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Are Offshore Summer Herring Distributions Useful Predictors of Recruitment Strength for Northern Herring Stocks?

Est-ce que la répartition extracôtière de harengs pendant l'été constitue un indicateur utile de la force du recrutement des stocks de harengs du Nord?

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Abstract

Reduced biomass for some northern British Columbia herring stocks has renewed interest in the accuracy of recruitment strength forecasting procedures. Such a forecast has been provided annually to PSARC for the West Coast Vancouver Island (WCVI) herring stock since the early 1990s and such a forecasting tool could be developed for northern herring stocks. This paper uses existing herring data collected during groundfish research cruises in Hecate Strait to develop and evaluate possible recruitment strength models for each of the northern herring stocks: Queen Charlotte Islands (QCI), Prince Rupert District (PRD), and Central Coast (CC). The models are based on the relationship between pre-recruit fish in summer feeding aggregations (age-2+ herring) and recruit fish (age-3 herring) encountered on winter spawning grounds. Although preliminary, the results to date are promising as positive relationships between pre-recruit herring in summer surveys and recruit herring in winter test fisheries were identified for each of the northern stocks (QCI, PRD and CC). Data deficiencies and limitations are identified and recommendations for future research on the northern herring stocks are proposed.

Résumé

La biomasse réduite de certains stocks de hareng du nord de la Colombie-Britannique fait en sorte qu’il y a un renouveau d’intérêt pour l’exactitude des méthodes de prévision du recrutement. De telles prévisions sont fournies chaque année depuis le début des années 1990 au Comité d’examen des évaluations scientifiques du Pacifique relativement au stock de hareng de la côte ouest de l’île de Vancouver. Une méthode de prévision semblable pourrait être élaborée pour les stocks de hareng du nord. Dans ce document, on a utilisé les données sur le hareng recueillies au cours des relevés du poisson de fond effectuées dans le détroit d’Hécate pour élaborer et évaluer des modèles de prévision du recrutement pour chacun des stocks de hareng du nord : île de la Reine-Charlotte; district de Prince Rupert; côte centrale. Ces modèles sont fondés sur la relation entre les prérecrues qui se nourrissent en groupes à l’été avant le recrutement (harengs d’âge 2+) et les recrues présentes dans les lieux de frai à l’hiver (harengs de trois ans). Bien que préliminaires, les résultats à ce jour sont prometteurs puisqu’on a observé des relations positives entre les prérecrues prises dans les relevés estivaux et les recrues prises dans les pêches expérimentales hivernales, et ce, pour chacun des stocks du nord. Les lacunes dans les données ainsi que les limites de celles-ci sont soulignées et des recommandations sont formulées à l’égard des recherches futures sur les stocks de hareng du nord.

Introduction

Pacific herring (*Clupea pallasi*) are distributed along the West Coast of North America from California to Alaska and is an important commercial species. In British Columbia, the commercial fishery is primarily a spring roe fishery with fishing taking place on spawning grounds after fish have completed their inshore migration. Following spawning, fish migrate offshore again to summer feeding grounds. In British Columbia, five major stocks have been identified for management purposes and are assessed annually (i.e., Schweigert 2002). These include Strait of Georgia (SOG), West Coast Vancouver Island (WCVI), Central Coast (CC), Prince Rupert District (PRD), and Queen Charlotte Islands (QCI). Annual stock assessments include a forecast of prefishery biomass expected the following year based on an age-structured model (ASM) that considers growth and survival of repeat spawning adults and the number (biomass) of expected recruits. For all stocks except WCVI, the number of recruits is determined using stock-specific, abundance time series data (historical average recruitment) (Schweigert 2002). For WCVI the number of recruits is determined using age composition data collected during an offshore summer herring survey that provides a forecast of recruitment strength (Ware and Tanasichuk 1997; Ware 1998). More recently, Tanasichuk (2001; 2002) has applied the same approach to forecast recruitment strength for SOG herring stocks based on the same offshore summer survey.

Reduced biomass in northern stock assessment regions, especially QCI, has renewed interest in the accuracy of recruitment forecasting procedures and the use of the assumption that recruitment is "average" by default. Independent offshore surveys could refine recruitment forecasts for northern herring stocks if a relationship existed between the proportion of age-2+ herring captured offshore during the summer and the proportion of age-3 herring in the prefishery biomass for the QCI, PRD, or CC stocks. Although there have been no offshore summer surveys for Pacific herring in northern stock assessment regions, multi-species bottom trawls are conducted routinely along the coast of British Columbia as part of groundfish stock assessments. These trawls collect basic scientific data including species composition and size distributions for the major species encountered, including Pacific herring. Thus, these surveys may be used as independent offshore surveys to determine the proportion of age-2+ fish in summer feeding aggregations assuming trawl catches are representative for herring. The purpose of this paper is to explore the relationship between age-2+ herring encountered in offshore summer surveys and age-3 herring in the prefishery biomass (test fishery) to determine if a recruitment strength forecasting tool is possible for northern herring stocks. Fisheries managers believe such a tool would be valuable and have formally requested a PSARC working paper to explore this possibility (Appendix 1).

Methods

Sampling Data

The GFBioSQL database contains biological sample data compiled from various groundfish research initiatives. Since Pacific herring, a pelagic species, is not directly targeted by groundfish surveys, any trawl event that lands herring can be considered a random sample for herring. Querying the groundfish database resulted in 154 fishing events that captured Pacific herring during spring or summer surveys (end of May through the end of August) in Hecate Strait (GF Areas 7 and 8) between 1984 and 2000. Eight additional fishing events in Hecate Strait not encountered in the GFBioSQL database provided data for 2001 and 2002.

Herring Age-Length Composition

Since herring was not the target species, fish were not aged. However, length frequency distributions can be used to determine age indirectly by modal analyses. Data were pooled for each year to create length frequency distributions used to determine fish ages. The proportion of age-2+ fish was determined for each fishing event based on the number of age-2+ herring relative to the total number of herring (i.e., fish younger than age-2+ and fish older than age-3+). The yearly proportion of age-2+ herring was determined by calculating the average over retained fishing events (see below), either weighted by the number of herring or unweighted. Three rejection criteria were established for fishing events in an attempt to ensure groundfish data were representative for determining the proportion of pre-recruit fish. These rejection criteria were 1) only immature herring (age-1+ or age-2+) in the fishing event; 2) only post-recruit herring (age-3+ or older) in the fishing event; 3) only single specimens of herring in the fishing event. The first two rejection criteria were established to eliminate fishing events that landed herring not expected to recruit. For example, immature herring would not spawn the following spring and post-recruit herring are already part of the spawning stock biomass (SSB). Thus, these trawls would not provided information on the proportion of pre-recruit (age-2+) herring in the population. The third rejection criterion was established to prevent biased weighting of single individuals on the proportion of recruits (i.e., one age-2+ herring in a set of one herring results in a proportion of 100%). Of the 162 fishing events available, 53 were retained for analyses. Thirty-four were eliminated because they contained only single herring and 67 were eliminated because they contained only post-recruit fish. No fishing events landed only immature herring. The location of fishing events that were retained is shown in Figure 1. In general, the spatial coverage of the groundfish survey was similar among years but the number of fishing events retained varied considerably among years with more herring samples in recent years.

Model Development

It is expected that the frequency of maturing age-2+ herring sampled in offshore summer surveys is proportional to the frequency of age-3 herring sampled from the spawning stock the following winter (early March) on their spawning grounds. Since the offshore samples were not associated with a specific stock and there is some potential for mixing, the proportions of age-2+ herring in the summer surveys were compared to the age-3 herring for each of the northern stocks (QCI, PRD, and CC). The potential for mixing arises due to shared offshore summer habitat utilisation by northern herring. For example, CC, SOG, WCVI, and QCI stocks potentially mix in Queen Charlotte Sound and PRD, CC, and QCI stocks in Hecate Strait and/or Dixon Entrance. These two potential areas of herring mixing were used to develop and test the models. Summer groundfish trawl surveys in Hecate Strait were used in model development and evaluation (see below). However, there is insufficient evidence to suggest that annual straying between the three northern herring stocks is substantial, a finding supported by a high level of fidelity within stocks (Ware and Schweigert 2001, Ware and Schweigert 2002). Considerable inter-annual variability in straying rates would lower the predictive capability of any model based on the assumption of a high degree of stock fidelity.

Model Evaluation
Models were evaluated based on three criteria: goodness of fit, predictive skill, and the ability to predict cases not used in the model building process (predictive power). The goodness of fit was measured by least squares regression (Model I) and geometric mean regression (Model II) at a significance level of a=0.05. The Model II regression was included for comparison since both variables are measured with error (Sokal and Rohlf, 1981). Predictive skill was measured by explained variance (R^2) of the relationship between the proportion of age-3 herring in the test fishery (prefishery biomass) and the proportion of age-2+ herring encountered in the spring or summer offshore trawl surveys. An important criterion for evaluating models is the ability to predict cases not used in model development (Drinkwater and Myers 1987). This was done using a "leave-one-out" retrospective analysis for each model. This approach sequentially removes one data point and re-fits the regression equation to the remaining points. The number of times a significant relationship between the proportion of age-2+ herring in summer surveys and the proportion of age-3 herring in the prefishery biomass was observed provides a measure of the stability of the relationship and the degree to which single data points drive the models. Residuals were examined for normality and compliance with model assumptions. Transformation of dependent or independent variables was not required for any of the models presented here as residuals were determined to be satisfactory.

