ESTIMATES OF MORTALITY RATES FROM MEAN LENGTH IN THE FULLY SELECTED SIZE RANGE FOR PORBEAGLE

Elizabeth A. Babcock[1]

SUMMARY

The method of Beverton and Holt was used to estimate fishing mortality rates from mean lengths of fully selected porbeagle sharks in each year for the northwest, southwest, and southeast stocks. Confidence intervals were calculated by bootstrapping the length data and drawing values of the parameters from a multivariate normal distribution. The analysis was conducted first with all the length data combined for each stock and then by fleet within each stock. Fishing mortality rates were estimated to be higher than M and declining in the northwest Atlantic, high and variable in the southeast Atlantic, and low in the northeast Atlantic. These results imply that the length distributions in the northwest and southeast are consistent with a population experiencing overfishing, while the southwest is not experiencing overfishing. However, since this method makes an equilibrium assumption, the results reflect historical overfishing more than current fishing mortality rates.

RÉSUMÉ

La méthode de Beverton et Holt a été utilisée pour estimer les taux de mortalité par pêche à partir des longueurs moyennes de requins-taupes communs entièrement sélectionnés chaque année pour les stocks du Nord-Ouest, du Sud-Ouest et du Sud-Est. Les intervalles de confiance ont été calculés en bootstrapant les données de longueur et en fixant les valeurs des paramètres à partir d'une distribution normale multivariée. L'analyse a d'abord été réalisée en combinant toutes les données de longueur pour chaque stock, puis par flottille au sein de chaque stock. On a estimé que les taux de mortalité par pêche étaient supérieurs à M et en baisse dans l'Atlantique Nord-Ouest, élevés et variables dans l'Atlantique Sud-Est et faibles dans l'Atlantique Nord-Est. Ces résultats impliquent que les distributions des longueurs dans le Nord-Ouest et le Sud-Est sont cohérentes avec une population qui est victime de surpêche, alors que le Sud-Ouest ne l'est pas. Toutefois, comme cette méthode repose sur un postulat en conditions d'équilibre, les résultats reflètent davantage la surpêche historique que les taux actuels de mortalité par pêche.

RESUMEN

Se utilizó el método de Beverton-Holt para estimar las tasas de mortalidad por pesca a partir de tallas medias de marrajos sardineros plenamente seleccionados cada año en los stocks del noroeste, sudoeste y sudeste. Los intervalos de confianza se calcularon por bootstrap de los datos de talla y extrayendo valores de los parámetros de una distribución normal multivariable. El análisis se realizó en primer lugar con todos los datos de talla combinados para cada stock y posteriormente por flota dentro de cada stock. Se estimó que las tasas de mortalidad por pesca eran superiores a M y decrecientes en el Atlántico noroccidental, altas y variables en el Atlántico sudeste y bajas en el Atlántico nororiental. Estos resultados implican que las distribuciones de talla en el noroeste y sudeste son coherentes con una población que está experimentando sobrepesca, mientras que el sudoeste no está experimentando sobrepesca. Sin embargo, dado que este método hace un supuesto en equilibrio, los resultados reflejan sobrepesca histórica más que tasas actuales de mortalidad por pesca.

KEYWORDS

Data limited assessment, porbeagle shark, size-frequency, shark fisheries, stock assessment

[1] Department of Marine Biology and Ecology, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Cswy., Miami, FL 33149. USA. ebabcock@rsmas.miami.edu

1. Introduction

Due to the lack of abundance trend data for Atlantic porbeagle sharks in the Atlantic in recent years, there is a need to estimate whether the population is overfished or experiencing overfishing from other sources of information. Size frequency data can be informative about fishing mortality rates, because the size distribution of the fish caught integrates the numbers at age (a function of mortality) and the size at age (a function of growth). Beverton and Holt (1957) derived an estimator of total mortality *Z* from the von Bertalanffy parameters L_∞ and *K*, the minimum fully selected size in the fishery L_c, and the mean length $\bar{L}$ of fish larger than L_c.

$$Z = \frac{K(L_\infty - \bar{L})}{(\bar{L} - L_c)}$$

Given an estimate of natural mortality *M*, fishing mortality *F* can be estimated as *Z-M*. A variation on this method by Ehrhardt and Ault (1992) allowed for an upper fully selected length as well to account for dome-shaped selectivity. These methods assume that recruitment, selectivity, growth, and mortality are consistent over time so that that the length distribution reaches an equilibrium. Thus, the estimates of *Z* from the length distribution in each year may not be an accurate estimate of current *Z* but can be interpreted as an index of mortalities in the recent past. Nevertheless, this index can be useful in tracking whether fishing mortality rates are increasing or decreasing over time in response to changes in management measures.

