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An assessment of the Witch flounder resource in NAFO Divisions 3NO

by

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Abstract

In 2021 Canadian catch was estimated at 386 t and non-Canadian catch estimated at 239 t for a total catch of 625 t of an available 1 175 t quota. Spring survey indices in NAFO Divs. 3NO increased from 2010 to 2013 before a sharp decline in both biomass and abundance from 2013 to 2015. Since then, levels have increased slightly or remained stable. The fall survey indices for NAFO Divs. 3NO declined sharply from 2009 to 2016 to values approaching the lowest of the time series . The fall biomass index increased from 2016-2019, but declined in 2020. Driven by abundance indices in NAFO Div. 3O, the fall survey abundance index for NAFO Div. 3NO combined increased sharply in 2019 before declining in 2020. COVID-19 and problems with the research vessels prevented surveys of NAFO Divs. 3NO in spring 2020 and 2021, as well as the fall survey in 2021.

A surplus production model in a Bayesian framework is used to provide TAC advice for this stock. Relative estimates from the model indicate that stock size decreased from the late 1960s to the late 1990s and then increased from 1999 to 2013. There was a large decline from 2013 to 2015, with a subsequent small increase since. The model suggests that a maximum sustainable yield (MSY) of 3 824 t (3 050 t – 4 650 t) can be produced by total stock biomass (B_{msy}) of 60 510 t (46 500 t – 73 800 t) at a fishing mortality rate (F_{msy}) of 0.062 (0.05-0.09). In 2021, the stock is at 47% B_{msy} with a 0.095 risk of being below B_{lim}. Median F was estimated to be 36% of F_{msy} with a low probability (0.01) of being above F_{msy} in 2021. The population was projected to 2025 under varying levels of fishing and catch. The probability of projected biomass being below B_{lim} by 2025 was 5 to 9% in all catch scenarios examined and for the F=0 projections, P(B< B_{lim}) was 3% or 4% by 2025, for catch in 2022 assumed at TAC (1 175 t) or recent levels (700 t; 2017-2021 average), respectively.

Key words: 3NO witch, surplus production model, assessment

Fisheries and Management

As noted in previous reports (Lee et al. 2014 and Brodie et al. 2011), species-specific catch statistics for flatfish prior to 1973 were largely developed from breakdowns of unspecified flounders and therefore should be considered with caution. Catches in the 1960s peaked at 11 000-12 000 tonnes (t) in 1967-68 and remained relatively high during the next several years (Table 1; Fig. 1). Catch reached a time series high of 15 000 t in 1971 and subsequently declined over the next decade to levels between 2 000 and 4 000 t in the early 1980s (Table1; Fig. 1).

The first total allowable catch (TAC) for witch flounder was introduced by ICNAF in 1974 at a level of 10 000 t, largely based on average historical catches (Table 1; Fig. 1). This remained in effect until 1979 when it was reduced to 7 000 t in consideration of declining commercial catch rates. It was further reduced to 5 000 t in 1981 and remained at that level until 1993. The Scientific Council (SC) advised that for 1994, catches from this stock should not exceed 3 000 t. A TAC of 3 000 t was agreed by the NAFO Fisheries Commission, however, it was also agreed that no directed fishery would be conducted for witch flounder in 1994 to permit rebuilding due to the poor state of the stock. The NAFO Fisheries Commission (FC) introduced a complete moratorium for directed fishing in 1995, which was continued through 2014. There was no directed fishing on this stock from 1994 to 2014. A 1 000 t TAC was adopted for 3NO witch flounder beginning in 2015. Despite the 1 000 t quota available, the catch reported for 2015 (359 t) was consistent with the bycatch range (300-400 t) reported since 2010. The TAC increased to 2 172 t and 2 225 t in 2016 and 2017 respectively, but decreased to 1 116 t in 2018. In the 2018, 2019 and 2020 assessments of this stock, based of the probability of the stock being below B_{lim} in the medium term (>10%), NAFO SC recommended no directed fishing on witch flounder in 2019-2022. However, FC adopted a TAC of 1 175 t in each year for 2019 to 2022.

Annual catches (Table 1; Fig. 1) rose rapidly to around 9 000 t in 1985 and 1986 as a result of an increase in fishing effort in the NAFO Regulatory Area, primarily on the "tail" of the Grand Bank in Division 3N. Catches remained relatively high in 1987 and 1988 at around 7 500 t. During 1990-93 estimated catches were in the range of 4 200-5 000 t. The estimated catch for 1994 was in the order of 1 100 t. A moratorium was introduced for this stock in 1995. The catch dropped to 300 t in 1995 likely as a result of a substantial reduction in fishing effort for Greenland halibut where witch flounder comprises a bycatch. Bycatch then increased steadily and by 1999 was about 800 t, although it declined again to an estimated 450 t in 2002. In 2003, several sources of catch data were available and a single source could not be considered as the most valid. As a result, catches were estimated to be 1 544 t in 2003 (midpoint of a range of estimates) which declined to about 200 t in 2007, increased to 421 t in 2010 then declined slightly to about 360 t in 2015. Catches increased in 2016 with the increase in TAC to just over a 1 000 t and from 2017 to 2021 catches have ranged from 625 t to 862 t. In 2018 the catch was estimated utilizing the Catch Data Advisory Group (CDAG) methodology. The CDAG method was refined and a new working group formed which developed the Catch Estimation Strategy (CESAG). The CESAG estimates are the accepted catch for this stock, and in 2021 the catch was 625 t.

Historically, the fishery was conducted primarily by Canada and the former Soviet Union (Table 1). Canadian catches fluctuated from between 1 200 and 3 000 t from 1985-91 but increased to about 4 300 t in 1992 and 1993. Canadian catches during the 1995-2014 moratorium averaged 34 t per year. Post moratorium catches by Canada have ranged from 221 t to 799 t, and in 2021 386 t of witch were taken. Catches by the Russian vessels declined from between 1 000 and 2 000 t in the period 1982-88 and averaged 39 t per year during the 1995-2014 moratorium. Catches by Russia were low since directed fishing on this stock resumed, and were primarily bycatch in the Greenland halibut and redfish fisheries. In 2019, Russian vessels resumed directed fishing for witch flounder in NAFO Divs. 3NO and their catch rose to 301 t (260 t directed catch; Fomin and Pochtar 2020), however declined again in 2020 and 2021 to 56 t and 82 t respectively. Combined catch from other countries since 1995 has ranged from 80 t (2019) to 1 400 t (2003) with an average annual catch of about 360 t.

Data from commercial fisheries

Length frequencies were available from observer data for Canadian, Spanish and Russian witch flounder fisheries in NAFO Divs. 3NO in 2019. Sampling of the Canadian witch flounder catch in 2019 to 2021 indicated the catch ranged between 29 and 60 cm. Mean length in 2019 was about 43 cm in both NAFO Divisions 3N and 3O, but Div. 3O had a wider range of fish with more fish in the 50-60 cm range. In both 2020 and 2021 mean size of fish in Div. 3N was slightly lower than that in 3O (Fig. 2). Spanish catches for this stock in 2021 were 34 t. Most of the Canadian and Spanish catches were taken in a directed fishery and as by-catch of the Redfish and Greenland halibut fisheries (83%) and to a lesser degree in the skate fishery (17%). The bulk of Spanish catches were in the range of 27-49 cm (Fig. 2). Catch of witch flounder by Russian trawlers was 19 t directed and 25 t as by-catch in the redfish fishery, and 41 t in other fisheries.

Research Vessel Surveys

Canadian RV surveys

Spring Surveys

Stratified-random research vessel surveys have been carried out by Canada on the Grand Banks in NAFO Divs. 3NO during spring since 1971, covering depth up to 366 meters until 1991, after which the survey was extended to 731 meters (Tables 2-5). In 1993 only, spring surveys were completed to a depth of 914 m. The 2006 Canadian spring survey in Divs. 3NO was considered to be incomplete due to poor coverage. Spring surveys in Divs. 3NO were completed for most strata in all years from 1991 to 2019 to a depth of 731 m. Due to Covid-19 restrictions, there was no survey completed in spring of 2020, and in 2021 vessel issues prevented completion of the survey in Divisions 3NO. A complete description of the survey, including timing and spatial coverage can be found in Rideout and Ings (2020).

Fall Surveys

In addition to spring surveys, a time series of fall surveys was begun in 1990 (Tables 6-9). Annual spatial and temporal extent of fall surveys are described in Rideout and Ings (2020). Note that due to operational difficulties there were no fall surveys of NAFO Divs. 3NO in 2014 or 2021. From fall 1998, the survey depth range in Div. 3N was further extended occasionally from the previous maximum depth range of 731 m to 1463 m, with coverage of these deeper strata being sporadic. From fall 2000 the survey depth range in Div. 3O was extended occasionally from the previous maximum depth range of 1097 m to 1463 m, with coverage of these deeper strata being sporadic.

Beginning with the fall survey in 1995, the survey gear was changed from an *Engel 145* groundfish trawl with steel bobbin footgear to a *Campelen 1800* shrimp trawl with rockhopper footgear. The data from the earlier Engel surveys have been converted to Campelen 1800 trawl catch equivalents. Only the converted survey data are presented but some caution should be used in comparing converted Engel data with data from the Campelen trawl series.

Biomass and abundance trends in NAFO Divs. 3NO

For spring surveys in NAFO Divs. 3NO the stock indices trends are primarily driven by the higher overall abundance and biomass estimated for NAFO Div. 3O. The NAFO Divs. 3NO combined indices for spring show a slow decline in biomass and abundance from 1984 to the late-1990s (Tables 6, 7 & 10; Figs. 3 & 5) and although fluctuations continue to occur, some minor improvement in the estimates had occurred from 1998 to 2003 until declining from 2003 to 2005. Values from 2007-2010 have fluctuated around the long-term mean (Fig. 5), however from 2010 to 2013 estimates of both biomass (7 000 to 24 000 t) and abundance (20 to 70 million fish) increased substantially, with the time series highest values in 2013 peaking at about 2.5 times the long term mean. This increase from 2010 to 2013 was followed by a sharp decline in both biomass and abundance from 2013 to 2015. Spring survey indices for NAFO Divs. 3NO increased to about the time series mean in 2019. The biomass index remained near the mean in 2019, but the abundance index increased to above the average. Restrictions due to Covid-19 prevented the spring survey in 2020, and problems with the research vessels prevented the 2021 spring survey in NAFO Divisions 3NO.

The fall survey series for Divisions 3NO combined (Tables 8, 9 & 11; Figs. 4 & 5) is less variable with a generally increasing trend in biomass and abundance from about 1997 until 2005. Variability increases substantially from 2006 to 2013. Both biomass and abundance increased substantially from 2007 to 2009 and were 2.75 and 2.5 times the mean, respectively (Fig. 5). This peak (the highest in the time series) is followed by a decreasing trend to 2016 when estimates were below the average. The fall survey biomass index for NAFO Divs. 3NO has increased slightly each year since 2016. The abundance index also showed a slight increase from 2016 to 2018, but increased sharply in 2019 to 1.75 times the average, driven by a three-fold increase in NAFO Div. 3O. In 2020, both biomass and abundance indices declined to levels similar to 2018. There was no survey in fall 2021 due to problems with the research vessels.

Depth distribution

Witch flounder have been described as a relatively deep water species, having been captured at depths of up to 1500 m. However, in the Newfoundland & Labrador area, they are thought to prefer depths of 184-366 m (Bowering and Brodie 1991) with previous studies showing that witch flounder in 3NO exhibit different depth preferences depending on season and division (Dwyer 2008; SCWP 15/014). A higher percentage of the biomass in 3N is found in deeper strata, but there is still a large percentage found in depths of less than 100m, especially in the fall. In Div. 3O where the main component of the stock is distributed, a large proportion of the biomass is found in depths less than 183 m in either spring or fall. This is despite the fact that in a number of years, the survey covered depths of up to 1500 m in the fall.

As discussed in Dwyer (2008), distribution plots indicated more witch flounder are distributed on the shallower, shelf area of the Grand Banks in some years, especially in Div. 3O and especially in the fall. Therefore, it seems likely that the RV survey coverage does adequately cover the depth distribution of witch flounder, particularly in the fall. The variation in the survey indices may be due to the movement of flounder onto and off of the shelf areas depending on water temperatures and spawning aggregations. Bowering and Orr (1996) suggested that the movement of witch flounder onto the shallow parts of the bank in large strata cause the high variability in annual stock size estimates. It is also likely that some witch flounder may be distributed outside the survey area, particularly in the spring, following spawning in deeper waters, and this may also contribute to variability in survey estimates.

Distribution Plots

Geographic distributions of witch flounder for recent years are presented in Figures 6-9 as number and weight (kg) per tow in the spring (2013-2021; no survey in 2020 or 2021) and fall surveys (2013 to 2021; 2014 survey incomplete and no survey in 2021). The witch flounder stock for Div. 3NO is mainly distributed in Div. 3O along the southwestern slope of the Grand Bank. In most years the distribution is concentrated along this slope but during the fall it has a wider distribution in the shallower parts of the bank. It is this variation in distribution from deeper to shallower strata in conjunction with the survey timing that is often responsible, in part, for the high variability in the annual biomass and abundance indices (Bowering and Orr 1996).

Length frequencies

Canadian (1996-2020) and Spanish (2003-2021) RV survey length frequency data for individual years from are presented in Figure 10 as abundance at length. Ageing information has not been available from Canadian RV surveys since the mid 1990's, making the tracking of cohorts from length frequency data difficult given the relatively slow growth of witch flounder. However, some trends in size classes of witch flounder are evident. Length frequencies of 30-50 cm fish (generally, recruited sizes) increased from 2003 to 2005, decreased to pre-2002 levels from 2006 to 2007, and were then consistently higher from 2008 to 2014 (note there was no survey data collected in the fall of 2014) with a mode generally within the mode of 40 cm. The increase in 30-50 cm fish is generally more pronounced in the fall survey data as opposed to the flatter distributions of the spring surveys. From 2015 to 2019, fish at this size mode were less prominent than seen in 2008 to 2014, although in fall 2020 this larger mode of fish increased.

Considering smaller fish and indications of recruitment to the stock, there have been a few identifiable peaks in the time series (Fig. 10) that could be followed in successive years (e.g. peak at 9 cm in 1997, 11 cm in 1998, and 20 cm in 1999; peak at 13 cm in 2011, and 20 cm in 2013). These smaller modes tracking through the survey series could indicate recruitment of year classes. In 2002, however, a peak at 12 cm was not observed subsequently. There have been less distinctive peaks, usually in the 10-20 cm range (2007, 2011, and 2015) although they were not identified in subsequent years. In the fall survey of 2017 a mode in the 10-15 cm range was observed, and this mode can be seen to progress through the spring survey at about 15 cm. The mode does not appear strong in the fall survey of that year, but is seen again in the 2019 spring survey (19-21 cm) and is a strong mode in the fall survey of 2019 (22-24 cm). In 2019, a strong mode is seen of fish in the 6 to 10 cm range. This mode is again observed in the fall survey advancing to 8 to 14 cm. Unfortunately, there was no spring survey in 2020, and in the fall survey, there was no indication of this significant peak of smaller fish. With no surveys in 2021, it is difficult to say if this apparent recruitment peak has persisted.

Abundance at length in the Spanish spring RV surveys was fairly consistent at 33-35 cm from 2003 to 2007 (a smaller range than the Canadian surveys during the same time period). From 2008 to 2017 the size range has generally increased with more fish in the 38-40 cm range. In 2018 the mode was in the 38-40 cm range (Fig. 10) and few fish are observed in the 2019 survey, with a very flat distribution. In 2021, this survey again shows fish in the 29-57 cm size range, but there is no indication of recruitment peaks of smaller fish in the areas covered by this survey.

Recruitment

Figure 11 shows the abundance index for fish less than 21 cm (a recruitment proxy) for NAFO Divs. 3NO combined, as measured in the spring and fall Canadian RV surveys. Up until 2018, recruitment indices from spring surveys were above the series mean in 1997 (3X), 2009 and 2013 and 2018. Fall indices were above the mean in 1998, 1999, 2000 and 2002. In 2019, both spring and fall surveys showed a recruitment index 5 times higher than the time series mean. The 2020 fall index was below average once again, however, and with lack of other surveys in 2020 and 2021, it is difficult to determine current recruitment. Most other values since 2002 have been consistently below or at the mean of the time series. Recruitment in spring and fall surveys in 2016 approached the lowest values of the time series. Previous work (Rogers and Morgan 2019) to answer a research recommendation has examined the apparent lack of fish in the 20-30 cm range as seen in the length frequency distributions of the stock prior to 2019, and did not find any evidence that pre-recruits might be coming from an adjacent stock area (NAFO Div. 3L or Subdivision 3Ps).

The distributions of juvenile (< 21 cm) witch flounder over the spring and fall Canadian surveys indicate a marginal pattern of fish being more widely distributed over the shallower depths in the larger strata during the fall. It is also possible that the weak pattern may be related to the distributions previously presented for the entire population which indicated a movement of fish to the shallower, larger strata during the fall. (Bowering and Orr 1996). The distribution of small witch flounder in the Canadian surveys of NAFO Divs. 3NO in spring and fall of 2018-2021 are shown in Fig. 12.

Recent History of the assessment of this stock

For many years, the status of the witch flounder stock in NAFO Divs. 3NO was assessed based on catch and survey results, as no analytical model was available. Complicating attempts to fit analytical models to the stock was the absence of aging data (there has been no aging available for witch flounder since 1994). In 2006, a non-equilibrium surplus production model incorporating covariates (ASPIC; Prager, 1994, 1995) was applied to catch and survey biomass indices in order to investigate the usefulness of this method in quantitative assessment of this stock. This production model was rejected based on indicators of poor model suitability including unreasonably high B/B_{msy} ratio, poor observed to estimated CPUE relationship, and strong residual patterns (Maddock Parsons 2006). A proxy for B_{lim} similar to those used in other stocks (15% highest observed survey biomass) was not considered appropriate in assessments conducted from 2006-2013, due to survey variability (over time, and between season) and depth coverage differences over the survey time series.

In 2014, the application of a surplus production model in a Bayesian framework was explored. A variety of combinations of input data and prior distributions on the parameters was tested. Model results were found to be sensitive to the choice of the prior on survey catchabilities, and therefore, the model was rejected. Proxies for B_{lim} and F_{lim} were accepted for the first time in this 2014 assessment. They were based on the two highest Canadian spring survey biomass index values from 1984-2013 as a proxy for B_{lim} and considering 30% of this value to be the limit (as in SCS Doc 04/12) and $F_{lim} = F_{msy}$ was derived from the catch/biomass ratio (Lee et al. 2014). Further work to explore the input series to the Bayesian surplus production model for this stock considered the input series and sensitivity of the model results to the choice of priors was conducted in 2015 (Morgan et al. 2015). Resulting from this work, a surplus production model in a Bayesian framework was accepted for the basis to assess this stock in 2015.

In the 2017 assessment, preliminary model runs indicated that model performance was slightly worse than the previous assessment, and further sensitivity analyses were undertaken to refine the estimates of r and K (Morgan and Lee 2017). In 2018, initial model results indicated that over 2014-2016 the survey indices were declining faster than can be explained by the process being modelled. To account for this a change to the model formulation was accepted to allow the process error to increase in 2014, 2015 and 2016 compared to the rest of the years (the sigma parameter was increased by 1 in those years). A recommendation by STACFIS in 2018 to further explore the prior distributions for the accepted model formulation resulted in no change to the model formulation used in the 2019 assessment (Morgan and Koen-Alonso 2019). The 2020 and 2022 assessment of the stock uses the 2019 accepted formulation, updated with catch and survey indices for most recent years.

Surplus production model in a Bayesian Framework

For the 2022 assessment model, the Schaefer (1954) form of a surplus production model was used:

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

Where:

P_{t-1} is exploitable biomass (as a proportion of carrying capacity) for year t-1
C_{t-1} is catch for year t-1
(Meyer and Millar, 1999a, 1999b).
K is carrying capacity (level of stock biomass at equilibrium prior to commencement of a fishery)
r is the intrinsic rate of population growth
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).

An observation equation is used to relate the unobserved biomass, Pt, to the research vessel survey indices:

$$It=q \cdot Pt \cdot \varepsilon t$$

Where:

q is the catchability parameter
Pt is an estimate of the biomass proportional to K at time t
εt is observation error

The priors used in the model were:

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(-1.763,3.252)	lognormal (mean, precision)
Carrying capacity	K~dlnorm(4.562,11.6)	lognormal (mean, precision)
Survey catchability	q =1/pq pq ~dgamma(1,1)	gamma(shape, rate)
Process error (sigma=standard deviation of process error in log-scale)	For 1960-2013 and 2017-2021 sigma ~ dunif(0,10) precision:isigma2= sigma^{-2} For 2014-2016 sigmadev <-sigma+1 precision: isigmadev2=sigmadev^{-2}	uniform(0 to 10)
Observation error (tau=variance of observation error in log-scale)	tau~dgamma(1,1) precision:itau2 = 1/tau	gamma(shape, rate)

Input data are given in Table 12 and shown in Figure 13 scaled to each series mean. The model formulation is given in Appendix 1. The prior on r was informed by that derived by Swain (2012) for witch flounder in the southern Gulf of St. Lawrence. The prior used here allowed for a higher r than derived by Swain (2012) as some of the morphometric methods explored indicated a higher r. Therefore the mean (0.17) derived by Swain (2012) was used as the central tendency (i.e. the median) but with a larger standard deviation. A mean of 0.2 and standard deviation of 0.12 gives a median of 0.17 on the log normal scale. The prior used therefore was: R~(-1.763,3.252)

The prior for K was based on Ecosystem Production Potential modelling (NAFO 2014). This modelling indicated that a reasonable distribution for K would have a mean of 100 and a standard deviation of 30. K~dlnorm(4.562,11.6).

The input data were catch from 1960-2021, Canadian spring survey series from 1984-1990 (survey max depth 366m), Canadian spring survey series from 1991-2019 (survey coverage expanded to depths up to 914m; 2006 survey incomplete; no spring surveys in 2020 or 2021) and the Canadian fall survey series from 1990-2020 (2014 survey incomplete; no fall survey in 2021).

The results of the 2017 assessment (Lee et al. 2017) indicated that over 2014-2016 the survey indices were declining faster than can be explained by the process being modelled. To account for this a change was made to allow the process error to increase in 2014, 2015 and 2016 compared to the rest of the years (the sigma parameter was increased by 1 in those years) (Morgan and Koen-Alonso 2019).

Resource Status

The surplus production model results are summarized in Table 13 and model fit and diagnostic indicators are shown in Table 16 and in Figures 14-17 as well as Appendix 2. All posteriors were updated from their priors (Figs. 16 & 17). Model fit to the survey data was relatively good for all surveys and very similar to the 2020 assessment (Figure 14). All convergence diagnostics (Table 16; Appendix 2) indicated that there were no issues with model convergence.

The model indicates that stock size decreased from the late 1960s to the late 1990s and then increased from 1995 to 2013. There was a large decline from 2013 to 2015, with a subsequent small increase since. The model suggests that a maximum sustainable yield (MSY) of 3 762 (80% Confidence Interval: 3 052 – 4 652) t can be produced by total stock biomass (B_{msy}) of 60 510 t (46 529 t – 73 782 t) at a fishing mortality rate (F_{msy}) of 0.062 (0.05-0.09).

The analysis showed that relative population size (median $B/\ B_{msy}$) was below B_{lim} =30% B_{msy} from 1993-1997. The stock size increased since 1994 to 2013 and then declined from 2013-2015 and has since increased slightly. In 2022 the stock is at 47% B_{msy} with a 0.095 risk of being below B_{lim} (Table 13; Fig. 18). Relative fishing mortality rate (median F/F^{msy}) was mostly above 1.0 from the late 1960s to the mid-1990s. F has been below F_{msy} since the moratorium implemented in 1995 (Table 13; Fig. 19). Median F was estimated to be 36% of F_{msy} with a very low probability (0.01) of being above F_{msy} in 2022.

Precautionary Approach Framework

The surplus production model outputs indicate that the stock is presently 47% of B_{msy} and F is below F_{msy} (53%; Fig. 20). 30% B_{msy} is considered a suitable limit reference point (B_{lim}) for stocks where a production model is used. At present, the risk of the stock being below B_{lim} = 30% B_{msy} is 9.5% and risk of F>F_{msy} is low (1%). Although no buffers (for F or B) are defined, this stock is in the cautious zone or the danger zone as defined in the NAFO Precautionary Approach Framework (NAFO 2004).

The posterior distributions (13 500 samples) for r, K, sigma, and biomass and the production model equation were used to project the population to 2025. Two catch scenarios were projected: catch in 2022 was assumed equal to the TAC of 1 175 t and catch in 2022 set to the recent five year average (700 t). For both scenarios, constant fishing mortality for 2023 and 2024 at several levels of F (F=0, F_{2021}, 2/3 F_{msy}, 85% F_{msy}, and F_{msy}) were applied and results are given in tables 14 and 15. A projection with constant levels of catch at 1 175t (TAC in 2022) was also conducted. Figure 21 shows the plot of the projections for the assumption of catch_{2022}= 1 175 t.

