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The effects of sampling time on the age-composition of herring test fishing samples

R. Tanasichuk

Fisheries and Oceans Canada
Pacific Biological Station
Stock Assessment Division
Nanaimo, B.C. V9R 5K6

Abstract

Test fishing data collected since 1972 from all major stock assessment regions was used to determine if age compositions varied over time during the test fishing programs. This analysis was conducted to improve the performance of the age-structured model, particularly in the Prince Rupert District. Analysis consisted of fitting logistic regressions of the proportion of age 2+ herring (the usually dominant age-class) on sampling date. The proportion of age 2+ fish changed over time by at least 20% in 8% of the fishing season/assessment region groups. It is difficult to interpret these results. For the three major herring stocks above Vancouver Island, test fishing ends substantially before spawning ends so spawners are likely not sampled completely. Detailed analysis of the age composition data for Port Simpson/Big Bay and Kitkatla indicated that the age compositions, based on test fishing samples, are consistent between areas for only 3 of 18 years in this assessment region.

Résumé

À l'aide des données des pêches d'essai effectuées depuis 1972 dans toutes les régions d'évaluation des stocks importants, on a cherché à déterminer si la composition selon l'âge a varié pendant la durée des programmes des pêches d'essai. Cette analyse a été effectuée en vue d'améliorer la performance du modèle structuré selon l'âge, en particulier pour le district de Prince Rupert. L'analyse a consisté à ajuster les régressions logistiques de la proportion des harengs d'âge 2+ (classe d'âge ordinairement dominante) en fonction de la date d'échantillonnage. La proportion des poissons d'âge 2+ a changé dans le temps d'au moins 20 % pour 8 % des groupes (saison de pêche/région d'évaluation). Il est difficile d'interpréter ces résultats. Dans le cas des trois stocks importants de hareng au nord de l'île de Vancouver, les pêches d'essai se terminent avant la fin du frai de sorte que les géniteurs ne sont probablement pas échantillonnés parfaitement. Une analyse détaillée des données sur la composition selon l'âge pour Port Simpson/Big Bay et Kitkatla indique que les compositions estimées à partir des échantillons des pêches d'essai sont cohérentes d'un endroit à l'autre pour seulement 3 des 18 années dans cette région d'évaluation

INTRODUCTION

Fisheries and Oceans Canada hires commercial seiners to test fish each herring fishing season. The goals of the test fishing program are to provide information for in-season herring management and to collect biological samples used primarily for stock assessment. The information used for fishery management includes roe quality, stock biomass estimates and fish movements. Age composition and size-at-age information are inputs to herring stock assessment. The timing of the test seining programs is determined by the long-term average spawning date. The goal is to have spawning begin halfway through the program so that the vessels have enough time to provide appropriate information for in-season management and they can sample over the whole time herring are on the spawning grounds. In some years, spawning is later than anticipated. In addition, spawning in some areas is protracted. Therefore, the test fishing program may not sample all pre-spawning aggregations adequately because the program ends before spawning does.

Age-structured (Fournier and Archibald 1982) and escapement (Schweigert and Stocker 1988) analytical models are used to forecast pre-fishery biomasses. Both models use the estimate of returning spawners, along with recruitment forecasts, to predict pre-fishery biomass for the next fishing season. The models use natural mortality (age-structured model) and apparent survival rate (escapement model) estimates to forecast the biomass or returning adults. A bias in age composition would have a significant effect on the predictive power of both models. The effect would be greater on the age-structured model because it operates through re-constructing cohorts.

There has been a concern that the age compositions for test fishing samples may be biased. This would be a consequence of test fishing programs ending before all spawners have arrived on the spawning grounds. Hay (1985) reported that second wave spawners in Barkley Sound in 1982 were smaller than first wave spawners. He also noted that the trend for larger fish to spawn earlier had been described for other herring stocks. Ware and Tanasichuk (1989) found that this tendency was widespread over a number of B. C. herring stocks over a number of years.

