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An assessment of the American plaice (*Hippoglossoides platessoides*) stock in NAFO Subdivision 3Ps

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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 increased substantially after 1995, and was over 1,000 t in each year from 2001 to 2003. However, catch has been declining since then and was 300 t, 151 t and 103 t in 2011, 2012 and 2013, respectively. Biomass and abundance indices from 1983-2013 from research vessel surveys showed a large decline from the mid 1980s to 1990. There was a general increase over 1992-2011 for both biomass and abundance indices but both declined from 2011 to 2013. The average abundance over the last 3 years is only 44 % and biomass only 21 % of the average from 1983-1985. 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. Biomass in 2013 is estimated to be only 40 % of B_{lim} and therefore the stock is in the Critical Zone. Taking uncertainty into account, the probability of being below B_{lim} is high (0.97). 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 declined since 2010 and current median fishing mortality is estimated to be 20 % of $F_{lim.}$ The probability of being above F_{lim} is low (0.05). If catch of American plaice were to be reduced to zero, the stock would show some increase over the next 3 years. By the end of 2016 the median of the ratio of biomass to B_{msy} is projected to be 0.22 (55 % of B_{lim}) but the probability of being below B_{lim} remains high (0.85). Projections determined that annual catches of 1000 t or more will likely result in stock decline. Any catch will result in even slower stock growth and an increased probability of being below B_{lim}.

Évaluation du stock de plie canadienne (*Hippoglossoides platessoides*) dans la sous-division 3Ps de l'OPANO

RÉSUMÉ

Un moratoire sur la pêche dirigée de la plie canadienne est en vigueur depuis septembre 1993. Depuis, il y a seulement eu des prises accessoires de plie canadienne dans d'autres pêches. Les prises ont augmenté considérablement après 1995, et elles ont été supérieures à 1 000 tonnes chaque année de 2001 à 2003. Toutefois, les prises sont en déclin depuis; elles étaient de 300 tonnes, 151 tonnes et 103 tonnes en 2011, 2012 et 2013, respectivement. Les indices de la biomasse et de l'abondance de 1983 à 2013 dans les relevés par navire de recherche montrent un important déclin du milieu des années 1980 jusqu'à 1990. Il y a eu une augmentation générale des indices de la biomasse et de l'abondance de 1992 à 2011, mais ils ont tous les deux diminué de 2011 à 2013. L'abondance moyenne au cours des trois dernières années n'est que de 44 %, et la biomasse représente seulement 21 % de la moyenne de 1983 à 1985. La taille du stock estimée à partir du modèle de production excédentaire a connu un déclin assez constant à partir de la fin des années 1960; elle a atteint son point le plus bas en 1994 avec moins de 10 % de la B_{RMS}. La biomasse a augmenté lentement de 1994 à 2008, mais elle n'a pas augmenté depuis. La biomasse de 2013 est estimée à seulement 40 % de la valeur de B_{lim}; par conséquent, le stock se situe dans la zone critique. En tenant compte de l'incertitude, la probabilité que la valeur du stock soit inférieure à la valeur de B_{lim} est élevée (0,97). La mortalité par pêche a atteint un sommet en 1991, après quoi elle a diminué pendant plusieurs années. La mortalité par pêche a augmenté de nouveau pour dépasser la valeur de F_{RMS} à la fin des années 1990, lorsque les débarquements ont commencé à augmenter. Elle a diminué depuis 2010, et la médiane actuelle de la mortalité par pêche est estimée à 20 % de la valeur de F_{lim}. La probabilité qu'elle soit supérieure à la valeur de F_{lim} est faible (0,05). Si les prises de plie canadienne étaient réduites à zéro, le stock connaîtrait une certaine augmentation au cours des trois prochaines années. D'ici la fin de 2016, la médiane du rapport entre la biomasse et la B_{RMS} devrait être de 0,22 (55 % de la B_{lim}), mais la probabilité qu'elle soit inférieure à la valeur de B_{lim} demeure élevée (0,85). Selon les projections, des prises annuelles de 1 000 tonnes ou plus entraîneraient probablement un déclin du stock. Tout niveau de prises entraînera une croissance du stock encore plus lente et augmentera la probabilité qu'il se situe en dessous de la valeur de B_{lim}.

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^{o}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 (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 2014.

FISHERY

Catches from this stock were highest from 1968 to 1973, exceeding 12,000 t on three occasions in this period (Table 1, 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 direct 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 has been declining since then and was 300 t, 151 t and 103 t in 2011, 2012 and 2013, respectively.

Data from the Newfoundland and Maritimes reported catch statistics were examined to determine which fisheries were taking the greatest portion of the American plaice bycatch. In recent years (Table 2) as in the past (Morgan et al. 2005), the bycatch of American plaice was taken in two main fisheries in most years, the directed cod (*Gadus morhua*) and the directed witch flounder (*Glyptocephalus cynoglossus*) fisheries. In 2011 and 2012 much more of the American plaice bycatch was taken in cod directed than in witch flounder directed fisheries. In 2013 the total amount of bycatch taken in the two fisheries was similar.

Length frequency data from the commercial fishery were examined from 2000 to 2011 (more recent data were not available). The sampling was conducted both by port samplers and by observers on board the vessels. Data were available from both the otter trawl and gillnet fisheries, although almost all of the sampling was from otter trawlers. Frequencies collected in port and at sea were very similar. For otter trawlers the distributions were very similar in each year with a mode at about 40 cm (Figure 2). The number of samples from the gillnet fishery was very small and no real conclusion could be drawn.

ABUNDANCE AND BIOMASS

Stratified-random surveys have been conducted by DFO in Subdiv. 3Ps in each year from 1972 to 2013. 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 in 1997.

Biomass and abundance indices from 1983-2013 are shown in Figure 3. From the mid 1980s to 1990 there was a large decline in both biomass and abundance indices. Stock size was lowest in the early 1990s. There was a general increase over the 1992-2011period for both biomass and abundance indices but both declined from 2011 to 2013. The average abundance over the last 3 years is only 44 % and biomass only 21 % of the average from 1983-1985.

American plaice are distributed throughout Subdivision 3Ps (Figure 4). There has been no real change in distribution in recent years except that the species is more widespread when the population is higher.

Ageing is not available for this stock for the last few 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 2009-2013 but there are no signs of any large year class arising after 2009 (Figure 5).

PRODUCTION MODELLING

The same formulation of the Bayesian surplus production model that was accepted as the basis for the assessment of this stock in 2012 was updated with 3 more years of data (Morgan et al. 2012). The probability that current stock size is below B_{lim} (40 % B_{msy}) and fishing mortality above F_{lim} (F_{msy}) was evaluated.

Model fit to the surveys was good (Figure 6 and 7). The posterior distributions for the main parameters that are estimated by the model were updated from their priors by the data (Figure 8 and 9). The posterior for the q on the Engel survey is skewed to the left, near the lower end of the prior (Figure 9) and this could be examined in more detail in future assessments. The process error (Figure 10) was small and generally without trend. Convergence criteria (not shown) were examined and also considered to be acceptable.

