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Stock Assessments for British Columbia Herring in 1988 and Forecasts of the Potential Catch in 1989

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ABSTRACT

Haist, V. and J. F. Schweigert. 1989. Stock assessments for British Columbia herring in 1988 and forecasts of the potential catch in 1989. Can. MS Rep. Fish. Aquat. Sci. 2028: 48 p.

Herring stock abundance in British Columbia waters was assessed for 1988 and forecasts were made for 1989 using two analytical methods: (1) escapement model; and (2) age-structured model. Diving spawn survey data was utilized in the escapement model wherever available.

Forecasts of pre-fishery biomass are obtained by weighting the estimates from the two models. The forecasts are for 101,500 tonnes to the northern and 104,500 tonnes to the southern stock assessment regions. These estimates represent significant increases from 1988 levels, reflecting average to good recruitments to all areas during the last spawning run.

The recommended 1989 catch (20% of the 1989 forecast herring run) for the entire B.C. coast is 41,200 tonnes. All areas should be available to the fishery in 1989.

Key words: Clupea harengus pallasi, Pacific herring, stock assessment, forecasts, age-structured analysis

RÉSUMÉ

Haist, V. and J. F. Schweigert. 1989. Stock assessments for British Columbia herring in 1988 and forecasts of the potential catch in 1989. Can. MS Rep. Fish. Aquat. Sci. 2028: 48 p.

Nous avons évalué l'abondance des stocks de hareng dans les eaux de Colombie-Britannique en 1988 et préparé des prévisions pour 1989 à l'aide de deux méthodes d'analyse : 1) modèle des échappées; et 2) modèle de la structure par âge. Autant que possible, on a utilisé pour le modèle des échappées les données recueillies par les plongeurs dans les frayères.

Nous avons établi les prévisions de la biomasse avant la pêche en pondérant les estimations des deux modèles. Les prévisions sont, selon la région d'évaluation, de 101 500 tonnes pour le stock du nord et de 104 500 tonnes pour celui du sud. Ces estimations représentent des augmentations significatives par rapport aux chiffres de 1988, et correspondent à un recrutement moyen ou bon dans toutes les régions pendant la dernière migration génétique.

Le niveau de capture recommandé pour 1989 (20% des prévisions des effectifs de 1989) sur l'ensemble de la côte de Colombie-Britannique se monte à 41 200. Toutes les régions devraient être ouvertes à la pêche en 1989.

Mots clés: Clupea harengus pallasi, hareng du Pacifique, évaluation des stocks, prévisions, analyse de la structure par âge

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FOREWORD

This report was prepared by the Populations Dynamics Program of the Herring Section (Biological Sciences Branch), and contains proposed catch levels for herring for the 1988/89 season. These recommended catches are based primarily on biological considerations, and many vary with those finally adopted by the PSARC Herring Sub-committee. The final fishing plans adopted by Fisheries Management will be based not only on biological considerations, but also economic, social, enforcement, and other factors.

Results contained in this report were presented to the PSARC Herring Sub-committee in September of 1988.

ACKNOWLEDGMENTS

This document represents not only the efforts of the Population Dynamics Program. Numerous other members of the departmental staff play key roles in the collection and processing of data. Herring ages were determined by Margaret Burke and Karen Charles of the Pacific Biological Station Ageing Unit. Lorena Hamer processed the catch, sample, and spawn data and maintained the pertinent data bases. Also, Fisheries Branch personnel and contractors contribute to the herring sampling effort, and Fisheries Officers conduct the annual herring spawn surveys.

1. INTRODUCTION

1.1 GENERAL

Forecasting the potential catch that can be removed from herring stocks requires an assessment of the current stock status and the determination of factors which affect stock dynamics, in particular, recruitment. Traditionally, equilibrium based methods such as yield models have been favoured. They assume constancy in age structure, growth, and mortality. However, herring are strongly affected by changes in environmental conditions thus making equilibrium models unattractive. The methods we use estimate current stock conditions on the basis of which potential catches are recommended. Catch levels have been formulated to ensure conservation of the stocks.

In this report we present two methods to assess present herring stock status: (1) an escapement model (Schweigert and Stocker 1988); and (2) an age-structured model (Fournier and Archibald 1982). Both methods use a 38-year time series of catch and spawn deposition information and age structure and size-at-age data obtained from biological samples.

1.2 DATA BASE

The primary data sources for the stock assessments are spawn survey data, commercial catch landing data, and age composition data from biological samples of commercial fishery, pre-fishery charter, and research catches. These data are available on computer files for the period 1951 to 1988. This time span includes the reduction fishery period to 1968 and the subsequent roe fishery period starting in the early 1970s.

Of the three data sets, the spawn data contain the largest measurement errors. We feel that the quality of spawn surveys has improved greatly over the 38-year span of these observations. This improvement is a result of increased numbers of people and vessels being involved in spawn surveys, increased attention to data measurements, increased coverage of subtidal spawnings, and increased research on estimating egg deposition from spawn observations. The consistent observations made during the 38 years of spawn surveys are the length, the width, and a measure of intensity of spawnings. The escapement model estimates absolute egg numbers from these observations and includes a width conversion to adjust for the inability to survey subtidal spawns adequately. In recent years many spawning areas have been surveyed using SCUBA methods. We assume these surveys provide reasonably accurate estimates of spawn width and egg density and these data have been used in the escapement model where available. The age-structured model uses a spawn index which sums lengths multiplied by standardized widths and intensities.

Catch information was obtained from landing slip data. Both models use the landing slip data summed by season (seasons run from July 1 to June 30). The 1987/88 catch figures are based on hailed estimates because sales slip data were not available for timely analysis. The sales slips record catch in tonnes. Numbers of fish in the catch were calculated using the average fish weight from catch samples for the season.

Age structure data are used in both models. The information from catch samples are used for years when there were commercial fisheries. For years with no fisheries, or when catch samples do not appear to be representative, pre-fishery and research samples are also used. Additional data used in the age-structured model are age specific fecundity and average weights at age.

1.3 STOCK CONSIDERATIONS

We continue to use the stock concept introduced for the 1985 assessment (Figs 1.1 and 1.2). In the Queen Charlotte Islands, herring spawning in the area from Skincuttle Inlet to Selwyn Inlet are treated as one stock. The stock concept for the Prince Rupert District remains unchanged encompassing Statistical Areas 3 to 5. The revised central coast stock concept separates the migratory stocks from the local stocks. The migratory component used in the current analysis includes all of Statistical Area 7 plus Kitasu Bay in Area 6 and Kwakshua Channel in Area 8. The Strait of Georgia is separated into two stock groupings. The northern area includes all of Statistical Areas 14 to 16, Area 17N and Deepwater Bay and Okisollo Channel in Area 13. The southern stock comprises Areas 17S, 18 and 19. The two stock groupings used for the west coast of Vancouver Island are southern (Areas 23 and 24) and northern (Areas 25 to 27).

Additionally, biomass estimates from the escapement model are presented for minor and resident stocks. The level of geographic aggregation used for these estimates is the section (Haist and Rosenfeld 1988).

2. ESCAPEMENT MODEL

2.1 INTRODUCTION

The escapement model was developed for the 1984 assessments (Haist *et al.* 1985; Schweigert and Stocker 1988). Subsequently, it has been modified to incorporate age structure information which allows separation of the growth and recruitment components of stock productivity. This also facilitates comparison of estimates with those from the age-structured model. As in past years, when diver spawn survey information is available it is used in preference to surface survey data. In 1988, fishery officers conducted dive surveys of most of the major herring spawns on the British Columbia coast. Where dive survey data are not available surface survey data are adjusted as described below. In this year's assessment, estimates are again presented for the 7 major stock assessment regions which contain distinct migratory stocks. Stock estimates are also presented for all sections which are not included in the major stock assessment regions. These minor or resident stocks may be capable of supporting very small fisheries, impoundments, or spawn-on-kelp operations.

2.2 METHODS

In the escapement model, estimates of the potential catch in each stock assessment region are calculated as 20% of the forecast run size. The forecast run size is the product of the estimated escapement in the previous year and an average annual survival rate (0.64) plus an estimate of anticipated recruitment to each stock. Recruitment is estimated for poor, average, and good levels by calculating the means of the third poorest, the middle third, and the third best recruitments observed during the historical time series from 1951-1988. The estimates of total catch (tonnes) and spawning escapement (billions of eggs) are converted to fish at age based on the sampling data for each area. For each area the age structure and average weight at each age are calculated for all samples available for that region. In some years, no data is available from a region and information from an adjacent area is utilized in the analysis. Estimates of repeat spawners and recruiting fish are converted back to tonnages using average weights at age for the current year. Estimates of spawning biomass in 1988 and forecasts for 1989 are presented for the seven stock assessment regions.

The estimated escapements for each region are derived from information on spawn deposition. Dive survey observations are used directly while surface survey observations are adjusted to render them comparable to dive estimates based on calibration equations derived from duplicate surveys (Schweigert and Stocker 1988). The calibration equations utilized for the 1988 assessments and 1989 forecasts are identical to those used in the previous year (Haist *et al.* 1988).

The equation used to adjust surface survey spawn width estimates to diver width estimates is:

$$\text{Adjusted width} = 74.727 + 0.816 \bullet \text{Surface survey width}$$

The regression equation used to estimate the average density of eggs for each spawn from the estimate of average egg layers is:

$$\text{Eggs/m}^2 = 183.252 + 76.738 \bullet \text{Average surface layers} \bullet 1000.$$

Surface survey data are adjusted using the foregoing equations in all areas except for Johnstone Strait (Statistical Areas 9-13). In this area no adjustment is applied to the spawn widths as previous dive surveys in the area (Schweigert and Haegele 1988a, b) indicated that widths were accurately assessed from the surface. Egg deposition is estimated from the product of total spawn length, adjusted width, and egg density as estimated from the average surface layer estimate. The total egg deposition is converted to tonnes of spawners based on the average estimate of 100 eggs per gram of spawning fish. Escapement plus catch provides an estimate of the total pre-fishery spawning stock biomass.

Estimates of egg deposition from the diver survey are based on a two-stage sampling design (Schweigert *et al.* 1985). Spawn lengths and widths are determined by exploratory raking, snorkelling, or by swimming along transects. Egg density for each spawn is estimated from the mean of a series of quadrats located along the transects. For each quadrat observations are made on several variables: dominant vegetation type, proportion of the quadrat covered by vegetation, number of layers of eggs on vegetation, proportion of the bottom substrate covered by eggs, and an estimate of the number of egg layers on bottom substrate. For the vegetation, egg density is estimated from the following equation:

$$\text{Eggs/m} = 1023.6530 \bullet L^{0.7008} \bullet P^{1.5395} \bullet V_i \bullet Q_j \bullet 1000.$$

where L = number of layers of eggs on the dominant vegetation type
P = proportion of quadrat covered by vegetation
V_1 = 1.0426 parameter for sea grasses
V_2 = 1.2260 parameter for rockweed
V_3 = 0.8930 parameter for flat kelp
V_4 = 1.1775 parameter for other brown algae
V_5 = 0.9029 parameter for leafy red and green algae
V_6 = 1.000 parameter for stringy red algae
Q_1 = 0.4874 parameter for 1.00 m^2 quadrats
Q_2 = 0.5511 parameter for 0.50 m^2 quadrats
Q_3 = 1.000 parameter for 0.25 m^2 quadrats

Eggs on rock are estimated from the product of the proportion of the quadrat covered by eggs, number of egg layers, times 340,000 egg/m^2 (Haegele *et al.* 1979). Total egg density for each quadrat is the sum of eggs on vegetation plus eggs on rock.

Samples of vegetation and attached eggs were also collected in 1988 from all assessment regions except the Queen Charlotte Islands as a check on the accuracy of the egg prediction model. Only a limited number of samples were obtained from several areas and in a few cases the samples collected were very nearly hatching resulting in potentially biased estimates of egg density.

2.3 RESULTS

The 1989 forecast spawning run to the lower east coast of the Queen Charlotte Islands is 11,700 tonnes assuming average recruitment (Table 2.1, 2.6). The decline in this stock following the demise of the very strong 1977 year-class has been buffered by recent above average recruitments in 1984 and 1988. A poor recruitment in 1989 would see a spawning run of 10,300 tonnes while a good recruitment would yield 17,400 tonnes. This stock remains marginally above the CUTOFF level (as defined in Section 4) but overall the stock appears healthier than last year.

The forecast runs for the Prince Rupert District with average and good recruitments are for 28,100 and 35,500 tonnes, respectively (Table 2.1, 2.6). This stock will probably decline slightly from the historically high levels of the past few years. A poor recruitment could see the stock drop to 25,200 tonnes, still well above the CUTOFF level.

Forecast run sizes for the Central Coast are for 44,900 and 55,300 tonnes with average and good recruitment, respectively. This stock has remained at healthy levels throughout the period of the roe fishery (Table 2.1, 2.6). The 1988 spawning biomass of 53,100 tonnes is among the highest on record due primarily to the largest recorded recruitment to this stock. Even a poor recruitment in 1989 should produce a spawning biomass of 41,000 tonnes in this area (Table 2.6).

The spawning biomass levels for the south coast stocks continue to surpass the levels of the early 1980s. The northern Strait of Georgia forecast run in 1989 is for 30,800 and 40,600 tonnes with average and good recruitment, respectively (Table 2.1, 2.6). The 1988 spawning biomass of 30,800 tonnes is similar to 1987 but down substantially from 1986 when the strong 1983 year-class recruited to this stock (Table 2.2). The forecast with poor recruitment is for 24,900 tonnes, still well above the CUTOFF level.

The southern Strait of Georgia stock forecast with average recruitment is 8,300 tonnes and 9,700 tonnes with good recruitment. A poor recruitment would yield 7,100 tonnes of spawners in this area (Table 2.2, 2.6). Recent stock levels are down somewhat from those during the earlier years of the roe fishery and may warrant continued concern about the possible demise of some of the local spawning populations in the area.

The stocks on the southern west coast of Vancouver Island are forecast at 30,700 and 38,700 tonnes with average and good recruitment, respectively (Table 2.2, 2.6). Stock levels have been increasing steadily since the low in 1982. Recent good recruitments in

1985, 1986, and 1988 have significantly increased the size of this stock. Even a poor recruitment in 1989 should see a spawning biomass of 26,400 tonnes, well above the CUTOFF level.

The stocks on the northern west coast of Vancouver Island have been stable at about 12,000 tonnes the past three years due to good recruitments in 1986 and 1988 (Table 2.2, 2.6). The forecast run sizes with average and good recruitment in 1989 are 14,000 and 21,700 tonnes, respectively. A poor recruitment would maintain the stock at 11,100 tonnes, very similar to present levels of abundance.

The minor and resident stock abundance estimates are presented in Tables 2.3 to 2.5. There are problems in assessing the stocks in many of the more remote locations due to inadequate spawn survey coverage and a general absence of age composition data, so absolute estimates of abundance are probably not very accurate. However, the abundance trends generally follow those of the nearby migratory stocks. Only the stocks in Area 2W appear healthy in relation to historical levels and could perhaps be considered as alternative sites for roe fisheries in the Queen Charlotte Islands assessment region. The minor stocks in the Central Coast assessment region are also not surveyed with sufficient regularity to discern possible trends, but no major fishable biomasses are apparent. The Johnstone Strait stocks are in many instances below the long term average, reflecting perhaps irregular and incomplete spawn survey coverage of some of the areas in this region.

A comparison of observed and predicted mean egg densities are presented by statistical area in Table 2.7. Although there are marked discrepancies for a few areas these may be due to unusual vegetation spawning substrates or a loss of eggs near hatching in a number of the preserved samples. Given some of the logistical difficulties in collecting the samples during 1988 some of the egg counts may be suspect. Consequently, we have opted to go with predictions from the egg density model rather than attempt adjustment of our estimates based on the observed egg counts from 1988 samples.

Table 2.1. Estimates of spawner biomass, catch, and total stock abundance (tonnes) for the Northern stock assessment regions for 1951-1988.

	Queen Charlotte Is.			Prince Rupert			Central Coast		
Season	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock
51	4299	2847	7146	29183	45865	75049	21477	42458	63936
52	3122	10147	13269	10361	52379	62740	10609	33195	43803
53	5764	0	5764	14599	1865	16464	20751	768	21519
54	11684	1786	13470	10197	27277	37473	16925	24616	41542
55	5936	498	6435	12997	17806	30802	16440	11594	28034
56	5556	77369	82924	12822	10182	23004	11991	43627	55618
57	1513	21338	22852	19895	28035	47929	6069	23261	29329
58	790	11147	11937	8666	4523	13189	8250	9849	18100
59	7112	6828	13940	16747	10224	26971	7362	27870	35233
60	3558	0	3558	13414	18476	31890	20970	4037	25007
61	6568	576	7145	14626	42746	57372	8545	31704	40249
62	4394	7632	12026	20475	27660	48135	22973	15709	38682
63	4549	14705	19254	15419	40228	55647	11186	44054	55240
64	3248	26958	30205	16698	30340	47037	11934	32064	43998
65	1472	32423	33895	6298	44211	50508	4528	15670	20198
66	3551	2746	6297	5857	17295	23152	5010	37482	42491
67	771	161	932	3051	7998	11049	8451	21890	30341
68	734	80	814	6420	2144	8563	9114	1529	10643
69	1865	0	1865	915	547	1462	3961	100	4061
70	2887	0	2887	11839	1498	13337	19770	209	19979
71	4592	0	4592	9737	3500	13237	8131	3614	11745
72	2897	1260	4157	10917	4494	15411	8511	9279	17790
73	2424	2231	4654	11252	1607	12859	24103	7799	31903
74	6980	2277	9257	8821	3819	12640	19659	8887	28547
75	3972	4408	8380	10625	1702	12326	18979	8739	27718
76	9214	9425	18638	16009	4307	20316	29962	12199	42161
77	11245	10024	21270	15358	8142	23500	28046	11106	39151
78	10059	9489	19547	7375	8588	15962	16747	14046	30793
79	7677	7953	15630	13803	4317	18120	14263	5	14268
80	24553	2274	26828	16985	3425	20411	30658	538	31196
81	23834	5631	29465	17181	3090	20271	33078	2573	35651
82	19373	3778	23151	14926	1984	16910	34139	6370	40509
83	16979	5597	22576	26146	0	26146	41896	5640	47535
84	20176	4719	24894	27921	3761	31681	28162	7193	35355
85	15624	6109	21733	32690	6747	39437	24266	5209	29475
86	5846	3503	9349	30217	8679	38896	21705	3386	25091
87	13708	2061	15769	38586	6271	44856	28917	3615	32533
88	13803	281	14084	32086	8307	40393	48632	4462	53094

Table 2.2. Estimates of spawner biomass, catch, and total stock abundance (tonnes) for the Southern stock assessment regions for 1951-1988.