The probability that $F > F_{\text{lim}}$ in 2022 is 14% at a catch of 1 175 t. The probability of $F > F_{\text{lim}}$ ranged from 1 to 50% for the catch scenarios tested (Table 14). The population is projected to grow under all scenarios, although except for projections of no or very low catch, the probability that the biomass in 2025 is greater than the biomass in 2022 is about 60%-70%, which translates into little to moderate growth to 2025. The population is projected to remain below B_{msy} through to the beginning of 2025 for all levels of F examined with a probability of greater than 85%. The probability of projected biomass being below B_{lim} by 2025 was 5 to 9% in all catch scenarios examined and for the F=0 projections, P(B< B_{lim}) was 3% or 4% by 2025, for catch in 2022 assumed at TAC (1 175 t) or recent levels (700 t; 2017-2021 average), respectively. Figure 21 shows the projected relative biomass over 2022-2025 for both catch scenarios: catch in 2022=TAC (1 175 t) and catch in 2022= 700 t.

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Table 1. Catches and TACs (t) of Witch flounder in Div. 3NO from 1960 to 2022.

Year	Canada	USSR (Russia)	Other	Total	TAC	Year	Canada	USSR (Russia)	Other	Total	TAC
1960	-	-	-	5799		1992	4328	-	632	4960	5000
1961	-	-	-	4627		1993	4337	3	250	4414	5000
1962	-	-	-	1228		1994	2	-	1117	1119	3000
1963	895	485	803	2183		1995	-	-	300	300	0
1964	1055	-	11	1066		1996	64	-	294	358	0
1965	1324	849	4	2177		1997	19	-	493	512	0
1966	3644	3828	50	7522		1998	2	5	605	612	0
1967	2863	8565	75	11503		1999	6	86	671	763	0
1968	1503	9078	18	10599		2000	12	50	483	545	0
1969	479	4215	6	4700		2001	13	34	647	694	0
1970	723	6039	1	6763		2002	26	112	312	450	0
1971	178	14774	13	14965		2003	62	59	1423*	1544*	0
1972	3419	5738	20	9177		2004	58	60	509	627	0
1973	4943	1714	34	6691		2005	49	8	200	257	0
1974	2807	5235	3	8045	10000	2006	94	2	385	481	0
1975	1137	5019	12	6168	10000	2007	21	27	174	222	0
1976	3044	2991	-	6035	10000	2008	46	17	201	264	0
1977	3013	2742	4	5759	10000	2009	41	22	313	376	0
1978	1165	2275	33	3473	10000	2010	39	28	354	421	0
1979	1193	1868	16	3077	7000	2011	11	2	337	350	0
1980	425	1994	1	2420	7000	2012	2	10	303	315	0
1981	381	2044	-	2425	5000	2013	62	54	212	328	0
1982	1760	1969	3	3732	5000	2014	11	57	267	335	0
1983	1674	1942	-	3616	5000	2015	221	36	102	359	1000
1984	834	1955	13	2802	5000	2016	799	26	237	1062	2172
1985	2746	1908	4117	8771	5000	2017	397	-	259	656	2225
1986	2937	1724	4470	9131	5000	2018	478	77	86	641	1116
1987	2829	1425	3342	7596	5000	2019	480	301	81	862	1175
1988	1927	1037	4361	7325	5000	2020	427	56	172	655	1175
1989	1241	81	2366	3688	5000	2021	386	82	157	625	1175
1990	2654	9	1516	4179	5000	2022					1175
1991	2624	-	2223	4847	5000						

Note: Although a TAC of 3000 t was agreed by the Fisheries Commission (FC), it was also agreed that no directed fishing on witch flounder in NAFO Divs. 3NO take place during 1994 due to the poor state of the stock. Canadian catch prior to 2017 was derived from combining Newfoundland and Maritimes commercial data. Canadian, Russian, and "Other". Catch in 2017 was derived from the Catch Data Advisory Group (CDAG) method and in 2018-2021 was estimated by the Catch Estimate Strategy Group (CESAG). A 1,175 ton quota for 3NO witch flounder has been adopted by the Fisheries Commission since 2019.

Table 2. Estimated Abundance (000s) of witch flounder (M+F) by stratum from surveys in Divs. 3NO during spring of 1984-2000 (Engel 145 data converted to Campelen Units 1984-1995). Totals and 95% confidence limits given in millions.

DIV	Max Depth (m)	Stratum	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
3N	55	375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		376	0	0	0	26	0	0	0	0	0	0	0	0	0	0	34	34	0
	91	360	2234	129	728	741	2641	220	0	0	59	224	0	0	0	132	65	224	613
		361	153	0	0	32	36	0	28	0	0	0	0	36	0	0	0	0	212
		362	0	95	25	27	173	0	0	0	0	0	0	0	0	0	0	0	0
		373	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		374	0	0	0	0	0	0	0	0	0	43	43	0	0	0	0	0	0
		383	0	62	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0
	183	359	405	58	232	58	985	203	0	0	0	29	0	0	0	0	0	203	405
		377	14	0	0	186	7	83	0	0	0	0	0	0	0	0	0	0	0
		382	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0
	274	358	77	557	93	279	31	46	93	0	93	294	232	31	77	83	261	15	41
		378	48	29	48	354	86	115	0	0	96	0	0	0	0	8	0	0	0
		381	25	13	42	163	75	0	25	0	0	0	0	0	0	0	13	0	0
	366	357	23	180	553		11	237	56	0	90	124	102	23	40	30	373	259	293
		379	66	36	68	423	102	44	109	7	44	0	22	0	0	18	6	102	28
		380	8	88	0	247	32	8	8	0	0	0	0	0	0	0	0	8	0
	549	723								288	341	256	53	181	45	51	149	96	171
		725								166		101	87	0	13	235	26	51	72
		727								0	11	55	22	0	0	11	33	33	21
	731	724								1134	580	597	188	119	128	432	144	550	500
		726								213	59	30	114	5	33	183	322	213	198
		728								182	21	139	29	172	134		64	158	145
	914	752											37						
		756											87						
		760											95						
3O	91	330	0	0	0	0	32	0	0	0	0	0	0	0	0	73	36	210	242
		331	3555	376	94	31	1004	0		0	0	0	0	0	63	0	94	1104	63
		338	209	11894	1509	1944	5418	2480	587	0	131	479	0	305	1417	0	671	1973	348
		340	59	210	0	26	0	0	52	0	142	0	0	0	0	0	0	0	142
		351	924	231	495	267	1317	240	116	0	0	0	0	0	0	0	0	39	43
		352	101	1807	431	2048	1839	928	1775	51	89	51	44	71	79	197	35	1814	197
		353	9347	1234	1713	2146	13050	3880	2910	0	265	353	0	35	35	265	459	5055	2539
	183	329	0	0	0	0	1454	53	34	763	0	0	12263	521	0	35	68	623	47
		332	11018	16592	6529	7230	16023	2852	10572	4513	5761	504	432	3925	2927	5665	1085	5045	2232
		337	130	9181	2634	3543	2641	2556	2608	3182	815	2087	87	1239	826	469	848	3709	3260
		339	443	0	80	268	134	0	0	0	0	0	0	0	161	36	80	36	80
		354	1174	239	3282	456	619	196	359	261	261	1663	0	0	98	33	563	3208	2739
	274	333	21	156	35	0	145	52	332	1361	187	301	13447	425	30	277	140	267	261
		336	25	17	175	67	208	0	158	1365	3287	266	3029	125	432	682	150	173	219
		355	92	418	128	135	0	383	510	340	28	99	340	99	168	195	157	38	41
	366	334	0	95	165	63	95	44	51	38	272	63	2238	40	462	880	7	161	167
		335	0	203	40	8	148	68	331	109	2340	223	215	108	192	243	12	169	368
		356	17	214	38	55	109	80	126	92	348	319	189	126	88	40	90	54	50
	549	717								32	371	166	5960	228	1362	11566	710	237	162
		719								288	2535	267	37	42	364	1161	150	112	228
		721								235	209	94	193	42	42	63	214	152	112
	731	718								282	122	512	1161	535	518	507	517	324	138
		720								361	376	1026	498	43	101	518	186	104	351
		722								45	166	512	518	601	274	819	177	364	207
	914	764											217						
		772											501						
3NO	Total (millions)		30.2	44.1	19.2	20.9	48.4	14.8	20.8	15.3	19.1	10.9	42.5	9.1	10.1	24.9	7.9	26.9	16.9
UCL	(millions)		41.6	64.4	31.3	28.6	71.3	21.7	47.2	22.4	29.7	21.1	78.0	12.8	13.6	146.3	10.3	36.0	26.4
LCL	(millions)		18.7	23.8	7.1	13.1	25.5	7.9	-5.6	8.2	8.5	0.7	6.9	5.4	6.6	-96.4	5.6	17.9	7.5

Table 3. Estimated Abundance (000s) of witch flounder (M+F) by stratum from surveys in Divs. 3NO during spring of 2001-2021 (Campelen). Totals and 95% confidence limits given in millions. There were no surveys conducted in Divs. 3NO in spring of 2020 or 2021.

DIV	Max Depth (m)	Stratum	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3N	55	375	0	0	0	0	0	73	44	0	44	0	0	0	0	0	0	0	0	0	0		
		376	0	0	0	0	0	0	88	0	0	0	0	0	0	0	0	0	0	0	0		
	91	360	0	0	82	123	1555	480	741	103	0	823	288	165	329	206	0	0	235	1770	51		
		361	85	0	0	0	36	255	0	51	85	0	203	0	170	64	0	0	0	0	0		
		362	0	0	0	0	0	173	0	0	0	0	39	0	0	0	0	0	0	0	0		
		373	0	0	0	0	0		0	0	0	0	39	39	0	0	0	0	0	0	0		
		374	0	85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		383	0	0	0	0	0		0	0	46	0	46	0	0	0	0	0	0	0	0		
	183	359	58	29	0	0	695		87	0	1448	1953	3475	608	116	1371	1158	174	6850	39	87		
		377	0	0	0	0	0		0	0	0	0	0	55	0	0	0	0	0	14	14		
		382	0	0	0	0	89		0	0	0	0	0	0	0	45	0	0	0	0	0		
	274	358	325	28	296	0	110		681	151	542	303	566	186	330	230	50	1594	312	139	763		
		378	8	33	8	0	17		0	0	0	0	19	112	0	0	17	0	0	0	172		
		381	11	0	0	0	0		81	25	33	0	22	51	38	38	438	50	0	0	0		
	366	357	63	55	150	45	0		23	0	23	98	361	317	45	64	180	97	26	0	60		
		379	13	0	16	0	40		0	0	7	29	49	284	192	515	7	0	14	0	146		
		380	0	0	8	0	0		0	7	0	0	0	54	11	21	8	0	24	16	0		
	549	723	88	322	152	96	313		107	245	33	364	99	107	353	582	199	380	171	64	245		
		725	19	6	17	0	264		40	10	110	13	26	51	18	154	116	36	147	982	165		
		727	10	0	0	31	68		31	73	0	20	82	77	179	69	11	260	830	275	20		
	731	724	516	267	283	145	171		645		407	262	176		206	395	55	312		111	156		
		726	346	65	134	63	18		59	73	112	238	128	74	62	178	181	202	69	106	149		
		728	258	136	143	161	64		70	319	1409	383	225	268	326	558	296	469	172	204	236		
	914	752																					
		756																					
		760																					
3O	91	330	0	0	0	146	205	1490	0	411	0	0	1797	123	82	575	0	0	0	82	411		
		331	721	94	0	0	784		2885	1129	2478	63	526	188	28	784	31	0	282	605	0		
		338	2263	305	609	2990	2089	5106	1697	870	1915	1480	2166	5669	6397	1044	2089	218	835	2306	6745		
		340	0	0	0	0	47	118	236	0	330	0	0	0	94	79	0	0	0	47	0		
		351	0	0	0	0	0	0	0	87	0	0	43	0	0	0	0	0	0	0	43		
		352	44	1952	44	1183	1065	2484	1198	843	152	1020	1252	4396	532	142	51	0	237	532	2687		
		353	901	831	1102	957	872	7616	794	1058	309	573	2405	6393	2214	2381	823	0	588	8509	4365		
	183	329	0	0	5303	0	742		1292	710	2320	1357	1768	2909	18229	158	1231	0	2036	379	331		
		332	8354	6769	32886	24519	5041		2496	12866	8652	6273	5804	4225	31302	25709	2256	5905	3361	4695	12994		
		337	6738	1826	1565	764	2454		1565	3912	2434	2536	1043	7079	3086	848	1826	3977	2282	522	2304		
		339	282	241	0	0	443	1753	851	322	1609	80	72	0	282	241	0	0	0	121	241		
		354	2100	1467	359	913	1960		1239	2282	1043	406	2402	652	1076	1346	1402	65	978	265	2934		
	274	333	576	940	215	225	273		174	72	253	117	54	37	192	30	10	536	149	819	101		
		336	583	1273	524	258	368		233	275	214	158	144	33	226	92	50	181	788	25	58		
		355	220	569	945	246	57		106	85	173	120	53	74	156	21	50	1884	186	92	13		
	366	334	30	376	533	238	20		69	33	132	71	38	32	53	46	18	255	7	7	9		
		335	60	47	131	35	78		22	7	18	30	57	68	35	60	0	12	52	8	18		
		356	67	78	131	25	82		16	15	24	20	10	17	194	17	25	147	88	13	19		
	549	717	273	651	468	46	181		91	117	682	167	59	46	278	85	284		171	175	115		
		719	97	268	89	19	131		81	80	28	28	284	102	50	16	74	6	33	91	75		
		721	204	139	84	31	19		60	56	251	26	244	42	52	21	0	10	37	5	88		
	731	718	525	1189	578	66	177		240	357	2050	345	652	170	1290	387	303		850	359			
		720	309	50	104	41	765		62	75	72	75		22	25	508	53	10	125	65	19		
		722	361	198	210	53	154		176	133	96	106	245	102	73	65	26	61	26	6	55		
	914	764																					
		772																					
3NO	Total (millions)		26.5	20.3	47.2	33.4	21.4	19.5	18.3	26.9	29.5	19.5	27.0	34.8	68.3	39.1	13.3	16.8	22.0	23.4	35.9		
UCL	(millions)		38.6	31.9	183.4	104.6	29.3	27.0	30.0	50.7	44.5	28.7	39.8	45.3	164.7	343.2	17.4	36.1	33.6	36.7	58.4		
LCL	(millions)		14.4	8.7	-89.0	-37.7	13.6	12.1	6.6	3.0	14.5	10.3	14.1	24.3	-28.0	-264.9	9.2	-2.4	10.3	10.2	13.4		

Table 4. Estimated Biomass (t) of witch flounder (M+F) by stratum from surveys in Divs. 3NO during spring of 1984-2000. (Engel 145 data converted to Campelen Units from 1990-1995). Totals and 95% confidence limits given in ('000 t).

DIV	Max Depth (m)	Stratum	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
3N	55	375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		376	0	0	0	19	0	0	0	0	0	0	0	0	0	0	8	18	0
	91	360	1715	89	629	461	1519	175	0	0	29	165	0	0	0	115	33	120	266
		361	119	0	0	39	50	0	20	0	0	0	0	39	0	0	0	0	242
		362	0	82	23	18	147	0	0	0	0	0	0	0	0	0	0	0	0
		373	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		374	0	0	0	0	0	0	0	0	0	18	34	0	0	0	0	0	0
		383	0	57	0	37	0	0	0	0	0	0	0	0	0	0	0	0	0
	183	359	231	47	99	43	306	121	0	0	0	19	0	0	0	0	0	67	149
		377	8	0	0	72	3	32	0	0	0	0	0	0	0	0	0	0	0
		382	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
	274	358	40	308	42	137	20	29	57	0	44	132	106	7	51	49	134	6	9
		378	22	19	32	155	31	42	0	0	29	0	0	0	0	3	0	0	0
		381	21	7	32	101	69	0	28	0	0	0	0	0	0	0	0	0	0
	366	357	8	87	154		4	60	21	0	31	49	81	20	36	12	159	21	75
		379	36	12	23	173	44	20	35	3	18	0	4	0	0	9	2	26	4
		380	6	53	0	134	24	7	4	0	0	0	0	0	0	0	0	6	0
	549	723								90	102	79	36	51	16	25	53	33	36
		725								62		40	44	0	5	28	4	20	32
		727								0	5	38	17	0	0	3	9	13	12
	731	724								327	181	218	51	36	29	157	53	105	106
		726								81	25	22	28	3	12	42	96	59	65
		728								92	19	82	22	152	21		15	32	45
	914	752											27						
		756											33						
		760											26						
3O	91	330	0	0	0	0	22	0	0	0	0	0	0	0	0	0	21	121	111
		331	1912	302	36	18	444	0		0	0	0	0	0	74	0	36	537	28
		338	134	7806	1108	1184	3075	1827	434	0	109	295	0	228	870	0	357	780	183
		340	40	146	0	21	0	0	15	0	147	0	0	0	0	0	0	0	83
		351	688	211	385	222	978	217	109	0	0	0	0	0	0	0	0	21	22
		352	82	951	225	1275	1330	664	1426	40	105	60	40	63	59	100	53	1196	130
		353	4519	1122	1067	1609	7208	2486	1637	0	243	209	0	42	23	2	272	2209	1300
	183	329	0	0	0	0	789	48	27	494	0	0	5071	193	0	11	51	240	26
		332	3779	8589	2485	3367	6829	1485	4599	2426	2182	359	58	1791	1180	235	460	981	407
		337	50	4129	1415	1506	1061	1543	1627	1581	580	675	50	654	330	163	321	879	936
		339	335	0	16	223	136	0	0	0	0	0	0	0	1	0	0	1	0
		354	495	105	1231	233	345	47	240	144	149	841	0	0	36	0	226	1062	826
	274	333	10	48	10	0	67	16	129	498	79	80	5196	162	7	109	25	27	30
		336	12	7	43	25	63	0	53	492	1374	100	1057	62	180	293	23	47	27
		355	45	181	38	71	0	97	126	136	16	34	129	43	86	48	50	18	14
	366	334	0	42	42	18	22	23	26	20	108	20	860	15	150	362	4	7	11
		335	0	98	18	2	51	22	92	42	1107	65	103	43	78	109	2	62	128
		356	5	83	17	23	18	29	55	39	129	77	75	62	40	11	29	23	14
	549	717								11	120	35	2375	53	465	4353	44	19	17
		719								148	1024	49	14	18	137	601	15	16	25
		721								76	48	31	72	18	16	19	38	37	28
	731	718								35	29	104	221	80	71	37	33	38	15
		720								217	134	182	95	15	21	150	32	21	40
		722								18	49	150	217	206	89	87	31	71	47
	914	764											60						
		772											75						
3NO	Total (millions)		14.3	24.6	9.2	11.2	24.7	9.0	10.8	7.1	8.2	4.2	16.3	4.1	4.1	7.1	2.7	8.9	5.5
UCL	(millions)		17.7	17.7	13.4	15.0	37.1	12.8	21.9	10.8	12.1	6.7	30.9	5.7	5.8	54.8	3.6	12.0	8.1
LCL	(millions)		10.9	10.9	5.0	7.4	12.2	5.2	-0.4	3.3	4.3	1.7	1.6	2.4	2.4	-40.6	1.8	5.9	2.9

Table 5. Estimated biomass (t) of witch flounder (M+F) by stratum from surveys in Divs. 3NO during spring of 2001-2021. (Engel 145 data converted to Campelen Units from 1990-1995). Totals and 95% confidence limits given in ('000 t). Survey coverage in 2006 was incomplete, and there were no spring surveys in Divs. 3NO in 2020 or 2021.

DIV	Max Depth (m)	Stratum	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3N	55	375	0	0	0	0	0	41	35	0	21	0	0	0	0	0	0	0	0	0	0		
		376	0	0	0	0	0	0	89	0	0	0	0	0	0	0	0	0	0	0	0		
	91	360	0	0	19	97	983	264	543	85	0	395	156	72	188	135	0	0	118	1072	1		
		361	45	0	0	0	35	139	0	18	72	0	131	0	92	75	0	0	0	0	0		
		362	0	0	0	0	0	133	0	0	0	0	17	0	0	0	0	0	0	0	0		
		373	0	0	0	0	0		0	0	0	0	15	20	0	0	0	0	0	0	0		
		374	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		383	0	0	0	0	0		0	0	0	0	23	0	0	0	0	0	0	0	0		
	183	359	58	13	0	0	334		52	0	593	719	1365	299	83	835	612	117	3622	14	0		
		377	0	0	0	0	0		0	0	0	0	0	38	0	0	0	0	0	9	0		
		382	0	0	0	0	40		0	0	0	0	0	0	0	42	0	0	0	0	0		
	274	358	154	14	168	0	42		316	68	237	156	241	86	189	135	24	884	194	86	461		
		378	5	8	1	0	0		0	0	0	0	14	55	0	0	6	0	0	0	22		
		381	7	0	0	0	0		53	13	18	0	0	30	0	23	267	0	0	0	0		
	366	357	17	26	65	42	0		19	0	4	31	83	134	25	42	94	56	17	0	27		
		379	4	0	4	0	6		0	0	7	12	23	101	88	237	5	0	7	0	31		
		380	0	0	3	0	0		0	5	0	0	0	22	5	12	4	0	0	15	0		
	549	723	23	130	60	34	108		50	82	13	137	54	42	125	245	87	171	44	12	76		
		725	8	3	7	0	103		15	3	36	4	18	28	8	68	56	25	55	498	86		
		727	3	0	0	23	41		11	27	0	14	32	34	99	43	10	179	514	120	9		
	731	724	127	96	101	54	65		207		146	82	61		76	150	10	121		56	58		
		726	84	18	50	21	8		19	25	41	105	46	32	23	77	93	104	21	41	60		
		728	98	43	53	75	42		34	175	748	164	117	142	187	371	202	266	72	97	105		
	914	752																					
		756																					
		760																					
3O	91	330	0	0	0	117	129	569	0	278	0	0	875	55	36	294	0	0	0	33	178		
		331	375	102	0	0	292		1301	425	1124	17	212	81	10	352	20	0	108	225	0		
		338	1354	121	320	1171	646	1675	1016	450	990	769	948	2569	2641	455	804	119	289	794	465		
		340	0	0	0	0	26	90	0	0	182	0	0	0	4	45	0	0	0	17	0		
		351	0	0	0	0	0	0	0	65	0	0	21	0	0	0	0	0	0	0	0		
		352	53	693	27	628	551	1199	733	555	102	562	791	1736	298	85	30	0	123	262	175		
		353	469	688	470	572	430	3390	576	529	172	299	1078	2982	1265	1264	413	0	279	2639	148		
	183	329	0	0	2209	0	147		559	215	983	559	752	1117	7541	65	495	0	857	122	112		
		332	3025	2458	10236	7945	1075		641	3188	2005	1669	1270	911	9766	4888	629	2120	970	1389	4095		
		337	1823	752	715	233	655		333	1211	563	630	198	1958	1007	140	453	1704	766	161	726		
		339	5	2	0	0	189	825	4	37	284	2	58	0	14	56	0	0	0	17	2		
		354	914	553	163	496	640		393	1148	430	147	968	164	378	429	478	56	398	154	975		
	274	333	122	375	63	36	39		27	9	32	20	6	9	42	0	2	155	28	140	17		
		336	163	598	211	61	51		44	61	16	16	26	10	38	18	15	74	310	3	8		
		355	87	193	340	117	12		27	34	67	44	12	26	14	3	24	797	62	11	5		
	366	334	2	143	133	29	3		11	5	14	6	6	1	10	4	2	92	2	3	1		
		335	8	8	53	10	11		2	1	4	3	3	17	12	8	0	3	11	1	1		
		356	34	38	49	13	18		3	6	6	5	0	4	29	2	9	73	49	7	7		
	549	717	41	201	142	5	17		10	12	55	12	6	16	16	7	28		26	9	10		
		719	12	95	39	3	14		15	11	6	7	38	8	7	3	17	1	8	8	21		
		721	85	38	26	9	4		10	11	25	11	15	6	4	3	0	5	4	0	12		
	731	718	57	55	43	13	13		20	43	157	22	36	18	62	38	24		76	28			
		720	38	7	23	9	69		9	9	9	9		4	6	43	6	1	18	8	8		
		722	121	62	64	12	27		11	21	17	15	30	18	8	9	7	11	5	0	19		
	914	764																					
		772																					
3NO	Total (millions)		9.4	7.6	15.9	11.8	6.9	8.3	7.2	8.8	9.2	6.6	9.7	12.8	24.4	10.7	4.9	7.1	9.1	8.1	7.9		
UCL	(millions)		14.2	11.7	57.1	38.2	9.3	11.4	12.6	13.6	13.5	9.2	14.4	16.8	53.9	60.5	6.6	13.8	15.2	12.0	14.4		
LCL	(millions)		4.6	3.4	-25.4	-14.6	4.4	5.2	1.8	4.0	4.8	4.1	5.1	8.9	-5.1	-39.1	3.3	0.5	2.9	4.1	1.4		

Table 6. Estimated abundance (000s) of witch flounder (M+F) by stratum from surveys in Divs. 3NO during fall of 1990-2005 (Engel 145 data converted to Campelen Units from 1990-1994). Totals and 95% confidence limits given in millions.

