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An Evaluation of a Recruitment Forecasting Procedure for Strait of Georgia Herring

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ABSTRACT

This report describes an evaluation of an extension of the recruitment forecasting procedure which has been used since 1987 to forecast recruitment (number of age 3 spawners) for the West Coast Vancouver Island (WCVI) stock of Pacific herring (*Clupea pallasi*) (Ware and Tanasichuk 1987). The extension is to forecast recruitment for Strait of Georgia herring. The forecasting procedure is based on the age composition of samples of herring trawled along the southwest coast of Vancouver Island during summer fisheries oceanography surveys. Results of analyses of data on observed proportion of age 3 fish in the subsequent spring's roe fishery showed that proportion of age 3 fish from the WCVI and Strait of Georgia stocks were correlated significantly and that the functional relationship had a slope and intercept which were not significantly different from 1 and 0 respectively. Therefore, year-specific proportion at age 3 was the same for both stocks which means that proportion at age 3 for either stock should not be biased by mixing on the summer feeding grounds. Results of regression analyses showed that proportion of age 3 fish observed in the prefishery can be predicted from the proportion of age 3 herring in the samples trawled the previous summer. Residual analysis showed no time trend in the residuals, or any effect of sampling time or the magnitude of the forecast. A retrospective analysis of the forecasts over 1994 – 2001 showed that observed proportions at age 3 were mostly within the 95% confidence interval of the forecast, and that the mean difference between forecasted and observed proportion at age 3 was less than 0.03 among the three stock assessment models. The approach provides acceptably accurate forecasts of recruitment for the Strait of Georgia stock. Recruitment for this stock is forecasted to be between average and good. Forecasts for WCVI herring are presented in an appendix. Recruitment for WCVI herring is forecasted to be poor.

Observations on fish species compositions and distributions made during the 2001 offshore survey were reported. Species compositions and herring distributions were different than in previous years. Whitebait smelt (*Allosmerus elongatus*) were common nearshore. There has only been one previous record of this species in Canadian waters. In addition, walleye pollock (*Theragra chalcogramma*) were common; they have been scarce since the early 1990's. Herring were concentrated on 40 Mile and especially Swiftsure Banks and were dispersed along the continental shelf slope to at least 49^{o} N.

RÉSUMÉ

Ce rapport décrit l'évaluation d'une extension de la procédure de prévision du recrutement (nombre de géniteurs âgés de trois ans) appliquée depuis 1987 au stock de hareng du Pacifique (*Clupea pallasi*) de la côte ouest de l'île de Vancouver (WCVI) (Ware and Tanasichuk 1987). L'extension consiste à prévoir le recrutement du hareng du détroit de Géorgie. La procédure de prévision se fonde sur la composition par âge d'échantillons de harengs capturés au chalut le long de la côte sud-ouest de l'île de Vancouver lors de relevés océanographiques et halieutiques estivaux. Selon les résultats d'analyses des données sur la proportion observée de poissons de trois ans dans la pêche du hareng rogué le printemps suivant, les proportions de poissons de trois ans dans les stocks de WCVI et du détroit de Géorgie étaient significativement corrélées, la relation présentant une pente et un point d'intersection qui ne différaient pas significativement de 1 et de 0, respectivement. Ainsi, les deux stocks présentaient la même proportion de poissons âgés de trois ans pour une année donnée, ce qui signifie que, pour chaque stock, cette proportion ne devrait pas être biaisée par le mélange des stocks sur les aires d'alimentation estivales. Les analyses de régression indiquent qu'on peut prévoir la proportion de poissons âgés de trois ans avant la saison de pêche à partir de la proportion de poissons âgés de trois ans dans les échantillonnages de harengs capturés au chalut l'été précédent. L'analyse des résidus a montré que ceux-ci ne présentaient aucune tendance temporelle et que le moment de l'échantillonnage et l'ampleur de la prévision n'avaient aucun effet. Selon une analyse rétrospective des prévisions pour la période 1994 – 2001, les proportions observées de poissons âgés de trois ans étaient pour la plupart comprises dans l'intervalle de confiance à 95 % de la prévision et que la différence moyenne entre les proportions prévue et observée des poissons âgés de trois ans était inférieure à 0,03 pour les trois modèles d'évaluation des stocks. La méthode donne des prévisions de recrutement au stock du détroit de Géorgie dont l'exactitude est acceptable. On prévoit que le recrutement pour ce stock sera de moyen à bon, tandis que celui du stock de hareng de WCVI sera faible. Les prévisions pour ce dernier stock sont présentées en annexe.

Le rapport présente aussi des observations faites pendant le relevé en haute mer de 2001 sur les espèces de poissons présentes et leurs répartitions. Les compositions spécifiques et les répartitions du hareng différaient de celles observées lors des années antérieures. L'éperlan blanchaille (*Allosmerus elongatus*), une espèce qui n'avait été observée qu'une seule fois auparavant dans les eaux canadiennes, était souvent trouvé près des côtes. On a aussi couramment capturé la goberge de l'Alaska (*Theragra chalcogramma*), une espèce qui était rare depuis le début des années 1990. Le hareng se concentrait sur le banc 40 Mile et surtout sur le banc Swiftsure et était dispersé le long de la plate-forme continentale au moins jusqu'à 49^{o} N.

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. Historically, there were two stock assessment models. One was the Escapement Model (Schweigert and Stocker 1988) which is based on spawn deposition. The second model, the Age-structured Model (Fournier and Archibald 1982), is based on age composition of catches. The forecasted recruit biomass was 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.

Surprisingly, there now appears to be a basis, as a result of tag returns and preliminary data analysis, for using the mid-water trawl survey data to forecast recruitment for Strait of Georgia herring as well. Historic tagging data (Tester 1948) supports the suggestion that these two populations share feeding grounds along the west coast of Vancouver Island. Subsequent tagging (1965, 1980, 1981) results (http://www-sci.pac.dfo-mpo.gc.ca/herspawn/hertags/wcvi_tab.htm) showed that herring tagged off the WCVI in the fall were recovered in the Strait of Georgia as well as from the WCVI. In addition, these populations have similar proportions of age 3 fish in the pre-fishery biomasses. Figure 1 presents a scatterplot of logit observed proportion of age 3 herring for the WCVI and Strait of Georgia stocks. Results of a functional regression analysis (Ricker 1973) showed that the regression had a slope and intercept which differed insignificantly from 1 and 0 respectively. This suggested that the proportion-at-age co-varied between the populations and there was no difference in proportion-at-age 3. Consequently, the trawl data should provide an equally accurate forecast of proportion of age 3 fish for the Strait of Georgia and mixing of stocks on summer feeding grounds would not bias the estimates.

The extension of the forecasting procedure to the Strait of Georgia stock was presented to the PSARC Subcommittee at the 2000 meeting. As requested by the Subcommittee, this extension has been evaluated. The objective of this report is to present the results of the evaluation. It consists of examining, retrospectively, the regression equations used to forecast recruitment and the forecasts' accuracy. The evaluations were done for the three stock assessment models considered for the 2002 forecasts. The models included the escapement (ESM), age-structured (RASM) and a revision of the age-structured model (RASM- 2q) (Schweigert 2001).

METHODS

The 2001 survey was conducted along the southwest coast of Vancouver Island between July 30 and August 4 (Fig. 2). Echosounding and fishing were done using the

R/V W. E. Ricker equipped with a CanTrawl 350 midwater trawl with a herring liner in the cod-end. The survey was part of a hydro-acoustic assessment for Pacific hake (*Merluccius productus*) along the WCVI. The assessment survey design was to run transects from the coast south to as far offshore as the shelf break (400 m depth) and at 10 nautical mile intervals; transects along the southwest coast of Vancouver Island were at 2.5 nautical mile intervals. The hydro-acoustic survey began on July 24 and most of the WCVI, except for the traditional herring survey area (Fig. 2), was covered by July 30. Herring concentrations encountered were fished (Tows 7 and 33). Sounding operations during the herring survey period were designed to cover the study area for herring comprehensively; hydro-acoustic transecting resumed whenever sounding for herring was suspended. Seventeen mid-water trawls were made (Table 1). The catch from each tow was brought aboard. Catch was segregated by species and weighed. Catch per unit effort for herring was estimated as kg $\bullet$ 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).

Herring sampling consisted of measuring mass and length and recording sex and stomach contents. As for other years, the lengths of 150 fish were measured for each tow. Prey were identified to species, if possible, or specific taxonomic group (eg. euphausiids, copepods). Prey volume was estimated using syringes as guides. In addition, scales were collected from herring trawled in each of the regions where they occurred. One scale sample from each of the first 100 fish measured was taken from samples collected during Tow 43 (Central Slope), Tow 47 (40 Mile Bank) and Tow 52 (Swiftsure Bank).

