FORECAST OF STOCK ABUNDANCE FOR 1999 ARCTIC-YUKON-KUSKOKWIM REGION

HERRING FISHERIES

By

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ABSTRACT

Biomass projections are made for each Arctic-Yukon-Kuskokwim herring district using postseason escapement estimates, historical mean rates of survival, assumed recruitment rates, and current mean weights. The projected 1999 spawning biomass of the northeastern Bering Sea herring stocks (Security Cove to Norton Sound) is 63,198 tons. This is a decline from the 1998 biomass of 79,815 tons. Districts with projected declines are either those with poor aerial survey conditions in 1998, or those in which a slight decline is expected due to natural mortality as the predominant year class ages. These projections do not include age classes, generally age 3, not yet seen in the fishery.

KEY WORDS: Herring, *Clupea pallasi*, herring forecast, herring projection, Bering Sea

INTRODUCTION

The Arctic-Yukon-Kuskokwim (AYK) Region of the Bering Sea consists of all waters of Alaska extending from the latitude of Cape Newenham to the latitude of Cape Prince of Wales and includes eight commercial herring districts (Figure 1). The districts, from south to north, are Security Cove, Goodnews Bay, Cape Avinof, Nelson Island, Nunivak Island, Cape Romanzof, Norton Sound and Port Clarence.

Forecasts of herring returning to spawn in the AYK Region of the Bering Sea are prepared annually for each district. Forecasts provide fishery managers, processors and fishermen with information on the expected biomass and age composition of herring for the coming season. Since 1987, the inshore herring fisheries in this area have been managed under the Bering Sea Herring Fishery Management Plan (5 AAC 27.060, ADF&G 1998), which specifies a threshold biomass level which must be reached in each district before commercial fishing can take place. Fishery managers may use forecasts of returning herring when evaluating whether the threshold level of biomass has been reached. In many years, poor aerial survey conditions have precluded inseason estimates of herring abundance and managers have used the forecasted abundance to set harvest levels. In addition, biomass forecasts are used by both the Alaska Board of Fisheries and North Pacific Fishery Management Council in making decisions regarding the Dutch Harbor food and bait fishery and the Bering Sea trawl fisheries, respectively.

This report documents forecasts of herring abundance in AYK herring districts for the 1999 season. Forecasts are made for the Security Cove, Goodnews Bay, Cape Avinof, Nelson Island, Nunivak Island, Cape Romanzof, and Norton Sound Districts. No forecast has been made for the Port Clarence District, which has a very limited fishery in some years, and from which almost no information on stock status is available.

METHODS

Biomass Assessment

Aerial surveys have been the primary method of assessing herring biomass, timing and distribution in the Bering Sea herring fisheries since 1978. Aerial survey procedures are outlined in Lebida and Whitmore (1985). It is often difficult to obtain biomass estimates from aerial surveys in the AYK Region because of unfavorable weather, ice conditions or turbid water. In these cases, the biomass is usually assumed to equal the preseason projection. Spawn deposition and catch rates from commercial, test and subsistence fisheries may also be used as indicators of herring abundance.

Commercial harvests are tallied from sales receipts issued to fishermen after each delivery. Harvests are either added to or subtracted from the biomass estimate to calculate total biomass, depending on the timing of the fishery. Escapements are determined by subtracting commercial and large subsistence harvests from the estimated biomass for each district.

Biomass Sampling

Samples are collected from the commercial fishery to estimate the age composition of harvests and the mean weight-at-age of harvested herring. Variable-mesh gillnets (VMG), consisting of four panels ranging from 1.5 to 3.0 inch mesh, are used to sample the population. More detailed information on the methods for collecting samples is presented in DuBois (1999). No samples were collected in the Nunivak Island District. Age composition from samples collected in the Nelson Island District were applied to biomass estimates for Nunivak Island.

VMG data are used to estimate the age composition of either the entire population or the escapement, depending on the area and timing of the commercial fishery. For Cape Romanzof and Norton Sound herring stocks, the commercial fishery has historically occurred on the front-end of the migration, and therefore VMG samples are assumed to represent the total run. In Kuskokwim Area districts, the timing of the commercial fishery compared to the total run is evaluated each year and a decision to consider VMG catches as representing the entire run or just the escapement is made for each district.

Weight at Age

Mean weight-at-age estimates in the current year were used to convert biomass estimates into numbers of fish, as well as to predict the weight-at-age for the next year. A growth model (Schnute 1981) was fit to the observed mean weight-at-age in each district. Model parameters were estimated by minimizing the sum of the squared residuals, weighted by the square root of the number of herring observed in each age class, using the solver bundled with the Microsoft Excel spreadsheet program. For age classes with less than 30 observations, the estimated mean weight-at-age was taken from the growth model; otherwise, the estimated mean weight-at-age was taken as the observed mean.

Recruitment Rates

Recruitment rates, the proportion of each age class that participate in the spawning migration and thereby recruit to the fishery, are from Wespestad (1982). The recruitment rate is 0.00 for ages less than 3, 0.43, 0.86, and 0.97 for ages 3, 4, and 5, and 1.0 for ages greater than 5.

Population Model

Some notation is required to introduce the population model. Let

f	=	the age at which herring first recruit to the fishery
r_i	=	the recruitment rate for age i herring
s_i	=	the probability an age i herring will survive, excluding fishery exploitation, to age $i + 1$
R_i	=	the number of herring from brood year i-f and that survive to age f in year i,
$N_{i,j}$	=	the number of age j herring in the spawning migration in year i, and
$E_{i,j}$	=	The number of $N_{i,j}$ that are not harvested.

The expected number of herring in the spawning population can be expressed as

$$N_{i,f} = R_i r_f \tag{1}$$

and

$$N_{i,j} = E_{i-1,j-1} s_{j-1} + R_{i-(j-f)} \left(\prod_{k=f}^{j-1} (1 - r_k) s_k \right) r_j \tag{2}$$

for $j > f$. The model expressed in equations (1) and (2) are used to develop methods of estimating survival rates and forecasting herring abundance.

Forecasting Herring Biomass

Equation (2) can be modified to provide an estimator of herring abundance in the subsequent year. The equation contains an unknown parameter, R. For the forecast of age $f + 1$ abundance in year $i + 1$ from the escapement of age f fish in year i, equation (1) provides an estimate of R_i, i.e.,

$$R_i = \frac{N_{i,f}}{r_f}. \tag{3}$$

Substituting equation (3) into equation (2) provides the estimator

$$N_{i+1,f+1} = E_{i,f} s_f + N_{i,f} \left(\frac{1 - r_f}{r_f} \right) s_f r_{f+1}. \tag{4}$$

For older ages, equation (2) can be expressed as

$$R_{i-(j-f)}\left(\prod_{k=f}^{j-1}(1-r_k)\,s_k\right) = \frac{N_{i,j} - E_{i-1,j-1}\,s_{j-1}}{r_j}. \quad (5)$$

Substituting the right-hand side of equation (5), with j replaced by j-1, into equation (2) yields the estimator

$$N_{i+1,k} = E_{i,k-1}\,s_{k-1} + (N_{i,k-1} - E_{i-1,k-2}\,s_{k-2})\left(\frac{1-r_{k-1}}{r_{k-1}}\right)s_{k-1}\,r_k \quad (6)$$

for $k > f + 1$.

Equations (4) and (6) are used to forecast herring abundance for ages greater than $f = 3$, given estimates of escapement by age, estimates of survival rates (discussed below), and assumed recruitment rates (Wespestad 1982). No forecasts of abundance are currently made for herring of age 3 or less.

Survival Rate Estimation

Because AYK herring fisheries take place over a short period of time, natural mortality during the fishery is assumed to be insignificant. Survival rates can be estimated from estimated escapements in one year and the estimated inshore returns in the subsequent year, accounting for increased abundance from recruitment.

Estimators of survival rates are obtained by expressing equations (4) and (6) in terms of survival rates, i.e.,

$$s_f = \frac{N_{i+1,f+1}}{E_{i,f} + N_{i,f}\left(\frac{1-r_f}{r_f}\right)r_{f+1}} \quad (7)$$

and

$$s_k = \frac{N_{i+1,k+1}}{E_{i,k} + \left(N_{i,k} - E_{i-1,k-1}s_{k-1}\right)\left(\frac{1-r_k}{r_k}\right)r_{k+1}} \quad (8)$$

for $k > f$, respectively. Note that, because the expression for s_k in equation (8) depends on s_{k-1}, survival rates must be estimated sequentially beginning with the youngest age f.

Observed survival rates were calculated using equations (7) and (8) for each age, year and district. Any ratio greater than one was replaced by one. Mean observed survival rates by age

were computed for all Kuskokwim Area herring districts combined and separately for Norton Sound. Survival rates were only included in the mean if a district had two successive years of acceptable surveys. A three parameter (quadratic) logistic function (Hosmer and Lemeshow, 1989) was fit to the means as a smoother. The parameters were estimated by minimizing the sum of the squared residuals, weighting by the number of observations included in the mean for each age, using the solver bundled with the Microsoft Excel spreadsheet program. These smoothed survival rates were used to project the 1999 return for the Kuskokwim Area and Norton Sound Districts. Because of turbid water, aerial surveys have not been successful in the Cape Romanzof Area. Therefore, survival rates estimated for the Kuskokwim Area were applied to Cape Romanzof herring.

RESULTS

Biomass Assessment and Sampling

A summary of the total biomass, harvest and escapement for each district in 1998 is presented in Table 1. DuBois and Hamner (1998) provide details on the biomass assessment and harvest for each district. Data from harvest and VMG sampling, used to estimate age composition and weight-at-age, are summarized by DuBois (1999). Observed mean weight-at-age and the growth model (Schnute, 1981) fit to the means are presented in Figures 2 to 7 for the Security Cove, Goodnews Bay, Cape Avinof, Nelson Island, Cape Romanzof and Norton Sound Districts, respectively.

Survival Rates

Annual estimates of herring abundance since 1980 were used to compute observed survival rates by age group for both the Kuskokwim Area and Norton Sound districts. In this time period in the Kuskokwim Area, there were only 15 data points out of a possible 77 (less than 20%) with two adjacent years with acceptable surveys (Table 2). These data include four years from Security Cove, one year from Goodnews Bay, one year from Cape Avinof, six years from Nelson Island and three years from Nunivak Island (Table 2). Mean survival rates for the Kuskokwim Area were most recently updated in 1995, when two adjacent years of acceptable surveys were flown in the Nelson Island District.

The observed survival rates (Table 2) should all be less than one, after adjusting for recruitment, because a cohort cannot increase in abundance with age. However, out of the 178 observed survival rates (age-year-district combinations), 75 or 42% were greater than one and were set to one. This occurred most frequently in the younger age classes. Some of the less abundant older and younger age groups were not observed in many of the adjacent year combinations included. For example, in the Kuskokwim Area, age-16 herring have only been observed in one year of the

data included in survival rates. The mean observed survival rates and the logistic function fit to the means are graphed in Figure 8.

In Norton Sound there were 9 data points out of a possible 18 with acceptable surveys in adjacent years (Table 3) that were used to calculate survival rates. Therefore one half of the data was acceptable, compared to less than one-fifth of the data from the Kuskokwim Area. Out of the 105 age and year combinations in the Norton Sound area, 47 or 45% were greater than one and were set to one. The mean survival rates and the logistic function fit to the means are graphed in Figure 9. Survival rates for older aged herring in Norton Sound were greater than in the Kuskokwim Area (Figure 10).

Biomass Forecasts

The 1999 projected return to the Security Cove District is 3,060 tons (Table 4). Age-6 herring are expected to dominate the return in both numbers (47.2%) and biomass (39.7%). Age-9 and older herring are expected to comprise almost one-third of the biomass. Figure 11 compares the 1999 projection with estimated total biomass in past years. Figure 12 shows the projected age composition of the 1999 return in both percent by number and percent by weight.

The projected return of herring to the Goodnews Bay District is 3,009 tons (Table 5 and Figure 13). Similar to Security Cove, ages 6 and 8 are expected to be the dominant age classes, and comprise 26.0% and 17.0%, respectively, of the returning biomass (Figure 14). Age 9 and older herring are expected to comprise 43.9% of the biomass.

The projected 1999 biomass for the Cape Avinof District is 3,555 tons (Table 6 and Figure 15). Ages 6, 8 and 9 herring are expected to comprise well over one-half of the returning population (32.4%, 15.3% and 15.2%, respectively) (Figure 16). Age 9 and older herring are expected to comprise over one-third of the biomass.

The spawning biomass projected to return to the Nelson Island District in 1999 is 5,826 tons (Table 7 and Figure 17). Similar to Cape Avinof ages 6, 8, and 9 herring are expected to dominate the returning population (32.4%, 17.3% and 16.3%, respectively) (Figure 18). Age 9 and older herring are expected to comprise over one-third of the biomass.

The biomass of herring projected to return to the Nunivak Island District in 1999 is 3,319 tons (Table 8 and Figure 19). Due to insufficient data having been collected from the Nunivak Island District in 1998, the estimated 1999 herring age composition was calculated using data from the Nelson Island District. Ages 6, 8 and 9 herring are expected to dominate the returning population (27.1%, 17.0% and 17.1%, respectively) (Figure 20). Age 9 and older herring are expected to comprise 45.3% of the biomass.

The projected return of herring to the Cape Romanzof District in 1999 is expected to be between 2,800 and 3,700 tons based on an assessed biomass of between 4,000 and 5,000 tons in 1998 (Table 9). The midpoint of this range for 1998 was 4,500 tons, which results in a projected biomass of

3,259 tons. Ages 11, 9, and 8 herring are expected to dominate the biomass, contributing 22.8%, 20.9%, and 19.9%, respectively (Figure 21). In numbers of fish, age 6 is expected to be the largest age group (23.1%). Age 9 and older herring are expected to comprise 59.4 % of the return.

The biomass projected to return to Norton Sound in 1999 is 41,169 tons (Table 10 and Figure 22). Ages 6 and 11 are expected to comprise over one-half the returning biomass (19.1% and 35.5%, respectively) (Figure 22). Age 9 and older herring are expected to contribute almost two-thirds of the return.

DISCUSSION

Comments on Current Methods

Abundance Estimates

Herring biomass estimates in the AYK area have historically been peak aerial survey estimates. However, herring spawning migrations frequently appear to consist of multiple modes of abundance. In the early to mid 1990's, herring managers began to sum aerial observations from multiple modes under some conditions. The length of time between modes, their location within a district and between-mode comparisons of age composition and gonad maturity may be used to evaluate whether, and how, to combine aerial observations. Because little is known about herring residency time or migration patterns within many districts, such evaluations may be fairly subjective. Consequently, the proportion of the population that is observed and identified as being unique can vary greatly between years.

A variety of other factors can also influence the accuracy of aerial survey biomass estimates. Environmental conditions during surveys are frequently poor in several districts, particularly in the Cape Romanzof and Kuskokwim Area districts. The training and experience of observers, errors in estimating the surface area of variously shaped schools, variability in the depth and density of schools, and the presence of other species all have the potential to influence the accuracy of estimates. In addition, very little data on the relationship between the surface area of schools at various water depths and biomass are available from AYK districts. Conversion factors being used were developed in the Togiak herring district, but their applicability in AYK districts has not been verified.

Because of the factors mentioned above, the accuracy of biomass estimates likely varies greatly between years. Forecasts can differ substantially from the aerial estimates in any given year, and between-year variability in the biomass estimates is thought to be the single greatest source of error in the forecasts.

Estimates of Age Composition

Age composition generally changes throughout the migration, with older fish arriving before younger fish (Dubois 1999). VMG samples are collected during the bulk of the migration in most districts in most years. However, abundance information with which to weight age composition estimates is not available through time, and samples are generally pooled. Therefore, data from the tails of the migration may overly influence age composition estimates. The degree to which this tends to bias age composition estimates is unknown. Measures of effort have been considered for use as weights, but no dedicated attempt to explore their utility has been made to date.

Several aspects of VMG sampling complicate estimation of age composition. Herring year classes have been documented to be segregated geographically (offshore vs nearshore) (Taylor 1969). Geographical segregation may also vary with year-class strength (Guiblin, P. et al., 1996). This age or size segregation may even occur in individual schools (Rowell et al., 1990). Although crews are instructed to make short sets and sample many schools, the logistics of weather and time may prevent this. The relatively small number of VMG sampling crews may not be sufficient to adequately sample some districts, particularly the larger districts such as Norton Sound. Finally, VMG nets, consisting of four panels with different mesh sizes, may not adequately sample the population. These nets were designed in the 1970's, when the large, older aged herring now present in many populations had not yet been observed.