DIV	Max Depth (m)	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
3N	55	375	0	73		0	0	0	0	0	0	0	0	0	55	0	0	0
		376	0	0	0	0	0	14	0	47	0	0	0	0	59	59	0	0
	91	360	265	171	1297	173	75	888	38	821	623	177	535	514	1080	1022	1132	4888
		361	28	467	463	0	32	0	0	0	0	268	28	204	255	102	0	211
		362	400	221	87	0	0	0	0	0	0	32	0	0	0	198	0	0
		373	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		374	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
		383	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
	183	359	0	0	278	0	0	22	0	0	1213	1	0	405	116	232	203	87
		377	0		0	0	8	0	0	0	0	0	0	0	0	0	0	0
		382	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	274	358	0	20	66	24	0	74	0	11	30	19	40	136	0	307	31	251
		378	0	41	15	0	0	0	0	1	0	0	0	8	10	0	0	0
		381		0		0	0	0	0	1	0	0	0	11	0	0	0	0
	366	357	0	234	9	187	43	85	0	27	0		52	33	20	102	34	98
		379	4		4	0	0	0	1	7	0	0	2	296	91	26	1915	13
		380		0		0	0	0	0	0	1	2	5	0	0	0	16	24
	549	723		41		163	180	57	15	28	74	27	28	190	57	347	43	299
		725			15	376	46	19	0	135	10	33	19	22	14	29		21
		727				0	38	0	0	29	7	4	0	13	0	11	11	59
	731	724		172		414	180	104	60	197	72	181	87	264	270		177	247
		726				310	54	48	40	21	38	34	16	37	176	129	84	42
		728					153	35	21	76	78	106	153	223	633	351	161	73
	914	752									120		23	0	74			
		756									124		51	182	22			175
		760									88		41	409	530			53
	1097	753									0		0	0	33			
		757									0		0	96	92			7
		761									46		147	202	24			412
	1280	754									0		0	0	12			
		758									0		0	0	8			0
		762											0	483	0			58
	1463	755									0		0	0	0			
		759									0		0	9	0			0
		763											19	18	88			0
3O	91	330	122	67	79	0	0	247	0	72	168	208	48	575	588	766	123	479
		331	22	315	134	0	0	108	0	0	256	946	243	1066	1850	1004	31	1098
		338	2226	438	837	3966	2193	4684	503	1329	483	2736	375	1984	2245	6893	11652	4774
		340	173	280	63	0	0	204	0	22	0	415	104	378	189	94	47	243
		351	1690	284	72	0	0	0	0	0	37	205	0	198	0	50	50	99
		352	1415	896	1352	946	228	379	80	1114	388	1491	920	1065	1448	2296	6584	2484
		353	2405	343	477	0	732	538	789	168	1066	2996	2379	2954	9523	3395	5291	6525
	183	329	99	85	0	18	0	417	0	173	305	0	0	805	1989	379	703	710
		332	2102	155	1724	813	321	1114	4569	190	245	1664	544	1392	4342	3738	6145	8381
		337	1333	188	954	563	2132	421	492	322	479	978	344	348	714	1434	397	5067
		339	1132	224	651	119	742	1911	0	481	261		344	563	3822	684	7559	4507
		354	1291	23	316	75	210	191	4647	215	201	103	766	630	1415	1989	1150	978
	274	333	221	11	22	30	90	25		4	6	33	4	118	90	243	30	51
		336	82	151	76	298	13	35	32	19	19	67	31	150	58	75	50	300
		355		497	93	120	25	16	343	6	14	110	35	21	28	21	92	35
	366	334	24	16	0	9	18	4		5	1	7	5	36	35	53	65	122
		335	194	25	25	30	18	1	23	0	1	23	8	8	39	12	18	7
		356		11	7	430	98	7	60	3	4	32	22	19	17	34	31	45
	549	717	30			0	57	65		12	42	260	0	91	203	351	117	10
		719	110	2		65	6	1	226	19	9	10	14	183	37	96	96	78
		721		18		169	67	21	54	6	14	67	17	10	84	81	11	135
	731	718				22	82	10		68	47	53	34	488	1432	1483	575	1040
		720				73	0	13	68		2	17	4	762	298	302	206	336
		722		9		81	21	14	39	12	12	26	8	94	34	50	90	199
	914	764									75		12	144	217			29
		768									18		7	163	374			34
		772									173		62		383	190		390
	1097	765									24		3	119	289			77
		769									17		5	237	380			142
		773									4		13	346	708	94		62
	1280	766											24	11	146			307
		770											4	185	460			88
		774											4	241	119	244		297
	1463	767											15	0	0			0
		771											0	132	0			60
		775											0	0	0	213		107
3NO	Total ('000 t)		15.4	5.5	9.1	9.5	7.9	11.8	12.1	5.6	6.9	13.3	7.6	7.0	11.1	10.3	18.6	18.1
UCL	('000 t)		19.3	7.3	12.6	15.0	12.6	20.4	37.7	7.9	13.8	17.7	9.4	8.7	15.1	13.7	29.5	25.8
LCL	('000 t)		11.4	3.7	5.7	4.0	3.1	3.2	-13.5	3.4	0.0	8.9	5.9	5.4	7.1	6.9	7.8	10.4

Table 7. Estimated abundance (000s) of witch flounder (M+F) by stratum from surveys in Divs. 3NO during fall of 2006-2021 (Campelen). Totals and 95% confidence limits given in millions. There were no fall surveys in Divs. 3NO for 2014 or 2021.

DIV	Max Depth (m)	Stratum	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3N	55	375	0	0	0	0	0	0	0	0		0	0	55	0	0	0	
		376	0	0	0	69	0	0	103	258		52	0	464	103	46	0	
	91	360	154	0	9290	17639	3224	2381	22490	17384		1286	1029	978	6380	2161	2572	
		361	51	1020	85	0	561	249	262	153		0	51	408	663	204	85	
		362	50	0	0	58	297	99	149	149		0	50	0	0	0	0	
		373	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
		374	0	0	0	0	0	0	0	0		0	0	43	0	0	0	
		383	0	0	46	0	0	0	0	93		46	0	0	0	0	0	
	183	359	145	524	1216	2635	869	956	331	270		844	58	434	116	579	319	
		377	0	0	0	34	44	21	110	0		0	0	14	7	83	14	
		382	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	274	358	252	31	230	190	174	155	650	120		0	58	234	185	248	55	
		378	200	8	19	8		38	112	359		765	51	19	19	86	19	
		381	0	0	0	11	0	0	0	0		0	0	0	0	45	0	
	366	357	242	116	259	29	72	11	143	68		346	11	35	50	40	34	
		379	6	15	350	24	81	1500	51	10		87	10	101	0	0	18	
		380	0	0	0	0	0	0	0	0		24	7	0	14	34	28	
	549	723	72	38	227	239	94	153	87	96		2644	117	91	11	776	40	
		725	15	32	58	91		37	29	155		166	39	1297	117	147	19	
		727	0	0	307	163	66	57	77	33		127	0	78	132	175	126	
	731	724	629	384	1651	771	381	432	245	213		26	119	102	92	111	178	
		726	106	125	102	303	20	44	78	11		116	113	278	566	366		
		728	204	343	428	893	860	118	245	354		204	230	311	335	268	409	
	914	752		9														
		756		185														
		760		339		618												
	1097	753		0														
		757		0														
		761		24		277												
	1280	754		0			0											
		758		0														
		762		97		204												
	1463	755		0														
		759		0														
		763		0		18												
3O	91	330	718	671	1149	2062	899	1197	144	2086		2402	1006	2477	527	3773	1221	
		331	345	439	345	1296	3907	2729	215	2164		220	125	251	63	1882	282	
		338	1567	1044	3220	5817	13606	7989	1816	3290		2141	574	2350	835	11755	9573	
		340	1416	47	1014	320	140	236	1054	2041		202	330	755	47	189	157	
		351	495	297	231	99	154	99	347	0		50	149	50	198	0	0	
		352	1787	811	2419	11915	3712	4817	2789	2563		862	152	2339	6186	7352	355	
		353	3357	1950	2469	16690	17768	7186	11243	4144		2381	6922	1631	1209	10405	3174	
	183	329	8181	0	10750	6155	300	4972	4856	2736		0	1184	237	758	1615	1473	
		332	13093	2939	8910	2603	5770	1509	14968	1632		2016	3649	3601	2785	10994	6337	
		337	696	1956	3775	1546	4482	782	1198	729		609	391	782	2434	3478	442	
		339	2374	4064	2070	4529	5754	4547	1927	885		2052	885	1742	966	1529	925	
		354	1206	2195	663	4492	1992	978	261	978		1304	359	2305	98	1141	261	
	274	333	153	81	108	27	54	57	30	18		10	73	152	870	40	198	
		336	150	422	518		72	83	50	72		50		164	166	92	96	
		355	27	50	246	94	64	50	101	16		8	28	99	14	21	48	
	366	334	0	7	0	24	18	65	75	47		40	32	13	36	20	40	
		335	24	18	18	0	11	0	27	0		7	4	27	4	16	21	
		356	0	7	0	37	4	56	8	4		0	0	18	4	21	15	
	549	717	93	41	1214	360	100	340	670	434		91	157	449	161	329	167	
		719	95	14	41	167	50	43	12	132		47	58	63	33	0	5	
		721	9	273	68	19	62	38	161	24		30	10	40	125	56	79	
	731	718		479	2013	959	1039	507	489	126		1155	374	1559	180	476	280	
		720	6	6	141	7	14	31	0	165		581	116	162	195	54	55	
		722	51	61	117	89	65	77	44	128		41	19		0	147	6	
	914	764		72		355												
		768		6		34												
		772		111		162												
	1097	765		64		157												
		769		133		218												
		773		79		37												
	1280	766		158		188												
		770		132		18												
		774		35		0												
	1463	767		10		12												
		771		0		0												
		775		28		96												
3NO	Total ('000 t)		14.6	7.7	22.7	37.7	27.0	17.9	27.0	17.7		10.1	7.9	9.5	11.6	15.2	10.2	
UCL	('000 t)		22.9	10.0	30.5	50.6	38.8	22.7	39.6	30.0		15.1	14.9	12.4	20.5	21.6	16.5	
LCL	('000 t)		6.4	5.4	15.0	24.9	15.3	13.2	14.5	5.3		5.1	0.9	6.6	2.7	8.7	3.9	

Table 8. Estimated biomass (t) of witch flounder (M+F) by stratum from surveys in Divs. 3NO during fall of 1990-2005. (Engel 145 data converted to Campelen Units from 1990-1994). Totals and 95% confidence limits given in ('000 t)

DIV	Max Depth (m)	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
3N	55	375	0	73		0	0	0	0	0	0	0	0	0	35	0	0	0
		376	0	0	0	0	0	14	0	47	0	0	0	0	38	28	0	0
	91	360	265	171	1297	173	75	888	38	821	623	177	535	326	520	586	836	2364
		361	28	467	463	0	32	0	0	0	0	268	28	170	148	99	0	168
		362	400	221	87	0	0	0	0	0	0	32	0	0	0	136	0	0
		373	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		374	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
		383	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
	183	359	0	0	278	0	0	22	0	0	1213	1	0	121	42	110	139	43
		377	0		0	0	8	0	0	0	0	0	0	0	0	0	0	0
		382	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	274	358	0	20	66	24	0	74	0	11	30	19	40	45	0	145	22	107
		378	0	41	15	0	0	0	0	1	0	0	0	3	5	0	0	0
		381		0		0	0	0	0	1	0	0	0	7	0	0	0	0
	366	357	0	234	9	187	43	85	0	27	0		52	18	21	41	27	37
		379	4		4	0	0	0	1	7	0	0	2	111	33	8	867	0
		380		0		0	0	0	0	0	1	2	5	0	0	0	9	11
	549	723		41		163	180	57	15	28	74	27	28	66	16	123	20	98
		725			15	376	46	19	0	135	10	33	19	7	5	10		7
		727				0	38	0	0	29	7	4	0	10	0	0	7	21
	731	724		172		414	180	104	60	197	72	181	87	70	90		70	95
		726				310	54	48	40	21	38	34	16	22	59	52	32	19
		728					153	35	21	76	78	106	153	103	286	178	93	19
	914	752									120		23	0	1			
		756									124		51	83	9			82
		760									88		41	78	173			18
	1097	753									0		0	0	3			
		757									0		0	37	7			0
		761									46		147	42	10			118
	1280	754									0		0	0	0			
		758									0		0	0	0			0
		762											0	109	0			15
	1463	755									0		0	0	0			
		759									0		0	2	0			0
		763											19	5	10			0
3O	91	330	122	67	79	0	0	247	0	72	168	208	48	284	342	438	74	312
		331	22	315	134	0	0	108	0	0	256	946	243	468	775	306	14	394
		338	2226	438	837	3966	2193	4684	503	1329	483	2736	375	943	976	2666	3899	1931
		340	173	280	63	0	0	204	0	22	0	415	104	172	123	57	28	116
		351	1690	284	72	0	0	0	0	0	37	205	0	172	0	25	35	54
		352	1415	896	1352	946	228	379	80	1114	388	1491	920	430	789	964	3377	1663
		353	2405	343	477	0	732	538	789	168	1066	2996	2379	1360	1490	1204	2657	3710
	183	329	99	85	0	18	0	417	0	173	305	0	0	282	732	97	484	250
		332	2102	155	1724	813	321	1114	4569	190	245	1664	544	343	1155	807	1512	2061
		337	1333	188	954	563	2132	421	492	322	479	978	344	67	211	352	114	1721
		339	1132	224	651	119	742	1911	0	481	261		344	338	1927	457	3755	1854
		354	1291	23	316	75	210	191	4647	215	201	103	766	258	470	967	438	316
	274	333	221	11	22	30	90	25		4	6	33	4	20	17	48	0	3
		336	82	151	76	298	13	35	32	19	19	67	31	37	23	10	5	35
		355		497	93	120	25	16	343	6	14	110	35	5	6	6	21	2
	366	334	24	16	0	9	18	4		5	1	7	5	14	9	8	0	16
		335	194	25	25	30	18	1	23	0	1	23	8	3	9	1	5	3
		356		11	7	430	98	7	60	3	4	32	22	7	3	6	2	7
	549	717	30			0	57	65		12	42	260	0	13	11	54	9	2
		719	110	2		65	6	1	226	19	9	10	14	29	6	15	3	6
		721		18		169	67	21	54	6	14	67	17	2	14	17	2	15
	731	718				22	82	10		68	47	53	34	50	54	161	48	130
		720				73	0	13	68		2	17	4	83	26	31	10	39
		722		9		81	21	14	39	12	12	26	8	15	5	7	14	29
	914	764									75		12	21	36			4
		768									18		7	18	38			4
		772									173		62		49	29		50
	1097	765									24		3	20	55			10
		769									17		5	28	59			20
		773									4		13	32	89	12		8
	1280	766											24	2	37			57
		770											4	23	67			13
		774											4	31	15	27		43
	1463	767											15	0	0			0
		771											0	17	0			10
		775											0	0	0	28		21

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
3NO	Total ('000 t)	15.4	5.5	9.1	9.5	7.9	11.8	12.1	5.6	6.9	13.3	7.6	7.0	11.1	10.3	18.6	18.1
UCL	('000 t)	19.3	7.3	12.6	15.0	12.6	20.4	37.7	7.9	13.8	17.7	9.4	8.7	15.1	13.7	29.5	25.8
LCL	('000 t)	11.4	3.7	5.7	4.0	3.1	3.2	-13.5	3.4	0.0	8.9	5.9	5.4	7.1	6.9	7.8	10.4

Table 9. Estimated biomass (t) of witch flounder (M+F) in each stratum from surveys in NAFO Divs. 3NO during fall of 2001-2021. Totals and 95% confidence limits given in ('000 t). There were no fall surveys in DIvs. 3NO in 2014 or 2021.

DIV	Max Depth (m)	Stratum	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3N	55	375	0	0	0	0	0	0	0	0		0	0	25	0	0	0	
		376	0	0	0	67	0	0	59	202		23	0	303	121	32	0	
	91	360	100	0	4788	10335	1627	1311	11992	7294		736	566	542	3515	1216	1485	
		361	38	584	25	0	410	190	188	78		0	28	228	366	132	51	
		362	40	0	0	46	192	55	70	90		0	31	0	0	0	0	
		373	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
		374	0	0	0	0	0	0	0	0		0	0	29	0	0	0	
		383	0	0	25	0	0	0	0	27		23	0	0	0	0	0	
	183	359	151	192	442	1080	288	398	190	156		523	42	339	56	72	36	
		377	0	0	0	39	31	10	94	0		0	0	12	7	38	9	
		382	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
	274	358	144	28	141	86	83	104	374	98		0	28	129	83	71	45	
		378	93	4	7	4		22	56	191		446	24	11	11	46	10	
		381	0	0	0	3	0	0	0	0		0	0	0	0	0	0	
	366	357	103	59	90	17	39	5	93	31		166	7	17	25	12	19	
		379	3	0	156	13	29	662	18	4		40	6	55	0	0	12	
		380	0	0	0	0	0	0	0	0		12	0	0	3	3	0	
	549	723	38	17	98	93	27	62	37	38		1278	4	42	7	23	9	
		725	7	11	21	40		12	12	71		83	17	600	43	59	25	
		727	0	0	143	82	21	22	32	17		70	0	45	77	34	62	
	731	724	206	127	455	204	117	143	72	79		10	40	36	24	52	42	
		726	49	45	42	105	6	17	23	4		57	53	149	309	159		
		728	122	191	269	404	434	51	125	213		108	145	149	222	173	298	
	914	752		6														
		756		67														
		760		110		221												
	1097	753		0														
		757		0														
		761		7		102												
	1280	754		0			0											
		758		0														
		762		28		40												
	1463	755		0														
		759		0														
		763		0		3												
3O	91	330	383	362	508	1087	344	708	48	837		984	431	1100	212	1525	588	
		331	108	144	114	564	1219	793	75	688		83	48	102	31	624	153	
		338	604	543	1407	2044	5483	2554	643	1222		884	231	831	403	3762	3379	
		340	654	1	494	116	81	142	575	959		132	154	324	23	1	101	
		351	369	158	165	28	75	65	234	0		34	89	0	120	0	0	
		352	1109	558	1409	5915	2305	2597	1335	1635		476	63	880	3423	662	174	
		353	1587	1121	1431	8037	8234	3098	4323	1446		1204	3689	731	271	2783	1153	
	183	329	2974	0	4484	1977	171	1616	1518	1096		0	465	121	275	630	414	
		332	3887	708	2453	500	1393	284	3372	283		485	963	924	690	1961	1691	
		337	190	576	1592	352	989	158	328	150		222	100	213	700	418	62	
		339	1070	1060	1147	2405	2693	2359	882	320		1273	489	891	303	386	176	
		354	505	694	306	1320	544	312	78	294		531	65	369	23	148	92	
	274	333	24	3	2	5	6	14	0	3		1	6	19	119	0	14	
		336	2	53	142		22	18	8	13		17		32	18	12	2	
		355	5	17	72	23	20	15	41	3		2	8	2	3	1	8	
	366	334	0	0	0	10	2	4	4	8		0	12	1	5	2	1	
		335	3	1	6	0	0	0	7	0		1	1	2	0	10	2	
		356	0	0	0	10	1	8	4	3		0	0	1	0	0	0	
	549	717	14	9	102	40	14	37	52	59		17	8	45	27	11	18	
		719	10	4	8	16	4	8	0	12		7	14	6	3	0	0	
		721	3	30	11	1	7	8	13	2		3	1	5	4	0	12	
	731	718		68	162	80	110	63	50	11		95	23	149	29	62	38	
		720	1	1	12	1	4	10	0	20		63	17	17	24	8	27	
		722	8	9	17	15	11	4	8	13		11	1		0	28	0	
	914	764		11		41												
		768		1		5												
		772		22		26												
	1097	765		11		25												
		769		16		26												
		773		10		5												
	1280	766		24		29												
		770		16		2												
		774		4		0												
	1463	767		3		2												
		771		0		0												
		775		3		13												
3NO	Total ('000 t)		14.6	7.7	22.7	37.7	27.0	17.9	27.0	17.7		10.1	7.9	9.5	11.6	15.2	10.2	
UCL	('000 t)		22.9	10.0	30.5	50.6	38.8	22.7	39.6	30.0		15.1	14.9	12.4	20.5	21.6	16.5	
LCL	('000 t)		6.4	5.4	15.0	24.9	15.3	13.2	14.5	5.3		5.1	0.9	6.6	2.7	8.7	3.9	

Table 10. Summary of abundance ('000s), mean number, biomass ('000t) and mean weight (kg) per tow for witch flounder in Canadian Spring surveys (1984-2021) of NAFO Divs. 3NO. Data prior to 1996 are Campelen equivalents. Survey converage was incomplete in 2006 and there were no spring surveys in Divs. 3NO in 2020 or 2021.

	Abundance ('000s)			Mean Number per tow			Biomass ('000t)			Mean Weight (kg) per tow		
	3N	3O	3NO	3N	3O	3NO	3N	3O	3NO	3N	3O	3NO
1984	3.1	27.1	30.2	1.3	11.0	6.3	2.2	12.1	14.3	1.0	4.9	3.0
1985	1.2	42.9	44.1	0.5	17.4	9.3	0.8	23.8	24.6	0.3	9.7	5.2
1986	1.8	17.3	19.2	0.8	7.0	4.0	1.1	8.1	9.2	0.5	3.3	1.9
1987	2.6	18.3	20.9	1.1	7.4	4.4	1.4	9.8	11.2	0.6	4.0	2.4
1988	4.2	44.2	48.4	1.8	18.0	10.2	2.2	22.4	24.7	1.0	9.1	5.2
1989	1.0	13.8	14.8	0.4	5.6	3.1	0.5	8.5	9.0	0.2	3.5	1.9
1990	0.3	20.5	20.8	0.1	8.6	4.4	0.2	10.6	10.8	0.1	4.4	2.3
1991	2.0	13.3	15.3	0.8	5.2	3.1	0.7	6.4	7.1	0.3	2.5	1.4
1992	1.4	17.7	19.1	0.6	7.0	3.9	0.5	7.7	8.2	0.2	3.0	1.7
1993	1.9	9.0	10.9	0.8	3.5	2.2	0.9	3.4	4.2	0.4	1.3	0.9
1994	1.1	41.4	42.5	0.5	16.0	8.4	0.5	15.8	16.3	0.2	6.1	3.2
1995	0.6	8.5	9.1	0.2	3.3	1.8	0.3	3.7	4.1	0.1	1.5	0.8
1996	0.5	9.6	10.1	0.2	3.8	2.0	0.2	3.9	4.1	0.1	1.5	0.8
1997	1.2	23.7	24.9	0.5	9.3	5.1	0.4	6.7	7.1	0.2	2.6	1.4
1998	1.5	6.4	7.9	0.6	2.5	1.6	0.6	2.1	2.7	0.2	0.8	0.5
1999	1.9	25.0	26.9	0.8	9.8	5.4	0.5	8.4	8.9	0.2	3.3	1.8
2000	2.7	14.2	16.9	1.1	5.6	3.4	1.0	4.4	5.5	0.4	1.7	1.1
2001	1.8	24.7	26.5	0.7	9.7	5.4	0.6	8.8	9.4	0.3	3.4	1.9
2002	1.0	19.3	20.3	0.4	7.5	4.1	0.4	7.2	7.6	0.2	2.8	1.5
2003	1.3	45.9	47.2	0.5	18.0	9.5	0.5	15.3	15.9	0.2	6.0	3.2
2004	0.7	32.8	33.4	0.3	12.8	6.7	0.3	11.5	11.8	0.1	4.5	2.4
2005	3.4	18.0	21.4	1.4	7.1	4.3	1.8	5.1	6.9	0.8	2.0	1.4
2006												
2007	2.7	15.6	18.3	1.1	6.1	3.7	1.4	5.7	7.2	0.6	2.3	1.5
2008	1.1	25.8	26.9	0.4	10.1	5.4	0.5	8.3	8.8	0.2	3.3	1.8
2009	4.3	25.2	29.5	1.8	9.9	6.0	1.9	7.2	9.2	0.8	2.8	1.9
2010	4.5	15.1	19.5	1.9	5.9	3.9	1.8	4.8	6.6	0.8	1.9	1.3
2011	5.8	21.1	27.0	2.4	8.3	5.5	2.4	7.3	9.7	1.0	2.9	2.0
2012	2.4	32.4	34.8	1.0	12.7	7.1	1.1	11.7	12.8	0.5	4.6	2.6
2013	2.4	65.9	68.3	1.0	25.8	13.8	1.2	23.2	24.4	0.5	9.1	4.9
2014	4.5	34.7	39.1	1.9	13.6	7.9	2.5	8.2	10.7	1.0	3.2	2.2
2015	2.7	10.6	13.3	1.1	4.2	2.7	1.5	3.5	4.9	0.6	1.4	1.0
2016	3.6	13.3	16.8	1.5	5.3	3.4	1.9	5.2	7.1	0.8	2.1	1.5
2017	8.8	13.1	22.0	3.7	5.1	4.4	4.7	4.4	9.1	2.0	1.7	1.8
2018	3.7	19.7	23.4	1.5	7.7	4.7	2.0	6.0	8.1	0.8	2.4	1.6
2019	2.3	33.6	35.9	0.9	13.3	7.3	0.9	7.0	7.9	0.4	2.8	1.6
2020												
2021												

Table 11. Summary of abundance (‘000s), mean number, biomass (‘000t) and mean weight (kg) per tow for witch flounder in Canadian Fall surveys (1990-2021) of NAFO Divs. 3NO. Data prior to 1995 are Campelen equivalents. There were no fall surveys in Div. 3NO for 2014 or 2021.

