Fisheries and Oceans
Science

Pêches et Océans
Sciences

C S A S
Canadian Stock Assessment Secretariat

S C É S
Secrétariat canadien pour l'évaluation des stocks

Research Document 2000/146

Document de recherche 2000/146

Not to be cited without
permission of the authors [1]

Ne pas citer sans
autorisation des auteurs [1]

Offshore herring biology and 2001 recruitment forecast for the West Coast Vancouver Island stock assessment region

R. W. Tanasichuk

Department of Fisheries and Oceans
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, B. C.
V9R 5K6

ISSN 1480-4883
Ottawa, 2000
Canada

ABSTRACT

An offshore trawl survey was done between July 25 and 30, 2000 to collect information on pelagic fish distribution and feeding, and to sample herring schools for a recruitment forecast for West Coast Vancouver Island (WCVI) herring in the 2001 fishing season. Herring (*Clupea pallasi*) dominated the pelagic biomass. Schools were numerous and distributed widely over the study area. Several sardine (*Sardinops sagax*) schools were observed. Pacific hake (*Merluccius productus*), traditionally the dominant pelagic fish, was absent. Stomach content examination indicated that herring continued to feed exclusively on euphausiids and that the daily ration estimate was similar to that for other years, in other words, feeding conditions were typical. Data analysis for the traditional (correlation) form of the recruitment forecast included three evaluations of potential bias. Results of the first test showed no effect of sampling time on forecast accuracy. The second test involved replicating the survey to compare estimated proportions of age 3 within a year. Estimated proportions were similar between replicate surveys. The third test showed no change in the forecast performance between years. The performance of the forecast did not change over the 1990's when WCVI recruitments were declining while Strait of Georgia recruitments were increasing. This suggested that any interaction between the two stocks did not affect the forecasting procedure. The forecasting procedure was re-expressed as a regression so that the uncertainty of the forecasts could be described. The forecasted biomass of recruits ranges between 700 and 1200 tonnes. This would be considered as poor based on the criteria used in the stock assessment process. A forecast based on risk analysis suggested that recruitment should be poor or average.

RÉSUMÉ

Un relevé hauturier au chalut a été effectué du 25 au 30 juillet 2000 pour recueillir de l'information sur la répartition et l'alimentation du poisson pélagique et échantillonner les bancs de hareng afin de pouvoir faire une prévision du recrutement du hareng sur la côte ouest de l'île de Vancouver (WCVI) lors de la saison de pêche 2001. Le hareng (*Clupea pallasi*) dominait dans la biomasse pélagique; les bancs, nombreux, étaient distribués à grande échelle dans la zone d'étude. Plusieurs bancs de sardine (*Sardinops sagax*) ont aussi été observés. Par contre, le merlu du Pacifique (*Merluccius productus*), qui était l'espèce pélagique dominante par le passé, était absent. L'examen des contenus stomacaux du hareng a révélé qu'il continue à se nourrir exclusivement d'euphausiacés et que l'estimation de la ration quotidienne était semblable à celle d'autres années; en d'autres mots, les conditions d'alimentation étaient typiques. L'analyse des données visant à établir la forme traditionnelle (corrélation) de la prévision du recrutement incluait trois évaluations du biais potentiel. Les résultats de la première évaluation n'ont pas révélé une incidence du moment de l'échantillonnage sur la précision de la prévision. La deuxième évaluation comprenait la répétition du relevé afin de pouvoir comparer les proportions estimées de hareng d'âge 3 en deçà d'un an, qui se sont révélées semblables. La troisième évaluation n'a pas révélé de changement entre années dans la performance de la prévision. Le fait que celle-ci n'ait pas varié au cours des années 90 lorsque le recrutement du hareng sur la côte ouest de l'île de Vancouver était à la baisse et que le recrutement dans le détroit de Georgia était à la hausse semble indiquer que toute interaction entre les deux stocks n'a pas eu d'incidence sur la méthode de prévision. Cette dernière a ensuite été exprimée de nouveau comme une régression de sorte à décrire l'incertitude des prévisions. La biomasse prévue de recrues variait entre 700 et 1 200 tonnes, niveau considéré comme faible d'après les critères utilisés pour l'évaluation des stocks. Une prévision fondée sur l'analyse du risque laisse supposer que le recrutement se situera à un niveau faible ou moyen.

INTRODUCTION

There has been a mid-water trawl survey for herring and other pelagics along the southwest coast of Vancouver Island every summer since 1985. The aim of this work was to learn about the distribution, abundance, size composition and trophic relationships among the fish species which use the area. Ware and Tanasichuk (1987) began using the observed proportion of age 3 (recruit) herring to forecast recruit biomass for the subsequent spring roe herring fishery on the West Coast Vancouver Island (WCVI) stock. The forecast is added to the stock assessment models' estimates of returning spawner biomass to provide an estimate of total spawner biomass and therefore potential harvest. The Herring PSARC Subcommittee has endorsed this work continually.

This report presents observations on the distribution and feeding of herring collected during this year's survey, along with a forecast of recruit biomass for the 2001 fishing season. Information on distribution and feeding are included to document interannual variations in these ecological characteristics. In addition to providing the recruitment forecast, several potential sources of bias were evaluated. These potential biases were brought forward at previous PSARC meetings. The first potential bias was the possible influence of variations in sampling time between years on the accuracy of the forecast. This was tested by examining the behaviour of residuals for the forecasts with respect to sampling time. The second potential bias dealt with how effectively herring in the study area were sampled. The study area was covered twice so that a replicate could be generated and the proportion of age 3 fish from the "two" surveys could be compared. Finally, there has been concern expressed about the influence of mixing between the West Coast Vancouver Island (WCVI) and Strait of Georgia stocks on the WCVI recruitment forecast. Recruitment to the Strait of Georgia stock has been much stronger in recent years (Schweigert and Fort 2000). Therefore, if the stocks mix in rearing and/or summer feeding areas, one would expect an erosion of recruitment forecast performance, as indicated by an increase in the variability of the residuals in the 1990's.

METHODS

The 2000 survey was conducted along the southwest coast of Vancouver Island between July 25 and 30 (Fig. 1). Echosounding and fishing were done using the R/V W. E. Ricker equipped with a CanTrawl 350 midwater trawl and a Western 34 bottom trawl; both nets included a herring liner in the cod-end. As in previous years, there were no prescribed transects. Sounding operations were conducted in areas where fish have been traditionally located. They were also designed to cover the study area comprehensively. Twenty mid-water and two bottom trawls were made (Table 1). The catch from each tow was brought aboard. Catch was segregated by species and weighed. Catch per unit effort was estimated as kg herring $\bullet$ m^{-3} fished. Volume of water fished was estimated as tow duration (minutes) x area of mouth opening (m^2) x 93 m $\bullet$ $minute^{-1}$ (vessel speed).

Fish sampling consisted of measuring weight and length and recording sex and stomach contents. Standard length of herring was measured, and the number of fish measured per tow followed the protocol used in all previous years. When possible, the lengths of 150 herring were measured for each tow; all fish were measured when less than 150 herring were captured. Prey were identified to fish species, if possible, or specific taxonomic group (eg. euphausiids, copepods). Prey volume was estimated using syringes as guides.

The proportion of recruit herring in a sample was estimated using the time series of length-at-age 3 fish from surveys during in earlier years (Fig. 2) and the length-frequencies of herring collected during this survey. The time series was developed from tombstone (length, age, sex, total mass, gonad mass) data from August mid-water trawl samples collected in previous years and archived in the DFO herring biological sampling database. It showed that: 1) there has been only one relatively large decline in length between successive years (1997 and 1998) and 2) mean length-at-age 3 should be about 170 mm this year. The length-frequency histograms for each tow are shown in Fig. 3. They are presented in an order which seemed to allow visual discrimination of the distribution of age 2, age 3 and age 4 and older length-frequency distributions. I tried, unsuccessfully, to use the procedure described by Macdonald and Pitcher (1979) to segregate the distributions objectively. I attribute the failure mainly to the distribution of length-frequencies for ages 4 and older. Herring exhibit the typical von Bertalanffy growth in length with age; therefore length-frequencies for older fish would converge and consequently obscure the normal distribution of length for a given age. One must remember that, in practice, the forecasting procedure attempts to segregate fish without any age data. The assignment of fish to age 3, or not to age 3, was conditional on the anticipated mean length-at-age 3, the apparent length-frequency distributions for age 2 and 3 fish (Fig. 3, Tows 8 and 7 respectively), and segregating fish so that the length-frequencies for age 3 fish were as normally distributed as possible.

I examined interannual variations in daily ration using the equation developed by Elliott and Persson (1978) where daily food consumption (C_t) is:

$$(1)\quad C_t = 24SR,$$

where S is mean percentage of individual predator mass accounted for by prey and R is the evacuation rate of 0.13% wet body mass • h^{-1} for euphausiids as estimated for hake and dogfish (Tanasichuk *et al.* 1991).

I tested the forecasting procedure's performance by comparing the proportion of age 3 estimated from the mid-water trawl survey with the estimated proportion of age 3 for the pre-fishery biomass in the subsequent spring. Estimates of proportion of age 3 fish in the pre-fishery biomass (observed proportion at age 3 in analyses) were made using age composition data from the test fishing samples collected over the last several weeks before any fishery, from the commercial seine and from the commercial gillnet fisheries. The method is described in Tanasichuk (*In press*). Briefly, the number of fish-at-age caught ($N_{i,j,k}$) by commercial gear type (seine, gillnet) in any year was estimated as the number of fish in the total mass of samples for each commercial gear type multiplied by the ratios of seine catch or gillnet catch to the total sample mass for the respectively sampling source, where:

$$(2)\ N_{i,j,k} = (N_{i,j,k,s}) \bullet (M_{i,k,c} / M_{i,k,s}),$$

and N is number of fish, M is mass, i is year, j is age, k is gear type, c is commercial catch and s is biological sample. The number of fish-at-age in the prefishery biomass was estimated as the number of fish-at-age in the total mass of test fishing samples for the prefishery period multiplied by the ratio of commercial catch plus escapement model spawning biomass (see Schweigert and Fort 2000) to total sample mass. (The test fishing samples are collected by seiners which are chartered to monitor the maturity of prespawning herring aggregations and collect biological samples from them.) The number of spawners-at-age was estimated as the number of fish-at-age not caught during the commercial fisheries, in other words, number of fish-at-age in the prefishery biomass minus number of fish-at-age removed by the commercial fishery.