The goal of this study was to review the age compositions of test fishing samples collected from all major herring stocks to look for changes in age composition within sampling seasons. In addition, the dates of the end of the testing fishing programs were compared with the dates that spawning began and ended to determine how adequately spawning herring would have been sampled.

MATERIALS AND METHODS

I used data for all test fishing samples collected in major stock assessment areas. Test fishing was intermittent between 1975 and 1980 fishing seasons and has been continuous for all fishing seasons since. Biological samples are collected from every test fishing set. Routine analysis consists of measuring standard length (mm), total mass (g) and gonad mass (g), assigning a subjective maturity stage and removing three scales from under the left pectoral fin for ageing.

I used logistic regression to test whether the age changed as a linear function of time. I regressed proportion of age 3 from each sample against sampling date using PROC LOGIT (SAS 1996). Regressions were done for all major stock assessment region/fishing season combination.

The relationship between the timing of test fishing sampling was compared with the dates that spawning began and ended. The dates of test fishing came from the sampling data. Dates of the beginning and end of spawning are archived at PBS in a herring spawn database. Biologically significant spawns were those greater than 1 km in length.

Most of the testing was for sampling regions currently considered to represent major herring stocks. There were two exceptions. Data representing the Strait of Georgia are for Area 14 where the majority of spawning and fishing has occurred over the last number of years. Because of the apparent differences between age compositions for aggregations for Port Simpson/Big Bay and Kitkatla, both of which are considered to be from the North Coast stock, I decided to test them separately, and to compare them.

I tested for differences in age composition using loglinear model analyses (Wilkinson et al. 1996) of numbers-at-age for ages 3 through 6 Port Simpson/Big Bay or Kitkatla. I accepted differences between locations if the main effects (Location+Age) did not explain the distribution of frequencies (Chi-square probability <0.05). This suggested an interaction between location and age, in other words, location and age were not independent.

RESULTS AND DISCUSSION

I present the results of the logistic regressions in two ways because it is unknown how sensitive the assessment models, especially the age-structured model, are to changes in age composition. Table 1 shows the occurrences of when the regression analysis showed significant linear changes in proportion of age 3 which exceeded 10%. Table 2 gives the occurrences of when proportion of age 3 changed by at least 20%. The proportion of fishing seasons when the change in proportion of age 3 exceeded 10% was 0.32, 0.33, 0.16, 0.28, 0.28 and 0.32 for the Southwest Coast Vancouver Island, Strait of Georgia, Central Coast, Port Simspon/Big Bay, Kitkatla and lower east coast Queen Charlotte Islands areas respectively. On average, 0.28 of the location/fishing season combinations had linear changes in proportion of age 3 which exceeded 10% over the test fishing period. The location-specific proportions were 0, 0.33, 0, 0.17, 0.17 and 0.11 respectively for instances where the change exceeded 20%. On average, 9% of the sampling events showed changes in proportion of age 3 with time which exceeded 20%. Seven of the 11 occurrences were increases in proportion of age 3 fish.

Although data from the test fishing period may describe age compositional changes over the sampling period, it may not describe how the age composition of a spawning population varies through the whole spawning season. Fig. 1 shows the relationship between when sampling ends and when spawning begins and ends. For all sampling areas, the end of the test fishing period was more closely related to spawning after 1980. Table 3 summarizes the relationships between sampling time and spawning time for 1980 through 1996. Sampling and spawning times were more closely related for the Strait of Georgia and SWCVI sampling areas.

To illustrate, test fishing in the LECQCI area ended 3 days before spawning began and 24 days before spawning ended. For the SWCVI, test fishing ended an average of 2 days after spawning began and 7 days before it ended. The relationship between test fishing and spawning was closest for the Strait of Georgia. On average, test fishing ended 14 days after spawning began and 3 days before it ended.

The implications of the discrepancy between test fishing and spawning season are different for each area. Ware and Tanasichuk (1989) reported that ripe herring can hold for a number of days before spawning, especially fish from the SWCVI and LECQCI. For these locations, there may or may not be a movement of fish onto the spawning grounds after test fishing finished. For the other locations, it is more likely that spawning after test fishing ended was by fish not sampled.