	Abundance ('000s)			Mean Number per tow			Biomass ('000t)			Mean Weight (kg) per tow		
	3N	3O	3NO	3N	3O	3NO	3N	3O	3NO	3N	3O	3NO
1990	0.9	21.1	21.9	0.4	8.6	4.7	0.7	14.7	15.4	0.3	6.0	3.3
1991	2.0	7.2	9.2	0.9	2.9	1.9	1.4	4.0	5.5	0.6	1.6	1.1
1992	3.3	14.5	17.8	1.8	5.9	4.1	2.2	6.9	9.1	1.2	2.8	2.1
1993	3.5	15.5	19.0	1.5	6.1	3.9	1.6	7.8	9.5	0.7	3.1	1.9
1994	1.8	15.5	17.3	0.7	6.1	3.5	0.8	7.1	7.9	0.3	2.8	1.6
1995	2.5	24.4	26.8	1.0	9.6	5.4	1.3	10.4	11.8	0.6	4.1	2.4
1996	0.5	25.5	26.0	0.2	10.3	5.3	0.2	11.9	12.1	0.1	4.8	2.5
1997	2.7	11.7	14.4	1.1	4.6	2.9	1.4	4.2	5.6	0.6	1.7	1.1
1998	5.7	20.3	26.0	2.2	7.6	4.9	2.5	4.4	6.9	1.0	1.6	1.3
1999	2.1	38.6	40.7	0.9	15.6	8.4	0.9	12.4	13.3	0.4	5.0	2.7
2000	3.2	22.9	26.1	1.2	8.3	4.8	1.2	6.4	7.6	0.5	2.3	1.4
2001	3.8	15.5	19.3	1.4	5.6	3.5	1.4	5.6	7.0	0.5	2.0	1.3
2002	3.7	33.6	37.3	1.4	12.1	6.8	1.5	9.6	11.1	0.6	3.5	2.0
2003	2.9	26.3	29.2	1.2	10.0	5.8	1.5	8.8	10.3	0.6	3.3	2.1
2004	3.8	41.1	44.9	1.6	16.1	9.1	2.1	16.5	18.6	0.9	6.5	3.8
2005	7.0	39.3	46.3	2.7	14.2	8.7	3.2	14.9	18.1	1.3	5.4	3.4
2006	2.1	35.8	38.0	0.9	14.1	7.7	1.1	13.5	14.6	0.5	5.3	3.0
2007	3.3	18.7	22.0	1.2	6.7	4.0	1.5	6.2	7.7	0.5	2.2	1.4
2008	14.3	41.5	55.8	5.9	16.3	11.3	6.7	16.0	22.7	2.8	6.3	4.6
2009	24.3	60.6	84.9	9.7	22.0	16.1	13.0	24.7	37.7	5.2	9.0	7.2
2010	6.7	60.0	66.8	2.8	23.5	13.5	3.3	23.7	27.0	1.4	9.3	5.5
2011	6.3	38.4	44.6	2.6	15.0	9.0	3.1	14.9	17.9	1.3	5.8	3.6
2012	25.2	42.5	67.6	10.5	16.6	13.7	13.4	13.6	27.0	5.6	5.3	5.5
2013	19.7	24.4	44.1	8.2	9.6	8.9	8.6	9.1	17.7	3.6	3.6	3.6
2014												
2015	6.7	16.3	23.0	2.8	6.4	4.6	3.6	6.5	10.1	1.5	2.6	2.0
2016	1.9	16.6	18.5	0.8	6.5	3.8	1.0	6.9	7.9	0.4	2.7	1.6
2017	4.9	21.3	26.2	2.1	8.4	5.3	2.7	6.8	9.5	1.1	2.7	1.9
2018	8.8	17.9	26.7	3.7	7.0	5.4	4.9	6.7	11.6	2.0	2.6	2.3
2019	5.4	55.4	60.8	2.2	21.7	12.3	2.1	13.0	15.2	0.9	5.1	3.1
2020	3.9	25.2	29.1	1.6	9.9	5.9	2.1	8.1	10.2	0.9	3.2	2.1
2021												

Table 12. Input Indices used in the Bayesian surplus production model for the 2022 assessment of witch flounder in NAFO Divs. 3NO.

Year	Nominal catch (000 t)	Campelen Spring (Late) (000 t)	Campelen Fall (000 t)	Campelen Spring (Early) (000 t)
1960	5.80			
1961	4.63			
1962	1.23			
1963	2.18			
1964	1.07			
1965	2.18			
1966	7.52			
1967	11.50			
1968	10.60			
1969	4.70			
1970	6.76			
1971	14.97			
1972	9.18			
1973	6.69			
1974	8.05			
1975	6.17			
1976	6.04			
1977	5.76			
1978	3.47			
1979	3.08			
1980	2.42			
1981	2.43			
1982	3.73			
1983	3.62			
1984	2.80			14.31
1985	8.77			24.58
1986	9.13			9.21
1987	7.60			11.20
1988	7.33			24.66
1989	3.69			8.99
1990	4.18		15.37	10.76
1991	4.85	7.07	5.48	
1992	4.96	8.22	9.12	
1993	4.41	4.23	9.47	
1994	1.12	16.28	7.82	
1995	0.30	4.06	11.74	
1996	0.36	4.09	12.28	
1997	0.51	7.13	4.69	
1998	0.61	2.69	6.69	
1999	0.76	8.94	13.33	
2000	0.55	5.49	7.64	
2001	0.69	9.42	7.02	
2002	0.45	7.56	11.13	
2003	1.54	15.86	10.32	
2004	0.63	11.83	18.63	
2005	0.26	6.87	18.13	
2006	0.48		14.61	
2007	0.22	7.19	7.72	
2008	0.26	8.83	22.74	
2009	0.38	9.18	37.71	
2010	0.42	6.64	27.04	
2011	0.35	9.75	17.94	
2012	0.32	12.84	27.03	
2013	0.33	24.40	17.67	
2014	0.34	10.70		
2015	0.36	4.93	10.10	
2016	1.06	7.13	7.87	
2017	0.66	9.05	9.48	
2018	0.64	8.05	11.58	
2019	0.86	7.92	15.16	
2020	0.67		10.21	
2021	0.63			

Table 13. Assessment results for Divs 3NO witch flounder: the accepted 2022 surplus production model in a Bayesian framework, compared to the previous two assessments of this stock.

	2019 assessment	2020 assessment	2022 assessment
Bmsy	60.02	59.88	60.51
Bratio 2018	0.39	0.41	0.42
Bratio 2019		0.44	0.44
Bratio 2021			0.47
MSY	3.78	3.79	3.762
Fmsy	0.063	0.063	0.062
Fratio 2018	0.463	0.440	0.559
Fratio 2019		0.526	0.410
Fratio 2021			0.361
K	120.0	119.8	121.0
r	0.126	0.127	0.124
q.spearly	0.414	0.416	0.413
q.splate	0.325	0.322	0.321
q.fallcam	0.487	0.484	0.478
Pin	0.813	0.814	0.817
deviance	354.0	363.6	368.4
sigma	0.067	0.066	0.061
tau.spearly	0.259	0.258	0.257
tau.splate	0.201	0.192	0.192
tau.fallcam	0.154	0.150	0.146

Table14. Projected yield (t) and the risk of $F>F_{lim}$, $B<B_{lim}$ and $B<B_{MSY}$ and probability of stock growth ($B_{2025}>B_{2022}$) under projected F values of F=0, F_{2021}, 2/3 F_{MSY}, 85% F_{MSY}, and F_{MSY}, and constant catch of 1 175t for two scenarios (catch in 2022=TAC (1 175t) and catch in 2022=700 t).

Catch 2022=1 175 t	Yield (t)		$P(F>F_{lim})$		$P(B<B_{lim})$			$P(B<B_{msy})$			
	2023	2024	2023	2024	2023	2024	2025	2023	2024	2025	$P(B_{2025}>B_{2022})$
F0	0	0	12%	<1%	8%	6%	4%	92%	89%	86%	73%
F_{2021} = 0.022	699	744	12%	1%	8%	7%	5%	92%	89%	87%	68%
$Catch_{2023}$ & $Catch_{2024}$= 1 175t	1175	1175	12%	11%	8%	7%	6%	92%	90%	87%	65%
2/3 Fmsy = 0.041	1295	1367	12%	19%	8%	8%	7%	92%	90%	88%	64%
85% Fmsy =0.053	1651	1724	12%	37%	8%	8%	8%	92%	90%	88%	62%
Fmsy=0.062	1943	2010	12%	50%	8%	9%	9%	92%	90%	89%	60%

Catch2022= 700 t	Yield (t)		$P(F>F_{lim})$		$P(B<B_{lim})$			$P(B<B_{msy})$			
	2023	2024	2023	2024	2023	2024	2025	2023	2024	2025	$P(B_{2025}>B_{2022})$
F0	0	0	<1%	0%	8%	5%	3%	92%	89%	85%	74%
F_{2019} = 0.033	710	755	<1%	1%	8%	6%	5%	92%	89%	86%	70%
$Catch_{2021}$ & $Catch_{2022}$= 1 175t	1175	1175	<1%	10%	8%	9%	8%	93%	91%	89%	65%
2/3 F_{msy} = 0.042	1315	1387	<1%	18%	8%	7%	6%	92%	90%	87%	66%
85% F_{msy} =0.054	1676	1749	<1%	37%	8%	7%	7%	92%	90%	88%	63%
F_{msy}=0.063	1972	2039	<1%	50%	8%	8%	8%	92%	90%	88%	62%

Table 15. Medium-term projections for witch flounder assuming TAC is taken in 2022. The 10th, 50th and 90th percentiles of catch and relative biomass B/B_{msy}, are shown, for projected F values of F=0, F_{2021}, 2/3 F_{msy}, 85% F_{msy}, F_{msy} and constant catch of 1 175 t. Two catch scenarios are projected, catch in 2022= TAC (1 175 t) and catch in 2022=700 t.

Projections with catch in 2022 = TAC (1 175 t)

Year	Yield (t) median	Projected relative Biomass(B/B_{msy}) median (80% CL)
F0		
2023	0	0.53 (0.31, 0.94)
2024	0	0.58 (0.34, 1.03)
2025		0.62 (0.37, 1.12)
F_{2021} = 0.022		
2023	699	0.53 (0.31, 0.94)
2024	744	0.56 (0.33, 1.01)
2025		0.60 (0.35, 1.09)
Catch 1 175t		
2023	1175	0.53 (0.31, 0.94)
2024	1175	0.56 (0.32, 1.00)
2025		0.58 (0.33, 1.07)
2/3 F_{msy} = 0.041		
2023	1295	0.53 (0.31, 0.94)
2024	1367	0.55 (0.32, 1.00)
2025		0.58 (0.33, 1.06)
85% F_{msy} =0.053		
2023	1651	0.53 (0.31, 0.94)
2024	1724	0.55 (0.32, 1.00)
2025		0.56 (0.32, 1.05)
F_{msy} =0.062		
2023	1943	0.53 (0.31, 0.94)
2024	2010	0.54 (0.31, 0.99)
2025		0.55 (0.31, 1.04)

Projections with catch in 2022=700 t

Year	Yield (t) median	Projected relative Biomass(B/B_{msy}) median (80% CL)
F0		
2023	0	0.54 (0.32, 0.95)
2024	0	0.58 (0.35, 1.04)
2025		0.63 (0.38, 1.13)
F_{2021} = 0.022		
2023	710	0.54 (0.32, 0.95)
2024	755	0.57 (0.34, 1.02)
2025		0.61 (0.36, 1.10)
Catch 1 175t		
2023	1175	0.49 (0.30, 0.90)
2024	1175	0.52 (0.31, 0.97)
2025		0.54 (0.31, 1.03)
2/3 F_{msy} = 0.041		
2023	1315	0.54 (0.32, 0.95)
2024	1387	0.56 (0.33, 1.01)
2025		0.58 (0.34, 1.07)
85% F_{msy} =0.053		
2023	1676	0.54 (0.32, 0.95)
2024	1749	0.56 (0.32, 1.01)
2025		0.57 (0.32, 1.06)
F_{msy} =0.062		
2023	1972	0.54 (0.32, 0.95)
2024	2039	0.55 (0.32, 1.00)
2025		0.56 (0.32, 1.05)

Table 16. Convergence criteria and diagnostics for 2022 witch flounder Bayesian surplus production model.

		Stats (miniter=1 maxiter=4500 sample=4500) Bin size for caculating Batch SE and (Lag 1) ACF=50									Geweke convergence diag. fraction in 1st window 0.1 fraction in last window 0.5 (between -2 and 2 is good)		Brooks, Gelman, and Rubin Convergence diagnostics (near 1 is good)		
	Chain	Mean	SD	Naïve SE	MC Error	Batch SE	Batch ACF	0.025	0.5	0.975	z-score	p-score	Potential Scale Reduction Factors	Multivariate SRF	Corrected SRF
r	1	0.13	0.04	0.00	0.00	0.00	0.03	0.08	0.13	0.22	1.65640393	0.09764005	1.000696	1.001155	Estimate 0.975
	2	0.13	0.04	0.00	0.00	0.00	-0.07	0.08	0.12	0.22	0.1972336	0.8436447			x 1.002498 1.00499
	3	0.13	0.04	0.00	0.00	0.00	0.00	0.08	0.12	0.22	-0.2634125	0.7922327			
sigma	1	0.076	0.061	0.001	0.002	0.002	0.077	0.003	0.062	0.227	1.3682419	0.1712364	1.000721	1.001192	Estimate 0.975
	2	0.074	0.061	0.001	0.002	0.002	0.020	0.003	0.060	0.222	0.1435649	0.8858441			x 1.000992 1.003527
	3	0.074	0.060	0.001	0.002	0.002	0.001	0.001	0.061	0.220	-0.3347164	0.737839			
K	1	120.475	21.795	0.325	0.639	0.643	0.084	77.800	120.400	165.553	-1.7614764	0.0781578	1.001338	1.002117	Estimate 0.975
	2	121.358	21.529	0.321	0.602	0.529	0.079	78.461	121.700	165.500	0.1254405	0.9001748			x 1.001446 1.005631
	3	120.808	21.707	0.324	0.580	0.573	-0.009	78.344	121.100	166.100	0.03805225	0.96964602			
logq.spearly	1	0.432	0.115	0.002	0.002	0.002	0.153	0.259	0.416	0.703	-0.2858475	0.7749949	1.000441	1.000772	Estimate 0.975
	2	0.426	0.112	0.002	0.002	0.002	-0.040	0.259	0.411	0.695	-0.72236	0.4700731			x 1.001203 1.002992
	3	0.430	0.123	0.002	0.002	0.002	0.119	0.254	0.411	0.729	1.6218036	0.1048454			
logq.splate	1	0.338	0.103	0.002	0.004	0.004	-0.055	0.179	0.322	0.579	-0.1837997	0.8541706	1.002961	1.004549	Estimate 0.975
	2	0.331	0.097	0.001	0.003	0.003	0.022	0.176	0.319	0.551	-0.4715244	0.6372663			x 1.003609 1.01215
	3	0.337	0.105	0.002	0.004	0.004	0.189	0.178	0.322	0.581	0.3725274	0.7095002			
logq.fall	1	0.504	0.151	0.002	0.006	0.005	-0.078	0.269	0.481	0.856	-0.2391951	0.8109543	1.002837	1.004363	Estimate 0.975
	2	0.495	0.144	0.002	0.005	0.005	0.049	0.264	0.475	0.842	-0.3949042	0.6929136			x 1.00302 1.011208
	3	0.503	0.155	0.002	0.007	0.006	0.192	0.267	0.478	0.862	0.4851887	0.6275425			

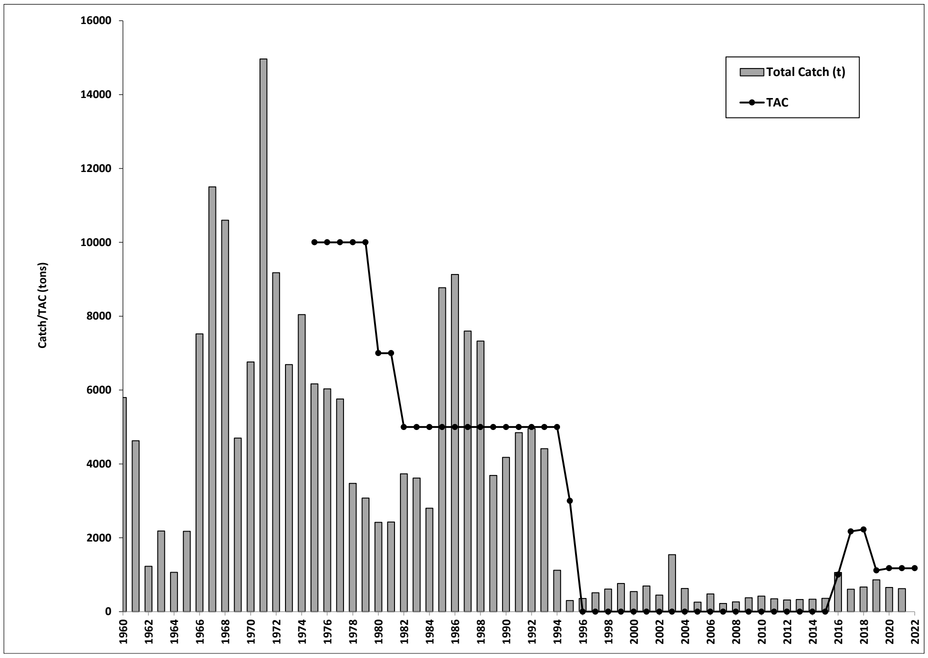


Figure 1. Commercial catch of witch flounder in NAFO Divs. 3NO from 1960-2022 and total allowable catch (TACs).

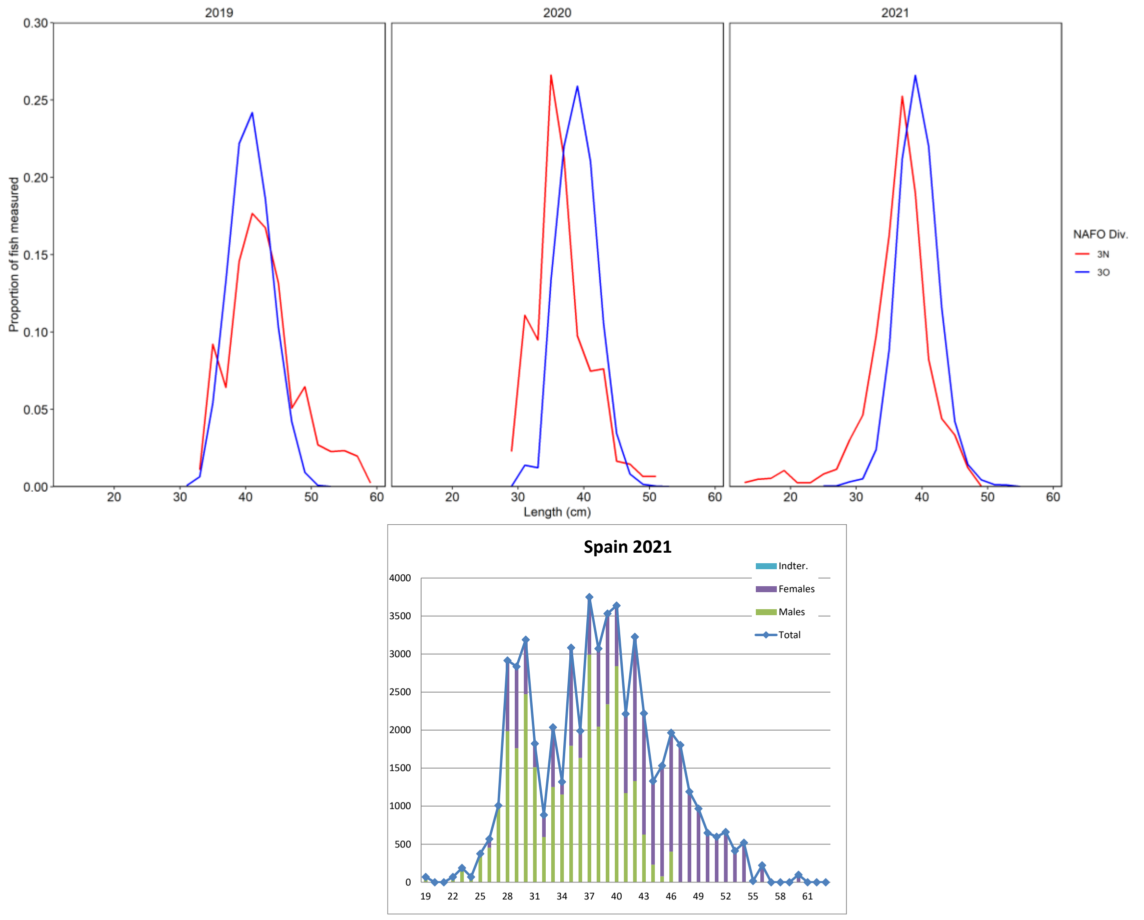


Figure 2. Witch flounder length frequency (cm) distributions for commercial fisheries by Spain and Canada in NAFO Divs. 3NO.

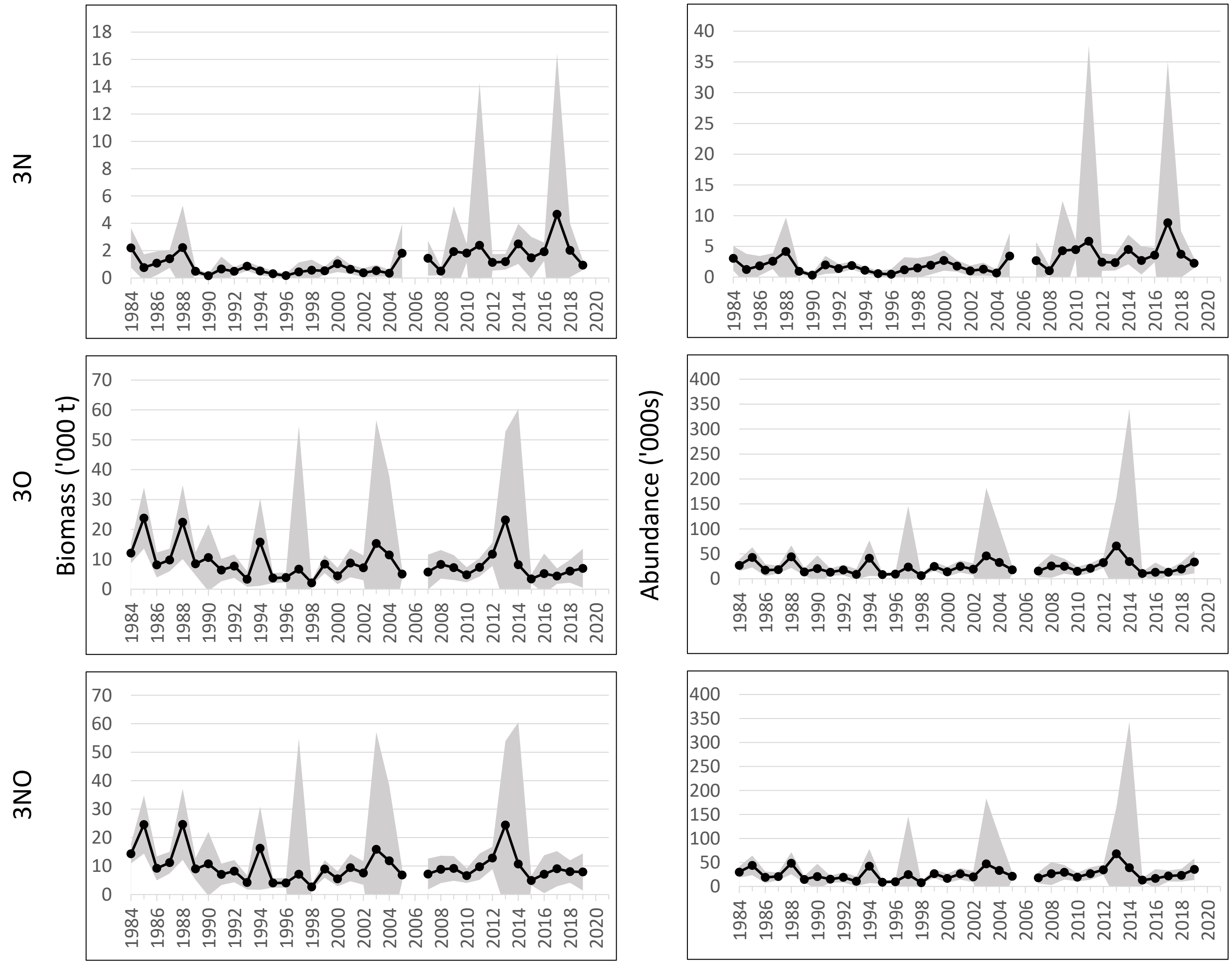


Figure 3. Biomass (‘000s t), abundance (millions), with associated 95% confidence intervals, for witch flounder from Canadian spring RV surveys in NAFO Divs. 3N and 3O during 1984-2021. The 2006 Canadian spring survey in NAFO Divs. 3NO was incomplete and coverage is not considered representative. There were no spring surveys in Divs. 3NO in 2020 or 2021.