Errors in ageing herring and differences between scale readers have been documented (Brannian 1988, Kimura and Lyons 1991). Ageing errors are most frequent between adjacent ages and are made more often with older aged fish. Errors in ageing may result in over estimating weak cohorts and under estimating strong cohorts.

Recruitment

The recruitment rates used in AYK herring districts are from early catches, 1959-1978, in the Bering Sea when stocks were near virgin levels (Wespestad 1980). Estimated survival rates greater than 1.0 for the younger age classes may be mostly caused by deviations from the assumed recruitment rates. In addition, although current methods assume that recruitment rates are fixed, they almost certainly vary between year classes. This component of current methods is probably most in need of modification, but improvements may be difficult to develop.

No biomass forecasts are made for age classes that have not yet been seen in the fishery. Herring show large fluctuations in recruitment, and methods of economically and accurately making such forecasts have not been developed.

Survival Rates

Current estimates of survival rates are strictly conditioned on the assumed recruitment rates (Equations 7 and 8). Difficulties in estimating abundance as well as ageing error may both contribute to inaccurate estimation of survival rates. The error in estimating survival rates may be

greater when recruitment is highly variable, as occurs in herring populations. In addition, as with recruitment rates, survival rates almost certainly vary through time. The degree to which survival rates vary is difficult to assess given the extreme variability inherent in biomass estimates.

Potential Alternative Methods

In recent years, many areas of the state have switched to using an age-structured-analysis model (ASA) to forecast herring returns. The feasibility of using ASA models to forecast AYK herring abundance was examined in 1993 and 1994. The models developed were very unstable and gave grossly different forecasts with only minor changes to the data or model assumptions. For that reason, the models were not adopted. We suspect that highly variable recruitment and biomass assessments, as well as errors in age composition estimates, were primary reasons the models were so unstable.

In spite of these problems, ASA models likely offer the greatest potential to improve future forecasts. In 1997, an ASA model was developed to forecast returns to the Norton Sound fishery (Williams, 1997). The properties of this model and its potential for implementation need to be investigated more fully.

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Table 1. Total biomass, harvest, and escapement in tons of herring by district for the Arctic-Yukon-Kuskowim Region, 1998.

District	Total Biomass	Assessment Method	Commerical Harvest	Escapement
Security Cove	4,017	projection	1,012	3,005
Goodnews Bay	4,064	projection	831	3,233
Cape Avinof	4,287	projection	656	3,631
Nelson Island	7,136	projection	1,250	5,886
Nunivak Island	3,778	projection	202	3,576
Cape Romanzof	4,500	spawn index	727	3,773
Norton Sound	52,033	aerial survey	2,632	49,401

Table 2. Estimated survival rates in consecutive years having acceptable biomass assessments in Kuskokwim area herring districts since 1980.

District	Years	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Age-9	Age-10	Age-11	Age-12	Age-13	Age-14	Age-15	Age-16	Age-17
SEC	1983-1984		1.0000	0.5002	0.7741	0.8970	0.8170	1.0000	0.6508	0.4398	0.0000	0.0000			0.0000		
SEC	1984-1985		1.0000	1.0000	1.0000	1.0000	0.6129	0.8473	0.1892	0.3323	0.0912						
SEC	1991-1992		1.0000	1.0000	0.8255	0.9236	1.0000	0.8711	1.0000	1.0000	0.5260	0.9375	0.5606	0.3230	0.0000		
SEC	1992-1993		1.0000	1.0000	0.6134	1.0000	1.0000	0.6221	0.7086	1.0000	0.4187	0.6697	0.4106	0.0000	0.0000		
GNB	1984-1985		1.0000	1.0000	0.9734	0.9613	1.0000	1.0000	0.5071	0.7974	0.7221	0.2196					
CAV	1991-1992		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9247	0.6241	0.0126	0.0000	0.0000		
NEL	1983-1984				1.0000	1.0000	0.8603	1.0000	1.0000	0.0000	0.2978						
NEL	1990-1991		1.0000	0.6994	0.7812	0.6960	0.9088	0.5156	0.6210	0.7309	0.7671	0.5387	0.7248	0.1828			
NEL	1991-1992		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8147	0.5708	0.0831	0.0000		
NEL	1992-1993		1.0000	1.0000	1.0000	1.0000	0.8940	0.6877	0.7339	0.3294	0.2293	0.3235	0.2186	0.1539	0.0000		
NEL	1993-1994		0.5850	0.6173	0.4459	0.9257	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5519	0.5424	0.3326		
NUN	1991-1992			1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3237	0.2431	0.0384	0.0000		
NUN	1992-1993		1.0000	1.0000	1.0000	0.3218	0.9858	0.8410	0.7136	0.8304	0.2114	0.0681	0.1348	0.0000	0.0000		
NUN	1993-1994		1.0000	0.7254	0.9667	0.7829	1.0000	1.0000	0.8628	0.8693	0.4416	0.5241	0.4032	0.4032			
NEL	1994-1995		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8564	0.9381	0.5091	0.5690	0.9323	1.0000	1.0000	1.0000	
No. Obs.		0	13	14	15	15	15	15	15	15	15	13	11	11	10	1	0
Mean			0.9681	0.8959	0.8920	0.9006	0.9386	0.8923	0.7896	0.7512	0.5426	0.5087	0.4330	0.2479	0.1333	1.0000	
Smoothed		0.9489	0.9437	0.9356	0.9235	0.9060	0.8808	0.8445	0.7932	0.7221	0.6283	0.5135	0.3875	0.2668	0.1673	0.0962	0.0514

Table 3. Estimated survival rates in consecutive years having acceptable biomass assessments in the Norton Sound herring district since 1980.

Years	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Age-9	Age-10	Age-11	Age-12	Age-13	Age-14	Age-15	Age-16	Age-17
1983-1984		1.0000	1.0000	0.7416	0.7036	0.4772	1.0000	0.3782	0.7425	0.3307						
1986-1987		1.0000	0.8615	1.0000	1.0000	1.0000	1.0000	0.8594	0.6865	0.2738	0.0000					
1987-1988		1.0000	1.0000	0.3401	0.7502	1.0000	1.0000	0.9811	0.5351	1.0000	1.0000		0.0000			
1990-1991		0.8251	0.6045	1.0000	1.0000	1.0000	1.0000	0.9392	0.6662	0.6581	1.0000	1.0000				
1991-1992		1.0000	1.0000	1.0000	1.0000	0.9358	0.9266	1.0000	0.7936	0.4881	0.6069	1.0000	1.0000			
1992-1993		1.0000	0.7394	0.4269	0.4764	0.6690	1.0000	1.0000	0.6269	0.5917	1.0000	0.4189	0.1609	0.0414		
1993-1994		0.5704	1.0000	1.0000	1.0000	1.0000	0.8607	0.4202	0.4765	0.3430	0.2999	0.1622	0.3622	0.0098		
1994-1995		1.0000	0.9376	1.0000	0.6464	1.0000	0.5923	1.0000	1.0000	1.0000	0.5232	1.0000	1.0000	0.2585		
1997-1998		0.6350	0.9511	1.0000	1.0000	0.9979	0.7319	1.0000	0.6590	0.8348	0.5215	1.0000	0.3667	0.5880		
No. Obs.	0	9	9	9	9	9	9	9	9	9	8	6	6	4	0	0
Mean		0.8923	0.8993	0.8343	0.8418	0.8978	0.9013	0.8420	0.6874	0.6134	0.6189	0.7635	0.4816	0.2244		
Smoothed	0.9129	0.9076	0.8998	0.8889	0.8741	0.8545	0.8287	0.7954	0.7527	0.6990	0.6333	0.5559	0.4692	0.3783	0.2898	0.2106

Table 4. Security Cove District summary of the 1998 Pacific herring harvest, escapement and total run biomass, and the 1999 projected biomass by age.

1998 Total Run Summary

		Harvest		Escapement		Total Run				
Year Class	Age Class	Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Estimated Weight (g)	Percent by Weight	Percent by Number
1996	2	0	0	0	0	0	0	74	0.0	0.0
1995	3	0	0	8	73,923	8	73,923	103	0.2	0.5
1994	4	0	0	90	609,868	90	609,868	134	2.2	4.1
1993	5	4	15,939	1,079	5,562,737	1,083	5,578,676	176	27.0	37.4
1992	6	29	87,665	294	1,275,179	322	1,362,844	215	8.0	9.1
1991	7	90	247,057	434	1,607,834	524	1,854,891	256	13.0	12.4
1990	8	166	462,235	294	961,004	461	1,423,240	294	11.5	9.5
1989	9	220	573,809	191	572,906	411	1,146,716	325	10.2	7.7
1988	10	232	573,809	382	1,053,409	614	1,627,218	342	15.3	10.9
1987	11	158	366,600	131	351,136	289	717,737	365	7.2	4.8
1986	12	55	127,513	71	184,809	126	312,322	367	3.1	2.1
1985	13	44	95,635	15	36,962	59	132,597	403	1.5	0.9
1984	14	15	31,878	15	36,962	30	68,840	396	0.7	0.5
1983	15	0	0	0	0	0	0	371	0.0	0.0
1982	16	0	0	0	0	0	0	375	0.0	0.0
1981	17	0	0	0	0	0	0	378	0.0	0.0
Totals & Means:		1,012	2,582,142	3,005	12,326,729	4,017	14,908,871	244	100.0	100.0

1999 Projection Summary

					Projection				
Year Class	Age Class	Recruitment Schedule	1997 Escapement	Survival Rates	Projected Weight (g)	Biomass (tons)	Number of Fish	Percent by Weight	Percent by Number
1997	2	0.00	0	0.949	74	0	0	0.0	0.0
1996	3	0.43	0	0.944	103	0	0	0.0	0.0
1995	4	0.86	7,503,671	0.936	134	22	149,290	0.7	1.4
1994	5	0.97	2,027,454	0.924	176	128	660,693	4.2	6.1
1993	6	1.00	3,093,435	0.906	215	1,216	5,137,187	39.7	47.2
1992	7	1.00	1,588,521	0.881	256	326	1,155,312	10.7	10.6
1991	8	1.00	606,146	0.845	294	458	1,416,180	15.0	13.0
1990	9	1.00	1,818,438	0.793	325	291	811,568	9.5	7.5
1989	10	1.00	794,260	0.722	342	171	454,429	5.6	4.2
1988	11	1.00	209,016	0.628	365	306	760,666	10.0	7.0
1987	12	1.00	146,311	0.514	367	89	220,619	2.9	2.0
1986	13	1.00	125,410	0.388	403	42	94,899	1.4	0.9
1985	14	1.00	20,902	0.267	396	6	14,323	0.2	0.1
1984	15	1.00	20,902	0.167	371	4	9,861	0.1	0.1
1983	16	1.00	0	0.096	375	0	0	0.0	0.0
1982	17	1.00	0	0.051	378	0	0	0.0	0.0
Totals & Means:			17,954,466		255	3,060	10,885,029	100.0	100.0

Table 5. Goodnews Bay District summary of the 1998 Pacific herring harvest, escapement and total run biomass, and the 1999 projected biomass by age.

1998 Total Run Summary

		Harvest		Escapement		Total Run				
Year Class	Age Class	Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Estimated Weight (g)	Percent by Weight	Percent by Number
1996	2	0	0	0	0	0	0	62	0.0	0.0
1995	3	0	0	18	157,529	18	157,529	104	0.4	1.2
1994	4	3	11,588	97	596,022	100	607,610	149	2.5	4.5
1993	5	8	28,969	682	3,279,130	689	3,308,099	189	17.0	24.7
1992	6	28	86,908	196	779,499	223	866,407	234	5.5	6.5
1991	7	79	237,547	514	1,754,064	593	1,991,611	270	14.6	14.9
1990	8	141	393,981	402	1,248,817	543	1,642,798	300	13.4	12.3
1989	9	127	318,661	306	874,055	433	1,192,716	329	10.6	8.9
1988	10	265	648,909	481	1,252,685	746	1,901,595	356	18.4	14.2
1987	11	114	272,310	288	740,373	402	1,012,683	360	9.9	7.6
1986	12	34	81,114	115	267,700	149	348,813	388	3.7	2.6
1985	13	21	46,351	74	167,438	95	213,789	404	2.3	1.6
1984	14	9	17,382	53	117,643	62	135,024	416	1.5	1.0
1983	15	2	5,794	8	16,710	11	22,504	426	0.3	0.2
1982	16	0	0	0	0	0	0	434	0.0	0.0
1981	17	0	0	0	0	0	0	441	0.0	0.0
Totals & Means:		831	2,149,513	3,233	11,251,666	4,064	13,401,178	275	100.0	100.0

1999 Projection Summary

					Projection				
Year Class	Age Class	Recruitment Schedule	1997 Escapement	Survival Rates	Projected Weight (g)	Biomass (tons)	Number of Fish	Percent by Weight	Percent by Number
1997	2	0.00	0	0.949	62	0	0	0.0	0.0
1996	3	0.43	0	0.944	104	0	0	0.0	0.0
1995	4	0.86	6,157,483	0.936	149	52	318,132	1.7	3.3
1994	5	0.97	1,920,668	0.924	189	135	647,406	4.5	6.7
1993	6	1.00	3,385,320	0.906	234	781	3,028,277	26.0	31.5
1992	7	1.00	1,689,150	0.881	270	210	706,227	7.0	7.4
1991	8	1.00	861,713	0.845	300	511	1,544,979	17.0	16.1
1990	9	1.00	1,736,043	0.793	329	382	1,054,626	12.7	11.0
1989	10	1.00	931,061	0.722	356	272	693,301	9.0	7.2
1988	11	1.00	220,487	0.628	360	359	904,564	11.9	9.4
1987	12	1.00	170,176	0.514	388	199	465,177	6.6	4.8
1986	13	1.00	202,248	0.388	404	61	137,464	2.0	1.4
1985	14	1.00	107,839	0.267	416	30	64,882	1.0	0.7
1984	15	1.00	45,100	0.167	426	15	31,387	0.5	0.3
1983	16	1.00	60,134	0.096	434	1	2,796	0.0	0.0
1982	17	1.00	0	0.051	441	0	0	0.0	0.0
Totals & Means:			17,487,422		284	3,009	9,599,215	100.0	100.0

Table 6. Cape Avinof District summary of the 1998 Pacific herring harvest, escapement and total run biomass, and the 1999 projected biomass by age.

1998 Total Run Summary

		Harvest		Escapement		Total Run				
Year Class	Age Class	Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Estimated Weight (g)	Percent by Weight	Percent by Number
1996	2	0	0	4	46,078	4	46,078	76	0.1	0.3
1995	3	0	0	31	253,430	31	253,430	109	0.7	1.7
1994	4	0	0	127	760,290	127	760,290	151	3.0	5.1
1993	5	3	12,232	1,030	4,895,093	1,033	4,907,325	191	24.1	33.2
1992	6	10	30,580	254	1,006,179	264	1,036,759	231	6.2	7.0
1991	7	72	201,829	544	1,802,572	616	2,004,400	279	14.4	13.6
1990	8	171	458,702	579	1,730,012	750	2,188,713	311	17.5	14.8
1989	9	97	250,757	286	786,002	383	1,036,759	335	8.9	7.0
1988	10	194	483,166	528	1,267,805	722	1,750,971	374	16.8	11.8
1987	11	74	177,365	94	214,300	168	391,664	390	3.9	2.6
1986	12	27	61,160	76	169,231	103	230,391	407	2.4	1.6
1985	13	8	18,348	56	119,886	64	138,235	420	1.5	0.9
1984	14	0	0	22	46,078	22	46,078	430	0.5	0.3
1983	15	0	0	0	0	0	0	438	0.0	0.0
1982	16	0	0	0	0	0	0	444	0.0	0.0
1981	17	0	0	0	0	0	0	448	0.0	0.0
Totals & Means:		656	1,694,138	3,631	13,096,955	4,287	14,791,093	263	100.0	100.0

1999 Projection Summary

					Projection				
Year Class	Age Class	Recruitment Schedule	1997 Escapement	Survival Rates	Projected Weight (g)	Biomass (tons)	Number of Fish	Percent by Weight	Percent by Number
1997	2	0.00	0	0.949	76	0	0	0.0	0.0
1996	3	0.43	102,631	0.944	109	5	43,724	0.1	0.4
1995	4	0.86	7,885,461	0.936	151	85	511,806	2.4	4.4
1994	5	0.97	838,151	0.924	191	170	809,342	4.8	6.9
1993	6	1.00	2,189,455	0.906	231	1,151	4,520,619	32.4	38.8
1992	7	1.00	2,753,924	0.881	279	280	911,598	7.9	7.8
1991	8	1.00	855,256	0.845	311	544	1,587,705	15.3	13.6
1990	9	1.00	2,052,614	0.793	335	540	1,460,995	15.2	12.5
1989	10	1.00	667,100	0.722	374	257	623,457	7.2	5.3
1988	11	1.00	256,577	0.628	390	393	915,482	11.1	7.8
1987	12	1.00	102,631	0.514	407	60	134,645	1.7	1.2
1986	13	1.00	102,631	0.388	420	40	86,900	1.1	0.7
1985	14	1.00	34,210	0.267	430	22	46,456	0.6	0.4
1984	15	1.00	0	0.167	438	6	12,294	0.2	0.1
1983	16	1.00	0	0.096	444	0	0	0.0	0.0
1982	17	1.00	0	0.051	448	0	0	0.0	0.0
Totals & Means:			17,840,641		277	3,555	11,665,021	100.0	100.0

Table 7. Nelson Island District summary of the 1998 Pacific herring harvest, escapement and total run biomass, and the 1999 projected biomass by age.