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. Biomass in 2013 is estimated to be only 40 % of B_{lim} and therefore the stock is in the Critical Zone (Figure 11). Taking uncertainty into account, the probability of being below B_{lim} is high (0.97). 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 declined since 2010 and current median fishing mortality is estimated to be 20 % of F_{lim} (Figure 12). The probability of being above F_{lim} is low (0.05).

Projections of stock size were conducted to end of 2016 under conditions of zero catch, current catch (average of the last 3 years), current catch minus 15 %, current catch plus 15 % and current fishing mortality. If bycatch of American plaice were to be reduced to zero, the stock would show some increase over the next 3 years (Table 3). By the end of 2016 median Bratio (Biomass/B_{MSY}) is projected to be 0.22 (55 % of B_{lim}) but the probability of being below B_{lim} remains high (0.85). At current fishing mortality (based on the average catch over the last 3 years: only 185 t) Bratio is projected to be the same as under zero catch but the probability of being below B_{lim} is higher. Any catch will result in even slower stock growth and an increased probability of being below B_{lim} (Table 3 and Table 4).

A series of projections were conducted to determine the catch level at which the population would decline (Table 4). These projections determined that annual catches of 1000 t or more will result in stock decline.

CONCLUSION

B_{lim} for American plaice in NAFO Subdivision 3Ps is 40 % B_{MSY}. Biomass of the stock in 2013 is estimated to be 60 % below B_{lim} and therefore the stock is in the Critical Zone. The probability of being below B_{lim} is high (0.97). Current median fishing mortality is estimated to be 20 % of F_{lim} and the probability of being above F_{lim} (F_{MSY}) is low (0.05).

Although fishing mortality is low, the stock has declined since 2010.

Projections of stock size were conducted under current productivity conditions at various catch levels from 2014 to 2016. Five scenarios were considered (zero catch, current catch, current catch + 15 % and current F). Although there was growth under all scenarios, the stock remained well below B_{lim} in all cases. Additional projections determined that annual catches of 1000 t or more will result in stock decline.

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 1. Total landings (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

Year	Landings	Engel	Campelen
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
2008	0.533	-	31.2
2009	0.562	-	20.4
2010	0.63	-	22
2011	0.301	-	25
2012	0.151	-	22.7
2013	0.103	-	15.2

Table 2. Bycatch of American plaice (tons) in Canadian fisheries by directed species, 2011 to 2013

Directed species	2011	2012	2013
Cod	168	118	40
Witch	69	16	42
Skate	32	1.6	0.7
other	12	14	14

Table 3. Results of projections of stock size and fishing mortality for Subdivision 3Ps American plaice from 2014 to 2016 at different catch and fishing mortality levels.

Scenario	Median Bratio	Percent of Blim	Probability below Blim	Median Fratio	Probability above Flim
F=0 Catch=0					
2014	0.18	0.45	0.94	NA	NA
2015	0.20	0.50	0.90	NA	NA
2016	0.22	0.55	0.85	NA	NA
Current catch					
2014	0.18	0.45	0.94	0.33	0.11
2015	0.20	0.50	0.90	0.31	0.11
2016	0.21	0.52	0.87	0.28	0.11
Current catch +15%					
2014	0.17	0.42	0.94	0.39	0.13
2015	0.18	0.48	0.91	0.36	0.13
2016	0.20	0.50	0.87	0.33	0.13
Current catch -15%					
2014	0.18	0.45	0.94	0.28	0.09
2015	0.20	0.50	0.91	0.26	0.09
2016	0.21	0.52	0.87	0.23	0.09
Current F					
2014	0.18	0.45	0.94	NA	NA
2015	0.20	0.50	0.91	NA	NA
2016	0.22	0.55	0.87	NA	NA

Table 4. Results of projections of stock size and fishing mortality for Subdivision 3Ps American plaice from 2014 to 2016 at different catch levels to determine the catch at which there is no growth in the stock.

Catch	Median Bratio	Percent of Blim	Probability below Blim	Median Fratio	Probability above Flim
600 t					
2014	0.173	0.43	0.95	1.14	0.58
2015	0.180	0.45	0.92	1.09	0.55
2016	0.186	0.48	0.90	1.04	0.52
800 t					
2014	0.169	0.42	0.95	1.53	0.77
2015	0.172	0.42	0.93	1.50	0.74
2016	0.174	0.42	0.93	1.48	0.71
900 t					
2014	0.167	0.42	0.95	1.75	0.84
2015	0.168	0.42	0.93	1.73	0.81
2016	0.168	0.42	0.91	1.73	0.78
1000 t					
2014	0.165	0.41	0.95	1.96	0.88
2015	0.164	0.41	0.94	1.97	0.86
2016	0.162	0.40	0.92	1.99	0.84

FIGURES

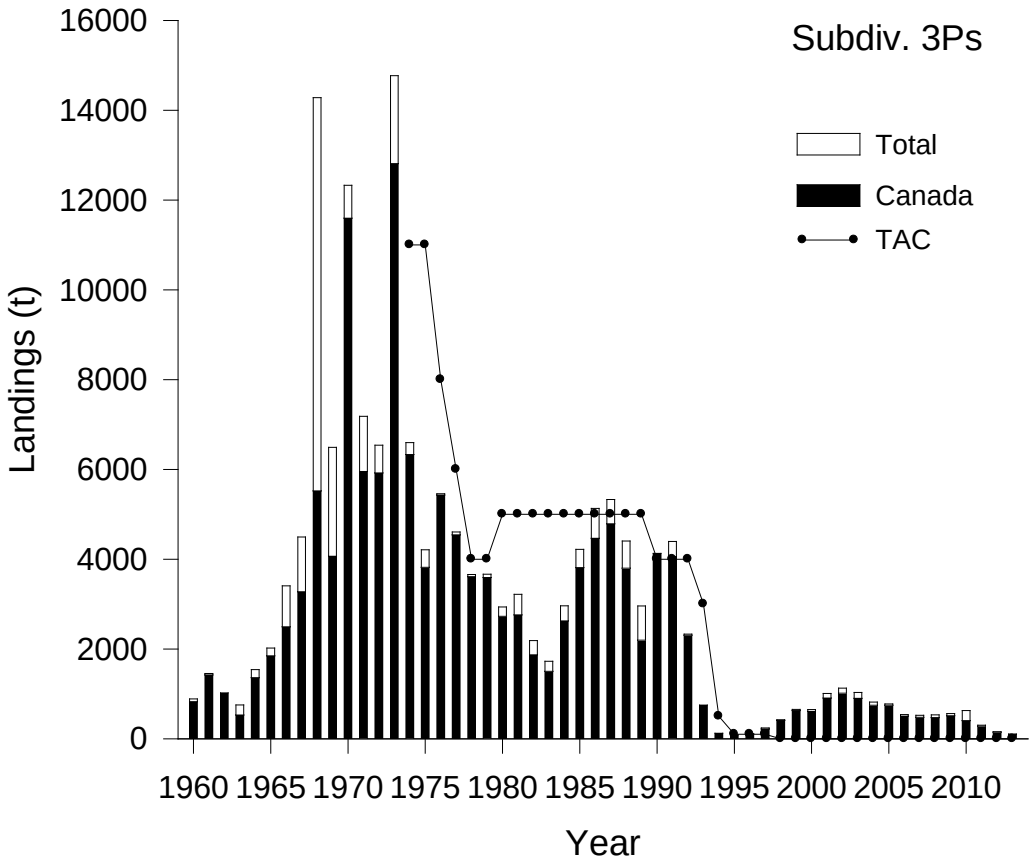

Figure 1. Landings and TAC (metric tons) of American plaice in Subdivision 3Ps by Canada and in total from 1960 to 2013.

