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Assessment of the American Plaice (*Hippoglossoides platessoides*) stock in NAFO Subdivision 3Ps in 2019

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

There has been a moratorium on direct fishing of American Plaice since September of 1993. Since then, there has been only by-catch of American Plaice in other fisheries. Catch has been less than 200 t in all but one year (2017) since 2011. From the mid-1980s to 1990 there was a large decline in both biomass and abundance indices. Indices of stock size were lowest in the early 1990s. There was a general increase over the 1992-2011 period for both biomass and abundance indices with both indices varying essentially without trend since. The average abundance over the last three years is only 39% and biomass only 20% of the average from 1983-1985. Ageing is not available for this stock for the last several years. Length frequencies from the survey from 2009-2013 were examined for indications of recruitment in recent years. A year class can be followed from 2008 and another from 2013. Despite the appearance of these year classes, from 2008-2019 there are few fish greater than 30 cm, indicating that these year classes have not survived to older ages. The surplus production model used to assess the status of the stock estimates that an MSY of 2,879 t can be taken from a biomass of 70,290 t at a fishing mortality of 0.041. Stock size estimated from the surplus production model decreased fairly steadily from the late 1960s to a low in 1994 of less than 10% of B_{MSY}. Biomass increased slowly from 1994 to 2008 but has not increased since. B_{lim} for American Plaice in NAFO Subdivision 3Ps is 40% B_{MSY}. Biomass of the stock in 2019 is estimated to be 65% below B_{lim} and therefore the stock is in the Critical Zone. The probability of being below B_{lim} is high (0.98). Current median fishing mortality is estimated to be 24% of F_{lim} and the probability of being above F_{lim} (F_{MSY}) is low (0.03). The stock has shown little or no growth since 2008. Projections of stock size were conducted to the beginning of 2023 under conditions of zero catch, current F, current F plus 15%, and current F minus 15%. Although the stock is projected to grow under all scenarios, at the end of the projection period there is a high probability of being below B_{lim}, even under zero catch. There is no catch which gives a high (95%) probability of stock growth. To increase the probability of stock recovery, there should be no directed fishing and bycatch should be kept to the lowest possible level.

INTRODUCTION

American Plaice (*Hippoglossoides platessoides*) is a benthic marine flatfish that is usually considered a cold-water species, being most numerous within a temperature range from just below zero to around -1.5˚C. American Plaice are generally a slow growing and moderately long-lived species that exhibit sexual dimorphism in that the females grow faster and are larger than the males at most ages. American Plaice spawn throughout 3Ps and are considered to be a single self-sustaining population in that area (Bowering et al. 1996).

This document gives the technical details of analyses that formed the basis for the assessment of the status of the Sudiv. 3Ps American Plaice stock in 2019.

FISHERY

Catches from this stock were highest from 1968 to 1973, exceeding 12,000 t on three occasions in this period (Table 2, Figure 1). Since 1977 only Canada and France were involved in the fishery. Catches averaged just under 4,000 t during the 1980's but rapidly declined after 1991. There has been a moratorium on directed fishing of American Plaice since September of 1993. Since then, there has been only by-catch of American Plaice in other fisheries. Catch increased substantially after 1995, and was over 1,000 t in each year from 2001 to 2003. However, catch declined since then and has been less than 200 t in all but one year (2017) since 2011. Catch values for 2019 were only available until October at the time of the assessment. Complete year catch for 2019 was estimated based on the percentage of total year catch taken until that date in the last three years.

Data from Newfoundland reported catch statistics were examined to determine which fisheries were taking the greatest portion of the American Plaice bycatch. In recent years as in the past (Morgan et al. 2005, 2014), the bycatch of American Plaice was taken in two main fisheries, the directed cod (*Gadus morhua*) and the directed Witch Flounder (*Glyptocephalus cynoglossus*) fisheries. Over the 2014-2018 period 70-90% of the American Plaice bycatch came from the directed cod fishery, while the directed Witch Flounder fishery accounted for 10-22% of the bycatch.

SURVEY INDICES

Stratified-random surveys have been conducted by DFO in Subdiv. 3Ps in each year from 1972 to 2019. Coverage prior to 1980 was poor. There were two surveys in 1993, one in February and one in April. Most of the surveys prior to 1993 were in February/March, while those since 1993 have been in April. Survey coverage in 2006 was too limited to be used as an index. The data can be split into three time periods based on the trawl used: 1971-1982 was Yankee 36, 1983-1995 was Engel 145, and 1996-2013 was Campelen 1800 (see McCallum and Walsh [1996] for a description of the various trawls). There is a conversion between the second and third survey gears (Morgan et al. 1998) but not the first and third. Only Campelen and Campelen-equivalent units are discussed in this section.

Inshore strata were added in Placentia Bay in 1994 and more were added in Fortune Bay in1997.

Biomass and abundance indices from 1983-2019 are shown in Figure 2. From the mid-1980s to 1990 there was a large decline in both biomass and abundance indices. Indices of stock size were lowest in the early 1990s. There was a general increase over the 1992-2011 period for both biomass and abundance, with both indices varying essentially without trend since. The average abundance over the last three years is only 39% and biomass only 20% of the average from 1983-1985.

Ageing is not available for this stock for the last several years. Length frequencies from the survey from 1983-2019 were examined for indications of recruitment in recent years. In recent years a year class can be followed from 2008 and another from 2013. These year classes appear to be less abundant than the year classes of the mid 1980s at equivalent lengths. Despite the appearance of these year classes, from 2008-2019 there are few fish greater than 30 cm, indicating that these year classes have not survived to older ages (Figure 3 and 4).

Both males and females are maturing at a smaller size in recent years (Figure 5). Females now mature at about 33-35 cm compared to 38 cm in the late 1980s. Males now mature at 16-18 cm compared to 24 cm in the late 1980s. This is a further decline for both sexes from about 40 cm in the 1970s for females and about 27 cm for males (Morgan and Colbourne, 1999).

American Plaice are distributed throughout Subdivision 3Ps (Figure 6). There has been no real change in distribution in recent years except that the species is more widespread than when the population was at its lowest.

PRODUCTION MODELLING

The formulation of the Bayesian surplus production model that was accepted as the assessment of this stock in 2012 formed the basis of the model used here (Morgan et al. 2012). Examination of the posterior for r indicated a small bimodality that was in fact present in previous assessments. To eliminate this a small change was made to the priors for both r and K. In the previous assessment the prior for r (on the normal scale) had a mean of 0.15 and a standard deviation of 1, while in this assessment it had a mean of 0.175 and a standard deviation of 1. The prior for K in the previous assessment (on the normal scale) had a mean of 300 and a standard deviation of 400. In this assessment the prior for K had a mean of 400 and a standard deviation of 500. All other priors were the same as used in the last assessment. The priors used in this assessment can be found in Table 1.