1998 Total Run Summary

Year Class	Age Class	Harvest Biomass (tons)	Harvest Number of Fish	Escapement Biomass (tons)	Escapement Number of Fish	Total Run Biomass (tons)	Total Run Number of Fish	Total Run Estimated Weight (g)	Total Run Percent by Weight	Total Run Percent by Number
1996	2	0	0	3	33,663	3	33,663	91	0.0	0.1
1995	3	0	0	38	286,132	38	286,132	120	0.5	1.2
1994	4	0	0	181	1,060,372	181	1,060,372	155	2.5	4.3
1993	5	4	16,653	1,709	7,995,049	1,713	8,011,702	194	24.0	32.4
1992	6	8	24,979	340	1,338,357	349	1,363,336	232	4.9	5.5
1991	7	171	466,279	995	3,421,753	1,166	3,888,032	272	16.3	15.7
1990	8	225	566,195	988	3,052,536	1,213	3,618,731	304	17.0	14.7
1989	9	248	599,501	532	1,521,244	781	2,120,745	334	10.9	8.6
1988	10	362	849,293	709	1,944,704	1,072	2,793,997	348	15.0	11.3
1987	11	154	349,709	206	559,182	361	908,891	360	5.1	3.7
1986	12	45	91,590	180	430,180	224	521,771	390	3.1	2.1
1985	13	21	41,632	7	25,693	28	67,325	382	0.4	0.3
1984	14	12	24,979	0	0	7	16,831	387	0.1	0.1
1983	15	0	0	0	0	0	0	390	0.0	0.0
1982	16	0	0	0	0	0	0	392	0.0	0.0
1981	17	0	0	0	0	0	0	393	0.0	0.0
Totals & Means:		1,250	3,030,810	5,886	21,668,865	7,136	24,691,527	262	100.0	100.0

1999 Projection Summary

Year Class	Age Class	Recruitment Schedule	1997 Escapement	Survival Rates	Projection Projected Weight (g)	Projection Biomass (tons)	Projection Number of Fish	Projection Percent by Weight	Projection Percent by Number
1997	2	0.00	0	0.949	91	0	0	0.0	0.0
1996	3	0.43	74,753	0.944	120	4	31,936	0.1	0.2
1995	4	0.86	9,736,580	0.935	155	99	577,727	1.7	3.0
1994	5	0.97	1,046,542	0.923	194	243	1,137,957	4.2	5.9
1993	6	1.00	4,167,480	0.906	232	1,888	7,381,829	32.4	38.6
1992	7	1.00	4,316,986	0.881	272	363	1,212,283	6.2	6.3
1991	8	1.00	1,382,931	0.845	304	1,010	3,013,196	17.3	15.8
1990	9	1.00	4,559,934	0.793	334	949	2,577,866	16.3	13.5
1989	10	1.00	1,663,255	0.723	348	463	1,206,955	7.9	6.3
1988	11	1.00	654,089	0.629	360	558	1,405,438	9.6	7.3
1987	12	1.00	672,777	0.515	390	151	351,949	2.6	1.8
1986	13	1.00	485,895	0.389	382	93	221,586	1.6	1.2
1985	14	1.00	261,636	0.269	387	4	10,005	0.1	0.1
1984	15	1.00	74,753	0.169	390	0	0	0.0	0.0
1983	16	1.00	37,377	0.098	392	0	0	0.0	0.0
1982	17	1.00	0	0.052	393	0	0	0.0	0.0
Totals & Means:			29,134,987		276	5,826	19,128,726	100.0	100.0

Table 8. Nunivak Island District summary of the 1998 Pacific herring harvest, escapement and total run biomass, and the 1999 projected biomass by age.

1998 Total Run Summary

		Harvest		Escapement		Total Run				
Year Class	Age Class	Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Estimated Weight (g)	Percent by Weight	Percent by Number
1996	2	0	0	2	17,822	2	17,822	91	0.0	0.1
1995	3	0	0	20	151,486	20	151,486	120	0.5	1.2
1994	4	5	32,892	91	528,499	96	561,391	155	2.5	4.3
1993	5	85	434,640	822	3,806,981	907	4,241,621	194	24.0	32.4
1992	6	18	84,579	166	637,210	185	721,789	232	4.9	5.5
1991	7	38	143,314	579	1,915,120	617	2,058,434	272	16.3	15.7
1990	8	25	89,277	617	1,826,581	642	1,915,858	304	17.0	14.7
1989	9	16	49,338	397	1,073,445	413	1,122,782	334	10.9	8.6
1988	10	12	32,892	556	1,446,329	567	1,479,221	348	15.0	11.3
1987	11	1	2,349	190	478,843	191	481,192	360	5.1	3.7
1986	12	1	2,349	118	273,891	119	276,240	390	3.1	2.1
1985	13	0	0	15	35,644	15	35,644	382	0.4	0.3
1984	14	0	0	4	8,911	4	8,911	387	0.1	0.1
1983	15	0	0	0	0	0	0	390	0.0	0.0
1982	16	0	0	0	0	0	0	392	0.0	0.0
1981	17	0	0	0	0	0	0	393	0.0	0.0
Totals & Means:		202	871,630	3,576	12,200,762	3,778	13,072,392	262	100.0	100.0

1999 Projection Summary

					Projection				
Year Class	Age Class	Recruitment Schedule	1997 Escapement	Survival Rates	Projected Weight (g)	Biomass (tons)	Number of Fish	Percent by Weight	Percent by Number
1997	2	0.00	0	0.949	91	0	0	0.0	0.0
1996	3	0.43	39,893	0.944	120	2	16,911	0.1	0.2
1995	4	0.86	5,196,096	0.936	155	52	305,930	1.6	2.9
1994	5	0.97	558,506	0.924	194	122	571,841	3.7	5.4
1993	6	1.00	2,224,049	0.906	232	899	3,515,747	27.1	33.3
1992	7	1.00	2,303,835	0.881	272	173	577,312	5.2	5.5
1991	8	1.00	738,025	0.845	304	565	1,686,838	17.0	16.0
1990	9	1.00	2,433,488	0.793	334	568	1,542,548	17.1	14.6
1989	10	1.00	887,625	0.722	348	327	851,456	9.8	8.1
1988	11	1.00	349,066	0.628	360	414	1,044,394	12.5	9.9
1987	12	1.00	359,039	0.514	390	129	300,857	3.9	2.8
1986	13	1.00	259,306	0.388	382	59	140,643	1.8	1.3
1985	14	1.00	139,626	0.267	387	6	13,812	0.2	0.1
1984	15	1.00	39,893	0.167	390	1	2,377	0.0	0.0
1983	16	1.00	19,947	0.096	392	0	0	0.0	0.0
1982	17	1.00	0	0.051	393	0	0	0.0	0.0
Totals & Means:			15,548,394		285	3,319	10,570,666	100.0	100.0

Table 9. Cape Romanzof District summary of the 1998 Pacific herring harvest, escapement and total run biomass, and the 1999 projected biomass by age.

1998 Total Run Summary

Year Class	Age Class	Harvest		Escapement		Total Run				
		Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Biomass (tons)	Number of Fish	Estimated Weight (g)	Percent by Weight	Percent by Number
1996	2	0	0	0	0	0	0	65	0.0	0.0
1995	3	0	0	4	36,409	4	36,409	105	0.1	0.3
1994	4	0	0	31	191,147	31	191,147	148	0.7	1.4
1993	5	2	6,397	482	2,302,872	484	2,309,269	190	10.8	17.4
1992	6	2	6,397	68	263,966	70	270,363	235	1.6	2.0
1991	7	66	195,119	652	2,157,236	718	2,352,355	277	16.0	17.7
1990	8	141	377,443	702	2,093,520	842	2,470,963	309	18.7	18.6
1989	9	26	63,973	128	336,784	154	400,757	349	3.4	3.0
1988	10	261	620,541	972	2,430,304	1,233	3,050,845	367	27.4	23.0
1987	11	108	252,695	407	964,840	515	1,217,534	384	11.4	9.2
1986	12	35	79,967	138	309,477	173	389,444	402	3.8	2.9
1985	13	47	102,357	88	191,147	136	293,505	419	3.0	2.2
1984	14	26	57,576	82	172,943	108	230,519	425	2.4	1.7
1983	15	9	19,192	13	27,307	23	46,499	443	0.5	0.4
1982	16	3	6,397	5	9,102	8	15,500	459	0.2	0.1
1981	17	1	3,199	0	0	1	3,199	424	0.0	0.0
Totals & Means:		727	1,791,253	3,773	11,487,054	4,500	13,278,307	307	100.0	100.0

1999 Projection Summary

Year Class	Age Class	Recruitment Schedule	1997 Escapement	Survival Rates	Projection				
					Projected Weight (g)	Biomass (tons)	Number of Fish	Percent by Weight	Percent by Number
1997	2	0.00	0	0.949	65	0	0	0.0	0.0
1996	3	0.43	87,283	0.944	105	0	0	0.0	0.0
1995	4	0.86	3,087,643	0.935	148	12	73,513	0.4	0.8
1994	5	0.97	240,029	0.923	190	41	194,848	1.3	2.1
1993	6	1.00	1,647,470	0.906	235	550	2,126,242	16.9	23.1
1992	7	1.00	1,854,768	0.881	277	73	239,100	2.2	2.6
1991	8	1.00	381,864	0.845	309	647	1,899,662	19.9	20.6
1990	9	1.00	4,058,669	0.793	349	681	1,767,978	20.9	19.2
1989	10	1.00	1,429,262	0.723	367	108	267,204	3.3	2.9
1988	11	1.00	425,506	0.629	384	743	1,756,381	22.8	19.1
1987	12	1.00	338,222	0.515	402	269	607,270	8.3	6.6
1986	13	1.00	523,699	0.389	419	74	159,412	2.3	1.7
1985	14	1.00	152,746	0.269	425	35	74,433	1.1	0.8
1984	15	1.00	76,373	0.169	443	23	46,487	0.7	0.5
1983	16	1.00	10,910	0.098	459	2	4,618	0.1	0.1
1982	17	1.00	0	0.052	424	0	888	0.0	0.0
Totals & Means:			14,314,445		321	3,259	9,218,035	100.0	100.0

Table 10. Norton Sound District summary of the 1998 Pacific herring harvest, escapement and total run biomass, and the 1999 projected biomass by age.

1998 Total Run Summary

		Harvest				Escapement		Total Run				
Year Class	Age Class	Gillnet (tons)	B. Seine (tons)	Total (tons)	Total (number)	Biomass (tons)	Number of Fish	Mean Weight (g)	Biomass (tons)	Number of Fish	Percent by Weight	Percent by Number
1996	2	0	0	0	0	0	0	81	0	0	0.0	0.0
1995	3	0	0	0	0	14	114,472	113	14	114,472	0.0	0.1
1994	4	0	0	0	0	180	1,087,486	151	180	1,087,486	0.3	0.7
1993	5	3	0	3	11,699	7,305	34,513,383	192	7,308	34,525,082	14.0	23.1
1992	6	0	0	0	0	462	1,831,556	229	462	1,831,556	0.9	1.2
1991	7	85	0	85	241,024	6,325	20,490,532	280	6,410	20,731,556	12.3	13.8
1990	8	149	0	149	383,889	4,715	13,622,198	315	4,864	14,006,087	9.3	9.4
1989	9	200	0	200	481,566	4,775	12,134,058	358	4,975	12,615,625	9.6	8.4
1988	10	1,603	0	1,603	3,709,236	19,370	46,361,261	380	20,973	50,070,497	40.3	33.4
1987	11	137	0	137	308,841	2,314	5,208,487	403	2,451	5,517,328	4.7	3.7
1986	12	207	0	207	451,225	2,152	4,636,126	421	2,359	5,087,351	4.5	3.4
1985	13	66	0	66	137,916	798	1,659,848	436	864	1,797,764	1.7	1.2
1984	14	93	0	93	194,130	846	1,717,084	446	939	1,911,214	1.8	1.3
1983	15	61	0	61	121,749	86	171,708	455	147	293,457	0.3	0.2
1982	16	28	0	28	51,361	29	57,236	475	57	108,597	0.1	0.1
1981	17	0	0	0	0	29	57,236	466	29	57,236	0.1	0.0
Totals & Means:		2,632	0	2,632	6,092,637	49,401	143,662,672	315	52,033	149,755,309	100.0	100.0

1999 Projection Summary

					Projection				
Year Class	Age Class	Recruitment Schedule	1997 Escapement	Survival Rates	Projected Weight (g)	Biomass (tons)	Number of Fish	Percent by Weight	Percent by ^Number
1997	2	0.00	0	0.952	81	0	0	0.0	0.0
1996	3	0.43	800,254	0.938	113	0	0	0.0	0.0
1995	4	0.86	32,133,257	0.921	151	38	229,847	0.1	0.2
1994	5	0.97	1,600,507	0.900	192	222	1,050,857	0.5	0.9
1993	6	1.00	19,575,433	0.874	229	7,877	31,203,226	19.1	27.8
1992	7	1.00	14,035,216	0.842	280	495	1,600,841	1.2	1.4
1991	8	1.00	16,805,324	0.804	315	5,994	17,259,341	14.6	15.4
1990	9	1.00	48,692,349	0.760	358	4,321	10,957,175	10.5	9.8
1989	10	1.00	8,371,883	0.709	380	3,862	9,220,240	9.4	8.2
1988	11	1.00	6,094,238	0.652	403	14,598	32,864,728	35.5	29.3
1987	12	1.00	3,447,246	0.590	421	1,574	3,395,971	3.8	3.0
1986	13	1.00	1,538,949	0.526	436	1,315	2,737,209	3.2	2.4
1985	14	1.00	800,254	0.460	446	429	872,756	1.0	0.8
1984	15	1.00	184,674	0.396	455	396	790,365	1.0	0.7
1983	16	1.00	0	0.335	475	36	68,013	0.1	0.1
1982	17	1.00	0	0.279	466	10	19,189	0.0	0.0
Totals & Means:			154,079,584		333	41,169	112,269,758	100.0	100.0

Figure 1. Commercial herring fishing districts within the Arctic-Yukon -Kuskokwim Region of the northeastern Bering Sea, Alaska.

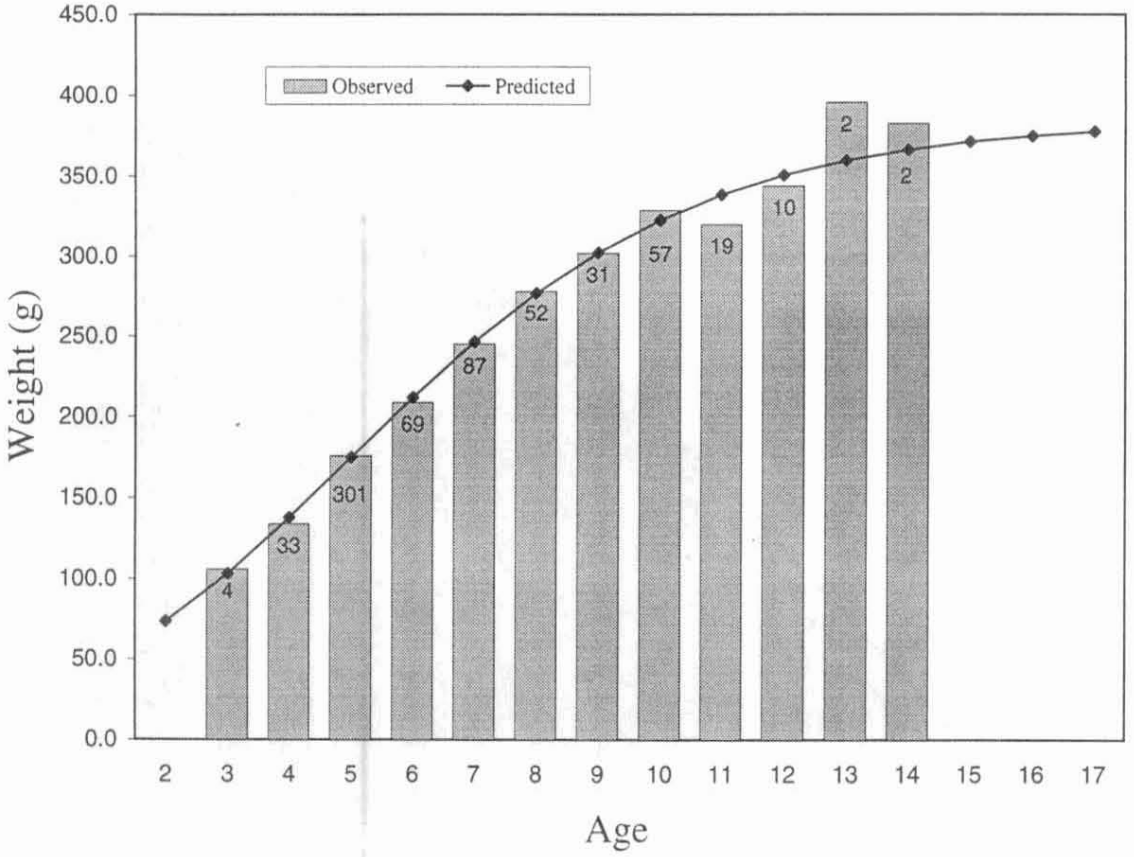

Figure 2. Growth curve fit to observed mean weights by age for Security Cove herring caught in variable mesh gillnets. Sample size is shown for each age.