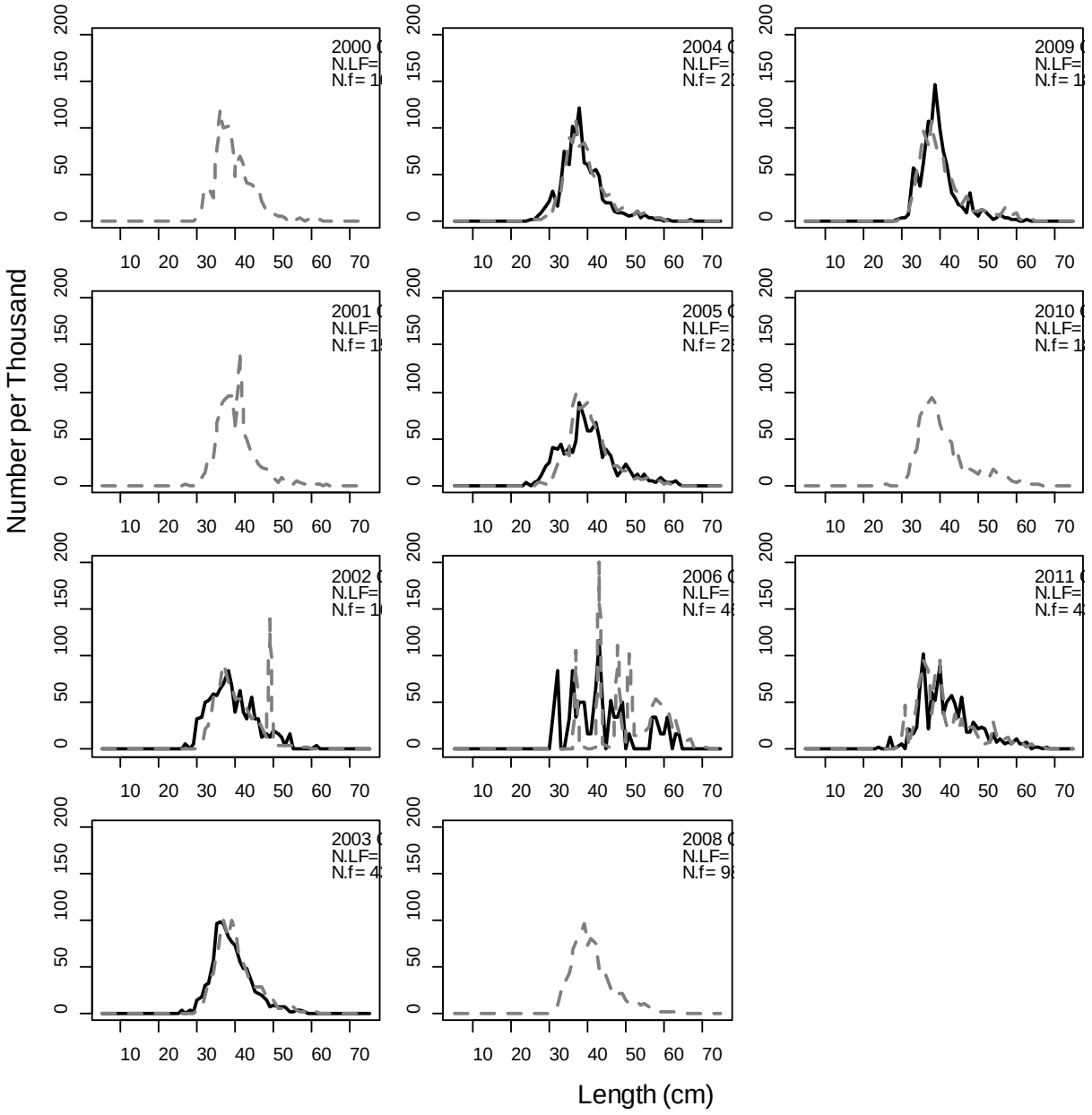

Figure 2. Number at length (in thousands) of American plaice in Subdiv. 3Ps from commercial sampling of the otter trawl fleet from 2000 to 2011. The solid line represents samples from onboard observers while the dashed line represent samples collected in port.

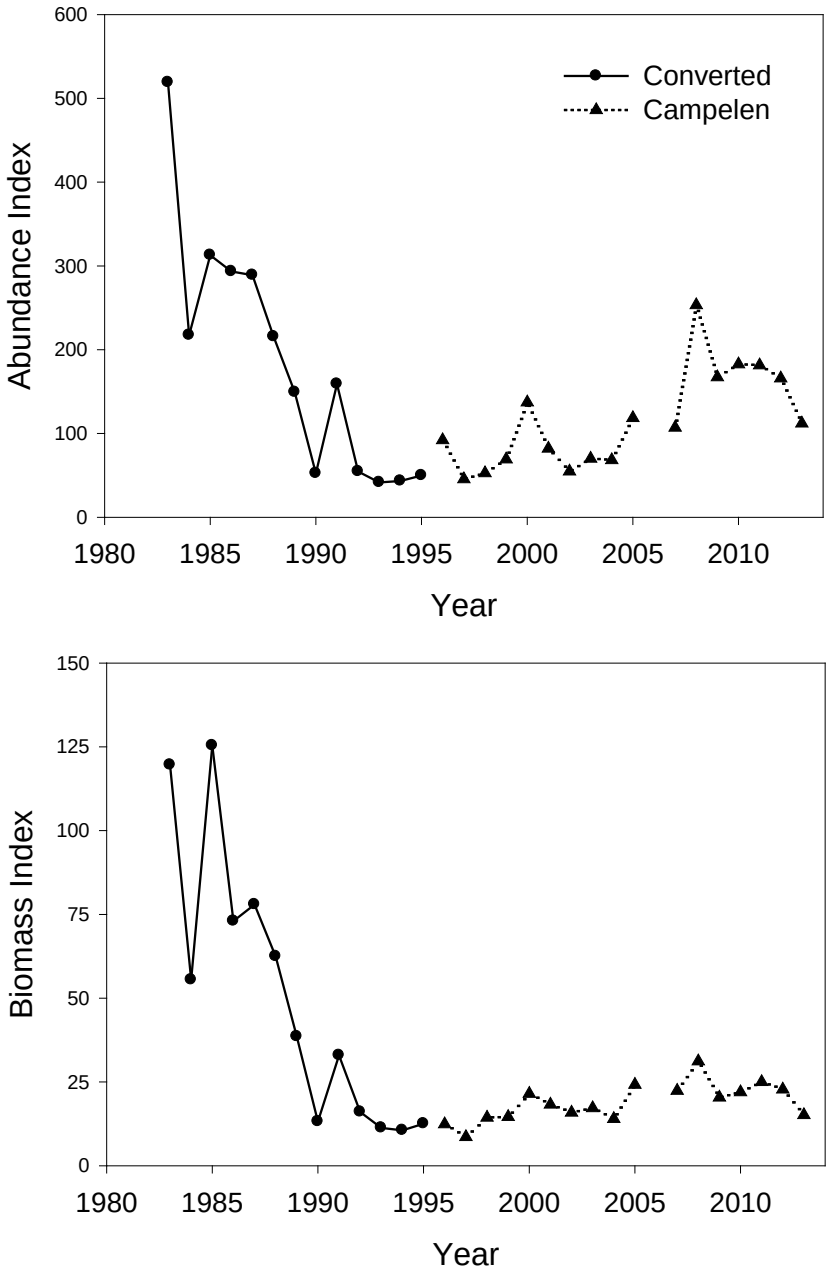

Figure 3. Abundance (top) and biomass (bottom) indices of American plaice from Canadian research vessel surveys in Subdivision 3Ps. Note that the survey was incomplete in 2006 and results from that year are not shown.