Table 1. Priors used in the Bayesian Surplus Production model of Subdiv. 3Ps American plaice.

Median initial population size (relative to carrying capacity)	Pin~dunif(0.5, 1)	uniform(0.5 to 1)
Intrinsic rate of natural increase	r ~ dlnorm(-3.5,0.2844)	lognormal (mean, precision)
Carrying capacity	K~dlnorm(5.521,1.063)	lognormal (mean, precision)
Survey catchability	logq.cam~dunif(0,10) q.cam<-exp(logq.cam)	uniform (0,10)
Process error (sigma=standard deviation of process error in log-scale)	sigma ~ dunif(0,10) precision:isigma2= sigma^{-2}	uniform(0 to 10)

Observation error (tau=variance of observation error in log-scale)

Engel	tau.eng~dunif(0.2,1.17) precision : sigma^{-2}	uniform(0.2,1.17)
Campelen	tau.eng~dunif(0.2,2.38) precision : sigma^{-2}	uniform(0.2,2.38)

Model fit to the surveys was good (Figure 7 and 8). The posterior distributions for the main parameters that are estimated by the model were updated from their priors by the data (Figure 9 and 10). The process error was small compared to the observation error (Figure 11 and Table 3) and generally without trend. Convergence criteria (not shown) were examined and also considered to be acceptable. Parameter estimates from the 2019 model were similar to those from the 2014 model (Table 3). The largest difference was for K, but all parameter estimates (medians) from the 2019 model were well within the credible intervals from the 2014 model and credible intervals for all parameters from both model runs showed large overlap.

The production model estimates that an MSY of 2,879 t can be taken from a biomass of 70,290 t at a fishing mortality of 0.041. Stock size estimated from the surplus production model decreased fairly steadily from the late1960s to a low in 1994 of less than 10% of B_{MSY}. Biomass increased slowly from 1994 to 2008 but has not increased since. Biomass in 2019 is estimated to be only 35% of B_{lim}, with a probability of 0.98 of being below B_{lim}. Therefore the stock is in the Critical Zone (Figure 12). Fishing mortality reached a peak in 1991 after which it declined for several years. Fishing mortality increased again to above F_{MSY} in the late 1990s when landings started to increase. It has below F_{MSY} since 2011 with current median fishing mortality estimated to be 24% of F_{lim} (Figure 13). The probability of being above F_{lim} is low (0.03).

Projections of stock size were conducted to the beginning of 2023 under conditions of zero catch, current F, current F plus 15%, and current F minus 15%. All projections made the same assumption about catch in 2019 as the assessment, that is catch in 2019 is 97 t. Although the stock is projected to grow under all scenarios, at the end of the projection period there is a high probability of being below B_{lim}, even under zero catch (Table 4). As current F is low, there is little difference in projection results among the different scenarios.

CONCLUSION

B_{lim} for American Plaice in NAFO Subdivision 3Ps is 40% B_{MSY}. Biomass of the stock in 2019 is estimated to be 65% below B_{lim} and therefore the stock is in the Critical Zone. The probability of being below B_{lim} is high (0.98). The stock has shown little or no growth since 2008. Current median fishing mortality is estimated to be 24% of F_{lim} and the probability of being above F_{lim} (F_{MSY}) is low (0.03).

Projections of stock size were conducted to the beginning of 2023 under conditions of zero catch, current F, current F plus 15%, and current F minus 15%. Although the stock is projected to grow under all scenarios, at the end of the projection period there is a high probability of being below B_{lim} even under zero catch. There is no catch which gives a high (95%) probability of stock growth.

To increase the probability of stock recovery, there should be no directed fishing and bycatch should be kept to the lowest possible level.

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TABLES

Table 2. Total landings ('000 metric tons) and survey indices (Engel and Campelen) used in the surplus production model for Subdivision 3Ps American Plaice.

Year	Landings	Engel	Campelen
1960	0.887	-	-
1961	1.455	-	-
1962	1.024	-	-
1963	0.754	-	-
1964	1.542	-	-
1965	2.022	-	-
1966	3.406	-	-
1967	4.494	-	-
1968	14.28	-	-
1969	6.491	-	-
1970	12.328	-	-
1971	7.182	-	-
1972	6.538	-	-
1973	14.769	-	-
1974	6.598	-	-
1975	4.211	-	-
1976	5.458	-	-
1977	4.605	-	-
1978	3.658	-	-
1979	3.666	-	-
1980	2.935	35.8	-
1981	3.217	26	-
1982	2.186	39.1	-
1983	1.726	45.2	-
1984	2.963	22.5	-
1985	4.22	64.5	-
1986	5.13	30.4	-
1987	5.331	33.9	-
1988	4.406	27.3	-
1989	2.957	17	-
1990	4.13	5.8	-
1991	4.395	12.1	-
1992	2.331	6.8	-
1993	0.751	4.6	-
1994	0.122	4.2	-
1995	0.085	3.9	-
1996	0.114	-	12.4
1997	0.243	-	8.6
1998	0.423	-	14.36
1999	0.654	-	14.6
2000	0.65	-	21.5
2001	1.01	-	18.3
2002	1.128	-	15.9
2003	1.033	-	17.2
2004	0.818	-	14
2005	0.776	-	24.2
2006	0.539	-	-
2007	0.524	-	22.4

Year	Landings	Engel	Campelen
2008	0.533	-	31.2
2009	0.562	-	20.4
2010	0.63	-	22
2011	0.301	-	25
2012	0.152	-	22.7
2013	0.108	-	15.2
2014	0.081	-	24.9
2015	0.102	-	21.2
2016	0.18	-	14.5
2017	0.235	-	18.5
2018	0.147	-	23.7
2019	0.097	-	18.7

Table 3. Comparison of parameter estimates from the surplus production model from 2014 and 2019 for Subdivision 3Ps American Plaice. The 2019 model has been updated with different priors on r and K and with data to 2019. Median and 95% credible intervals are shown.

-	2014			2019		
Parameter	**2.5%**	**50%**	**97.5%**	**2.5%**	**50%**	**97.5%**
B_{MSY}	32.15	56.71	188.4	35.74	70.29	197.0
F_{MSY}	0.005	0.055	0.101	0.009	0.041	0.081
MSY	0.426	3.139	6.713	0.807	2.879	6.899
K	64.3	113.4	376.9	71.48	140.6	394.0
r	0.001	0.109	0.202	0.019	0.082	0.162
sigma	0.027	0.152	0.314	0.085	0.160	0.283
tau.cam	0.202	0.246	0.392	0.201	0.231	0.337
tau.eng	0.256	0.391	0.640	0.258	0.389	0.640

Table 4. Results of projections of stock size for Subdivision 3Ps American Plaice from 2019 to 2022 at different fishing mortality levels. All scenarios assume that catch in 2019 is 97 t.

