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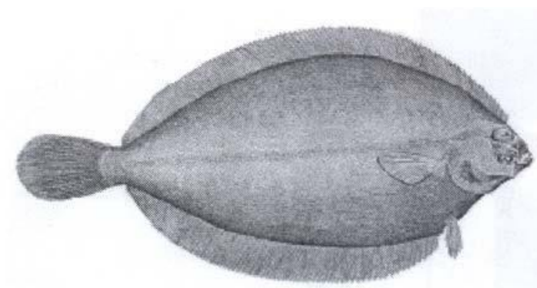
Gulf Region
Science Advisory Report 2017/036

STOCK ASSESSMENT OF WITCH FLOUNDER (*GLYPTOCEPHALUS CYNOGLOSSUS*) IN THE GULF OF ST. LAWRENCE (NAFO DIVS. 4RST) TO 2016



Witch Flounder (Glyptocephalus cynoglossus)

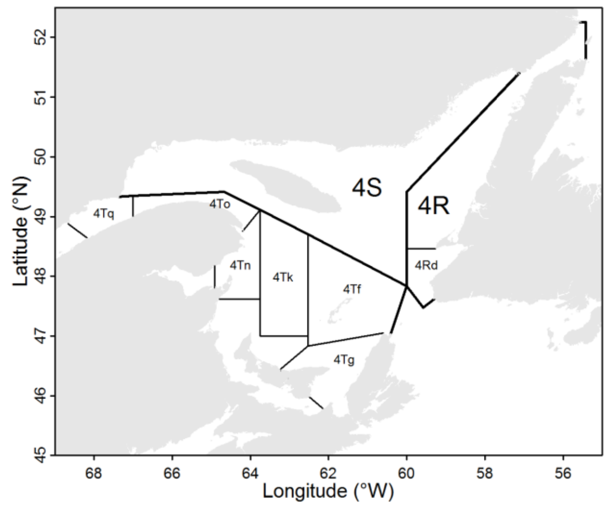


Figure 1. NAFO Divisions 4R, 4S and 4T (bordered by heavy solid line). The NAFO unit areas where most Witch Flounder are caught in commercial fisheries are labelled in lower case.

Context:

The commercial fisheries for Witch Flounder (Glyptocephalus cynoglossus) in the northern Gulf of St. Lawrence (NAFO Divisions 4RS) came under quota management in 1977, with a quota of 3,500 t. In 1979, the Total Allowable Catch (TAC) in NAFO Divs. 4RS was increased to 5,000 t to remove an old and slow-growing component of the stock. This measure succeeded in reducing the age composition of the stock; however, landings declined and by 1982, the TAC was reduced to 3,500 t. During the 1980s, landings from NAFO Div. 4T increasingly dominated the Gulf of St. Lawrence Witch Flounder landings. The first detailed assessment of NAFO Divs. 4RS Witch Flounder was conducted in 1978 and continued yearly until 1981. When stock assessments resumed in 1991 and following the recommendation of the Fisheries Resource Conservation Council in 1994, the management unit was extended to NAFO Divs. 4RST in 1995. The last full assessment of this stock occurred in 2012 (DFO 2012; Swain et al. 2012).

This Science Advisory Report is from the March 2, 2017 science peer review meeting on the stock status and fishery advice for May 2017 to May 2022 for Witch Flounder from NAFO Divisions 4RST, Gulf of St. Lawrence. Participants at the meeting included DFO Science (Gulf, Newfoundland and Labrador regions), DFO Fisheries Management (Gulf, Newfoundland and Labrador regions), and the fishing industry and a non-governmental organization.

SUMMARY

- During 2013 to 2016, the total allowable catch (TAC) of Witch Flounder in the Northwest Atlantic Fisheries Organization (NAFO) Div. 4RST was set at 300 t. Landings in 2013 to 2016 were 250 t to 296 t. Preliminary landings for 2016 were 263 t.
- The fishery for Witch Flounder is now primarily a directed fishery, with most of the catch taken by seines in southwest Newfoundland (NAFO Div. 4R) and northwestern Cape Breton Island (NAFO Div. 4T).
- There has been a contraction in the size composition of Witch Flounder in the landings. Fish 40 cm or longer made up 70% to 80% of the landings in the late 1970s but only 20% of the landings in 2006 to 2011. The proportion of these large fish has increased in recent years, accounting for up to 23% of the landings.
- Based on research vessel surveys, the abundance of Witch Flounder measuring 30 cm and greater has increased throughout the GSL where it was historically found, including the Estuary, western Newfoundland, and around Anticosti Island.
- Reference points for spawning stock biomass of Witch Flounder >= 30 cm total length were derived from a surplus production model. The Limit Reference Point (LRP), defined as 40% of biomass for maximum sustainable yield (B_{msy}), is estimated at 10,480 t[1], the Upper Stock Reference default of 80% B_{msy} at 20,960 t[1], and the maximum removal rate equivalent to F_{msy} at 0.072[1].
- DFO (2012) indicated that a strong pulse of recruitment evident in the 2009 to 2011 survey data was approaching commercial sizes and that protecting this incoming fishery recruitment by keeping catches as low as possible for the following decade could promote rebuilding of the 40+ cm size group. The imposition of a TAC of 300 t for the 2013 to 2016 fishery years seems to have contributed to the increased biomass of the stock as anticipated.
- The 2016 median estimate of the spawning stock biomass (SSB) is 13,270 t[1], slightly above the LRP (10,480 t[1]) with a 38%[1] chance that the estimated biomass is at or below the LRP. The fishing removal rate was estimated at < 0.04, below the maximum removal rate.
- Projections of stock biomass after fishing for 2017 to 2021 indicate that the biomass is expected to increase at annual catch options to 500 t. The probability of the biomass being below the LRP in 2021 is 23%[1] even in the absence of fishing and increases to 29% under a TAC of 500 t. The probability that the stock biomass will be in the healthy zone in 2021 is 46% with no fishery removals and 37% at an annual catch of 500 t.
- An interim year update will be provided mid-way in the five-year assessment cycle in early December 2019, to determine if the indicator signals that a re-assessment is warranted. The trigger for a re-assessment will be if the three-year running average of the biomass index from the combined RV surveys in NAFO Div. 4RST falls below the Limit Reference Point, rescaled to the biomass index.

INTRODUCTION

Witch Flounder (*Glyptocephalus cynoglossus* L.) is a righteye flounder species distributed over the northern Atlantic Ocean. In the western Atlantic Ocean, the species occurs from Cape

[1] Erratum: February 2020, corrected the values to correspond to those in the body of the report.

Hatteras to the Labrador Sea. They most commonly occur in deep holes and channels and along the shelf slope on muddy bottom. In the Gulf of St. Lawrence, Witch Flounder form dense concentrations in deep water in winter months and become more widely dispersed throughout the Gulf in the summer. In the Gulf of St. Lawrence (Northwest Atlantic Fisheries Organization, (NAFO) Divisions 4RST), spawners aggregate in the lower Esquiman Channel and the eastern Laurentian Channel in January and February. Spawning in the Gulf is believed to occur in deep water in spring. The females are highly fertile, releasing as many as 500,000 eggs in a single spawn. In the late 1970s and early 1980s, 50% of females reached maturity at lengths of 40 to 45 cm (9 to 14 years of age) and 50% of males matured at lengths of 30 to 34 cm (5 to 8 years of age) (Bowering and Brodie 1984). The fertilized eggs float and hatching occurs after several days, followed by a lengthy pelagic stage that may last a year. Juveniles eventually settle to the bottom in deep waters.

A stock structure review of Witch Flounder in NAFO Subarea 4 was undertaken in 2001 to examine a proposal that the Witch Flounder moving into the Cape Breton Trough in eastern NAFO Div. 4T each summer were more closely affiliated with Witch Flounder on the northeastern Scotian Shelf (NAFO Div. 4VW) than with those in other regions of the Gulf of St. Lawrence. The review acknowledged that the stock affiliations of Witch Flounder in eastern NAFO Div. 4T are uncertain but concluded that there was insufficient evidence to warrant a revision of the 4RST management unit (O'Boyle 2001; Fig. 1).

Growth of Witch Flounder is slow for both sexes, with a mean length at age 12 years of 40 cm for males and 41 cm for females. Estimated asymptotic lengths (L_∞) in the 1970s were 69 cm for females and 54 cm for males. Size-at-age begins to diverge between males and females at 12 to 15 years of age, consistent with the earlier age at maturity of males.

The Fisheries

Landings of Witch Flounder in the Gulf of St. Lawrence (GSL) averaged 3,400 t from 1960 to 1975 (Fig. 2). Fisheries in Div. 4R and Div. 4T contributed roughly equally to these landings, with relatively minor contributions from Div. 4S (Fig. 2). The spike in landings in 1976 resulted from the onset of a winter fishery by large otter trawlers exploiting winter concentrations of Witch Flounder in the Esquiman Channel (Div. 4R). Landings dropped sharply in 1981 when these large trawlers were excluded from the northern Gulf cod fishery. Landings increased from low levels near 1,000 t in the early 1980s to levels near 2,500 t by the late 1980s. However, landings declined throughout the early 1990s to a historical low of 320 t in 1995. Since 2000, the total allowable catch (TAC) has been set at 1,000 t. Landings remained near the TAC until 2003. Landings began to decline again in 2008, falling to a record low of 229 t in 2010, less than 25% of the TAC. The TAC was reduced to 500 t in 2012 and then to 300 t in 2013 where it remained into 2016. Since 2013, the TAC has been allocated equally to the 4R and the 4T fleets, and both fleets have since caught the near totality of the yearly TAC. Preliminary landings in 2016 are 263 t.

In 1991, it became a license condition for mobile gear captains to maintain a logbook. Since 1991, 87% to 100% of the landings of Witch Flounder have been from unit areas 4Rd, 4Tf, 4Tg, 4Tk and 4Tnoq (Figs. 1, 3). Landings have remained fairly steady in 4Tf and 4Tg. Since 1998, 4Rd and 4Tfg have contributed roughly equal portions of the landings, and contributions from 4Tk and 4Tnoq are now fairly minor.