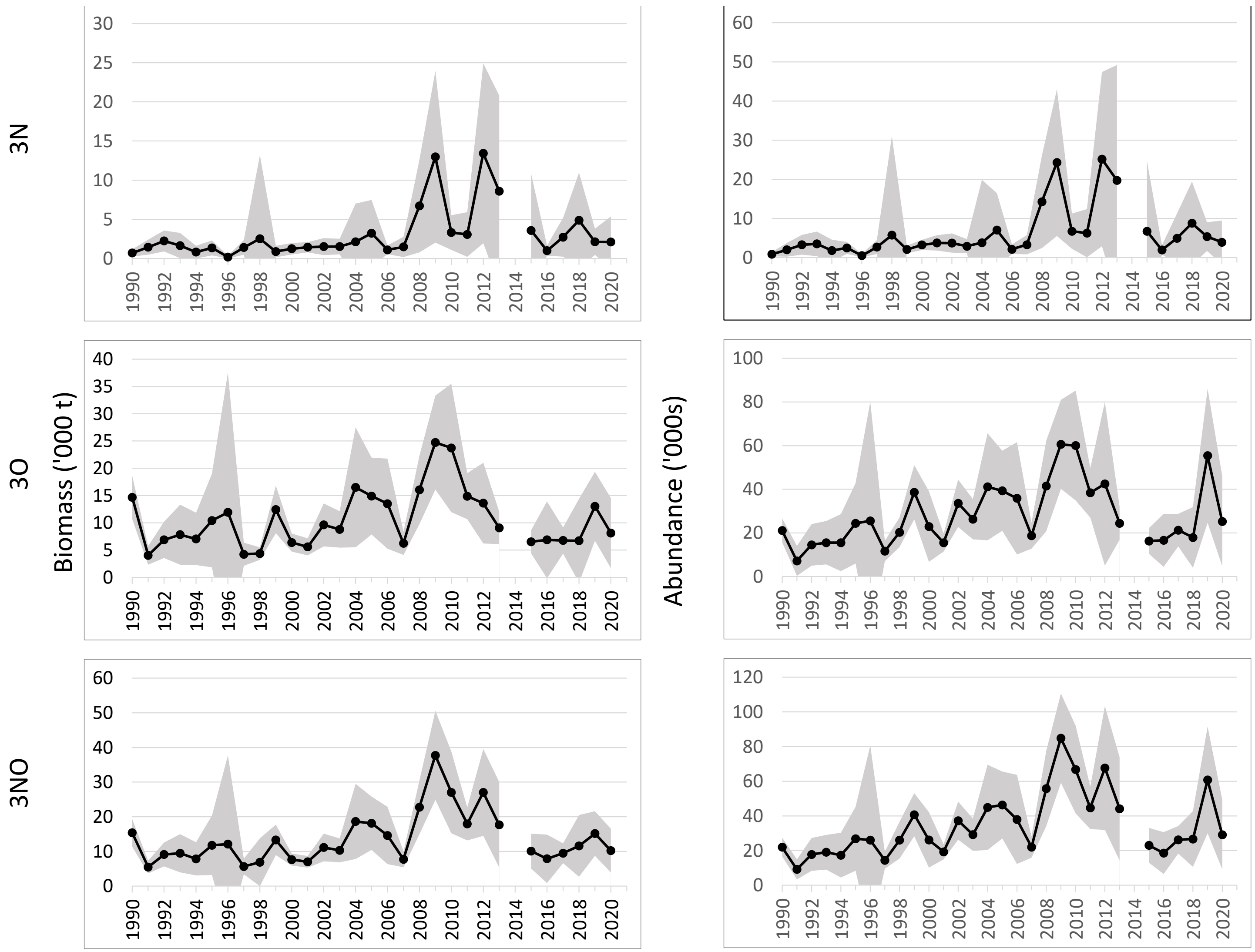


Figure 4. Biomass ('000s t), abundance (millions), with associated 95% confidence intervals, for witch flounder from Canadian fall RV surveys in NAFO Divs. 3N and 3O during 1984-2021. The 2014 Canadian fall survey in NAFO Divs. 3NO was incomplete and coverage is not considered representative. There was no fall survey in Divs. 3NO in 2021.

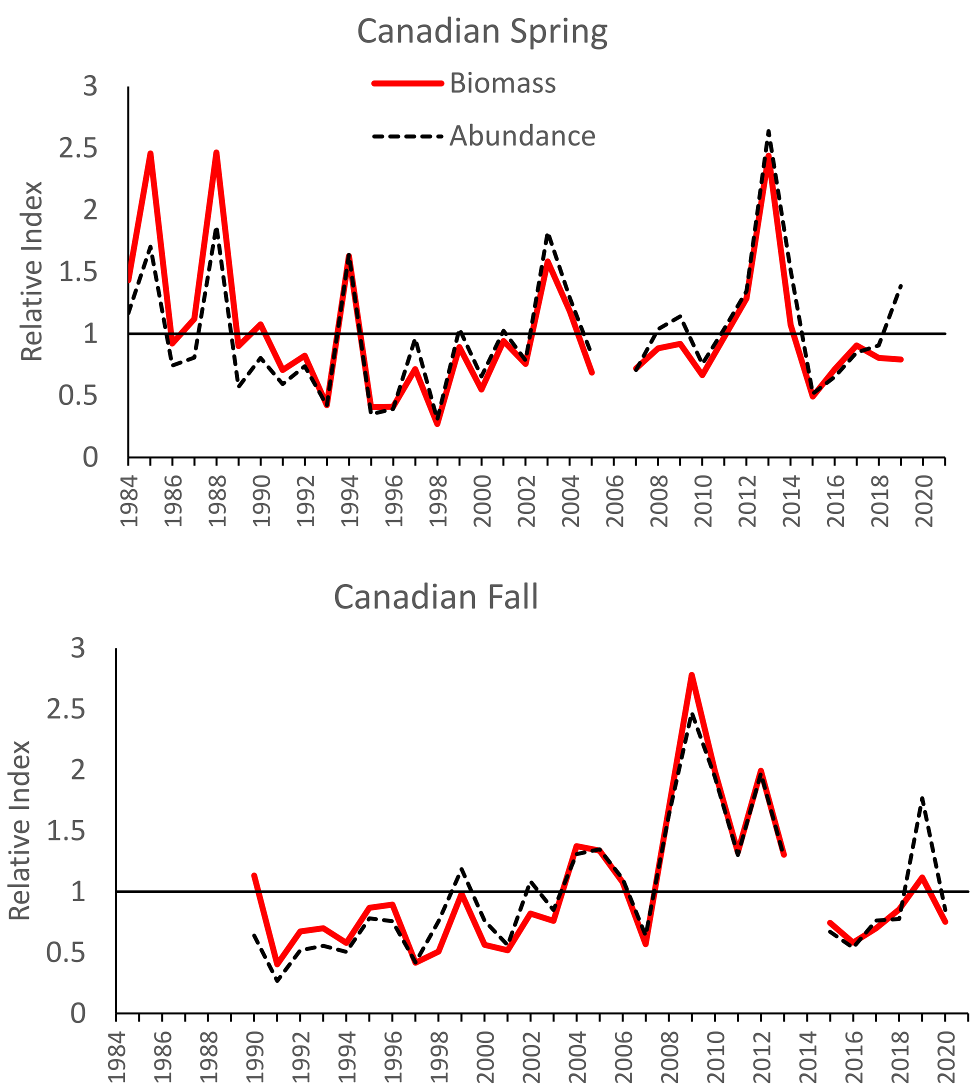


Figure 5. Biomass and abundance indices scaled to the series means for witch flounder from Canadian fall RV surveys in NAFO Divs. 3N and 3O during 1984-2021. The 2006 spring and 2014 fall surveys in NAFO Divs. 3NO were incomplete and coverage is not considered representative. There were no surveys in Divs. 3NO in spring of 2020 or 2021 nor in fall of 2021.

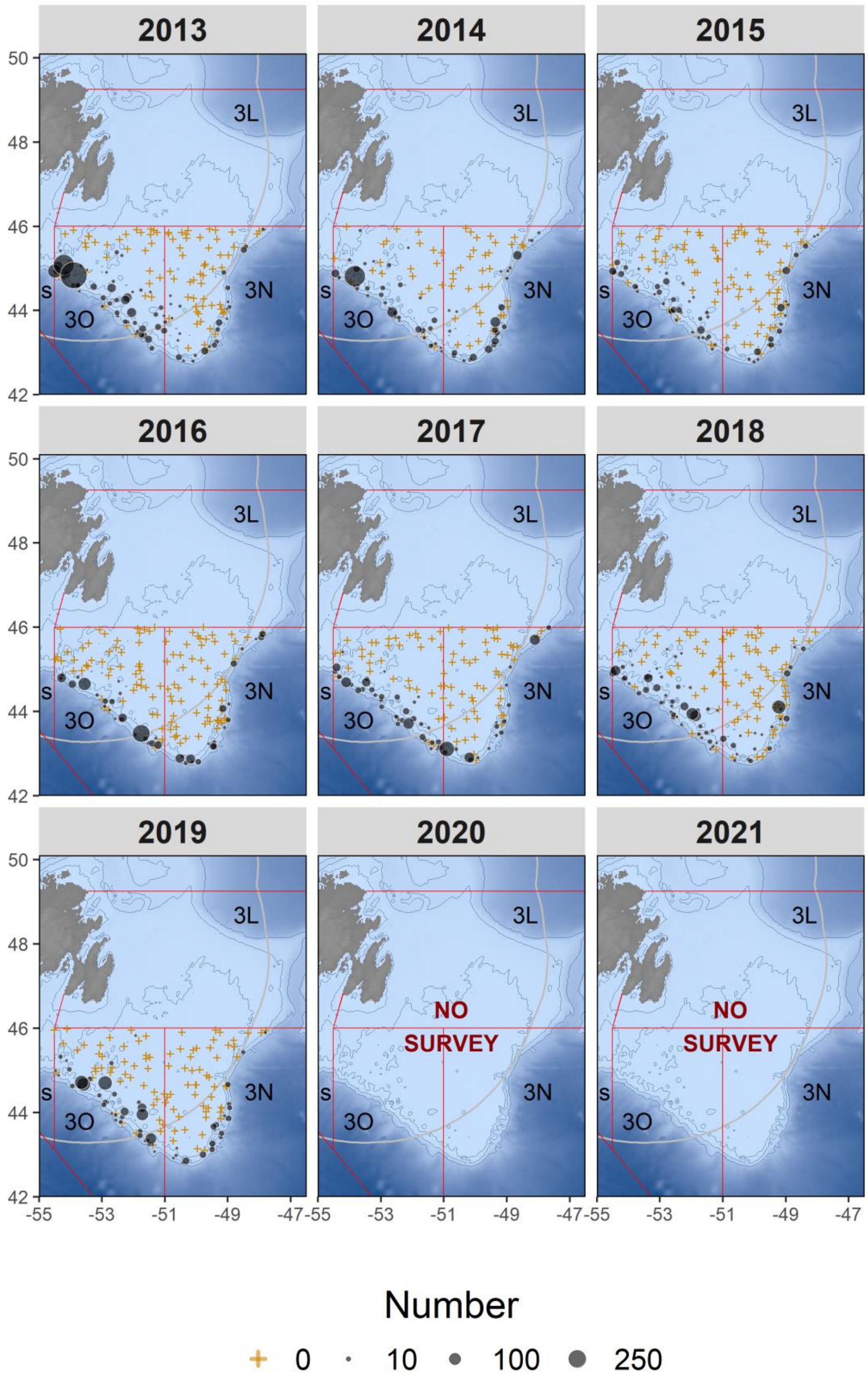


Figure 6. Distribution of witch flounder (total number per tow) from Canadian spring RV surveys in NAFO Divs. 3NO from 2013 to 2021. Spring surveys were not conducted in 2020 or 2021.

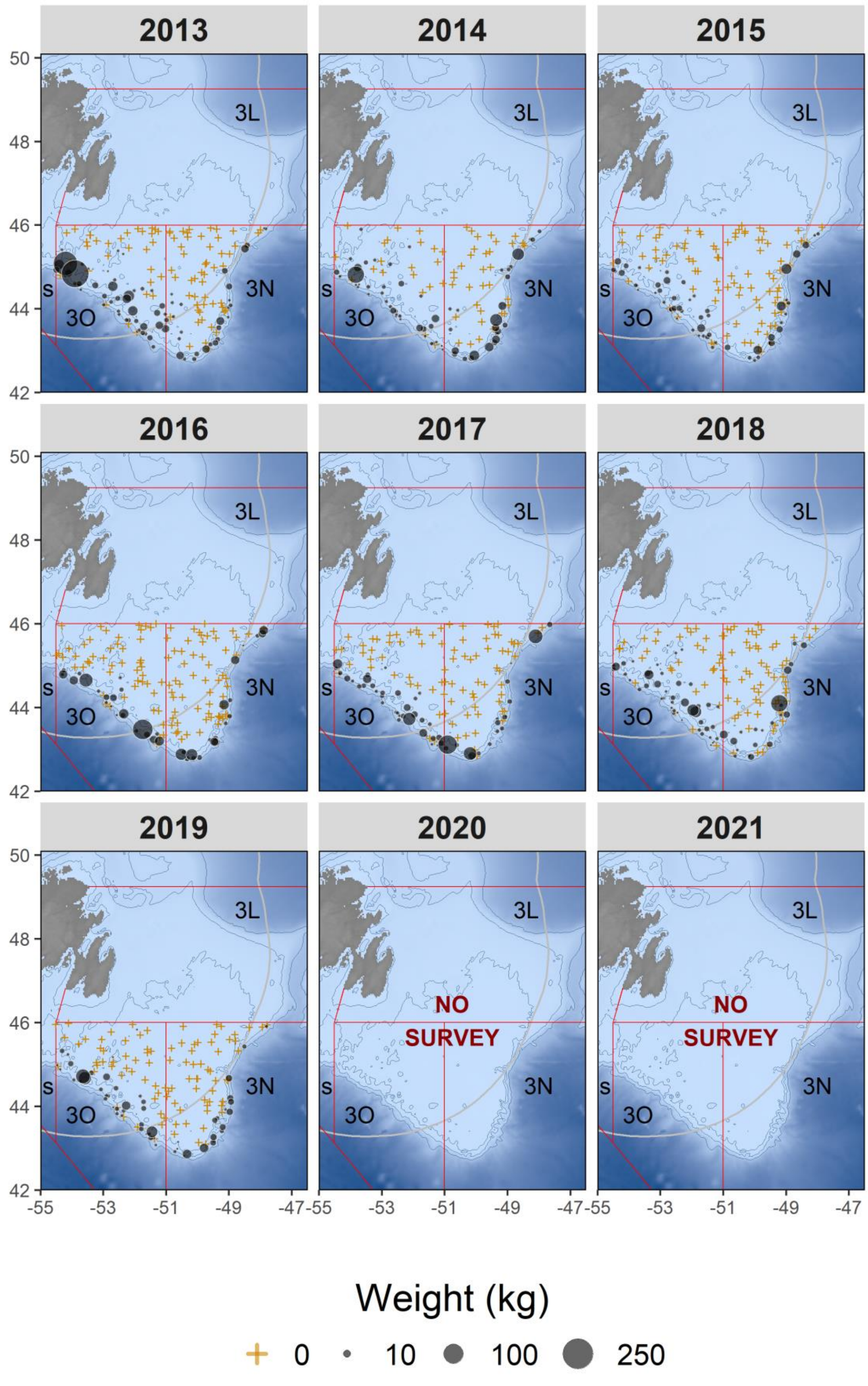


Figure 7. Distribution of witch flounder (total weight (kg) per tow) from Canadian spring RV surveys in NAFO Divs. 3NO from 2013 to 2021. Spring surveys were not conducted in 2020 or 2021.

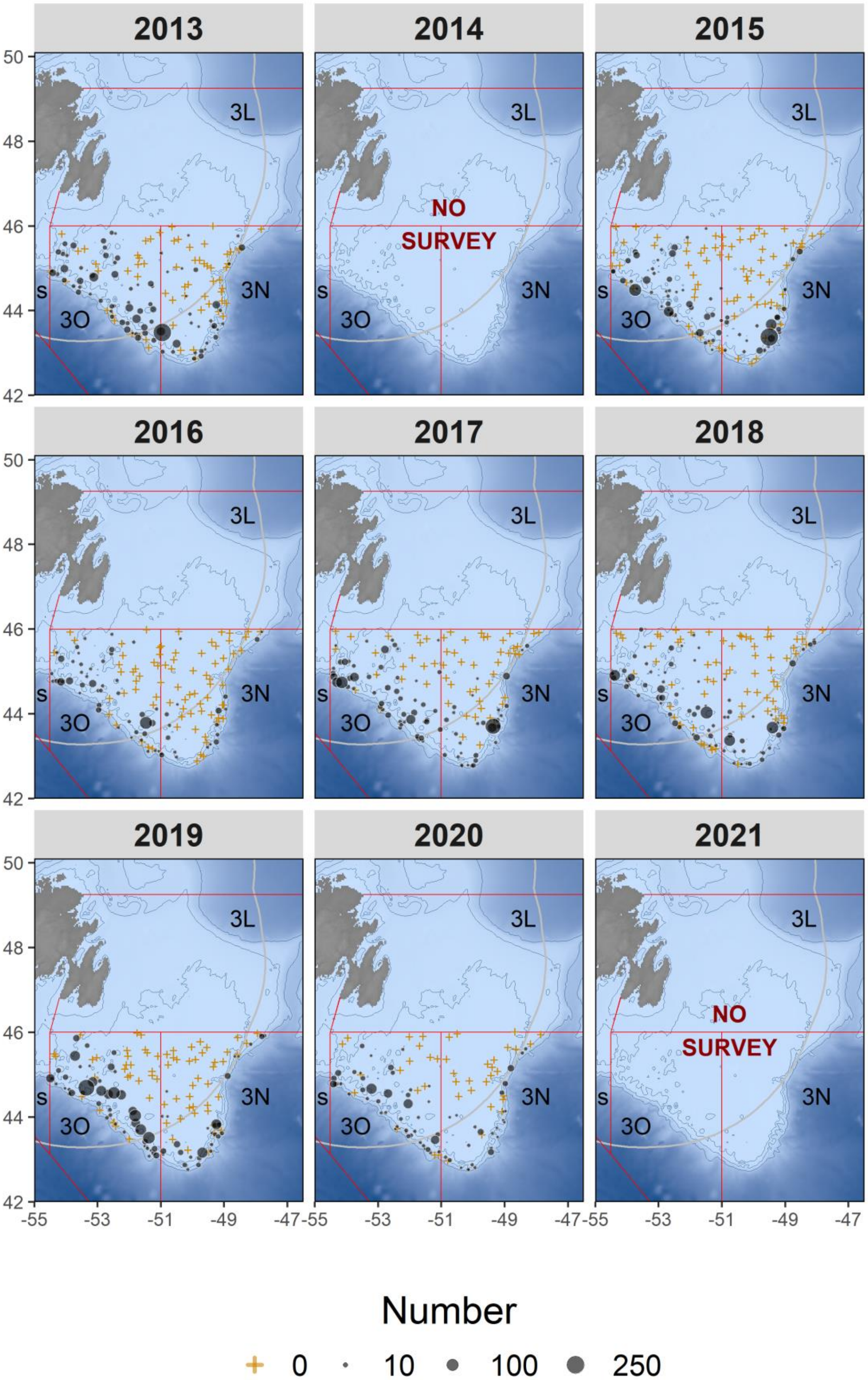


Figure 8. Distribution of witch flounder (total number per tow) from Canadian fall RV surveys in NAFO Divs. 3NO from 2013 to 2021. There were no fall surveys in 2014 or 2021.

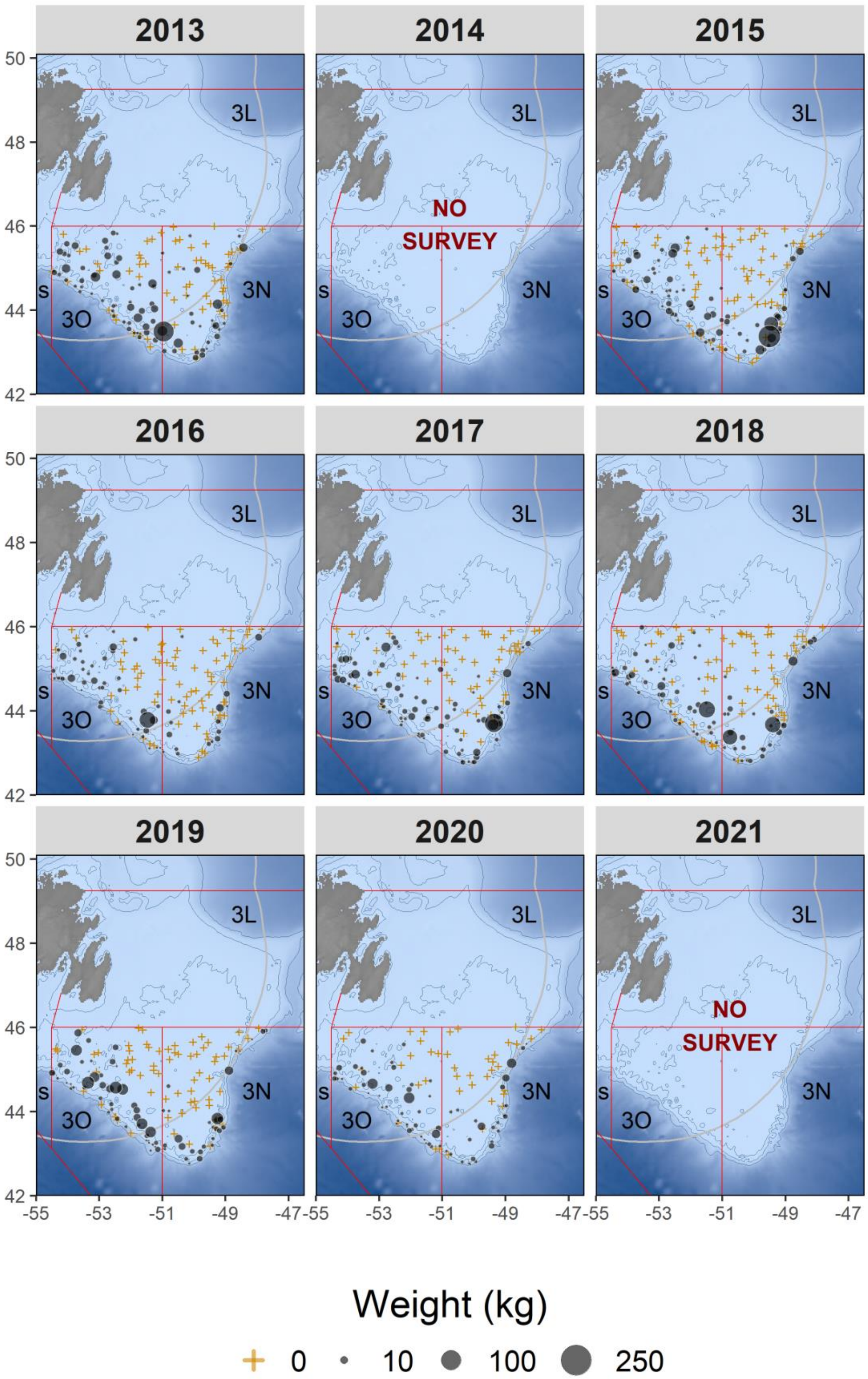


Figure 9. Distribution of witch flounder (total weight (kg) per tow) from Canadian fall RV surveys in NAFO Divs. 3NO from 2013 to 2021. There were no fall surveys in 2014 or 2021.