-	B_{ratio}	$p<B_{lim}$	$p>F_{MSY}$	$p>B_{2019}$	Catch (t)
F=0	-	-	-	-	-
2020	0.151	0.965	-	0.564	-
2021	0.163	0.943	-	0.623	-
2022	0.175	0.915	-	0.677	-
2023	0.189	0.887	-	0.719	-
$F_{current}$=0.0096	-	-	-	-	-
2020	0.151	0.965	0.040	0.564	104
2021	0.161	0.944	0.046	0.614	110
2022	0.172	0.919	0.054	0.660	117
2023	0.184	0.892	-	0.697	-
F+15%=0.011	-	-	-	-	-
2020	0.151	0.965	0.052	0.564	119
2021	0.161	0.944	0.059	0.613	126
2022	0.172	0.920	0.069	0.657	134
2023	0.183	0.893	-	0.694	-
F-15%=0.0082	-	-	-	-	-
2020	0.151	0.965	0.029	0.564	88
2021	0.161	0.944	0.035	0.615	94
2022	0.172	0.919	0.039	0.663	100
2023	0.185	0.891	-	0.700	-

FIGURES

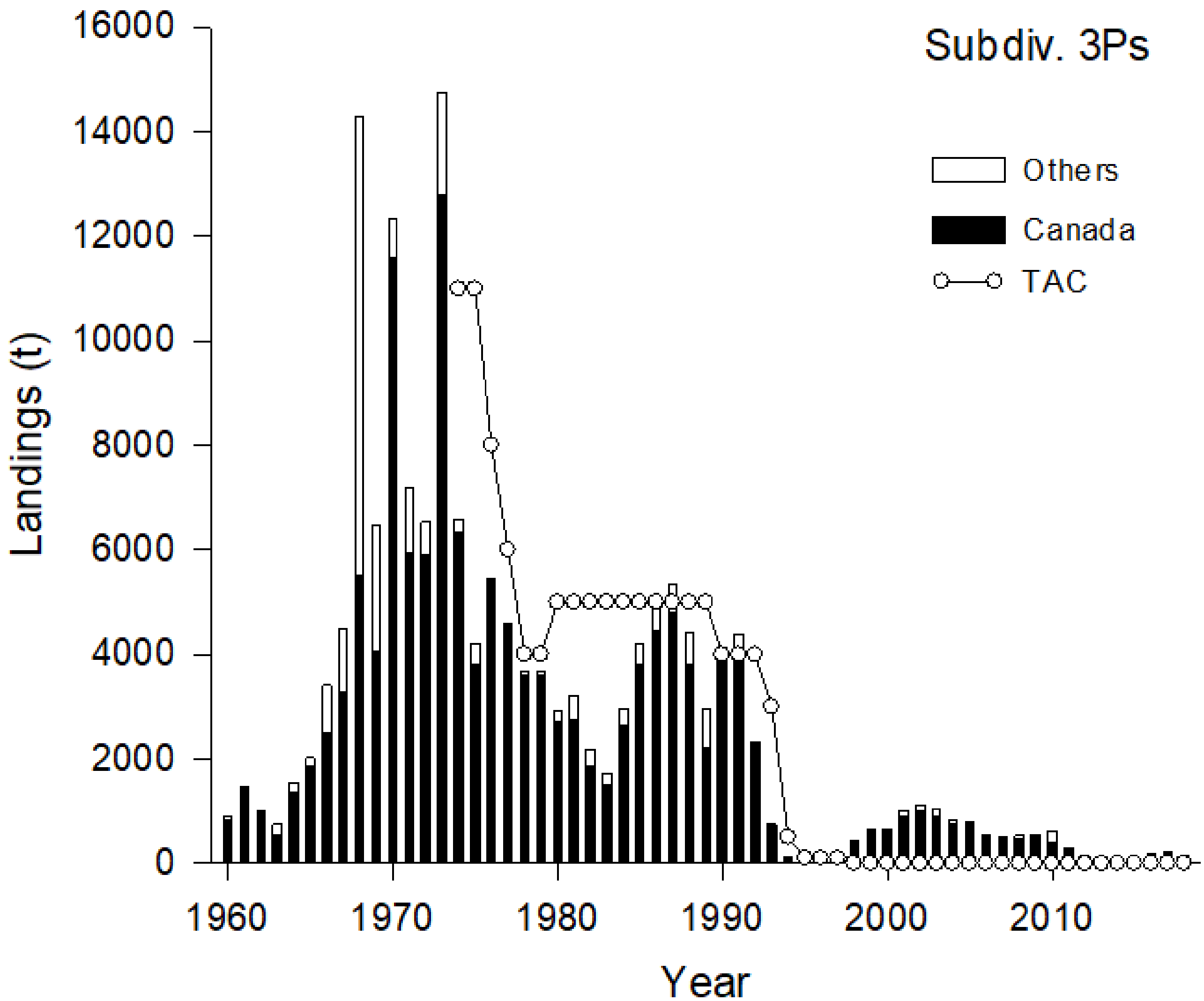

Figure 1. Landings and TAC (metric tons) of American Plaice in Subdivision 3Ps by Canada and others from 1960 to 2019.