The proportion of recruit (age 3) herring was estimated using age data collected during the 2001 survey instead of using the mean length-at-age 3 from aged samples of fish collected during the previous summer's survey, which is the traditional approach. This was because an abrupt change in length-at-age 3 (Fig. 3) in 2000 resulted in a substantial underestimate of proportion of recruit fish for the 2001 WCVI forecast (see Appendix). Fish were aged by the Ageing Laboratory at the Pacific Biological Station. Age-length data were pooled over tows and stratified by 2 mm length intervals. For the pooled data, the proportion of fish at age *j* in length interval *l* was estimated as:

$$(1) \quad P_{j,l} = N_{j,l} / N_l \,.$$

Number of fish at age 3 in each tow (N_3) was then estimated as:

$$(2) \quad N_3 = \sum_{l=120}^{240} P_{3,l} \bullet N_l \,.$$

Proportion of age 3 fish in a sample in a given tow was estimated by dividing N_3 by 150, the number of fish sampled from each tow. As in previous years, tows consisting of fish 3 or younger were excluded from analyses because these are assumed to be immature fish, which will not spawn next spring.

I tested the forecasting procedures' performance by comparing the proportion of age 3 herring estimated from the mid-water trawl survey with the estimated proportion of age 3 fish for the prefishery biomass in the subsequent spring. Estimates of proportion of age 3 fish in the prefishery biomass were available for all stock assessment models. For the escapement model, estimates of proportion of age 3 fish in the prefishery biomass 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 (2000a). 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:

$$(3)\quad N_{i,j,k} = (N_{i,j,k,s}) \bullet (M_{i,k,c} / M_{i,k,s}),$$

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. Estimates of numbers of fish at age 3 for the two forms of the age-structured model were provided by Schweigert (Dept. of Fisheries and Oceans, Nanaimo, B. C.). Numbers of fish-at-age were multiplied by the availability parameter (Schweigert and Fort 2000) to estimate the number of fish-at-age in the prefishery biomass.

Statview (1999) was used for correlation and regression analyses and SAS (1996) for log-linear model analysis. Proportion data were transformed using the logit transformation (Sokal and Rohlf 1995). Standard errors for the forecasted proportion age 3 ($S_{y\text{-hat}}$) were calculated using the equation given by Sokal and Rohlf (1995), where,

$$(4)\quad S_{y-hat} = \sqrt{S^2{}_{y\bullet x}\left[1/n + \left(\left(X_i - \overline{X}\right)^2 / \sum x^2\right)\right]}$$

and $S^2{}_{Y\bullet X}$ is the error mean square for the regression, n is the number of data pairs used to 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

$$(5)\quad R = observed - predicted\,.$$

RESULTS

a) Recruitment forecasts

i) Proportion of age 3 fish

Length-frequency histograms for age 3 fish trawled during the 2001 survey are presented in Fig. 4. Results of log-linear model analysis showed no effect of tow on the number of fish in a length interval; in other words, there was no significant difference in the length-frequency histograms between tows. The assignment of age 3 fish for each tow is shown in Fig. 5 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 0.65. Tanasichuk (2000b) showed that the proportion of age 3 fish estimated during two consecutive surveys agreed well.

ii) Statistical analysis

Scatterplots for the predictive regressions and their residual analyses for the three assessment models are presented in Figs. 6 - 8. Data from the 1988 and 1994 mid-water surveys appeared to be outliers and were excluded from the regression analyses. The residuals were presented as their back-transformed values to simplify interpretation. There were no patterns in the residuals which showed that there was no effects of forecast magnitude, sampling time or year on the forecasts. Parameter estimates for assessment model-specific regressions are presented in Table 2.

A retrospective analysis of model performance indicates that forecasts would have been acceptably accurate in 6 of 8 years. The analysis was done by estimating regression parameters using data up to and including $year_x$. Retrospective analysis began for the 1994 fishing season, when forecasting regressions became statistically significant. The proportion of age 3 fish estimated from trawled samples was used to forecast proportion at age 3 for $year_{x+1}$; the proportion of age 3 fish was estimated using the refinement adopted this year, that is length-at-age was based on scale readings instead of the assumption that length-at-age did not vary significantly between consecutive years. Before analysis, length of aged fish had to be corrected for the effect of freezing using the equation:

$$(6)\ L_{fresh}=0.9939*L_{frozen} + 4.907,$$

where L_{fresh} is the standard length (mm) of a freshly caught fish and L_{frozen} is its frozen standard length (Schweigert, 2001 pers. comm.). This was necessary because all fish are measured fresh during the surveys and all data for aged fish are from frozen samples. Results of the retrospective analyses are shown in Fig. 9. Mean differences between the observed and forecasted proportion at age 3 were 0.02 ± 0.086, 0.03 ± 0.086 and 0.02 ± 0.076 (mean ± 2 S.E.) for the ESM, RASM and the RASM-2q models respectively.

iii) Forecasted biomass

I used the weighted proportion at age 3 (0.65) from 2001 trawl survey, the estimated pooled 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. The back-transformed forecasted proportion at age 3 and confidence limits are presented in Table 3.

The forecasted number of age 3's (N_3) was then estimated following Ware and Tanasichuk (1999). To begin, number of adults ($N_{a,m}$) in the returning spawner biomass forecasted by each model *m* was estimated as:

$$(7) \quad N_{a,m} = B_m \bullet W_a^{-1},$$

where B_m is the model-specific biomass forecast (Schweigert 2001) and W_a is the mean mass of adult fish from prefishery samples (0.000086 tonnes) for the 2001 fishing season. Number of age 3 fish in the prefishery biomass (B_3) was estimated as:

$$(8) \qquad N_3 = (N_{a,m} / (1 - p)) - N_{a,m},$$

where *p* is the proportion of age 3 fish as estimated from the offshore survey and W_3 is the mean mass (0.000070 tonnes) of age 3 fish from prefishery samples collected during the 2001 fishing season. The forecasted number of age 3 fish, and their lower and upper 95% confidence limits are presented in Table 4. Schweigert (2001) presented a time series of number of recruit estimates, by year, for the RASM-2q model. He ordered the recruit estimates numerically and divided the series into thirds to represent ranges of poor, average and good. The ranges are as follows:

Recruitment	Number of recruits ($\bullet 10^{-6}$)
Poor	<401
Average	401-699
Good	>699

Estimated numbers of age 3 fish correspond to good recruitment for the ESM and RASM models, and to average recruitment for the RASM-2q model.

b) Observations of fish species composition and distribution

Fish species compositions were dramatically different in 2001. The largest difference was the occurrence of whitebait smelt (*Allosmerus elongatus*). There has only been one previous record of them in Canadian waters (Hart 1973). In addition, walleye pollock (*Theragra chalcogramma*) were common after being scarce since the early 1990's. M. Saunders (Dept. of Fisheries and Oceans, Nanaimo, B. C., *pers. comm.*) attributed this to movement of animals from Alaskan waters where there has been a strong year-class. Pollock were mixing with Pacific hake (*Merluccius productus*) and complicating hake fishing operations.

Herring abundance seemed high and R. Kieser (Dept. of Fisheries and Oceans, Nanaimo, B. C.) will be providing a hydro-acoustic estimate for herring ensonified during the survey. Herring were concentrated on 40 Mile and especially Swiftsure Banks and were dispersed along the continental shelf slope to at least 49^{o} N (Fig. 10). Sardine (*Sardinops sagax*) were also widely distributed.

SUMMARY AND CONCLUSIONS

1) A trawl survey of the southwest coast of Vancouver Island was done between July 31 and August 4, 2001.

2) A statistical analysis of the performance of the recruitment forecasting procedure for Strait of Georgia herring showed no effect of sampling time nor potential mixing between the WCVI and Strait of Georgia herring stocks on forecast accuracy.

3) Retrospective analysis showed that forecasts for Strait of Georgia herring would have been accurate.

4) Forecasts of number of recruits and their 95% confidence limits are presented.

5) Species compositions were unusual because of the occurrence of whitebait smelt and the re-appearance of walleye pollock. Herring was the predominant species and hake were virtually absent.

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

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

Tow	Date	Time	Location	CPUE	Prop. age 3
7	27/07	818	Central Slope	0.0004	0.67
33	30/07	1108	Central Slope	0.0030	0.32
40	31/07	0730	Potholes	0	0
41	31/07	0814	Potholes	0	0
42	31/07	0854	Potholes	0	0
43	01/08	1146	Central Slope	0.0017	0.71
44	01/08	1700	Central Slope	0.0047	0.39
45	02/08	847	12 Mile Bank	0.0035	0.63
46	02/08	1308	Bottleneck	0	0
47	02/08	1603	40 Mile Bank	0.0007	0.64
48	02/08	1845	40 Mile Bank	0.0024	0.63
49	03/08	0805	40 Mile Bank	0.0181	0.63
50	03/08	0950	Finger Bank	0.0091	0.63
51	03/08	1240	Finger Bank	0.0109	0.61
52	03/08	1510	Swiftsure Bank	0.0061	0.49
53[a]	04/08	0708	Swiftsure Bank	.	.
54	04/08	1054	Swiftsure Bank	0.0053	0.37

Table 2. Summary of simple regression statistics. All regression were calculated using the logits of the proportions and the proportion age 3 from the summer trawl survey was the independent variable. S. E. is the standard error of the estimate. ESM – escapement model; RASM – age-structured model.