Results

Herring Age-Length Composition
Length frequency distributions for herring encountered in offshore groundfish research trawls for 1984, 1987, 1989, 1991, 1993, 1998, 2000, 2001, and 2002, including fish presumed to be age-2+, are shown in Figures 2 to 10, respectively. In general, age-2+ northern herring ranged between 160 and 180 mm in fork length and this range was relatively consistent among years. Two limitations of the groundfish data should be noted. First, herring were only measured to the nearest centimetre rather than nearest millimetre making it more difficult to distinguish among age classes. Also, herring length was measured as fork length rather than standard length so length comparisons among different databases will require a conversion factor.

Proportion of Age-2+ Herring
The proportion of age-2+ herring for each survey year ranged between 11% and 50% depending on whether the proportions were weighted (number of herring) or not (Table 1). I expected the frequency of age-2+ herring encountered in offshore summer surveys to be related to the proportion of age-3 herring encountered in the prefishery biomass (test fishery data). The proportion of age-3 herring in the test fishery ranged between 3%

and 69% for QCI, 5% and 60% for PRD, and 6% and 69% for CC (Table 1). Correlations between the proportion of age-3 herring in the test fishery and the proportion age-3 herring in the commercial seine roe fishery were generally strong (Table 2). However, since the intent of this modelling exercise was to forecast recruitment strength, the test fishery data were assumed most representative of the prefishery biomass and used for model development and evaluation.

Weighting the proportion of pre-recruit herring in offshore summer surveys was believed to improve predictive capabilities of the models. This was not the case as no significant relationships were identified using Model I or Model II analyses (regressions, $p>0.05$). However, positive relationships between the proportion of age-2+ herring in summer surveys and the proportion of age-3 herring in test fisheries were evident using the unweighted proportion of age-2+ herring (Figures 11 to 13). Thus, the relationships between the proportion of age-2+ herring in summer surveys and the proportion of age-3 herring in winter test fisheries for the three northern BC herring stocks resulted in the following models based on least squares regression (Model I). For each model, the slope was not significantly different from one.

For the QCI stock:

proportion age-3 herring = – 0.0453 + 1.3330 * proportion age-2+ herring (Equation 1)

$R^2 = 0.5315$; $F_{1,7} = 7.94$; and $p=0.0258$

For the PRD stock:

proportion age-3 herring = 0.0556 + 0.7941 * proportion age-2+ herring (Equation 2)

$R^2 = 0.2751$; $F_{1,7} = 2.66$; and $p=0.1471$

For the CC stock:

proportion age-3 herring = – 0.0101 + 1.3998 * proportion age-2+ herring (Equation 3)

$R^2 = 0.5568$; $F_{1,7} = 8.79$; and $p=0.0209$

Furthermore, the relationships between the proportion of age-2+ herring in summer surveys and the proportion of age-3 herring in winter test fisheries for the three northern BC herring stocks resulted in the following models based on geometric mean regression (Model II).

For the QCI stock:

proportion age-3 herring = 0.00 + 0.7291 * proportion age-2+ herring (Equation 4)

$R^2 = 0.5315$; $F_{1,7} = 7.94$; and $p=0.0258$

For the PRD stock:

proportion age-3 herring = 0.00 + 0.5245 * proportion age-2+ herring (Equation 5)

$R^2 = 0.2751$; $F_{1,7} = 2.66$; and p=0.1471

For the CC stock:
proportion age-3 herring = 0.00 + 0.7462 * proportion age-2+ herring (Equation 6)

$R^2 = 0.5568$; $F_{1,7} = 8.79$; and p=0.0209

Retrospective Analyses
A "leave-one-out" approach was used as a retrospective analysis to evaluate model predictions. This approach allows model parameters to be estimated by excluding one data pair at a time and then comparing the predicted value (including 95% confidence interval) with the observed value. Model parameters for these iterations are provided for the Model I design (Table 3) as Model II designs did not result in increased predictive skill (R^2). For the QCI stock, six of the nine retrospective analyses resulted in significant positive relationships between the proportion of age-2+ herring in offshore surveys and the proportion of age-3 herring in the test fishery the following winter (Table 3). Similarly, for the CC stock, seven of the nine retrospective analyses resulted in significant positive relationships between the proportion of age-2+ herring in offshore surveys and the proportion of age-3 herring in the test fishery the following winter (Table 3). However, for the PRD stock, positive relationships between the proportion of age-2+ herring in offshore surveys and the proportion of age-3 herring in the test fishery the following winter were identified but the relationships were not statistically significant (Table 3). In general, models for the QCI and CC stock performed well. The QCI models tended to slightly overpredict observed proportions (Table 4) while CC models did not show this trend, overpredicting and underpredicting almost equally (Table 4). However, the QCI retrospective analyses showed that in eight of nine cases, the observed value was contained in the 95% confidence interval (Table 4). This contrasts to only five of nine cases for the CC models (Table 4). Furthermore, in four of the five cases where the observed value did not fall within the 95% confidence interval, the observed proportion of age-3 herring was greater than predicted (Table 4).

Discussion

Herring were not targeted by the groundfish bottom trawl surveys but the significant relationships between the proportion of age-2+ herring encountered in offshore surveys and the proportion of age-3 herring in test fisheries suggest there is promise for continued development of this type of recruitment strength forecasting tool. Such a relationship has been established for the WCVI stock (Ware and Tanasichuk 1997, Ware 1998) and it appears that the relationship holds for northern stocks as well. However, before this tool can be used for forecasting, it will be important to verify that the relationship between pre-recruit and recruit herring is maintained when independent, targeted fishing on northern herring aggregations take place. For this modelling exercise, I have assumed that the groundfish bottom trawls are representative for northern herring but this may not be the case. The number of herring caught in the groundfish bottom trawl was small and sampling might not have included major aggregations of herring. Thus, targeted fishing should provided better estimates as effort will be directed at herring specifically and more fishing events on the target species will provide a more comprehensive picture of northern herring summer feeding aggregations, especially with respect to their spatial distribution.

Existing groundfish data are limited by the accuracy of data collected for herring. For example, groundfish data were recorded as fork length, which alone is not problematic but it is problematic that the data were recorded only to the nearest centimetre rather than millimetre. This coarse resolution makes detection of age classes in the length frequency distributions more difficult. In this paper, I assumed that misclassification of herring was equal (i.e., small age-3+ herring classified as age-2+ was equal to the large age-2+ herring classified as age-3+). It is recommended that future studies on northern herring stocks for recruitment strength forecasting also collect scale samples for age validation. This will provide confirmation of the age classes inferred from the length frequency data.

The positive relationship between the proportion of age-2+ herring in offshore summer aggregations and the proportion of age-3 herring the following winter in the prefishery biomass was significant for both the QCI and CC stocks and evident for the PRD stock. Thus, it is probable the northern herring stocks are using the same summer feeding grounds with substantial mixing at this time of year. Alternatively, the high level of synchrony among stocks is a result of larger scale process that affect herring similarly on different feeding grounds (i.e., climate). Identifying the degree of potential mixing would help to refine model parameterisation for future forecasts. Metapopulation models suggest that both the QCI and CC stocks are major importers of herring from other stocks (i.e., SOG and PRD) during both cold-water regimes (Ware and Schweigert 2002) and warm-water ones (Ware and Schweigert 2001). In contrast, PRD is a major exporter of herring during cold-water regimes (Ware and Schweigert 2002) but exports less biomass during warm-water regimes (Ware and Schweigert 2001). Thus, an environmental component might help reduce variability in the relationship between the proportion of age-2+ herring encountered in offshore summer surveys and the proportion of age-3 herring landed in test fisheries (prefishery biomass) if immigration or emigration is identified as important factors for northern herring stocks. Also, future research might require a measure of the degree of mixing among stocks on summer feeding grounds in Hecate Strait, Queen Charlotte Sound and Dixon Entrance. It is possible that DNA sampling could provide one measure of the relative frequency of each stock encountered in mixed stock aggregations on summer feeding grounds. However, it is likely that other stock assessment tools might be able to provide this information as well. For example, Gao et al. (2001) were successful in discriminating among migratory and non-migratory stocks of Pacific herring in Puget Sound using stable isotopes. Thus, stable isotopes might provide information on the number of summer feeding grounds used by each of the three northern BC herring stocks and the number that are shared among stocks. Unfortunately, any method of differentiation of stock components in a mixed sample presents enormous logistical restraints and information is unlikely to be available within the current PSARC/fisheries management framework.

Weighting the proportion of age-2+ herring in offshore bottom trawl surveys did not improve goodness of fit or predictive skill (R^2) for any of the models evaluated (QCI, PRD or CC). This is contrary to pre-recruit midwater trawl surveys for the WCVI stock (e.g., Ware and Tanasichuk 1997, Ware 1998) where weighting did improve the relationship, albeit marginally. One reason for this apparent difference is likely due to selectivity of the gear used and the intended target(s) of the fishing event. Pacific herring caught in the groundfish bottom trawl surveys were not targeted but rather represent incidental catches. This is contrary to the midwater trawl survey where herring are targeted and fishing events that land more herring likely provide more information on the stock. Because herring only represent incidental catches in the bottom trawl surveys, the three rejection criteria were established to ensure the data were as representative as possible for evaluating a potential recruitment strength forecasting tool and since significant relationships were detected, the rejection criteria appear to be valid. Most fishing events that were eliminated were ones containing only post-recruit herring. It is possible that the groundfish bottom trawls are more selective for these larger herring and they are not representative of the stock structure. Thus, by excluding these fishing events, the retained data were more representative of the actual stock structure.

