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An evaluation of a recruitment forecasting procedure for Strait of Georgia herring

Évaluation d'une méthode de prévision du recrutement chez le hareng du détroit de Georgia

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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.

There are two components of the forecasting methodology. The first is a regression equation. It was developed to forecast the proportion of age 3 fish estimated to be in the prefishery biomass based on the proportion of age 2+ fish in the samples trawled the previous summer. Results of geometric mean regression analyses showed a significant linear relationship with parameter estimates that are stable over time. Residual analysis showed no time trend in the residuals, nor any effect of sampling time or the magnitude of the forecast. A retrospective analysis over 1995 – 2002 showed that observed proportions at age 3 were within the 95% confidence interval of the forecast for all 8 years. On average, the forecasted proportion of age 3 fish was 0.02 ± 0.084 (mean $\pm$ 2 SE) less than observed proportion.

The second part consists of forecasting the recruitment category using the forecasted proportion age 3 and the assessment model's forecast of returning adults. By convention, recruitment is categorised as Poor, Average or Good based on the cumulative frequency distributions of the time series of number of recruits estimated by the assessment model. Also by convention, recruitment is generally anticipated to be Average. Results of a retrospective analysis showed that the forecast was accurate for 6 of the 8 years. The convention of assuming Average recruitment would have been accurate in 2 of the 8 years.

RÉSUMÉ

Est évaluée dans ce rapport une adaptation de la méthode de prévision du recrutement (Ware et Tanasichuk, 1987), utilisée depuis 1987 pour le stock de hareng du Pacifique (*Clupea pallasi*) de la côte ouest de l'île de Vancouver (COIV) (nombre de reproducteurs d'âge 3), en vue de prédire le recrutement chez le hareng du détroit de Georgia. La méthode de prévision repose sur la composition par âge des échantillons de hareng prélevés au chalut le long de la côte sud-ouest de l'île de Vancouver lors des relevés océanographiques effectués pendant les pêches d'été.

La méthode de prévision se compose de deux éléments. Le premier, une équation de régression, sert à prédire la proportion estimative de hareng d'âge 3 dans la biomasse avant la pêche d'après la proportion de hareng d'âge 2+ dans les échantillons prélevés au chalut l'été précédent. Les résultats des analyses de régression des moyennes géométriques ont révélé que ces dernières étaient en étroite relation linéaire avec les estimations des paramètres stables au fil du temps. Une analyse des résidus n'a révélé ni tendance temporelle dans les résidus ni effet du moment de l'échantillonnage, ni l'ampleur de la prévision. Une analyse rétrospective portant sur la période 1995–2002 a révélé que les proportions observées de hareng d'âge 3 se situaient dans l'intervalle de confiance à 95 % de la prévision pour les huit années. En moyenne, la proportion prévue de ces individus était de $0{,}02 \pm 0{,}084$ (moyenne $\pm$ 2 ET) inférieure à la proportion observée.

Le deuxième élément de la méthode consiste en la prévision de la catégorie de recrutement d'après la proportion prévue de hareng d'âge 3 et la prévision du nombre de reproducteurs issue du modèle d'évaluation. Par convention, le recrutement est classé comme faible, moyen ou bon d'après les distributions des fréquences cumulées des séries chronologiques du nombre de recrues issues du modèle d'évaluation. Par convention aussi, le recrutement est généralement prévu comme étant moyen. Les résultat d'une analyse rétrospective ont révélé que la prévision était précise pour six des huit années en question. La convention à l'effet de considérer le recrutement comme moyen aurait été précise pour deux de ces huit années.

INTRODUCTION

The general biology of adult Pacific herring (*Clupea pallasi*) in British Columbian waters consists of spawning during the local spring (March – April), subsequent movement to offshore summer feeding areas, followed by migration back to the spawning grounds over winter. Most of the harvest is taken during spring roe fisheries that occur on or near spawning grounds when fish aggregate in large schools. The current stock concept is that there are five major populations (Strait of Georgia, West Coast Vancouver Island (WCVI), Central Coast, North Coast and Queen Charlotte Islands) (Schweigert 2001).

Forecasts of prefishery biomass are based on forecasts of numbers of fish expected to be in the prefishery aggregations multiplied by observed mass-at-age from the last fishing season. Forecasts of numbers of returning adults (age 3+ and older) are made using an age-structured model (Schweigert 2001). Anticipated recruitment (number of maturing age 2+ fish) is added to the returning adult forecast.

For all stocks, except WCVI herring, these anticipated recruitments are based on the age-structured model time series of age 2+ fish for 1951 through forecast year –1. Boundaries between Poor and Average, and Average and Good recruitments, are calculated as the 33 and 66 percentiles respectively of the cumulative frequency distributions of the stock-specific age 2+ abundance time series. By default, recruitment is assumed to be Average. Poor or Good recruitments are assumed when a recruitment time series indicates a persistent (3-year) trend of one of those states of recruitment.

In contrast, recruitment to the WCVI herring population has been forecast using age compositions of herring trawled along the southwest coast of Vancouver Island during summer fisheries oceanography surveys. There has been a midwater 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 and size composition of the dominant pelagic fish species (Pacific herring (*Clupea pallasi*), Pacific hake (*Merluccius productus*), spiny dogfish (*Squalus acanthias*)) and trophic relationships among the fish species which use the area. Ware and Tanasichuk (1987) began using the trawled proportion of age 2+ (recruit) herring to forecast the number of age 3 fish and their biomass for the subsequent spring roe herring fishery on the WCVI stock. (The working aging convention is that birthdays are at spawning time.) The forecasted recruitment was categorised as Poor, Average or Good based on the age-structured model time series of recruitment for this stock. The corresponding biomass was added to the stock assessment model estimate of returning spawner biomass to provide an estimate of total spawner biomass and therefore potential harvest. The Pelagics PSARC Subcommittee has endorsed this work continually.

There appears to be a basis for testing the use of the proportion of age 3 herring 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 WCVI. Subsequent tagging (1965, 1980, 1981) results (http://www.pac.dfo-mpo.gc.ca/sci/herring/hertags/wcvi_tab.htm) showed that herring tagged off the WCVI in the fall were recovered during spring roe fisheries in the Strait of Georgia as well as from the WCVI. The test of recruitment forecasting for Strait of Georgia herring is intriguing because the recruitment forecasts have worked for WCVI herring, these populations show similar size-at-age trends and different trends in recruitment, and mix to unknown extents annually.

The objective of this report is to present the results of the evaluation of the extension of the forecasting procedure to the Strait of Georgia stock. It consists of examining, retrospectively, the regression equations used to forecast recruitment as well as the accuracy of forecasting recruitment category.

