NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N6061 **NAFO SCR Doc. 12/034**

SCIENTIFIC COUNCIL MEETING – JUNE 2012

Bayesian surplus production models applied to American plaice in NAFO Div. 3LNO

M. Joanne Morgan

Fisheries and Oceans Canada, PO Box 5667, St. John's, NL, A1C 5X1, Canada

Abstract

Bayesian surplus production models were fit to data for Div. 3LNO American plaice and the results compared to the results for MSY reference points derived from a Loess smoother applied to log-transformed recruitment values from the American plaice VPA assessment. A comparison of results from different methods can provide information on the uncertainty in the MSY reference points. All models give very similar results, especially for Bratio. All show that current biomass is well below Bmsy. The results of the Bayesian surplus production modes support the MSY reference points based on the Loess smoother applied to log-transformed recruitment values from the American plaice VPA assessment.

Key words: Bayesian surplus production model, Div. 3LNO American plaice, MSY, reference points

Introduction

In 2011, Scientific Council provided estimates of MSY reference points for Div. 3LNO American plaice. These were based on a Loess smoother applied to log-transformed recruitment values from the 2010 American plaice VPA assessment (Shelton and Morgan MS 2011) and referred to here as the stock recruit (S-R) method. The Fisheries Commission has requested that the uncertainty in these reference points be examined. One way to do this is to apply a different method and compare the results. In this study I apply two forms of a Bayesian surplus production model to data for Div. 3LNO American plaice and compare the results to those of Shelton and Morgan (MS 2011).

This is not presented as an alternative assessment to the present accepted assessment of Div. 3LNO American plaice. It is simply presented as another way to examine the MSY reference points.

Methods

Bayesian surplus production models of two types were applied to data for Div. 3LNO American plaice.

The Schaefer (1954) form of a surplus production model used here is:

$P_t = [P_{t-1} + r \cdot P_{t-1} (1 - P_{t-1}) - C_{t-1}/K] \cdot \eta_t$

where P_{t-1} and C_{t-1} denote exploitable biomass (as a proportion of carrying capacity) and catch, respectively, for year t-1 (Meyer and Millar, 1999a, 1999b). Carrying capacity, K, is the level of stock biomass at equilibrium prior to commencement of a fishery, r is the intrinsic rate of population growth, and η_t is a random variable describing stochasticity in the population dynamics (process error). The model utilizes biomass proportional to an estimate of K in order to aid mixing of the Markov Chain Monte Carlo (MCMC) samples and to help minimize autocorrelation between each state and K (Meyer and Millar, 1999a, 1999b).

Previous analyses indicated that the yield curve was skewed (Shelton and Morgan MS 2011) so a form of the Pella Tomlinson production model was also applied:

Pt<- log(max(P[t-1] + r*P[t-1]*(1-pow(P[t-1],shape)) - (L[t-1]/K), 0.0001))

The symbols are as described above and the shape parameter allows the production curve to be non-symmetrical.

In both models an observation equation is used to relate the unobserved biomass, P_t, to the research vessel survey indices:

$I_t = q \cdot P_t \cdot \varepsilon_t$

where q is the catchability parameter, P_t is an estimate of the biomass proportional to K at time t, and ε_t is observation error.

Data explored were as follows: (TABLE1)

(1) Landings – 1960-2009

(2) Canadian RV spring Survey Indices: Engels Trawl – 1975-1984

(3) Canadian RV spring Survey Indices: Campelen Trawl or equivalent – 1985-2009

(4) Canadian RV fall survey indices: Campelen Trawl or equivalent – 1990-2009

(5) EU RV Survey Indices – 1997-2009

These were the same data as used in the Div. 3LNO American plaice assessment except for the Engel RV series. This was included to provide a survey series that extended farther into the past. Data to 2009 only were used simply for convenience. Adding 1 more year of data would not change the overall results.

Non-informative or vague priors were used for all parameters as the initial prior distributions (Table 2). Priors on the catchability (q) were uniform and broad. Uniform priors were also used for observation error. Priors on the process error were also broad and uniform.