Future Steps

In order for the models from each northern stock assessment area to have predictive capabilities for recruitment strength, it is necessary to convert the predicted proportion of age-3 herring into a number of recruiting fish and a corresponding biomass estimate. This will depend on a number of factors including the existing stock biomass that is projected to survive and its corresponding growth factor (based on the change in body weight of repeat spawners between years). Consideration also must be given to the availability of recruiting herring to various fisheries. Ultimately, recruitment strength predictions will need to be indexed to the long-term average recruitment strength as is currently done for forecasts made using the age-structured model. The biomass of recruiting herring is classifying as poor, average, or good based on the observed recruitment strength with the lowest 33% representing “poor” recruitment, the middle 33% representing “average” recruitment, and the highest 33% representing “good” recruitment. Thus, projections of the total prefishery biomass for each northern stock assessment would include the biomass of returning fish combined with the projected biomass of recruiting fish. When this information is combined with current cutoff levels for each stock, a suitable harvest strategy can be selected.

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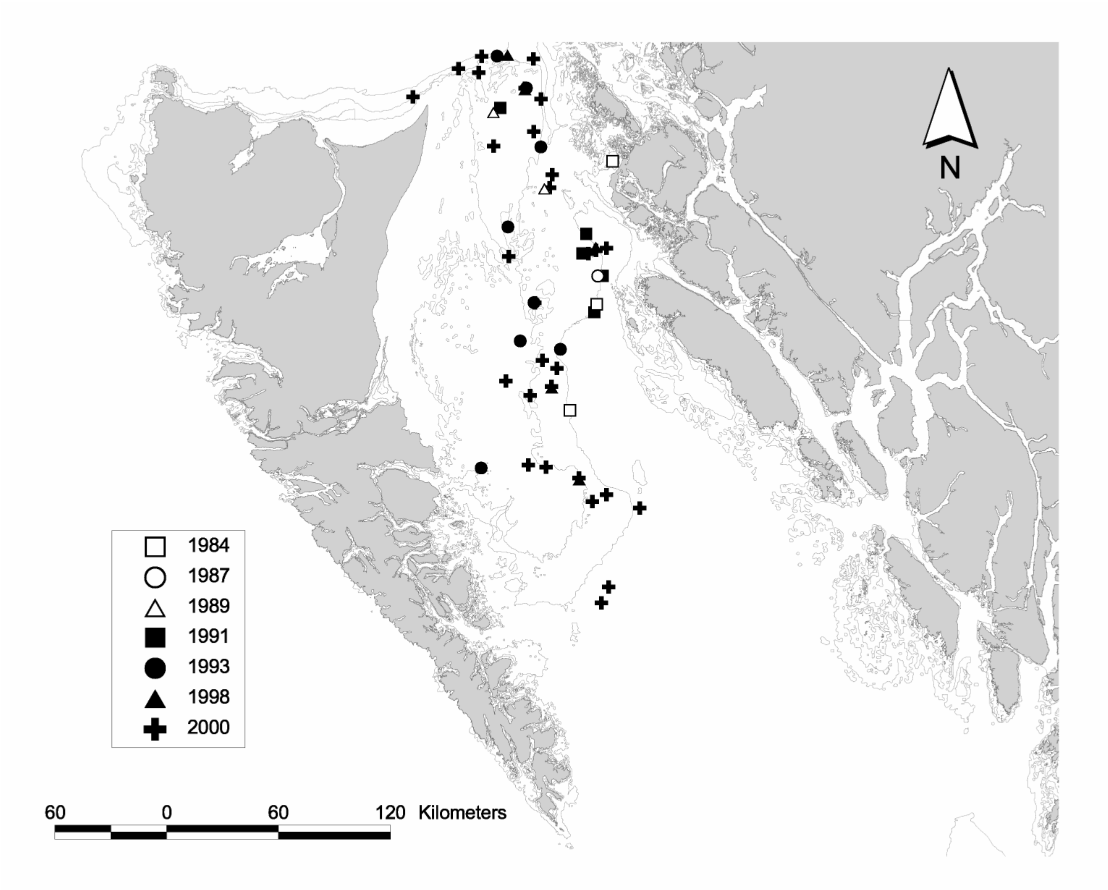

Figure 1: Location of the 45 fishing events between 1984 and 2000 that landed Pacific herring in Hecate Strait. Fishing events that were excluded from the analyses were in the same area(s) as those retained.

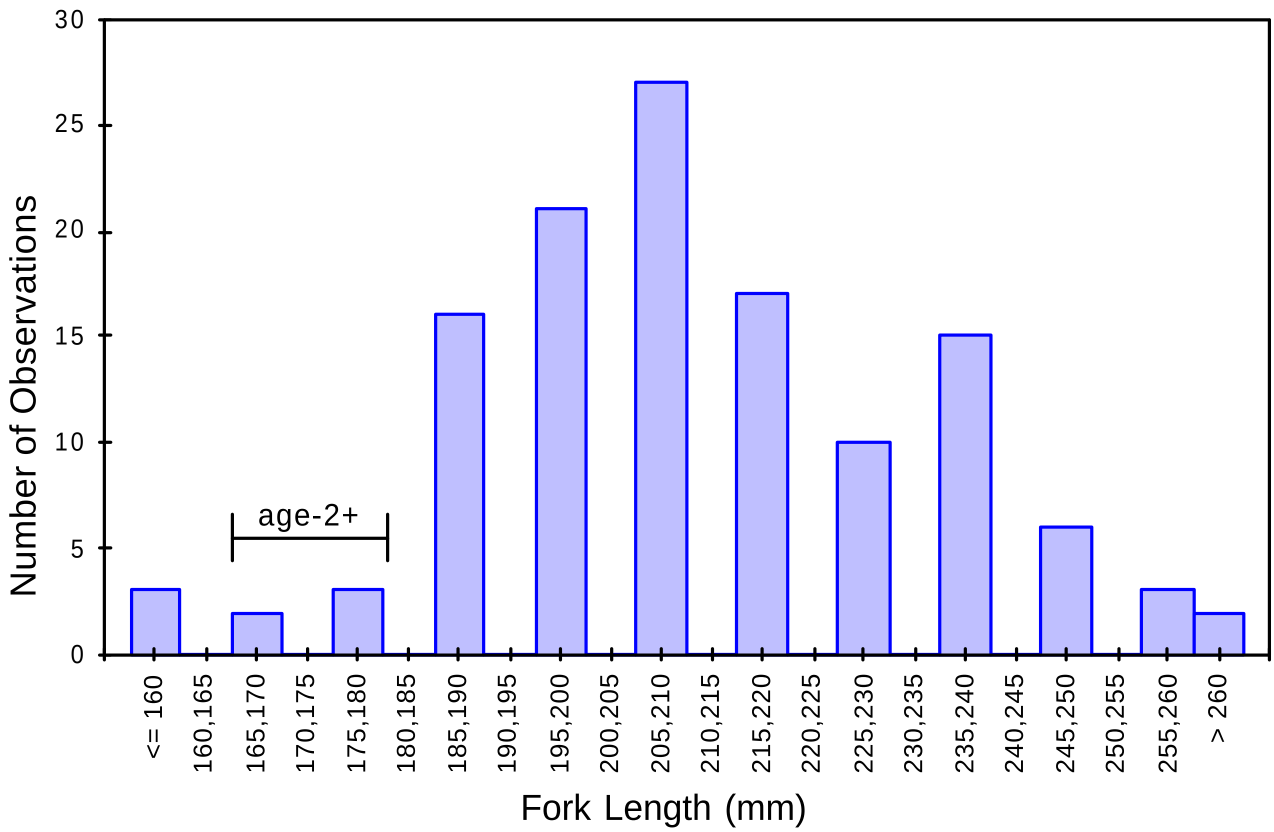

Figure 2: Length frequency distribution of herring landed in groundfish bottom trawl surveys in May and June 1984.