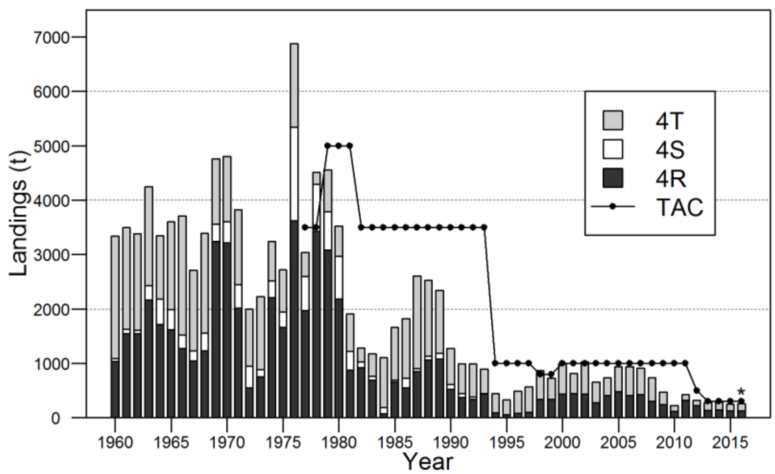


Figure 2. Witch Flounder landings (t) from 1960 to 2016, by NAFO Div. 4R, 4S, and 4T. The annual total allowable catch (TAC) is shown as the black dotted line. The asterisk above the landings data for 2016 indicate that these results are preliminary.

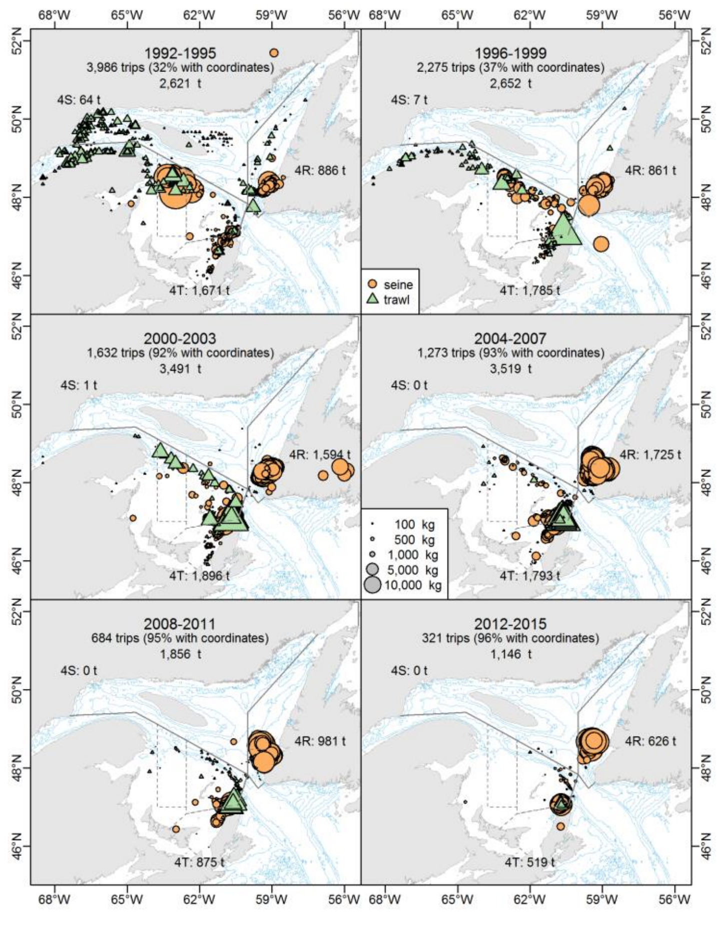


Figure 3. Spatial distribution of total Witch Flounder catches as recorded in logbooks with geographic coordinates by four-year periods and by fishing gear in the Gulf of St. Lawrence, 1992 to 2015. Shown in each panel map are the total number of trips, total landings in the Gulf of St. Lawrence and by NAFO Division. The size of the symbols is proportional to the catches.

The fishery for Witch Flounder is primarily a directed fishery prosecuted by seines between May and September (Fig. 4). During 1993 to 2005, over half the landings were reported from September and October. Since 2012, the fishery has occurred primarily between May and August.

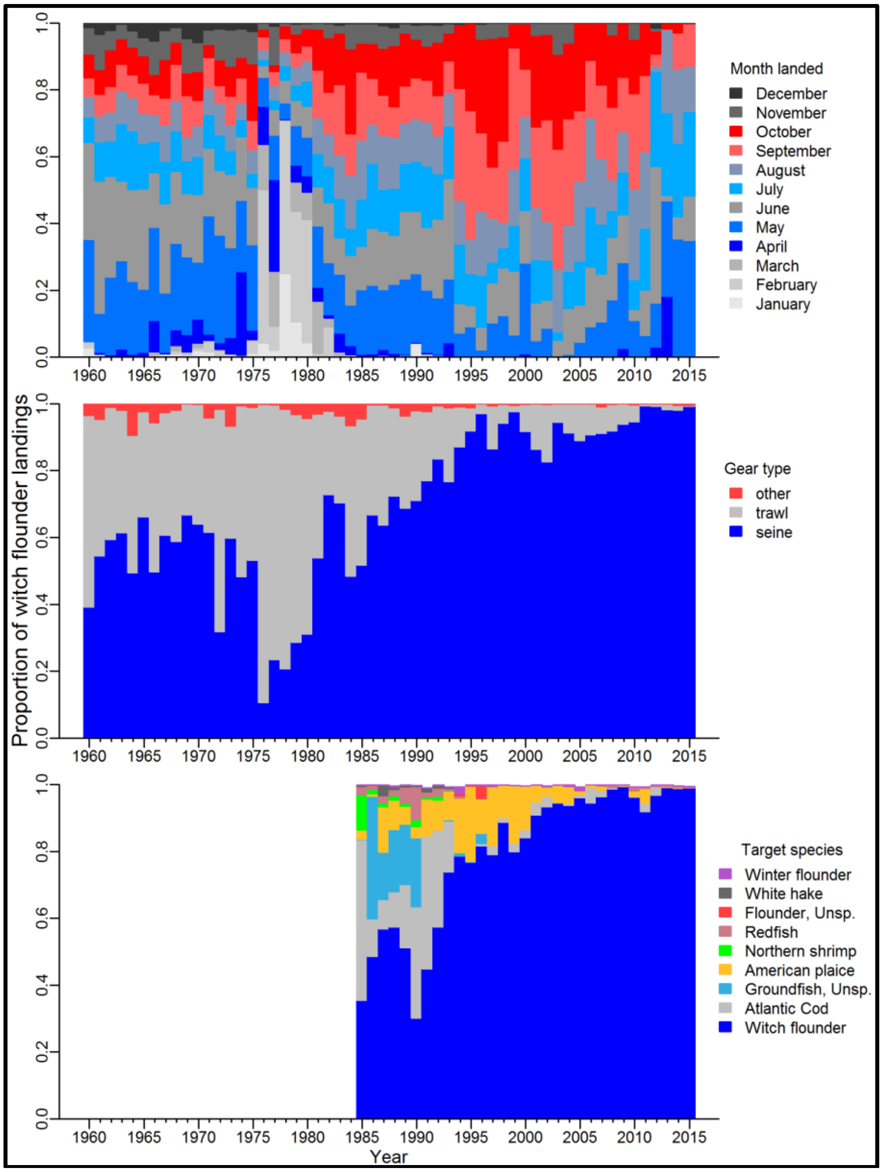


Figure 4. Proportion of annual landings of Witch Flounder, by fishing month (top panel), by type of fishing gear (middle panel), and by reported target fish species (bottom panel), 1960 to 2015.

The fishery for Witch Flounder has been conducted almost entirely by mobile gears (Fig. 4). Danish seines have dominated the landings, except during the 1976 to 1980 period when winter catches by offshore trawlers contributed up to 80% of the landings. Prior to the Atlantic Cod moratorium, important proportions of the Witch Flounder landings were from trips with Atlantic Cod as the target species. Since the early 2000s, over 90% of the Witch Flounder landings are recorded from Witch Flounder directed trips and this level is essentially 100% since 2013 (Fig. 4).

The commercial size limit for Witch Flounder in the GSL 4RST fisheries is 30 cm. The length composition of samples from the commercial fishery differed dramatically for the samples from the 1970s and early 1980s and the samples from the 2000s (Fig. 5). The percentage of fish 40 cm and longer was 76% for the period 1975 to 1979 compared to 16% to 22% for the period 2005 to 2009. The length frequencies from the commercial fishery in recent years show an increased proportion of fish 40 cm and longer, a size group that was historically abundant.

