2A94-29

FORECAST OF THE PACIFIC HERRING BIOMASS IN TOGIAK DISTRICT, BRISTOL BAY, 1992

By

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and

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REGIONAL INFORMATION REPORT [1]/ N0. 2A94-29

Alaska Department of Fish and Game
Division of Commercial Fisheries Management and Development
333 Raspberry Rd
Anchorage, Alaska 99518

October 1994

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ACKNOWLEDGEMENTS

Many people contributed toward the collection and processing of herring age, size, sex, and abundance data used in the report. In particular we would like to acknowledge Gene Sandone who in developing the 1988 Prince William Sound herring forecast prepared the template for our spreadsheets. We would also like to acknowledge Wes Bucher and Dick Russell for collecting aerial survey data and Tim Baker for updating our age-weight relationship and estimates of natural mortality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The 1991 Togiak District spawning migration consisted of 228 million Pacific herring *Clupea harengus pallasi* weighing 83,229 tons. A total of 16,296 tons was harvested by the inshore sac roe fishery and the Dutch Harbor food-and-bait fishery. The 1992 spawning biomass of herring in the Togiak District is forecast to be 60,214 tons. An estimated 20.4% of the population and 27.4% of the biomass will be age 10 or older. The average size of an individual is expected to be 331g. The 1977 and 1978 year classes that have dominated the biomass since 1983 are expected to contribute 4% of the population and 6% of the biomass.

The 1992 recommended total allowable harvest is 12,043 tons and represents 20% of the forecasted biomass. In accordance with the Bering Sea herring management plan, the allocation would be 1,500 tons of herring for the Togiak District spawn-on-kelp fishery, 738 tons for the Dutch Harbor food-and-bait fishery, and 9,805 tons for the Togiak District sac roe fishery.

INTRODUCTION

The Togiak District of Bristol Bay, Alaska extends from Cape Constantine to Cape Newenham (ADF&G 1991) and supports the largest spawning population of Pacific herring *Clupea harengus pallasi* in the eastern Bering Sea (Figure 1). Though studies have yet to demonstrate genetic variation among spawning populations of herring in the eastern Bering Sea, differences in growth due to environmental influences are apparent. Herring that spawn in the Togiak District are most similar to herring from the Security Cove and Goodnews Bay Districts but show significant differences in growth and run timing from herring which spawn along the Alaska Peninsula and north of Kuskokwim Bay (Barton 1978, Wespestad and Barton 1981, Walker and Schnepf 1982, Rogers et al. 1983, 1984, Schnepf 1984, Rogers and Schnepf 1985). Herring move into the Togiak District from their overwintering grounds near the Pribilof Islands in the spring to spawn (Shaboneev 1965). After spawning, these herring undertake a feeding migration southward along the Alaska Peninsula, concentrate in the vicinity of Unalaska Island, and return to their overwintering grounds in the fall (Shaboneev 1965, Rumyantsev and Darda 1970). These herring are harvested at various points during their migration, the primary harvest occurs in the Togiak District by a sac roe fishery during the spring (Table 1). Catches since 1978 have ranged from 2,536 to 23,466 tons. Lesser harvests are taken during the summer months in the Dutch Harbor food-and-bait fishery and as bycatch of the domestic pollock trawl fishery.

Beginning in late April the nearshore area of Togiak District is surveyed daily from small aircraft to monitor relative abundance, distribution, and spawning of Pacific herring. Biomass estimates are derived from the number and size of herring schools observed during these surveys (Lebida and Whitmore 1985). Use of aerial surveys to estimate the Togiak herring spawning biomass began in 1978. Observed abundance has ranged from 242,298 tons[1] in 1979 to 76,960 tons in 1980 (Figure 2). The 1980 biomass was probably underestimated due to the poor survey conditions experienced that season.

Year class strength of Togiak herring, as represented by abundance of 5-year-old herring, has varied greatly between 1971 and 1985 (Figure 3). The 1974 year class was the largest in this series and contributed 586 million 5-year-old recruits to the 1979 biomass. Strong recruitment was last detected in 1982 and 1983 when the 1977 and 1978 year classes representing 197 and 189 million age-5 fish joined the spawning biomass. Year class strength of age-5 herring has since averaged 12.5 million fish annually.

The purpose of this report is to provide a forecast of herring returning to spawn in the Togiak District, Bristol Bay in 1992. Specific objectives are (1) to document data sources and forecast methodology, (2) to document and evaluate the performance of historic forecasts, and (3) to present the forecast and, through application of the Bristol Bay herring management plan (ADF&G 1991), propose a harvest guideline for the 1992 season.

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[1] Tons = 2,000 pounds and is often referred to as short tons. Tonnes = 2,204.62 pounds or 1,000 kg.

METHODS

The 1992 Togiak herring biomass was projected from the 1991 unharvested spawning biomass (escapement), adjusting for growth, mortality, and recruitment. Components necessary to prepare a forecast include (1) estimates of the spawning biomass and commercial harvests, (2) age composition of the spawning biomass and harvest, (3) estimates of weight-at-age from an age-weight relationship, (4) age-specific rates of natural mortality, and (5) availability or recruitment by age.

Biomass Estimation

Biomass estimates of herring in the Togiak District are attained through aerial assessment of herring schools (Lebida and Whitmore 1985). The location, number, and size of herring schools observed during aerial surveys are recorded by index area throughout the fishing district. Climatological and survey conditions are also noted for each survey. In past years surveys have been flown by both helicopter and fixed wing aircraft twice daily, usually at low tide. Cumulative herring school surface area is multiplied by depth specific conversion factors to attain a biomass estimate for the surveyed index area. The biomass estimate for a given survey is the summation of index area estimates for that flight. Aerial survey data are calibrated through capturing and weighing herring schools for which the biomass and surface area has been estimated from the air.

Movement and residence time of herring schools on the fishing grounds has not been studied. Therefore, in addition to surveillance by aerial surveys, the population is monitored for changes in age composition and gonad maturity to indicate whether herring are entering or exiting the district. Data for peak biomass estimates, are adjusted for harvests and summed with consideration for run timing, age, and maturity information to attain the final biomass estimate or total inshore return. The unharvested biomass or escapement becomes the total inshore return minus all commercial harvests.

Harvest figures for the Togiak District sac roe fishery and the Dutch Harbor food and bait fishery were derived from fish ticket receipts (ADF&G 1992a,b). An estimate of herring bycatch from the domestic pollock trawl fishery was not available for the 1991 season.

Age Composition

The age composition of the 1991 herring spawning population was estimated from herring sampled from commercial fishery harvests as well as from areas where significant herring biomass was observed within Togiak District. During fishery closures, volunteered commercial and departmental vessels made multiple purse seine or variable mesh gillnet sets to capture herring throughout the duration of the spawning migration. Samples were pooled across three day periods, whenever possible, to obtain sample sizes large enough to represent the estimated

biomass within each fishing section. For commercial harvest, samples were collected from tenders and fishing boats for each gear type and fishing section at the close of each fishing period. Herring from both test fishing and commercial harvest samples were used to obtain data on age, size, and gonad condition.