	Slope			Intercept			
Dependent	Estimate	S. E.	p	Estimate	S. E.	p	R^2
ESM_{obs}	0.58	0.139	0.0014	0.16	0.169	0.35	0.58
$RASM_{obs}$	0.52	0.130	0.0019	0.15	0.158	0.12	0.56
$RASM\text{-}2q_{obs}$	0.53	0.128	0.0016	0.15	0.156	0.36	0.58

Table 3. Forecasted proportion of age 3 fish for Strait of Georgia herring returning in the 2002 fishing season.

		Prop. age 3	
Model	Lower 95% CL	Estimate	Upper 95% CL
ESM	0.42	0.62	0.79
RASM	0.48	0.65	0.79
RASM-2q	0.43	0.62	0.79

Table 4. Forecasted numbers of recruits (age 3 herring) to the Strait of Georgia stock. Estimates for the RASM and RASM-2q are multiplied by λ, the availability parameter.

		Number of recruits ($\bullet 10^{-6}$)		
Model	No. adults ($\bullet 10^{-6}$)	Lower 95% C. L.	Estimate	Upper 95% CL
ESM	908	661	1482	3416
RASM	787	396	1125	2278
RASM-2q	587	315	681	1570

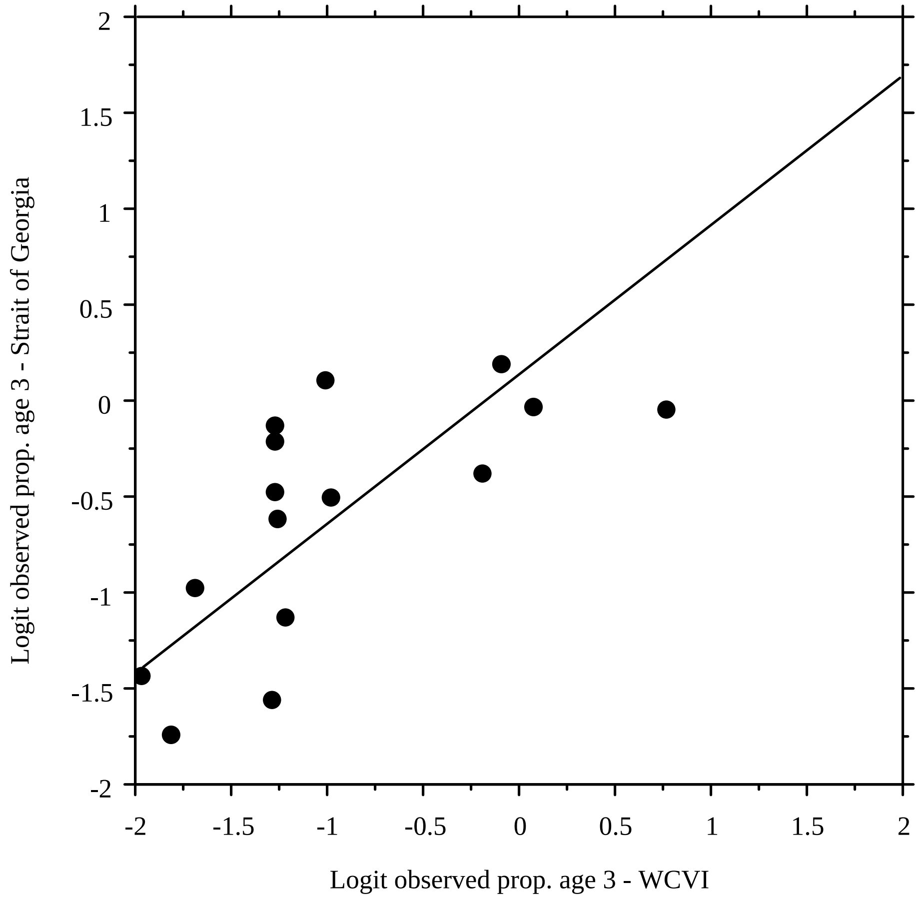


Fig. 1. Scatterplot of logit proportion age 3 for WCVI (x′) and (y′) Strait of Georgia herring. Line is for the geometric mean regression equation $y'=1.22 \bullet x'-0.25$, $p=0.005$, $R^2=0.47$, standard errors are 0.248 and 0.210 for the slope and intercept respectively.

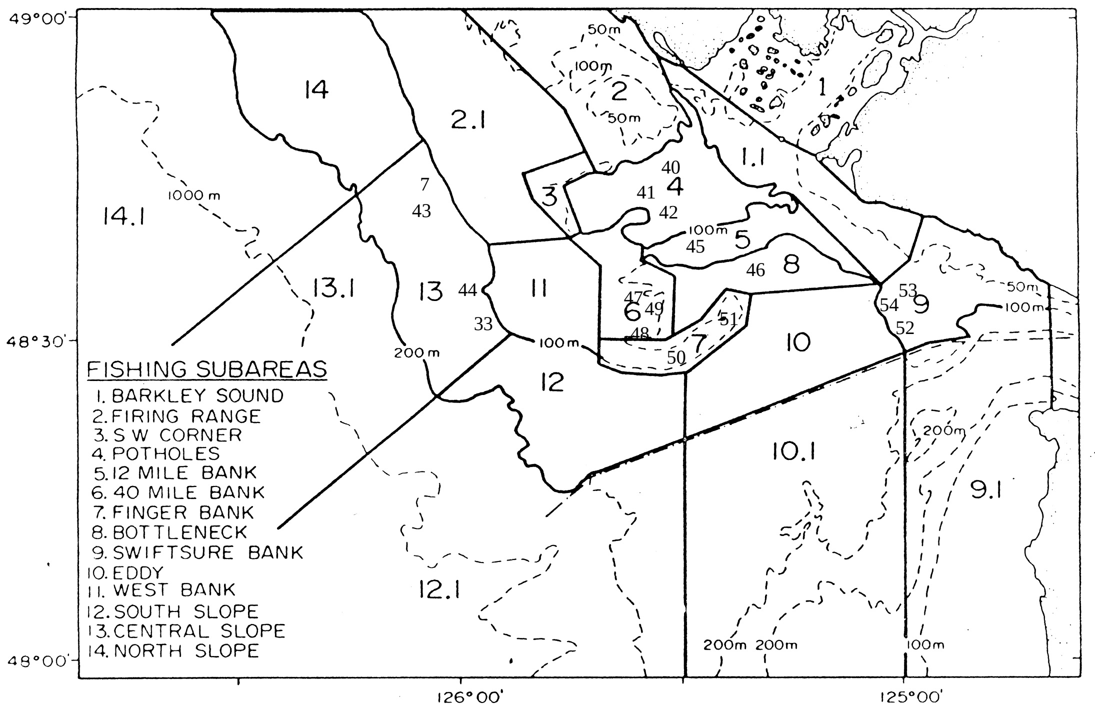


Fig. 2. Study area. Tow locations are shown as outlined numbers.

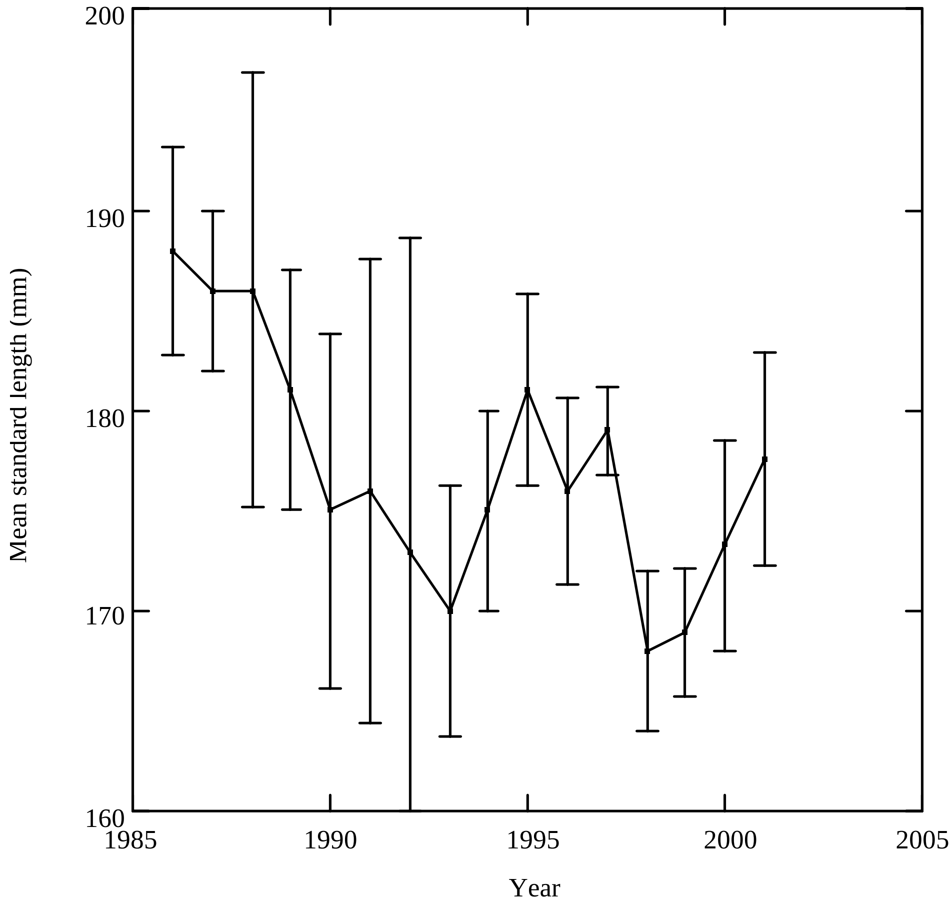


Fig. 3. Standard length (mean $\pm$ 2 SE) for age 3 herring trawled along the southwest coast of Vancouver Island, 1986 - 2001.