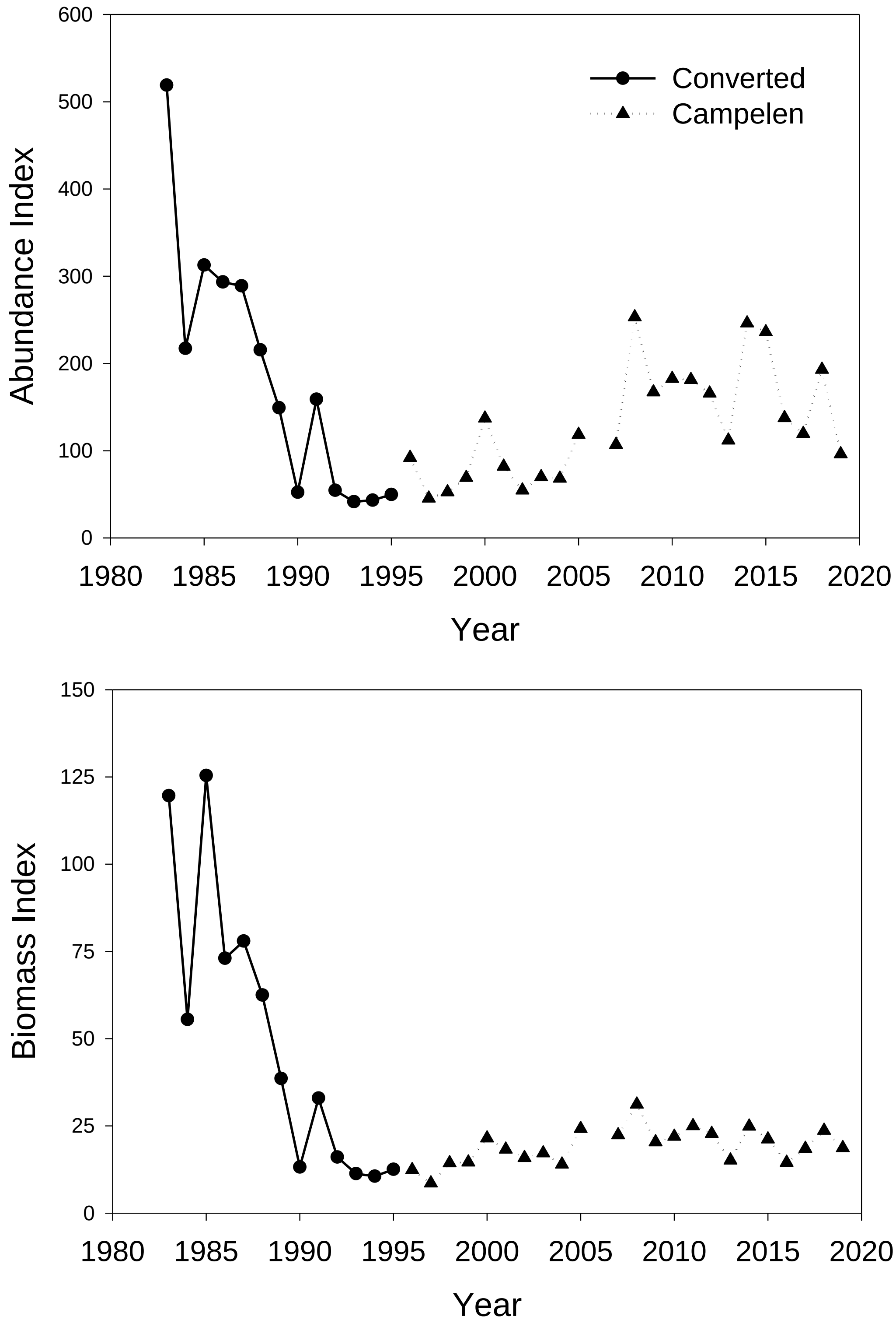

Figure 2. Abundance (top) and biomass (bottom) indices of American Plaice from Canadian research vessel surveys in Subdivision 3Ps. Note that the survey was incomplete in 2006 and results from that year are not shown.

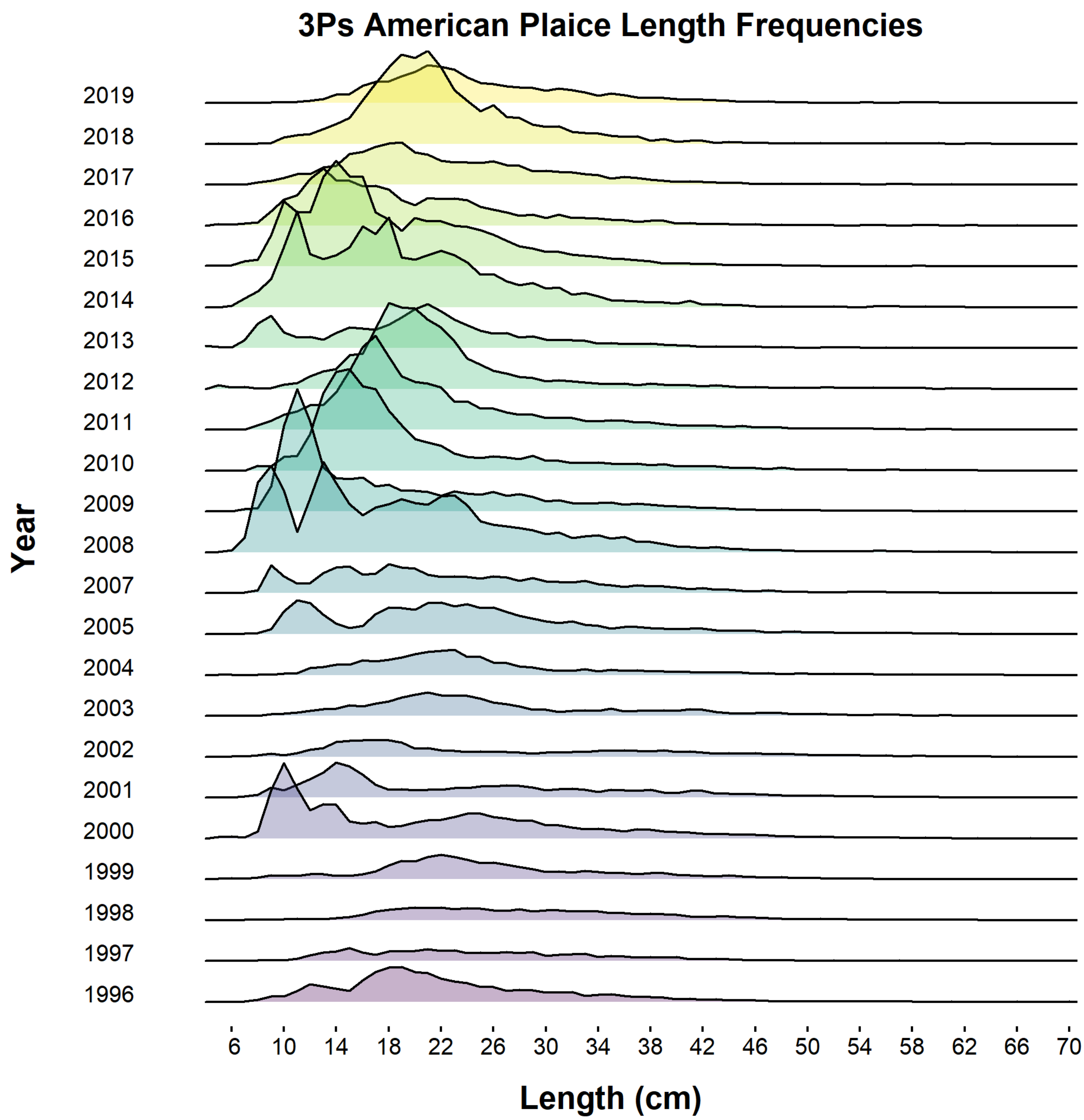

Figure 3. Length frequency distributions from Canadian research vessel surveys in Subdivision 3Ps from 1996-2019. Note that the survey was incomplete in 2006 and results from that year are not shown.