Statistical analysis (correlation, predictive regressions of proportion of age 3 observed in the prefishery on forecasted proportion age 3 from mid-water trawl survey) were done using Statview (1999). Proportion data were transformed using the logit transformation (Sokal and Rohlf 1995). I calculated simple linear regressions, even though both variables were estimated with error, because Sokal and Rohlf (1995) recommend this approach over the geometric mean regression for prediction purposes. Standard errors for the observed proportion age 3 ($S_{y\text{-hat}}$) were calculated using the equation given by Sokal and Rohlf (1995), where,

$$(3)\ S_{y-hat} = \sqrt{S^2{}_{y \bullet x}\left[1/n + \left(\left(X_i - \overline{X}\right)^2 / \sum x^2\right)\right]}$$

and $S^2_{Y \cdot X}$ is the error mean square for the regression, n is the number of data pairs used the estimate the regression, X_i is the forecasted proportion age 3, and Σx^2 is the sum of the squared deviations for X. Residuals (R) were estimated as

$$(4) \quad R = observed - predicted \; .$$

RESULTS

a) Offshore herring biology

Figs. 4 and 5 show the distribution of herring and sardine in the study area during the two surveys, July 25-28 and July 29-30. Herring dominated the pelagic biomass. There were many schools located in traditional areas, for example, 40-Mile Bank, Swiftsure Bank and the Southwest Corner. Fish were also found in non-traditional areas, in waters deeper than 100 m, and in bank areas (<100 m deep), away from the 100 m isobath. A number of sardine schools were sounded. The absence of Pacific hake (*Merluccius productus*) was striking. Hake biomass is usually expressed in the hundreds of thousands of tonnes. Only 17 hake were collected during all tows.

The time series of diet and daily ration estimated for herring is presented in Fig. 6. Euphausiids were still the exclusive prey and the estimated daily ration varied significantly in 1986 and 1990 only.

b) Recruitment forecasts

i) Proportion of age 3 fish

The assignment of age 3 fish for each tow is shown in Fig. 3 and the proportion of age 3 fish by tow is given in Table 1. The mean proportion of age 3 herring, weighted by the CPUE, was 11.44% for and 7.58% for Replicates 1 and 2 respectively. The significance of the differences could not be tested because the values are weighted means; however the estimates are similar.

ii) Statistical analysis

This analysis began by evaluating the effect of sampling time and mixing with Strait of Georgia herring, and in addition forecast magnitude, on the recruitment forecast for WCVI herring. Plots of residuals against the forecasted proportion of age 3, sampling date and year are shown in Fig. 7. It appeared that variability in the residuals increased at forecasted proportion age 3 greater than 0.40. There was no effect of the timing of the offshore survey because there was no trend in the residuals with respect to sampling date. The lack of interannual variability suggested that herring off the west coast of Vancouver Island are being sampled as effectively between years. In addition, there appears to be no influence of any presence of Strait of Georgia herring. If there was, then forecasts should have become less accurate in the 1990's when the Strait of Georgia stock showed stronger recruitments, by number, as stock size increased (Schweigert and Fort 2000). Finally, the stability of the forecasts over a period when length-at-age was dropping substantially (Fig. 2) suggested that there was no change in age-at-maturity or that age 3 fish persisted in joining the adult biomass as they matured.

The forecast was re-stated as a simple linear regression for two reasons. First, the correlation analysis used in previous years implicitly assumed that a regression calculated from the data would have a slope of 1 and an intercept of 0; however this was never tested. Second, the uncertainty of the forecast proportion of age 3 fish could be described if the relationship was described as a regression. Fig. 8 shows the fit of a simple linear regression line to the data and the studentised residuals for the regression. Sokal and Rohlf (1995) defined outliers with studentised residuals $> |2.5|$ and leverage coefficients which are > 4/n. No data pair was an outlier. In addition, there was no apparent trend in the residuals with respect to the fitted values. The mean residual was 0.003 ± 1.258 $(\bar{X} \pm 2S)$. The increased variability in the residuals beyond logit forecast of –0.5 (proportion = 0.38) suggests that the forecast may not be as accurate at higher proportions of age 3 fish.

The analyses described above were repeated using proportion of age 3 fish as estimated from age-structured and revised age-structured stock assessment models of numbers of fish-at-age (see Schweigert 2000). There are two models used for B. C. herring stock assessment. These are the escapement model and the age-structured model; a revised form of the age-structured model was also presented at the 2000 PSARC Herring Subcommittee meeting. The escapement and age-structured models differ in how spawn survey results are interpreted and in assumptions made about natural mortality. The results presented thus far better reflect the escapement model which assumes that all spawn is surveyed. The age-structured models assume that 80% of the spawn is surveyed to fit the catch-at-age data.

The proportion of age 3 fish, as estimated by the age-structured models, was forecast as accurately as it was based on escapement model estimates of proportion of age 3 fish (Figs. 9-12). Plots of diagnostic residuals showed the same results as for the escapement model, that is an increase in bias at greater forecasted proportions but no effects of sampling time or year.

The regression statistics for each estimate of proportion age 3 fish are summarised in Table 2.

iii) Forecasted biomass

I used the weighted proportion at age 3 from this year's trawl survey, the estimated regressions and the equation for calculating the standard error of the regression estimate to calculate the logit of the forecasted proportion of age 3 fish and it's 95% confidence limits. I used the weighted mean proportion of age 3 fish (8.62%) for all tows combined because of the small difference in the means of the replicate estimates of proportion age 3. The back-transformed forecasted proportion at age 3 and confidence limits are presented in Table 3.

The forecasted number of age 3's ($N_{j=3}$) was then estimated following Ware and Tanasichuk (1999) as:

$$(5) \quad N_{j=3} = \left(\left(A/(1-p)\right) - A\right) \bullet W,$$

where A is the number of adults forecast to return by the age-structured or escapement stock assessment models (Schweigert 2000), p is the proportion of age 3 fish as estimated from the offshore survey and W is the mean mass (0.000087 tonnes) of age 3 fish from pre-fishery samples collected during the 2000 fishing season. Tanasichuk and Schweigert (1998) showed that the observed mass-at-age in a year is the best estimate of mass-at-age in the next year. The forecasted biomasses of recruit fish are presented in Table 4.

iv) Risk analysis

A risk analysis based on environmental factors was done using the procedure described in Ware and Tanasichuk (1999). They reported that, over 1935-98, WCVI herring year-class strength tends to be inversely related to annual sea surface temperature and hake biomass during the first year of life of herring. Temperatures were from Amphitrite Point lighthouse which is on the southwest coast of Vancouver Island. A contingency table has been developed which related categories of poor, average and good recruitment, as defined by age-structured model estimates, to levels of temperature and hake biomass (see Ware and Tanasichuk 1999). Figs. 14 and 15 show that sea temperature (11.0 ^{o}C) is in the 90th percentile of the temperature distribution and hake biomass (79,000 tonnes) is in the 10th percentile. Consequently, temperature would be classified as positive because it is relatively high whereas hake biomass would be classified as negative because it was relatively low in 1998. This combination would predict a 60% chance of poor recruitment, a 40% chance of average recruitment and no chance of good recruitment.

SUMMARY AND CONCLUSIONS

1) A trawl survey of the southwest coast of Vancouver Island was done between July 25 and 30, 2000.

2) Species compositions were unusual because herring was the predominant species and hake were virtually absent.

3) Herring concentrations were widespread and occurred in traditional locations on banks and in unusual locations on banks and in deeper waters.

4) Diet analysis for herring showed that euphausiids continue to be the exclusive prey and that feeding conditions were typical.

5) A statistical analysis of the performance of the recruitment forecasting procedure for WCVI herring showed no effect of sampling time nor potential mixing between the WCVI and Strait of Georgia herring stocks on forecast accuracy. Forecasts above 40% age 3 appear to be less accurate.

6) Forecasts of recruit biomass and their 95% confidence limits are presented.

7) An analysis of environmental factors suggested that the combined effects of mean annual sea surface temperature and hake biomass during the first year of life would predict recruitment to be poor or average for the WCVI herring stock in 2001.

ACKNOWLEDGEMENTS

I thank Dennis Chalmers, John Hepples, Carol Cooper, Al Hirst, Al Young and Capt. Dave Wensley for their help and enthusiasm.

REFERENCES

Elliott, J. M. and Persson, L. 1978. The estimation of daily ration of food consumption for fish. J. Anim. Ecol. **47**:977-991.

Macdonald, P. D. M. and T. J. Pitcher. 1979. Age-groups from size-frequency data: a versatile and efficient method for analysing distributional mixtures. J. Fish. Res. Board Can. **36**:987-1001.

Schweigert. J. F. 2000. Stock assessment for British Columbia herring in 1999 and forecasts of potential catch in 2000. PSARC Working Paper P00-02. 68p.

Schweigert, J. F. and Fort, C. 2000. Stock assessment for British Columbia herring in 1999 and forecasts of potential catch in 2000. DFO Can. Stock Assess. Res. Doc. 99/178 69p.

Sokal, R. R. and F. J. Rohlf. 1995. Biometry. 3rd edition. W. H. Freeman and Co. New York, NY. 887p.

Statview. 1999, SAS Institute Inc., SAS Campus Drive, Cary, NC. USA.

Tanasichuk, R. W., Ware, D. M., Shaw, W. and McFarlane, G. A. 1991. Variations in the diet, daily ration and feeding periodicity of Pacific hake (*Merluccius productus*) and spiny dogfish (*Squalus acanthias*) off the lower west coast of Vancouver Island. Can. J. Fish. Aquat. Sci. **48:**2118-2128.

Tanasichuk, R. W. and Schweigert, J. F. 1998. Variations in size-at-age of British Columbian stocks of Pacific herring (*Clupea pallasi*) and its implications for quota recommendations and fisheries management. PSARC Working Paper H98-3. 23p.

