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Stock assessment for British Columbia herring in 2000 and forecasts of the potential catch in 2001

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ABSTRACT

Herring stock abundance in British Columbia waters was assessed for 2000 and forecasts were made for 2001 using two analytical methods: (1) escapement model; and (2) age-structured model. These models have been applied to assess herring abundance since 1984 and no significant changes were implemented in either model in conducting the current assessment. All available biological data on total harvest, spawn deposition, and age and size composition of the spawning runs were used to determine current abundance levels. No significant problems were evident in the extent and comprehensiveness of the data collections. Coastwide, the estimated pre-fishery stock biomass for all assessment regions in 2000 was 157,000 tonnes based on the escapement model. This represents a 16% decrease from 1999 abundance levels. This reflects the recruitment of an average 1997 year-class in all areas except the west coast of Vancouver Island where recruitment was poor.

Forecasts of the pre-fishery spawning stock biomass in 2001 are presented for both models but PSARC adopted forecasts from the escapement model in all areas. Stock forecasts for the northern stock assessment regions total 66,000 tonnes and 97,000 tonnes for the southern regions assuming average recruitment to all areas except the west coast of Vancouver Island where recruitment is expected to again be poor.

The estimated harvestable surplus in 2001 (20% of the 2001 forecast herring run) is 28,500 tonnes for the entire B.C. coast. Forecasts indicate that abundance in the Queen Charlotte Islands and west coast of Vancouver Island will be below the Cutoff level so no roe fisheries are anticipated in these assessment regions.

RÉSUMÉ

La présente étude porte sur une évaluation de l'abondance des stocks de hareng en Colombie-Britannique en 2000 et des prévisions de l'abondance en 2001 faisant appel à deux méthodes analytiques, soit (1) le modèle de l'échappée et (2) le modèle de la structure par âge. Aucun changement important n'a été apporté aux deux modèles utilisés pour évaluer l'abondance du hareng depuis 1984 pour faire la présente évaluation. Toutes les données biologiques disponibles sur les prises totales, la ponte et la composition selon l'âge et la taille des remontées ont servi au calcul des niveaux d'abondance actuels. Aucun problème important n'a été relevé dans l'étendue et la représentativité des séries de données. À l'échelle de la côte, la biomasse estimative pré-pêche des stocks en 2000 dans l'ensemble des pêcheries évaluées se chiffrait à 157 000 tonnes selon le modèle de l'échappée. Ce niveau qui représente une baisse de 16% par rapport aux niveaux d'abondance de 1999 reflète le recrutement d'une classe d'âge 1997 moyenne dans toutes les pêcheries, sauf la côte ouest de l'île de Vancouver où le recrutement était pauvre.

Des prévisions présentées de la biomasse pré-pêche des stocks de reproducteurs en 2001 tirées des deux modèles, le CEESP a adopté pour toutes les pêcheries les prévisions issues du modèle de l'échappée. Les prévisions pour les pêcheries du nord se chiffrent à 66 000 tonnes et à 97 000 tonnes pour les pêcheries du sud, dans l'hypothèse d'un recrutement moyen dans toutes les pêcheries, sauf la côte ouest de l'île de Vancouver, où l'on prévoit que le recrutement sera à nouveau pauvre.

L'excédent pêchable estimatif en 2001 (20% de la remontée prévue de hareng en 2001) se chiffre à 28 500 tonnes pour l'ensemble de la côte de la Colombie-Britannique. Les prévisions révèlent que l'abondance dans les eaux des îles de la Reine-Charlotte et de la côte ouest de l'île de Vancouver sera inférieure au niveau seuil, de sorte qu'aucune pêche du hareng rogué n'est prévue dans ces régions d'évaluations.

INTRODUCTION

Herring have been one of the most important components of the British Columbia commercial fishery over the past century with catch records dating from 1877. The fishery has evolved from a dry salted product in the early 1900s, to a reduction fishery in the 1930s that collapsed in the late 1960s. After a four year closure the current roe fishery began in 1972. Roe fisheries occur just prior to spawning when the fish are highly aggregated and very vulnerable to exploitation. Since 1983, herring roe fisheries have been managed with a fixed quota system. Under this system harvest levels are determined prior to the season based on a fixed percentage (20%) of forecast stock size. In addition, threshold biomass or Cutoff levels were introduced in 1985 to restrict harvest during periods of reduced abundance.

In this report we present stock assessments from two analytical models which have been developed explicitly for British Columbia herring: (1) a modification of the escapement model described by Schweigert and Stocker (1988); and (2) a modification of the age-structured model described by Fournier and Archibald (1982). Both models reconstruct stock abundance for the period 1951-2000 and forecast pre-spawning abundance for the 2001 season. Forecasts of upcoming run size are based on the combination of estimates of surviving repeat spawners and newly recruiting spawners which are presented as poor, average, and good, based on historic recruitment levels.

1.1. 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 2000. This time span includes the reduction fishery period to 1968 and the subsequent roe fishery period which began in 1972.

Of the three data sets, the spawn data contain the largest measurement errors. While the quality of spawn surveys has generally improved over the 50 year span of these data due to increased effort and better quality control of the surveys, there are occasional problems with equipment and weather which may hamper data completeness and accuracy in some years. The consistent observations made during all years of surveys are the total length, the average width, and a measure of egg density for each spawning site. Since 1987 an increasing number of egg beds have been assessed using Scuba rather than traditional surface survey methods. We assume all surveys provide reasonably accurate estimates of spawn bed width and egg density and these data have been used in the escapement model where available. All major herring spawnings were surveyed in 2000, as were many of the minor spawnings outside the assessment areas. In addition, an underwater video system was tested in Area 23 to locate and delimit any spawning events deeper than 30 meters. However, no such areas were identified although areas of spawn in shallower locations were accurately identified by the video system.

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 1997/98 catch figures are based on validated plant weights as a result of the introduction of the pool fishery for all areas except the Strait of Georgia and Prince Rupert gillnet fisheries. In 1998/99 and 1999/00 validated plant weights are available for all food and roe fisheries coastwide. The spawn-on-kelp (SOK) fishery includes a total of 46 licensed operators who pond a substantial quantity of herring of which an unknown quantity dies each year. For assessment purposes it has been assumed since 1990 that the 100 tons (91 tonnes) allocated to each license are killed and this is treated as additional seine catch. Additional information on the scope of the SOK fishery which dates back to 1975 is being tabulated for inclusion in future assessments.

Age structure data are used in both models. The information from catch samples is used for years when there were commercial fisheries. Pre-fishery charters began in 1975 and these samples are used in addition to samples taken from the catch particularly in areas with no fisheries, or when catch samples are few in number or not representative of the entire catch. Additional data used in both models are annual mean weights-at-age. During the 1999/00 season a total of 339 herring samples (93 roe, 19 food, 187 test fishery and 40 miscellaneous others) were collected and processed compared to 308 in the previous year. Of the roe and test fishery samples, 25 were taken in the Queen Charlotte Islands assessment area (another 1 from Area 2W), 50 in the Prince Rupert area, 56 in the Central Coast, 89 in the Strait of Georgia, and 56 on the west coast of Vancouver Island (plus 4 from Area 27). 11 samples were obtained from SOK operations. We believe that this provides adequate coverage of all the assessment regions for the age-structured and escapement model assessment analysis.

In the current assessment we continue to use the year of life convention for ageing adopted in the 1991 assessment. Fish which were previously named age 3 are now referred to as the 2^{+} age class. In a few instances the text refers to age class 2^{++} which indicates all fish that are age 2^{+} and older.

1.2. STOCK CONSIDERATIONS

The stock concept used for managing British Columbia herring is based on current knowledge of stock structure which is necessarily incomplete. Given incomplete knowledge of population structure it is prudent to manage fisheries to ensure maintenance of the greatest potential biological diversity. In addition, we do not feel that stock forecasts for smaller geographic regions than those used in the current assessments would be accurate enough for fisheries management. Therefore, we recommend that fisheries should continue to focus on the major aggregations within each assessment region to minimize the potential over-exploitation of any of the smaller, spatially discrete spawning groups. In the 2000 spawning season, the research study using a combination of coded wire tagging and micro-satellite DNA analysis to further investigate stock structure of British Columbia herring was continued. Preliminary results of the tagging study are presented in a separate report and results of the genetic analyses should be available within the next year.

The stock groupings used for the current assessments are identical to those used since 1993 (Fig. 1.). The Queen Charlotte Islands stock assessment region spans from Cumshewa Inlet in the north to Louscoone Inlet in the south. The stock concept for the Prince Rupert District encompasses Statistical Areas 3 to 5. The Central Coast stock management unit separates the major migratory stocks from the minor spawning populations in the mainland inlets. The areas included in the Central Coast assessment region are Statistical Area 7 plus Kitasu Bay in Area 6 and Kwakshua Channel in Area 8. The Strait of Georgia stock includes all of Statistical Areas 14 to 19, and Deepwater Bay and Okisollo Channel in Area 13, and Areas 28 and 29. The west coast of Vancouver Island assessment region encompasses Statistical Areas 23 to 25. Haist and Rosenfeld (1988) outline current geographical stock boundaries.

Abundance estimates are not presented for other areas outside of the major assessment regions which may support additional small herring runs, because we believe that both the spawn survey and catch data are incomplete for many of these areas; therefore presentation of stock estimates could lead to erroneous conclusions regarding either absolute abundance or stock trends. Recent attempts to conduct a complete age-structured assessment for Areas 2W and 27 have been unsuccessful. An escapement model estimate of current stock abundance is available for these areas but no forecast of abundance in the coming year is possible.

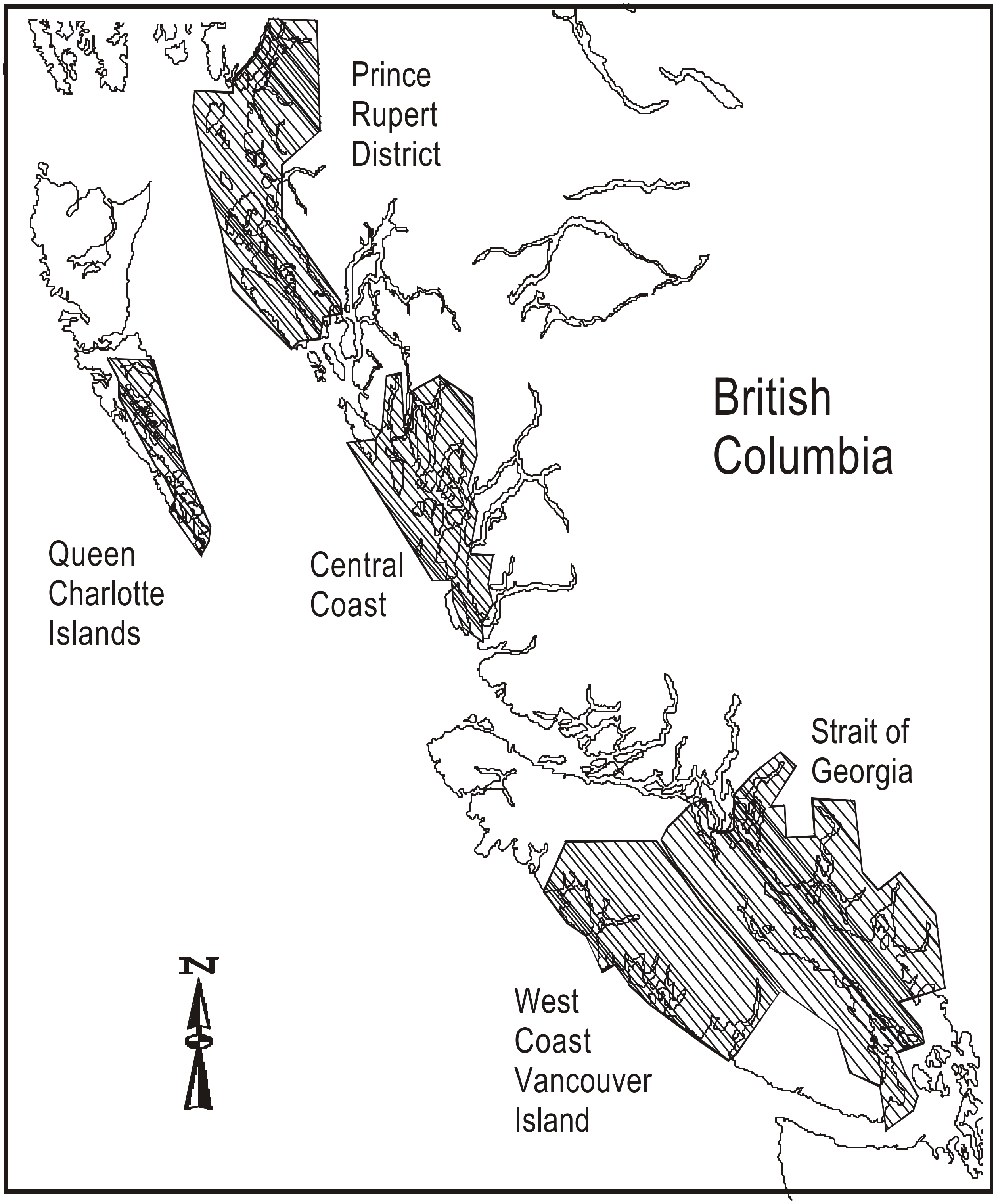


Fig. 1. Herring stock assessment regions in British Columbia.

2. ESCAPEMENT MODEL

2.1 INTRODUCTION

The escapement model, developed for the 1984 assessments (Haist et al. 1985; Schweigert and Stocker 1988), is based on egg deposition information and provides a direct estimate of escapement from the fishery. For most stock assessment regions, recent estimates of escapement are based on a combination of surface and Scuba survey data. Scuba surveys have been used routinely since 1987 and an increasing proportion of the herring spawning beds have been surveyed using this technique. A summary of the recent spawn survey coverage for the British Columbia coast is presented below. As a result of reductions in DFO resources and the consequent contracting of diving surveys to industry there was again virtually no DFO effort directed to surface surveys in 2000, particularly outside of the assessment regions. No organized surface surveys were conducted in the Queen Charlotte Islands, Prince Rupert District, and Strait of Georgia. However, all areas did receive good Scuba survey coverage. Limited surface surveys occurred in the Central coast and Johnstone Strait, primarily outside of the major assessment areas through industry funded contractors. Coastwide there was a marked decrease in the total length of spawn surveyed by Scuba and surface surveys relative to 1999. Most of the difference is attributable to declines in spawn in the Queen Charlotte Islands, Central Coast, and in the non-assessment areas although the latter could be a function of lack of effort.

Summary of the kilometres of herring spawning beds surveyed by Scuba and surface methods for major and minor stocks on the British Columbia coast in recent years, 1997-2000.

	1997			1998			1999			2000*		
Assessment Region	Scuba	Surface	Total	Scuba	Surface	Total	Scuba	Surface	Total	Scuba	Surface	Total
Queen Charlotte Is.	36.4	0.0	36.4	58.4	0.0	58.4	42.1	2.4	44.5	25.1	0.0	25.1
Prince Rupert District	68.9	0.0	68.9	47.1	0.0	47.1	83.7	1.1	84.8	73.5	0.0	73.5
Central Coast	142.4	0.0	142.4	141.0	23.4	164.4	159.4	3.2	162.6	96.5	0.7	97.2
Strait of Georgia	119.1	3.5	122.6	140.8	6.2	147.0	133.8	3.5	137.3	152.1	0.0	152.1
W.C. Vancouver Is.	78.3	0.0	78.3	42.9	0.5	43.4	48.9	0.3	49.2	40.7	0.0	40.7
Other Areas	14.3	46.5	60.8	26.1	13.8	39.9	28.3	48.1	76.4	23.4	1.1	24.5
Coastwide Total	459.3	50.0	509.4	456.3	43.9	500.2	496.2	58.6	554.8	411.3	1.8	413.1

*Preliminary – some surface data from minor areas not yet entered into database.

2.2 METHODS

In the escapement model, the forecast run size is based on the estimated escapement in the previous season, growth of the escaped fish during the current season, an age-specific apparent survival rate which accounts for both survival and partial recruitment of recruited year-classes, and an estimate of age 2^+ 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 recruitment observed during the historical time series from 1951-2000. Estimates of total catch (tonnes) and spawn abundance (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-age are calculated from samples available for that region. In rare instances, no data are available for a region and information from an adjacent area is utilized in the analysis. Forecasts of repeat spawners and recruit fish are converted to forecast tonnage of fish using average weights-at-age from the previous season.

Pre-Fishery Biomass and Spawn Index Estimates

Escapement from the fishery plus total catch provides an estimate of the pre-fishery spawning stock biomass for each assessment region. The following relationship may be used to estimate pre-fishery biomass for each area (Schweigert 1993) if all pertinent data are available:

$$B_j = C_j + Eggs_j \bullet \left(\frac{\sum_{3}^{10} P_{ij} F_{ij} SR_{ij}}{\sum_{3}^{10} P_{ij} W_{ij}} \right)^{-1}$$

where

B_j = total pre-fishery mature biomass in tonnes in year j,
C_j = total catch in tonnes in year j,
$Eggs_j$ = total egg deposition in billions in year j,
P_{ij} = proportion of fish at age i in year j in the spawning run,
F_{ij} = fecundity of females of age i in year j,
SR_{ij} = sex ratio or proportion of females at age i in year j,
W_{ij} = mean weight of fish at age i in year j in tonnes.

However, some of these data are not always available so a more synoptic estimate of total biomass is calculated using the following data. The total catch is obtained from sales slip information except for the current season when validated landings estimates are used. The estimated escapement for each region is derived from information on spawn deposition. Dive survey observations of egg deposition are used directly while surface survey observations are adjusted to emulate Scuba estimates. Total egg deposition is calculated as the product of: total length parallel to the shore of each spawning bed; the observed or adjusted width of the spawning bed; and egg density as estimated from the average number of egg layers determined from the surface survey, or average predicted egg density from quadrat observations of egg layers, or average egg layer and plant density estimates in giant kelp (*Macrocystis* sp.) beds from Scuba surveys. Total egg deposition estimates for all spawning beds are summed within each assessment region and the total egg deposition is converted to tonnes of spawning fish based on an estimate of 100 eggs per gram of herring on average (Hay 1985) as described above.

Surface Surveys

Since the late 1920s there have been organized efforts to assess the amount of herring eggs deposited throughout the British Columbia coast as an indicator of stock abundance. The parameters which have been monitored consistently are total length of each spawning bed measured parallel to the shoreline, the average width of each spawning bed, and an estimate of intensity of the spawn deposition. Prior to 1981 intensity was estimated subjectively on either a 1-5 or 1-9 scale of light to heavy (Hay and Kronlund 1987). Subsequently, intensity of egg deposition was recorded as the number of egg layers observed on each of several types of algal substrate. Beginning in 1987 an increasing proportion of the spawning beds have been surveyed using Scuba techniques as outlined below.

To provide a consistent coastwide assessment of total egg deposition throughout the time period from 1951-2000, it was necessary to intercalibrate the surface and Scuba surveys of egg deposition. Initially, the intercalibration took the form of linear equations which converted the surface survey estimates of spawning bed width and egg layers to comparable Scuba estimates (Schweigert and Stocker 1988). However, the data available for this intercalibration were limited in time and space to particular spawning beds over the course of a few years. As Scuba surveys of the spawning beds became widespread, an extensive database of estimates of the dimensions of herring spawning beds in most areas of the coast became available and a new procedure for calibrating the width of herring spawning beds estimated by surface surveys was proposed (Schweigert et al. 1993). The methodology consisted of defining spawn pools which consisted of one or more geographically adjacent and geomorphologically similar herring spawning locations. Hence, diver width estimates developed for such a 'pool' were felt to be characteristic of all locations within that pool. For the small number of locations which could not be assigned to a pool, the median width for the section (Haist and Rosenfeld 1988) was used to adjust width estimates for the location. The median width was preferable to the mean because of the non-normal distribution of the spawn width estimates. Any pools for which fewer than 25 observations of median width existed were also adjusted using the section median. For the rare instances where no median estimate was available at the section level the median width for the assessment region was applied to calculate spawn area. The long term median spawn width for each pool was then applied to each surface survey record to estimate a ‘diver’ width and combined with the estimated surface length to determine the total area of egg deposition.

To estimate egg density we assumed that surface and dive survey estimates of the number of egg layers in a spawning bed were equivalent and employed the database of 5111 observations of egg density per square meter from laboratory egg counts of Scuba surveyed quadrat samples to develop a predictive model of egg density from egg layers:

$$Eggs / m^2 = 14.698 + 212.218\ Layers$$

The relationship is statistically significant ($P<0.001$). Total egg deposition for each egg bed is then estimated from the product of total spawning bed area, and egg density predicted from the average surface egg layer estimate.

At present no methods exist for adjusting surface survey data in most areas outside the major assessment regions except in a few locations such as Johnstone Strait (Statistical Areas 9-13) where some dive surveys have been conducted. These surveys indicated that no adjustments are required for the spawn widths in Johnstone Strait because widths are very narrow and were accurately assessed from the surface in this area (Schweigert and Haegele 1988a, b). Additional dive surveys still need to be conducted in other areas outside of the major assessment regions to develop width adjustments for the spawn pools in these locations.

Scuba Surveys

For Scuba surveys spawning bed lengths are determined by exploratory raking or snorkelling to define the limits of the areas of egg deposition. A systematic sampling regime is employed whereby transects are set across the egg bed perpendicular to shore at 350 m intervals. Corresponding spawning bed widths are estimated as the mean of all transect lengths within the spawning bed. Estimates of mean egg density are based on a two-stage sampling design (Schweigert et al. 1985, 1990). Average egg density for each spawning area is estimated as the weighted mean of the means of a series of quadrats located along each transect. For each quadrat, observations are made on several variables: type of algal substrate; proportion of the quadrat covered by each algal type; number of layers of eggs on each algal type; proportion of the bottom substrate covered by eggs; and an estimate of the number of egg layers on the bottom substrate. In some areas, assessments are also made of the egg deposition on the giant kelp as described in a following section.

Egg deposition for each sampling quadrat is estimated from the predictive equation described in the 1989 assessment (Haist and Schweigert 1990, Schweigert 1993). Egg density for each vegetation subfraction is estimated as follows:

$$Eggs_{ij} = 1033.6694\ L_{ij}^{0.7137}\ P_{ij}^{1.5076}\ V_{ij}\ Q_j.$$

where

$Eggs_{ij}$ = estimated number of eggs in thousands per m^2 on vegetation type i in quadrat j,
L_{ij} = number of layers of eggs on algal substrate i in quadrat j,
P_{ij} = proportion of quadrat covered by algal substrate i in quadrat j,
V_{1j} = 0.9948 parameter for sea grasses in quadrat j,
V_{2j} = 1.2305 parameter for rockweed in quadrat j,
V_{3j} = 0.8378 parameter for flat kelp in quadrat j,

V_{4j} = 1.1583 parameter for other brown algae in quadrat *j*,
V_{5j} = 0.9824 parameter for leafy red and green algae in quadrat *j*,
V_{6j} = 1.0000 parameter for stringy red algae in quadrat *j*,
Q_1 = 0.5668 parameter for 1.00 m^2 quadrats,
Q_2 = 0.5020 parameter for 0.50 m^2 quadrats,
Q_3 = 1.0000 parameter for 0.25 m^2 quadrats.

Total egg density (thousands of eggs per m^2) for each quadrat is then estimated by summing the egg density estimates over the vegetation types,

$$Eggs_j = \sum_i eggs_{ij}.$$

Eggs on Bottom and *Macrocystis*

Eggs on rock are estimated from the product of the proportion of the quadrat covered by eggs, number of egg layers, and 340,000 eggs/m^2 (Haegele *et al*. 1979). Eggs on rock also includes eggs on other inorganic substrata as well as egg deposition on very short (1-2 cm) red algae, calcareous encrusting algae, worm tubes, logs, etc. Total egg density for each quadrat is the sum of eggs on vegetation plus eggs on rock.

In some northerly areas such as the Queen Charlotte Islands and the Prince Rupert District a significant proportion of the total egg deposition can occur on the giant kelp, *Macrocystis* sp., with smaller amounts in some localities on the central coast and west coast of Vancouver Island. The approach we have adopted for routine Scuba surveys follows that outlined by Haegele and Schweigert (1985). The Scuba transects which are used to assess egg density on understorey vegetation are also used to enumerate *Macrocystis* plants and fronds within 1 m on either side of the transect line. An egg prediction equation has been developed (Haegele and Schweigert 1990) to estimate egg numbers for an individual plant:

$$Eggs/Plant = 0.073\ Layers^{0.673}\ Height^{0.932}\ Fronds^{0.703}$$

where

Eggs/Plant = total number of eggs on the *Macrocystis* plant in millions,
Layers = average number of egg layers on each *Macrocystis* plant,
Height = total height of the *Macrocystis* plant in metres,
Fronds = total number of fronds per *Macrocystis* plant.

This equation estimates the number of eggs occurring on a plant of a specific height with a certain number of fronds and egg layers. In practice, the synoptic Scuba survey estimates only the average number of egg layers per plant, the average plant height, and the average number of fronds per plant along each transect. These quantities are used in the above equation to estimate the total egg numbers per plant for each transect. These estimates are averaged across transects to obtain an average number of eggs per plant for the entire *Macrocystis* bed.

This information may then be combined with the estimate of the density of plants and the estimated area of the *Macrocystis* bed to obtain an estimate of the total number of eggs deposited on the kelp:

$$\textit{Total Eggs on Macrocystis} = \textit{Eggs Plant}^{-1} \cdot \textit{Plants m}^{-2}$$

This egg deposition is then added to the estimated eggs on the understorey vegetation to determine a total egg deposition for that spawn pool.

Enumerated Egg Samples

Beginning in 1988 samples of algae and the attached eggs from entire quadrats were collected and processed to evaluate model predictions of egg density relative to sample egg counts. Due to funding shortfalls, no samples have been collected since 1997 and model predictions of egg numbers per sample quadrat are assumed to be unbiased for use in the assessment of egg density.

Abundance Forecasts and Survival Estimates

The escapement model forecasts abundance of returning adult spawners by applying an apparent survival rate to the estimate of spawning escapement in the most recent year. Mean age-specific apparent survival rates were introduced in 1991 to adjust for apparent under-forecasting of returning adults based on their abundance in the previous year's escapement due to partial recruitment of younger age-classes and other factors.

Several estimates of the instantaneous natural mortality rate are available for British Columbia herring. Tester (1955) estimated the age-specific mortality for the Strait of Georgia (0.45 to 0.79) and west coast of Vancouver Island (0.43 to 1.14) for ages 3^+ to 6^+. Taylor (1964) reported a natural mortality rate of 0.55 for ages 5^+ to 8^+ for Barkley Sound samples taken from unfished stocks. Schweigert and Hourston (1980) estimated natural mortality at 0.36 from Barkley Sound catch and effort data during 1954 to 1967 for ages 2^+ to 4^+. Since the spawning herring stocks currently consist mostly of ages 2^+ to 7^+ we used an instantaneous natural mortality of 0.45, implying an annual survival rate of 64 percent, in forecasting the number of returning adults (3^+ and older fish) prior to the 1991 assessment. Subsequently, we have used the ratio of the estimated number of returning fish at age this year relative to the estimated escapement at the previous age last year to provide an estimate of the apparent age-specific survival rate:

$$A_{ij} = \frac{E_{ij} + O_{ij}}{E_{i-1,j-1}}$$

where

A_{ij} = apparent survival of age j fish in season i,
E_{ij} = estimated number of spawning fish at age j in season i,
O_{ij} = estimated number of age j fish in the catch in season i.

Comparison of the estimated numbers of returning fish at age with the escapement estimate the previous year indicated a tendency to underestimate recruitment and led to the adoption of the apparent survival rate. The apparent age-specific survival rate includes not only the effect of survival, but also factors such as: biases in estimates of the spawning stock, partial recruitment of the younger age classes, and inconsistencies in the age composition data. To ensure that forecasts of stock abundance are consistent with the observed data the geometric means of the age-specific apparent survivals for each stock assessment region were re-calculated for the entire 1971-1999 roe period (Table 2.1) and are used to forecast 2001 abundance.

Table 2.1. Geometric mean age-specific apparent survival estimated for each stock assessment region over the roe fishery period, 1971-1999.

	Age Class				
Assessment Region	2^+-3^+	3^+-4^+	4^+-5^+	5^+-6^+	6^+-7^{++}
Queen Charlotte Is.	1.47	1.17	1.01	0.89	0.55
Prince Rupert	1.26	1.21	1.06	0.87	0.55
Central Coast	1.52	1.31	1.16	1.00	0.69
Georgia Strait	0.83	0.69	0.60	0.57	0.42
W.C. Vancouver Is.	1.05	0.85	0.80	0.74	0.47

Hence, the equation used to forecast the tonnage of herring expected to return in the coming season is:

$$B_{i+1,j+1} = N_{ij} A_{ij} W_{i+1,j}$$

where

$B_{i+1,j+1}$ = forecast tonnes of mature biomass at age $i+1$ in year $j+1$,
N_{ij} = number of fish at age i in the escapement in year j, estimated from $B_{i,j}/W_{i,j}$.
A_{ij} = estimated apparent survival rate of fish at age i in year j,
$W_{i+1,j}$ = observed average weight at age $i+1$ in year j.

Forecasts of mature biomass for each stock assessment region based on this analysis are presented in Section 4.

2.3 RESULTS

Estimates of historical and current year stock abundance and total catch for the major stock assessment regions are presented in Tables 2.2 and 2.3. Similar estimates for the minor stocks in Areas 2W and 27 are presented in Table 2.4 and discussed in Section 4.

Table 2.2. Estimates of spawning stock biomass, catch, and total pre-fishery abundance (tonnes) for the northern stock assessment regions for 1971-2000.