METHODS

a) Sample collection and processing

Midwater trawl surveys of the southwest coast of Vancouver Island (SWCVI) (Fig. 1) have taken place annually since 1985. Commercial trawlers were chartered for the 1985 – 1991 surveys; some 1988 tows were made using the R/V W. E. Ricker. All surveys since 1992 have been done using the R/V W. E. Ricker. Herring aggregations were located hydroacoustically and fished to obtain biological samples. Information for each of the 190 tows which caught herring during the 1986 – 2001 surveys is presented in Appendix Table 1. Tow information for the 1985 survey was excluded. This survey provided no data for the analysis because no herring lengths were measured and no samples were collected for subsequent laboratory analysis.

The catch from each tow was brought aboard. It 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) $\bullet$ area of mouth opening (m^2) $\bullet$ vessel speed (m $\bullet$ $minute^{-1}$).

Herring sampling consisted of measuring total mass (g) and standard length (mm) and recording sex and stomach contents. When possible, the lengths of 150 fish were measured for each tow. Samples from most sets were frozen for subsequent analysis in the laboratory.

b) Data analysis

The proportion of recruit herring in the trawl samples was estimated using age-length data. Fish from samples frozen for laboratory analysis were aged by the Ageing Laboratory at the Pacific Biological Station. Length of aged fish had to be corrected for the effect of freezing using the equation:

$$(1)\ L_{fresh} = 0.9939 \bullet L_{frozen} + 4.907,$$

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 were measured fresh during the surveys and all data for aged fish are from frozen samples. For each year, 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:

$$(2) \quad P_{j,l} = N_{j,l} \bullet N_l^{-1}.$$

Number of fish at age 2+ in each tow (N_{2+}) was then estimated as:

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

Proportion of age 2+ fish in a sample in a given tow was estimated by dividing N_{2+} by the number of fish sampled. Annual estimates of proportion of age 2+ fish were described as means, weighted by catch per unit effort (Appendix Table 1). Tows consisting of fish age 2+ or younger, as indicated by length, were excluded from analyses. These tows were assumed to be of immature fish, which would not spawn next spring.

The forecasting procedure's performance was evaluated by testing the two components of the method retrospectively. The first test was of the statistical significance and accuracy of the regression of proportion age 3 (P_3) estimated by the age-structured model on weighted mean proportion age 2+ fish from the trawl survey done the previous summer. Annual estimates of numbers of fish at age came from the stock assessment model (RASM- 2q, Schweigert 2001) considered for the 2002 forecasts. Numbers of fish-at-age were multiplied by the age-specific availability parameter (λ) and age-independent survival rate ($S=e^{-M}$) to estimate the number of fish-at-age in the prefishery biomass. Estimated proportion age 3 for each year was calculated as:

$$(4) \quad P_3 = \lambda_3 \bullet N_{RASM-2q,3} \bullet S \bullet (\sum_{i=3}^{10} \lambda_j \bullet N_{RASM-2q,j} \bullet S)^{-1}.$$

Differences between the forecasted and estimated proportions were considered significant when the estimated proportion age 3 fell outside the 95% confidence interval for the forecast.

Statview (1999) was used for regression analyses. Proportion data were transformed using the logit transformation (Sokal and Rohlf 1995). Predictive regressions were re-expressed as geometric mean regressions (GMR) because both variables were measured with error (Ricker 1973). Leverage coefficients and studentised residuals were used to test for outliers (Sokal and Rohlf 1995). Standard errors for the forecasted proportion age 3 ($\hat{S}_y$) were calculated using the equation given by Sokal and Rohlf (1995), where,

$$(5)\quad \hat{S}_y = \sqrt{S^2_{y\bullet x}\left[1+\frac{1}{n}+\frac{\left(X_i-\overline{X}\right)^2}{\sum x^2}\right]}$$

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 trawled proportion age 2+ for the forecast, and Σx^2 is the sum of the squared deviations for X. Residuals (R) were estimated as

$$(6)\quad R = observed - predicted\,.$$

The second component of the methodology is the forecast of recruitment category. It is based on the forecasted proportion age 3 and the assessment model's forecast of returning adults (age 3+ and older). The forecasted number of age 3's (R_t) was estimated following Ware and Tanasichuk (1999) as:

$$(7)\quad R_t = (N_t \bullet (1-p_{t-1})^{-1}) - N_t\,,$$

where t is year, N_t is the forecasted number of returning adults and p is the forecasted proportion of age 3 fish as estimated from the previous summer offshore survey. Forecasts were assigned to the recruitment categories defined using the age 2+ time series described in Schweigert (2001). Estimates of numbers of fish were multiplied by year-specific survival ($=e^{-M}$) and availability (λ) to calculate number of age 3 fish in the prefishery biomass. Recruitment distribution breakpoints, as defined by the cumulative density function (JMP 2002), were estimated for Poor/Average (p=0.33) and Average/Good (p=0.67) recruitments respectively for each of the 1995-2002 forecasts.

RESULTS

a) Example of proportion age 2+ estimation

Assignments of fish as age 2+ or not age 2+ for tows made in 2001 are shown in Fig. 2. Tows 44 and 54 were of immature fish. Estimates of proportion age 2+ fish for each tow are presented in Appendix Table 1. The weighted mean proportion age 2+ was 0.61.

b) Forecasting regressions and retrospective analysis

Figure 3 shows the relationship between logit proportion age 3 observed in the Strait of Georgia prefishery biomass and logit proportion age 2+ from the previous summer's offshore survey for the dataset to date, that is, 1986-2001. The regression is statistically significant (Table 1). Regression diagnostics showed that no data pairs were outliers (leverage coefficients > $4/n$ and |studentised residual |>2.5) (Sokal and Rohlf 1995). There was no apparent trend in the plot of the residual of the forecast and the logit predicted proportion age 3.

Results of retrospective analyses of the GMR equations are presented in Table 1. Regressions became statistically significant as of the 1995 prefishery. Slope and parameter estimates were stable; in other words, there were no statistically significant differences among slopes or intercepts for any years when regressions were significant. Residuals for the regression to date are presented in Fig. 4. There appear to be a pattern in the residuals when plotted against fishing season. However, the magnitude of the residuals is small and consequently the pattern was interpreted as being inconsequential.

Retrospective forecasts for proportion age 3 are given in Table 1. On average, the forecasted proportion of age 3 fish was 0.02 ± 0.084 (mean $\pm$ 2 SE) less than observed proportion. The observed proportion of age 3 fish fell within the 95% confidence interval of the forecast for all 8 years (Fig. 5).

c) Recruitment forecasts and retrospective analysis

Table 2 presents the retrospective analysis of the recruitment forecasts. Forecasts agreed with age-structured model estimates in 6 of 8 years. The influence of the recruitment forecasts was evaluated by substituting the forecasted proportion age 3 with the observed and re-estimating the recruitment category. Results suggested that error in the 1996 and 1998 forecasts appeared to be due to error in the forecast of proportion age 3 fish. The recruitment forecasts were more accurate that the convention of assuming Average recruitment which would have been accurate in 2 of 8 instances.