2. Methods

Length frequencies converted to fork length were taken from Cardosa (2020). Life history parameters L_∞, *K* and longevity t_{max} were taken from Cortes and Semba (2020). Natural mortality rates were calculated using three methods: (1) the method of Then *et al*. (2017) using t_{max},, (2) Then's equation using the growth parameters, and (3) the method of Jenson using *K* (from Cortes and Semba 2020). L_c was calculated as the mode of each length frequency distribution using the method of Babcock *et al*. (2013, 2018). The values of *F* were calculated at the mean value of each parameter. Uncertainty was calculated by bootstrapping the length frequency data in each stock and year, and drawing the parameters L_∞, *K* and *M* from a multivariate normal distribution (Babcock *et al.* 2013, 2018). The mean and variance of *M* were calculated by using the Then *et al.* (2017) value from t_{max} as the mean, and assuming that the range of values calculated by the three methods was 6 standard deviations, implying that the range of *M* values calculated is a 98% confidence interval. The variance-covariance matrix was calculated using the standard errors in **Table 1**, and the correlations from Babcock *et al.* (2013, 2018). One thousand Monte Carlo and bootstrap draws were made in each stock and year. The *F* values were calculated first for all data in each stock, and then by fleet for those fleets with sufficient data. Values of *F* were only calculated for years, stocks and fleets with at least 30 data points above the calculated L_c.

3. Results

When L_c was calculated as the mode of the size data for all fleets combined, the fully selected size range was relatively narrow for all three stocks (**Figure 1**). The southwest population had a bimodal distribution so that only a small fraction of the distribution could be interpreted as fully selected. The trend in the fully selected mean size was similar to the trend for mean length in the whole size range for the southeast, but not the other stocks (**Figure 2**). Values of *F* calculated by the Beverton and Holt method were nearly identical to the Ehrhardt and Ault results (not shown), so only Beverton and Holt results are shown. The values of *F* calculated from the best values of the parameters (**Table 1**) were higher than *M* in the northwest and southeast, but close to *M* in the southwest (**Figure 3**). The trend in recent years was decreasing in the northwest and increasing in the southwest and southeast. The bootstrap and Monte Carlo confidence intervals were quite broad (**Figure 4**), implying uncertainty about the direction of recent trends.

When the calculations were made by fleet, only six combinations of fleet and stock had a large enough sample size to do the calculations (**Table 2**, **Figure 5**). For the southeast stock, the data were dominated by the Japanese longline fleet, so that the results were the same whether all data or only the Japanese data were used (**Figure 6**). In the southeast, the two fleets, Uruguay and Japan-Uruguay, had very similar length distributions and so had similar results. In the northwest, the three fleets were Canada, Japan, and USA. Canada had high *F/M* through 2003, but their catches were too low to calculate mortality rates in recent years. Both the US and Japan show decreasing trends in *F/M* relative to the values ten years ago (**Figure 7**).

4. Discussion

The average lengths of fully selected porbeagle sharks imply that the population in the northwest Atlantic is experiencing overfishing, as is the population in the southeast Atlantic, but not the population in the southwest Atlantic. The trend in the northwest Atlantic appears to show some rebuilding as the *F/M* ratio is declining. However, these results should be interpreted with caution because the equilibrium assumption is not met. It is expected that the populations should be increasing due to the decrease in catches over the last decade. However, the relatively small mean lengths imply that the length frequency in the northwest has not yet recovered to what it would be if the population were not experiencing overfishing.

References

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Table 1 Life history parameters used in the analysis, with standard errors. Growth parameters and t_{max} are from Cortes and Semba (2020).