	Georgia Strait - N			Georgia Strait - S			WCVI - South			WCVI - North		
Season	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock
51	31902	17787	49689	3633	25824	29457	6464	15914	22378	13135	6117	19252
52	28828	17635	46463	14392	28084	42476	6492	10630	17122	3303	16415	19719
53	34728	4376	39104	53093	3966	57060	8997	20	9017	25713	0	25713
54	24235	20560	44795	36987	44284	81270	5279	28699	33978	11125	8875	20000
55	31833	26818	58651	31712	41619	73331	6384	6041	12425	10438	6524	16962
56	14059	27273	41332	14844	44572	59416	8910	17098	26008	13015	508	13523
57	12925	21374	34299	6992	38202	45194	6344	2600	8944	18939	491	19430
58	8149	9012	17160	17385	11616	29001	11551	513	12063	7282	43	7325
59	16237	34189	50426	16285	15765	32051	6049	37385	43434	5632	32370	38002
60	21353	22540	43893	9457	43107	52564	5577	17652	23229	3717	38145	41861
61	17466	15784	33251	9247	30410	39657	7968	13489	21457	5531	17356	22887
62	16636	30358	46993	5558	34945	40503	9076	15597	24673	14794	12777	27571
63	16652	33746	50398	8725	35101	43826	8764	4019	12783	4289	17230	21520
64	15685	36808	52493	6689	40179	46868	17749	20230	37978	8537	1914	10450
65	13829	27931	41760	2505	19888	22393	7052	14063	21115	8980	4741	13721
66	4819	20996	25816	2723	12337	15059	3346	8169	11516	2861	4207	7068
67	6716	11157	17873	2504	19885	22389	2100	9171	11271	4655	6260	10915
68	7029	966	7994	5247	981	6227	4073	0	4073	3628	0	3628
69	9312	325	9636	7377	420	7797	5530	0	5530	9256	0	9256
70	22799	519	23318	12793	365	13157	17157	0	17157	8344	0	8344
71	27871	948	28819	10764	745	11509	17946	0	17946	8496	0	8496
72	14145	6443	20588	8946	2368	11315	17549	4285	21835	13100	2609	15709
73	15211	6679	21890	9647	970	10617	6167	10409	16576	10983	7894	18877
74	28017	3212	31229	15660	791	16451	13408	6371	19780	5549	10489	16038
75	35921	5115	41036	16951	1063	18014	21043	18593	39636	11512	7515	19027
76	39347	8163	47510	9453	4075	13528	28724	33441	62165	5363	5520	10883
77	47523	11304	58827	5988	6205	12193	29326	26453	55779	7312	3688	11000
78	53927	13874	67800	13558	10129	23686	18687	18050	36737	16769	4846	21615
79	74011	8638	82650	19318	11699	31018	28795	9876	38671	36820	9510	46330
80	55067	4525	59592	11720	1294	13014	27500	2276	29776	32089	2226	34315
81	32225	7407	39631	12197	4645	16842	24790	4928	29718	13033	3833	16866
82	65733	5746	71479	8024	7086	15110	11142	3110	14252	14294	2947	17242
83	35284	16220	51504	11613	949	12562	11094	6141	17234	12332	2597	14930
84	15645	9869	25515	11947	1175	13122	16115	5718	21833	6394	1032	7426
85	20483	6239	26722	7596	791	8387	25941	178	26119	3796	0	3796
86	55367	287	55654	7814	307	8121	28475	204	28679	12646	0	12646
87	29517	5294	34811	9144	4059	13203	24274	13463	37737	11175	2471	13646
88	22900	7879	30779	5230	0	5230	30031	9651	39682	11710	0	11710

Table 2.3. Estimates of the total biomass and average reduction and roe catches (tonnes) for minor and resident stocks in the Queen Charlotte Islands for 1951-1988.

	Section							Section	
Season	001	002	003	004	005	006	Total Area 2W	022	023
51	0	0	0	0	0	0	0	848	0
52	0	0	0	0	0	0	0	660	0
53	0	0	790	163	0	0	953	18088	0
54	0	0	0	0	0	0	0	25360	0
55	0	0	0	0	0	0	0	19017	0
56	0	0	0	0	0	0	0	5895	93
57	0	0	147	0	0	464	611	1195	0
58	0	0	221	0	40	0	261	87	0
59	1672	1164	1614	0	1024	1078	6552	11196	0
60	92	667	1411	0	116	3738	6024	3627	0
61	1127	410	520	0	379	2094	4530	4320	0
62	403	1962	1620	0	301	970	5256	8031	0
63	0	2407	0	0	0	0	2407	3034	0
64	430	1375	772	187	164	3595	6523	4044	0
65	285	0	308	103	1490	3455	5641	5671	0
66	0	62	24	0	17	0	103	3800	0
67	80	1203	0	0	157	66	1506	636	184
68	0	6	107	0	75	85	273	275	0
69	24	280	327	0	949	0	1580	1199	0
70	0	417	363	0	807	412	1999	1053	5109
71	0	159	805	0	580	1833	3377	2069	6727
72	0	452	476	0	2022	3375	6325	3573	7577
73	0	130	1505	0	2334	5380	9349	1151	9421
74	0	0	1388	0	3016	4014	8418	1632	6277
75	0	306	1401	253	1567	5768	9295	2239	5318
76	0	405	491	0	1855	9197	11948	3028	5079
77	0	283	647	207	2484	5379	9000	3097	4205
78	651	0	2071	0	2200	3579	8501	3994	3559
79	1293	50	682	102	873	987	3987	1642	3624
80	1151	1384	1864	0	2375	2870	9644	31	0
81	1193	3954	2089	406	1204	1174	10020	695	2076
82	0	6174	3542	437	4124	2258	16535	877	544
83	254	3491	4268	543	5288	1362	15206	581	1756
84	591	2648	1115	0	2167	735	7256	2295	1765
85	0	2176	882	36	1947	1093	6134	407	1212
86	0	1109	298	0	1413	0	2820	2609	920
87	0	2040	0	0	730	564	3334	865	969
88	692	4251	1397	343	2276	2776	11735	0	0
Avg Biomass	262	1025	872	73	1157	1797	5187	3488	1748
Avg Catch (1951-1967)	35	0	6	0	57	322	420	5197	5
Avg Catch (1972-1988)	0	12	134	0	297	626	1069	170	900

Table 2.4. Estimates of the total biomass and average reduction and roe catches (tonnes) for minor and resident stocks in the Central Coast for 1951-1988.

	Section									Area	Area	
Season	061	062	063	064	065	066	082	083	084	9	10	Total
51	0	0	12	116	0	3180	0	9	0	762	191	4270
52	0	0	0	104	211	0	2374	10	0	557	70	3326
53	0	0	0	0	0	0	0	0	0	200	675	875
54	0	181	0	810	223	59	309	994	0	2170	489	5235
55	0	367	95	2923	2118	113	709	274	279	5334	1401	13613
56	0	271	48	16	280	8	0	307	18	164	153	1265
57	6610	149	22	54	1805	0	1505	766	0	3077	2170	16158
58	186	295	18	1	284	0	0	1754	0	642	458	3638
59	1748	233	694	58	67	366	75	1134	0	2870	1232	8477
60	19	615	2523	250	1644	0	0	330	26	405	586	6398
61	82	673	680	11	3666	0	289	457	0	1037	911	7806
62	70	2298	90	0	5056	138	6478	24	0	5827	1563	21544
63	991	2506	1282	180	65	0	2345	1169	0	4106	496	13140
64	1112	1578	2117	0	934	31	1509	953	529	8397	1203	18363
65	3977	1237	137	0	656	40	353	673	641	1488	316	9518
66	2827	1966	599	277	37	147	3251	822	978	5664	1354	17922
67	2184	1761	131	117	191	0	270	270	544	3196	3508	12172
68	498	59	52	1	0	0	0	913	51	380	442	2396
69	0	0	6	34	0	0	282	16	0	115	46	499
70	0	0	71	62	14	27	672	272	8	1603	335	3064
71	0	0	44	15	29	0	264	493	211	623	819	2498
72	0	0	14	0	0	444	169	429	258	1031	1164	3509
73	0	79	43	0	0	0	147	137	1217	3804	138	5565
74	0	40	37	0	0	0	62	129	641	1050	300	2259
75	0	0	39	0	5	0	368	126	1152	884	299	2873
76	0	193	0	0	30	0	115	141	922	732	180	2313
77	0	0	30	0	2	0	0	134	499	657	59	1381
78	57	0	4	0	0	0	37	64	249	419	212	1042
79	0	208	0	0	0	168	0	41	223	118	80	838
80	0	0	0	0	0	573	0	141	0	302	241	1257
81	189	27	0	0	0	0	0	75	111	71	191	664
82	482	0	0	0	0	0	0	38	0	964	754	2238
83	0	119	0	0	0	0	0	15	133	228	591	1086
84	0	0	0	0	0	0	0	35	287	54	704	1080
85	10	269	0	0	0	0	0	0	87	144	222	732
86	0	828	0	0	0	0	0	100	53	1702	601	3284
87	387	205	0	0	0	609	0	213	182	1451	78	3125
88	0	0	0	0	0	0	64	241	9	1015	158	1487
Average Biomass	564	427	231	132	456	155	570	361	245	1664	642	5445
Avg Catch (1951-1967)	1165	829	471	264	1013	144	1144	576	130	2477	811	9024
Avg Catch (1972-1988)	15	0	0	0	0	0	0	0	124	210	91	440

Table 2.5. Estimates of total biomass and average reduction and roe catches (tonnes) for minor and resident stocks in Johnstone Strait for 1951-1988.

Season	Area 11	Section 126	Section 127	Other Area 12	Other Area 13	Total
51	1	986	339	3236	116	4678
52	5	2292	347	5728	88	8460
53	0	214	264	1269	181	1928
54	2	871	415	5102	81	6471
55	6515	323	1083	1138	228	9287
56	257	565	198	1095	520	2635
57	13	638	129	12191	83	13054
58	15	29	183	4074	0	4301
59	145	3436	1093	1624	291	6589
60	675	979	2516	5543	494	10207
61	272	819	282	4698	300	6371
62	780	112	749	9324	407	11372
63	2187	591	1039	8802	766	13385
64	127	448	5753	5880	1620	13828
65	1226	996	2893	11034	3154	19303
66	1171	297	2107	18169	681	22425
67	253	139	997	10656	3299	15344
68	8	51	156	2722	3	2940
69	21	198	187	1518	170	2094
70	48	303	239	2657	179	3426
71	71	154	91	1867	427	2610
72	31	1502	1163	4172	745	7613
73	11	1143	3651	8864	280	13949
74	7	569	3640	1765	299	6280
75	28	1170	3358	1867	638	7061
76	33	1229	2042	822	116	4242
77	15	415	1696	1157	106	3389
78	16	570	574	250	61	1471
79	60	61	67	175	181	544
80	14	246	395	831	269	1755
81	9	184	278	486	1316	2273
82	0	138	549	67	252	1006
83	17	93	241	101	134	586
84	9	163	477	644	2	1295
85	0	412	935	126	228	1701
86	37	162	194	488	40	921
87	12	144	167	473	90	886
88	6	264	398	892	0	1560
Avg Biomass	371	603	1076	3724	470	6243
Avg Catch (1951-1967)	756	714	1083	5966	530	9050
Avg Catch (1972-1988)	1	258	99	60	43	1260

Table 2.6. Estimates of 1988 spawning biomass and forecasts of age 4+ and recruit biomass in 1989 (in thousands of tonnes) from escapement model analysis.

Stock Assessment Region	1988 Spawning Biomass	1989 Forecasts			
		Age 4+	Age 3 recruits		
			Poor	Average	Good
Queen Charlotte Islands	13.8	9.6	0.6	2.1	7.8
Prince Rupert District	32.1	23.9	1.3	4.2	11.6
Central Coast	48.6	38.2	2.8	6.7	17.1
Strait of Georgia					
Northern stock	22.9	17.2	7.7	13.6	23.4
Southern stock	5.2	3.8	3.3	4.5	5.9
West Coast of Vancouver Is.					
Southern stock	30.0	22.4	4.0	8.3	16.4
Northern stock	11.7	9.0	2.1	5.0	12.7

Table 2.7. Comparison of 1988 egg counts and model predictions (in thousands).

Statistical area	Number of samples	Mean egg density	
		Observed	Predicted
3	8	389.411	290.022
4	25	248.986	622.236
7	48	765.583	576.557
14	52	486.136	610.284
17	3	1142.257	1091.384
23	53	467.902	426.918

3. AGE-STRUCTURED MODEL

3.1 INTRODUCTION

A modified version of the age-structured model described in Fournier and Archibald (1982) has been used to assess B.C. herring stocks since 1982. The model has undergone numerous revisions to make it more consistent with the life history of herring and the fisheries being analyzed. The current version, which is described here, incorporates auxiliary information in the form of spawn survey data, separates catch at age data by gear type, and includes an availability term to model partial recruitments to the spawning stock. The model includes realistic assumptions about the form of both measurement and process error. A maximum likelihood method is used to simultaneously estimate all model parameters.

3.2 METHODS

The Population Model

Two types of fishing gear are commonly used in B.C. herring fisheries. Of these, seine nets are assumed to be non-selective while gillnets are selective for larger, older fish. Herring fisheries have primarily concentrated on spawning fish or fish migrating to spawning grounds, so the relative availability of age classes to the non-selective gear should be equivalent to the partial recruitment of age-classes to the spawning stock. We have therefore developed a model which explicitly separates availability (partial recruitment) and gear selectivity. Seine and gillnet fisheries are temporally separate so catch-at-age data is partitioned into fishing periods, separating data for the different gears. Three fishing periods are modelled. The first period encompasses all catch data prior to the spring roe-herring fisheries. This includes all the reduction fishery catches prior to 1968 and the winter food and bait fisheries since 1970. Most of this catch was taken by seine gear although small amounts are caught with trawl nets (which are also not size selective). The second fishing period includes all seine caught roe-herring fishery data and the third period includes all gillnet caught roe-herring data.

Let T_{ij} be the total number of fish in age class j at the beginning of season i, and λ_{ij} be the proportion of age j fish which are available to the fishery. Then N_{ij1}, the total number of age class j fish which are available at the start of period 1 in season i is given by

$$N_{ij1} = \lambda_{ij} T_{ij} \tag{3.1}$$

To model the fishing process we assume that the Baranov (1918) catch equations are valid for the available fish,

$$C_{ijr} = \frac{F_{ijr}}{F_{ijr} + M_r} \left[1 - \exp(-F_{ijr} - M_r) \right] N_{ijr} ,$$

and, for $r < p$

$$N_{ij,r+1} = N_{ijr} \exp(-F_{ijr} - M_r),$$

where
C_{ijr} is the catch of age class j in season i for period r
F_{ijr} is the fishing mortality of age class j in season i for period r
M_r is the natural mortality for period r
N_{ijr} is the number of fish in age class j in season i for period r
p is the number of fishing periods (p=3)
n is the number of seasons (n=38)
k is the number of age classes (k=10).

$N_{i+1,j+1,1}$ is defined by equation 3.1 where for $j+1 < k$

$$T_{i+1,j+1} = N_{ijp} \exp(-F_{ijp} - M_p) + T_{ij}(1 - \lambda_{ij}) \exp(\sum_r -M_r). \qquad (3.2)$$

In our model the last age class, k, consists of all fish aged k and older so for j+1=k equation 3.2 is replaced by

$$T_{i+1,k} = N_{i,k\text{-}1,p} \exp(-F_{i,k\text{-}1,p} - M_p) + T_{i,k\text{-}1}(1 - \lambda_{i,k\text{-}1}) \exp(\sum_r -M_r) +$$
$$N_{ikp} \exp(-F_{ikp} - M_p) + T_{ik}(1 - \lambda_{ik}) \exp(\sum_r -M_r).$$

To reduce the number of parameters to be estimated we make certain assumptions with respect to the availabilities and mortalities. We assume that availability increases with age, reaching a value of 1 by age 7. Additionally, we assume that the availability of fish age 4 and older does not vary from year to year. However, the proportion of mature 3-year olds does vary between years (Haist and Stocker 1985) and some fisheries have targeted on immature 2-year-old stocks (eg. 1957/58 Queen Charlotte Islands fishery, Appendix Table 1.1). We therefore parameterize availability for these two age classes with annual deviations from an average availability for the age class ($\bar{\lambda}_j$). Availability for ages 2 and 3 for seasons 1 to n-1 is

$$\lambda_{ij} = \bar{\lambda}_j + d_{ij} ,$$

where the d_{ij} are constrained such that

$$\sum_{i=1}^{n-1} d_{ij} = 0.$$

For ages 4 to 6 and ages 2 and 3 in year n

$$\lambda_{ij} = \bar{\lambda}_j ,$$

and for ages 7 and older,

$$\lambda_{ij} = 1.$$

Deviations from the average availability are not estimated for ages 2 and 3 in the final year because there is not enough information in the data to estimate these parameters.

For the selective fishery (ie. the gillnet fishery) we assume that fishing mortality is separable into an age selectivity component and a fishing intensity component. Following Doubleday (1976),

$$\log(F_{ijr}) = a_{ir} + b_{jr}$$

where a_{ir} represents the general level of fishing mortality due to fishery r in season i, and b_{jr} represents the relative vulnerability of age class j in fishery r. For non-selective fisheries the model is

$$\log(F_{ijr}) = a_{ir} .$$

We assume that natural mortality is constant over ages and seasons.

Additional structure is built into the model through the inclusion of annual spawning stock egg production data (spawn index, I_i) and the assumption of a stock-recruit relationship. Spawning occurs at the end of the season so the number of spawners at age j in season i (G_{ij}) is estimated by

$$G_{ij} = N_{ijp} \exp(-F_{ijp} - M_p).$$

and the reproductive potential (R_i) in season i is

$$R_i = \sum_j f_j G_{ij}$$

where f_j is the relative fecundity at age j. We assume the error in the spawn index observations (I_i) is multiplicative so that

$$I_i = q R_i \exp(\xi_i) \qquad (3.3)$$

where q is a spawn conversion factor and ξ_i is a normally distributed random variable with mean 0 and variance σ_I^2 . We assume a standard Ricker stock-recruit relationship with multiplicative error,

$$T_{i+1,1} = \alpha R_i \exp(-\beta R_i) \exp(\xi_i), \qquad (3.4)$$

where ξ_i is a normally distributed random variable with mean 0 and variance σ_2^2.