DISCUSSION

The results of this evaluation suggest that the recruitment to the Strait of Georgia prefishery biomass can be forecast with acceptable accuracy. It is intriguing that age compositions of one set of trawl samples can provide accurate forecasts for two distinct populations. The forecasts for WCVI (Schweigert 2002) are as accurate as the ones for the Strait of Georgia. WCVI forecasts are 0.03 ± 0.096 (mean $\pm$ 2 SE) greater than the observed over 1994-2001. The slopes of the GMR's differ significantly (WCVI, 1.22 ± 0.074; Georgia 0.80 ± 0.018 (mean $\pm$ 2 SE)) and the regression parameter estimates for the WCVI GMR's are stable as well (Schweigert 2002). This suggests a persistence in the proportion of the recruits of each population caught in the trawl samples over years. The stability of the GMR regression parameter estimates and the retrospective performance suggest that the methodology and trawl samples provide useful recruitment forecasts for both the Strait of Georgia and WCVI herring populations. The procedure used for real-time forecasting differs from that described above only in that scales are collected from the trawl samples so that current age-length distributions are used to assign fish to age 2+ or not age 2+.

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Table 1. Retrospective analysis of recruitment forecasting regressions. Regression statistics are for regressions based on all data up to and including the year of trawling. Regressions were used to forecast proportion age 3 fish in year x+1 based on trawled proportion age 2+ in year x. Forecasted proportion and 95% CL for the prediction for year+1 appear in the entry for year x+1. For example, the regression statistics for 1993 appearing in the entry for 1993 were calculated using all data pairs to 1993 inclusive. This regression was used with the trawled proportion age 2+ (0.27) for 1994 to predict that the proportion age 3 in the 1995 prefishery biomass would be 0.38. The observed proportion age 3 was 0.23. Regression analyses began with five years of data because smaller sample sizes were considered to be inadequate. β, α - predictive regression slope and intercept respectively. β', α' - GMR regression slope and intercept respectively.

Year	Prop. Age		Regression statistics									Lower		Upper
	Trawled (Year)	Obs. (Year+1)	β	s_β	p	β'	α	s_α	p	α'	R^2	95% CL	Estimate	95% CL
1986	0.19	0.26												
1987	0.46	0.61												
1988	0.25	0.20												
1989	0.25	0.47												
1990	0.10	0.24	0.80	0.410	0.15	1.06	0.30	0.561	0.62	0.63	0.56			
1991	0.62	0.51	0.59	0.264	0.09	0.79	0.01	0.334	0.99	0.19	0.56			
1992	0.16	0.36	0.54	0.235	0.07	0.75	0.01	0.312	0.98	0.23	0.52			
1993	0.24	0.39	0.54	0.217	0.05	0.76	0.03	0.283	0.92	0.26	0.51			
1994	0.27	0.23	0.53	0.229	0.05	0.81	-0.06	0.293	0.86	0.23	0.44	0.17	0.38	0.65
1995	0.25	0.40	0.53	0.218	0.04	0.81	-0.03	0.274	0.91	0.26	0.42	0.14	0.34	0.63
1996	0.34	0.48	0.55	0.206	0.03	0.83	0.01	0.251	0.96	0.30	0.44	0.20	0.43	0.70
1997	0.19	0.48	0.49	0.213	0.04	0.84	0.02	0.264	0.95	0.37	0.35	0.12	0.29	0.55
1998	0.14	0.26	0.51	0.195	0.02	0.82	0.02	0.251	0.92	0.37	0.39	0.08	0.24	0.51
1999	0.42	0.41	0.49	0.180	0.02	0.79	-0.02	0.224	0.92	0.30	0.38	0.26	0.52	0.78
2000	0.38	0.44	0.49	0.169	0.01	0.78	-0.02	0.205	0.92	0.28	0.39	0.24	0.48	0.73
2001	0.61	0.51										0.37	0.65	0.85

Table 2. Retrospective recruitment forecasts for Strait of Georgia herring, 1995-2002. Numbers of fish - • 10^{-5}. All observed estimates are age-structured model output and are multiplied by $e^{-M} \bullet \lambda$ (age-independent and year-dependent survival • age-and year-dependent availability) to generate prefishery estimates. Recruitment distribution breakpoints Poor/Average (p=0.33) and Average/Good (p=0.67) were estimated from age 2+ time series for each of the 1995-2002 forecasts. APE – absolute percent error, $\left((observed - forecasted) \bullet observed^{-1}\right) \bullet 100$.

	Proportion age 3		Forecast		Observed		Proportion age 3		No. age 4++			
Season	Forecast	Observed	Number	Category	Number	Category	Residual	APE	Observed	Forecast	Residual	APE
1995	0.38	0.23	2827	Average	1699	Average	-0.15	65	4864	4613	251	5
1996	0.34	0.40	1910	Average	4442	Good	0.06	15	3354	3708	-354	11
1997	0.43	0.48	3602	Good	5343	Good	0.05	10	3981	4775	-794	20
1998	0.29	0.48	2329	Average	4156	Good	0.19	40	4267	5703	-1436	34
1999	0.24	0.26	1567	Average	2305	Average	0.02	8	6051	4961	1090	18
2000	0.52	0.41	5139	Good	3388	Good	-0.11	27	4227	4743	-516	12
2001	0.48	0.44	3854	Good	5053	Good	-0.04	9	5572	4176	1396	25
2002	0.65	0.51	11634	Good	8046	Good	-0.14	27	6410	6264	146	2
Mean							-0.02	25			-27	16