Tanasichuk, R. W. 1999. Natural mortality rates of adult Pacific herring (*Clupea pallasi*) from southern British Columbia. DFO Can. Stock Assess. Res. Doc 99/168.. 34p.

Tanasichuk, R. W. *In press*. Age-specific natural mortality rates of adult Pacific herring (*Clupea pallasi*) from southern British Columbia. Can. J. Fish. Aquat. Sci.

Ware, D. M. and R. W. Tanasichuk. 1987. Offshore herring distribution, length composition and recruitment forecast for the lower west coast of Vancouver Island herring stock. PSARC Working Paper H87-7. 5 p.

Ware, D. M. and R. W. Tanasichuk. 1999. Offshore herring distribution, length composition and recruitment forecast for the lower west coast of Vancouver Island herring stock. PSARC Working Paper P99-4. 5 p.

Table 1. Summary of fishing activity and proportion of age 3 herring by tow. Units of CPUE are kg • m^{-3}.

Tow	Date	Time	Location	CPUE	% age 3
Mid-water tows					
Replicate 1					
1	25	1147	Eddy	0.07	17.8
2	25	1640	40-mile Bank	0.07	13.3
3	26	0828	40-mile Bank	0.0001	1.4
4	26	0911	12-mile Bank	0.0001	1.6
5	26	1100	12-mile Bank	0.14	15.2
6	26	1309	SW Corner	0	0
7	26	1441	Potholes	0.005	65.3
8	27	0642	Potholes	0.00009	0
9	27	1104	Bottleneck	0.12	0
10	28	0635	South Slope	0	0
11	28	1003	West Bank	0	0
14	29	0637	Subarea 2.1	0.02	15.2
Replicate 2					
15	29	1538	Swiftsure	0.05	0
16	29	1649	Swiftsure	0.25	10.7
17	30	0745	Finger Bank	0.08	6.8
18	30	0857	Finger Bank	0.09	2.0
19	30	1036	40-mile Bank	0.12	6.0
20	30	1227	40-mile Bank	0.42	6.7
21	30	1452	40-mile Bank	0	0
22	30	1648	SW Corner	0.06	17.1
Bottom tows					
12	28	1451	North Slope	0	0
13	28	1627	North Slope	0	0

Table 2. Summary of simple regression statistics. All regression were calculated using the logits of the proportions and the forecast was the independent variable. S. E. is the standard error of the estimate. ESM – escapement model; ASM – age-structured model.

	Slope			Intercept			
Dependent	Estimate	S. E.	p	Estimate	S. E.	p	R^2
ESM_{obs}	0.79	0.330	0.04	-0.29	0.352	0.42	0.28
ASM_{obs}	0.84	0.330	0.03	-0.18	0.352	0.61	0.32
$Rev.ASM_{obs}$	0.84	0.330	0.03	-0.18	0.352	0.61	0.32

Table 3. Forecasted proportion of age 3 fish for WCVI herring returning in the 2001 fishing season.

		Prop. age 3	
Model	Lower 95% CL	Estimate	Upper 95% CL
Empirical	0.06	0.10	0.16
ASM	0.06	0.10	0.16
Rev. ASM	0.06	0.10	0.16

Table 4. Forecasted numbers and biomass of recruits (age 3 herring) to the WCVI stock. Estimates for the ASM and Rev. ASM are not multiplied by λ, the availability parameter.

		Number of recruits (x 10^{-6})			Recruit biomass (tonnes)		
Model	No. adults (x 10^{-6})	Lower 95% C. L.	Estimate	Upper 95% CL	Lower 95% C.L.	Estimate	Upper 95% CL
ESM	75.4	4.82	8.37	14.36	419	729	1249
ASM	126.5	8.07	14.05	24.09	702	1223	2096
Rev. ASM	93.4	5.96	10.37	17.78	518	902	1547

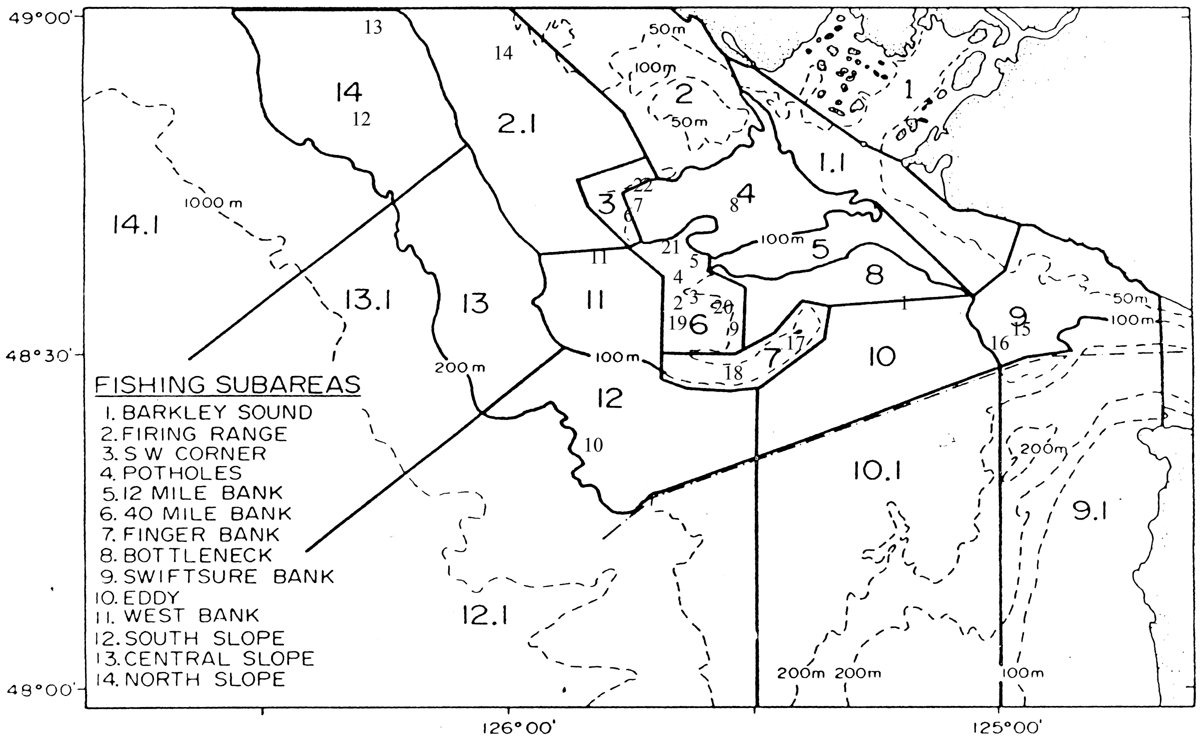


Fig. 1. Study area. Tow locations are shown as outlined numbers.

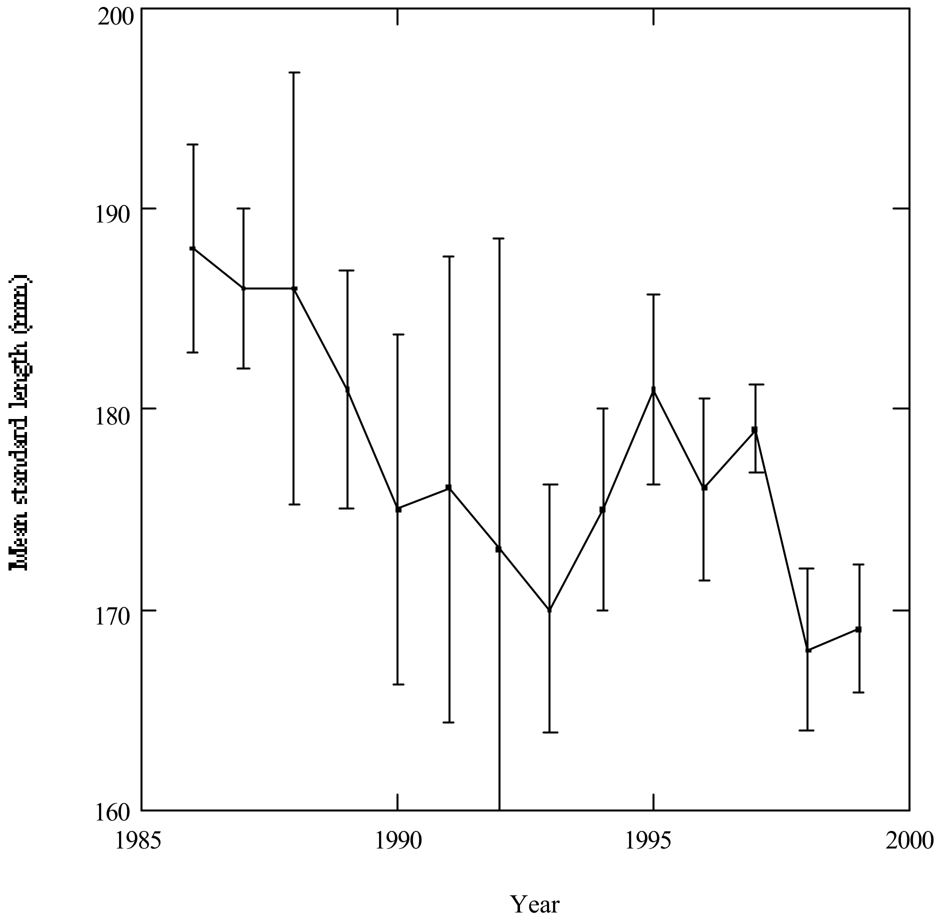


Fig. 2. Standard length (mean ± 2 SE) for age 3 herring trawled along the southwest coast of Vancouver Island, 1986-99.