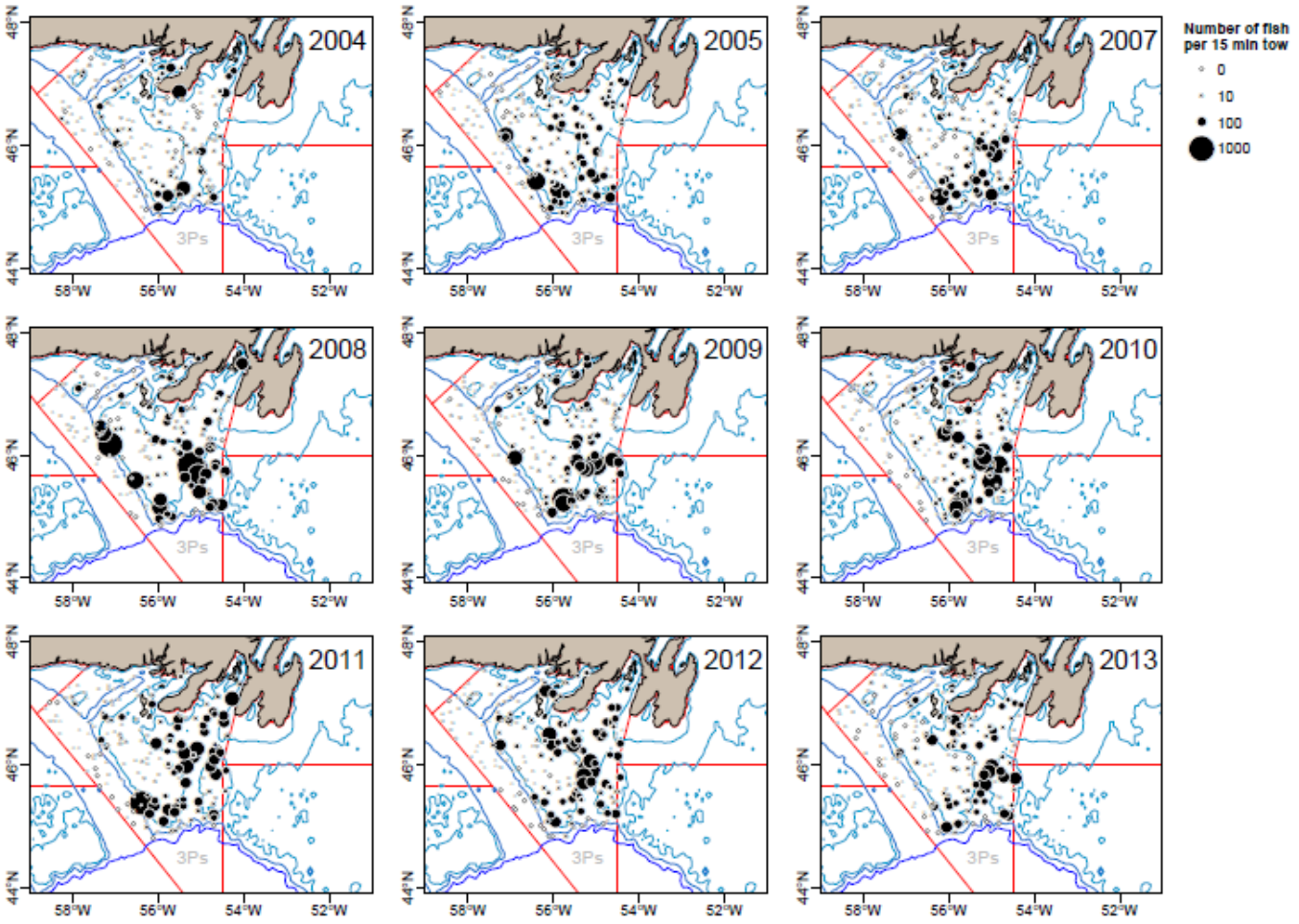

Figure 4. Number of American plaice caught in survey sets in Subdivision 3Ps from 2004 to 2013. Symbol size is related to the number caught as in the legend at the side of the figure. Note that survey coverage in 2006 was incomplete and that year is not included.

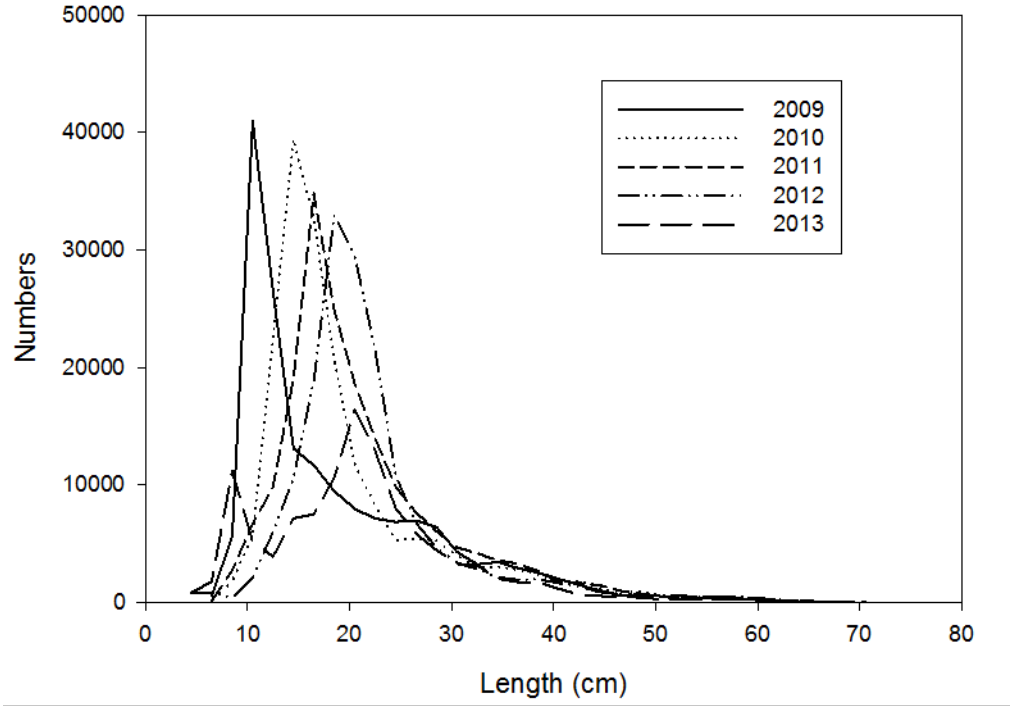

Figure 5. Numbers at length of Subdiv. 3Ps American plaice from the research vessel survey from 2009-2013.