In summary, these results suggest that 91% of the test fishing seasons collect samples which are not biased by the relationship between spawning time and test fishing operations. However, this conclusion must be considered in the context of the relationship between the timing of test fishing and spawning. Sampling is likely unbiased for the Strait of Georgia and SWCVI. For the other areas, there is a much poorer overlap between test fishing and spawning. Although fish from the LECQCI hold, the duration of holding (15 days) is less than the average number of days (24) that test fishing ends before spawning does. Therefore it appears that test fishing activities above Vancouver Island do not sample later spawns of presumably younger spawners. This has implications for both stock assessment and future studies which presume that the number of fish-at-age 3 is an accurate estimate of recruitment. The escapement model currently uses apparent survival rates of greater than 1 for forecasting the number of age 3 spawners returning as age 4. I suggest that this reflects, at least in part, the incomplete sampling of age 3 fish. The age structured model estimates an availability parameter which essentially reflects this incomplete sampling. Two important immediate consequences of this biased sampling are: 1) age compositions may not accurately reflect the true proportion of fish at age and therefore ultimately bias natural mortality and apparent survival rate estimates, and 2) the numbers of age 3 fish for stocks, calculated using the test fishing samples, may not be an accurate estimate of the number of recruit herring for stocks above Vancouver Island.

<u>Port Simpson/Big Bay and Kitkatla</u>

These sampling areas represent a special case because of the large disparity between spawning biomass estimates by the escapement and age-structured model for the North Coast (Port Simpson+Kitkatla) stock assessment region. The apparently difficulty is with the age-structured model being unable to give a "reasonable" biomass estimate. There are major computational and theoretical differences between the two stock assessment models. One of the largest operational differences is that the escapement model has no history whereas the age-structured model is based on it. In other words, sampling problems have a compounding effect on the age-structured model because it re-constructs cohorts. Therefore sampling irregularities are much more persistent and have a larger effect on age-structured model estimates.

I found no persistent relationship between age compositions for herring from Port Simpson/Big Bay and Kitkatla. There were 18 common years of data. Table 1 shows that, for 8 years, changes in proportion of age 3 exceeded 10% in at least one location. Results of loglinear analyses of age frequencies showed that years there were significant differences in age composition in eight of the remaining 10 years (Fig. 2). Therefore, only two (1981, 1985) of the 18 years of data showed comparable age compositions.

I compared size-at-age as a preliminary test of whether these sampling areas may reflect two stocks. Size-at-age trends (Fig. 3) are similar therefore suggesting that one stock is being sampled.

The inconsistency in age composition and similarities in size-at-age suggest that the age compositions of herring from these two sampling areas are biased by sampling difficulties. Herring in the Port Simpson/Big Bay area tend to move into exceptionally shallow (<10 m) water a varying number of days before spawning and become inaccessible to the test seiners. The variability in age composition for these herring could then be a consequence of the relationship between spawning time and sampling time, as well as the relationship between the time fish move into shallow water and the time spawning begins. In conclusion, the lack of consistency of differences in age composition between these two areas makes resolving the lack of agreement between the age-structured and escapement models that much more difficult.

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Table 1. Changes in proportion of age 3 fish over the test fishing period. Data are for year/locations combinations where logistic regressions were statistically significant and changes in proportion of age 3 exceeded 10%. Values are regression estimates for the first and last days of the test fishing program. ND - No data. SWCVI - Southwest coast Vancouver Island. Georgia - Strait of Georgia. Central - Central Coast. LECQCI - Lower east coast Queen Charlotte Islands.