Stock	L_∞	SE	K	SE	t_{max}	L_c	L_λ	M	SE
NW	309.80	13.36	0.061	0.007	79	138	285	0.090	0.009
SE	210.86	9.62	0.086	0.012	65	100	209	0.107	0.012
SW	210.86	9.62	0.086	0.012	65	163	224	0.107	0.012

Table 2. Sample size by stock and fleet, along with the L_c calculated by fleets separately.

Stock	Fleet	n	Lc
NW	CAN	14627	146
NW	JPLL	1727	104
NW	USA LL	2311	92
SE	EU.PRT	3	NA
SE	JPLL	4526	100
SE	URY	9	NA
SE	ZAF	16	NA
SW	JP_Ury	937	164
SW	URY	2068	161

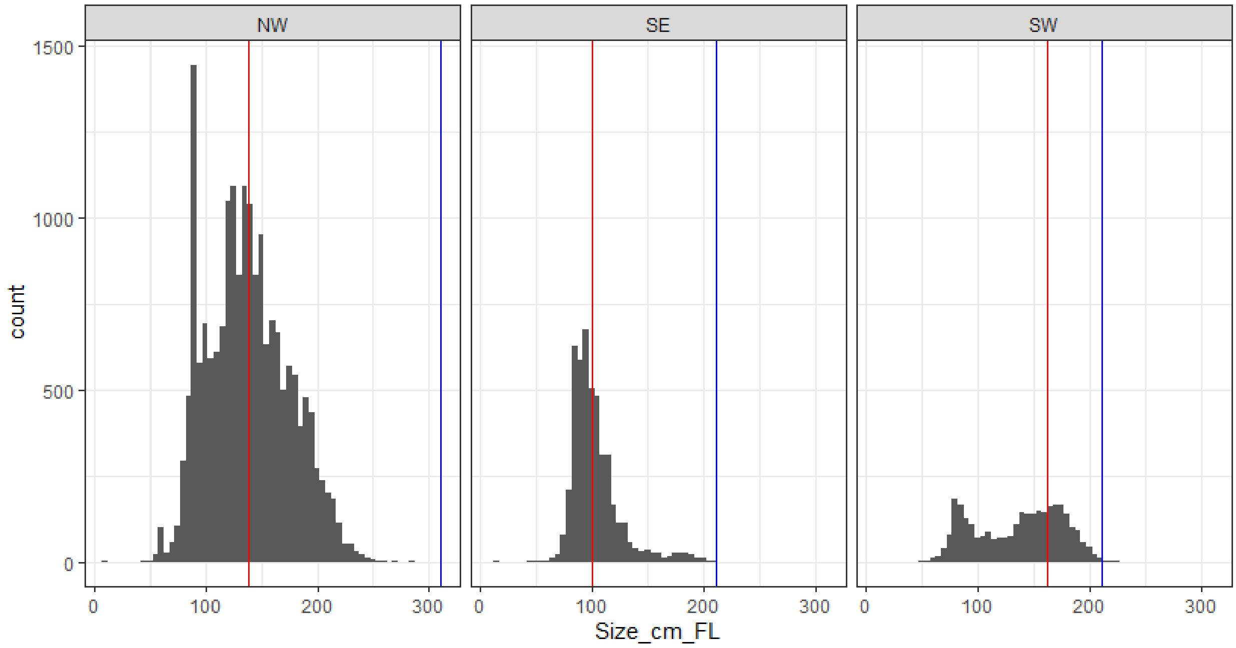

Figure 1. Fork length distributions of porbeagle shark by stock, along with the calculated length at full selectivity (L_c, left vertical line in red) and the asymptotic length L_∞ (right vertical line in blue).