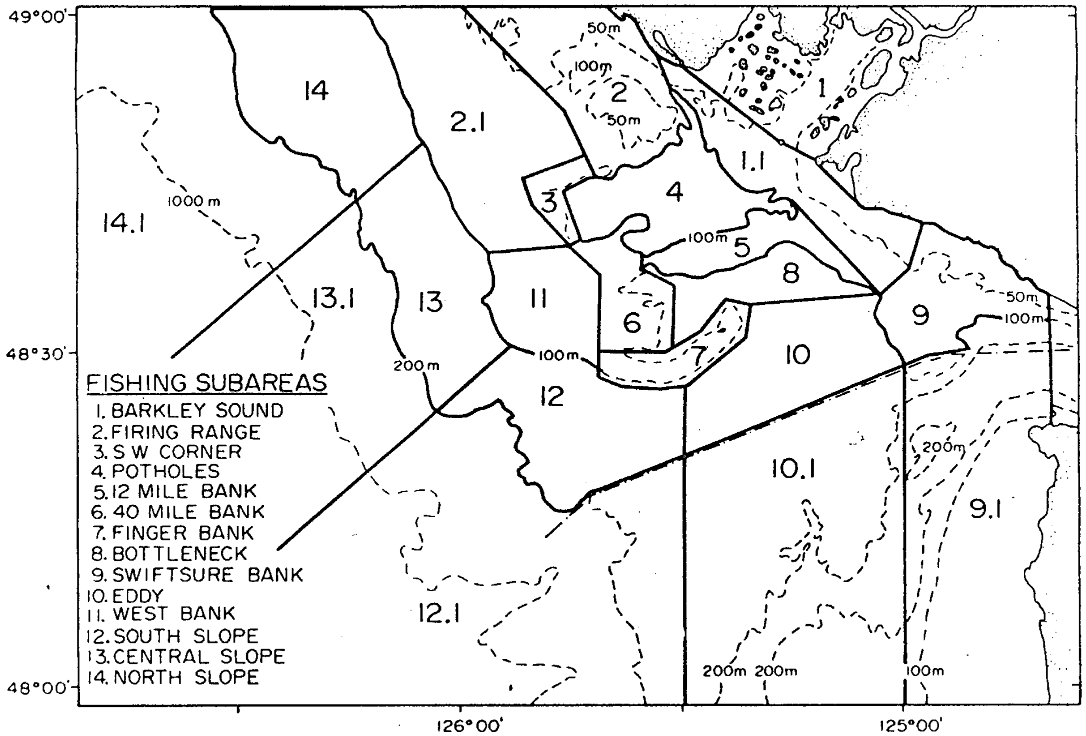


Fig. 1. Southwest coast Vancouver Island study area showing fishing subareas.

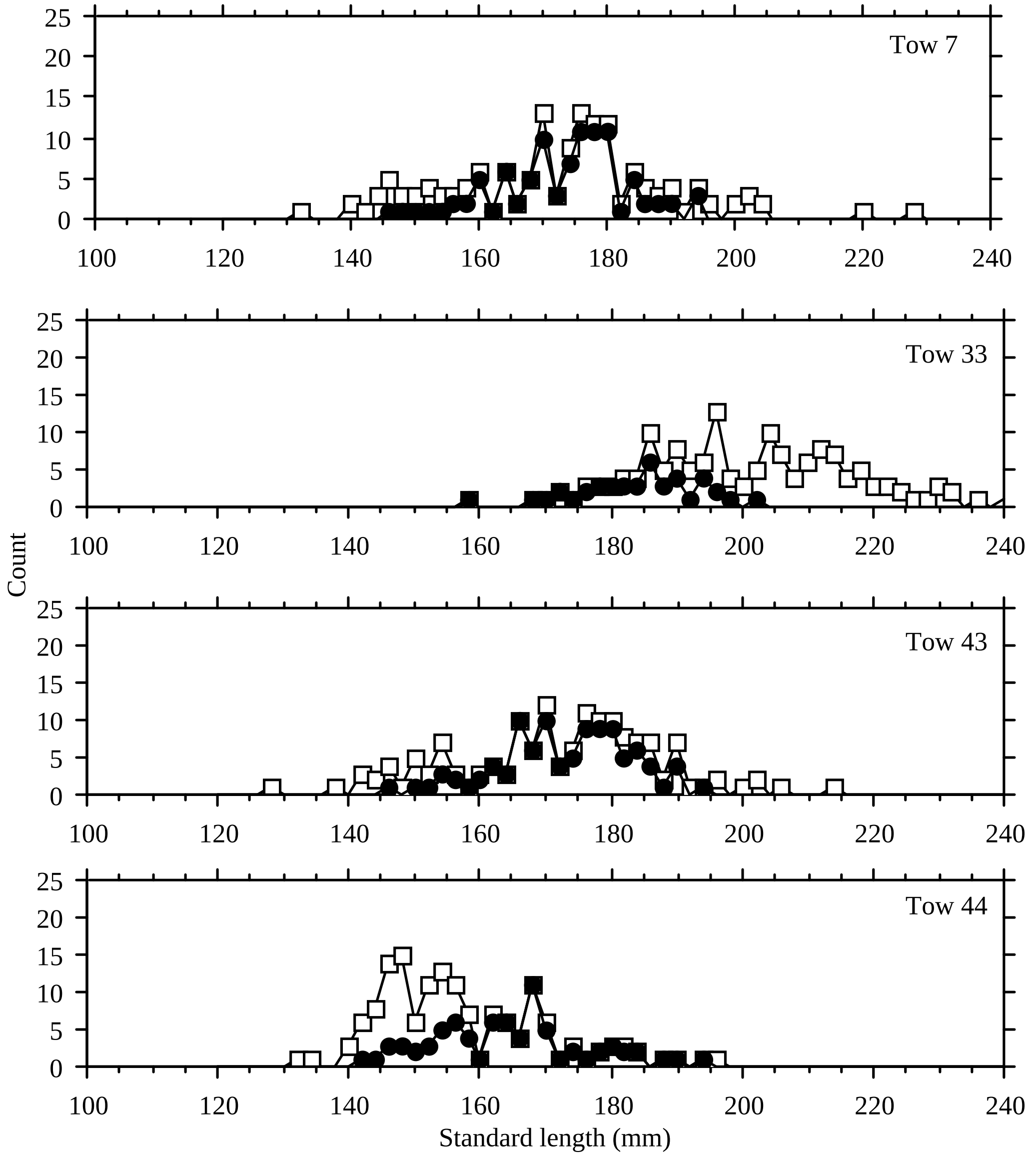
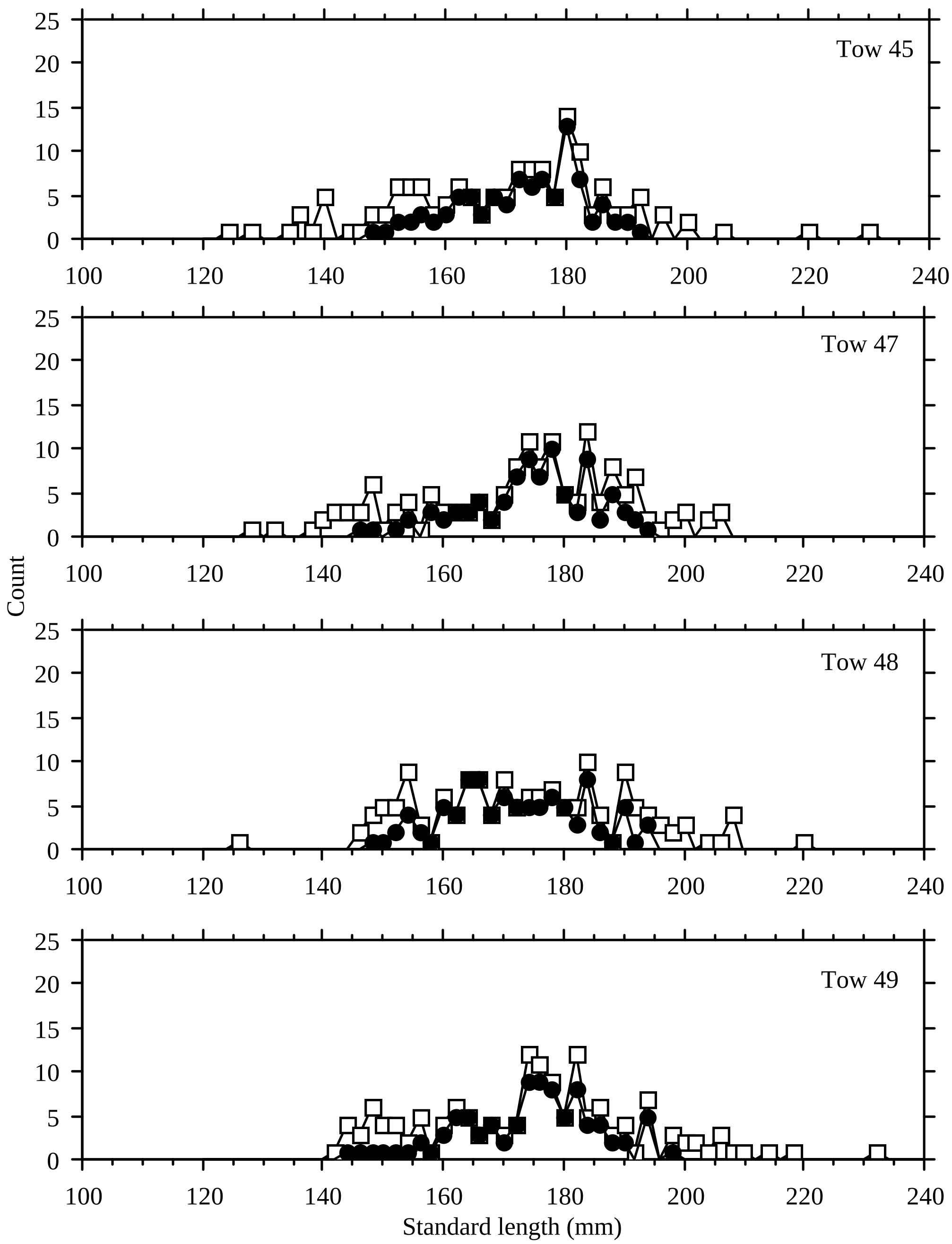