For the model described above the parameters to be estimated are:

T_{i1} , for all seasons i
T_{1j} , for age classes 2 to k
$\bar{\lambda}_j$, for age classes 2 to 7
d_{ij} , for age classes 2 and 3, for seasons 1 to n-1
a_{ir} , for all fisheries i,r
b_{jr} , for all selective fisheries (ie. $r=3$)
α, β,. and q.

The $\bar{\lambda}_j$ and d_{ij} are reparameterized to constrain the values of λ_{ij} between 0 and 1. The parameters σ_1^2 and σ_2^2 are not estimated in the reconstructions, but are fixed at specified values as discussed later on.

The Objective Function

Data input to the stock reconstruction are:

S_{ijr} , the number of sampled fish aged j in season i for period r
O_{ir} , the estimated number of fish caught in period r of season i
f_j , the estimated fecundity at age j

We assume the same error structure for the observations S_{ijr} and O_{ir} as employed by Fournier and Archibald (1982), that is:

1) The S_{ijr} are obtained from ageing a random sample of fish from the catch and there are no ageing errors (i.e. a multinomial sampling distribution).

2) The error structure for the estimated number of fish caught (O_{ir}) is log-normal. That is,

$$O_{ir} = C_{ir} \exp(\xi_i),$$

where C_{ir} is the actual number of fish caught in period j in season i ($C_{ir} = \sum_j C_{ijr}$) and the ξ_i are independent normally distributed random variables with mean 0 and variance σ_3^2.

3) The random variables S_{ijr} and O_{ir} are independent.

Given the above stochastic assumptions the log-likelihood function for the parameters P_{ijr} ($P_{ijr} = C_{ijr}/C_{ir}$), C_{ir}, and σ_3^2 is

$$\sum_{ijr} S_{ijr} \log(P_{ijr}) - \sum_{ir} \tfrac{1}{2} \frac{[\log(O_{ir}) - \log(C_{ir})]^2}{\sigma_3^2} - n \log(\sigma_3). \qquad (3.5)$$

The assumptions of log-normal measurement error in the observed spawn -actual spawn relationship and log-normal process error in the spawn-recruit relationship introduce the following contributions to the log-likelihood function

$$- \sum_{i} \tfrac{1}{2} \frac{[\log(I_i) - \log(R_i)]^2}{\sigma_1^2} \qquad (3.6)$$

from equation 3.2, and

$$- \sum_{i} \tfrac{1}{2} \frac{[\log(T_{i+1,1}) - \log(R_i) - \log(\alpha) + \beta R_i]^2}{\sigma_2^2} \qquad (3.7)$$

from equation 3.3.

The objective function described above (eqn. 3.5 + 3.6 + 3.7) incorporates both measurement (observational) and process (deviations from modelled relationships) error assumptions, with the relative magnitude of the errors related through the variance terms σ_1^2, σ_2^2, and σ_3^2, and the sample sizes $\sum_r S_{ijr}$. Because there is not enough information in the data to estimate the relative error in either the observations or processes, with the exception of scaling the S_{ijr}, the variance terms are not estimated but are held at fixed values. We assume the following variances:

$\sigma_1^2 = .05,$
$\sigma_2^2 = .25,$
$\sigma_3^2 = .0025.$

These correspond to approximately a 4% average error in estimating the total number of fish caught, an 18% average error in spawn index observations, and a 45% average deviation from the spawn-recruit relationship.

The actual number of fish aged, S_{ijr}, could be used in the objective function, however, we do not feel this would give a realistic estimate of the precision of the proportion at age data. That is, we do not feel the sampling process strictly adheres to binomial sampling assumptions. The between load (samples from different catching vessels) variability in age composition is significantly different between years, and this is more related to the spatial and temporal distribution of the fisheries than to the number of loads sampled or total fish aged. Therefore, we make use of the information in the subsamples (between load samples) which are pooled to obtain an estimate of the age composition for a given fishery.

The theoretical variance of the observed proportion of fish at age j ($\hat{p}_j$) for a random sample of size S is

$$\sigma^2_{\hat{p}_j} = \frac{p_j\,(1 - p_j)}{S}$$

where p_j is the true proportion at age j. We can calculate an estimate of the variance of $\hat{p}_j$,

$$s^2_{\hat{p}_j} = \frac{\sum\,(p_{jm} - \hat{p}_j)^2}{M - 1}$$

where p_{jm} is the proportion at age j in subsample m and M is the number of subsamples. This variance between subsamples results from the variance generated by randomly sampling an individual catch plus the variance in the true proportion at age between individual vessel catches. Using $\hat{p}_j$ as the best estimate for p_j we calculate the theoretical sample size (S') which would generate the observed variance at age j as,

$$S' = \frac{\hat{p}_j\,(1 - \hat{p}_j)}{s^2_{\hat{p}_j}}$$

We use these theoretical sample sizes, calculated from the between sample variance for 4-year old fish (Appendix Table 1), in the objective function.

Stock Forecasts

Forecasts of stock abundance for 1989 are calculated by assuming all natural mortality for the first period will occur prior to the fisheries. The numbers of fish at age prior to the fisheries are then the numbers estimated at the beginning of the 1988/89 season multiplied by survival for the first period and the estimated availability at age. Recruitment is calculated for three scenarios based on estimated numbers at age 3 for the 1951-88 time series. Poor, average, and good recruitment are calculated as the mean of the lowest 33%, the mid 33%, and the highest 33% of historic age 3 numbers. Biomass is calculated using the average weights at age for roe seine fisheries in the final season.

To investigate the bias and variance of the estimated parameters, in particular current stock estimates and the stock forecast, we applied bootstrap techniques (Efron and Gong 1983) to each of the seven data sets. The bootstrap technique involves resampling the original data set with replacement to generate a new data matrix which has the same statistical properties as the original data set. To resample the age composition data we used a two stage procedure. First random subsamples were selected from the original data set, then individual fish were randomly selected from the subsample. Because we have no information about the error structure of the spawn observations or the total catch estimates these data were resampled under the same assumptions as used in the analytical model. We assumed log normal errors with a variance of 0.05 and 0.0025 for the observed spawn and observed catch, respectively. In addition, a second set of bootstrap runs with an increased variance of 0.15 for the log normal spawn errors were also conducted. The data for each stock grouping were resampled 50 times and reanalysed producing 50 sets of parameter estimates for both of the spawn error variance assumptions.

Input data used for age-structured model analysis are shown in Appendix Table 1 for all stock groupings. Where no sample data are available, but catches were taken, the catch is included with an alternate fishery where age-structure data are available. The same spawn index is used as for last year's assessments. This index sums the lengths of spawnings multiplied by a width/intensity factor, standardized by section (Hay and Kronlund 1985).

3.3 RESULTS

Results from age-structured model stock reconstructions are shown in Appendix Table 2 for the seven major stock assessment regions. Estimates of spawning biomass in 1988 and forecasts of age 4 and recruit biomass for 1989 are shown in Table 3.1, and results of the bootstrap analysis are shown in Table 3.2.

To evaluate if the age-structured analysis produced biased estimates of current stock size and forecast stock biomass we applied a t-test under the null hypothesis that the bootstrap mean was no different than the original estimate. For the set of analyses where the spawn index data were resampled with log normal error with variance of 0.05 there were no significant differences between the original estimates and bootstrap means at the 5% level. With a variance of 0.15 on the spawn index data only the Queen Charlotte Islands bootstrap means were significantly different from the original estimate. Thus, the age-structured model estimates of current stock size do not appear to be biased.

Estimates of 1988 pre-fishery age 4+ biomass are compared with the forecast biomass range (95% confidence interval) from bootstrap analyses from last year's stock assessments in Table 3.3. Bootstrap analyses were conducted with the same model as this year, but only with a spawn error having a variance of 0.05. For three of the seven stocks the current estimate is within the forecast 95% confidence interval. For the other four stocks the current estimates are only slightly outside the 95% confidence interval.

For the Queen Charlotte Islands, the stock reconstruction indicates a slight increase in spawning biomass in 1988 following a steady decline from 1983 to 1987. However, the spawn index is lower in 1988 than in 1987. The 1987 year-class, which recruited as 3-year-olds this year, comprised 42% of the stock and is estimated as average in size relative to the historic (1951-1987) year classes. Forecast pre-fishery biomass for the Queen Charlotte Islands stock assessment area in 1989 are 17,100 tonnes assuming poor recruitment and 19,100 tonnes assuming average recruitment.

For the Prince Rupert District, age-structured analysis shows a relatively stable spawning biomass since 1984 with an estimated 40,000 tonnes of spawners in 1988. Current spawning stocks are well above the long term average. Given average recruitment a run size of 47,100 tonnes is forecast for this area.

The estimated 1988 spawning biomass for the central coast is 42,100 tonnes from age-structured analysis. This is a substantial increase from 1987 and is consistent with the increase in the spawn index. Recruit (3-year-old) fish comprised 68% of the stock in 1988 and this year-class appears to be one of the largest in the historic time series. The forecast 1989 pre-fishery biomass for the central coast is 52,000 tonnes given average recruitment.

Spawning biomass estimates for 1988 indicate substantial increases over 1987 for both the northern and southern Strait of Georgia. This is the result of above average recruitment to both stock assessment areas. Forecasts for the northern and southern stocks in 1989, given average recruitment, are 51,500 tonnes and 16,900 tonnes, respectively.

The spawning biomass estimate for the southern west coast of Vancouver Island is up slightly over 1987, however the spawn index suggests a more substantial increase in spawn. Recruitment to this area was also above average in 1988. The forecast 1989 stock abundance is 32,800 tonnes assuming average recruitment.

Age-structured model stock reconstruction for the northern west coast of Vancouver Island continue to suggest a major increase in stock size over the past five seasons. The estimate of 36,200 tonnes of spawners in 1988 seems unrealistically high given spawning estimates from synoptic dive surveys and in-season hydroacoustic surveys. The age-structured model appears to have consistently overestimated stock size for this area in recent years.

Table 3.1. Estimates of 1988 spawning biomass and forecasts of age 4+ and recruit biomass in 1989 (in thousands of tonnes) from age-structured model analysis.

Stock Assessment Region	1988 Spawning Biomass	1989 Forecasts			
		Age 4+	Age 3 recruits		
			Poor	Average	Good
Queen Charlotte Islands	18.4	16.2	0.9	2.9	10.2
Prince Rupert District	40.0	41.7	1.9	5.4	17.7
Central Coast	42.1	45.1	3.2	6.9	16.8
Strait of Georgia					
Northern stock	44.2	42.0	4.2	9.5	19.2
Southern stock	15.2	13.9	1.5	3.0	6.7
West Coast of Vancouver Is.					
Southern stock	26.0	24.6	3.9	8.2	20.0
Northern stock	36.2	33.0	1.7	5.7	11.8

Table 3.2 Bootstrap results of estimates of 1988 spawning biomass (tonnes) and forecast 1989 age 4+ biomass (tonnes) for herring stock assessment areas. For both parameters the original estimate and bootstrap means and standard deviations are given. Bootstrap set 1 and set 2 are analyses assuming 0.05 and 0.15 variance on spawn index data, respectively.

	1988 Spawning Biomass	1989 Age 4+ Biomass Forecast
Queen Charlotte Islands	18,373	16,180
bootstrap set 1 - mean	19,130	16,961
- st. dev.	2,854	2,802
bootstrap set 2 - mean	19,642	17,478
- st. dev.	3,986	3,746
Prince Rupert District	39,955	41,678
bootstrap set 1 - mean	39,805	41,492
- st. dev.	4,608	4,908
bootstrap set 2 - mean	39,522	41,210
- st. dev.	5,645	5,937
Central Coast	42,120	45,127
bootstrap set 1 - mean	42,904	45,839
- st. dev.	4,735	4,979
bootstrap set 2 - mean	42,746	45,630
- st. dev.	7,265	7,578
Strait of Georgia		
Northern Stock	44,219	42,001
bootstrap set 1 - mean	45,921	43,679
- st. dev.	7,138	6,641
bootstrap set 2 - mean	46,802	44,537
- st. dev.	10,431	9,642
Southern Stock	15,245	13,910
bootstrap set 1 - mean	15,235	13,919
- st. dev.	2,000	1,837
bootstrap set 2 - mean	15,167	13,859
- st. dev.	2,838	2,599
W. Coast Vancouver Island		
Southern Stock	26,013	24,613
bootstrap set 1 - mean	26,868	25,416
- st. dev.	4,472	4,164
bootstrap set 2 - mean	27,484	25,985
- st. dev.	6,764	6,230
Northern Stock	36,178	33,022
bootstrap set 1 - mean	37,234	34,182
- st. dev.	4,589	4,395
bootstrap set 2 - mean	37,733	34,640
- st. dev.	6,995	6,431

Table 3.3 Comparison of forecast and estimated 1988 age 4+ pre-fishery biomass (tonnes) for herring stock assessment regions. The forecast 95% confidence intervals are from bootstrap analyses from last year's assessment. The estimated values are from the current year's age-structured model analyses.

	1988 Age 4+ Pre-fishery biomass	
	Forecast 95% CI	Estimated
Queen Charlotte Islands	8,811-15,616	13,290
Prince Rupert District	32,054-47,181	37,933
Central Coast	12,531-20,164	21,404
Strait of Georgia		
Northern Stock	25,202-39,427	25,160
Southern Stock	5,648-9,760	4,558
W. Coast Vancouver Is.		
Southern Stock	11,285-18,356	17,433
Northern Stock	18,666-35,601	17,268

4. POTENTIAL CATCH

We recommend catch levels at 20% of the forecast stock biomass for those stocks that are well above CUTOFF. The 20% harvest rate is based on an analysis of stock dynamics which indicates this level will stabilize both catch and spawning biomass while foregoing minimum yield over the long term. A fixed escapement policy would theoretically produce higher yields and spawning stock stability but is not attainable at the operational level. For those stocks which are marginally above CUTOFF we recommend the following reduced catch level:

Catch = Weighted Run - CUTOFF

This will provide for smaller fisheries for areas where the 20% harvest rate would bring the escapement down to levels below the CUTOFF.

CUTOFF levels are established at one-forth the unfished average biomass. Estimates of unfished mean biomass have been revised this year based on more recent estimates of stock parameters from age-structured model analyses. For the seven stock assessment regions the revised CUTOFF levels are:

Queen Charlotte Islands	10,600 t
Prince Rupert District	12,100 t
Central Coast	10,600 t
Strait of Georgia	22,100 t
W.C. Vancouver Is.-south	15,100 t
W.C. Vancouver Is.-north	8,700 t

To provide an overall stock forecast we assigned subjective probabilities to the alternate assessment models. Based on intuition and past performance, we believe the age-structured model makes the most likely predictions of forecast runs. The escapement model incorporates diving survey information on most major spawns in 1988, and we feel these direct estimates of egg deposition provide a reasonably accurate estimate of current stock size. Hence, we used equal probabilities for the two models in most assessment regions. The only exception to this was for the northern west coast of Vancouver Island where age-structured analysis has produced inconsistent forecasts in recent years. This may result from a limited number of representative ageing samples for this area. Consequently, we felt that the age-structured model estimates for this region may be biased and we used a 80:20 weighting in favour of the escapement model for this area.

The assigned probabilities were used to weight the forecast runs obtained from each method to provide a single "weighted run" for each of the stock groupings (Table 4.1).

The forecast weighted run size to the Queen Charlotte Islands in 1989 is 15,400 tonnes assuming average recruitment. Although no exceptional recruitments have materialized in recent years, an average level in the last years has stabilized the recent decline in this stock at a level near the long term average spawning biomass. Since this stock would be above CUTOFF levels even given poor recruitment, a small fishery should be considered for this region.

The Prince Rupert District spawning stock may be declining slightly from historically high levels. Given the average to good recruitment levels in recent years, an optimistic recruitment assumption may again be warranted for 1989. Assuming average recruitment yields a forecast biomass of 37,600 tonnes. This produces a potential catch of 7,520 tonnes for the Prince Rupert District in 1989.

The forecast for the Central Coast with average recruitment is 41,200 tonnes. The recommended catch for this region is 8,240 tonnes. Given the very healthy state of this stock more optimistic recruitment estimates may be warranted.

The south coast stocks declined relative to 1986 when the strong 1983 year class boosted biomass levels in most areas. The weighted forecast run to the northern Strait of Georgia in 1989 is 41,200 tonnes, and to the southern strait 12,600 tonnes. An average recruitment assumption would yield potential catches of 8,240 and 2,520 tonnes, respectively.

The forecast run to the southern west coast of Vancouver Island is 31,800 tonnes for an allowable catch of 6,360 tonnes. The forecast for the northern area, even with the low weighting on the age-structured model, is 18,900 tonnes for a recommended catch of 3,780 tonnes.

The catch levels suggested in this summary are based purely on biological considerations, reflecting the best biological analyses given the available data bases. Management of the various fisheries has practical constraints not considered in this report. As well, there are economic considerations which are beyond the scope of our analysis. Hence, the quotas ultimately adopted by DFO may differ from those recommended herein.

Table 4.1. Summary of 1989 predicted stock biomass (thousands of tonnes) from age-structured and escapement models and weighted runs for poor, average, and good recruitment levels.

	AGE STRUCTURED MODEL				ESCAPEMENT MODEL				WEIGHTED RESULTS			
		Stock + recruitment				Stock + recruitment				Stock + recruitment		
	AGE 4+	Poor	Avg.	Good	AGE 4+	Poor	Avg.	Good	Rel. Weight	Poor	Avg.	Good
Queen Charlotte Islands	16.2	17.1	19.1	26.4	9.6	10.3	11.7	17.4	50:50	13.7	15.4	21.9
Prince Rupert District	41.7	43.6	47.1	59.4	23.9	25.2	28.1	35.5	50:50	34.4	37.6	47.5
Central Coast	45.1	48.3	52.0	61.9	38.2	41.0	44.9	55.3	50:50	44.7	48.5	58.6
Strait of Georgia northern stock	42.0	46.2	51.5	61.2	17.2	24.9	30.8	40.6	50:50	35.6	41.2	50.9
southern stock[a]	13.9	15.4	16.9	20.6	3.7	7.1	8.3	9.7	50:50	11.3	12.6	15.2
West Coast of Vancouver Is. southern stock	24.6	28.5	32.8	44.6	22.4	26.4	30.7	38.7	50:50	27.5	31.8	41.7
northern stock	33.0	34.7	38.7	44.8	9.0	11.1	14.0	21.7	20:80	15.8	18.9	26.3

[a]Recruitment estimates based on data from roe fishery only.