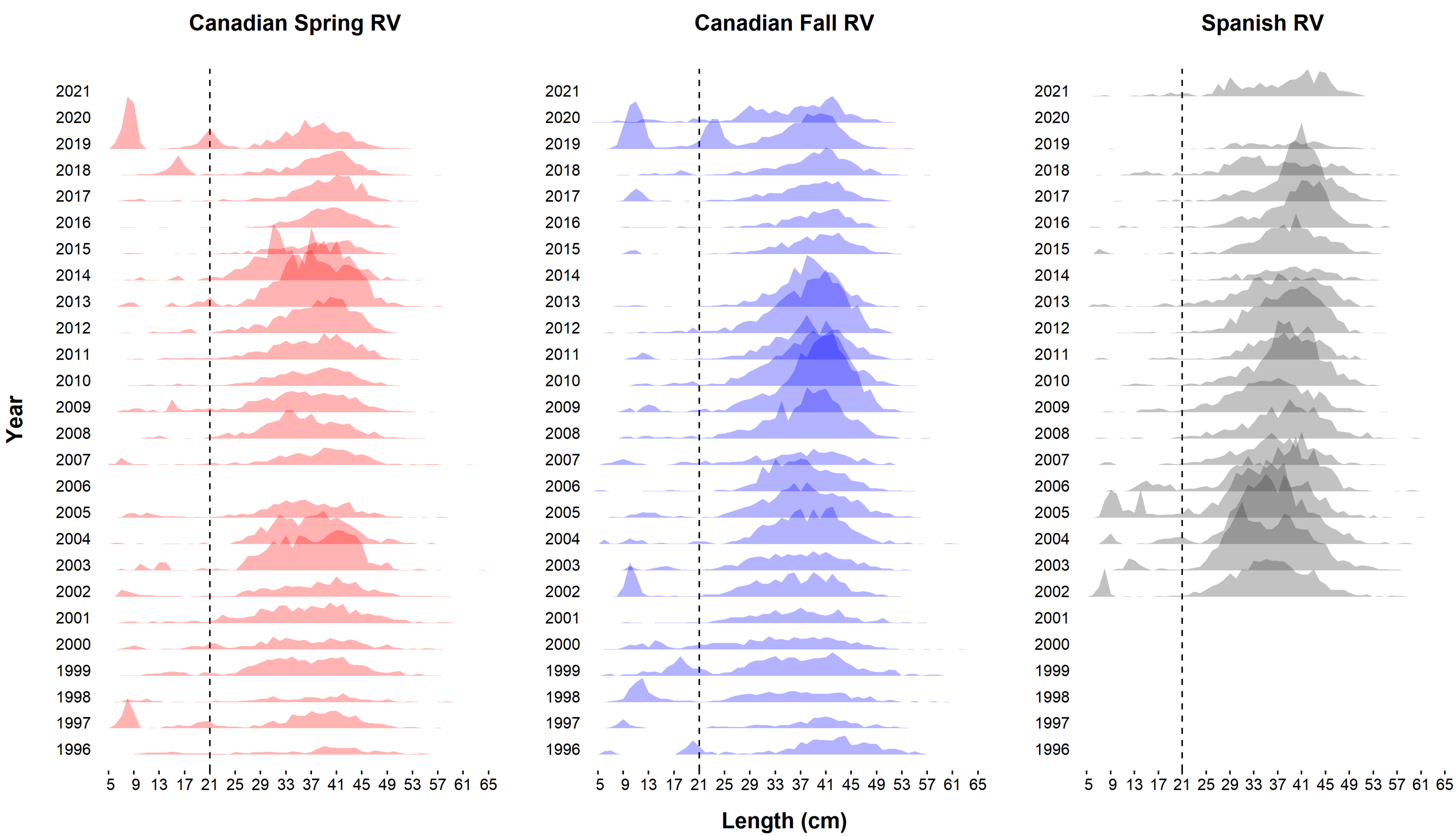


Figure 10. Length frequency distributions of witch flounder from Canadian spring and fall and Spanish spring surveys using the Campelen 1800 shrimp trawl. Estimates represent abundance at length (cm) of the surveyed area. All distributions are for NAFO Divs. 3NO combined.

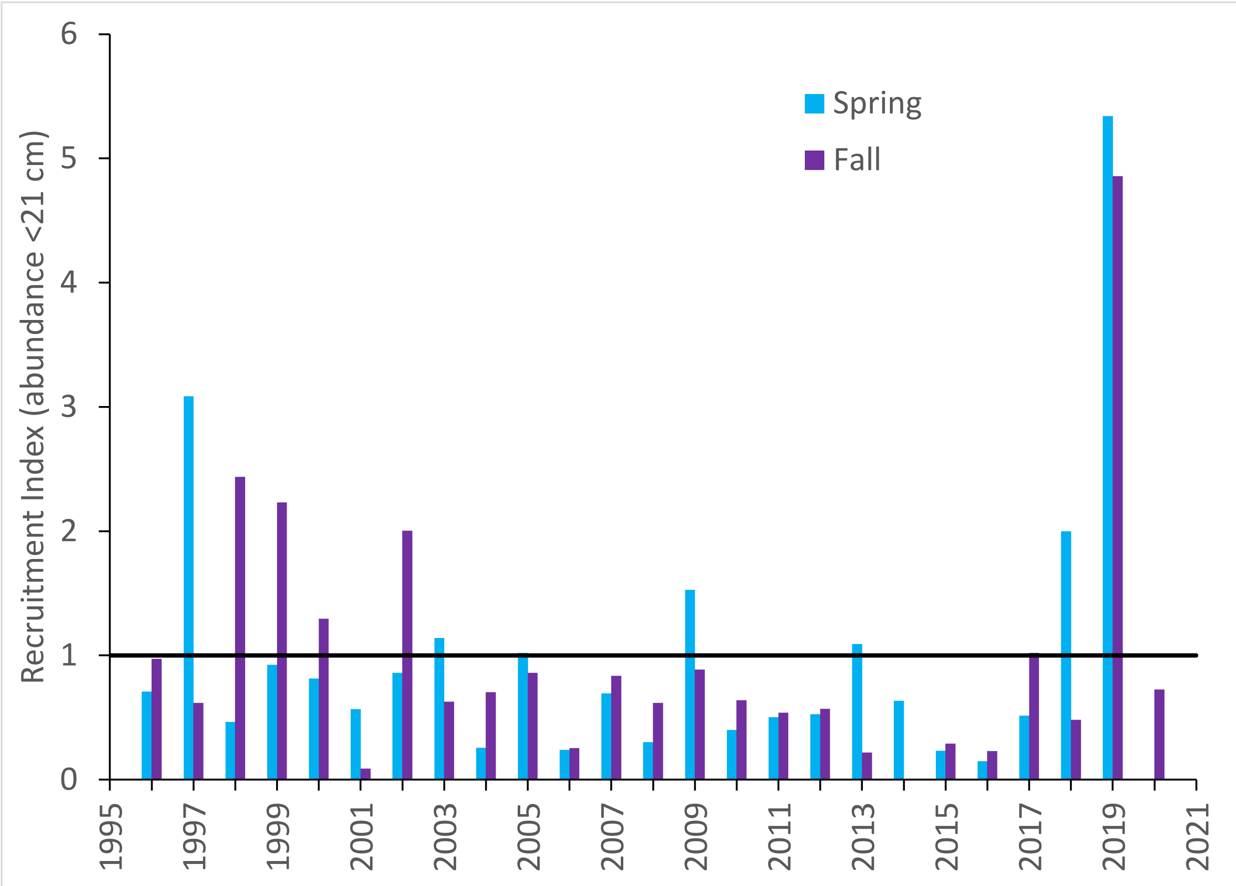


Figure 11. Recruitment index (annual number of witch flounder <21cm scaled to the series mean) spring and fall Canadian RV surveys in NAFO Divs. 3NO 1996-2021. Surveys in spring 2006 and fall 2014 were incomplete and are not considered representative. There were no surveys in Divs. 3NO in spring of 2020 and 2021, nor in fall of 2021.

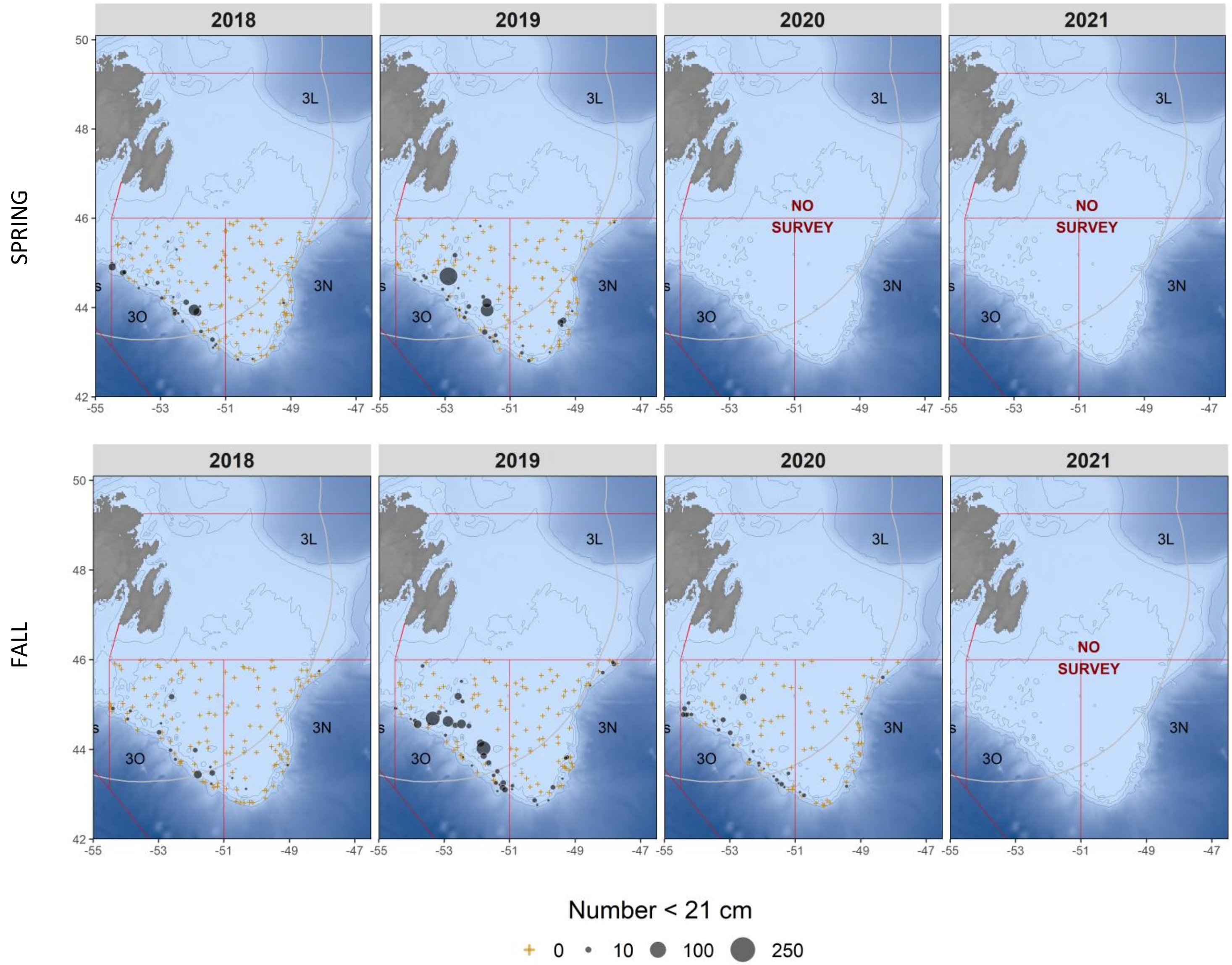


Figure 12. Distribution of pre-recruit (<21cm) witch flounder abundance for Canadian spring (top panels) and fall (bottom panels) surveys of NAFO Divs. 3NO. Sets without witch flounder <21cm are denoted by "+".

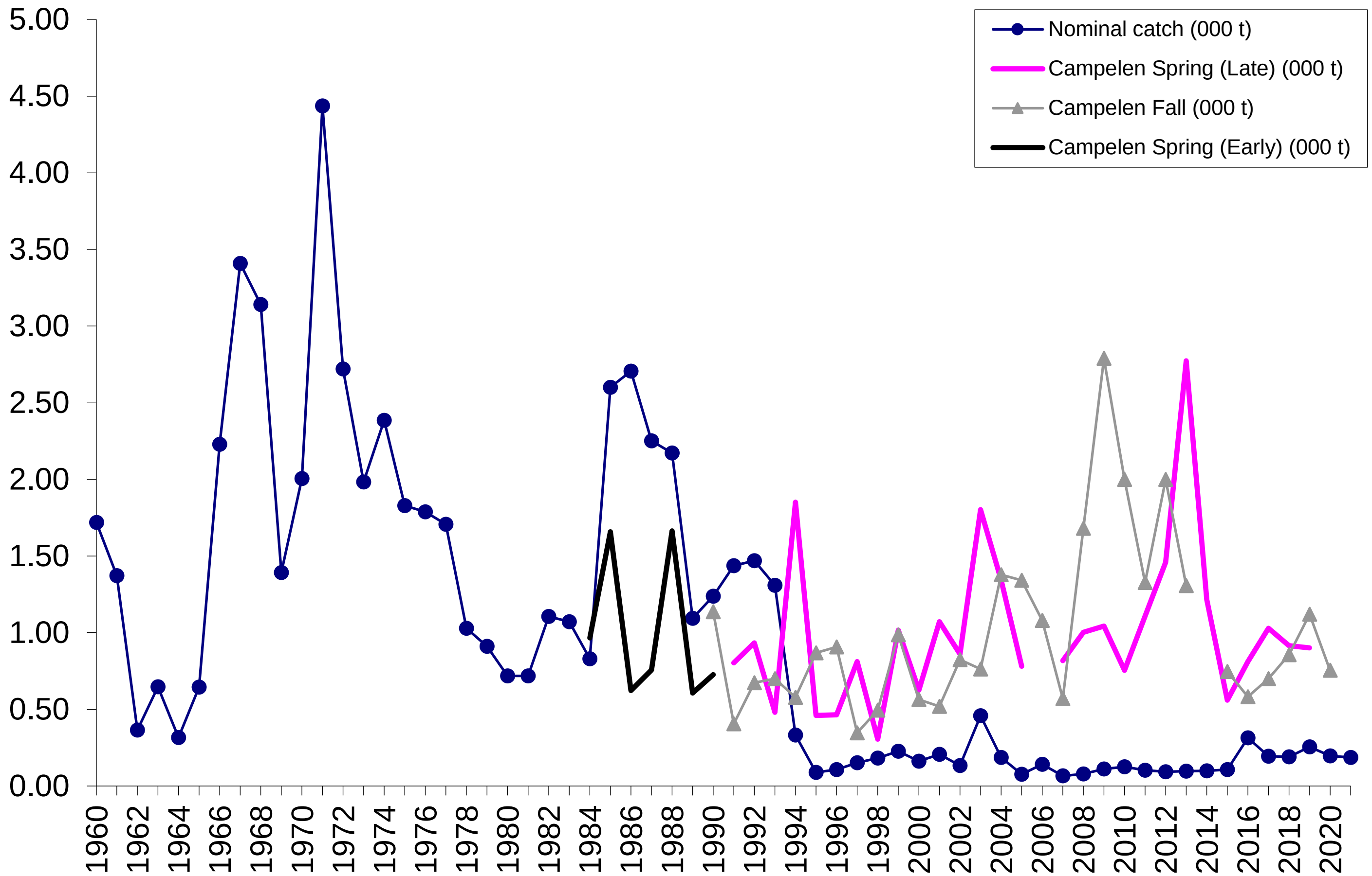


Figure 13. Catch and indices (scaled to the series mean) input into the surplus production model in a Bayesian framework for the 2022 assessment of witch flounder in NAFO Divs. 3NO.

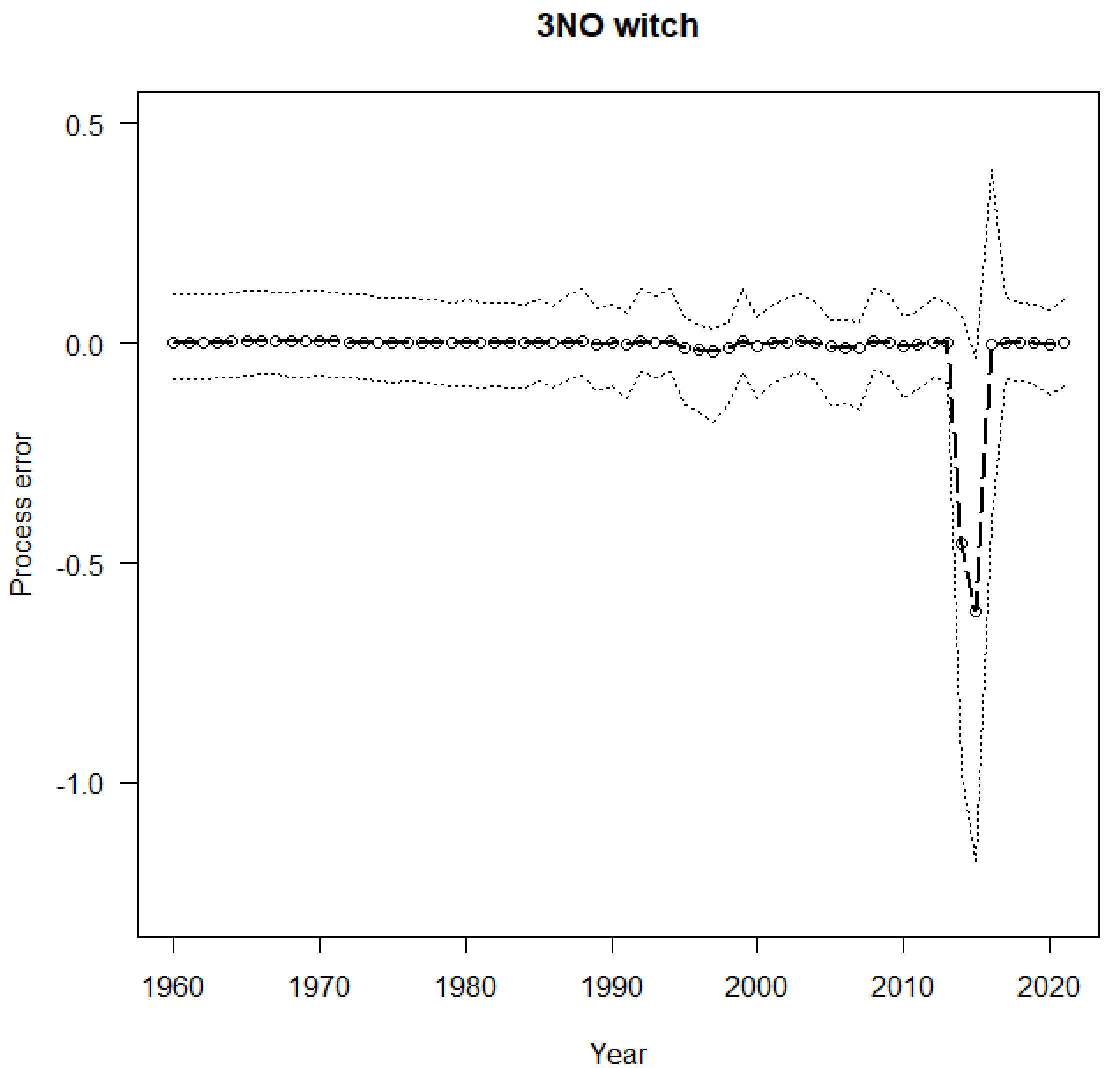


Figure 14. Process error (with 10th and 90th credible intervals) from the surplus production model fit to 3NO witch flounder with process error allowed to increase in 2014-2016.

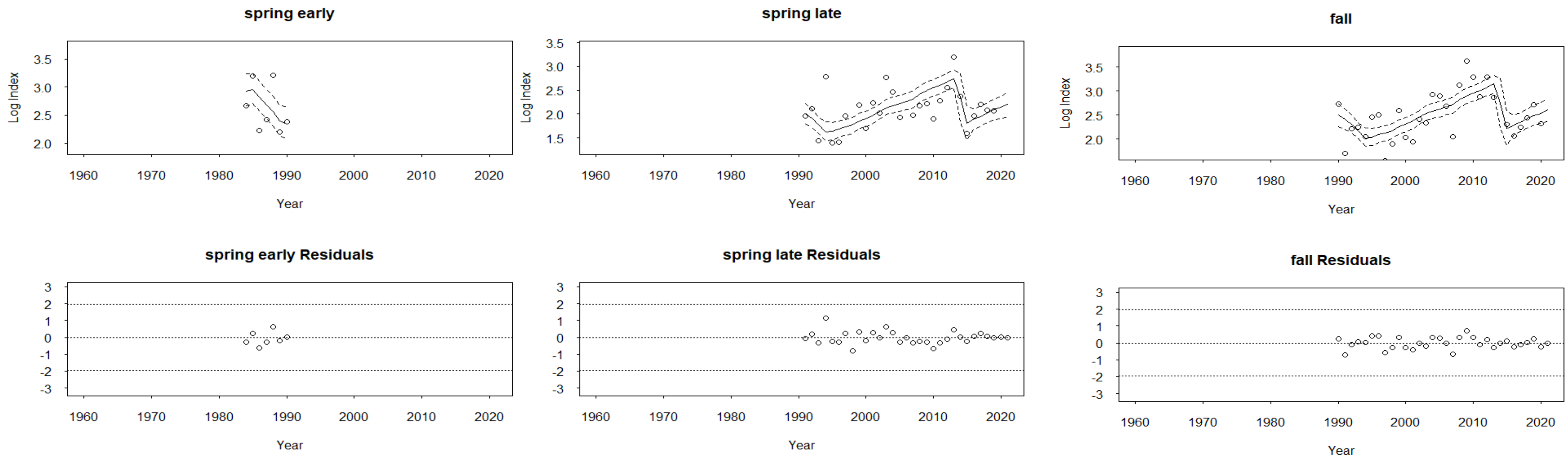


Figure 15. Observed and predicted survey indices from each of the three surveys used in the model. For each survey the top panel gives the observed and predicted values with 10th and 90th credible intervals while the bottom panel presents standardized residuals.

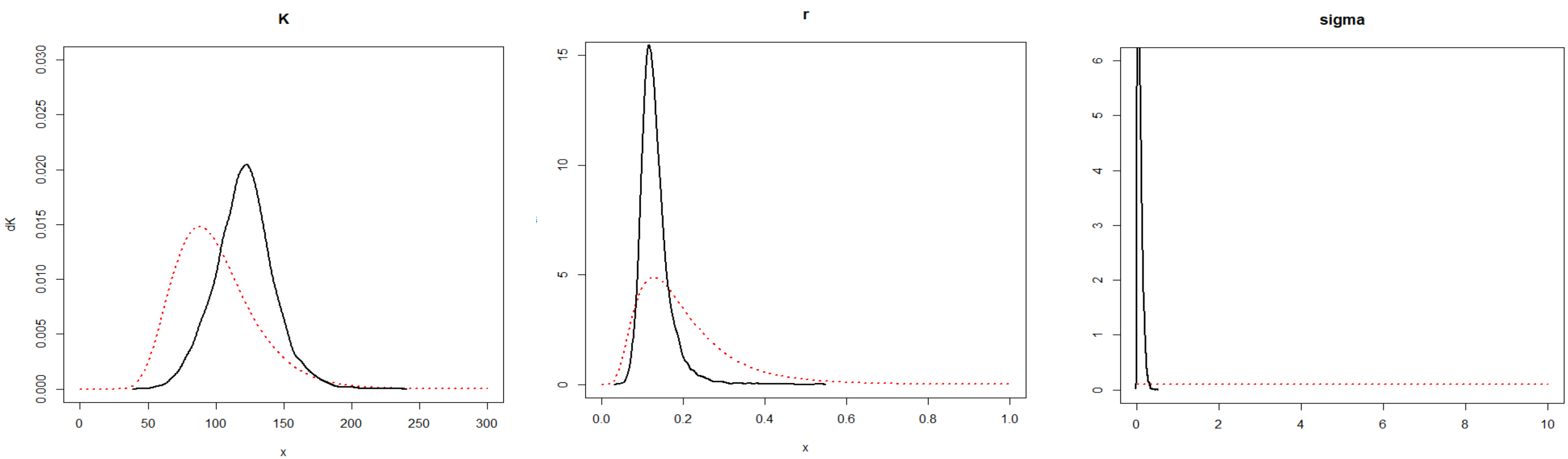


Figure 16. Priors (red dotted line) and posteriors (black line) for K, r and sigma (process error).