	Queen Charlotte Islands			Prince Rupert District			Central Coast		
Season	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock
1970/71	13616	102	13718	9751	3500	13252	6056	3615	9671
1971/72	9951	3972	13923	9852	4494	14346	3928	9279	13207
1972/73	7706	7520	15226	11260	1607	12867	14471	7799	22270
1973/74	9903	6192	16222	8893	3819	12712	10624	8887	19511
1974/75	8951	7724	16675	11109	1702	12811	9165	8739	17903
1975/76	15143	14116	29258	14213	4307	18520	16134	12411	28545
1976/77	12516	12635	25151	9736	8142	17877	18481	11106	29587
1977/78	11452	11726	23177	4738	8588	13325	10097	14046	24143
1978/79	8657	7953	16610	7554	4317	11871	6550	5	6555
1979/80	21204	3316	24520	10236	3425	13661	15978	538	16517
1980/81	19023	5631	24654	10532	3090	13622	16949	2573	19522
1981/82	19009	3778	22788	12631	1984	14616	18412	6370	24782
1982/83	19082	5597	24679	19653	0	19653	16618	5640	22258
1983/84	20438	4647	25084	22927	3706	26633	14197	7171	21368
1984/85	14393	6109	20501	35858	6747	42605	8480	5209	13689
1985/86	5636	3503	9140	32526	8679	41205	15534	3386	18920
1986/87	13132	2061	15193	31422	6271	37693	12992	3615	16607
1987/88	14456	32	14488	33680	7968	41647	27018	4527	31544
1988/89	23986	1461	25448	12783	8474	21257	32335	9442	41776
1989/90	25011	7801	32812	19398	5505	24903	31048	8805	39853
1990/91	14220	5530	19750	21544	4326	25869	20155	9357	29512
1991/92	9500	3612	13112	35992	5993	41984	46038	8756	54795
1992/93	5405	3951	9356	21440	7177	28617	39713	11060	50773
1993/94	4895	1387	6282	13439	5413	18852	29781	12332	42113
1994/95	4946	0	4946	15858	2877	18735	18918	10307	29225
1995/96	5827	0	5827	22104	4178	26282	17941	5209	23150
1996/97	11686	273	11959	20744	6542	27286	25208	4806	30011
1997/98	18871	2100	20971	16734	4218	20952	29386	9965	39351
1998/99	9714	3792	13506	25699	3114	28813	28924	8738	37662
1999/00	5119	2674	7793	15658	5316	20974	23811	8640	32451

Table 2.3. Estimates of spawning stock biomass, catch, and pre-fishery stock abundance (tonnes) for the southern stock assessment regions from 1971-2000.

	Strait of Georgia			W.C. Vancouver Island		
Season	Spawners	Catch	Stock	Spawners	Catch	Stock
1970/71	47312	1694	49005	32476	0	32476
1971/72	25875	8811	34686	36069	6894	42963
1972/73	18255	7649	25903	16219	18303	34522
1973/74	64619	4004	68622	24775	16334	41110
1974/75	76692	6179	82871	44594	26109	70703
1975/76	57133	12235	69368	63335	38825	102160
1976/77	58003	17509	75512	57398	30043	87441
1977/78	97082	24002	121084	39931	22745	62676
1978/79	59041	20337	79378	63663	18694	82357
1979/80	74848	5818	80666	62619	3982	66601
1980/81	48230	12052	60282	58518	8090	66608
1981/82	90239	12833	103072	29424	5486	34911
1982/83	47423	17218	64641	15329	8575	23904
1983/84	27587	11035	38622	22142	6577	28719
1984/85	26629	7030	33659	29132	178	29310
1985/86	61097	594	61690	38347	204	38551
1986/87	39037	9353	48390	29915	15934	45849
1987/88	25351	8215	33566	39289	9724	49013
1988/89	54078	8369	62447	43331	13289	56620
1989/90	58912	8119	67031	38337	10121	48458
1990/91	43421	11103	54524	25907	8906	34813
1991/92	80122	13419	93541	36811	3986	40797
1992/93	84961	13741	98702	29237	5884	35122
1993/94	60862	17650	78512	19764	6310	26075
1994/95	59708	13190	72897	25039	2586	27625
1995/96	76291	14113	90404	31929	1516	33445
1996/97	53442	16571	69266	39114	7383	46497
1997/98	68669	13604	82303	36898	7363	44261
1998/99	70165	13285	83450	18829	4824	23653
1999/00	67694	15203	82897	10940	1990	12930

Table 2.4. Estimates of spawning stock biomass, catch , and pre-fishery stock abundance (tonnes) for the minor stocks in areas 2W and 27 for 1971-2000.

	Area 2W*			Area 27		
Season	Spawners	Catch	Stock	Spawners	Catch	Stocks
1970/71	655	0	655	356	0	356
1971/72	1026	0	1026	333	0	333
1972/73	1782	706	2488	2293	0	2293
1973/74	1705	403	2109	0	526	526
1974/75	1446	449	1895	1409	0	1409
1975/76	1066	0	1066	227	79	306
1976/77	1228	0	1228	568	0	568
1977/78	1898	575	2472	3016	150	3166
1978/79	547	691	1237	6067	693	6760
1979/80	2658	0	2658	12094	519	12613
1980/81	2016	770	2786	1683	671	2354
1981/82	6348	1225	7573	3452	571	4023
1982/83	6120	2518	8638	2256	163	2419
1983/84	2552	0	2552	2520	171	2690
1984/85	1544	199	1743	1408	0	1408
1985/86	649	0	649	3772	0	3772
1986/87	757	0	757	2643	0	2643
1987/88	3202	0	3202	1518	0	1518
1988/89	3696	0	3696	3835	0	3835
1989/90	10487	2272	12759	4645	245	4890
1990/91	2789	2558	5347	3277	245	3522
1991/92	3564	1284	4848	2682	539	3221
1992/93	88	1307	1395	5216	707	5923
1993/94	193	0	193	3120	708	3828
1994/95	0	0	0	2014	542	2556
1995/96	0	0	0	1501	363	1864
1996/97	0	0	0	1598	273	1871
1997/98	372	180	552	1732	273	2005
1998/99	0	0	0	564	273	837
1999/00	290	0	290	967	273	1240

*- No estimates of stock biomass are available in area 2W for 1995-97 and 1999. Spawning activity was observed in the area but no surveys were conducted or surveys did not detect spawn.

3. AGE-STRUCTURED MODEL

3.1. INTRODUCTION

An age-structured model, based on the error structure suggested by Fournier and Archibald (1982), has been used to assess B.C. herring stocks since 1982. Ongoing revisions to the model have made it more consistent with the life history of herring and the fisheries that are analyzed. The current version uses auxiliary information in the form of spawning escapement data, separates catch and age composition data by gear type, and includes availability parameters to estimate partial recruitment to the spawning stock. Model parameters are estimated simultaneously using a maximum likelihood method. The model formulation used this year is the same as that used beginning with the 1994 assessment (Schweigert and Fort 1994). The model uses escapement model estimates of spawning stock biomass as the abundance or spawn index for parameter estimation. The model is implemented in the C^{++} programming language using AD model builder software (Otter Research Ltd, 1996) for derivative calculations replacing the AUTODIF version used in earlier assessments. A comparison of abundance estimates from the two implementations of the age-structured model was presented in the 1997 assessment.

3.2. METHODS

<u>The Population Model</u>

Two types of fishing gear are used commonly in B.C. herring fisheries. Seine nets are assumed to be non-selective while gillnets are selective for larger, older fish. Herring fisheries have concentrated primarily on fish which are on, or migrating to the spawning grounds. Therefore, the relative availability of age classes to non-selective gear should be equivalent to the partial recruitment of age classes to the spawning stock. The age-structured model explicitly separates availability (partial recruitment) and gear selectivity. Seine and gillnet fisheries are temporally separate so catch and age-composition are partitioned into fishing periods, separating data for the different gears. Three fishing periods are modelled. The first period encompasses all catch prior to the spring roe herring fisheries. This includes 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 were caught with trawl nets (which are also assumed to be non-size selective). The second fishing period includes all seine roe herring catch and the third period includes all gillnet roe herring catch.

Let T_{ij} be the total number of fish in age class *j* at the beginning of season *i*, where season is equivalent to year, and $\mathbf{l}_{ij}$ 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

$$N_{ij1} = \mathbf{l}_{ij} T_{ij} \text{, where } 0 \langle \mathbf{l}_{ij} \langle 1 \qquad 3.1$$

To model the fishing process a form of the catch equations which models fishing and natural mortality as continuous processes over time period r, is used:

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

and, for $r < p$

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

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=49),
k	is the number of age classes (k=9).

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

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

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

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

To reduce the number of parameters to be estimated assumptions are made about the form of the availabilities and mortalities. The availabilities are formulated to increase with age and are set to 1 for age 6+ and older. For age 3+ to 5+ the availabilities are constant between years, that is,

$$\lambda_{ij} = \lambda_{\bullet j},$$

The proportion of age 2^+ fish which are mature appears to vary among years (Haist and Stocker 1985) and some reduction fisheries targeted on immature 1^+ fish. Therefore, the availabilities for these two age classes are estimated for each year for which there is age-composition data with the exception of the final year. In the final year the availabilities for age 1+ and 2+ fish are set equal to the average over all years in the time series.

For the selective gillnet fishery (i.e. fishing period 3), fishing mortality is separated into age selectivity and fishing intensity components. Following Doubleday (1976),

$$\ln\left(F_{ij3}\right) = a_{i3} + b_j \qquad 3.2a$$

where a_{i3} represents the general level of fishing mortality due to the gillnet fishery in season i, and b_j represents the relative selectivity of the gear for age-class j. The b_j are reparameterized such that age selectivity is modelled as a function of annual average weights-at-age. A modified logistic equation is used,

$$b_{ij} = \frac{1}{1+\exp(r - t\, g_{ij}^{w})}$$

where g_{ij} is $\log_e$ of the geometric mean weight-at-age j in year i. The b_{ij} replace the b_j in equation 3.2a.

For non-selective fisheries (i.e. fishing periods 1 and 2) only fishing intens ity parameters are estimated, that is

$$\ln\left(F_{ijr}\right) = a_{ir}\,.$$

As in last year's assessments a natural mortality parameter, $M_{\bullet}$, is estimated. A series of alternative assumptions about natural mortality were also investigated in the current assessment and are discussed in more detail in Section 6. It is assumed that most of the natural mortality occurs following spawning and over the course of the summer and early winter prior to the first fishery (period 1). Little or no natural mortality is assumed during the course of the roe fisheries (periods 2 and 3) which occur over a roughly 2 week period at the end of the year. Hence, various proportions of the annual natural mortality for the three fishing periods is modelled as,

$$M_1 = 0.95M_{\bullet}$$
$$M_2 = M_3 = 0.025M_{\bullet}$$

Additional structure is built into the model through the inclusion of annual spawn data (spawn index, I_i). Spawning occurs at the end of the season so the number of spawners at age j in season i (G_{ij}) is estimated by

$$G_{ij} = N_{ijp} \exp\left(-F_{ijp} - M_r\right) \qquad \text{where } j>1$$

and the spawning stock biomass, which is assumed to be equivalent to egg production, in season $i, (R_i)$ is

$$R_i = \sum_j w_{ij} G_{ij},$$

where w_{ij} is the average weight-at-age j in season i. The error in the spawn index observations (I_i) are assumed to be 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_1^2. For the model described above the parameters to be estimated are:

T_{i1}, for all seasons i,
T_{ij}, for age classes 1+ to k,
$\lambda_j^\bullet$, for age classes 3+ to 5+,
λ_{ij}, for age classes 1+ and 2+, for seasons 1 to n-1,
α_{ir}, for all fisheries I, r,
$\rho, \tau, \omega, M_\bullet$ and q.

The $\lambda_j^\bullet$ and λ_{ij} are parameterized to constrain their values between 0 and 1. The parameter σ_1^2 is not estimated in the reconstructions, but is fixed 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,
I_i, the estimated escapement biomass or spawn index in season i,
w_{ij}, the mean weight-at-age j in season i,
g_{ij}, the $\log_e$ of the geometric mean weight-at-age j in season i.

The error structure suggested by Fournier and Archibald (1982) for the observations S_{ijr} and O_{ir} is used:

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

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

That is,

$$O_{ir} = C_{ir} \exp\left(x_i\right),$$

where C_{ir} is the actual number of fish caught in period j in season i ($C_{ir} = \sum_j C_{ijr}$) and the x_i are independent normally distributed random variables with mean 0 and variance s_3^2.

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

Given these stochastic assumptions, the log-likelihood function (ignoring the constant term), for the parameters P_{ijr} $\left(P_{ijr} = C_{ijr} / C_{ir}\right), C_{ir}$, and s_3^2 is

$$\sum_{ijr} S_{ijr} \ln\left(P_{ijr}\right) - \sum_{ir} \frac{\left(\ln(O_{ir}) - \ln(C_{ir})\right)^2}{2\, s_3^2} \qquad 3.5$$

The assumption of log-normal measurement error in the observed spawn-actual spawn relationship introduces the following contribution to the log-likelihood function:

$$- \sum_{i} \frac{\left(\ln(I_i) - \ln(q\, R_i)\right)^2}{2\, s_1^2} \qquad 3.6$$

The w_{ij} and g_{ij} are assumed to be estimated without error.

The objective function described above (eqn. 3.5 & 3.6) incorporates measurement error in the proportion at age data, the total catch data and the spawn index data, with the relative magnitude of the errors related through the variance terms s_1^2, s_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 these observations, with the exception of scaling the S_{ijr}, the variance terms are not estimated but are held at fixed values. The following variances are assumed:

$$s_1^2 = 0.05,$$
$$s_3^2 = 0.0025,$$

These correspond to approximately a 4% average error in estimating the total number of fish caught and an 18% average error in spawn index observations.

The actual number of fish aged could be used in the objective function, however, this may not give a realistic estimate of the precision of the proportion-at-age data. That is, the biological samples obtained may not reflect a homogeneous population. The among-load (i.e.

samples from different catching vessels) variability in age composition is significantly different among years, and this is related more to the spatial and temporal distribution of the fisheries than to the number of loads sampled or total fish aged. Therefore, the information in the subsamples (between load samples), which are pooled to obtain an estimate of the age composition for a given fishery, is used to scale the S_{ijr}.

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

$$\mathbf{s}^2_{\hat{p}_j} = \frac{p_j\left(1 - p_j\right)}{S}$$

where p_j is the true proportion at age j. An estimate of the variance of $\hat{p}_j$ is:

$$s^2_{\hat{p}_j} = \frac{\sum_k \left(p_{jk} - \hat{p}_j\right)^2}{K - 1}$$

where p_{jk} is the proportion at age j in sub-sample k and K is the number of subsamples. This among sub-sample variance results from the variance generated by randomly sampling an individual catch plus the variance in the true proportion at age among vessel catches. Using $\hat{p}_j$ as the best estimate for p_j the theoretical sample size (S') which would generate the observed variance at age j is:

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

These theoretical sample sizes, calculated from the among sample variance of age 3+ fish (Appendix Table 1), are used in the objective function.

To facilitate an assessment of the lack of model fit to the age composition data the standard deviates of the observed versus predicted proportions-at-age (Z_{ijr}) are calculated:

$$Z_{ijr} = \frac{S_{ijr} - \left(\sum_r S_{ijr}\right) P_{ijr}}{\sqrt{S_{ijr}\left(1 - \frac{S_{ijr}}{\sum_r S_{ijr}}\right)}}$$

The contribution to the objective function from the lack of fit for the age composition data for a fishery in period r in season i is:

$$V_{ir} = \sum_r S_{ijr} \ln P_{ijr} - \sum_r S_{ijr} \ln\left(\frac{S_{ijr}}{\sum_r S_{ijr}}\right)$$

The second term in this equation is a constant. Inclusion of this term allows comparison of the contribution to the lack of fit for the age composition data for each fishery. If the predicted and observed proportion at age data were identical, the V_{ir} would be zero.

Stock Forecasts

Forecasts of stock abundance for 2001 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 2000/01 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 2^+ for the 1951-2000 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 2^+ numbers.

Alternative assessments are also presented for various assumptions about age or time dependent changes in natural mortality. These assumptions are discussed in more detail in section 6 below.

Input data used for age-structured model analysis are shown in Appendix Tables 1.1 to 1.5 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. Beginning with the 1994 assessment the estimate of total egg deposition as determined by the escapement model is used as the spawn index. Estimates of numbers of fish at age from the age-structured model are presented in Appendix Tables 2.1 to 2.5 for all stock groupings.

4. STOCK TRENDS, FORECASTS AND POTENTIAL CATCH

4.1 STOCK TRENDS

Estimates of pre-fishery stock biomass over the period 1951 to 2000 from the age-structured (ASM) and escapement (ESM) models and for time varying M (RASM) are shown in Figures 4.1 and 4.2 for the five major coastal regions and for Area 27. Details pertaining to the implementation of the RASM are presented in Section 6.

For the Queen Charlotte Islands region the models indicate similar trends in stock biomass. However, the age-structured models suggests much higher peaks in abundance in the mid 1970s and the early 1980s resulting from good recruitment of the 1971, 1972 and 1977 year-classes. All models suggest a decrease in abundance from 1990 through 1995 with increasing abundance subsequently although the ESM and RASM suggest a decline beginning in 1998 and 1999, respectively. The 1993, 1994, and 1995 year classes all appear to be of average or above average abundance. The 1996 year-class poor while the recruiting 1997 year-class appears average accounting for 19% of the run. The strong 1995 year-class accounted for 59% of the spawning run. The estimates of 2000 mature biomass are 35,600, 18,200, and 7,800 tonnes from ASM, RASM, and ESM analyses, respectively.

Estimates of 2000 stock abundance for the Prince Rupert District assessment region are more consistent for the three models than in recent assessments (Fig. 4.1). All models indicate a decline in abundance from 1992 through 1995 with stable or slight decline in the last few years. The estimate of 2000 mature biomass is 41,100 tonnes from the ASM, 30,000 from the RASM, and 21,000 tonnes from the ESM, respectively. The dominant 1995 year-class comprises 28% of the stock. The 1994 and 1993 year-classes represent 12% and 17% of the run while the recruiting 1997 year-class accounted for 28% of the spawning biomass and appears to be above average.

Estimates of pre-fishery biomass for the Central Coast assessment region are very similar for all three models (Fig. 4.1). All models indicate increases in abundance since 1996 followed by slight declines since 1998. The predominant 1995 year-class of age 4^+ fish comprised 35% of the stock while the 1994 year-class accounted for 26% of the spawning run and the recruiting 1997 year-class another 19%. The 2000 mature biomass estimate from the ASM is 35,500, from the RASM is 41,900 and from the ESM is 32,100.

For the Strait of Georgia assessment region the pre-fishery stock trends estimated by the models are similar except for the last 3 years, with the ESM suggesting stable stock size and the age-structured models indicating a slight decline (Fig. 4.2). The 1995 year-class remains abundant contributing 22% of the stock while the 1996 year-class constituted 19% of the run. The recruiting 1997 year-class contributed another 38% of the total run and appears to be average or slightly better. The ASM estimate of pre-fishery abundance in 2000 is 56,700 tonnes, the RASM is 58,100 while the ESM estimate is 82,900 tonnes.

The pre-fishery biomass estimates for the west coast of Vancouver Island stock follow similar trends since the mid 1970s (Fig. 4.2). All models indicate a long-term decline in abundance since 1989 with a recent recovery through 1997 followed by declines the past three years. The 1994 year-class remains predominant in this stock comprising 27% of the run with the 1995 and 1996 year-classes adding 18 and 20% of the total run, respectively. The recruiting 1997 year-class accounts for 23% of the 2000 spawning run and appears to be poor. The ESM estimate of 2000 mature biomass is 12,900 tonnes while the ASM estimate is 16,700 tonnes and the RASM estimate is 22,500 tonnes.

The mature biomass estimate for Area 27 stocks was available only from the ESM and indicated that 1240 tonnes returned to this area during 2000. Although abundance estimates are erratic it appears that abundance has declined since 1993 (Fig. 4.2). The 1996 year-class comprised 47% of the run while the recruiting 1997 year-class accounted for 52% of the total run and appears of average strength or better.

In 2000 limited surveys of spawn deposition occurred in Area 2W. Small spawns in Kano Inlet accounted for 290 tonnes of stock. Only one biological sample was obtained from all of Area 2W and indicated an abundance of recruiting fish with the 1997 year-class accounting for 64% of the sample. The 1996 and 1998 year-classes of age 4+ and 1+ accounted for 18 and 15% of the sample, respectively.

4.2 STOCK FORECASTS AND POTENTIAL CATCH

Management Considerations

PSARC has reviewed the biological basis for target exploitation rate, considering both the priority of assuring conservation of the resource and allowing sustainable harvesting opportunities (Schweigert and Ware 1995). The review concluded that 20% is an appropriate exploitation rate for those stocks that are well above Cutoff or minimum spawning biomass threshold levels (PSARC 1995). 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 (Hall et al. 1988, Zheng et al. 1993). 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 = Forecast Run - Cutoff.

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

As described in the 1995 report, a bootstrap procedure was used to annually re-evaluate Cutoff levels for each major assessment region beginning in 1993/94. The bootstrap procedure relies on the recruitment estimates from the age-structured model (N_{i1}), to forecast recruitment and assumes the natural mortality rate estimated by the age-structured model for each area in the population simulations (Efron and Gong 1983). The average of 100 estimates of the mean of 200 years of simulated stock sizes was taken as the measure of the equilibrium unfished biomass. Cutoff levels were established at one-fourth the unfished average biomass. However, in 1995 the Subcommittee recommended that a fixed Cutoff level should be established for each stock based on the long-term production characteristics in relation to current environmental conditions and that this Cutoff level need not be re-evaluated on an annual basis. As a result, the Subcommittee fixed Cutoff at 1994/95 levels until the analyses of individual stock productivities could be completed. These Cutoff levels for the five major stocks are:

	1992/93 Cutoff[a]	1994/95 Cutoff	1996/97 Cutoff	**2000/01 Cutoff[c]**
Queen Charlotte Islands	11700	10700	10700	**10700**
Prince Rupert District[b]	12100	12100	12100	**12100**
Central Coast	10600	18800	17600	**17600**
Strait of Georgia	22100	21200	21200	**21200**
W.C. Vancouver Island	20300	18800	18800	**18800**

[a] – Cutoff level based on simulation model with stock-recruitment relationship, and two assessment areas on the WCVI.

[b] - Because of the poor performance of the age-structured model in this region in the past the Cutoff has not been recalculated using the bootstrap approach but is based on a stock-recruitment relationship.

[c] – A Cutoff of 14,000 tonnes was proposed for the Central Coast in 1998. Uncertainty about ASM performance in 1998 resulted in retention of the existing Cutoff.

In contrast to recent practice, a weighted forecast based on the ESM and ASM assessment models is not provided. Instead, independent forecasts of abundance from each model are provided for consideration by the review committee (Table 4.1).

Abundance Forecasts and Potential Catches

An accurate forecast of abundance for herring requires good estimates of the numbers of returning adults, growth rate of each age group over the year, and an estimate of upcoming recruitment. Prior to the 1990 assessment, the observed weight-at-age from the previous season was used as the best forecast of the weight-at-age for the coming year. Since 1990 forecast weights-at-age from a predictive equation were used in forecasting the mature biomass for the next season. Analyses conducted during 1998 indicate that weight-at-age has been declining for several years and that the equations used to forecast weights for the coming year were inflated (Tanasichuk and Schweigert 1998). As a result, the current assessment has reverted to using observed weights-at-age from the previous season as the best forecast of weight-at-age for the upcoming year. Figures 4.3 and 4.4 present cumulative probability distributions of forecast abundances for the three assessment models. The cumulative probability distributions are for the ESM and ASM models are plots of the expected run size in the coming year given the escapement last year, average growth and survival of this adult biomass and the addition of each of the historically observed recruiting year-classes to the projected adult biomass. In addition, Fig. 4.5 and 4.6 present the ASM and RASM or ESM estimates of historical recruitment of three year old fish to the spawning runs in each assessment region.

The forecast run size to the Queen Charlotte Islands in 2001 is 32,200 tonnes from the ASM, 15,000 tonnes from the RASM and 8,700 tonnes from the ESM assuming average recruitment (Table 4.1). This represents a decrease from the 2000 forecasts and reflects the low spawn deposition observed this year. The ESM forecast is below Cutoff for 2001 and would result in a closure to rebuild stock levels. Harvestable surpluses of 6,450 or 3,000 tonnes are projected from the ASM and RASM, respectively (Table 4.2). Indications are that the 1993-1995 year-classes are average or above average while the 1996 year-class is poor and the recruiting 1997 year-class is average (Fig. 4.5). The cumulative probability plots indicate that there is 80% probability of the 2001 run being below Cutoff based on the ESM forecasts whereas there is 0% probability of falling under Cutoff based on either ASM projection (Fig. 4.3).

The age-structured model assessments for the Prince Rupert District provide estimates of abundance which are more consistent with ESM estimates than recent assessments for this stock. The forecast run size of 38,500 tonnes based on the ASM is well above the 24,800 tonnes forecast by the RASM and the 23,100 tonnes forecast by the ESM (Table 4.1). Assuming an average recruitment level, a harvestable surplus of 7,690 tonnes (ASM) or 4,960 tonnes (RASM), or 4,630 tonnes (ESM) should be available for the Prince Rupert District in 2001 (Table 4.2). The 1993 to 1995 year-classes are average or above while the 1996 year-class was poor (Fig. 4.5). The recruiting 1997 year-class appears to be average or better. The projected stock abundances indicate that there is zero probability that the 2001 run will be less than the Cutoff level based on all three models (Fig. 4.3).

The forecast run size for the Central coast in 2001 with average recruitment is 34,300 tonnes based on the ASM, 29,000 tonnes (RASM), and 36,800 tonnes based on the ESM, levels slightly lower than the 2000 forecast (Table 4.1). The 1994 and 1995 year-classes are both above average followed by a poor 1996 year-class and an average 1997 year-class (Fig. 4.5). Nevertheless, the cumulative probability plots indicate that there is zero probability that the 2001 run will be below the Cutoff level based on any of the assessment models (Fig. 4.3). The forecast run sizes suggest a harvestable surplus of 6,860 tonnes (ASM), 5,810 tonnes (RASM), and 7,350 tonnes (ESM) should be available assuming average recruitment (Table 4.2).

The forecast run size to the Strait of Georgia in 2001 is 53,000 tonnes for the ASM, 54,600 tonnes (RASM), and 82,600 tonnes (ESM) assuming average recruitment, levels similar to 2000 (Table 4.1). The 1994 and 1995 year-classes are above average while the 1993 and 1996 year-classes were poor (Fig. 4.6). The recruiting 1997 year-class appears to be average. The projected stock abundances indicate that this stock remains well above the Cutoff level (Fig. 4.4). The projected abundances suggest a harvestable surplus of 10,590 tonnes (ASM), 10,920 tonnes (RASM), or 16,520 tonnes (ESM) (Table 4.2).

The run forecast to the west coast of Vancouver Island assessment region in 2001, assuming an average recruitment, is 27,400 tonnes based on the ASM, 21,100 tonnes (RASM), and 20,800 tonnes based on the ESM, which is moderately less than the forecast for 2000 (Table 4.1). While the 1994 year-class was above average, the 1995 and 1996 year-classes are poor to average and the recruiting 1997 year-class appears poor. The stock biomass projections for 2001 indicate that there is about a 40% probability of the run being below Cutoff based on the ASM and ESM while the RASM places this risk at 20% (Fig. 4.4). An average recruitment assumption for this stock yields a harvestable surplus of 5,480 tonnes (ASM), or 2,290 tonnes (RASM), and 1,990 tonnes (ESM). The latter two estimates are reduced from 20% harvest rates to maintain the forecast abundance at the Cutoff level (Table 4.2).

There is no forecast run size available for the minor stocks in Area 27. However, based on recent policy for this area the estimated pre-fishery biomass of 1240 tonnes permits a harvest of no more than 10% of the 2000 biomass in 2001. This suggests a maximum potential harvest of 124 tonnes for the area. Estimates of recent recruitments indicates good 1994 and 1995 year-classes followed by a poor 1996 year-class (Fig. 4.2, 4.6). However, the 1997 year-class also appears to be average or better.

Profile Likelihoods

The herring age-structured model is programmed with AD model builder software which provides a feature to estimate variation in any model parameters using Bayesian inference. One application of this procedure is to evaluate the posterior distribution of the forecast stock biomass from the age-structured model. In this analysis, model forecasts of pre-fishery biomass are calculated differently than shown in Table 4.1 where three levels of recruitment are added to the estimate of returning adult abundance. In determining the forecast biomass for the profile likelihood analysis, the estimate of numbers of fish at ages 2-9 in the current year is projected ahead to ages 3-10 in the forecast year assuming the average natural mortality rate, average availability, and current weight-at-age to estimate mature stock biomass. The estimated probability distributions of forecast 2001 biomass for the five assessment regions are presented in Figures 4.7 and 4.8. These profiles provide another perspective on expected stock levels in the forecast year given all the available data and projecting it forward without making assumptions about recruitment level and so suggest whether conditions are likely to be better or worse than average as is assumed for the assessments.

In the Queen Charlotte Islands the profile likelihood agrees very well with the ASM forecast of average recruitment suggesting that abundance in 2001 is well above that projected by the ESM. The likelihood model projects a run size of 30,700 with a 95% probability that abundance will be greater than 23,800 tonnes.

In the Prince Rupert District the profile likelihood is lower than the ASM and higher than the ESM indicating a projected lower than average recruitment. The likelihood model projects an abundance of 33,500 tonnes and that the run will exceed 28,000 tonnes with a 95% probability.

In the Central Coast the profile likelihood is slightly lower than projected by either the ASM or ESM suggesting that expected recruitment may be poorer than average. The most probable forecast biomass for this stock is 23,100 tonnes with a 95% probability that biomass will exceed 17,500 tonnes.

The profile likelihood for the Strait of Georgia also indicates a forecast abundance lower than projected by either assessment model. The most likely biomass level is 52,300 tonnes with an 95% probability that abundance will be greater than 42,400 tonnes.

Finally, the profile likelihood for the west coast of Vancouver Island indicates a most likely projected biomass of 15,800 tonnes with a 95% probability that 2001 run size will exceed 11,800 tonnes. It should also be noted that retrospective analyses for the two southern stocks have consistently indicated a tendency to under forecast abundance suggesting that for both the Strait of Georgia and west coast of Vancouver Island stocks these forecasts should be considered conservative..