Historical estimates of the peak spawning biomass, by age class, were reconstructed for 1978-1989 using the same methods applied in 1988 (Brannian and Rowell 1989, and Rowell and Brannian 1989, 1993). An attempt was made to obtain sample sizes of 200-400 fish from each strata. Only AWL samples collected from purse seine and variable mesh gillnets were used. Biomass observations used for the peak estimate were stratified by commercial fishing section (Figure 1). AWL data bracketing the peak date, spanning up to a week, were used to estimate age class composition in each section.

Growth

Age-specific instantaneous growth rates (G_i) were used to forecast the 1992 spawning biomass. Weight at age estimates were obtained from Baker (1991) who used Schnute's (1981) general growth model:

$$W_i = W_\infty e^{-e^{-g(i-i_o)}} , \qquad (1)$$

where W_i is the estimated weight at age i, W_∞ is asymptotic weight, g is a relative growth parameter, and i_o is an initial age parameter. This relationship was fit using a non-linear least squares estimation procedure employing a modified Marquardt algorithm. Mean weight at age data from 1980-1989 Togiak commercial purse seine fishery samples were used to estimate model parameters. The resulting weight-age relationship was:

$$W_i = 515 e^{-e^{-0.264(i-4.63)}} . \qquad (2)$$

Growth rates were estimated for ages 3-17 as:

$$G_i = \ln\left(\frac{W_{i+1}}{W_i}\right) . \qquad (3)$$

Natural Mortality and Availability

Since natural mortality is thought to increase with age (Vetter 1988), age-specific instantaneous rates of natural mortality and availability were used to forecast the 1992 spawning biomass. Availability is defined as the proportion of a cohort that migrates inshore to spawn in any given year and that will be available to inshore sac roe fisheries. This assumes that juveniles do not migrate inshore with sexually mature herring. Baker (1991) used biomass estimates from 1980-1989 aerial surveys to estimate natural mortality, including availability, as:

$$M_{y,i} = -\log\left(\frac{N_{y+1,i+1}}{N_{y,i}-C_{y,i}}\right) \quad , \tag{4}$$

where $M_{y,i}$ is natural mortality in year y at age i, $N_{y,i}$ is the number of age i herring in the spawning population in year y, and $C_{y,i}$ is the number of herring of age i in the commercial harvest in year y. This relationship assumes catch was taken over a short time period. Fishing time for herring in the Togiak District has declined from 26 d in 1981 to less than 3 d in recent years.

An average natural mortality was then calculated for each age across all years. Because a linear trend was evident for ages-4 through -14, a linear regression model was fit through these averages as:

$$M_i = -1.588 + 0.205\,i \, , \tag{5}$$

with 9 df and R^2 of 0.854. Estimates of mortality became positive at age 8, so herring were assumed to be fully recruited ($A_i=1$) at this age. Equation 5 was used to estimate M_i for herring ages 8 to 17, even though data for ages 15 to 17 were not used to fit the equation. Since mortality was confounded with estimates of availability, model values for ages 4-7 were a combination of mortality and availability and designated as availability (A_i). Full recruitment at age 8 assumed by Baker (1991) may be a result of our inability to assess and sample younger herring in the later stages of the run due to poor weather conditions. Full maturity by age 6 has been documented on overwintering grounds (Wespestad 1982).

Forecast of Inshore Return

Each year class present in the 1991 total run biomass was projected forward one year to forecast the return of that year class in 1992 as:

$$B_{1992,i+1} = (B_{1991,i}e^{-A_{1991,i}} - C_{1991,i})e^{A_{1992,i+1}+G_i-M_i} \quad (6)$$

where:

$B_{1992,i+1}$ = 1992 projected biomass for age i+1
$B_{1991,i}$ = 1991 spawning biomass for age i
$A_{1991,i}$ = Availability in 1991 of age i
$A_{1992,i+1}$ = Availability in 1992 of age i+1
G_i = Instantaneous rate of growth for age i
M_i = Instantaneous rate of natural mortality for age i

The total 1992 forecasted biomass was the sum of individual, age-specific biomass projections.

Harvest Projection

Harvest levels for 1992 commercial fisheries targeting on herring which spawned in Togiak District were set by the Alaska Board of Fisheries, Bering Sea Herring Management Plan (AAC 27.060) and Bristol Bay Herring Management Plan (AAC 27.865). These regulatory plans specify a maximum exploitation rate of 20%, and a minimum total biomass of 35,000 tons on the grounds before commercial harvest can occur (ADF&G 1991). Before opening the sac roe fishery, approximately 1,500 tons of herring are set aside for the Togiak District herring spawn-on-kelp harvest, and 7% of the remaining available harvest is set aside for the Dutch Harbor food-and-bait fishery. The remaining harvestable surplus is allocated to the sac roe fishery by gear type: 25% for the gillnet fleet and 75% for the purse seine fleet. In years when circumstances prevent adequate biomass assessment during the season, the fishery harvest will be based solely on the pre-season forecast. Should a manageable separation of the year classes occur, a harvest of up to 20% of the younger age classes (age-4 years or less) may be allowed if at least 20,000 tons of these younger herring are present in the district.

RESULTS AND DISCUSSION

The 1991 Togiak District spawning migration consisted of 228 million herring with a total weight of 83,229 tons (Table 2). The biomass estimate was the sum of (1) the peak biomass estimate on May 16 (51,498 tons); (2) the entire biomass of spawned-out herring observed exiting the spawning grounds along the Nushagak Peninsula May 13 and 15 (8,684 tons) 3) the removal by the commercial fishery of 14,970 tons, less the test fish estimates of 226 tons; and 4) the entire biomass observed May 24 (8,303 tons, Table 3). Age composition and biomass

were monitored on the grounds after field camps were dismantled. Herring were observed on the grounds from May 31 through June 8. Data from these surveys were not included in either revised biomass or age composition estimates since we were not sure how many of these herring had been observed earlier in the season and because the 1991 season is the only the second year this extended stock assessment program has been conducted.

Age-9 and older herring represented 57% of the total biomass and 44% of the total number of individuals in the 1991 spawning run. The 1977 and 1978 year classes that have supported the biomass since 1983 continued to represent a significant though diminished proportion of the biomass. Combined, these two year classes represented 20% of the biomass and 15% of the population. The number of age-5 herring present in the population was 3.4 million fish, well below the long term average of 12.5 million fish. The number of age-4 herring appearing this season was double the size of that of the 5-year old fish and may represent recruitment into the biomass. This new year class represented 7.2% of the biomass and 16.7% of the population. Herring in the eastern Bering Sea are assumed to reach full biological maturity at age 6 (Wespestad 1991) and therefore are expected to fully recruit into the biomass at the same stage. Baker (1991) determined that herring did not fully recruit into the biomass until age 8. Therefore, the full significance of the age class abundance of age-4 herring in the 1991 return as significant recruitment into the biomass will be determined in subsequent years. An estimated 66,933 tons remained after harvests by the sac roe and food-and-bait fisheries were removed from the spawning biomass.

The total inshore return estimate for 1991 was nearly 1.5 times greater than the 54,772 tons forecasted from the 1991 escapement (Rowell and Brannian 1993). The overall forecast error of 34% was due to greater than expected appearance of age -8 and -10 herring as well as the successful appearance of the incompletely recruited age-4 herring (Figures 4 and 5). A forecast error of this type could have occurred if the abundance estimate for 1990 was too low, and estimates of age class abundance for older herring were too high as a result from sampling bias due to poor weather affecting the ability to sample the younger year classes at the end of the run.