Often, K is set to the stock biomass in the year prior to the onset of fishing (P0; see Meyer and Millar, 1999a). However, in the models used here, initial stock biomass was not assumed to be the virgin biomass as fishing began on these stocks prior to 1960. P0 was allowed to vary between 0.5 and 1 (i.e. initial biomass was allowed to vary between K/2 and K). A lognormal distribution for K was specified here with a mean of 900 ('000t) and a standard deviation of 1000 ('000t).

The prior for r was based on the expert opinion that it is unlikely to vary greatly from that of cod in Newfoundland waters which has been estimated at 0.26 (Hutchings, 1999). The prior for r was only vaguely informative, utilizing a mean with a very wide lognormal distribution about the mean.

The prior on the shape parameter for the Pella-Tomlinson version of the model was uniform (1,4).

Results and Discussion

The results described are for initial runs. There has been little examination of model fit diagnostics nor any attempts to optimize the model. This exercise is simply to provide some information on the reliability of the MSY reference points estimated by Shelton and Morgan (2011).

The two forms of the production model gave similar perceptions of stock history (Fig. 1). The Pella-Tomlinson model shows the stock at a slightly higher level at the beginning of the time series but both models declined greatly over the time period and have shown some increase in the recent period. The ratio of F to Fmsy (Fratio) from both models shows a very large increase to the early 1990's followed by a precipitous decline, with another increase to the early 2000's followed by another decline. The Schaefer model indicates higher levels of F relative to Fmsy throughout most of the time series.

The absolute levels of Bmsy and Fmsy can not be compared between the two different methods. For example Bmsy from the S-R method is expressed in terms of spawning stock biomass while from the production models is it total biomass. However, the ratios of Biomass to Bmsy (Bratio) and Fratio from the two different approaches can be compared. If the ratios from the two approaches are similar over time then this indicates that both the production models and the stock recruit approach provide consistent estimates of Bmsy and Fmsy.

Bratio from the production models is plotted along with Bratio (SSB/SSBmsy) from Shelton and Morgan (MS 2011) in Figure 2. All models show a similar trend over time although the production models are smoother and indicate a much bigger biomass relative to Bmsy at the beginning of the time series. However, for most of the time period the results from the S-R method are within the 95% credible intervals of the production models. More importantly all models indicate a very similar (and low) level of biomass to Bmsy in recent years.

Fratio from the production models is plotted along with Fratio (average F 9-14/Fmsy) from Shelton and Morgan (MS 2011) in Figure 3. The pattern in Fratio over time is very similar across all models, although Fratio from the S-R method is below the credible intervals for the Schaefer model for most of the time period. All models show a similar level of Fratio in recent years.

All models give very similar results, especially for Bratio. All show that current biomass is well below Bmsy. The results of the Bayesian surplus production modes support the MSY reference points derived from the Loess smoother applied to log-transformed recruitment values from the American plaice VPA assessments.

Acknowledgments

The Bayesian surplus production models are based on programs originally developed by Jason Bailey.

References

MEYER, R., and R.B. MILLAR. 1999a. BUGS in Bayesian stock assessments. Can. J. Fish. Aquat. Sci. 56: 1078-1086.

MEYER, R., and R.B. MILLAR. 1999b. Bayesian stock assessment using a state–space implementation of the delay difference model. Can. J. Fish. Aquat. Sci. 56: 37-52.

SCHAEFER, M.B. 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. Bull. Int.-Am. Trop. Tuna Com. 1: 25-56.

SHELTON, P.A. and M.J. MORGAN MS 2011. Further considerations regarding reference points, harvest control rules and rebuilding strategies for 3LNO American plaice and 3NO cod. NAFO SCR Doc. 11/39 Ser. No. N5924.

PELLA, J. J. and P. K. TOMLINSON. 1969. A generalized stock production model. Bull. Int.-Am. Trop. Tuna Com. 13: 419–496.

Table 1. Data used in the Bayesian Surplus Production models.