Fig. 2. Length-frequency histograms for herring trawled during the 2001 offshore herring survey. Solid symbols indicate fish presumed to be age 2+.


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

Fig. 2 cont.

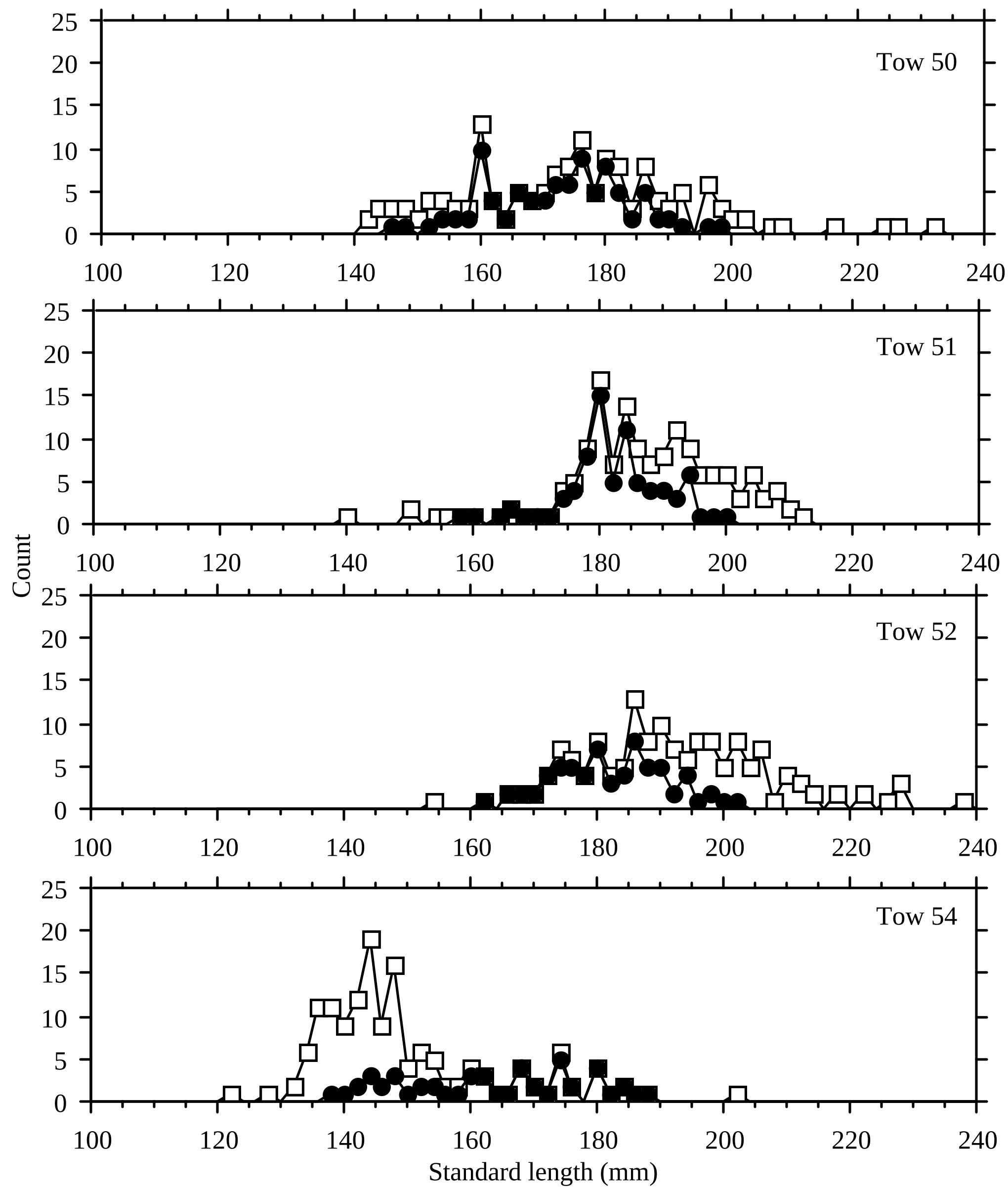
Tow 50
Tow 51
Tow 52
Tow 54
Count
Standard length (mm)
0
5
10
15
20
25
100
120
140
160
180
200
220
240

Fig. 2 cont.