The 1992 forecast of spawning herring biomass for Togiak District is 60,214 tons (Table 2, 4). The average size of an individual is expected to be 331g. An estimated 41% of the individuals and 51% of the biomass are expected to be age 9 or older in 1992 (Figure 6 and 7). The contribution of the 1977 and 1978 year classes, returning as age-14 and age-15 herring, is expected to decrease to 4% of the total biomass since natural mortality rates increase for these older aged herring. Cohorts which are also expected to make large contributions to the 1992 run are the 1984 (age-8), 1983 (age-9), and 1987 (age-5) year classes, which should account for respectively 24%, 29%, and 16% of the total biomass (Figures 7 and 8).

In past years, older herring have arrived on the fishing grounds before the younger and newly recruited age classes. The fishery and therefore, biomass assessments have been directed towards these older herring. Temporal separation of older and younger age classes while useful for management has resulted in little information being collected on younger and later arriving

herring. Forecasts for the youngest age classes (age 3 and 4), which are not fully recruited, are incomplete and constitute a source of forecast error. The Togiak herring forecast has been less than the observed biomass since 1984 (Figure 8), and average forecast error (1984-91) has been 32%.

For 1992, the total allowable harvest based on the forecast is 12,043 tons (20% of forecasted biomass). In accordance with existing management plans, the allocation would then be 1,500 tons for the Togiak District spawn-on-kelp fishery, 738 tons for the Dutch Harbor food-and-bait fishery, and 9,805 tons for the Togiak District sac roe fishery.

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Table 1. Total inshore run and commercial harvests for Togiak herring, 1968-1991.

Year	Total Biomass in Tons [a]	Harvest in Tons: Togiak Sac Roe [b]	Togiak Spawn-on-Kelp [c]	Dutch Harbor Food and Bait [d]
1968		82	2	
1969		43	5	
1970		25	18	
1971		31	23	
1972		73	29	
1973		46	5	
1974		112	57	
1975		51	50	
1976			134	
1977		2,536	125	
1978	191,450	7,016	150	
1979	242,298	10,485	188	
1980	76,960	22,288	86	
1981	158,860	11,353	172	704
1982	98,022	19,837	107	3,565
1984	113,471	17,654	184	3,578
1985	132,420	23,466	31	3,480
1986	94,390	14,796	170	2,394
1987	89,086	14,117	139	2,503
1988	134,717	14,382	245	2,004
1989	98,965	12,258	280	3,084
1990	88,105	12,307	207	821
1991	83,229	14,970	174	1,325

[a] Brannian and Rowell (1989) through 1988, Rowell and Brannian (1989, 1993) for 1989 and 1990; Rowell (1992) for 1991.

[b] Data source: Sandone and Brannian (1988) through 1987 and ADF&G(1992a) for 1989-1991.

[c] Data source: ADF&G (1988) through 1987 and ADF&G (1992) 1988-1991.

[d] Data source: ADF&G (1992b). Catches documented since 1929. Fishery did not occur between 1946 and 1980.

Table 2. Year class composition of the 1991 Togiak herring harvest, escapement, and total run biomass, and forecasted biomass for 1992.

		1991 Harvest (tons)				1991	1991 Total Run				1992 Togiak Projected Herring Biomass					
Year Class	Age Class	Sac Roe P.Seine	Sac Roe G.Net	Food/Bait Harvest	Total (tons)	Escapement (tons)	Biomass (tons)	No.of Fish (* 1,000)	% by Wt.	% by No.	Year Class	Age Class	Biomass (tons)	No.of Fish (* 1,000%)	% by Wt	% by No.
1990	1	0	0	0	0	0	0	0	0.0	0.0						
1989	2	0	0	0	0	0	0	0	0.0	0.0	1990	2	0	0	0.0	0.0
1988	3	0	0	0	0	11	11	75	0.0	0.0	1989	3	0	0	0.0	0.0
1987	4	94	5	1	100	5,928	6,028	36,875	7.2	16.1	1988	4	57	326	0.1	0.2
1986	5	12	0	1	13	650	663	3,408	0.8	1.5	1987	5	9,741	42,486	16.2	25.8
1985	6	63	12	2	77	920	997	3,665	1.2	1.6	1986	6	916	3,244	1.5	2.0
1984	7	904	325	86	1,315	11,957	13,272	42,043	15.9	18.4	1985	7	1,427	4,302	2.4	2.6
1983	8	1,455	675	119	2,249	12,671	14,920	41,472	17.9	18.2	1984	8	17,399	46,289	28.9	28.1
1982	9	499	191	70	760	3,843	4,603	11,335	5.5	5.0	1983	9	14,175	34,292	23.5	20.8
1981	10	2,228	453	176	2,857	7,245	10,102	23,165	12.1	10.2	1982	10	1,957	4,395	3.3	2.7
1980	11	862	288	155	1,305	3,760	5,065	10,811	6.1	4.7	1981	11	6,202	13,177	10.2	8.0
1979	12	2,026	510	312	2,848	7,170	10,018	20,631	12.0	9.0	1980	12	1,180	2,400	2.0	1.5
1978	13	2,549	567	254	3,370	7,952	11,322	22,297	13.6	9.8	1979	13	3,754	7,388	6.2	4.5
1977	14	832	135	132	1,099	4,385	5,484	10,910	6.6	4.8	1978	14	2,953	5,663	4.9	3.4
1976	15	144	0	15	159	365	524	1,059	0.9	0.6	1977	15+	595	1,121	0.8	0.4
1975	16	117	21	0	138	54	192	322	0.2	0.1	1976					
1974	17+	3	0	3	6	22	28	55	0.0	0.0						
Total		11,788	3,182	1,326	16,296	66,933	83,229	228,123	100.0	100.0			60,214	164,821	100.0	100.0

Table 3. Daily observed biomass estimates of herring during the 1991 season by index area, Togiak District, Bristol Bay, Alaska. [a]