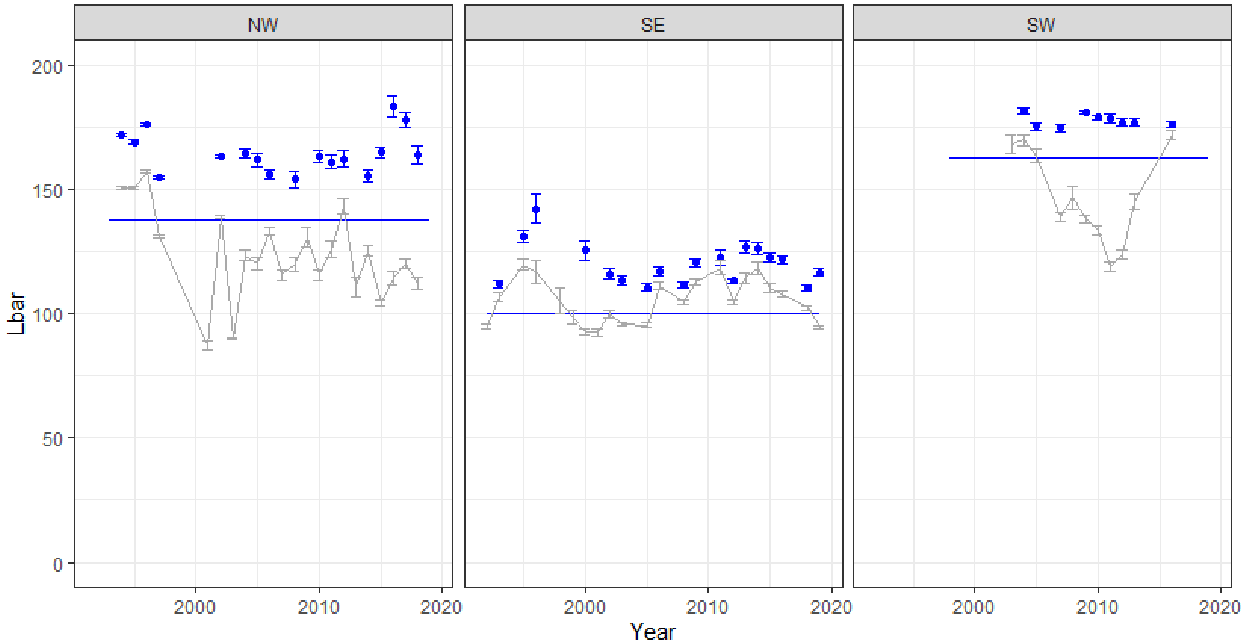

Figure 2. Mean length across whole data set (grey with line), and in the fully selected range (blue), along with L_c (horizontal blue line) by stock.

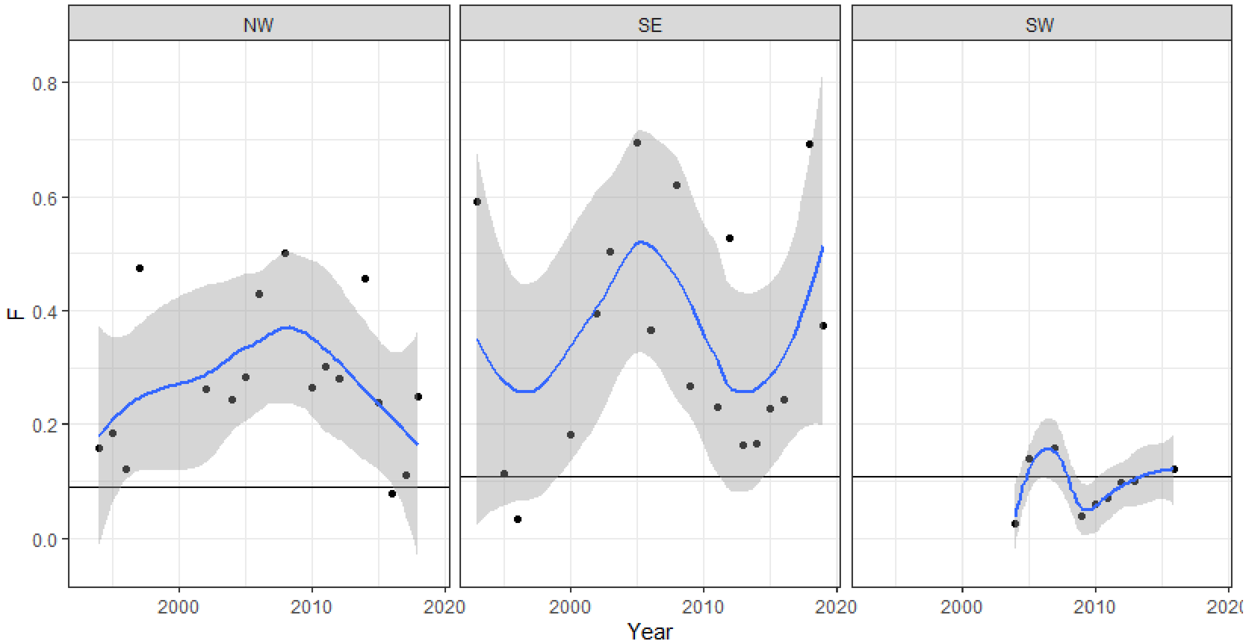

Figure 3. Deterministic estimates of *F* in each year and stock with loess smooth. Horizontal line is *M*.