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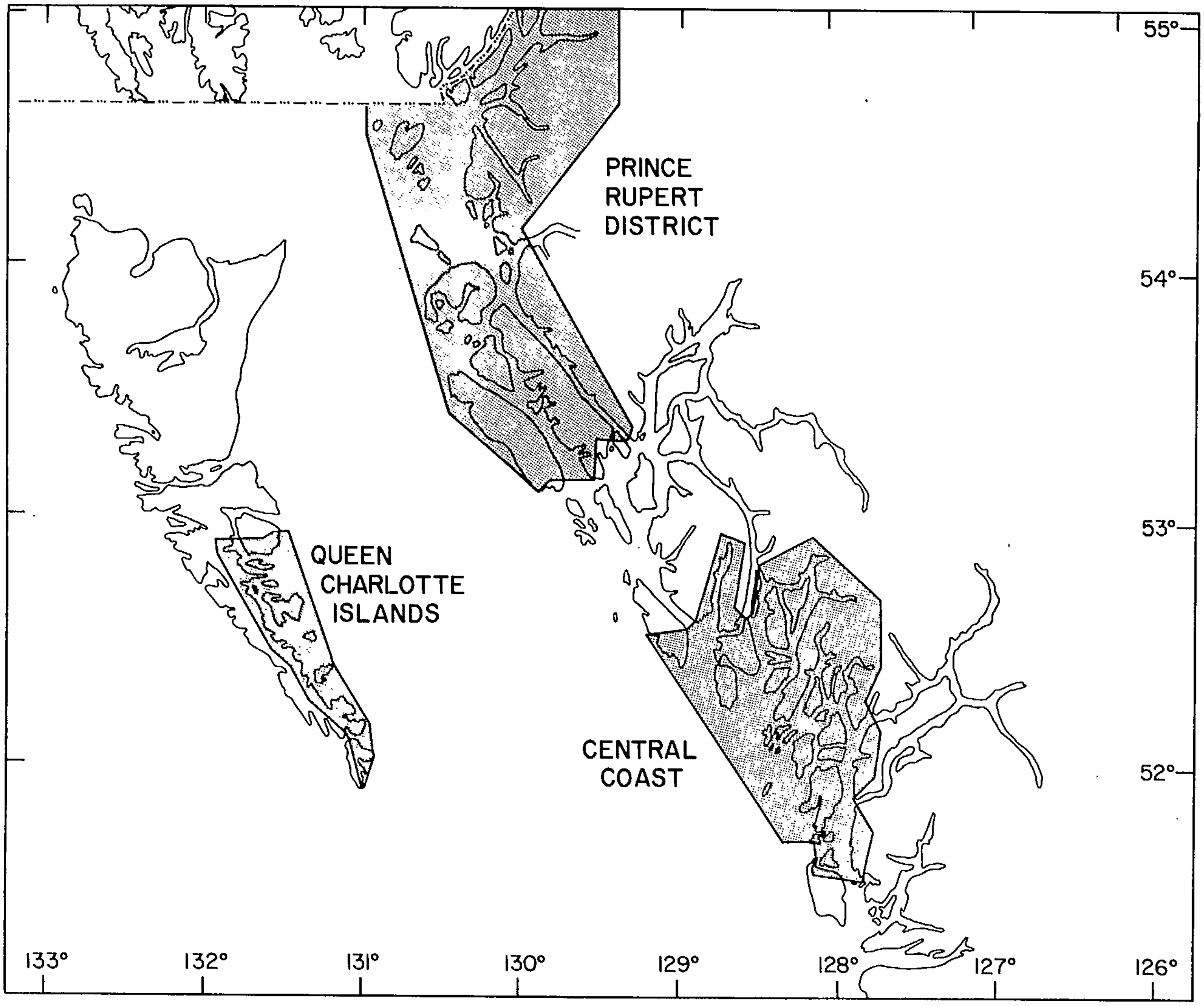

Fig. 1.1. Herring stock assessment regions in northern B.C.

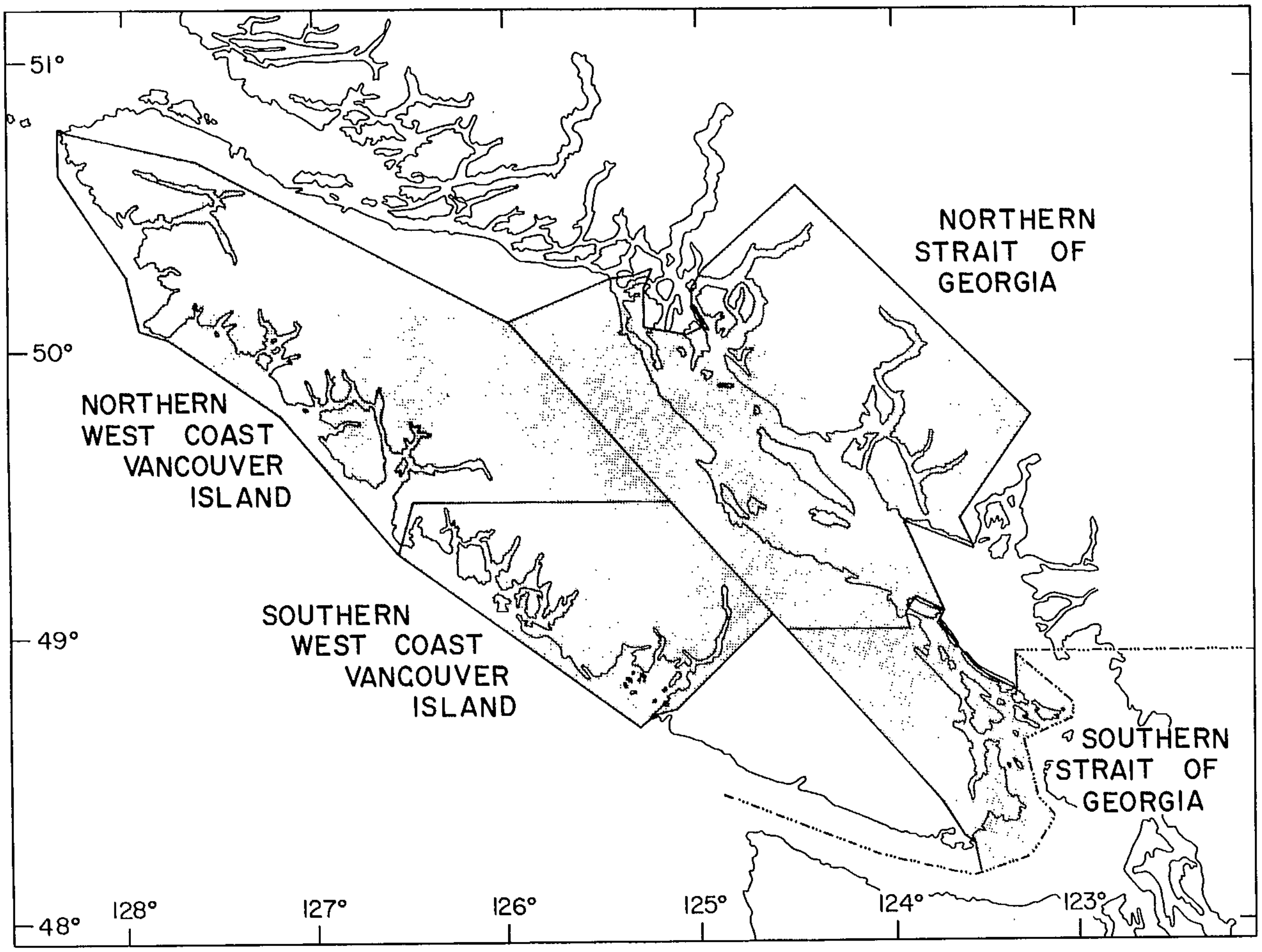

Fig. 1.2. Herring stock assessment regions in southern B.C.

Appendix Table 1.1. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the the Queen Charlotte Islands stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	PERCENT AT AGE 1	2	3	4	5	6	7	8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10^{-5})
1950/51	REDUCTION	0.0	0.1	15.3	52.9	15.3	11.5	4.2	0.6	0.1	0.0	1476	1544	317.44
1951/52	REDUCTION	1.2	16.9	21.5	33.8	21.3	4.1	1.1	0.1	0.0	0.0	2251	165	1136.50
1953/54	REDUCTION	0.1	3.0	29.0	21.3	33.6	10.2	1.9	0.7	0.2	0.1	0*	25	231.77
1954/55	REDUCTION	0.0	8.7	14.1	39.4	18.1	14.8	4.4	0.3	0.1	0.1	0*	25	52.94
1955/56	REDUCTION	0.0	0.1	16.0	9.6	62.2	8.4	2.7	0.7	0.0	0.1	1348	681	6544.00
1956/57	REDUCTION	0.2	21.1	23.7	15.7	9.5	26.9	2.3	0.4	0.1	0.0	4649	2106	2051.45
1957/58	REDUCTION	0.0	81.9	16.4	1.2	0.2	0.1	0.1	0.0	0.0	0.0	2838	514	2146.22
1958/59	REDUCTION	0.0	1.1	63.2	28.4	7.4	0.0	0.0	0.0	0.0	0.0	95	6	735.74
1960/61	REDUCTION	0.0	4.2	32.6	36.0	24.8	1.3	0.4	0.2	0.4	0.0	0*	25	59.00
1961/62	REDUCTION	0.0	3.0	37.6	41.4	9.6	6.5	1.6	0.2	0.0	0.0	428	170	693.85
1962/63	REDUCTION	0.0	0.4	50.0	27.1	18.2	2.1	2.0	0.0	0.1	0.1	804	411	1342.32
1963/64	REDUCTION	0.0	0.9	15.3	59.5	17.8	5.3	1.1	0.0	0.0	0.0	528	297	2347.52
1964/65	REDUCTION	0.0	1.6	79.8	11.0	4.4	2.1	0.9	0.2	0.0	0.0	1053	165	3132.24
1965/66	REDUCTION	1.7	18.0	32.2	16.1	10.2	7.3	5.8	4.8	2.0	1.7	0*	25	213.13
1966/67	REDUCTION	0.0	0.9	67.3	26.5	2.7	2.7	0.0	0.0	0.0	0.0	0*	25	14.23
1967/68	REDUCTION	0.8	29.7	50.2	17.1	2.2	0.0	0.0	0.0	0.0	0.0	0*	25	8.48
1971/72	ROE-SN	0.0	4.7	37.6	46.5	4.5	4.5	1.5	0.4	0.2	0.0	465	54	90.92
1972/73	ROE-SN	0.0	0.3	37.3	19.7	32.8	6.8	2.4	0.7	0.0	0.0	702	869	148.90
1973/74	ROE-SN	0.0	0.3	59.7	23.4	9.6	5.3	1.1	0.4	0.1	0.0	697	272	195.48
	ROE-GN	0.0	0.0	1.4	37.5	29.2	25.0	5.6	0.0	0.0	1.4	72	72	4.02
1974/75	ROE-SN	0.0	0.1	33.3	45.4	13.5	5.3	1.7	0.5	0.2	0.0	3026	788	370.01"
	ROE-GN	0.0	0.0	0.0	22.5	40.0	30.0	5.0	2.5	0.0	0.0	40	40	6.19
1975/76	ROE-SN	0.0	0.3	2.9	52.8	33.5	7.6	2.2	0.6	0.0	0.0	2629	1293	690.30`
1976/77	ROE-SN	0.0	0.0	17.3	10.3	43.1	22.6	5.5	1.0	0.2	0.0	1824	653	688.84"`
1977/78	ROE-SN	0.0	0.1	24.7	17.1	11.1	33.0	12.2	1.7	0.0	0.0	784	1347	661.74`
1978/79	ROE-SN	0.0	5.6	4.4	31.6	18.7	21.3	15.1	2.8	0.4	0.1	1020	441	387.56"
	ROE-GN	0.0	0.0	0.0	25.1	25.1	25.1	20.1	3.5	0.5	0.5	199	65	128.20
1979/80	ROE-SN	0.0	0.3	85.3	4.5	4.9	2.5	1.8	0.6	0.1	0.0	2223	1399	143.46
	ROE-GN	0.0	0.0	4.5	4.0	40.5	20.5	24.5	5.0	1.1	0.0	756	1008	60.13
1980/81	ROE-SN	0.0	0.2	3.0	85.3	5.4	3.2	2.0	0.7	0.2	0.1	4586	424	331.01"
	ROE-GN	0.0	0.0	0.2	74.8	8.3	9.4	4.9	1.9	0.6	0.0	905	339	121.41
1981/82	ROE-SN	0.0	0.5	3.4	3.7	87.6	2.1	1.4	0.8	0.5	0.1	2813	1889	186.62"
	ROE-GN	0.0	0.0	0.2	3.4	88.2	3.4	2.7	1.1	0.8	0.2	526	341	99.20
1982/83	ROE-SN	0.0	4.1	4.8	3.5	6.4	74.9	3.7	1.5	0.8	0.2	1706	1282	316.02"
	ROE-GN	0.0	0.0	0.0	1.3	2.8	89.0	3.1	2.5	0.7	0.5	747	637	58.91
1983/84	OTHER	0.0	5.9	36.6	2.2	4.3	8.6	39.2	2.2	0.5	0.5	186	186	16.18
	ROE-SN	0.0	1.9	35.8	4.8	2.7	10.4	42.9	1.1	0.4	0.2	3013	1473	313.87
	ROE-GN	0.0	0.0	2.8	1.3	4.6	9.0	80.1	1.8	0.3	0.3	391	427	34.59
1984/85	ROE-SN	0.0	1.3	14.9	31.8	4.0	4.5	11.4	31.5	0.4	0.1	3556	699	311.61"
	ROE-GN	0.0	0.0	0.0	15.3	2.1	4.2	11.1	66.7	0.7	0.0	144	83	85.78
1985/86	ROE-SN	0.0	0.2	2.8	22.0	40.2	4.0	3.3	8.0	19.1	0.3	4733	2821	157.73
	ROE-GN	0.0	0.0	0.0	11.9	50.6	5.4	5.2	10.4	16.0	0.5	405	383	55.79
1986/87	ROE-SN	0.0	1.8	9.9	5.4	25.1	37.9	3.8	4.3	5.7	6.1	3096	1221	130.61"
1987/88	ROE-SN	0.0	4.2	41.8	8.6	5.7	14.1	17.9	1.6	2.0	4.1	1394	619	21.60

FISHERY	AVERAGE WEIGHT AT AGE (gms) 1	2	3	4	5	6	7	8	9	10
REDUCTION	11.7	52.0	84.4	106.6	126.0	147.7	156.8	172.2	147.3	183.5
ROE-SN	0.0	66.4	98.5	127.1	151.4	173.4	189.0	201.5	210.8	209.2
ROE-GN	0.0	0.0	117.5	139.9	151.7	168.0	176.7	188.6	188.8	193.4
OTHER	11.7	60.6	93.4	119.7	142.6	165.6	179.1	194.2	200.6	202.3

* - Age composition from published reports.
~ - No seine roe fishery in this season. Age composition from pre-fishery charter samples only.
" - includes catch from "other" fisheries
^ - includes catch from seine roe fisheries
` - includes catch from gillnet fisheries