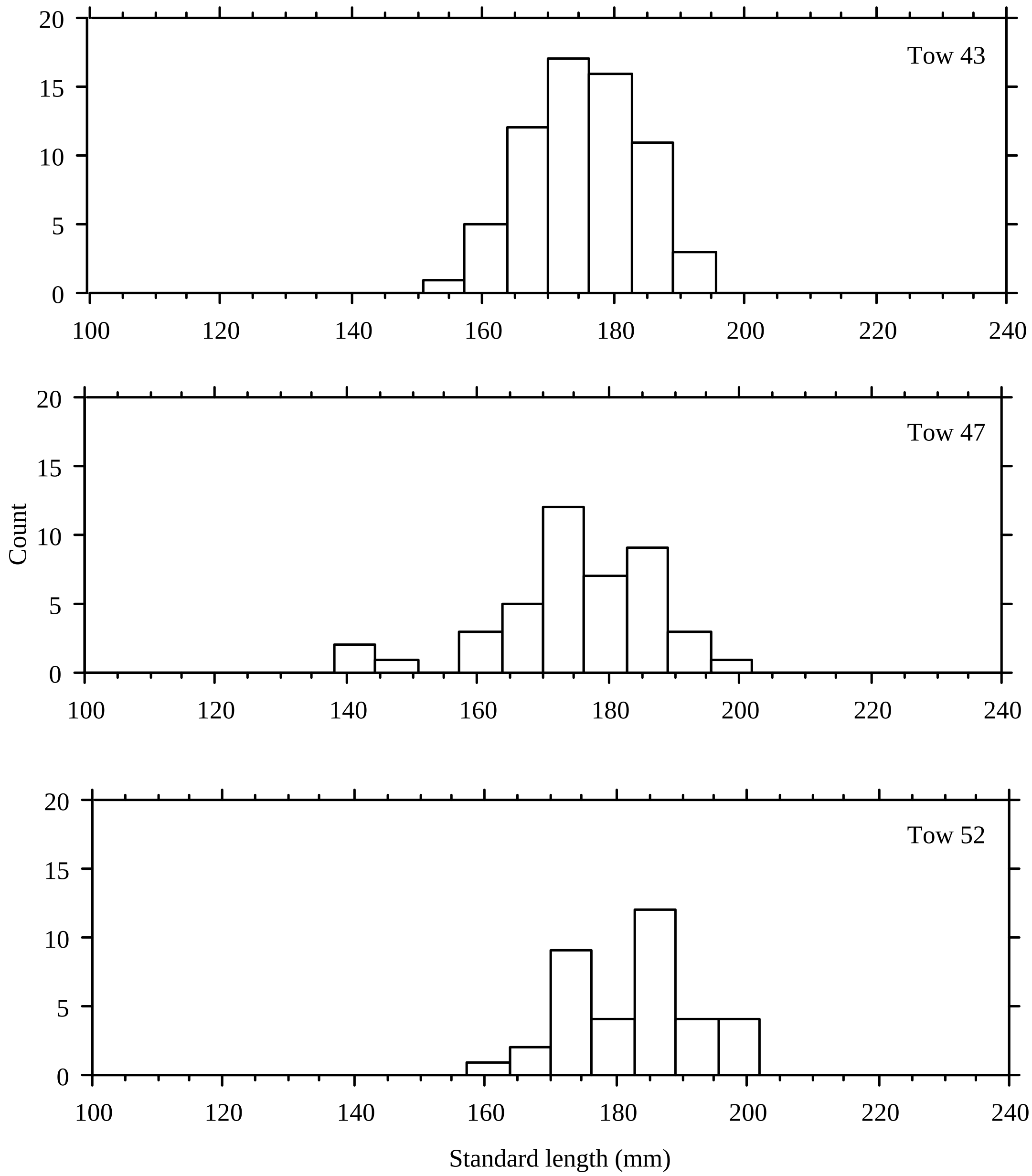


Fig. 4. Length-frequency histograms of age 3 fish trawled during the 2001 Laperouse survey.

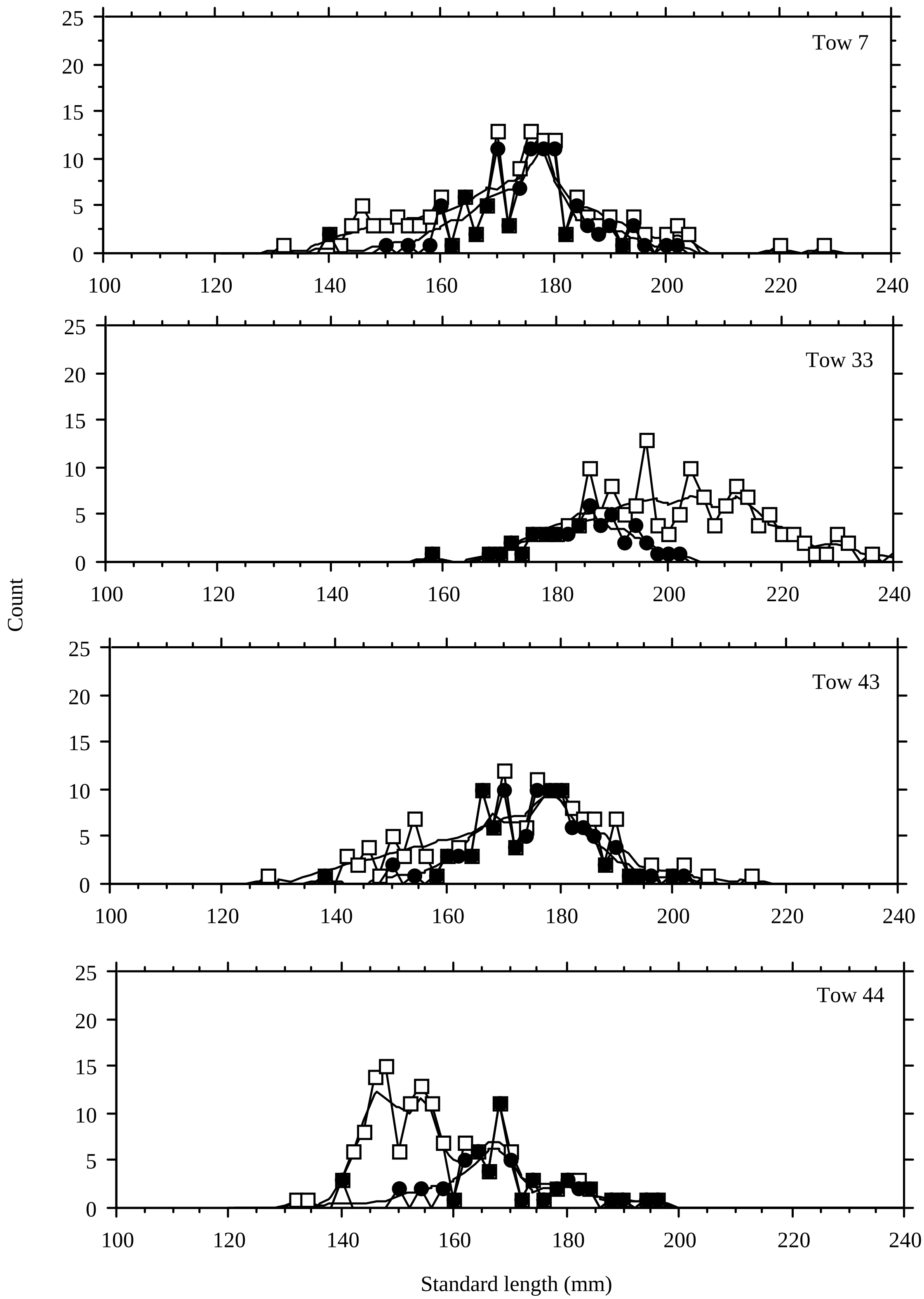


Fig. 5. Length-frequency histograms for herring trawled during the 2001 offshore herring survey. Solid symbols indicate fish presumed to be age 3.