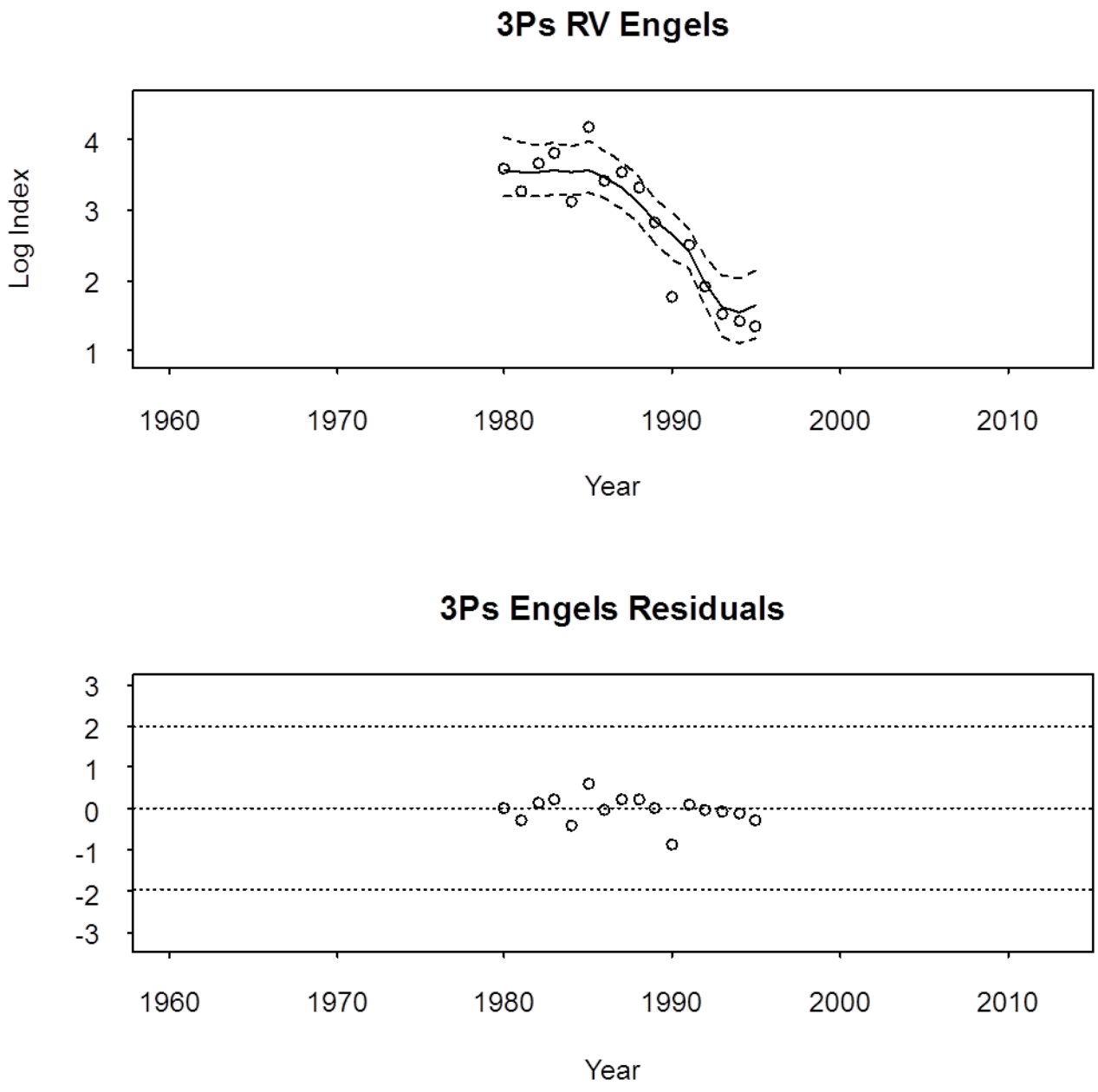

Figure 6. Predicted (from production model) and observed survey index for the Engel time series for Subdivision 3Ps American plaice (top panel). Standardized residuals are given in the bottom panel.