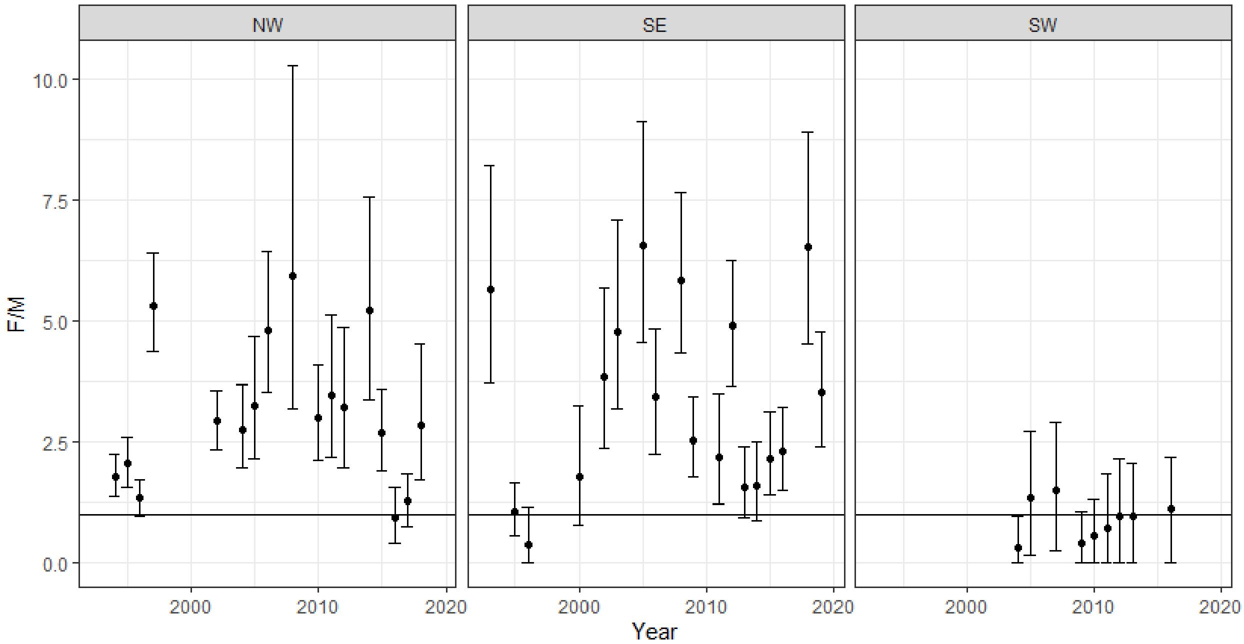

Figure 4. *F/M* mean with 95% confidence intervals, by stock. Horizontal line is *F/M*=1.

