appendix H.22 Goodness of fit of Cat Island/Kah Shakes ASA model estimates to spawn survey estimates of total eggs and mature biomass. a. ASA vs. survey estimates of total egg deposition. b. Residuals for total egg production(i.e. ASA estimate minus survey estimate).



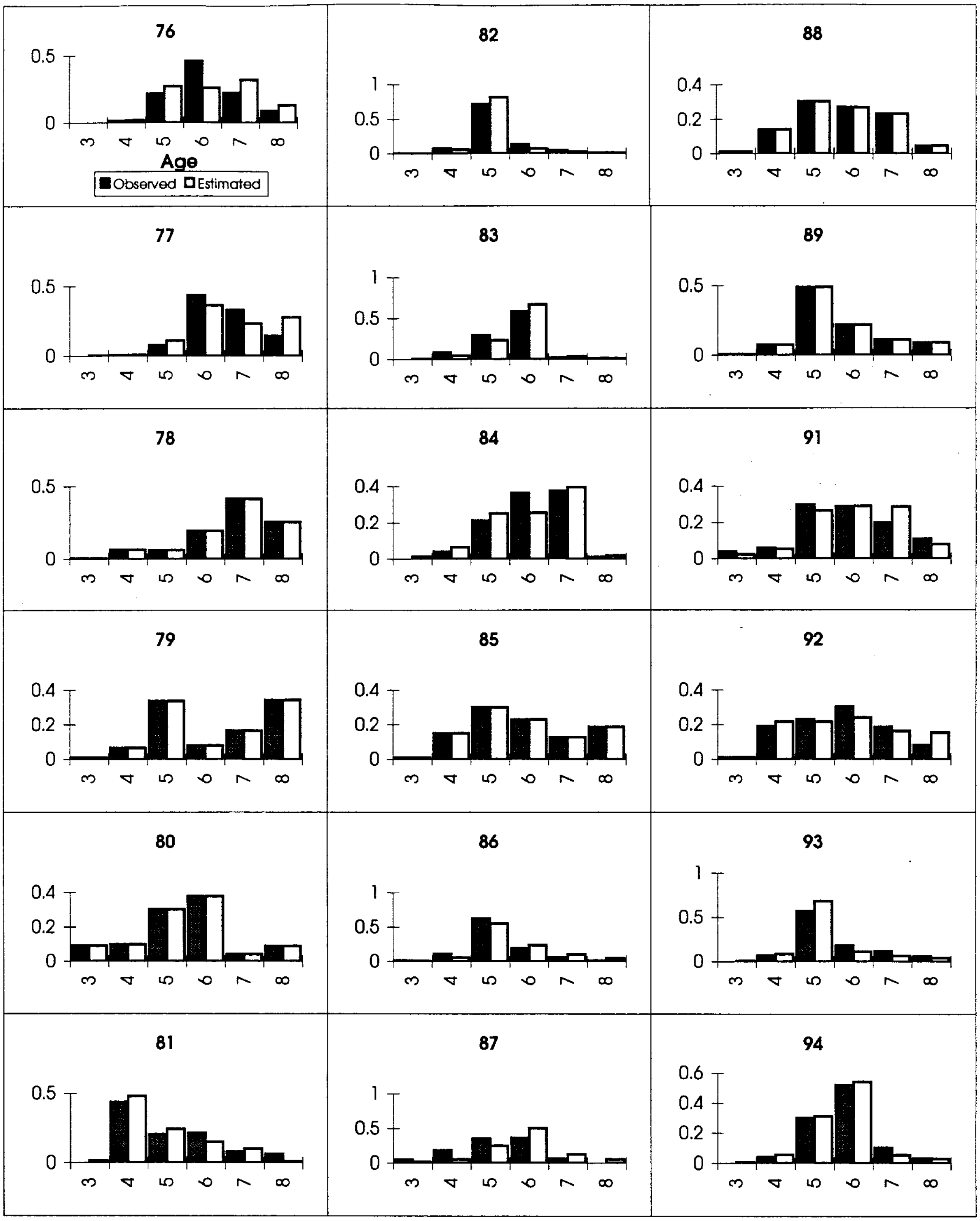
Appendix H.23. Cat Island/Kah Shakes observed and ASA-estimated spawning run age compositions.