Date	Survey Conditions	Survey Time	Milt Sightings No.	Milt Sightings Length (Mi)	Estimated Biomass in tons by Index Area. [b] NUS	KUK	MET	NUK	UGL	TOG	TNG	MTG	HAG	OSK	PYR	CN	WAL	Daily Total
4/19	Good	pm	0	0.00	-[c]	0	0	0	0	0	0	0	0	0	0	-	-	0
4/24	Fair	pm	0	0.00	-	0	0	0	0	0	-	-	-	-	-	-	-	0
4/28	Good	am	0	0.00	-	0	0	0	0	0[d]	0	0	0	-	-	-	-	0
5/01	Fair-Poor	pm	0	0.00	-	-	0	0	0	-	-	0[d]	0	-	-	-	-	0
5/03	Fair	pm	0	0.00	-	0	0	0	0	0	0[d]	0[d]	0	0	-	-	-	0
5/06	Poor	am	0	0.00	-	0	0	0	0	0	0	0	0	-	-	-	-	0
5/06	Fair	pm	0	0.00	0	-	-	-	0	0	0[d]	0	65[d]	-	-	-	-	65
5/07	Poor	am	0	0.00	-	-	0	0	8	0		0	0	0	-	-	-	8
5/07	Fair	pm	0	0.00	-	0	0	0	0	0	0[d]	0[d]	38	-	-	-	-	38
5/08	Fair-Poor	am	0	0.00	-	-	-	0	0	0	0	0	0	-	-	-	-	0
5/09	Fair	pm	3	1.00	-	-	0	0	3,920	68	1,440	3,785	0	0	-	-	1,607	10,820
5/10	Fair-Poor	am	24	17.75	-	0	0	1,968	3,963	3,599	0	2,909	3,073	-	-	-	-	15,512
5/11	Fair	am	21	24.50	-	0	1,711	396	17	2,729	637	1,210	2,150	924	-	-	-	9,774
5/12	Fair-Poor	am-pm	24	20.75	-	-	-	-	395	2,276	571	1,246	99	427	0	-	-	5,014
5/13	Good	am	5	2.10	7,878	916	3,092	3,368	2,829	11,027	794	1,863	305	1,913	115	-	85	34,185
5/14	Good	am	1	0.50	-	-	-	-	1,871[e]	7,313	594	779	3,269	1,832	-	-	-	15,658
5/15	Good-Fair	am	1	0.10	806	6,163	450	1,667	2,015	27,396	969	1,868	5,144	2,817	382	-	-	49,677
5/16	Fair	am	1	0.50	0	11,195	146	1,883	683	28,931	23	1,327	4,867	220	1,637	586	-	51,498
5/18	Fair	pm	0	0.00	8	3,212	2,103	3,736	389	1,658	1,258	469	0	3,136	-	-	-	15,969
5/20	Good-Fair	pm	2	0.20	226	3,673	4,166	8,469	2,641	9,223	769	578	648	3,963	0	0	-	34,356
5/24	Good	pm	5	1.00	0	1,436	2,797	2,235	193	0	1,040	274	0	328	-	-	-	8,303
5/28	Good	am-pm	0	0.00	0	368	213	1,390	7,163	0	360	1,260	224	599	-	-	-	11,577
5/31	Fair-Poor	pm	2	0.50	348	267	5,394	1,458	122	0	0	0	0	-	-	-	-	7,589
6/05	Fair	pm	1	0.50	0	216	633	1,162	261	1,353	4,388	0	1,299	0	-	-	551	9,863
6/08	Fair	pm	0	0.00	13	0	1,340	1,092	2,468	3,303	5,302	5	812	0[e]	-	-	-	14,335
Total			90	69.40														

[a] Togiak District Pacific herring biomass was estimated at 83,229 short tons for the 1991 season. The revised biomass estimate was derived from the peak biomass observed 16 May summed with the biomass observed during the 24 May survey, the commercial sac-roe harvest taken 10-12 May, and the biomass observed exiting the Nushagak index area, May 13 and May 15.

[b] Index Areas: NUS- Nushagak Peninsula; KUK-Kulukak; MET-Metervik; NUK-Nunavachak; UGL-Ungalikthluk; Togiak; TOG-Togiak; TNG-Tongue Point; MTG-Matogak; HAG;Hagemeister; OSK-Osviak; PYT-Pyrite Point; CN-Cape Newenham; WAL-Walrus Islands.

[c] Partial survey.

[d] Smelt schools observed.

[e] ' - ' denotes no survey conducted.

Table 4. Information used to forecast the herring biomass expected to return to Togiak District in 1992.

Age (i)	Mean Wt.[a] at time (i)	Age Interval	G[b]	M[c]	A[d]	e^{-A}	$A_{(i+1)}-M_i+G$	Class	Age	1991 Total Return (tons)	1991 Harvest (tons)	1992 Projection[e] (tons)	% by Weight (X 1,000)	Number of Fish	% by Number
2		2-3		0.000			-2.05	2		0	0				
3	110.0	3-4	0.362	0.000	-2.05	7.745	- 0.40	3		11	0	0	0.0	0	0.0
4	158.0	4-5	0.275	0.000	-0.77	2.153	-0.29	4		6,028	100	57	0.1	326	0.2
5	208.0	5-6	0.208	0.000	-0.56	1.754	-0.15	5		663	13	9,741	16.2	42,486	25.8
6	256.0	6-7	0.162	0.000	-0.36	1.429	0.01	6		997	77	916	1.5	3,244	2.0
7	301.0	7-8	0.125	0.000	-0.15	1.163	0.12	7		13,272	1,315	1,427	2.4	4,302	2.6
8	341.0	8-9	0.095	0.054	0.00	1.000	0.04	8		14,920	2,249	17,399	28.9	46,289	28.1
9	375.0	9-10	0.074	0.259	0.00	1.000	-0.18	9		4,603	760	14,175	23.5	34,292	20.8
10	404.0	10-11	0.055	0.465	0.00	1.000	-0.41	10		10,102	2,857	1,957	3.3	4,395	2.7
11	427.0	11-12	0.044	0.670	0.00	1.000	-0.63	11		5,065	1,305	6,202	10.2	13,177	8.0
12	446.0	12-13	0.033	0.875	0.00	1.000	-0.84	12		10,018	2,848	1,180	2.0	2,400	1.5
13	461.0	13-14	0.026	1.080	0.00	1.000	-1.81	13		11,322	3,370	3,754	6.2	7,388	4.5
14	473.0	14-15	0.019	1.286	0.00	1.000	-1.27	14		5,484	1,094	2,953	4.9	5,663	3.4
15	482.0	15-16	0.016	1.491	0.00	1.000	-1.47	15+		744	303	595	0.8	859	0.4
16	490.0	16-17	0.010	1.696	0.00	1.000	-1.69								
17+	495.0	17-18	0.000	1.902	0.00	1.000	-1.90								
								Total		83,229	16,296	60,214	100.0	164,821	100.0

[a] Weight at time i = 515 $\exp[-\exp^{-0.264(i-4.63)}]$.
[b] Instantaneous growth rate $G = \ln(W_{i+1}/W_i)$.
[c] Instantaneous natural mortality schedule based on the average age-specific mortality for 1980-89.
[d] Availability (A) schedule based on biomass at age data, 1980-1989.
[e] Projection $_{i,1992}$ = [Total Return$_{(i,1991)}\exp(-A_i)-C_{i,1991}]\exp(A_{i+1}-M_i+G_i)$.