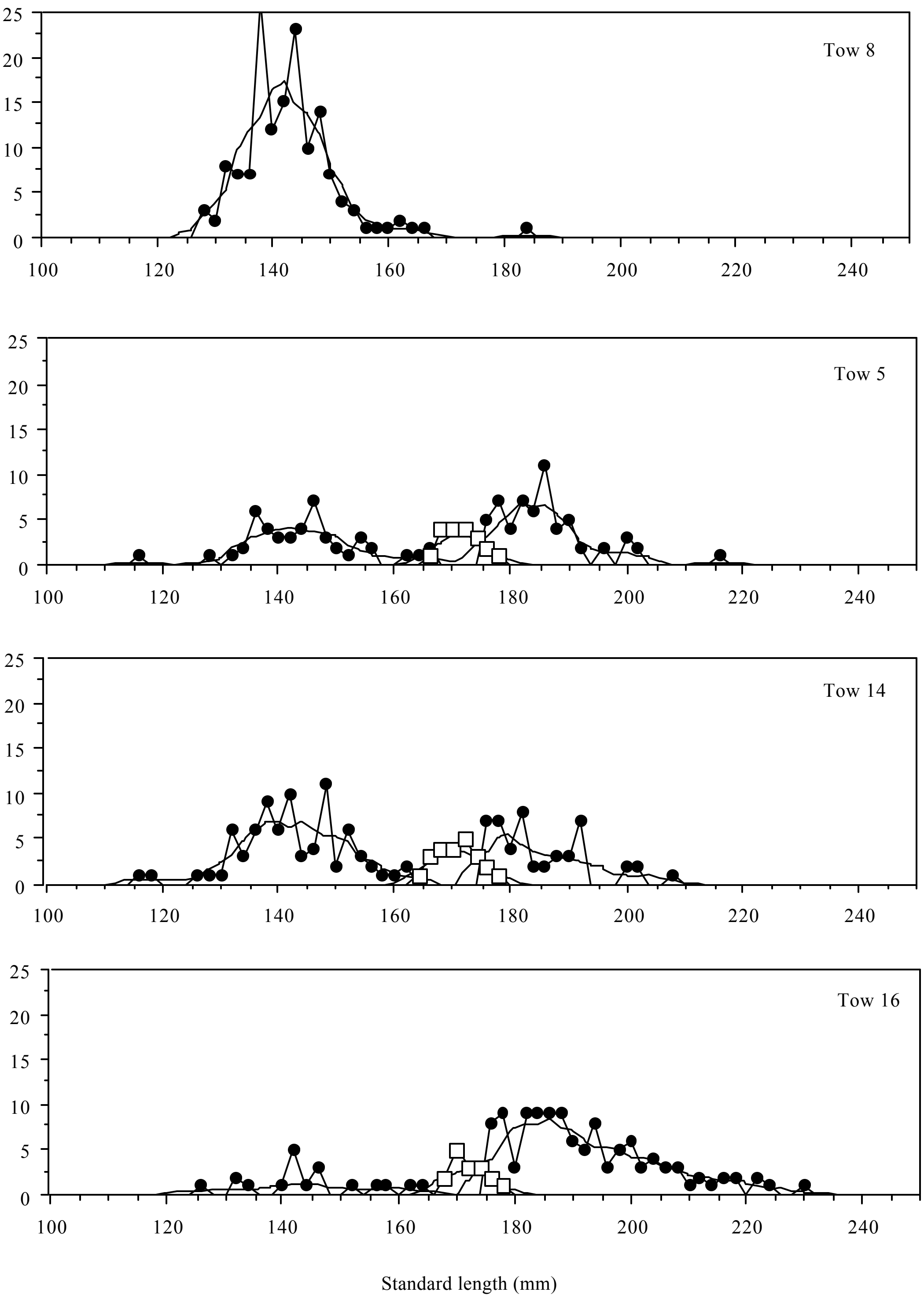


Fig. 3. Length-frequency histograms for herring trawled during the 2000 offshore herring survey. Open symbols indicate fish presumed to be age 3. Histograms are presented in the order that helped discern the size distribution of age 3 herring.

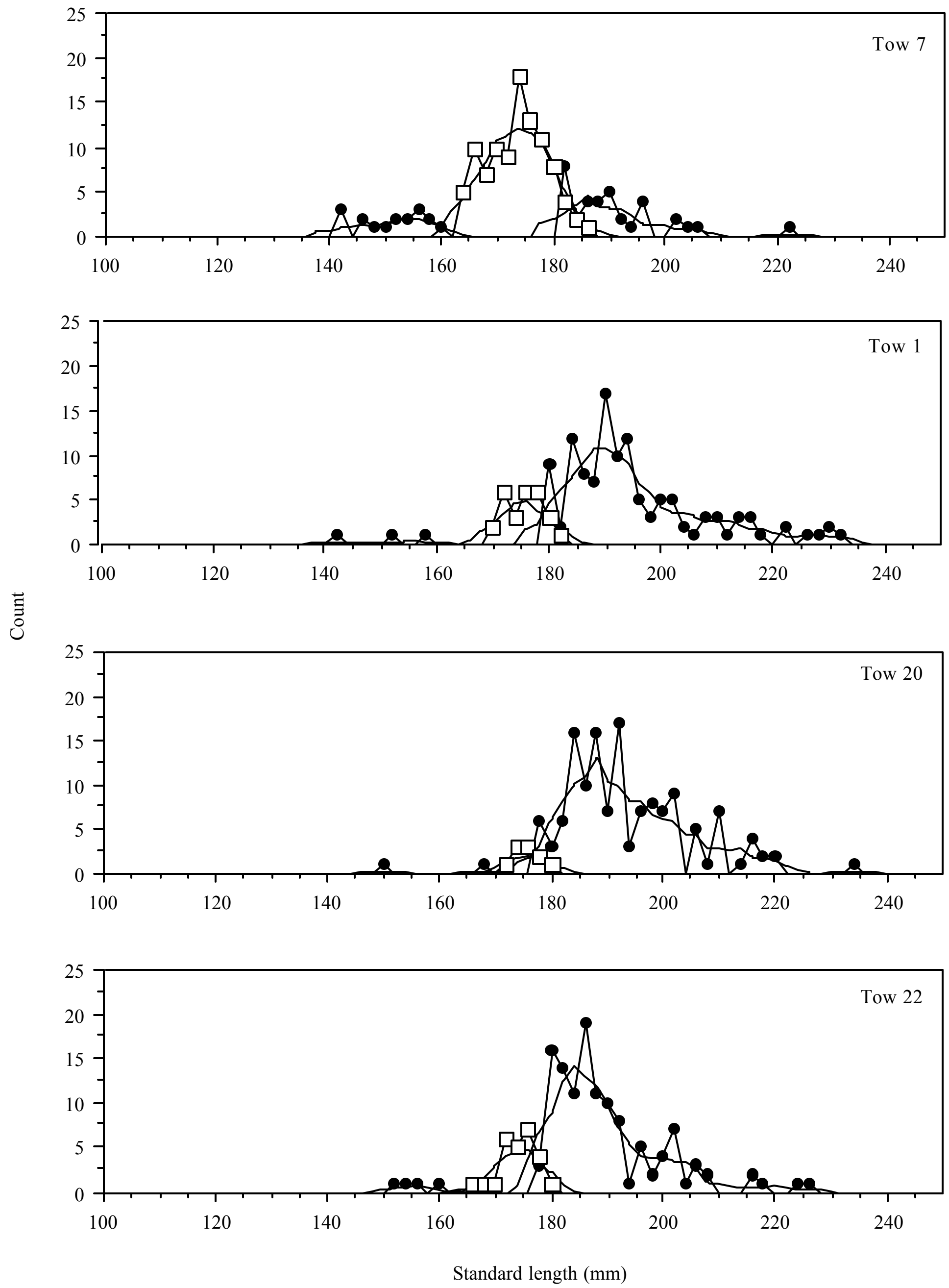

Tow 7
Tow 1
Tow 20
Tow 22
Count
Standard length (mm)
0
5
10
15
20
25
100
120
140
160
180
200
220
240

Fig. 3 cont.