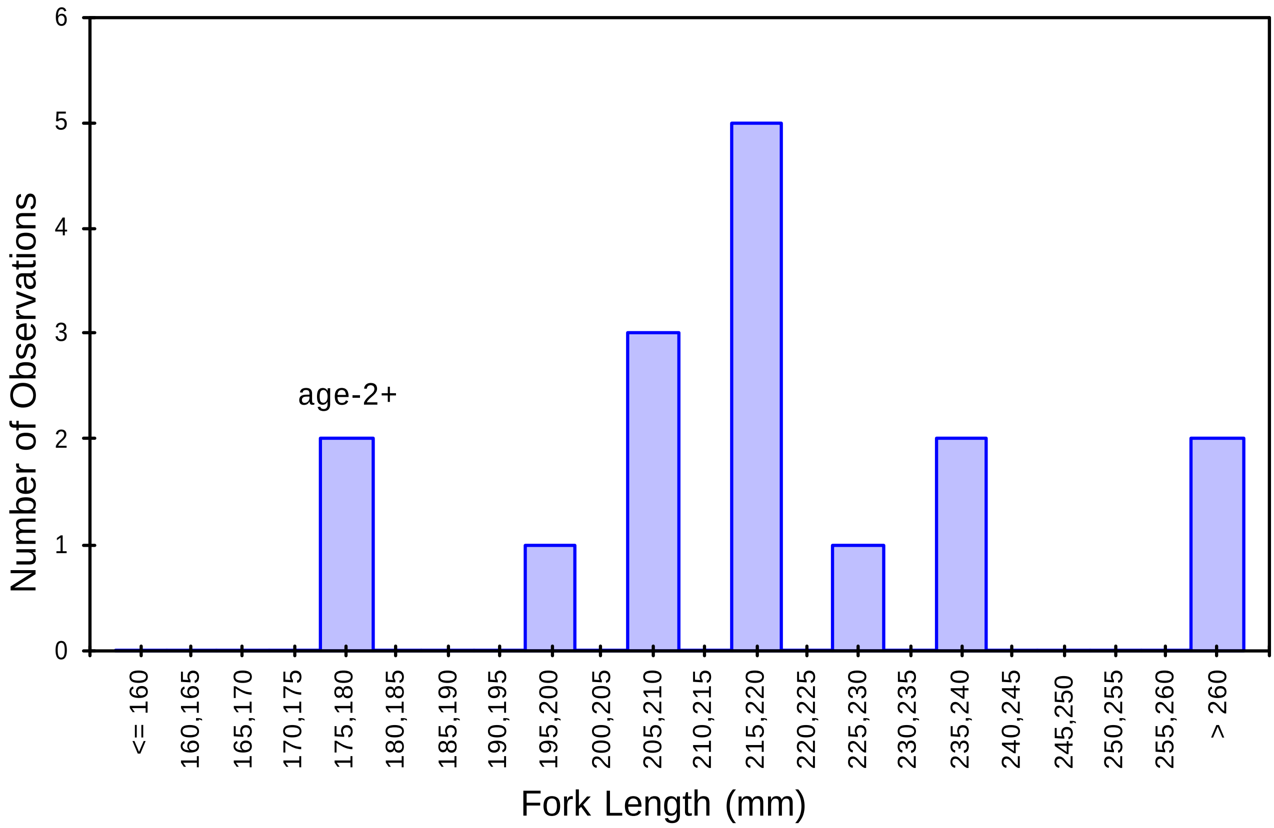

Figure 3: Length frequency distribution of herring landed in groundfish bottom trawl surveys in May and June 1987.

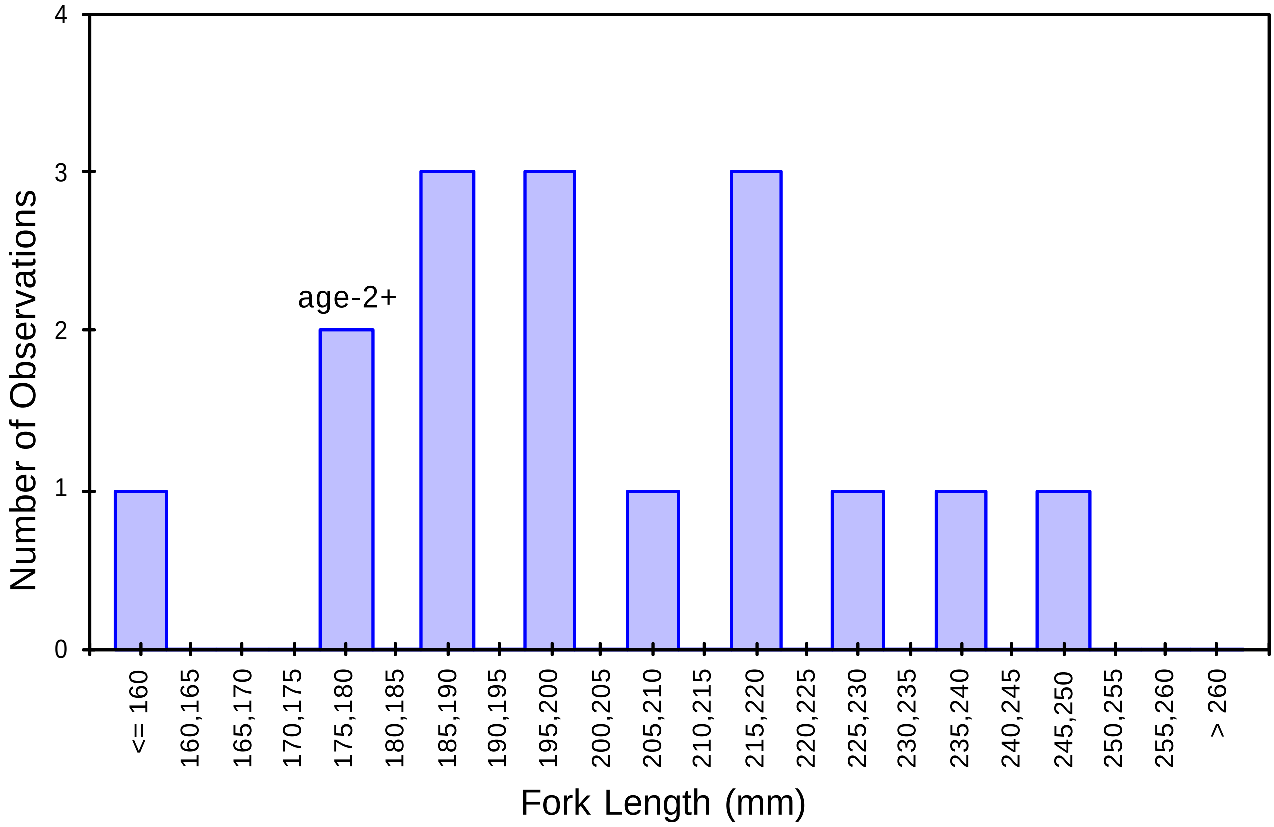

Figure 4: Length frequency distribution of herring landed in groundfish bottom trawl surveys in June 1989.

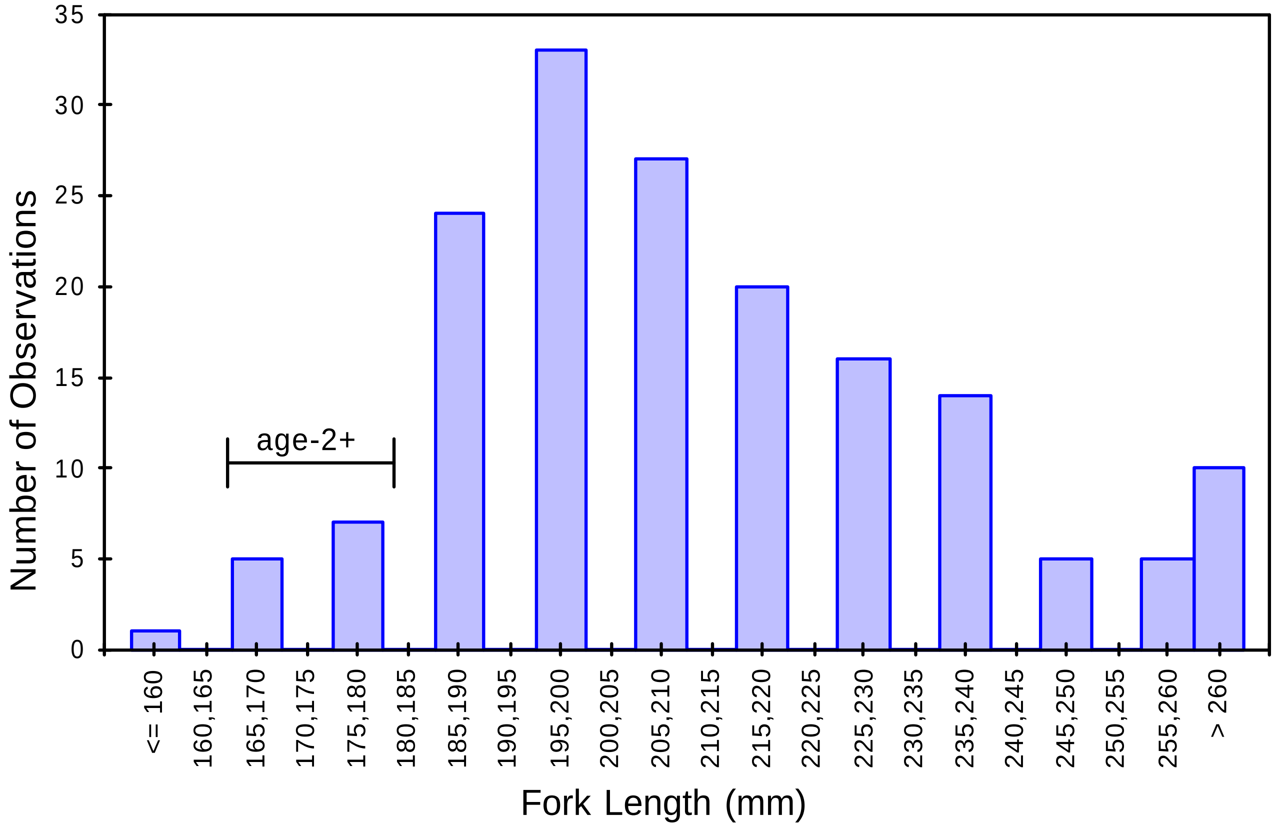

Figure 5: Length frequency distribution of herring landed in groundfish bottom trawl surveys in May and June 1991.