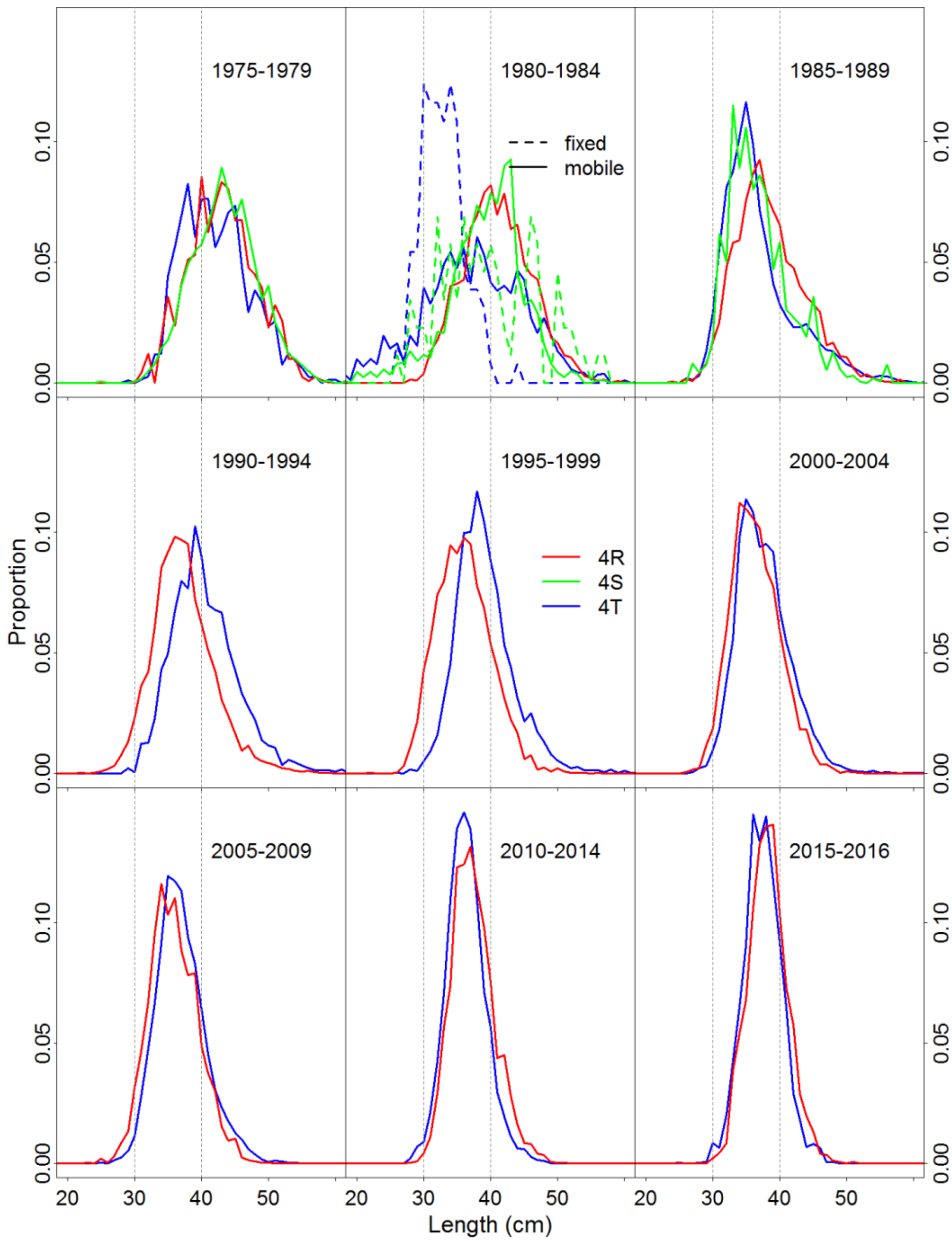


Figure 5. Average length frequencies (proportion) of sampled Witch Flounder catches of the Gulf of St. Lawrence by NAFO Division and gear type (fixed versus mobile) for nine periods during 1975 to 2016. Catches-at-length were weighted by the landings associated with each sample. Data from the earlier time periods, 1975 to 1989 are from less intensive sampling among gear types and fishing areas.

ASSESSMENT

Two stratified random bottom-trawl Research Vessel (RV) surveys were available to provide fisheries-independent information about Witch Flounder in the GSL. One survey has been conducted in the southern Gulf of St. Lawrence (NAFO Div. 4T) each September since 1971 and the second survey has been conducted in the Estuary and the northern Gulf of St. Lawrence (NAFO Div. 4RST) since 1984 (Fig. 6). Witch Flounder length frequency data (required for standardization between the two surveys) are only available since 1987 for the August survey. Survey indices were calculated using a set of strata sampled in most years (415-439 in the September survey and 401-414, 801-824, 827-832 in the August survey).

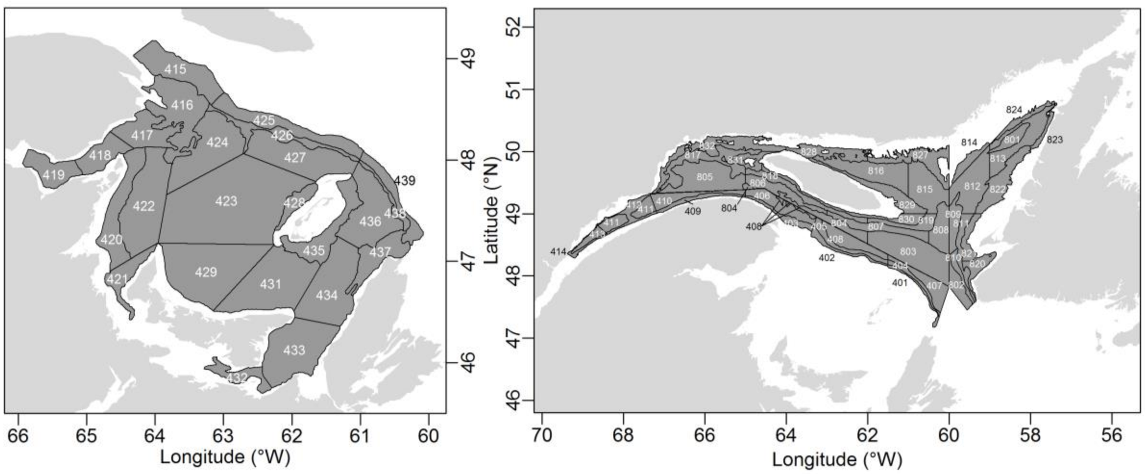


Figure 6. Strata boundaries for the September bottom trawl survey of the southern Gulf of St. Lawrence (left panel) and for the August bottom trawl survey of the northern Gulf of St. Lawrence (right panel). The strata appearing on the map are those used in the analyses.

The RV surveys follow a stratified random sampling design. Based on analyses of the comparative fishing experiments, and additional analyses on diel variation in catchability of Witch Flounder, catches in the September and August surveys were standardized to a 1.75 nautical miles night tow by the Lady Hammond using the Western IIA trawl for most analyses.

A summer mobile-gear sentinel survey has been conducted annually in the northern Gulf of St. Lawrence since 1995. The survey is conducted using industry vessels with a trawl equipped with rockhopper gear and a restrictor cable to standardize the horizontal opening of the trawl. The surveys follow a stratified random design using the same strata as the August research vessel survey except that the sentinel surveys do not extend as far into the Estuary as does the RV survey. A similar sentinel survey, using the same gear and fishing procedures (except for the restrictor cable), has been conducted in August in the southern Gulf of St. Lawrence since 2003. This survey uses the same strata as the September RV survey.

Length and Maturity

RV survey length distributions for the whole stock area are available since 1987 (Fig. 7). At the start of the time series (1987 to 1989), Witch Flounder > 40 cm represented 16 % to 22% of the fish in the combined survey area. Abundance of commercial sizes (30+ cm) declined sharply in the early 1990s. Abundance of fish 30 to 40 cm in length increased in the late 1990s and early 2000s, but abundance of larger (40+ cm) fish has shown no sign of an increase (Fig. 7). Relatively high abundances in the 15 to 25 cm interval in the early 1990s, the late 1990s and early 2000s and in 2009 to 2012 suggest the appearance of a number of strong year-classes which may be responsible for the increased and sustained abundances of the smaller commercial sizes (30 to 40 cm). However, these periodic increases in abundance do not translate into increased abundances at larger sizes (40+ cm). Since the last assessment in 2012, the abundance of commercial sizes has steadily increased and there is evidence that a recent mode of recruitment has entered the commercial sizes for the stock.

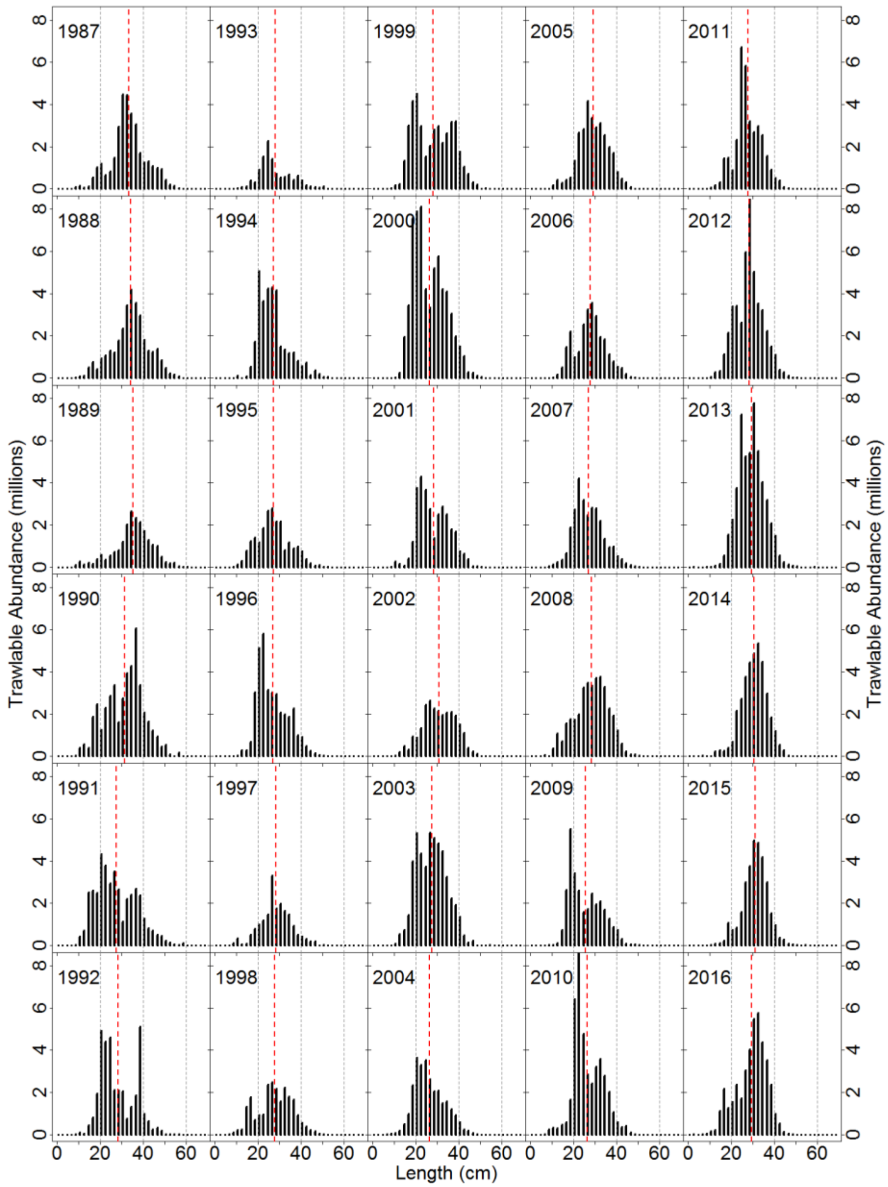


Figure 7. Abundance (in units of trawlable abundance; millions) by length distributions of Witch Flounder caught in the combined August and September surveys of the Gulf of St. Lawrence.

Based on data from 1971 to 1982, the estimated lengths and ages at 50% maturity (L50, A50) were 37.0 cm and 10.4 years for females and 30.9 cm and 7.5 years for males. The data from surveys in the 2000s suggest that maturation is now at smaller sizes than in the 1970s, with L50 estimated to have decreased from 33.0 and 39.6 cm for males and females respectively, to approximately 26 for males and 28 to 29 cm for females (Fig. 8).