Year	Landings	springconv	fallconv	springeng	EU
1960	24				
1961	18				
1962	18				
1963	26				
1964	39				
1965	53				
1966	65				
1967	94				
1968	73				
1969	79				
1970	67				
1971	68				
1972	59				
1973	53				
1974	46				
1975	43			196.5	
1976	52			274.6	
1977	44			395	
1978	50			330.6	
1979	49			336.5	
1980	49			352.9	
1981	50			368.6	
1982	51			324.3	
1983	39				
1984	39			209.8	
1985	54	762.8			
1986	65	657.4			
1987	55	783.7			
1988	41	713.7			
1989	43	632.7			
1990	32	476.7	641		
1991	34	267.5	469		
1992	13	136	299		
1993	17	146.9	293		
1994	7.4	83.5	154		
1995	0.6	60	152.1		
1996	0.9	106.1	153.6		
1997	1.407	92.4	162.3		21.8
1998	1.618	103	187.9		64.6
1999	2.565	192.3	190		110.0

2000	5.176	154.7	268.2	153.0
2001	5.739	192.7	201.5	101.1
2002	4.87	129.6	249.2	69.5
2003	8.727	159.2	222.6	116.8
2004	6.158	142.9		129.4
2005	4.11	214.7	223.4	123.2
2006	2.828		232.9	170.9
2007	3.606	231.1	241.9	112.1
2008	2.515	234.1	333.4	172.7
2009	3.015	123.1	254.3	93.0

Table 2: Priors for parameters used in surplus production models for Div. 3LNO American plaice

Parameter	Description	Prior Distribution
K	Carrying Capacity	normal(u=1000kt,std=1500kt)
r	Intrinsic rate of increase	normal (u=0.15, sdt=1)
logq.eng	Catchability, Engels	U(0,10)
logq.cams	Catchability spring Campelen	U(0,10)
logq.camf	Catchability fall Campelen	U(0,10)
logq.eu	Catchability EU survey	U(0,10)
sigma	Process error	U(0,10)
tau.eng	Observation error Engel	U(0.2,1.17)
tau.cams	Observation error Campelen spring	U(0.2,2.38)
tau.camf	Observation error Campelen fall	U(0.2,2.38)
tau.eu	Observation error EU	U(0,1.55)
tau.shape	shape parameter Pella-Tomlinson	U(1,4)