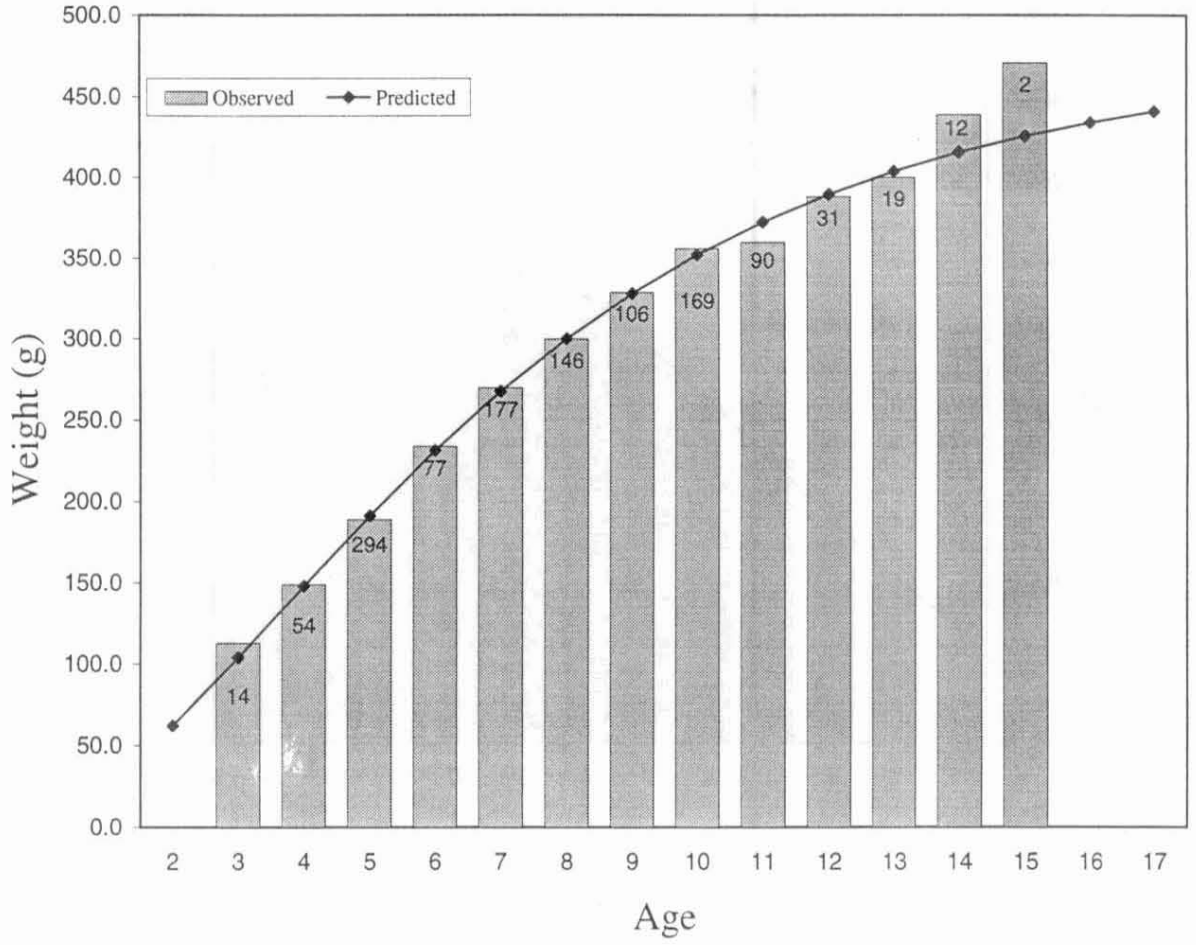

Figure 3. Growth curve fit to observed mean weights by age for Goodnews Bay herring caught in variable mesh gillnets. Sample size is shown for each age.

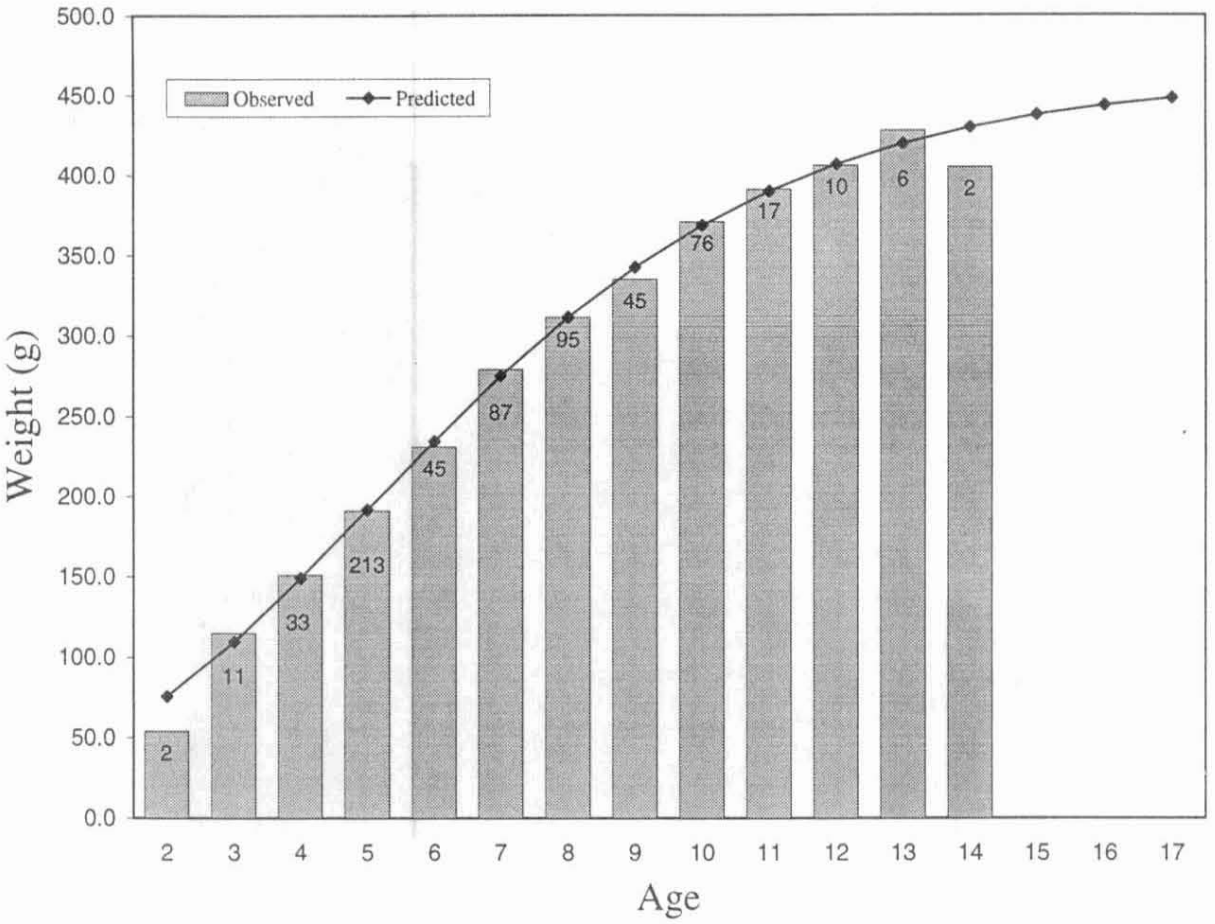

Figure 4. Growth curve fit to observed mean weights by age for Cape Avinof herring caught in variable mesh gillnets. Sample size is shown for each age.

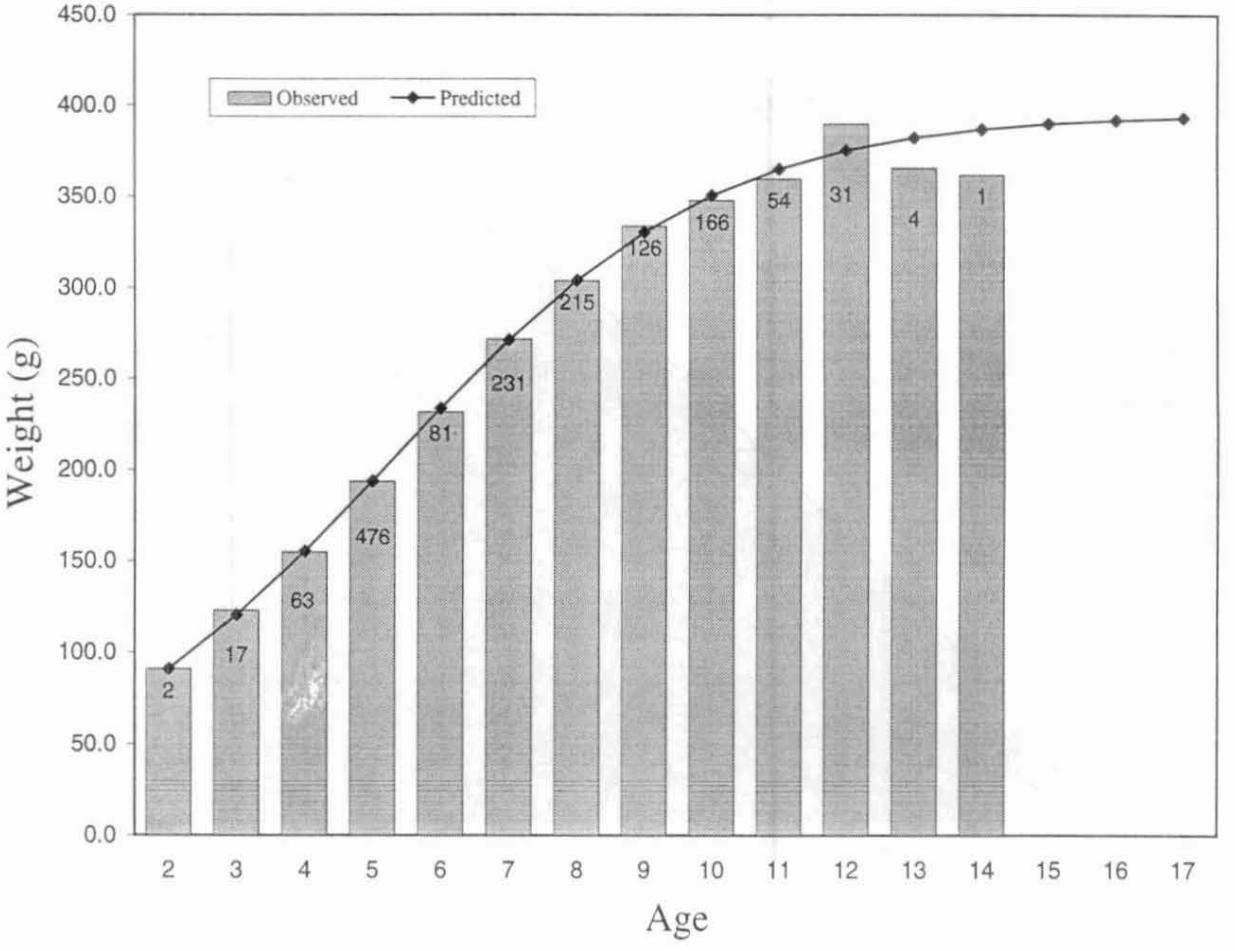

Figure 5. Growth curve fit to observed mean weights by age for Nelson Island herring caught in variable mesh gillnets. Sample size is shown for each age.

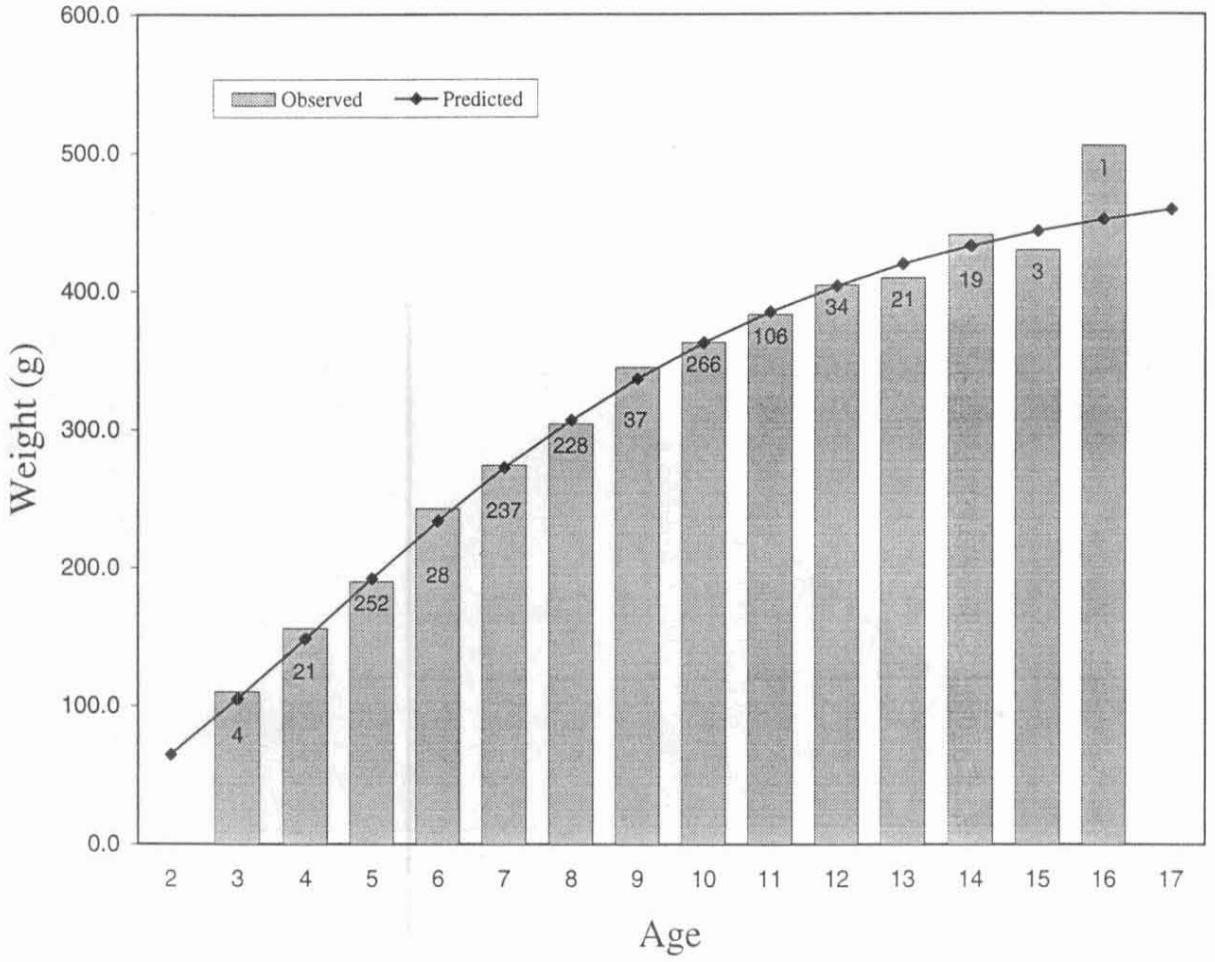

Figure 6. Growth curve fit to observed mean weights by age for Cape Romanzof herring caught in variable mesh gillnets. Sample size is shown for each age.