Table 4.1. Summary of 2001 forecast spawning stock biomass (thousands of tonnes) from age-structured and escapement models and weighted runs for poor, average, and good age 2^+ recruitment levels.

	AGE-STRUCTURE				AGE-STRUCTURED –VAR M				ESCAPEMENT MODEL			
	Age 3^+	Age 2^+ Recruitment			Age 3^+	Age 2^+ Recruitment			Age 3^+	Age 2^+ Recruitment		
Assessment Regions	Older	Poor	Avg	Good	Older	Poor	Avg	Good	Older	Poor	Avg	Good
Queen Charlotte Islands	28.75	29.60	32.24	39.42	12.38	13.33	15.00	20.51	6.30	6.82	8.7	13.78
Prince Rupert District	33.29	34.93	38.46	49.85	19.76	21.28	24.79	35.27	18.88	20.17	23.15	32.21
Central Coast	28.94	31.75	34.30	46.81	24.69	26.33	29.05	37.35	32.24	33.87	36.76	47.33
Strait of Georgia	33.19	45.09	52.96	68.99	34.49	43.01	54.59	68.27	55.48	66.59	82.61	103.62
W.C. Vancouver Island	16.95	22.02	27.38	50.78	12.51	15.98	21.09	37.11	10.10	14.55	20.79	34.97

Table 4.2. Summary of 2001 Cutoff levels and forecast harvest surpluses given poor, average, and good age 2^+ recruitment for each of the assessment regions based on the ASM and ESM.

		Abundance Forecast			Cutoff	Potential Harvest		
Assessment Regions	Model	Poor	Avg	Good	Level	Poor	Avg	Good
Queen Charlotte Islands	ASM	29.60	32.24	39.42	10.70	5.92	6.45	7.88
	ASM – Var. M	13.33	15.00	20.51	10.70	2.63*	3.00	4.10
	ESM	6.82	8.70	13.78	10.70	0.00	0.00	2.76
Prince Rupert District	ASM	34.93	38.46	49.85	12.10	6.99	7.69	9.97
	ASM – Var. M	21.28	24.79	35.27	12.10	4.26	4.96	7.05
	ESM	20.17	23.15	32.21	12.10	4.03	4.63	6.44
Central Coast	ASM	31.75	34.30	46.81	17.60	6.35	6.86	9.36
	ASM – Var. M	26.33	29.05	37.35	17.60	5.27	5.81	7.47
	ESM	33.87	36.76	47.33	17.60	6.77	7.35	9.47
Strait of Georgia	ASM	45.09	52.96	68.99	21.20	9.02	10.59	13.80
	ASM – Var. M	43.01	54.59	68.27	21.20	8.60	10.92	13.65
	ESM	66.59	82.61	103.62	21.20	13.32	16.52	20.72
W.C. Vancouver Island	ASM	22.02	27.38	50.78	18.80	4.40	5.48	10.16
	ASM – Var. M	15.98	21.09	37.11	18.80	0.00	2.29*	7.42
	ESM	14.55	20.79	34.97	18.80	0.00	1.99*	6.99

* Harvest rate is the forecast-Cutoff to maintain stock at Cutoff level.

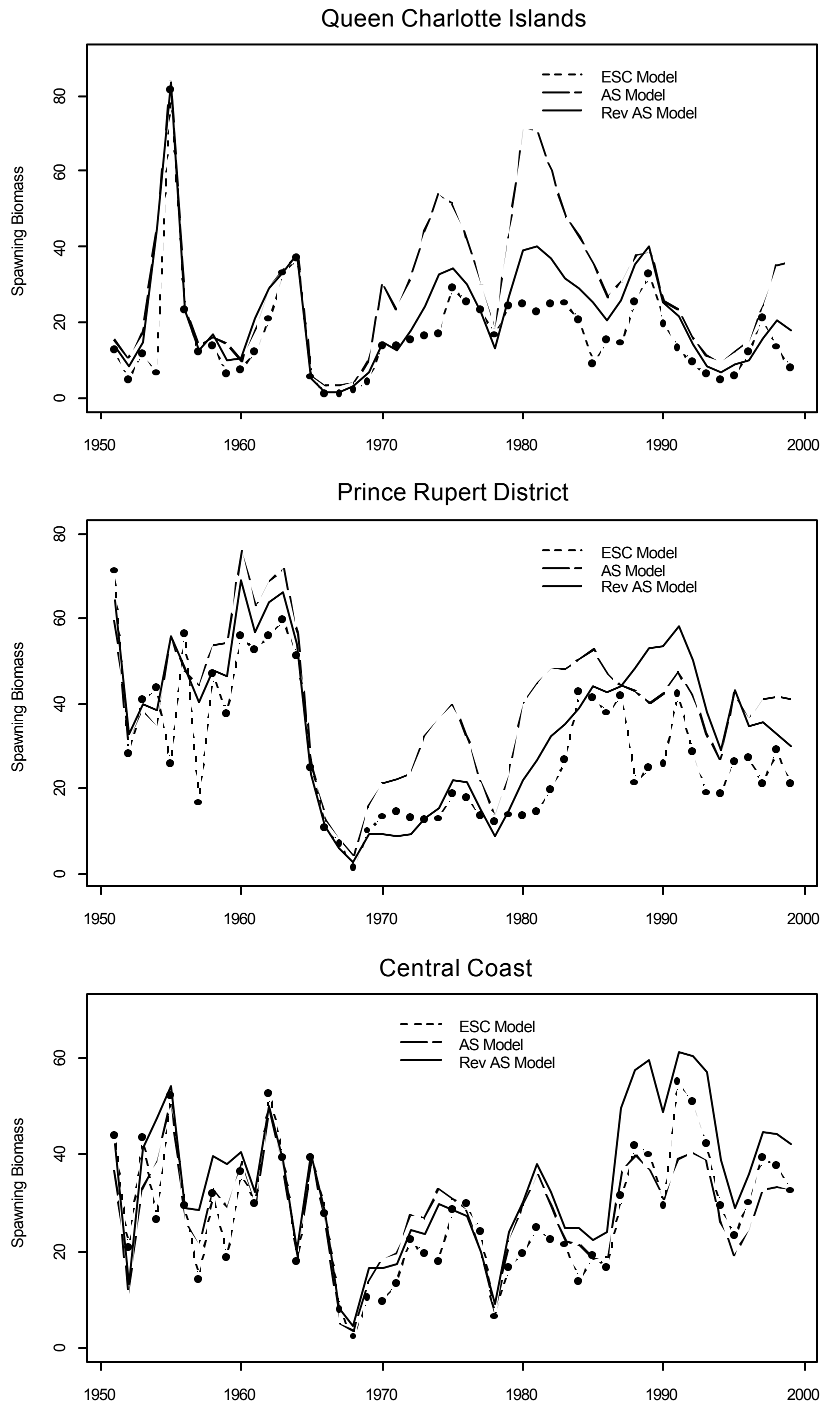


Fig. 4.1 Estimates of pre-fishery spawning stock biomass (tonnes x 1000) from age-structured (ASM and RASM) and escapement model (ESM) analyses for northern B.C. herring stock assessment regions, 1951-2000. Horizontal line indicates the Cutoff level for each stock.

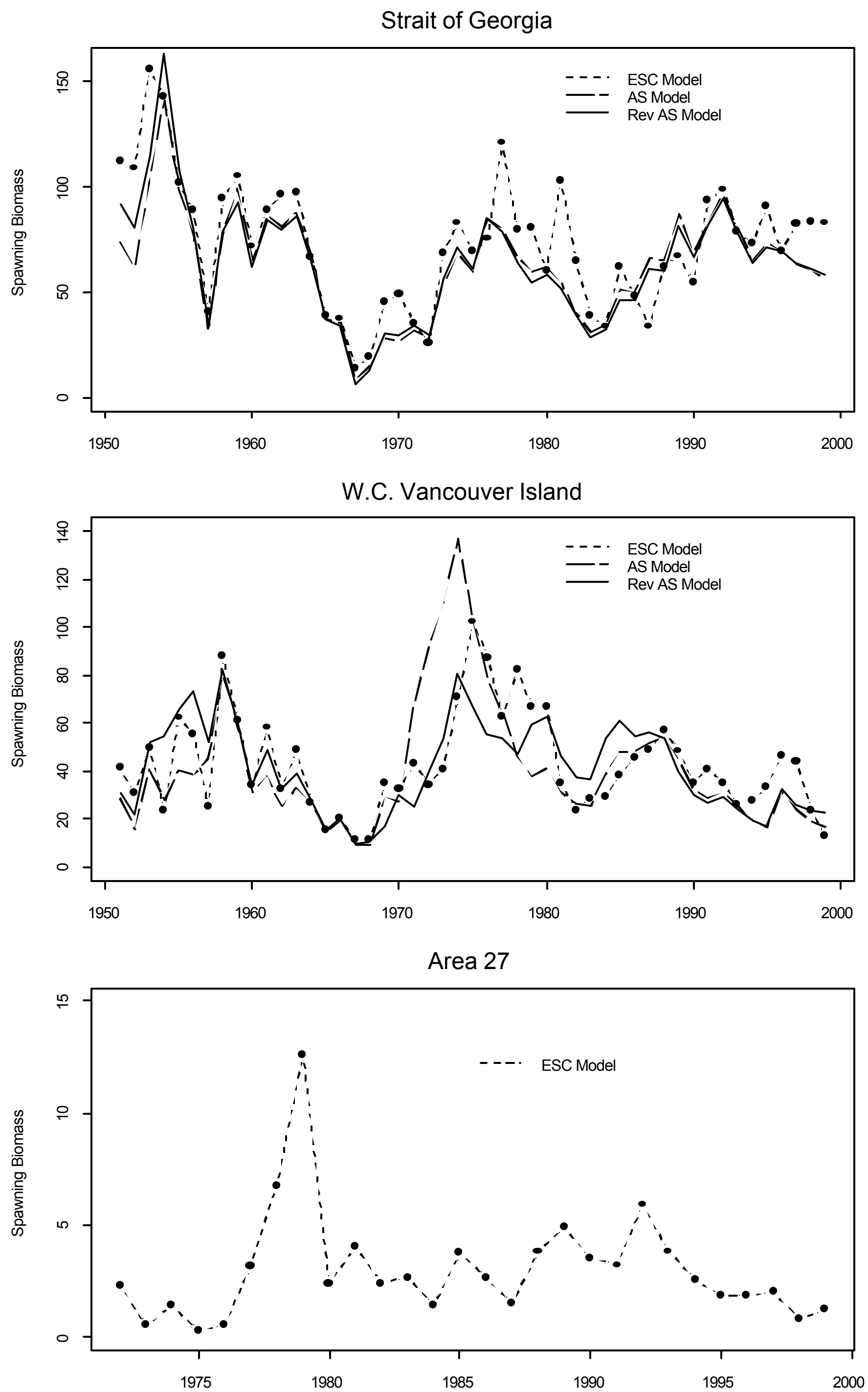


Fig. 4.2 Estimates of pre-fishery spawning stock biomass (tonnes x 1000) from age-structured (ASM and RASM) and escapement model (ESM) analyses for southern B.C. herring stock assessment regions and Area 27, 1951-2000. Horizontal line indicates the Cutoff level for each stock.

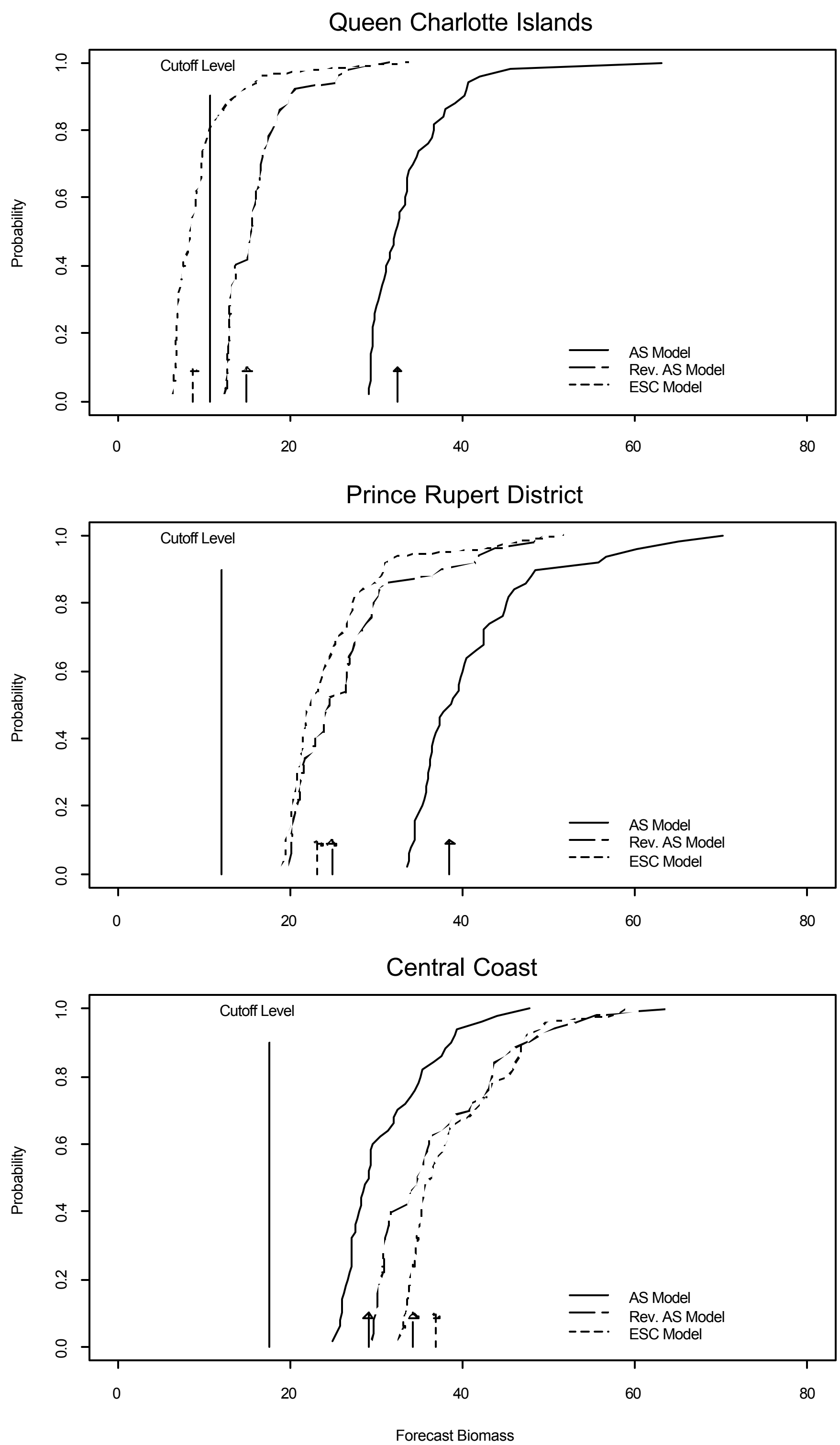


Fig. 4.3. Cumulative probability distributions of forecast spawning biomass for northern B.C. herring stock assessment regions in 2000. Arrows represent forecasts assuming average recruitment.

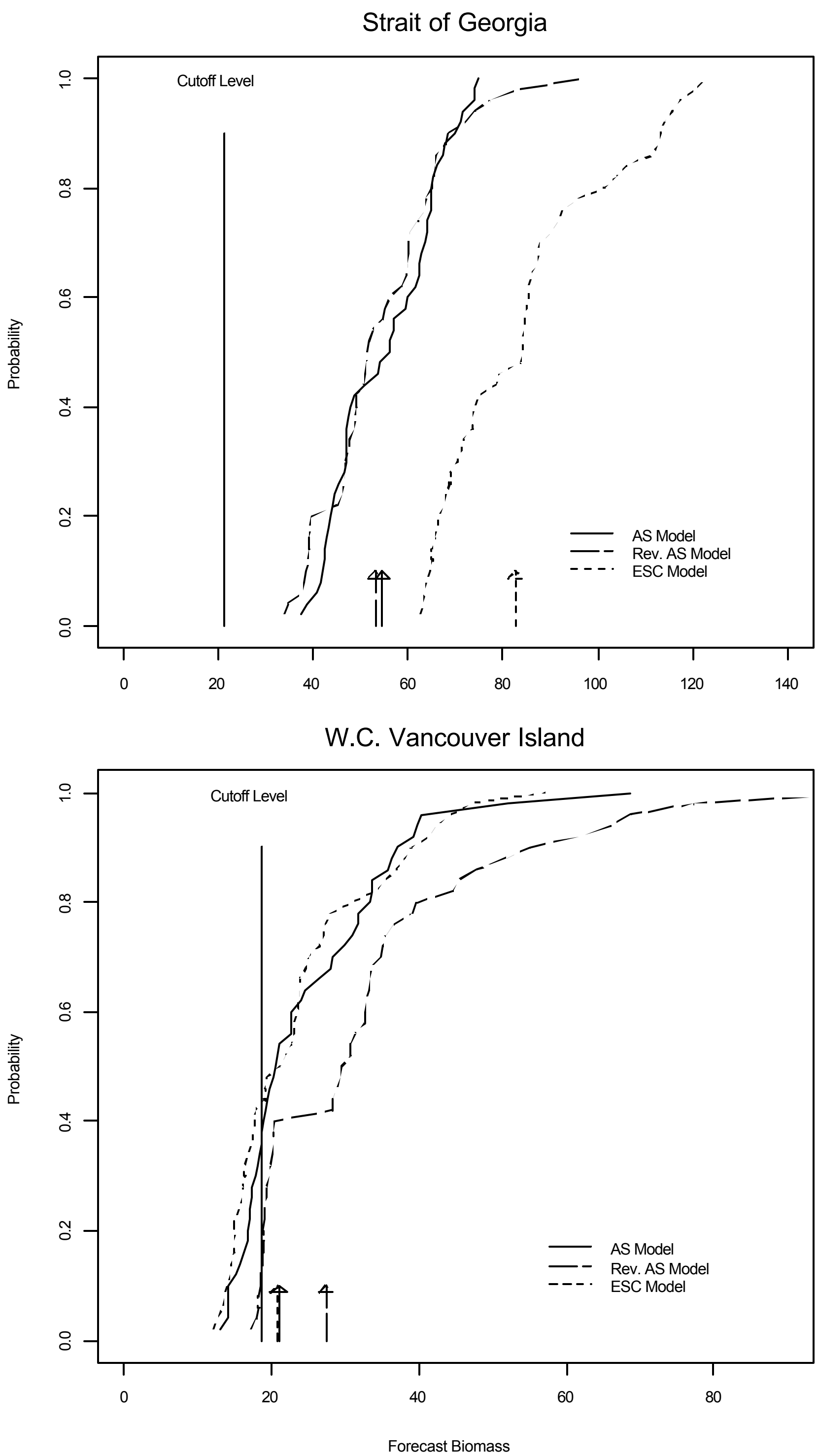


Fig. 4.4. Cumulative probability distributions of forecast spawning biomass for southern B.C. herring stock assessment regions in 2000. Arrows represent forecasts assuming average recruitment.

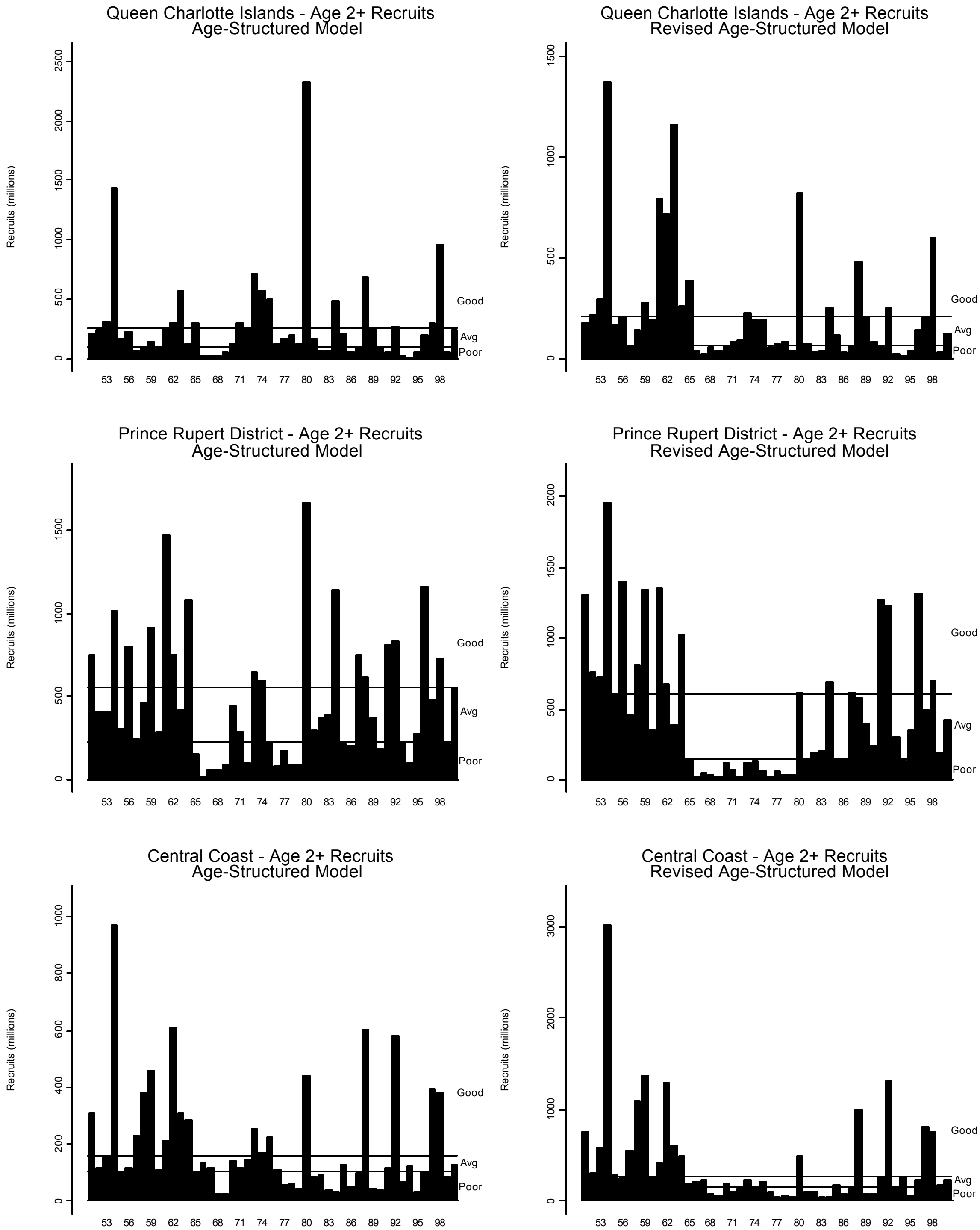


Fig. 4.5. Estimates of abundance of recruiting age 2^+ year-classes from age-structured analysis for northern B.C. herring stock assessment regions, 1951-2000. The horizontal lines delimit poor, average, and good recruitment categories and are the 33 and 66 percentiles of the cumulative frequency distribution.

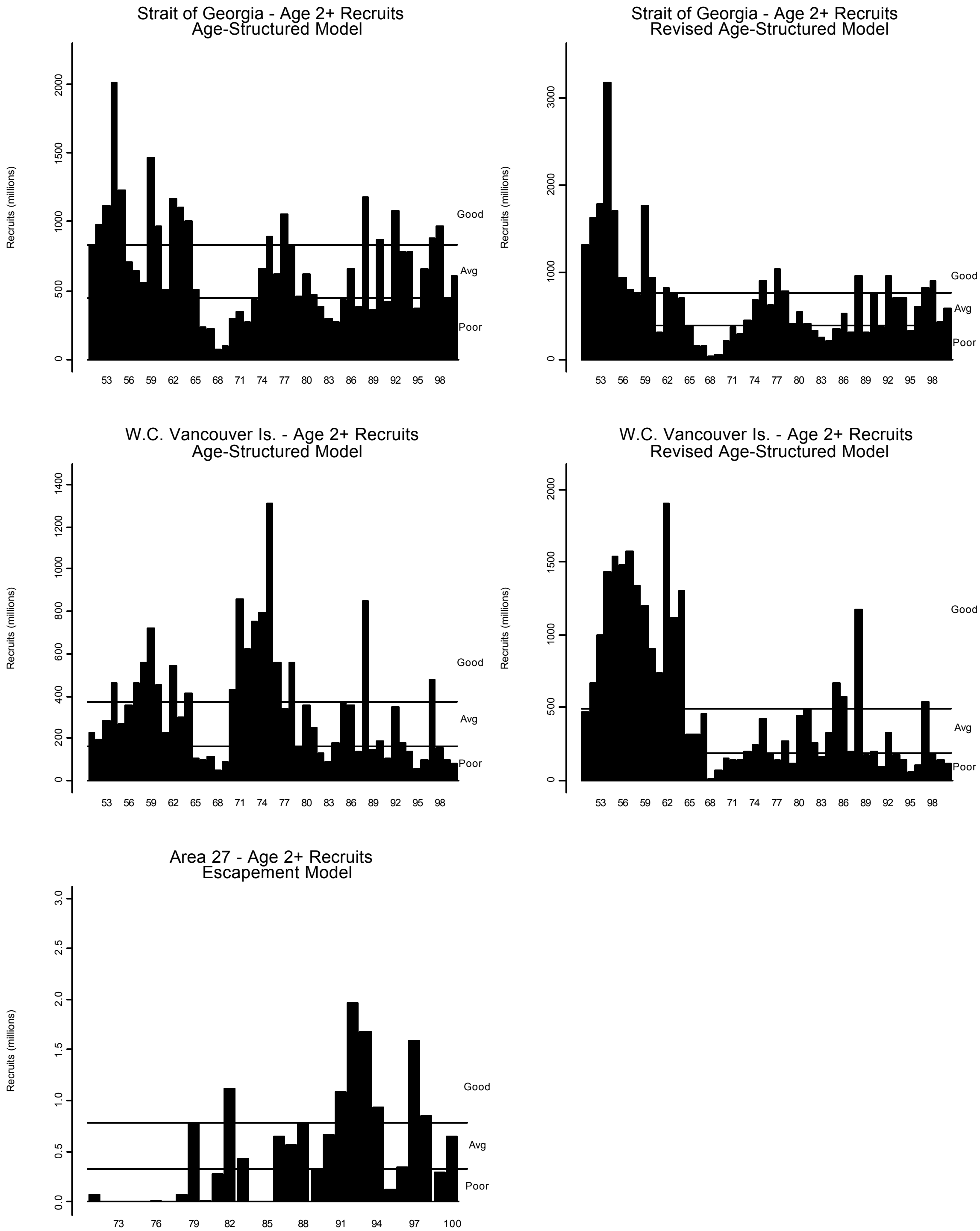


Fig. 4.6. Estimates of abundance of recruiting age 2^+ year-classes from age-structured analysis for southern B.C. herring stock assessment regions, 1951-1999 and for the minor stock in area 27 for 1972-2000. The horizontal lines delimit poor, average, and good recruitment categories and are the 33 and 66 percentiles of the cumulative frequency distribution.