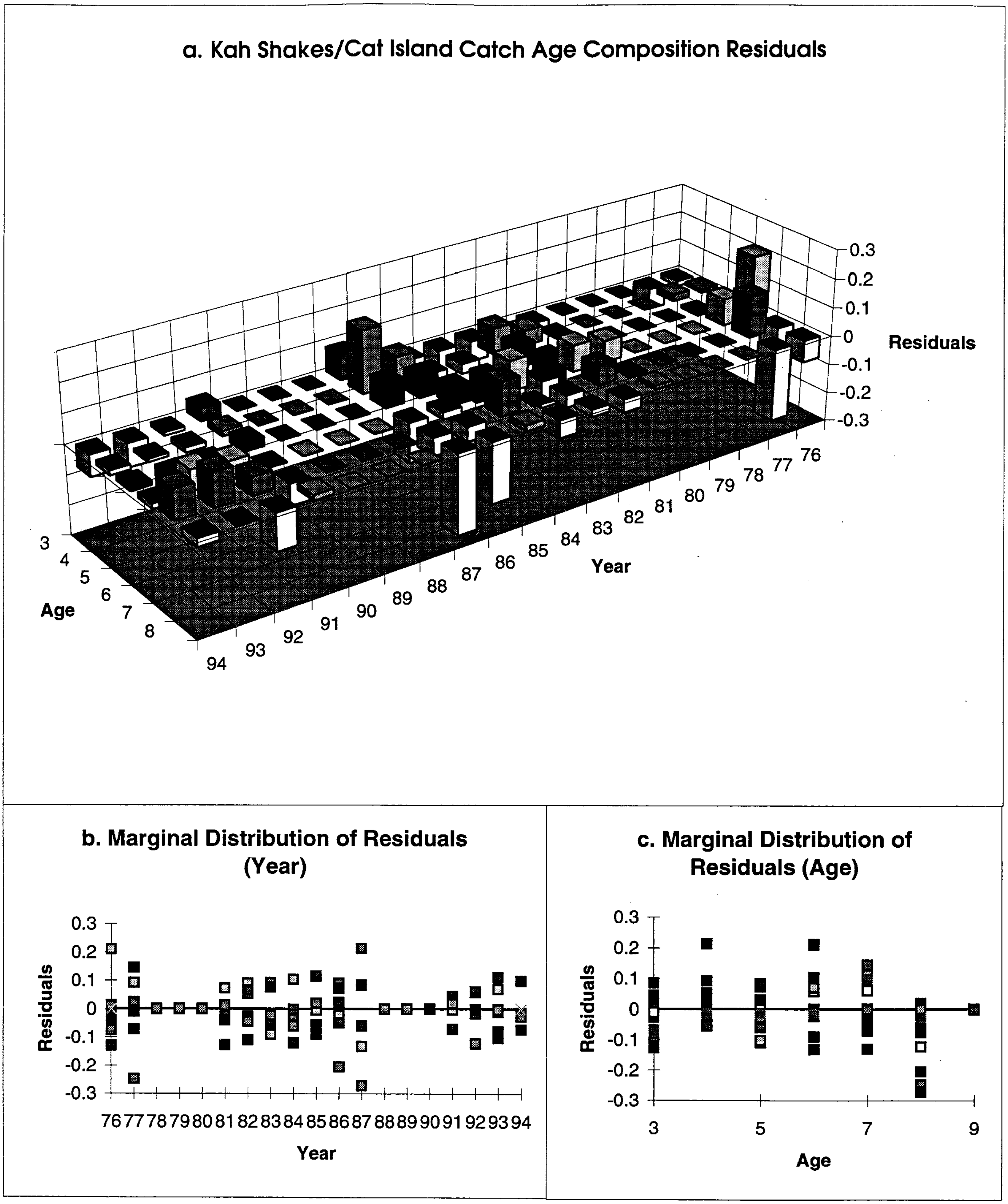
Appendix H.24 Spawning age composition residuals for Kah Shakes/Cat Island. These residuals are the deviations of the arcsine transformed ASA-estimated spawning age compositions from the arcsine transformed observed age compositions.