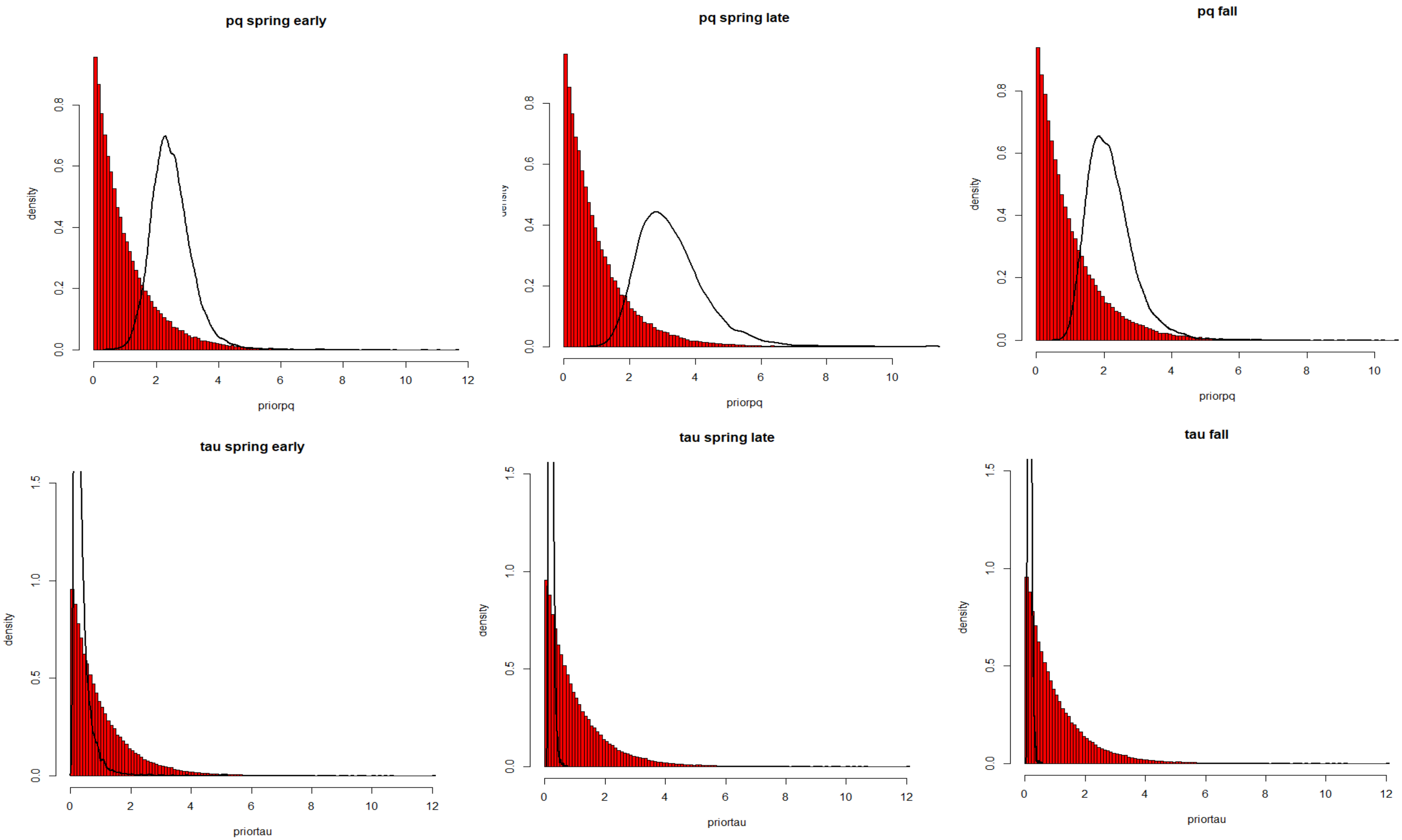


Figure 17. Priors (red histogram) and posteriors (black lines) for pq (inverse of q) and observation error for the 3 survey indices used in the model.

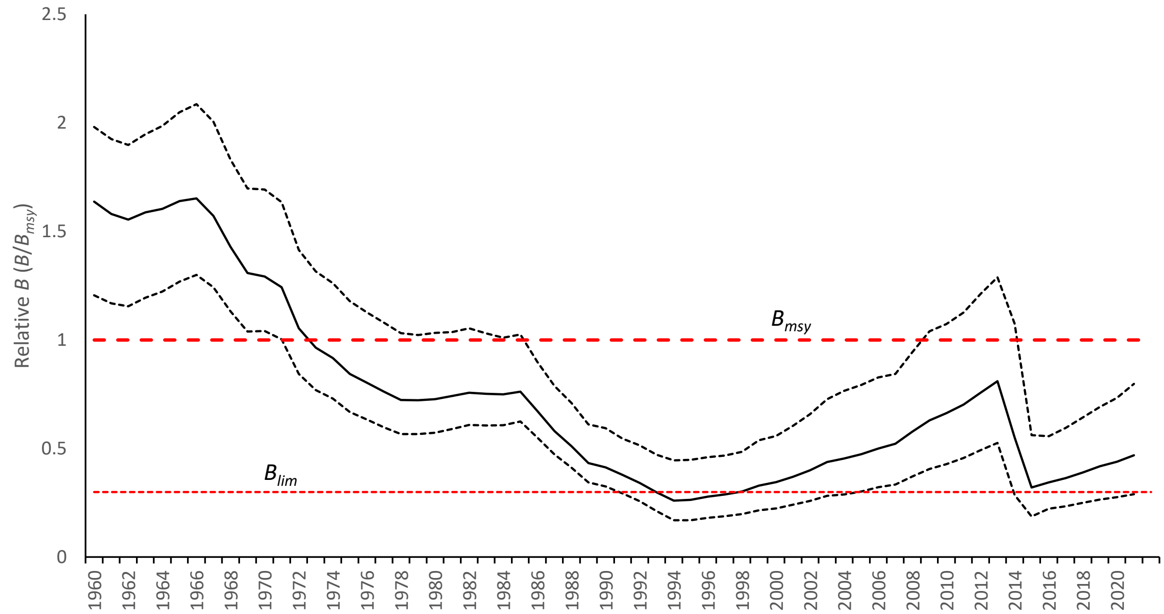


Figure 18. Witch flounder in Divs. 3NO. Median relative biomass (*Biomass/B_{MSY}*) with 10th and 90th percentiles 1960-2021. The horizontal lines are B_{msy} and $B_{lim}=30\%B_{msy}$.

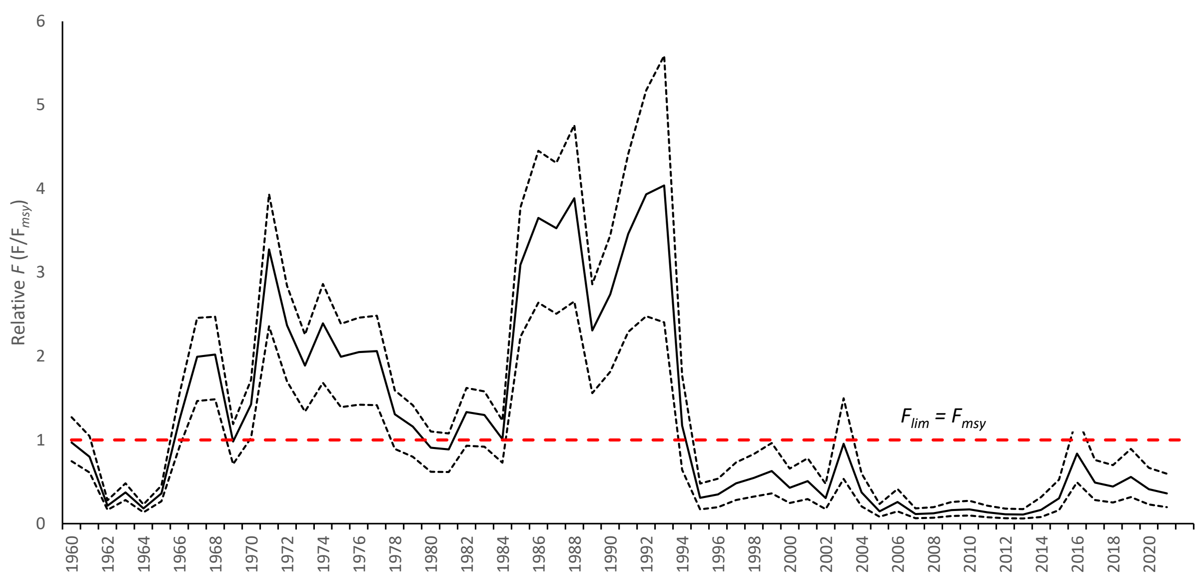


Figure 19. Witch flounder in Divs. 3NO. Median relative fishing mortality (F/F_{MSY}) with 10th and 90th percentiles shown from 1960-2021. The horizontal line is $F_{lim}=F_{MSY}$.

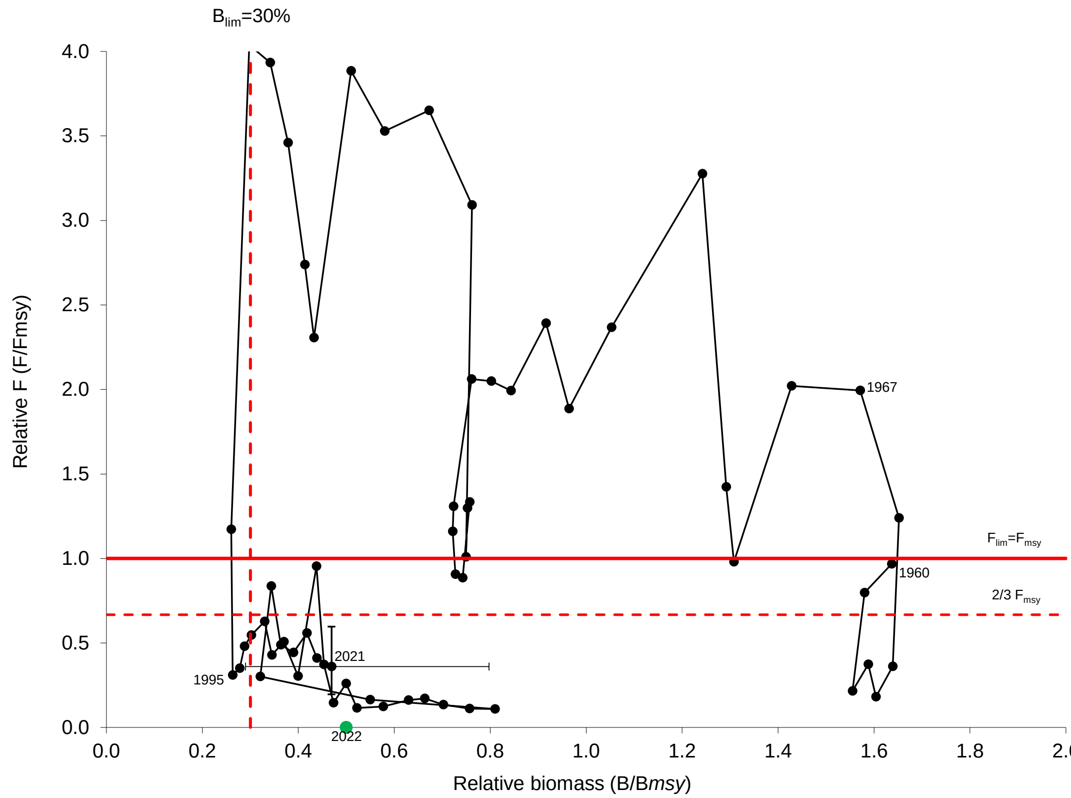


Figure 20. Witch flounder in Divs. 3NO: a stock trajectory estimated in the surplus production analysis, under a precautionary approach framework.

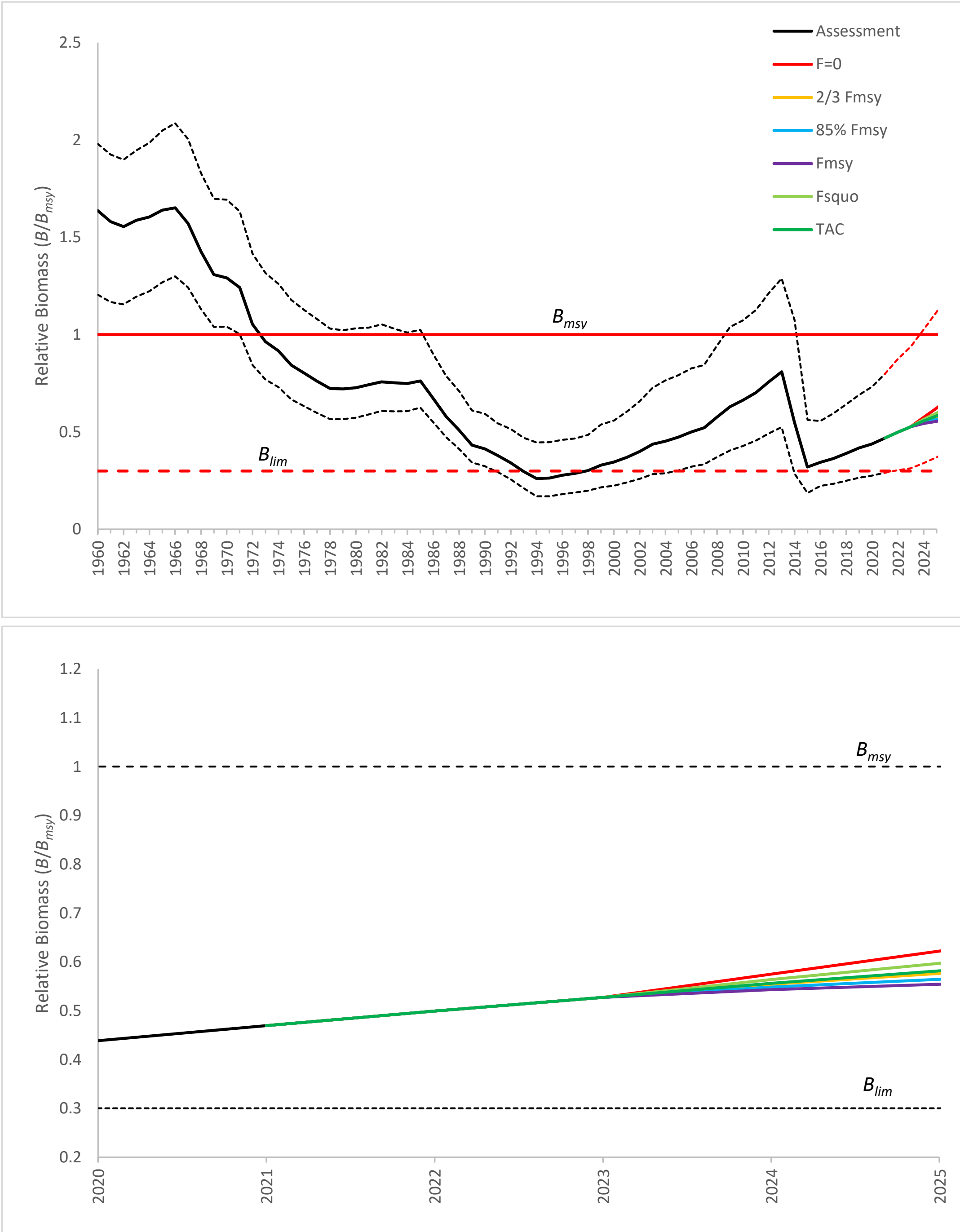


Figure 21. Witch flounder in Divs. 3NO: medium term projections of relative biomass ($B/\ B_{msy}$) at five levels of F (*F=0*, F_{2021}, 2/3 F_{msy}, 85% F_{msy}, F_{msy} and constant catch of 1 175 t. A catch of 1 175 t (TAC) is assumed in 2022. The 10th and 90th credible intervals are shown for the model results up to 2021 (top panel) and for the *F*0 projection from 2021-2025.

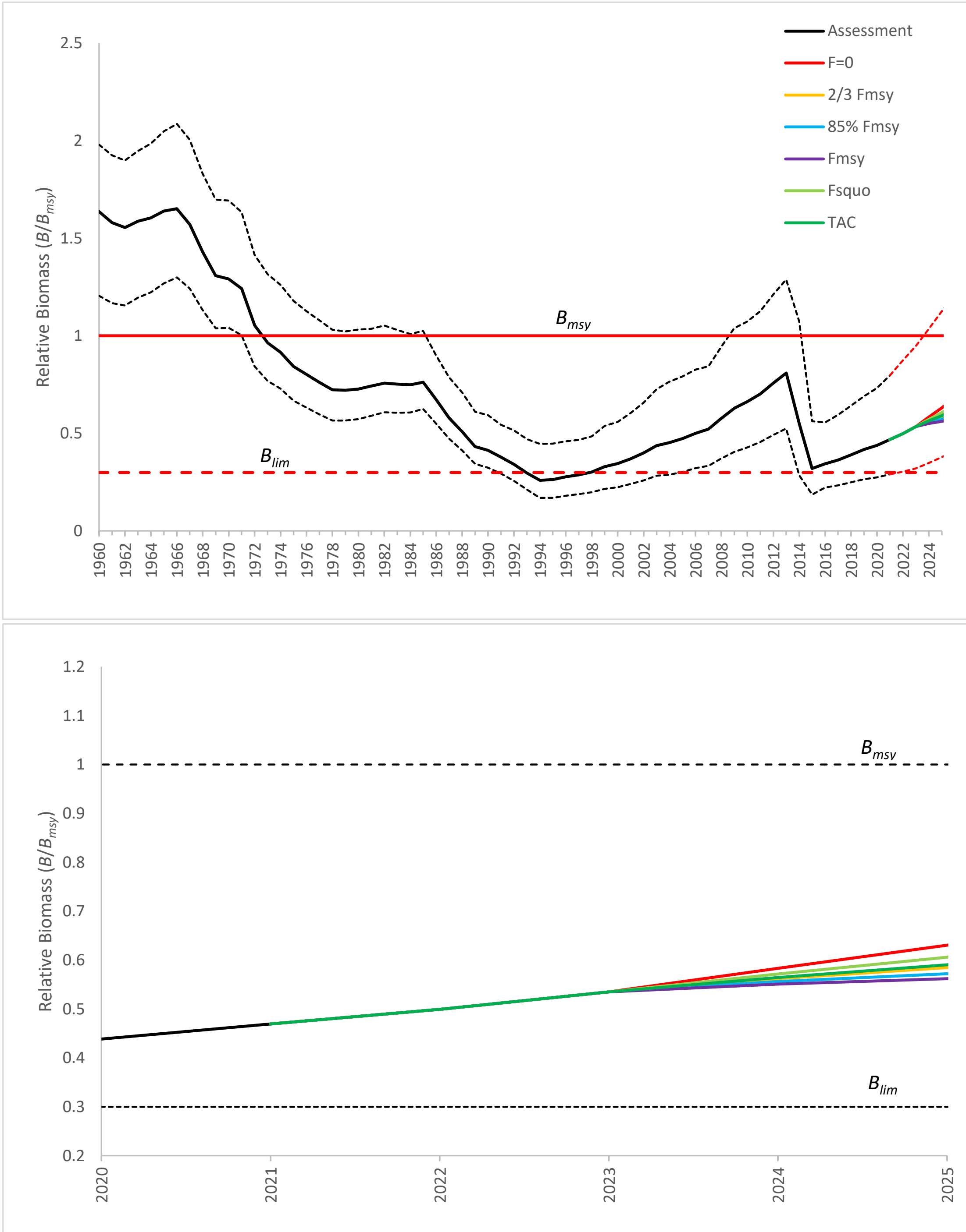
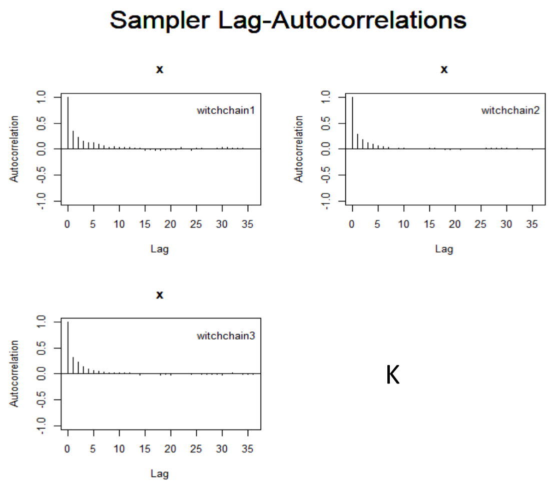


Figure 22. Witch flounder in Divs. 3NO: medium term projections of relative biomass (B/ B_{msy}) at five levels of F (F=0, F_{2021}, 2/3 F_{msy}, 85% F_{msy}, F_{msy} and constant catch of 1 175 t. A catch of 700 t (average catch 2017-2021) is assumed in 2022. The 10th and 90th credible intervals are shown for the model results up to 2021 (top panel) and for the $F0$ projection from 2021-2025.

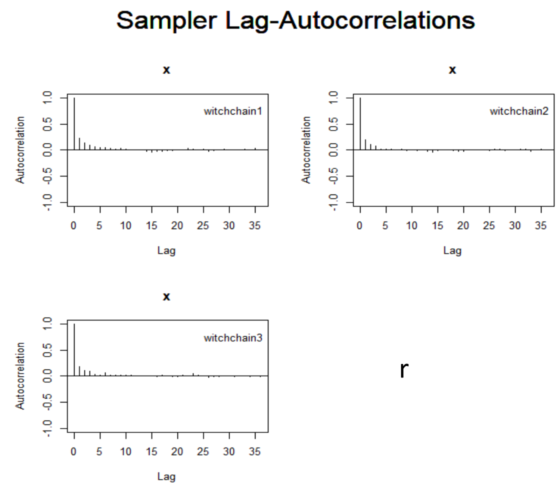
Appendix 1. Model script for 2022 Assessment of 3NO witch flounder in NAFO Divs. 3NO.

```
model
{
#prior for r based on info from swain
r ~ dlnorm(-1.763,3.252)
# prior distribution of K based on EPP 100,30
K~dlnorm(4.562,11.6)
# prior distribution of q's
pq.splate~dgamma(1,1)
q.splate<-1/pq.splate
pq.fallcam ~ dgamma(1,1)
q.fallcam<-1/pq.fallcam
pq.spearly~dgamma(1,1)
q.spearly<-1/pq.spearly
# Prior for process noise, sigma
sigma ~ dunif(0,10)
isigma2 <- pow(sigma, -2)
sigmadev <-sigma+1
isigmadev2<- pow(sigmadev, -2)
# Prior for observation errors, tau.
a0<-1
b0<-1
tau.splate~dgamma(a0,b0)
itau2.splate <- 1/tau.splate
tau.fallcam~dgamma(a0,b0)
itau2.fallcam <- 1/tau.fallcam
tau.spearly~dgamma(a0,b0)
itau2.spearly <- 1/tau.spearly
# Prior for initial population size as proportion of K,
P[1]. Limited between 0.0001 and 5.
Pin~dunif(0.5, 1)
Pm[1] <- log(Pin)
P[1] ~ dlnorm(Pm[1], isigma2)I(0.001,5)
P.res[1]<-log(P[1])-Pm[1]
# State equation - SP Model.
for (t in 2:(54))   {
Pm[t] <- log(max(P[t-1] + r*P[t-1]*(1-P[t-1]) - L[t-1]/K,
0.0001))
P[t] ~ dlnorm(Pm[t], isigma2)I(0.001,5)
P.res[t]<-log(P[t])-Pm[t]
}
for (t in 55:(57))   {
Pm[t] <- log(max(P[t-1] + r*P[t-1]*(1-P[t-1]) - L[t-1]/K,
0.0001))
P[t] ~ dlnorm(Pm[t], isigmadev2)I(0.001,5)
P.res[t]<-log(P[t])-Pm[t]
}
for (t in 58:(N))   {
Pm[t] <- log(max(P[t-1] + r*P[t-1]*(1-P[t-1]) - L[t-1]/K,
0.0001))
P[t] ~ dlnorm(Pm[t], isigma2)I(0.001,5)
P.res[t]<-log(P[t])-Pm[t]
}
# Observation equations
for (t in 32:(N)) {
Isplatem[t] <- log(q.splate*K * P[t])
Isplate[t] ~ dlnorm(Isplatem[t], itau2.splate)
}
for (t in 31:(N)) {
Ifallcamm[t] <- log(q.fallcam*K * P[t])
Ifallcam[t] ~ dlnorm(Ifallcamm[t], itau2.fallcam)
}
for (t in 25:(31)) {
Ispearlym[t] <- log(q.spearly*K * P[t])
Ispearly[t] ~ dlnorm(Ispearlym[t], itau2.spearly)
}
# Output. Using the proportion and K to estimate
biomass, B.
for(t in 1:N) {
B[t] <- P[t] * K
#Zp[t] <- (L[t]/K+M[t]/K)
#Z[t]<-Zp[t]*K
F[t]<-L[t]/B[t]
#F[t]<- Z[t]-M[t]/K
#M[t]~dunif(0.0001,1000)
#Biomass Ratio: Showing what percent the stock would
be at if fished at MSY for a given year, t
Bratio[t] <- B[t]/BMSY
}
#F Ratio: indicates the ratio of fishing mortality to that
estimated for FMSY.
#e.g. 1.65=65% higher than that estimated for FMSY
for(t in 1:N) {
Fratio[t] <- F[t]/FMSY
}
# further management parameters and predictions:
MSP <- r*K/4;
#MSP<-FMSY*BMSY
#FMSY<-r/(pow((shape+1),(1/shape)))
FMSY<-r/2
#EFMSY.f.cam<-r/2*q.f.cam
BMSY<-K/2
#BMSY<-K/(pow((shape+1),(1/shape)))
#generate replicate data sets
for (i in 32:N){
        Isplate.rep[i] ~
dlnorm(Isplatem[i],itau2.splate)
p.smaller.splate[i] <- step(log(Isplate[i])-
log(Isplate.rep[i]))
#residuals of log values of replicate data
        res.Isplate.rep[i] <- log(Isplate[i])-
log(Isplate.rep[i])
}
for (i in 31:N){
        Ifallcam.rep[i] ~
dlnorm(Ifallcamm[i],itau2.fallcam)
p.smaller.fallcam[i] <- step(log(Ifallcam[i])-
log(Ifallcam.rep[i]))
#residuals of log values of replicate data
        res.Ifallcam.rep[i] <- log(Ifallcam[i])-
log(Ifallcam.rep[i])
}
for (i in 25:31){
        Ispearly.rep[i] ~
dlnorm(Ispearlym[i],itau2.spearly)
p.smaller.spearly[i] <- step(log(Ispearly[i])-
log(Ispearly.rep[i]))
#residuals of log values of replicate data
        res.Ispearly.rep[i] <- log(Ispearly[i])-
log(Ispearly.rep[i])
}
} ## END
```