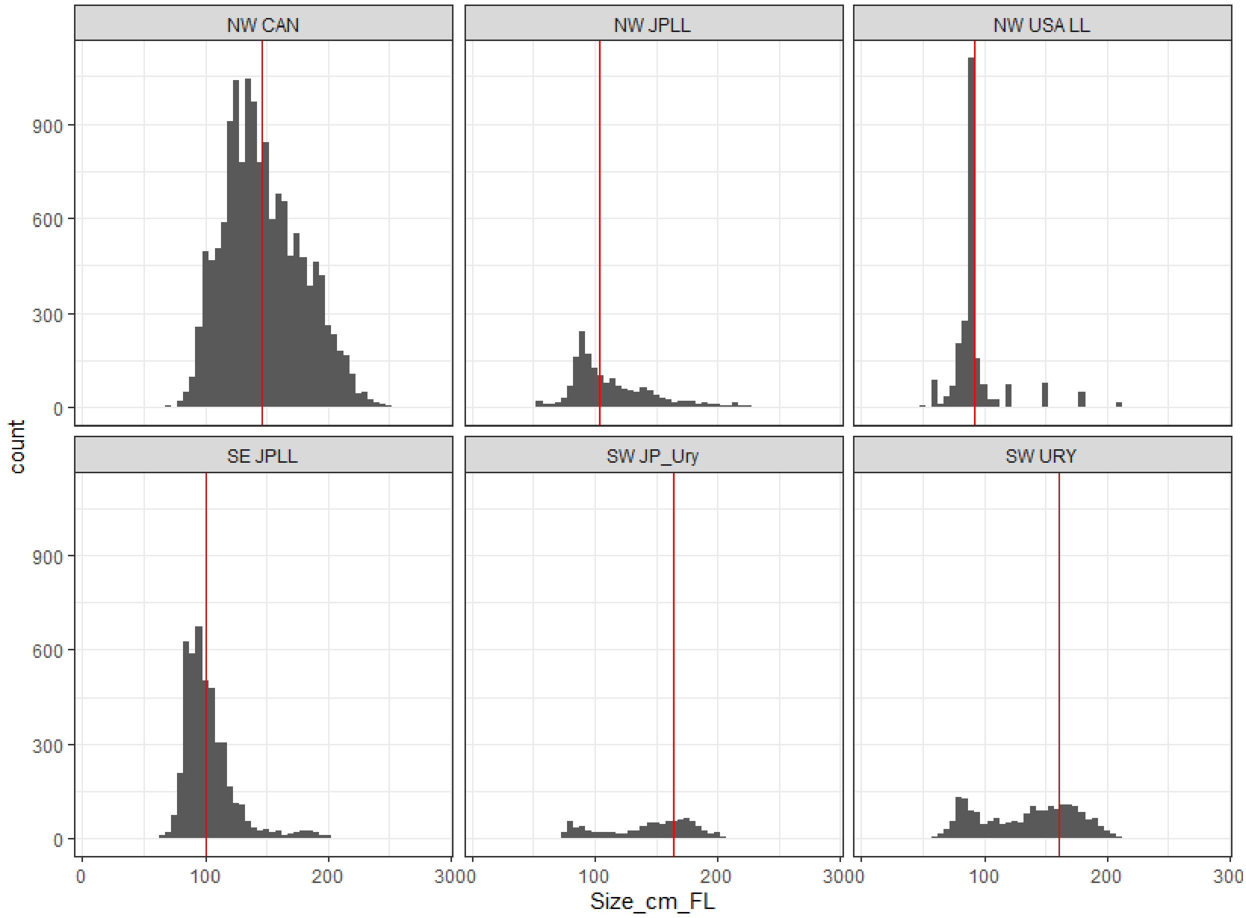

Figure 5. Length frequency and L_c values by fleet.