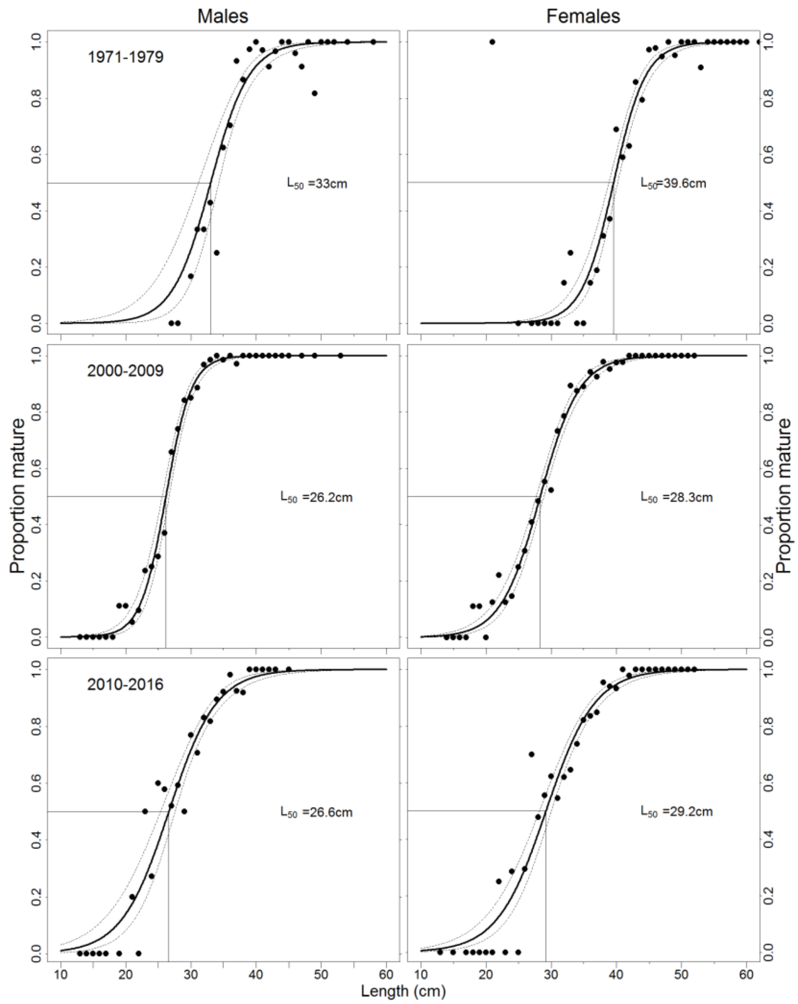


Figure 8. Maturity ogives for Witch Flounder based on September survey data from the southern Gulf of St. Lawrence. The predicted length at 50% maturity is presented for males (left column) and females (right column) for the period 1971 to 1979 (top row), 2000 to 2009 (middle row) and 2010 to 2016 (bottom row).

Spatial Distribution

The spatial distributions of large commercial-sized (>= 30 cm) Witch Flounder biomass indices (kg per tow) from the September RV survey are shown in Figure 9 and for the August northern Gulf of St. Lawrence Survey in Figure 10. Larger Witch Flounder tend to move up onto the shelves during the summer feeding season, with concentrations occurring in the Cape Breton Trough west of Cape Breton Island, the Chaleur Trough and Shediac Valley east of the Gaspe Peninsula and the shelf off western Newfoundland, as well as in the Estuary (Figs. 9 and 10). Since the last assessment in 2012, the biomass indices of Witch Flounder 30 cm and greater have increased in the Estuary, in western Newfoundland and around Anticosti Island (Fig. 10).

Small pre-commercial sizes of Witch Flounder (<30 cm in length) tend to be restricted to the deep waters of the St. Lawrence Estuary and the Laurentian, Anticosti and Esquiman Channels and biomass indices of these small fish in both the Estuary and in the channels have increased since 2008 (Figs. 11 and 12).

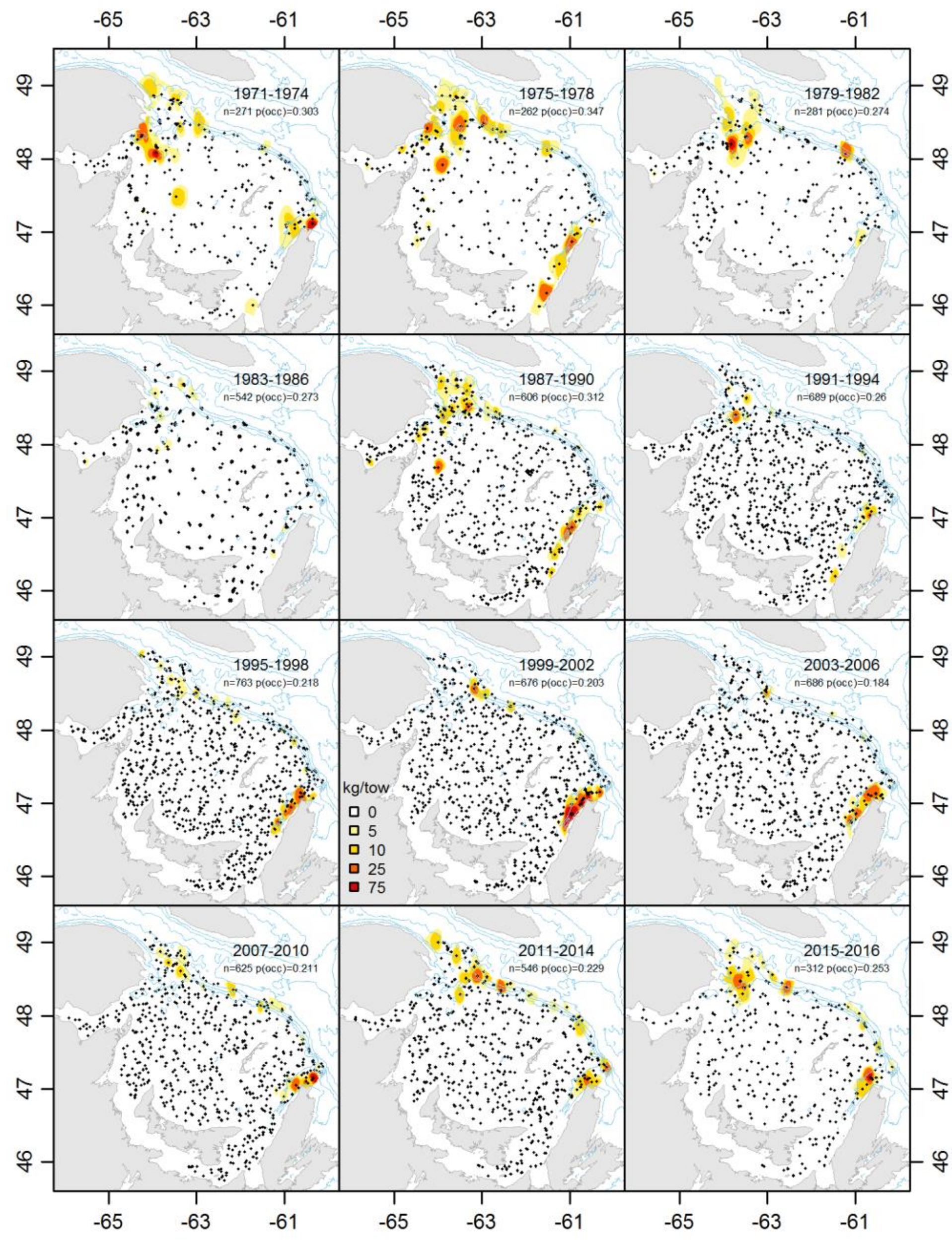


Figure 9. Distribution of biomass indices (kg per tow) of Witch Flounder >= 30 cm in the September surveys of the southern Gulf of St. Lawrence by blocks of years, 1971 to 2016. Shown in each panel are the total number of tows used in the analyses and the proportion of tows having non-zero catches [P(occ)].

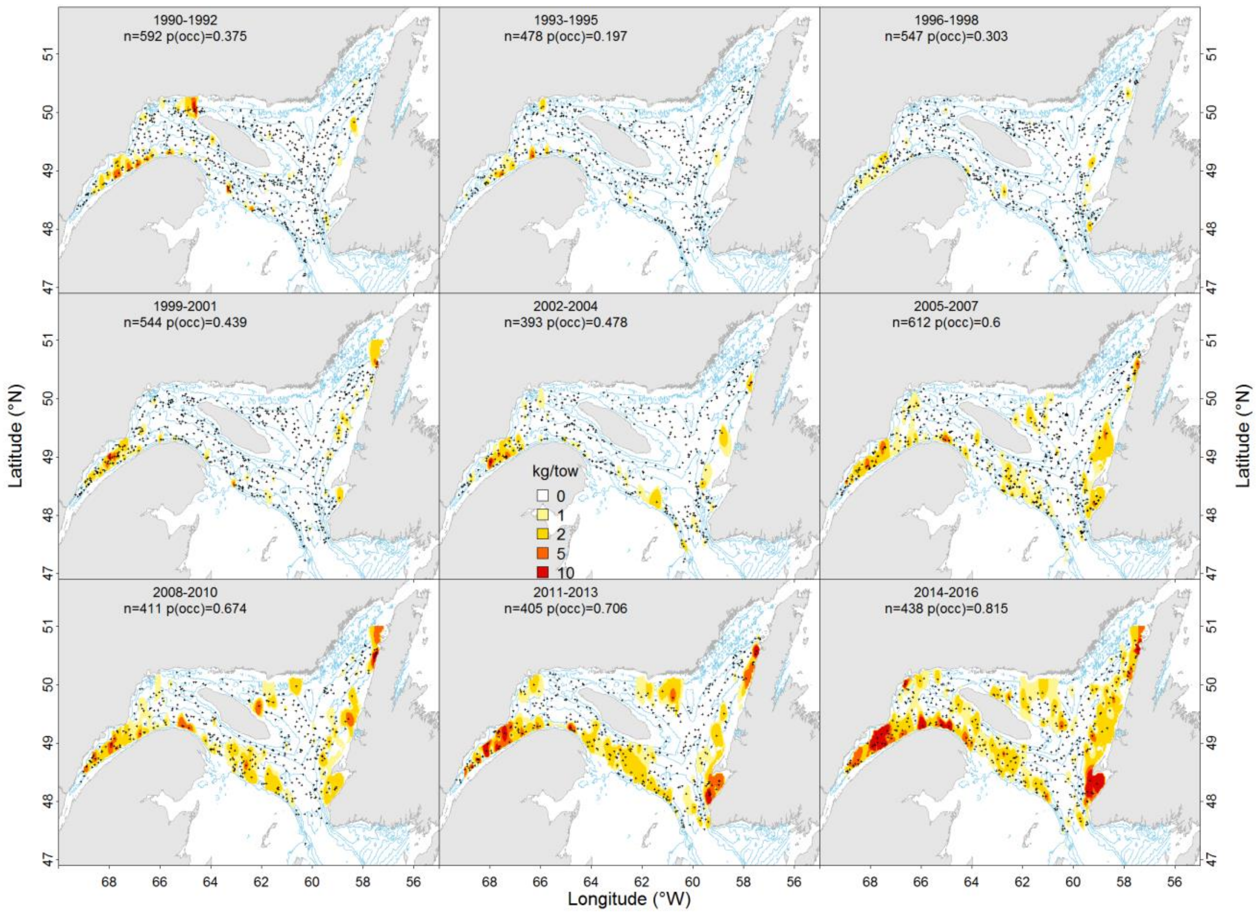


Figure 10. Distribution of biomass indices (kg per tow) of Witch Flounder >= 30 cm Witch Flounder in the August surveys of the northern Gulf of St. Lawrence by block of years, 1971 to 2016. Shown in each panel are the total number of tows used in the analyses and the proportion of tows having non-zero catches [P(occ)].