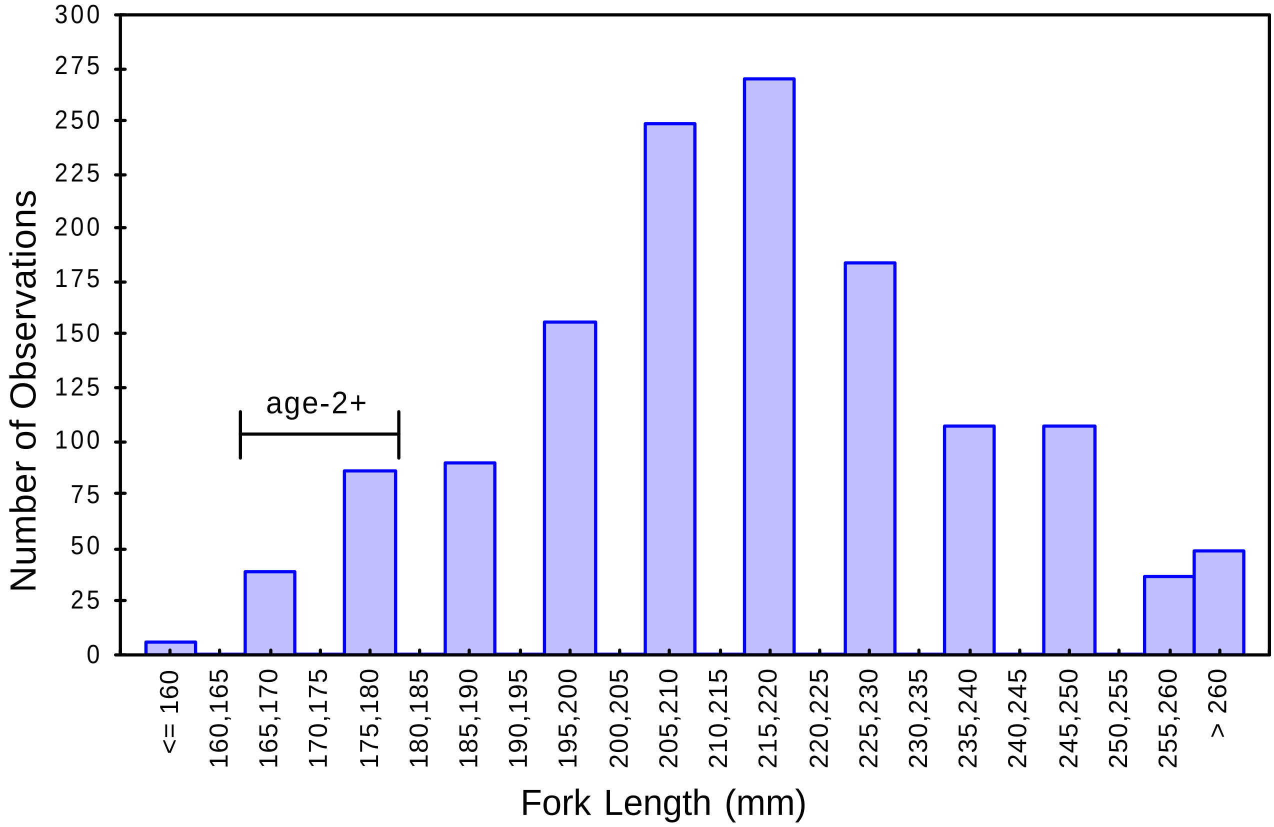

Figure 6: Length frequency distribution of herring landed in groundfish bottom trawl surveys in May 1993.

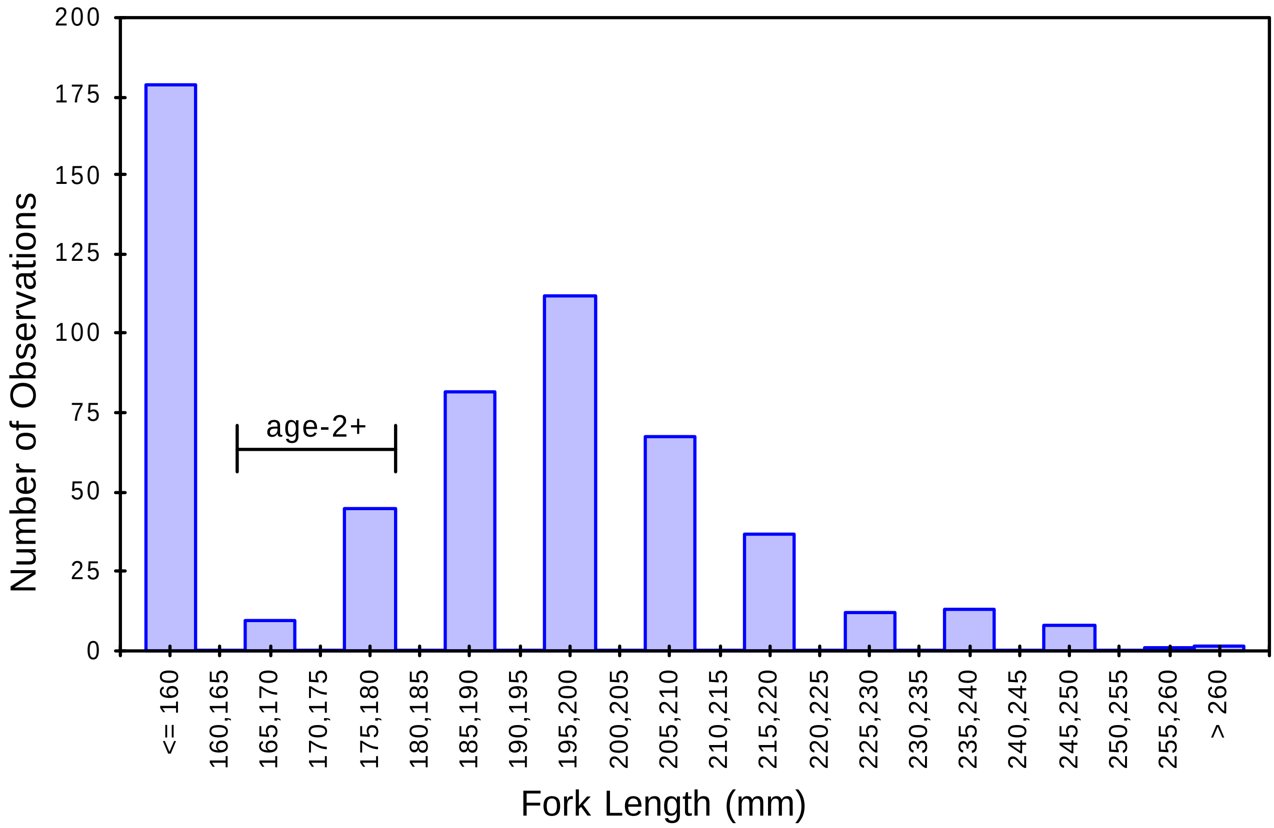

Figure 7: Length frequency distribution of herring landed in groundfish bottom trawl surveys in June 1998.

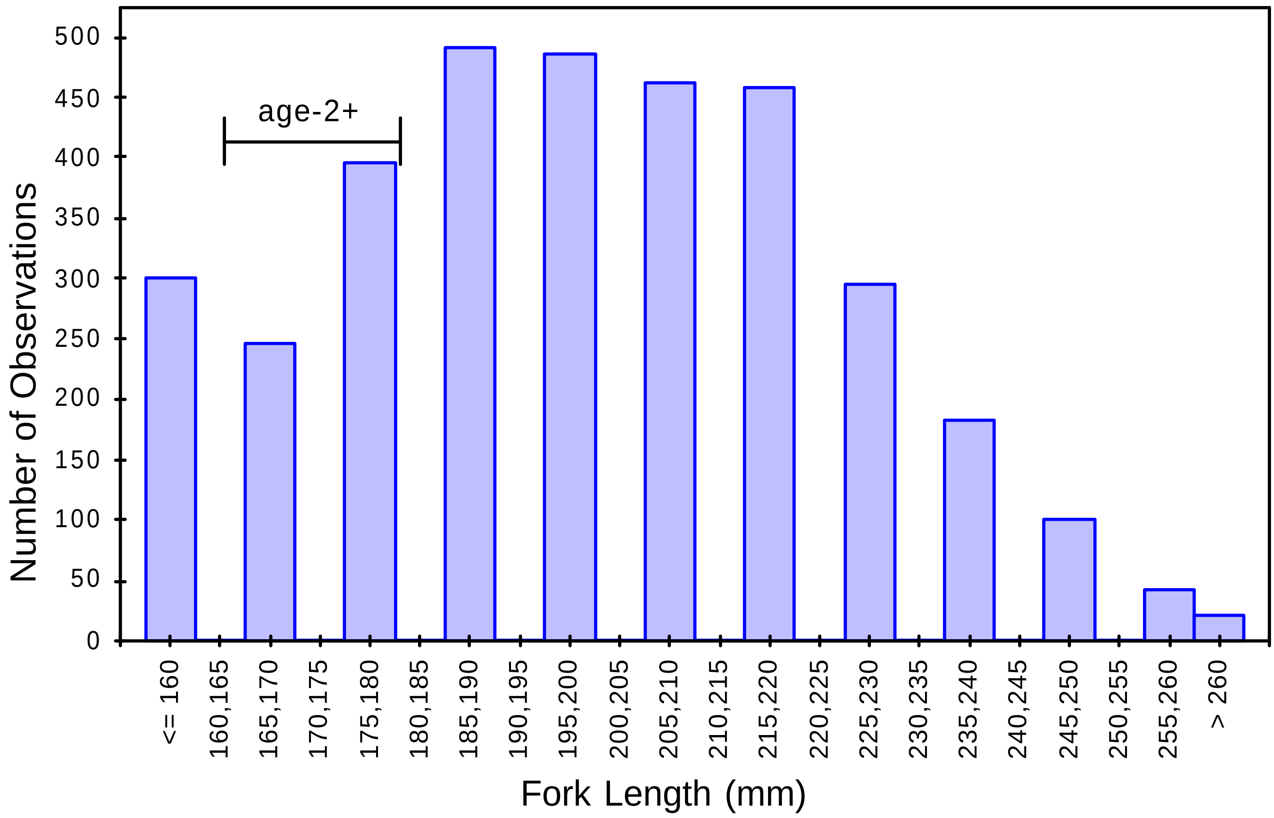

Figure 8: Length frequency distribution of herring landed in groundfish bottom trawl surveys in May and June 2000.