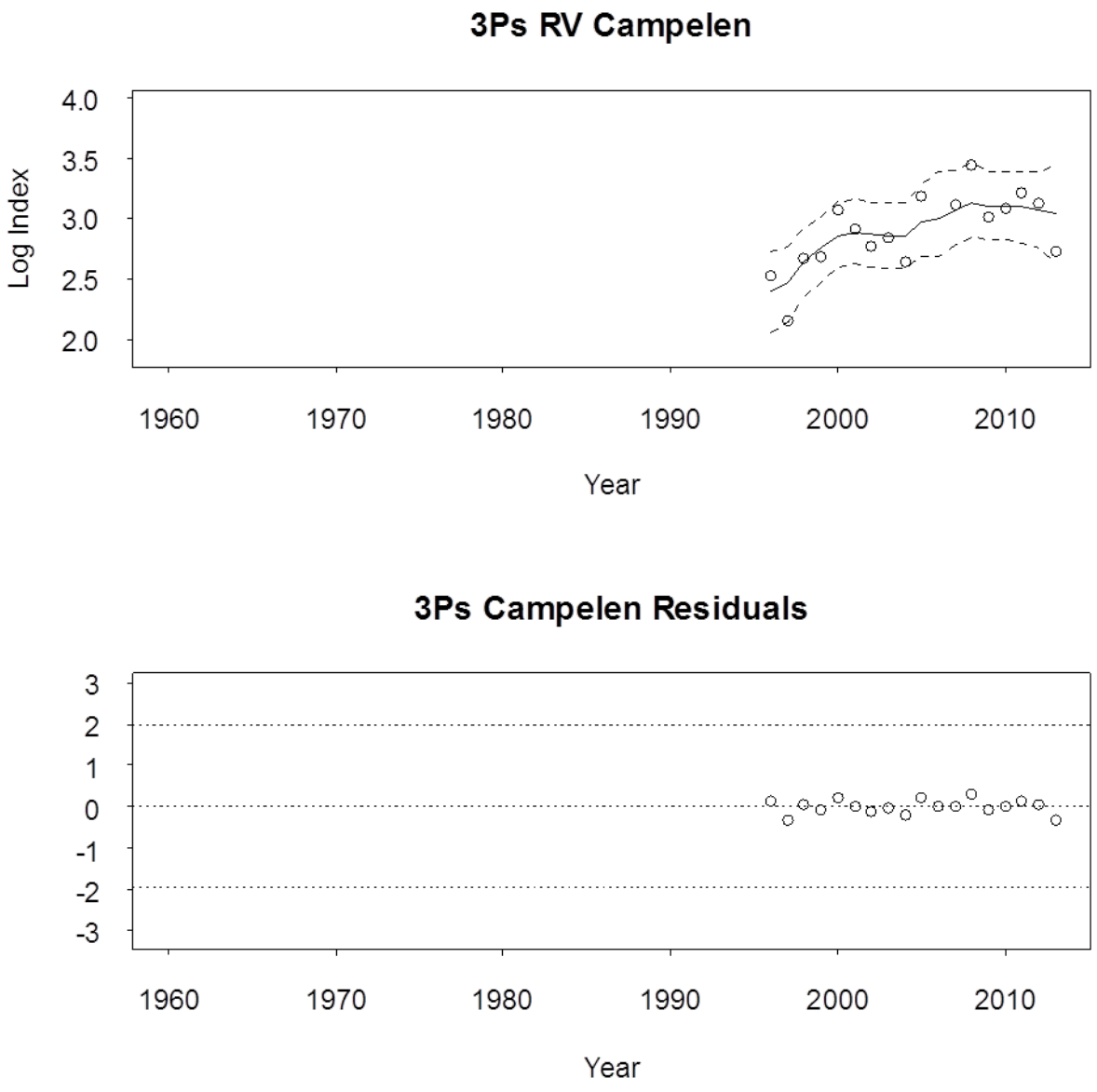

Figure 7. Predicted (from production model) and observed survey index for the Campelen time series for Subdivision 3Ps American plaice (top panel). Standardized residuals are given in the bottom panel.

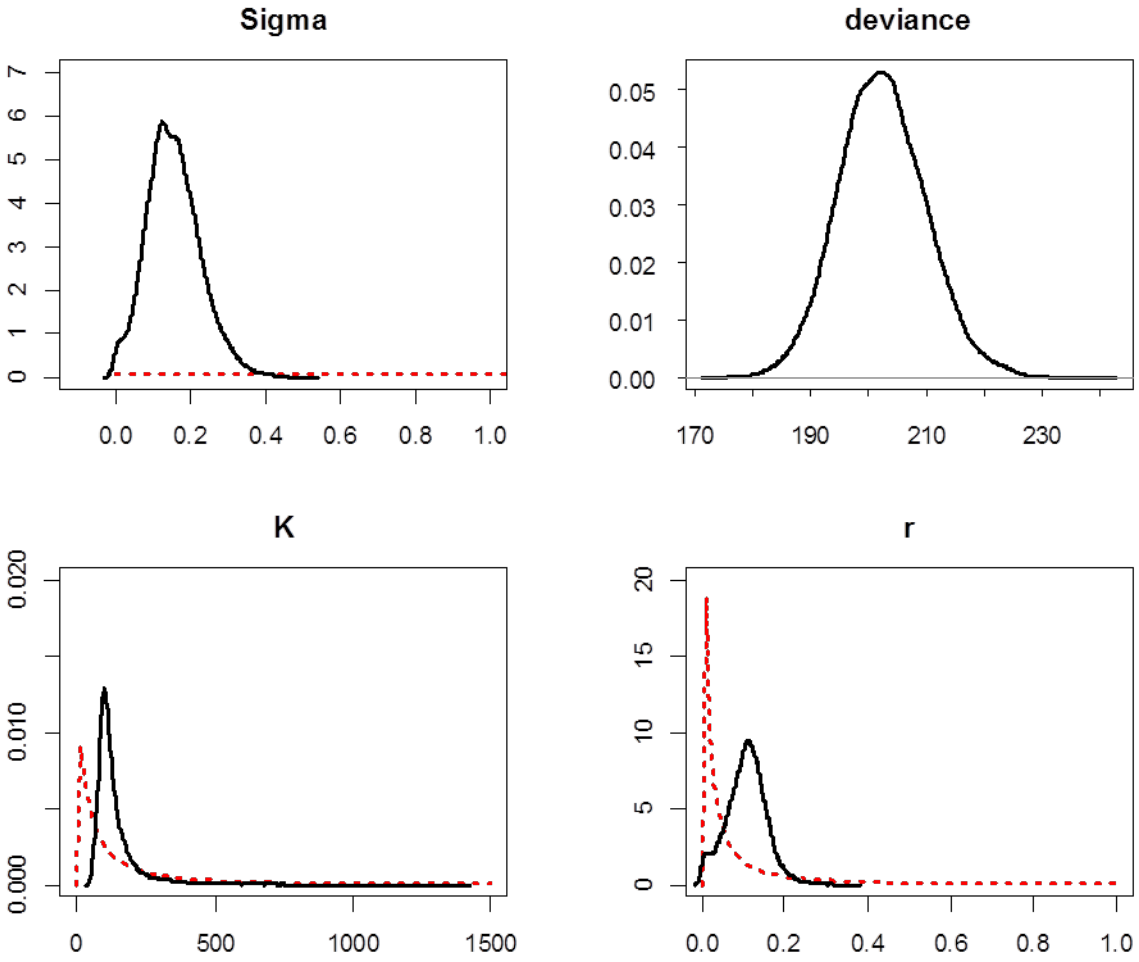

Figure 8. Prior (dotted line) and posterior (solid line) distributions for process error (sigma), carrying capacity (K) and intrinsic rate of growth (r), as well as the posterior distribution of the total model deviance from the production model for American plaice in Subdivision 3Ps.