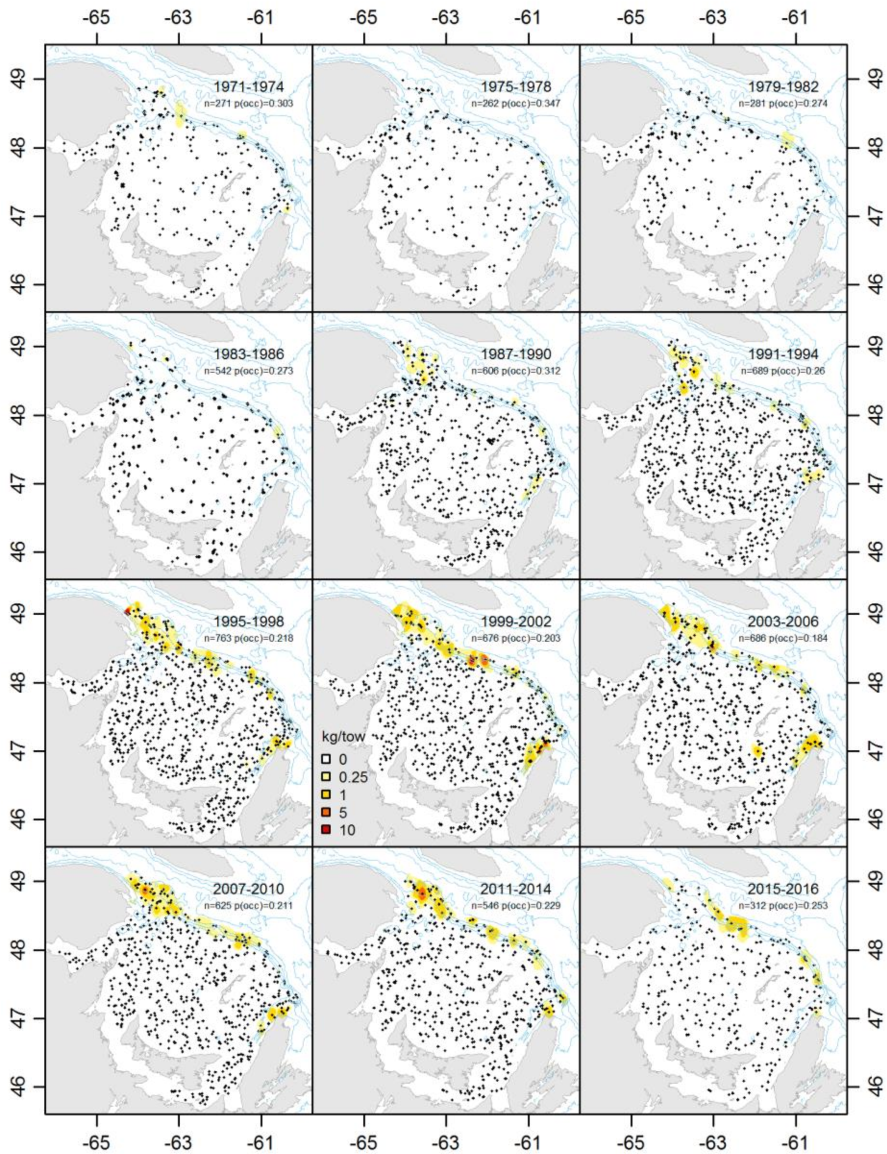


Figure 11. Distribution of biomass indices (kg per tow) of Witch Flounder < 30 cm in the September surveys of the southern Gulf of St. Lawrence by blocks of years, 1971 to 2016. Shown in each panel are the total number of tows used in the analyses and the proportion of tows having non-zero catches [P(occ)].

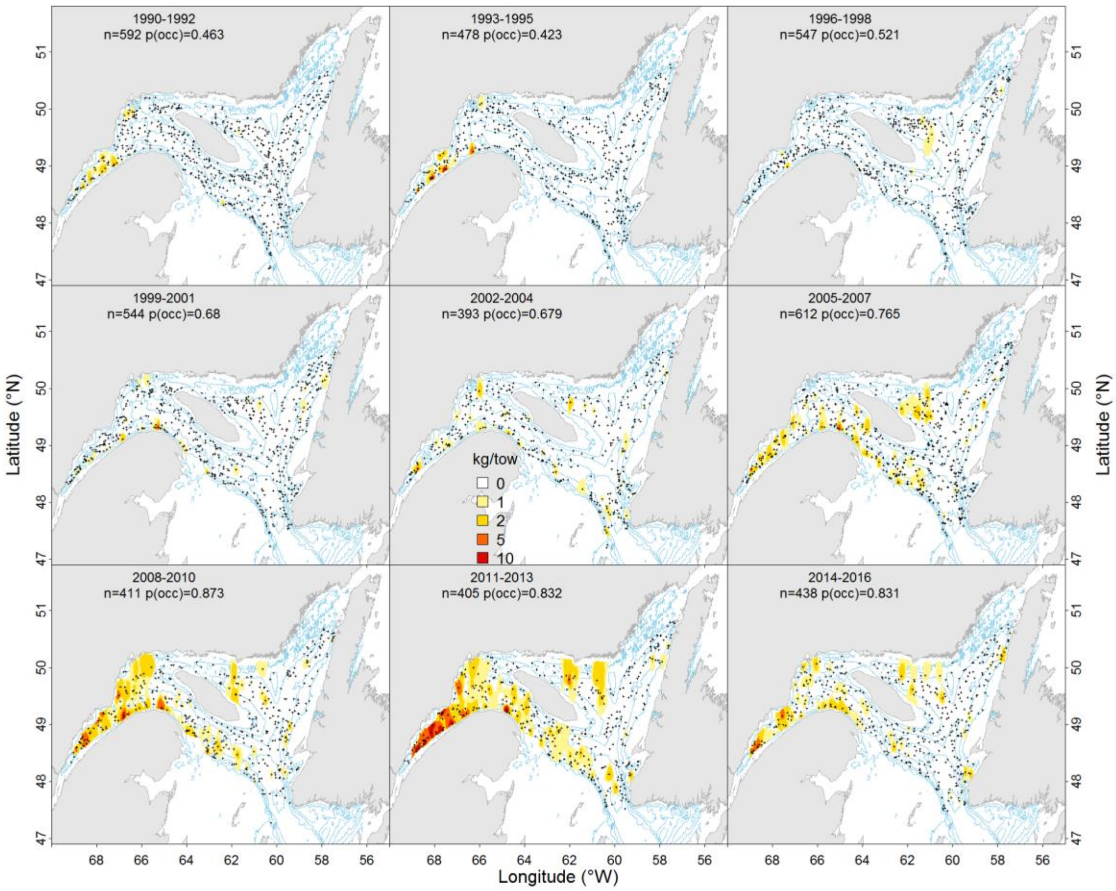


Figure 12. Distribution of biomass indices (kg per tow) of Witch Flounder < 30 cm Witch Flounder in the August surveys of the northern Gulf of St. Lawrence by block of years, 1971 to 2016. Shown in each panel are the total number of tows used in the analyses and the proportion of tows having non-zero catches [P(occ)].

Population Modelling

Witch Flounder in the Gulf of St. Lawrence (NAFO Divs. 4RST) was modelled as a single population.

Methods

A similar population model to the previous assessment was used; a state-space Schaefer production model adjusted using a Bayesian approach. Inputs were:

- The reported landings for the period 1960 to 2016 (Fig. 2);
- A trawlable biomass index of 30+ cm Witch Flounder for the September RV survey from Div. 4T for 1971 to 1992. This index does not cover the entire stock area and was used only for this period because the proportion of the stock occurring in the September survey area changed as the stock declined in the early 1990s (Swain et al. 2012) (Fig. 13).
- A trawlable biomass index of 30+ cm Witch Flounder for the combined August and September RV surveys for NAFO Divs. 4RST for the period 1987 to 2016 (Fig. 13).
- A trawlable biomass index of 30+ cm Witch Flounder for the combined July and August sentinel surveys in NAFO Divs. 4RST for the period 2003 to 2016 (Fig. 13).

Two model variants were explored. The first model had the intrinsic rate of population growth (r) fixed at a constant level over the whole time period. The second model had r varying by decade. The prior probability distributions used for the Schaefer model parameter r and for the catchability coefficients of the different surveys were the same as those used in the previous assessment (Swain et al. 2012).

Of the model variants examined, the model with a constant r over the time series was retained because there was weak evidence of a decadal change in productivity.

Results

The retained model fit the abundance indices fairly well (Fig. 13). The model accounted for the long term trend but had difficulty fitting the higher frequency bumps and valleys in the indices (Fig. 13).