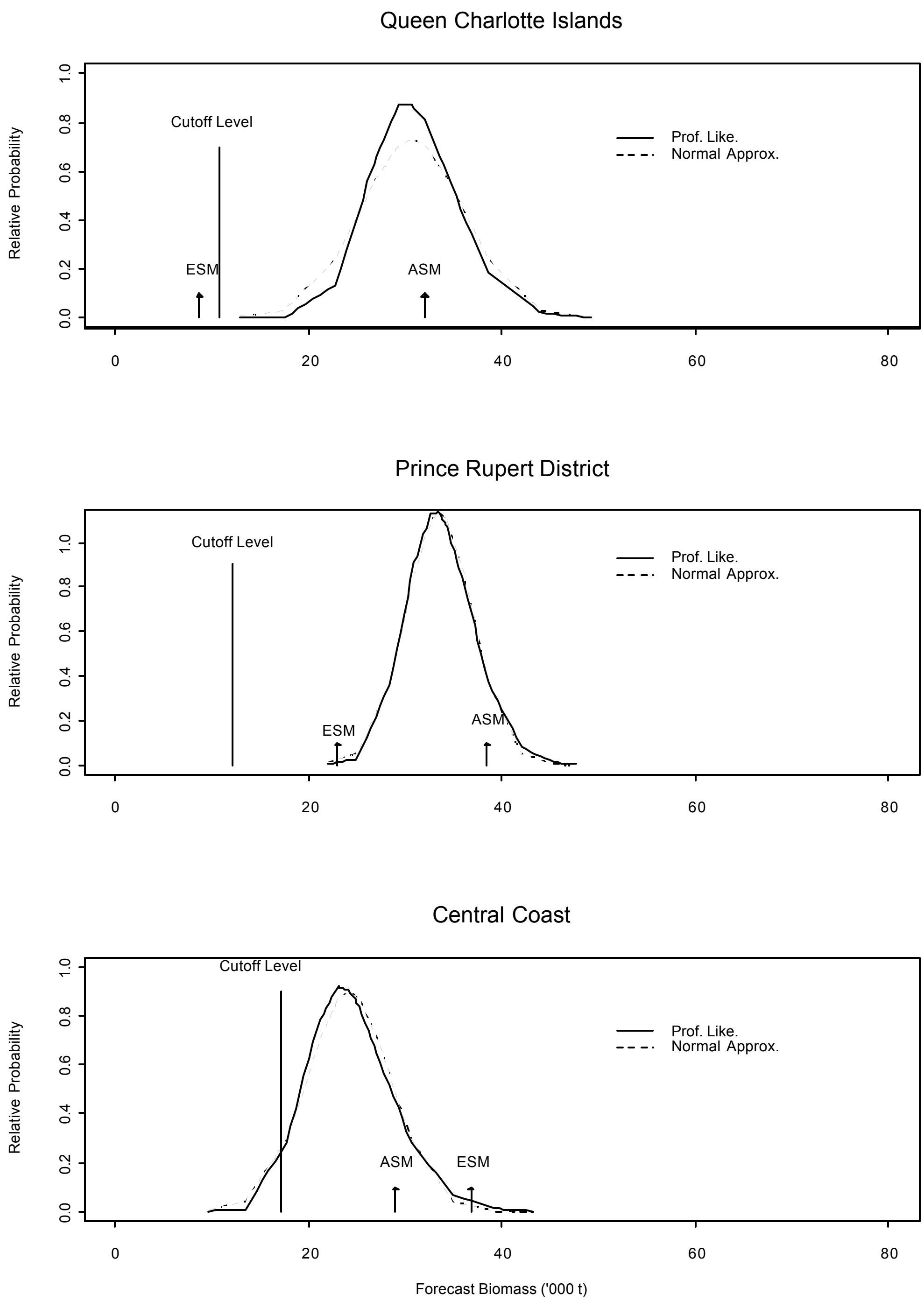
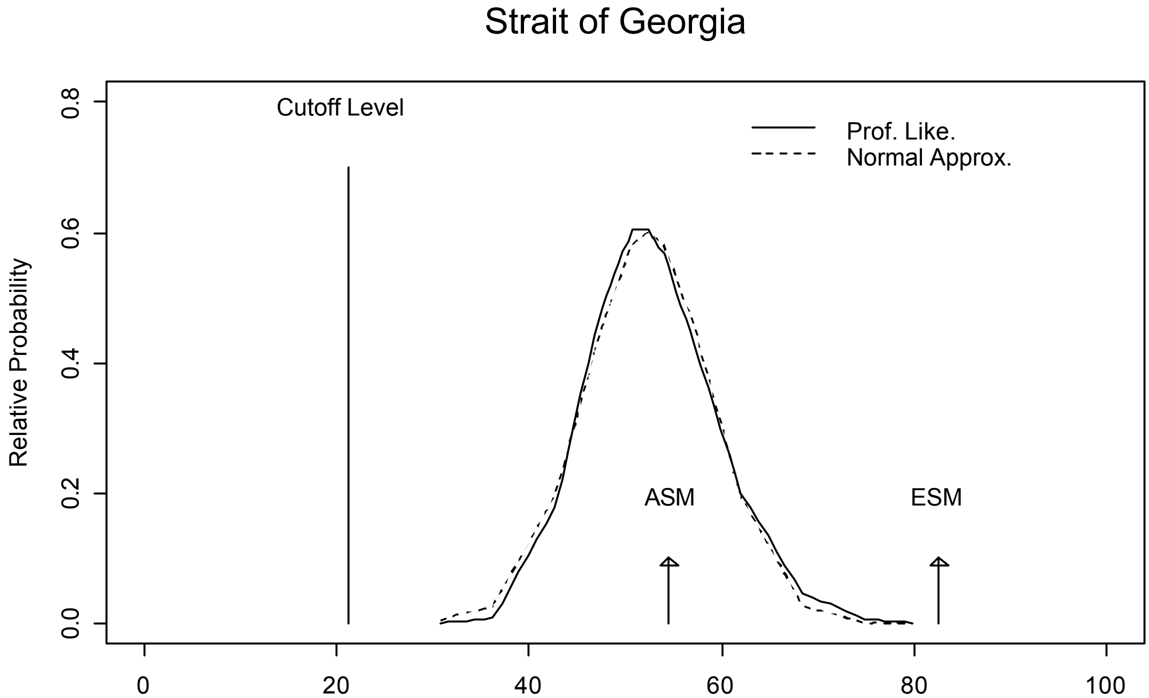


Fig. 4.7. Estimated Bayesian profile likelihood distributions and their normal approximations for the forecast 2000 mature biomass in the northern stock assessment regions. The arrows denote the forecasts assuming average recruitment for escapement and age-structured models.



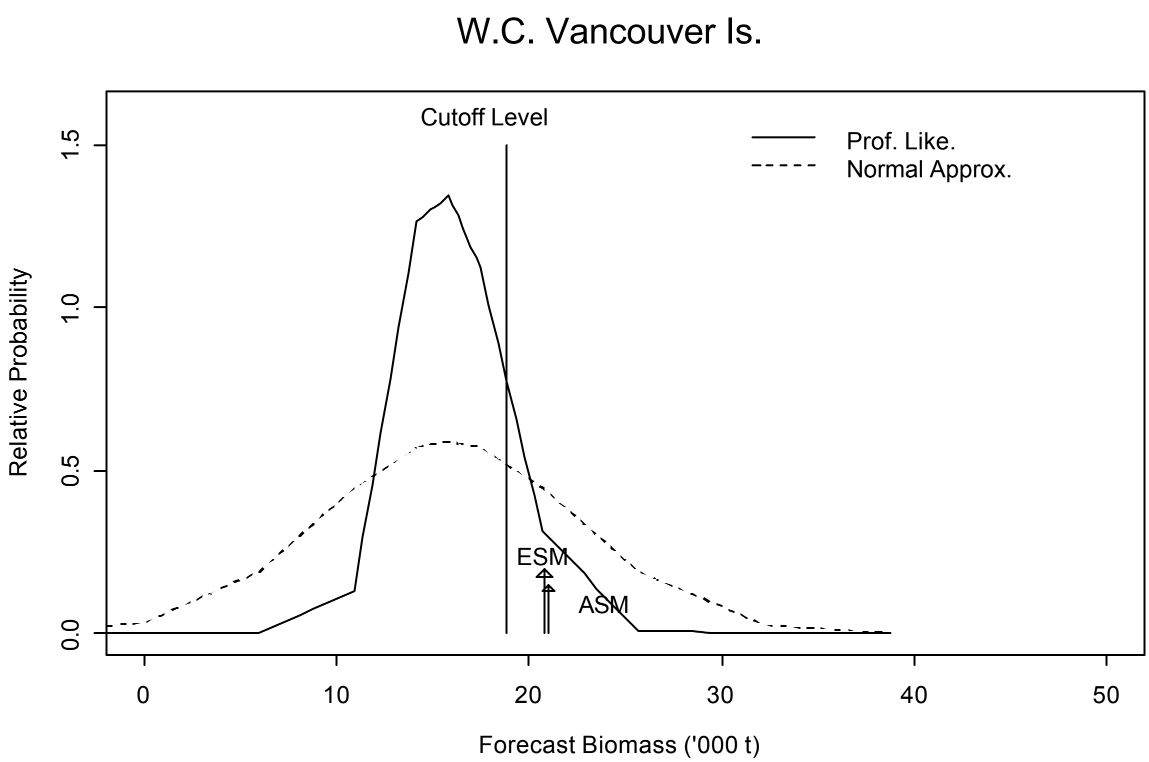


Fig. 4.8. Estimated Bayesian profile likelihood distributions and their normal approximations for the forecast 2000 mature biomass in the southern stock assessment regions. The arrows denote the forecasts assuming average recruitment for escapement and age-structured models.

5. RETROSPECTIVE ANALYSES

Age-structured Model

Schweigert (1996) presented a retrospective analysis for the herring age-structured model that indicated a tendency for slight over-forecasting in the northern assessment regions and under-forecasting in the southern assessment areas. An explanation for this conflicting trend was not apparent but appeared to be related to the inverse relationship between the estimated natural mortality and the spawn index conversion factor. The retrospective plots presented in the current assessment (Fig. 5.1, 5.2), are based on the ASM with time varying M and indicate similar patterns to the base ASM retrospective patterns of previous assessments. Therefore, it appears that the relationship between the spawn index conversion factor and the natural mortality is not the primary explanation for this phenomenon since the retrospective problem still exists in most areas even with M able to change over time. However, the small alterations in M during the time series does result in more cohesive retrospective analyses for some areas such as Prince Rupert during parts of the time series.

In the northern assessment areas estimates of current spawning biomass and consequent forecasts of run sizes have been reasonably consistent although there have been some exceptions in the Queen Charlotte Islands and Central Coast for some years. A couple of outliers occur for the Queen Charlotte Islands when the minimizer stopped prematurely. Estimates for Prince Rupert have been erratic since the 1980s but are becoming more consistent. In the southern assessment regions, stock reconstructions have been consistent in the Strait of Georgia and to a lesser extent on the west coast of Vancouver Island. In part, the greater variability in retrospective pattern associated with the time varying M relative to the constant M results from the model trying to estimate M for part of the most recent decade based on a few years of data. Subsequently, this estimate of M is altered as additional years of data become available thereby changing the estimate of M and the resultant retrospective assessment of abundance for that time series.

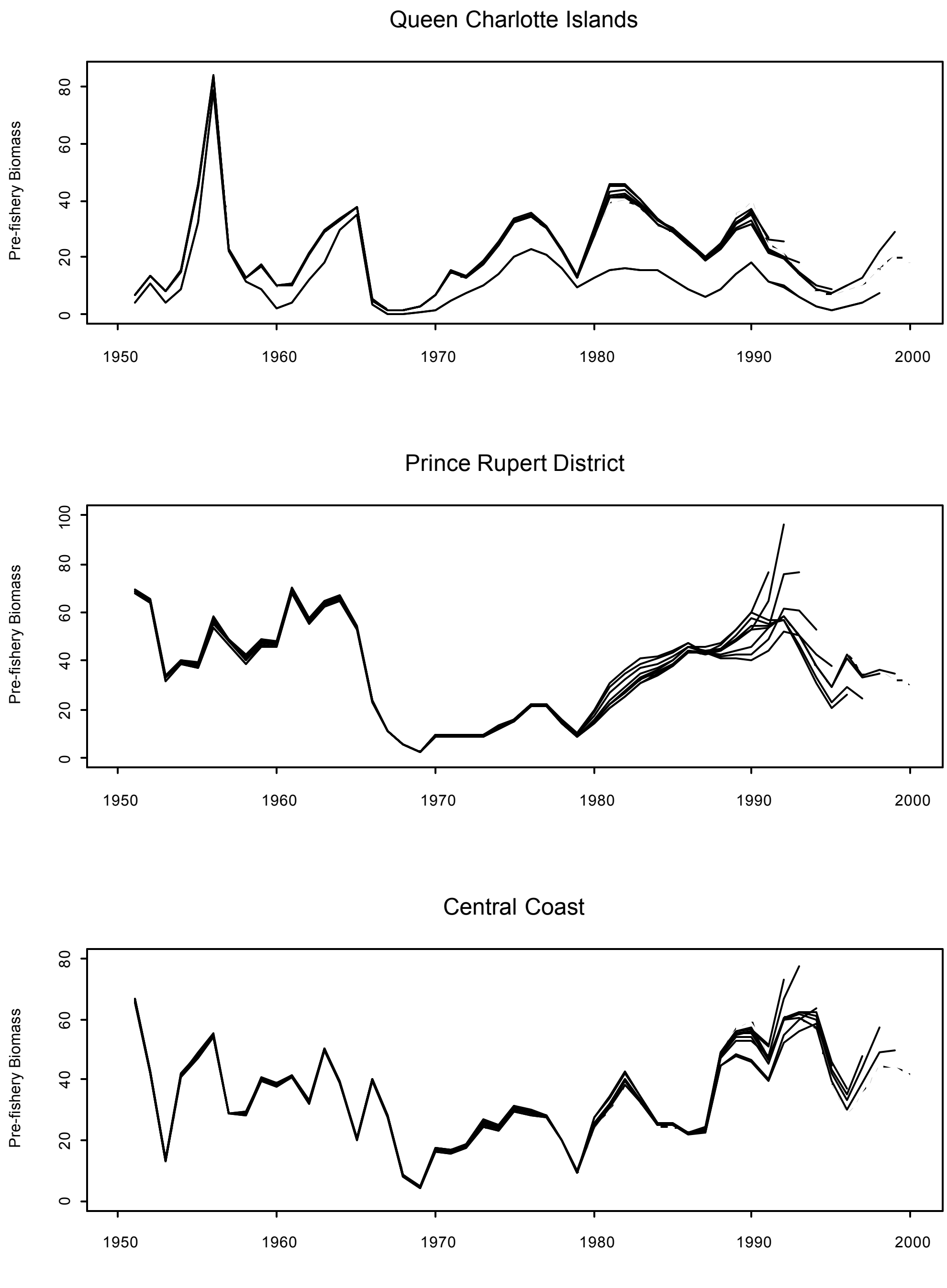


Figure 5.1. Retrospective analysis of estimated spawning biomass from revised age-structured assessment for northern B.C. herring stocks from 1951-2000. Dashed line indicates the most recent assessment.

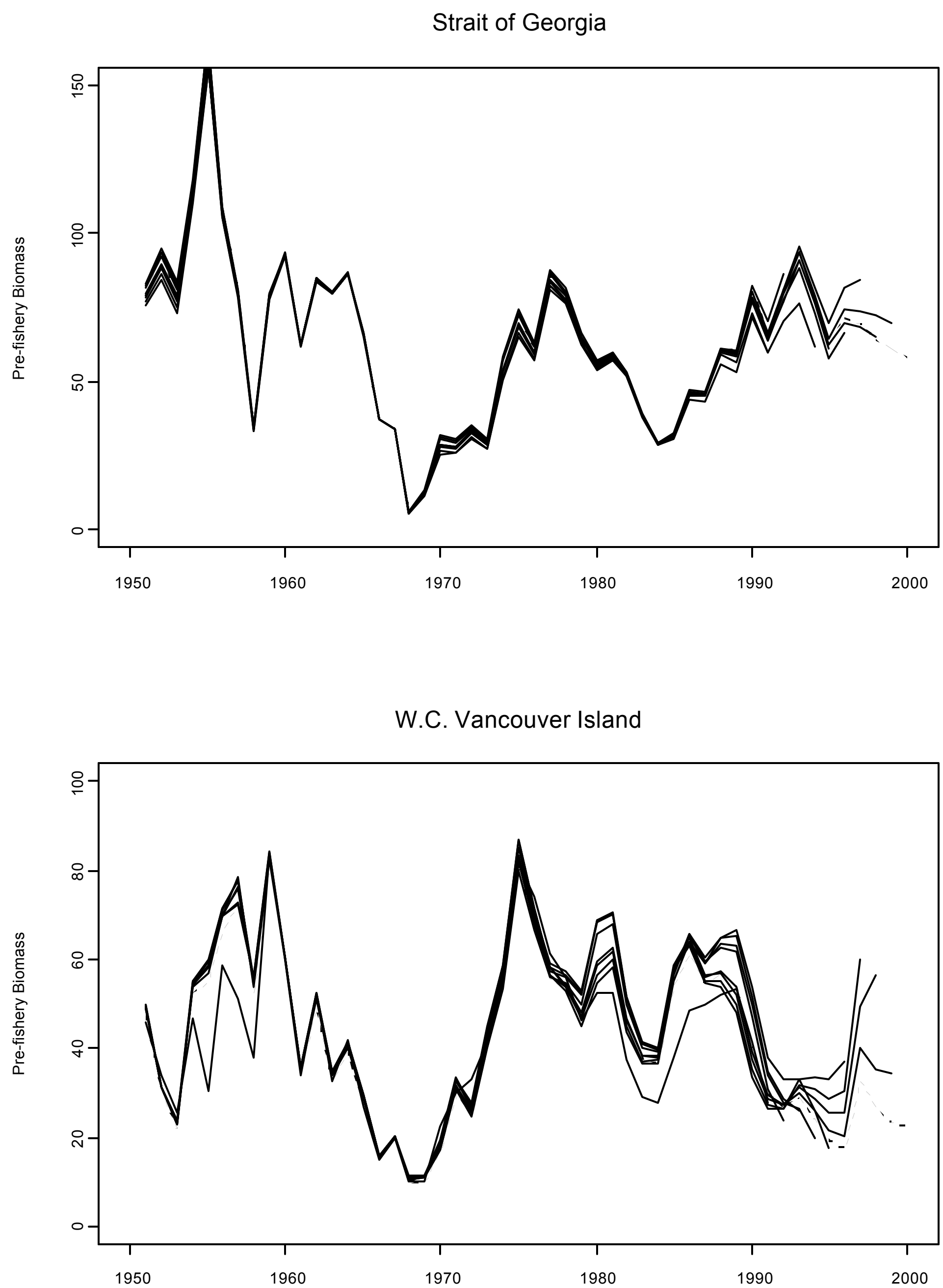


Figure 5.2. Retrospective analysis of estimated spawning biomass from age-structured assessment for southern B.C. herring stocks from 1951-2000. Dashed line indicates the most recent assessment.

6. NATURAL MORTALITY

Age-specific M

During the 1999 assessment review, analyses based on the apparent survival rates of section 2 were presented to support the notion of natural mortality increasing with age (Tanasichuk 1999). In the current assessment this hypothesis was tested by incorporating functions that increased M exponentially with age:

$$M_a = \alpha \exp^b$$

The age-structured model was fit for each area and alpha and beta parameters were estimated for each stock. Tanasichuk's (1999) analysis suggested alpha=.11 and beta=.25 and these values were used to start the minimizations. The parameters estimated for each area were:

	alpha	beta	Function Value*	ASM F-value*
QCI	0.24	0.10	631	634
PRD	0.36	0.05	1212	1208
CC	0.09	0.20	593	611
GS	0.14	0.21	1362	1219
WCVI	0.13	0.19	992	1015

*Objective function value of the model at the minimum.

The estimated parameters in the two southern stocks and the Central Coast were similar to the starting values whereas in the other two areas there was little evidence of M increasing with age. Similarly, in the Central Coast and west coast of Vancouver Island the estimated function values obtained with an age-specific M were significantly lower than with a single M whereas in the other areas the function values were similar. It is evident from Figures 6.1-6.3 that the inclusion of an age-specific M does not markedly change the model performance relative to assuming a constant M over all ages.

Hampton has suggested an alternative formulation for estimating age-specific M which estimates age-specific deviations from an average value and incorporates moderate smoothing penalties to the objective function to avoid large changes in M_a between successive age classes and extreme deviation from the mean [See (http://www.spc.int/oceanfish/html/SAM/Multifan.pdf)]

The smoothing penalties are:

$$\Theta_M = p_{M_1} \sum_{a=1}^{A-2} (M'_a - 2M'_{a+1} + M'_{a+2r})^2 + p_{M_2} \sum_{a=1}^{A-1} (M'_a - M'_{a+1})^2 + p_{M_3} \sum_{a=1}^{A} (M'_a)^2$$

where

$M_a^{'} = \ln(M_a) - \frac{\sum_a \ln(M_a)}{A}$ and p_{M1}, p_{M2}, and p_{M3} are weights set equal to 25, 5, and 10.

The objective of the Hampton model is to provide a U-shaped natural mortality function which assumes that mortality decreases with age and size as fish grow and then increases again as fish reach old age and become senescent. Results of this analyses and parameter values are presented in Figures 6.1 to 6.3. It is again evident that the addition of age-specific natural mortality does not result in any significant differences in stock trends over time. In fact, for most areas there are no detectable differences between the model estimates of stock abundance over time except for the Strait of Georgia where the model was not well determined. The estimates of age-specific M are presented in Figure 6.3. The results are not very encouraging with only a couple of areas suggesting a decline in mortality with age followed by an increase with the onset of senescence. This pattern did not change markedly with alternative assumptions for penalty weightings.

Time Varying M (RASM)

As well as the likely change in natural mortality with age is the possibility that M changes with time and this was investigated by assuming an average M value and allowing for annual deviations from the mean value. Unfortunately, this parameterization resulted in some very large deviations in some years and a generally very poor fit of the model in all areas. However, this approach has worked well for some invertebrates (Zheng and Quinn, MS) and merits further investigation. As an alternative approach, I investigated the possibility of breaking the time series into a few smaller groupings and looked at 2, 5, and 10 groups with separate M parameters for each block of years. The most promising approach appears to be the estimation of different M values for each decade of the time series and the results of this analysis are included in the current assessment as the revised age-structured model assessment (RASM). A comparison of function values and the AIC (Akaike Information Criterion) at the minimum for the RASM and the ASM model indicates the superior performance of this formulation in all areas except the Strait of Georgia:

	ASM – F. value	AIC	RASM – F. value	AIC
QCI	634	1719	580	1618
PRD	1208	2894	1110	2708
CC	611	1706	535	1564
GS	1219	2978	1234	3018
WCVI	1015	2496	860	2196

In general, a lower function value or AIC indicates a better model fit. The AIC is useful for comparing different model formulations that contain different numbers of parameters since adding parameters to a model usually results in a lower function value but may not necessarily indicate a statistically better fit to the data. In this application, the AIC was calculated as the function value at the minimum plus twice the number of parameters in the model following Venables and Ripley (1994).

The stock abundance estimates from this implementation are presented in Figures 4.1 and

4.2 and provide a closer correspondence to the ESM estimates for most areas except perhaps the Central Coast and overall the trends and trajectories of abundance closely match the current ASM. The forecast stock sizes from this formulation (Figure 4.3 and 4.4) also more closely match the ESM results than the current ASM results in all areas except the west coast of Vancouver Island where it is slightly more optimistic about expected stock size. The plots of estimated historic recruitment are somewhat problematic (Fig. 4.5 and 4.6). While they generally indicate similar recruitment trends and identify similar rankings of strong and weak year-classes there are some obvious anomalies particularly between the reduction and roe fishing periods. Allowing M to vary over time results in the catch-age model altering the relative sizes of year-classes during certain periods. For example, assuming constant M on the west coast of Vancouver Island yields the strongest year-classes in the 1970s whereas time varying M results in much larger year-classes in the 1950s. In other words, a slightly higher estimated M for the west coast Vancouver Island in the 1950s results in much higher estimated recruitment since fish are dying at a higher rate and so there must have been more of them there to support the observed catch and spawn levels. While this does not greatly affect the historic abundance estimates it has important implications for abundance forecasting and harvest management because it alters the perspective of the overall productivity of each stock during various time periods. For example, it suggests that all stocks have been considerably less productive than they were in the 1950s and so would require a re-evaluation of Cutoff levels for all areas, possibly resulting in reduced thresholds for all stocks. Unfortunately, there is no unequivocal data available to assess the relative abundance of stocks during the reduction and roe fishery periods since the reduction fishery is characterized by large catches and smaller spawnings and the roe period by the opposite. However, since the spawn assessments were conducted differently during each period, intercalibrating these data requires some difficult to quantify assumptions about egg densities and so a true reflection of relative abundance during these periods remains elusive.

The notion of a time varying M is attractive because it makes biological sense. Whether the resulting parameters are biologically meaningful or analytical artifacts remains unclear. However, it appears worthwhile to investigate this further in future assessments and such a model should be considered along with the existing ESM and ASM results.

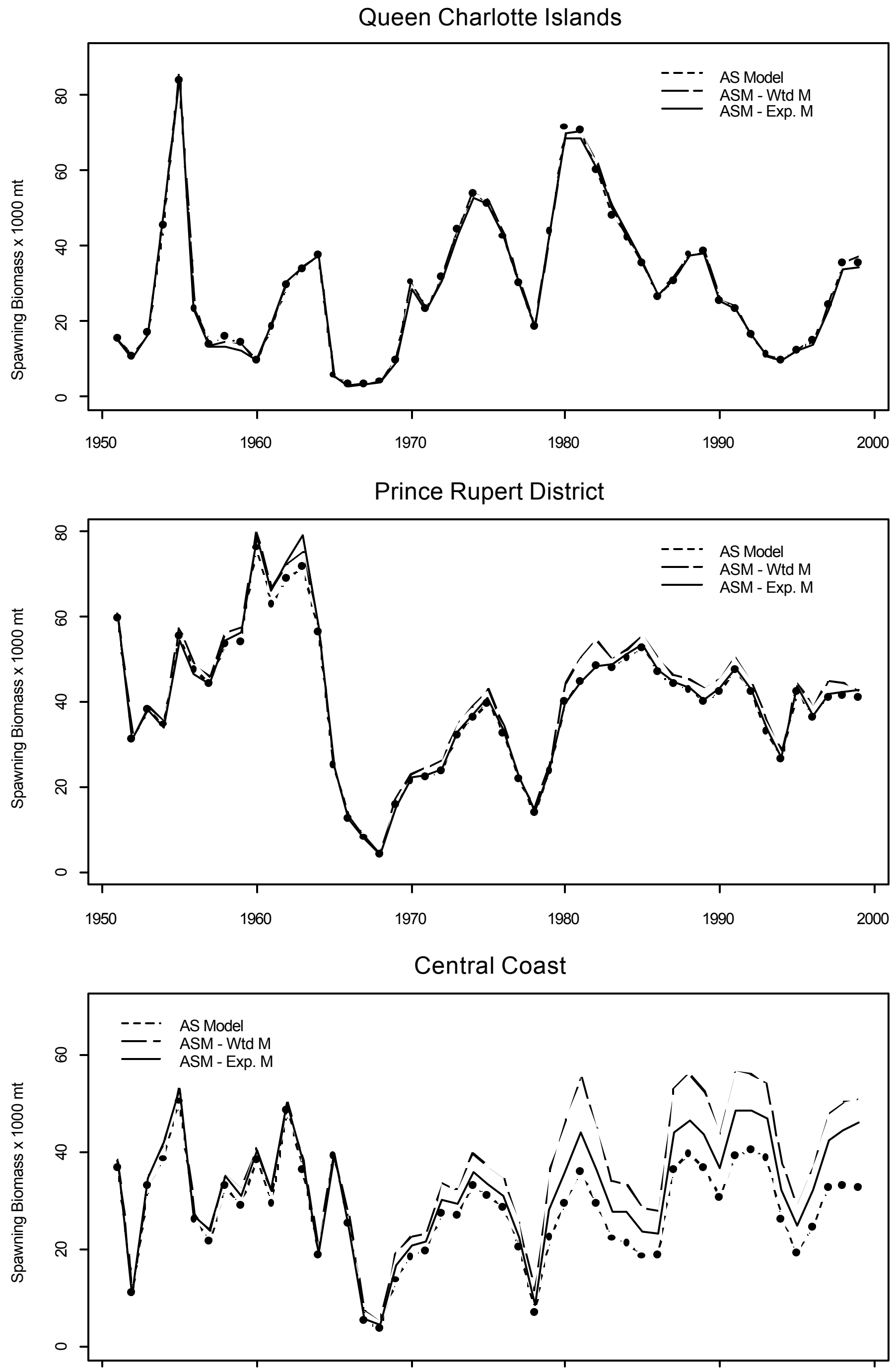


Figure 6.1. Estimates of stock abundance assuming age-specific weighted M and exponential M at age relative to the base age-structured model for northern stock assessment regions, 1951-2000.

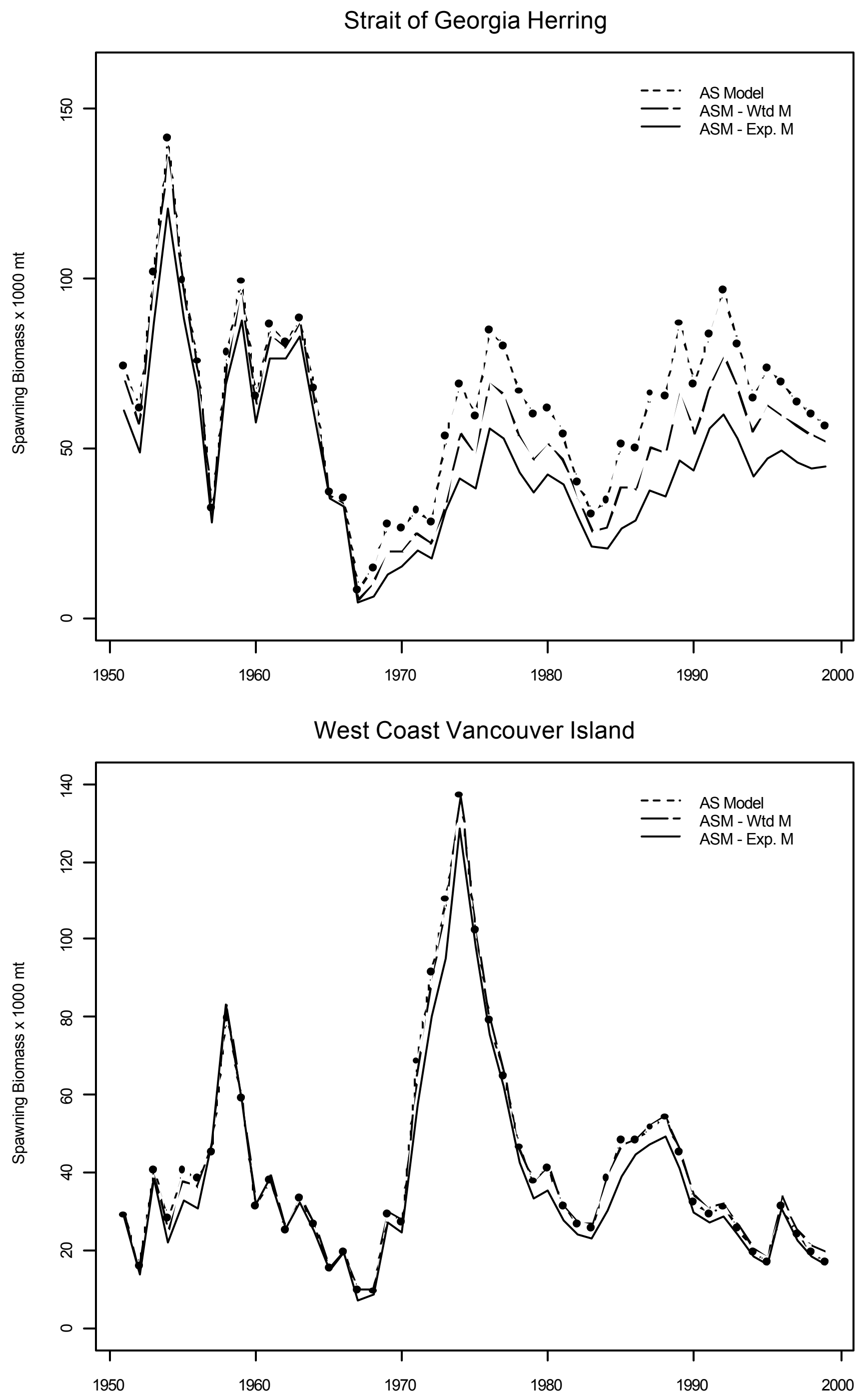
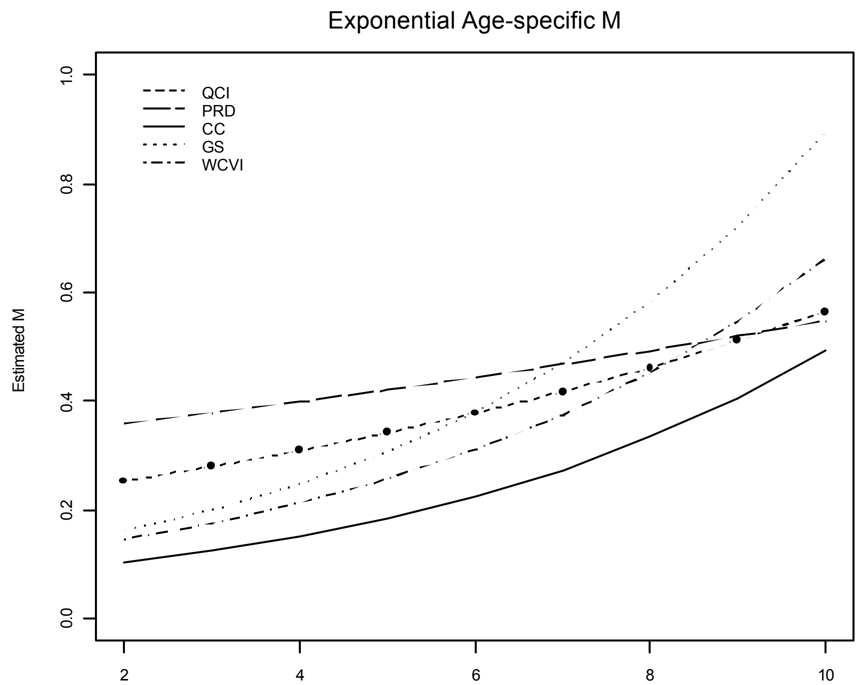


Figure 6.2. Estimates of stock abundance assuming age-specific weighted M and exponential M at age relative to the base age-structured model for southern stock assessment regions, 1951-2000.