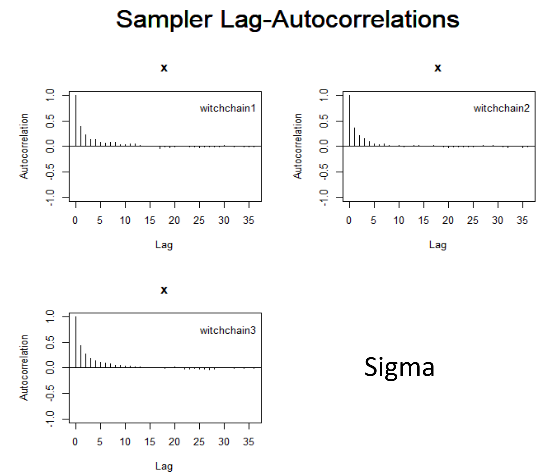
Appendix 2. Diagnostic plots for witch flounder



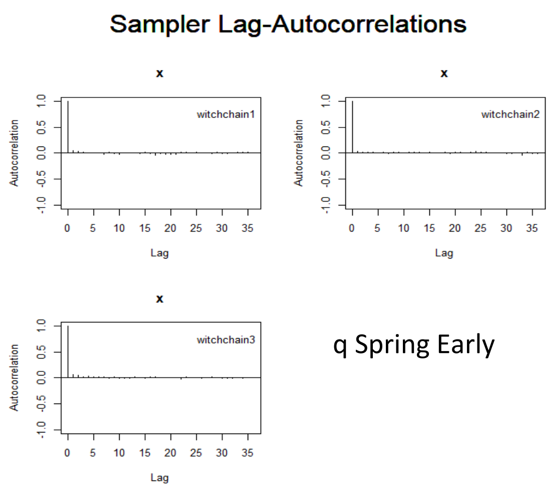
K



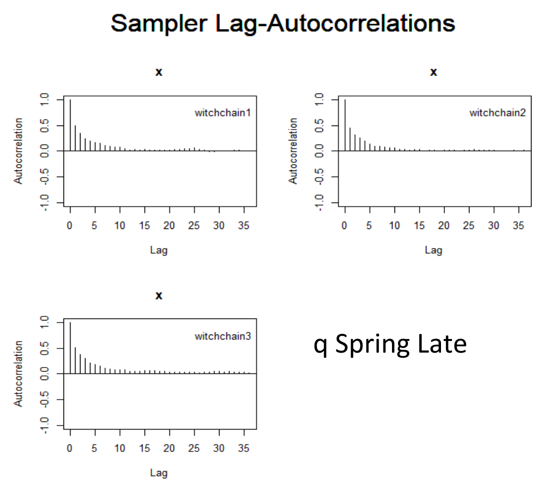
r



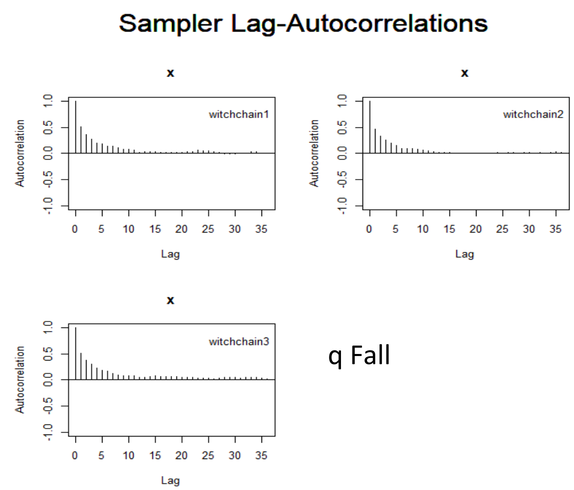
Sigma



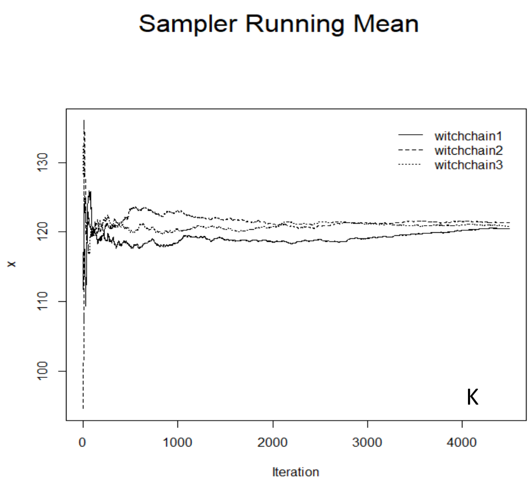
q Spring Early

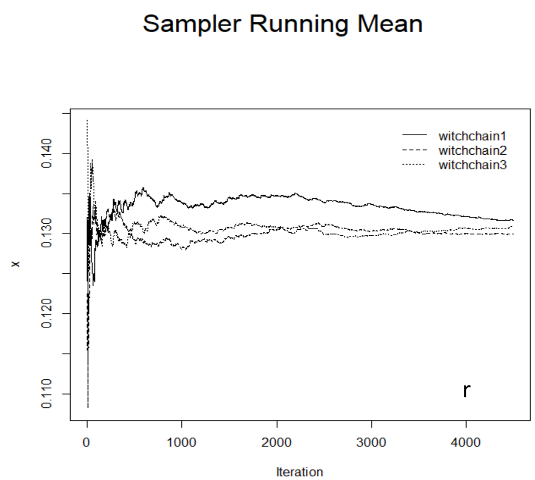


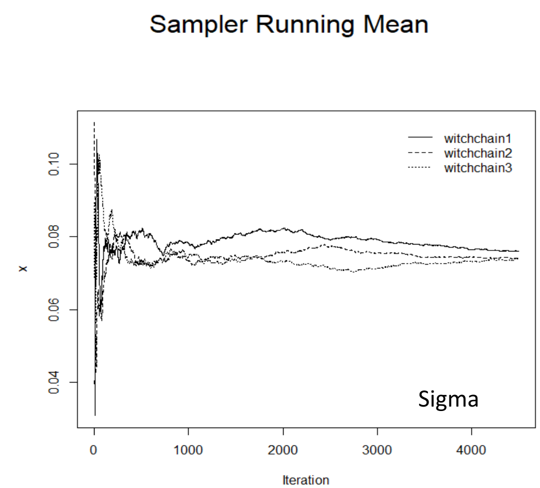
q Spring Late

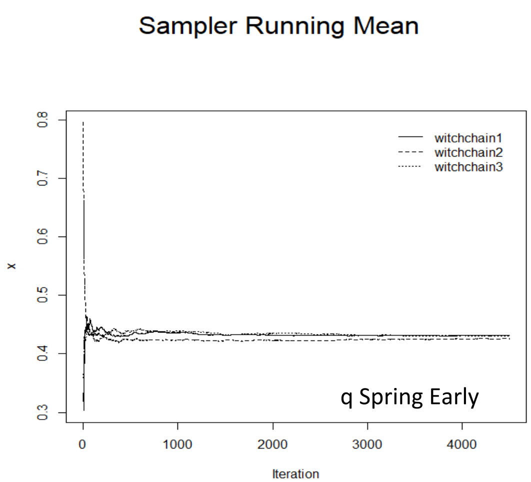


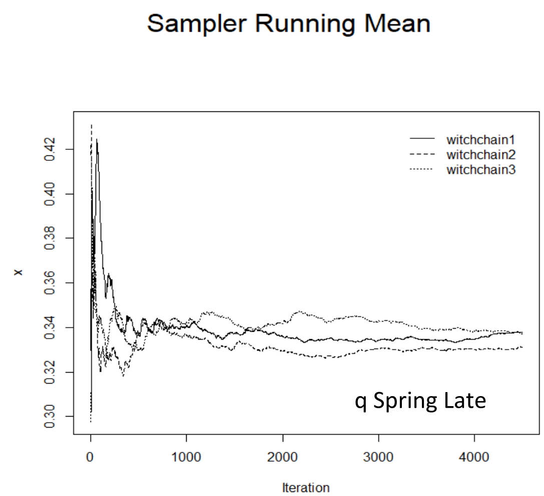
q Fall

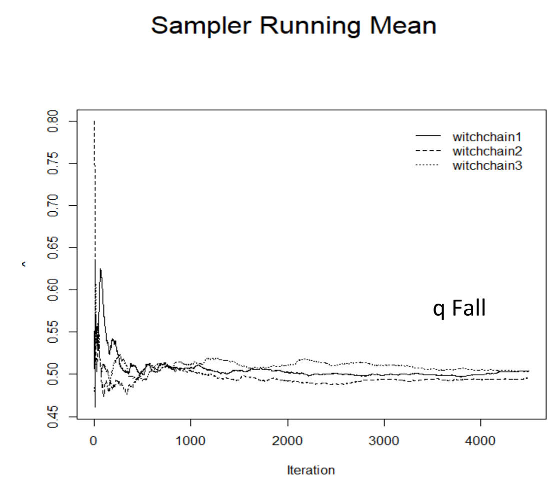

Sampler Running Mean
witchchain1
witchchain2
witchchain3
K
x
100 110 120 130
0 1000 2000 3000 4000
Iteration


Sampler Running Mean
witchchain1
witchchain2
witchchain3
r
x
0.110 0.120 0.130 0.140
0 1000 2000 3000 4000
Iteration


Sampler Running Mean
witchchain1
witchchain2
witchchain3
Sigma
x
0.04 0.06 0.08 0.10
0 1000 2000 3000 4000
Iteration

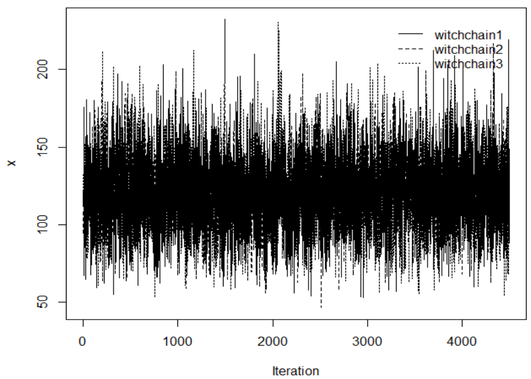

Sampler Running Mean
witchchain1
witchchain2
witchchain3
q Spring Early
x
0.3 0.4 0.5 0.6 0.7 0.8
0 1000 2000 3000 4000
Iteration


Sampler Running Mean
witchchain1
witchchain2
witchchain3
q Spring Late
x
0.30 0.32 0.34 0.36 0.38 0.40 0.42
0 1000 2000 3000 4000
Iteration


Sampler Running Mean
witchchain1
witchchain2
witchchain3
q Fall
0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80
0 1000 2000 3000 4000
Iteration

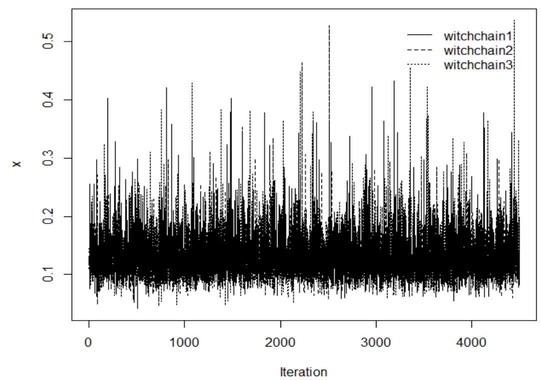
Sampler Trace

K



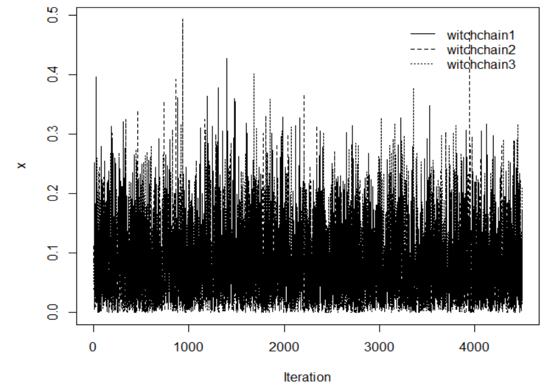
Sampler Trace

r



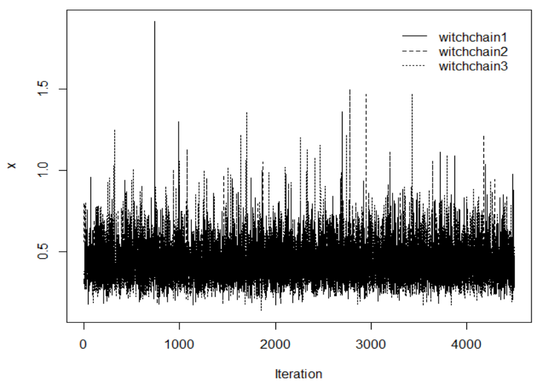
Sampler Trace

Sigma



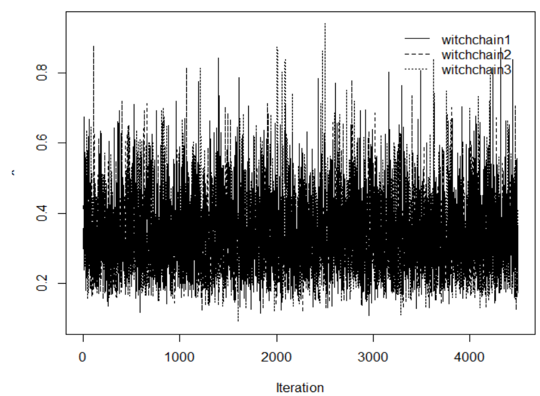
Sampler Trace

q Spring Early



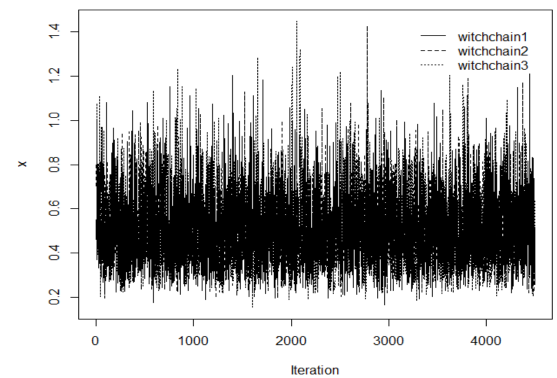
Sampler Trace

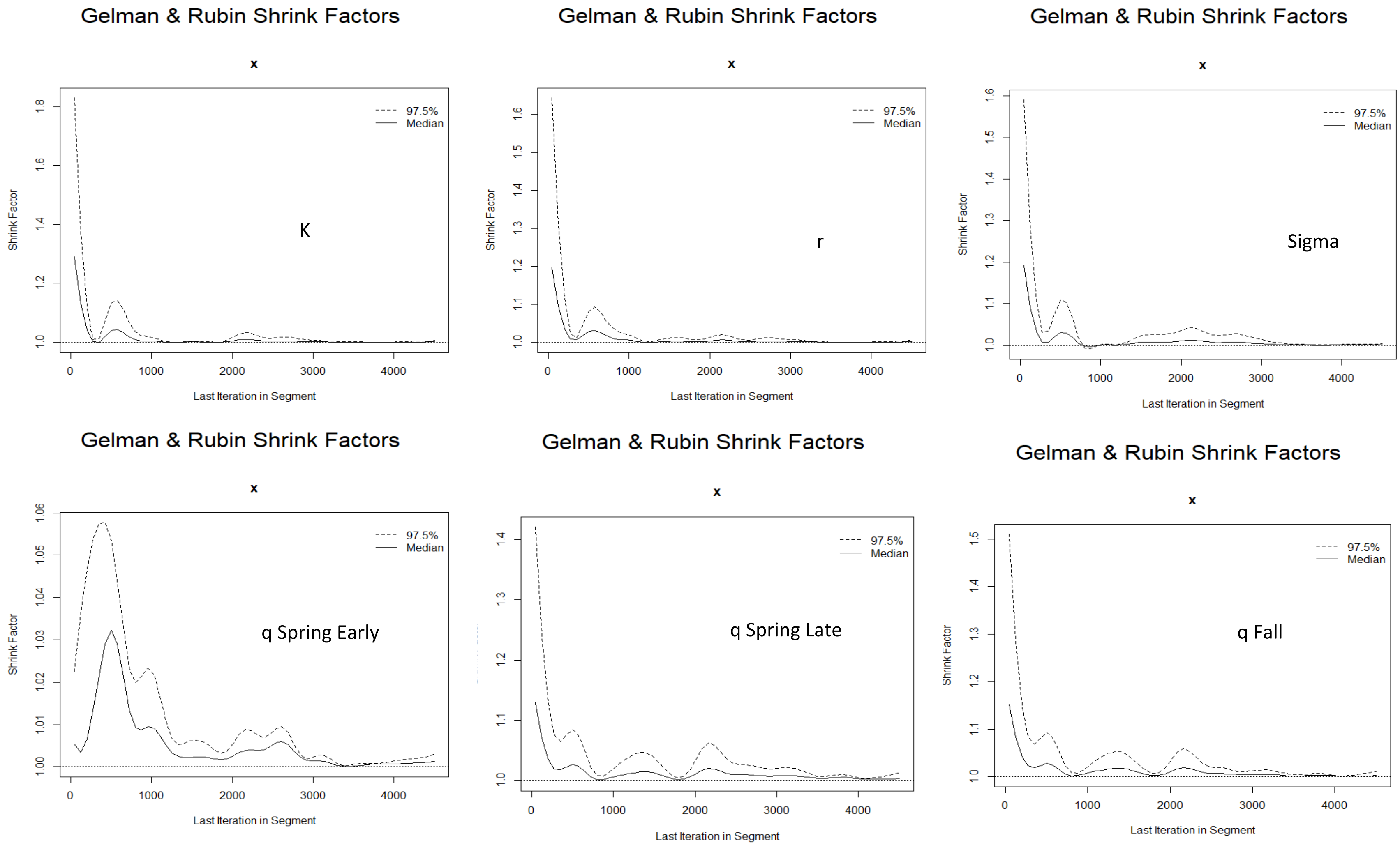
q Spring Late

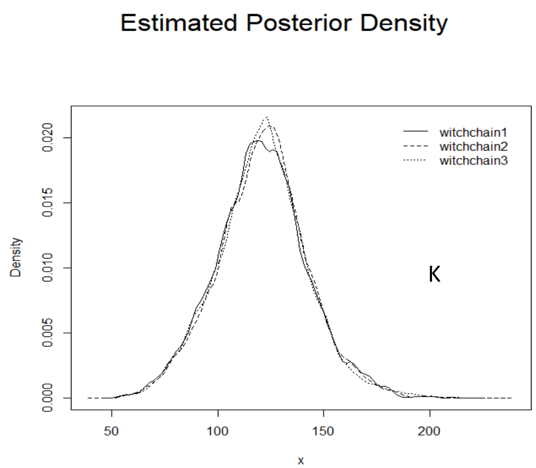


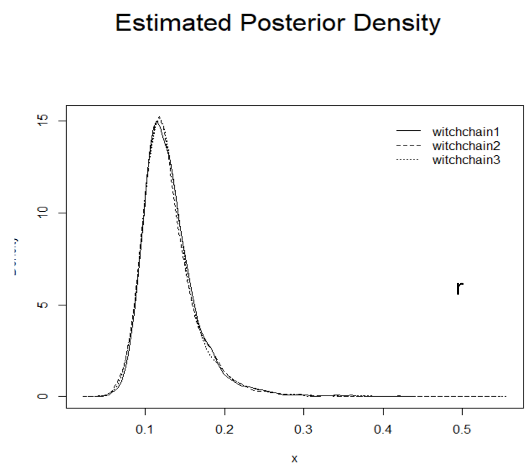
Sampler Trace

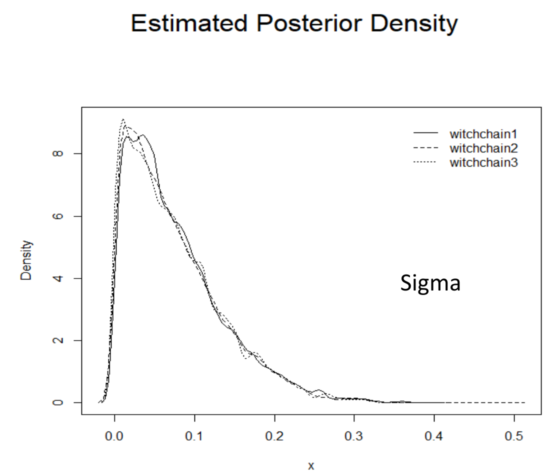
q Fall

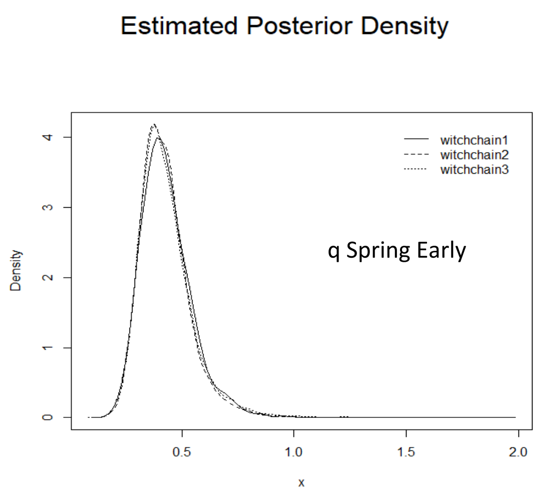


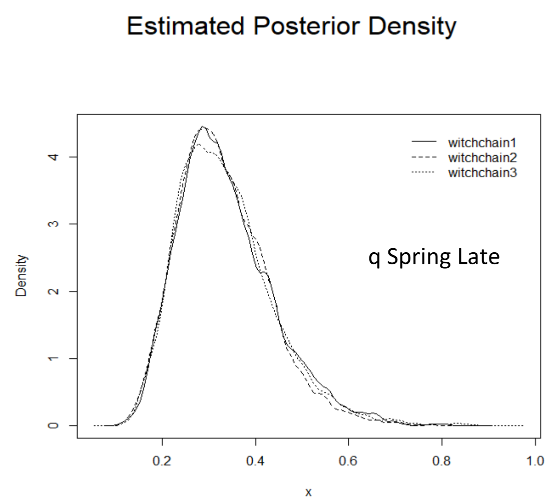

Gelman & Rubin Shrink Factors
x
K
r
Sigma
q Spring Early
q Spring Late
q Fall
97.5%
Median
Shrink Factor
Last Iteration in Segment

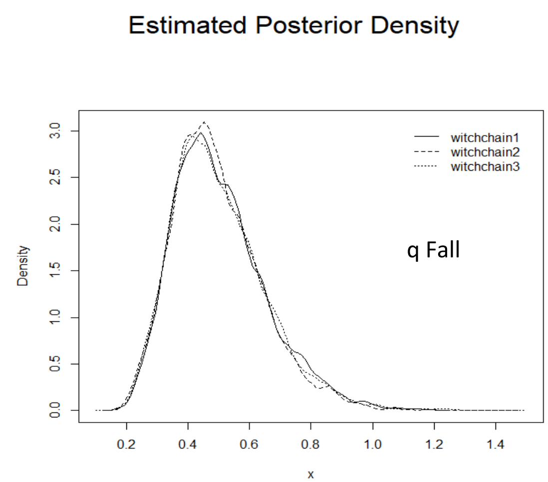

Estimated Posterior Density
witchchain1
witchchain2
witchchain3
K
Density
x


Estimated Posterior Density
witchchain1
witchchain2
witchchain3
r
x


Estimated Posterior Density
witchchain1
witchchain2
witchchain3
Sigma
Density
x


Estimated Posterior Density
witchchain1
witchchain2
witchchain3
q Spring Early
Density
x


Estimated Posterior Density
witchchain1
witchchain2
witchchain3
q Spring Late
Density
x


Estimated Posterior Density
witchchain1
witchchain2
witchchain3
q Fall
Density
x