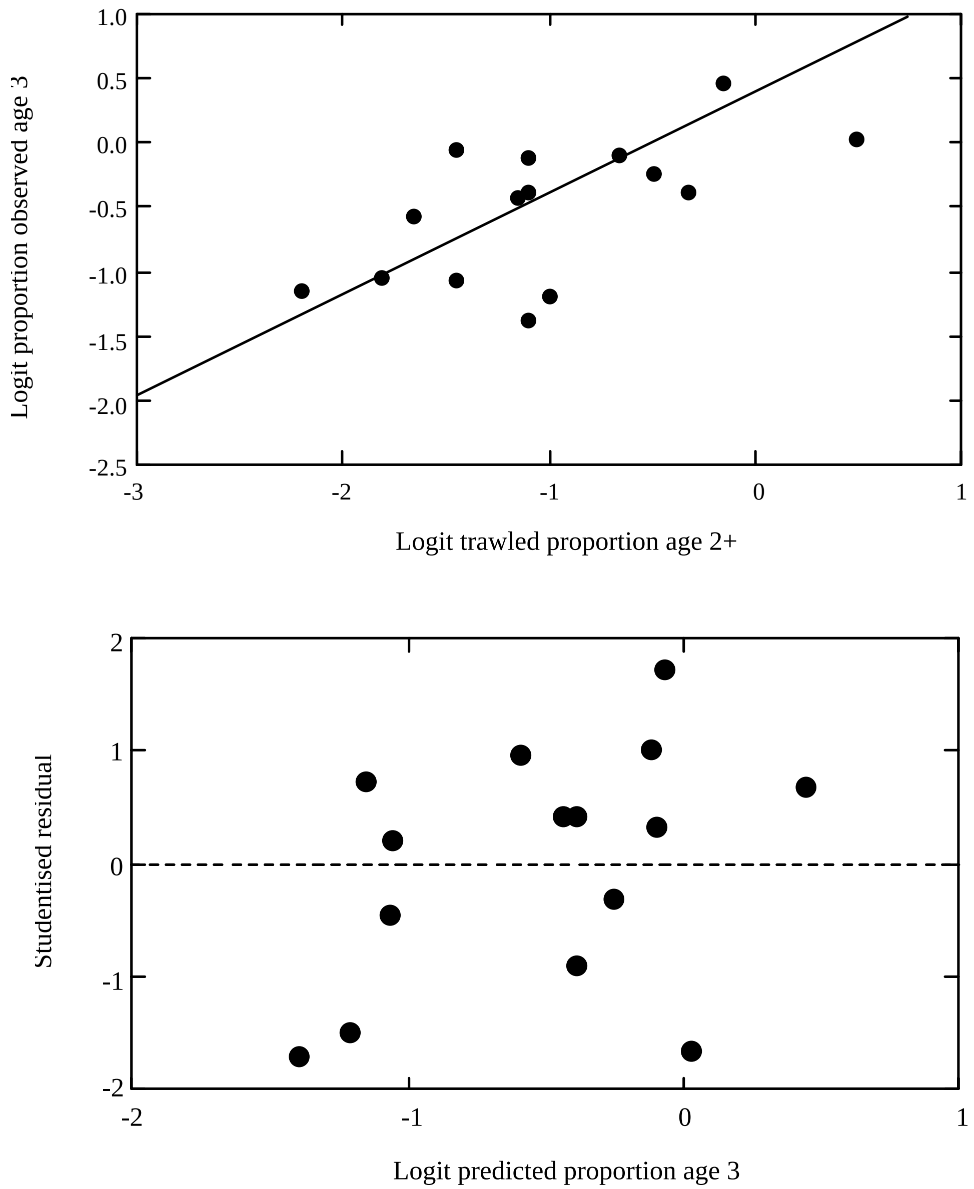

Fig. 3. Scatterplot and residual plot for geometric mean regression (GMR) of logit proportion age 3 observed in Strait of Georgia prefishery biomass on logit proportion age 3 trawled during the offshore survey conducted the previous summer, 1986-2001. Line is GMR.

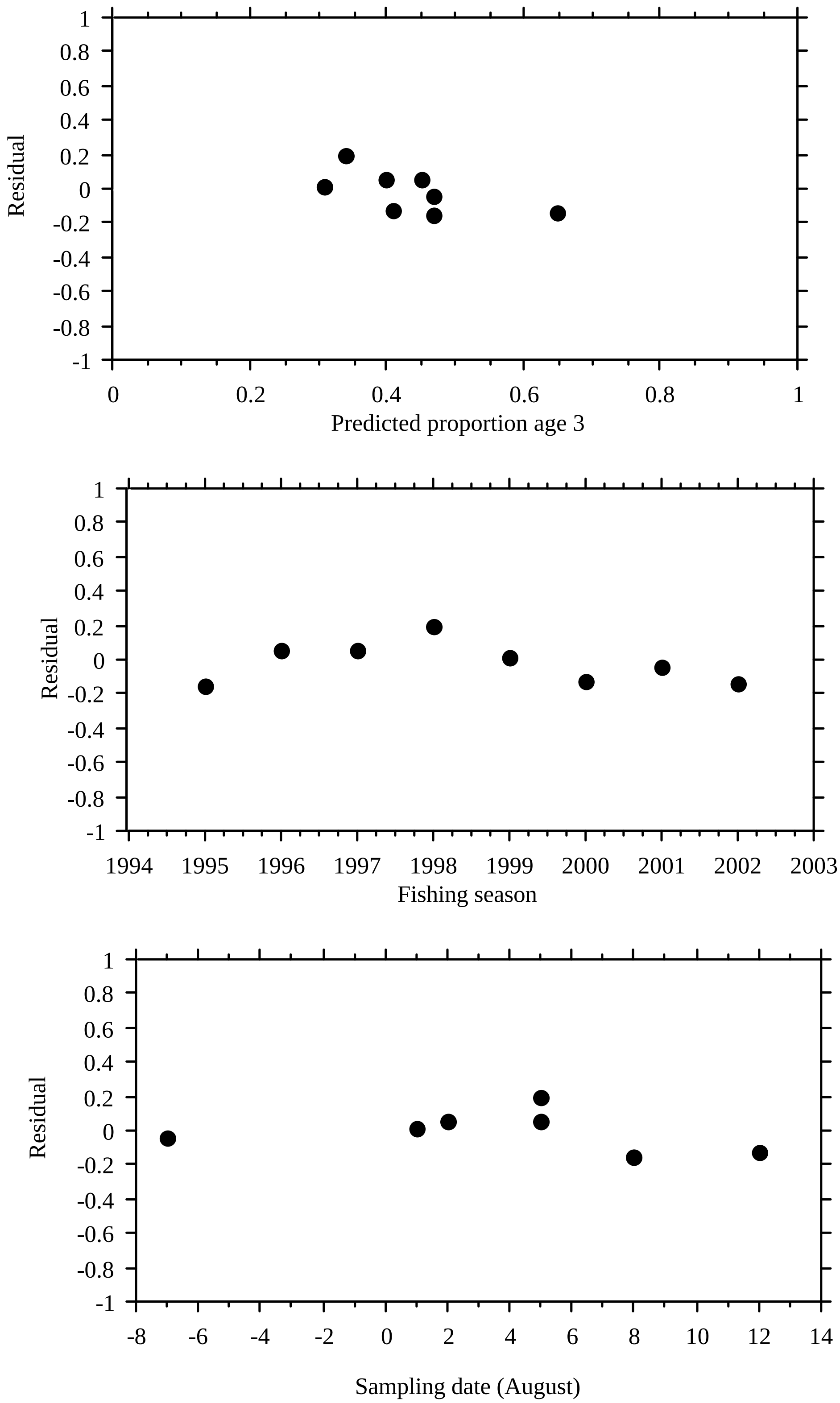

Fig. 4. Plots of retrospective analysis residuals against forecast magnitude, year and sampling date.