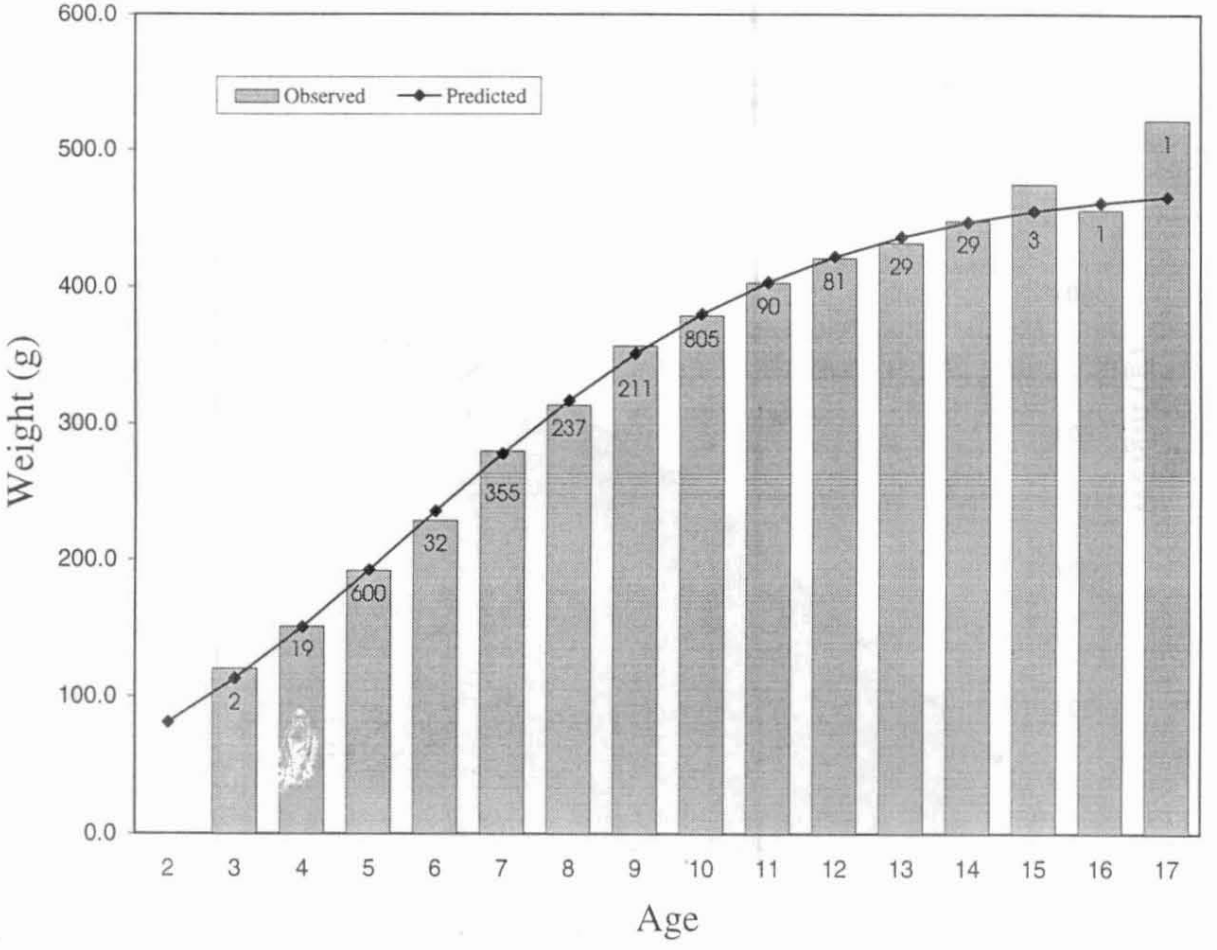

Figure 7. Growth curve fit to observed mean weights by age for Norton Sound herring caught in variable mesh gillnets. Sample size is shown for each age.

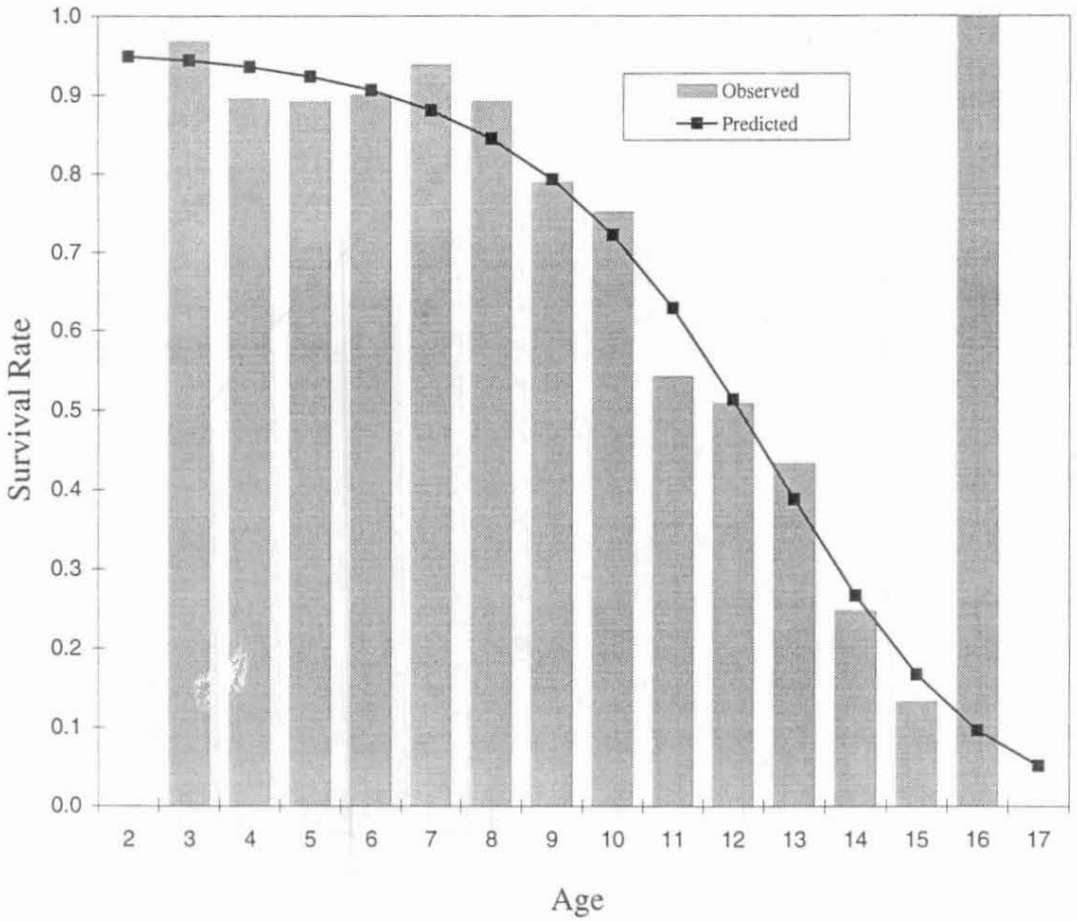

Figure 8. Observed and smoothed survival rates for Kuskokwim Area herring used for forecasting the 1999 herring returns to both the Kuskokwim Area and the Cape Romanzof District.

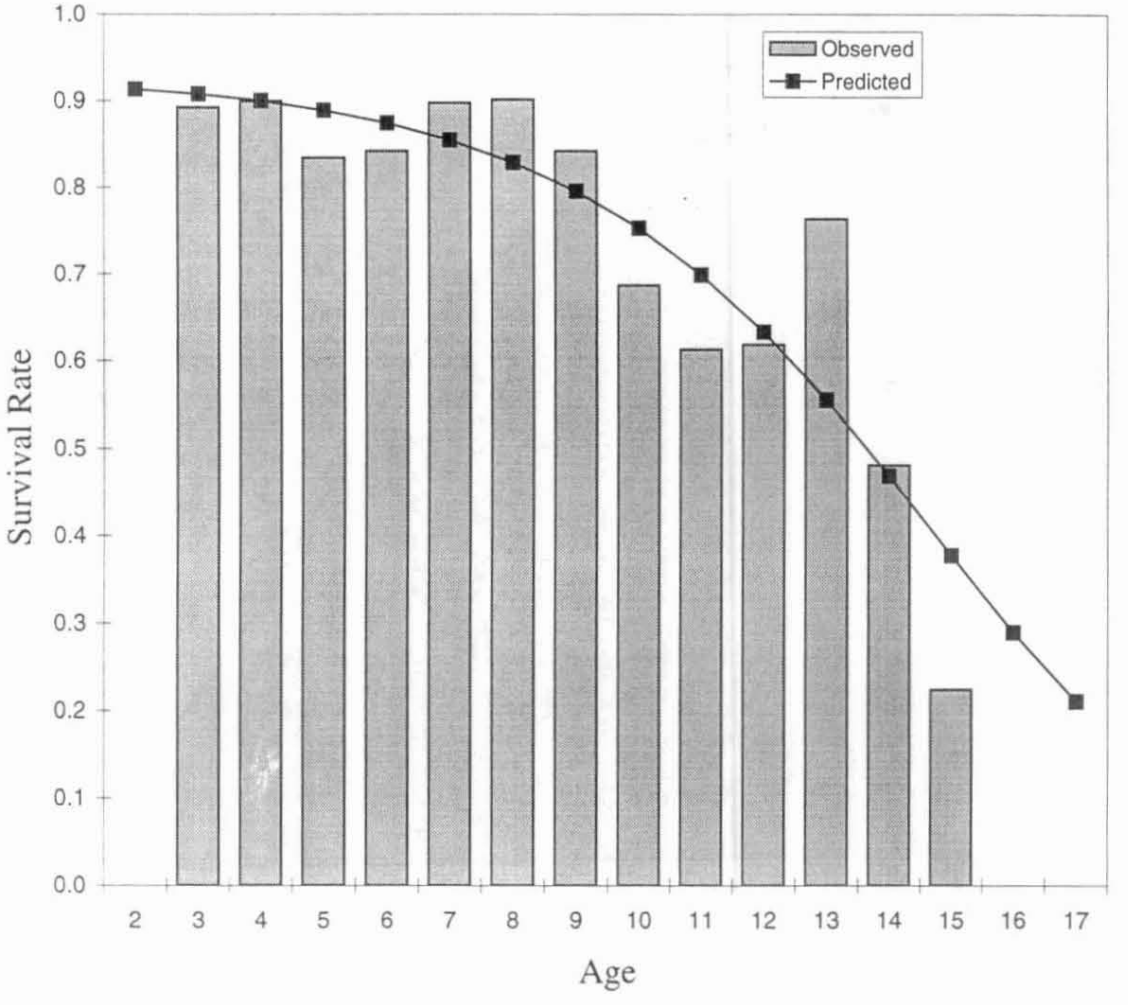

Figure 9. Observed and smoothed survival rates for Norton Sound Area herring used for forecasting the 1999 herring returns.

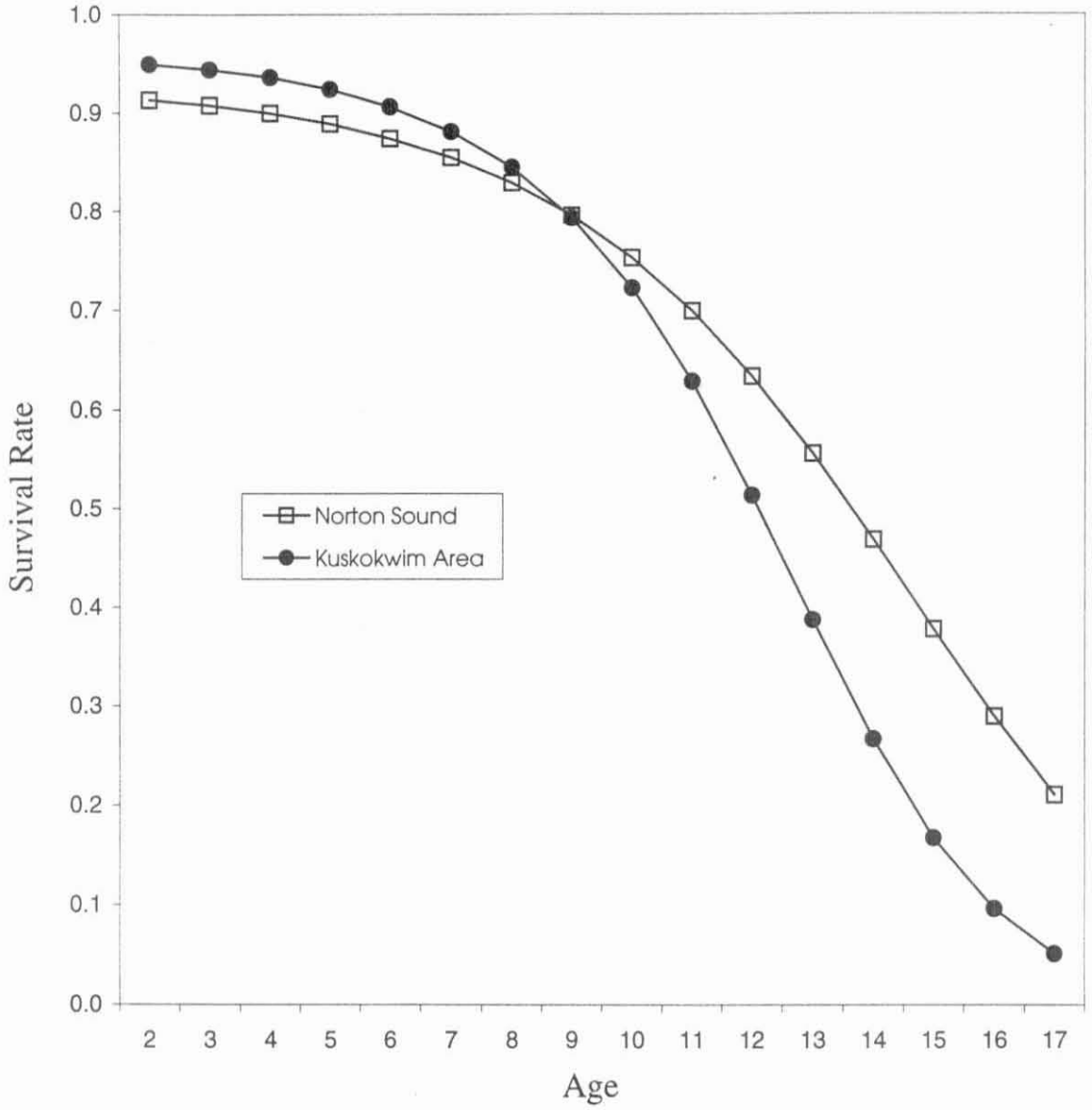

Figure 10. Comparison of Kuskokwim Area and Norton Sound herring survival rates.

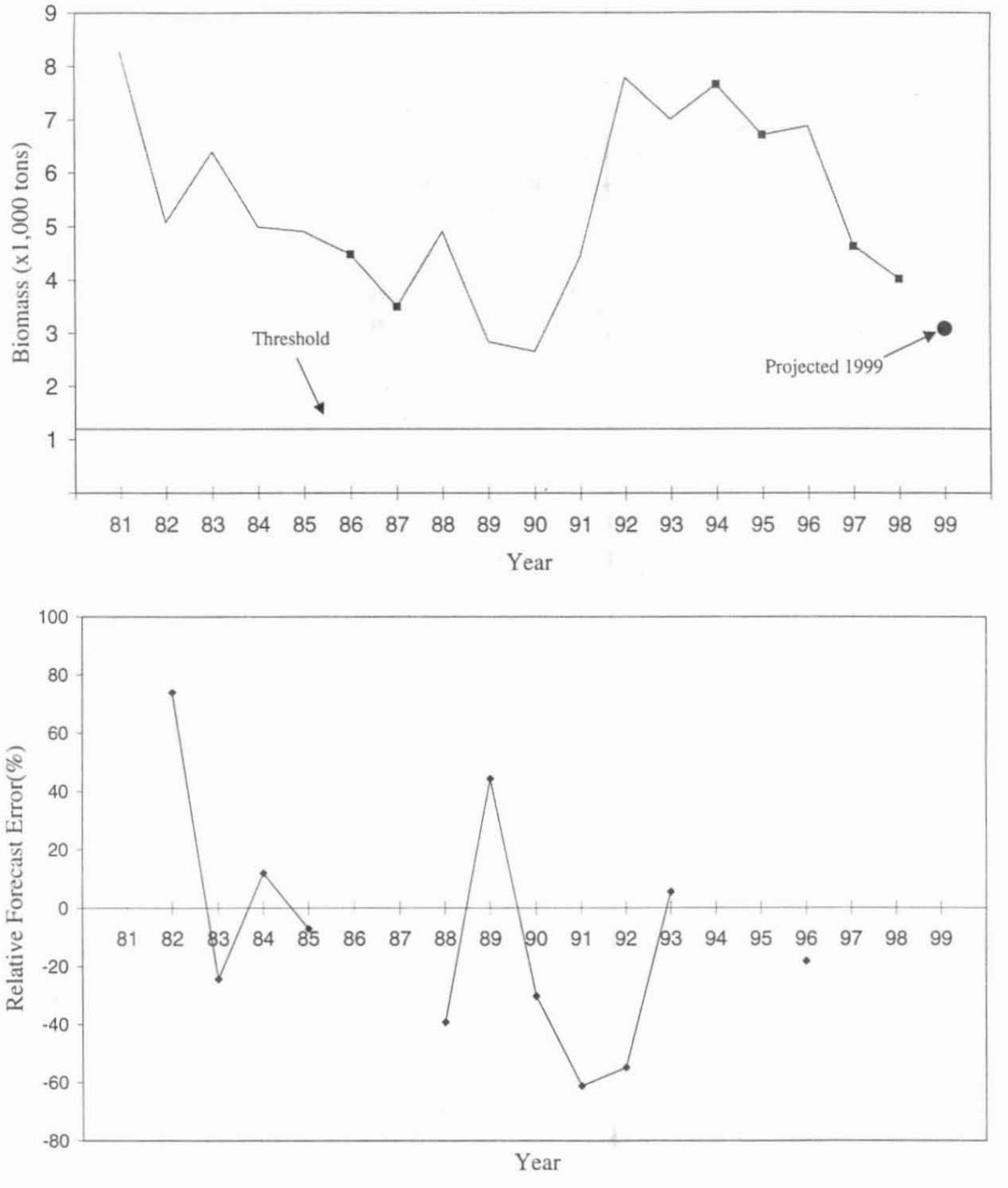

Figure 11. Security Cove District herring biomass, 1981-1998 with 1999 projected biomass (top) and the relative forecast error (bottom). Squares in the top graph and gaps in the bottom graph denote years when it was not possible to obtain an aerial survey estimate of biomass; therefore the preseason projection or some other method was used to estimate biomass.