	Stock Assessment Region					
Year	SWCVI	Georgia	Central	Port Simpson/ Big Bay	Kitkatla	LEQCI
75			0.20-0.33		0.31-0.01	
76		ND		ND	ND	
77			ND	ND	ND	ND
78	0.48-0.34	0.25-0.55	ND	ND	ND	ND
79	0.06-0.19		ND	ND	ND	ND
80	0.49-0.34	0.27-0.66			0.20-0.86	
81	0.28-0.17	0.29-0.49	0.09-0.22			
82						0.02-0.14
83				0.19-0.52	0.33-0.09	
84		0.37-0.20		0.31-0.44	0.27-0.39	0.35-0.46
85						0.11-0.25
86						
87		0.23-0.38		0.16-0.46		
88	0.60-0.42	0.41-0.65				0.79-0.32
89						
90		0.36-0.55		0.02-0.19		
91					0.31-0.48	
92						
93						
94						
95	0.07-0.23					0.23-0.11
96	0.14-0.26		0.25-0.13	0.62-0.39		0.15-0.69

Table 2. Changes in proportion of age 3 fish over the test fishing period. Data are for year/locations combinations where logistic regressions were statistically significant and changes in proportion of age 3 exceeded 20%. Values are regression estimates for the first and last days of the test fishing program. ND - No data. SWCVI - Southwest coast Vancouver Island. Georgia - Strait of Georgia. Central - Central Coast. LECQCI - Lower east coast Queen Charlotte Islands.

	Stock Assessment Region					
Year	SWCVI	Georgia	Central	Port Simpson/ Big Bay	Kitkatla	LEQCI
75					0.31-0.01	
76		ND		ND	ND	
77			ND	ND	ND	ND
78		0.25-0.55	ND	ND	ND	ND
79			ND	ND	ND	ND
80		0.27-0.66			0.20-0.86	
81						
82						
83				0.19-0.52	0.33-0.09	
84						
85						
86						
87				0.16-0.46		
88		0.41-0.65				0.79-0.32
89						
90						
91						
92						
93						
94						
95						
96				0.62-0.39		0.15-0.69

Table 3. Relationship between dates that test fishing ended and spawning started and ended for 1980-96. Negative values indicate that fishing continued after spawning began or ended.

	Beginning of spawning			End of spawning		
		95 % confidence limit			95% confidence limit	
Location	Mean	Lower	Upper	Mean	Lower	Upper
LECQCI	3	-1	6	24	20	28
Port Simpson	-1	-4	1	16	12	20
Kitkatla	2	-1	6	12	9	15
Central	-6	-10	-2	16	11	20
Georgia	-14	-17	-11	3	-1	7
SWCVI	-2	-6	2	7	4	10