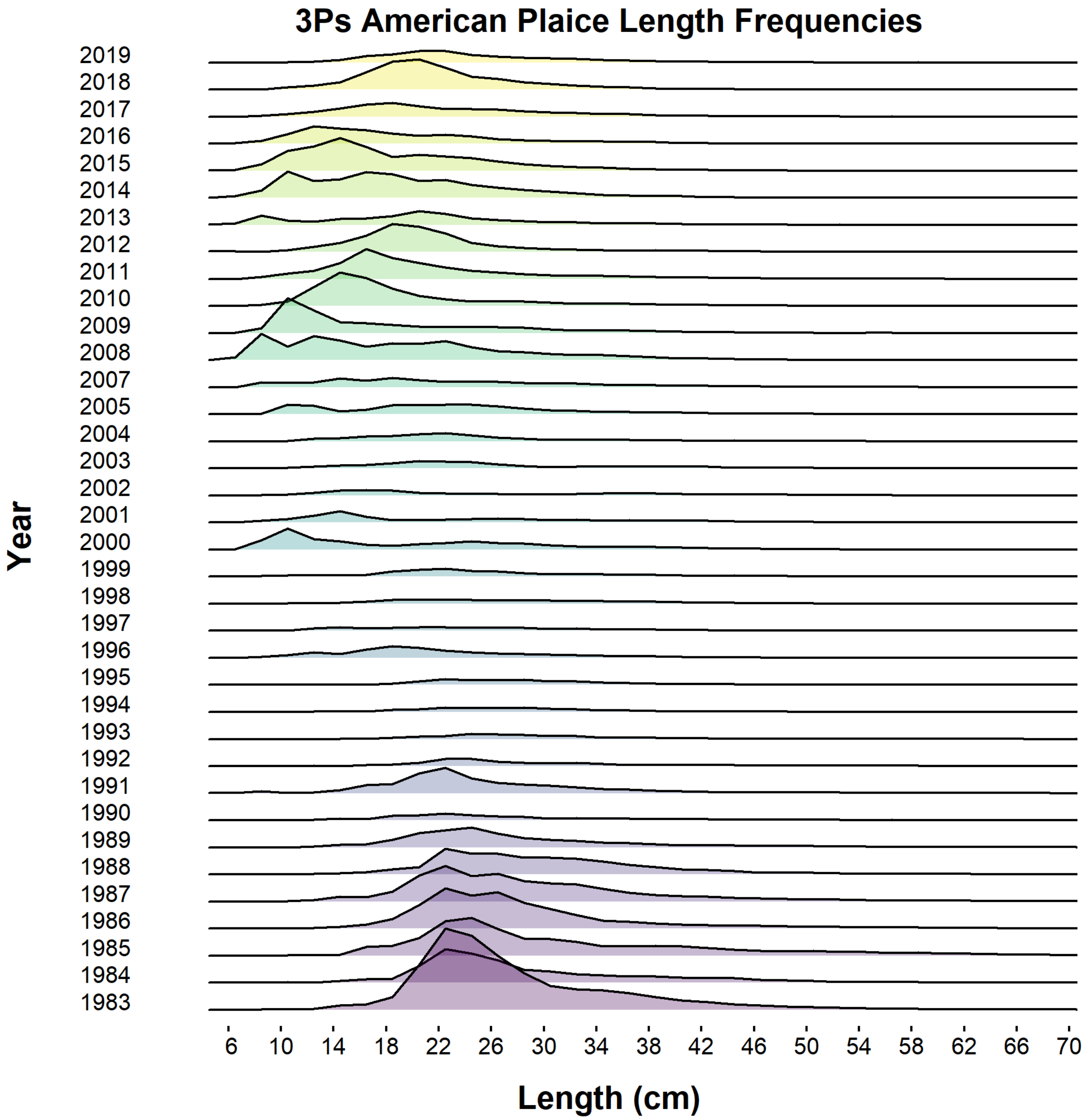

Figure 4. Length frequency distributions from Canadian research vessel surveys in Subdivision 3Ps from 1983-2019. Note that the survey was incomplete in 2006 and results from that year are not shown. Data from 1983-1995 are converted to Campelen equivalents while data from 1996-2019 are from the Campelen trawl.