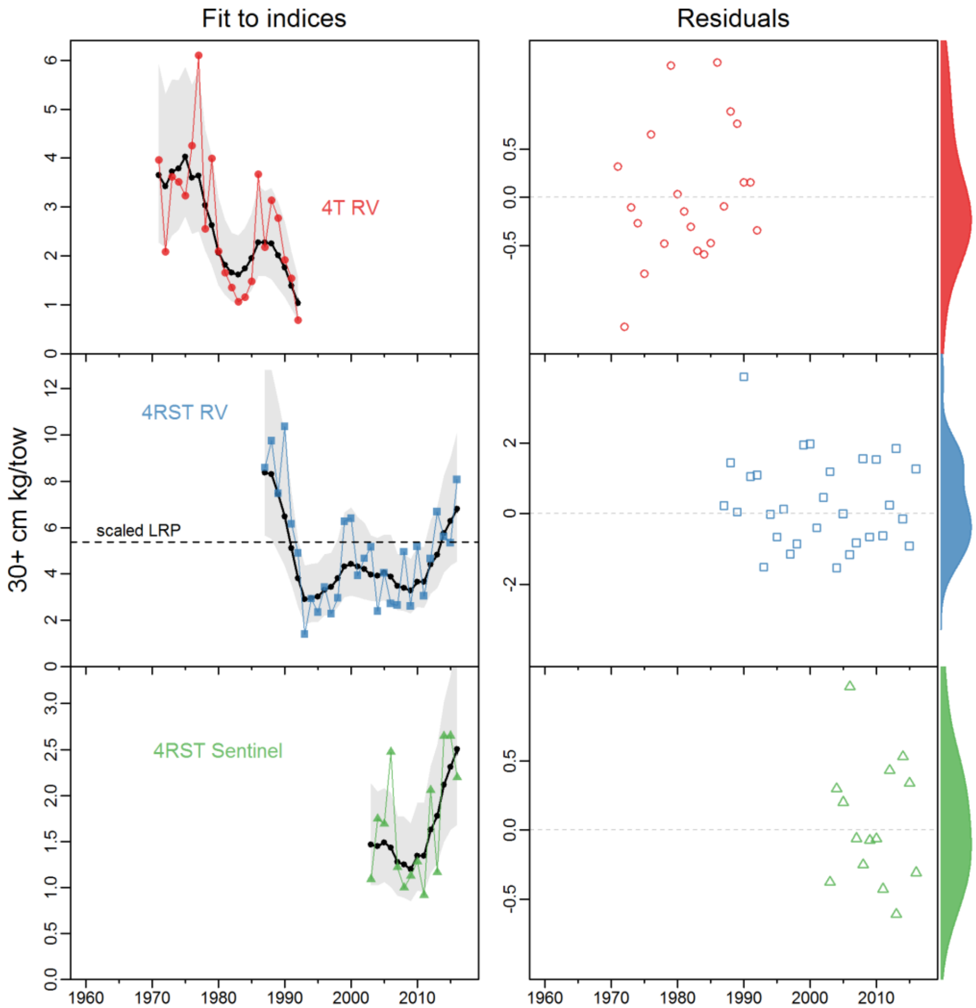


Figure 13. Comparison of catchability-corrected predicted indices and observed indices (left panels) and residuals between observations and predictions for the three indices used (right panel) for the surplus production model. In the left column panels, the median is the solid black line with black dots and the 2.5 to 97.5 percentiles defined the grey polygon around the median. The observed indices are the coloured symbols and lines in each panel.

To examine model robustness, the biomass index data for the four most recent years were removed (while retaining the landings data) and the model projected forward over the years of missing data. The predictions of population biomass using the shortened time series matched the model predictions using data from the entire time series indicating that the model performed well. As expected, the uncertainty around the predicted biomass trajectory increased greatly for the years without index data (Fig. 14).

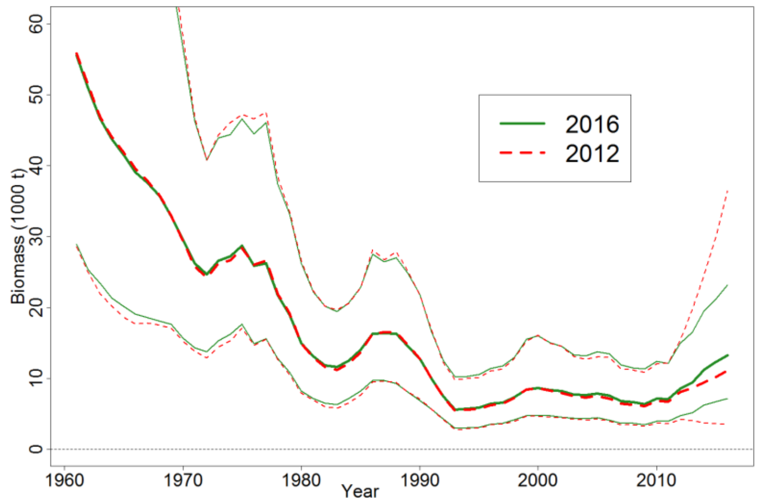


Figure 14. Estimated biomass of 30+ cm Witch Flounder obtained by fitting the single productivity regime Schaefer model with all the biomass index data to 2016 (solid green line) and by fitting with index data up to 2012 (dashed red line). Heavy lines are the median estimates and thin lines show the 2.5 to 97.5 percentiles.

The model outputs in this assessment are comparable to the values from the previous assessment. Estimates of several quantities of management interest (with 80% credible limits in parentheses) and those obtained from the 2012 assessment are shown in Table 1.

Table 1. Comparison of population model parameter estimates and estimates of management parameters of interest (median,80% credibility interval) from the assessment of Witch Flounder to 2016 and the previous assessment using data to 2011 (Swain et al. 2012).

Parameter	This assessment (y = 2016)	Previous assessment (y = 2011)
r	0.1453 (0.0974 - 0.1995)	0.1440 (0.0935 - 0.1984)
K	52.4 kt (32.9 - 153.2)	52.6 kt (30.9 - 166.1)
B_{msy}	26.2 kt (16.6 - 76.6)	26.3 kt (15.5 - 83.0)
LRP	10.5 kt (6.6 - 30.6)	10.5 kt (6.2 - 33.2)
USR	21.0 kt (13.2 - 61.3)	21.0 kt (12.4 - 66.4)
B_y	13.3 kt (8.8 -19.3)	5.0 kt (3.3 - 7.4)
C_{msy}	2.0 kt (1.2 - 4.7)	1.9 kt (1.1 - 5.0)
F_{msy}	0.072 (0.049 - 0.099)	0.072 (0.047 - 0.099)
B_y / LRP	1.20 (0.41 - 2.28)	0.46 (0.14 - 0.91)
$P(B_y < LRP)$	38%	93%
$P(B_y >= LRP)$	62%	7%

Reference Points for Witch Flounder from NAFO Divs. 4RST

Following DFO (2009), the Limit Reference Point (LRP) used calculated as 40% of the estimated biomass producing the maximum sustainable yield (B_{msy}). For the NAFO Divs. 4RST stock of Witch Flounder, the B_{msy} was estimated at 26,200 t (Table 1). The LRP is calculated at

10,480 t and the Upper Stock Reference value corresponding to 80% of B_{msy} is 20,960 t. The maximum removal rate (E_{msy}), equivalent to F_{msy} is 0.072 (Table 1).

Stock Status Relative to Reference Points

The median estimate of the spawning stock biomass (SSB; >= 30 cm) of Witch Flounder for the GSL has been consistently below the LRP since 1991 although there has been greater than 5% chance of SSB being below the LRP since 1979 (Fig. 15). The median of the SSB estimates rose above the LRP in 2014, 2015 and 2016. In 2016, the SSB was estimated at 13,270 tons, 127% of the LRP, with a 38% chance of being below the LRP (Table 1; Fig. 15).

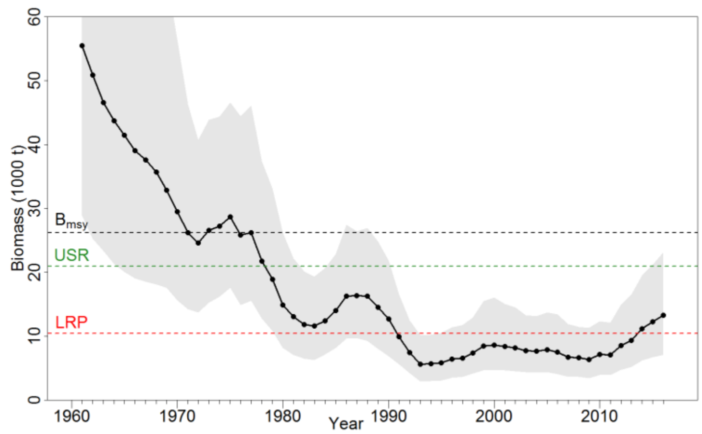


Figure 15. Model estimates of spawning stock biomass (>= 30 cm; by 1000 t) of Witch Flounder from the Gulf of St. Lawrence, 1960 to 2016. The spawning stock biomass corresponding to the Limit Reference Point (LRP), the Upper Stock Reference point (USR) and to the biomass at maximum sustainable yield (B_{msy}) are also shown as dashed horizontal lines. The annual median stock biomass is the dark line with black circles and the 95 % credibility interval is shown by shading.

Over most of the time series, the estimate exploitation rate has been above the maximum removal rate (E_{msy}*; calculated* as C_{msy}/B_{msy}) with exception to 1995 and 1996, and from 2010 to 2016 (Fig. 16).

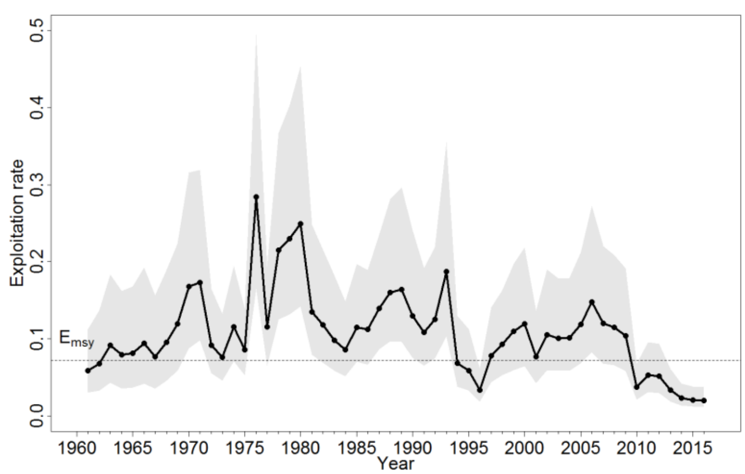


Figure 16. Model estimates of the exploitation rate on Witch Flounder from the Gulf of St. Lawrence, 1960 to 2016. The median of the maximum removal rate corresponding to E_{msy} (C_{msy}/B_{msy}) is also shown as the dotted horizontal line. The medians of the annual exploitation rates are the dark line with black circles and the 95% credibility intervals are defined by shading.

Sustained high fishing rates essentially from the start of the time series in 1961 led to the decline in SSB for this stock (Fig. 17).