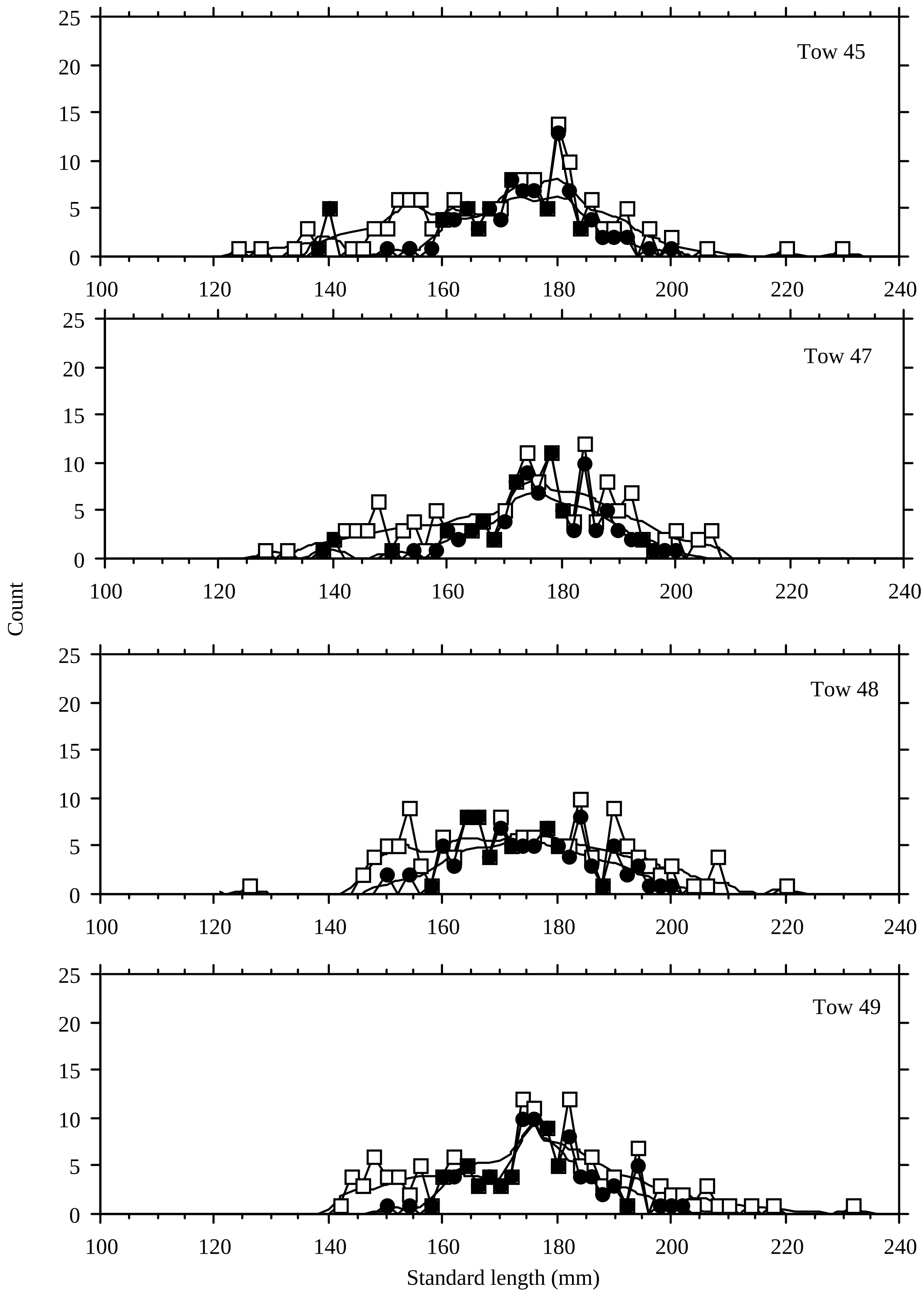

Tow 45
Tow 47
Tow 48
Tow 49
Count
Standard length (mm)
0
5
10
15
20
25
100
120
140
160
180
200
220
240

Fig. 5 cont.

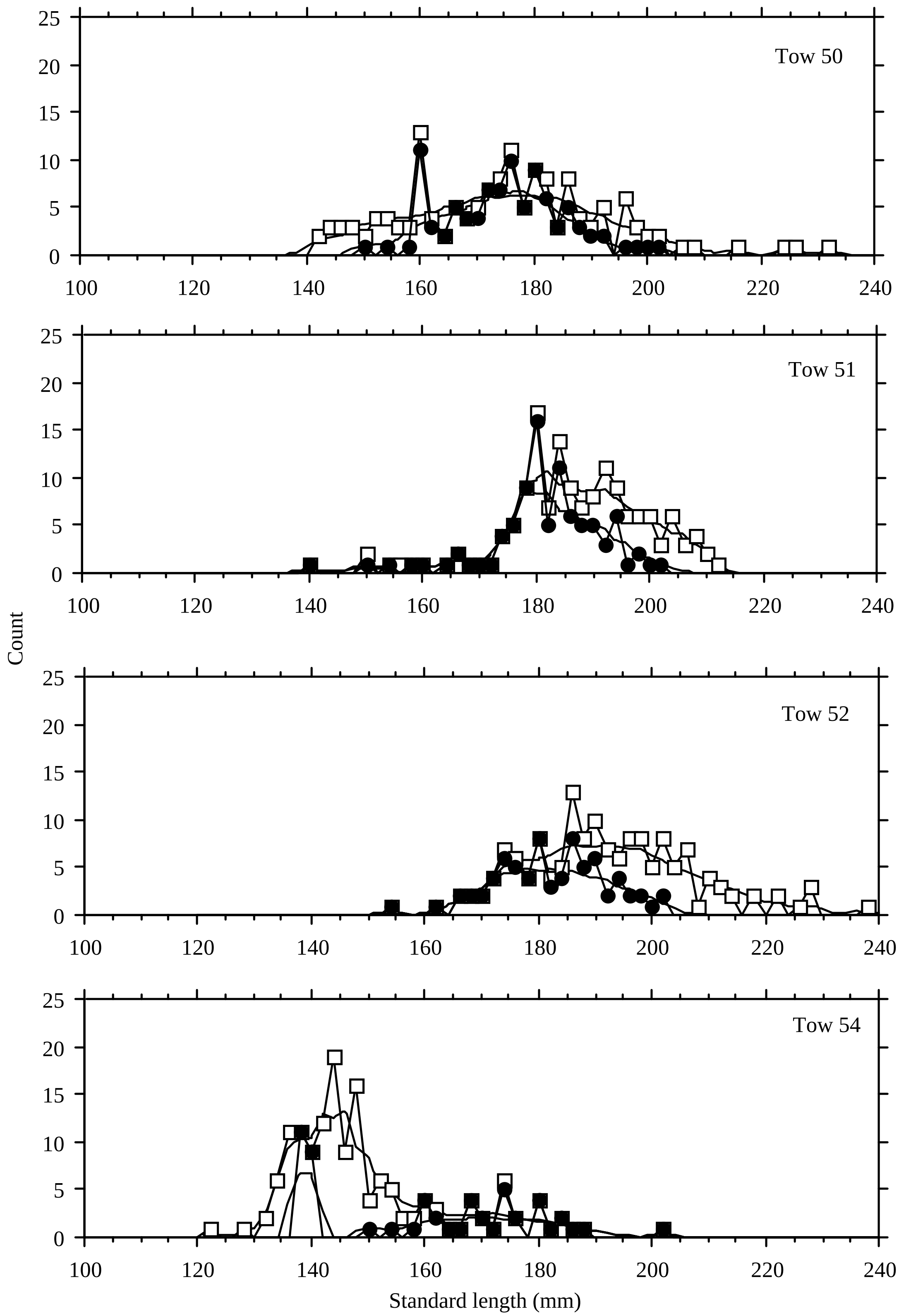

Tow 50
Tow 51
Tow 52
Tow 54
Count
Standard length (mm)
0
5
10
15
20
25
100
120
140
160
180
200
220
240

Fig. 5 cont.