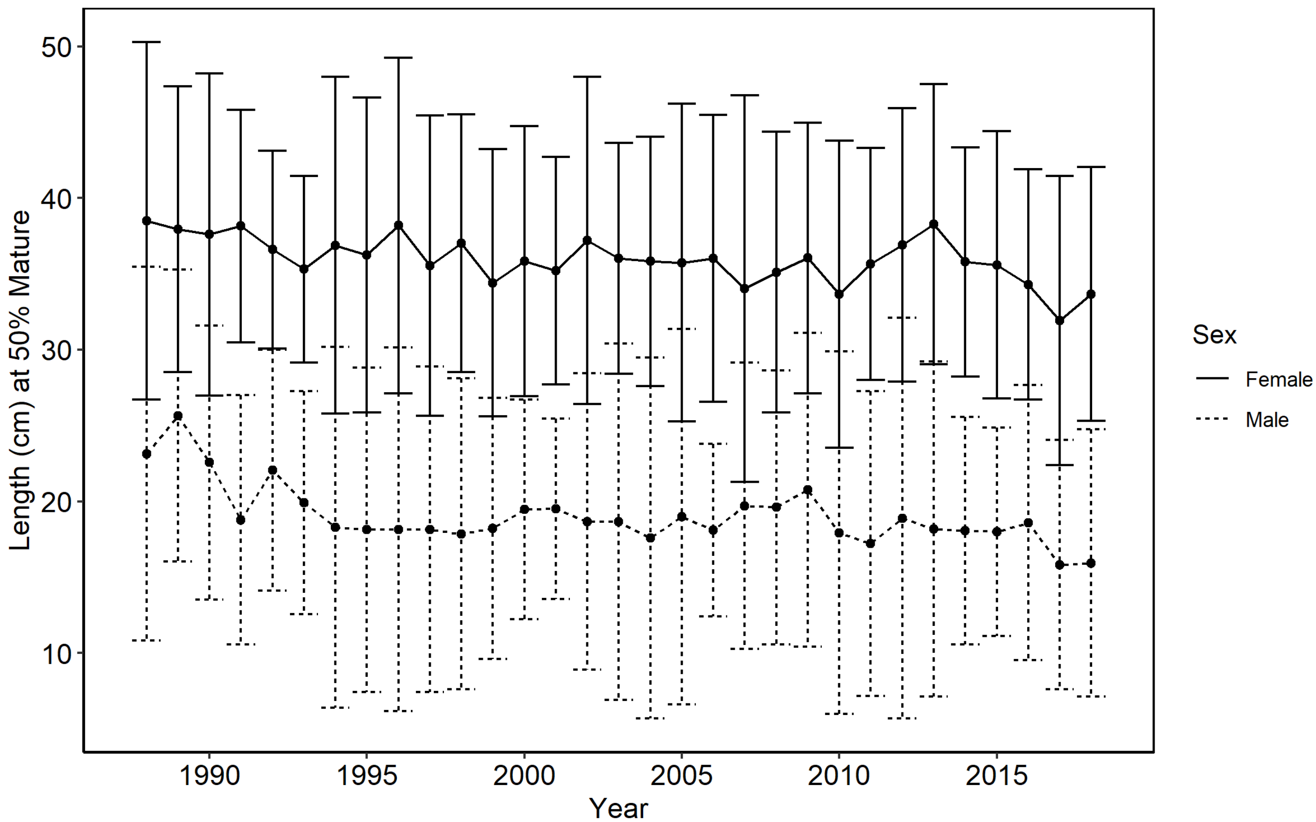

Figure 5. Length at 50% maturity (± 95% Confidence Intervals) for male and female American Plaice in Subdivision 3Ps.

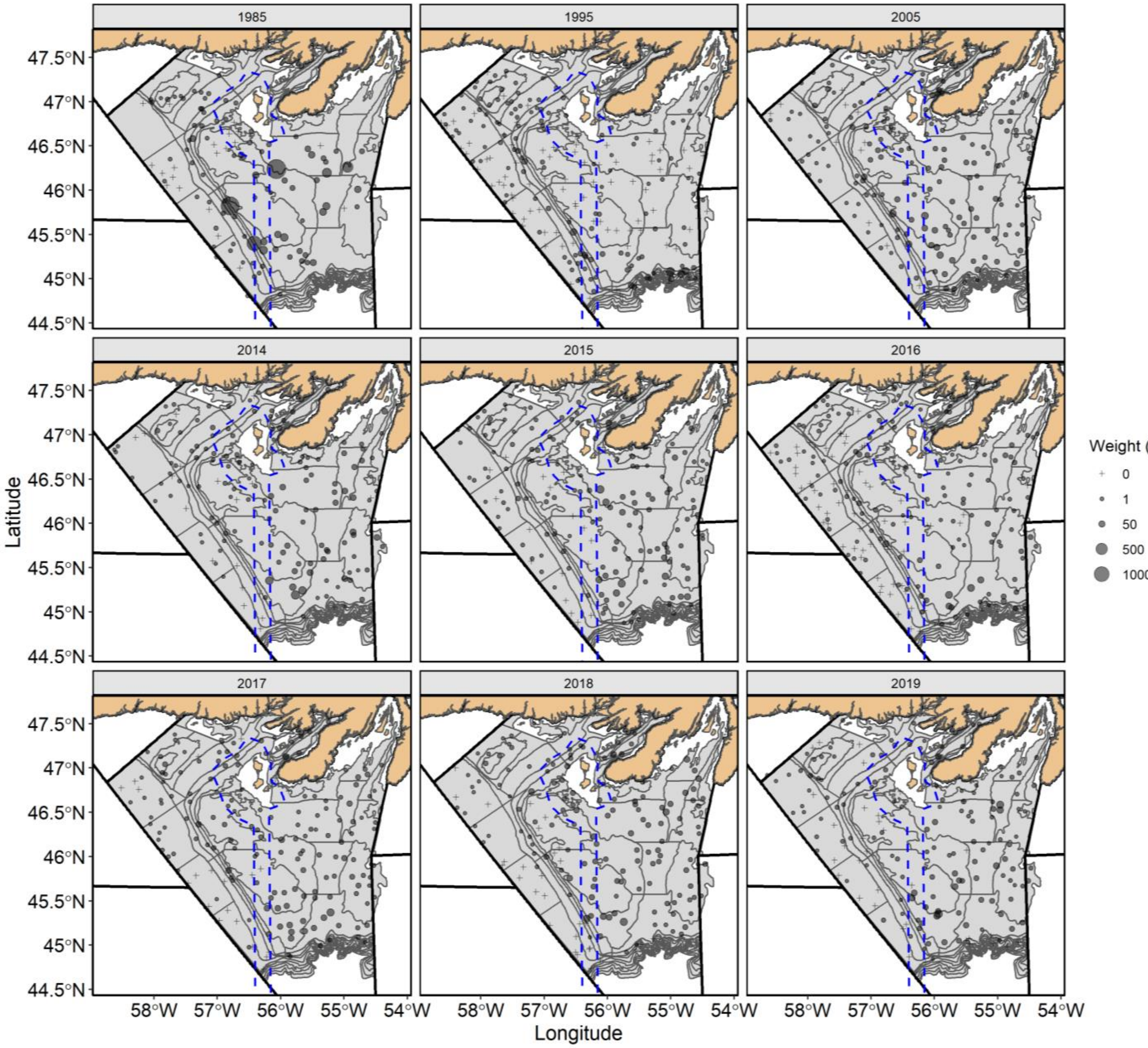

Figure 6. Weight (kg) of American Plaice caught in survey sets in Subdivision 3Ps from selected years. Symbol size is related to the weight caught as in the legend at the side of the figure. Crosses indicate sets where no American Plaice were caught.

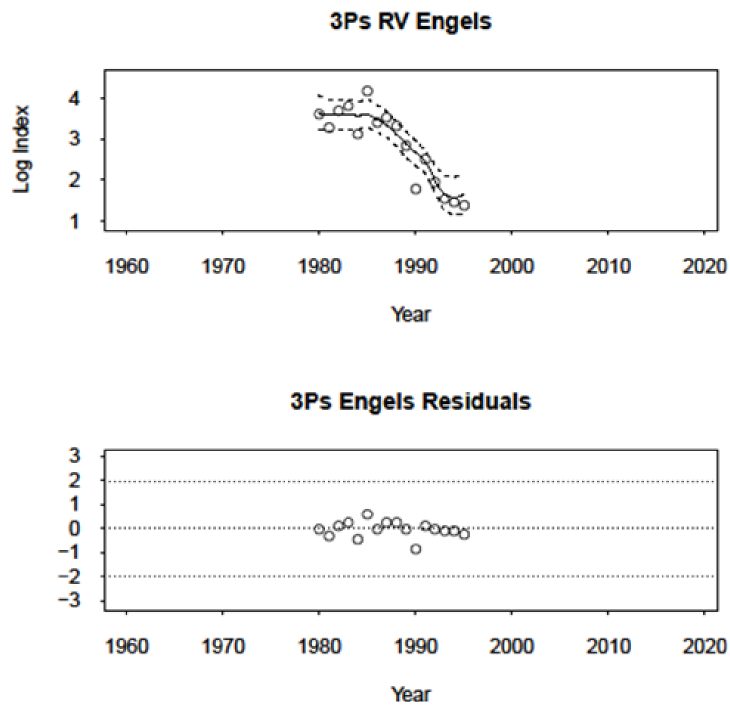

Figure 7. Predicted (from production model) and observed survey index for the Engel time series for Subdivision 3Ps American Plaice (top panel). Standardized residuals are given in the bottom panel.