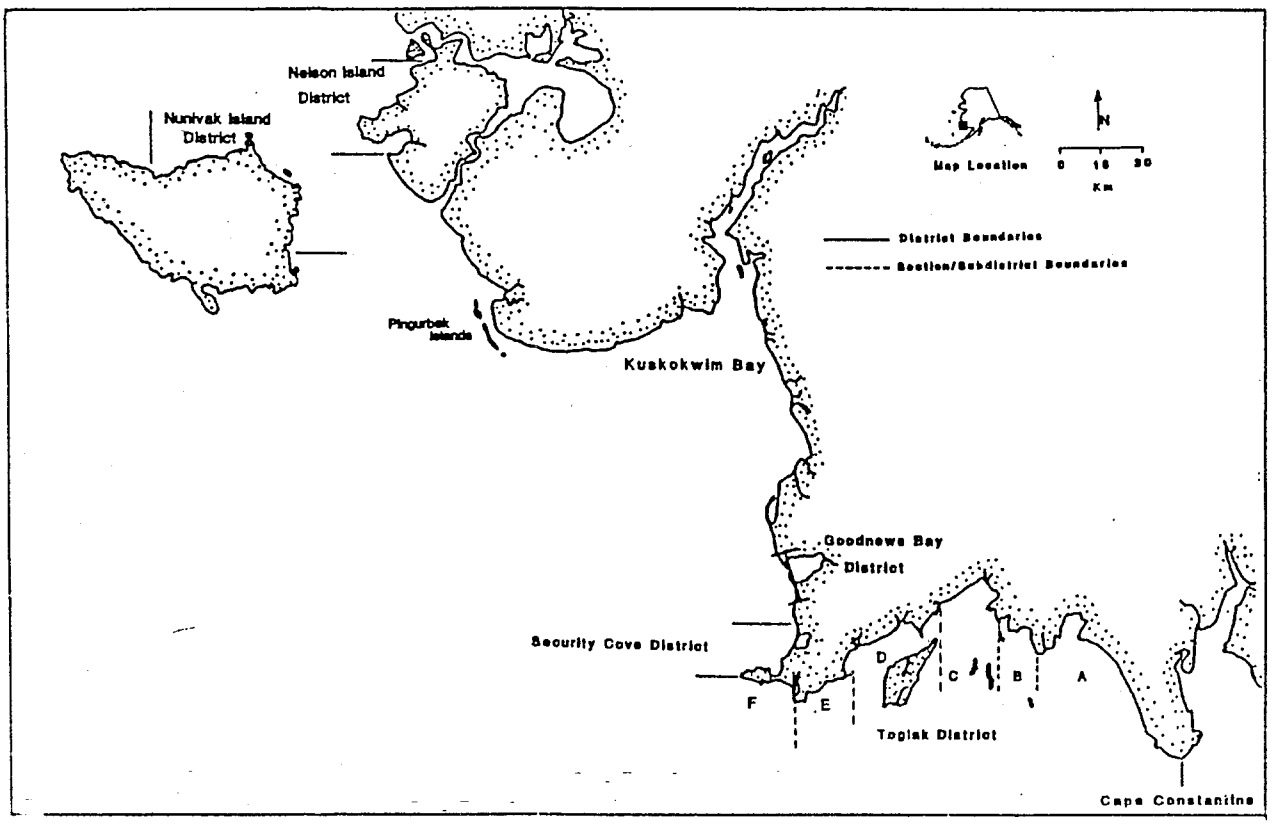

Figure 1. Togiak (A=Kulukak, B=Nunavachak, C=Togiak, D=Hagemeister, E=Pyrite Point, F=Cape Newenham Sections), Security Cove, Goodnews Bay, Nelson Island, and Nunivak Island Pacific herring commercial fishing districts, Bering Sea, Alaska.

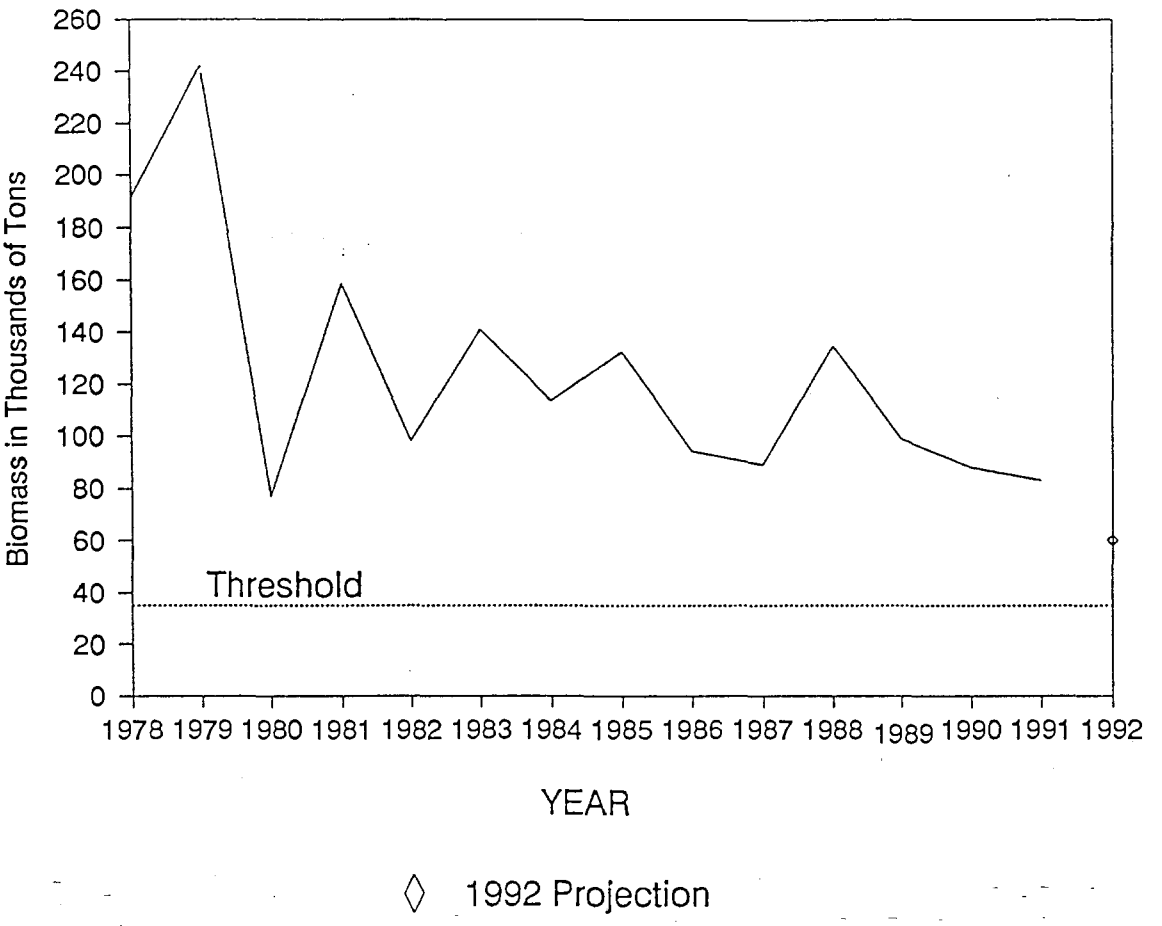

Figure 2. Togiak District herring biomass as estimated from aerial surveys. The 1992 forecasted biomass (diamond) was projected from the 1991 spawning biomass.