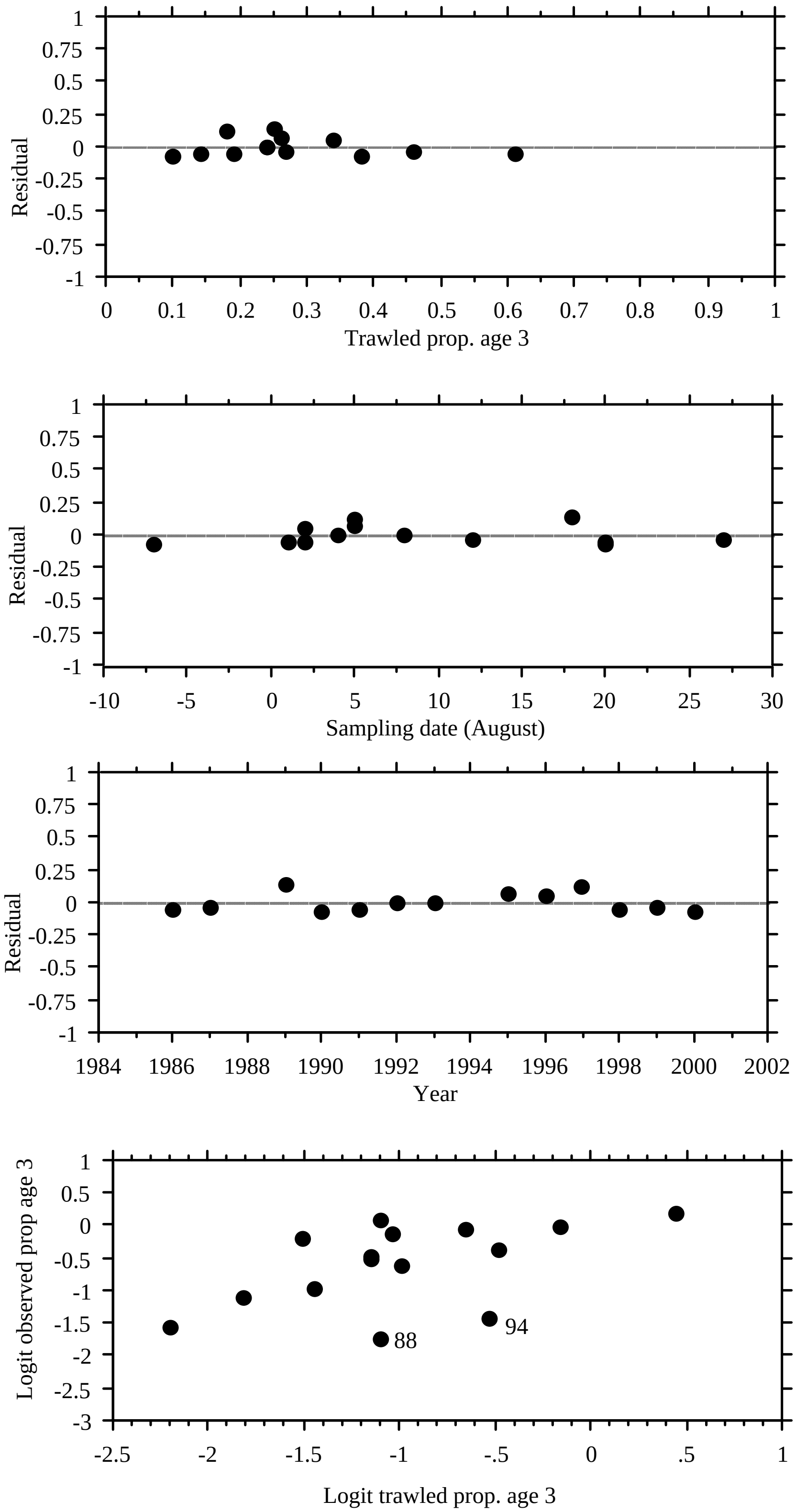


Fig. 6. Residuals and scatterplot for the regression of logit trawled proportion age 3 on logit forecasted proportion age 3, ESM.

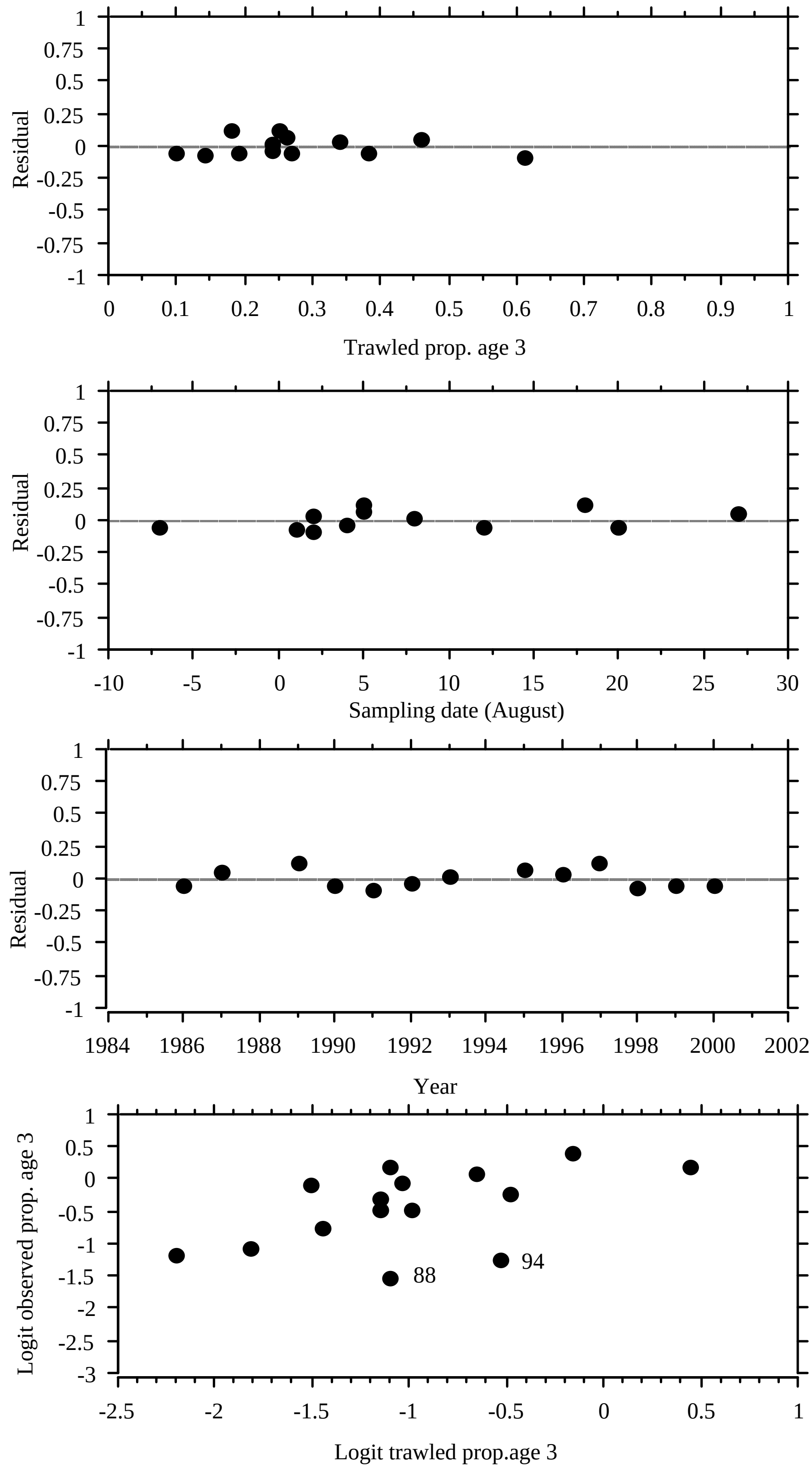


Fig. 7. Residuals and scatterplot for the regression of logit trawled proportion age 3 on logit forecasted proportion age 3, RASM.