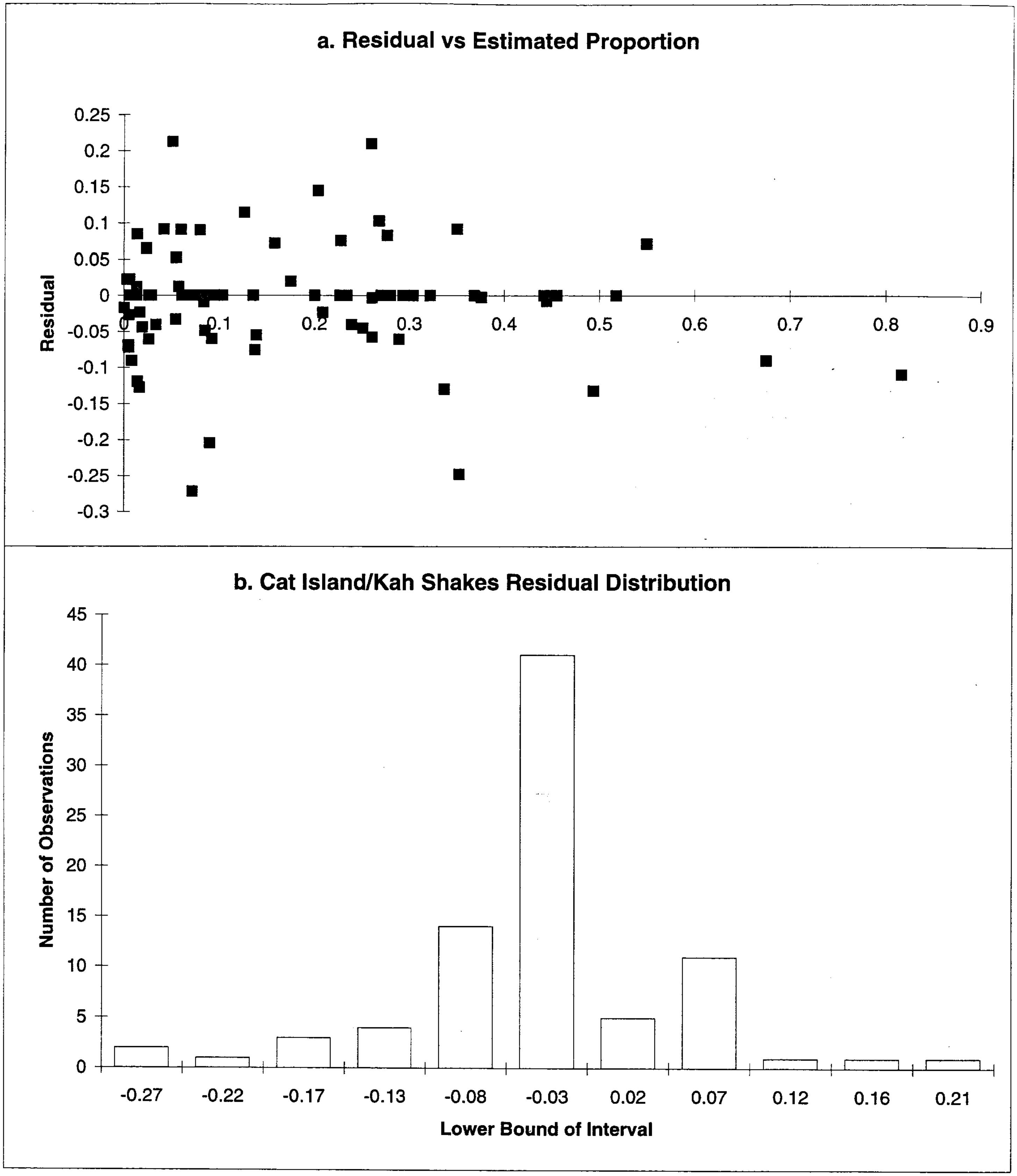
Appendix H.25 Kah Shakes/Cat Island spawning age composition residual diagnostics. a. Distribution of residuals versus magnitude of proportions in age class. b. Frequency distribution of residuals.