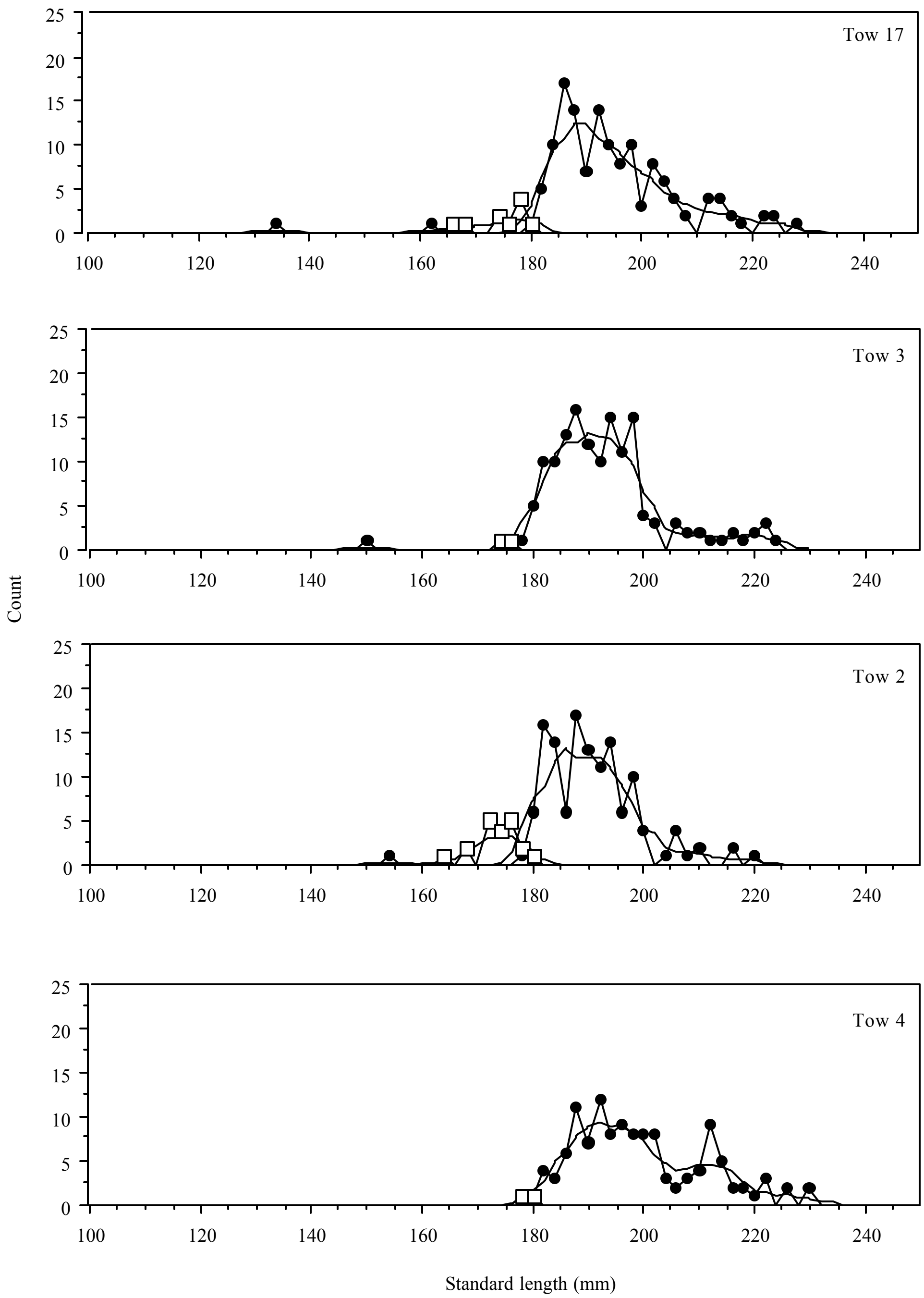
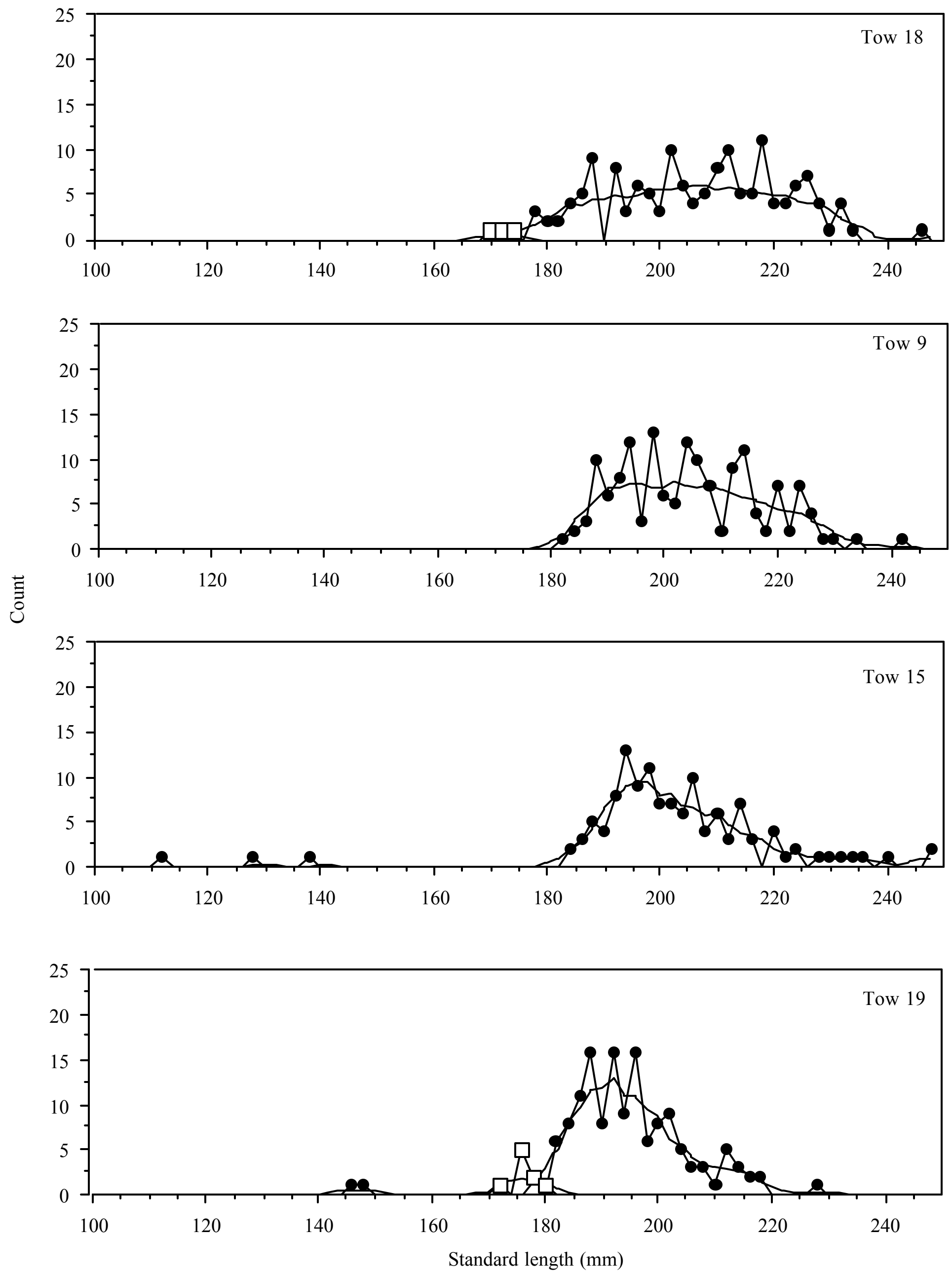

Tow 17
Tow 3
Tow 2
Tow 4
Count
Standard length (mm)
0
5
10
15
20
25
100
120
140
160
180
200
220
240

Fig. 3 cont.



Tow 18
Tow 9
Tow 15
Tow 19
Count
Standard length (mm)
0
5
10
15
20
25
100
120
140
160
180
200
220
240

Fig. 3 cont.

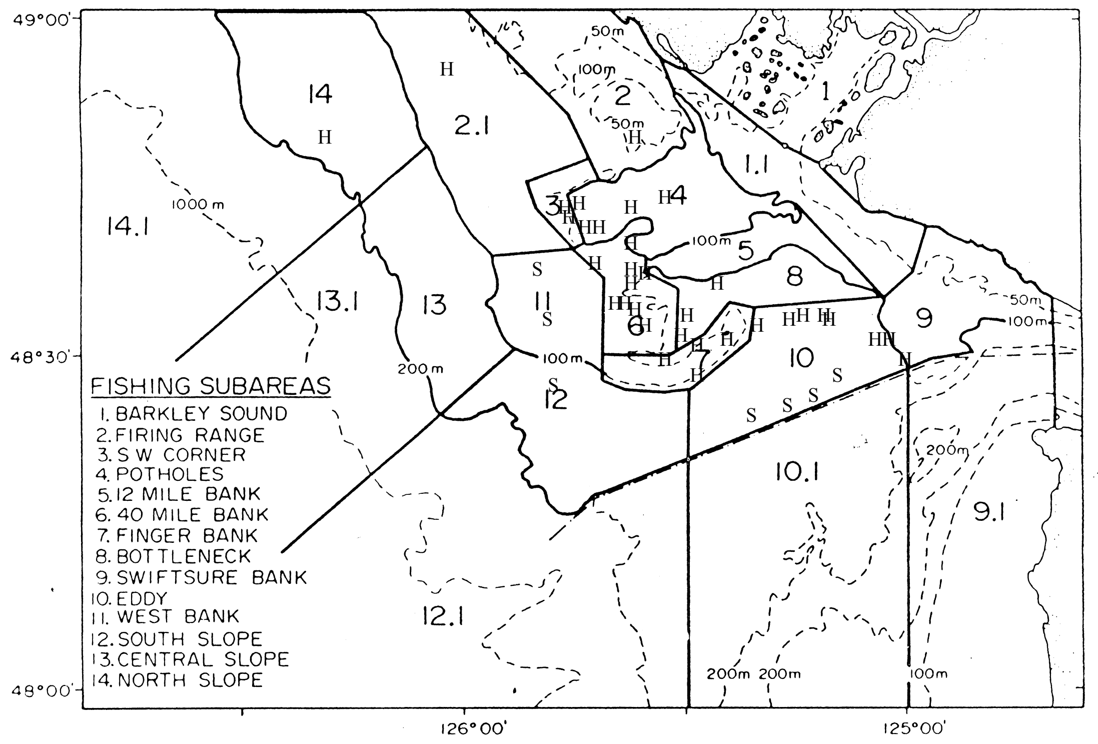


Fig. 4. Concentrations of herring (H) and sardine (S), July 25-28.

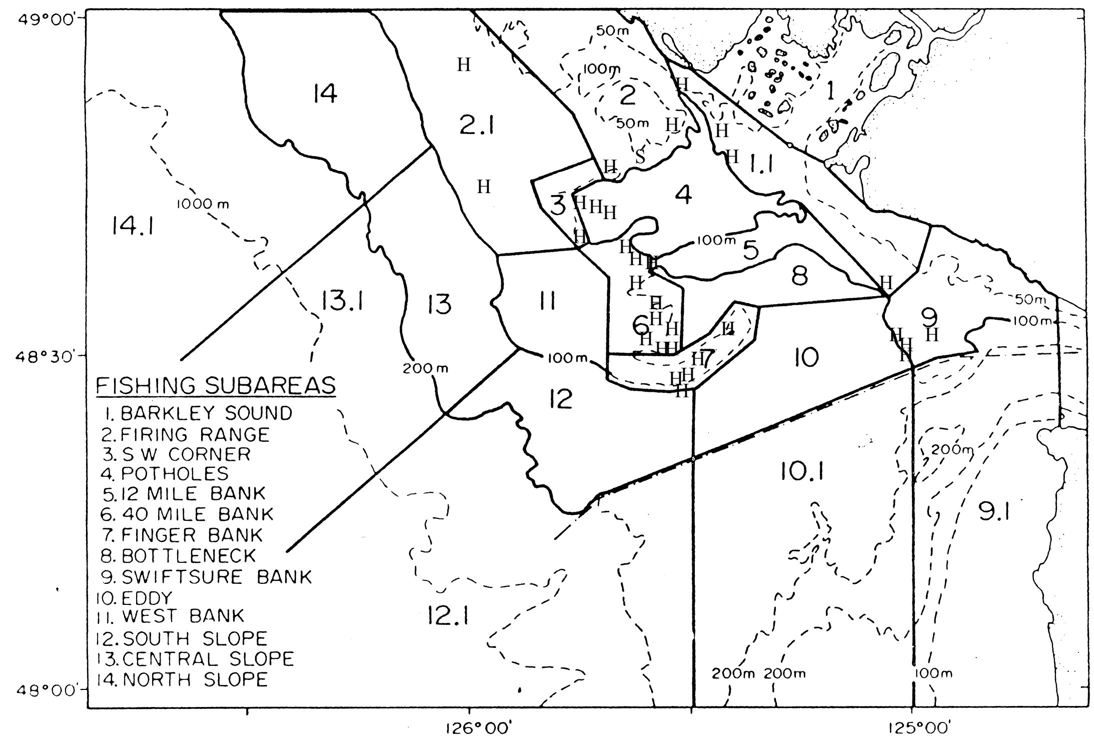


Fig. 5. Concentrations of herring (H) and sardine (S), July 29-30.