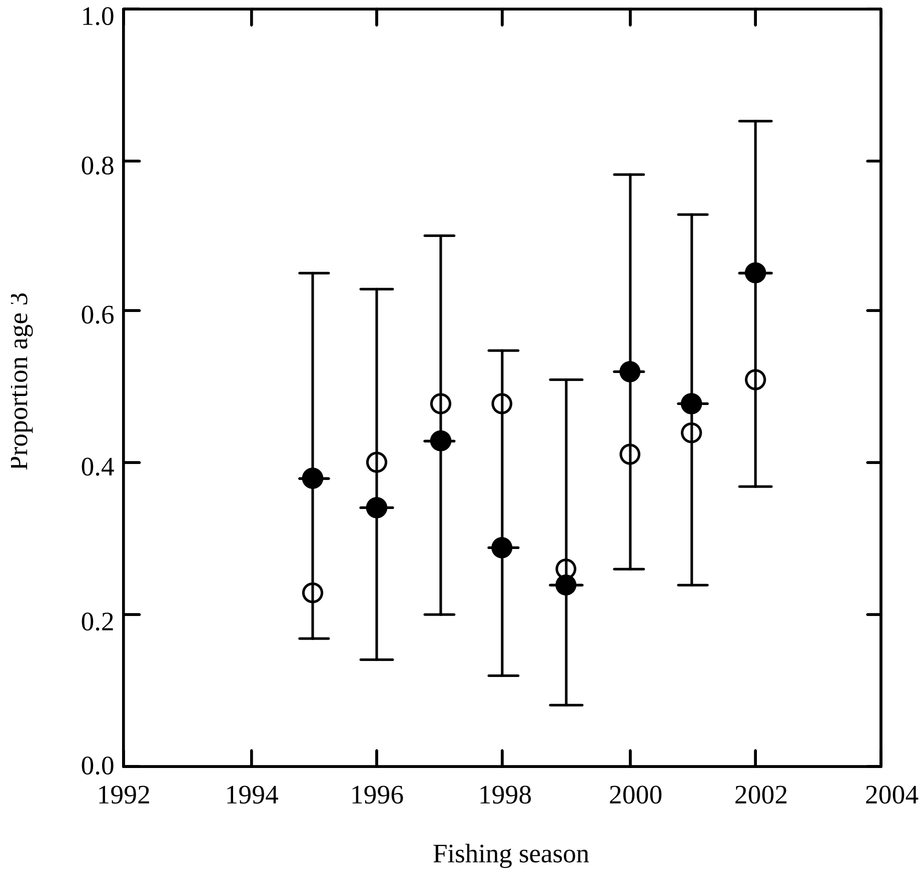

Fig. 5. Results of retrospective analysis of recruitment forecasts. Closed circles – forecast. Open circles – observed. Bars are 95% CL.

APPENDICES

Appendix Table 1. Tow information, herring catch, proportion of age 2+ herring from midwater trawl tows along the southwest coast of Vancouver Island, 1986-2001. Subareas are defined in Fig. 1. indicates missing data. I indicates tows on schools of immature herring. * indicates 1988 R/V W. E. Ricker tows.

Tow	Day	Month	Subarea	Catch (kg)	CPUE (kg • m^{-3})	Prop Age 2+
				1986		
20	19	8	2	1	3.1 e-06	.
22	20	8	6	1	1.5 e-06	.
23	21	8	6	455	0.00078	0.18
24	21	8	6	273	0.00094	.
33	23	8	10	1	8.1 e-07	.
36	24	8	2	1	2.3 e-06	.
37	24	8	6	91	4.6 e-05	0.40
				1987		
4	19	8	7	1	8.9 e-07	.
18	22	8	6	159	7.8 e-05	0.18
20	23	8	2	1	6.3 e-07	0.32
24	25	8	10	907	0.00156	0.46
26	25	8	12	14	1.4 e-05	0.68
27	25	8	12	9	8.3 e-06	.
28	26	8	12	91	6.4 e-05	0.57
34	27	8	6	55	4.2 e-05	0.35
36	28	8	6	18	9.9 e-05	0.54
				1988		
3	5	8	6	8	8.1 e-06	.
13	8	8	14.1	1	5.7 e-07	.
16	8	8	2	1	5.7 e-07	.
19	10	8	2.1	20	1.4 e-05	I
20	10	8	3	150	4.7 e-05	0.43
22	10	8	3	180	8.6 e-05	0.24
26	11	8	10	200	0.00069	0.42
30	12	8	6	1000	0.00055	0.37
31	12	8	6	200	0.00022	0.05
33	13	8	12	1	4.4 e-07	.
2*	16	8	6	1	4.6 e-07	.
4*	16	8	6	100	5 e-05	0.10
8*	17	8	6	60	0.00011	0.12
9*	17	8	6	200	0.0002	0.25
11*	17	8	6	1000	0.00036	0.15
13*	18	8	6	180	0.00033	0.15
14*	18	8	6	400	0.00014	0.16
15*	19	8	2	1	2.3 e-06	.
17*	20	8	7	3	2 e-06	.

Appendix Table 1 cont.

Tow	Day	Month	Subarea	Catch (kg)	CPUE (kg • m^{-3})	Prop. Age 2+
				1989		
1	13	8	6	7	7.7 e-06	0.14
3	14	8	6	4	3.2 e-06	.
4	14	8	7	5	3 e-06	.
6	14	8	12.1	20	6.1 e-06	.
15	17	8	12	2	1.5 e-06	.
16	17	8	6	1040	0.0038	0.01
17	17	8	6	250	0.00076	0.32
19	18	8	2.1	1636	0.00136	I
23	19	8	8	5	1.3 e-05	.
26	20	8	10	600	0.001	0.20
28	21	8	12	3	1.8 e-06	.
				1990		
1	15	8	3	5	2.8 e-06	0.36
2	15	8	6	5	2.6 e-06	0.09
16	19	8	9	1590	0.00166	0.08
17	19	8	10	5180	0.01626	0.07
19	19	8	6	15000	0.07849	0.10
20	20	8	6	2455	0.00214	0.25
21	20	8	12	8	1.1 e-05	.
23	20	8	14	113	5.4 e-05	0.13
24	20	8	14	10	1 e-05	.
25	21	8	2	114	4.3 e-05	0.18
26	21	8	2.1	886	0.0007	0.03
27	21	8	3	318	0.00012	0.26
28	21	8	4	1000	0.00052	.
39	25	8	14	889	0.00035	0.13
				1991		
6	1	8	5	5	1.5 e-06	0.33
11	2	8	6	227	0.00013	0.55
16	3	8	2.1	1	3.5 e-07	.
17	3	8	2.1	1200	0.00137	0.67
18	3	8	6	907	0.00131	0.87
19	3	8	6	2721	0.00289	0.64
21	4	8	13	431	0.00033	0
22	4	8	10	1796	0.00168	0.36
				1992		
1	30	7	9	172	0.00081	0.19
2	30	7	10	626	0.00181	0.25
11	2	8	14	130	0.00017	0.06

Appendix Table 1 cont.