Appendix Table 1.2. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the the Prince Rupert District stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	PERCENT AT AGE 1	2	3	4	5	6	7	8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10^{-5})
1950/51	REDUCTION	0.0	4.3	18.2	58.5	10.4	5.6	2.6	0.3	0.0	0.0	4684	2202	4954.74
1951/52	REDUCTION	0.1	4.8	8.8	33.7	45.2	6.1	1.0	0.3	0.0	0.0	5925	2500	4392.63
1952/53	REDUCTION	0.0	1.2	38.1	23.0	25.4	11.1	1.0	0.1	0.0	0.0	1419	752	173.50
1953/54	REDUCTION	0.0	2.1	28.4	29.1	24.0	13.2	2.6	0.6	0.0	0.0	2656	891	2522.89
1954/55	REDUCTION	0.0	2.7	4.9	70.3	15.6	5.2	1.1	0.2	0.0	0.0	1131	467	1698.85
1955/56	REDUCTION	0.0	10.0	58.1	9.5	19.0	2.6	0.5	0.2	0.1	0.0	1683	555	1218.10
1956/57	REDUCTION	0.0	11.5	17.8	39.8	13.2	16.0	1.4	0.3	0.0	0.0	3491	515	2827.98
1957/58	REDUCTION	0.0	45.8	30.2	8.0	11.8	1.8	2.4	0.0	0.0	0.0	847	123	644.16
1958/59	REDUCTION	0.0	3.1	56.7	20.9	5.8	9.9	1.7	1.9	0.1	0.0	1741	349	1037.09
1959/60	REDUCTION	0.0	49.1	6.3	28.2	8.9	4.1	2.5	0.7	0.2	0.0	4206	337	2451.31
1960/61	REDUCTION	0.0	9.7	58.3	7.3	18.0	4.3	1.6	0.6	0.1	0.0	4300	763	4815.52
1961/62	REDUCTION	0.0	3.0	30.3	44.7	6.9	9.9	3.4	0.9	0.5	0.3	1845	752	2476.36
1962/63	REDUCTION	0.0	39.3	13.3	18.2	22.0	3.6	3.0	0.5	0.1	0.1	3415	433	4788.66
1963/64	REDUCTION	0.0	3.7	64.9	10.1	10.9	8.9	0.7	0.6	0.1	0.0	3400	1914	3555.87
1964/65	REDUCTION	0.0	6.0	13.6	51.0	8.5	11.0	8.5	1.0	0.3	0.1	3360	459	3649.12
1965/66	REDUCTION	0.0	0.0	5.3	21.4	23.4	16.3	19.1	9.7	3.2	1.6	435	59	1071.96
1966/67	REDUCTION	0.9	56.7	31.9	5.3	1.9	2.7	0.4	0.2	0.0	0.0	0*	25	1225.88
1967/68	REDUCTION	3.2	33.7	38.5	18.8	4.4	0.7	0.3	0.1	0.3	0.0	0*	25	281.72
1968/69	OTHER	1.3	29.7	44.5	20.3	3.8	0.2	0.2	0.0	0.0	0.0	0*	25	69.79
1969/70	OTHER	0.7	18.5	62.4	15.0	3.1	0.0	0.1	0.1	0.0	0.0	0*	25	184.71
1970/71	OTHER	0.0	6.5	50.4	29.3	8.0	4.3	0.8	0.5	0.2	0.0	601	38	413.67
1971/72	ROE-SN	0.0	0.0	5.3	17.9	64.4	5.9	3.8	2.4	0.1	0.1	714	209	278.66"\
1972/73	OTHER	0.0	22.9	47.7	7.8	13.1	4.6	2.6	1.3	0.0	0.0	153	14	35.70
	ROE-SN	0.0	0.3	33.0	4.4	30.4	26.6	3.4	1.3	0.8	0.0	797	662	94.37
1973/74	ROE-SN	0.0	0.2	17.9	53.2	7.4	16.5	4.4	0.3	0.2	0.0	632	121	174.36"
	ROE-GN	0.0	0.0	1.0	39.4	21.2	34.6	2.9	1.0	0.0	0.0	104	83	90.07
1974/75	OTHER	0.0	1.2	10.5	15.1	43.0	14.0	11.6	2.3	2.3	0.0	86	86	14.18
	ROE-SN	0.3	1.3	9.4	22.1	43.0	11.1	9.6	2.5	0.6	0.2	3084	769	116.58
	ROE-GN	0.0	0.0	0.0	31.9	59.6	8.5	0.0	0.0	0.0	0.0	47	47	0.76
1975/76	OTHER	0.0	0.0	4.9	6.8	9.9	16.7	17.9	35.2	8.6	0.0	162	1661	30.99
	ROE-SN	0.0	0.0	0.8	6.9	31.7	50.1	7.3	2.4	0.8	0.0	713	654	204.01
	ROE-GN	0.0	0.0	0.0	15.8	57.9	22.8	3.5	0.0	0.0	0.0	57	57	17.93
1976/77	OTHER	0.0	0.4	23.5	15.7	22.9	16.6	10.8	7.4	2.3	0.4	511	276	61.55
	ROE-SN	0.0	0.1	16.0	3.7	22.7	37.8	15.0	3.3	0.9	0.5	1310	1344	370.40
	ROE-GN	0.0	0.0	1.1	2.1	19.9	54.1	14.6	6.8	1.4	0.0	281	1104	89.48
1977/78	OTHER	0.0	1.3	9.6	27.8	18.2	18.1	14.6	6.9	2.4	1.0	982	124	238.36
	ROE-SN	0.0	1.1	11.7	32.8	9.6	21.1	20.4	2.4	0.6	0.3	795	131	136.94
	ROE-GN	0.0	0.0	0.0	20.5	6.0	32.5	33.1	6.6	1.3	0.0	151	37	181.42
1978/79	OTHER	0.0	1.8	9.3	9.8	25.9	17.8	16.2	9.5	5.7	4.0	1435	856	118.66
	ROE-SN	0.0	2.7	18.2	11.5	29.2	11.5	18.3	6.5	1.4	0.8	958	1475	84.40
	ROE-GN	0.0	1.1	1.1	8.0	41.4	15.7	22.2	8.0	1.9	0.4	261	255	74.00
1979/80	OTHER	0.0	1.1	61.2	6.5	7.9	8.2	6.5	4.9	2.1	1.6	1161	560	66.18
	ROE-SN	0.0	0.6	77.9	7.3	5.1	3.8	3.5	1.3	0.4	0.1	2811	535	171.81
	ROE-GN	0.0	0.0	3.4	8.7	31.2	22.3	21.1	9.1	3.4	0.6	493	915	63.73
1980/81	OTHER	0.0	1.0	7.4	54.6	9.3	10.2	9.3	4.3	2.3	1.5	6524	1129	137.14
	ROE-SN	0.0	0.5	11.2	81.2	3.3	1.7	1.5	0.4	0.2	0.1	3238	1059	106.00
	ROE-GN	0.0	0.0	0.5	38.9	15.5	23.0	14.8	5.6	1.9	0.0	427	557	23.77
1981/82	OTHER	0.0	1.5	11.5	20.5	41.1	10.5	6.6	5.0	2.1	1.1	2669	555	138.82
	ROE-SN	0.0	2.7	18.8	7.4	66.3	2.8	1.4	0.4	0.2	0.0	1544	576	16.50
1982/83	ROE-SN	0.0	1.4	20.8	17.7	5.3	49.2	3.7	1.1	0.6	0.2	4583	1448	1.00~
1983/84	OTHER	0.0	2.8	36.2	15.7	13.9	9.8	16.4	2.8	1.1	1.4	654	303	23.68
	ROE-SN	0.0	0.5	35.5	14.4	10.3	14.4	23.6	1.0	0.2	0.1	2837	618	159.00
	ROE-GN	0.0	0.0	1.0	2.0	12.9	21.4	57.4	3.4	1.2	0.8	505	961	127.31
1984/85	OTHER	0.0	15.4	8.2	25.8	28.2	11.7	5.4	4.1	0.8	0.3	631	45	28.24
	ROE-SN	0.0	0.2	7.8	54.7	11.9	6.4	10.6	8.2	0.1	0.1	3664	969	278.16
	ROE-GN	0.0	0.0	0.4	16.4	14.9	15.8	21.8	29.8	0.4	0.5	550	543	235.00
1985/86	OTHER	0.0	11.7	9.9	8.0	21.3	18.6	11.7	6.6	6.9	5.2	767	512	25.39
	ROE-SN	0.0	1.8	13.8	9.4	46.3	10.8	5.3	7.1	5.5	0.1	5655	4566	277.60
	ROE-GN	0.0	0.0	0.4	4.3	53.8	19.0	8.7	7.8	5.7	0.2	1274	558	311.02
1986/87	ROE-SN	0.0	0.9	38.6	10.2	6.9	29.9	5.9	3.5	2.9	1.2	4731	4068	187.95"
	ROE-GN	0.0	0.0	0.6	3.0	6.9	55.3	16.1	8.8	6.0	3.4	1761	819	270.57
1987/88	ROE-SN	0.0	0.5	30.9	39.0	5.9	8.4	11.6	1.9	1.4	0.4	4222	2993	364.94
	ROE-GN	0.0	0.0	0.4	6.5	7.2	21.5	44.8	11.7	5.1	2.8	710	421	291.00

FISHERY	AVERAGE WEIGHT AT AGE (gms) 1	2	3	4	5	6	7	8	9	10
REDUCTION	21.8	43.9	79.3	107.9	128.2	146.1	163.1	173.5	188.7	206.8
ROE-SN	8.6	53.1	84.4	115.0	139.5	158.5	172.9	186.2	195.7	206.6
ROE-GN	0.0	90.3	115.5	136.9	148.4	163.2	170.6	178.0	189.2	196.2
OTHER	17.4	46.6	80.9	110.5	133.3	151.5	166.9	178.8	189.0	204.1

Appendix Table 1.3. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the Central Coast stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	PERCENT AT AGE 1	2	3	4	5	6	7	8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH ($x 10^{-5}$)
1950/51	REDUCTION	0.0	2.4	28.5	50.6	12.0	5.1	1.2	0.1	0.0	0.0	5318	2484	3905.26
1951/52	REDUCTION	1.1	5.1	19.9	29.7	37.7	4.4	1.5	0.4	0.0	0.0	5214	1352	2954.66
1952/53	REDUCTION	0.4	9.3	28.0	23.9	26.5	10.1	1.3	0.4	0.0	0.0	2939	537	73.85
1953/54	REDUCTION	0.1	3.9	69.6	20.2	4.6	1.3	0.2	0.0	0.1	0.0	3191	477	3478.53
1954/55	REDUCTION	0.3	6.6	7.7	74.4	9.1	1.5	0.4	0.0	0.0	0.0	2350	164	1237.50
1955/56	REDUCTION	0.0	16.9	13.6	9.2	57.0	2.9	0.3	0.0	0.0	0.0	5054	1351	4136.15
1956/57	REDUCTION	0.0	16.7	50.7	10.8	6.2	14.8	0.7	0.0	0.0	0.0	4688	1703	2635.45
1957/58	REDUCTION	0.0	23.5	61.4	12.7	1.3	0.6	0.6	0.0	0.0	0.0	3743	847	1445.86
1958/59	REDUCTION	0.4	3.8	49.3	36.7	8.1	0.8	0.4	0.4	0.0	0.0	4996	1337	3305.21
1959/60	REDUCTION	0.0	43.5	23.2	26.5	5.6	1.1	0.1	0.1	0.0	0.0	1416	165	639.45
1960/61	REDUCTION	0.0	16.1	32.2	10.8	29.7	10.1	0.9	0.1	0.1	0.0	2799	1227	3463.55
1961/62	REDUCTION	0.0	9.7	57.4	17.9	2.6	9.9	2.4	0.1	0.0	0.0	808	146	1721.99
1962/63	REDUCTION	0.0	0.4	30.3	58.0	5.4	2.9	2.9	0.2	0.0	0.0	1087	885	4376.33
1963/64	REDUCTION	0.0	13.1	47.4	27.7	10.3	1.4	0.1	0.0	0.0	0.0	1258	198	3507.73
1964/65	REDUCTION	0.0	8.2	36.4	33.8	15.8	5.4	0.3	0.1	0.0	0.0	1750	684	1326.51
1965/66	REDUCTION	8.7	61.5	18.7	6.7	3.3	1.0	0.2	0.0	0.0	0.0	0*	25	5565.20
1966/67	REDUCTION	1.2	37.0	45.6	12.9	2.0	1.0	0.2	0.1	0.0	0.0	0*	25	2538.06
1967/68	REDUCTION	1.8	32.0	47.2	16.7	2.1	0.3	0.0	0.1	0.0	0.0	0*	25	172.48
1968/69	OTHER	16.1	27.0	23.2	22.4	9.5	1.6	0.1	0.0	0.0	0.0	0*	25	11.56
1969/70	OTHER	39.5	32.7	26.9	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0*	25	39.77
1970/71	OTHER	0.1	14.4	39.6	36.8	3.8	4.2	0.9	0.1	0.1	0.0	953	135	339.63
1971/72	ROE-SN	0.0	4.4	29.8	27.7	25.7	6.9	4.4	1.1	0.1	0.0	1837	598	762.73"
	ROE-GN	0.0	0.0	0.9	14.9	65.0	10.6	7.9	0.6	0.0	0.0	329	503	8.47
1972/73	ROE-SN	0.0	1.2	50.5	18.6	15.5	11.7	1.9	0.5	0.2	0.0	1328	593	539.55"
	ROE-GN	0.0	0.0	2.5	25.3	44.9	20.9	4.4	1.3	0.6	0.0	158	114	71.26
1973/74	ROE-SN	0.0	2.8	17.7	38.6	19.7	13.4	6.6	0.9	0.3	0.0	1587	202	282.57
	ROE-GN	0.0	0.0	0.4	22.8	37.7	24.8	12.3	1.8	0.2	0.0	496	101	332.81
1974/75	ROE-SN	0.3	1.2	32.9	25.4	27.8	8.6	3.2	0.7	0.1	0.0	8923	3300	278.78
	ROE-GN	0.0	0.0	3.3	25.6	46.2	16.4	6.4	2.1	0.0	0.0	519	117	348.42
1975/76	ROE-SN	0.0	3.0	11.8	41.2	20.9	16.8	4.5	1.5	0.2	0.0	5418	973	493.71
	ROE-GN	0.0	0.0	0.8	18.8	29.8	35.3	11.8	3.0	0.4	0.1	1222	253	383.45
1976/77	OTHER	0.0	1.0	32.8	18.7	29.8	8.1	6.6	3.0	0.0	0.0	198	144	32.75
	ROE-SN	0.0	0.7	17.4	22.6	31.8	16.6	8.5	1.9	0.4	0.0	2496	925	284.27
	ROE-GN	0.0	0.0	1.1	13.0	35.5	31.6	13.5	4.0	1.3	0.0	453	169	411.71
1977/78	ROE-SN	0.0	0.2	25.7	15.2	19.9	23.1	10.9	3.5	1.1	0.4	1396	589	354.31
	ROE-GN	0.0	0.0	1.3	8.9	29.6	38.1	17.7	3.8	0.5	0.1	1075	474	576.00
1979/80	ROE-SN	0.0	3.7	73.1	6.4	9.0	4.0	2.6	0.7	0.4	0.1	2582	1401	1.12"
	ROE-GN	0.0	0.0	3.3	2.6	24.8	23.7	26.3	11.3	6.6	1.5	274	210	32.46
1980/81	ROE-SN	0.0	2.0	12.3	66.6	8.4	7.0	2.6	0.6	0.3	0.1	2952	492	25.75"
	ROE-GN	0.0	0.3	1.5	50.7	13.6	15.4	10.6	5.5	1.8	0.7	1536	276	163.04
1981/82	ROE-SN	0.0	1.7	15.6	10.7	60.2	5.2	4.6	1.5	0.5	0.1	3508	2296	188.15"
	ROE-GN	0.0	0.0	2.4	5.9	76.0	6.7	5.9	2.3	0.7	0.1	1337	301	287.08
1982/83	ROE-SN	0.0	0.5	7.0	15.4	10.8	57.1	5.0	3.1	0.7	0.3	5445	1082	154.75
	ROE-GN	0.0	0.0	0.5	7.2	13.1	69.4	5.0	3.9	0.6	0.3	1793	994	244.49
1983/84	ROE-SN	0.0	4.4	7.3	10.1	18.2	16.1	40.7	2.3	0.8	0.1	6294	2209	284.16"
	ROE-GN	0.0	0.0	0.3	2.9	13.1	17.3	60.1	4.7	1.1	0.5	1159	338	242.25
1984/85	ROE-SN	0.0	2.7	37.5	7.5	8.6	13.1	11.9	18.2	0.4	0.1	5157	5529	222.13
	ROE-GN	0.0	0.0	3.2	5.4	9.4	19.5	22.5	38.2	1.0	0.8	1288	1407	143.53
1985/86	ROE-SN	0.0	3.9	16.4	40.2	8.6	6.3	6.7	6.1	11.3	0.5	5819	2074	163.81"
	ROE-GN	0.0	0.0	1.8	23.9	12.0	10.0	16.0	13.2	22.3	0.8	1069	262	73.95
1986/87	ROE-SN	0.0	4.1	22.6	14.6	32.2	5.7	4.5	5.8	4.7	5.8	5038	2319	193.73
	ROE-GN	0.0	0.0	0.8	7.7	44.9	11.7	7.8	9.9	8.2	9.0	981	1199	55.71
1987/88	ROE-SN	0.0	1.1	67.9	11.7	6.3	7.1	1.7	1.5	1.5	1.2	5205	2732	349.26
	ROE-GN	0.0	0.0	4.2	10.2	14.8	27.2	15.2	7.4	10.1	10.8	566	158	52.37

FISHERY	AVERAGE WEIGHT AT AGE (gms) 1	2	3	4	5	6	7	8	9	10
REDUCTION	16.1	43.8	79.8	104.7	125.6	138.1	150.4	156.2	153.5	179.0
ROE-SN	16.2	54.5	88.9	115.3	136.9	155.6	170.1	183.9	196.9	207.3
ROE-GN	0.0	39.3	114.2	138.1	150.5	161.9	171.2	181.8	189.2	186.8
OTHER	16.1	48.7	84.8	110.3	131.7	147.1	161.0	172.1	186.5	202.0