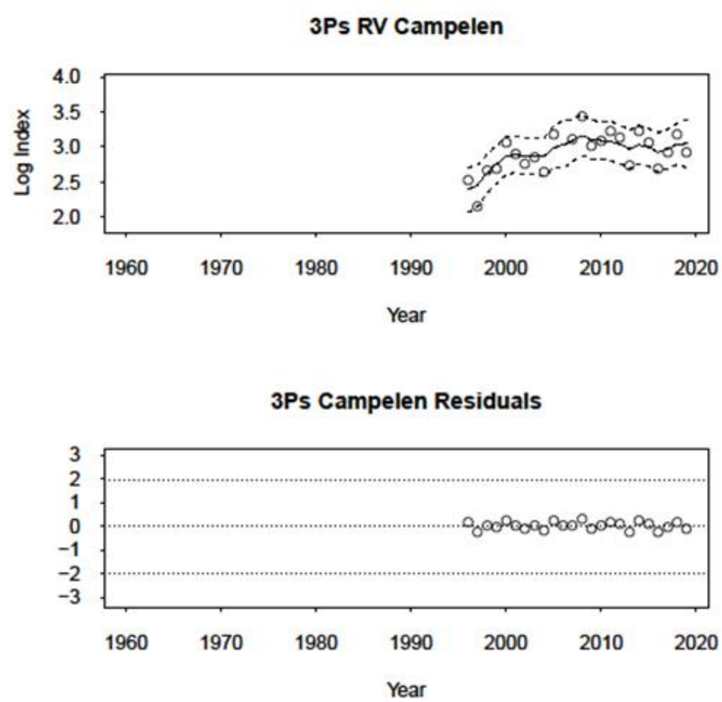

Figure 8. Predicted (from production model) and observed survey index for the Campelen time series for Subdivision 3Ps American Plaice (top panel). Standardized residuals are given in the bottom panel.

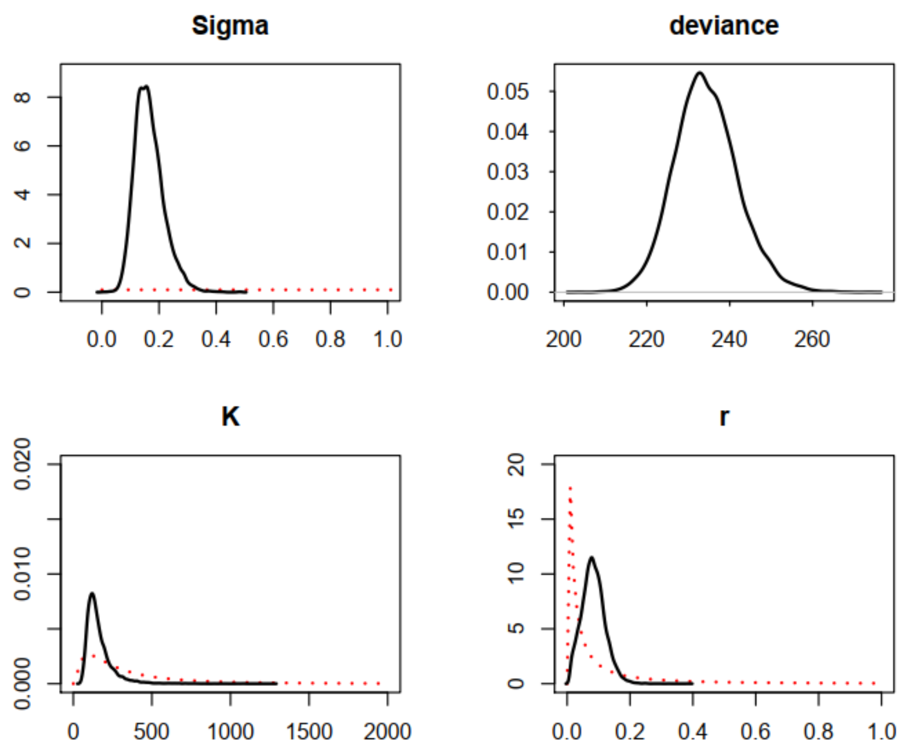

Figure 9. Prior (dotted line) and posterior (solid line) distributions for process error (sigma), carrying capacity (K) and intrinsic rate of growth (r), as well as the posterior distribution of the total model deviance from the production model for American Plaice in Subdivision 3Ps.

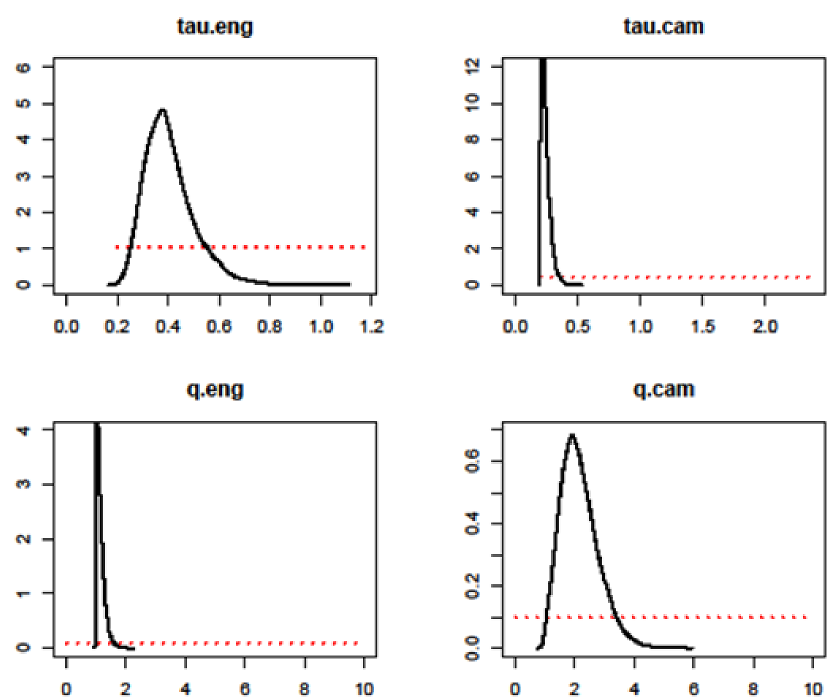

Figure 10. Prior (dotted line) and posterior (solid line) distributions for observation error on the Engel and Campelen surveys (tau), and on the catchability of the two surveys (q) from the production model for American Plaice in Subdivision 3Ps.