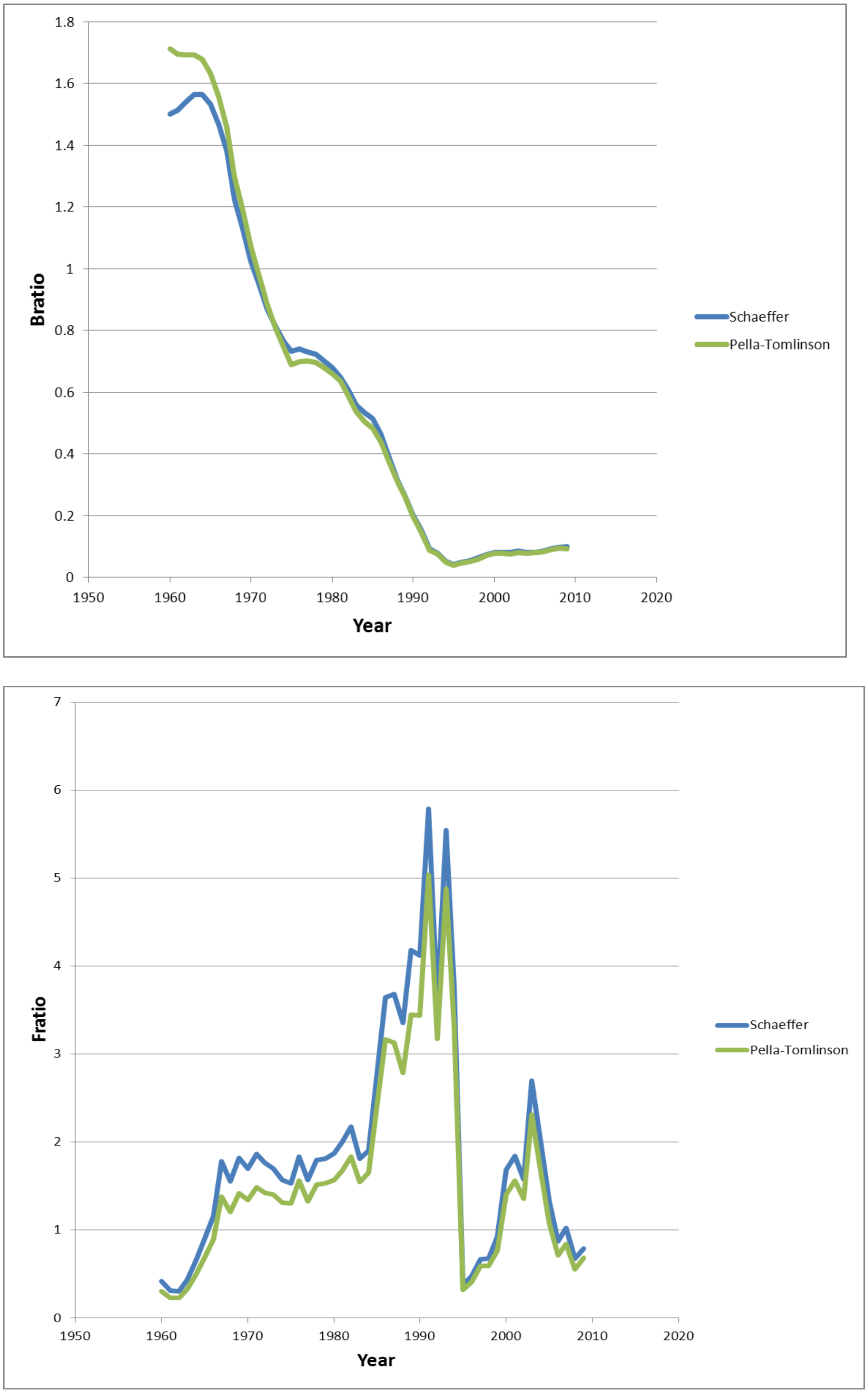
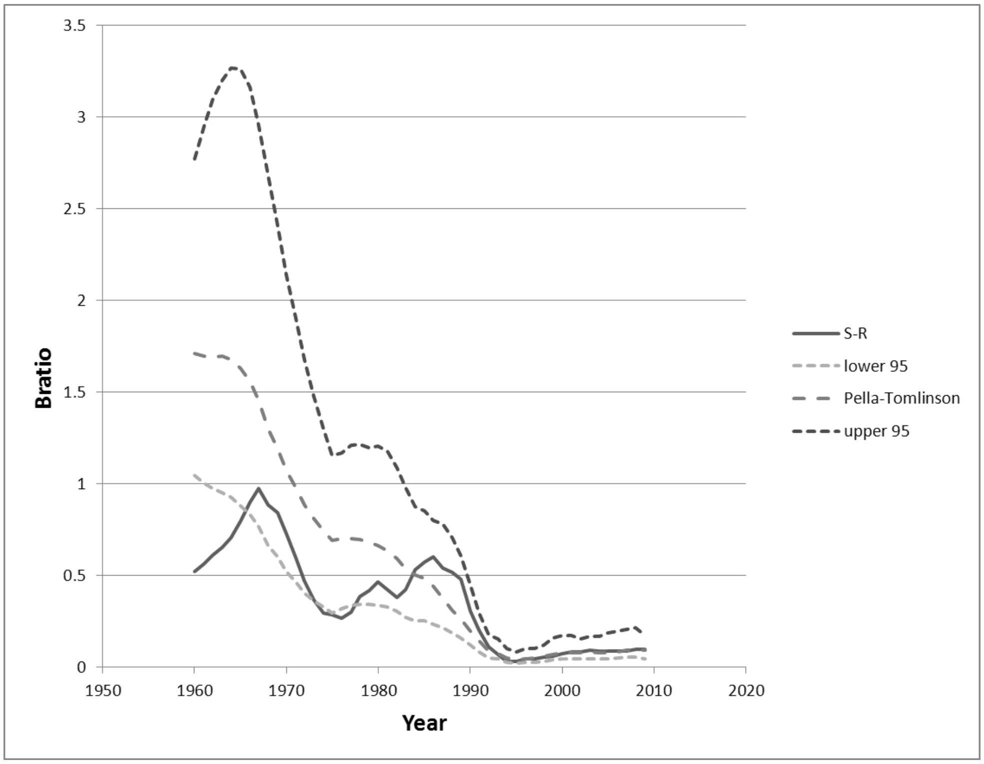


Figure 1. Ratio of biomass to Bmsy (Bratio, top) and fishing mortality to Fmsy (Fratio, bottom) for the two formulations of surplus production model applied to Div. 3LNO American plaice.