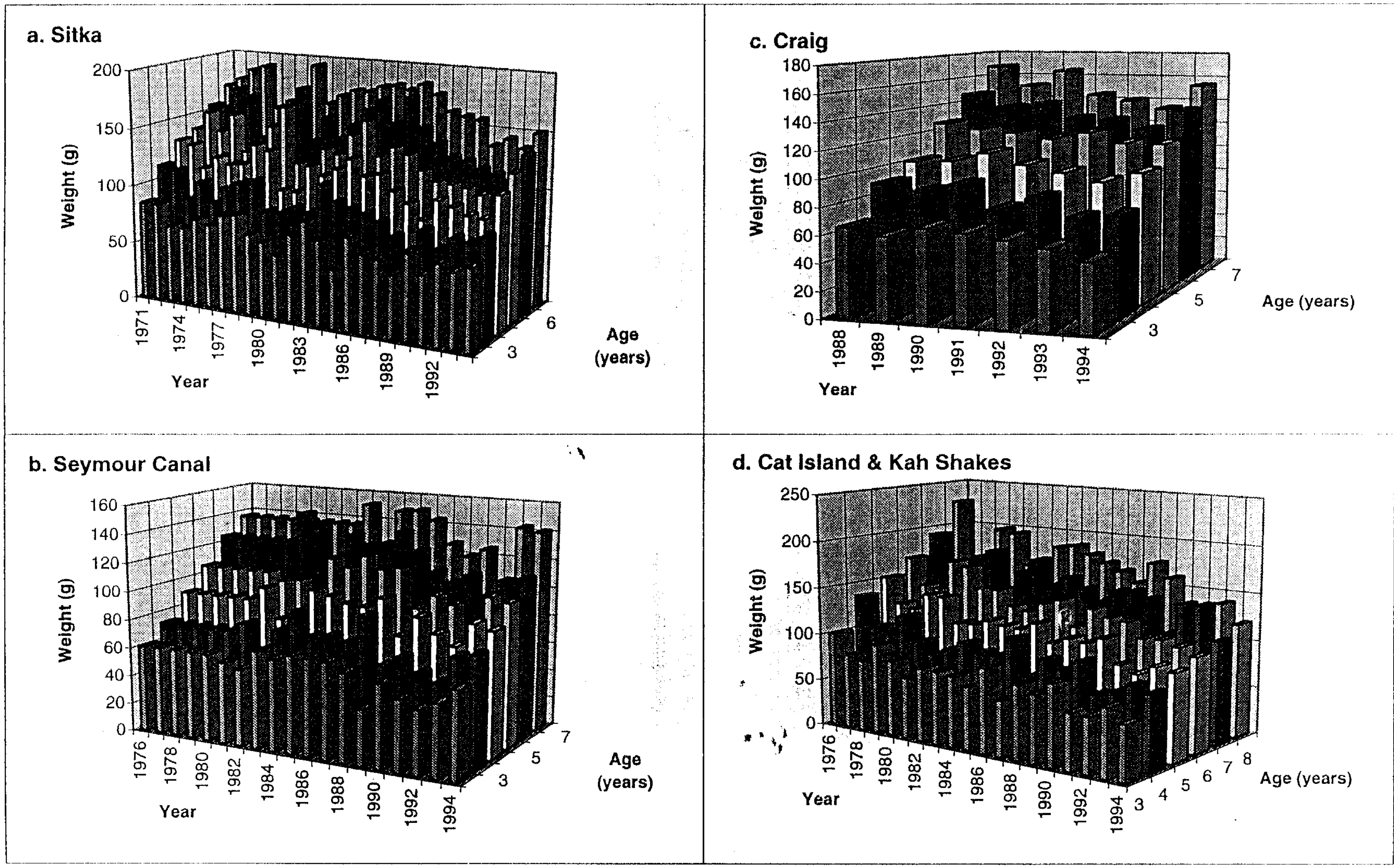
Appendix H.26 Kah Shakes/Cat Island observed and ASA-estimated catch age compositio
Years between 1976 and 1993 that are not shown had no commercial catch.



Appendix H.27 Catch age composition residuals for Kah Shakes/Cat Island. These residuals are the deviations of the arcsine transformed ASA-estimated catch age compositions from the arcsine transformed observed catch age compositions.



Appendix H.28 Kah Shakes/Cat Island catch age composition residual diagnostics. a. Distributions of residuals vs magnitude of proportions in age class. b. Frequency distribution of residuals.



Appendix I. Mean annual weights-at-age for some Southeast Alaska herring.

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