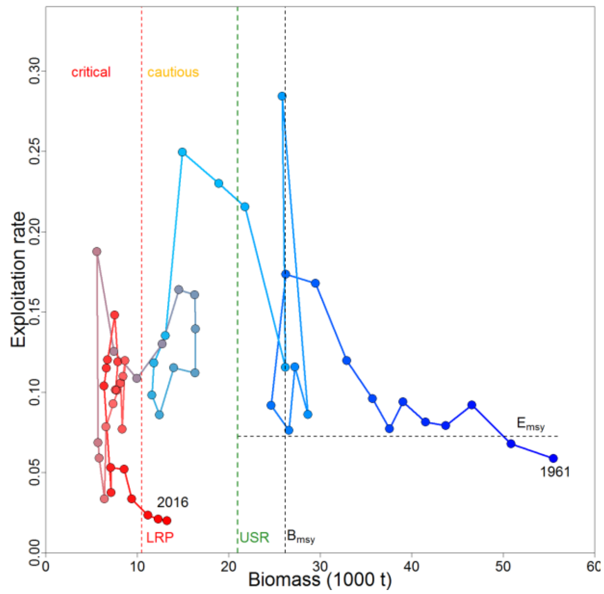


Figure 17. Trajectory of the spawning stock biomass (median of the estimate) relative to the exploitation rate (median of the estimate) for the Witch Flounder stock of the Gulf of St. Lawrence, 1961 to 2016. The symbols and lines are coloured from red to blue sequentially for the years 1961 to 2016. The dashed red vertical line corresponds to the Limit Reference Point, the dashed vertical green line corresponds to the Upper Stock Reference point, and the dashed horizontal line is the maximum removal rate. Also shown as a dashed black vertical line is the value corresponding to B_{msy}.

A relatively strong recruitment pulse (fish < 30 cm) in 1999 and 2000 (Fig. 7 and 18) did not translate into increased abundances of large Witch Flounder (>= 30 cm), as these fish were presumably fished down (Figs. 7 and 17). Lower fisheries removals and removal rates from 2010 to 2016 have allowed a recent recruitment pulse, first detected in 2009 and 2010, to persist and grow into the larger size group (>= 30 cm) leading to an increase in SSB in 2011 to 2016 (Figs. 7 and 17)

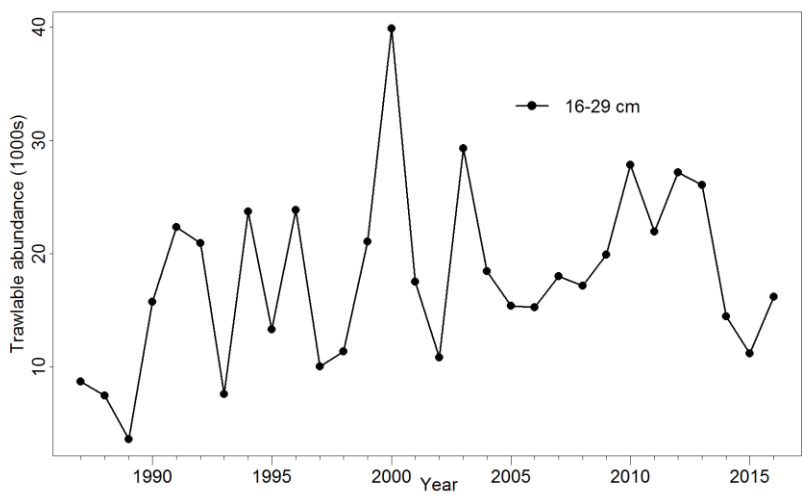


Figure 18. Combined recruitment index (trawlable abundance in thousands) of Witch Flounder < 30 cm length for the Gulf of St. Lawrence, 1987 to 2016.

Projections Relative to Different Catch Options

Five-year after fishery projections for 2017 to 2021 were made at four levels of annual catch; 0 t, 100 t, 300 t and 500 t. Median estimates of biomass of Witch Flounder (>= 30 cm) increased over the five year period at all catch options (Fig. 19).

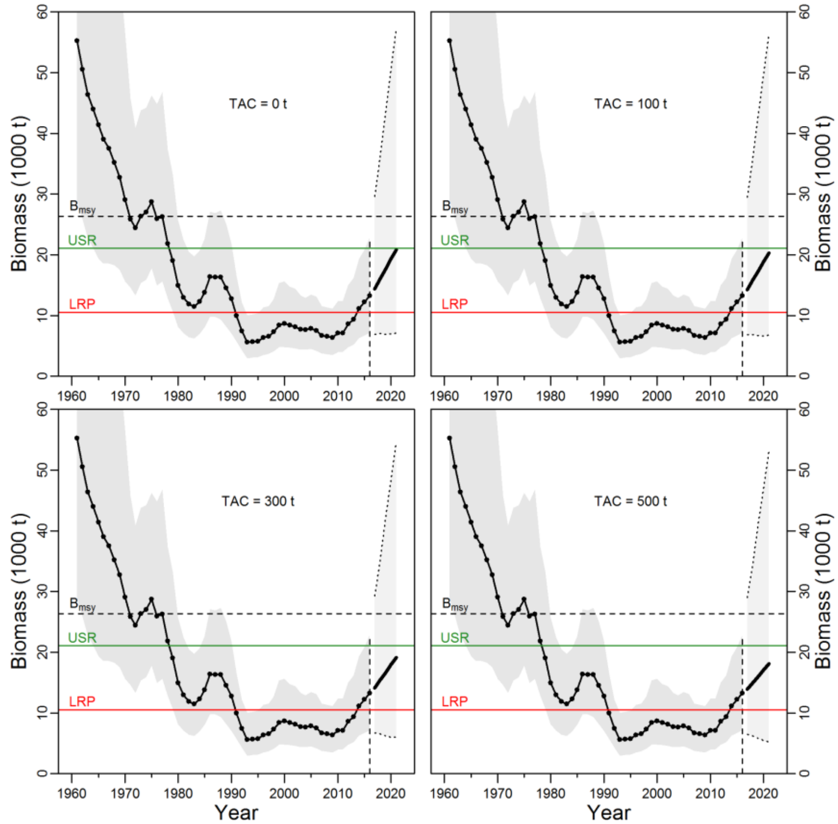


Figure 19. Projected biomass (by 1000 t) after the fishery of Gulf of St. Lawrence Witch Flounder >= 30 cm for four annual levels of catch in 2017 to 2021 (0 t; 100 t, 300 t, and 500 t) using the single productivity regime model. In each panel, the solid black lines with symbols are the predicted biomass values (medians) and the grey polygon spans the 2.5 to 97.5 percentiles of the estimates. The red horizontal line shows the LRP corresponding to 40% of B_{msy}, the green horizontal line the USR corresponding to 80% of B_{msy}, and the black dashed horizontal line B_{msy} value.

The probabilities that the 30 cm+ biomass after fishing will remain at or below the LRP decreases over the period 2017 to 2021 at all considered catch levels. By 2021, the probabilities that the SSB after fishing will be below the LRP are 24% under a catch option of 100 t, 26% for a catch option of 300 t and 29% for a catch option of 500 t. Even in the absence of any fishery removals, there is a 23% chance that the SSB will be below the LRP in 2021 (Table 2; Fig. 20).

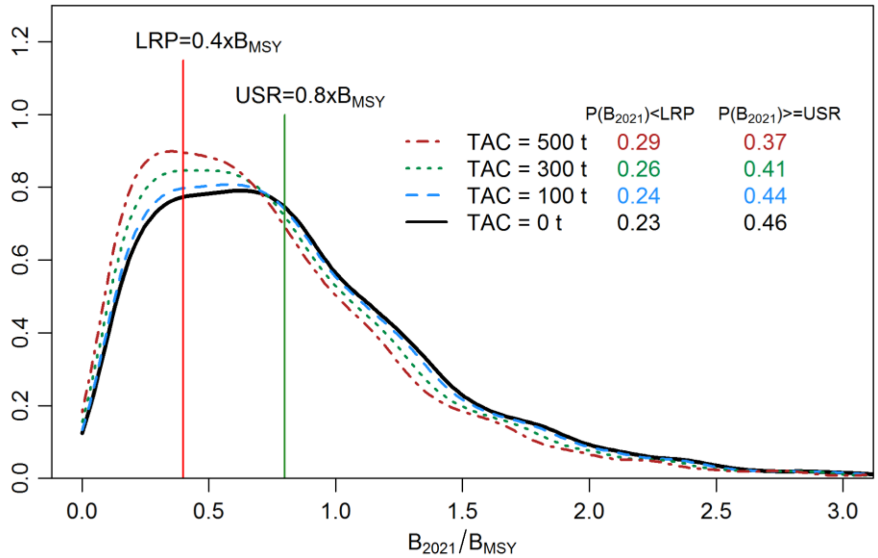


Figure 20. Estimated biomass of Witch Flounder after fishing in 2021 as a proportion of B_{msy} for four levels of annual catch (Total Allowable Catch, TAC) in 2017 to 2021. The vertical red line indicates the LRP corresponding to 40% of B_{msy} and the vertical green line indicates the USR corresponding to 80% of B_{msy}. The probability that the biomass after fishing in 2021 will be below the LRP and the probability that the biomass in 2021 will be above the USR are reported for the four catch options in the figure legend.

Table 2. The annual probabilities that the estimated biomass of Witch Flounder >= 30 cm after fishing will be less than or equal to the Limit Reference Point (LRP) and greater than or equal to the Upper Stock Reference Point (USR) for four levels of annual catch in 2017 to 2021. Also shown are the percentages (median; 80% credibility interval) of the projected surplus production of biomass which would be extracted annually for each annual catch option.

		Catch option			
Reference	Year	0 t	100 t	300 t	500 t
B_{year} <= LRP	2017	34%	35%	36%	37%
	2018	31%	32%	33%	35%
	2019	28%	28%	30%	33%
	2020	25%	26%	28%	30%
	2021	23%	24%	26%	29%
B_{year} >= USR	2017	23%	23%	22%	21%
	2018	29%	28%	27%	25%
	2019	35%	34%	32%	30%
	2020	41%	39%	36%	33%
	2021	46%	44%	41%	37%
Percentage of surplus production removed	2017	0%	7.0% (4.6 - 11.3)	21.1% (13.7 - 34.2)	35.4% (23.0 - 57.7)
	2018	0%	6.8% (4.2 - 11.6)	20.6% (12.7 - 35.3)	34.8% (21.5 - 60.2)
	2019	0%	6.5% (3.7 - 11.6)	19.9% (11.5 - 35.9)	33.8% (19.7 - 61.8)
	2020	0%	6.3% (3.3 - 11.8)	19.5% (10.4 – 36.5)	33.2% (18.1 - 63.4)
	2021	0%	6.1% (3.0 - 12.0)	19.0% (9.5 - 37.4)	32.7% (16.7 -65.1)

When a stock is in the cautious zone, removals should be at a level that allows rebuilding of the stock towards the healthy zone (DFO 2009). The percentages of the projected surplus production which is removed annually increases with increasing catch levels but decreases over time as the projected SSB increases (Table 2). For example, at a catch option of 300 t in 2017, the percentage of predicted surplus production extracted is 20.6% compared to 34.8% at a catch option of 500 t (Table 2).