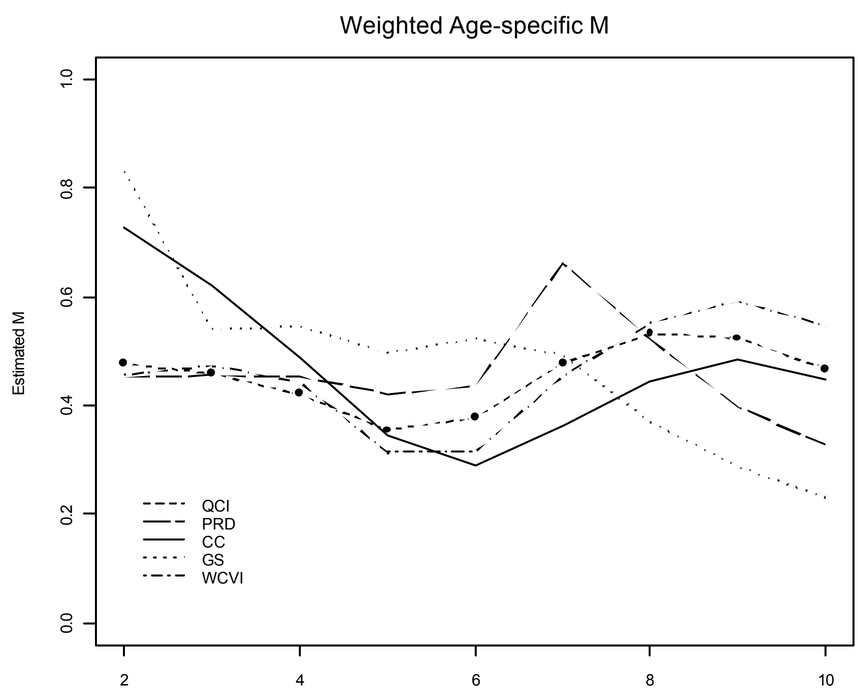


Figure 6.3. Estimated natural mortality at age assuming exponential and weighted M as estimated by the age-structured model for the five stock assessment regions.

7. SIZE AT AGE TRENDS

A major issue during the 1998 assessment review was the recent downward trend in the size at age of herring and its impacts on estimates of forecast biomass as well as the availability and catchability of herring for the gillnet fleet. In the 1999 fishing plan adjustments were made to the available quotas to account for the decreased size of herring and the availability of sufficient catchable tonnages for the gillnet sector. Figure 7.1 presents the available data on size at age of herring since 1971 and indications are that size at age in 2000 has increased slightly for most age-classes in all areas over the past few years suggesting that the pattern of declining size at age has reversed itself which should provide better opportunities for gillnet fisheries.

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Lorena Hamer and Peter Midgley updated the catch and sampling data bases and reviewed all 1999 biological sampling data. Chuck Fort updated and reviewed the spawn survey databases. Howard Stiff provided programming support for the Access databases used to summarize the catch and spawn data and was funded by the Herring Conservation and Research Society.

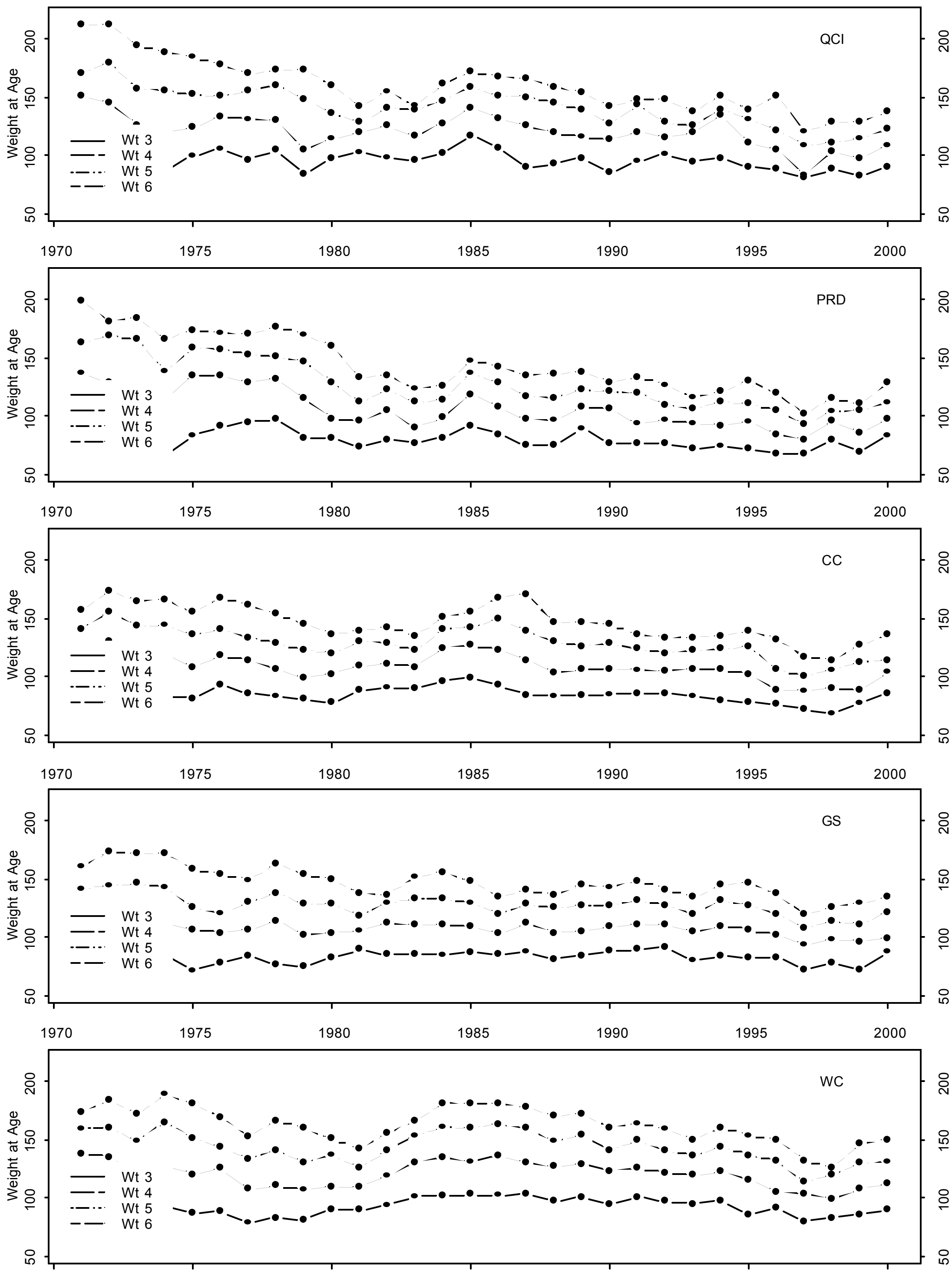

Figure 7.1. Estimates of weight-at-age (g) for 3-6 year old herring from 1951-2000 for the five major assessment areas.

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8. APPENDIX TABLES

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

					PERCENT AT AGE						NUMBER	SAMPLE	CATCH
SEASON	FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+	AGED	WEIGHT	(x 10)
1950/51	WINTER	0.07	15.31	52.91	15.31	11.52	4.20	0.61	0.07	0.00	1476	1544	317.44
1951/52	WINTER	17.13	21.81	34.17	21.54	4.14	1.12	0.09	0.00	0.00	2224	166	1124.25
1953/54	WINTER	2.96	29.02	21.28	33.66	10.19	1.93	0.71	0.19	0.06	0*	25	231.66
1954/55	WINTER	8.74	14.08	39.42	18.06	14.85	4.37	0.29	0.10	0.10	0*	25	52.94
1955/56	WINTER	0.15	16.02	9.64	62.17	8.38	2.74	0.74	0.00	0.15	1348	681	6551.83
1956/57	WINTER	20.77	24.13	15.76	9.59	26.73	2.45	0.44	0.13	0.00	4733	2180	2089.67
1957/58	WINTER	81.89	16.42	1.23	0.18	0.14	0.14	0.00	0.00	0.00	2838	514	2146.22
1958/59	WINTER	1.05	63.16	28.42	7.37	0.00	0.00	0.00	0.00	0.00	95	6	735.74
1960/61	WINTER	4.21	32.63	36.00	24.84	1.26	0.42	0.21	0.42	0.00	0*	25	59.00
1961/62	WINTER	3.04	37.62	41.36	9.58	6.54	1.64	0.23	0.00	0.00	428	170	693.85
1962/63	WINTER	0.37	50.00	27.11	18.16	2.11	1.99	0.00	0.12	0.12	804	411	1342.32
1963/64	WINTER	0.95	15.34	59.47	17.80	5.30	1.14	0.00	0.00	0.00	528	297	2515.06
1964/65	WINTER	1.61	79.77	11.02	4.37	2.09	0.95	0.19	0.00	0.00	1053	165	3424.55
1965/66	WINTER	18.36	32.77	16.38	10.40	7.45	5.89	4.92	2.07	1.75	0*	25	210.12
1966/67	WINTER	0.88	67.26	26.49	2.65	2.72	0.00	0.00	0.00	0.00	0*	25	18.83
1967/68	WINTER	29.95	50.57	17.23	2.25	0.00	0.00	0.00	0.00	0.00	0*	25	8.43
1971/72	ROE-SN	3.04	32.60	38.34	16.05	6.08	2.45	0.93	0.42	0.08	1184	94	276.24"
1972/73	ROE-SN	0.17	40.56	21.55	27.29	8.00	1.68	0.75	0.00	0.00	1726	914	524.51
1973/74	ROE-SN	0.12	30.49	40.38	17.69	9.09	1.86	0.31	0.06	0.00	1617	185	482.78
	ROE-GN	0.00	5.73	48.41	25.48	16.56	3.18	0.00	0.00	0.64	157	25	8.24
1974/75	ROE-SN	0.63	25.31	34.21	27.90	9.53	1.95	0.37	0.10	0.00	6010	655	587.13"
	ROE-GN	0.00	0.00	22.50	40.00	30.00	5.00	2.50	0.00	0.00	40	40	6.19
1975/76	ROE-SN	0.43	2.78	37.34	29.38	22.73	6.31	0.96	0.07	0.00	4170	247	813.57"
	ROE-GN	0.00	0.00	0.75	21.80	60.90	14.29	2.26	0.00	0.00	133	186	91.86
1976/77	ROE-SN	0.09	19.57	8.01	29.41	22.95	15.09	4.47	0.40	0.00	3220	1113	801.25"`
1977/78	ROE-SN	0.16	26.18	17.34	9.48	26.18	14.10	5.27	0.97	0.32	1234	1932	620.46
	ROE-GN	0.00	0.61	4.85	11.52	19.39	39.39	20.00	3.64	0.61	165	126	129.55
1978/79	ROE-SN	5.59	4.41	31.57	18.73	21.27	15.10	2.84	0.39	0.10	1020	441	387.56"
	ROE-GN	0.00	0.00	25.13	25.13	25.13	20.10	3.52	0.50	0.50	199	65	128.20
1979/80	ROE-SN	0.50	83.22	4.45	5.37	2.77	1.89	1.15	0.56	0.09	3390	2427	222.15
	ROE-GN	0.00	3.73	4.48	40.09	20.79	22.28	6.93	1.60	0.11	938	1028	74.53
1980/81	ROE-SN	0.18	3.54	84.99	5.40	3.05	1.82	0.71	0.18	0.12	4943	489	331.92"
	ROE-GN	0.00	0.22	74.81	8.29	9.39	4.86	1.88	0.55	0.00	905	339	121.41
1981/82	ROE-SN	0.84	4.46	4.43	84.63	2.42	1.62	0.95	0.53	0.14	3591	1725	185.38"
	ROE-GN	0.00	0.19	3.42	88.21	3.42	2.66	1.14	0.76	0.19	526	341	99.20
1982/83	ROE-SN	4.88	5.23	3.51	6.86	72.87	3.91	1.58	0.91	0.25	1968	1609	317.79"
	ROE-GN	0.00	0.00	1.34	2.81	89.02	3.08	2.54	0.67	0.54	747	637	58.91
1983/84	WINTER	5.91	36.56	2.15	4.30	8.60	39.25	2.15	0.54	0.54	186	186	9.25
	ROE-SN	2.06	35.34	4.90	2.77	10.53	42.85	1.03	0.35	0.16	3104	1554	312.33
	ROE-GN	0.00	2.81	1.28	4.60	8.95	80.05	1.79	0.26	0.26	391	427	34.59
1984/85	ROE-SN	1.32	14.93	31.83	4.05	4.50	11.36	31.47	0.45	0.08	3556	699	311.61"
	ROE-GN	0.00	0.00	15.28	2.08	4.17	11.11	66.67	0.69	0.00	144	83	85.78
1985/86	ROE-SN	0.21	2.83	21.99	40.19	4.04	3.27	8.03	19.12	0.32	4733	2821	157.73
	ROE-GN	0.00	0.00	11.85	50.62	5.43	5.19	10.37	16.05	0.49	405	383	55.79
1986/87	ROE-SN	1.74	10.42	5.85	24.35	37.76	3.84	4.33	5.79	5.91	3281	1144	131.07"
1987/88	ROE-SN	3.64	51.01	7.52	4.77	11.75	14.86	1.37	1.67	3.40	1676	575	2.56"
1988/89	ROE-SN	2.27	17.46	66.35	4.01	1.57	3.90	2.78	0.62	1.04	3563	199	121.30"
1989/90	ROE-SN	0.22	9.64	18.17	60.02	3.94	1.84	3.82	1.70	0.65	5053	409	411.22"
	ROE-GN	0.00	0.46	8.31	43.65	10.16	8.55	17.09	8.55	3.23	433	397	77.90
1990/91	ROE-SN	6.70	4.13	10.66	28.70	38.47	3.69	1.80	3.99	1.86	3387	1964	383.94"
	ROE-GN	0.00	0.00	2.54	21.57	44.42	9.14	6.85	10.41	5.08	394	457	35.85
1991/92	ROE-SN	0.71	38.51	4.93	8.36	12.45	30.73	2.39	0.59	1.33	3228	2333	267.96
1992/93	ROE-SN	0.32	3.45	60.34	4.45	6.06	12.07	11.75	1.16	0.40	3712	304	314.80`
1993/94	ROE-SN	6.15	4.27	5.00	48.40	10.58	10.91	10.83	3.20	0.66	1219	1516	108.79
1994/95	ROE-SN	14.14	16.93	1.92	4.71	39.09	8.73	7.33	4.71	2.44	573	252	1.00~
1995/96	ROE-SN	10.77	53.87	9.31	3.24	3.35	15.59	2.41	1.15	0.31	956	410	1.00~
1996/97	ROE-SN	22.64	26.17	33.41	5.23	1.52	4.44	5.36	0.85	0.37	1643	299	27.99
1997/98	ROE-SN	0.30	53.28	28.17	11.85	2.92	0.69	1.33	1.07	0.39	2329	1450	239.76
1998/99	ROE-SN	3.46	2.20	64.78	17.03	8.09	2.71	0.70	0.47	0.56	2138	1188	312.26
	ROE-GN	0.00	0.67	30.78	22.80	29.12	9.98	2.66	1.33	2.66	601	413	35.99
1999/00	ROE-SN	4.98	18.51	3.91	59.07	7.95	4.51	0.42	0.47	0.19	2150	1827	248.93`

AVERAGE WEIGHT AT AGE (gms)

FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+
WINTER	52.0	84.4	106.6	125.9	147.7	156.8	172.1	147.3	183.5
ROE-SN	64.8	95.4	120.7	141.8	160.6	174.9	186.3	195.5	196.9
ROE-GN	0.0	119.8	140.3	150.9	166.9	176.1	188.2	186.0	192.7

* - 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 Prince Rupert District stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	1+	2+	3+	4+	PERCENT AT AGE 5+	6+	7+	8+	9+	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10)
1950/51	WINTER	4.34	18.20	58.50	10.38	5.62	2.65	0.26	0.04	0.02	4682	2200	4953.11
1951/52	WINTER	4.76	8.81	33.67	45.24	6.15	1.03	0.30	0.03	0.00	5922	2508	4390.81
1952/53	WINTER	1.20	38.13	23.04	25.44	11.13	0.99	0.07	0.00	0.00	1419	752	173.50
1953/54	WINTER	2.11	28.35	29.07	24.02	13.22	2.60	0.60	0.04	0.00	2656	891	2522.89
1954/55	WINTER	2.74	4.86	70.29	15.65	5.22	1.06	0.18	0.00	0.00	1131	467	1698.85
1955/56	WINTER	10.04	58.11	9.51	18.95	2.55	0.53	0.18	0.12	0.00	1683	555	1218.10
1956/57	WINTER	11.49	17.76	39.79	13.21	16.04	1.37	0.32	0.03	0.00	3491	515	2827.98
1957/58	WINTER	45.81	30.22	8.03	11.81	1.77	2.36	0.00	0.00	0.00	847	123	644.16
1958/59	WINTER	3.10	56.69	20.85	5.80	9.88	1.72	1.90	0.06	0.00	1741	349	1037.09
1959/60	WINTER	49.14	6.25	28.20	8.89	4.14	2.52	0.67	0.19	0.00	4206	337	2451.31
1960/61	WINTER	9.74	58.33	7.28	18.00	4.35	1.60	0.58	0.12	0.00	4300	763	4815.52
1961/62	WINTER	3.04	30.30	44.66	6.88	9.92	3.41	0.92	0.54	0.33	1845	752	2476.36
1962/63	WINTER	39.30	13.29	18.18	22.05	3.60	2.96	0.50	0.06	0.06	3415	433	4788.66
1963/64	WINTER	3.71	64.94	10.12	10.94	8.85	0.71	0.59	0.12	0.03	3400	1914	3555.87
1964/65	WINTER	5.98	13.57	50.95	8.54	11.01	8.45	1.04	0.33	0.12	3360	459	3649.12
1965/66	WINTER	0.00	5.29	21.38	23.45	16.32	19.08	9.66	3.22	1.61	435	59	1071.96
1966/67	WINTER	57.22	32.21	5.37	1.88	2.70	0.41	0.20	0.00	0.00	0*	25	1218.55
1967/68	WINTER	34.87	39.74	19.40	4.59	0.73	0.26	0.14	0.27	0.00	0*	25	274.98
1968/69	WINTER	30.04	45.04	20.58	3.90	0.18	0.21	0.04	0.00	0.00	0*	25	69.11
1969/70	WINTER	18.67	62.91	15.11	3.12	0.03	0.08	0.08	0.00	0.00	0*	25	183.69
1970/71	WINTER	6.49	50.42	29.28	7.99	4.33	0.83	0.50	0.17	0.00	601	38	413.67
1971/72	ROE-SN	0.00	5.32	17.93	64.43	5.88	3.78	2.38	0.14	0.14	714	209	278.66"`
1972/73	ROE-SN	0.25	33.00	4.39	30.36	26.60	3.39	1.25	0.75	0.00	797	662	109.21"
1973/74	ROE-SN	0.16	17.88	53.16	7.44	16.46	4.43	0.32	0.16	0.00	632	121	174.36"
	ROE-GN	0.00	0.96	39.42	21.15	34.62	2.88	0.96	0.00	0.00	104	83	90.07
1974/75	ROE-SN	1.30	9.40	22.19	43.10	11.16	9.63	2.47	0.59	0.16	3074	778	127.95"
	ROE-GN	0.00	0.00	31.91	59.57	8.51	0.00	0.00	0.00	0.00	47	47	0.76
1975/76	ROE-SN	0.00	0.84	6.87	31.70	50.07	7.29	2.38	0.84	0.00	713	654	237.22"
	ROE-GN	0.00	0.00	15.79	57.89	22.81	3.51	0.00	0.00	0.00	57	57	17.93
1976/77	ROE-SN	0.08	16.03	3.74	22.67	37.79	15.04	3.28	0.92	0.46	1310	1344	420.46"
	ROE-GN	0.00	1.07	2.14	19.93	54.09	14.59	6.76	1.42	0.00	281	1104	89.48
1977/78	ROE-SN	1.13	11.70	32.83	9.56	21.13	20.38	2.39	0.63	0.25	795	131	373.38"
	ROE-GN	0.00	0.00	20.53	5.96	32.45	33.11	6.62	1.32	0.00	151	37	181.42
1978/79	ROE-SN	2.71	18.16	11.48	29.23	11.48	18.27	6.47	1.36	0.84	958	1475	204.57"
	ROE-GN	1.15	1.15	8.05	41.38	15.71	22.22	8.05	1.92	0.38	261	255	74.00
1979/80	ROE-SN	0.64	77.94	7.26	5.09	3.81	3.49	1.28	0.39	0.11	2811	535	249.07"
	ROE-GN	0.00	3.45	8.72	31.24	22.31	21.10	9.13	3.45	0.61	493	915	63.73
1980/81	ROE-SN	0.46	11.18	81.22	3.30	1.73	1.51	0.37	0.15	0.06	3238	1059	275.60"
	ROE-GN	0.00	0.47	38.88	15.46	22.95	14.75	5.62	1.87	0.00	427	557	23.77
1981/82	ROE-SN	2.72	18.78	7.38	66.32	2.85	1.36	0.39	0.19	0.00	1544	576	193.03"
1982/83	ROE-SN	1.35	20.82	17.74	5.26	49.16	3.73	1.13	0.59	0.22	4583	1448	1.00~
1983/84	ROE-SN	0.49	35.46	14.42	10.29	14.38	23.62	0.99	0.25	0.11	2837	618	175.68"
	ROE-GN	0.00	0.99	1.98	12.87	21.39	57.43	3.37	1.19	0.79	505	961	127.31
1984/85	ROE-SN	0.22	7.75	54.69	11.93	6.39	10.56	8.19	0.14	0.14	3664	969	301.45"
	ROE-GN	0.00	0.36	16.36	14.91	15.82	21.82	29.82	0.36	0.55	550	543	235.00
1985/86	ROE-SN	1.75	13.76	9.44	46.26	10.80	5.27	7.09	5.53	0.09	5655	4566	305.47"
	ROE-GN	0.00	0.39	4.32	53.85	19.00	8.71	7.77	5.73	0.24	1274	558	311.02
1986/87	ROE-SN	0.89	38.64	10.21	6.89	29.87	5.90	3.49	2.87	1.25	4731	4068	187.95"
	ROE-GN	0.00	0.57	3.01	6.93	55.25	16.07	8.80	5.96	3.41	1761	819	270.57
1987/88	ROE-SN	0.45	30.94	39.00	5.95	8.34	11.56	1.94	1.45	0.38	4221	2992	353.54"
	ROE-GN	0.00	0.42	6.48	7.18	21.55	44.79	11.69	5.07	2.82	710	421	276.81
1988/89	ROE-SN	0.61	21.68	36.14	27.68	4.92	4.48	3.57	0.64	0.28	3616	1265	357.83"
	ROE-GN	0.00	0.00	4.62	30.46	13.66	23.53	21.85	3.36	2.52	476	432	317.93
1989/90	ROE-SN	0.65	18.15	22.55	28.24	20.52	4.01	3.31	2.15	0.41	5068	3572	194.38"
	ROE-GN	0.00	0.00	6.25	21.32	42.46	10.29	11.58	6.07	2.02	544	180	161.00
1990/91	ROE-SN	0.95	48.03	9.49	12.60	15.75	9.49	1.65	0.87	1.17	4120	2451	214.06"
	ROE-GN	0.00	0.00	4.26	18.67	31.44	31.33	6.66	4.37	3.28	916	502	148.32
1991/92	ROE-SN	0.35	39.84	37.21	5.89	5.35	6.73	3.42	0.61	0.61	4265	529	228.23"
	ROE-GN	0.00	0.35	13.08	9.35	22.78	26.29	19.16	3.97	5.02	856	114	260.14
1992/93	ROE-SN	0.12	10.73	44.28	30.20	4.02	4.40	4.35	1.56	0.35	4027	372	293.46"
	ROE-GN	0.00	0.00	8.32	40.54	9.53	18.52	13.29	8.19	1.61	745	666	306.61
1993/94	ROE-SN	0.68	4.88	13.36	48.68	22.64	4.12	3.68	1.42	0.54	6459	1430	287.05"
	ROE-GN	0.00	0.00	2.38	17.62	47.55	12.73	11.19	6.43	2.10	715	760	174.03
1994/95	ROE-SN	3.19	15.32	6.76	11.27	43.21	15.75	2.44	1.27	0.80	4393	2013	136.57
	ROE-GN	0.00	0.12	1.18	16.98	34.79	39.39	4.13	1.89	1.53	848	1013	103.11
1995/96	ROE-SN	1.09	64.00	9.79	3.17	4.61	11.06	5.70	0.35	0.23	1736	1241	122.25
	ROE-GN	0.00	0.78	4.11	5.68	25.83	32.68	26.42	3.13	1.37	511	171	230.53
1996/97	ROE-SN	0.94	18.40	56.15	8.59	3.10	5.40	5.07	2.11	0.23	2130	489	110.79
	ROE-GN	0.00	0.16	19.49	11.57	13.95	20.29	20.60	11.09	2.85	631	568	415.50
1997/98	ROE-SN	0.19	33.18	21.98	36.29	4.44	1.42	1.09	1.28	0.14	2116	1270	120.37
	ROE-GN	0.00	0.65	3.05	43.07	20.52	9.89	11.28	7.02	4.53	1082	851	251.59
1998/99	ROE-SN	0.99	5.52	41.05	20.35	24.71	4.42	1.05	0.87	1.05	1720	305	121.60
	ROE-GN	0.00	0.00	10.82	16.50	49.51	13.45	4.58	1.94	3.19	721	331	147.57
1999/00	ROE-SN	1.91	28.02	9.57	28.25	12.49	16.51	2.30	0.52	0.44	3876	3384	234.58
	ROE-GN	0.00	0.12	2.10	23.06	20.47	42.17	9.37	1.11	1.60	811	428	230.02

AVERAGE WEIGHT AT AGE (gms)

FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+
WINTER	40.6	79.0	107.8	128.1	145.3	161.4	172.0	181.5	194.1
ROE-SN	52.1	80.3	106.2	127.3	143.8	156.7	168.9	177.6	187.2
ROE-GN	90.3	114.9	129.8	139.2	149.1	155.2	162.0	168.5	174.5