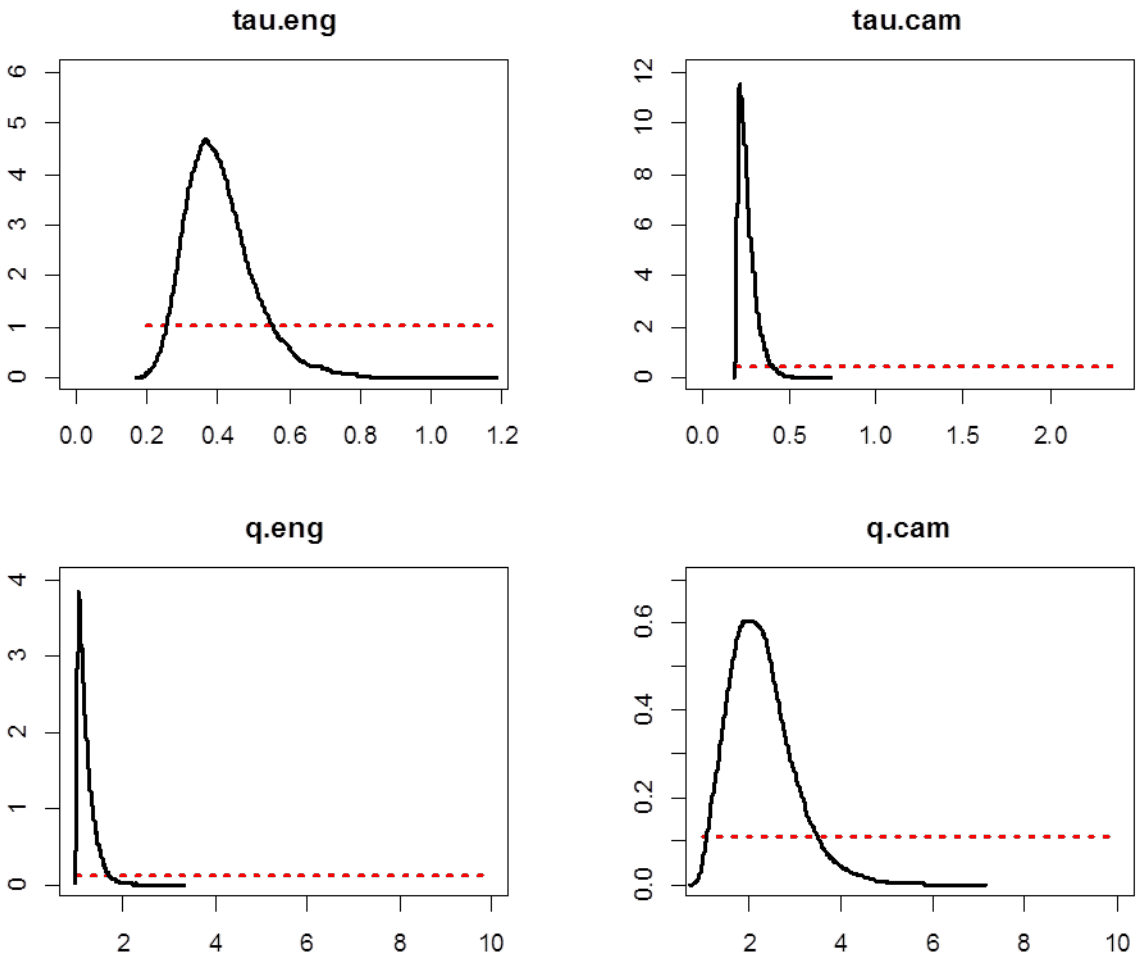

Figure 9. Prior (dotted line) and posterior (solid line) distributions for observation error on the Engel and Campelen surveys (tau), and on the catchability of the two surveys (q) from the production model for American plaice in Subdivision 3Ps.

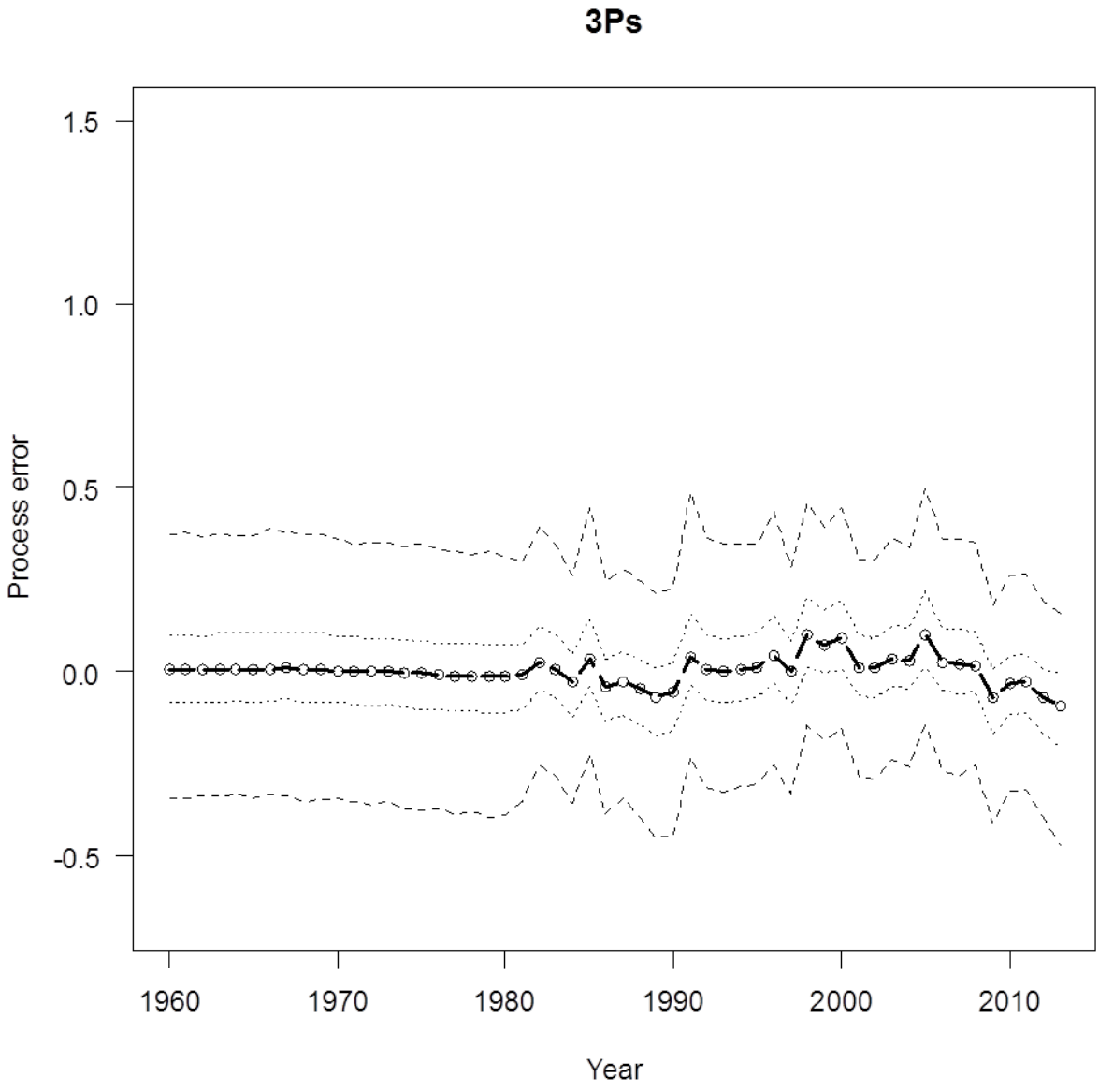

Figure 10. Median (solid line with open circles), 50 % (small dash) and 95 % (long dash) credible intervals for the process error from the production model for American plaice in Subdivision 3Ps.