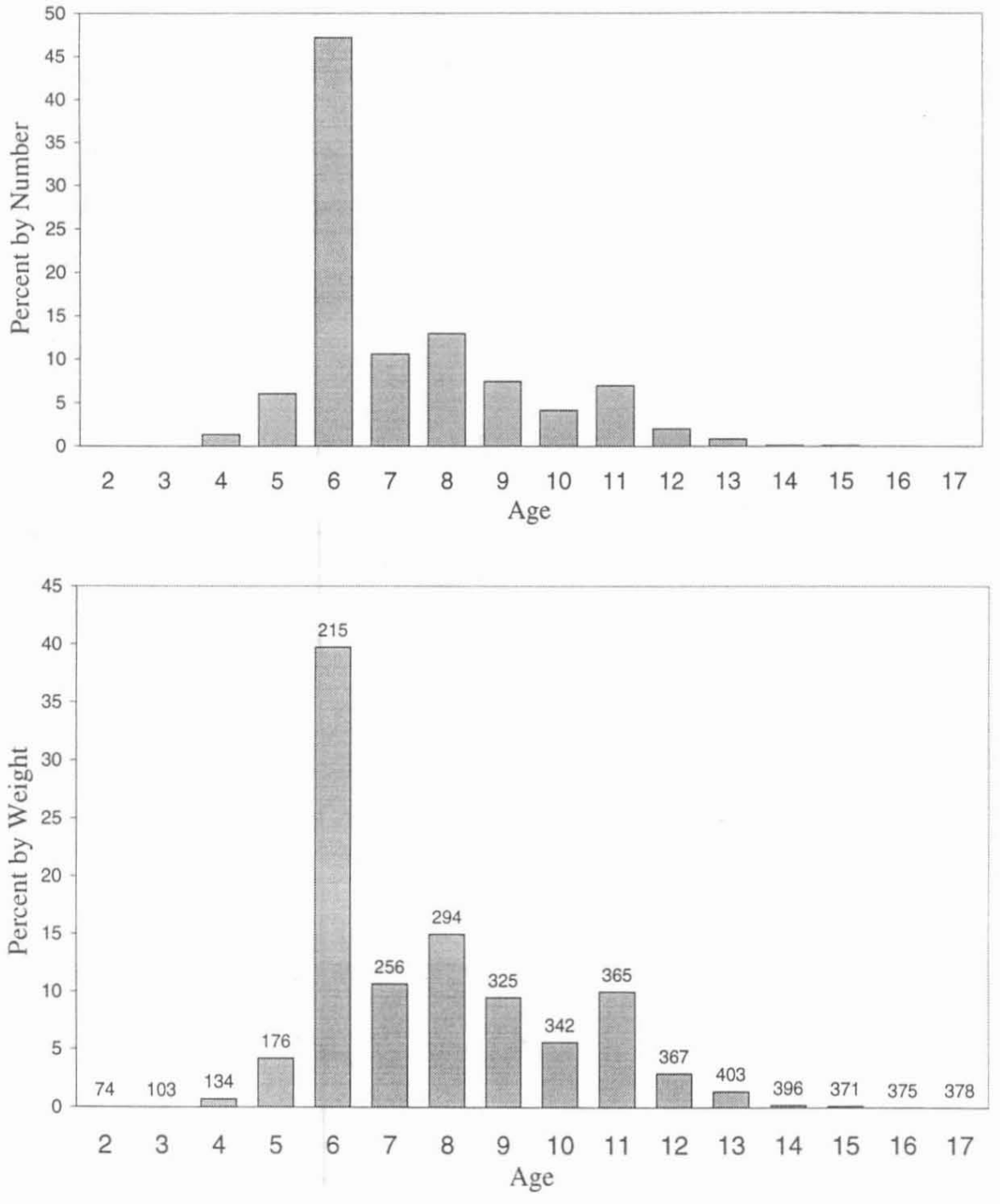

Figure 12. Projected age composition for 1999 Security Cove District herring in percent by number (top) and percent by weight (bottom) with projected weight at age in grams.

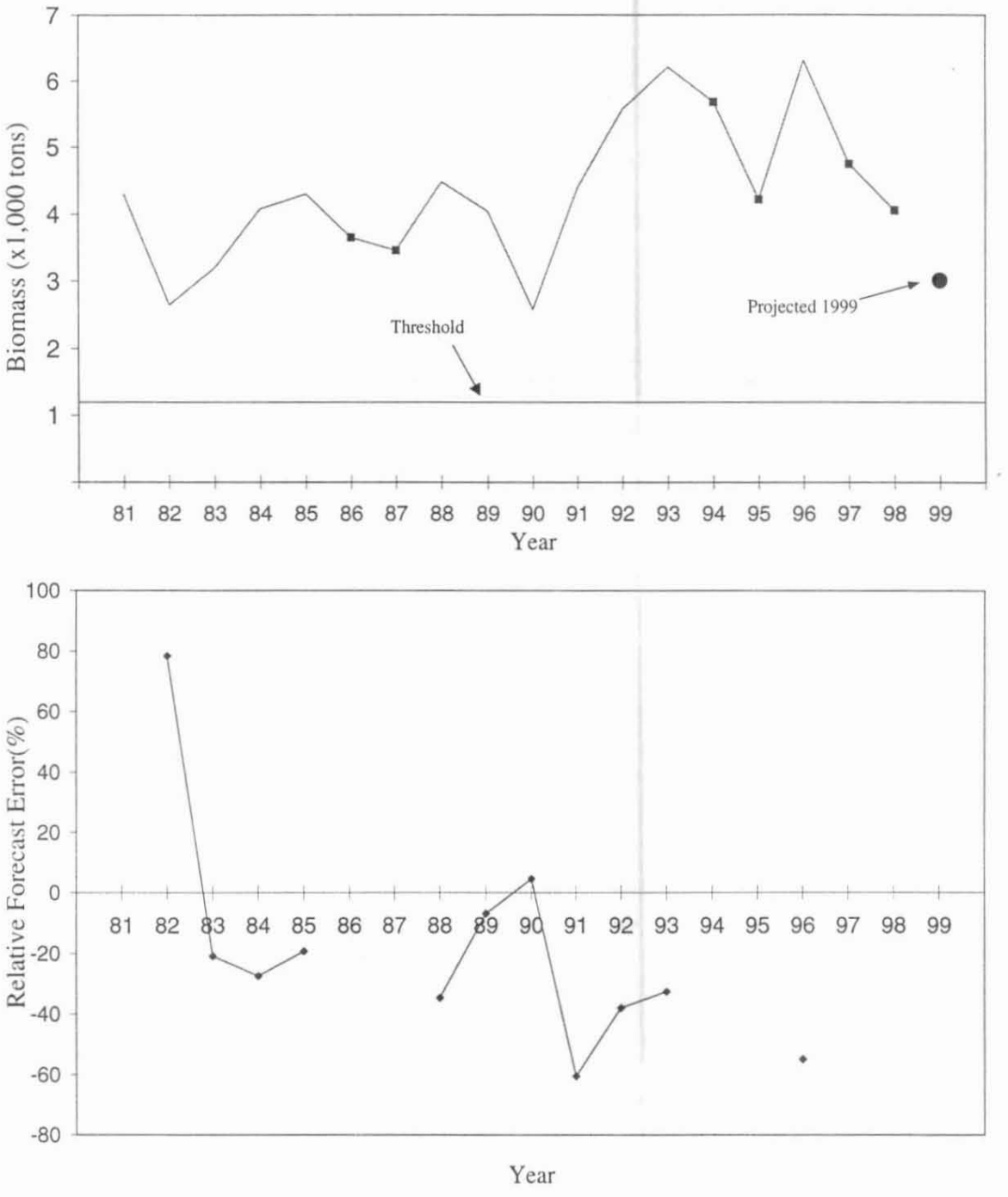

Figure 13. Goodnews Bay District herring biomass, 1981-1998 with 1999 projected biomass (top) and the relative forecast error (bottom). Squares in the top graph and gaps in the bottom graph denote years when it was not possible to obtain an aerial survey estimate of biomass; therefore the preseason projection or some other method was used to estimate biomass.

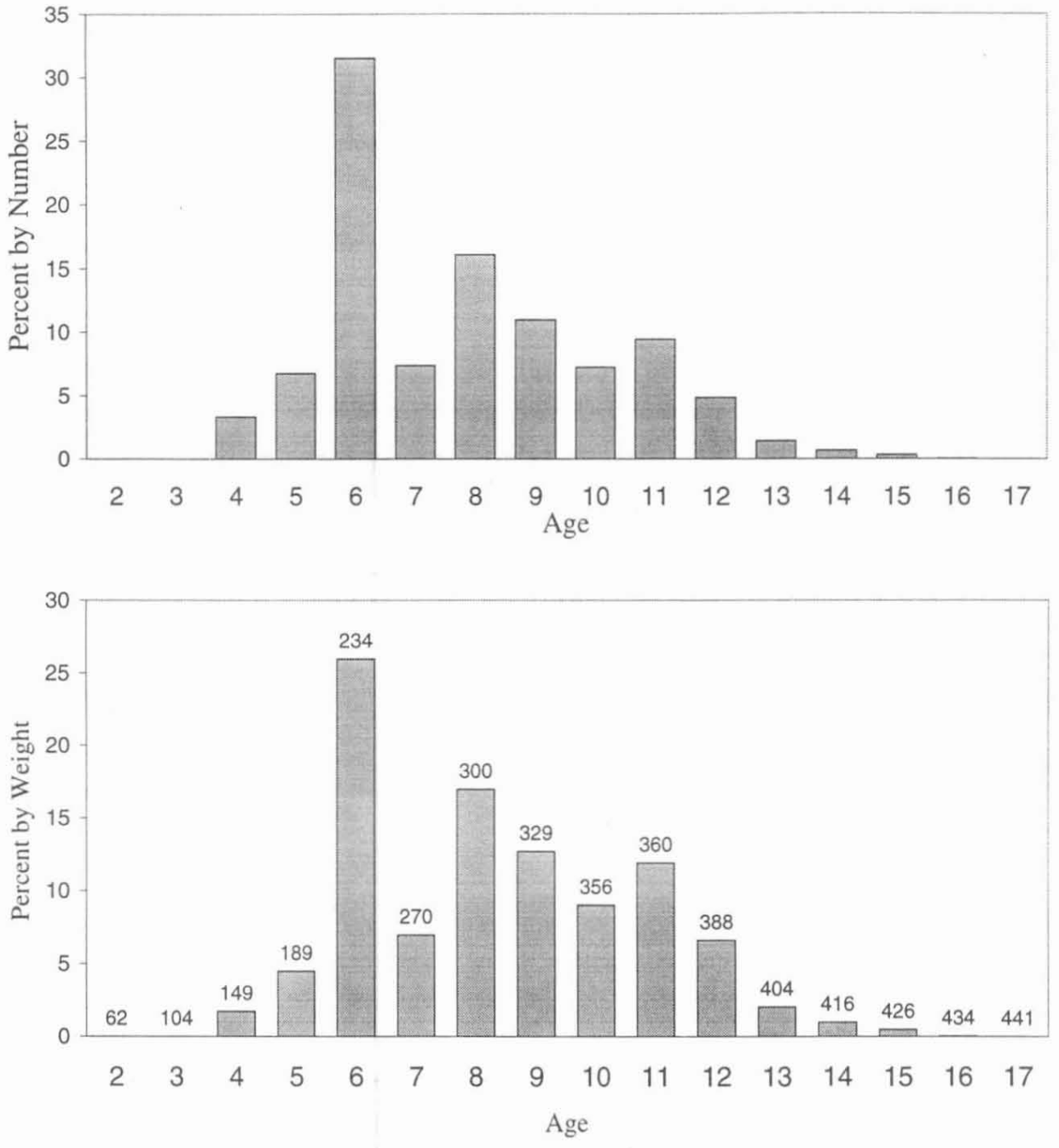

Figure 14. Projected age composition for 1999 Goodnews Bay District herring in percent by number (top) and percent by weight (bottom) with projected weight at age in grams.

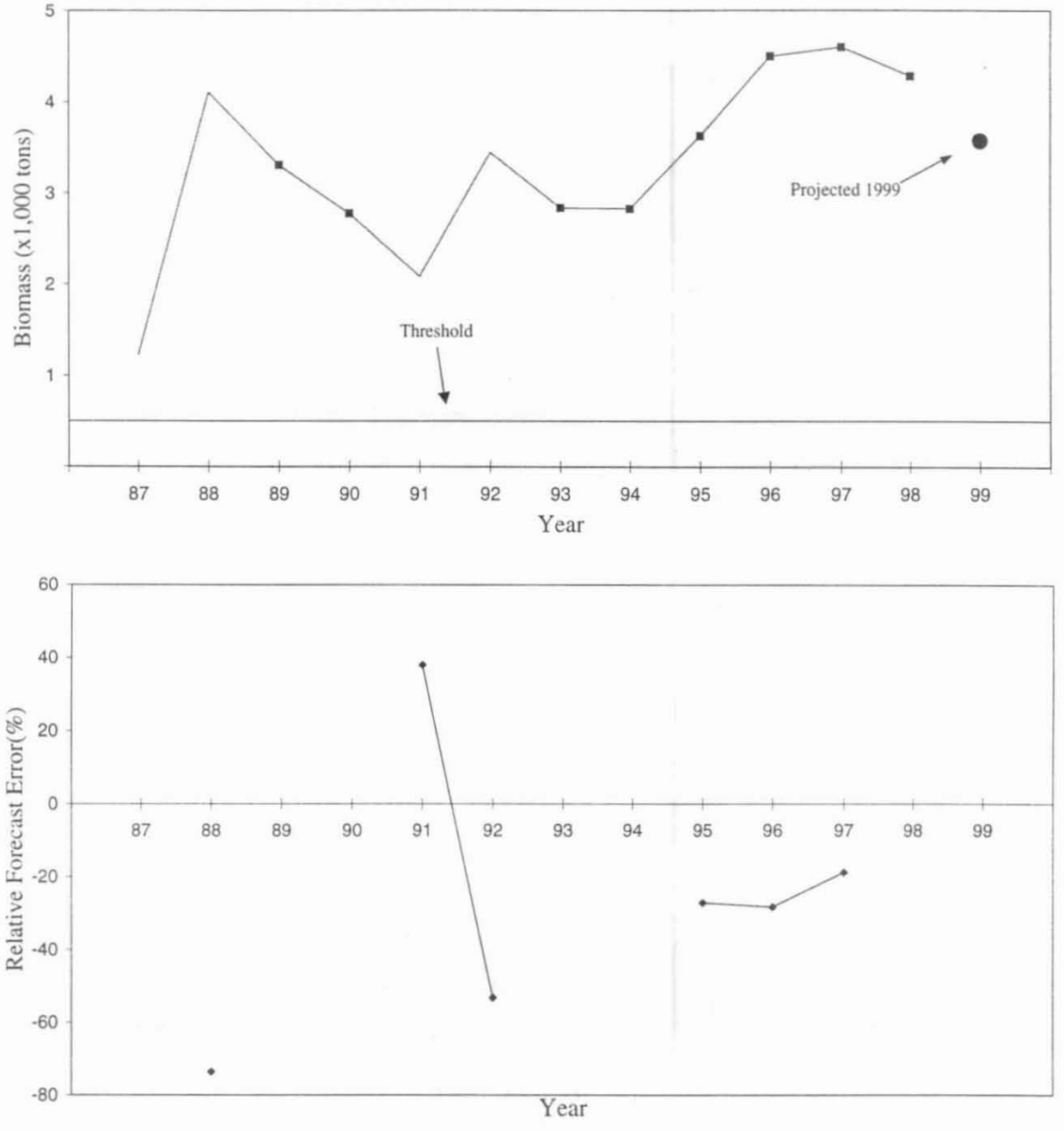

Figure 15. Cape Avinof District herring biomass, 1987-1998 with 1999 projected biomass (top) and the relative forecast error (bottom). Squares in the top graph and gaps in the bottom graph denote years when it was not possible to obtain an aerial survey estimate of biomass; therefore the preseason projection or some other method was used to estimate biomass.