* - 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 1.3. 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	1+	2+	3+	4+	PERCENT AT AGE 5+	6+	7+	8+	9+	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10)
1950/51	WINTER	2.43	28.56	50.66	12.00	5.06	1.24	0.06	0.00	0.00	5316	2487	3904.06
1951/52	WINTER	5.18	20.07	30.08	38.13	4.50	1.53	0.45	0.04	0.02	5156	1431	2925.93
1952/53	WINTER	9.36	28.09	23.99	26.62	10.15	1.33	0.44	0.00	0.00	2926	543	73.57
1953/54	WINTER	3.95	69.68	20.26	4.61	1.29	0.16	0.00	0.06	0.00	3189	478	3476.95
1954/55	WINTER	6.66	7.72	74.62	9.09	1.54	0.38	0.00	0.00	0.00	2344	165	1235.03
1955/56	WINTER	16.88	13.62	9.20	57.01	2.89	0.34	0.04	0.00	0.02	5052	1347	4134.75
1956/57	WINTER	16.74	50.70	10.79	6.23	14.78	0.73	0.02	0.00	0.00	4688	1703	2635.45
1957/58	WINTER	23.51	61.39	12.66	1.28	0.59	0.56	0.00	0.00	0.00	3743	847	1445.86
1958/59	WINTER	3.80	49.52	36.89	8.10	0.80	0.44	0.42	0.02	0.00	4974	1352	3293.36
1959/60	WINTER	43.50	23.16	26.48	5.58	1.13	0.07	0.07	0.00	0.00	1416	165	639.45
1960/61	WINTER	16.08	32.23	10.79	29.69	10.08	0.93	0.11	0.07	0.04	2799	1227	3463.55
1961/62	WINTER	9.65	57.43	17.95	2.60	9.90	2.35	0.12	0.00	0.00	808	146	1721.99
1962/63	WINTER	0.37	30.27	57.96	5.43	2.85	2.94	0.18	0.00	0.00	1087	885	4376.33
1963/64	WINTER	13.12	47.38	27.74	10.25	1.43	0.08	0.00	0.00	0.00	1258	198	3507.73
1964/65	WINTER	8.17	36.40	33.77	15.83	5.43	0.34	0.06	0.00	0.00	1750	684	1326.51
1965/66	WINTER	67.32	20.43	7.33	3.60	1.13	0.19	0.00	0.00	0.00	0*	25	5216.79
1966/67	WINTER	37.40	46.19	13.10	2.04	1.02	0.17	0.07	0.01	0.00	0*	25	2514.89
1967/68	WINTER	32.53	48.02	17.02	2.11	0.25	0.00	0.06	0.00	0.00	0*	25	170.14
1968/69	WINTER	32.21	27.70	26.72	11.30	1.95	0.12	0.00	0.00	0.00	0*	25	10.08
1969/70	WINTER	54.02	44.42	1.16	0.40	0.00	0.00	0.00	0.00	0.00	0*	25	28.32
1970/71	WINTER	14.39	39.60	36.87	3.78	4.20	0.95	0.11	0.11	0.00	952	136	339.30
1971/72	ROE-SN	4.35	29.83	27.65	25.69	6.91	4.35	1.14	0.05	0.00	1837	598	762.73"
	ROE-GN	0.00	0.91	14.89	65.05	10.64	7.90	0.61	0.00	0.00	329	503	8.47
1972/73	ROE-SN	1.20	50.45	18.60	15.51	11.75	1.88	0.45	0.15	0.00	1328	593	539.55"
	ROE-GN	0.00	2.53	25.32	44.94	20.89	4.43	1.27	0.63	0.00	158	114	71.26
1973/74	ROE-SN	2.77	17.71	38.63	19.72	13.36	6.62	0.95	0.25	0.00	1587	202	282.57
	ROE-GN	0.00	0.40	22.78	37.70	24.80	12.30	1.81	0.20	0.00	496	101	332.81
1974/75	ROE-SN	1.16	32.96	25.51	27.84	8.59	3.18	0.67	0.07	0.02	8896	3314	278.00
	ROE-GN	0.00	3.28	25.63	46.24	16.38	6.36	2.12	0.00	0.00	519	117	348.42
1975/76	ROE-SN	3.01	11.76	41.23	20.89	16.83	4.54	1.48	0.24	0.02	5418	973	511.14
	ROE-GN	0.00	0.82	18.82	29.79	35.27	11.78	3.03	0.41	0.08	1222	253	383.45
1976/77	WINTER	1.01	32.83	18.69	29.80	8.08	6.57	3.03	0.00	0.00	198	144	32.75
	ROE-SN	0.68	17.43	22.64	31.77	16.59	8.53	1.92	0.40	0.04	2496	925	284.27
	ROE-GN	0.00	1.10	13.02	35.54	31.57	13.47	3.97	1.32	0.00	453	169	411.71
1977/78	ROE-SN	0.21	25.72	15.19	19.91	23.14	10.89	3.51	1.07	0.36	1396	589	354.31
	ROE-GN	0.00	1.30	8.93	29.58	38.14	17.67	3.81	0.47	0.09	1075	474	576.00
1979/80	ROE-SN	3.68	73.08	6.43	9.02	3.99	2.59	0.70	0.39	0.12	2582	1401	1.12"
	ROE-GN	0.00	3.28	2.55	24.82	23.72	26.28	11.31	6.57	1.46	274	210	32.46
1980/81	ROE-SN	1.96	12.30	66.57	8.40	7.05	2.64	0.64	0.34	0.10	2952	492	25.75"
	ROE-GN	0.26	1.50	50.72	13.61	15.36	10.61	5.47	1.82	0.65	1536	276	163.04
1981/82	ROE-SN	1.68	15.62	10.72	60.21	5.19	4.56	1.45	0.48	0.09	3508	2296	188.15"
	ROE-GN	0.00	2.39	5.91	75.99	6.66	5.91	2.32	0.75	0.07	1337	301	287.08
1982/83	ROE-SN	0.53	7.00	15.43	10.82	57.10	5.03	3.10	0.73	0.26	5445	1082	154.75
	ROE-GN	0.00	0.50	7.19	13.05	69.44	5.02	3.90	0.61	0.28	1793	994	244.49
1983/84	ROE-SN	4.35	7.31	10.12	18.16	16.14	40.73	2.26	0.83	0.10	6293	2210	282.42"
	ROE-GN	0.00	0.26	2.93	13.11	17.26	60.05	4.75	1.12	0.52	1159	338	242.25
1984/85	ROE-SN	2.66	37.54	7.47	8.55	13.11	11.94	18.19	0.45	0.10	5157	5529	222.13
	ROE-GN	0.00	3.18	5.43	9.39	19.49	22.52	38.20	1.01	0.78	1288	1407	143.53
1985/86	ROE-SN	3.92	16.39	40.25	8.59	6.27	6.68	6.08	11.26	0.55	5819	2074	163.81"
	ROE-GN	0.00	1.78	23.95	11.97	10.01	16.00	13.19	22.26	0.84	1069	262	73.95
1986/87	ROE-SN	4.13	22.57	14.59	32.18	5.72	4.55	5.84	4.66	5.78	5038	2319	193.73
	ROE-GN	0.00	0.82	7.75	44.85	11.72	7.85	9.89	8.15	8.97	981	1199	55.71
1987/88	ROE-SN	1.14	67.92	11.67	6.28	7.12	1.68	1.46	1.50	1.23	5194	2730	343.88"
	ROE-GN	0.00	4.24	10.25	14.84	27.21	15.19	7.42	10.07	10.78	566	158	59.81
1988/89	ROE-SN	1.28	4.61	76.21	9.16	3.58	2.80	0.74	0.80	0.82	5642	1939	596.24
	ROE-GN	0.00	0.28	27.61	25.07	17.32	16.48	5.77	3.66	3.80	710	259	195.14
1989/90	ROE-SN	0.97	5.66	4.99	72.59	7.49	3.82	2.95	0.75	0.78	6677	6353	415.05
	ROE-GN	0.00	0.00	1.18	65.05	16.88	6.26	7.79	1.06	1.77	847	502	203.56
1990/91	ROE-SN	2.03	18.82	6.76	6.19	55.55	6.38	2.34	1.48	0.46	7105	5044	576.33
	ROE-GN	0.00	0.50	2.32	6.80	69.15	9.95	7.30	3.15	0.83	603	423	116.55
1991/92	ROE-SN	2.01	58.38	11.40	2.74	3.44	18.75	2.13	0.61	0.54	7264	4356	722.92"
	ROE-GN	0.00	6.92	6.92	4.23	6.54	60.90	9.74	3.33	1.41	780	544	69.73
1992/93	ROE-SN	2.85	6.71	64.15	9.68	2.02	2.55	10.46	1.12	0.46	8664	3221	784.75
	ROE-GN	0.00	0.26	43.79	14.34	5.63	5.76	27.02	2.18	1.02	781	188	146.71
1993/94	ROE-SN	1.19	21.29	8.52	52.95	7.48	2.01	2.76	3.48	0.32	7127	4910	875.10
	ROE-GN	0.00	1.47	4.95	65.08	12.66	3.36	4.42	7.18	0.88	1698	838	158.40
1994/95	ROE-SN	0.75	6.06	23.16	9.44	48.04	6.46	2.01	2.31	1.76	9148	4236	700.37
	ROE-GN	0.00	0.22	9.37	8.11	64.45	10.25	2.06	2.36	3.17	1356	746	105.27
1995/96	ROE-SN	11.63	19.56	5.81	16.70	6.81	30.61	5.96	1.49	1.43	5316	3344	398.77
	ROE-GN	0.00	0.35	1.41	18.02	11.48	54.06	10.42	2.12	2.12	566	175	27.42
1996/97	ROE-SN	2.13	56.65	16.89	3.62	6.14	3.99	8.49	1.54	0.55	6870	3214	451.35
	ROE-GN	0.00	1.36	2.92	6.23	22.76	19.26	38.33	7.20	1.95	514	477	24.01
1997/98	ROE-SN	0.53	36.34	42.39	8.47	2.38	3.12	3.04	2.97	0.77	6473	3967	1023.85
	ROE-GN	0.00	0.48	14.45	13.77	8.73	17.75	15.91	21.05	7.86	1031	222	45.17
1998/99	ROE-SN	0.71	8.76	42.65	34.28	6.52	1.66	2.18	1.95	1.29	4816	1689	711.10
	ROE-GN	0.00	0.11	14.24	44.88	17.91	6.69	5.50	6.15	4.53	927	411	116.52
1999/00	ROE-SN	0.35	19.11	10.82	34.72	26.20	5.81	1.17	0.91	0.91	4527	2678	683.06
	ROE-GN	0.00	0.44	2.04	40.44	41.61	10.36	1.61	0.88	2.63	685	2114	73.07

AVERAGE WEIGHT AT AGE (gms)

FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+
WINTER	43.8	79.8	104.7	125.6	138.1	150.4	156.2	153.5	179.0
ROE-SN	53.3	84.9	108.6	129.1	146.3	161.1	173.6	184.9	193.2
ROE-GN	39.3	114.5	133.3	144.3	153.5	162.7	170.5	175.7	175.7

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

SEASON	FISHERY	1+	2+	3+	4+	PERCENT AT AGE 5+	6+	7+	8+	9+	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10)
1950/51	WINTER	4.17	56.48	30.35	7.12	1.41	0.35	0.10	0.03	0.00	7813	1085	4404.07
1951/52	WINTER	11.17	55.37	25.06	6.74	1.32	0.27	0.07	0.01	0.00	9025	1541	4821.55
1952/53	WINTER	9.47	56.02	28.96	4.09	1.23	0.20	0.05	0.00	0.00	8640	1489	1038.41
1953/54	WINTER	1.52	45.67	36.81	11.55	3.28	0.94	0.21	0.02	0.00	13162	4357	6463.55
1954/55	WINTER	4.40	48.63	39.05	6.73	1.08	0.11	0.00	0.00	0.00	5291	805	7070.11
1955/56	WINTER	7.00	35.08	28.78	23.67	4.45	0.73	0.21	0.05	0.02	9832	2632	7200.60
1956/57	WINTER	1.40	59.78	22.33	10.70	5.08	0.60	0.07	0.01	0.03	7478	2184	5972.40
1957/58	WINTER	8.98	54.48	22.13	5.99	5.06	2.89	0.41	0.07	0.00	7397	1589	2238.02
1958/59	WINTER	17.11	63.89	15.48	2.58	0.55	0.24	0.12	0.02	0.01	9964	3899	6104.01
1959/60	WINTER	7.70	51.34	36.56	3.61	0.53	0.16	0.08	0.00	0.03	3742	1215	6919.14
1960/61	WINTER	31.53	27.21	26.87	12.73	1.49	0.16	0.00	0.00	0.00	4351	820	5244.59
1961/62	WINTER	9.05	70.06	13.18	5.28	2.03	0.37	0.03	0.00	0.00	3203	936	7130.68
1962/63	WINTER	17.63	50.93	26.85	2.99	1.00	0.52	0.09	0.00	0.00	2309	403	8123.36
1963/64	WINTER	5.94	60.95	29.88	2.56	0.52	0.10	0.05	0.00	0.00	4026	1190	7537.03
1964/65	WINTER	14.90	55.13	26.15	2.54	0.96	0.18	0.15	0.00	0.00	3350	910	4622.10
1965/66	WINTER	25.15	34.78	23.38	13.51	2.12	1.06	0.00	0.00	0.00	851	98	3229.67
1966/67	WINTER	36.90	45.72	12.18	3.21	1.59	0.29	0.05	0.06	0.00	0*	25	3307.57
1967/68	WINTER	30.37	50.62	14.68	3.04	0.88	0.18	0.23	0.00	0.00	0*	25	199.84
1968/69	WINTER	62.04	27.10	8.08	2.06	0.72	0.00	0.00	0.00	0.00	0*	25	95.62
1969/70	WINTER	25.64	60.32	9.49	3.27	0.72	0.56	0.00	0.00	0.00	0*	25	89.93
1970/71	WINTER	12.38	40.17	36.49	7.14	2.83	0.92	0.07	0.00	0.00	1414	370	147.08
1971/72	WINTER	10.32	31.86	34.62	18.21	3.49	1.34	0.14	0.03	0.00	3663	1460	229.07
	ROE-SN	8.50	36.12	32.86	17.93	3.46	0.99	0.12	0.02	0.00	5036	766	545.88
	ROE-GN	4.44	11.50	46.47	28.99	6.86	1.45	0.19	0.10	0.00	1035	251	9.76
1972/73	WINTER	1.00	27.94	31.02	25.45	12.51	1.74	0.30	0.04	0.00	4707	1573	295.59
	ROE-SN	4.22	54.88	21.37	12.93	6.07	0.53	0.00	0.00	0.00	379	615	141.70
	ROE-GN	0.00	17.41	30.36	37.50	11.16	3.13	0.45	0.00	0.00	224	106	136.90
1973/74	WINTER	17.44	73.26	8.14	1.16	0.00	0.00	0.00	0.00	0.00	86	86	112.05^
	ROE-GN	0.00	4.85	42.22	31.31	16.67	4.04	0.91	0.00	0.00	990	548	196.73
1974/75	WINTER	22.35	61.06	12.44	2.07	1.38	0.46	0.00	0.23	0.00	434	16	70.07
	ROE-SN	3.68	54.91	27.96	7.86	3.35	1.60	0.48	0.17	0.00	5194	1210	46.28
	ROE-GN	0.00	4.97	43.09	35.91	12.15	3.31	0.55	0.00	0.00	181	20	351.18
1975/76	WINTER	6.25	20.45	41.35	21.52	6.27	2.77	0.93	0.41	0.05	4401	1271	401.26
	ROE-SN	12.02	24.84	40.61	14.78	3.38	2.32	1.51	0.45	0.09	1123	164	20.37
	ROE-GN	0.00	0.57	39.48	43.55	12.67	2.94	0.68	0.11	0.00	884	354	468.85
1976/77	WINTER	4.15	50.85	22.01	16.55	4.45	1.24	0.49	0.15	0.11	2653	911	518.05
	ROE-SN	3.35	55.79	20.11	14.47	3.86	1.27	0.76	0.25	0.13	2357	1054	394.81
	ROE-GN	0.00	3.38	28.54	47.25	16.46	3.75	0.50	0.13	0.00	1598	147	514.34
1977/78	WINTER	2.31	36.01	40.47	10.34	7.42	2.64	0.41	0.28	0.12	2466	380	1182.89
	ROE-SN	0.85	35.31	43.14	11.57	7.39	1.37	0.29	0.03	0.06	3424	2450	354.62
	ROE-GN	0.00	0.71	20.32	30.04	35.69	11.48	1.41	0.35	0.00	566	1022	485.32
1978/79	WINTER	1.76	18.25	37.65	28.52	8.38	3.95	1.08	0.27	0.13	5463	1858	1085.01
	ROE-SN	1.63	20.01	32.72	27.96	9.37	5.18	2.06	0.64	0.43	1409	389	1.00~
	ROE-GN	0.00	1.15	23.23	54.70	13.51	5.77	1.48	0.00	0.16	607	290	441.80
1979/80	WINTER	2.99	43.51	23.26	18.15	8.30	2.16	1.24	0.31	0.08	4914	3044	228.46
	ROE-SN	2.49	49.82	15.90	17.71	9.86	2.61	1.23	0.27	0.12	4139	1495	16.94
	ROE-GN	0.00	1.99	9.15	44.56	33.42	8.75	1.86	0.27	0.00	754	1139	215.21
1980/81	WINTER	3.66	34.26	34.21	15.60	8.57	3.02	0.52	0.16	0.00	5160	2376	421.38
	ROE-SN	6.92	36.99	30.47	11.33	9.61	3.73	0.63	0.28	0.03	7731	2525	202.00
	ROE-GN	0.09	2.19	18.16	22.98	37.37	16.05	2.81	0.26	0.09	1140	338	333.10
1981/82	WINTER	3.36	38.13	31.72	16.14	5.74	3.80	0.91	0.08	0.12	2528	1506	316.45
	ROE-SN	6.31	34.70	25.07	20.87	4.69	5.22	2.50	0.56	0.07	5400	2796	313.69
	ROE-GN	0.00	4.44	15.37	28.45	14.77	20.77	14.17	1.68	0.36	833	543	367.36
1982/83	WINTER	3.06	19.28	30.43	21.91	12.30	4.45	5.26	2.78	0.53	2090	1037	58.60
	ROE-SN	2.99	31.42	28.48	17.84	11.47	3.19	3.06	1.25	0.29	11962	7026	696.76
	ROE-GN	0.00	0.49	27.76	29.48	23.59	9.34	7.37	1.72	0.25	407	305	563.81
1983/84	WINTER	14.82	31.77	23.11	17.06	8.13	3.35	1.01	0.43	0.32	1882	581	70.14
	ROE-SN	8.08	37.75	28.97	12.93	7.16	3.33	1.13	0.49	0.15	7152	1852	392.25
	ROE-GN	0.00	7.05	30.16	31.07	19.19	9.27	1.70	0.65	0.91	766	759	421.50
1984/85	WINTER	27.95	40.76	19.11	7.61	3.09	1.03	0.36	0.08	0.00	2522	507	77.78
	ROE-SN	23.91	43.83	18.95	7.92	3.40	1.33	0.59	0.06	0.01	7832	3009	297.73
	ROE-GN	0.09	3.10	26.09	32.48	23.63	9.22	3.74	0.82	0.82	1096	650	237.16
1985/86	WINTER	13.44	58.05	20.51	5.79	1.74	0.35	0.12	0.00	0.00	863	185	40.18
	ROE-SN	12.56	56.18	22.20	6.18	1.92	0.75	0.14	0.08	0.00	6411	1413	17.24
1986/87	WINTER	21.77	34.69	30.95	9.98	1.93	0.45	0.23	0.00	0.00	882	204	22.53
	ROE-SN	9.34	33.15	37.03	15.29	3.55	1.07	0.38	0.13	0.07	7689	2111	318.01
	ROE-GN	0.00	2.50	35.63	33.44	16.51	8.49	2.60	0.57	0.26	1920	944	413.31
1987/88	WINTER	3.50	60.18	17.29	15.32	2.74	0.66	0.22	0.11	0.00	914	1104	69.17
	ROE-SN	4.38	60.06	14.92	15.22	4.09	1.03	0.22	0.07	0.00	5912	1835	148.13
	ROE-GN	0.00	9.14	14.86	48.11	19.49	5.48	2.31	0.37	0.24	821	383	414.24
1988/89	WINTER	26.50	16.59	42.90	7.05	5.91	0.86	0.19	0.00	0.00	1049	298	93.71
	ROE-SN	10.01	18.01	53.48	9.45	7.10	1.59	0.31	0.03	0.02	6423	1619	140.64
	ROE-GN	0.00	1.58	40.22	21.99	25.88	7.78	2.19	0.36	0.00	823	1143	421.70
1989/90	WINTER	4.97	57.32	13.69	19.33	2.15	2.55	0.00	0.00	0.00	745	323	22.74
	ROE-SN	7.92	57.18	10.74	18.96	3.01	1.72	0.41	0.05	0.02	5644	2499	1.00~
	ROE-GN	0.00	8.39	11.67	56.24	12.18	9.70	1.46	0.29	0.07	1371	815	556.90
1990/91	WINTER	18.35	32.39	35.45	6.46	6.34	0.79	0.23	0.00	0.00	883	439	54.37
	ROE-SN	9.42	21.74	40.64	9.20	15.06	2.27	1.45	0.20	0.02	5106	1604	103.87

	ROE-GN	0.00	1.29	28.15	17.20	40.11	7.27	4.69	1.20	0.09	1087	637	644.61
1991/92	WINTER	3.96	69.60	16.30	9.03	0.66	0.22	0.22	0.00	0.00	454	143	91.46
	ROE-SN	5.10	54.85	13.72	16.74	3.49	5.16	0.60	0.32	0.02	5036	4330	346.46
	ROE-GN	0.00	6.33	14.88	43.63	11.72	18.91	2.65	1.45	0.43	1169	865	600.81
1992/93	WINTER	25.90	31.04	32.48	6.89	2.67	0.31	0.62	0.10	0.00	973	75	62.36
	ROE-SN	15.17	37.83	31.39	6.87	5.75	1.36	1.45	0.15	0.04	5445	1959	440.36
	ROE-GN	0.00	11.47	40.02	16.98	21.61	4.08	5.40	0.22	0.22	907	562	633.26
1993/94	WINTER	5.65	50.00	25.43	16.30	1.52	1.09	0.00	0.00	0.00	460	142	92.93
	ROE-SN	4.67	42.19	26.71	18.77	3.99	2.82	0.70	0.15	0.00	5968	3788	528.54
	ROE-GN	0.00	3.53	25.10	44.92	15.20	7.98	2.43	0.67	0.17	1191	703	865.23
1994/95	WINTER	22.08	27.18	34.32	10.90	4.46	0.71	0.28	0.00	0.07	1413	360	63.14
	ROE-SN	8.98	21.79	36.13	17.73	11.08	2.74	1.10	0.35	0.11	5658	3092	397.08
	ROE-GN	0.00	2.27	26.21	36.79	26.11	5.61	2.37	0.43	0.22	927	340	586.53
1995/96	WINTER	25.36	49.46	11.99	9.46	2.47	1.08	0.18	0.00	0.00	1660	473	62.22
	ROE-SN	12.98	48.36	14.05	14.43	5.80	3.38	0.69	0.23	0.08	8296	4663	759.67
	ROE-GN	0.00	3.86	15.81	45.40	21.88	10.29	1.84	0.74	0.18	544	452	449.47
1996/97	WINTER	21.96	59.61	13.73	3.14	0.78	0.20	0.39	0.20	0.00	510	53	56.14
	ROE-SN	7.85	52.10	23.23	6.01	6.51	2.59	1.51	0.13	0.07	7107	3423	989.32
	ROE-GN	0.00	4.74	17.85	16.43	31.91	17.06	8.53	2.53	0.95	633	501	449.74
1997/98	WINTER	4.09	47.22	40.06	6.70	1.19	0.57	0.11	0.06	0.00	1760	293	110.55
	ROE-SN	4.15	47.43	30.99	11.94	2.57	1.97	0.74	0.19	0.02	8416	3225	676.28
	ROE-GN	0.00	3.22	32.19	31.33	13.23	13.66	4.08	1.86	0.43	1398	383	548.84
1998/99	WINTER	11.48	27.62	42.83	14.28	3.08	0.57	0.14	0.00	0.00	1394	109	160.79
	ROE-SN	6.41	24.85	41.04	18.58	6.46	1.77	0.69	0.15	0.05	4069	1088	519.83
	ROE-GN	0.00	2.15	29.31	36.72	21.05	6.70	3.35	0.60	0.12	836	338	522.51
1999/**	WINTER	24.62	42.94	15.11	12.25	3.79	1.05	0.12	0.12	0.00	1714	437	151.32
	ROE-SN	10.15	37.80	19.13	21.73	8.66	2.05	0.28	0.19	0.01	6770	3633	715.41
	ROE-GN	0.00	1.10	14.42	44.95	27.99	9.08	2.12	0.34	0.00	1179	1017	566.28

AVERAGE WEIGHT AT AGE (gms)

FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+
WINTER	54.4	89.7	114.5	137.5	151.9	165.4	176.7	184.0	203.0
ROE-SN	57.5	83.1	108.1	128.2	146.4	160.8	170.2	177.3	187.7
ROE-GN	66.2	117.5	133.6	144.1	153.7	161.1	170.5	168.7	172.3

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

		PERCENT AT AGE									NUMBER	SAMPLE	CATCH
SEASON	FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+	AGED	WEIGHT	(x 10)
1950/51	WINTER	12.58	37.63	41.27	6.74	1.44	0.30	0.02	0.02	0.00	4037	580	2223.54
1951/52	WINTER	1.97	29.16	24.99	37.07	4.98	1.46	0.33	0.04	0.00	4921	2483	2287.45
1952/53	WINTER	14.28	56.10	27.45	1.64	0.48	0.05	0.00	0.00	0.00	3957	607	2.46
1953/54	WINTER	2.68	63.23	27.59	5.55	0.69	0.15	0.08	0.02	0.02	6092	1607	3570.83
1954/55	WINTER	16.82	59.39	19.69	3.43	0.64	0.04	0.00	0.00	0.00	2509	698	715.69
1955/56	WINTER	10.00	58.10	9.50	19.00	2.60	0.50	0.20	0.10	0.00	0*	25	1751.84
1956/57	WINTER	2.72	71.94	24.83	0.34	0.17	0.00	0.00	0.00	0.00	588	497	314.44
1957/58	WINTER	12.94	48.66	27.06	6.30	2.86	1.68	0.42	0.08	0.00	1190	344	69.90
1958/59	WINTER	4.23	45.02	27.39	14.41	3.85	2.40	2.02	0.57	0.11	3665	2199	7436.55
1959/60	WINTER	8.86	54.74	23.32	8.76	2.82	0.94	0.35	0.14	0.07	2877	2160	5631.14
1960/61	WINTER	41.08	37.18	17.69	3.90	0.15	0.00	0.00	0.00	0.00	667	84	3143.83
1961/62	WINTER	4.68	81.76	10.31	2.46	0.79	0.00	0.00	0.00	0.00	1261	551	2543.14
1962/63	WINTER	1.73	43.62	49.16	4.69	0.62	0.18	0.00	0.00	0.00	2258	893	1779.64
1963/64	WINTER	2.53	60.22	25.76	10.39	0.84	0.25	0.00	0.00	0.00	1184	1057	2078.97
1964/65	WINTER	2.18	34.34	49.88	9.95	3.28	0.36	0.00	0.00	0.00	824	372	1302.20
1965/66	WINTER	13.59	26.83	26.12	23.17	9.07	1.23	0.00	0.00	0.00	0*	25	791.48
1966/67	WINTER	12.86	60.28	20.52	4.84	1.15	0.18	0.15	0.02	0.00	0*	25	1289.24
1971/72	ROE-SN	3.25	18.52	48.12	24.63	3.50	1.15	0.76	0.06	0.00	1571	650	503.52
1972/73	ROE-SN	0.70	30.43	24.26	31.95	10.75	1.55	0.27	0.08	0.00	2576	1744	1204.92
	ROE-GN	0.00	7.85	22.92	51.76	13.46	2.88	0.96	0.16	0.00	624	526	95.73
1973/74	ROE-SN	8.04	43.04	23.95	13.62	8.86	2.21	0.22	0.04	0.02	5420	3103	1112.16
	ROE-GN	0.00	26.14	30.68	26.14	13.64	3.41	0.00	0.00	0.00	176	30	288.53
1974/75	ROE-SN	0.59	53.76	19.82	11.40	7.97	4.99	1.29	0.17	0.01	10114	4380	1451.92"
	ROE-GN	0.00	2.97	30.48	37.92	21.19	7.06	0.37	0.00	0.00	269	145	493.67
1975/76	ROE-SN	0.21	8.86	46.93	19.80	12.96	8.08	2.72	0.43	0.00	9230	1628	1626.81
	ROE-GN	0.00	0.68	40.26	33.87	15.68	6.62	2.51	0.30	0.08	1314	127	1053.75
1976/77	ROE-SN	0.52	12.42	31.09	37.16	12.36	4.46	1.66	0.28	0.04	6746	1395	1281.46"
	ROE-GN	0.56	3.35	16.48	42.74	17.60	12.29	5.31	1.40	0.28	358	49	813.02
1977/78	WINTER	1.27	43.83	23.50	13.70	14.21	2.16	0.81	0.30	0.21	2357	521	257.67
	ROE-SN	0.69	40.18	17.88	16.77	18.51	4.43	1.29	0.18	0.07	5963	2622	457.42
	ROE-GN	0.00	1.16	4.46	20.66	46.94	19.17	6.61	0.66	0.33	605	168	936.91
1978/79	ROE-SN	0.77	13.64	50.60	14.26	10.66	7.88	1.54	0.51	0.13	3885	564	849.26"
	ROE-GN	0.00	1.23	25.92	26.62	25.04	18.91	1.93	0.35	0.00	571	257	519.39
1979/80	ROE-SN	2.86	43.86	14.95	22.01	7.26	6.06	2.43	0.47	0.10	3003	469	152.30"
	ROE-GN	0.00	0.00	5.31	47.12	22.57	14.38	9.73	0.66	0.22	452	497	145.27
1980/81	ROE-SN	3.36	34.58	29.40	11.00	12.95	5.79	2.40	0.51	0.00	3745	853	433.90"
	ROE-GN	0.00	1.78	21.00	14.95	36.30	18.86	7.12	0.00	0.00	281	81	207.25
1981/82	ROE-SN	3.17	23.98	27.76	26.08	5.45	9.24	2.62	1.41	0.30	5046	2597	204.20"
	ROE-GN	0.00	0.58	11.94	43.34	11.70	27.11	4.06	1.16	0.12	863	365	221.31
1982/83	ROE-SN	4.21	22.56	21.87	21.90	17.66	4.43	5.40	1.06	0.90	3205	1818	477.79
	ROE-GN	0.00	0.35	14.19	23.82	44.83	6.48	9.81	0.35	0.18	571	159	176.62
1983/84	ROE-SN	21.73	37.22	13.58	9.16	10.04	5.91	1.07	1.07	0.23	3079	1182	492.36
	ROE-GN	0.00	1.68	6.72	17.98	32.61	31.93	5.38	3.36	0.34	595	464	55.40
1984/85	ROE-SN	20.47	53.62	14.22	3.71	2.74	3.17	1.70	0.13	0.23	2995	644	16.34"
1985/86	ROE-SN	3.78	50.45	29.70	8.29	3.13	2.24	1.76	0.58	0.07	4151	602	16.77"
1986/87	ROE-SN	14.83	16.59	34.39	21.45	7.35	2.55	1.38	1.08	0.38	4708	1971	1007.50
	ROE-GN	0.00	1.82	24.55	61.82	5.45	2.18	2.91	0.91	0.36	550	408	144.31
1987/88	ROE-SN	2.56	60.97	7.66	14.75	9.87	2.80	0.74	0.44	0.21	7459	4721	667.13
	ROE-GN	0.00	5.40	7.00	40.80	29.40	12.80	3.00	1.20	0.40	500	607	86.67
1988/89	ROE-SN	2.56	15.81	60.96	6.58	8.67	4.53	0.68	0.18	0.04	5712	2510	756.40
	ROE-GN	0.00	0.26	54.45	10.99	22.25	9.42	1.57	1.05	0.00	382	145	232.76
1989/90	ROE-SN	0.48	27.17	12.43	47.33	4.49	5.94	1.83	0.23	0.09	6831	6315	563.72
	ROE-GN	0.00	1.35	7.87	68.99	8.31	10.34	2.47	0.67	0.00	445	428	125.93
1990/91	ROE-SN	6.59	21.41	21.11	10.67	33.10	3.01	3.43	0.66	0.03	7311	4577	497.89
	ROE-GN	0.00	0.29	7.16	11.75	63.90	8.02	8.02	0.57	0.29	349	223	147.29
1991/92	ROE-SN	1.62	47.83	10.54	13.43	6.02	17.01	2.11	1.22	0.22	5979	3775	259.62
	ROE-GN	0.00	6.29	13.49	30.76	13.85	29.86	2.88	2.52	0.36	556	617	40.66
1992/93	ROE-SN	3.94	27.77	40.59	6.85	7.51	4.11	7.72	0.94	0.57	5430	2772	473.30
1993/94	ROE-SN	2.98	22.32	23.76	30.53	8.05	5.10	5.41	1.59	0.25	6098	3120	447.32"
	ROE-GN	0.00	4.78	31.96	56.01	5.44	1.15	0.49	0.16	0.00	607	581	53.41
1994/95	ROE-SN	0.83	13.35	24.05	20.45	25.99	6.85	4.55	3.21	0.72	4832	1060	182.15"
1995/96	ROE-SN	14.20	21.22	13.04	18.79	13.11	14.17	3.15	1.37	0.95	6126	3332	123.92"
1996/97	ROE-SN	2.49	68.99	8.13	4.51	6.60	4.98	3.39	0.56	0.35	5698	3736	705.43
1997/98	ROE-SN	2.33	21.78	60.30	6.46	2.86	3.10	1.76	1.13	0.30	5065	2119	571.46
	ROE-GN	0.00	0.56	38.26	11.01	9.68	20.13	12.35	5.67	2.34	899	424	111.91
1998/99	ROE-SN	1.52	22.66	24.18	38.63	7.78	2.72	1.40	0.74	0.37	4077	3893	359.48
	ROE-GN	0.00	0.90	11.94	59.35	17.91	4.95	3.49	1.35	0.11	888	173	50.80
1999/00	ROE-SN	6.23	23.32	19.68	17.72	27.32	3.73	1.24	0.58	0.18	4447	2883	110.10
	ROE-GN	0.00	1.28	7.52	27.04	52.80	6.24	2.56	2.24	0.32	625	475	48.21

	AVERAGE WEIGHT AT AGE (gms)								
FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+
WINTER	56.0	90.1	112.4	131.0	148.2	155.4	173.2	176.0	183.6
ROE-SN	63.8	93.0	120.6	144.1	163.0	176.8	186.5	194.8	198.2
ROE-GN	45.5	117.0	135.8	149.7	159.9	169.8	174.8	178.1	177.2

* - 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 1.6. Age-composition and catch in numbers by fishery and season and weight-at-age averaged over all seasons for Area 27. These data are used for age-structured model analysis.