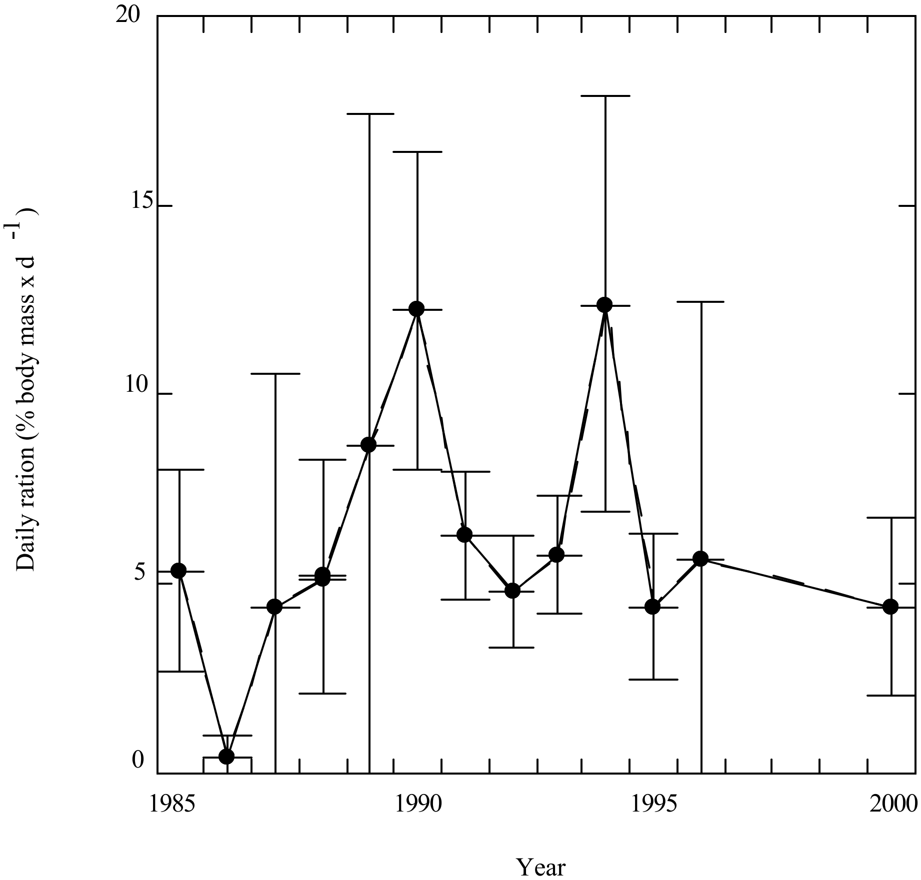


Fig. 6. Diet and daily ration for herring trawled during July-August fisheries surveys. The overlap of euphausiid ration (dotted line) and total ration (solid line) shows that euphausiids are the exclusive prey. Error bars are 95% confidence intervals. Data for 1997-99 are not available yet.

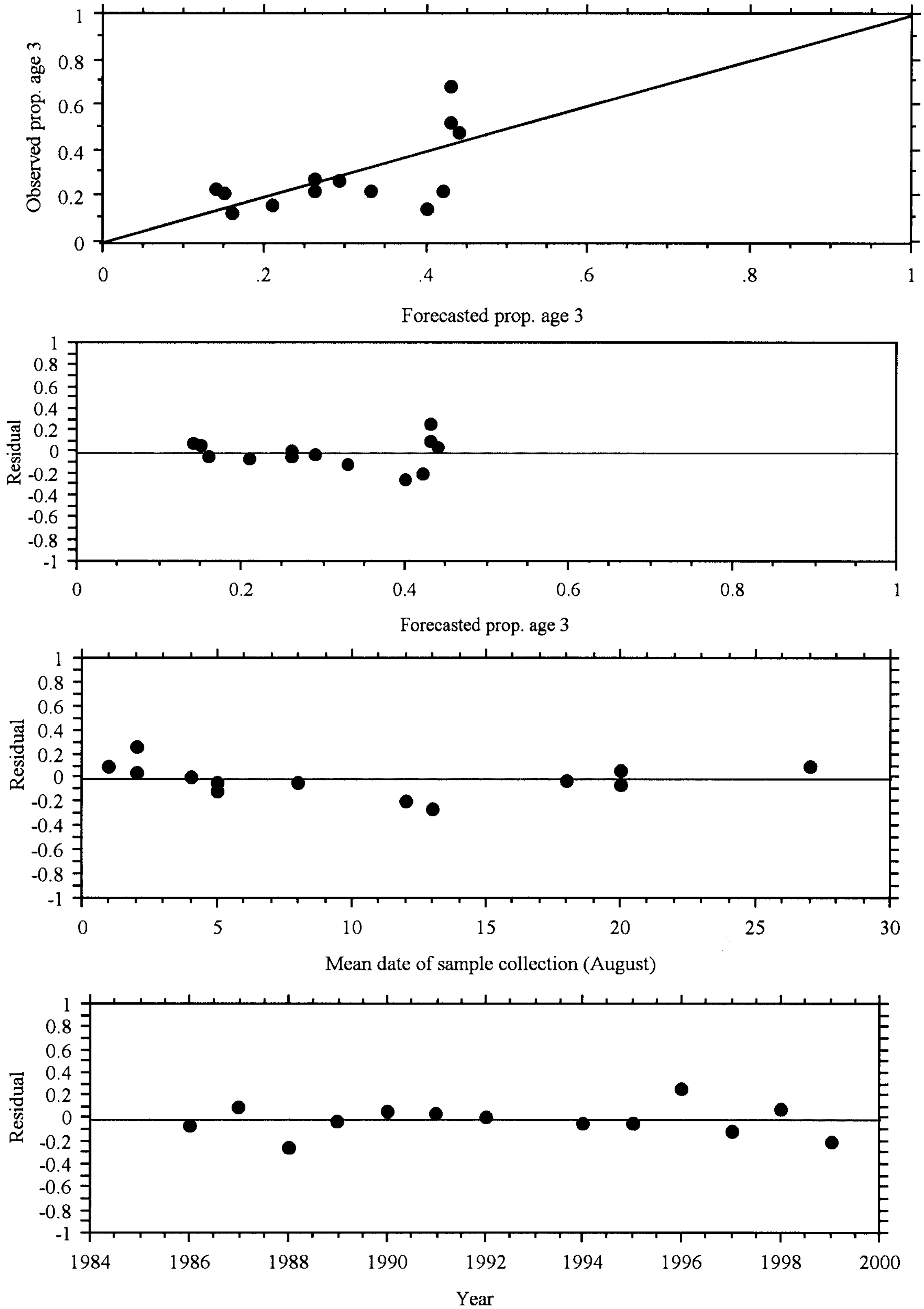


Fig. 7. Observed and forecasted proportion age 3 herring for WCVI stock and diagnostic residual plots; escapement model.

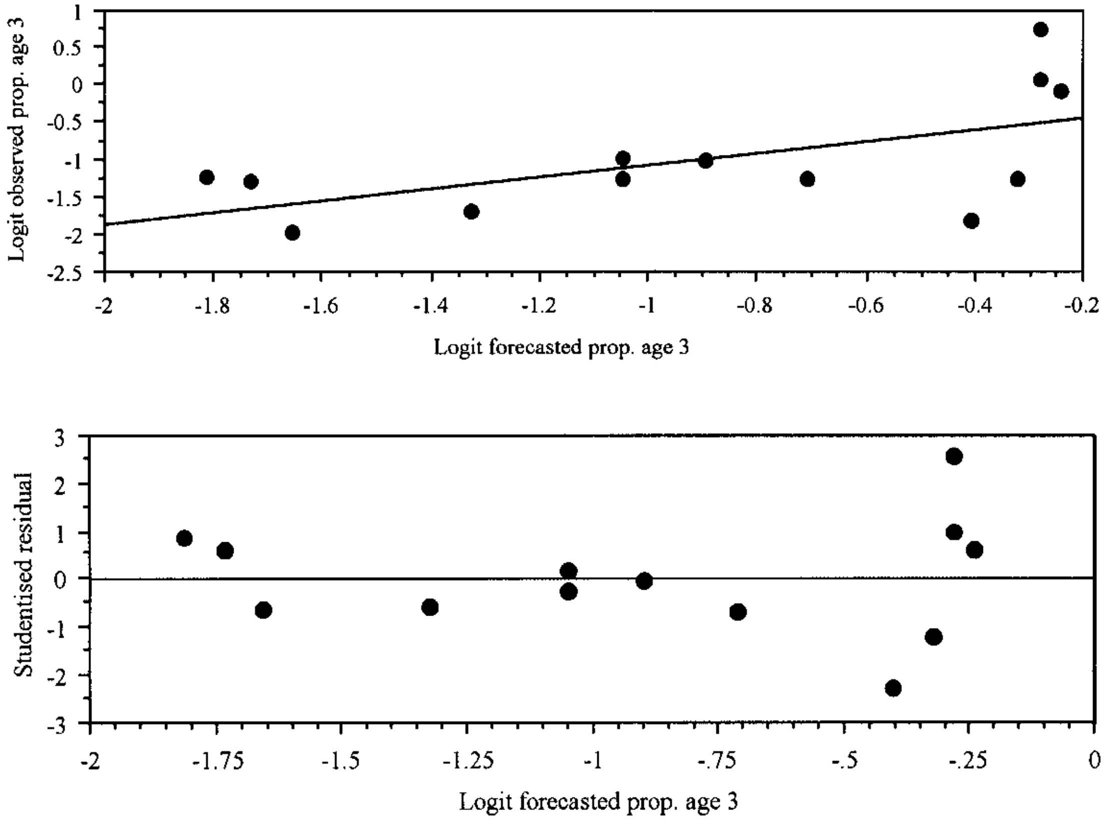


Fig. 8. Plot and studentised residuals for the regression of logit observed proportion age 3 for WCVI herring on logit forecasted proportion age 3, escapement model. Solid line is the simple linear regression fit.