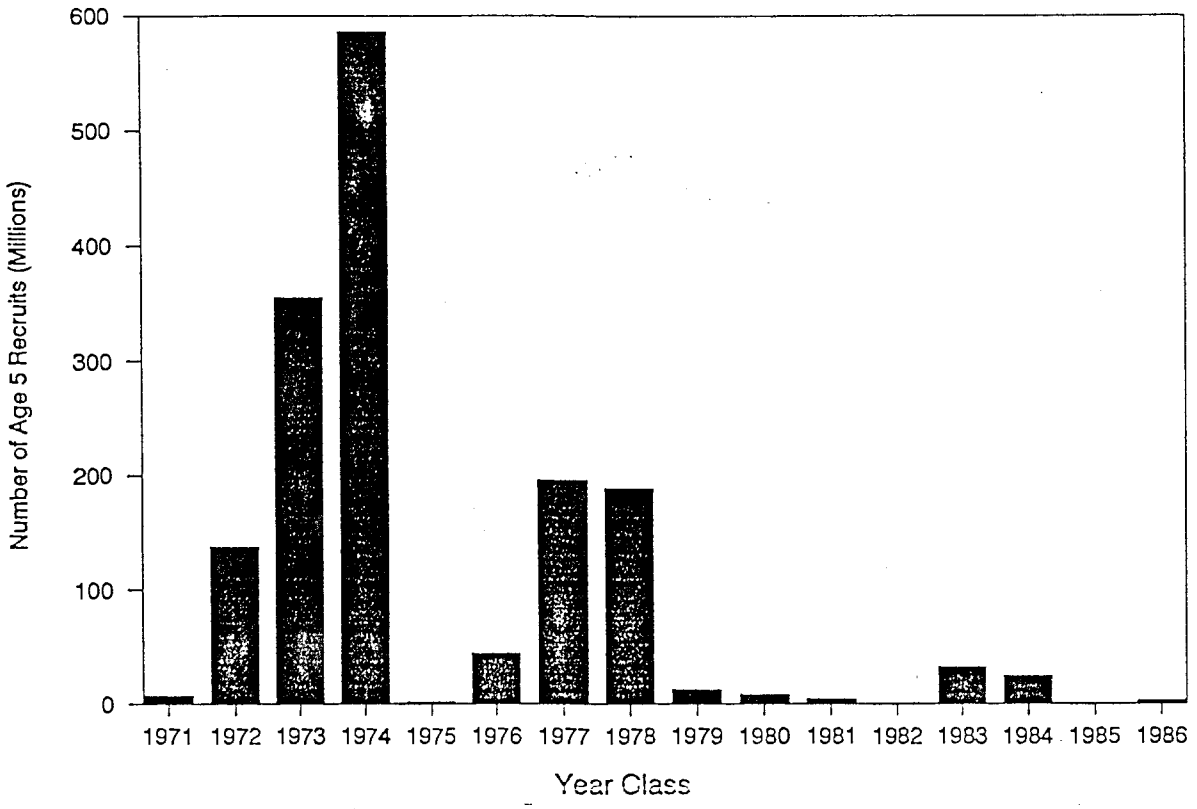

Figure 3. Historical year class strength of Togiak District herring in numbers of 5-year old fish.

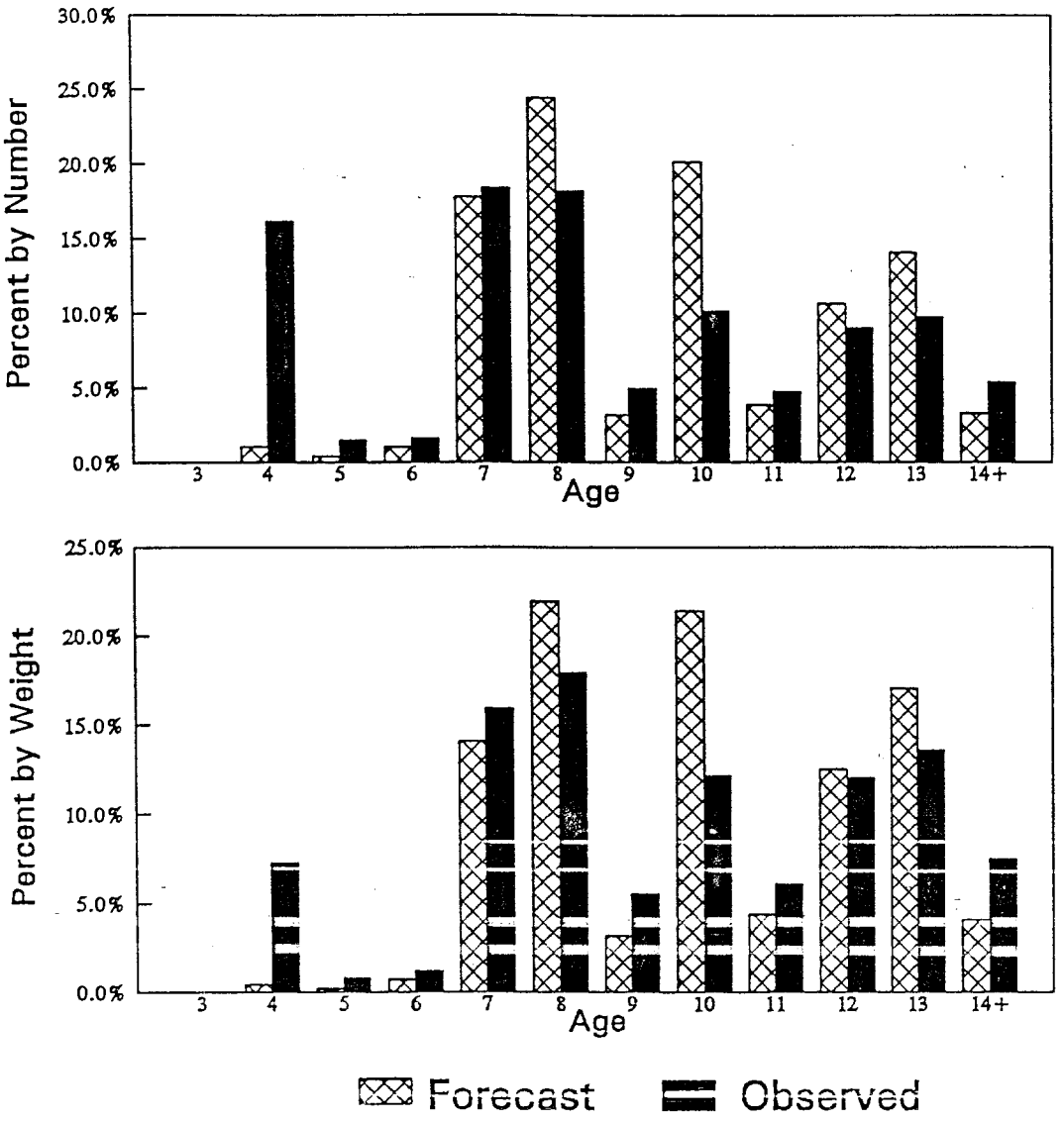

Figure 4. Age composition in numbers of fish (top) and biomass (bottom) of the Togiak District herring run biomass in 1991 compared to that forecasted from the 1990 run biomass.