Tow	Day	Month	Subarea	Catch (kg)	CPUE (kg • m^{-3})	Prop. Age 2+
				1992		
12	2	8	2.1	48	6.9 e-05	I
13	3	8	2	406	0.0005	I
14	3	8	2	89	8.6 e-05	0.24
15	3	8	11	171	0.00022	0.34
16	3	8	3	1	1 e-06	.
17	4	8	6	565	0.00587	.
18	4	8	6	1500	0.00243	0.09
19	4	8	7	528	0.00034	0.02
20	5	8	4	50	0.0001	.
25	6	8	4	17	1.5 e-05	0.16
27	6	8	4	102	8 e-05	.
32	7	8	1	15	2.6 e-05	.
				1993		
4	5	8	10.1	1	6.2 e-07	.
6	6	8	12	440	0.00018	0.08
10	7	8	14	60	6 e-05	0
11	7	8	14	443	0.00013	0
12	8	8	12	28	9.6 e-06	0.67
13	8	8	7	1459	0.00066	0.01
14	8	8	6	179	5.1 e-05	0.46
15	9	8	7	63	2.1 e –05	0.5
16	9	8	8	1	4.7 e -07	.
17	9	8	7	4	7.3 e-07	.
18	10	8	13	4	8.7 e-07	0
19	10	8	3	1545	0.00086	0.75
21	11	8	1.1	1	5.9 e-07	.
22	11	8	1	30	5e-05	0.07
23	12	8	1	255	7.3e-05	0.46
				1994		
2	3	8	9	.	.	I
3	3	8	1.1	6	6.4e-06	0.04
4	4	8	3	1513	0.01047	0.54
5	4	8	3	865	0.00544	0.66
6	4	8	3	3	8.6 e-06	I
8	5	8	9	105	0.00043	0.10
13	6	8	12	1321	0.01143	0.03
20	9	8	11	40	0.00013	0.22
23	10	8	6	12	6.4e-05	0.45
24	10	8	6	37	6.6e-05	.
25	10	8	6	1078	0.00678	0.17

Appendix Table 1 cont.

Tow	Day	Month	Subarea	Catch (kg)	CPUE (kg • m^{-3})	Prop. Age 2+
				1994		
26	10	8	6	404	0.00699	0.1
30	11	8	2	11	1.3e-05	.
31	11	8	1.1	410	0.00073	0.16
				1995		
2	1	8	10	1	3.8 e-06	.
4	2	8	4	1	1.8 e-06	.
8	4	8	6	76	0.00075	0.09
9	4	8	6	597	0.00269	0.33
11	5	8	3	132	0.00047	0.25
13	5	8	4	1	4.9e-06	.
14	6	8	6	50	6.2 e-05	0.22
16	6	8	7	166	0.00046	0.19
18	7	8	1.1	17	1.4 e-05	I
20	7	8	9	285	0.0002	0.07
21	8	8	1	67	0.00017	0.02
				1996		
6	31	7	7	2228	0.03044	0.29
8	1	8	9	552	0.00503	0.55
9	2	8	9	324	0.0014	0.41
10	2	8	9	187	0.00255	0.48
12	2	8	6	116	0.0005	0.49
13	3	8	12	60	0.00025	0.03
14	3	8	12	1	5.9 e-06	.
15	4	8	13	2	6.1 e-06	.
16	4	8	13	1	5.5 e-06	.
18	5	8	1	1	7.5 e-06	.
				1997		
1	3	8	9	35	2.3 e-05	0.17
3	3	8	10	102	5.2 e-05	0.17
5	4	8	6	335	9.6 e-05	0.66
6	4	8	6	880	0.00121	0.23
12	5	8	12	382	0.00059	0.01
15	6	8	6	1327	0.00234	0.17
16	6	8	13	380	0.00052	0.14
19	7	8	9	203	5 e-05	0
				1998		
3	30	7	6	223	0.00072	0.66
4	30	7	6	351	0.00063	0.4
5	30	7	6	3000	0.00692	0.3

Appendix Table 1 cont.

Tow	Day	Month	Subarea	Catch (kg)	CPUE (kg • m^{-3})	Prop. Age 2+
				1998		
6	30	7	8	1	2.7 e-07	.
10	31	7	3	119	0.00011	0.35
12	31	7	6	6000	0.01614	0.12
13	1	8	9	111	9.4e-05	0.17
16	1	8	6	56	0.00018	0.08
17	1	8	6	10000	0.02017	0.08
				1999		
1	11	8	6	255	0.00014	0.56
2	11	8	6	635	0.00035	0.69
4	11	8	6	3	1.3e-06	.
6	12	8	9	226	0.00032	0.18
11	12	8	6	3000	0.01006	0.40
12	13	8	3	124	0.00012	0.52
15	13	8	6	160	0.00017	0.54
17	14	8	6	241	0.00027	0.52
20	15	8	1.1	1	2.8e-07	.
22	15	8	6	697	0.00117	0.47
23	15	8	1	1	4.5e-07	.
				2000		
1	25	7	10	1711	0.0007	0.45
2	25	7	6	5125	0.02247	0.5
3	26	7	6	6	3.9e-05	0.38
4	26	7	6	94	4.1e-05	0.26
5	26	7	5	3382	0.04448	0.47
7	26	7	4	110	0.00145	0.68
8	27	7	4	74	2.8 e-05	I
9	27	7	8	2909	0.03826	0.16
14	29	7	2.1	514	0.00676	0.38
15	29	7	9	1652	0.01086	0.17
16	29	7	9	6000	0.07891	0.46
17	30	7	7	1863	0.0245	0.38
18	30	7	7	2142	0.02817	0.19
19	30	7	6	2791	0.03671	0.34
20	30	7	6	10000	0.13152	0.39
22	30	7	4	1416	0.01862	0.56
				2001		
7	27	7	13	33	0.0004	0.64
33	30	7	13	264	0.003	0.28
43	1	8	13	109	0.0017	0.67
44	1	8	13	409	0.0047	I

Appendix Table 1 cont.

Tow	Day	Month	Subarea	Catch (kg)	CPUE (kg • m^{-3})	Prop. Age 2+
				2001		
45	2	8	5	303	0.0035	0.61
47	2	8	6	42	0.0007	0.59
48	2	8	6	242	0.0024	0.63
49	3	8	6	1902	0.0181	0.61
50	3	8	7	950	0.0091	0.61
51	3	8	7	950	0.0109	0.53
52	3	8	9	530	0.0061	0.45
53	4	8	9	18	.	.
54	4	8	9	464	0.0053	I