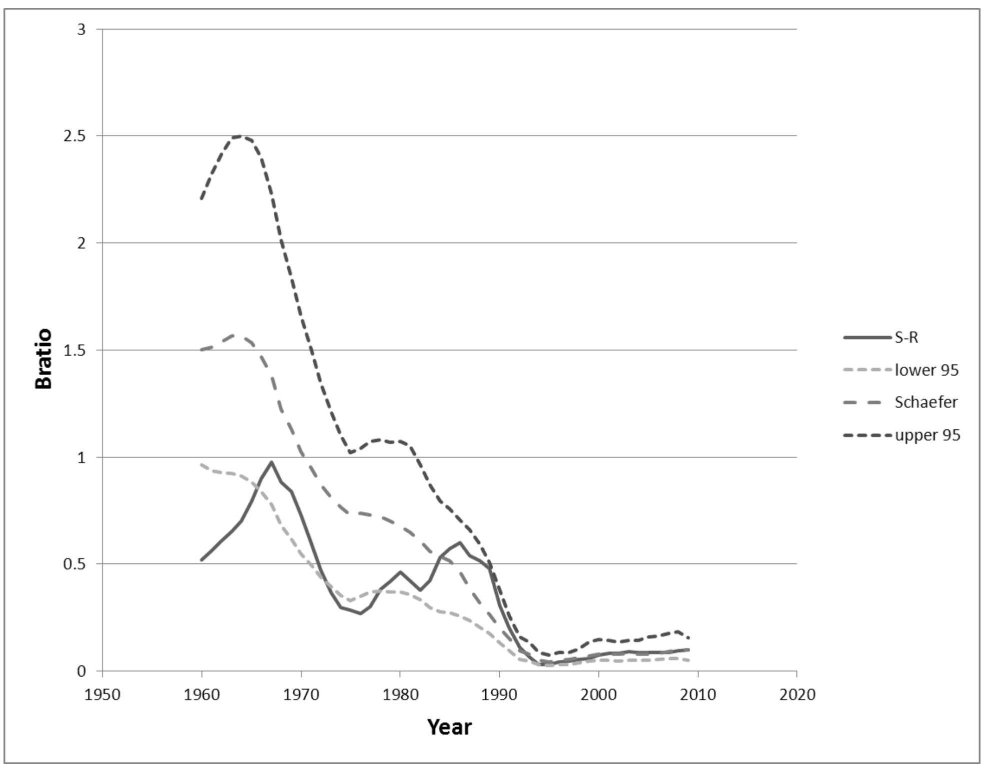
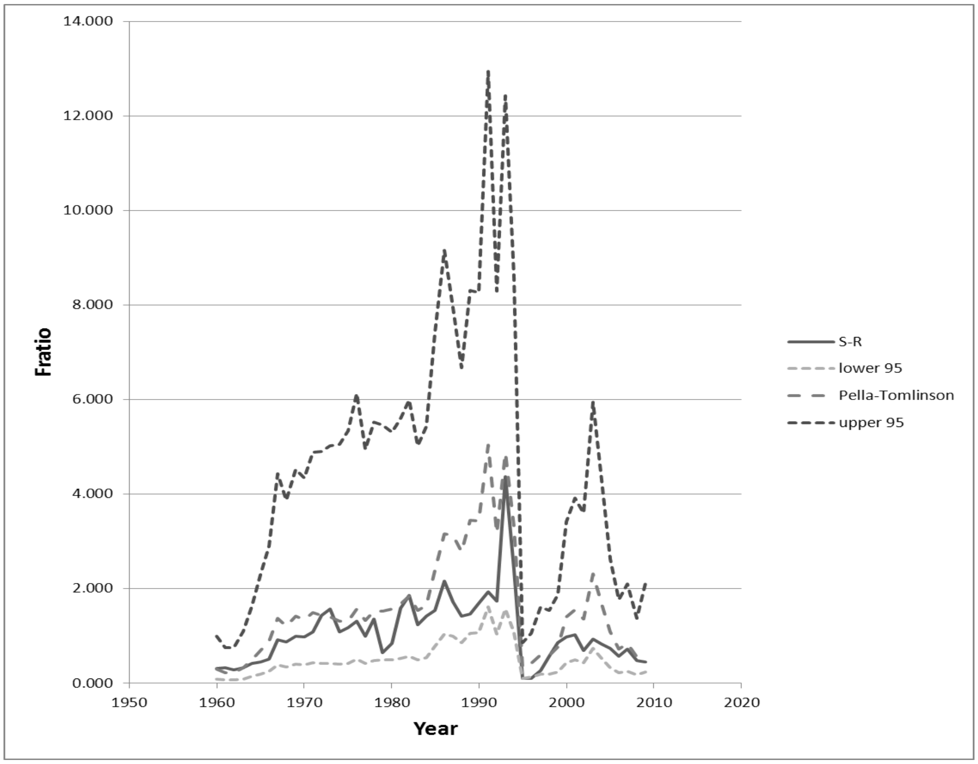