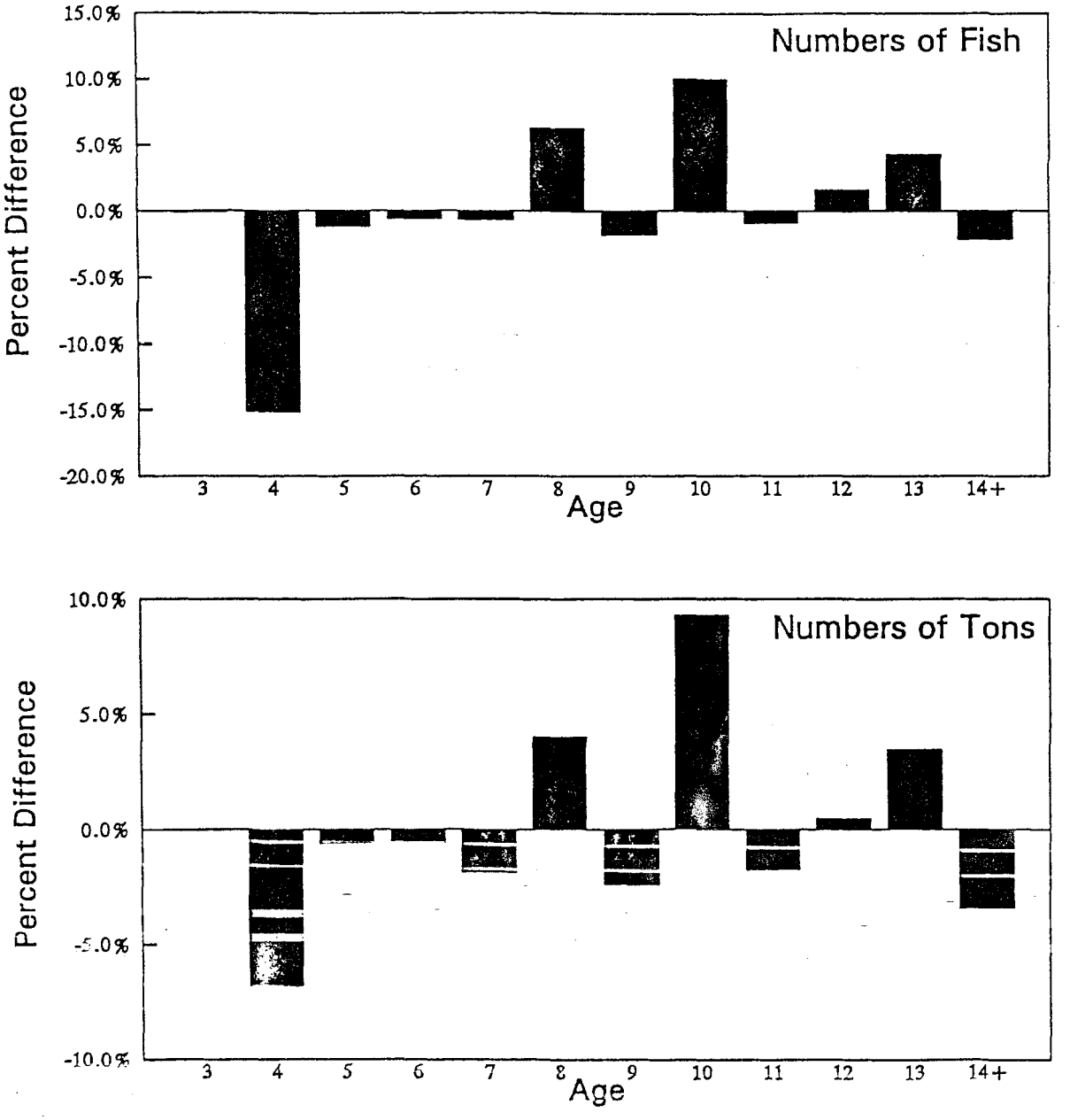

Figure 5. Forecast error (percent) by age class for numbers of fish (top) and biomass (bottom) of the Togiak herring run biomass in 1991 compared to the forecast from the 1990 run biomass.

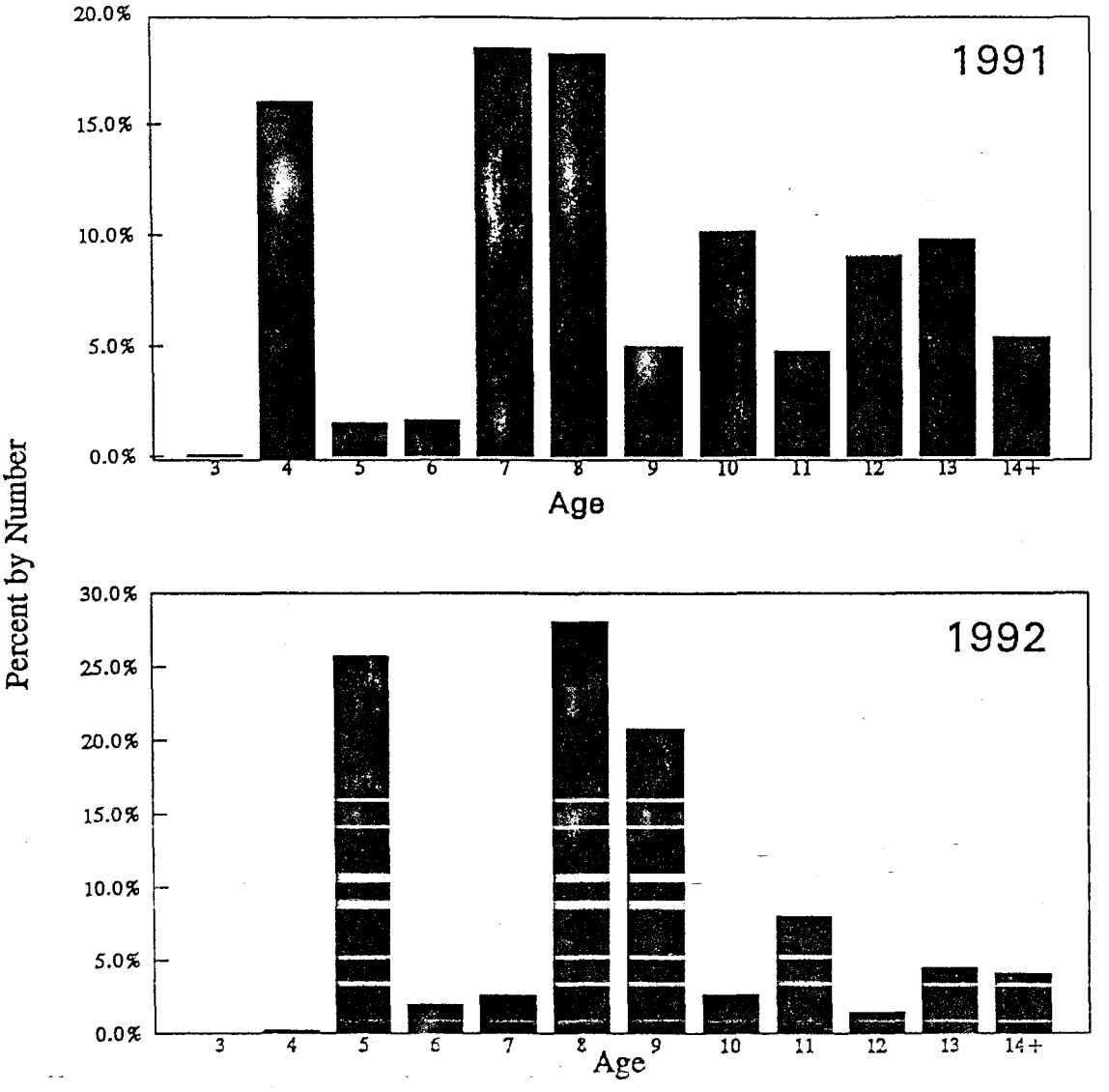

Figure 6. Age composition of the 1991 Togiak District herring run biomass in numbers of fish (top) compared to that forecasted for 1992 (bottom).