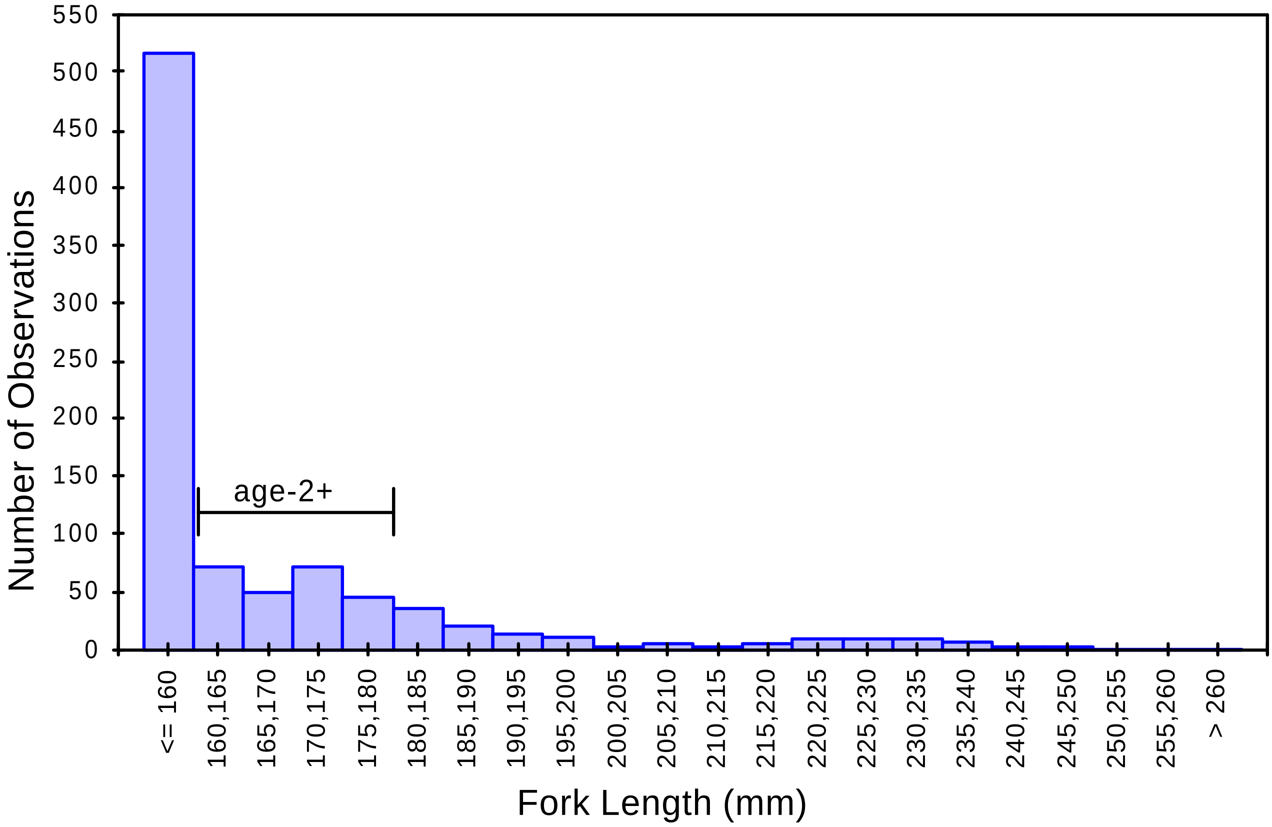

Figure 9: Length frequency distribution of herring landed in groundfish bottom trawl surveys in June 2001.

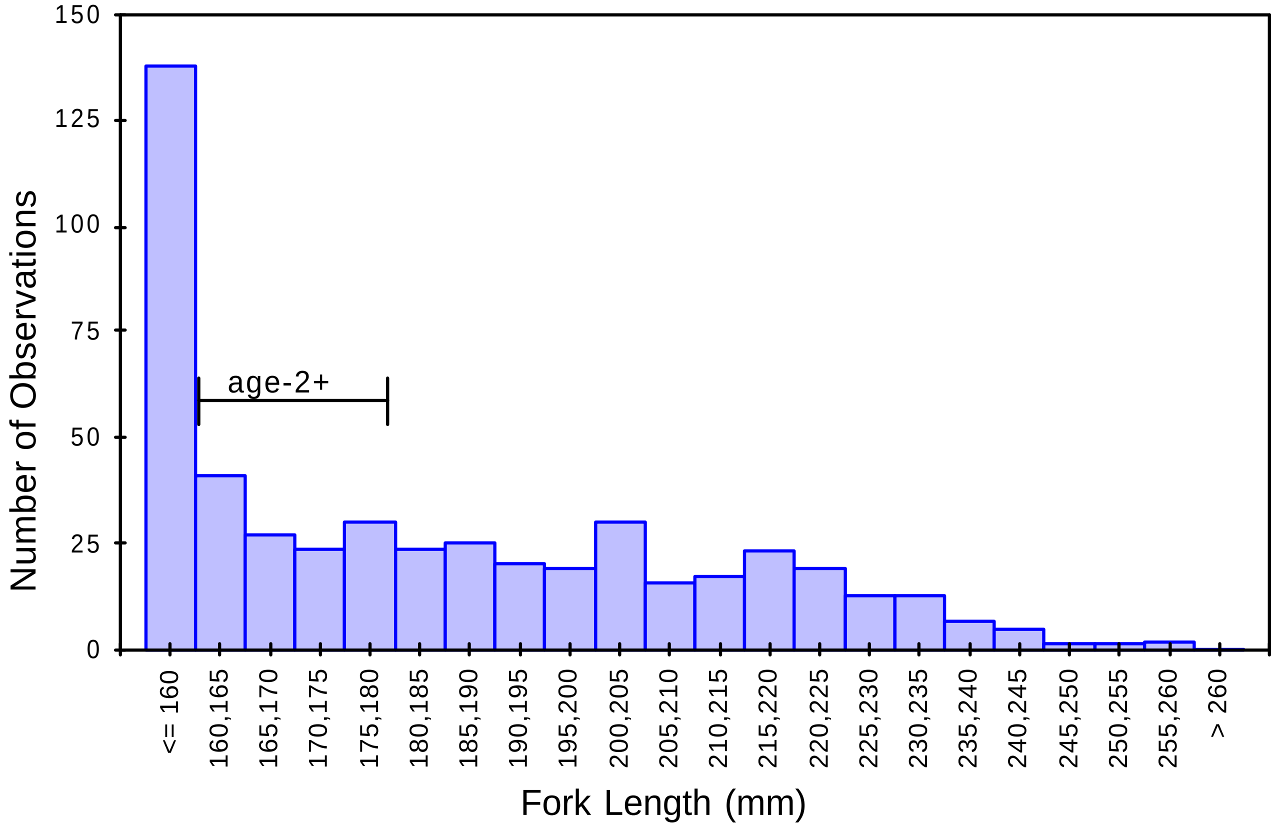

Figure 10: Length frequency distribution of herring landed in groundfish bottom trawl surveys in June 2002.