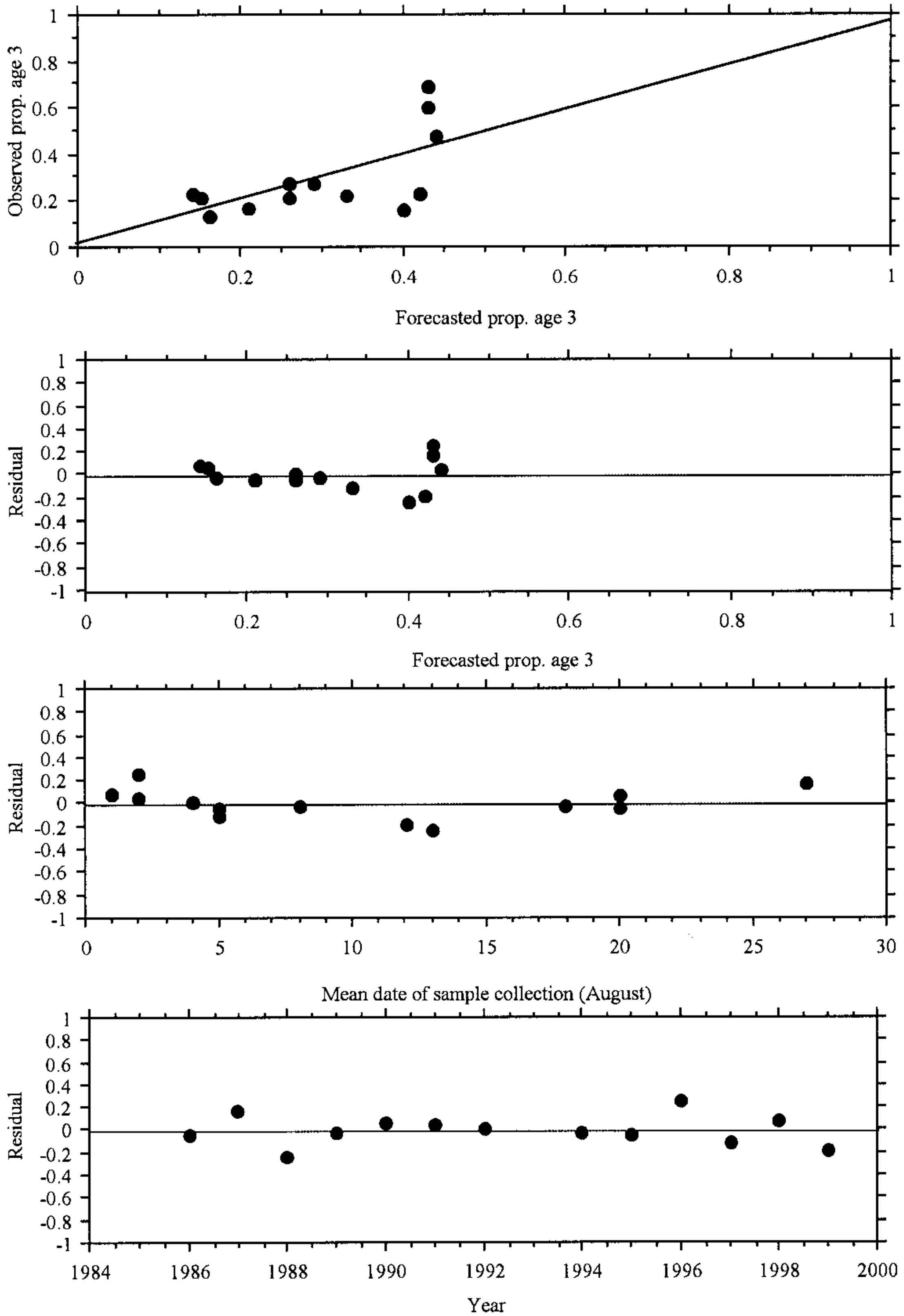


Fig. 9. Observed and forecasted proportion age 3 herring for WCVI stock and diagnostic residual plots; age-structured model.

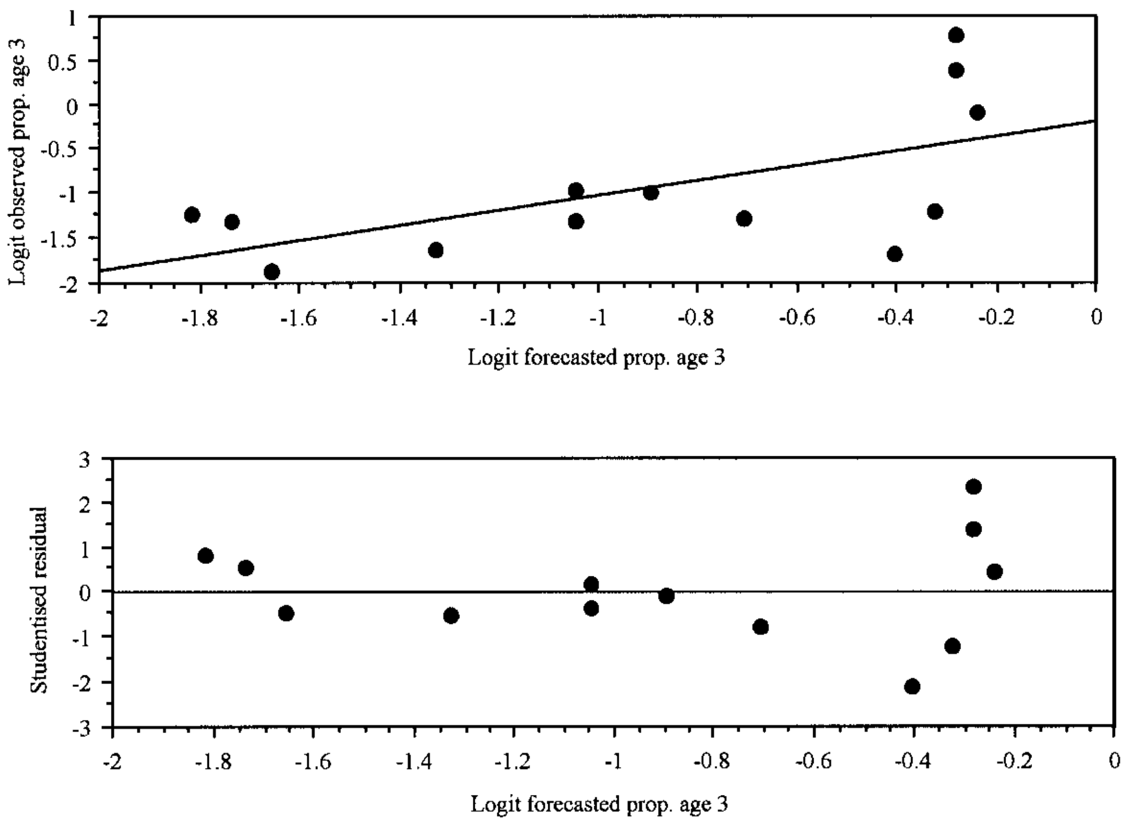


Fig. 10. Plot and studentised residuals for the regression of logit observed proportion age 3 for WCVI herring on logit forecasted proportion age 3, age-structured model. Solid line is the simple linear regression fit.