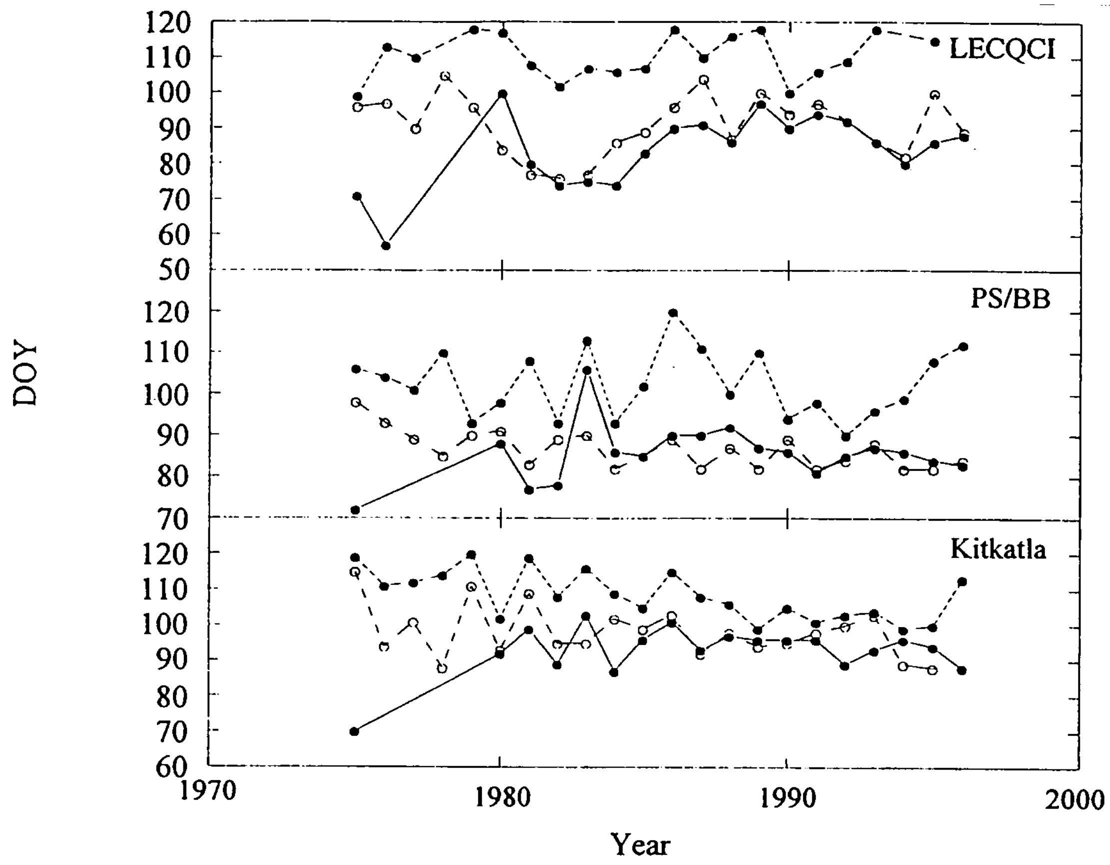


Figure 1. Dates test fishing ended (● —), spawning began (O ---) and spawning ended (● ---). PS/BB - Port Simpson/Big Bay.