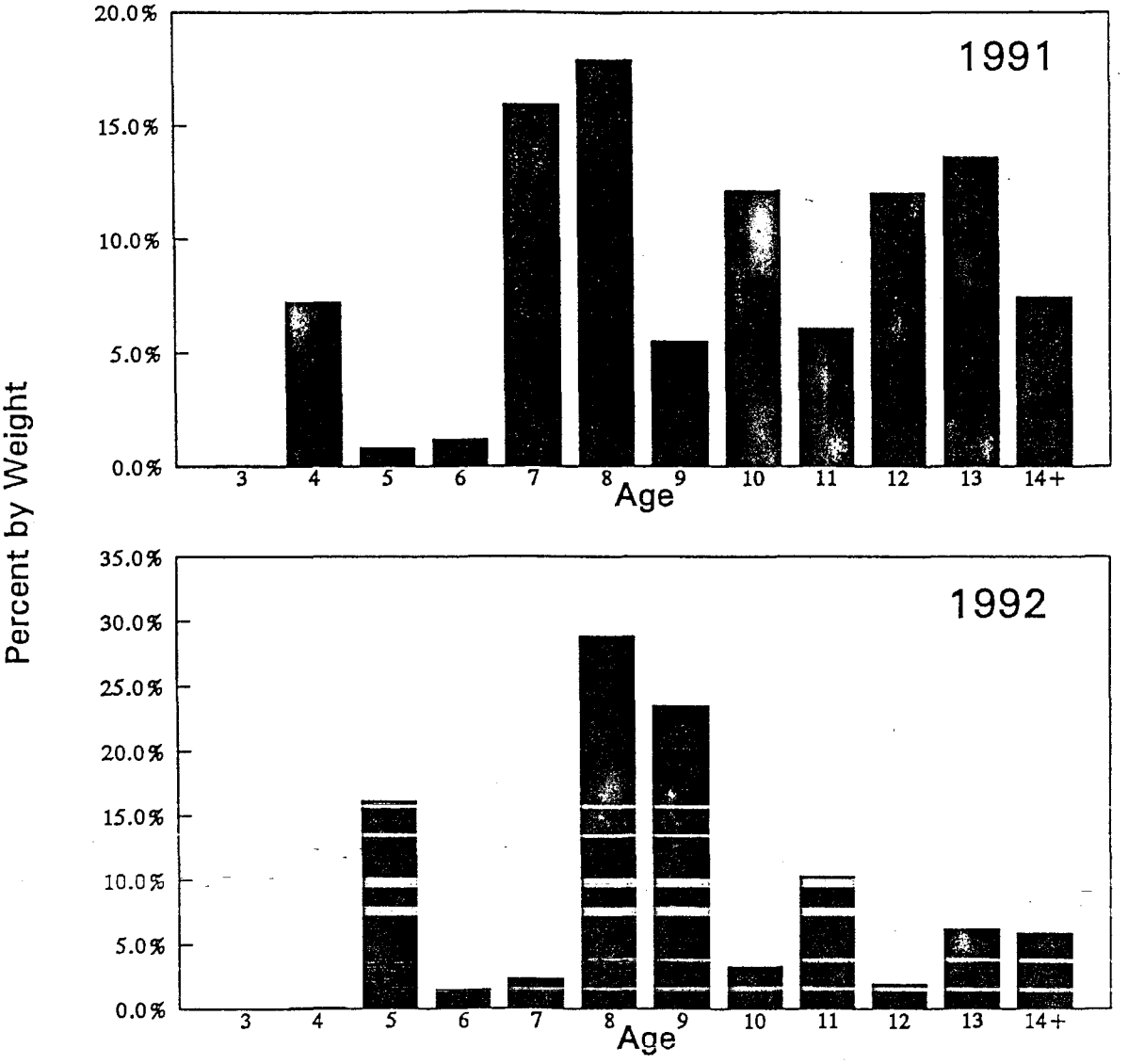

Figure 7. Age composition of the 1991 Togiak District herring run biomass (top) by weight compared to that forecasted for 1992 (bottom). The mean weight of the fish in 1992 is projected at 331 grams.

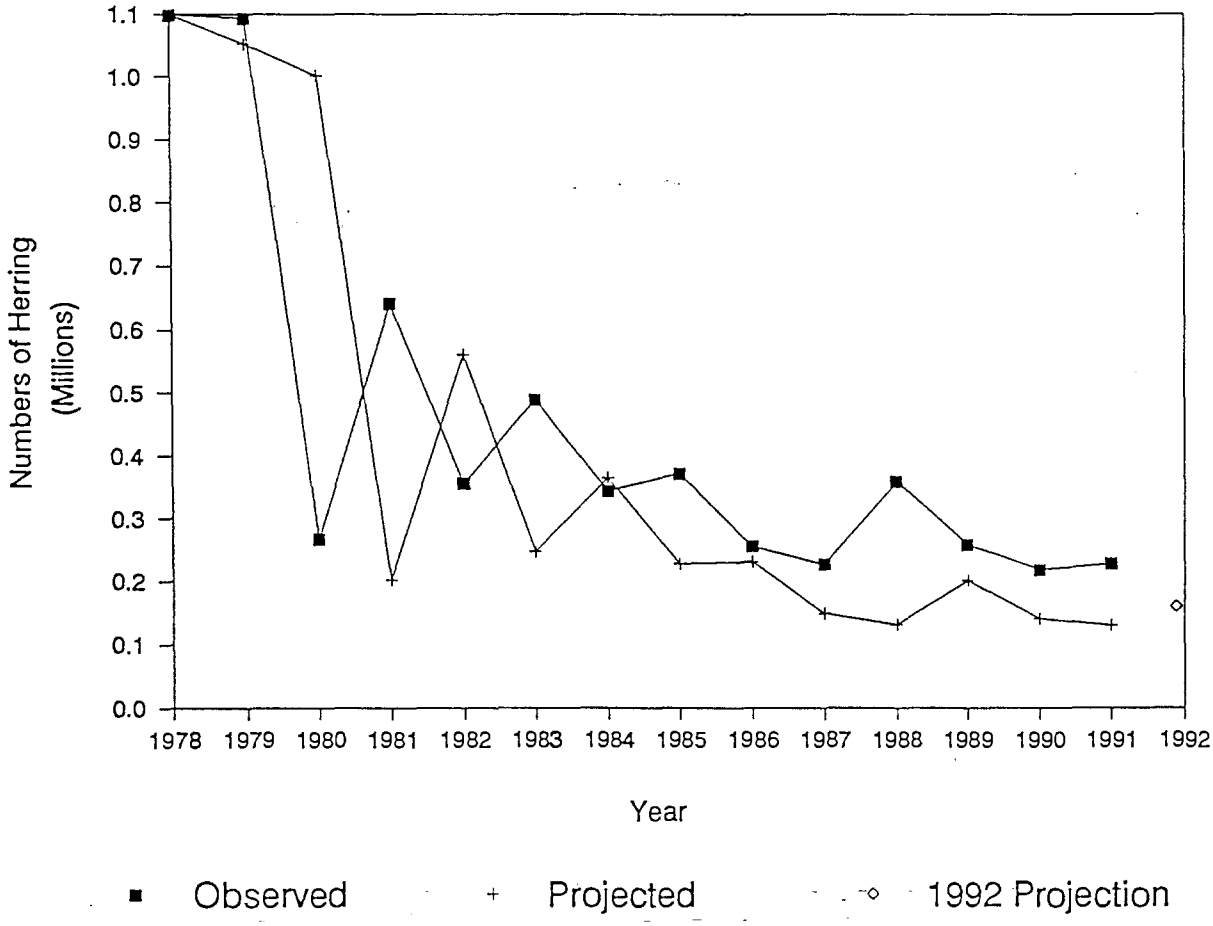

Figure 8. Performance of the Togiak District herring forecast based on a schedule of increasing mortality with age.