Figure 2. Bratio from the stock-recruit method (S-R) and from the surplus production models, Pella-Tomlinson (top) and Schaefer (bottom). For the surplus production models the median and upper and lower 95% credible intervals are shown.



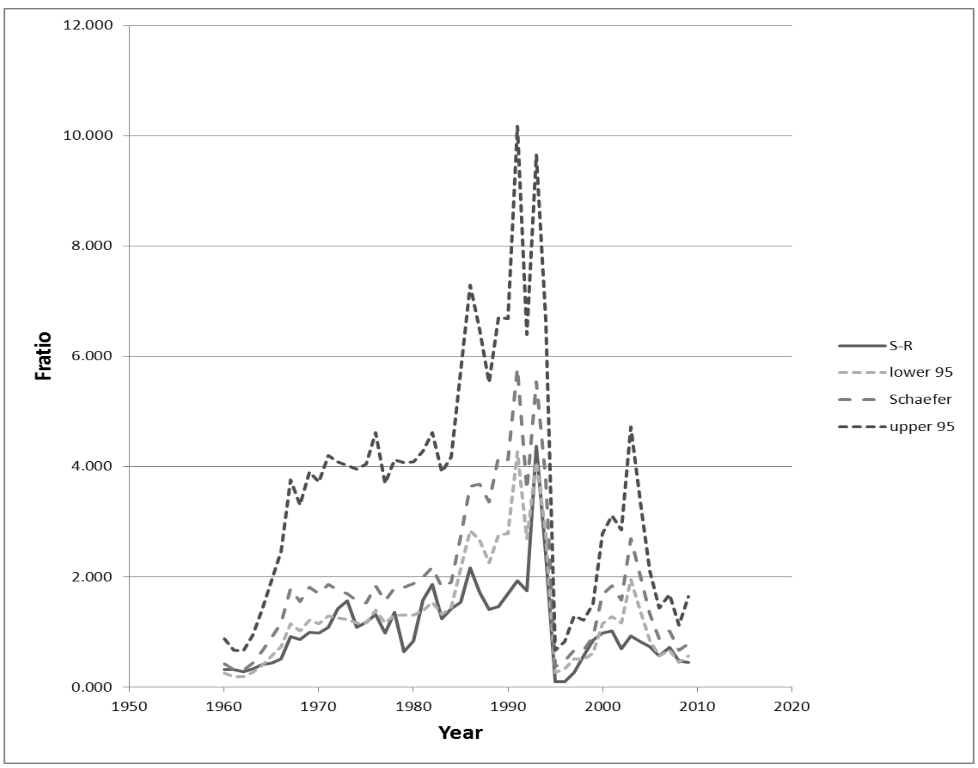


Figure 3. Fratio from the stock-recruit method (S-R) and from the surplus production models, Pella-Tomlinson (top) and Schaefer (bottom). For the surplus production models the median and upper and lower 95% credible intervals are shown.