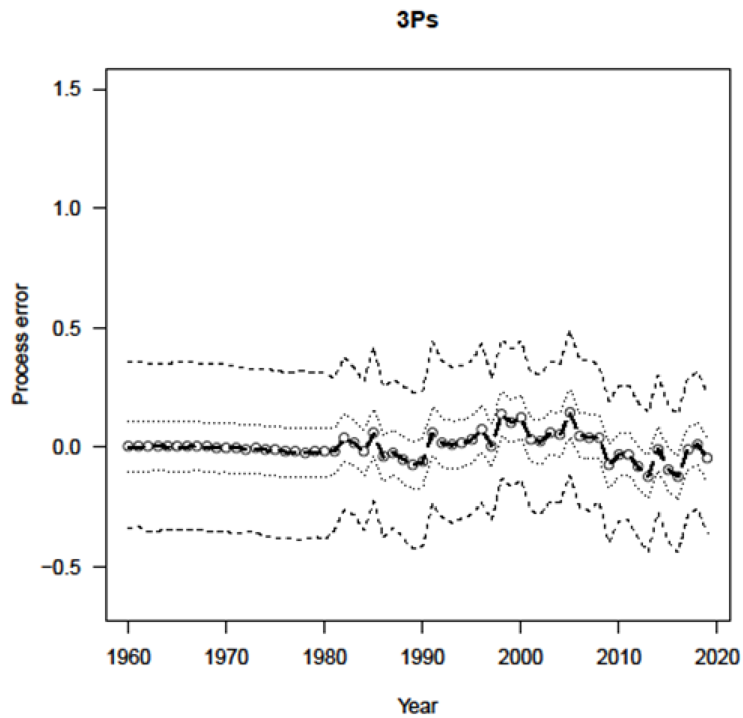

Figure 11. Median (solid line with open circles), 50% (small dash) and 95% (long dash) credible intervals for the process error from the production model for American Plaice in Subdivision 3Ps.

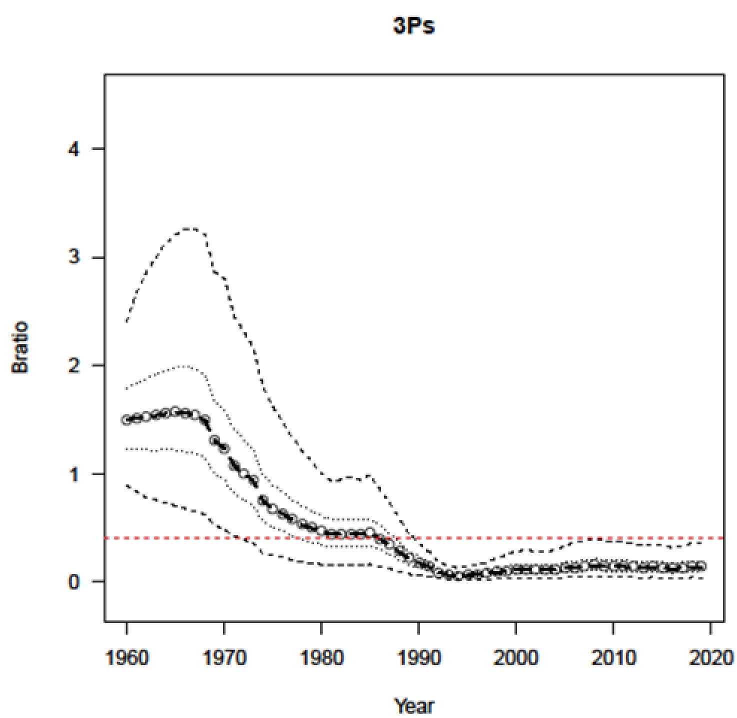

Figure 12. Ratio of Biomass to B_{MSY} (B_{ratio}) for American Plaice in Subdivision 3Ps from a surplus production model from 1960 to 2019. The solid line with circles is the median B_{ratio}, the dotted lines are the 50% credible intervals and the dashed black lines are the 95% credible intervals. The horizontal red dashed line is 40% B_{msy} which is B_{lim}.

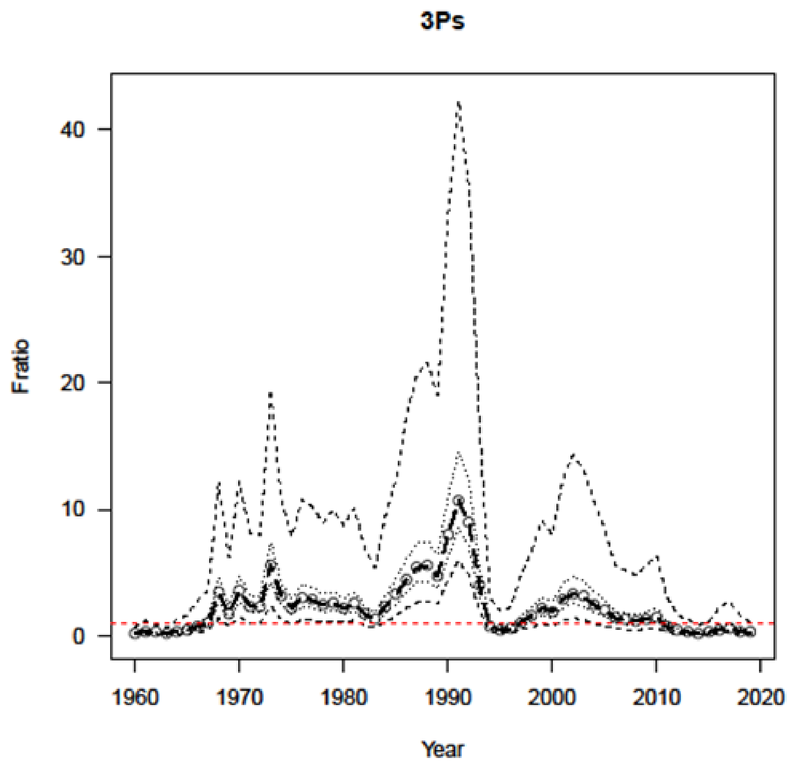

Figure 13. Ratio of fishing mortality to F_{MSY} (F_{ratio}) for American Plaice in Subdivision 3Ps from a surplus production model from 1960 to 2019. The solid line with circles is the median F_{ratio}, the dotted lines are the 50% credible intervals and the dashed black lines are the 95% credible intervals. The horizontal red dashed line is an F_{ratio} of 1 (i.e., where $F=F_{msy}$) which denotes F_{lim}.