Sources of Uncertainty

For the research vessels, fishing efficiency for Witch Flounder varies substantially between day and night. Efficiencies also vary among the vessels and gears used to conduct the summer and fall research surveys. Adjustments have been made for these changes in fishing efficiency using calibration factors estimated from comparative fishing experiments. However, there is uncertainty around these estimated factors.

The inclusion of the 4T index in the model assumes that there is no time trend in the proportion of the stock occurring in the 4T September survey area over the 1971 to 1992 period. Information on geographic distribution and changes in stock abundance in the 1970s and 1980s are consistent with this assumption, but its validity remains uncertain. Excluding this index results in a more severe decline in estimated biomass between 1961 and 2011.

There is no information on growth and age-at-maturation that is more recent than the early 1980s. Thus the extent to which the decline in size at maturation since the early 1980s reflects a response to high mortality versus an effect of slower growth is uncertain. Likewise, it is uncertain whether a decline in growth explains some of the observed loss of 40+ cm fish from the population.

The Schaefer production models do not provide support for changes in productivity regime for this stock. However, in these models, the intrinsic rate of population increase integrates recruitment, growth and natural mortality. Thus, it is possible that there have been counter-acting changes between the components of productivity. For example, a decline in growth rate or an increase in natural mortality rate could be obscured in the modeling by an increase in recruitment rate.

Stock structure is a source of uncertainty for this resource. It is possible that the dynamics of Witch Flounder in the Gulf, particularly those in eastern 4T, are linked to those of Witch Flounder in NAFO Div. 4VW.

CONCLUSIONS AND ADVICE

Witch Flounder is a species of low productivity and is vulnerable to overexploitation. Growth is slow and maturation is at a late age. In the 1974 to 1981 period, the mean length at 12 years was estimated to have been only 40 cm for males and 41 cm for females. For this same period, estimated ages at 50% maturity were 7.5 years for males and 10.4 years for females. An apparent shift towards earlier maturation in the 4RST stock between the 1970s and the 2000s suggests that this stock has experienced relatively high adult mortality.

There has been a contraction in the size composition of the stock since the 1970s and early 1980s. Fish 40 cm or longer made up 70% to 80% of the landings and 86% of the September RV catch in the late 1970s but only 20% of the landings and 8% of the September RV catch in 2006 to 2011. The proportion of these large fish has increased in recent years, accounting for up to 23% of the landings and 13% of the September RV catch.

A surplus production model fit to landings data from 1961 to 2016 and indices beginning in 1971 provides an estimate for B_{msy} of 26,200 t (80% C.I. range 16,470 to 76,590 t), a maximum sustainable yield estimate of 1,960 t (80% C.I. range 1,180 to 4,670 t) and a corresponding exploitation rate estimate at maximum sustainable yield of 0.072 (80% C.I. range 0.049 to 0.099).

The landings of this stock have exceeded the model estimated catch at MSY of 1,960 t in 23 of the 56 assessed years beginning in 1961. The exploitation rate has exceeded the maximum removal rate of 0.072 throughout most of the time series, in 44 of 56 years, with the exception of the most recent seven years.

A relatively strong recruitment pulse (fish < 30 cm) in 1999 and 2000 did not translate in increased abundances of large Witch Flounder (>= 30 cm), this recruitment presumably having been fished down.

DFO (2012) indicated that a strong pulse of recruitment evident in the 2009 to 2011 survey data was approaching commercial sizes and that protecting this incoming fishery recruitment by keeping catches as low as possible for the following decade could promote rebuilding of the 40+ cm size group. Catch levels less than 300 t during the 2013 to 2016 fishery years seem to have contributed to the increased biomass of the stock as anticipated. The indices of 30+ cm biomass show increasing trends and the population model estimates that the stock is rebuilding.

The 2016 median estimate of the SSB is 13,270 t, slightly above the LRP (10,480 t) with a 38% chance that the estimated biomass is at or below the LRP.

Projections of stock biomass after fishing for 2017 to 2021 indicate that the biomass is expected to increase for examined annual catch options to 500 t. The probability of the biomass after fishing being below the LRP in 2021 is 23% even in the absence of fishing, 24% at an annual catch of 100 t, 26% for an annual catch of 300 t, and 29% at a catch option of 500 t. The probability that the stock biomass will be in the healthy zone, i.e. at or above USR, in 2021 after fishing is 46% with no catch, 41% at an annual catch of 300 t and 37% at an annual catch of 500 t. Caution is however advised as the available evidence indicates that incoming recruitment of Witch Flounder < 30 cm is not as strong as the recruitment noted in 2009 and 2010.

The biomass indices of Witch Flounder 30 cm and greater have increased throughout the GSL where the species has historically been found, including the Estuary, western Newfoundland, and around Anticosti Island.

Increased abundance of Witch Flounder in the Gulf is in contrast to the decreasing abundance trends of other large demersal fish species such as American Plaice (DFO 2016b), Yellowtail Flounder (DFO 2016d), Winter Flounder (DFO 2017b), Atlantic Cod (DFO 2016a), White Hake (DFO 2016e) and skates (DFO 2017a) that are distributed in shallower waters of the southern Gulf of St. Lawrence. These other species show evidence of strong declines in productivity associated with increases in natural mortality. A model that considered changes in productivity for Witch Flounder over time was examined but there was no evidence of a change in productivity over the 1960 to 2016 period.

OTHER CONSIDERATIONS

Stock Status Indicators

The NAFO Divs. 4RST Witch Flounder stock is currently assessed and managed on a five-year cycle. Indicators are needed to characterize stock status in the intervening years between assessments (DFO 2016c). The chosen indicator is the combined biomass indices for Witch Flounder >= 30 cm from the RV surveys conducted in the northern and southern Gulf of St. Lawrence. Since these indices can have large observation error and changes in stock status should not be inferred from annual variations in the index, a three-year moving average is used.

Since the Witch Flounder stock of NAFO Divs. 4RST is projected to increase in abundance and have a low probability (< 30%) of being below the LRP by 2021, even at the highest catch option examined (500 t), a re-assessment would be recommended if the stock status indicator signaled a decline of the SSB to below the LRP. If the index indicates that the SSB is staying above the LRP, a re-assessment would not be recommended as the stock trajectory would be consistent with expectation from this assessment and the catch advice would still be relevant.

In order to implement this approach it is necessary to relate the LRP from its modelled population scale to the scale of the combined RV index in August and September. This is done by scaling the biomass over the whole stock area to the scale of the combined 4RST index using the catchability coefficient estimated from the model. The median value of the index catchability coefficient is 0.5124. The LRP value of 10,480 t is equivalent to a re-scaled LRP of 5.37 kg/tow of Witch Flounder >= 30 cm for the combined RV index (Fig. 21).

An interim year update will be provided mid-way in the five-year assessment cycle, i.e. in early December 2019, to allow sufficient time to complete a full assessment and plan the peer review if the indicator signals that a re-assessment is warranted in the winter of 2020.

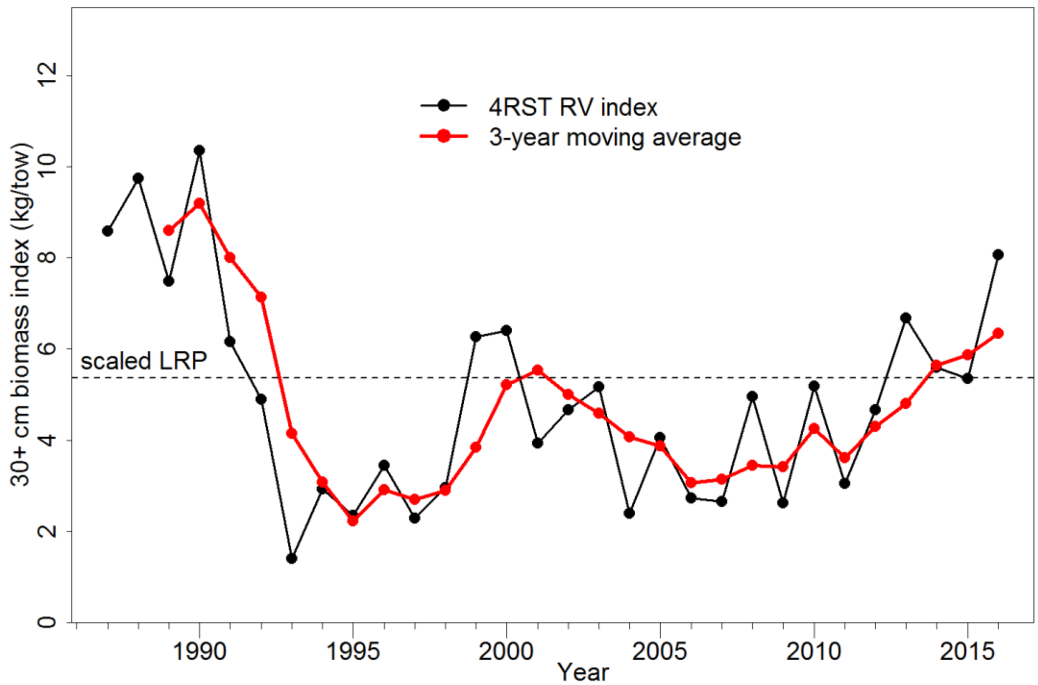


Figure 21. The combined NAFO Divs. 4RST 30+ cm biomass index from the RV surveys of the Gulf of St. Lawrence, 1987 to 2016. The 3 year moving average of the index is also shown. The horizontal dashed line shows the limit reference point (LRP) scaled to the biomass index in units of kg per tow.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 2, 2017 regional peer review meeting on the Stock status and fishery advice for May 2017 to May 2022 for Witch Flounder (*Glyptocephalus cynoglossus*) from NAFO Divisions 4RST, Gulf of St. Lawrence. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.

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Aussi disponible en français :

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