Appendix Table 1.4. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the northern Strait of Georgia stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	PERCENT AT AGE 1	2	3	4	5	6	7	8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10^{-5})
1950/51	REDUCTION	0.1	3.5	45.5	38.5	9.5	2.1	0.6	0.2	0.0	0.0	3554	526	1733.55
1951/52	REDUCTION	0.1	13.0	52.2	26.4	6.8	1.5	0.1	0.0	0.0	0.0	4533	570	1857.54
1952/53	REDUCTION	0.4	12.9	49.7	30.3	4.8	1.6	0.3	0.1	0.0	0.0	5343	707	545.54
1953/54	REDUCTION	0.0	2.3	34.0	39.2	16.7	5.7	1.7	0.4	0.0	0.0	6856	2388	1934.55
1954/55	REDUCTION	0.0	5.5	40.9	44.2	7.7	1.6	0.1	0.0	0.0	0.0	2657	360	2903.78
1955/56	REDUCTION	0.0	9.5	16.4	28.1	36.9	7.4	1.2	0.4	0.1	0.0	4919	925	2587.73
1956/57	REDUCTION	0.0	0.9	36.8	25.1	24.3	11.5	1.3	0.1	0.0	0.0	2420	497	1848.17
1957/58	REDUCTION	0.0	6.4	44.3	23.4	9.5	9.6	5.8	0.8	0.1	0.0	3473	617	890.18
1958/59	REDUCTION	0.8	16.8	62.4	16.3	2.8	0.5	0.3	0.1	0.0	0.0	4454	1799	4185.81
1959/60	REDUCTION	0.0	14.1	39.7	39.2	5.8	0.8	0.3	0.1	0.0	0.1	1252	231	2428.73
1960/61	REDUCTION	0.0	21.7	22.8	30.0	22.0	3.1	0.4	0.0	0.0	0.0	1302	222	1771.58
1961/62	REDUCTION	0.0	13.3	63.4	12.7	7.2	2.8	0.6	0.0	0.0	0.0	1506	584	3439.44
1962/63	REDUCTION	0.0	20.8	48.3	24.5	3.4	1.8	0.9	0.2	0.0	0.0	1161	144	4278.29
1963/64	REDUCTION	0.0	5.8	64.7	26.5	2.3	0.6	0.1	0.0	0.0	0.0	2224	639	3714.95
1964/65	REDUCTION	0.2	14.1	53.3	28.3	2.7	1.1	0.3	0.1	0.0	0.0	2095	529	2668.48
1965/66	REDUCTION	0.0	19.5	36.8	23.0	15.9	3.2	1.6	0.0	0.0	0.0	435	77	1851.57
1966/67	REDUCTION	8.1	28.4	47.7	10.5	3.0	1.9	0.3	0.0	0.0	0.0	0*	25	1198.37
1967/68	REDUCTION	13.0	20.0	50.6	13.0	2.5	0.6	0.2	0.1	0.0	0.0	0*	25	103.87
1968/69	OTHER	18.2	59.4	19.6	2.4	0.4	0.0	0.0	0.0	0.0	0.0	0*	25	52.86
1969/70	OTHER	0.6	23.6	62.9	11.1	1.4	0.5	0.0	0.0	0.0	0.0	0*	25	51.64
1970/71	OTHER	0.5	12.9	42.3	34.4	6.6	2.8	0.5	0.0	0.0	0.0	1060	239	82.74
1971/72	OTHER	0.0	1.5	27.6	36.8	26.1	5.4	2.3	0.3	0.0	0.0	1039	3596	73.26
	ROE-SN	0.0	4.0	42.3	30.3	18.4	4.0	1.0	0.0	0.0	0.0	2773	265	518.15
	ROE-GN	0.0	1.1	12.5	50.2	28.0	6.5	1.1	0.4	0.4	0.0	279	214	0.22
1972/73	OTHER	0.1	0.5	23.5	33.0	26.8	13.9	1.9	0.3	0.0	0.0	3915	1785	266.29
	ROE-SN	0.0	4.2	54.9	21.4	12.9	6.1	0.5	0.0	0.0	0.0	379	615	141.70
	ROE-GN	0.0	0.0	5.5	27.3	52.7	10.9	3.6	0.0	0.0	0.0	55	55	88.52
1973/74	ROE-GN	0.0	0.0	3.6	43.1	33.1	16.9	2.9	0.3	0.0	0.0	661	320	204.10"^
1974/75	OTHER	1.1	22.1	60.4	12.3	2.1	1.4	0.5	0.0	0.2	0.0	439	15	65.94
	ROE-SN	1.7	3.5	57.3	27.0	7.1	2.6	0.5	0.2	0.1	0.0	3092	662	50.23
	ROE-GN	0.0	0.0	6.7	31.9	43.7	13.4	3.4	0.8	0.0	0.0	119	26	283.37
1975/76	OTHER	0.1	7.9	17.6	34.9	25.5	8.6	3.7	1.3	0.2	0.1	1380	553	150.55
	ROE-SN	0.0	13.3	26.3	43.3	14.1	2.2	0.3	0.4	0.0	0.0	729	97	20.92
	ROE-GN	0.0	0.0	0.5	39.1	44.0	12.9	3.0	0.4	0.1	0.0	737	269	405.21
1976/77	OTHER	0.0	3.2	19.7	24.8	36.9	14.6	0.6	0.0	0.0	0.0	157	254	46.34
	ROE-SN	0.1	3.3	57.8	20.8	14.4	3.0	0.4	0.2	0.0	0.0	2234	1269	370.86
	ROE-GN	0.0	0.0	3.2	26.1	48.7	17.2	4.1	0.6	0.1	0.0	1423	162	466.14
1977/78	OTHER	0.1	4.7	38.0	28.4	9.6	11.6	5.7	1.2	0.5	0.1	758	205	364.13
	ROE-SN	0.0	0.8	34.8	42.8	11.9	7.7	1.5	0.3	0.0	0.1	3146	2299	353.53
	ROE-GN	0.0	0.0	0.4	19.7	31.4	35.1	11.3	1.7	0.4	0.0	462	690	426.90
1978/79	OTHER	0.0	1.2	16.2	36.6	25.3	10.9	7.7	1.6	0.4	0.1	764	201	164.24
	ROE-SN	0.0	1.0	17.7	31.0	32.5	10.2	5.8	1.5	0.2	0.0	889	311	1.00~
	ROE-GN	0.0	0.0	1.2	23.2	54.7	13.5	5.8	1.5	0.0	0.2	607	290	441.80
1979/80	OTHER	1.4	5.0	40.4	21.9	18.6	8.1	2.8	1.5	0.3	0.0	2101	1071	126.33
	ROE-SN	0.0	2.4	48.5	16.5	18.0	10.4	2.6	1.3	0.3	0.1	3548	1368	16.93
	ROE-GN	0.0	0.0	2.0	9.2	44.6	33.4	8.8	1.9	0.3	0.0	754	1139	215.21
1980/81	OTHER	0.0	1.8	40.6	36.5	13.3	4.7	2.1	0.5	0.5	0.0	655	212	26.24
	ROE-SN	0.0	6.8	36.9	30.5	11.4	9.7	3.8	0.6	0.3	0.0	7083	2254	202.01
	ROE-GN	0.0	0.1	2.2	18.2	23.0	37.4	16.1	2.8	0.3	0.1	1140	338	333.10
1981/82	OTHER	0.0	0.0	25.8	35.2	28.3	4.4	2.5	2.5	0.0	1.3	159	123	12.34
	ROE-SN	0.0	4.8	31.5	26.3	23.1	5.2	5.7	2.7	0.6	0.1	3304	1659	1.28
	ROE-GN	0.0	0.0	4.4	15.4	28.5	14.8	20.8	14.2	1.7	0.4	833	543	367.36
1982/83	OTHER	0.0	27.2	47.2	13.9	7.8	2.8	0.0	1.1	0.0	0.0	180	523	10.56
	ROE-SN	0.0	2.4	31.8	28.4	17.8	12.1	3.3	2.9	1.2	0.2	9836	6124	676.25
	ROE-GN	0.0	0.0	0.5	27.8	29.5	23.6	9.3	7.4	1.7	0.2	407	305	563.81
1983/84	OTHER	0.0	8.7	39.4	28.5	11.0	7.3	3.7	1.4	0.0	0.0	355	66	19.33
	ROE-SN	0.0	4.7	39.3	31.4	12.8	6.6	3.5	1.0	0.5	0.1	5747	1917	351.51
	ROE-GN	0.0	0.0	7.0	30.2	31.1	19.2	9.3	1.7	0.7	0.9	766	759	421.50
1984/85	OTHER	0.0	13.1	50.8	20.3	10.2	4.0	1.3	0.3	0.0	0.0	679	380	11.60
	ROE-SN	0.0	21.9	45.6	19.1	8.5	3.1	1.3	0.5	0.1	0.0	5677	2317	288.55
	ROE-GN	0.0	0.1	3.1	26.1	32.5	23.6	9.2	3.7	0.8	0.8	1096	650	237.16
1985/86	OTHER	0.0	16.3	48.8	27.9	2.3	4.7	0.0	0.0	0.0	0.0	86	86	14.64
	ROE-SN	0.1	8.9	54.8	25.9	7.1	2.2	0.8	0.2	0.1	0.0	4454	1587	17.16
1986/87	ROE-SN	0.0	5.8	32.6	38.8	17.0	4.0	1.2	0.4	0.2	0.1	6433	2405	321.49"
	ROE-GN	0.0	0.0	2.0	32.7	34.5	17.6	9.7	2.7	0.5	0.3	1277	652	145.34
1987/88	ROE-SN	0.0	3.8	57.7	15.6	16.7	4.7	1.1	0.3	0.1	0.0	4996	1541	154.41
	ROE-GN	0.0	0.0	9.1	14.9	48.1	19.5	5.5	2.3	0.4	0.2	821	383	437.38

AVERAGE WEIGHT AT AGE (gms)

FISHERY	1	2	3	4	5	6	7	8	9	10
REDUCTION	14.9	45.6	83.8	110.5	132.7	149.2	169.0	174.4	194.0	188.3
ROE-SN	16.5	56.7	82.7	110.8	131.7	150.2	167.1	177.4	178.0	185.7
ROE-GN	0.0	67.2	119.0	137.5	149.5	161.3	170.0	182.5	179.6	186.4
OTHER	16.4	51.5	84.5	111.0	133.2	151.3	169.2	171.1	178.7	181.0

Appendix Table 1.5. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the southern Strait of Georgia stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	PERCENT AT AGE 1	2	3	4	5	6	7	8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10^{-5})
1950/51	REDUCTION	0.0	4.7	65.6	23.5	5.1	0.9	0.1	0.0	0.0	0.0	4262	1605	2688.26
1951/52	REDUCTION	0.1	9.3	58.5	23.7	6.7	1.2	0.4	0.1	0.0	0.0	4499	1222	2966.21
1952/53	REDUCTION	0.1	3.9	65.9	26.6	3.0	0.6	0.0	0.0	0.0	0.0	3320	1258	493.14
1953/54	REDUCTION	0.0	0.7	58.4	34.2	5.9	0.6	0.1	0.0	0.0	0.0	6306	2318	4668.76
1954/55	REDUCTION	0.0	3.3	56.4	33.8	5.7	0.6	0.1	0.0	0.0	0.0	2634	714	4115.48
1955/56	REDUCTION	0.0	4.5	53.8	29.5	10.4	1.5	0.2	0.0	0.0	0.0	4913	2414	4726.81
1956/57	REDUCTION	0.0	1.6	70.8	21.0	4.2	2.0	0.3	0.1	0.0	0.0	5059	2139	4146.45
1957/58	REDUCTION	0.0	11.3	63.5	21.0	2.9	1.0	0.3	0.1	0.0	0.0	3924	1050	1379.36
1958/59	REDUCTION	0.8	17.1	64.2	14.6	2.4	0.6	0.2	0.1	0.0	0.0	5586	2067	1946.50
1959/60	REDUCTION	0.0	4.5	57.2	35.2	2.5	0.4	0.1	0.1	0.0	0.0	2490	1351	4499.74
1960/61	REDUCTION	0.0	35.7	29.1	25.5	8.8	0.8	0.1	0.0	0.0	0.0	3049	620	3469.79
1961/62	REDUCTION	0.0	5.2	76.0	13.6	3.6	1.4	0.2	0.1	0.0	0.0	1697	412	3696.98
1962/63	REDUCTION	0.0	14.4	53.6	29.2	2.6	0.2	0.1	0.0	0.0	0.0	1148	308	3870.31
1963/64	REDUCTION	0.1	6.2	56.3	34.0	2.9	0.4	0.1	0.1	0.0	0.0	1804	625	3796.46
1964/65	REDUCTION	0.0	16.2	58.1	22.6	2.3	0.7	0.0	0.2	0.0	0.0	1259	451	1965.81
1965/66	REDUCTION	0.0	31.0	32.7	23.8	11.1	1.0	0.5	0.0	0.0	0.0	416	36	1332.91
1966/67	REDUCTION	13.6	37.4	33.8	11.2	2.7	1.0	0.2	0.0	0.1	0.0	0*	25	2516.94
1967/68	REDUCTION	69.3	15.8	9.0	4.3	1.0	0.4	0.0	0.2	0.0	0.0	0*	25	245.19
1968/69	OTHER	24.6	38.1	23.0	10.4	2.8	1.1	0.0	0.0	0.0	0.0	0*	25	60.68
1969/70	OTHER	0.4	27.4	57.2	7.8	5.1	1.0	1.1	0.0	0.0	0.0	0*	25	38.15
1970/71	OTHER	0.0	10.6	33.4	42.1	8.6	2.8	2.2	0.3	0.0	0.0	359	162	64.38
1971/72	OTHER	0.0	13.8	33.5	33.8	15.1	2.7	1.0	0.1	0.0	0.0	2625	807	154.95
	ROE-SN	0.0	14.0	28.6	36.0	17.4	2.8	1.0	0.2	0.0	0.0	2263	597	38.49
	ROE-GN	0.0	5.7	11.1	45.1	29.4	7.0	1.6	0.1	0.0	0.0	756	151	9.59
1972/73	OTHER	0.0	3.4	49.6	21.2	18.6	5.5	1.1	0.5	0.1	0.0	797	203	27.12
	ROE-GN	0.0	0.0	21.3	31.4	32.5	11.2	3.0	0.6	0.0	0.0	169	56	43.63
1973/74	OTHER	0.0	17.4	73.3	8.1	1.2	0.0	0.0	0.0	0.0	0.0	86	86	39.04
	ROE-GN	0.0	0.0	7.3	40.4	27.7	16.1	6.4	2.1	0.0	0.0	329	268	30.21
1974/75	ROE-SN	0.0	3.9	50.1	28.6	8.7	4.3	3.1	0.9	0.3	0.0	2154	597	2.49"
	ROE-GN	0.0	0.0	1.6	64.5	21.0	9.7	3.2	0.0	0.0	0.0	62	62	68.22
1975/76	OTHER	0.0	5.5	21.7	44.3	19.7	5.2	2.3	0.8	0.5	0.0	3023	965	249.87
	ROE-SN	0.0	9.6	22.1	35.5	16.0	5.6	6.1	3.6	1.3	0.3	394	108	1.00~
	ROE-GN	0.0	0.0	0.7	41.5	41.5	11.6	2.7	2.0	0.0	0.0	147	126	63.84
1976/77	OTHER	0.6	4.2	52.5	21.7	15.2	3.8	1.3	0.5	0.2	0.1	2512	788	472.92
	ROE-SN	0.0	4.8	18.4	8.0	15.2	19.2	16.0	11.2	4.8	2.4	125	136	23.00
	ROE-GN	0.0	0.0	4.6	48.6	35.4	10.3	1.1	0.0	0.0	0.0	175	5	48.06
1977/78	OTHER	0.0	1.2	35.1	45.8	10.6	5.6	1.3	0.1	0.2	0.1	1709	391	819.26
	ROE-SN	0.0	1.1	40.5	46.2	7.5	4.3	0.4	0.0	0.0	0.0	279	132	1.00~
	ROE-GN	0.0	0.0	1.9	23.1	24.0	38.5	12.5	0.0	0.0	0.0	104	433	57.85
1978/79	OTHER	0.0	1.9	18.6	37.8	29.0	8.0	3.3	1.0	0.3	0.1	4699	1796	922.01
	ROE-SN	0.0	2.7	24.0	35.6	20.2	7.9	4.0	3.1	1.3	1.2	520	98	1.00~
1979/80	OTHER	0.0	1.4	45.4	24.0	17.7	8.4	1.7	1.1	0.3	0.1	2842	1954	109.21
	ROE-SN	0.0	3.0	57.9	12.0	15.9	6.8	2.9	0.8	0.2	0.5	591	189	1.00~
1980/81	OTHER	0.0	3.9	33.3	33.9	15.9	9.1	3.2	0.5	0.1	0.0	4505	2225	390.60
	ROE-SN	0.0	8.6	38.4	29.9	10.6	8.8	2.8	0.6	0.2	0.0	648	255	1.00~
1981/82	OTHER	0.0	3.6	39.0	31.5	15.3	5.8	3.9	0.8	0.1	0.0	2369	1384	303.92
	ROE-SN	0.0	8.7	39.7	23.1	17.4	3.8	4.5	2.2	0.5	0.0	2096	1168	302.55
1982/83	OTHER	0.0	0.8	16.6	32.0	23.2	13.2	4.9	5.7	3.0	0.6	1910	1526	47.33
	ROE-SN	0.0	5.8	29.8	28.7	18.3	8.7	2.8	3.8	1.6	0.5	2126	975	22.47
1983/84	OTHER	0.0	16.2	30.0	21.9	18.5	8.3	3.3	0.9	0.5	0.4	1527	555	52.95
	ROE-SN	0.0	21.9	31.4	18.8	13.4	9.3	2.6	1.5	0.6	0.3	1406	790	43.55
1984/85	OTHER	0.0	33.4	37.1	18.7	6.7	2.8	0.9	0.4	0.1	0.0	1843	288	64.51
	ROE-SN	0.0	29.3	39.1	18.5	6.3	4.2	1.5	0.9	0.1	0.0	2155	693	12.24
1985/86	OTHER	0.0	13.1	59.1	19.7	6.2	1.4	0.4	0.1	0.0	0.0	777	156	27.93
	ROE-SN	0.0	20.8	59.2	13.8	4.1	1.3	0.7	0.1	0.1	0.0	1961	542	1.00~
1986/87	OTHER	0.0	21.8	34.7	31.0	10.0	1.9	0.5	0.2	0.0	0.0	882	204	14.91
	ROE-SN	0.0	27.6	35.8	28.0	6.4	1.4	0.6	0.2	0.0	0.1	1257	246	1.00~
	ROE-GN	0.0	0.0	3.6	41.4	31.4	14.3	6.1	2.5	0.6	0.2	643	926	266.33
1987/88	ROE-SN	0.0	8.0	72.3	11.1	7.0	1.0	0.5	0.0	0.0	0.0	922	494	1.00~

FISHERY	AVERAGE WEIGHT AT AGE (gms) 1	2	3	4	5	6	7	8	9	10
REDUCTION	13.1	57.9	93.6	118.5	142.9	160.3	174.7	188.1	193.1	222.2
ROE-SN	0.0	59.6	87.3	112.9	135.3	161.1	172.2	192.7	201.4	211.9
ROE-GN	0.0	59.4	112.0	140.0	154.0	167.8	178.1	176.7	199.0	213.0
OTHER	15.2	56.0	88.9	112.4	134.8	158.9	168.8	181.5	197.1	210.4