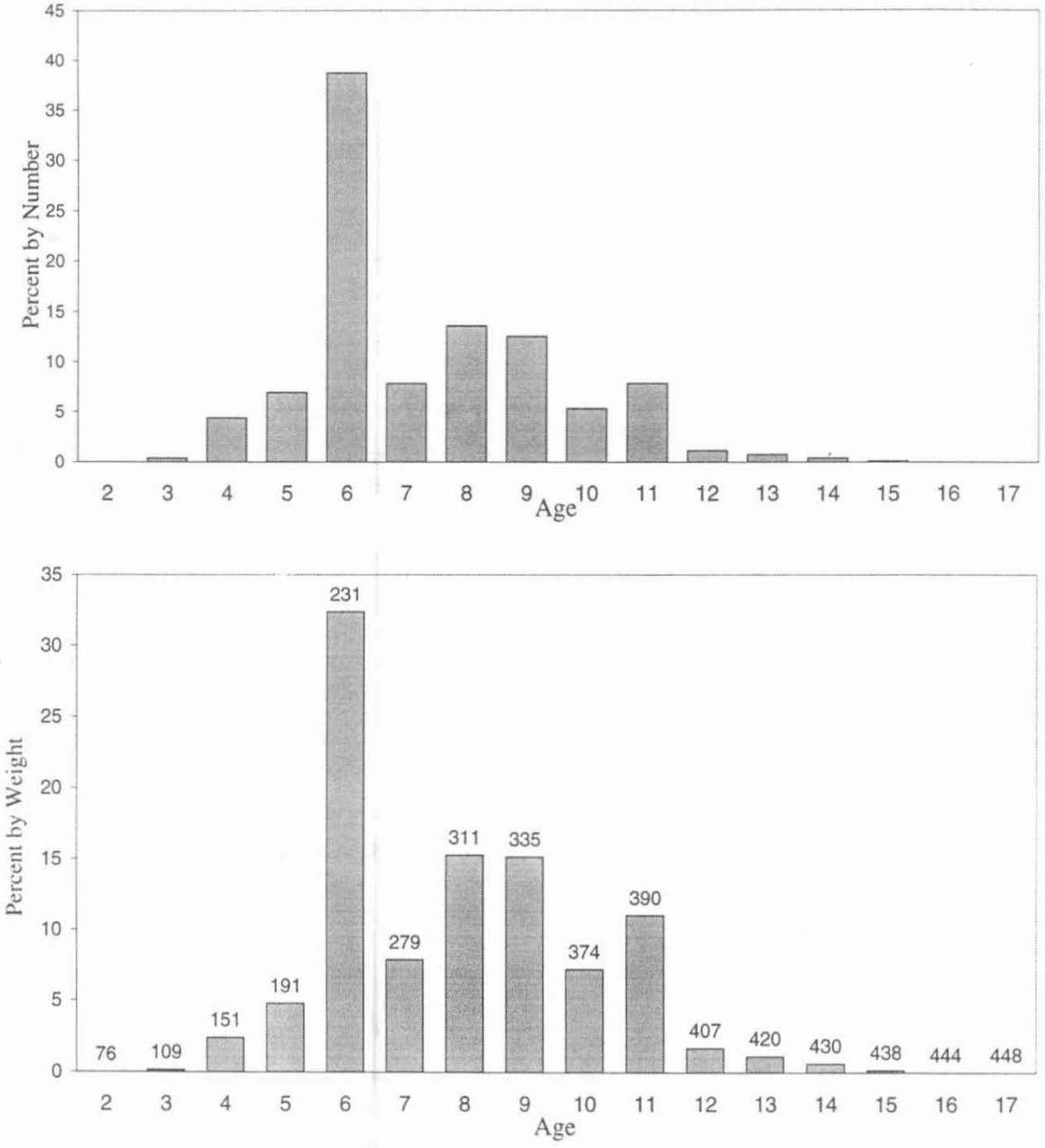

Figure 16. Projected age composition for 1999 Cape Avinof District herring in percent by number (top) and percent by weight (bottom) with projected weight at age in grams.

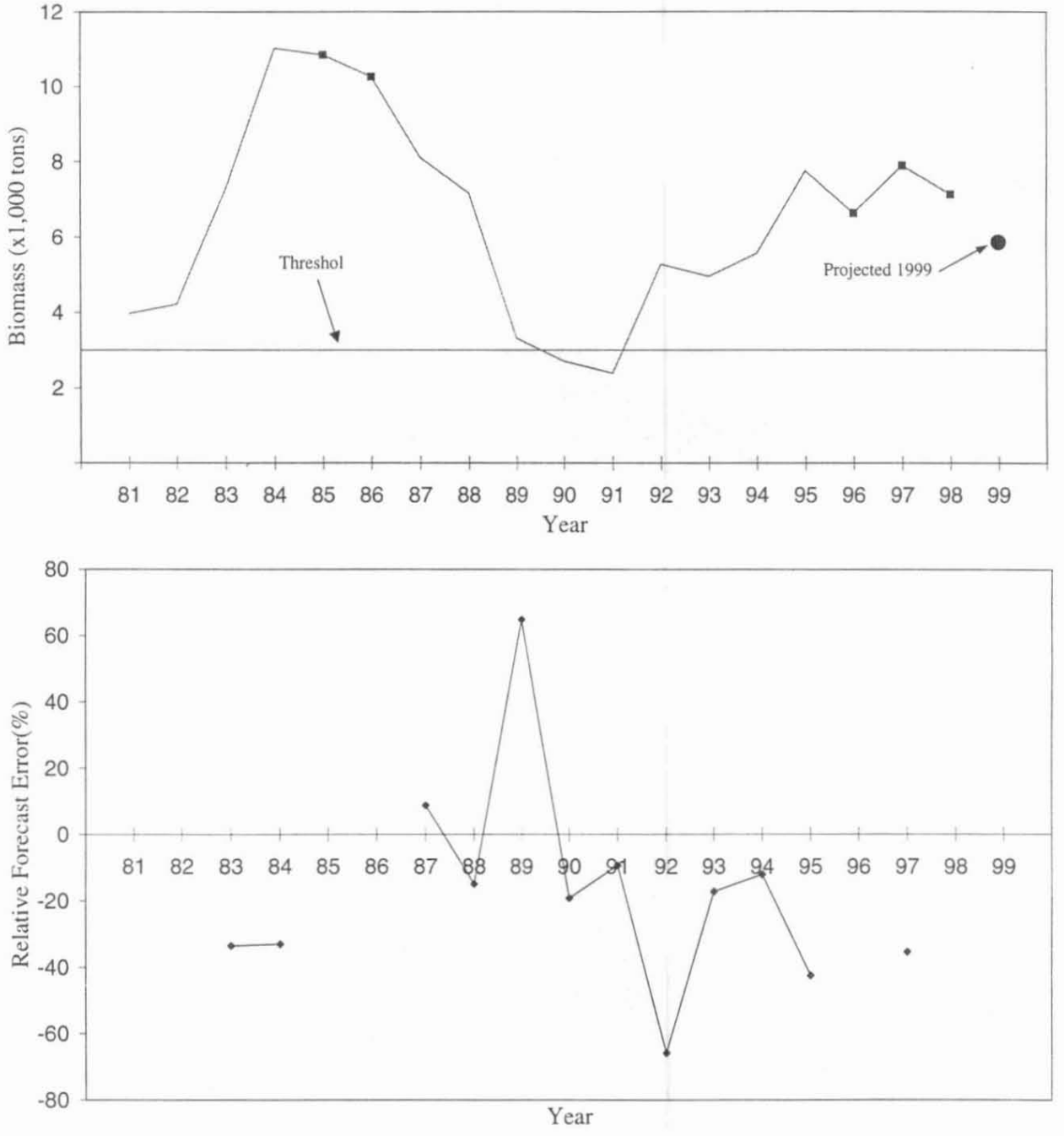

Figure 17. Nelson Island District herring biomass, 1981-1998 with 1999 projected biomass (top) and the relative forecast error (bottom). Squares in the top graph and gaps in the bottom graph denote years when it was not possible to obtain an aerial survey estimate of biomass; therefore the preseason projection or some other method was used to estimate biomass.

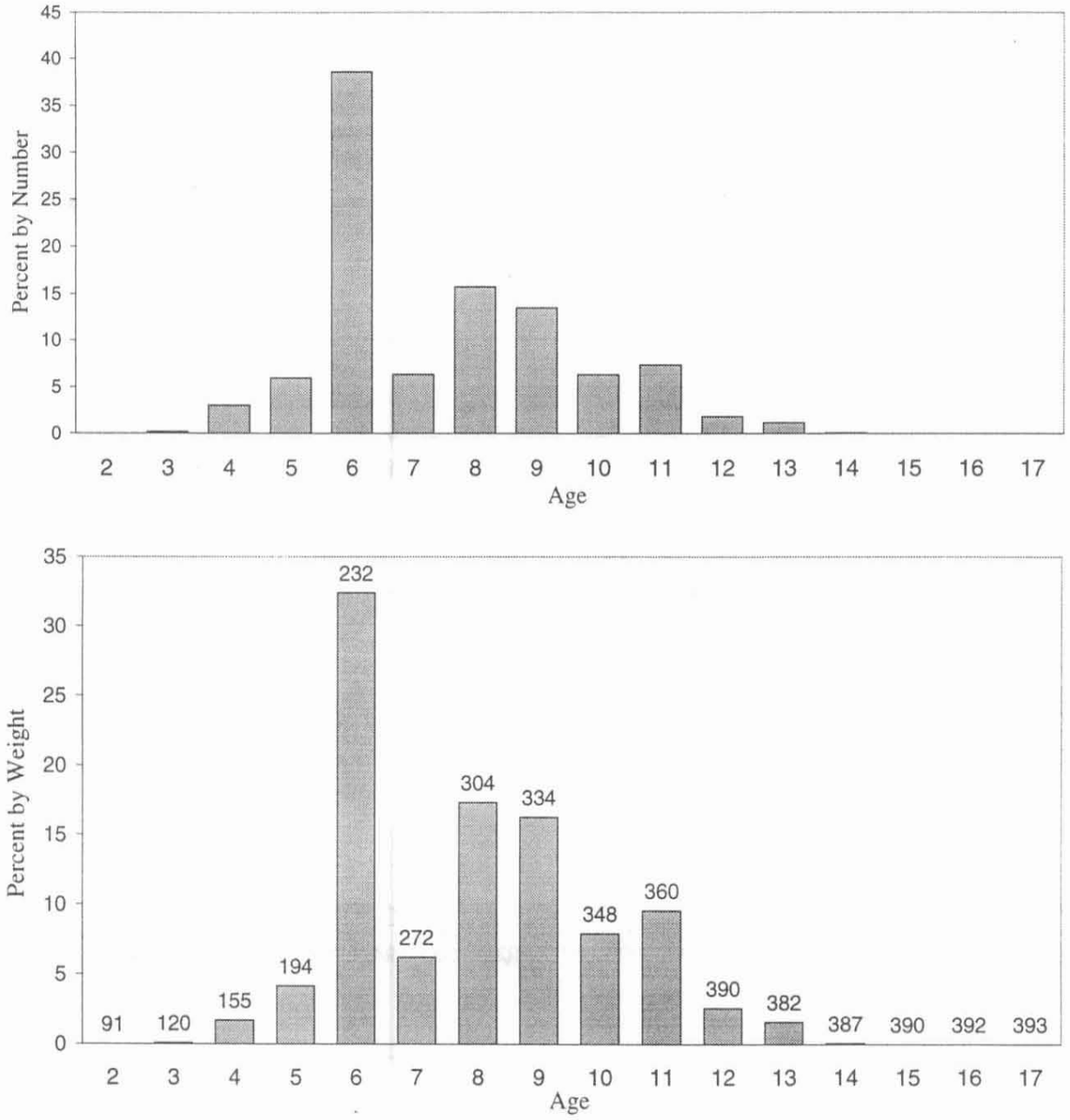

Figure 18. Projected age composition for 1999 Nelson Island District herring in percent by number (top) and percent by weight (bottom) with projected weight at age in grams.

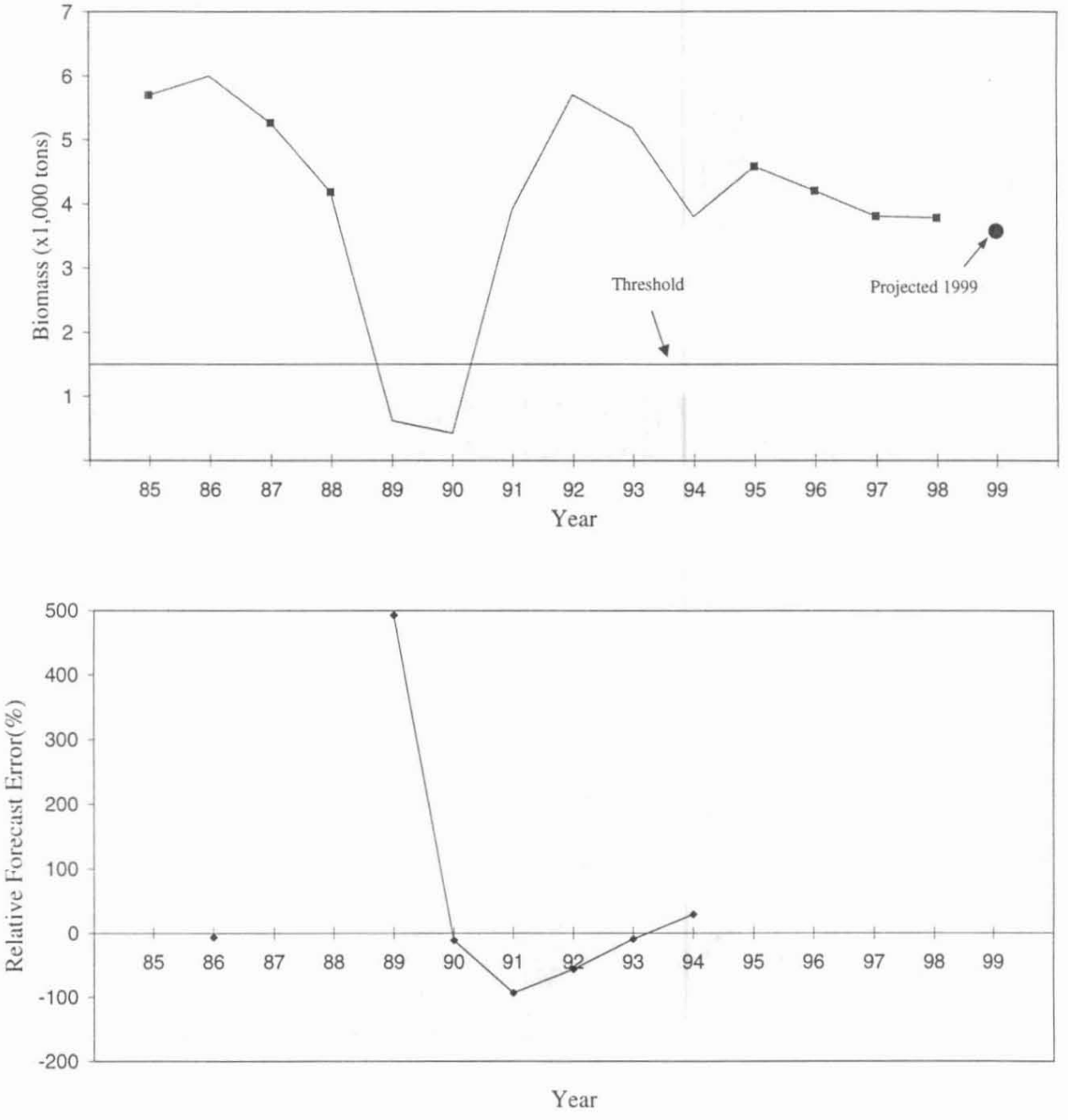

Figure 19. Nunivak Island District herring biomass, 1985-1998 with 1999 projected biomass (top) and the relative forecast error (bottom). Squares in the top graph and gaps in the bottom graph denote years when it was not possible to obtain an aerial survey estimate of biomass; therefore the preseason projection or some other method was used to estimate biomass.