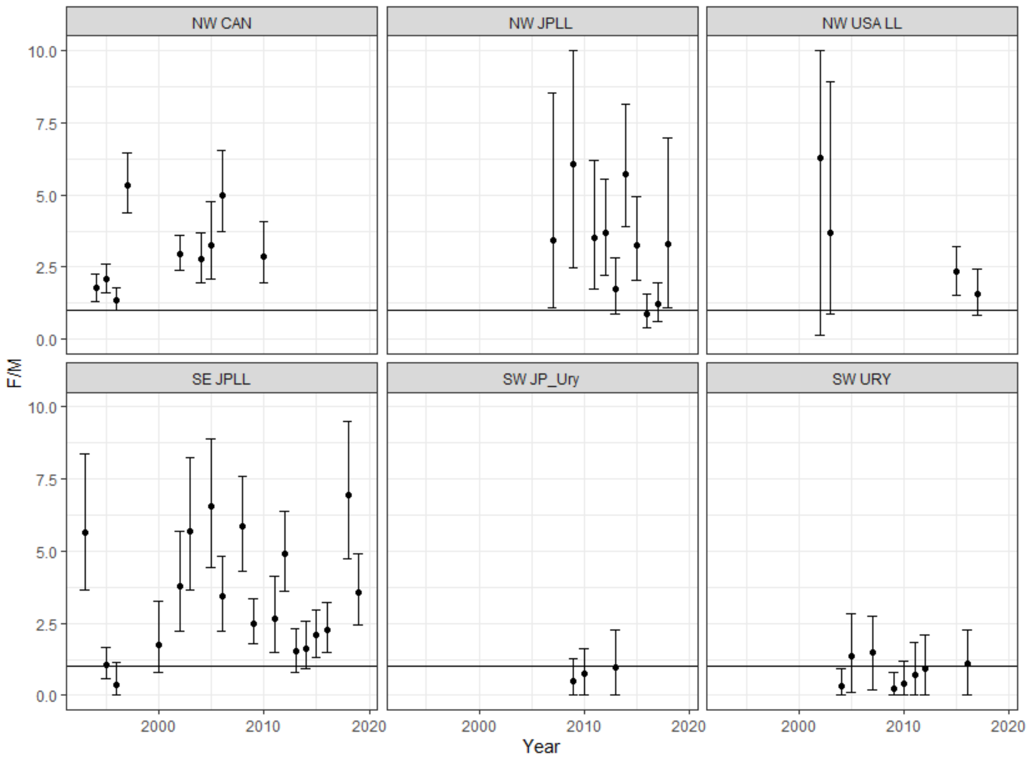

Figure 6. *F/M* by fleet with 95% confidence intervals. The upper C.I. is truncated to 10.

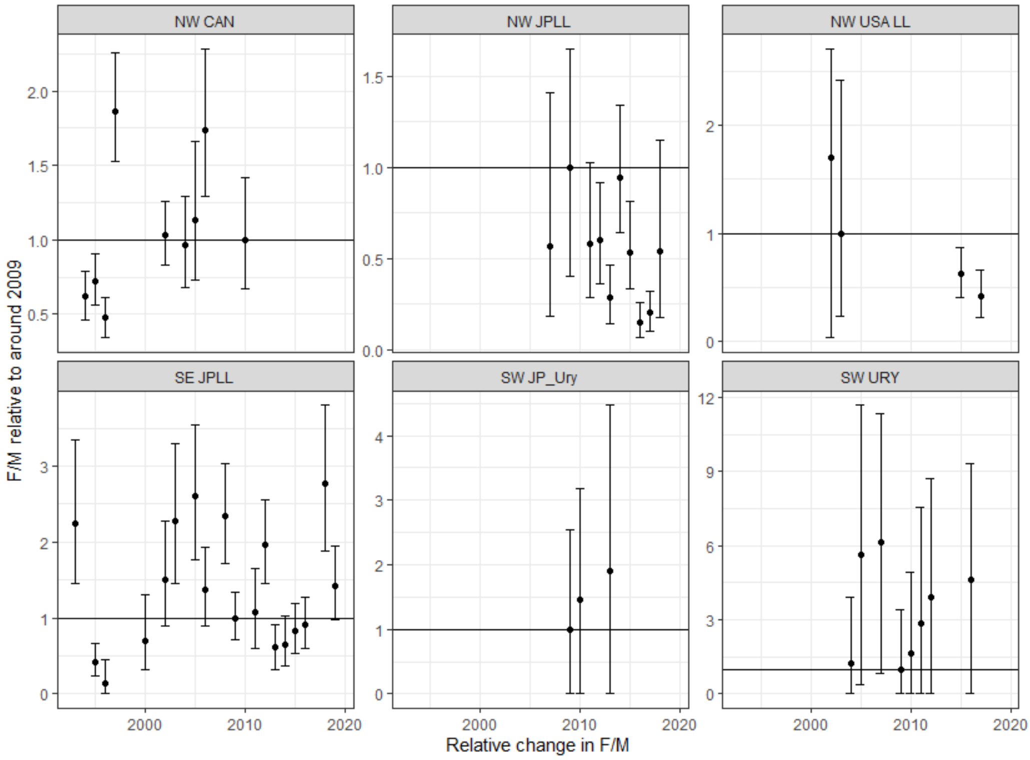

Figure 7. *F/M* by fleet relative to a value from before the rebuilding period, 2009 for most fleets, 2010 for USA and 2003 for Canada.