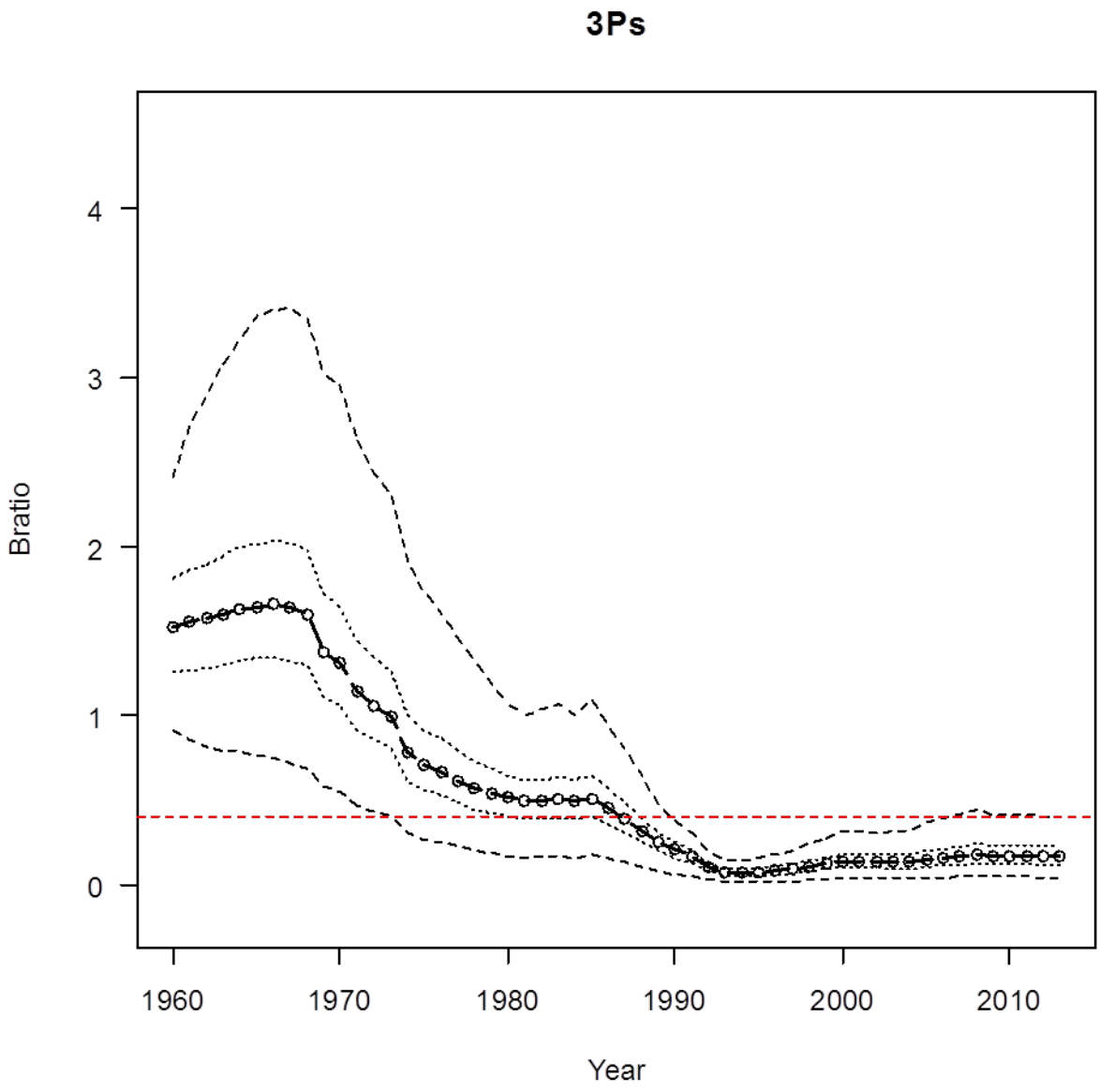

Figure 11. Ratio of Biomass to B_{MSY} (Bratio) for American plaice in Subdivision 3Ps from a surplus production model from 1960 to 2013. The solid line with circles is the median Bratio, the dotted lines are the 50 % credible intervals and the dashed black lines are the 95 % credible intervals. The horizontal red dashed line is 40 % B_{msy} which is B_{lim}.

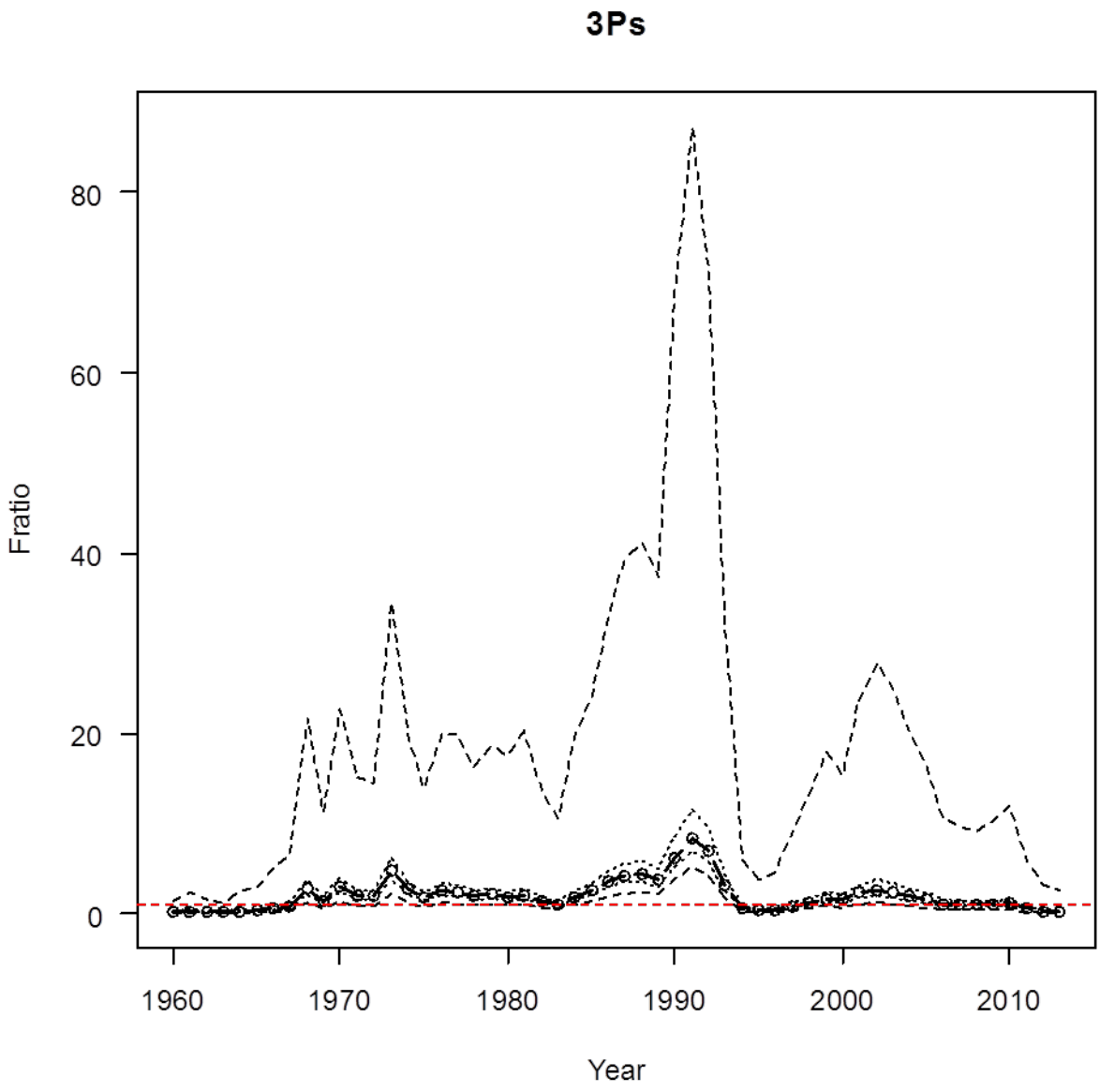

Figure 12. Ratio of fishing mortality to F_{MSY} (Fratio) for American plaice in Subdivision 3Ps from a surplus production model from 1960 to 2013. The solid line with circles is the median Fratio, the dotted lines are the 50 % credible intervals and the dashed black lines are the 95 % credible intervals. The horizontal red dashed line is an Fratio of 1 (i.e. where $F=F_{msy}$) which denotes F_{lim}.