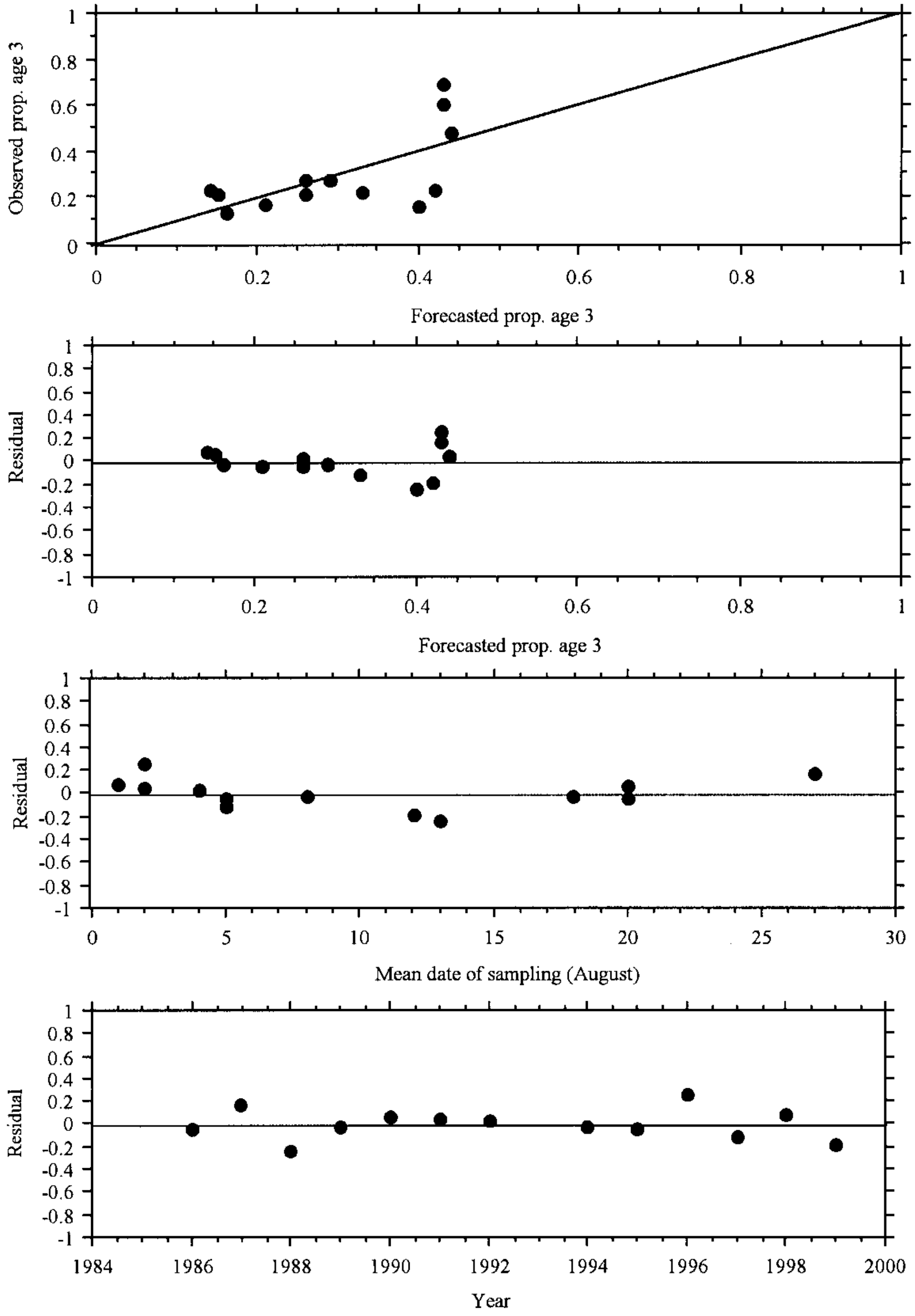


Fig. 11. Observed and forecasted proportion age 3 herring for WCVI stock and diagnostic residual plots, revised age-structured model.

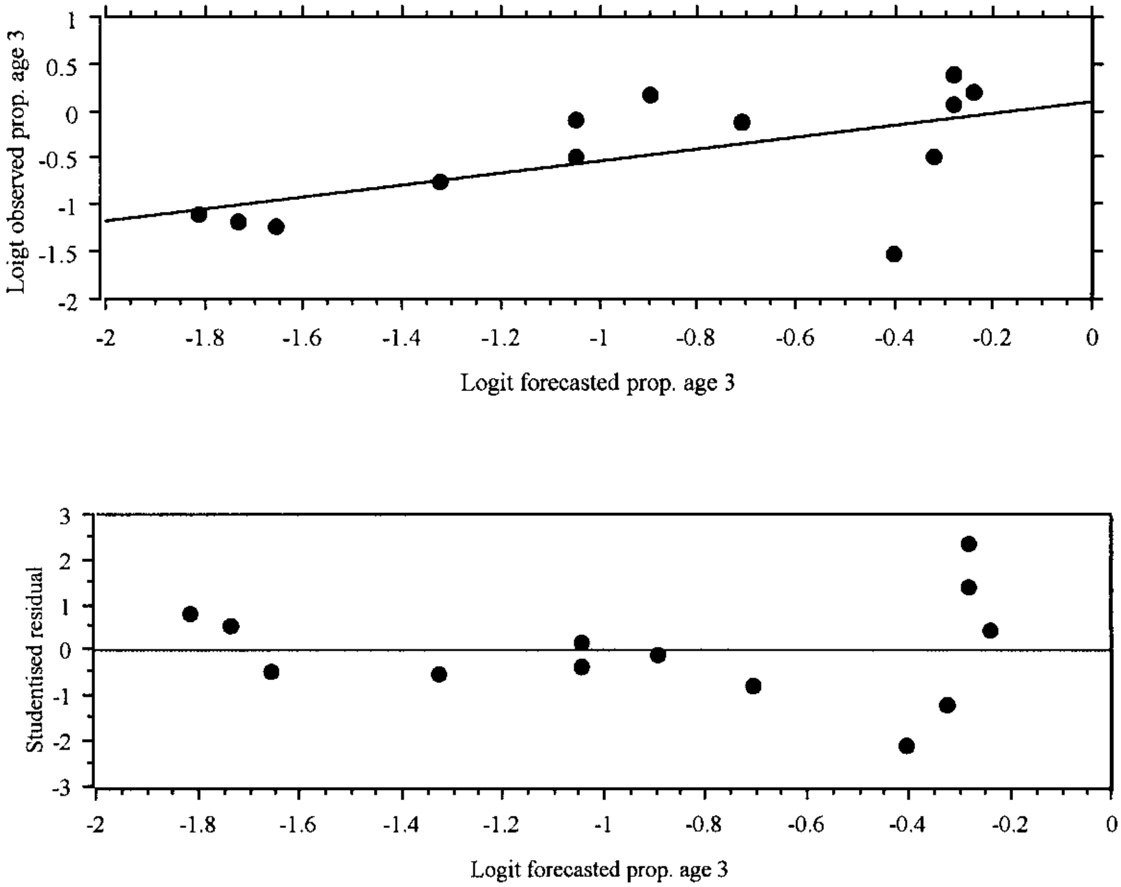


Fig. 12. Plot and studentised residuals for the regression of logit observed proportion age 3 for WCVI herring on logit forecasted proportion age 3, revised age-structured model. Solid line is the simple linear regression fit.

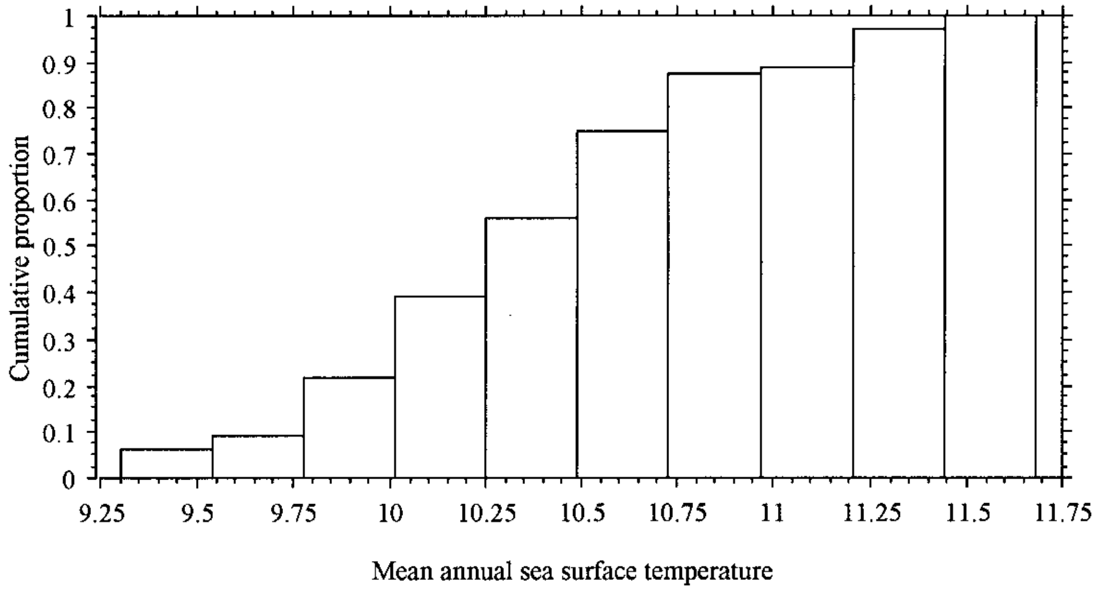


Fig. 13. Cumulative distribution of mean annual sea surface temperature.

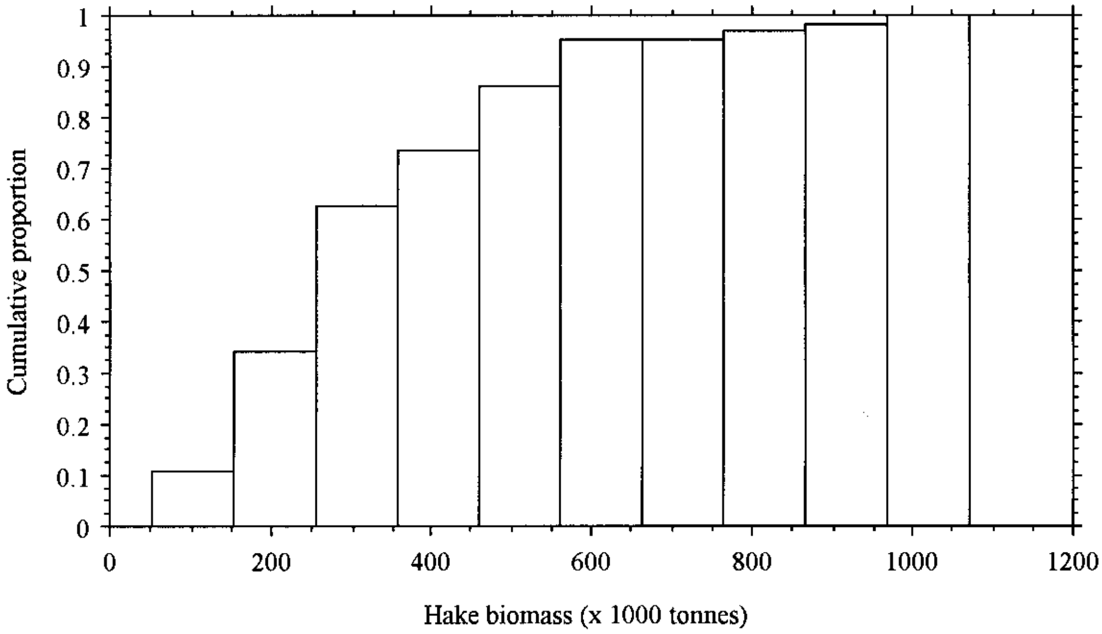


Fig. 14. Cumulative distribution of hake biomass.