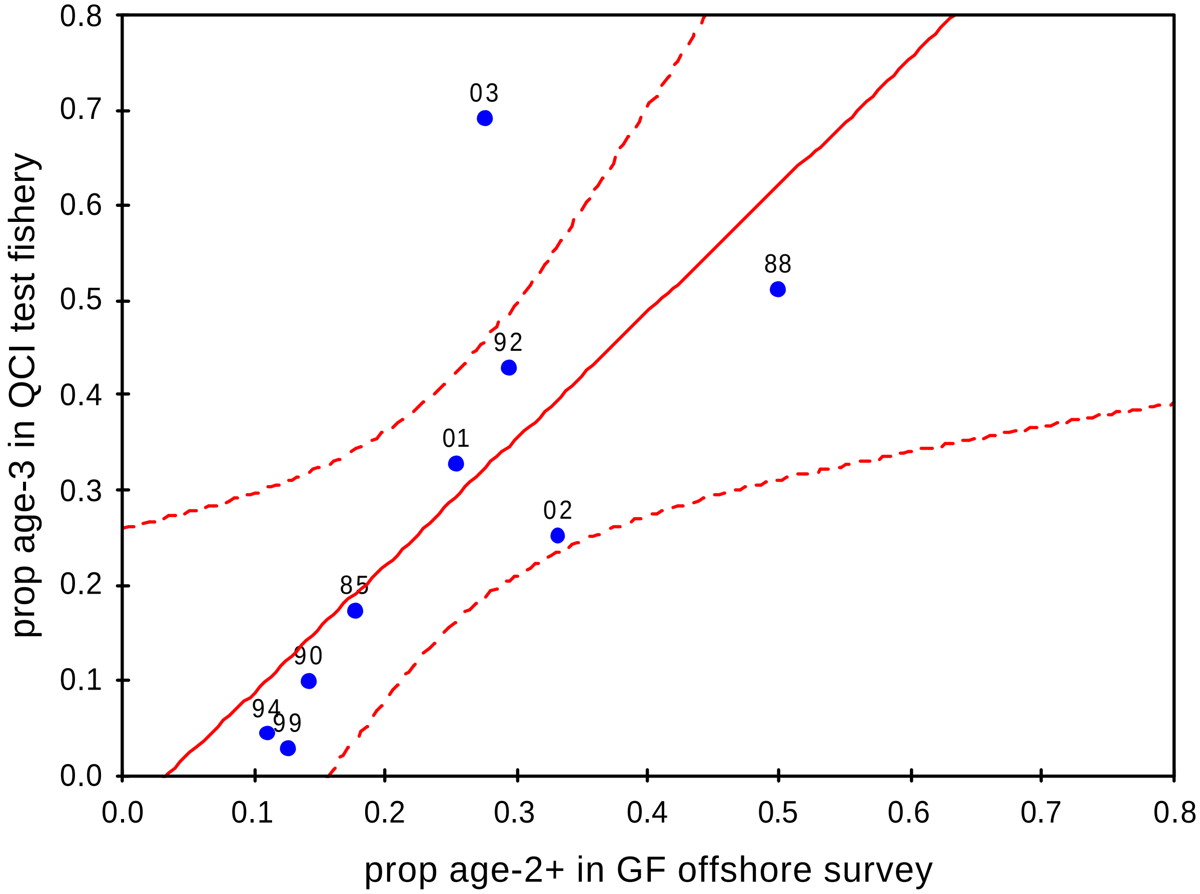

Figure 11: Relationship between the proportion of age-2+ herring encountered in summer groundfish bottom trawl surveys in Hecate Strait and the proportion of age-3 herring encountered in the QCI test fishery (prefishery). 95% confidence bands also are shown.

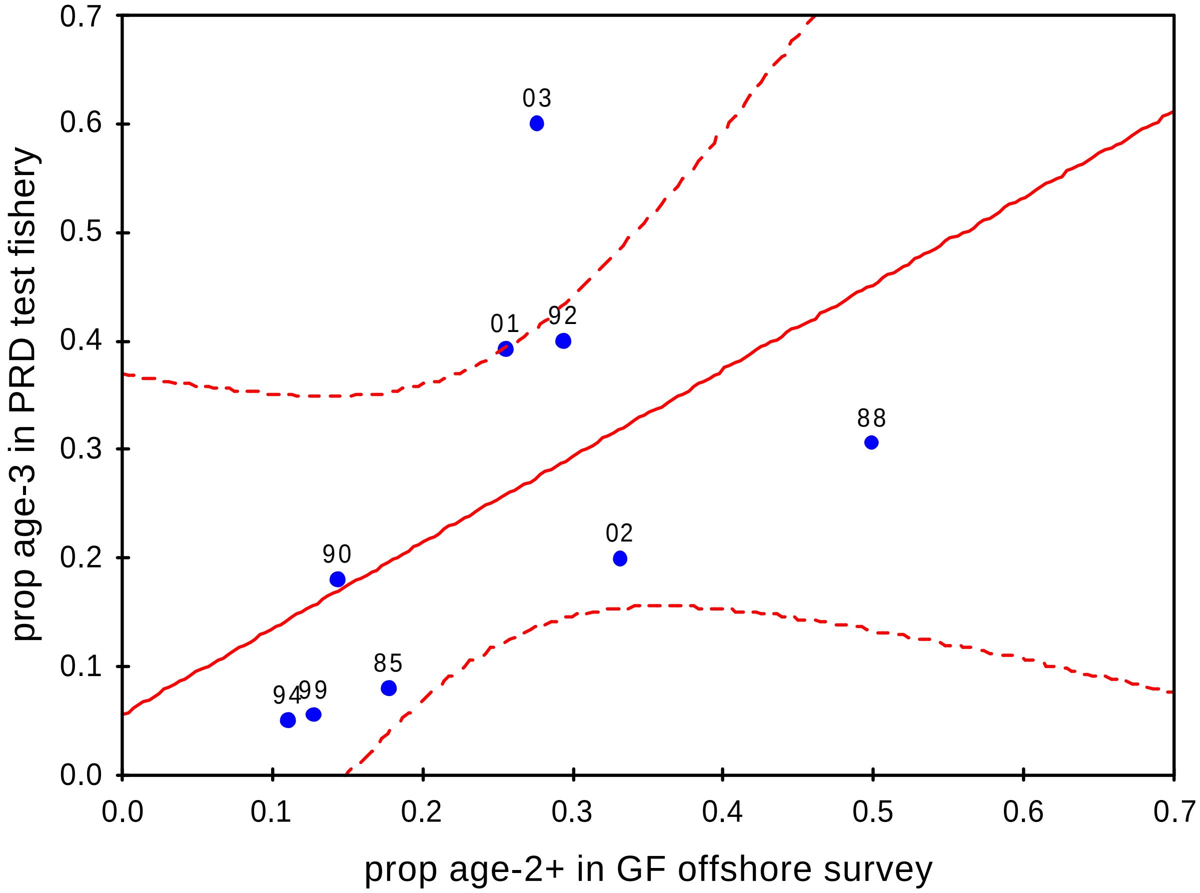

Figure 12: Relationship between the proportion of age-2+ herring encountered in summer groundfish bottom trawl surveys in Hecate Strait and the proportion of age-3 herring encountered in the PRD test fishery (prefishery). 95% confidence bands also are shown.

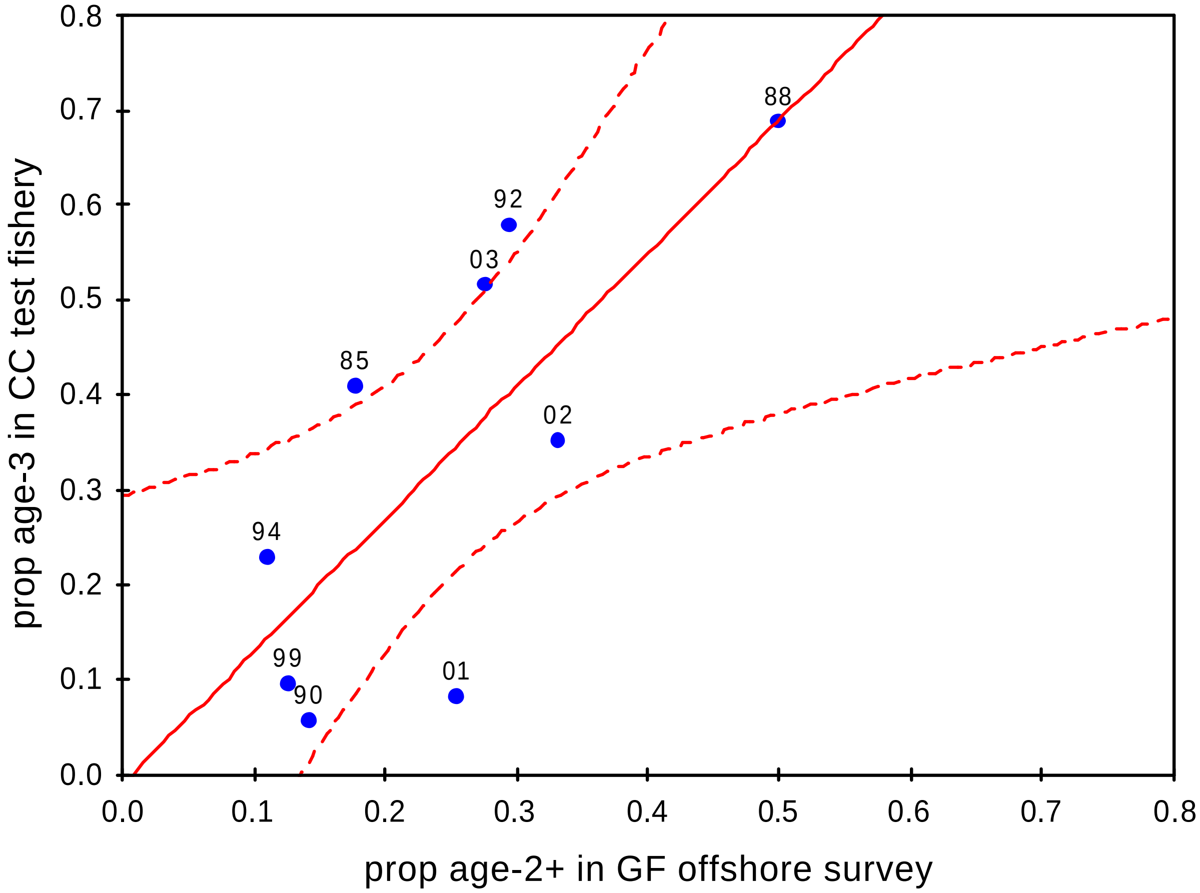

Figure 13: Relationship between the proportion of age-2+ herring encountered in summer groundfish bottom trawl surveys in Hecate Strait and the proportion of age-3 herring encountered in the CC test fishery (prefishery). 95% confidence bands also are shown.