						PERCENT AT AGE					NUMBER	SAMPLE	CATCH
SEASON	FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+	AGED	WEIGHT	(x 10)
1953/54	WINTER	0.00	47.57	40.45	10.11	0.75	1.12	0.00	0.00	0.00	267	4376	206.40
1954/55	WINTER	6.80	34.77	49.72	6.94	1.42	0.28	0.07	0.00	0.00	1412	510	614.00
1963/64	WINTER	0.00	46.32	30.53	22.11	1.05	0.00	0.00	0.00	0.00	95	440	29.70
1964/65	WINTER	1.41	18.31	36.62	33.10	7.04	0.70	1.41	1.41	0.00	142	131	55.25
1975/76	ROE-GN	0.00	3.74	41.18	27.27	17.65	6.42	3.74	0.00	0.00	187	18	5.55
1977/78	WINTER	1.41	53.52	5.63	19.72	16.90	2.82	0.00	0.00	0.00	71	71	14.38`
1978/79	ROE-SN	1.25	12.50	68.75	12.50	2.50	1.25	1.25	0.00	0.00	80	80	40.35
	ROE-GN	0.00	1.06	48.94	17.02	20.21	11.70	1.06	0.00	0.00	94	3599	18.68
1979/80	ROE-GN	0.00	4.00	9.33	70.67	12.00	2.67	1.33	0.00	0.00	75	39	36.66
1980/81	ROE-SN	2.23	13.50	61.21	8.26	13.24	1.57	0.00	0.00	0.00	763	412	59.41`
1981/82	ROE-SN	0.66	35.00	9.93	41.53	4.07	7.95	0.76	0.09	0.00	1057	656	20.77
	ROE-GN	0.00	0.92	6.42	55.05	9.17	25.69	2.75	0.00	0.00	109	187	22.70
1982/83	ROE-SN	3.96	20.79	31.68	10.89	28.71	0.00	3.96	0.00	0.00	101	2997	1.00~
	ROE-GN	0.00	0.00	8.75	15.00	62.50	2.50	11.25	0.00	0.00	80	80	11.73
1983/84	ROE-GN	0.00	0.00	4.17	42.13	16.67	33.33	2.55	1.16	0.00	432	206	11.07
1985/86	ROE-SN	2.21	23.62	63.47	2.58	1.48	1.85	2.58	2.21	0.00	271	101	1.00~
1986/87	ROE-SN	17.02	27.66	15.96	35.46	1.06	0.00	1.06	0.35	1.42	282	216	1.00~
1987/88	ROE-SN	2.16	62.53	11.05	6.20	15.36	1.62	0.81	0.00	0.27	371	406	1.00~
1988/89	ROE-SN	0.21	12.66	57.51	8.15	8.37	11.37	1.29	0.43	0.00	466	139	1.00~
1989/90	ROE-SN	1.84	22.68	14.25	39.63	5.83	7.13	7.78	0.65	0.22	926	785	1.00~
1990/91	ROE-SN	8.97	39.40	8.97	10.33	22.55	2.72	4.89	2.17	0.00	368	257	19.05"
1991/92	ROE-SN	3.48	71.21	11.21	3.40	2.91	5.04	0.99	1.28	0.50	1410	668	46.16
1992/93	ROE-SN	10.50	33.33	40.88	5.52	1.29	1.66	5.71	0.37	0.74	543	310	30.55
	ROE-GN	0.00	3.28	53.28	14.09	7.92	7.53	11.58	0.97	1.35	518	283	25.02
1993/94	ROE-SN	1.48	31.75	24.55	30.90	5.50	2.12	2.86	0.53	0.32	945	677	30.39
	ROE-GN	0.00	1.28	19.40	61.19	9.81	3.41	3.84	0.43	0.64	469	325	24.55
1994/95	ROE-SN	1.68	6.37	35.29	24.37	24.65	4.13	1.33	1.61	0.56	1428	421	41.24"
1995/96	ROE-SN	14.18	22.70	6.38	20.57	15.60	16.67	2.84	0.35	0.71	282	403	30.09"
1996/97	ROE-SN	4.01	76.83	7.32	1.57	4.01	4.70	1.57	0.00	0.00	574	142	30.38
1997/98	ROE-SN	1.39	38.89	48.61	4.86	0.35	2.78	2.43	0.69	0.00	288	393	30.08
1998/99	ROE-SN	7.07	32.51	26.86	27.92	4.24	0.71	0.35	0.35	0.00	283	369	28.81
1999/00	ROE-SN	2.34	52.21	23.64	10.65	9.35	1.56	0.00	0.00	0.26	385	313	27.54

AVERAGE WEIGHT AT AGE (gms)

FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+
WINTER	69.2	91.1	119.9	146.3	164.8	174.1	202.7	208.7	0.0
ROE-SN	56.8	93.8	118.0	138.1	157.0	171.2	181.9	200.4	212.3
ROE-GN	0.0	114.9	134.4	144.1	152.1	155.8	166.3	179.0	196.2

* - 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 1.7. Age-composition and catch in numbers by fishery and season and weight-at-age averaged over all seasons for Area 2W. These data are used for age-structured model analysis.

		PERCENT AT AGE									NUMBER	SAMPLE	CATCH
SEASON	FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+	AGED	WEIGHT	(x 10)
1956/57	WINTER	0.00	63.41	31.71	2.44	2.44	0.00	0.00	0.00	0.00	41	41	12.10
1964/65	WINTER	0.00	46.00	8.00	28.00	8.00	6.00	4.00	0.00	0.00	50	50	85.99
1972/73	ROE-SN	0.00	7.80	19.86	18.44	46.81	4.96	1.42	0.71	0.00	141	655	43.98
1973/74	ROE-SN	7.62	25.71	23.33	21.90	8.10	11.43	1.90	0.00	0.00	210	110	32.07
1974/75	ROE-SN	0.53	45.72	32.89	12.57	3.48	3.74	1.07	0.00	0.00	374	161	30.56
1975/76	ROE-SN	23.71	6.70	41.24	23.71	4.64	0.00	0.00	0.00	0.00	194	593	1.00~
1977/78	ROE-SN	0.00	7.28	25.73	10.19	41.75	6.31	5.83	2.91	0.00	206	124	34.05
1978/79	ROE-SN	1.49	18.84	22.95	16.23	22.95	13.81	1.87	1.12	0.75	536	91	45.46"
1979/80	ROE-SN	0.00	70.00	15.29	6.47	4.71	2.94	0.00	0.59	0.00	170	45	1.00~
1980/81	ROE-SN	4.35	3.78	66.50	11.66	7.06	4.60	1.64	0.41	0.00	1218	100	57.30
1981/82	ROE-SN	1.80	37.54	1.45	51.39	4.11	2.14	1.16	0.35	0.06	1726	939	87.26
1982/83	ROE-SN	0.69	1.34	56.41	3.01	33.10	2.92	1.25	0.74	0.54	3356	140	161.04
1983/84	ROE-SN	6.45	1.61	0.60	35.28	2.42	51.01	1.81	0.60	0.20	496	427	1.00~
1984/85	ROE-SN	0.50	2.90	5.21	2.80	21.82	2.80	63.16	0.70	0.10	999	381	9.62
1985/86	ROE-SN	0.82	0.27	11.48	11.75	5.46	20.77	7.38	41.53	0.55	366	38	1.00~
1986/87	ROE-SN	22.14	61.32	0.25	1.27	1.27	1.27	8.14	1.02	3.31	393	398	1.00~
1987/88	ROE-SN	1.79	74.01	19.31	0.26	0.53	0.66	0.79	1.65	0.99	1512	166	1.00~
1988/89	ROE-SN	0.49	3.42	76.06	15.88	0.49	0.49	0.98	0.81	1.38	1228	330	1.00~
1989/90	ROE-SN	0.20	1.47	1.72	77.69	16.84	0.45	0.20	0.57	0.86	2447	2792	135.97
1990/91	ROE-SN	0.52	12.62	1.64	2.43	65.78	15.24	0.79	0.46	0.52	3288	2178	153.62
1991/92	ROE-SN	1.53	9.10	13.25	1.53	2.72	58.38	12.01	0.54	0.94	2023	804	71.79
1992/93	ROE-SN	1.01	13.77	16.84	14.48	2.06	4.69	41.15	5.25	0.75	2666	681	81.95
1993/94	ROE-SN	5.32	12.23	43.62	14.89	9.57	2.13	5.85	5.32	1.06	188	104	1.00~
1997/98	ROE-SN	18.50	34.75	23.10	18.68	2.62	0.63	1.53	0.18	0.00	1108	449	14.90
1998/99	ROE-SN	15.60	32.38	28.09	14.30	7.28	1.56	0.52	0.26	0.00	769	201	1.00~
1999/00	ROE-SN	14.77	63.64	18.18	0.00	2.27	0.00	1.14	0.00	0.00	88	88	1.00~

	AVERAGE WEIGHT AT AGE (gms)								
FISHERY	1+	2+	3+	4+	5+	6+	7+	8+	9+
WINTER	50.0	89.2	122.1	125.7	166.0	196.0	216.5	0.0	0.0
ROE-SN	67.8	104.4	133.3	162.0	185.0	191.5	203.7	208.9	214.7
ROE-GN	53.2	81.9	139.8	162.0	187.7	191.9	199.0	0.0	0.0

* - 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 2.1. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from age-structured analysis for the Queen Charlotte Islands stock assessment region.

	Estimated numbers at age (x 10^{-5}) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
1950/51	3837	2057	1058	211	138	59	0	0	0	4623	2510	0.19
1951/52	5240	2360	1230	527	94	59	25	0	0	5327	2398	0.00
1952/53	23375	3084	1275	487	157	24	15	6	0	10610	4759	0.00
1953/54	2787	14376	1897	784	299	96	15	9	4	15235	9853	0.36
1954/55	3565	1708	8779	1114	451	171	55	8	7	44891	6143	-1.19
1955/56	1113	2190	1047	5374	680	275	104	34	10	6392	4014	0.34
1956/57	1845	678	629	294	704	47	19	7	3	1739	1578	0.70
1957/58	4381	836	69	175	37	45	3	1	1	2815	787	-0.47
1958/59	1676	1443	265	22	34	5	6	0	0	9091	6940	0.53
1959/60	4069	760	655	137	11	16	2	3	0	14397	6469	0.00
1960/61	4922	2502	468	403	84	6	10	1	2	9052	6975	0.54
1961/62	9305	3025	1517	280	238	50	4	6	2	10893	4654	-0.05
1962/63	1918	5708	1674	735	119	96	20	2	3	14818	6177	-0.07
1963/64	4928	1176	3022	762	282	42	34	7	2	5220	4224	0.59
1964/65	409	3014	437	957	139	36	5	4	1	2324	1446	0.33
1965/66	317	215	143	117	108	7	2	0	0	3047	2764	0.70
1966/67	407	164	81	67	47	40	2	1	0	2979	710	-0.63
1967/68	746	250	95	48	39	27	23	1	0	3370	750	-0.70
1968/69	2102	457	152	57	29	24	16	14	1	4178	1876	0.00
1969/70	4757	1293	281	93	35	18	14	10	9	9592	4307	0.00
1970/71	4132	2925	795	173	57	22	11	9	12	30316	13616	0.00
1971/72	11535	2541	1799	489	106	35	13	7	13	19633	9950	0.12
1972/73	9187	7086	1478	1001	259	55	18	7	10	24365	7706	-0.35
1973/74	8095	5649	4161	785	494	124	26	9	8	37827	9903	-0.54
1974/75	2124	4978	3340	2352	425	262	66	14	9	46086	8950	-0.84
1975/76	2770	1303	2926	1886	1272	225	139	35	12	37227	15142	-0.10
1976/77	3209	1700	781	1539	895	568	100	62	21	29943	12516	-0.07
1977/78	1919	1973	901	399	714	398	253	45	37	18564	11452	0.32
1978/79	37909	1179	1062	444	165	268	145	92	30	10714	8657	0.59
1979/80	2722	23294	709	514	169	56	88	48	40	40456	21204	0.15
1980/81	1093	1673	14152	422	276	84	27	43	43	65820	19024	-0.44
1981/82	1170	672	1018	8358	237	144	43	14	43	66867	19009	-0.46
1982/83	7829	718	405	610	4919	136	80	24	32	54560	19083	-0.25
1983/84	3469	4800	426	237	348	2758	76	45	31	43516	20438	0.04
1984/85	802	2126	2846	249	134	194	1533	42	42	36365	14394	-0.13
1985/86	1627	490	1264	1627	135	71	101	797	44	32017	5637	-0.94
1986/87	11210	1000	297	737	917	75	39	56	463	24686	13132	0.17
1987/88	4226	6892	602	174	424	523	43	22	296	30722	14457	0.05
1988/89	1446	2599	4238	370	107	261	322	26	196	36336	23985	0.39
1989/90	913	887	1578	2546	220	63	154	190	131	30780	25011	0.59
1990/91	4336	561	508	883	1331	110	31	75	157	20180	14220	0.45
1991/92	346	2643	330	277	450	651	53	15	111	19871	9500	0.06
1992/93	212	211	1529	185	148	237	342	28	66	12536	5405	-0.04
1993/94	824	130	120	803	90	70	111	160	44	9840	4895	0.10
1994/95	3127	501	75	68	443	49	38	60	111	9615	4946	0.14
1995/96	4822	1923	308	46	42	272	30	23	105	12562	5827	0.03
1996/97	15614	2966	1182	189	28	26	167	18	79	14449	11686	0.59
1997/98	908	9597	1817	719	115	17	16	101	59	22386	18871	0.63
1998/99	3825	558	5782	1062	411	65	10	9	90	31477	9714	-0.38
1999/00	2248	2342	336	3350	595	221	34	5	51	32878	5119	-1.06

Estimated average availability at age (S_i)

0.12 0.42 0.61 0.89 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.01 0.03 0.19 0.52 0.77 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 0.45

Estimated instantaneous natural mortality rate is 0.486

Appendix table 2.2. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from age-structured analysis for the Prince Rupert stock assessment region.

	Estimated numbers at age (x 10^{-5}) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
1950/51	7082	7475	8944	1204	436	231	0	0	0	15445	30098	1.18
1951/52	7187	4068	3826	3365	330	86	45	0	0	7312	18725	1.45
1952/53	17156	4134	2153	1237	662	33	9	5	0	29152	26180	0.41
1953/54	5263	10211	2412	1250	710	377	19	5	3	10959	13290	0.71
1954/55	13463	3093	5547	914	348	143	76	4	2	16842	25629	0.93
1955/56	4344	7981	1780	2498	350	115	48	25	2	45262	15498	-0.56
1956/57	8218	2498	4245	976	1314	178	59	24	14	19519	28279	0.88
1957/58	15660	4658	1119	1809	339	378	51	17	11	39680	12044	-0.68
1958/59	4925	9122	2647	635	1003	185	206	28	15	43579	36608	0.34
1959/60	26090	2908	4998	1447	333	508	94	104	22	35735	19072	-0.11
1960/61	13100	14670	1622	2519	668	143	218	40	54	33520	12881	-0.44
1961/62	7145	7463	6732	708	913	204	44	67	29	35228	24760	0.16
1962/63	20323	4199	3902	3213	299	347	78	17	36	28636	15652	-0.09
1963/64	2697	10763	2049	1679	1136	88	103	23	16	41336	29266	0.17
1964/65	653	1511	4761	989	723	444	34	40	15	12246	6710	-0.09
1965/66	1027	237	556	1724	251	124	76	6	9	7669	7487	0.49
1966/67	1629	611	99	229	561	65	32	20	4	4408	2719	0.03
1967/68	1698	633	173	38	65	117	14	7	5	5882	4788	0.31
1968/69	7404	936	295	91	19	30	55	6	5	3512	843	-0.91
1969/70	4837	4397	544	164	49	10	16	28	6	14193	8437	-0.01
1970/71	1749	2854	2533	311	92	27	5	9	19	17836	9753	-0.09
1971/72	10930	1022	1551	1405	167	48	14	3	15	17735	9853	-0.07
1972/73	9964	6506	595	830	712	81	23	7	8	21885	11261	-0.15
1973/74	3727	5931	3840	342	469	398	45	13	8	28413	8893	-0.65
1974/75	1331	2219	3503	2168	181	239	202	23	11	34602	11109	-0.62
1975/76	2992	791	1310	2038	1248	103	136	115	19	35401	14213	-0.40
1976/77	1526	1781	469	738	1115	668	55	73	72	24351	9736	-0.40
1977/78	1633	908	996	245	354	501	299	25	65	13056	4738	-0.50
1978/79	27906	968	500	484	99	123	173	103	31	9507	7554	0.28
1979/80	5053	16606	541	253	217	40	49	69	54	20077	10236	-0.16
1980/81	6289	3007	9708	299	124	98	18	22	55	36849	10532	-0.74
1981/82	6529	3743	1762	5566	165	66	51	9	41	42846	12631	-0.71
1982/83	19089	3882	2195	1025	3205	94	37	29	29	48275	19652	-0.38
1983/84	3586	11363	2311	1306	610	1907	56	22	35	44389	22927	-0.15
1984/85	3364	2134	6705	1347	742	334	1011	30	30	43672	35858	0.32
1985/86	12654	2002	1248	3829	733	375	157	477	28	44082	32525	0.21
1986/87	10380	7528	1151	697	1989	359	179	75	241	40627	31422	0.26
1987/88	6131	6177	4411	660	373	987	171	86	151	36080	33679	0.44
1988/89	3190	3648	3576	2492	346	170	416	72	100	34243	12783	-0.47
1989/90	13677	1897	2100	2009	1285	147	65	159	66	35233	19398	-0.08
1990/91	13932	8140	1095	1200	1098	658	72	32	111	38000	21544	-0.05
1991/92	3616	8291	4749	628	658	574	328	36	71	41393	35992	0.37
1992/93	1703	2152	4848	2741	331	307	249	142	47	34974	21440	0.02
1993/94	4713	1013	1253	2739	1447	146	117	95	72	27533	13439	-0.20
1994/95	19429	2804	590	704	1463	718	63	50	72	23743	15858	0.11
1995/96	8090	11562	1649	340	391	782	366	32	62	38323	22104	-0.04
1996/97	12266	4815	6807	961	189	185	348	163	42	29927	20744	0.15
1997/98	3551	7301	2846	3955	498	68	39	74	43	36863	16734	-0.28
1998/99	9277	2113	4306	1660	2208	252	14	8	25	38209	25699	0.12
1999/00	1950	5521	1252	2506	945	1193	128	7	17	35764	15658	-0.31

Estimated average availability at age (S_i)

0.07 0.36 0.55 0.80 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.00 0.13 0.18 0.46 0.72 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 0.60

Estimated instantaneous natural mortality rate is 0.519

Appendix table 2.3. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from age-structured analysis for the Central Coast stock assessment region.

	Estimated numbers at age (x 10^{-5}) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
1950/51	1658	3075	3995	738	296	76	0	0	0	13892	23134	0.54
1951/52	2229	1179	1409	1394	181	64	16	0	0	3655	10709	1.10
1952/53	12805	1566	412	359	178	16	6	1	0	10268	20001	0.69
1953/54	1523	9701	1169	298	257	127	12	4	1	8321	18635	0.83
1954/55	1647	1038	5272	396	70	52	26	2	1	26961	14984	-0.56
1955/56	3828	1184	714	3174	223	38	29	14	2	6812	8244	0.22
1956/57	5480	2313	422	196	484	26	4	3	2	2979	6223	0.76
1957/58	6406	3798	671	112	28	51	3	0	1	11684	4226	-0.99
1958/59	1567	4570	2142	344	50	12	22	1	0	5028	4105	-0.18
1959/60	3123	1086	2132	618	59	7	2	3	0	25105	14684	-0.51
1960/61	8638	2142	722	1466	414	39	5	1	2	6729	4567	-0.36
1961/62	4231	6099	726	221	282	66	6	1	1	13789	14180	0.05
1962/63	3777	3063	3761	352	92	112	26	2	0	4535	8466	0.65
1963/64	1834	2851	1267	957	45	8	10	2	0	4395	7058	0.50
1964/65	1918	1022	801	333	133	5	1	1	0	3130	2365	-0.25
1965/66	5389	1363	372	234	58	19	1	0	0	1811	1773	0.00
1966/67	1901	1179	149	81	20	3	1	0	0	3275	5904	0.61
1967/68	455	255	158	43	14	3	0	0	0	3533	6366	0.61
1968/69	1860	289	141	96	24	8	1	0	0	3601	2331	-0.41
1969/70	1575	1408	217	105	71	18	6	1	0	13432	10134	-0.26
1970/71	2006	1183	1059	163	79	53	13	4	1	14819	6056	-0.87
1971/72	3415	1482	796	696	103	49	33	8	3	10259	3928	-0.93
1972/73	2231	2558	928	391	293	41	20	13	5	19686	14471	-0.28
1973/74	2968	1685	1681	558	212	153	21	10	9	17971	10624	-0.50
1974/75	1433	2243	1228	1022	272	90	63	9	8	24194	9164	-0.95
1975/76	739	1083	1607	790	538	129	42	29	8	18488	16133	-0.11
1976/77	829	546	762	975	363	207	46	15	13	17382	18481	0.09
1977/78	575	627	348	461	464	146	80	18	11	6194	10097	0.51
1978/79	5820	436	376	166	113	57	14	8	3	6730	6551	0.00
1979/80	1115	4412	330	285	126	86	43	11	8	21876	15979	-0.29
1980/81	1192	845	3341	248	207	88	59	29	13	26970	16949	-0.44
1981/82	530	903	636	2445	167	125	48	32	23	29565	18413	-0.45
1982/83	443	399	653	444	1533	99	70	27	31	23599	16618	-0.33
1983/84	1720	335	291	455	282	918	58	41	33	15054	14197	-0.03
1984/85	712	1292	233	186	258	145	449	28	36	16021	8480	-0.61
1985/86	1347	534	894	150	107	142	77	239	34	15158	15532	0.05
1986/87	7945	1015	378	596	94	65	86	46	164	15176	12992	-0.13
1987/88	561	6015	728	251	369	57	39	51	126	31897	27016	-0.14
1988/89	496	422	4334	505	164	232	35	24	111	30328	32335	0.09
1989/90	1566	369	293	2822	286	85	113	17	66	27917	31047	0.13
1990/91	7673	1184	256	194	1712	160	46	60	45	21234	20156	-0.03
1991/92	932	5806	793	157	108	900	82	23	54	30288	46038	0.44
1992/93	1644	693	3989	510	94	62	508	46	43	29360	39713	0.33
1993/94	440	1225	474	2488	289	50	31	252	44	26491	29780	0.14
1994/95	1410	323	748	285	1337	145	24	15	141	15934	18918	0.20
1995/96	5202	1064	205	422	141	621	65	11	70	13858	17941	0.28
1996/97	5026	3899	730	126	241	78	341	36	44	19701	25208	0.27
1997/98	1122	3801	2709	482	80	147	47	204	48	22806	29385	0.28
1998/99	1746	845	2518	1620	266	42	70	22	120	24339	28924	0.20
1999/00	95	1319	581	1592	938	146	19	31	63	24004	23811	0.02

Estimated average availability at age (S_i)

0.15 0.55 0.76 0.94 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.00 0.03 0.21 0.52 0.77 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 0.97

Appendix table 2.4. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from age-structured analysis for the Strait of Georgia stock assessment region.

	Estimated numbers at age (x 10^{-5}) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
1950/51	17919	8322	3118	680	133	45	0	0	0	24130	66064	0.74
1951/52	20783	9835	2926	845	175	33	11	0	0	28342	66048	0.57
1952/53	36466	11181	3623	826	227	46	9	3	0	53418	100512	0.36
1953/54	22313	20199	5807	1826	414	114	23	4	1	36132	90437	0.65
1954/55	13064	12333	9164	1561	466	103	28	6	1	72468	74225	-0.25
1955/56	12172	7046	4490	3196	529	155	34	9	2	27418	29493	-0.20
1956/57	10101	6421	2190	998	659	105	31	7	2	15992	28997	0.32
1957/58	26614	5559	1223	415	172	108	17	5	1	11662	20357	0.29
1958/59	18596	14654	2255	334	108	43	27	4	2	28407	44280	0.17
1959/60	9696	9621	5478	614	86	27	11	7	1	31099	37222	-0.09
1960/61	22955	5028	2942	1344	141	19	6	2	2	19025	25521	0.02
1961/62	20589	11646	1834	689	294	30	4	1	1	21106	23282	-0.17
1962/63	19763	11012	3143	380	131	53	5	1	0	12242	27751	0.55
1963/64	9736	10026	3320	472	50	16	6	1	0	11236	20366	0.32
1964/65	4977	5114	2521	431	52	5	2	1	0	19847	18627	-0.33
1965/66	4854	2301	1125	585	93	11	1	0	0	3900	5109	0.00
1966/67	2695	2165	542	126	53	7	1	0	0	4318	6344	0.11
1967/68	1747	637	217	71	14	5	1	0	0	6352	12021	0.37
1968/69	5433	922	293	101	33	6	2	0	0	14003	18207	-0.01
1969/70	6217	2979	495	157	54	18	3	1	0	26918	44195	0.22
1970/71	4903	3437	1619	269	86	29	10	2	1	24738	47312	0.38
1971/72	7908	2712	1869	862	143	45	16	5	1	22900	25875	-0.15
1972/73	11929	4328	1279	804	364	60	19	7	3	20377	18255	-0.38
1973/74	16093	6624	2279	559	331	147	24	8	4	49740	64619	-0.01
1974/75	11097	8931	3626	1186	260	142	61	10	5	62575	76691	-0.07
1975/76	19007	6164	4893	1866	521	107	58	25	6	47386	57133	-0.08
1976/77	15058	10543	3362	2421	801	186	37	20	11	67037	58003	-0.42
1977/78	8129	8342	5449	1592	1018	314	71	14	12	56087	97082	0.28
1978/79	11225	4506	4228	2430	610	352	105	24	9	46461	59041	-0.03
1979/80	8549	6226	2362	1900	959	225	128	38	12	54081	74847	0.05
1980/81	6873	4746	3378	1254	941	447	104	59	23	49656	48230	-0.30
1981/82	5451	3794	2461	1675	556	384	177	41	32	41456	90239	0.51
1982/83	4821	3003	1908	1171	734	214	137	63	26	22768	47423	0.46
1983/84	7836	2659	1450	725	338	188	45	29	19	19746	27587	0.06
1984/85	12037	4315	1310	593	211	79	42	10	11	27835	26629	-0.32
1985/86	6804	6610	2244	602	221	67	24	13	6	50479	61097	-0.08
1986/87	21321	3776	3649	1238	332	122	37	13	11	40548	39037	-0.31
1987/88	6484	11818	1979	1774	507	112	35	11	7	57944	25351	-1.10
1988/89	15712	3596	6420	983	780	205	42	13	7	56661	54078	-0.32
1989/90	7579	8708	1958	3307	437	317	78	16	8	78709	58912	-0.56
1990/91	19519	4211	4797	1038	1530	180	126	31	9	57805	43420	-0.56
1991/92	13972	10833	2292	2429	458	606	67	47	15	70197	80120	-0.14
1992/93	14238	7746	5761	1125	1027	175	223	25	23	82599	84961	-0.24
1993/94	6587	7844	4079	2830	484	401	64	83	18	62757	60862	-0.30
1994/95	11848	3635	4099	1937	1102	152	115	19	29	51820	59708	-0.13
1995/96	16062	6543	1921	1983	799	417	54	41	17	59185	76291	-0.02
1996/97	17490	8823	3261	921	825	294	148	19	21	53593	53442	-0.27
1997/98	8047	9645	4383	1499	361	265	86	43	12	50014	68699	0.05
1998/99	10969	4444	5014	2080	588	108	51	17	11	46721	70165	0.14
1999/00	12185	6056	2312	2386	844	194	30	14	7	41531	67694	0.22

Estimated average availability at age (S_i)

0.11 0.70 0.93 0.98 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.00 0.02 0.21 0.57 0.85 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 1.31

Estimated instantaneous natural mortality rate is 0.587

Appendix table 2.5. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from age-structured analysis for the west coast Vancouver Island stock assessment region.