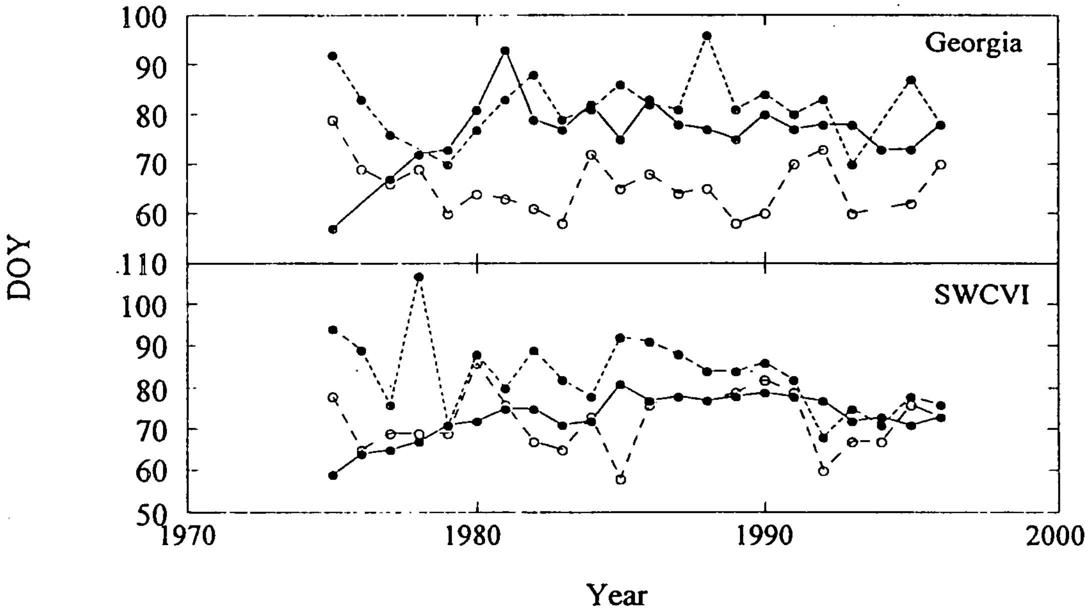


Figure 1. Cont'd

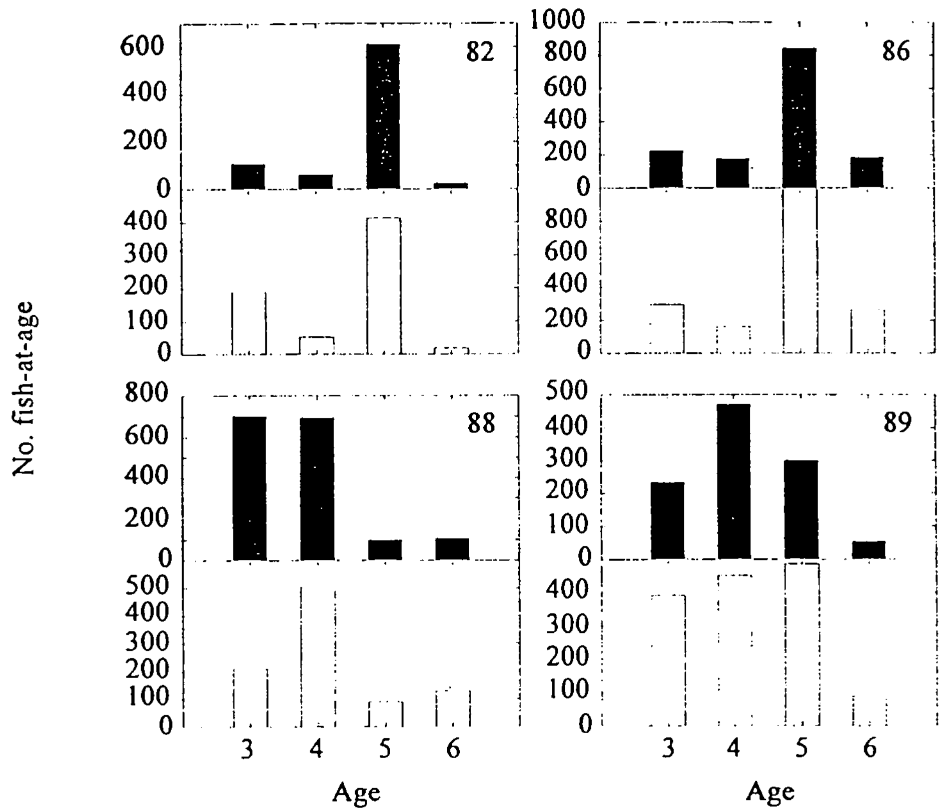
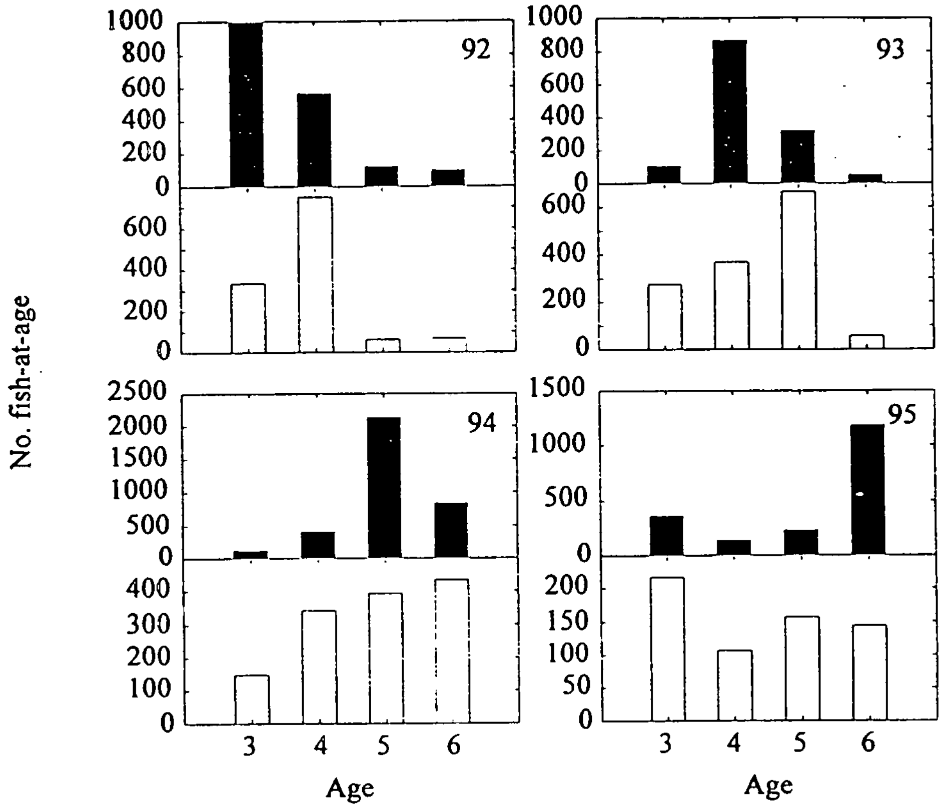