Appendix Table 1.6. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the southern west coast of Vancouver Island stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	PERCENT AT AGE 1	2	3	4	5	6	7	8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10^{-5})
1950/51	REDUCTION	0.1	13.1	38.1	40.6	6.4	1.3	0.3	0.0	0.0	0.0	3843	551	1630.59
1951/52	REDUCTION	0.1	5.3	65.5	20.1	7.9	0.8	0.2	0.0	0.0	0.0	1686	593	1105.57
1952/53	REDUCTION	0.1	8.9	55.7	32.8	2.0	0.5	0.0	0.0	0.0	0.0	2777	1417	2.36
1953/54	REDUCTION	0.0	2.8	64.3	26.5	5.5	0.6	0.1	0.1	0.0	0.0	5730	2473	3086.25
1954/55	REDUCTION	0.0	16.8	59.4	19.7	3.4	0.6	0.0	0.0	0.0	0.0	2510	699	706.20
1955/56	REDUCTION	0.0	12.4	64.3	16.0	6.1	1.1	0.2	0.0	0.0	0.0	4653	2257	1931.15
1956/57	REDUCTION	0.0	2.7	71.9	24.8	0.3	0.2	0.0	0.0	0.0	0.0	588	497	312.93
1957/58	REDUCTION	0.0	15.6	55.3	25.0	4.0	0.1	0.0	0.0	0.0	0.0	707	432	68.62
1958/59	REDUCTION	0.0	6.4	61.0	25.1	6.0	1.0	0.1	0.2	0.1	0.0	2066	1383	4315.70
1959/60	REDUCTION	0.0	26.9	48.2	19.7	4.1	0.6	0.4	0.2	0.0	0.0	539	189	1988.85
1960/61	REDUCTION	0.0	52.7	33.9	10.0	3.1	0.2	0.0	0.0	0.0	0.0	419	54	1719.68
1961/62	REDUCTION	0.0	5.1	78.2	12.1	3.7	0.9	0.0	0.0	0.0	0.0	751	386	1659.51
1962/63	REDUCTION	0.0	3.5	44.4	45.5	5.6	0.8	0.2	0.0	0.0	0.0	886	316	404.28
1963/64	REDUCTION	0.0	2.6	60.8	25.5	10.1	0.8	0.3	0.0	0.0	0.0	1134	1003	1989.83
1964/65	REDUCTION	0.0	2.3	34.7	49.3	9.8	3.5	0.4	0.0	0.0	0.0	775	344	1141.93
1965/66	REDUCTION	0.0	0.3	41.3	33.3	21.3	2.7	1.0	0.0	0.0	0.0	300	403	636.21
1966/67	REDUCTION	2.4	20.7	55.5	16.7	3.4	0.8	0.3	0.2	0.0	0.0	0*	25	859.81
1971/72	ROE-SN	0.0	4.1	19.9	50.8	20.0	3.3	1.1	0.8	0.0	0.0	1222	843	319.50
1972/73	ROE-SN	0.0	0.9	32.3	24.1	31.0	10.1	1.3	0.3	0.1	0.0	1967	1330	678.19
	ROE-GN	0.0	0.0	7.9	22.9	51.8	13.5	2.9	1.0	0.2	0.0	624	526	63.80
1973/74	ROE-SN	0.0	12.1	45.1	25.7	11.0	5.0	1.0	0.1	0.0	0.0	3022	1434	341.88
	ROE-GN	0.0	0.0	26.1	30.7	26.1	13.6	3.4	0.0	0.0	0.0	176	30	207.72
1974/75	ROE-SN	0.0	0.7	46.5	21.9	14.2	9.4	5.7	1.4	0.2	0.0	6191	3025	901.22"
	ROE-GN	0.0	0.0	3.0	30.5	37.9	21.2	7.1	0.4	0.0	0.0	269	145	407.98
1975/76	ROE-SN	0.0	0.1	7.6	45.5	20.8	14.4	8.3	2.8	0.5	0.0	7026	1218	1358.83
	ROE-GN	0.0	0.0	0.7	41.8	33.6	15.3	5.9	2.3	0.3	0.1	1238	125	932.28
1976/77	ROE-SN	0.0	0.5	11.8	32.1	37.5	12.5	4.1	1.5	0.2	0.0	6171	1298	1226.50"
	ROE-GN	0.0	1.0	6.1	23.0	45.4	16.8	6.1	1.5	0.0	0.0	196	26	669.58
1977/78	OTHER	0.0	1.3	41.9	26.2	13.7	13.5	2.0	0.9	0.3	0.3	1727	416	183.29
	ROE-SN	0.0	0.5	35.1	18.7	18.6	20.8	4.8	1.3	0.2	0.1	5067	2353	381.15
	ROE-GN	0.0	0.0	1.2	5.3	20.1	49.6	17.3	5.8	0.5	0.2	417	84	730.95
1978/79	ROE-SN	0.0	0.5	9.9	39.2	18.5	16.4	11.9	2.6	0.8	0.2	2165	1149	411.88"
	ROE-GN	0.0	0.0	1.0	25.1	27.2	26.3	18.0	2.1	0.4	0.0	518	214	263.70
1979/80	ROE-SN	0.0	3.5	45.0	11.4	18.2	9.2	8.4	3.5	0.7	0.1	2037	1241	146.54"
	ROE-GN	0.0	0.0	0.0	4.4	40.7	25.6	16.8	11.4	0.8	0.3	386	717	36.65
1980/81	ROE-SN	0.0	4.0	37.7	26.4	10.6	11.5	6.4	2.8	0.6	0.0	3162	1247	251.13"
	ROE-GN	0.0	0.0	1.8	21.0	14.9	36.3	18.9	7.1	0.0	0.0	281	81	136.27
1981/82	ROE-SN	0.0	4.0	24.8	28.7	23.5	5.3	8.5	3.1	1.7	0.4	3930	2036	201.06"
	ROE-GN	0.0	0.0	0.3	17.3	39.5	11.4	23.3	5.4	2.6	0.3	352	216	49.47
1982/83	ROE-SN	0.0	4.5	23.3	22.8	21.7	16.2	4.0	5.3	1.2	1.1	2761	1911	476.41
1983/84	ROE-SN	0.0	20.5	36.8	14.1	9.6	10.5	6.1	1.1	1.1	0.2	2903	1266	485.38
1984/85	ROE-SN	0.0	21.1	50.2	16.1	4.1	2.9	3.4	1.8	0.1	0.3	2341	603	15.98"
1985/86	ROE-SN	0.0	4.2	48.8	27.2	10.3	3.9	2.7	2.1	0.7	0.1	3127	1073	16.49"
1986/87	ROE-SN	0.0	15.1	16.0	35.7	19.0	8.1	2.9	1.6	1.2	0.4	4050	2121	1014.35
1987/88	ROE-SN	0.0	2.5	60.9	7.3	15.5	9.2	3.1	0.8	0.5	0.3	6293	4239	667.34
	ROE-GN	0.0	0.0	5.4	7.0	40.8	29.4	12.8	3.0	1.2	0.4	500	607	81.48

FISHERY	AVERAGE WEIGHT AT AGE (gms) 1	2	3	4	5	6	7	8	9	10
REDUCTION	22.9	57.2	89.9	112.9	132.2	149.3	156.4	166.8	173.2	237.6
ROE-SN	21.0	63.8	94.0	124.3	149.8	170.4	184.7	194.6	204.2	206.9
ROE-GN	0.0	45.5	107.6	136.6	154.5	168.8	180.2	185.4	188.1	194.6
OTHER	22.6	60.3	92.1	119.1	141.3	159.9	171.2	188.1	196.8	206.9

Appendix Table 1.7. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the northern west coast Vancouver Island stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	PERCENT AT AGE 1	2	3	4	5	6	7	8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10^{-5})
1950/51	REDUCTION	0.0	1.5	27.0	54.1	12.8	3.6	1.0	0.0	0.0	0.0	196	190	566.14
1951/52	REDUCTION	0.0	0.2	10.2	27.5	52.2	7.1	2.1	0.5	0.1	0.0	3236	3206	1266.30
1953/54	REDUCTION	0.0	0.0	45.8	42.6	8.8	2.0	0.8	0.0	0.0	0.0	712	96	960.00
1954/55	REDUCTION	0.0	6.7	34.5	50.1	6.7	1.6	0.3	0.1	0.0	0.0	1486	558	628.76
1955/56	REDUCTION	0.0	10.0	58.1	9.5	19.0	2.6	0.5	0.2	0.1	0.0	0*	25	52.03
1956/57	REDUCTION	0.0	0.0	51.5	28.9	15.5	4.1	0.0	0.0	0.0	0.0	97	81	48.52
1957/58	REDUCTION	0.0	9.1	38.9	30.0	9.7	6.8	4.1	1.0	0.2	0.0	483	80	4.98
1958/59	REDUCTION	0.0	1.4	24.4	30.3	25.3	7.6	5.3	4.3	1.2	0.3	1599	1014	3194.28
1959/60	REDUCTION	0.0	5.0	56.8	23.8	9.6	3.2	1.0	0.4	0.2	0.1	2435	2242	3941.18
1960/61	REDUCTION	0.0	19.3	42.4	31.9	6.1	0.3	0.0	0.0	0.0	0.0	295	82	1840.47
1961/62	REDUCTION	0.0	7.1	78.7	9.4	3.1	1.1	0.6	0.0	0.0	0.0	1090	574	1362.97
1962/63	REDUCTION	0.0	0.5	47.3	47.4	3.7	0.9	0.1	0.0	0.0	0.0	1718	553	1658.16
1963/64	REDUCTION	0.0	1.0	53.8	28.2	15.9	1.0	0.0	0.0	0.0	0.0	195	239	182.93
1964/65	REDUCTION	0.0	0.9	22.2	43.6	26.5	4.7	0.4	0.9	0.9	0.0	234	93	352.62
1965/66	REDUCTION	0.0	13.6	26.8	26.1	23.2	9.1	1.2	0.0	0.0	0.0	0*	25	307.10
1966/67	REDUCTION	0.0	4.7	63.6	23.9	6.1	1.5	0.1	0.1	0.0	0.0	0*	25	506.07
1971/72	ROE-SN	0.0	0.3	13.8	38.7	40.7	4.3	1.4	0.6	0.3	0.0	349	99	177.82
1972/73	ROE-SN	0.0	0.2	24.5	24.8	35.0	13.0	2.3	0.2	0.2	0.0	609	358	557.43'
1973/74	ROE-SN	0.0	3.0	40.4	21.7	16.9	13.8	3.7	0.4	0.1	0.0	2398	2045	862.72'
1974/75	ROE-SN	0.0	0.5	66.3	16.3	6.6	5.4	3.7	1.1	0.1	0.0	4185	2248	685.51"'
1975/76	ROE-SN	0.0	0.5	12.8	51.5	16.7	8.2	7.5	2.5	0.3	0.0	2204	492	259.12
	ROE-GN	0.0	0.0	2.7	33.8	30.4	18.6	9.9	4.6	0.0	0.0	263	24	139.02
1976/77	ROE-SN	0.0	0.9	19.5	20.3	33.9	11.3	8.9	3.7	1.6	0.0	575	1613	52.30
	ROE-GN	0.0	0.0	0.0	8.6	39.5	18.5	19.8	9.9	3.1	0.6	162	92	180.00
1977/78	OTHER	0.0	1.3	49.6	15.0	14.4	16.3	2.6	0.6	0.3	0.0	701	259	81.77
	ROE-SN	0.0	1.7	69.0	13.3	6.4	5.8	2.2	1.5	0.1	0.1	896	650	78.36
	ROE-GN	0.0	0.0	1.1	2.7	21.8	41.0	23.4	8.5	1.1	0.5	188	65	209.21
1978/79	ROE-SN	0.0	1.2	18.1	65.2	9.1	3.3	2.7	0.3	0.1	0.1	1800	724	495.07
	ROE-GN	0.0	0.0	2.0	43.5	18.4	17.7	17.7	0.7	0.0	0.0	147	126	299.06
1979/80	ROE-SN	0.0	1.6	41.5	22.5	30.1	3.2	1.0	0.1	0.0	0.0	966	84	1.00~
	ROE-GN	0.0	0.0	2.1	9.9	77.3	8.5	1.4	0.7	0.0	0.0	141	123	159.85
1980/81	ROE-SN	0.0	1.3	15.2	54.5	10.5	16.5	1.9	0.1	0.0	0.0	1346	386	185.26
	ROE-GN	0.0	0.0	0.0	98.1	1.9	0.0	0.0	0.0	0.0	0.0	53	53	154.75
1981/82	ROE-SN	0.0	0.5	27.8	17.5	38.2	5.0	9.9	0.9	0.2	0.0	2173	499	21.25
	ROE-GN	0.0	0.0	0.8	7.9	47.6	11.5	29.0	3.1	0.2	0.0	620	564	197.84
1982/83	ROE-SN	0.0	2.8	18.3	19.1	20.9	27.2	5.7	5.9	0.2	0.0	545	132	1.00~
	ROE-GN	0.0	0.0	0.3	13.5	22.7	47.0	6.0	10.0	0.3	0.2	651	191	188.25
1983/84	ROE-SN	0.0	42.0	44.9	4.5	1.1	2.3	3.4	0.6	1.1	0.0	176	369	0.29"
	ROE-GN	0.0	0.0	1.0	5.6	28.1	25.9	32.5	4.2	2.4	0.2	1027	626	66.55
1984/85	ROE-SN	0.0	18.2	65.7	7.5	2.4	2.3	2.4	1.2	0.2	0.0	654	215	1.00~
1985/86	ROE-SN	0.0	2.4	47.2	44.1	2.5	1.1	1.2	0.9	0.6	0.0	1389	85	1.00~
1986/87	ROE-SN	0.0	14.1	22.6	23.1	36.4	2.1	0.3	0.5	0.4	0.4	940	289	1.00~
	ROE-GN	0.0	0.0	1.8	24.5	61.8	5.5	2.2	2.9	0.9	0.4	550	408	144.31
1987/88	ROE-SN	0.0	2.9	63.7	9.3	9.2	13.2	1.0	0.4	0.1	0.1	1637	814	1.00~

FISHERY	AVERAGE WEIGHT AT AGE (gms) 1	2	3	4	5	6	7	8	9	10
REDUCTION	9.8	57.3	89.2	111.2	131.7	145.4	157.3	175.4	190.2	156.6
ROE-SN	0.0	61.3	91.6	120.2	143.9	165.0	176.5	186.1	197.0	213.6
ROE-GN	0.0	0.0	117.2	131.7	147.3	156.9	162.4	170.3	163.7	182.0
OTHER	9.8	59.7	90.7	116.4	138.3	155.5	168.4	181.8	193.9	199.4

Appendix Table 2.1. Estimates of numbers at age, spawn, and other parameters from age-structured model analysis for the Queen Charlotte Islands stock assessment region.

Season	Estimated numbers at age ($x10^{-5}$) for period one 3	4	5	6	7	8	9	10+	Spawn Index	Estimated Spawn	Spawning Biomass (t)
1950/51	1738	1037	207	139	16	5	19	19	172	144	4664
1951/52	1692	1070	532	94	61	7	2	17	122	121	4534
1952/53	2393	895	412	144	22	14	2	4	254	524	18642
1953/54	12896	1526	571	262	92	14	9	4	451	406	11754
1954/55	1552	8166	912	331	150	53	8	7	277	1219	41652
1955/56	2111	986	5178	577	209	95	33	10	372	182	7347
1956/57	673	605	287	694	48	17	8	4	71	39	1680
1957/58	743	73	168	33	44	3	1	1	41	73	2601
1958/59	1284	213	24	30	4	6	0	0	332	209	7618
1959/60	610	565	110	11	13	2	3	0	134	148	4923
1960/61	2071	389	360	70	7	9	1	2	343	195	7906
1961/62	2529	1299	240	219	42	4	5	2	210	201	9273
1962/63	4837	1414	624	98	84	16	2	3	213	241	11266
1963/64	1085	2578	618	216	31	27	5	1	128	72	3133
1964/65	2754	412	764	88	20	3	2	1	56	34	1744
1965/66	244	113	109	74	4	1	0	0	145	51	2745
1966/67	184	91	53	43	27	1	0	0	24	48	2689
1967/68	162	113	56	32	26	17	1	0	36	64	3480
1968/69	150	101	71	35	20	16	10	1	59	54	2969
1969/70	319	96	65	45	22	13	10	7	81	75	4036
1970/71	1026	204	61	41	29	14	8	11	121	119	6551
1971/72	698	654	130	39	26	18	9	12	121	140	8290
1972/73	1626	413	382	73	21	14	10	12	123	153	8717
1973/74	4274	982	231	200	37	11	7	11	416	344	17558
1974/75	5699	2610	582	131	112	21	6	10	209	481	22605
1975/76	1384	3514	1497	315	70	59	11	9	471	563	26983
1976/77	1505	863	1885	734	150	33	28	9	621	521	25737
1977/78	1755	843	456	903	340	69	15	17	509	367	18260
1978/79	671	958	425	203	384	144	29	14	397	216	11253
1979/80	16032	410	478	165	68	134	50	15	981	911	42661
1980/81	1041	10099	252	274	90	38	74	36	966	1115	49845
1981/82	462	653	6071	141	147	49	21	60	870	1212	50047
1982/83	486	289	403	3630	83	87	29	48	603	862	40208
1983/84	3207	295	172	230	2031	47	49	43	677	696	32063
1984/85	1440	1928	174	97	127	1123	26	51	610	493	25305
1985/86	306	872	1103	90	48	63	563	38	205	416	22123
1986/87	544	191	517	613	49	26	34	326	538	329	16863
1987/88	2035	334	114	297	349	28	15	205	433	363	18373
Estimated availability at age (λ_j)	0.46	0.62	0.91	1.00	1.00	1.00	1.00	1.00			
Estimated relative selectivity at age for gillnet gear	0.01	0.23	0.72	1.00	0.84	0.84	0.84	0.84			

The coefficients for the Ricker stock-recruitment curve are: α = 35.25, β = 0.2624E-02

The estimated spawn index-escapement conversion factor is 0.971E-02

Appendix Table 2.2. Estimates of numbers at age, spawn, and other parameters from age-structured model analysis for the Prince Rupert District stock assessment region.

Season	Estimated numbers at age ($x10^{-5}$) for period one 3	4	5	6	7	8	9	10+	Spawn Index	Estimated Spawn	Spawning Biomass (t)
1950/51	6270	7928	1093	401	0	0	0	211	1058	505	11080
1951/52	3264	3344	3018	284	64	0	0	34	641	174	4432
1952/53	3373	1812	1111	569	20	5	0	2	961	1016	26072
1953/54	7643	2099	1122	678	343	12	3	1	835	311	7787
1954/55	2226	4303	800	292	109	55	2	1	869	454	10769
1955/56	6022	1355	1893	277	79	30	15	1	951	1431	33734
1956/57	1933	3296	773	1019	142	40	15	8	1279	484	11460
1957/58	3555	841	1360	237	224	31	9	5	507	1131	26178
1958/59	7421	2136	497	774	131	124	17	8	1285	1224	32503
1959/60	2482	4277	1215	267	395	67	63	13	1087	1321	28632
1960/61	12617	1465	2232	568	113	167	28	32	990	1130	27866
1961/62	6285	5920	662	814	167	33	49	18	1530	1120	30230
1962/63	3643	3429	2940	285	306	63	12	25	783	1014	23315
1963/64	9569	1841	1512	1024	78	83	17	10	1185	1534	36464
1964/65	1429	4344	928	667	399	30	33	11	501	368	10129
1965/66	496	533	1641	237	104	62	5	7	332	260	6560
1966/67	825	271	226	530	57	25	15	3	222	253	6258
1967/68	801	278	119	78	142	15	7	5	433	350	8819
1968/69	1461	423	161	65	41	75	8	6	74	231	5940
1969/70	7345	917	257	96	38	24	44	8	886	894	23439
1970/71	5269	4594	569	158	58	23	15	32	716	1310	30194
1971/72	2521	3230	2794	338	92	34	13	27	1000	1324	42291
1972/73	4798	1593	1959	1653	196	53	20	23	730	1816	57547
1973/74	4248	3020	1000	1220	1023	121	33	27	670	1666	51364
1974/75	2048	2679	1870	598	705	600	71	35	814	1688	46369
1975/76	1349	1294	1676	1159	368	433	369	65	1158	1420	45919
1976/77	2201	852	790	997	674	215	253	253	1438	1107	35205
1977/78	1311	1330	496	428	504	347	111	261	750	756	23749
1978/79	1361	801	764	249	186	232	160	171	814	646	20461
1979/80	11765	841	476	420	127	97	122	173	1529	1261	36075
1980/81	2221	7347	516	276	230	71	55	165	1175	1531	37215
1981/82	2341	1397	4529	310	161	135	42	130	1305	1839	39680
1982/83	2821	1474	875	2816	191	100	84	106	1826	1892	46988
1983/84	8577	1798	940	558	1795	122	64	121	2032	1839	43098
1984/85	1721	5405	1116	558	316	1040	71	107	2056	1718	40264
1985/86	1639	1074	3277	622	284	168	552	94	2084	1530	41787
1986/87	7786	1005	647	1796	308	147	87	335	2555	1519	40330
1987/88	5873	4891	617	365	926	166	80	228	1865	1661	39955
Estimated availability at age (λ_i)	0.37	0.54	0.79	1.00	1.00	1.00	1.00	1.00			
Estimated relative selectivity at age for gillnet gear	0.01	0.15	0.66	1.00	0.72	0.72	0.72	0.72			

The coefficients for the Ricker stock-recruitment curve are: α = 35.74, β =0.1330E-02

The estimated spawn index- escapement conversion factor is 0.162E-01

Appendix Table 2.3. Estimates of numbers at age, spawn, and other parameters from age-structured model analysis for the Central Coast stock assessment region.