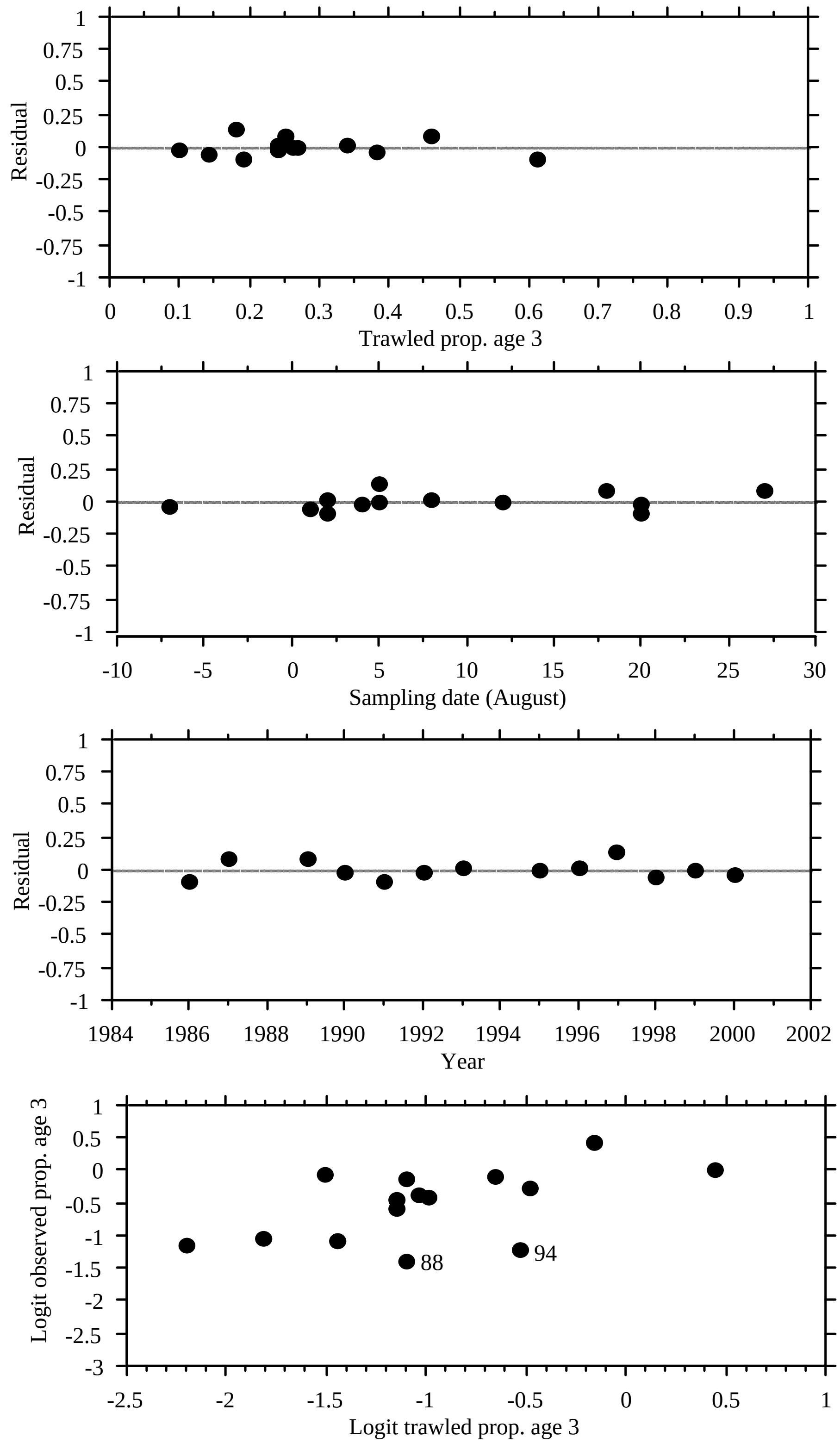


Fig. 8. Residuals and scatterplot for the regression of logit trawled proportion age 3 on logit forecasted proportion age 3, RASM-2q.

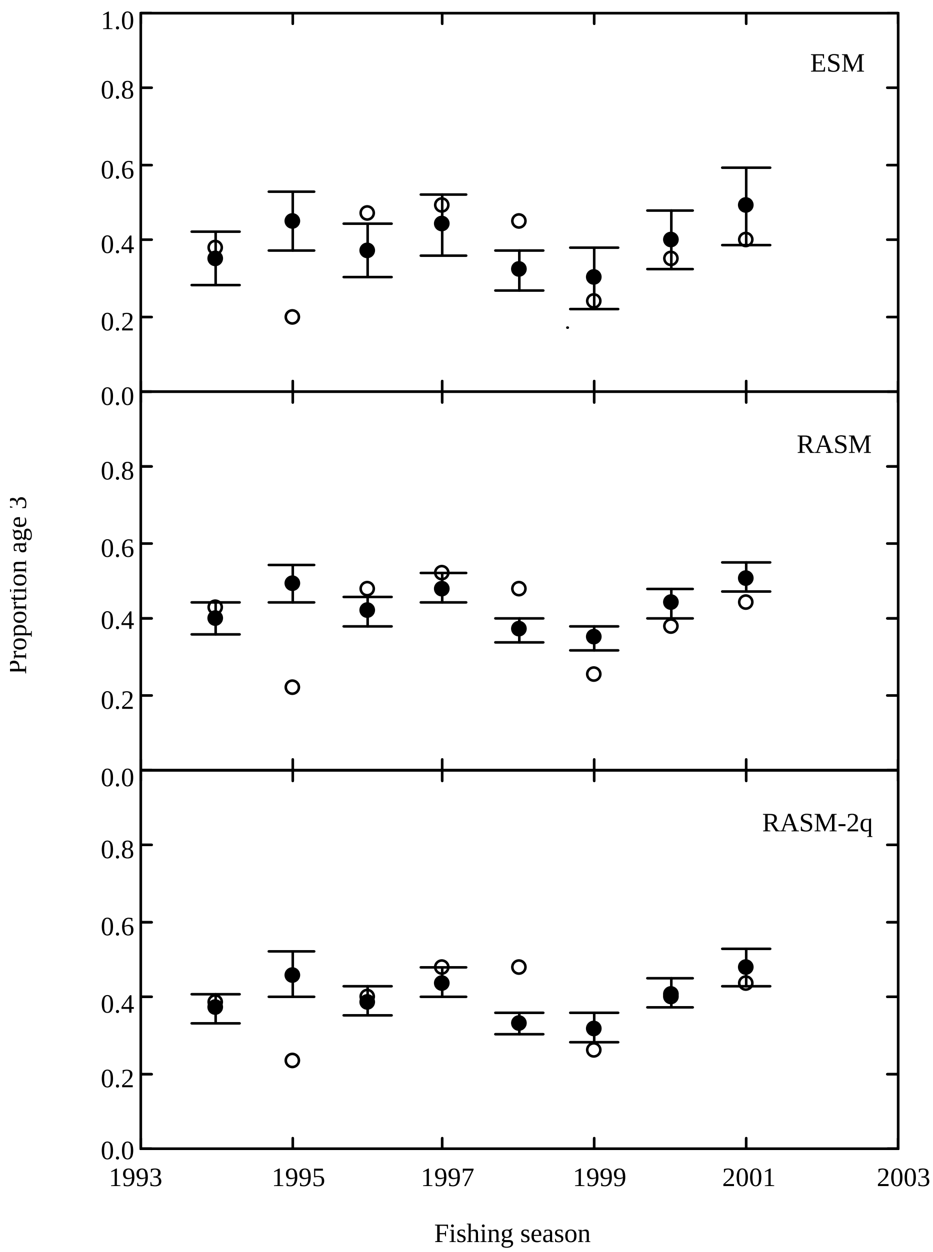


Fig. 9. Retrospective analysis of forecasts for Strait of Georgia herring, 1994 – 2001 prefishery seasons. Filled circles – forecasted proportion age 3. Open circles – observed proportion age 3. Error bars are 95% confidence intervals. ESM – escapement model. RASM – age-structured model. RASM-2q – revised age-structured model.

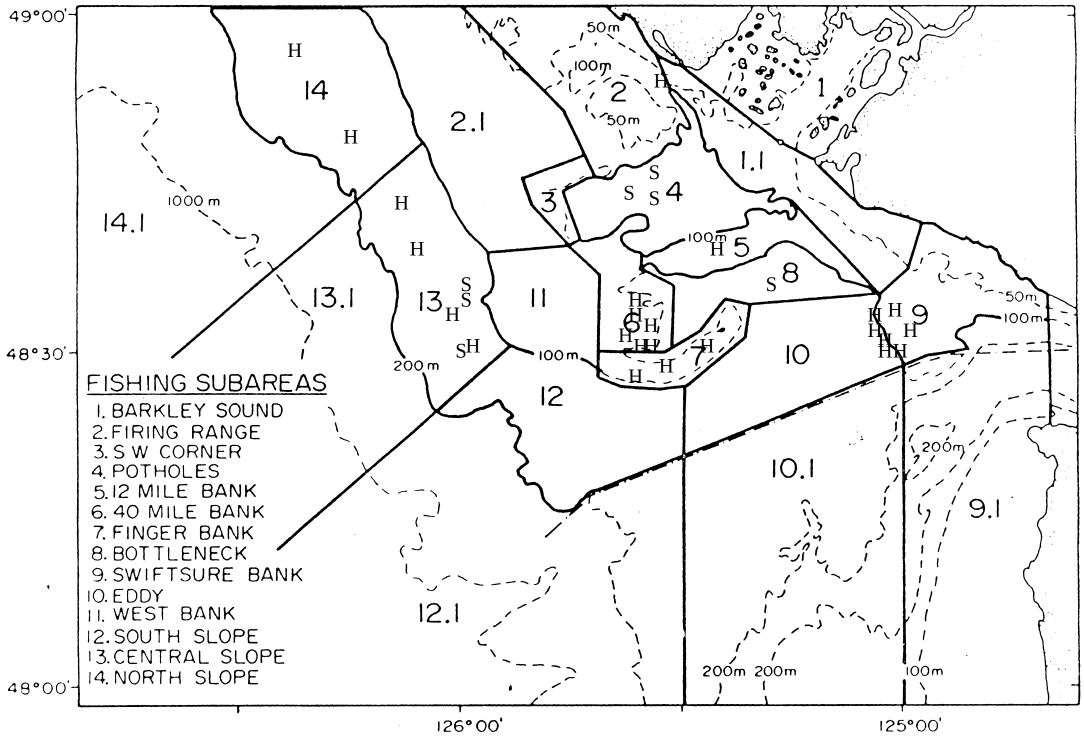


Fig. 10. Distribution of herring (H) and sardine (S) during the July 31 – August 4 survey.