Figure 2. Age composition for ages 3-6 herring for Kitkatla (●) or Port Simpson/Big Bay.(O). Years are those for which age compositions were significantly different.



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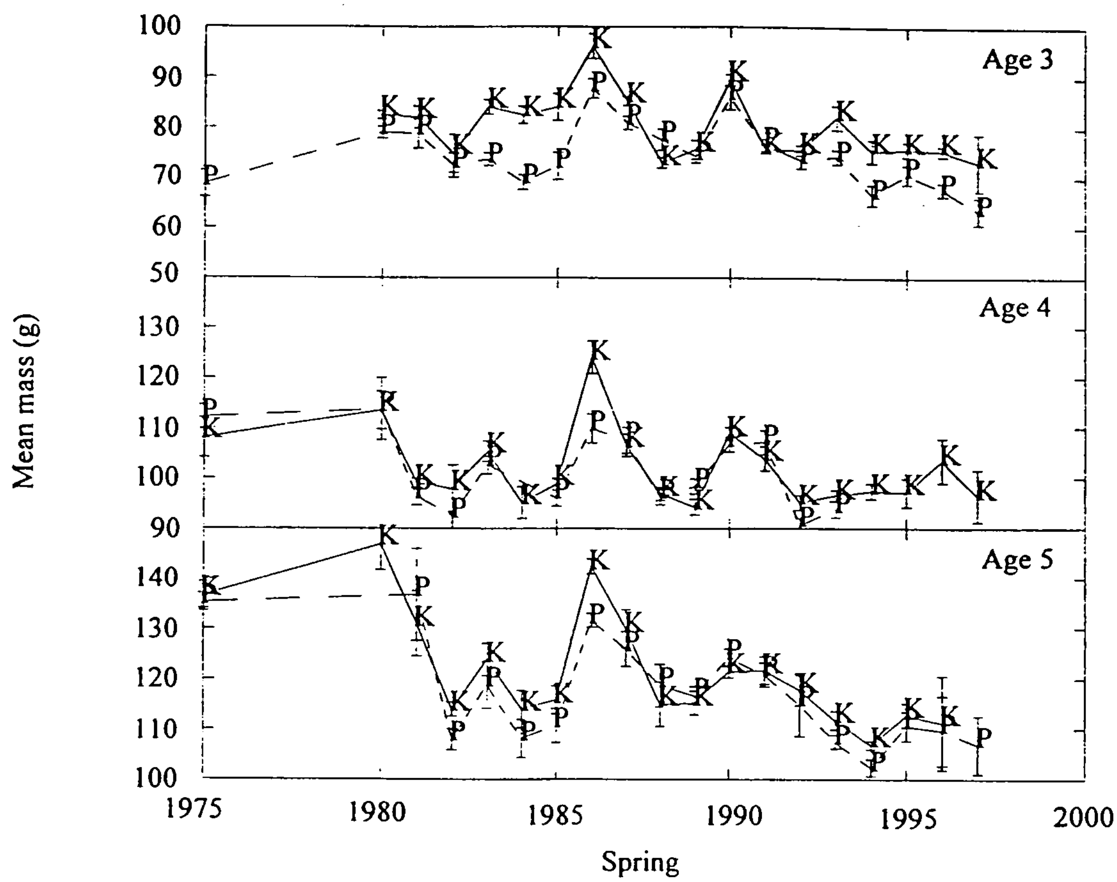

Figure 3. Mean mass-at-age for herring collected from Kitkatla (K) or Port Simpson/Big Bay (P). Error bars are 95% confidence intervals.