Season	Estimated numbers at age ($x10^{-5}$) for period one 3	4	5	6	7	8	9	10+	Spawn Index	Estimated Spawn	Spawning Biomass (t)
1950/51	3884	4759	836	335	0	0	86	0	834	513	13925
1951/52	1475	1643	1571	184	66	0	0	17	343	146	3920
1952/53	2305	508	417	184	16	6	0	2	629	369	9651
1953/54	13484	1454	311	251	110	10	4	1	487	351	7796
1954/55	1423	6741	459	63	45	20	2	1	553	1173	27060
1955/56	1495	838	3538	223	30	21	9	1	394	329	8243
1956/57	3019	527	236	547	29	4	3	1	213	135	3504
1957/58	5473	933	141	32	59	3	0	0	367	658	15448
1958/59	6452	2809	455	61	14	25	1	0	364	344	8323
1959/60	1572	2907	896	93	11	2	5	0	681	1417	29022
1960/61	2759	901	1722	516	54	6	1	3	314	382	9142
1961/62	8308	930	286	351	93	10	1	1	860	622	16808
1962/63	4065	4488	424	112	133	35	4	1	394	202	5237
1963/64	3916	1640	1153	51	10	12	3	0	430	276	7378
1964/65	1660	1264	478	194	7	1	2	1	171	262	8276
1965/66	1949	688	467	131	49	2	0	1	158	134	3761
1966/67	1493	282	165	46	9	3	0	0	322	231	6638
1967/68	661	297	93	37	9	2	1	0	376	266	8052
1968/69	722	366	172	52	20	5	1	0	172	213	6464
1969/70	3147	458	231	108	33	13	3	1	637	492	14788
1970/71	2565	1996	288	145	68	20	8	3	341	769	23671
1971/72	3313	1539	1175	165	82	38	12	6	435	657	19200
1972/73	5538	1896	762	519	71	35	16	8	964	1086	35551
1973/74	3860	3263	1067	394	258	35	17	12	893	1078	31582
1974/75	5162	2410	1854	510	167	108	15	12	795	1407	41144
1975/76	2586	3194	1404	942	236	76	49	12	1426	1227	33473
1976/77	1630	1589	1772	662	401	99	32	26	1223	1103	32937
1977/78	1966	976	901	853	286	170	42	24	732	668	19649
1978/79	1433	1156	509	338	253	82	49	19	694	1164	29778
1979/80	13350	914	737	325	216	162	52	43	1159	1840	50681
1980/81	2367	8509	579	460	200	133	100	59	1320	2232	56241
1981/82	2326	1505	5323	347	266	115	77	91	1302	2255	59794
1982/83	989	1452	920	3072	193	147	64	93	1605	1661	44551
1983/84	813	619	886	531	1713	107	82	87	1075	1103	28241
1984/85	2971	498	359	468	266	853	53	84	1155	935	28925
1985/86	1123	1809	293	195	242	137	438	70	1262	824	25389
1986/87	1868	689	1078	165	106	132	74	276	1160	757	23660
1987/88	9304	1148	405	600	89	57	71	189	1871	1405	42120
	Estimated availability at age (λ_j)										
	0.51	0.70	0.95	1.00	1.00	1.00	1.00	1.00			
	Estimated relative selectivity at age for gillnet gear										
	0.02	0.23	0.65	0.95	1.00	1.00	1.00	1.00			

The coefficients for the Ricker stock-recruitment curve are: α = 40.70, β =0.1577E-02

The estimated spawn index- escapement conversion factor is 0.155E-01

Appendix Table 2.4. Estimates of numbers at age, spawn, and other parameters from age-structured model analysis for the northern Strait of Georgia stock assessment region.

Season	Estimated numbers at age ($x10^{-5}$) for period one 3	4	5	6	7	8	9	10+	Spawn Index	Estimated Spawn	Spawning Biomass (t)
1950/51	2859	1381	328	0	0	0	0	31	2795	1263	8868
1951/52	3426	1210	384	85	0	0	0	8	2905	2036	14723
1952/53	3371	1431	417	127	28	0	0	3	3259	3822	23466
1953/54	7580	1938	799	231	70	16	0	1	1850	2260	14517
1954/55	4361	4326	639	251	73	22	5	0	2493	5365	33737
1955/56	1770	1895	1771	254	100	29	9	2	1235	2430	15478
1956/57	1608	813	556	490	70	28	8	3	1381	1104	7778
1957/58	2450	508	193	121	107	15	6	2	735	771	5233
1958/59	6622	1263	150	54	34	30	4	2	2059	1906	13055
1959/60	3153	2298	298	32	12	7	6	1	2044	2317	15724
1960/61	1979	1286	741	92	10	4	2	2	1558	1591	9670
1961/62	4739	935	391	213	26	3	1	1	1450	1801	12523
1962/63	4755	1387	229	88	48	6	1	1	1198	938	5759
1963/64	5082	1451	205	28	11	6	1	0	1354	1024	8020
1964/65	2619	1451	241	29	4	2	1	0	1439	1473	12024
1965/66	1059	600	361	55	7	1	0	0	267	241	2064
1966/67	785	162	60	27	4	0	0	0	498	355	2878
1967/68	261	132	31	10	4	1	0	0	556	366	3129
1968/69	431	130	67	15	5	2	0	0	837	746	5685
1969/70	1484	266	79	40	9	3	1	0	2444	1861	16131
1970/71	1579	923	166	49	25	6	2	1	2350	2129	17800
1971/72	1266	979	566	101	30	15	4	2	1579	1503	10832
1972/73	1819	637	397	223	40	12	6	2	1375	1239	9831
1973/74	2786	1047	277	148	73	13	4	3	2840	2174	16303
1974/75	3794	1768	593	124	53	25	4	2	3808	4906	34065
1975/76	2575	2339	993	271	47	19	9	2	3745	3987	26216
1976/77	4450	1610	1280	435	96	16	7	4	5625	5441	39347
1977/78	3571	2609	851	546	152	33	5	4	4586	4557	31042
1978/79	1698	2048	1286	342	182	49	11	3	4546	3992	28968
1979/80	2996	1056	1137	587	130	67	18	5	4473	4920	32415
1980/81	2270	1853	626	617	294	64	33	11	3017	4910	33491
1981/82	2067	1358	1047	309	270	126	27	19	4949	4229	27593
1982/83	1953	1307	800	529	135	115	54	20	2946	2542	17641
1983/84	1484	1009	541	224	104	25	21	14	2202	2021	13952
1984/85	2352	783	437	150	41	18	4	6	1970	2620	18519
1985/86	3532	1350	383	157	40	10	5	3	4074	4426	31290
1986/87	2133	2237	854	242	99	25	7	5	3771	4530	29625
1987/88	6529	1253	1252	440	116	47	12	5	3299	6105	44219
Estimated availability at age (λ_j)	0.71	0.95	1.00	1.00	1.00	1.00	1.00	1.00			
Estimated relative selectivity at age for gillnet gear	0.02	0.20	0.58	0.94	1.00	1.00	1.00	1.00			

The coefficients for the Ricker stock-recruitment curve are: α = 8.511, β =0.4090E-03

The estimated spawn index- escapement conversion factor is 0.619E-01

Appendix Table 2.5. Estimates of numbers at age, spawn, and other parameters from age-structured model analysis for the southern Strait of Georgia stock assessment region.

Season	Estimated numbers at age ($x10^{-5}$) for period one: 3	4	5	6	7	8	9	10+	Spawn Index	Estimated Spawn	Spawning Biomass (t)
1950/51	3607	1124	230	46	9	0	0	0	285	738	8633
1951/52	3486	979	229	45	9	2	0	0	768	394	4512
1952/53	4630	943	126	27	5	1	0	0	2489	1592	15819
1953/54	7675	2696	503	67	14	3	1	0	1774	1199	13338
1954/55	5862	2787	499	88	12	2	0	0	1380	1732	20285
1955/56	4721	1998	711	123	22	3	1	0	890	767	8239
1956/57	4234	1151	279	91	16	3	0	0	409	384	4234
1957/58	2071	537	111	23	8	1	0	0	895	535	5608
1958/59	5365	644	137	27	6	2	0	0	1074	979	10449
1959/60	5020	2468	195	41	8	2	1	0	504	885	10497
1960/61	2509	1312	399	29	6	1	0	0	602	576	6285
1961/62	5582	827	199	56	4	1	0	0	324	441	5211
1962/63	4930	1526	98	21	6	0	0	0	489	453	5102
1963/64	3429	1616	180	10	2	1	0	0	513	314	3944
1964/65	2072	618	143	14	1	0	0	0	151	204	2609
1965/66	1293	491	65	13	1	0	0	0	193	164	2047
1966/67	1136	469	61	7	2	0	0	0	138	129	1561
1967/68	118	67	33	4	0	0	0	0	230	137	1554
1968/69	141	39	22	11	1	0	0	0	346	197	2290
1969/70	439	77	21	12	6	1	0	0	576	364	4614
1970/71	551	264	47	13	7	4	0	0	491	305	3794
1971/72	454	334	147	26	7	4	2	0	465	404	4832
1972/73	588	238	154	65	11	3	2	1	455	548	6694
1973/74	1004	361	136	78	29	5	2	1	699	951	11483
1974/75	1350	622	216	76	41	16	3	2	704	1112	13300
1975/76	993	856	371	116	37	21	8	2	541	978	9520
1976/77	2030	590	439	175	50	17	10	5	315	1131	11743
1977/78	1551	1112	279	195	73	22	7	6	696	1001	10450
1978/79	730	766	437	100	64	26	8	5	1492	476	4997
1979/80	813	334	200	110	25	16	6	3	746	728	7851
1980/81	744	478	192	114	63	14	9	6	551	585	6309
1981/82	547	371	203	80	48	26	6	6	206	304	3472
1982/83	204	138	91	48	19	11	6	3	419	223	2451
1983/84	324	117	69	45	24	9	6	5	466	249	3056
1984/85	482	180	57	33	22	11	5	5	465	465	5494
1985/86	861	283	104	33	19	12	7	5	476	825	9851
1986/87	537	537	177	65	21	12	8	7	639	681	7500
1987/88	2430	326	225	38	7	4	2	3	425	1333	15245
Estimated availability at age (λ_j)	0.73	0.98	1.00	1.00	1.00	1.00	1.00	1.00			
Estimated relative selectivity at age for gillnet gear	0.02	0.23	0.60	1.00	0.69	0.69	0.69	0.69			

The coefficients for the Ricker stock-recruitment curve are: α = 9.535, β =0.5632E-03

The estimated spawn index- escapement conversion factor is 0.395E-01

Appendix Table 2.6. Estimates of numbers at age, spawn, and other parameters from age-structured model analysis for the southern west coast Vancouver Island stock assessment region.

Season	Estimated numbers at age ($x10^{-5}$) for period one 3	4	5	6	7	8	9	10+	Spawn Index	Estimated Spawn	Spawning Biomass (t)
1950/51	1234	992	146	30	0	3	3	1	475	171	3362
1951/52	1625	306	160	21	4	0	0	0	387	104	2155
1952/53	1822	466	46	21	3	1	0	0	660	443	8014
1953/54	3136	1161	297	29	13	2	0	0	453	172	3370
1954/55	1268	447	121	24	2	1	0	0	602	383	7402
1955/56	2112	488	177	47	9	1	0	0	597	192	3794
1956/57	1369	376	78	25	7	1	0	0	424	413	7552
1957/58	2592	697	190	39	12	3	1	0	857	882	14442
1958/59	4155	1623	433	118	24	8	2	0	387	366	6715
1959/60	1715	651	228	52	14	3	1	0	449	344	6997
1960/61	1307	371	152	49	11	3	1	0	396	366	7381
1961/62	2822	377	102	39	13	3	1	0	671	375	8005
1962/63	1751	793	103	26	10	3	1	0	371	397	7685
1963/64	3271	979	364	46	12	5	1	0	915	440	9182
1964/65	1251	1159	249	87	11	3	1	0	652	326	7350
1965/66	771	490	316	64	22	3	1	0	239	246	5750
1966/67	1061	290	154	95	19	7	1	0	117	156	3775
1967/68	381	382	66	32	20	4	1	0	364	288	6967
1968/69	604	243	243	42	21	13	3	1	429	425	10005
1969/70	2488	385	155	155	27	13	8	2	959	943	23271
1970/71	5484	1586	246	99	99	17	8	7	1256	1970	52196
1971/72	4344	3497	1012	157	63	63	11	10	1107	2068	47764
1972/73	5905	2708	2057	593	92	37	37	12	471	2609	61501
1973/74	5915	3539	1504	1116	317	49	20	26	678	4272	88609
1974/75	10477	3621	2128	864	620	179	28	26	1229	4043	94507
1975/76	4529	6262	2006	1081	413	304	88	26	1426	2905	61893
1976/77	2457	2784	2970	769	358	146	107	40	1558	2130	45293
1977/78	2687	1425	1289	1151	265	130	53	53	1355	1759	34360
1978/79	835	1509	717	508	383	95	46	38	1291	1057	22217
1979/80	2013	491	752	310	200	157	39	34	1264	1212	24784
1980/81	1636	1221	291	437	177	115	90	42	1272	1189	24076
1981/82	1017	946	676	147	208	86	56	64	821	993	19666
1982/83	885	599	535	368	78	111	46	65	534	679	14336
1983/84	1519	456	274	240	166	35	50	50	799	717	16584
1984/85	2209	794	220	130	115	79	17	48	844	1336	32260
1985/86	2602	1401	503	140	83	73	50	41	944	1552	36871
1986/87	792	1652	888	319	89	52	46	58	1138	1047	24359
1987/88	3710	347	702	370	133	37	22	43	1617	1072	26013
	Estimated availability at age (λ_j)										
	0.73	0.96	1.00	1.00	1.00	1.00	1.00	1.00			
	Estimated relative selectivity at age for gillnet gear										
	0.03	0.23	0.68	1.00	0.87	0.87	0.87	0.87			

The coefficients for the Ricker stock-recruitment curve are: α = 16.58, β =0.7163E-03

The estimated spawn index- escapement conversion factor is 0.222E-01

Appendix Table 2.7. Estimates of numbers at age, spawn, and other parameters from age-structured model analysis for the northern west coast Vancouver Island stock assessment region.

Season	Estimated numbers at age ($x10^{-5}$) for period one 3	4	5	6	7	8	9	10+	Spawn Index	Estimated Spawn	Spawning Biomass (t)
1950/51	1147	1999	288	85	5	5	6	7	792	907	15338
1951/52	679	614	1018	141	41	2	3	7	316	214	3772
1952/53	1379	337	133	162	21	6	0	1	1133	634	10307
1953/54	3376	879	215	85	103	14	4	1	839	409	6444
1954/55	1392	1796	308	67	26	31	4	2	724	973	17211
1955/56	1442	721	915	151	33	13	15	3	1098	1308	23015
1956/57	2859	903	452	573	95	20	8	11	1790	1539	25092
1957/58	2995	1803	568	284	360	59	13	12	625	1878	27211
1958/59	3097	1909	1148	362	181	229	38	16	529	497	7370
1959/60	3531	1396	414	182	55	27	35	8	253	245	4309
1960/61	1552	655	226	40	16	5	2	4	308	216	3839
1961/62	3514	335	142	36	6	2	1	1	639	492	9484
1962/63	1890	1417	119	45	11	2	1	1	449	277	4998
1963/64	1118	613	340	22	8	2	0	0	612	638	11564
1964/65	548	637	352	192	12	5	1	0	809	446	9026
1965/66	631	284	303	160	87	6	2	1	284	327	7170
1966/67	820	355	130	130	68	37	2	1	394	360	8298
1967/68	315	321	151	51	51	27	14	1	272	343	7595
1968/69	314	201	204	96	33	33	17	10	485	368	8208
1969/70	1326	200	128	130	61	21	21	17	676	589	13769
1970/71	2586	846	128	82	83	39	13	24	495	1060	25460
1971/72	1869	1649	539	81	52	53	25	24	923	991	20529
1972/73	1546	1168	953	307	46	30	30	28	727	996	20193
1973/74	1789	853	569	444	142	21	14	27	301	845	16430
1974/75	2634	803	363	225	174	56	8	16	659	1134	22548
1975/76	702	1262	402	175	108	83	27	12	453	699	13121
1976/77	768	415	640	180	71	39	30	14	589	573	10089
1977/78	3297	479	231	307	76	25	14	15	1000	862	14377
1978/79	694	2005	249	95	103	19	6	7	1364	616	10084
1979/80	1828	349	797	67	19	13	2	2	1516	778	12776
1980/81	542	1162	202	396	29	7	5	1	728	617	10311
1981/82	372	317	592	87	150	9	2	2	909	487	8003
1982/83	131	231	176	270	34	45	3	1	669	250	4255
1983/84	467	83	122	69	81	7	9	1	482	400	7526
1984/85	2628	296	48	60	29	28	2	3	296	645	13154
1985/86	1331	1675	189	30	38	19	18	4	741	1176	24532
1986/87	779	848	1068	120	19	24	12	14	1023	1159	25212
1987/88	4233	495	512	592	62	9	11	12	571	1684	36178
Estimated availability at age (λ_j)	0.69	0.86	0.98	1.00	1.00	1.00	1.00	1.00			
Estimated relative selectivity at age for gillnet gear	0.01	0.20	0.44	0.66	1.00	1.00	1.00	1.00			

The coefficients for the Ricker stock-recruitment curve are: α = 9.233, β =0.8432E-03

The estimated spawn index- escapement conversion factor is 0.249E-01