	Estimated numbers at age ($x 10^{-5}$) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
1950/51	3391	2243	2725	385	110	26	0	0	0	17320	17006	-0.20
1951/52	4579	1919	793	1038	133	36	9	0	0	1952	14383	1.82
1952/53	7314	2839	759	133	104	8	2	1	0	15557	30676	0.50
1953/54	4371	4581	1777	475	83	65	5	1	0	7307	16554	0.64
1954/55	5848	2663	1102	401	79	11	9	1	0	21872	17555	-0.40
1955/56	7569	3573	1368	589	209	40	6	4	0	23327	45167	0.48
1956/57	8898	4623	1456	611	247	85	16	2	2	35702	52651	0.21
1957/58	11487	5567	2738	872	363	146	50	10	3	44682	24399	-0.79
1958/59	7662	7189	3463	1702	541	225	91	31	8	10597	18396	0.37
1959/60	4218	4571	2071	712	243	59	25	10	4	5013	7040	0.16
1960/61	10192	2282	637	362	76	17	4	2	1	4783	7912	0.32
1961/62	4907	5454	563	138	56	9	2	1	0	14308	34579	0.70
1962/63	6615	2985	1850	195	42	16	3	1	0	7029	14618	0.55
1963/64	1724	4121	1293	537	47	9	3	1	0	11967	27862	0.66
1964/65	1558	1041	1641	433	157	13	2	1	0	10687	10863	-0.16
1965/66	1958	955	327	580	135	46	4	1	0	4317	4584	-0.12
1966/67	893	1168	484	94	138	29	10	1	0	4384	5119	-0.03
1967/68	1473	446	207	125	19	24	5	2	0	9414	11277	0.00
1968/69	6865	923	280	130	78	12	15	3	1	9357	11206	0.00
1969/70	13683	4300	578	175	81	49	8	9	3	29159	34923	0.00
1970/71	9933	8571	2694	362	110	51	31	5	8	27185	32477	0.00
1971/72	12040	6222	5369	1687	227	69	32	19	8	61677	36070	-0.72
1972/73	12627	7527	3812	3107	964	129	39	18	15	73148	16218	-1.69
1973/74	20991	7901	4362	2025	1591	485	65	20	17	94004	24775	-1.51
1974/75	8926	13067	4505	2429	1060	806	245	33	18	110920	44594	-1.09
1975/76	5460	5583	7453	2422	1189	503	382	116	24	63408	63335	-0.18
1976/77	8878	3417	3363	3566	910	398	167	126	46	48859	57398	-0.02
1977/78	2560	5555	1991	1584	1435	324	140	58	61	41870	39931	-0.23
1978/79	5730	1599	3220	1061	622	439	90	39	33	27771	63664	0.65
1979/80	4002	3583	887	1569	386	185	126	26	20	33675	62619	0.44
1980/81	2138	2502	2181	528	877	200	94	64	23	33178	58519	0.39
1981/82	1439	1325	1421	1207	259	401	88	41	38	25832	29424	-0.05
1982/83	2837	895	781	809	630	121	177	39	35	18047	15329	-0.34
1983/84	6166	1758	458	383	349	251	47	69	29	19119	22143	-0.03
1984/85	5697	3762	935	229	179	158	113	21	44	38190	29130	-0.45
1985/86	2230	3565	2349	584	143	111	98	70	40	47852	38347	-0.40
1986/87	13827	1396	2226	1466	364	89	70	61	69	32113	29914	-0.25
1987/88	2351	8523	717	1041	632	151	37	29	54	41850	39289	-0.24
1988/89	2942	1457	4954	384	528	313	75	18	41	40909	43332	-0.12
1989/90	1670	1825	798	2541	180	236	139	33	26	34852	38338	-0.09
1990/91	5542	1044	998	420	1262	87	114	67	29	23491	25906	-0.08
1991/92	2898	3441	553	507	197	558	38	50	42	25044	36811	0.20
1992/93	2200	1812	2037	311	275	105	298	20	49	25123	29236	-0.03
1993/94	990	1360	1012	1091	163	142	54	153	35	19296	19764	-0.16
1994/95	1606	608	757	520	530	76	66	25	87	16854	25039	0.22
1995/96	7595	1005	358	427	288	291	42	36	62	15369	31929	0.55
1996/97	2464	4741	605	209	246	165	167	24	56	23793	39114	0.32
1997/98	1621	1527	2511	310	103	120	80	81	39	16614	36898	0.62
1998/99	1334	1003	840	1237	140	39	40	27	40	14596	18829	0.07
1999/00	1745	831	551	440	605	66	17	17	29	14742	10940	-0.48

Estimated average availability at age (S_i)

0.08 0.64 0.81 0.94 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.00 0.03 0.30 0.68 0.89 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 1.20

Estimated instantaneous natural mortality rate is 0.468

Appendix table 3.1. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from revised age-structured analysis (RASM) for the Queen Charlotte Islands stock assessment region.

	Estimated numbers at age (x 10^{-5}) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
1950/51	3467	1714	881	183	121	51	0	0	0	3795	2510	0.02
1951/52	4874	2168	1035	422	78	48	20	0	0	3509	2398	0.05
1952/53	21893	2904	1172	363	103	15	10	4	0	8273	4759	-0.12
1953/54	2696	13691	1816	733	227	65	10	6	3	13217	9853	0.14
1954/55	3352	1681	8506	1072	423	129	37	5	5	44580	6143	-1.55
1955/56	1060	2094	1048	5291	665	262	80	23	6	6020	4014	0.03
1956/57	2695	656	579	278	673	44	17	5	2	1304	1578	0.62
1957/58	6466	1385	60	148	32	34	2	1	0	1620	787	-0.29
1958/59	3105	2757	610	17	22	3	3	0	0	10070	6940	0.06
1959/60	12677	1935	1249	309	8	10	1	1	0	9983	6469	0.00
1960/61	19011	7928	1210	781	193	5	6	1	1	9891	6975	0.08
1961/62	30848	7158	2974	446	286	70	2	2	1	13563	4654	-0.64
1962/63	6775	11606	2557	945	132	81	20	1	1	14105	6177	-0.39
1963/64	10323	2549	4002	736	240	31	19	5	0	4270	4224	0.42
1964/65	1154	3875	750	763	88	21	3	2	0	2427	1446	-0.08
1965/66	690	408	168	122	61	4	1	0	0	2469	2764	0.55
1966/67	1443	231	101	50	32	15	1	0	0	1535	710	-0.34
1967/68	1042	543	81	36	17	11	5	0	0	1501	750	-0.26
1968/69	1743	391	203	30	13	6	4	2	0	2895	1876	0.00
1969/70	2258	656	147	76	11	5	2	2	1	6644	4307	0.00
1970/71	1073	850	247	55	29	4	2	1	1	14934	13616	0.34
1971/72	2800	866	686	199	45	23	3	2	1	8960	9950	0.54
1972/73	2410	2250	600	447	118	25	13	2	2	10559	7706	0.12
1973/74	2321	1943	1600	354	226	55	12	6	2	18072	9903	-0.17
1974/75	645	1872	1421	1078	218	134	33	7	5	24816	8950	-0.59
1975/76	937	516	1364	972	683	134	82	20	7	20468	15142	0.13
1976/77	961	752	395	835	501	316	61	37	12	17480	12516	0.10
1977/78	475	774	449	233	422	235	148	29	23	10841	11452	0.49
1978/79	10128	382	462	255	101	155	83	52	18	5019	8657	0.98
1979/80	876	8147	290	246	90	28	41	22	19	23547	21204	0.33
1980/81	438	705	6384	220	155	49	15	22	22	33626	19024	-0.14
1981/82	501	307	484	4122	129	80	24	7	21	36442	19009	-0.22
1982/83	3531	350	207	323	2665	80	47	14	17	31492	19083	-0.07
1983/84	1626	2465	230	133	198	1587	47	28	18	26819	20438	0.16
1984/85	394	1134	1617	147	81	118	942	28	27	23097	14394	-0.04
1985/86	852	272	750	1005	85	44	64	505	30	21769	5637	-0.92
1986/87	6775	598	187	484	618	51	26	38	319	18401	13132	0.10
1987/88	2911	4756	406	123	309	391	32	17	225	25708	14457	-0.14
1988/89	1114	2044	3338	285	86	217	274	22	170	34064	23985	0.08
1989/90	786	780	1414	2280	193	58	146	184	129	32125	25011	0.18
1990/91	4256	551	508	897	1356	110	32	81	175	19571	14220	0.11
1991/92	306	2481	309	261	430	623	49	14	115	17899	9500	-0.20
1992/93	181	178	1359	163	131	212	307	24	64	10278	5405	-0.21
1993/94	679	106	94	653	72	55	89	129	37	7300	4895	0.03
1994/95	2444	393	58	50	331	35	27	44	82	6843	4946	0.11
1995/96	3480	1439	231	34	29	194	21	16	74	8772	5827	0.02
1996/97	10220	2049	846	136	20	17	114	12	53	9956	11686	0.59
1997/98	519	6010	1199	490	78	11	10	65	37	13922	18871	0.74
1998/99	2162	305	3412	647	255	40	6	5	53	16982	9714	-0.12
1999/00	1538	1262	172	1790	320	117	17	3	25	15496	5119	-0.67

Estimated average availability at age (S_i)

0.10 0.41 0.64 0.89 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.01 0.03 0.19 0.54 0.79 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 0.65

Estimated instantaneous natural mortality rate is Variable

Appendix table 3.2. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from revised age-structured analysis (RASM) for the Prince Rupert stock assessment region.

	Estimated numbers at age (x 10^{-5}) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
	16755	13051	13487	1699	593	313	0	0	0	22976	30098	0.52
1951/52	15975	7647	5492	4424	444	122	65	0	0	12054	18725	0.69
1952/53	42015	7290	3310	1567	874	55	15	8	0	31014	26180	0.08
1953/54	12961	19514	3343	1507	706	391	25	7	4	12308	13290	0.32
1954/55	30293	5987	8614	1073	378	136	75	5	2	20379	25629	0.48
1955/56	10003	14041	2727	3241	358	112	40	22	2	45711	15498	-0.83
1956/57	17928	4568	6074	1181	1354	145	46	16	10	20040	28279	0.59
1957/58	29363	8122	1800	2127	347	335	36	11	7	35975	12044	-0.85
1958/59	7496	13459	3661	800	923	148	143	15	8	37493	36608	0.22
1959/60	30727	3461	5866	1566	328	365	58	56	9	28117	19072	-0.14
1960/61	11677	13504	1510	2302	559	107	120	19	21	26259	12881	-0.47
1961/62	6450	6825	6228	659	805	155	30	33	11	29040	24760	0.09
1962/63	19044	3905	3628	2991	273	290	56	11	16	23415	15652	-0.16
1963/64	2439	10300	1927	1570	1028	74	78	15	7	35812	29266	0.05
1964/65	575	1400	4608	942	671	387	28	30	8	9541	6710	-0.10
1965/66	822	195	503	1690	231	97	56	4	6	6266	7487	0.43
1966/67	1219	505	77	207	530	54	23	13	2	3153	2719	0.10
1967/68	574	398	108	29	54	88	9	4	3	3646	4788	0.52
1968/69	1962	267	167	55	13	23	37	4	3	2080	843	-0.66
1969/70	1281	1193	149	92	29	7	11	18	3	7791	8437	0.33
1970/71	289	756	640	85	51	15	4	6	11	5989	9753	0.73
1971/72	1542	207	409	428	51	27	8	2	9	4385	9853	1.06
1972/73	1675	1253	153	243	210	21	11	3	5	7558	11261	0.65
1973/74	794	1361	982	113	171	141	14	7	5	8945	8893	0.24
1974/75	315	645	1075	689	65	87	72	7	6	13849	11109	0.03
1975/76	704	255	512	824	513	47	63	52	10	17405	14213	0.04
1976/77	397	572	205	373	564	333	31	41	40	13370	9736	-0.07
1977/78	416	322	394	134	210	277	163	15	40	6128	4738	-0.01
1978/79	7591	334	218	231	57	64	83	49	16	4521	7554	0.76
1979/80	1752	6162	233	135	114	22	25	32	25	11694	10236	0.11
1980/81	2877	1422	4817	167	79	57	11	12	28	18928	10532	-0.34
1981/82	3155	1934	927	3018	98	43	31	6	22	24848	12631	-0.43
1982/83	10160	2117	1265	599	1914	61	27	19	17	32044	19652	-0.24
1983/84	2115	6833	1424	851	403	1287	41	18	24	31512	22927	-0.07
1984/85	2178	1422	4533	930	535	240	734	23	24	31980	35858	0.36
1985/86	9076	1464	933	2884	554	288	118	361	23	35229	32525	0.17
1986/87	8567	6099	941	580	1637	290	146	60	196	36585	31422	0.09
1987/88	5877	5761	4027	606	345	893	152	77	135	36039	33679	0.18
1988/89	3585	3951	3766	2568	358	176	423	72	100	39739	12783	-0.89
1989/90	18754	2409	2581	2405	1515	177	80	193	78	48168	19398	-0.66
1990/91	22435	12613	1584	1683	1515	908	104	47	158	49262	21544	-0.58
1991/92	5577	12313	6822	844	865	749	434	49	98	52121	35992	-0.12
1992/93	2509	3060	6668	3651	419	389	319	185	63	43091	21440	-0.45
1993/94	6296	1377	1650	3504	1812	179	148	122	94	32416	13439	-0.63
1994/95	24002	3454	742	862	1750	846	74	61	89	26322	15858	-0.26
1995/96	9112	13171	1875	395	444	868	403	35	72	39074	22104	-0.32
1996/97	12802	5000	7151	1008	203	195	359	167	44	27846	20744	-0.05
1997/98	3454	7026	2724	3827	480	66	38	69	41	31458	16734	-0.38
1998/99	7682	1896	3815	1461	1949	216	11	6	18	29798	25699	0.10
1999/00	1282	4216	1034	2036	757	944	97	5	11	24724	15658	-0.21

Estimated average availability at age (S_i)

0.08 0.37 0.53 0.79 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.00 0.01 0.19 0.47 0.73 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 0.78

Estimated instantaneous natural mortality rate is Variable

Appendix table 3.3. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from revised age-structured analysis (RASM) for the Central Coast stock assessment region.

	Estimated numbers at age (x 10^{-5}) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
1950/51	7023	7646	7837	1306	501	129	0	0	0	23470	23134	0.32
1951/52	13372	3084	2734	2273	310	106	27	0	0	9056	10709	0.51
1952/53	67576	5890	1023	659	390	43	15	4	0	12600	20001	0.80
1953/54	6629	30226	2622	446	285	168	19	6	2	16648	18635	0.45
1954/55	5642	2881	12006	792	113	66	39	4	2	36047	14984	-0.54
1955/56	13097	2474	1232	4758	300	42	24	14	2	10352	8244	0.11
1956/57	24979	5437	766	286	759	38	5	3	2	5631	6223	0.44
1957/58	31048	10914	1639	180	47	99	5	1	1	18691	4226	-1.15
1958/59	6274	13678	4337	608	62	16	33	2	0	11757	4105	-0.71
1959/60	9801	2731	5141	1173	128	11	3	6	0	34134	14684	-0.51
1960/61	28086	4214	1135	2190	491	53	5	1	3	8936	4567	-0.33
1961/62	12908	13043	1336	296	412	76	8	1	1	16657	14180	0.18
1962/63	10256	6035	5528	481	95	125	23	2	0	5716	8466	0.73
1963/64	4621	4876	2088	1202	63	8	11	2	0	6828	7058	0.37
1964/65	4762	1922	1297	494	188	7	1	1	0	4861	2365	-0.38
1965/66	9232	2200	613	338	93	29	1	0	0	2478	1773	0.00
1966/67	3198	2315	415	116	32	4	1	0	0	6382	5904	0.26
1967/68	1478	824	369	110	22	5	1	0	0	6961	6366	0.25
1968/69	4306	664	343	161	46	9	2	0	0	4403	2331	-0.30
1969/70	2333	2049	315	162	76	22	4	1	0	16287	10134	-0.14
1970/71	1732	1102	969	149	76	36	10	2	1	12806	6056	-0.41
1971/72	2924	1323	757	660	96	48	22	6	2	8236	3928	-0.40
1972/73	1989	2272	839	386	272	35	17	8	3	16811	14471	0.19
1973/74	2626	1561	1521	521	210	139	18	9	6	14830	10624	0.00
1974/75	1320	2062	1178	952	252	84	54	7	6	21160	9164	-0.50
1975/76	682	1037	1529	786	509	117	38	24	6	16288	16133	0.33
1976/77	785	523	756	967	368	190	41	13	10	16249	18481	0.47
1977/78	582	616	343	480	477	148	74	16	9	5885	10097	0.88
1978/79	6178	458	380	177	127	55	14	7	2	9184	6551	0.00
1979/80	1280	4870	361	300	139	100	43	11	7	23578	15979	-0.05
1980/81	1447	1009	3834	283	228	102	72	31	13	27696	16949	-0.15
1981/82	671	1081	750	2779	189	137	56	40	24	31702	18413	-0.21
1982/83	585	498	775	522	1751	112	78	31	36	26580	16618	-0.13
1983/84	2346	436	360	540	335	1056	66	46	40	17669	14197	0.12
1984/85	1029	1741	304	235	316	176	536	34	43	19684	8480	-0.50
1985/86	2062	763	1212	200	141	180	98	298	43	19110	15532	0.13
1986/87	13413	1535	542	824	129	88	111	61	210	20370	12992	-0.11
1987/88	1043	10017	1104	369	530	81	55	69	169	44809	27016	-0.17
1988/89	1026	775	7252	778	248	345	52	36	155	47871	32335	-0.05
1989/90	3675	759	552	4936	481	144	193	29	106	50526	31047	-0.15
1990/91	20666	2742	544	384	3252	301	88	118	83	39190	20156	-0.33
1991/92	2450	13214	1648	310	206	1674	153	45	102	52160	46038	0.21
1992/93	4109	1553	8035	963	173	111	894	82	78	49217	39713	0.12
1993/94	1124	2608	942	4594	516	88	55	440	79	44608	29780	-0.07
1994/95	3676	709	1484	526	2382	254	42	26	247	28361	18918	-0.07
1995/96	12743	2347	413	803	261	1121	117	19	126	23703	17941	0.06
1996/97	11971	8109	1425	235	434	137	587	61	76	30999	25208	0.13
1997/98	2616	7651	4938	840	134	240	75	321	75	34545	29385	0.18
1998/99	3683	1669	4528	2722	435	66	111	35	184	35394	28924	0.14
1999/00	191	2352	1006	2575	1448	220	29	49	97	33301	23811	0.00

Estimated average availability at age (S_i)

0.11 0.48 0.67 0.89 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.00 0.03 0.22 0.54 0.79 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 0.71

Estimated instantaneous natural mortality rate is Variable

Appendix table 3.4. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from revised age-structured analysis (RASM) for the Strait of Georgia stock assessment region.

	Estimated numbers at age (x 10^{-5}) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
1950/51	36034	13141	4500	985	193	65	0	0	0	36951	66064	0.31
1951/52	39867	16272	4415	1211	260	51	17	0	0	45662	66048	0.10
1952/53	70169	17791	5718	1259	339	72	14	5	0	71955	100512	0.06
1953/54	37691	31848	7716	2424	532	143	31	6	2	49609	90437	0.33
1954/55	21015	17079	12628	1999	615	134	36	8	2	94228	74225	-0.51
1955/56	18296	9361	5613	3993	624	191	42	11	3	35626	29493	-0.46
1956/57	16284	8011	2707	1193	822	127	39	8	3	20589	28997	0.07
1957/58	38866	7355	1509	486	205	138	21	7	2	13578	20357	0.13
1958/59	22127	17551	2588	368	116	48	33	5	2	29185	44280	0.14
1959/60	7511	9416	5566	594	82	25	11	7	2	24666	37222	0.14
1960/61	11025	3090	2108	1002	102	14	4	2	1	15854	25521	0.20
1961/62	9293	8090	1376	549	244	24	3	1	1	19312	23282	-0.09
1962/63	9607	7513	2458	326	121	52	5	1	0	11003	27751	0.65
1963/64	4817	7050	2653	395	46	16	7	1	0	9449	20366	0.50
1964/65	2516	3787	1870	345	43	5	2	1	0	18153	18627	-0.25
1965/66	2436	1554	941	509	88	11	1	0	0	3907	5109	0.00
1966/67	2008	1386	334	116	52	8	1	0	0	2970	6344	0.49
1967/68	561	220	126	40	12	5	1	0	0	3881	12021	0.86
1968/69	2394	412	132	77	24	7	3	0	0	11764	18207	0.16
1969/70	4181	2031	339	109	63	20	6	2	0	29142	44195	0.14
1970/71	5104	3625	1723	288	92	54	17	5	2	27443	47312	0.27
1971/72	8132	2822	1970	918	153	49	29	9	4	25090	25875	-0.24
1972/73	12121	4445	1325	845	389	65	21	12	5	21929	18255	-0.46
1973/74	16198	6726	2337	578	349	158	26	8	7	52428	64619	-0.06
1974/75	11025	8984	3679	1215	269	151	66	11	6	65339	76691	-0.11
1975/76	18565	6120	4917	1890	534	112	62	27	7	48900	57133	-0.12
1976/77	14248	10291	3333	2422	809	190	38	21	12	67822	58003	-0.43
1977/78	7343	7886	5284	1563	1008	314	72	14	12	55135	97082	0.29
1978/79	9810	4066	3952	2310	584	340	102	23	9	43631	59041	0.03
1979/80	7269	5436	2111	1730	880	208	119	36	11	49254	74847	0.15
1980/81	5616	4032	2933	1111	842	401	93	53	21	46181	48230	-0.23
1981/82	4345	3278	2184	1512	507	352	162	38	30	39323	90239	0.56
1982/83	3714	2528	1714	1077	684	200	128	59	25	21365	47423	0.52
1983/84	5880	2164	1253	655	306	172	41	26	17	17977	27587	0.16
1984/85	9106	3418	1094	516	184	68	36	9	9	24784	26629	-0.20
1985/86	5208	5272	1846	512	190	57	20	11	5	45513	61097	0.02
1986/87	16316	3059	3076	1076	299	111	33	12	9	36656	39037	-0.21
1987/88	5066	9567	1673	1546	445	100	31	9	6	53045	25351	-1.01
1988/89	12900	2973	5473	863	696	183	38	12	6	52212	54078	-0.24
1989/90	6340	7565	1707	2949	395	289	71	15	7	73205	58912	-0.49
1990/91	16743	3729	4409	953	1422	169	118	29	9	55891	43420	-0.53
1991/92	12048	9639	2100	2295	428	571	64	45	14	68320	80120	-0.11
1992/93	12326	6927	5282	1055	986	165	213	24	22	80487	84961	-0.22
1993/94	5717	7034	3755	2659	462	391	62	79	17	61090	60862	-0.28
1994/95	10665	3269	3779	1821	1046	145	112	18	28	50428	59708	-0.10
1995/96	14381	6105	1779	1869	762	401	52	40	16	57181	76291	0.02
1996/97	15747	8181	3124	870	789	284	144	19	20	53572	53442	-0.28
1997/98	7302	8999	4161	1464	346	257	84	43	12	50411	68699	0.04
1998/99	10095	4180	4820	2024	587	106	50	16	10	47663	70165	0.11
1999/00	9733	5778	2242	2356	843	198	30	14	7	42928	67694	0.18

Estimated average availability at age (S_i)

0.13 0.74 0.96 0.99 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.00 0.02 0.21 0.57 0.85 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 1.31

Estimated instantaneous natural mortality rate is Variable

Appendix table 3.5. Estimates of numbers at age, spawn index (SI), estimated spawning stock biomass (SB), estimated spawn-observed spawn residuals (RES), and other parameters from revised age-structured analysis (RASM) for the west coast Vancouver Island stock assessment region.

	Estimated numbers at age (x 10^{-5}) for period 1											
Season	1+	2+	3+	4+	5+	6+	7+	8+	9+	SB	SI	RES
1950/51	18231	4668	5671	733	205	49	0	0	0	25886	17006	-0.20
1951/52	26614	6735	1301	1621	198	52	13	0	0	3934	14383	1.82
1952/53	38073	10038	2208	204	195	17	4	1	0	22103	30676	0.50
1953/54	40846	14392	3794	834	77	73	6	2	0	19174	16554	0.64
1954/55	39242	15387	4167	893	177	15	14	1	0	48685	17555	-0.40
1955/56	42000	14766	5578	1494	317	62	5	5	1	48865	45167	0.48
1956/57	35522	15780	5046	1848	483	100	20	2	2	70731	52651	0.21
1957/58	31800	13423	5837	1877	685	179	37	7	1	51888	24399	-0.79
1958/59	24229	12016	5055	2196	705	257	67	14	3	13010	18396	0.37
1959/60	20153	9000	2848	864	299	73	27	7	2	5862	7040	0.16
1960/61	63759	7364	1834	407	89	20	5	2	1	7948	7912	0.32
1961/62	36385	18995	1729	301	57	11	2	1	0	25272	34579	0.70
1962/63	42307	11120	4801	404	67	12	2	0	0	14433	14618	0.55
1963/64	10461	12983	3037	1048	82	13	2	0	0	17875	27862	0.66
1964/65	10376	3188	3372	674	218	16	2	0	0	12093	10863	-0.16
1965/66	15064	3174	763	726	135	40	3	0	0	4353	4584	-0.12
1966/67	466	4579	880	138	116	19	6	0	0	4778	5119	-0.03
1967/68	2221	66	1047	147	20	14	2	1	0	9475	11277	0.00
1968/69	4987	682	20	322	45	6	4	1	0	10346	11206	0.00
1969/70	4778	1532	210	6	99	14	2	1	0	17295	34923	0.00
1970/71	1437	1468	471	64	2	30	4	1	1	29933	32477	0.00
1971/72	2099	1352	1381	443	61	2	29	4	1	18157	36070	-0.72
1972/73	2578	1959	1178	1029	316	41	1	19	3	22319	16218	-1.69
1973/74	4575	2417	1448	724	563	155	20	1	11	37505	24775	-1.51
1974/75	1966	4217	1796	1055	458	321	88	11	7	54262	44594	-1.09
1975/76	1441	1841	3173	1278	633	249	174	48	10	28262	63335	-0.18
1976/77	2933	1353	1584	1899	506	185	72	50	17	25628	57398	-0.02
1977/78	1276	2753	1108	961	892	183	65	25	24	30758	39931	-0.23
1978/79	4732	1195	2293	846	492	314	58	21	15	28668	63664	0.65
1979/80	5311	4446	1001	1689	472	220	137	25	16	55647	62619	0.44
1980/81	4740	4993	4116	913	1482	395	183	114	34	54186	58519	0.39
1981/82	3005	2597	2598	2097	432	667	174	81	65	40553	29424	-0.05
1982/83	6004	1649	1379	1346	1027	196	293	77	64	28989	15329	-0.34
1983/84	12326	3287	801	646	581	416	78	117	56	30075	22143	-0.03
1984/85	10471	6685	1638	380	294	256	183	34	76	53825	29130	-0.45
1985/86	3699	5764	3674	900	209	161	140	100	61	60959	38347	-0.40
1986/87	21589	2037	3167	2019	494	115	89	77	88	38820	29914	-0.25
1987/88	3312	11748	958	1373	819	190	44	34	64	46718	39289	-0.24
1988/89	3694	1808	6068	460	629	364	84	20	43	40809	43332	-0.12
1989/90	1800	2016	876	2758	192	247	142	33	25	30183	38338	-0.09
1990/91	5194	989	958	399	1178	78	100	58	23	21028	25906	-0.08
1991/92	2766	3304	529	492	188	511	34	43	35	22908	36811	0.20
1992/93	2171	1772	1997	304	272	101	274	18	42	23106	29236	-0.03
1993/94	1009	1376	1008	1088	160	140	52	140	31	18060	19764	-0.16
1994/95	1683	635	783	528	536	75	64	24	79	16699	25039	0.22
1995/96	8359	1079	384	453	300	300	42	36	57	15913	31929	0.55
1996/97	2949	5352	667	231	269	176	176	24	55	25532	39114	0.32
1997/98	2111	1876	2949	356	119	134	88	88	40	19071	36898	0.62
1998/99	1885	1343	1082	1539	172	48	49	32	46	18454	18829	0.07
1999/00	1447	1205	781	603	812	87	23	23	37	20543	10940	-0.48

Estimated average availability at age (S_i)

0.13 0.58 0.76 0.88 1.00 1.00 1.00 1.00 1.00

Estimated average relative selectivity at age for gillnet fisheries

0.00 0.04 0.34 0.72 0.91 1.00 1.00 1.00 1.00

Spawn index-escapement conversion factor (q) is 1.08

Estimated instantaneous natural mortality rate is Variable