APPENDIX

West Coast Vancouver Island herring recruitment forecast

Appendix 1. Recruitment forecast for West Coast Vancouver Island herring

This Appendix presents the recruitment forecast for WCVI herring for the 2002 fishing season. At the 2000 meeting, it was recommended that the forecasting procedure for WCVI herring need not be reviewed subsequently. As discussed in this Paper, there was an abrupt change in size-at-age in 2000. In addition to the forecast for 2002, the effect of this change in size-at-age on the 2001 forecast for WCVI herring will be discussed.

a) Recruitment forecast for 2002

The recruitment forecasts are based on the observed weighted mean proportion (0.65) of age 3 fish in the mid-water trawl samples and the regressions for the ESM, RASM and RASM-2q models (Appendix Table 1). The forecasted proportion of age 3 fish are from Table 3. Numbers of adults are based on forecasted adult biomasses of 12,995, 18,584 and 13,853 tonnes for the ESM, RASM and RASM-2q models respectively. The mean mass of adults was 0.000103 tonnes and number of returning adults was estimated from equation 7. Forecasted number of age 3 fish was estimated using equation 6 and a mean mass of 0.000087 tonnes for age 3 fish from the test fishing samples collected in the spring of 2001. Recruitment categories, based on the recruitment time series for WCVI herring presented in Schweigert (2001) are as follows:

Recruitment	Number of recruits ($\bullet\ 10^{-6}$)
Poor	<180
Average	180-400
Good	>400

Forecasted numbers of recruits (age 3 herring) to the WCVI stock are given in Appendix Table 3. Recruitment is forecasted to be poor for all stock assessment models.

b) Error in the 2001 forecast

Recruitment to the WCVI herring population in 2001 was underestimated because of an unusual and abrupt change in size-at-age over the 2000-01 growth season. Tanasichuk (2001) forecasted that recruits would represent 10% of the spawning biomass. This was much lower than the observed (45%).

I re-analysed the 2000 data using length-at-age data from samples collected during the 2000 survey and processed early in 2001. I estimated the proportion of age 3 fish following the procedure described in the Materials and Methods. I assumed that this approach was similar to that in place now, that is, scales are collected at during the survey and the resulting length-at-age data used to assign fish to ages. Appendix Fig. 1 shows how the estimated proportion of age 3 fish differs depending on whether it was assumed that length-at-age 3 did change since 1999 or length-at-age data from the survey were used. Based on this analysis, the weighted mean proportion of age 3 fish in samples collected in 2000 is 0.30. Using the equation to forecast recruitment for 2001, the forecasted proportion at age 3 would have been 33% with lower and upper 95% confidence limits of 22 and 44% respectively; this estimate was based on the escapement model forecast, the one recommended by the PSARC Subcommittee. Testing fishing samples showed that 45% of the fish were age 3.

c) Risk analysis

Unlike previous recruitment forecasts, this forecast could not include one based on a risk analysis of environmental factors as described in Ware and Tanasichuk (1999). Over 1935-98, WCVI herring year-class strength tended 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 was developed which related categories of poor, average and good recruitment, as defined by age-structured model estimates, to levels of temperature and hake biomass. There is no hake biomass estimate for 1999 because of vessel time constraints. This is also true for 2000. Hake surveys are now done every three years. Therefore, there will be no risk analysis until the 2004 fishing season because hake biomass estimates will be available for 2001 only.

Appendix Table 1. Forecasted proportion of age 3 fish for WCVI herring returning in the 2002 fishing season.

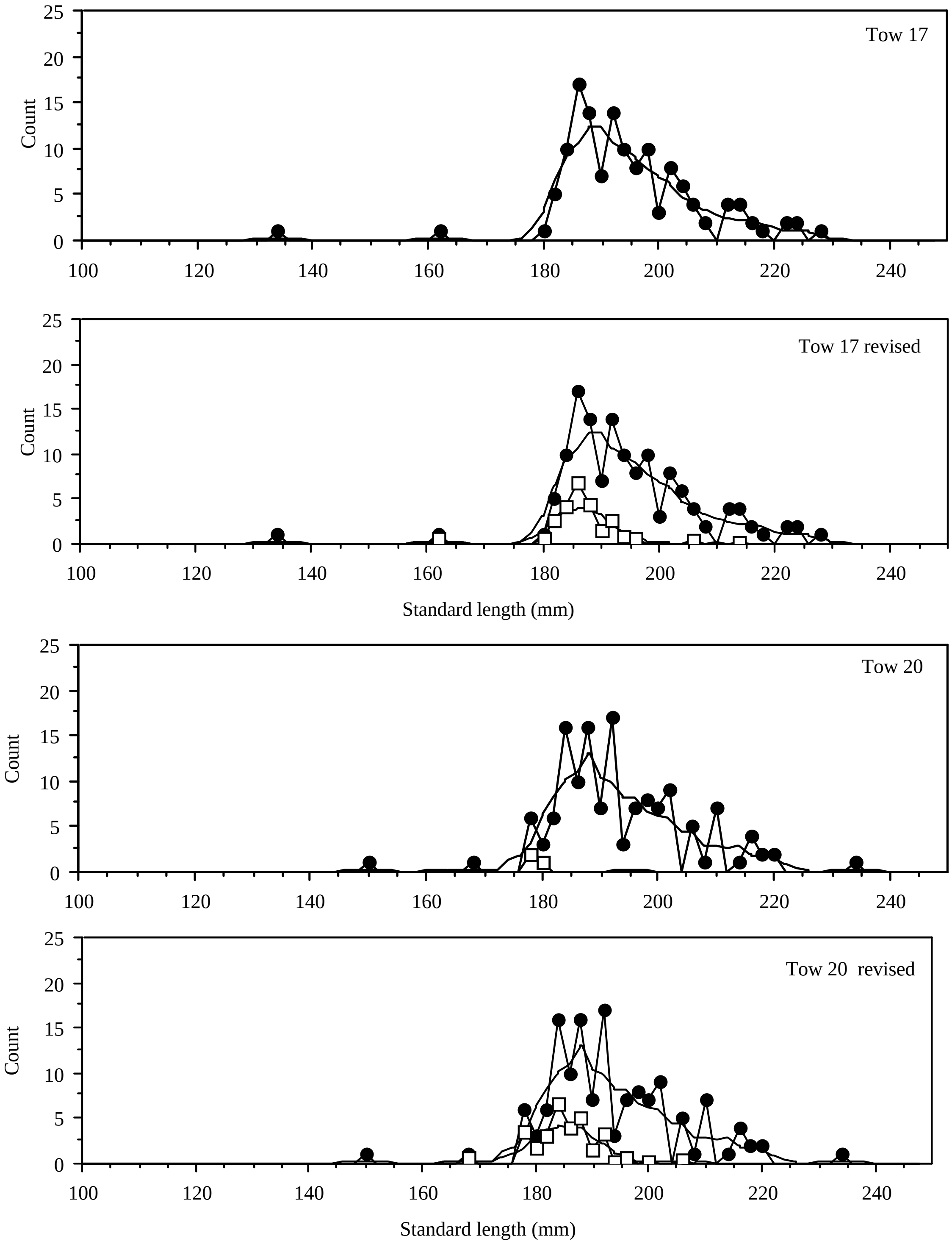
		Prop. age 3	
Model	Lower 95% CL	Estimate	Upper 95% CL
ESM	0.27	0.52	0.76
RASM	0.47	0.56	0.65
RASM-2q	0.57	0.66	0.74

Appendix Table 2. Summary of simple regression statistics, WCVI herring. All regression were calculated using the logits of the proportions and the proportion age 3 from the summer trawl survey was the independent variable. S. E. is the standard error of the estimate.

	Slope			Intercept			
Dependent	Estimate	S. E.	p	Estimate	S. E.	p	R^2
ESM_{obs}	0.66	0.167	0.0023	-0.33	0.208	0.14	0.55
$RASM_{obs}$	0.91	0.202	0.0009	0.13	0.251	0.62	0.62
$RASM\text{-}2q_{obs}$	0.91	0.198	0.0008	0.09	0.247	0.73	0.62

Appendix Table 3. Forecasted numbers of recruits (age 3 herring) to the WCVI stock. Estimates for the RASM and RASM-2q are multiplied by λ, the availability parameter.

		Number of recruits ($\bullet 10^{-6}$)		
Model	No. adults ($\bullet 10^{-6}$)	Lower 95% C. L.	Estimate	Upper 95% CL
ESM	126	47	137	400
RASM	180	109	156	228
RASM-2q	134	125	177	260



Appendix Fig. 1. A subsample of length-frequency histograms for herring trawled during the 2000 offshore herring survey. Open symbols indicate fish presumed to be age 3. The revised age assignment is based on length-at-age data from the survey samples.