Table 1: Proportion of age-3 herring in test fisheries for each of the northern stocks: Queen Charlotte Islands (QCI), Prince Rupert District (PRD) and Central Coast (CC) and proportion of age-2+ herring in summer offshore surveys. The proportion of age-2+ herring was determined as an unweighted average and as a weighted average (based on the number of herring).

Survey Year	Fishery Year	QCI prop. 3	PRD prop. 3	CC prop. 3	Weighted prop. 2+	Unweighted prop. 2+
2002	2003	0.6908	0.6000	0.5172	0.2747	0.2760
2001	2002	0.2506	0.1990	0.3519	0.2812	0.3326
2000	2001	0.3268	0.3926	0.0819	0.2723	0.2554
1998	1999	0.0267	0.0552	0.0968	0.1236	0.1273
1993	1994	0.0427	0.0505	0.2304	0.1706	0.1103
1991	1992	0.4285	0.3982	0.5796	0.1781	0.2944
1989	1990	0.0987	0.1798	0.0562	0.1667	0.1429
1987	1988	0.5101	0.3056	0.6886	0.5000	0.5000
1984	1985	0.1726	0.0795	0.4092	0.1724	0.1778

Table 2: Correlation matrix of the relationship between the proportion of age-3 herring in the test fishery (T), the commercial seine roe fishery between Jan-Apr (R), and both combined (C) for each of the three northern stocks: Queen Charlotte Islands (QCI), Prince Rupert District (PRD) and Central Coast (CC). Significant correlations are indicated by * following pairwise deletion of missing data (i.e., commercial seine closures).

	QCI_T	PRD_T	CC_T	QCI_R	PRD_R	CC_R	QCI_C	PRD_C	CC_C
QCI_T									
PRD_T	0.92 *								
CC_T	0.73 *	0.45							
QCI_R	0.96 *	0.92 *	0.79						
PRD_R	0.91 *	0.93 *	0.55	0.87					
CC_R	0.57	0.33	0.90 *	0.86	0.51				
QCI_C	0.98 *	0.91 *	0.64	1.00 *	0.87 *	0.46			
PRD_C	0.94 *	0.96 *	0.60	0.90 *	1.00 *	0.54	0.90 *		
CC_C	0.62	0.36	0.95 *	0.85	0.52	0.99 *	0.52	0.56	

Table 3: Leave-one-out retrospective analyses of the relationship between the proportion of age-2+ herring in offshore summer groundfish surveys and the proportion of age-3 herring in test fisheries for northern stock assessment areas: Queen Charlotte Islands (QCI), Prince Rupert District (PRD) and Central Coast (CC). Year excluded is the year of the summer offshore survey. Observed and Predicted values for the proportion of age-3 herring in test fishery samples also is shown.

Stock	Year Excluded	intercept	slope	R^2	$F_{1,6}$	p	Obs. prop. 3	Pred. prop. 3
QCI	2002	-0.0668	1.2322	0.8258	28.45	0.0018	0.6908	0.2733
	2001	-0.0562	1.4577	0.5941	8.78	0.0252	0.2506	0.4286
	2000	-0.0486	1.3303	0.5318	6.82	0.0401	0.3268	0.2912
	1998	-0.0012	1.2109	0.4655	5.23	0.0623	0.0267	0.1529
	1993	-0.0146	1.2446	0.4573	5.06	0.0656	0.0427	0.1227
	1991	-0.0466	1.2964	0.5224	6.56	0.0428	0.4285	0.3351
	1989	-0.0268	1.2842	0.4908	5.78	0.0530	0.0987	0.1567
	1987	-0.1655	1.9583	0.5501	7.34	0.0352	0.5101	0.8137
	1984	-0.0397	1.3204	0.5164	6.41	0.0446	0.1726	0.1951
PRD	2002	0.0365	0.7051	0.4179	4.31	0.0833	0.6000	0.2311
	2001	0.0466	0.8962	0.3301	2.96	0.1363	0.1990	0.3447
	2000	0.0415	0.7829	0.2904	2.46	0.1682	0.3926	0.2415
	1998	0.1013	0.6674	0.1998	1.50	0.2670	0.0552	0.1863
	1993	0.0136	0.6556	0.1856	1.37	0.2866	0.0505	0.0859
	1991	0.0537	0.7452	0.2595	2.10	0.1972	0.3982	0.2731
	1989	0.0513	0.8053	0.2606	2.11	0.1961	0.1798	0.1664
	1987	-0.1036	1.6214	0.4781	5.50	0.0575	0.3056	0.7071
	1984	0.0898	0.7174	0.2435	1.93	0.2140	0.0795	0.2174
CC	2002	-0.0184	1.3612	0.5717	8.01	0.0299	0.5172	0.3573
	2001	-0.0178	1.4874	0.5863	8.50	0.0268	0.3519	0.4769
	2000	0.0176	1.4219	0.6882	13.24	0.0108	0.0819	0.3808
	1998	0.0220	1.3108	0.4982	5.96	0.0504	0.0968	0.1889
	1993	-0.0548	1.5286	0.5676	7.88	0.0309	0.2304	0.1138
	1991	-0.0132	1.3200	0.5741	8.09	0.0294	0.5796	0.3754
	1989	0.0429	1.2598	0.5095	6.23	0.0468	0.0562	0.2229
	1987	-0.0114	1.4064	0.3431	3.13	0.1271	0.6886	0.6918
	1984	-0.0598	1.5112	0.6302	10.23	0.0186	0.4092	0.2089

Table 4: Leave-one-out retrospective analyses for two northern stock assessment areas: Queen Charlotte Islands (QCI) and Central Coast (CC) showing the difference between predicted and observed proportions of age-3 herring in test fisheries. Year excluded is the year of the summer offshore survey. 95% Confidence Intervals also are shown. No significant relationships were observed for the Prince Rupert District (PRD) stock (see Table 3).

Stock	Year Excluded	Obs. prop. 3	Pred. prop. 3	Difference (pred - obs)	Lower 95% CI	Upper 95% CI
QCI	2002	0.6908	0.2733	-0.4175	0.2009	0.3456
	2001	0.2506	0.4286	0.1780	0.2431	0.6142
	2000	0.3268	0.2912	-0.0356	0.1360	0.4464
	1998	0.0267	0.1529	0.1262	-0.0764	0.3824
	1993	0.0427	0.1227	0.0800	-0.1350	0.3804
	1991	0.4285	0.3351	-0.0934	0.1689	0.5011
	1989	0.0987	0.1567	0.0580	-0.0597	0.3731
	1987	0.5101	0.8137	0.3036	0.2893	1.3378
	1984	0.1726	0.1951	0.0225	0.0116	0.3786
CC	2002	0.5172	0.3573	-0.1599	0.2067	0.5079
	2001	0.3519	0.4769	0.1250	0.2845	0.6693
	2000	0.0819	0.3808	0.2989	0.2618	0.4998
	1998	0.0968	0.1889	0.0921	-0.0437	0.4215
	1993	0.2304	0.1138	-0.1166	-0.1397	0.3672
	1991	0.5796	0.3754	-0.2042	0.2231	0.5278
	1989	0.0562	0.2229	0.1667	0.0184	0.4274
	1987	0.6886	0.6918	0.0032	0.1158	1.2678
	1984	0.4092	0.2089	-0.2003	0.0426	0.3751

Appendix 1: PSARC Request for Working Paper

Date Submitted: July 29, 2003

Individual or group requesting advice:

Proposed PSARC Presentation Date: September 2-5, 2003

Subject of Paper (title if developed): Development of model for recruitment forecasting. Data collected in 2003 will be used to refine model parameters and provide recruitment strength forecasts for 2004.

Stock Assessment Lead Author: Dr. T. Therriault

Fisheries Management Author/Reviewer:

Rationale for request:

Preliminary results suggest that an offshore mid-water herring survey in Queen Charlotte Sound / Hecate St region holds promise that it can be used as a recruitment forecasting tool for the Central Coast, and possibly the QCI and Prince Rupert stocks. The forecasting methods employed by this survey would be similar to those developed by the La Perouse survey, which has been utilized quite successfully by DFO to forecast recruitment to the WCVI stock for over a decade.

A model that can provide forecasts of recruitment for northern areas would be a valuable assessment tool.

Question(s) to be addressed in the Working Paper:

(To be developed by initiator)

- Can a reliable recruitment forecasting model be produced for Central Coast, Prince Rupert District, and QCI areas, (recognizing that the recruitment index provided by this survey will take several years to assess)
- Is the model adequately described? (i.e. is there enough detail about model development presented in this paper to allow reviewers to evaluate the model?)
- What is the suitability of the historical groundfish cruise data for this model?

- What is the relationship between 2002 data collected on the groundfish cruise to 2003 actual recruits found in biological sampling data.
- Are there some areas where the model works better than others? If so, is it possible to hypothesize explanations for this discrepancy in performance?
- Are there differences between the 2003 data collected during the groundfish cruise and the data collected by the dedicated herring survey? (Note - data may not be available until later in season.)
- What is the predicted recruitment for Central Coast, Prince Rupert District, and QCI areas for 2004?

Objective of Working Paper:

(To be developed by FM & StAD for internal papers)

- Describe the recruitment forecasting model in sufficient detail to allow reviewers to understand and evaluate it.
- Provide recruitment forecast for 2004 for QCI. Prince Rupert, and Central Coast areas

Stakeholders Affected:

All users of herring resource

How Advice May Impact the Development of a Fishing Plan:

Better refined recruitment models for PRD, CC and QCI management areas may alter TAC in a management area.

Timing Issues Related to When Advice is Necessary