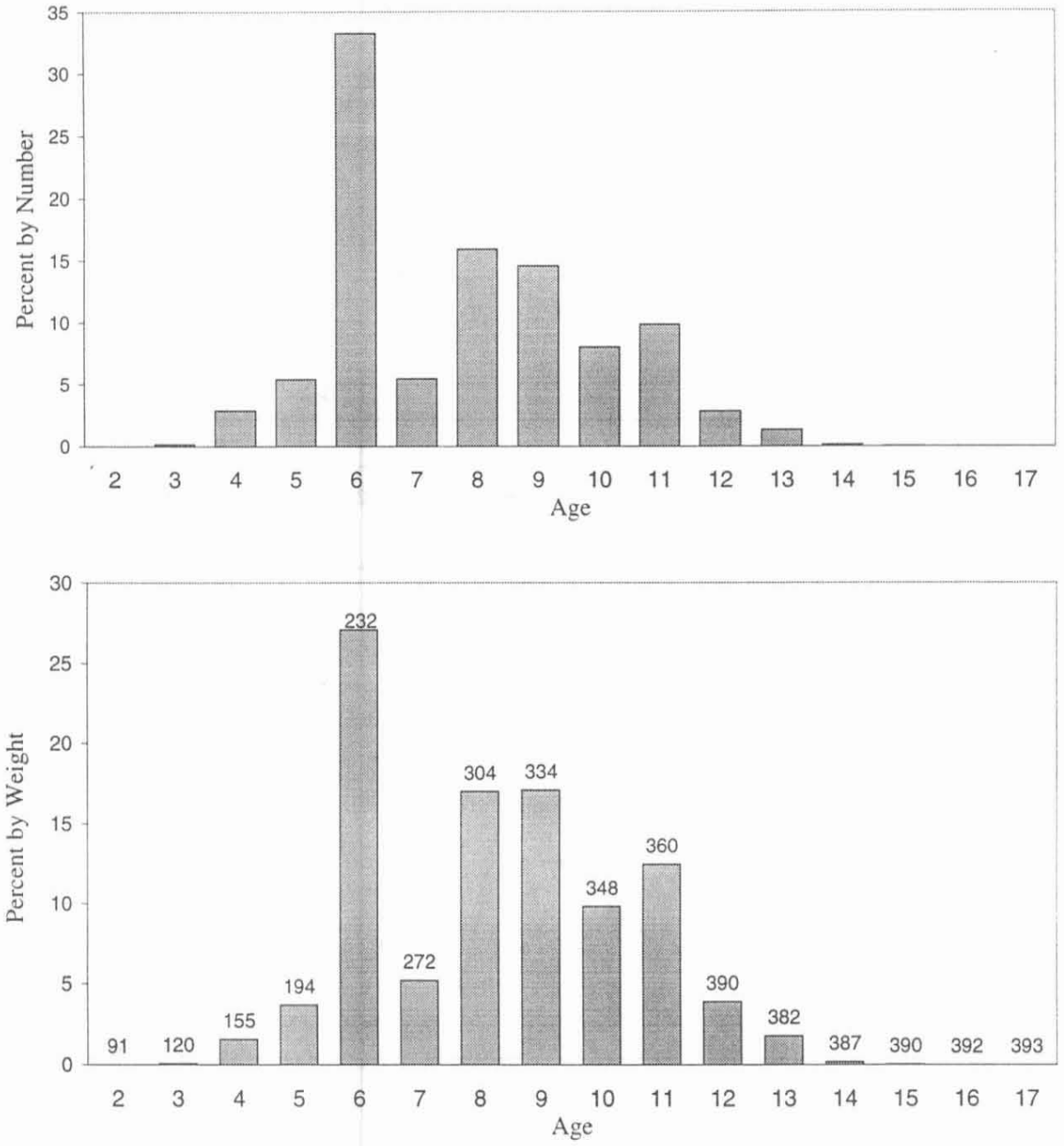

Figure 20. Projected age composition for 1999 Nunivak Island District herring in percent by number (top) and percent by weight (bottom) with projected weight at age in grams.

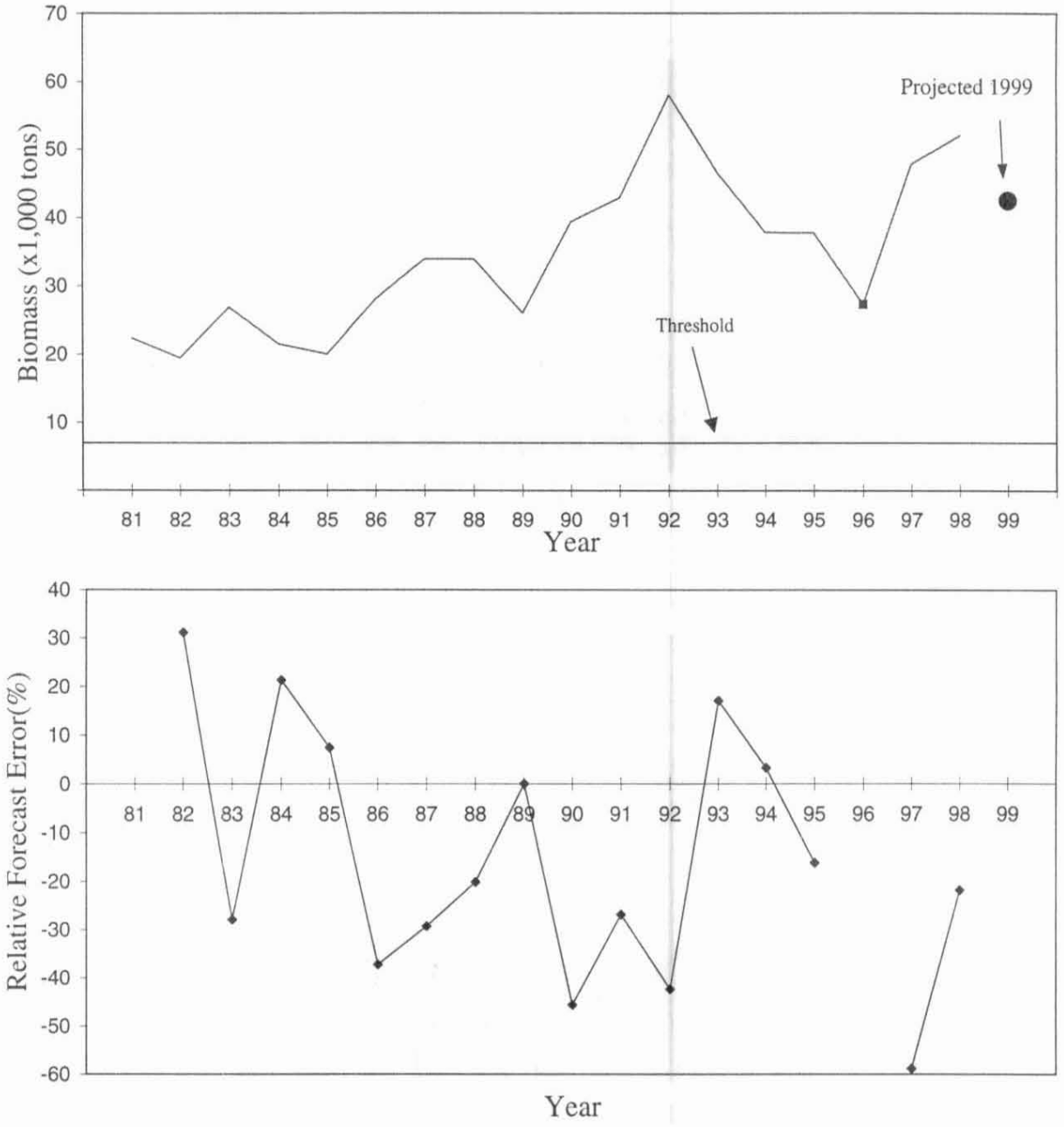

Figure 22. Norton Sound District herring biomass, 1981-1998 with 1999 projected biomass (top) and the relative forecast error (bottom). Squares in the top graph and gaps in the bottom graph denote years when it was not possible to obtain an aerial survey estimate of biomass; therefore the preseason projection or some other method was used to estimate biomass.

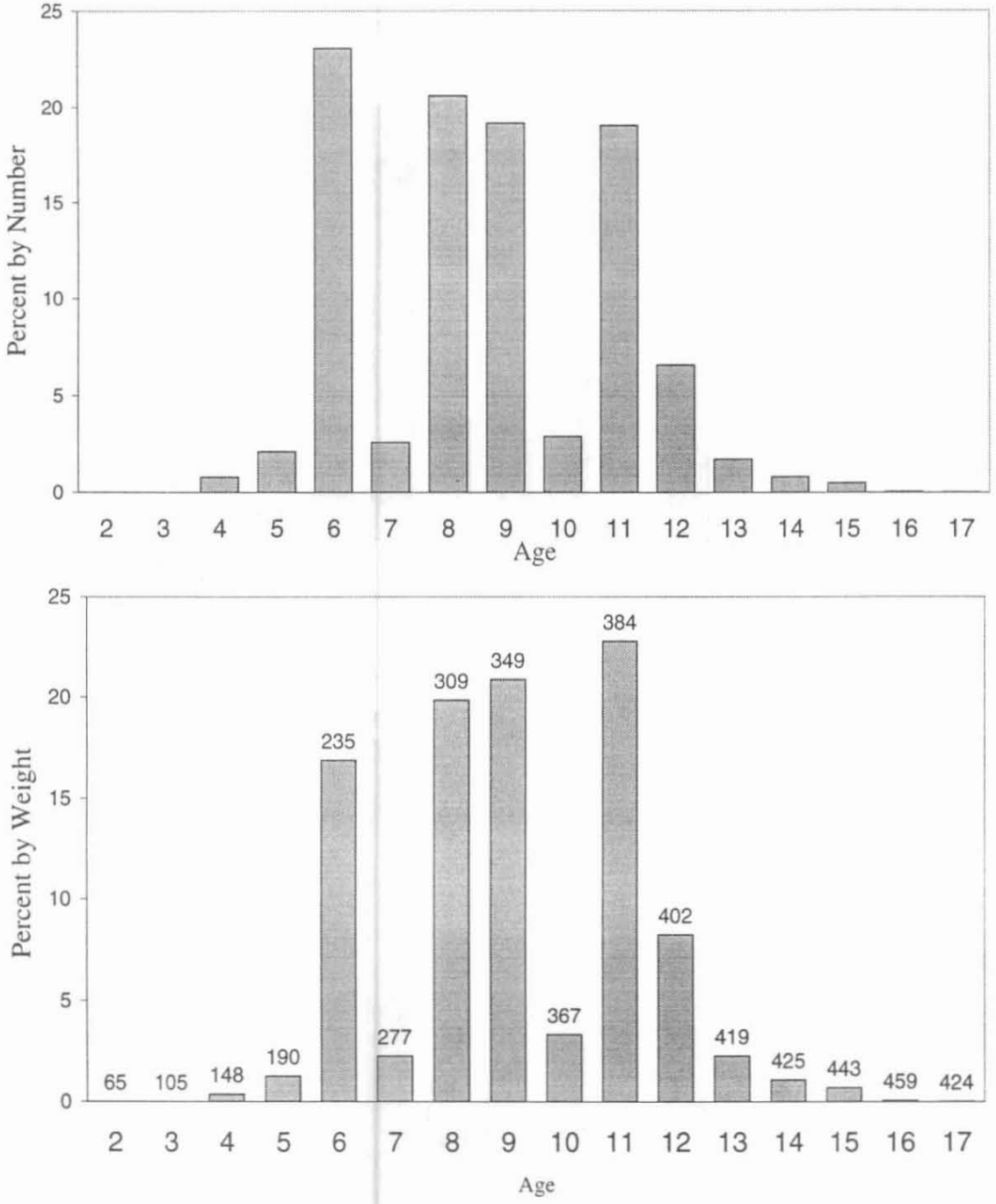

Figure 21. Projected age composition for 1999 Cape Romanzof District herring in percent by number (top) and percent by weight (bottom) with projected weight at age in grams.

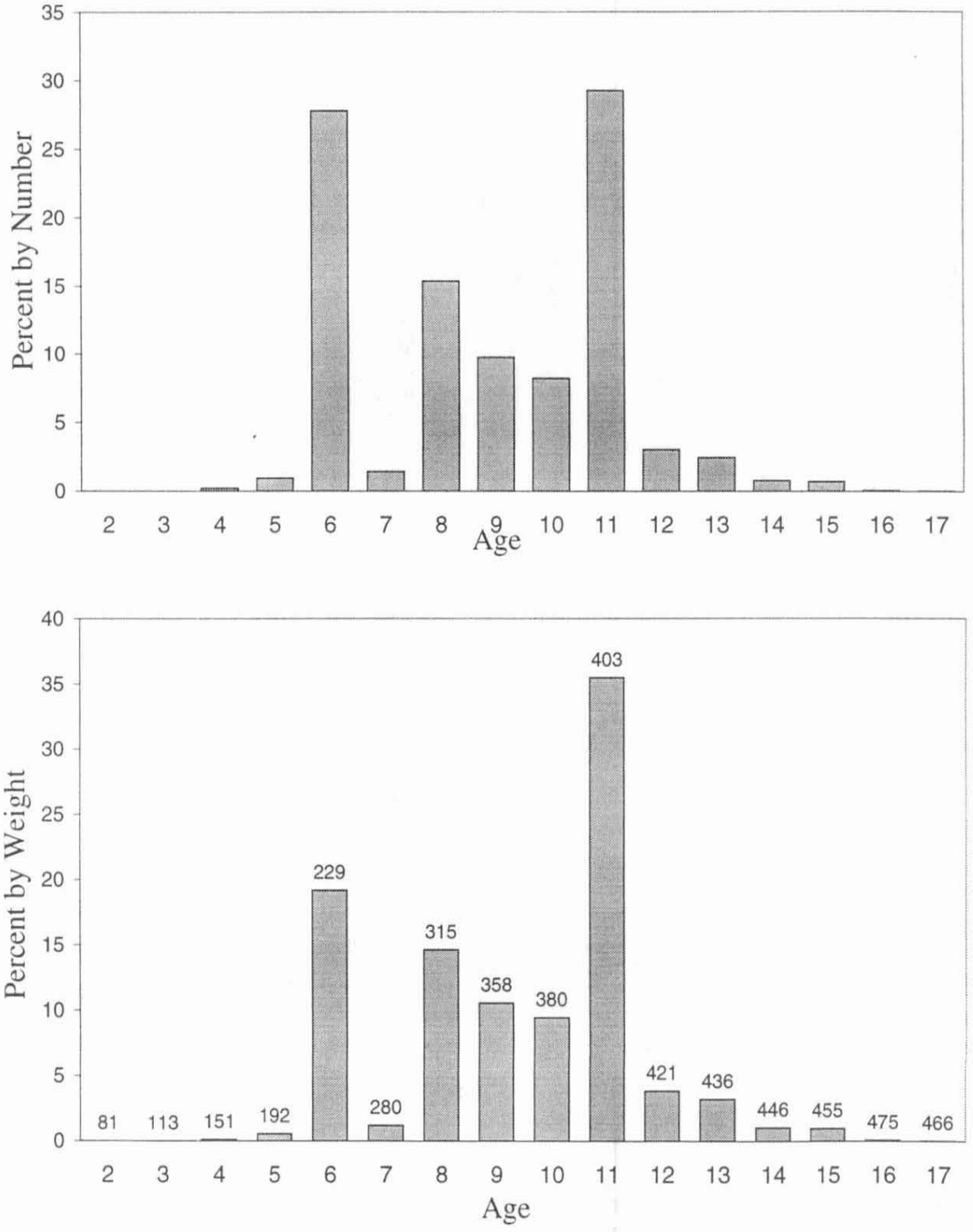

Figure 23. Projected age composition for 1999 Norton Sound District herring in percent by number (top) and percent by weight (bottom) with projected weight at age in grams.